BY-PRODUCTS OF AVERSIVE CONTROL

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An experimental organism may receive a shock when it emits a specific response ("punishment"), or only if it fails to emit such a response ("avoidance"). Observations based upon these techniques are characteristically confined to the behavior whose occurrence or nonoccurrence explicitly controls the shock Estes and Skinner, however, noted that shocks may generate additional effects upon other behavior which is independent of any programmed correlation with the shock, and they presented a technique for studying such effects (4). They found that a lever-pressing operant, maintained by food reinforcement on a fixed-interval schedule, will decrease in frequency in the presence of a stimulus that has preceded unavoidable shock ("free" shock). Occurrence of the shock was in no way under the control of the recorded behavior.

The Estes-Skinner conditioned-suppression phenomenon was confirmed in later studies which utilized variations of the original procedure. Among such variations was the use of different reinforcement schedules to maintain the baseline behavior, e.g., continuous reinforcement (1, 8), variable interval (2), and fixed ratio (1). More recently, however, it has been shown that if the baseline operant has had a history of avoidance conditioning, the pre-shock stimulus will, at least temporarily, be accompanied by an increased rate of response instead of suppression (7, 10). The suggestion was offered that the responses in the presence of the stimulus actually constitute adventitiously reinforced avoidance behavior. The present series of experiments began with an attempted *tour de force*, designed to provide evidence consistent with the latter suggestion. The plan was to demonstrate in the individual rhesus monkey both the suppressive and facilitative functions of the pre-shock stimulus simultaneously. Behavior under the control of food reinforcement was expected to display suppression in the presence of a pre-shock stimulus, while at the same time a second response, with a history of shock avoidance, was expected to show an increase in rate.

METHOD

Concurrent VI and Avoidance, Two Levers

Two levers, 6 inches apart vertically, were on one wall of the experimental primate chamber (3, 10). Responses on the lower lever (Lever A) produced food reinforcement on a 4-minute, variable-interval (VI) schedule, while each depression of Lever B postponed a shock for 20 seconds. Shock was delivered any time 20 seconds elapsed without a response on Lever B. Both the VI schedule and the avoidance program were in effect concurrently. Each food reinforcement consisted of 1 milliliter of canned orange-grapefruit juice, with sucrose added to a concentration of 15 per cent by weight. Shock intensity was approximately 5 milliamperes, and the duration of each shock was fixed at approximately 1 second (10).

Stimulus followed by Unavoidable Shock

In certain phases of the investigation, indicated in the body of the report, the subjects received unavoidable ("free") shocks. When unavoidable shocks were administered, they were spaced 10 minutes apart, and were preceded by a stimulus (clicking noise) 5 minutes long. The free-shock procedure, therefore, consisted of 5-minute periods of stimulus-off alternating with 5-minute periods of stimulus-on. An unavoidable shock always occurred simultaneously with stimulus termination. Whenever the free-shock procedure was used, avoidance extinction was programmed at the same time. That is to say, the only shocks delivered were the unavoidable ones, regardless of whether or not the subject pressed the avoidance lever.

All experimental sessions were 6 hours. Prior to each session, the monkeys were deprived of food and water for approximately 36 hours.

RESULTS

I. *Stimulus and Unavoidable Shock Superimposed upon Concurrent VI and Avoidance Extinction. Two levers.*

Monkey R-15 had been exposed to concurrent VI and avoidance procedures for 19 sessions (114 hours). The number of responses on each lever during the last five of these sessions may be seen in the first frame of Fig. 1.

The stimulus-followed-by-free-shock procedure was then instituted for the first time, and was continued through the next four sessions. During this period, shock avoidance was no longer programmed and the baseline procedure was, therefore, concurrent VI and avoidance extinction. One response (Lever A) was maintained by food reinforcement and the other (Lever B) simultaneously by a *history* of shock avoidance. On the basis of previous analyses (7, 10), the pre-shock stimulus was ex-

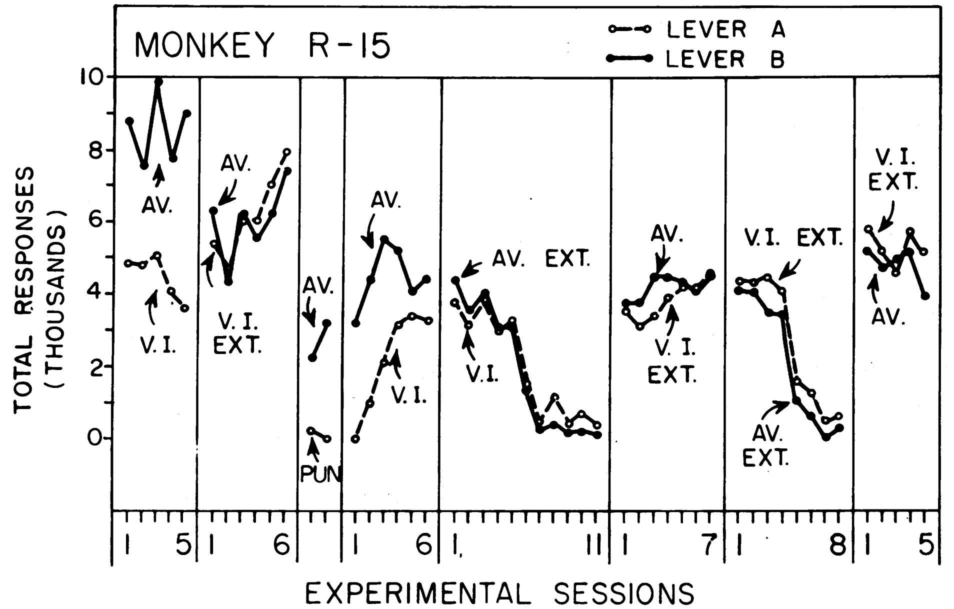

Figure 1. Monkey R-15. Total responses per session on each lever. Labels on each curve refer to the experimental procedures. AV-shock avoidance; VI-variable-interval food-reinforcement schedule; AV. EXT.-shock disconnected; VI. EXT-feeder disconnected; PUN-each response produces the shock. Beginning with the second frame, all sessions are consecutive.

pected to suppress the food response and increase the rate of the former avoidance response.

The failure of this expectation is evident, in summary form, in the leftmost frame of Fig. 2. For each lever separately, the total number of responses during the stimuli was divided by the total number in the absence of the stimuli. The first frame of Fig. 2 shows this ratio, plotted on a logarithmic ordinate, during the initial five sessions of stimulus-shock pairings.

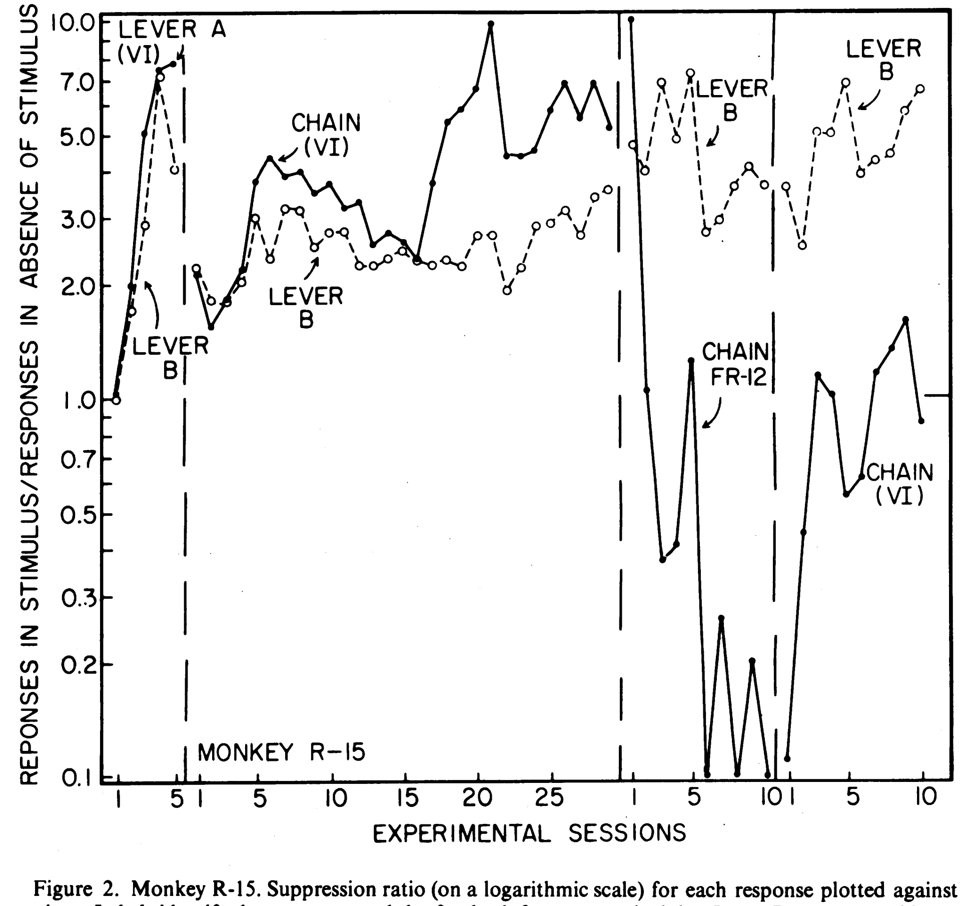

Figure 2. Monkey R-15. Suppression ratio (on a logarithmic scale) for each response plotted against sessions. Labels identify the responses and the food-reinforcement schedules. Lever B was on avoidance extinction throughout all the sessions of this figure. Beginning with the second frame, all sessions are consecutive.

If there were no difference in rate during and between stimuli, the ratio would equal 1.0. Response suppression during the stimulus would bring the ratio below 1.0, while a relatively higher rate of responding during the stimulus would increase the ratio above 1.0. During the first session there was no relative change in rate on either lever in the presence of the stimulus. In the four succeeding sessions, however, both responses displayed a markedly higher rate while the pre-shock stimulus was on. Instead of the expected suppression of the food response and facilitation of the avoidance response, there was facilitation of both responses during the stimulus.

Behavior on the two levers was recorded concurrently and independently on separate cumulative recorders. A portion of the records from Session 2, presented in Fig. 3, illustrates in detail the remarkable correspondence between the behavior on the two levers. There are few responses on either lever between stimuli. During the stimuli the initial periods of no response appear simultaneously on each record, as do the high terminal rates prior to the unavoidable shock. There is a high correlation between the total number of responses on each lever during the stimulus periods.

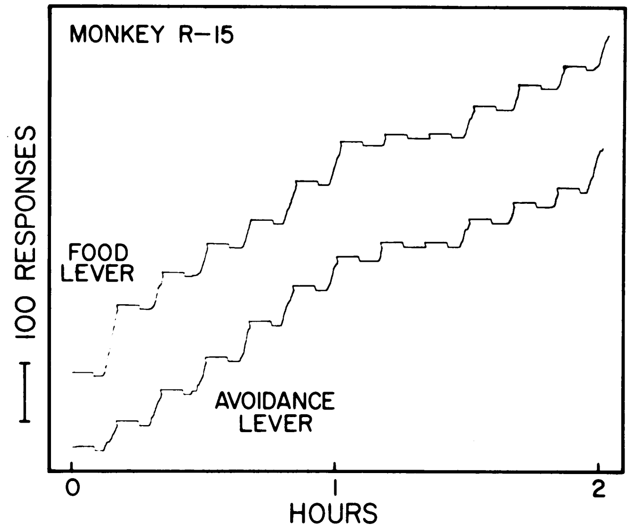

Figure 3. Monkey R-15. Concurrent cumulative records of responding on both levers. The portions of the records displaced obliquely downward denote periods during which the pre-shock stimulus was present.

II. *Independent Conditioning and Extinction of the Two Lever-pressing Responses*

As noted previously, the investigation began as an attempt to demonstrate simultaneously the suppressive and facilitative functions of a pre-shock stimulus, depending upon the reinforcement history of the two responses. The facilitative effect had previously been interpreted as avoidance behavior (10), and was demonstrated to occur even in a food-reinforced response that had a history of shock avoidance (7). The appearance of facilitation, as described above, in a response that had no avoidance history might have led to a reconsideration of the earlier interpretation. Before attempting such a re-evaluation, however, it was necessary to determine whether the concurrent procedure in the attempted demonstration actually generated two independent operants.

Nonindependence in the present case might have resulted from any or all of several possible factors. The two responses, for example, were similar in topography and the levers were spatially close together. Another possible mechanism is that of adventitious chaining, through which the two responses might have acquired an overlapping reinforcement history.

The animal was free to perform the two responses in any sequence. While the programming apparatus required only a response on Lever B to postpone the shock, a frequent occurrence of the sequence "Lever A followed by Lever B" might well establish the *sequence* as a superstitious avoidance response (12). Lever A would consequently possess an avoidance component and it, too, might then show an increased rate in the presence of the pre-shock stimulus.

The first task was to determine whether the concurrent procedure actually generated two independent operants. A simple method of testing for independence was to attempt extinction and reconditioning of each response separately. Details of the procedure are most conveniently presented in conjunction with the results.

Figure 1 presents the results of a series of experiments with Monkey R-15. Reference has already been made to the first frame, which shows the avoidance and VI rates prior to the stimulus-shock pairings of Phase I. The second frame begins immediately after the latter pairings, and all subsequent sessions are consecutive.

After the last of the stimulus-shock pairings, the avoidance contingency was reinstated on Lever B. At the same time, the feeder was disconnected and Lever A was placed on extinction. The second frame of Fig. 1, however, shows no decline in rate on the former VI lever for six sessions.

During the next two sessions, each response on Lever A was punished. That is to say, each Lever A response produced a shock. The feeder remained disconnected. As the third frame of Fig. 2 shows, the number of responses on Lever A dropped to zero. Although the rate of avoidance responding also declined, a substantial output was still maintained on Lever B. The separation of response rates indicates that the two levers were discriminable from each other, at least on a program of concurrent punishment and avoidance.

During the following six sessions, the punishment contingency was eliminated, and the feeder again delivered reinforcement on the variable-interval schedule. The fourth frame of Fig. 1 shows the gradual recovery of responding on Lever A.

Up to this point the data strongly suggested that the Lever A response, though reinforced by food on a variable-interval schedule, was also being controlled by the avoidance contingency. In order to check this suggestion further, the shock power supply was disconnected during the next 11 sessions, thus placing the avoidance response (Lever B) on extinction. During this period, Lever A responses could produce reinforcement on the variable-interval schedule. The changes in response rate on both levers may be seen in the fifth frame of Fig. 1. Following the elimination of the shock the rate of avoidance responding declined, as was to be expected. At the same time, the rate on the food-reinforced lever declined.

It seemed clear at this point that the behavior on Lever A was, indeed, being controlled in some way by the avoidance contingency. The following sessions provided additional confirmation. During the next seven sessions provided additional con-
additional confirmation. During the next seven sessions the shock was again connected and the avoidance contingency reinstated. At the same time, the feeder was disconnected from the circuit. The rate on both levers increased markedly (sixth frame in Fig. 1). In the following eight sessions, both feeder and shock were taken

out, and extinction occurred on both levers (seventh frame in Fig. 1). But when the avoidance contingency alone was re-established during the next five sessions, the output on both levers returned to a high level, in spite of the fact that Lever A was still on an experimental extinction procedure (last frame of Fig. 1).

A similar series of manipulations was carried out for Monkeys R-10 and R-17. The data for Monkey R-10 may be seen in Fig. 4. Again, the Lever A response failed to extinguish completely until the avoidance response was also extinguished. The variable-interval schedule did, however, appear to exercise greater control over Lever A than it did for Monkey R-15. In Monkey R-17, however, a high degree of dependence upon the avoidance contingency was again demonstrated by the food-reinforced lever (Fig. 5).

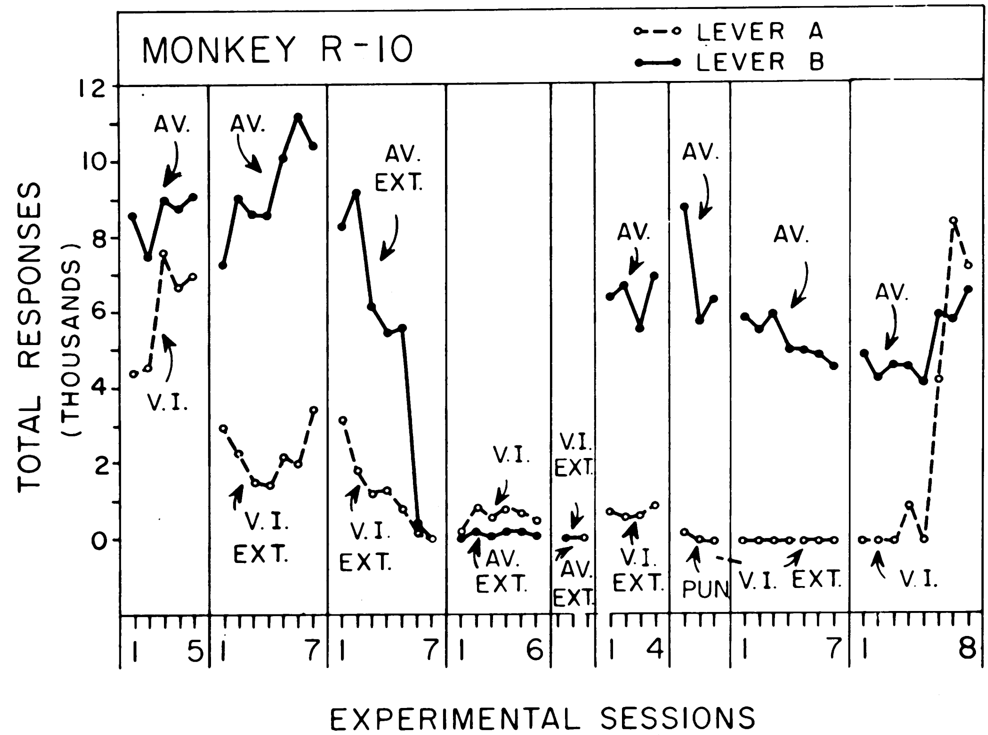

Figure 4. Monkey R-10. Total responses per session on each lever. Labels are the same as in Fig. 1. Beginning with the second frame, all sessions are consecutive.

III. *Substitution of a Chain-pulling Response for Lever A. Independent Conditioning and Extinction of the Two Responses.*

The initial failure of the pre-shock stimulus to produce suppression of responding on the food-reinforced lever now becomes somewhat more comprehensible. Although the programming apparatus set up a variable-interval food-reinforcement schedule, Lever A had somehow become involved in the avoidance contingency that was programmed for Lever B. The avoidance component could be responsible for the increased rate on Lever A during the pre-shock stimulus (Phase I).

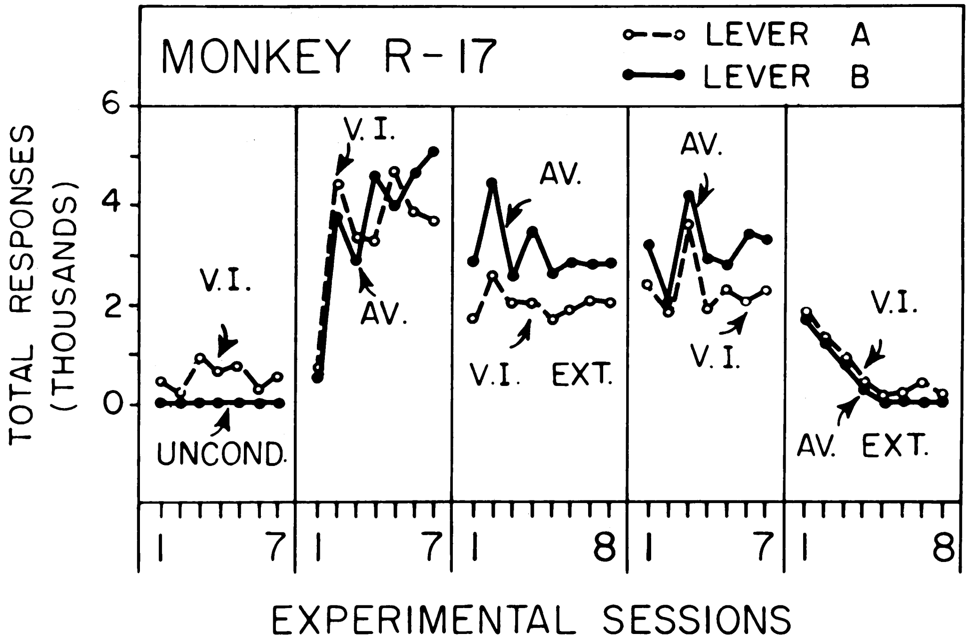

Figure 5. Monkey R-17. Total responses per session on each lever. UNCOND.—rate on Lever B prior to avoidance conditioning. Other labels are the same as in Fig. 1 and 4. All sessions are consecutive.

While it seemed far afield from the original objective of the experiment, the involvement of ostensibly irrelevant behavior in the avoidance contingency appeared to constitute a by-product of aversive control that was worth following up experimentally. In order to test for topographical induction (11), Lever A was removed from the chamber and a chain was hung from the center of the ceiling. Chain-pulling responses now produced food reinforcement while Lever B responses still postponed the shock. In order to determine the effects of the difference in apparent topography and location of the two responses, another series of conditioning and extinction experiments was carried out, similar to Phase II.

With Monkey R-10, the food-reinforced chain-pull displayed the same dependence upon the avoidance contingency as had the Lever A response in the preceding experiments. Monkeys R-15 and R-17 showed a mixed and perhaps contradictory effect. The chain-pulling response did extinguish almost completely when the feeder was disconnected, even though the avoidance contingency was still in effect for Lever B. On the other hand, with the feeder connected, the rate of chain-pulling was higher when avoidance was programmed concurrently than when the avoidance response was extinguished.

IV. *Stimulus and Unavoidable Shock Superimposed upon Concurrent VI and Avoidance Extinction. Chain and Lever*

The evidence for or against complete independence of the chain and lever responses was unclear for Monkeys R-15 and R-17 in Phase III. Substitution of the chain for Lever A did, however, seem to increase the degree of independence of the two responses with these animals. The stimulus-unavoidable-shock pairings were therefore re-introduced, as in Phase I. With a baseline schedule of concurrent VI and avoidance extinction, the stimulus was presented during alternate 5-minute periods. The only shocks were those delivered coincidentally with the termination of each stimulus.

The left-hand section of Fig. 6 (labelled VI) presents the summary data for Monkey R-17 during the 16 consecutive sessions of stimulus-shock pairings. In the first few sessions, the rate of both responses increased during the pre-shock stimuli. Although the higher rates in the presence of the stimulus eventually disappeared, as has been reported previously in a single-response situation (10), a large difference with respect to the degree of suppression failed to develop between the two responses.

Monkey R-15 also displayed a relatively higher rate of both responses during the stimulus, as is shown in the second section of Fig. 2. The cumulative records for this animal strongly resembled the one reproduced in Fig. 3, in spite of the substitution of a chain for Lever A. This monkey was somewhat unusual with respect to the large number of sessions over which the higher rates persisted during the pre-shock stimulus.

V. *Measurement of Response Sequences*

Substitution of the chain-pulling response for lever response A did not completely eliminate the dependence of the food-reinforced behavior upon the avoidance contingency (Phase III). Nor did it prevent facilitation of the food-reinforced response in the presence of the pre-shock stimulus (Phase IV). The next stage of the investigation was devoted to an examination of the possibility that the food-reinforced behavior had become adventitiously linked to the avoidance response. If the two responses were frequently emitted in sequence, the reinforcement for the avoidance behavior might be expected to extend also to response A. In that case, the food-reinforced response would develop an avoidance component, even though its

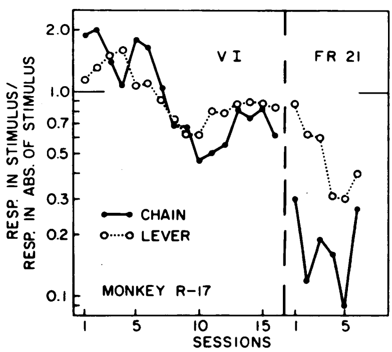

Figure 6. Monkey R-17. Suppression ratio (on a logarithmic scale) for each response plotted against sessions. VI and FR 21 identify the food-reinforcement schedules for the chain-pulling response. The lever was on avoidance extinction throughout.

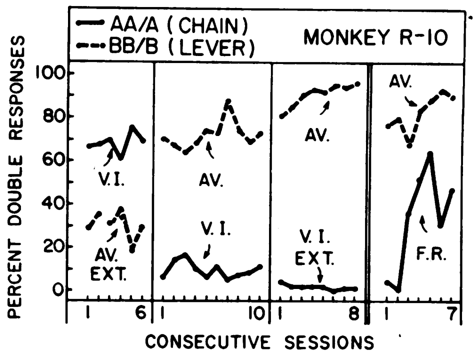

Figure 7. Monkey R-10. Percentage of double responses on the chain and the lever during consecutive sessions. Labels identify the program for each response.

occurrence prior to response B was not required in order for the shock to be postponed.

The first step was to determine whether the two responses were actually occurring in sequences of the sort that would favor the development of a superstitious chain. A recording system was therefore instituted to determine a count of the four possible double sequences (AB, AA, BA, and BB) in which the two responses could participate during each session.

With Monkey R-10 the sequence recording was begun part way through Phase III of the investigation (independent conditioning and extinction of the chain and lever responses). The results may be seen in the first three sections of Fig. 7. Plotted here is the percentage of double responses during each session, i.e., the proportion of all A-responses (food chain) that was followed by another A-response, and the proportion of all B-responses (avoidance lever) that was followed by another B-response. The higher the proportion of double responses, the lower the percentage of alternations. During the first six sessions represented in Fig. 7, the procedure was concurrent VI on the chain and extinction on the avoidance lever. During this stage there was a relatively high probability (about 0.70) that the chain-pulling response would be followed by a repetition of itself. There was only a low probability, however (about 0.30), that two avoidance responses would occur in succession.

When the avoidance contingency was reinstated during the following 10 sessions, there was a marked change in the response sequences (second frame of Fig. 7). Not only was there a high probability that two avoidance responses would occur in sequence, but also that a chain-pull would be followed by an avoidance response rather than by another chain-pull. This is exactly the pattern that would bequired in order for the food-reinforced response to come under control of the reinforcement for avoidance behavior. When food reinforcement was discontinued, during the following eight sessions, the differences shown in the second frame of Fig. 7 were simply accentuated, as might be expected.

Monkey R-17 displayed a similar but somewhat more complex picture. Sequence recording was begun during Phase IV of the investigation, when the stimulus-shock pairings were being programmed. Sequence counts were recorded separately in the presence and absence of the pre-shock stimulus. The results may be seen in the first frame of Fig. 8. During the first seven sessions there was an extremely high likelihood that the B-response (lever) would be followed by a repetition of itself, both in the presence and absence of the stimulus. In the following sessions, the probability of BB sequences declined markedly. Repetitions of the food-reinforced response show an opposite trend. These began low and gradually increased in probability. A comparison of the first frames of Fig. 6 and 8 will reveal a relation between the probability of alternating sequences and the degree of suppression or facilitation of each response. The start of the decline in the probability of AB alternation slightly precedes the emergence of suppression during the pre-shock stimulus.

The response sequences again show just those conditions that are likely to involve the chain-pulling response in the avoidance contingency. In Monkey R-15, the situation is particularly clear. Sequence recording was also instituted during Phase IV, when the clicker-shock pairings were being presented. It may be recalled (the second section of Fig. 2) that in this monkey the facilitating effect of the pre-shock

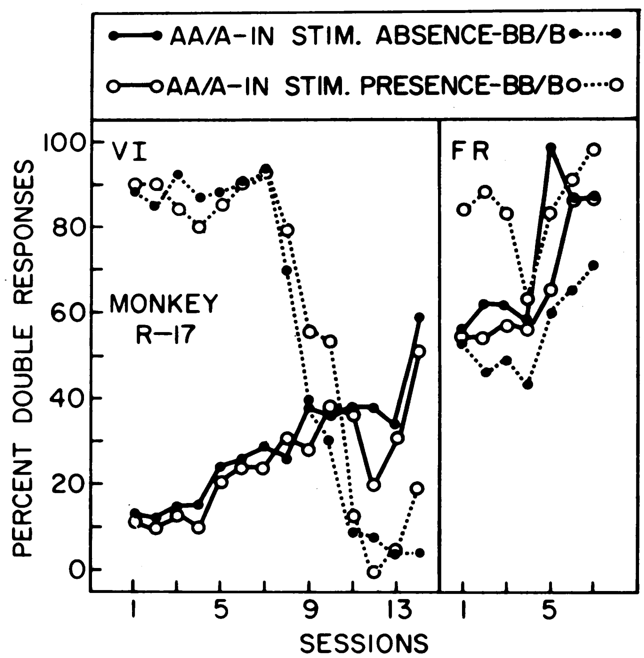

Figure 8. Monkey R-17. Percentage of double responses per session on the chain (A) and the lever (B). Solid lines represent the chain-pulling response, and dotted lines the lever-pressing response. Open and filled circles represent the stimulus and between-stimulus periods, respectively. VI and FR refer to the food-reinforcement schedule.

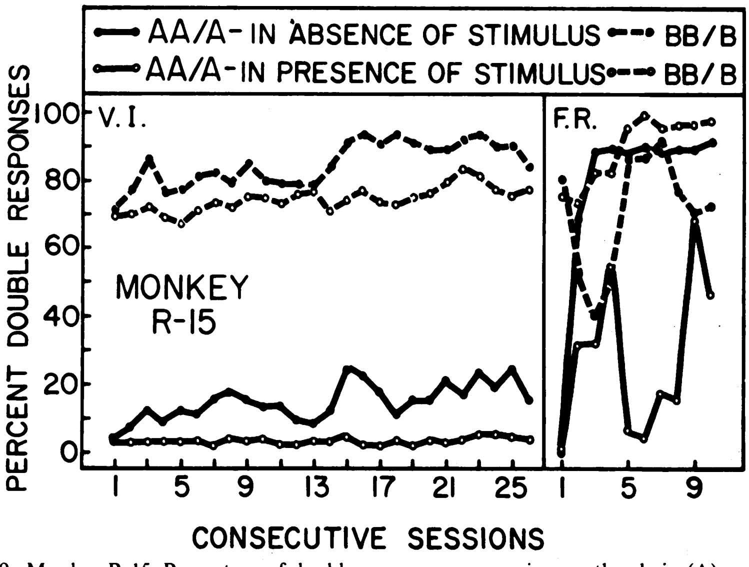

Figure 9. Monkey R-15. Percentage of double responses per session on the chain (A) and the lever (B). The key is the same as in Fig. 8. The sessions are the same as those beginning with Session 4 in the second frame of Fig. 2.

stimulus was both marked and persistent. The first frame of Fig. 9 shows a corresponding consistency in percentages of double-response sequences. B-responses tended to be repeated both in the presence and absence of the pre-shock stimulus, while chain-pulling responses tended to be followed by lever-pressing responses throughout. Both responses displayed a slightly but consistently greater tendency toward alternation in the presence of the stimulus than in its absence.

VI. *Stimulus and Unavoidable Shock Superimposed upon Concurrent FR and Avoidance Extinction. Chain and Lever*

The high probability of AB pairings revealed a mechanism through which the food-reinforced response could have been reinforced adventitiously by shock avoidance. There was abundant opportunity for accidental correlations between the food-reinforced response and the reinforcement for the avoidance behavior. The avoidance component of the food-reinforced response could likely be eliminated by breaking up the AB sequences in some manner.

The technique that was selected to decrease the frequency of AB pairings was to place the food-reinforced response on a fixed-ratio reinforcement schedule, rather than the variable-interval schedule that had been used up to this point. Since the fixed-ratio schedule tends to favor reinforcement of rapid bursts of responses (6, 11), several A-responses would probably now occur in succession before the animal switched over to the B-response.

The last frame of Fig. 7 presents the double-response sequences for Monkey R-10 after the introduction of a requirement of 12 responses per reinforcement. The percentage of times that the chain-pulling response was followed by a repetition of itself now increased markedly.

Immediately following the seventh session on the new schedule, the pairings of stimulus and unavoidable shock were introduced. The baseline was now concurrent FR and avoidance extinction. This was the initial exposure of Monkey R-10 to the stimulus-shock pairings in the present experiments, though the animal had participated in a similar single-lever experiment (10).

Figure 10 shows an initial facilitation of the former avoidance response by the pre-shock stimulus, and, for the first time, a simultaneous suppression of the food-reinforced response. As noted previously, the facilitative effect declined with continued exposure to the procedure (10), but even after 16 sessions there was a marked difference in the degree of suppression of the two responses.

Monkey R-17 was changed to a fixed-ratio schedule of 21 A-responses per reinforcement, and the avoidance response was concurrently reconditioned immediately after Phase IV. The unavoidable-shock procedure was then initiated. Changes in the double-response sequences, both in the presence and absence of the pre-shock stimuli, may be seen in the right-hand frame of Fig. 8. (Since the avoidance response had been reconditioned prior to the re-introduction of the stimulus-shock pairings, the data under FR should be compared with the *early* VI data in the first section of Fig. 8.) Both in the presence and absence of the stimulus, the percentage of AA sequences was considerably higher with a fixed-ratio schedule than with a variable-interval. The new schedule was, to a certain extent, successful in breaking up the AB alternation pattern. There were also some changes in the BB sequences,

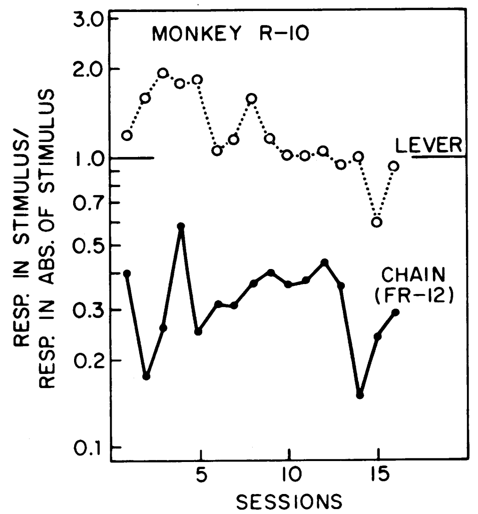

Figure 10. Monkey R-10. Suppression ratio (on a logarithmic scale) for the lever- and chain-pulling response plotted against consecutive sessions.

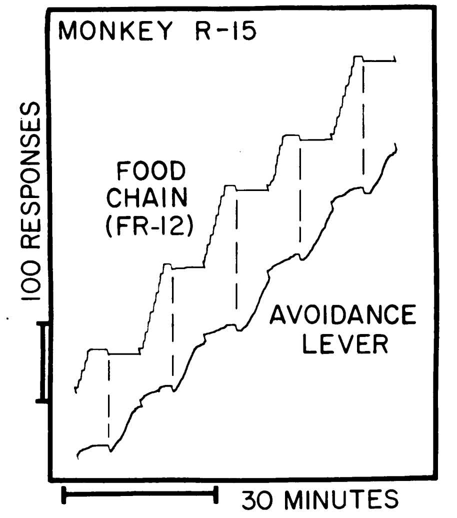

Figure 11. Monkey R-15. Concurrent cumulative records of responding on the chain and on the lever. The portions of the records displaced obliquely downward denote periods during which the pre-shock stimulus was present. The broken lines connect temporally corresponding points (stimulus onset) on each curve.

e.g., the percentage of times that B-responses followed upon each other was consistently lower in the absence of the pre-shock stimulus than in its presence.

The effects of the pre-shock stimulus upon the new baseline behavior are shown in the right-hand section of Fig. 6. While the lever-pressing response did not show facilitation in the presence of the stimulus (the reasons for this will be discussed below), the chain-pulling response was considerably more suppressed throughout the six sessions. Even in 16 sessions on the VI schedule (left-hand section of Fig. 6) the food-reinforced response had never displayed a comparable degree of suppression.

Monkey R-15 was switched to FR-12 while the stimulus-followed-by-free-shock procedure was in effect. The sessions shown in the right-hand frame of Fig. 9 follow those in the left-hand frame without any intervening manipulations. On the VI schedule, as we have seen, the percentage of AA sequences was low in both the presence and absence of the pre-shock stimulus. After the change to fixed ratio, the percentage of AA sequences in the absence of the stimulus increased to about 0.90. There was also a marked but lesser increase in AA sequences during the stimuli. The fixed-ratio schedule had, therefore, again succeeded in breaking up the AB alternation pattern to a considerable extent.

Concomitant with the decline in frequency of AB alternation was a striking change in the rate of the chain-pulling response during the pre-shock stimulus. The change may be seen in the third section of Fig. 2. The 10 sessions shown here were immediately consecutive to those in the preceding section of the figure. Instead of facilitation, the food-reinforced responses now showed almost complete suppression in the presence of the pre-shock stimulus. Lever B, on the other hand, continued to display a relatively higher response rate during the stimulus than in its absence.

A sample of the cumulative records of the two responses is presented in Fig. 11, which may be compared with Fig. 3 for a striking demonstration of the behavioral changes induced by the fixed-ratio schedule. Between stimuli, the curve for the chain-pulling response (Fig. 11) displays the alternating high rates and post-reinforcement pauses characteristic of fixed-ratio behavior (11). In the presence of the stimuli, the rate of chain-pulling is close to zero. (Temporal conditioning may also be observed in that the suppression actually begins prior to the stimulus onset.) On the avoidance lever, in contrast, the response rate during the stimuli is considerably higher than between stimuli, though there is occasional evidence of suppression even in this response just prior to the shocks.

Immediately after the 10 sessions in which the fixed-ratio schedule was used with Monkey R-15, the chain-pulling response was returned to the variable-interval program. The last section of Fig. 2 suggests that the return to VI markedly attenuated the suppression. The rate of chain-pulling, however, was extremely low, both in the presence and absence of the stimulus, and the behavior did not at all resemble that in Fig. 3. Of greater interest here is the fact that the food-reinforced rate *remained* low for as long as ten sessions. The low rate indicates that the exposure to FR broke up the AB alternation pattern to an extent sufficient to remove the influence of the avoidance contingency from the food-reinforced response relatively permanently.

SUMMARY AND DISCUSSION

The investigation began as an attempt to demonstrate in the individual monkey two effects simultaneously of a stimulus that immediately precedes unavoidable electric shock: (a) facilitation of lever-pressing behavior that has had an avoidance history, and (b) suppression of food-reinforced lever-pressing behavior that has never previously been explicitly involved in a shock contingency. When the stimulus was found to facilitate both lever-pressing responses, emphasis shifted to an investigation of the degree of interdependence between the two responses. It was found that the avoidance contingency was exerting a high degree of control over both responses.

Substitution of chain-pulling for the food-reinforced lever-pressing response did not completely remove the latter from the control of the avoidance contingency, nor did it prevent facilitation of that response by the pre-shock stimulus. The measurement of response sequences revealed a behavior pattern through which the food-reinforced response could have been adventitiously reinforced by shock avoidance. While the avoidance response was nearly always followed by a repetition of itself, the food-reinforced response was most often followed by an avoidance response. Although a different function was programmed for each response, there were adventitious correlations between the food-reinforced behavior and the reinforcement for avoidance.

In order to break up the sequence "food response followed by avoidance response," the food-reinforcement schedule was changed from variable interval to fixed ratio. The new schedule markedly decreased the occurrence of such sequences;

and by removing the avoidance component from the food-reinforced behavior, it permitted the original objective to be realized successfully. The pre-shock stimulus then produced facilitation of the avoidance response and, simultaneously, suppression of the food-reinforced behavior.

Demonstration of the nonindependence of the two responses thus revealed an additional consequence of aversive control, namely, the participation of "irrelevant" behavior in the shock contingency. The effect is analogous to the "superstitious" behavior described by Skinner in a food-reinforcement situation (12). The present data raise a problem concerning the direction of the spurious control. The food response was here maintained also by shock avoidance; why was the avoidance response not adventitiously reinforced by the food reinforcement as well?

The answer probably lies in the parameters that govern the degree of control exercised by the two programmed contingencies. The 4-minute, variable-interval schedule, for example, generated a very low rate of food-reinforced responding, whereas the 20-second, response-shock interval maintained a relatively high rate of avoidance responding. Furthermore, food reinforcements were relatively infrequent, while reinforcement of shock avoidance may be presumed to occur with each response.

Some data from Monkey R-17 may be relevant, since it does provide evidence for chaining in the opposite direction. It will be recalled that this animal did show some suppression of the avoidance response after the fixed-ratio schedule had been introduced (Fig. 6). After the change to the fixed-ratio schedule, Monkey R-17's

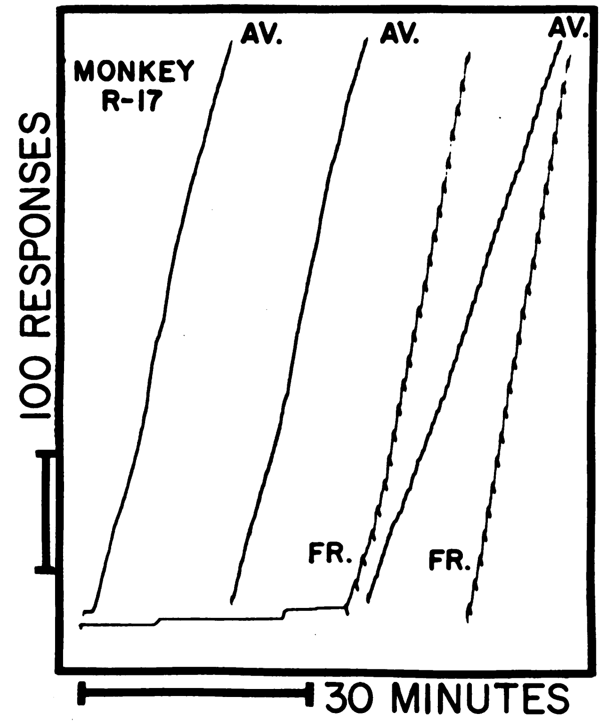

Figure 12. Monkey R-17. Concurrent lever-pressing (avoidance) and chain-pulling (FR) cumulative records superimposed upon the same coordinates.

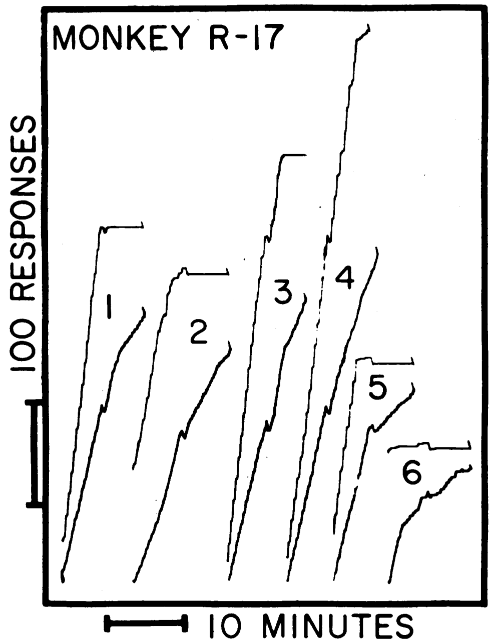

Figure 13. Monkey R-17. Temporally corresponding segments of cumulative records of lever-pressing and chain-pulling responses. In each numbered pair of records, the upper curve is the chain-pulling response, and the lower curve is the lever-pressing response. The last portion of each segment, beginning with the oblique downward displacement of the curve, depicts the behavior in the presence of the pre-shock stimulus.

avoidance behavior began to show typical fixed-ratio characteristics, as may be seen in Fig. 12. Concurrent portions of the cumulative records of each response have been superimposed upon the same time axis in Fig. 12 in order to facilitate comparison. The initial portion of the avoidance curve, corresponding temporally to the low-rate segment of the fixed-ratio curve, displays a relatively smooth grain. When the ratio curve assumes its characteristic appearance—alternating high rates and pauses—a similar grain develops in the avoidance curve. Many like instances were observed when the fixed-ratio behavior showed signs of strain. It may also be noted that the pauses in the avoidance curve were simultaneous with the fixed-ratio pauses after reinforcement. It appears, then, that when a more powerful variable, e.g., the fixed-ratio schedule, controls the food response, the avoidance response might also come spuriously under the control of the food reinforcement.

Figure 13 shows that the avoidance response was indeed suppressed some during the pre-shock stimulus. These are selected segments of temporally corresponding records of both responses between and during the pre-shock stimuli. The first sample, which shows an initial acceleration and then a decline in the rate of the avoidance response during the stimulus, is most typical of this animal's behavior. Each of the other patterns, in Segments 2–6, was observed at least once, and provides a fair selection of the variations that were recorded. The feature common to all of them is the correspondence between periods of relatively low rate in the avoidance records and suppression or strain in the ratio behavior. Therefore, under suitable conditions not adequately explored here, facilitation of avoidance behavior by unavoidable shock might possibly be reduced by spurious correlation of the avoidance response with food reinforcement. Monkey R-15 also displayed an occasional indication of suppression of the avoidance response just prior to the shock (Fig. 11). That such instances are correlated with the concurrent fixed-ratio behavior is suggested by the fact that they were no longer observed after the food-reinforcement schedule had reverted back to variable interval.

The above analysis is by no means an exhaustive one. Additional complications, for example, are suggested by Ferster's report of chimpanzee behavior on concurrent fixed-ratio and variable-interval schedules in which there was little evidence of interaction between the two responses (5).

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