ACTUAL VERSUS POTENTIAL SHOCK IN MAKING SHOCK SITUATIONS FUNCTION AS NEGATIVE REINFORCERS¹

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The relative importance of potential and actual shocks in making shock situations function as negative reinforcers was studied. Shocks were scheduled to occur at the same rate during two stimuli. During one, squirrel monkeys could avoid the shocks; during the other, they were unavoidable. For the two stimuli the potential rate of shocks was the same, but the actual rate was lower during avoidance because of avoidance responding. Fixed-ratio responding was maintained by the change from unavoidable shock to avoidance, indicating that the change was reinforcing when it resulted in a reduction in actual shock rate with no reduction in potential shock rate. Further increases in the rate of potential shock during avoidance had little effect upon the fixed-ratio responding until the rate was increased to the point that the actual shock rate during avoidance was comparable with that during unavoidable shock. At that point, the fixed-ratio response rate decreased nearly to zero. These findings show that actual shocks are more important than potential shocks in determining whether or not a shock situation will function as a negative reinforcer; this explains why the change from unavoidable shock to avoidable shock is reinforcing.

A stimulus may be defined as a negative reinforcer when a response terminates or reduces that stimulus and the rate of that response increases. Recent experiments have shown that animals will respond to postpone or to terminate avoidance schedules. Verhave (1962) and Sidman (1962) found that responding could be maintained if it terminated a nondiscriminated avoidance schedule (Sidman, 1953a) for a specified duration. Also, animals will respond to terminate (Findley and Ames, 1965) or to postpone (Findley, Schuster, and Zimmerman, 1966) discriminated avoidance schedules. In all of these experiments, situations containing an avoidance schedule functioned as negative reinforcers relative to situations without an avoidance schedule.

These experiments raise the question as to what variable or variables contributed to making the avoidance situations function as

negative reinforcers. One factor could have been the occasional occurrence of shock. Several experiments have shown that animals will terminate a stimulus during which shocks are delivered only occasionally and at irregular intervals even though the stimulus does not embody an avoidance schedule, *e.g.*, (Dinsmoor, 1962; Azrin, Holz, and Hake, 1962; Morse and Kelleher, 1966). Such findings suggest that situations containing an avoidance schedule may function as negative reinforcers because of occasional shocks, rather than the avoidance schedule *per se*.

The number of actual shocks received during avoidance situations is usually quite small relative to the number scheduled. It is also possible that this much larger scheduled or potential shock rate is what makes avoidance situations function as negative reinforcers. Several studies have shown that potential shock rate controls behavior during nondiscriminated avoidance: each change in the potential shock rate (change in response-shock interval) typically results in a change in the rate of avoidance responding to levels slightly higher than, but comparable to, the rate of potential shock (Sidman, 1953b; Verhave, 1959a, 1959b; Herrnstein and Brady, 1958; Clark and Hull, 1966). This degree of control exerted by potential shock rate over the avoidance response suggests that potential

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shock rate also may determine the extent to which an avoidance situation is a negative reinforcer. Support for this explanation comes from Anger (1963), who has suggested that during nondiscriminated avoidance, the subject learns the potential shock rate from responding and receiving shocks correlated with certain postresponse times and the temporal stimuli that vary with postresponse time. The shock closely follows these temporal stimuli at long postresponse times making these stimuli function as negative reinforcers. It follows that as the potential shock rate is increased, shorter postresponse times will more likely be paired with shock, and the stimuli correlated with shorter postresponse times will become negative reinforcers. It also follows that if the shorter temporal stimuli become negative reinforcers, a greater portion of the time during the avoidance situation will be occupied by negative reinforcers. In this way, the potential shock rate of an avoidance situation may determine the extent to which that situation functions as a negative reinforcer.

Findley and Ames (1965) used two widely different potential shock rates during avoidance and measured the rate of responding to terminate the avoidance situation during each of the potential shock rates. They found the highest rate of escape responding during the highest potential shock rate. It is not possible, however, to identify potential shock rate as the most important determinant of the escape behavior, since there was also a greater number of shocks actually received at the highest potential shock rate.

The present study investigated the relative importance of potential and actual shocks in making shock situations function as negative reinforcers. The role of actual shock could be evaluated by making the change from one unavoidable shock rate to another contingent upon responding. However, two unavoidable shock situations would not allow evaluation of potential shock, since potential shock rate cannot differ from actual shock rate during unavoidable shock. On the other hand, potential shock rate is higher than actual shock rate during an avoidance situation because of avoidance responding. Hence, the relative importance of actual and potential shock could be evaluated by procedures in which the change from unavoidable to avoidable shock (or *vice versa*) was contingent upon respond-

ing. For example, if actual shock is the more important variable, responding should be maintained by the change from unavoidable to avoidable shock when the change results in a reduction in the actual shock rate but the same or a higher potential shock rate. However, another possible result of this procedure is that responding would not be maintained, or maintained only when the change from unavoidable to avoidable shock resulted also in a reduction in the potential shock rate. That result would point to potential shock rate as the more important variable and suggest the procedure in which the response-contingent change is from avoidable to unavoidable shock with the change resulting in a reduced potential shock rate but the same or a higher actual shock rate.

The present experiment made the change from unavoidable to avoidable shock contingent upon responding. In addition to the above question concerning actual and potential shocks, this procedure will bear on the question heretofore not investigated: whether the change from unavoidable to avoidable shock is reinforcing.

METHOD

Subjects and Apparatus

Eight experimentally naive squirrel monkeys were individually seated in a restraining chair that imposed minimal restraint on peripheral body movement (Hake and Azrin, 1963). The horizontal plate that served as a waistlock left the monkey free from the waist up. Electric shock was delivered through the tail by two electrodes resting on a shaved portion of the tail. The tail was immobilized by a tail-stock and the monkey was prevented from reaching its tail by the waistlock which extended to the walls of the chamber. To ensure a low resistance electrical contact, the tail was massaged with electrode paste (EKG Sol). The ac shock, specified as the voltage at the secondary of a step-up transformer, was delivered through a 10K-ohm series resistor. Since the resistance of the monkeys was about 6000 ohms across the range of voltages employed, a fluctuation as large as 1000 ohms in the monkey's resistance would result in less than a 10% change in current. Oscilloscope tests showed no peak transients. Each shock was 0.1 sec; this brief duration reduced the duration of elicited skeletal reactions.

Two experimental compartments were used. In both, the work space above the horizontal waistlock was 8 by 12 by 10-in. high. In the compartment used with the first four monkeys (M-11, M-518, M-30, M-7), the response bar protruded from the front wall 3 in. above the horizontal waistlock and was situated about 5 in. from the monkey. The response bar was 1-in. wide and protruded only 0.5 in. from the front wall, thereby minimizing contact by incidental movements. A bar-press of about 25 g defined a response. In the second compartment used with the last four monkeys (M-38, M-50, M-126, M-154) the response bar was more accessible. It was also located 3 in. above the horizontal waistlock, but was mounted in a box attached to the front wall of the compartment. The bar protruded 1 in. from the box, making the bar about 2 in. from the monkey. A bar-press of 15 g was required for operation. Both experimental compartments were within sound-attenuating, light-proof enclosures.

The stimuli used to signal the experimental conditions in both chambers were: (1) a stimulus light 1 in. in diameter located above the response bar; (2) 90 db of white noise measured from the location of the monkey; (3) response feedback consisting of an ac buzzer that sounded for 75 msec after a response. The avoidance situation was signalled by red illumination of the stimulus light, white noise, and response feedback. The unavoidable shock situation was signaled by white illumination of the stimulus light, no white noise, and no response feedback. Programming and recording were accomplished automatically by circuits in an adjacent room.

After the monkey was seated in the chamber, a timer automatically provided a 5-min session delay to allow the monkey to recover from any possible effects of handling. During the session delay, the chamber lights were extinguished, shocks were not delivered, and responses had no programmed consequence. After the 5-min session delay, the start of the session was signaled by illumination of the overhead lights and the stimuli of either the avoidable or unavoidable shock situation.

Basic Procedure

The experiment was divided into five phases. The first three dealt with whether or not responding during one shock situation

could be maintained by the change to another when this change resulted in the same potential shock rate but a reduction in the actual shock rate. Specifically, would monkeys respond during an unavoidable shock situation for the change to an avoidance situation with the same potential shock rate but, because of avoidance responding, a lower actual shock rate? In the first phase, responding was conditioned under a nondiscriminated avoidance schedule. The second phase was a multiple schedule consisting of the avoidance component alternating with an unavoidable shock component that had the same rate of scheduled shocks. This multiple-schedule phase allowed evaluation of responding during unavoidable shock resulting from (1) operant level, (2) skeletal responses elicited by shock, and (3) induction from the avoidance component. The third phase was a chain schedule during which the change from the unavoidable shock component to the avoidance component was contingent upon fixed-ratio responding during unavoidable shock. More than one response was required for the change, since some responding during unavoidable shock might result from the factors mentioned above, *e.g.*, skeletal responses elicited by shock. The reinforcing effect of the change was evaluated by comparing the rate of responding during the unavoidable shock component of the chain schedule with the rate of responding during the unavoidable shock component of the multiple schedule where the change was independent of responding.

In the fourth phase, the potential shock rate of the avoidance component in the chain schedule was varied to determine if the monkeys would respond for the change to the avoidance component when it resulted in a higher rather than the same potential shock rate. This phase also provided functional relationships between the rate of responding for the change and (1) the potential shock rate during avoidance and (2) the actual shock rate during avoidance.

The fifth phase attempted to determine the duration of the avoidance component necessary to maintain responding for the change from unavoidable to avoidable shock.

Simple-avoidance phase. Responding under nondiscriminated avoidance was initially conditioned using short response-shock (R-S) and shock-shock (S-S) intervals. The R-S and S-S

Table 1

Session duration and parameter values used during final performance in the first three phases.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Monkeys	Session Duration	Shock Intensity (Volts)	R-S Interval During Avoidance	Duration Avoidance Component	Mean Interval Between Unavoidable Shocks	Fixed- Ratio
M-11	3 hr	120	60 sec	15 min	60 sec, regular	30
M-518 ^a	6 hr	120	60 sec	15 min	60 sec, regular	25
M-30 ^b	4 hr	140	60 sec	15 min	60 sec, irregular	10
	4 hr	180	60 sec	8 min	60 sec, irregular	25
M-7	4 hr	400	60 sec	20 min	60 sec, irregular	50
M-38	4 hr	200	60 sec	30 min	60 sec, irregular	50
M-50	4 hr	300	60 sec	20 min	60 sec, irregular	45
M-126	2 hr	200	60 sec	30 min	60 sec, irregular	30
M-154 ^b	2 hr	300	20 sec	15 min	60 sec, regular	25
	2 hr	300	60 sec	8 min	60 sec, irregular	40

NOTE. For five of the monkeys, the duration of the avoidance component was reduced in the chain-schedule phase to allow more observations of the fixed-ratio responding. The durations of the avoidance component for these monkeys in the chain-schedule phase were 8 min (518, 154), 10 min (7, 126), and 12 min (30).

^aFor M-518 the unavoidable shocks were delivered at irregular intervals during the chain-schedule phase.

^bThe second row of parameter values for Monkeys 30 and 154 refers only to a second determination during the chain schedule phase.

intervals were gradually increased until both were 60 sec for all except M-154, which had R-S = S-S 20 sec. Hereafter, only the R-S interval will be indicated, since the S-S interval was always the same as the R-S for the rest of the experiment. The first four columns of Table 1 show the session duration, shock intensity, and R-S interval for each of the monkeys during the simple-avoidance phase. The simple-avoidance phase continued until there was at least one session during which 95% of the scheduled shocks were avoided. This required from two to nine sessions at the final R-S value.

Multiple-schedule phase. During this phase, the avoidance component alternated in time with an unavoidable shock component. The avoidance component was signaled by red illumination of the stimulus light, white noise, and response feedback. The unavoidable shock component was signaled by white illumination of the stimulus light, no white noise, and no response feedback. The R-S interval of the avoidance component remained at 60 sec (20 sec for M-154) as in the simple-avoidance phase. The unavoidable shocks were delivered at the rate of one every 60 sec and were scheduled at regular intervals of time for three of the monkeys (M-11,

M-518, and M-154) and at irregular intervals for the others. The avoidance and unavoidable shock components were always the same duration, but to provide adequate exposure to the new condition, unavoidable shock, the components were longer at the start of the multiple-schedule phase. All monkeys had at least four sessions at the end of this phase during which the duration of the avoidance and unavoidable shock components remained constant. The duration of the components as well as other parameter values during final performance on this phase are given in the first six columns of Table 1. The multiple schedule was in effect until there were at least two consecutive sessions during which responding during unavoidable shock was less than 1.5 responses per min, or, if the response rate did not decrease to that level, four consecutive sessions during which the rate of responding during unavoidable shock was lower than the rate of responding during the avoidance component. The multiple schedule continued for 20 sessions on the average, the range being 5 to 40 sessions.

Chain-schedule phase. During this phase, the change from unavoidable shock to avoidance was contingent upon fixed-ratio responding during unavoidable shock. Each session

started with unavoidable shock. If the monkey made the required number of responses during unavoidable shock, that condition terminated and the avoidance situation was in effect for a specified duration, after which the unavoidable shock component was reinstated. If the monkey failed to make the required number of responses, the unavoidable shock continued. The fixed-ratio (FR) requirement for the change was gradually increased over sessions from FR-1 to at least FR-25.

Columns 1 through 7 of Table 1 show the highest fixed-ratio requirement as well as the other parameter values for each of the monkeys. The shock intensity, mean interval between unavoidable shocks, and the R-S interval were the same as in the previous phases. For M-518, however, the unavoidable shock schedule was changed such that the unavoidable shocks occurred at irregular instead of regular intervals. For five of the monkeys (M-518, M-30, M-7, M-126, M-154), the duration of the avoidance component was reduced (see Table 1) in this chain-schedule phase to allow more observations of the fixed-ratio responding. There were two determinations during the chain-schedule phase for two monkeys. For M-30, the shock intensity was increased from 140 v to 180 v at FR-10 in order to reach the fixed-ratio requirement of 25. For M-154, tested with R-S = 20 sec, there was a second determination with R-S = 60 sec. A minimum of four sessions was given at the highest fixed-ratio requirements of 25 to 50. The chain-schedule phase lasted 30 sessions on the average, with a range of 13 to 60 sessions.

The shocks during the avoidance and unavoidable shock components were programmed by separate timers. The timer for the avoidance component was programmed so that the first R-S interval upon the change from unavoidable shock to avoidance was of variable duration, so that the onset of the avoidance situation would not automatically be free of shock for a time equal to the R-S interval. The timer that programmed the unavoidable shocks was stopped but not reset by the termination of the unavoidable shock component. Hence, the fixed-ratio responding could not alter the rate of shocks during the unavoidable shock component.

Varying the potential shock rate during avoidance. During this phase, the chain-schedule procedure continued and the R-S interval of the avoidance component was gradually reduced over sessions while the unavoidable shock rate remained constant. Four of the monkeys used above and one additional monkey (M-156) served as subjects. The sequences of R-S intervals and other parameter values are given for each monkey in Table 2. After the shortest R-S interval for a given monkey, a longer R-S interval was reinstated, usually the initial and longest one. M-50 had to be discontinued before the initial R-S interval was reinstated. A minimum of four sessions was provided at each R-S interval.

Varying the duration of the avoidance component. During this phase, the duration of the avoidance component in the chain schedule was varied for two of the monkeys. For M-38, the duration was gradually reduced; the sequence of durations being 15, 7, 3, 1,

Table 2
Session duration and parameter values when the potential shock rate of the avoidance component was varied.

(1) Monkeys	(2) Session Duration	(3) Shock Intensity (Volts)	(4) Sequence of R-S Intervals (Seconds)	(5) Duration Avoidance Component	(6) Mean Interval between Unavoidable Shocks	(7) Fixed- Ratio
M-518	3 hr	180	60, 30, 15, 5, 60	12 min	60 sec, irregular	50
M-126	3 hr	400	60, 30, 20, 12, 6, 4, 3, 60	15 min	60 sec, irregular	35
M-50	2 hr	300	60, 30, 15, 8, 4, 2, 1, 0.5	7 min	180 sec, irregular	100
M-154	2 hr	300	60, 30, 15, 10, 5, 3, 2, 1, 10, 5, 3, 2, 1, 10	8 min	120 sec, irregular	40
M-156	3 hr	300	60, 30, 20, 10, 5, 3, 2, 1, 0.5, 60	10 min	120 sec, irregular	40

and 0.5 min. For M-518, the sequence of durations was 12, 30, 3, 1, and 0.5 min. After the shortest duration, both monkeys were returned to the initial duration. The other parameters remained constant. For both monkeys the R-S interval was 60 sec and the unavoidable shock was delivered at irregular intervals averaging 60 sec. The shock intensity was 180 v for M-518 and 200 v for M-38. The ratio required to terminate the unavoidable shock was FR-30 for M-518 and FR-50 for M-38. A minimum of four 3-hr sessions was provided at each duration of the avoidance component.

RESULTS

Simple avoidance. The second column of Table 3 shows the response rate of each monkey for the last session of the simple-avoidance phase. For the seven monkeys on the basic procedure with R-S = 60 sec, response rates were between 3.7 and 13.0 responses per min, with most monkeys averaging about 4 to 7 responses per min. This responding was effective in reducing the scheduled 60 shocks per hr to 0.5 to 2.6 per hr, meeting the criterion of a reduction of at least 95%. The monkey (M-154) tested with R-S = 20 sec averaged 22.8 responses per min and reduced

the scheduled 180 shocks per hr to four, a 95% reduction.

Multiple schedule. When the multiple schedule was introduced (not shown), the rate of responding during the unavoidable shock component was as high as the response rate during the avoidance component. However, after an average of 20 sessions, a discrimination was evident as the rate of responding during unavoidable shock met either the criterion of fewer than 1.5 responses per min for two consecutive sessions or the criterion of being lower than the avoidance rate for four consecutive sessions. This discrimination may be seen in Fig. 1 which shows segments of continuous response records taken from the start of the last session of the multiple-schedule phase for each of the seven monkeys on the basic procedure with R-S = 60 sec. With the exception of M-50, the change from avoidance to unavoidable shock or *vice versa* was characterized by an immediate change in response rate. Columns 3 and 4 of Table 3 show that for this last session, the response rates during the avoidance component were higher than the response rates during unavoidable shock for all monkeys and, with the exception of M-50, at least twice as high.

Chain schedule. Stable performances on fixed-ratio requirements of 25 to 50 were

Table 3

Responses per minute during final performance on the simple-avoidance, multiple-schedule, and chain-schedule phases.

(1) <i>Monkeys</i>	<i>Simple Avoidance</i>	<i>Multiple Schedule</i>		<i>Chain Schedule</i>	
	(2) <i>Avoidance</i>	(3) <i>Avoidance</i>	(4) <i>Unavoidable Shock</i>	(5) <i>Avoidance</i>	(6) <i>Unavoidable Shock</i>
M-11	10.5	6.7	0.3	6.9	72.2
M-518	6.1	3.0	0.6	4.3	80.4
M-30 ^a	6.6	5.2	1.3	4.3	33.8
				4.0	48.3
M-7	4.8	3.6	0.7	3.4	51.5
M-38	5.0	2.9	1.1	9.0	52.8
M-50	13.0	2.9	2.3	2.5	50.4
M-126	3.7	3.2	0.3	6.5	82.6
M-154 ^b	22.8	20.5	3.4	16.12	44.9
				9.1	37.7

NOTE. Data of the simple-avoidance and multiple-schedule phases are from the last session.

Data of the chain-schedule phase are averages of the last three sessions.

^aThe second row of data for M-30 under the chain-schedule phase was obtained after the shock intensity was increased from 140 to 180 v.

^bThe second row of data for M-154 under the chain-schedule phase was obtained after changing the R-S interval from 20 to 60 sec and the fixed ratio from 25 to 40.

Fig. 1. Final performance on the multiple-schedule phase. Each of the continuous response records is from the start of the last session of the multiple-schedule phase. The nondiscriminated avoidance and unavoidable shock components alternated in time and are separated by the heavy vertical lines across the records. Each session started with unavoidable shock. Shocks are indicated by the downward displacements of the response pen.

reached after an average of 30 sessions. Figure 2 shows segments of continuous response records taken from the start of the last session for each of the seven monkeys tested on the basic procedure. As during the multiple schedule, the change from unavoidable to avoidable shock or *vice versa* was characterized by an immediate change in response rate but in the opposite direction: response rate decreased upon the change to the avoidance component and increased upon the change to unavoidable shock. The response rates during the two components are shown in columns 5 and 6 of Table 3. The response rates during avoidance did not differ greatly from those during the multiple-schedule phase but response rates during unavoidable shock increased markedly from the rates of 0.3 to 2.3 responses per min in the multiple-schedule phase to rates of 33 to 82 responses per min. Similar changes were observed for M-154, tested with R-S = 20 sec. For all monkeys, the actual shock rate during the unavoidable

shock component was 60 per hr while during the avoidance component the actual shock rate was only 0.2 to 4.1 per hr. Hence, the change from unavoidable shock to avoidance resulted in at least a 93% reduction in actual shock rate but the same (R-S = 60 sec) or a higher (R-S = 20 sec) rate of potential shock.

Figure 3 shows continuous response records of one monkey at fixed-ratio requirements larger than those shown in Fig. 2. These larger ratio requirements allow a closer examination of the fixed-ratio pattern of responding and the changes in it as a function of increasing the ratio requirement. The sequence of ratio-requirements was 40, 50, 60, 70, 90, 100, 120, 140. The fixed-ratio pattern of responding during unavoidable shock was similar to that observed with fixed-ratio schedules of positive reinforcement. First, the characteristic bi-valued rate of responding was evident; an initial period of low response rate (ratio pause) was followed by an abrupt

Fig. 2. Final performance on the chain-schedule phase. Each of the continuous response records is from the start of the last session of the chain-schedule phase. Shocks are indicated on the event recording beneath each of the continuous response records and the avoidance and unavoidable shock components are separated by the downward displacements of the response pen. Each session started with unavoidable shock.

change to a higher response rate (running rate). Second, the usual types of "ratio strain" occurred as the ratio requirement increased; the ratio pause became longer, and there were occasional pauses after the monkey had started responding. At the largest fixed-ratio requirement of 140, the ratio pause lasted for the major portion of the session.

Potential shock rate during avoidance. Figure 4 shows the effects of gradually reducing the R-S interval upon response rate during the avoidance component. Each R-S interval is expressed as the scheduled or potential number of shocks per minute. For example, $R-S = 60$ is expressed as 1 shock per min and $R-S = 0.5$ sec is 120 shocks per min. Figure 4

Fig. 3. The pattern of responding as a function of the fixed-ratio requirement. Each of the continuous response records is from the last session at a given fixed-ratio requirement. The avoidance and unavoidable shock components are separated by the downward displacements of the response pen. Each record starts with unavoidable shock. The R-S interval was 60 sec and the unavoidable shocks were delivered at irregular intervals averaging 60 sec. The shock intensity was 180 v.

shows that the rate of avoidance responding increased with every increase in potential shock rate. Figure 5 shows the per cent of the potential shocks avoided as a function of the R-S interval. Again, each R-S interval is expressed as the potential shocks per minute. It can be seen that 96 to 100% of the scheduled shocks were avoided at each R-S interval, even at intervals as short as 0.5 sec (120 shocks/min). Figures 4 and 5 taken together indicate that with each increase in the rate of potential shocks, the monkeys increased their response rate and avoided at least 96% of the potential shocks.

Figure 6 shows the effects of varying the R-S interval (potential shock rate) upon performance during unavoidable shock. It can be seen that the response rate was lowest when the potential shock rate was highest. However, it can be seen also that the monkeys responded for the change from unavoidable shock to avoidance even when the change resulted in an increase in potential shock rate. (The arrows on the abscissa indicate the unavoidable shock rate, which remained constant across all values of the R-S interval.) At the first point in each function the potential shock rate during avoidance was 1 per min

Fig. 4. Response rate during the avoidance component as a function of the potential shock rate (R-S interval) during avoidance. Each point is the mean of the last three sessions. The unconnected points are redeterminations.

while the unavoidable shock rates were only 1.0 (M-518, M-126), 0.5 (M-154, M-156), or 0.33 (M-50) shocks per min. Yet, the monkeys responded at a high rate for the change. Even with further increases in the potential shock rate, the response rate during unavoidable shock remained unaffected. Responding during unavoidable shock decreased nearly to zero only after the potential shock rate of the avoidance component was 12 (M-518), 20 (M-126), 60 (M-154), 240 (M-156), or 360 (M-50) times greater than the unavoidable shock rate. This raises the question of why the response rate during unavoidable shock decreased at these particular potential shock rates, which have no apparent relation to the unavoidable shock rates.

An answer is suggested in Fig. 7, which shows the actual shock rate during the avoidance component as a function of the potential shock rate. Although the avoidance responding was effective in avoiding 96 to

100% of the potential shocks at every R-S interval, Fig. 7 shows that the rate of actual shocks received during avoidance also increased as the potential shock rate increased. Hence, the actual shock rate during avoidance was highest at the highest potential shock rates where responding for the change to avoidance had dropped to a near-zero level (Fig. 6). Figure 8 shows the data points of Fig. 6 replotted according to the actual rather than the potential shock rate during avoidance. For all monkeys, the response rate was high when the change to avoidance resulted in few actual shocks. It can be seen also that responding for the change from unavoidable shock to avoidance reached a near-zero level when the actual shocks during the avoidance component increased. For four of the five monkeys, the lowest response rate was reached when the actual shock rate during avoidance was less than 1 per min from the unavoidable shock rate. (The constant unavoidable shock

Fig. 5. Per cent of potential shocks avoided during the avoidance component as a function of potential shock rate (R-S interval). Each point is the mean of the last three sessions. The unconnected points are redeterminations.

rate is indicated by an arrow on the abscissa.) For the fifth monkey (M-156), response rate did not reach a near-zero level until there were 5 shocks per min during avoidance as contrasted with the 0.5 per min during unavoidable shock. Even for this monkey, examination of the point at which the response rate during unavoidable shock decreased nearly to zero reveals that the unavoidable shock rate was more comparable with the actual shock rate during avoidance than with the potential shock rate during avoidance. Figure 8 suggests that the properties of the unavoidable shock and avoidance components approached a point of equality when the actual shock rates of the two components became comparable.

Duration of the avoidance component. Figure 9 shows the rate of responding during unavoidable shock as a function of the duration of the avoidance component. For both monkeys, decreasing the duration of the avoidance component did not decrease the response rate during unavoidable shock until durations of

30 sec (M-518) or 1 min (M-38) were reached. In fact, the response rate was usually higher at the shorter durations up to the point at which responding nearly ceased.

The continuous response records of M-38 in Fig. 10 illustrate the pattern of fixed-ratio responding at the various durations of the avoidance component. At durations as short as 3 min, the fixed-ratio responding began soon after onset of the unavoidable shock component and continued at a high and steady rate until that component was terminated. Ratio strain became evident when the duration of the avoidance component was reduced to 1 min: the length of the ratio pause increased and pauses after responding had started were more frequent. Ratio strain was most evident at the 30-sec duration and became more pronounced from the first to the last session at that duration. Upon reinstating the 15-min duration, evidence of ratio strain decreased gradually from the first to the last session at that duration. Similar changes in the pattern of fixed-ratio respond-

Fig. 6. Response rate during unavoidable shock as a function of the potential shock rate (R-S interval) during avoidance. Each point is the mean of the last three sessions. The unconnected points are redeterminations. The arrow on the abscissa indicates the shock rate during unavoidable shock.

ing occurred when the R-S interval of the avoidance component was gradually decreased.

DISCUSSION

Previous experiments have shown that situations containing an avoidance schedule can function as negative reinforcers, *i.e.*, animals will respond to terminate avoidance situations (Verhave, 1962; Sidman, 1962; Findley and Ames, 1965; Findley, Schuster, and Zimmerman, 1966). The present results reveal that animals will respond also for the change from an unavoidable shock situation to an

avoidance situation when this change results in a lower shock rate. That the change from unavoidable shock to avoidance was reinforcing was shown by a comparison of the rate and pattern of responding during unavoidable shock in the multiple and chain schedules. The much lower response rate during the unavoidable shock component of the multiple schedule indicated that the fixed-ratio responding during the unavoidable shock component of the chain schedule could not be attributed to elicited skeletal reactions to shock or to inductive effects from the avoidance component. Similarly, the pattern of fixed-ratio responding during the chain

Fig. 7. Actual shock rate during the avoidance component as a function of potential shock rate (R-S interval). Each point is the mean of the last three sessions. The unconnected points are the redeterminations.

schedule was characteristic of fixed-ratio schedules of positive (Ferster and Skinner, 1957) and negative reinforcement (Kaplan, 1956; Azrin, Holz, Hake, and Ayllon, 1963;

Winograd, 1965; Morse and Kelleher, 1966). These changes in rate and pattern of responding during the chain schedule indicate that responding was reinforced and maintained by

Fig. 8. Response rate during unavoidable shock as a function of the actual shock rate during avoidance. The data points of Fig. 6 are replotted according to the actual rather than the potential shock rate during avoidance. The arrow on the abscissa indicates the shock rate during unavoidable shock.

the change from unavoidable shock to avoidance.

That actual shock was the critical variable in this type of reinforcement was indicated by the findings that (1) fixed-ratio responding was maintained when the change to avoidance resulted in a lower shock rate but (2) was not maintained when the actual shock rate during avoidance became comparable with that during unavoidable shock. If potential shock had been the most important variable, the change from unavoidable shock to avoidance would not have maintained responding when the change resulted in an increase in rate of potential shock. The change from unavoidable shock to avoidance did maintain responding even when the potential shock rate during avoidance was many times greater than that existing during unavoidable shock. In fact, increasing the potential shock rate during avoidance had little effect upon the

fixed-ratio responding until the potential shock rate was increased to the point that the actual shock rate during avoidance approached or reached that existing during unavoidable shock. These findings show that actual shocks are more important than potential shocks in determining whether or not a shock situation will function as a negative reinforcer, which explains why the change from unavoidable to avoidable shock is reinforcing.

It might be argued that the eventual decrease in the fixed-ratio response rate was due to the response requirement during avoidance; the lowest fixed-ratio response rate was obtained when the response rate during the avoidance component was at its highest level. Experiments have shown that increasing the response requirement can affect the reinforcing properties of a situation (Azrin, 1961; Thompson, 1964). The response requirement during avoidance may have made the change

Fig. 9. Response rate during unavoidable shock as a function of the duration of the avoidance component. Each point is the average of the last three sessions. The unconnected points are redeterminations.

from unavoidable to avoidable shock less reinforcing, but it was not a major factor in this study. The initial reductions in the R-S interval produced large increases in the rate of avoidance responding with no corresponding decrease in the fixed-ratio response rate. The fixed-ratio response rate decreased only at that point where the actual shock rate during the avoidance component approached or reached the shock rate existing during unavoidable shock.

Although a reduction in actual shock rate was the most important determinant of whether or not the monkeys responded for the change from unavoidable shock to avoidance, this relationship was not perfect. For example, in some cases, the monkey virtually stopped responding for the change even when it resulted in a slight reduction in shock rate. There are at least two factors that may have been responsible for this. First, shock occurred during both components; hence, whether or not the unavoidable shock situation functioned as a negative reinforcer depended upon the discrimination of a difference between two shock rates rather than a discrimination between the mere presence and absence of

shock. In most escape procedures, escape responses do result in the absence of shock. To have a difference between two shock rates requires using a higher shock rate than would be necessary to provide a difference between no shock and shock. Application of the Weber fraction, which indicates that a just-detectable difference is a constant fraction of the stimulus, suggests that a discrimination between two moderate shock rates would require a larger absolute difference than a discrimination between a very low and a low shock rate. Second, the amount of shock reduction obtained by the change from unavoidable shock to avoidance was rarely consistent, since the shock rate during the avoidance component was controlled by the subject, not by the experimenter. Variability in the response rate for the change may have been a function of the variability of the shock rate during the avoidance component. For example, the change to avoidance could result at any time in a lower shock rate, an equal shock rate, or a higher shock rate, depending upon the subject's behavior.

The reinforcing effect of the change from unavoidable shock to avoidance was also a function of the duration of the avoidance component (Fig. 9). The relationship was curvilinear: response rate dropped to a near-zero level at the shortest durations, but short durations up to that value produced increased responding. Azrin *et al.* (1963), using a procedure in which fixed-ratio responding terminated intermittent and unavoidable shocks, also found that response rate was lowest when unavoidable shock was terminated for the briefest duration. However, durations as brief as 10 sec maintained responding in that experiment; 60 sec was the shortest effective duration in the present study. Squirrel monkeys served as subjects in both experiments and most of the other parameter values were comparable. This suggests that the greater effectiveness of the Azrin *et al.* (1963) procedure was due to the complete rather than partial reduction in the unavoidable shock. The relationship between fixed-ratio response rate and duration was not curvilinear in the study of Azrin *et al.* (1963), but the longest duration in that experiment was only 4 min. In the present experiment, response rate was high at durations of 3 to 7 min but decreased at the longer durations of 15 to 30 min. The curvi-

Fig. 10. Fixed-ratio pattern of responding as a function of the duration of the avoidance component. A 30-min segment from the last session is given for each duration. Segments from the first session are also shown at the 30-sec and 15-min durations. The avoidance and unavoidable shock components are separated by the downward displacement of the response pen. Each record starts with unavoidable shock.

linear relationship of the present study is, however, reminiscent of relationships obtained when timeout from positive reinforcement has been contingent upon incorrect responses in matching-to-sample procedures (Ferster and Appel, 1961; Zimmerman and Ferster, 1963). In these experiments, accuracy increased as a function of the duration of timeout until durations of 2 min (Ferster

and Appel, 1961) or 10 min (Zimmerman and Ferster, 1963) were reached. At those points, accuracy and the rate of correct responses decreased. In the timeout studies and in the present one, a period of lower (nondiscriminated avoidance) or zero (timeout) response rate was interspersed between the responses under consideration. One can only speculate as to whether this factor is responsible or, for

that matter, whether there is a common factor responsible for these curvilinear relationships. It does appear that some as yet unspecified factors come into play at these longer durations.

The present procedure differed from most escape experiments in at least two ways. First, in most escape experiments, the escape response *per se* terminates or reduces the unconditioned negative reinforcer. In the present experiment, the fixed-ratio responding during unavoidable shock terminated a stimulus but not the unconditioned negative reinforcer. Additional avoidance responding was necessary for reduction in the unconditioned negative reinforcer. Without the avoidance responding, the actual shock rate during avoidance would have been equal to or higher than that existing during unavoidable shock. Because of this appended response requirement, it may be useful to look at the present procedure as a chain schedule. In a two-component chain schedule of positive reinforcement, responding in the presence of one stimulus according to a schedule of reinforcement produces a second stimulus in the presence of which additional responses produce unconditioned reinforcement according to a schedule of reinforcement. In a chain schedule of negative reinforcement, responding according to the first schedule of reinforcement would not terminate or reduce the shock, but it would produce a stimulus in the presence of which additional responding according to a second schedule would terminate or reduce the shock. In the present experiment, fixed-ratio responding in the presence of intermittent and unavoidable shocks produced a stimulus in the presence of which additional responding, according to an avoidance schedule, reduced the shocks. The chain schedule has been used extensively in the study of positive reinforcement (Kelleher and Gollub, 1962) but only rarely (Dinsmoor and Clayton, 1963) in the study of negative reinforcement. The present results and those of Dinsmoor and Clayton (1963) indicate the feasibility of using the chain-schedule procedure to evaluate the reinforcing effects of schedules of negative reinforcement.

A second difference between the present experiment and most escape experiments was the partial rather than complete reduction of shock that resulted after the unavoidable

shock stimulus was terminated. Only a few experiments have used a partial or fractional escape procedure in which responses only reduce the intensity (Campbell and Kraeling, 1953; Campbell, 1955; Weiss and Laties, 1958, 1959) or the rate (Herrnstein and Hineline, 1966) of the unconditioned negative reinforcer. The partial escape procedure appears to have at least one advantage over the usual procedure in which escape responses are followed by the termination of the unconditioned negative reinforcer. When using the complete termination procedure, the effects of shock intensity or shock rate must be studied by varying the shock intensity or shock rate in the stimulus during which the subject responds. Changes in the intensity or rate of shock will also affect the extent to which the shock produces unconditioned skeletal reactions and, as a result, unconditioned bar-presses, *e.g.*, biting the response bar (Azrin, Hutchinson, and Hake, 1967). In the partial escape procedure, the effects of shock intensity or shock rate may be studied by varying the rate or intensity of the shock in the stimulus into which the subject is escaping. The rate or intensity of the shock during the stimulus in which the animal responds will remain constant as in the present experiment.

The emphasis of this paper has been upon the behavior that terminates a shock situation. Actual shock was the most important variable in determining whether a monkey would respond to terminate a shock situation. Consider now the avoidance behavior. Potential shock controlled avoidance responding, as evidenced by the increase in the rate of avoidance responding as a direct function of the rate of scheduled shock. Although not presented, the relationship between the actual shock rate during avoidance and the rate of avoidance responding could not have been such a direct function. In the present experiment (Fig. 7) the actual shock rate was a function of the potential shock rate, but increases in potential shock rate did not always result in increases in actual shock rate. Hence, for those points where the potential shock rate increased with no increase in actual shock rate, the avoidance rate increased with no change in actual shock rate. It appears that potential shock will determine the rate of avoidance responding during an avoidance

situation but actual shocks will determine the rate of the responding to terminate that situation.

Other studies have shown also that, with equal R-S and S-S intervals, the rate of nondiscriminated avoidance responding increases as the R-S interval is decreased (Sidman, 1953b; Herrnstein and Brady, 1958; Verhave, 1959a, 1959b; Clark and Hull, 1966). In these studies the R-S interval was reduced to 2.5 (Sidman, 1953b) to 5 sec (Herrnstein and Brady, 1958). In the present study, avoidance responding was maintained when the R-S interval was as short as 1.0 to 0.5 sec. Hence, the direct function between the rate of avoidance responding and potential shock rate has been extended to include the range from 24 shocks per min (R-S = 2.5 sec) to 120 shocks per min (R-S = 0.5 sec) which suggests that a direct function describes this relationship over at least the major portion of the range of potential shock rates.

With unequal R-S and S-S intervals, however, the rate of avoidance responding is not a direct function of the potential shock rate. For example, Sidman (1953b) found that avoidance responding dropped to a near-zero level when the R-S interval was 2.5 sec and the S-S interval was 5 sec. One way of describing the classificatory scheme of nondiscriminated avoidance is that the R-S interval determines the rate of shock when a response is emitted and the S-S interval determines the rate of shock when a response is not emitted. The present results show that a subject will change from one shock situation to another when this change results in a reduction in the actual shock rate. Hence, these results suggest that it may be possible to predict whether a subject will respond during a given nondiscriminated avoidance schedule by comparing the shock rate specified by the S-S interval and the rate of shocks received when the R-S interval is in effect. According to the present results, the subject should emit avoidance responses only when the actual shock rate obtained by responding is less than that specified by the S-S interval. This is the result when R-S and S-S intervals are equal. If, on the other hand, the rate of shocks is higher when the R-S interval is in effect, the subject may stop responding and allow the S-S interval to go into effect. Although the shock rates are not given, it is possible that this was the case in the

study of Sidman (1953b) where the animals stopped responding when the R-S interval was 2.5 sec and the S-S interval was 5 sec.

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