*THE EFFECTS OF STIMULI FOLLOWED
BY RESPONSE-INDEPENDENT SHOCK
ON SHOCK-AVOIDANCE BEHAVIOR¹*

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Four rhesus monkeys were trained on a non-discriminated shock-avoidance schedule (baseline). Stimuli followed by response-independent shock were then presented with the avoidance baseline no longer in effect. The main portion of the experiment consisted of superimposing (independently of responding) the stimuli followed by response-independent shock on the avoidance baseline. Different temporal values of stimulus duration and delay of shock (produced by an avoidance response) were presented successively, using each subject as his own control. When the stimulus duration was short or the delay of shock was long, so that avoidance rate during the stimulus could assume any value without resulting in baseline (avoidable) shocks during the stimulus, a lowered or "suppressed" rate of responding developed during the stimulus. When the stimulus duration was long or the delay of shock was brief, so that avoidable shocks resulted from a response decrement during the stimulus, high or "facilitated" rates of responding developed for a large proportion of the time that the stimulus was present.

When stimuli followed by response-independent shock are superimposed on a non-discriminated shock-avoidance baseline, an elevated or facilitated rate of avoidance during the stimulus is the result most frequently reported (Herrnstein and Sidman, 1958; Rescorla, 1967; Sidman, 1958; Sidman, Herrnstein, and Conrad, 1957; Waller and Waller, 1963). Sidman (1966) in his analysis of the phenomenon has characterized the effects of stimuli associated with response-independent shock on avoidance as opposite in direction to the effects of the same stimuli on positively reinforced responding; the implication is that under equivalent stimulus conditions, avoidance will be facilitated while positively reinforced responses will be suppressed. There are at least two avoidance studies with findings

that constitute an important exception to this generalization. Brady, Libber, and Dardano (1967) presented stimuli followed by response-independent shock to subjects responding on a non-discriminated shock-avoidance schedule. When the avoidance response produced a short delay from aversive stimulation, there was little difference in response rates before and during the stimulus; when the delay was longer, however, three of the four subjects gave lowered or suppressed rates during the stimulus. Stebbins and Smith (1964) alternated stimuli followed by response-independent shock with a non-discriminated shock-avoidance baseline (during the stimulus, baseline shocks were withheld). Early in conditioning, response rates during the stimulus became suppressed and remained so for the duration of the experiment.

In the avoidance studies cited above, a lowered rate of responding during the stimulus was reported under experimental conditions in which few or no baseline shocks occurred as a consequence of decreased response rates during the stimulus; facilitated rates were found under conditions in which the consequence of decreased response rates during the stimulus was the presentation of baseline (avoidable) shocks during that stimulus. This suggested that the interaction between the parameters of stimulus duration and the

¹Portions of this study were reported at the meeting of the Eastern Psychological Association, Philadelphia, April, 1969. The data are based on a dissertation submitted to the Department of Psychology, Columbia University, in partial fulfillment of the requirements for the Ph. D.

²The author wishes to thank Prof. W. N. Schoenfeld and Dr. A. G. Snapper for their advice and encouragement throughout the course of this study. The study was supported primarily by the National Institute of Mental Health under Grant MH 13049. Additional funds were made available by the Veterans Administration. Reprints may be obtained from the author, Psychology Research Laboratory, F.D.R. V.A. Hospital, Montrose, New York 10548.

delay of shock produced by an avoidance response was crucial in determining the pattern of avoidance during the stimulus. Moreover, there seemed to be a parallel with the conditioned-suppression literature—suppressed responding during a stimulus preceding response-independent shock was reported under experimental conditions in which decreased rates of responding during the stimulus had little effect on the number of positive reinforcements received; loss of suppression during the stimulus was reported under conditions in which decreased response rates during the stimulus significantly lowered the reinforcement density (Blackman, 1968; Carlton and Didamo, 1960; Lyon, 1968; Stein, Sidman, and Brady, 1958).

While the parameters of stimulus duration and baseline reinforcement density have been examined systematically in the case of positive reinforcement baselines (Lyon, 1968), the effect of these variables has not been explored as thoroughly for negative reinforcement baselines. In the present study, stimuli followed by response-independent shock were superimposed on free avoidance; several combinations of stimulus duration and response-produced delay of shock were presented successively, using each subject as his own control. Values of the two parameters were so arranged that for some conditions no baseline shocks were received during the stimulus, no matter how much avoidance rate during the stimulus decreased; for other conditions, baseline shocks during the stimulus were generated by decreases in avoidance rate during the stimulus. The primary questions posed were: (1) Would suppression during the stimulus occur when the parameters were such that baseline shocks during the stimulus were not produced by lowered rates of responding? and (2) If suppression was produced, could it be removed by an appropriate manipulation of the two parameters?

Pavlovian conditioning terminology is used in referring to stimuli followed by response-independent shock. The usage was dictated more by ease of reference (standard abbreviations) than by theoretical considerations. The stimulus is referred to as the conditional stimulus (CS) and the response-independent shock as the unconditional stimulus (US). The CS paired with the US is referred to as the Pavlovian stimuli.

METHOD

Subjects

Four experimentally naive male rhesus monkeys (*Macaca mulatta*: designated M3E, M3F, M4G, and M4H) sat in restraint chairs inside light- and sound-attenuating booths. Located above each monkey's head was a 7.5-w red light, which was on from 0800 hr to 2000 hr. External sounds were masked inside the booths by a loud white noise. The booths were opened only for feeding and for preparing the monkeys for experimental sessions. The monkeys were fed four meals of standard banana pellets a day, one of which was supplemented with fruit; water was available at all times.

Apparatus

The conditional stimulus (CS) was the visual pattern of a black, vertical rectangle, 0.1 by 1 in. (0.3 cm by 2.5 cm) on a lighted background (circular light field of 2.5 cm diameter) on a stimulus projector (Grason-Stadler, Model 168) placed about 5 in. (12 cm) in front of the monkey's face. Two colored Dialco lights (using number 327 bulbs) were mounted near the projector: the amber light signalled the duration of the experimental session; the red light went on when the response lever was operated. The response lever (G.E. push-button unit CR104A12 with a 5-cm wobble stick) was located approximately 12 cm below the stimulus projector, within easy reach of the monkey; when not in use, the manipulandum was removed.

A constant-current shock source was used to deliver an 11 mA tail shock that varied less than 1% (for the tail electrode resistance range of 500 to 1500 ohms). Taking 1000 ohms as the average, a potential of 11 v ac was developed across the tail electrode. The shock was delivered to the tail (shaved, except for 6 cm at the tip) using surface electrodes (Pomerleau, 1969). A "ground" tail electrode was attached approximately 2 in. (5 cm) below the base of the tail, and a "hot" electrode about 1.2 in. (3 cm) below that. To prevent the monkey from removing the electrodes, the tip of the tail was tied down and several strips of Velcro were wrapped around the electrodes. The tail was shaved once a week.

Responses were monitored on Gerbrands cumulative recorders. A Digital Electronics Corporation PDP-8 computer with attendant

input-output hardware was used for on-line data recording and for scheduling all experimental dependencies and durations (Snapper and Kadden, 1969).

Procedure

A half-hour before the start of a session, the monkeys were fed and electrodes were strapped to the tails. When all session preparations were completed, the projector lights and manipulanda were swung into position, the doors of the booths were shut, and the session was started. Immediately after a session, fruit and pellets were given and the tail electrodes were removed.

Sessions were 152 min long, with the amber light above the projector signalling the duration. A trial was defined as the presentation of CS; when given, there were 50 trials per session, presented at random intervals (range, 2 min to 4 min) with a mean interval of 3 min. Responses were recorded in the following intervals: during the 12-sec interval preceding CS (Pre-CS), during CS, and during the 16-sec interval starting 0.3 sec after CS terminated (Post-CS); each interval was divided into 4-sec segments.

Prior to experimentation, the monkeys were given four months of adaptation to the primate chairs. The experimental procedure consisted of four successive stages.

Avoidance training. After several sessions of operant-level determination, the monkeys were taught to use the manipulandum to avoid shocks. An avoidance response earned a timeout from a train of shocks in which shock duration was 0.3 sec and the interval between shocks was 4.7 sec; responses during shock had no effect. (See Sidley, 1963, for a similar description of avoidance, within the framework of a temporal classification of reinforcement schedules.) Each timeout could be added to timeouts already accumulated, up to 10 timeouts (Sidman, 1962). The train of shocks was synchronized independently of responding, which meant that a shock could be received with an equal probability from 0 to 5 sec after the earned timeouts were allowed to elapse (the best estimate of shock delivery is 2.5 sec, the mean of the equiprobable temporal distribution). The duration between a response and the next scheduled shock was equal to the time earned by the responses since the previous shock (each response earn-

ing an amount equal to timeout), minus the amount of time elapsed since the response nearest the last shock, plus 2.5 sec on the average.

Accumulating avoidance was used instead of non-accumulating avoidance to make possible long response-produced delays of shock while maintaining fairly high and stable rates of responding. This property made it possible to schedule conditions in which response rate during CS could take on any value without resulting in baseline (avoidable) shocks (assuming that response rates before CS were equal to or exceeded the minimum required to avoid all shocks). Thus, when the timeout was 20 sec, the maximum delay of shock that could be accumulated was 200 sec (plus 2.5 sec on the average), and even during the longest CS (84 sec), response rate could fall to zero during the CS without resulting in baseline shocks.

Different maximum response-produced delays of shock were generated by varying the length of timeout; the shock duration, the interval between shocks, and the limit of 10 timeouts remained the same throughout the experiment. In the avoidance training procedure, 11 sessions were given over consecutive days using a 20-sec timeout. During all of these 11 sessions, CS and US were never presented.

CS superimposed on avoiding. The unconditioned response to CS was measured for four sessions while the subjects were responding on the avoidance baseline (timeout was 20 sec). The US was not presented. The procedure is comparable to the control sessions in conditioned suppression studies.

Pavlovian conditioning with the manipulandum absent. In the next 12 daily sessions, a Pavlovian conditioning procedure was in effect. The avoidance schedule was not in effect and the response lever was absent. The CS duration was 48 sec; its termination was followed immediately by US, a 0.3-sec tail shock. Pavlovian conditioning was performed in the absence of the avoidance baseline to guarantee that when avoidance was reintroduced, the initial effects of CS on avoiding would be the result of CS-US pairings, uncontaminated by prior occurrence of baseline (avoidable) shocks during CS.

Pavlovian conditioning superimposed on avoiding. For the remainder of the experi-

ment, avoidance baseline training alternated with Pavlovian conditioning superimposed on the baseline. Five sessions of avoidance training (totaling 12.5 hr), during which CS followed by US was never presented, were immediately followed by seven-session units (each unit totaling 17.5 hr; 350 trials) of Pavlovian conditioning, during which CS followed by US was superimposed (uncorrelated with behavior) on avoidance. Baseline training was given whenever the duration of timeout was changed, to allow the development of a stable avoidance performance before the Pavlovian procedure was superimposed. Sessions were given on consecutive days.

The interaction of CS duration and maximum delay of shock, which was the major consideration of this experiment, was studied in eight combinations of CS and timeout. There were three CS durations (12, 48, and 84 sec) and four timeout lengths (1.0, 2.5, 5.0, and 20.0 sec). Each seven-session unit, with its particular combination of CS and timeout, and its position in the sequence of combinations, is called a "condition". Table 1 indicates the ordinal position of a condition (shown by the Roman numeral to the left of the parentheses) and the sessions (shown by "S" followed by the session numbers) that constituted a condition. The first condition given [I(S40-S46)] was the combination of a 48-sec CS (followed by US) and a timeout of 20 sec; this condition was preceded by five days of baseline training, as were the fifth, sixth, seventh, and tenth conditions.

Table 1

Experimental conditions: sequence of combinations of CS and timeout.

Timeout Duration	CS Duration		
	12 Sec	48 Sec	84 Sec
20.0 sec	II(S47-S53)	I(S40-S46), IV(S61-S67), X(S123-S129)	III(S54-S60)
5.0 sec		V(S73-S79)	
2.5 sec		VI(S85-S91)	
1.0 sec	VIII(S104-S110)	VII(S97-S103)	IX(S111-S117)

In Session 115, five days into the ninth condition, severe *râles* were observed in M3E and it was withdrawn from the experiment at this time; no data are presented after Session 114 for this monkey.

RESULTS

Effects of CS Before Pavlovian Conditioning; Response Rates in the Absence of the Pavlovian Stimuli

The CS was superimposed on avoiding maintained by a timeout of 20 sec. Before pairing with US, the effect of CS on avoidance was negligible, as shown in the left-hand column of Fig. 1.

Mean response rates for the avoidance training sessions were considerably in excess of the minimum required to avoid all baseline (avoidable) shocks. Pre-CS response rates, shown in Fig. 1, were similar to the avoidance training rates at the same timeout length. Thus, in the absence of the Pavlovian stimuli (during the avoidance training procedure as well as during the interval before the presentation of CS-US), response rate was such that baseline shocks were rarely received. As timeout length was decreased later in the experiment, response rates remained equal to or in excess of the minimum required to avoid all baseline shocks, both in Pre-CS and in baseline training sessions. (The minimum response rate required to avoid all baseline shocks is defined as one response per timeout duration—thus 3, 12, 24, or 60 responses per minute.)

Pavlovian Conditioning Superimposed on Avoiding

After Pavlovian conditioning in the absence of baseline, a repeating cycle of baseline training followed by Pavlovian conditioning during avoidance was given. In the figures that follow, conditions are compared in such a way that a separate evaluation of the effects of CS duration and maximum delay of shock is possible. For some comparisons, timeout is constant while CS assumes different values; for other comparisons, the situation is reversed.

Initial effects. Suppressed rates of avoidance responding during the latter portion of CS developed early in the first session in which Pavlovian conditioning during avoidance was scheduled (condition I); in this condition, the maximum response-produced delay of shock (200 sec) was longer than the CS duration (48 sec). For two of the subjects, the rate decrease during the latter portion of CS was evident on the first CS presentation; for the other two subjects, the decrease was noticeable on the second or third CS presentation.

Fig. 1. Response rate in 4-sec segments for Pre-CS, CS, and Post-CS. Shown on the extreme left is the last session in which CS was superimposed on avoiding; shown on the right are the sessions in which Pavlovian conditioning with different CS durations was superimposed—the last session at conditions II, IV, and III. In all cases, baseline responding was maintained by a 20-sec timeout (TO). Each point is the mean of 50 samples.

Condition IV used the same experimental parameters as condition I (see Table 1), and, as can be seen in Fig. 1 (second column from the right), the data are consistent with the pattern just described. Rate of responding during the beginning of CS was variable (among subjects) and was followed by a progressive rate decline, with rate approaching zero during the last few seconds of CS. Since most of the responding during CS was below the level of the interval before CS, the avoidance pattern is referred to as "suppressed".

Effects of different CS durations when the maximum response-produced delay of shock was longer than CS. The effects of the 12-, 48-, and 84-sec CSs (conditions II, IV, and III) on responding maintained by a 20-sec timeout

(the maximum response-produced delay was 200 sec) are shown in the three columns on the right of Fig. 1. There were no systematic changes in either Pre-CS levels or the pattern of responding during CS with different CS durations; the response pattern during CS is generally in keeping with the definition of "suppressed".

Effects of different maximum response-produced delays when CS duration was constant at 48 sec. The maximum response-produced delay was varied by changing the timeout duration; the effects on avoidance responding are shown in Figs. 2 and 3. As timeout was decreased (conditions IV, V, VI, VII), response rate during Pre-CS increased monotonically. There were two patterns of respond-

Fig. 2. Response rate in 4-sec segments for Pre-CS, CS, and Post-CS for the last session at conditions with a 48-sec CS and different timeouts (TO)—from left to right, conditions IV, V, VI, and VII. Each point is the mean of 50 samples. Data for subjects M3E and M3F.

ing during CS: for the two longer timeouts (maximum response-produced delays of 200 sec and 50 sec), the "suppressed" response pattern prevailed; for the two shorter timeouts (maximum delays of 25 and 10 sec), however, a new pattern appeared. In the new avoidance pattern, rates during early CS sharply exceeded rates during Pre-CS and remained high until the middle of CS; at this point, a sharp decline occurred, with responding reaching low levels during the last few seconds of CS. This avoidance pattern is referred to as "facilitated". (The terms "suppressed" and "facilitated" are used in the present study only as convenient labels; while the mean avoidance rate during CS was generally lower than Pre-CS levels during the "suppressed" avoidance conditions and generally greater than Pre-CS levels during the

"facilitated" avoidance conditions, such a statistic does not do justice to the complexity of the response pattern.) The "facilitated" response pattern during CS was given by M3E and M4H when timeout was 2.5 and 1 sec (conditions VI and VII), by M3F when timeout was 1 sec (condition VII), and not at all by M4G.

Effects of different CS durations when the maximum response-produced delay was shorter than CS. Figures 4 and 5 show the effects of the 12-, 48-, and 84-sec CSs on responding maintained by a 1-sec timeout (maximum response-produced delay was 10 sec). For all subjects, increasing CS duration had no systematic effect on Pre-CS levels but did increase the tendency to respond during CS. The response pattern was "suppressed" during the 12-sec CS (condition VIII) and was

Fig. 3. Response rate in 4-sec segments for Pre-CS, CS, and Post-CS for the last session at conditions with a 48-sec CS and different timeouts (TO)—from left to right, conditions IV, V, VI, and VII. Each point is the mean of 50 samples. Data for subjects M4G and M4H.

“facilitated” during the 48-sec CS (condition VII) and the 84-sec CS (condition IX) for three of the subjects. M4G gave an attenuated version of the “facilitated” response pattern only during the 84-sec CS (condition IX).

The shift in the pattern during CS from “suppressed” responding in the early conditions to “facilitated” in later conditions cannot be ascribed to continued exposure to the schedule as such, since it was possible to obtain “suppression” in condition VIII after “facilitation” in condition VII. Nor can the “facilitated” response pattern be seen as an effect of high response rates *per se*: By changing CS duration alone it was possible to shift from “suppressed” responding to “facilitated” without affecting Pre-CS response rates (conditions VII, VIII, and IX). This suggests that while response rate and continued exposure

to the schedule may have had some influence on the response pattern during CS, the crucial determinant was the interaction between duration of the CS and the maximum delay of shock.

Relationship between responses and shocks. As mentioned previously, avoidance rates in the absence of the Pavlovian stimuli usually exceeded the minimum required to avoid all baseline shocks, and the number of shocks received was low and fairly constant for all combinations of CS and timeout. The shock rate during CS was also low when the maximum delay of shock was longer than CS duration; however, when the maximum delay of shock was shorter than CS, CS shock rates increased sharply.

“Facilitated” responding was not simply an effect of baseline shocks occurring early during

Fig. 4. Response rate in 4-sec segments for Pre-CS, CS, and Post-CS for the last session at conditions with different CS durations and a 1-sec timeout (TO)—from left to right, conditions VIII, VII, and IX. Each point is the mean of 50 samples. Data for subjects M3E and M3F.

CS. In the two conditions in which the “facilitated” response pattern was first evinced (VI, 2.5-sec timeout, and VII, 1-sec timeout), few shocks were received early during CS. M3E and M4H began “facilitated” responding in the first session of condition VI—M3E received no shocks in the first 12 sec of CS while M4H received one shock; M3F began “facilitated” responding in the first session of condition VII and received no shocks in the first 12 sec of CS during this session. (No data are given for

M4G since it did not produce a “facilitated” response pattern in the two conditions mentioned.) In the later sessions of conditions VI and VII, overall shock rate during CS was generally lower than in the earlier sessions; as in the earlier sessions, most of the shocks were received during the latter portion of CS. As shown in Table 2, on the following page, the distribution of baseline shocks approximates an inverse relationship to response rate during CS.

Fig. 5. Response rate in 4-sec segments for Pre-CS, CS, and Post-CS for the last session at conditions with different CS durations and a 1-sec timeout (TO)—from left to right, conditions VIII, VII, and IX. Each point is the mean of 50 samples. Data for subjects M4G and M4H.

Table 2

Number of shocks in 12-sec segments during CS. Shown on the left is the last session in condition VI (48-sec CS and 2.5-sec timeout) and on the right the last session in condition VII (48-sec CS and 1-sec timeout). CS was presented 50 times per session.

Subject	Time in Seconds after Onset of CS							
	12	24	36	48	12	24	36	48
M3E	0	0	0	0	0	1	4	15
M3F	0	0	2	1	0	0	1	8
M4G	0	0	7	9	0	2	6	8
M4H	1	2	5	3	0	5	11	32

Stability and representativeness. The Pre-CS level and CS pattern of responding were quite stable over the last three sessions of the seven that constituted an experimental condition. With few exceptions, the last session at a particular condition was practically identical (for a given subject) to the two sessions that preceded it. In addition, the mean response rate of the 50 trials of a given session was representative of single trials within the session.

DISCUSSION

Previous investigators using accumulating avoidance schedules (Field and Boren, 1963; Sidman, 1962) have reported that subjects tend to spend most of the session at the maximum duration from the shock train. This finding is consistent with the present results: in the absence of the Pavlovian stimuli, average avoidance rates exceeded the minimum required to avoid all baseline shocks, and few baseline shocks were received.

A number of experiments have studied the effects of stimuli associated with response-independent shock on avoidance. In these studies, the shock-avoidance schedules differ from that of the present study in two ways: (1) there is a fixed relationship between the last response and the next scheduled shock (called the response-shock or RS interval); and (2) the response-shock interval cannot be accumulated (Sidman, 1953). When the studies are organized so that the CS duration is progressively longer than the maximum delay of shock (RS), the pattern of avoidance reported shifts from suppressed to facilitated (as CS to RS ratio increases).

In the study by Stebbins and Smith (1964), the CS to RS ratio was, in effect, zero (the avoidance baseline was not scheduled during CS); after several sessions, response rate during CS became suppressed and remained so for the duration of the experiment. For Rescorla (1967), the ratio of CS to RS was equal to one (CS and RS were both 30 sec); avoidance rates during CS greatly exceeded rates during Pre-CS. In the study by Brady *et al.* (1967), the CS to RS ratio varied from two (CS was 2 min and RS was 60 sec) to 12 (CS was 2 min and RS was 10 sec). When the ratio was two, response rates during CS were suppressed in three out of four subjects; when the ratio was 12, there were no reliable differences between rates of avoidance during Pre-CS and CS. Sidman *et al.* (1957) had a CS to RS ratio of 15 (CS was 5 min and RS was 20 sec). Initially, rates increased during both CS and Pre-CS; after several sessions, rates during Pre-CS decreased, but rates during CS remained high.

In summary, the literature and the present results support the notion that when the parameters of maximum delay of shock and CS duration are such that response rate can vary

freely without producing baseline shocks in CS, the pattern of avoidance will be "suppressed"; When the parameters are such that baseline shocks result from a response decrement during CS, responding will assume high, or "facilitated", rates for a large proportion of the time that the stimulus is present.

One of the main findings of the present experiment must be qualified. The "suppressed" pattern of responding was obtained when CS was 48 sec and timeout was 20 sec (condition I); the combination was presented again and the pattern was replicated (condition IV). After the "facilitated" pattern of responding was obtained (after condition IX), however, it was not possible to recover the "suppressed" response pattern at the original combination (within seven sessions). The response pattern in condition X was neither "suppressed" nor "facilitated" (as previously defined) and was variable among subjects. This indicates that the avoidance history of the subject cannot be ignored when specifying the conditions under which a particular avoidance pattern will occur.

A biphasic pattern similar to the "suppressed" avoidance pattern of the present study has been reported in the conditioned-suppression literature (Hendry and Vantoller, 1965; Lyon, 1967; Matos, 1969; Milenson and Hendry, 1967). In addition, the pattern of avoiding during CS in the present experiment was modified by the manipulation of parameters equivalent to those used in conditioned-suppression studies (Blackman, 1968; Stein *et al.*, 1958). The parallel between positive reinforcement baselines and avoidance merits further exploration. For example, the relationship between avoidance rate and response-produced delay of shock might be studied using the techniques developed for conditioned suppression by Blackman (1968), where response rate and reinforcement frequency are controlled independently by using several variable-interval schedules of reinforcement with different response-pacing requirements.

Some final observations on avoidance patterns are in order. When the Pavlovian stimuli were first superimposed on avoidance (following Pavlovian conditioning without avoidance), lowered rates of avoiding during the latter part of CS were apparent in the first few trials. Suppression during the latter part of

CS was in some way controlled by CS-US pairing, since there was no history of baseline shocks during any portion of CS. Moreover, lowered rates of responding toward the end of CS were demonstrated under nearly all conditions, even those in which sharply elevated rates of avoiding occurred in the beginning of CS ("facilitated" response pattern). One can speculate that avoidance rates during CS might be under the control of different variables at different times during CS. Response rates during the latter part of CS might be more under the control of CS-US pairing, as indicated by the fact that lowered avoidance rates at the end of CS appeared in the first few trials and were present under nearly all conditions. Response rates early in CS might be more heavily influenced by the interaction of CS duration and maximum delay of shock, as indicated by the fact that changes in these parameters produced large differences in response rates during the first portion of CS.

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Received 15 May 1969.