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PERSISTENT BEHAVIOR MAINTAINED BY UNAVOIDABLE SHOCKS

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Squirrel monkeys were trained on a multiple schedule in which 10-min periods on a continuous shock avoidance schedule, indicated by a yellow light, alternated with 10-min periods on a 1.5-min variable interval schedule of food reinforcement (VI 1.5). A white light indicated that VI 1.5 was in effect, except for the middle 2 min of the period on VI 1.5, in which a blue light appeared and terminated with the delivery of a 0.5-sec unavoidable shock. Stable response rates developed in the avoidance and VI 1.5 components. However, the highest response rates occurred in the blue, preshock stimulus. A series of experiments showed that responding in the blue stimulus persisted even when responding had been extinguished on both the VI schedule of food reinforcement and the shock avoidance schedule. Responding in the blue stimulus ceased when the blue stimulus terminated without shock or when it terminated with a response-contingent shock. Each time responding ceased, it was restored by terminating the blue stimulus with an unavoidable shock. When the blue stimulus was on throughout each session and unavoidable shocks were delivered at regular 10-min intervals, responding was well maintained. These results show that in monkeys that have been trained on a continuous avoidance schedule, unavoidable shocks can maintain responding even under conditions where responses have no programmed consequences.

Estes and Skinner (1941) demonstrated that a stimulus (pre-aversive stimulus) that repeatedly preceded an unavoidable shock suppressed the responding of rats on a fixed-interval schedule of food reinforcement. Many subsequent studies have extended this finding by showing that a pre-aversive stimulus suppresses the response rates of several other species on various schedules of positive reinforcement (*e.g.*, Brady, 1955; Brady and Hunt, 1955; Azrin, 1956; Sidman, 1956; and Valenstein, 1959). The general procedure of superimposing a pre-aversive stimulus on ongoing behavior is referred to in this paper as the Estes-Skinner procedure.

Some recent experiments have revealed conditions in which the Estes-Skinner procedure does not suppress responding. Using a VI schedule of reinforcement to maintain behavior, Stein, Sidman, and Brady (1958) found that the degree of suppression produced by the Estes-Skinner procedure depended upon the relative durations of the presence and absence of the pre-aversive stimulus; the degree of suppression was inversely related to the percentage of time that the pre-aversive stimulus was present.

Sidman, Herrnstein, and Conrad (1957) first demonstrated that a pre-aversive stimulus could increase responding when a continuous shock avoidance schedule (Sidman, 1953) was used to maintain behavior; with further exposure to this procedure, however, the response rate during the pre-aversive stimulus gradually decreased toward the response rate that prevailed between presentations of the pre-aversive stimulus. When the conditioned avoidance response was extinguished, response rates decreased more slowly in the presence of the pre-aversive stimulus than in its absence.

Herrnstein and Sidman (1958) found that if monkeys had been previously conditioned on a shock avoidance schedule, the Estes-Skinner procedure produced increased response rates in the pre-aversive stimulus even when a VI schedule of food reinforcement was used to maintain behavior. If the conditioned avoidance response was extinguished before the Estes-Skinner procedure was instituted, response rates in the pre-aversive stimulus were

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relatively low. In summary, the degree of suppression produced by a pre-aversive stimulus is determined by the relative duration of the pre-aversive stimulus, the schedule of reinforcement on which it is superimposed, and the history of the experimental subject.

The purpose of the present investigation was to study the interactions between performance on a schedule of continuous shock avoidance and performance in the presence of a pre-aversive stimulus superimposed on a VI schedule of food reinforcement. A multiple schedule was used to compare performances on each type of schedule for a single subject within each experimental session. It was found that response rates were relatively high in the pre-aversive stimulus. Experiments were conducted to determine the variables that controlled responding in the pre-aversive stimulus.

METHOD

Subjects

Four male squirrel monkeys were maintained at 75 to 80 per cent of their free-feeding weights. All subjects (*Ss*) had brief experimental histories of responding on a schedule of continuous food reinforcement.

Apparatus

Two experimental chambers, designated Box A and Box B, were used. Each box was 9¼ by 7⅝ by 11½ in. Two walls and the ceiling were Plexiglas; the other two walls were aluminum, and the floor was constructed of stainless steel grids. A Lehigh Valley Electronics rat lever (LVE1352) which projected through the center of one of the aluminum walls, could be activated by a pressure of 15 g or more. Each depression of the lever produced the audible click of a relay. The visual stimuli were 1.12-w white, blue, and yellow jewel lights located above the lever.

In Box A, reinforcements were 94 mg food pellets, delivered to a small receptacle at the left of the lever.

In Box B, reinforcements were 0.25 ml portions of liquid food (Herndon, Greenberg, Van Loon, Kelleher, Cook, and Davidson, 1958) presented for 3 sec. The liquid food was delivered by a motor-driven dipper to an opening in the bottom of a small recessed cubicle at the left of the lever. The recessed cubicle was illuminated by a 6-w lamp during reinforcement cycles.

Electric shocks of 0.5-sec duration were delivered through a grid scrambler (Grason-Stadler, E1064GS) to the floor grids and the aluminum walls of either box. In Box A the shock intensity was 1 ma; in Box B 3 ma.

The procedures were programmed automatically by relay switching circuits and timers. Responses were recorded on counters and cumulative response recorders.

General Procedure

Experimental sessions were 4 to 5 hr long, conducted daily, Monday through Friday. On weekends *Ss* were weighed daily and maintained at appropriate body weights. Water was available at all times.

The basic procedure was a three-component multiple schedule. In the presence of a white stimulus a VI 1.5 schedule of food reinforcement was in effect. In the presence of a blue stimulus VI 1.5 was also in effect; the blue stimulus terminated with an unavoidable shock. In the presence of a yellow stimulus a continuous avoidance schedule was in effect (Sidman, 1953). If *S* did not respond on the avoidance schedule, shocks occurred every 30 sec; each response postponed shock for 30 sec. These components were presented in the following temporal sequence: 4 min of white stimulus (VI 1.5); 2 min of blue stimulus (VI 1.5) terminating with an unavoidable shock; 4 min of white stimulus (VI 1.5); 10 min of yellow stimulus (avoidance). This sequence of stimuli was repeated throughout each session in which the basic procedure was in effect.

The preliminary experiments (Sessions 1A to 250A) were conducted in Box A; main experiments (Sessions 1 to 260) in Box B.

PRELIMINARY EXPERIMENTS

Procedure

In Sessions 1A to 94A the basic procedure was in effect. In Sessions 1A to 60A, however, the procedure was frequently interrupted by failures of the food-dispenser. In Sessions 95A to 120A, extinction was in effect in the yellow stimulus. In Sessions 111A to 120A, extinction was also in effect in both white and blue stimuli. Because Monkey K32 was frequently ill, it was dropped from the study in Session 125A and replaced by Monkey K5 in Session

130A. Between Sessions 150A and 250A, drugs were occasionally administered to *Ss*. Baseline performance was recovered following each drug session.

Results

Basic Procedure. The initial development of performance was similar for each *S*. In the first few sessions response rates were erratic, and *Ss* received many shocks on the avoidance schedule. By the 10th session, *Ss* had developed stable response rates (ranging from 10 to 30 responses per min) which were about the same in the presence of each of the stimuli. In subsequent sessions, response rates remained about the same in the presence of white (VI 1.5) and yellow (avoidance) stimuli, but became relatively high in the presence of the blue, pre-aversive stimulus. Except for drug sessions, performances were stable between Sessions 150A and 250A. These performances were comparable to those on the basic procedure in Box B (Sessions 1-15).

VI Extinction and Avoidance Extinction. During VI extinction, response rates decreased in the presence of the white stimulus but not in the presence of the blue stimulus. In the sessions in which both VI extinction and avoidance extinction were in effect, response rates in the presence of the white stimulus were near zero; response rates in the presence of the yellow stimulus gradually decreased; response rates in the presence of the blue, pre-aversive stimulus decreased only slightly. These results, which will not be presented in further detail, are consistent with the results of the more extensive experiments reported below.

EXPERIMENT I

The purpose was to determine the extent to which the relatively high response rates in the pre-aversive stimulus were controlled by food reinforcements and by unavoidable shocks.

Procedure

In Sessions 1-15, the basic procedure was in effect. When Monkey K28 started Session 14, a 110v AC electrical source was accidentally connected across some of the floor grids. This *S* received several severe shocks over a 10-min period and was prostrate when removed from the experimental chamber. In the following session, the performance of Monkey K28 appeared normal so it was continued in the study. In Sessions 16 to 56, experimental extinction was in effect in the presence of the blue stimulus. In Sessions 45 to 56, shocks did not occur at the termination of the blue stimulus.

Except as noted, procedural changes were made only when inspection of cumulative response records and daily average response rates indicated that performance was stable in the presence of each of the three stimuli.

Results

Basic Procedure. Even after prolonged exposure to the basic procedure (220 sessions for Monkeys K31 and K28 and 91 sessions for Monkey K5, including preliminary experiments), the highest response rates consistently occurred in the blue, pre-aversive stimulus. The cumulative response records in Frame A of Fig. 1 show that responding occurred at fairly constant rates in the presence of the white and yellow stimuli, while responding tended to be positively accelerated in the presence of the blue stimulus.

The magnitudes of the rate differences in the three stimuli are shown in the points indicated by VI SH on the abscissa of each frame of Fig. 2. For Monkeys K31 and K28 the distribution of response rates in the presence of the blue stimulus did not overlap the distribution of rates in the presence of the white or yellow stimuli. Although the distributions of rates for K5 did overlap slightly, the average response rate in the presence of the blue stimulus was higher in every session than the rate in the presence of the white or yellow stimuli.

Extinction in Blue With Unavoidable Shocks. Experimental extinction in the presence of the blue stimulus had little effect as long as the blue stimulus terminated with unavoidable shocks. Patterns of responding are shown in Frame B of Fig. 1, and rates of responding are shown in the points indicated by EXT SH on the abscissa of each frame of Fig. 2. For Monkeys K31 and K28, the distribution of the response rates in the white and blue stimuli still did not overlap; for Monkey K5, however, response rates in the presence of the white stimulus were equal to response rates in the presence of the blue stimulus. For all three *Ss*, avoidance response

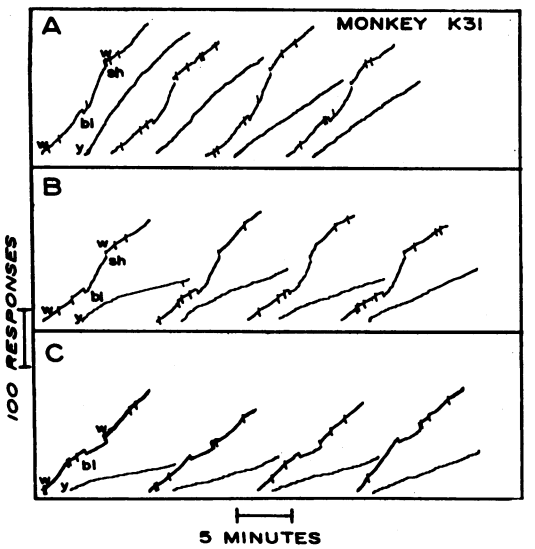

Fig. 1. Final performance of Monkey K31 with the basic procedure (A), with experimental extinction in blue (B,C), and with unavoidable shocks omitted (C). The individual 10-min record segments have been displaced along the abscissa. The letters adjacent to the first pair of records in each frame indicate the succession of stimuli. In Frame A the first record starts with VI 1.5 in the presence of the white stimulus (w); the offset portion shows VI 1.5 in the presence of the blue stimulus (bl), terminating with an unavoidable shock (sh); the shock is followed by VI 1.5 in the presence of the white stimulus (w). The short diagonal lines in white or blue indicate food reinforcements. The recorder did not run during reinforcement cycles. The second record shows avoidance in the presence of the yellow stimulus (y). Short diagonal lines on the avoidance records indicate shocks.

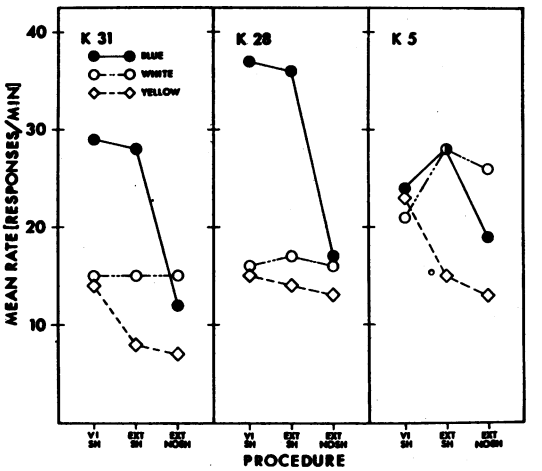

Fig. 2. Medians of average response rates in each stimulus during the last five sessions on each procedure in Exp. I. The notations on the abscissa indicate both the schedule that was in effect in the presence of the blue stimulus (VI: 1.5-min variable-interval; EXT: extinction) and whether the blue stimulus terminated with a shock (SH: shock; NO SH: no shock).

rates became consistently lower than VI response rates; however, these avoidance rates were still high enough that avoidable shocks were infrequent. Responding in the presence of the blue pre-aversive stimulus persisted even when food reinforcements no longer occurred in blue.

Extinction in Blue Without Unavoidable Shocks. When unavoidable shocks were not presented at the termination of the blue stimulus, response rates in the presence of the blue stimulus decreased markedly. Patterns of responding are shown in Frame C of Fig. 1, and rates of responding are shown in the points indicated by EXT NO SH on the abscissa of Fig. 2. For Monkeys K31 and K28, response rates in the presence of the blue stimulus decreased and became comparable to rates in the presence of the white stimulus; for Monkey K5, response rates in the presence of the blue stimulus became consistently lower than rates in the presence of the white stimulus. For all *Ss*, response rates in the presence of the blue stimulus were still decreasing slowly at the end of Exp. I. If this procedure had been continued, these rates might have stabilized near the values shown in Fig. 1 because of superstitious chaining to VI in the presence of white. The results of the first procedure in Exp. II, however, suggest that these rates would have decreased to lower values. In any event, the results of Exp. I show that the relatively high response rates that had prevailed in the presence of the blue, pre-aversive stimulus were primarily controlled by the unavoidable shocks.

EXPERIMENT II

The purpose was to determine the effects of avoidance extinction on performance in the pre-aversive stimulus.

Procedure

Avoidance extinction was in effect throughout in the presence of the yellow stimulus, VI extinction was in effect in the presence of the blue stimulus, and VI 1.5 was in effect in the presence of the white stimulus. In Sessions 57 to 64 (as in Sessions 45 to 56) shocks did not occur at the termination of the blue stimulus.

In Sessions 65 to 84, unavoidable shocks again occurred at the termination of the blue stimulus.

In Sessions 85 to 92, shocks did not occur at the termination of the blue stimulus, but a 2.5-min time-out (TO) followed each presentation of the blue stimulus. During TO, the experimental chamber was dark, and responses were not reinforced. Response rates were always zero during TO. In Sessions 93 to 110, the blue stimulus terminated with a shock followed by TO. The TO was used to attempt to minimize interactions between response rates in the presence of the blue and white stimuli.

Procedural changes were made only when inspection of cumulative response records and daily average response rates indicated that performance was stable in the presence of the blue and white stimuli. Response rates in the presence of the yellow stimulus were declining throughout the experiment.

Results

No Shocks at the Termination of the Blue Stimulus. Response rates were relatively low in the presence of the blue and the yellow stimuli. Response rates in the presence of the white stimulus tended to be higher than in Exp. I. The magnitudes of the rate differences in the three stimuli are shown in the points indicated by NO SH on the abscissa of each frame of Fig. 3. The response rates were lower in the presence of the blue stimulus than in the presence of the white stimulus; the distribution of rates in these stimuli did not overlap.

Unavoidable Shocks at the Termination of Blue. Response rates in the presence of the blue stimulus increased markedly when unavoidable shocks occurred at the termination of the blue stimulus. The rates that developed in each stimulus are shown in the points indicated by SH on the abscissa of each frame of Fig. 3. For Monkeys K31 and K28, rates in the presence of the blue stimulus were about the same as rates in the presence of white. For Monkey K5, rates were still lower in the presence of the blue stimulus than in the presence of white. Avoidance response rates in the presence of yellow continued to decrease. These results show that unavoidable shocks can increase responding in the preaversive stimulus even while avoidance responses are being extinguished.

TO at the Termination of Blue. The response rates that developed in each stimulus are shown in the points indicated by NO SH TO on the abscissa of each frame of Fig. 3. Patterns of responding are shown in Frame A of Fig. 4. Response rates in the presence of the blue stimulus were relatively low when the unavoidable shocks were removed. For Monkeys K31 and K28, these rates were no lower than

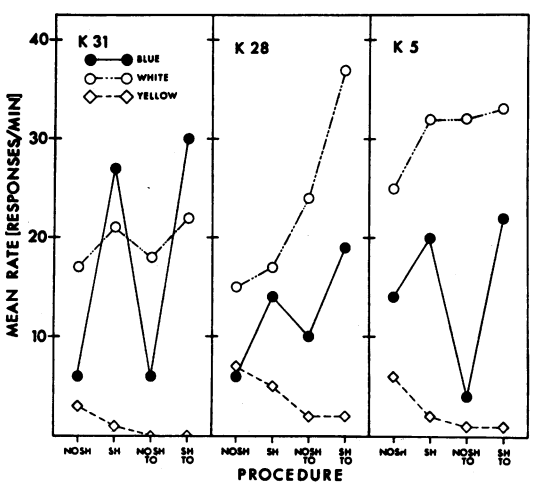

Fig. 3. Medians of average response rates in each stimulus during the last five sessions on each procedure in Exp. II. The notations on the abscissa indicate whether the blue stimulus terminated with a shock (SH: shock; NO SH: no shock) and whether TO followed the blue stimulus.

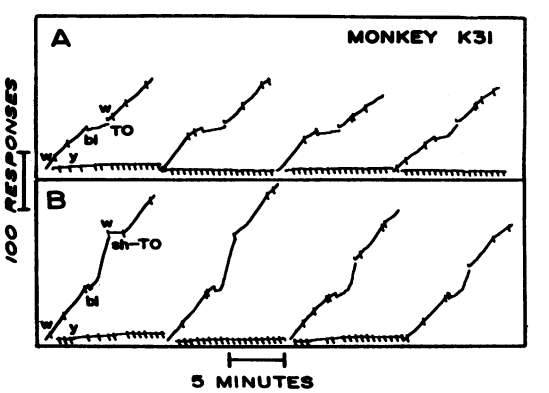

Fig. 4. Final performances of Monkey K31 during avoidance extinction with no shock at the termination of the blue stimulus and TO following it (A); and with shock at termination of the blue stimulus and TO following (B). The short diagonal lines in white indicate food reinforcements. The short diagonal lines in yellow do not indicate shocks; they indicate points at which shocks would have been delivered if the avoidance schedule were in effect.

they had been when TO did not follow the blue stimulus; however, for Monkey K5, response rates were consistently lower with TO than they had been without it.

Unavoidable Shock and TO Following Blue. Response rates became relatively high again in the presence of the blue stimulus, while avoidance response rates decreased to near zero. The response rates that developed in each stimulus are shown in the points indicated by SH TO on the abscissa of each frame of Fig. 3. Frame B of Fig. 4 shows that positively accelerated responding developed in the presence of blue. These results again show that responding in the presence of the blue stimulus was primarily controlled by unavoidable shocks terminating the stimulus, and that this effect can be demonstrated while avoidance responses are being extinguished.

Because the changes in VI response rate in this experiment were not consistent among the three *Ss* they are difficult to interpret. Presumably, the general trend toward high response rates in the VI component resulted from interactions among the components of the multiple schedule, such as contrast effects because of avoidance extinction, and TO (Reynolds, 1961). To minimize these interactions in subsequent experiments, *Ss* were on free-feeding and food reinforcements did not occur.

EXPERIMENT III

The purpose was to determine whether responding could be maintained in the pre-aversive stimulus after both avoidance responding and VI responding had been eliminated.

Procedure

Throughout this experiment (Sessions 111 to 155) *Ss* were on free-feeding, and both VI extinction and avoidance extinction were in effect. Shocks did not occur at the termination of the blue stimulus in Session 141 but were reinstated during Session 142 for Monkeys K28 and K5, and during Session 144 for Monkey K31.

Procedural changes were made only when inspection of cumulative response records and daily rates of responding indicated that performances were stable in each component of the multiple schedule.

Results

In Sessions 136 to 140, medians of average response rates in the presence of white and yellow stimuli were zero for all *Ss*. Medians of average response rates in the presence of the blue stimulus were 44 for Monkey K31, 11 for Monkey K28 and 9 for Monkey K5. These results show that responding can be maintained in a pre-aversive stimulus even when avoidance and VI performances have been extinguished. Figure 5 shows the effects of removing and reinstating unavoidable shocks at the termination of blue. The cumulative records have been cut into segments that show 2 min of white, 2 min of blue, and 2 min of white; time in yellow is not shown. Frame A shows records from Session 140. Positively accelerated responding was maintained in the blue stimulus. Frame B shows that response rates decreased to zero when shocks were eliminated in Session 141. Frame C shows that positively accelerated responding gradually recovered in the blue stimulus when shocks were reinstated in Session 142. Frame D shows records of the final performance in Session 155. Qualitatively similar results were obtained with Monkeys K28 and K31.

EXPERIMENT IV

The purpose was to determine whether responding in the presence of the blue stimulus could be maintained if responses produced the shock.

Procedure

In Session 156, the first response occurring after 2 min in the presence of the blue stimulus produced a shock, and the white stimulus appeared. After 4 min in the presence of white, blue reappeared. The blue stimulus remained in effect until a response produced a shock. For Monkeys K28 and K5, unavoidable shocks were again delivered in Sessions 157 to 168. For Monkey K31 response contingent shocks were in effect in Sessions 156 to 159; unavoidable shocks were delivered in Sessions 160 to 168.

Results

Monkeys K28 and K5 did not respond in the latter half of the first session (Session 156) in which shocks were response-contingent. In

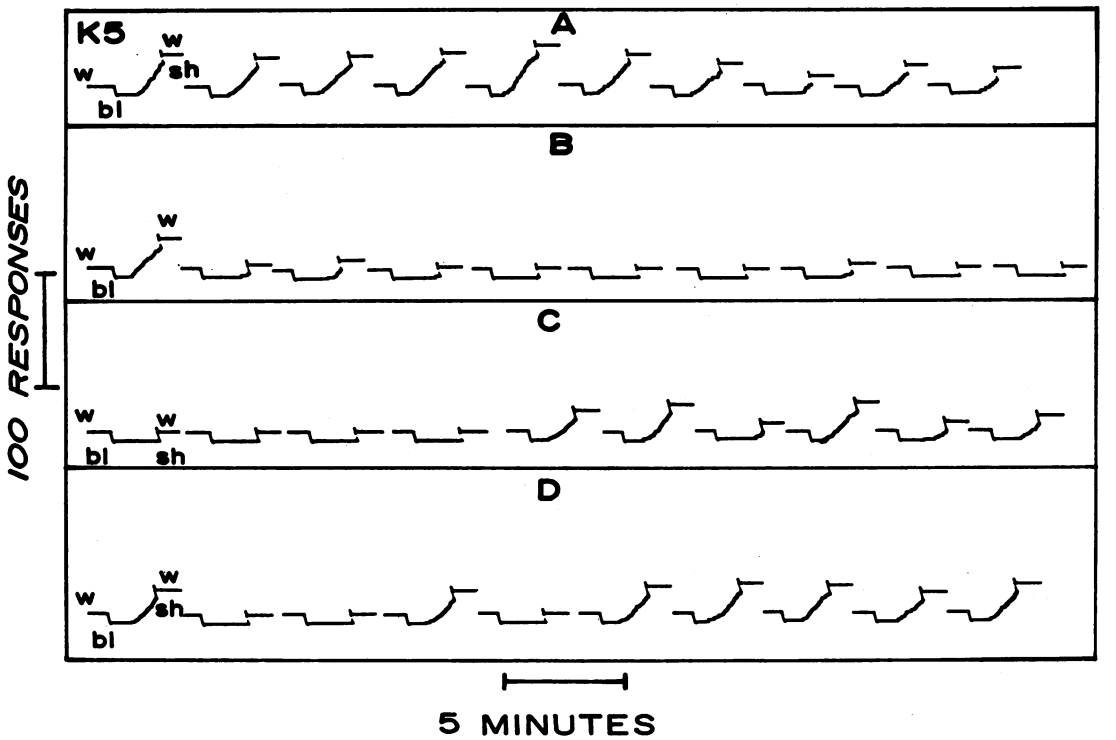

Fig. 5. Performance of Monkey K5 in the presence of the blue stimulus as a function of removing and reinstating the unavoidable shock. (A) An unavoidable shock occurs at the termination of the blue stimulus; (B) unavoidable shocks do not occur; (C) first session in which shocks are reinstated; (D) final performance with unavoidable shocks at the termination of the blue stimulus.

the following sessions, in which unavoidable shocks again terminated the blue stimulus, responding recovered in the presence of the blue stimulus. For Monkey K31, response-contingent shocks were in effect for four sessions. Cumulative response records from these four sessions are shown in Frames A to D of Fig. 6. Positively accelerated responding persisted in the presence of the blue stimulus; however, response rates slowly decreased until they were near zero at the end of Session 159. These results show that response-contingent shocks can eliminate responding in the presence of the blue stimulus.

EXPERIMENT V

The purpose was to determine the effects of reinstating and re-extinguishing avoidance responding.

Procedure

In Sessions 169 to 188 and Sessions 198 to 210, 10-min periods of yellow alternated with the 10-min periods of white and blue stimuli. Extinction was in effect in the presence of white, blue, and yellow stimuli; no shocks were delivered. In Sessions 189 to 197, the avoidance schedule was again in effect in the presence of the yellow stimulus; however, no shocks occurred at the termination of blue.

In Sessions 211 to 249, extinction was in effect in the presence of white, blue, and yellow stimuli; however, unavoidable shocks terminated the blue stimulus.

Results

Extinction in All Components. The response rates that developed in each stimulus are shown in the points indicated by NO SH EXT on the abscissa of each frame of Fig. 7. Response rates were near zero in all three components for Monkeys K31 and K5; however, Monkey K28 responded at an average rate of about 5 responses per min in all components.

Reinstatement of Avoidance in the Presence of Yellow. When shocks were again delivered in the presence of the yellow stimulus, re-

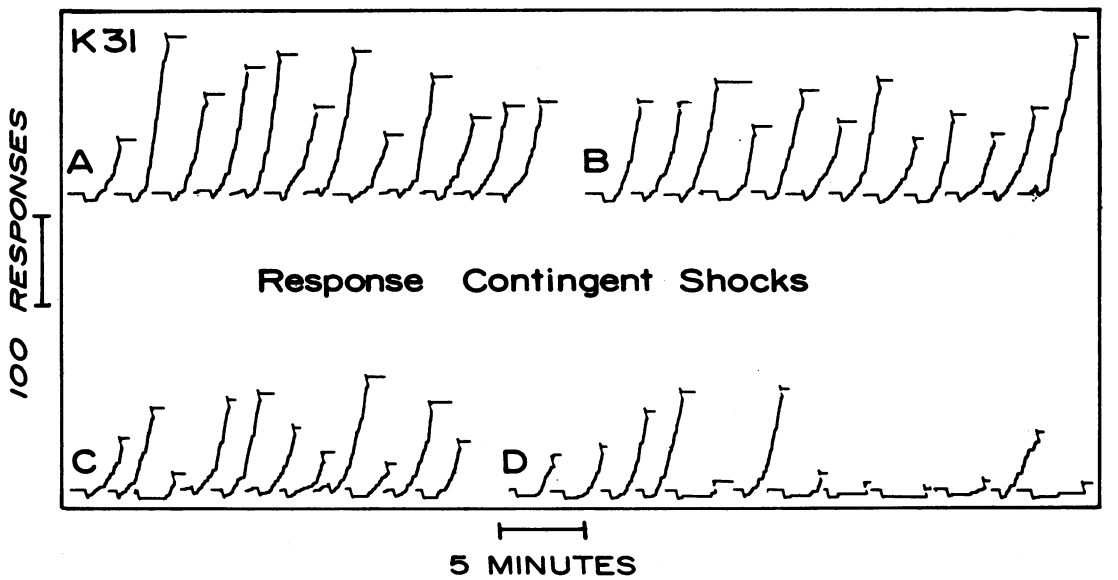

Fig. 6. Performance of Monkey K31 from four successive sessions in which response-contingent shocks occurred at the termination of the blue stimulus.

sponse rates increased to levels comparable to those maintained at the end of Exp. I. The points indicated by NO SH AV on the abscissa of each frame of Fig. 7 show that responding was consistently higher in the avoidance component than in the other components. For Monkeys K28 and K5, there was no overlap between the distributions of rates in the avoidance component and the other components. For Monkey K31, there was some overlap, but the response rate in the avoidance component was highest in every session.

Unavoidable Shock at the Termination of Blue with Extinction in All Components. The points indicated by SH EXT on the abscissa of each frame of Fig. 7 show that response rates in the presence of the blue stimulus increased markedly when unavoidable shocks again terminated the blue stimulus. The distributions of response rates in the presence of the blue stimulus did not overlap the distributions of rates in the other stimuli. These results show that even after a third extinction of avoidance responding (including preliminary experiments) in the presence of the yellow stimulus, unavoidable shocks generated and maintained responding in the presence of the blue stimulus.

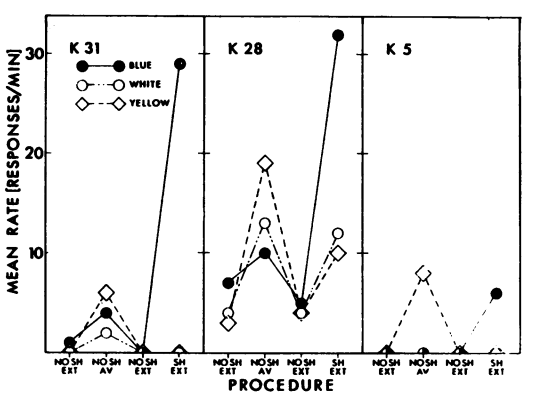

Fig. 7. Medians of average response rates in each stimulus during the last five sessions on each procedure in Exp. V. The notations on the abscissa indicate whether shocks terminated the blue stimulus (SH: shock; NO SH: no shock) and the schedule in the presence of the yellow stimulus (AV: avoidance; EXT: extinction). Throughout Exp. V, VI extinction was in effect in the presence of the white stimulus.

EXPERIMENT VI

The purpose was to determine whether unavoidable shocks could maintain responding in the presence of the blue stimulus even if the blue stimulus were present throughout each session.

Procedure

In Sessions 250 to 260, the blue stimulus was present throughout each session. Unavoidable shocks were delivered at 10-min intervals.

Responses were recorded, but they had no programmed consequences.

Results

The cumulative response records in Fig. 8 show representative performances of each *S* in Session 260. The medians of the average response rates in the last five sessions were 6 responses per min for Monkey K31, 14 responses per min for Monkey K28, and 5 responses per min for Monkey K5. The cumulative records show some instances of positively accelerated responding between shocks; however, responding frequently increased and then decreased as the 10-min interval elapsed. This experiment shows that responding in the presence of the blue stimulus is determined by unavoidable shocks rather than by the termination of the blue stimulus.

DISCUSSION

Under the multiple schedule used in the basic procedure, relatively high response rates in the presence of the blue, pre-aversive stimulus were maintained for more than 880 experimental hr. This finding confirms and extends the results of Herrnstein and Sidman (1958) in showing that a pre-aversive stimulus will increase rather than suppress food-reinforced responding in monkeys that have a history of avoidance conditioning.

Responding in the presence of a pre-aversive stimulus is jointly controlled by several variables. Experiment I showed that food reinforcements in the presence of the blue, pre-aversive stimulus were not necessary for the maintenance of responding as long as unavoidable shocks occurred at the termination of the blue stimulus. Similar results have occurred in studies of discrimination and stimulus generalization with continuous avoidance. Using multiple schedules comprised of alternating avoidance and extinction components, Appel (1960) and Hearst (1962) found that unavoidable shocks generated and maintained responding in the extinction components. After monkeys have been trained on a continuous avoidance schedule, unavoidable shocks can maintain responding in the presence of a stimulus that has never been correlated with avoidable shocks.

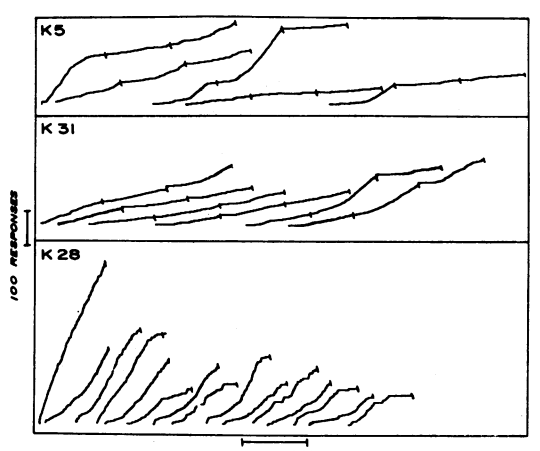

Fig. 8. Final performance with blue stimulus on throughout session, and unavoidable shocks occurring at 10-min intervals. Short diagonal lines indicate shocks.

Experiment II showed that unavoidable shocks could maintain responding in the presence of the blue stimulus even while avoidance responding was being extinguished by the omission of avoidable shocks.[2] Herrnstein and Sidman (1958) found that after avoidance extinction, the Estes-Skinner procedure suppressed food-reinforced responding. They concluded that avoidance extinction counteracts the effects of avoidance conditioning on responding in the pre-aversive stimulus. Their results do indicate that both monkeys continued to respond at low rates during most presentations of the pre-aversive stimulus. Although Monkeys K28 and K5 responded at lower rates in the pre-aversive stimulus than on the VI schedule in the white stimulus, the results of Exp. II showed that responding in the pre-aversive stimulus was primarily controlled by unavoidable shocks even when avoidance response rates were near zero. In the Herrnstein and Sidman study, the responding that occurred in the pre-aversive stimulus after avoidance extinction may have been maintained by unavoidable shocks. As shown in Exp. III and V the effects of unavoidable shocks were most apparent when the pre-aversive stimulus was superimposed on ex-

[2]After this article was submitted for publication, a similar study appeared in which Waller and Waller (1963) showed that Beagle dogs that had been trained on continuous shock avoidance would continue to respond in a pre-aversive stimulus even when avoidance responses had been extinguished. The results of the present study with squirrel monkeys are generally consistent with the results Waller and Waller obtained with dogs.

tinction. Even when *Ss* had free access to food and extinction was in effect in all stimuli, responding persisted in the pre-aversive stimulus.

It is possible that responding in the presence of the pre-aversive stimulus persisted because of accidental correlations with the termination of the blue stimulus; *i.e.*, positively accelerated responding in the presence of the pre-aversive stimulus might have been superstitious escape behavior. Experiment VI showed that responding could be maintained even when the blue light was on throughout each session and unavoidable shocks occurred at 10-min intervals.

Why was responding maintained by unavoidable shocks? To date, this type of phenomenon has been demonstrated only in animals that have a history of responding on a continuous avoidance schedule. Some investigators have interpreted responding in pre-aversive stimuli as superstitious avoidance responding (Sidman, *et al.*, 1957; Herrnstein and Sidman, 1958). Although shocks are actually unavoidable there are variable time intervals between responses and shocks, and Sidman and Boren (1957) have shown that responding can be maintained with variable response-shock intervals. In Exp. III shocks occurred immediately after a response, and responding was eliminated. It seems likely that the paradoxical increases in responding that are generated and maintained by unavoidable shocks are instances of superstitious avoidance conditioning; however, it is difficult to interpret all the findings in this way.

Herrnstein and Sidman (1958) found that when the monkeys were returned to the Estes-Skinner procedure after avoidance conditioning, increased response rates occurred in the first presentation of the pre-aversive stimulus. As the pre-aversive stimulus had not been present during avoidance training, and an unavoidable shock had not yet occurred following responding in the pre-aversive stimulus, the usual conditions for the development of superstitious conditioning were not present. In the present study, changes in avoidance response rates did not correlate with changes in the response rates in the pre-aversive stimulus; responding persisted in the pre-aversive stimulus even when avoidance responding had been eliminated. A careful specification of the essential conditions for superstitious avoidance conditioning will be required if this interpretation is to be useful.

The substantial levels of behavior shown in Fig. 8 were maintained only by the intermittent delivery of unavoidable electric shocks. Behavior that persists because of the repeated occurrence of an unavoidable aversive stimulus could be classified as abnormal. As Sidman (1960) has indicated, however, the meaning of the term abnormal must be specified. In the present experiment, all *Ss* exhibited this abnormal behavior, and presumably the results could be replicated with other monkeys. Since abnormal behavior is a normal occurrence under these experimental conditions, it is the experimental conditions that are abnormal. To the extent that the essential aspects of these experimental conditions can be specified, the abnormal behavior can be understood and controlled. On the basis of the present results, as well as those of others, it appears that a history of continuous avoidance conditioning is sufficient to establish the unusual effects of subsequent unavoidable shocks. Many questions remain to be answered by future studies of this phenomenon. For example, how much avoidance training is necessary? Can the effects of avoidance training be reversed? Can the phenomenon be demonstrated after training on other schedules of aversive control, such as escape schedules? Experiments designed to answer such questions are currently in progress.

REFERENCES

Appel, J. B. Some schedules involving aversive control. *J. exp. Anal. Behav.*, 1960, **3**, 349-359.

Azrin, N. H. Some effects of two intermittent schedules of immediate and non-immediate punishment. *J. Psychol.*, 1956, **42**, 3-21.

Brady, J. V. Extinction of a conditioned "fear" response as a function of reinforcement schedules for competing behavior. *J. Psychol.*, 1955, **40**, 25-34.

Brady, J. V. and Hunt, H. F. An experimental approach to the analysis of emotional behavior. *J. Psychol.*, 1955, **40**, 313-324.

Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *J. exp. Psychol.*, 1941, **29**, 390-400.

Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. Appleton-Century-Crofts, New York: 1957.

Hearst, E. Concurrent generalization gradients for food-controlled and shock-controlled behavior. *J. exp. Anal. Behav.*, 1962, **5**, 19-31.

Herndon, J. F., Greenberg, S. M., Van Loon, E. J., Kelleher, R. T., Cook, L., and Davidson, A. A

liquid diet for animals in behavioral studies. *J. exp. Anal. Behav.*, 1958, **1**, 291-292.

Herrnstein, R. J. and Sidman, M. Avoidance conditioning as a factor in the effects of unavoidable shocks on food-reinforced behavior. *J. comp. physiol. Psychol.*, 1958, **51**, 380-385.

Kelleher, R. T. and Cook, L. An analysis of the behavior of rats and monkeys on concurrent fixed-ratio avoidance schedules. *J. exp. Anal. Behav.*, 1959, **2**, 203-211.

Morse, W. H. An analysis of responding in the presence of a stimulus correlated with periods of nonreinforcement. Unpublished doctoral dissertation, Harvard University, 1955.

Morse, W. H. and Skinner, B. F. A second type of superstition in the pigeon. *Amer. J. Psychol.*, 1957, **70**, 308-311.

Reynolds, G. S. An analysis of interactions in a multiple schedule. *J. exp. Anal. Behav.*, 1961, **4**, 107-117.

Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953, **118**, 157-158.

Sidman, M. Drug-behavior interaction. *Ann. N. Y. Acad. Sci.*, 1956, **65**, 282-302.

Sidman, M. Normal sources of pathological behavior. *Science*, 1960, **163**, 61-68.

Sidman, M., Herrnstein, R. J., and Conrad, D. G. Maintenance of avoidance behavior by unavoidable shocks. *J. comp. physiol. Psychol.*, 1957, **50**, 553-557.

Sidman, M. and Boren, J. J. The use of shock-contingent variations in response-shock intervals for the maintenance of avoidance behavior. *J. comp. physiol. Psychol.*, 1957, **50**, 558-562.

Stein, L., Sidman, M., and Brady, J. V. Some effects of two temporal variables on conditioned suppression. *J. exp. Anal. Behav.*, 1958, **1**, 153-162.

Valenstein, E. S. The effect of reserpine on the conditioned emotional response in the guinea pig. *J. exp. Anal. Behav.*, 1959, **2**, 219-225.

Waller, M. B. and Waller, P. F. The effects of unavoidable shocks on a multiple schedule having an avoidance component. *J. exp. Anal. Behav.*, 1963, **6**, 29-37.

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