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NEGATIVE REINFORCEMENT WITHOUT SHOCK REDUCTION[1]

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Stable lever-press responding in rats was reliably produced and maintained by a procedure in which responses could delay shocks without affecting overall shock frequency. Responding was not maintained when the delay-of-shock involved an increase in overall shock frequency.

Standard avoidance conditioning procedures have several features that could contribute to avoidance responding. For example, in discriminated avoidance, where the subject's response removes a warning stimulus as well as preventing the occurrence of a noxious event such as electric shock, the response: (a) reduces the frequency of noxious events; (b) achieves a delay before the next noxious event is due; (c) removes a stimulus that has been paired with shock; and (d) produces a sort of "timeout" from the avoidance situation, analogous to timeout used in appetitive situations, but opposite in its potential effect. The Sidman avoidance procedure (Sidman, 1953*a*) eliminates explicit warning stimuli, but still leaves at least two variables operative: (a) a response reduces the overall shock rate; (b) a response delays the onset of the next shock. These last two variables, delay-of-shock and shock-frequency reduction, are most often confounded in avoidance experiments. Both could strengthen responding. Both are embodied in current avoidance theories (Anger, 1963; Sidman, 1962). Thus, it is desirable to dissociate them and compare their relative potency for establishing and maintaining behavior.

Using programs of randomly delivered shocks, Herrnstein and Hineline (1966) eliminated fixed delays, stressing shock frequency reduction as a major controlling variable; they found it sufficient to establish and maintain a lever-press response. But other variables could also suffice to establish and maintain avoidance responding; perhaps no single one is necessary. The present experiments were part of an attempt to assess the potency of delay-of-shock for maintenance of responding. Rats' responses could delay shocks: sometimes this delay involved no change in shock frequency; sometimes the delay-of-shock involved an increase in overall shock frequency.

GENERAL METHOD

Subjects[2]

Sixteen naive brown rats, some female and some male, of the Lashley strain were housed in individual home cages with food and water freely available. They were 90 to 120 days old when introduced into the experiments. Their designations were: AA-1, AA-2, AA-3, AA-4, AD-1, AD-3, AD-4, AD-7, AD-10, AD-16, T-2, T-16, U-2, U-5, V-1, and V-10. Two additional rats, U-4 and U-7, had previously been conditioned on discriminated avoidance procedures, and had been subjected to a pilot procedure similar to the first procedure described below. Identical letter prefixes identify littermates; identical double letters identify females.

Apparatus

The experimental chamber was a standard rat box 9.0 in. (23 cm) long, 8.5 in. (21 cm)

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[2]In conducting the research described in this report, the investigator adhered to the "Guide for Laboratory Animal Facilities and Care", as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Sciences—National Research Council.

wide, and 8.0 in. (20 cm) high, with metal ends and Plexiglas sides and ceiling. Its floor was composed of grid bars 0.25 in. (6.3 mm) in diameter, spaced 1 in. (2.54 cm) apart, center-to-center. The response lever, described in more detail elsewhere (Hineline, 1968), was mounted on a wedge-shaped carriage that could rotate rapidly, making the lever either a vertical panel flush with the chamber wall when retracted, or, when extended, a horizontal surface protruding 1.25 in. (3.2 cm) into the chamber, 3 in. (7.5 cm) above the grid floor, and centered on an end wall. The lever was electrically insulated from the wall and grid floor. For odd-numbered rats a buzzer sounded whenever the lever was in the extended position; for even-numbered rats the buzzer sounded whenever the lever was retracted. Shocks of 0.3 sec duration and approximately 0.8 mA intensity were delivered through a scrambling device to walls, floor, and lever. Conventional switching circuits controlled the events and recorded the data. The chamber was enclosed in a sound-resistant chest with white noise supplied at all times, and with diffuse illumination during experimental sessions.

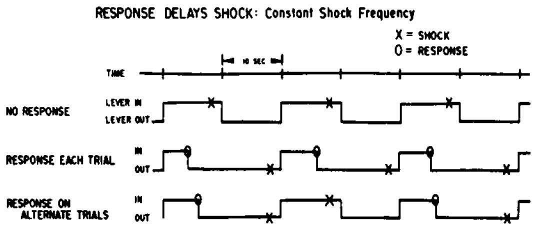

Fig. 1. Schema for the procedure in Exp. I. Time is represented linearly from left to right, as indicated on the top line. The remaining three lines describe sequences of events that would occur with three hypothetical performances: no responding, a response on each cycle, and a response on every-other cycle. Upward displacement of a line indicates insertion of the lever at the beginning of a cycle. Downward displacement indicates retraction of the lever. An "X" marks the delivery of a shock; an "O" indicates the occurrence of a response. Note that the overall rate of shock is constant, irrespective of responding.

EXPERIMENT I. RESPONSES DELAY SHOCKS, WITH CONSTANT SHOCK FREQUENCY

The first experiment was an attempt to eliminate overall shock frequency as a variable in an avoidance conditioning procedure. Responses could produce short-term delays of shock, but could not affect the number of shocks per minute, or more specifically, the number of shocks per 20-sec period.

Procedure

The procedure, schematized in Fig. 1, was based on 20-sec cycles; insertion of the lever into the chamber initiated a cycle. If the rat did not press the lever, a brief shock was delivered at the eighth second, and the lever was retracted at the tenth second, remaining retracted for the rest of the 20-sec cycle (see line labelled "no response" in Fig. 1). If the rat responded before the eighth second of the cycle (bottom two lines in Fig. 1), the lever retracted immediately and the shock was delayed until the eighteenth second. The lever remained retracted until the twentieth second, when its re-extension initiated a new cycle. These shocks were presented at the eighth and eighteenth seconds, instead of the more obvious tenth and twentieth, to avoid pairing shocks with movements of the lever. With this placement, responses between the eighth and tenth second produced shock at the eighteenth as well as the eighth second for the cycles on which they occurred. Such responses seldom occurred.

Hence, with few exceptions there was one shock per cycle; a response could influence only the position of the shock within the cycle. Also, there could be no more than one response per cycle, since the lever retracted immediately after each response and remained retracted for the rest of the cycle.

Three naive rats, AD-7, AD-10, and AD-16 were run on this procedure for at least 30 daily 100-min sessions each. The two rats with previous avoidance training, U-4 and U-7, were each run for 14 sessions.

RESULTS

Figure 2, showing per cent responses (responses x 100/total cycles) as a function of sessions, describes the performance of a representative animal, Rat AD-16, on this procedure. Responding increased quite steadily, with responses ultimately occurring on more than 80% of the trials in each session. The arrow at Session 33 indicates the point at which an intermittent failure was discovered in the shock apparatus. Responding was quickly re-

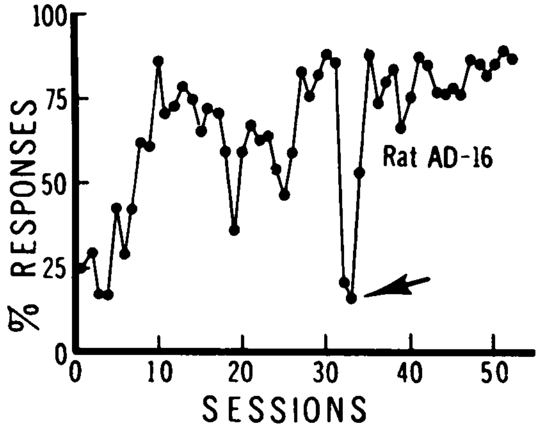

Fig. 2. Acquisition of responding for Rat AD-16 on the procedure where responses had no effect on shock frequency. Each data point shows the percent of cycles on which a response occurred during a 300-cycle, 100-min session. The arrow indicates when an intermittent failure in the shock apparatus was discovered and corrected.

stored in Session 34, when shock was again delivered reliably. Rats AD-10 and AD-7 showed slightly more rapid acquisition, levelling off at 95% and 75% respectively. Rat AD-7 had occasional, single-session lapses to the 40% level.

Mimicking their previous performances on avoidance procedures, Rats U-4 and U-7 responded on this procedure at approximately the 75% and 85% levels, respectively, throughout their 14 sessions on this procedure.

Figures 3 and 4 describe, for Rats AD-10 and AD-16, estimates of the momentary probability of a response as a function of time since the beginning of a cycle. The measure, conditional probability of response, is the number of responses in a given class of time intervals divided by the number of times the lower limit of that class-interval was reached with the lever still extended into the chamber. This measure is analogous to "interresponse times per opportunity" in free-operant situations (Anger, 1963). The vertical dashed line indicates when a shock was due if no response occurred during the preceding 8 sec. Each plot shows a distinct rise at the beginning of the interval, reaching a sharp maximum, followed by a steep descent. This pattern was characteristic in all sessions with more than 50% responding.

Figure 5 describes shock rates in the presence of the extended lever, and in the presence

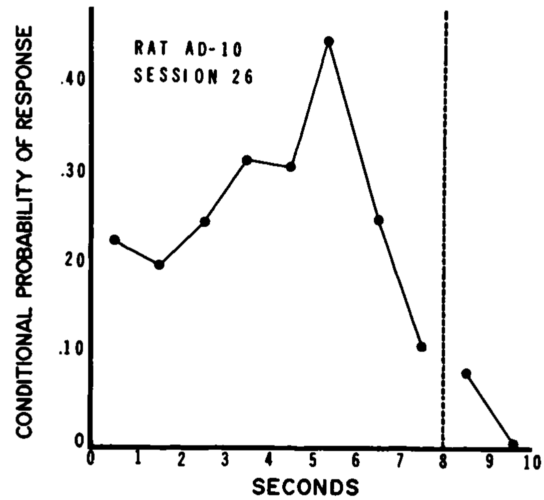

Fig. 3. Estimates of response probability for successive seconds of cycles, taken during the twenty-sixth session for Rat AD-10 in Exp. I. The measure, conditional probability of response, is obtained by dividing the number of responses in a given class-interval by the number of cycles containing latencies that exceed the lower limit of that class-interval. Seconds since the beginning of the cycle is indicated on the abscissa; the vertical dashed line indicates when, on any given cycle, a shock was delivered if a response had not yet occurred.

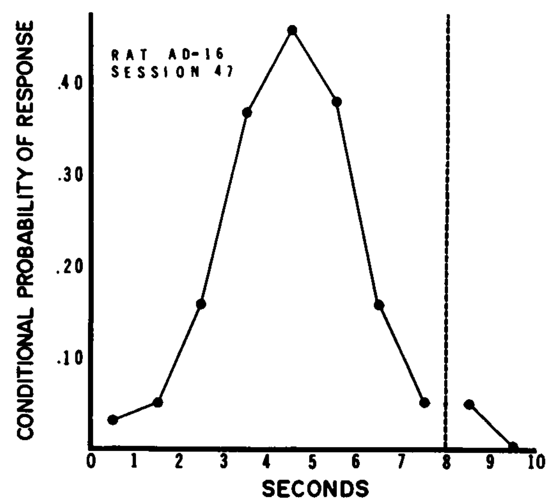

Fig. 4. Estimates of response probability for successive 1-sec class-intervals of cycles, taken during the forty-seventh session for Rat AD-16 in Exp. I. As for Fig. 3, conditional probability of response was computed by dividing the number of responses in a given class-interval by the number of times that class interval occurred during the session. The vertical dashed line indicates when, on any given cycle, a shock was delivered if a response had not yet occurred.

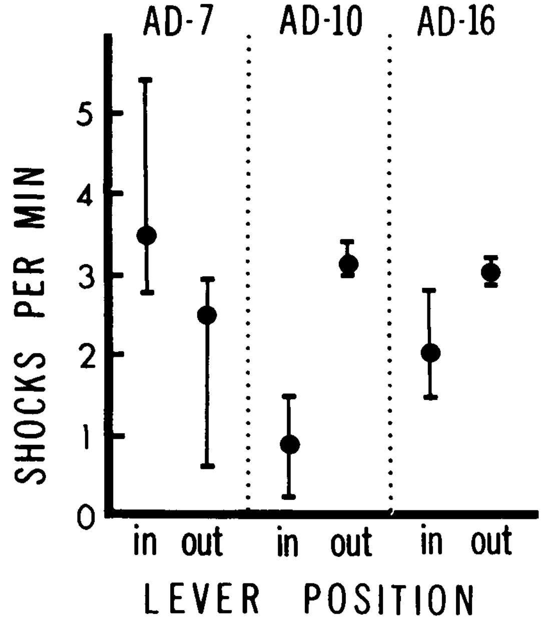

Fig. 5. Median and range of daily shock rates with the lever in and with the lever out, for Rats AD-7, AD-10, and AD-16, during the final 10 sessions of conditioning in Exp. I. For each 100-min session, the shock rate with lever in was computed by dividing the number of shocks occurring with the lever in the chamber by the cumulated time (from all cycles) that the lever was in the chamber. Similarly, the shock rate with lever out was computed by dividing the number of shocks occurring with the lever out (equal to the number of responses) by the cumulated time that the lever was out of the chamber. Taking these measures for the last 10 sessions, the median for each measure was determined for each animal, and plotted with dots; the ranges, also for the last 10 sessions, are indicated by the vertical lines passing through those dots.

of the retracted lever, for Rats AD-7, AD-10, and AD-16 during their final 10 days on the procedure. Both the ranges of daily rates and the median daily rates are shown. For Rats AD-10 and AD-16, which responded on about 95% and 80% of the cycles respectively, the shock rates with the lever in were consistently lower than the shock rates with the lever out. This relation was response-produced, for in the absence of responding all shocks would occur with the lever in. For Rat AD-7, which responded on approximately 75% of the trials during these sessions, shock rates were consistently higher in the presence of the lever, than in its absence.

In summary, this procedure produced stable and frequent responding in both pretrained and experimentally naive rats, comparing favorably with standard avoidance procedures both in this and in other laboratories (*e.g.*, Weissman, 1962).

EXPERIMENT II. RESPONSES DELAY SHOCKS, BUT INCREASE SHOCK FREQUENCY

Experiment I produced acquisition and maintenance of stable responding in the face of a constant overall shock rate. This leads to the question of whether shock frequency is a superfluous feature, constant in Exp. I, but redundantly variable in avoidance experiments that provide many of the features present in Exp. I. Experiment II addressed this question with a procedure in which shock frequency changes should oppose responding, but in which the features that produced responding in Exp. I should still be operative.

Procedure

The apparatus was the same as in Exp. I, and in the absence of responding the sequence of events remained unchanged as well: insertion of the lever into the chamber initiated a cycle; a shock was delivered 8 sec later; the lever retracted at the tenth second; and a new cycle began at the twentieth second (Fig. 6, second line from top). If a response occurred, the lever retracted immediately and a shock was delivered 8 sec after the response; 2 sec later the lever returned to the chamber to initi-

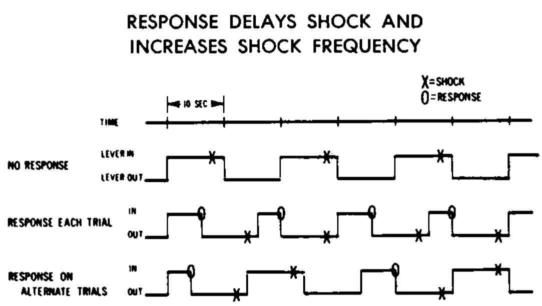

Fig. 6. Schema for the procedure in Exp. II. Time is represented linearly from left to right, as indicated on the top line. The remaining three lines describe the sequences of events that would occur with three hypothetical performances: no responding, a response on each cycle, and a response on every other cycle. Upward displacement of a line indicates insertion of the lever at the beginning of a cycle; downward displacement indicates retraction of the lever. "X" marks the delivery of a shock; "O" indicates the occurrence of a response. Note that each response shortens a cycle, producing an increase in overall shock rate.

ate a new cycle. Examples are shown in the bottom two lines in Fig. 6. Thus, on this procedure there was still one shock per cycle (except on cycles with a response between the eighth and tenth second, which produced an extra shock), but responses shortened the cycles, increasing the overall rate of shock. While the cycle length was constant in Exp. I, the time between a response and the beginning of the subsequent cycle was constant in the present experiment.

Eleven of the remaining 13 naive rats were run on this procedure, each for a minimum of 18 daily 100-min sessions. Rats U-4 and U-7, with previous exposure to avoidance contingencies as well as Exp. I, each were run for 12 sessions on this procedure.

Results

The two rats with previous training, U-4 and U-7, both emitted more than 200 responses in the first session. Their subsequent responding steadily decreased, with U-4 emitting very few responses after the fifth session and with U-7 reaching negligible response rates by the ninth session of exposure to the procedure of Exp. II. The 11 naive rats placed directly on this procedure never responded on more than 30% of the cycles in a session. Typically, the response rate would rise sometime during the first few sessions, and then fall to near zero over the subsequent 8 or 10 sessions. These performances are characterized by the plots in Fig. 7, showing response rates as functions of sessions for rats AA-1 and AA-4.

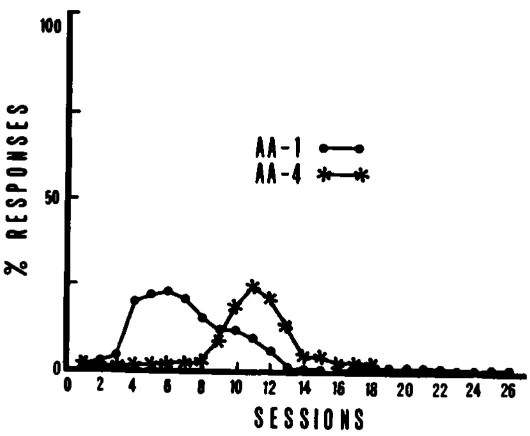

Fig. 7. Two typical performances during initial exposure to the procedure of Exp. II, where responses delayed shocks, but increased overall shock frequency. Each data point indicates the per cent of cycles on which a response occurred, during a 100-min session containing at least 300 cycles.

Discussion

The main implications of these results are dealt with later in the General Discussion. For the present, a parenthetical observation is in order regarding the relation between procedures of Exp. I and II: Response-produced delay-of-shock is usually considered to be invariably related to shock at specific post-response times. That relation holds in most avoidance procedures, most notably in the Sidman (1953) procedure, where delay-of-shock is synonymous with time from response to shock. In the present experiments, these two variables are still related, in that each is affected by responses, but they are not identical. In Exp. I, delay-of-shock—measured as the difference between the moment when the shock would have occurred with no response and the moment when the shock occurred given the response—was fixed at 10 sec, while the response-shock interval varied between 10 and 18 sec. In Exp. II, the delay-of-shock varied, with a maximum of 8 sec, while the response-shock interval was exactly 8 sec. The distinction rests on the difference between time as measured from a discrete event, and time as measured by a continuously running clock.

EXPERIMENT III. SHOCKS PAIRED WITH RETRACTION OR INSERTION OF THE LEVER

Concurrently with the beginning of Exp. II, two animals were first placed on a modified version of the procedure used in Exp. II. The original rationale for the modified procedure was to examine the effects of pairing shock with insertions and retractions of the lever, presumably making lever motion a conditioned aversive stimulus that would oppose responding. As will become evident, the results were more useful for other purposes.

Procedure

The procedure was identical to that of Exp. II, except that each shock was delivered 2 sec later than in the procedure of Exp. II. In the absence of responding, a shock always occurred at the tenth second, simultaneously with the retraction of the lever. A response eliminated the shock at the tenth second, but resulted in a shock 10 sec after the response, at the moment when the lever was re-extending to initiate a new cycle.

Two naive rats, U-5 and T-16, were run on this modified procedure for 46 sessions, and were then placed on the procedure described in Exp. II, for 13 and 28 additional 100-min sessions, respectively.

Results

Beginning on the modified procedure, where shocks coincided with movements of the lever, Rats U-5 and T-16 responded considerably more than the animals in Exp. II. By the fifth session, Rat U-5 was responding on more than 80% of the cycles. However, this responding persisted only through the fifteenth session, after which the response rate dropped precipitously to zero. A few responses occasionally occurred after the thirty-fifth session, but responding showed no signs of persistence, even with 13 sessions on the procedure of Exp. II. Rat T-16 responded more persistently on the modified procedure. As shown in Fig. 8, this animal emitted several hundred responses per session, raising its shock rate to nearly twice the 3 per min that would occur with no responding. When placed on the procedure of Exp. II in Session 47, indicated by the vertical dashed line in Fig. 8, the rate of responding decreased steadily, reaching zero by Session 67.

The response latencies of Rat T-16 differed greatly from those of rats in Exp. I. This is shown in Fig. 9, where for T-16, conditional probability of response is plotted as a function of time, comparable to Figs. 3 and 4 for rats in Exp. I. The data in Fig. 9 are taken from Session 49, this animal's third session on the procedure of Exp. II. Figure 9 reveals that the probability of response decreased with time during the first few seconds of a cycle. As the time for shock (8 sec) approached, the probability of response increased slightly, but was still far below that of the first 2 sec of the cycle. On the cycles where shock occurred at the eighth second, there was a relatively high probability of response during the 2 sec following those shocks, even though such responses produced

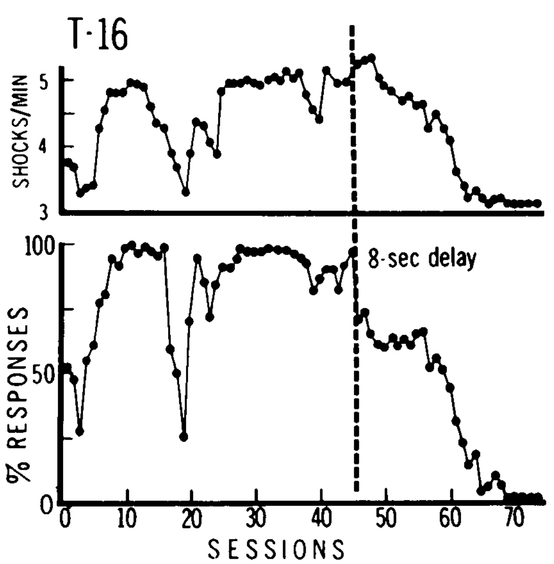

Fig. 8. Per cent responses, and corresponding shock rates, during successive sessions of exposure to a modified procedure, during sessions indicated to the left of the vertical dashed line, and of subsequent exposure to the exact procedure used in Exp. II. Per cent responses was obtained by dividing the number of responses in a session by the number of cycles in that session. With no responding, the shock rate was 3 per min, indicated at the origin on the ordinate of the upper graph. Each data point is based on a single 100-min session containing at least 300 cycles.

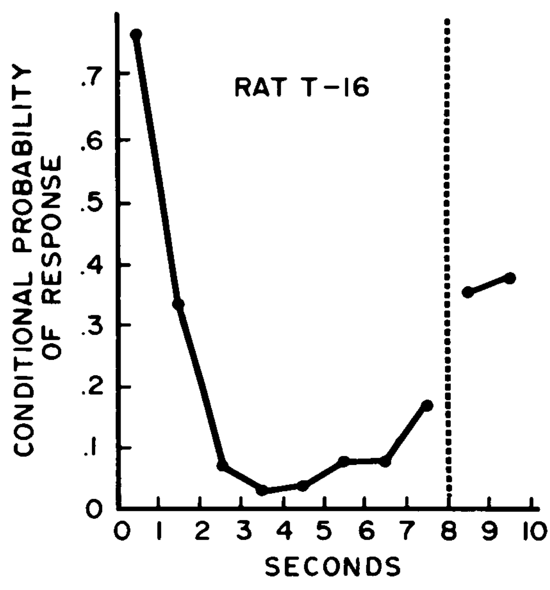

Fig. 9. Estimates of response probability as a function of time since the beginning of cycle, for Rat T-16, during Session 49, the third session of exposure to the procedure of Exp. II. The measure, conditional probability of response, was computed by dividing the number of responses in a given 1-sec class-interval by the number of times that class-interval occurred (with the lever extended) during a session. The vertical dashed line indicates when, on any given cycle, a shock was delivered if a response had not yet occurred on that cycle.

additional shocks. The shape of the initial portion (up to 8 sec) of this plot is representative of plots taken from all sessions in which this animal responded appreciably. The probability of response between the eighth and tenth second was much lower on the preceding, modified procedure, where shocks occurred at the tenth instead of the eighth second. When the overall response rate dropped, in the sessions following that shown, the distributions of latencies retained the same general shape, but all probabilities were proportionately reduced.

Discussion

Before this experiment it was anticipated that, since the loud noise produced by lever retraction resembled that of lever insertion, shocks paired with either retraction or insertion would give conditioned aversive properties to the sound of lever retraction. If present, this conditioned aversiveness should have opposed responding, since responses always produced immediate lever retraction. The predicted result was not obtained; pairing of shock with retraction and insertion of the lever did not oppose responding. Instead, this placement of shocks supported responding. The response latencies suggest that these responses were directly elicited by shock, rather than supported by delay-of-shock. Azrin, Hutchinson, and Sallery (1964) found that shock-elicited behavior (aggression, in their case) is most probable immediately after shocks. In the session contributing to Fig. 9, shocks occurred just before the beginning of a cycle, when there had been a response on the preceding cycle, and at the eighth second on cycles where there had been no intervening response. Hence, shock-elicited responding would be predicted at the beginnings of the cycles, and immediately after the eighth second, when the opportunities for such responses had not been obviated (along with the eighth-second shocks) by responses earlier in the cycles. The conditional probability plots should reveal high response probabilities at the beginning of the cycle, and again between the eighth and tenth second. This is exactly what Fig. 9 shows.

Although the responding of T-16 occurred at the times predicted for elicited responding in the second phase of the present experiment (that is, on the same procedure as in Exp. II), responding gradually disappeared on this procedure, which suggests that shock-elicited responding would not be acquired with shocks occurring at the eighth or eighteenth seconds of a 20-sec cycle. The latencies of responses in Exp. I verify this, giving no evidence for shock-elicited responding.

GENERAL DISCUSSION

Overall shock frequency was virtually invariant in Exp. I, where the procedure produced and maintained stable responding. The effectiveness of the procedure in Exp. I is particularly interesting in light of the importance attributed to shock-frequency reduction in other procedures. Sidman (1962) proposed it as the principal source of response strength in his free-operant avoidance procedure. Herrnstein and Hineline (1966) found it adequate to produce and maintain responding when it was the only variable affected by responses. Bolles, Stokes, and Younger (1966) identified it (although they labelled it "omission of the unconditional stimulus") as a major factor in learning on a more traditional, discriminated avoidance procedure employing a warning stimulus.

While response-produced changes in overall shock frequency cannot account for the presence of responding in Exp. I, such changes can account for the absence of responding in Exp. II, where most procedural features were very similar to those of Exp. I, but where each response produced an increase in overall shock frequency. Shock-frequency increase is an attractive basis for explaining the difference between results of Exp. I and II because it was clearly absent in Exp. I, and just as clearly present in Exp. II. Further, to characterize shock-frequency increase as the variable that opposed responding in Exp. II is to relate the procedure of Exp. II to punishment procedures in a way analogous to the way the Sidman avoidance procedure—and to a greater extent the shock-frequency reduction procedure of Herrnstein and Hineline (1966)—can be related to standard escape procedures where responses remove continuous shock. The analogy goes further, for we know that for punishment, the exact temporal relation between individual responses and individual shocks is important as well as the response-produced changes in shock frequency (Azrin and Holz, 1966; Baron, Kaufman, and Fazzini, 1969); comparable relations are equally important in the present situation, as shown by Exp. I, where responding was maintained by shocks in the face of constant shock frequency.

But what produced and maintained the responding in Exp. I? In most other instances of responding produced by constant shock rates, the behavior has been quite clearly of an elicited nature, as in the case of shock-elicited aggression, or else it has been produced by adding shocks after a creature has already learned to avoid on a standard avoidance procedure (*e.g.*, Byrd, 1969). The results of Exp. II and III above tend to negate any shock-elicited component in Exp. I, as noted above in the discussion of Exp. III. The use of naive animals in Exp. I eliminates prior avoidance training as a possible source of the responding observed here.

A straightforward application of two-factor avoidance theory (Mowrer and Lamoreaux, 1946; Rescorla and Solomon, 1967) would stress the pairing of exteroceptive stimuli with shocks, proposing that these stimuli would take on aversive properties (perhaps with correlated emotional states) that make their removal a reinforcing consequence of the response. In the present experiments, the only exteroceptive stimuli systematically paired with shock were those associated either with the extended or with the retracted position of the lever. If conditioned aversive properties of the lever's presence *vs.* its absence were important to reinforcement of the lever pressing in Exp. I, we should have seen either particular combinations of response probabilities and response latencies, or oscillations between periods of responding and periods of non-responding, *such that the shock rate in the absence of the lever never appreciably exceeded that in the presence of the lever.* In the case of oscillation, the periods of responding would result from response-contingent removal of the lever, which had been paired with shock; the subsequent non-responding would result from response-produced disruption of this pairing. That is, responses removed the lever, which had been paired with shock, but this entailed pairing of shock with the absence of the lever, which should have eliminated the same relative aversiveness of the lever. Rescorla (1968) has presented evidence for such relative aversiveness of stimuli, using various shock rates correlated with stimuli (or the absence of stimuli) used in conditioned suppression on the Estes-Skinner paradigm.

This application of two-factor theory is opposed by the present data. Figure 5 shows that two of the three naive rats in Exp. I responded persistently in such a way that the higher shock rate occurred in the absence of the lever. The third naive rat, responding less persistently, experienced relatively fewer shocks in the absence of the lever. In each case, the responding was stable beyond the acquisition stage. Hence, traditional two-factor theory, predicated on conditioned aversive properties of the lever, cannot account for the responding in Exp. I. This conclusion is consistent with a growing body of evidence that on standard avoidance procedures, the pairing of shock with the warning (or conditioned) stimulus plays no more than a minor role in the maintenance of responding (Bolles, Stokes, and Younger, 1966; Taub and Berman, 1963).

The occurrence of shocks at specified time intervals measured from responses permits direct application of Anger's (1963) ingenious adaptation of two-factor theory, which was originally developed to account for Sidman avoidance. According to this theory, time intervals, however sensed by the animal, can become aversive through their pairing with shock. In the present procedures, as the time since lever insertion approaches 8 sec the stimuli experienced by the rat should more and more closely resemble those that have accompanied the interval paired with shock, and hence should be more and more aversive. A response initiates a new stimulus situation, characterized as "post-response time", and since shocks never occur immediately after responses, this new set of stimuli should be nonaversive. The response thus replaces conditioned aversive (temporal) stimuli with nonaversive ones and is reinforced by the reduction in conditioned aversiveness.

The rising portions of the conditional probability curves in Fig. 3 and 4 suggest that Anger's type of reinforcement may have indeed contributed to responding in Exp. I, for they show that the probability of response increased with time since lever insertion. Anger's theory predicts this since responses of longer latency remove stimuli that more closely resemble those that were paired with shock, producing greater reductions in aversiveness. But

Anger's theory does not predict the descending portions of those curves, which reveal decreases in response probability when time for shock was closely approached. Also, taken by itself, without consideration for changes in shock frequency, Anger's theory would have predicted stable responding in Exp. II as well as in Exp. I. The theory cannot allow for appreciably less potent reinforcement in Exp. II, since the 8-sec response-shock interval in that experiment is comparable to response-shock intervals that readily support responding on the Sidman avoidance procedure (Sidman, 1953*b*).

Credit must be given, that Anger's is the only current theory that predicted, before the fact, that responding would occur in Exp. I. However, Anger has attempted to account for all the shock-frequency data, such as those presented by Sidman (1962) and by Herrnstein and Hineline (1966) in terms of his theory. The disparity between results of Exp. I and II reported here argues strongly that shock frequency must at least sometimes be considered separately from the occurrence of shocks at specific post-response times.

The distinction between short-term delay-of-shock and changes in overall shock frequency is part of a more general issue, regarding our longstanding preference for explaining instrumental behavior in terms of its immediate consequences. Most theories of avoidance conditioning claim validity by describing plausible immediate consequences that could maintain responding on procedures whose name, avoidance, implies that the major consequence is not an immediate one. In contrast, a few experimenters have argued that avoidance responding is maintained directly by its long-term effect, the omission or reduction of primary aversive stimulation (Keehn, 1966; Sidman, 1962; Herrnstein and Hineline, 1966; Bolles, Stokes, and Younger, 1966). Herrnstein (1969) made a tentative extension of this position, describing the present experiments in terms of shock-frequency reduction coupled with stimulus control. To account for details of the present experiments, his computations of shock rate for a given stimulus condition had to be based only on stimulus exposures during which shock occurred, deleting other stimulus exposures. It is not yet clear whether these deletions are justified by other, independent data.

We badly need a new rubric for handling aversive conditioning procedures in a more general way, perhaps a rubric analogous to that used for behavior maintained by positive reinforcement. Experiments that will advance this are likely to cut across previous names and categories that we have used to describe conditioning with aversive stimuli. Perhaps, as Schoenfeld (1969) suggested, the standard nomenclature for aversive conditioning procedures should be abandoned. The current literature contains other, more implicit arguments for this. For example, Bolles (1970) argued that much of the avoidance behavior in nature is best analyzed in terms of species-specific reactions. The present experiments show that behavior strongly resembling avoidance can be produced without providing the feature that gives a standard avoidance procedure its name.

REFERENCES

Anger, D. The role of temporal discriminations in the reinforcement of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 477-506.

Azrin, N. H., Hutchinson, R. R., and Hake, D. F. Attack, avoidance and escape reactions to aversive shock. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 131-148.

Azrin, N. H. and Holz, W. C. Punishment. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 380-447.

Azrin, N. H., Hutchinson, R. R., and Sallery, R. D. Pain-aggression toward inanimate objects. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 223-228.

Baron, A., Kaufman, A., and Fazzini, D. Density and delay of punishment of free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 1029-1037.

Bolles, R. C. Species-specific defense reactions and avoidance learning. *Psychological Review*, 1970, **77**, 32-48.

Bolles, R. C., Stokes, L. W., and Younger, M. S. Does CS termination reinforce avoidance behavior? *Journal of Comparative and Physiological Psychology*, 1966, **62**, 201-207.

Byrd, L. D. Responding in the cat maintained under response-independent electric shock and response-produced electric shock. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 1-10.

Herrnstein, R. J. Method and theory in the study of avoidance. *Psychological Review*, 1969, **76**, 49-69.

Herrnstein, R. J. and Hineline, P. N. Negative reinforcement as shock-frequency reduction. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 421-430.

Hineline, P. N. A rapid retractable response lever.

Journal of the Experimental Analysis of Behavior, 1968, **11,** 127-128.

Keehn, J. D. Avoidance responses as discriminated operants. *British Journal of Psychology,* 1966, **57,** 375-380.

Mowrer, O. H. and Lamoreaux, R. R. Fear as an intervening variable in avoidance conditioning. *Journal of Comparative and Physiological Psychology,* 1946, **39,** 29-50.

Rescorla, R. A. Probability of shock in the presence and absence of CS in fear conditioning. *Journal of Comparative and Physiological Psychology,* 1968, **66,** 1-5.

Rescorla, R. A. and Solomon, R. L. Two-process learning theory; relationships between pavlovian conditioning and instrumental learning. *Psychological Review,* 1967, **74,** 151-182.

Schoenfeld, W. N. "Avoidance" in behavior theory. *Journal of the Experimental Analysis of Behavior,* 1969, **12,** 669-674.

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

Sidman, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *Journal of Comparative and Physiological Psychology,* 1953, **46,** 253-261. (*b*)

Sidman, M. Reduction of shock frequency as reinforcement for avoidance behavior. *Journal of the Experimental Analysis of Behavior,* 1962, **5,** 247-257.

Taub, E. and Berman, A. J. Avoidance conditioning in the absence of relevant proprioceptive and exteroceptive feedback. *Journal of Comparative and Physiological Psychology,* 1963, **56,** 1012-1016.

Weissman, A. Nondiscriminated avoidance behavior in a large sample of rats. *Psychological Reports,* 1962, **10,** 591-600.

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