DURATION-REDUCTION OF AVOIDANCE SESSIONS AS NEGATIVE REINFORCEMENT

MARK MELLITZ, PHILIP N. HINELINE, WAYNE G. WHITEHOUSE,
AND MICHAEL T. LAURENCE

TEMPLE UNIVERSITY AND U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

Five rats were exposed to a shock-postponement procedure in which responses on each of two levers initially had equivalent effects. After an initial training sequence that ensured at least some responding on each lever, an additional consequence was made conjointly operative on the previously less-preferred lever for each animal. Each response on this lever continued to postpone shock, but also reduced the session duration by one minute. The conjoint contingencies were operative until, through session-shortening responses and the passage of time, the session was scheduled to end in two minutes; during the final two minutes the session-shortening contingency was disabled while the shock-postponement contingency continued to be operative on both levers. When responding shifted to a predominance on the session-shortening lever, the conjoint contingency was shifted to the other lever; for four of the five rats this reversal was followed by two additional reversals. Two of the rats' responding showed clear, strong, and unambiguous sensitivity to the session-shortening contingency. The responding of two others was also systematically controlled by that contingency, but the effects were less clearcut. The fifth animal showed an initial shift when session-shortening was introduced, but its subsequent behavior proved insensitive to reversals of procedure. The results clearly indicate a sensitivity of behavior to events on a time scale quite distinct from that of immediate consequences. They also support an interpretation of avoidance sessions, considered in their entirety, as events whose contingent relationship to behavior can affect that behavior—even in the absence of stimuli that delineate those relationships. Finally, these results support an interpretation of aversively based conditioning within a broader context, analogous to the "open versus closed economy" interpretation of appetitively controlled behavior.

Key words: shock postponement, negative reinforcement, avoidance behavior, molar contingencies, rats

Negative reinforcement is the strengthening of behavior through removal, prevention, or postponement of aversive stimulation. The latter two, commonly labeled "avoidance," have provided fertile ground for theoretical controversy, especially in cases where avoidance is often well maintained despite the virtual absence of primary aversive stimulation, and in those instances characterized by extremely high resistance to extinction (Solomon, Kamin, & Wynne, 1953).

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Early two-process theories (e.g., Dinsmoor, 1954; Mowrer, 1947; Schoenfeld, 1950) attempted to resolve the apparent paradox of avoidance conditioning by assigning a significant role to mediating events in the maintenance of avoidance behavior. Although these accounts varied in terminology, the emergence of the presumed mediators generally was ascribed to Pavlovian operations inherent in the avoidance procedures of the day. Thus during acquisition trials, supplementary "warning stimuli" that occasioned the opportunity for avoidance were said to acquire conditioned aversive properties by virtue of their pairing (due to nonavoidance) with the primary aversive stimulus. The acquired aversiveness of such stimuli increased over trials until their response-contingent removal became sufficient to reinforce. Assuming occasional re-pairing of these stimuli with the primary aversive stimu-

lus owing to less than perfect avoidance performance, such conditioned aversive mediators should be capable of maintaining avoidance behavior indefinitely.

Such two-process accounts of avoidance learning are not limited to cases explicitly involving the procedural elements of classical conditioning. Even radical departures from the prototypical discriminated avoidance procedure, such as Sidman's (1953) unsignaled free-operant procedure and the random-shock procedure of Herrnstein and Hineline (1966) are susceptible to two-process interpretations (e.g., see Anger, 1963, and Dinsmoor, 1977). It is perhaps this very flexibility of two-process theory, coupled with a lack of concordance between the momentary strength of the putative avoidance mediator and other measures of conditioned aversion (Kamin, Brimer, & Black, 1963; Mineka, 1979; Rescorla & Solomon, 1967), that has rendered it suspect.

More recently, a single-factor account of avoidance phenomena (Herrnstein, 1969; see also Hineline, 1977, 1981) has been gaining advocacy. This approach represents an abandonment of the contiguity principle in favor of a contingency basis for reinforcement (e.g., Baum, 1973). A growing body of empirical work indicates that transitions from aversive to relatively less aversive situations may function as negative reinforcers of behavior upon which they are made contingent (Hineline, 1981). The reinforcing properties of situations correlated with relatively less aversive characteristics of electric shock have been demonstrated in studies investigating (a) shock-frequency reduction (Herrnstein & Hineline, 1966), (b) delay to shock (Gardner & Lewis, 1976; Hineline, 1970; Lewis, Gardner, & Hutten, 1976), (c) shock-intensity reduction (Bersh & Alloy, 1978), (d) shock-duration reduction (Bersh & Alloy, 1980; Lewis, Gardner, & Lopatto, 1980), and (e) shock predictability (Badia, Harsh, & Abbott, 1979). In a review of these studies, two comments are in order. First, in all cases responding was established and maintained by a situation of lower relative aversiveness than that incurred by not responding, despite the fact that the low-aversiveness condition was considerably aversive in its own right. These results are consistent, however, with a generalized matching relation (Baum & Rachlin, 1969; de Villiers, 1977), which predicts distributions of number of responses or

time spent responding proportional to the relative value of alternative outcomes. A second point concerns the absence of strict contiguity between responding and its consequences in these experiments. An extreme example of this occurs in the experiment by Herrnstein and Hineline (1966). In this study, rats were exposed to randomly occurring shocks on both high- and low-density schedules. In the absence of responding, shocks were delivered in accordance with the high-density program. A lever-press response switched control of the next scheduled shock to the low-density program until its delivery returned control to the high-density schedule. Since shocks occurred randomly on either schedule, the only discriminable feature of these schedules was the average intershock interval. Despite the obvious subtlety of the distinguishing characteristics of the two shock schedules, acquisition was reliable even when the average difference between the two schedules was as small as three shocks per minute. It is precisely, however, the random character of shock delivery on both schedules that calls into question the necessity of the contiguity principle. Indeed, the sensitivity of behavior to these contingencies can scarcely be based upon local shock rates, since the variability of the shock schedules often results in local reversals of shock rates between the two schedules. Instead, what is indicated by this and several of the other above-mentioned studies is that behavior may be reinforced effectively under certain conditions by its long-term consequences, the sensitivity to which depends upon a kind of temporal integration of the relationship between behavioral and environmental events.

The present experiment was conceived as a means to demonstrate the sensitivity of behavior to its long-term consequences under conditions in which more proximal consequences might be expected to prevail. Since avoidance sessions themselves are known to produce at least some effects attributed to aversive events (Hineline, 1972), we speculated that a procedure involving equivalent concurrent response-shock (RS) schedules with a conjoint session-length-reduction contingency superimposed upon one of the alternatives, might result in an asymmetrical distribution of responding favoring the conjoint schedule alternative. This procedure would provide a

critical test of the notion of integration of events over time since the effectiveness of differentiated responding would be revealed only by the relative duration of the session and not by any immediate consequence of the response.

METHOD

Subjects

Five experimentally naive adult female albino rats, obtained from the Holtzman Company, served. Animals were individually housed and maintained on ad lib food and water throughout the experiment.

Apparatus

All phases of the experiment were carried out in a standard rodent test chamber (24 cm long, 22 cm wide, 20 cm high) housed in a sound-attenuating shell. Two sidewalls and the ceiling of the chamber were constructed of clear Plexiglas; the front and rear walls were made of aluminum. Two stainless steel response levers (Gerbrands) protruded 2.8 cm from the front wall at a height of 4.8 cm from the grid floor and were separated by a distance of 12 cm. A downward force of .18 N was required to operate either lever. The floor of the chamber consisted of stainless steel grids, .3 cm in diameter, spaced 1.5 cm apart. Scrambled shock of 1.5-mA intensity and .5-sec duration was delivered to the grid floor by a BRS/Foringer Model SG-901 shock generator and SC-901 scrambler. A 7.5-W houselight, mounted centrally on the front wall, approximately 7 cm above the two response levers, illuminated the chamber during each experimental session. Masking noise of 72 db was provided by a ventilating fan and an external speaker coupled to a white noise generator. Contingency programming and data collection were provided by electromechanical equipment located in an adjacent room.

Procedure

Pretraining. All subjects were initially exposed to a maximum of 20 152-min sessions of avoidance conditioning using Sidman's (1953) procedure. In the absence of responding, shocks were delivered according to a fixed-time shock-shock (SS) schedule of 10 sec. A single lever-press response switched control of shock delivery to a response-shock (RS) schedule of 20 sec, scheduled identically with re-

spect to both levers. After delivery of the first shock by the RS schedule, control was returned to the SS schedule unless additional responses intervened. Each response reinitiated the RS interval, making it possible for the animal to avoid all scheduled shocks. During pretraining, responses on either lever instituted control by the RS schedule, but only one lever was available during any session. The second lever was made inaccessible by the insertion of an aluminum cover. The position of the inaccessible lever was alternated for each daily session in an attempt to mitigate the development of position preferences by the subjects. Pretraining was continued until the animals met a criterion of at least 85% avoidance of the possible 900 shocks per session with less than 10% variation in performance over four consecutive sessions on each lever. All animals met the criterion in fewer than 20 sessions.

Session-length reduction. Following the pretraining phase, both levers were made available. As before, the SS schedule was 10 sec and the RS schedule was 20 sec for responses on either lever. In addition, however, a session-shortening contingency was superimposed upon the RS contingency of one of the levers. Thus, each response on the lever with the conjoint schedule resulted in immediate shock postponement of 20 sec and decreased the programmed session length by one minute. During the final two minutes of each session, the session-shortening contingency was disabled. When the session terminated, an auditory signal from the programming equipment alerted the experimenter, whereupon the subject was removed immediately from the conditioning chamber and returned to its home cage. To avoid a possible confound of the effects of the conjoint schedule with position preference, all subjects were initially exposed to the procedure with the conjoint scheduled on their nonpreferred lever as determined by pretraining response rates on both levers. For Subjects R-15, R-17, and R-18, the session-shortening contingency was scheduled on the right lever; for Subjects R-9 and R-12, session-shortening resulted from responses on the left lever.

This procedure was continued until the subjects met a criterion of at least 50% allocation of responses on the conjoint alternative for three consecutive days, with the additional constraint that a minimum of five sessions be

completed. The next three phases involved reversing the consequences of responding on the two levers to demonstrate sensitivity of the animals' behavior to the reinforcement contingencies as opposed to simple position preference. Transitions from one reversal phase to the next were governed by the performance criteria stated above.

Test phase: avoidance extinction with session-length reduction. Immediately following the completion of the third reversal, the temporal parameters of shock delivery were programmed for avoidance extinction (i.e., SS = 10 sec; responses ineffective), and the conjoint session-shortening contingency was made available, contingent upon responding on the lever opposite to the one where it had been effective during the preceding phase. This procedure constituted a test of the efficacy of session-shortening as a source of reinforcement for differentiated responding in the absence of behavior maintenance by shock-postponement in the short term. During the test phase, therefore, lever pressing had no effect upon shock delivery and, hence, no contiguous consequences. However, responses on the lever with the conjoint schedule were effective in reducing session duration at a rate of 1 min for each response. When the subjects had reached the criterion of at least 50% allocation of responses on the conjoint schedule lever for three consecutive days, the consequences of responding on the two levers were reversed. Subject R-12 was dropped from the experiment before the avoidance extinction condition was put into effect due to the development of a strong position preference coupled with extremely efficient shock-avoidance.

RESULTS

During the pretraining baseline phase of the experiment, avoidance performance, based upon Sidman's shock-postponement procedure, met the 85% proficiency criterion over four consecutive sessions within 15 to 16 sessions for all subjects. The influence of the avoidance contingency led to response-contingent reductions in overall session shock rates of 92, 63, 83, 57, and 41% for Subjects R-9, R-12, R-15, R-17, and R-18, respectively, when the averages of the two initial and two terminal session shock rates are contrasted. Criterion perfor-

mances for all animals fell in the range of 45 to 55 accumulated shocks per session out of a possible 900 shocks.

Table 1 summarizes the performances of individual animals during each phase of the experiment with respect to response rates on right and left levers, session length, and total number of shocks received, averaged for the initial (first three sessions) and terminal (last three sessions) portions of each procedure, exclusive of the test phases for which only terminal means are provided. For each subject, the introduction of the conjoint session-shortening contingency occasioned an initially substantial reduction in the duration of subsequent avoidance sessions. With the exception of Subject R-12, for which training was discontinued during the second reversal, the terminal session-length values of each phase were systematically lower than the corresponding initial values, indicating the sensitivity of these animals' behavior to the session-length contingency. Three reversals replicated an increase in response rate on the lever producing session-length reduction plus shock-postponement, with a corresponding decrease in response rate on the lever producing shock-postponement only. Test performances, during which shocks were scheduled according to an FT 10-sec schedule and were therefore unavoidable, reveal a similar though attenuated result. In the case of R-17 and R-18, the session-shortening contingency by itself was sufficient to produce two reversals of responding. For R-9 and R-15, it produced a first reversal but not a second.

Figure 1 shows the performance of the single subject (R-12) for which the immediate shock-postponement consequences of responding prevailed. The decline in baseline response rate, coupled with increasing avoidance efficiency, is characteristic of subjects which demonstrate extreme sensitivity to the temporal properties of the Sidman (1953) procedure. Nevertheless, with the introduction of the conjoint session-shortening contingency, the rat's responding shifted reliably to the lever producing the conjoint-scheduled consequences and continued to do so through the first reversal. Despite such ostensive control by the session-shortening contingency, however, the subject continued to maintain extremely low shock rates. Thus, the failure to obtain a second reversal might be due, in part, to the potential reduction in the

Table 1
Means of performance measures for each experimental phase.

Sub- ject	Procedure ^a	Response Rate		Session Length (min)	Total Shocks
		Left	Right		
R-9	I	3.67	4.20	152.60	472.83
	Baseline				
	T	10.53	8.57	152.60	53.00
	I	3.70	14.60	39.61	38.67
	conj L				
	T	10.60	1.97	25.99	17.67
	I	10.93	2.53	61.11	40.00
	conj R				
	T	3.90	6.63	26.67	29.33
	I	1.90	11.70	62.06	28.33
	conj L				
	T	7.40	3.33	23.86	8.00
	I	5.07	4.10	50.18	27.67
	conj R				
R-12	T	4.13	6.30	25.99	13.00
	Test L	6.63	3.63	23.86	145.33
	Test R	6.10	3.13	30.16	182.33
	I	14.80	22.53	152.60	76.00
	Baseline				
	T	16.90	12.93	152.60	31.83
	I	1.73	15.50	92.99	5.67
	conj L				
	T	11.27	1.50	14.67	5.67
	I	9.77	9.30	18.48	1.67
	conj R				
	T	5.13	10.07	15.78	2.00
	I	2.67	10.73	57.72	2.33
	conj L				
R-15	T	0.10	11.67	147.66	10.67
	I	4.80	5.83	152.60	233.17
	Baseline				
	T	8.60	5.23	152.60	62.83
	I	5.57	5.27	33.33	25.33
	conj R				
	T	0.07	7.90	19.77	15.67
	I	1.43	7.60	79.53	89.00
	conj L				
	T	5.30	2.57	28.16	70.67
	I	3.73	4.17	32.98	55.67
	conj R				
	T	3.33	4.50	30.88	50.00
	I	4.87	4.30	29.68	44.00
	conj L				
	T	5.50	2.50	26.23	40.00
R-17	I	12.83	5.77	152.60	122.00
	Baseline				
	T	13.23	5.37	152.60	64.67
	I	5.27	4.00	35.39	51.00
	conj R				
	T	1.23	5.60	27.04	51.33
	I	2.77	3.50	43.48	57.67
	conj L				
	T	7.47	3.50	27.07	24.00
	I	4.37	3.70	37.71	48.67
	conj R				
	T	2.83	4.20	30.86	53.67
	I	2.87	5.10	45.79	61.00
	conj L				
R-18	T	4.23	1.23	37.58	50.00
	Test R	8.07	1.33	18.78	110.67
	Test L	3.43	2.83	37.37	224.67
	I	10.93	5.73	152.60	124.50
	Baseline				
	T	11.67	6.53	152.60	78.50
	I	6.27	4.20	42.94	46.33
	conj R				
	T	1.43	6.23	28.06	27.33
	I	3.10	6.97	51.44	79.67
	conj L				
	T	4.40	3.73	35.63	44.33
	I	3.30	5.93	49.48	68.33
	conj R				
	T	4.53	2.70	34.74	54.00
	I	1.57	5.80	105.68	89.33
	conj L				
	T	5.77	4.33	27.17	29.00
	Test R	3.13	4.43	36.91	223.00
	Test L	4.13	2.87	38.73	232.67

^a"I" denotes initial three sessions, "T" denotes terminal three sessions. Means for "Test" phases are for terminal sessions only since some subjects required fewer than six sessions to meet the performance criterion.

overall aversiveness of avoidance sessions as a consequence of proficient shock avoidance.

Subjects R-9 and R-18 both showed strong evidence of the reinforcing value of the con-

joint contingency. To illustrate this, detailed performance data for each phase are plotted for R-9 in Figure 2. A large initial decrease in session length occurred when the conjoint contingency was instituted, while the response rate on the opposite lever rose substantially

Fig. 1. Performance across sessions for Subject R-12, as shown by three dependent measures: session length, total shocks, and response rates for right and left levers. During the initial "baseline" phase, shock-postponement was the only operative contingency for either lever, and access was restricted to only one lever per session with the available lever being alternated over successive sessions. The labels "conj L" and "conj R" specify procedures in which the session-shortening contingency was scheduled on the left and right levers, respectively.

Fig. 2. Three measures of performance for Subject R-9, representative of behavior strongly controlled by the session-shortening contingency. The label "Test" refers to the phases during which shock-postponement was suspended while session-shortening was contingent upon responses on the left (L) or right (R) lever.

over terminal baseline rates on that lever. Despite the increased responding in the initial session, avoidance efficiency did not change appreciably, with the total shocks received remaining at baseline levels. Over the next seven sessions, however, responding gradually came to be distributed in favor of the conjoint alternative, producing both a steady decline in the length of the avoidance sessions and increased avoidance efficiency as indexed by systematic reductions in the number of shocks per session. Performance over three subsequent reversals revealed this same characteristic improvement in avoidance efficiency coupled with decreasing session durations as the proportion of responses allocated to the conjoint lever increased. The autonomy of the session-shortening contingency as a source of negative reinforcement is best assessed by performance during the two test phases in which reinforcement due to shock-postponement was suspended for both levers. Here again, response allocations shifted appropriately in favor of the lever on which the session-shortening contingency was scheduled, indicating sensitivity of the animal's behavior to long-term consequences.

Two animals, R-15 and R-17, provide more modest evidence of behavior controlled by the session-shortening contingency. Figure 3 depicts the performance of Subject R-15. Exposure to the conjoint contingency resulted in a rapid shift of responding to the lever producing session-length reduction. Responding on the opposite lever underwent a marked corresponding decrease. As a result, recovery of responding on that lever during the first four sessions of the first reversal was erratic; however, during subsequent sessions, responding reliably increased on the conjoint lever. Two subsequent reversals supported the reinforcing function of response-dependent reductions in session duration. However, responding had become distributed on both levers such that the magnitude of session-length reduction was rather consistently maintained from session to session. Furthermore, although reductions in shock frequency did occur across sessions within each reversal of the conjoint procedure, they were neither large nor systematic. This pattern of responding persisted during the first test phase during which the shock-postponement contingency was eliminated. The subsequent reversal test led to a general depression of response rates on both

levers, although responding on the lever with the session-length reduction contingency occurred at a stable rate while responding on the nonfunctional lever was stable but lower.

DISCUSSION

For two of the five rats (R-9 and R-18) each reversal of session-shortening contingencies produced a large and systematic shift in the allocation of responding on the two levers. For a third animal (R-12), the shifts were equally large, except that behavior failed to be affected by the session-shortening contingency after the first reversal. For the two remaining rats (R-15 and R-17), with each reversal there were systematic shifts of relative responding on the two levers, but the magnitudes of shift were much less impressive. Thus, although the strength of behavioral control varied substantially across subjects, the results clearly support the conclusion that response-dependent shortening of sessions is a variable that can influence behavior. Avoidance sessions, construed as unitary events, can be viewed as affecting behavior within the sessions themselves, as well as affecting behavior outside the avoidance sessions as has been previously demonstrated (Hineline, 1972, 1978).

The clarity of the session-shortening effect probably depends upon the particular use of a multiple-response procedure, allowing for additional variables to control initial acquisition and to support the maintenance of responding. Verhave (1962) tried using a single-response procedure to assess the effects of response-contingent timeouts from avoidance. In his initial experiment, baseline levels of responding were maintained by a shock-postponement contingency, with the response-produced timeout periods superimposed according to a fixed-interval schedule. With this procedure, he found no evidence for reinforcing effects of the timeout periods. In an additional experiment, Verhave arranged for the clearly delineated timeouts to be produced by responses on a second lever, separate from the one that continued to be operative for the postponement of shocks (except during timeout periods). With this arrangement the timeout periods had clearly distinguishable but weak reinforcing effects, sufficient to maintain responding on small ratio schedules. In the present procedure, with responding on each of

Fig. 3. Three measures of performance for Subject R-15, demonstrating an intermediate degree of behavior control by the session-shortening contingency.

the two levers equivalently supported by the shock-postponement procedure, reinforcing effects of the added session-shortening contingency could be assessed through substantial shifts in allocation of responding that, during most of the experiment, continued to be supported by the shock-postponement procedure. Interestingly, responding as well as its allocation continued to be maintained by the session-shortening contingency in the final phases of the present experiment, when the shock-postponement contingency was disabled. It remains to be seen whether the session-shortening contingency would be effective for initial acquisition of behavior.

Our three-session criterion (of response allocation beyond 50% on the side that produced session-shortening) for initiating reversals might be viewed as not very robust as a measure of stability. In preliminary experimentation we had used more stringent criteria for stability before reversing and encountered difficulty in producing behavior change beyond the first reversal. Fortunately, with the less stringent criterion, the systematic character of the behavioral changes with most reversals allows reasonable confidence that the shifts in response allocation were indeed attributable to the manipulations of procedure.

A major point of interest in the present experiment lies in the fact that the session-shortening contingency was effective even though it was disabled during the final two minutes of each session, thus arguing for a fairly molar relationship between responses and their controlling consequences. To be sure, it was possible that a lever press could be immediately followed by an end of session. However, this could occur equally easily after presses on either lever; it does not account for the reversals of response allocation when the session-shortening contingencies were reversed. Mediating processes of the sort posited by traditional two-process theory would be massively overridden by the events occurring between responses and the consequent changes in session duration. Interpretations positing shock-frequency reduction over the short term as accounting for the interpretation of shock-postponement procedures (Sidman, 1962) or for response-contiguous density-reduction procedures such as that of Herrnstein and Hineline (1966) or of de Villiers (1974) are similarly compromised, especially if the interpretations

are based on average time from individual responses to shocks (e.g., Dinsmoor, 1977). Lambert, Bersh, Hineline, and Smith (1973) and Lewis *et al.* (1976) have shown that the effective consequences of a rat's behavior are integrated over periods on the order of a minute, allowing for behavior to be maintained even when it is followed by unavoidable shocks in the short term. The present results imply even greater periods of integration over time.

More promising are accounts based on reinforcing effects of changes of situation—situational transitions that involve changed response-contingent events as well as changed frequencies of aversive events (e.g., Baum, 1973; Hineline, 1977). Clearly, before it would be appropriate to ask what kinds of mediational processes are involved, it is essential to explore further the range over which events are integrated in conditioning. There are likely parallels between this work and research on appetitively controlled behavior that has been interpreted in terms of open vs. closed economies (Hursh, 1980). There, the effects of variables operative within conditioning sessions have been found to interact with the availability/nonavailability of food outside the sessions. The present effects also reveal sensitivity to events outside the session, in the sense of making a dimension of the session as a whole, a variable operating "from outside in." The analogy might be pursued by varying the aversiveness of events outside of the avoidance session. It is possible that these, as well as results in the appetitive case, can be satisfactorily accounted for by extending the range of conventional variables such as the frequency and temporal distribution of consequential events. Whatever interpretive approach is used to account for such effects, the controlling events in behavior called avoidance can include streams of events that are far more complex and extensive than those posited by traditional theory and experimentation.

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