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PUNISHMENT: THE INTERACTIVE EFFECTS OF DELAY AND INTENSITY OF SHOCK[1]

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A discrete-trial punishment procedure, with rats, was used to examine how delay-of-shock intervals of 0 to 28 sec and shock intensity interact to decrease the frequency and increase the latency of a positively reinforced response. For delay-of-shock intervals of 0, 7, 14, and 28 sec, there was a range of shock intensities, for some subjects, over which the punishing effect of shock was an increasing, monotonic function of shock intensity. For other subjects this transition was abrupt. Functions relating response frequency and latency measures to shock intensity were displaced toward higher values on the shock intensity axis with an increase in delay-of-shock interval. The effects of "gradual" and "abrupt" introduction to "severe" shock, as well as re-exposure to previously used shock intensities, were examined under both the immediate and delay-of-shock conditions. With delay-of-shock intervals of 7, 14, or 28 sec, shock intensities of approximately 0.50 milliamperes or greater were necessary to decrease substantially the number and increase the latency of the lever-pressing response. For the immediate punishment group this intensity was approximately 0.20 ma. These facts were related to Annau and Kamin's (1961) conditioned emotional response experiment in which a shock intensity of 0.49 ma or greater was required to suppress the rate of a positively reinforced response.

The intensity of a punishing stimulus, as well as the temporal interval between a response and punishing stimulus, affect the future probability of occurrence of the punished response. Experiments by Appel (1963) with rats, Azrin (1960) with pigeons, and Hake, Azrin, and Oxford (1967) with monkeys have all shown that over a limited range of shock intensities, the rate of a positively reinforced response is inversely related to the intensity of response-contingent shock.

The results of several punishment studies in which the temporal interval between a response and punishing stimulus was varied, suggest that the rate of a punished response is directly porportional to the delay-of-shock interval. For example, Kamin (1959) trained rats to avoid shock in a shuttlebox. During extinction of the avoidance response, each response was punished with shock. Kamin observed that the total number of responses made during punishment trials was directly proportional to delay-of-shock intervals of 0 to approximately 30 sec. Karsh (1965), also using rats, reported that the rate of a punished, positively reinforced response was directly proportional to delay-of-shock intervals of 0 to 20 sec.

There has been little study of the manner in which delay-of-shock interval and shock intensity interact to reduce the frequency of occurrence of a punished response. Karsh (1965), in the above mentioned study, exposed four groups of rats to delay-of-shock intervals of either 2, 5, 10, or 20 sec and gradually increased the shock intensity from 65 to 105 v. Under these conditions, successive increments in shock intensity resulted in a decrease in response rate which lasted only for several sessions. On the other hand, Camp, Raymond, and Church (1967), using a procedure in which a rat's lever-pressing response was both positively reinforced and punished with a variable delay-of-shock interval, found response rate to be inversely related to shock intensity.

This experiment examines how delay-of-shock interval and intensity of a response-

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[2]These data are based on a dissertation submitted to the Department of Psychology, Columbia University, in partial fulfillment of the requirements for the PhD. Reprints may be obtained from the author, Department of Psychology, 3813-15 Walnut St., University of Pennsylvania, Philadelphia, Penna., 19104.

contingent shock interact to affect a positively reinforced response. Equal-frequency and equal-latency contours (or, more generally, iso-punishment contours) are constructed. Such contours represent the various combinations of shock intensity and delay-of-shock interval to which subjects exhibit the same decrement in response frequency and increment in response latency.

METHOD

Subjects

Twenty-four male albino rats, obtained from Carworth Farms, ranged in age from 90 to 120 days at the beginning of the experiment. On arrival in the laboratory, they were given free access to Purina Chow and water for 10 days. Beginning on Day 11, they were given 5 g of food every other day until body weights were reduced to 65% of free-feeding weights as measured on Day 11. To maintain this body weight, each subject was given a small daily ration of food after each experimental session; they had free access to water in the home cages.

Apparatus

A 13-in. long, 10.5-in. wide, and 14-in. high stainless steel test chamber, isolated in a sound-attenuated chamber, was employed. A covered "peephole" on top of the attenuation chamber provided an unrestricted view of the inside of the chamber. A 6-w light bulb, mounted on the ceiling of the isolation chamber, illuminated the test chamber from above through its Plexiglas ceiling. A blower provided continuous air ventilation of the experimental box. Seven stainless steel floor grids (Dinsmoor, 1958), together with the stainless steel chamber walls, served as shock electrodes. A retractable lever and a dipper, neither of which functioned as shock electrodes, were mounted (3.5 in. center-to-center) on one 13-in. wall perpendicular to the length of the floor grids. The lever was a 0.03- by 0.50-in. wide stainless steel tab that extended 0.06 in. into the chamber and required a minimum force of 20 g to operate. The lever entered into or retracted from the chamber in 0.20 sec and was not manipulative by the subject until it was completely extended into the enclosure. When activated, the dipper delivered a 0.02-cc drop of Borden's Eagle Brand condensed milk mixed in a 40% solution by volume with water.

A Grason-Stadler constant current shock source and scrambler were used. The shock source was modified to obtain additional shock values of intermediate intensity. A click generator provided a repetitive auditory click stimulus of 26.7 clicks per sec, calibrated to be 72 db re SPL inside the attenuation chamber. Experimental contingencies and recordings were automatically arranged by a system of relays, timers, and counters.

Procedure

Initial experimental session. For the initial "shaping" procedure, the response lever was temporarily extended 0.25 in. into the chamber. Each subject was trained by successive approximations to press the lever, and was then exposed to the trial procedure with the lever restored to its normal excursion (0.06 in.).

Trial procedure. Figure 1 is a temporal diagram of the gated trial procedure (Jenkins, 1965). A trial began with the onset of the click stimulus, followed 1 sec later by insertion of the lever into the chamber. The lever remained in the chamber and the click stimulus remained on as long as the subject failed to make a lever-pressing response. A response produced a dipper of milk, retracted the lever, and initiated a delay interval of either 0, 7, 14, or 28 sec. The trial and click stimulus coterminated at the end of this delay interval. During sessions in which an electric shock (0.50-sec duration) was scheduled to follow a

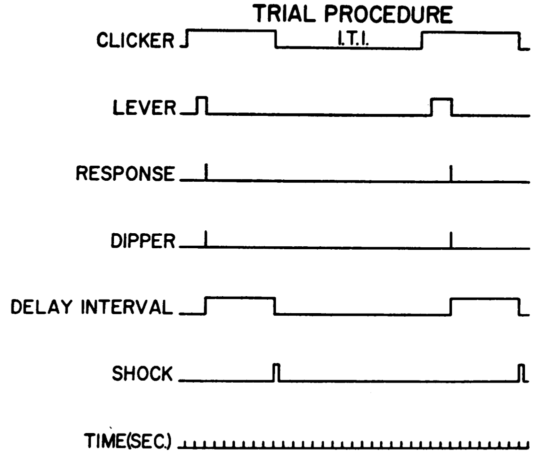

Fig. 1. A temporal diagram of the gated trial procedure employed.

Table 1

Experimental design for subjects in the 0-, 7-, 14-, and 28-sec delay-interval groups. Included is the ascending sequence of shock intensities (ma) to which subjects could be exposed under the four delay-interval conditions. The asterisks indicate that half of the subjects in each delay-interval group were initially exposed to a 0.05-ma shock and the other half to a 0.20-ma shock. The shock intensity (ma) to the left of the subject number corresponds to the shock intensity at which each subject met the "punishment criterion". The mean shock intensity (ma) at which this "punishment criterion" was met is included in the bottom row of the table for subjects in each group that were initially exposed to a 0.05-ma shock and for those initially exposed to a 0.20-ma shock.

	Delay Interval (sec) Group							
Shock Intensity (ma)	*0*		*7*		*14*		*28*	
0.05	*		*		*		*	
0.08								
0.13								
0.20		*CF 8 CF 11 CF 13		*		*		*
0.25	CF 9							
0.28	CF 12							
0.30			CF 4					
0.32								
0.35	CF 10							
0.40				CF 5				
0.42								
0.44								
0.50								
0.54			CF 7					
0.60			CF 6		CF 14			
0.62						CF 15 CF 18		
0.66				CF 1 CF 3				
0.72								
0.80								
1.00							CF 20	CF 23
1.30					CF 19			
1.60						CF 21	CF 25	CF 22
Mean shock intensity at which the "punishment criterion" was met.	0.29	0.20	0.48	0.57	0.95	0.95	1.30	1.15

response, the shock occurred simultaneously with the end of the delay interval and termination of the click stimulus. The shock was followed by a 15-sec intertrial interval (ITI) during which the click stimulus remained off and the lever retracted.

Subjects that were ultimately exposed to either a 14- or a 28-sec delay interval were initially given 50 trials with a 7-sec delay interval after having acquired the lever-pressing response. For these subjects, the delay interval was then increased in 7-sec steps (50 trials at each step) until the appropriate delay interval was reached. All subjects were given a total of 305 consecutive trials during the initial session. The data from the last 105 trials constituted the first daily session on the trial procedure. All subsequent daily sessions consisted of 105 consecutive trials. If, during any daily session, a subject failed to complete all 105 trials within a 6-hr period, that subject was removed from the apparatus and the session was terminated.

Design. Six subjects were randomly assigned to each of four delay-of-shock groups with either a 0-, 7-, 14-, or 28-sec delay interval. Once the maximum delay interval was reached, it remained constant for all subjects in each group, but all subjects in all four groups were exposed to an ascending sequence of shock intensities, which is described in Table 1.

The group design used is also outlined in Table 1. The four columns of this table correspond to the four groups of subjects exposed to 0-, 7-, 14-, and 28-sec delay intervals. The rows correspond to the shock intensities to which the subjects could be exposed. Following the eleventh daily session on the trial procedure without shock, all subjects were exposed to two successive sessions with the shock contingency. As indicated by the asterisks in Table 1, the initial shock intensity was 0.05 ma for half of the subjects in each group and 0.20 ma for the other half. During the next four daily sessions, the shock contingency was removed for all subjects. This alternation of two days with shock and four days without was continued for each subject. Over successive two-day exposures to the shock contingency, the intensity was increased for every subject until that subject met a "punishment criterion". The "punishment criterion" was defined as a failure to complete 10 trials over a 6-hr period for the second of two successive shock sessions. The shock intensity at which each subject met this "punishment criterion" corresponded to the maximum intensity to which it was exposed and is designated for individual subjects in Table 1.

The experiment was terminated for Subjects CF 11 and CF 13 of the 0-sec delay group following exposure to a 0.20-ma shock, since they failed to complete 105 trials over a 6-hr period on each of four successive non-shock sessions. The other subjects (except CF 22 and CF 23) that were initially exposed to a 0.20-ma shock were given the three lowest shock intensities, 0.05, 0.08, and 0.13 ma, after meeting the "punishment criterion". Finally, all subjects were re-exposed to a shock intensity which was used previously.

RESULTS

Two subjects in the 28-sec delay-interval group were discarded because of illness, and one in the 14-sec delay-interval group was discarded after it learned to balance itself on one shock grid, thereby avoiding shock.

Figures 2 to 5 are shock intensity functions obtained under 0-, 7-, 14-, and 28-sec delay-interval conditions, respectively. In each figure, individual shock intensity functions are presented for each animal. The total number of trials that a subject completed during Days 1 and 2 at each shock intensity (excluding the first trial of each day) is plotted on the right-hand ordinate and is denoted by a broken line. Since a subject did not necessarily complete the same number of trials on Day 2 as it did on Day 1, the median latency was computed for each of the two shock sessions and the mean of these two medians was used as an index of response latency for that shock intensity. The logarithm of this mean median response latency is plotted on the left-hand ordinate and is denoted by a solid line. The logarithm of the mean median response latency was not plotted for shock intensities for which a subject completed five or fewer responses over both shock sessions.

Figures 2 to 5 show that during the final two days of original training without shock (0 ma), all subjects completed all (208) trials and had a mean median latency of less than 1 sec. As the shock intensity was increased, the number of trials that a subject completed, and

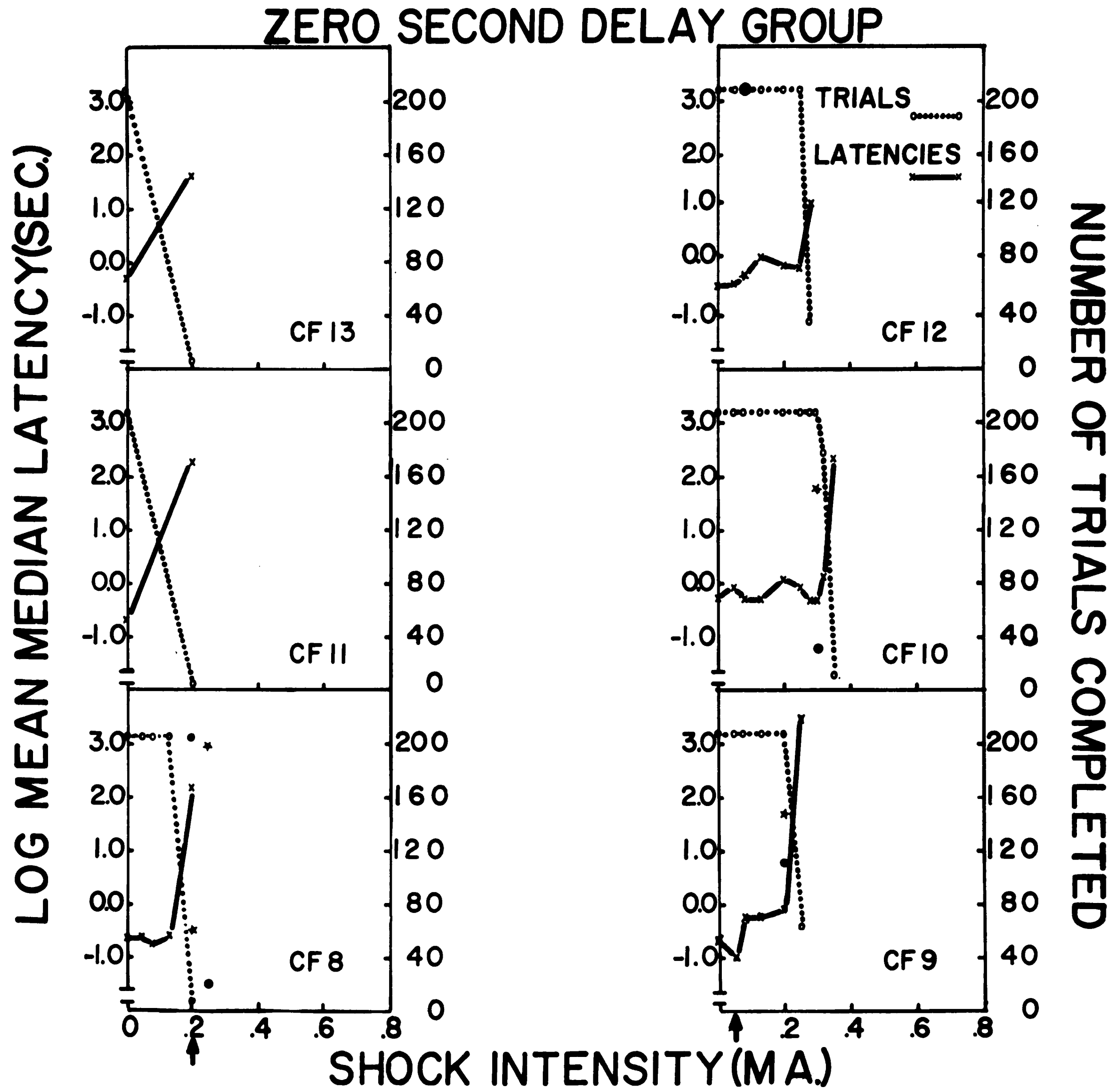

Fig. 2. Intensity of shock functions for six subjects in the 0-sec delay-interval group. The total number of trials (right-hand ordinate) that a subject completed during Days 1 and 2, as well as the logarithm of the mean median response latency on those trials (left-hand ordinate), are plotted as a function of shock intensity (ma). The dark circles correspond to the number of trials completed and the stars correspond to the logarithm of the mean median response latency for a two-day re-exposure period. The arrows on the abscissae correspond to the initial shock intensity to which subjects in that panel were exposed.

the mean median response latencies on those trials, characteristically passed through a transition from all trials completed with short latencies at "low" shock intensities to few trials completed with long latencies at "higher" shock intensities. Since successive increments in shock intensity were not of equal size, and since the transitions in response frequency and latency occurred at different shock values, it is impossible to compare quantitatively, across subjects, the slopes of these functions. One can, however, make a qualitative comparison. For 11 of the 21 subjects in all four delay-interval groups, there was at least one shock intensity at which the "punishment criterion" was not met but at which fewer than 208 trials were completed. For the remaining 10 subjects, the transition in response frequency was all-or-none.

The arrows on the abscissae of Fig. 2 to 5 indicate that the subjects represented in the left-hand panels of each figure were initially

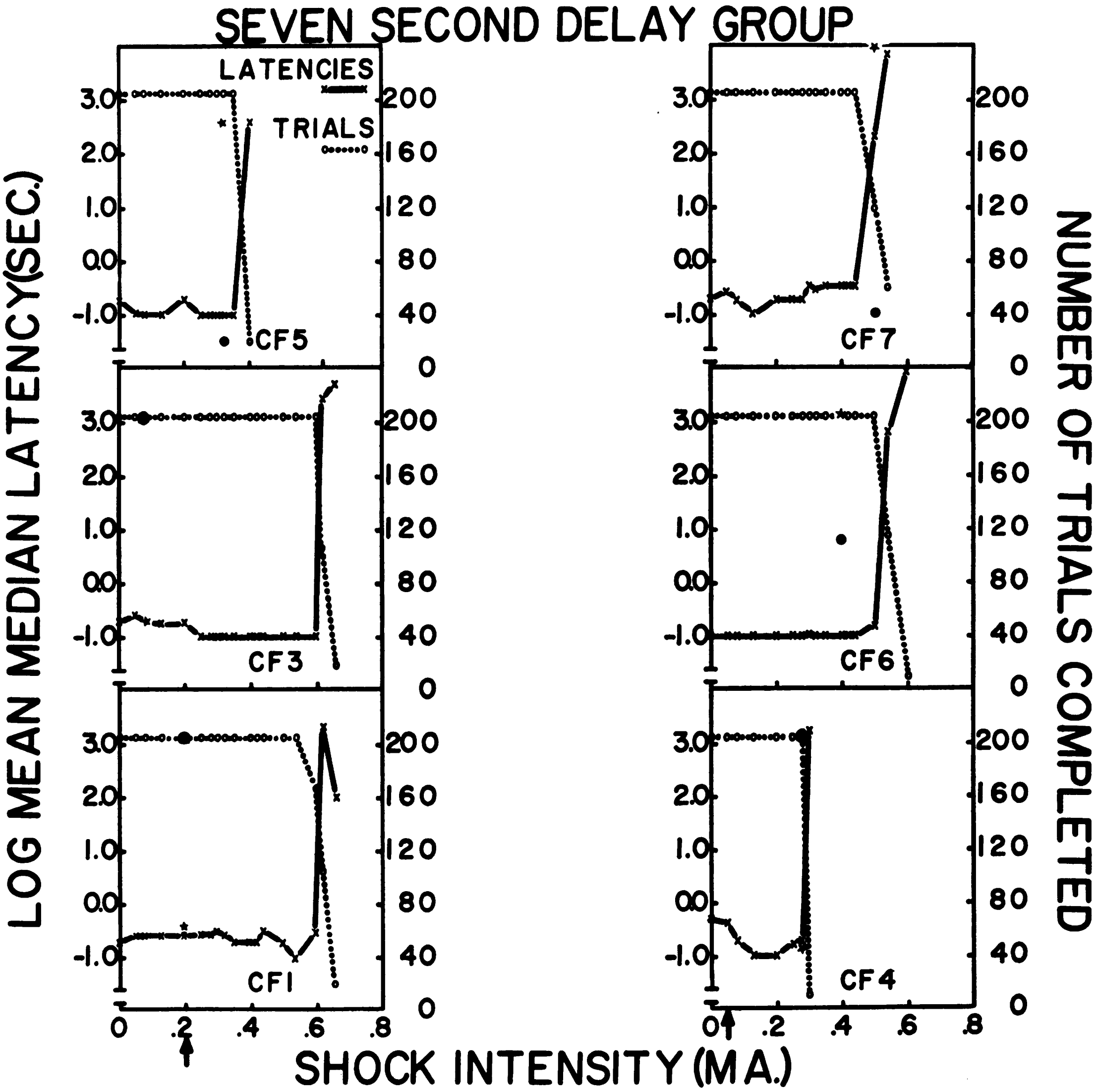

Fig. 3. Intensity of shock functions for six subjects in the 7-sec delay-interval group. See legend of Fig. 2 for additional details.

exposed to a 0.20-ma shock and that those in the right-hand panels were initially exposed to a 0.05-ma shock. Table 1 shows, for each delay-interval group, the mean (and individual) shock intensities at which the "punishment criterion" was met for subjects initially exposed to a 0.05-ma shock and for subjects initially exposed to a 0.20-ma shock. A one-tailed randomization test for two independent samples suggests ($p = 0.05$) that under a 0-sec delay-interval condition, the mean shock intensity at which the "punishment criterion" was met was higher for subjects initially exposed to a 0.05-ma shock than for subjects initially exposed to a 0.20-ma shock. On the other hand, under the 7-sec delay-interval condition, the mean shock intensity at which the "punishment criterion" was met was not higher for subjects initially exposed to a 0.05-ma shock than it was for subjects initially exposed to a 0.20-ma shock. The same appears to be true for subjects in the 14- and 28-sec delay groups, although there were too few subjects in these groups to make a statistical comparison.

To check the reliability of the individual shock intensity functions plotted in Fig. 2 to 5, most subjects were re-exposed for two suc-

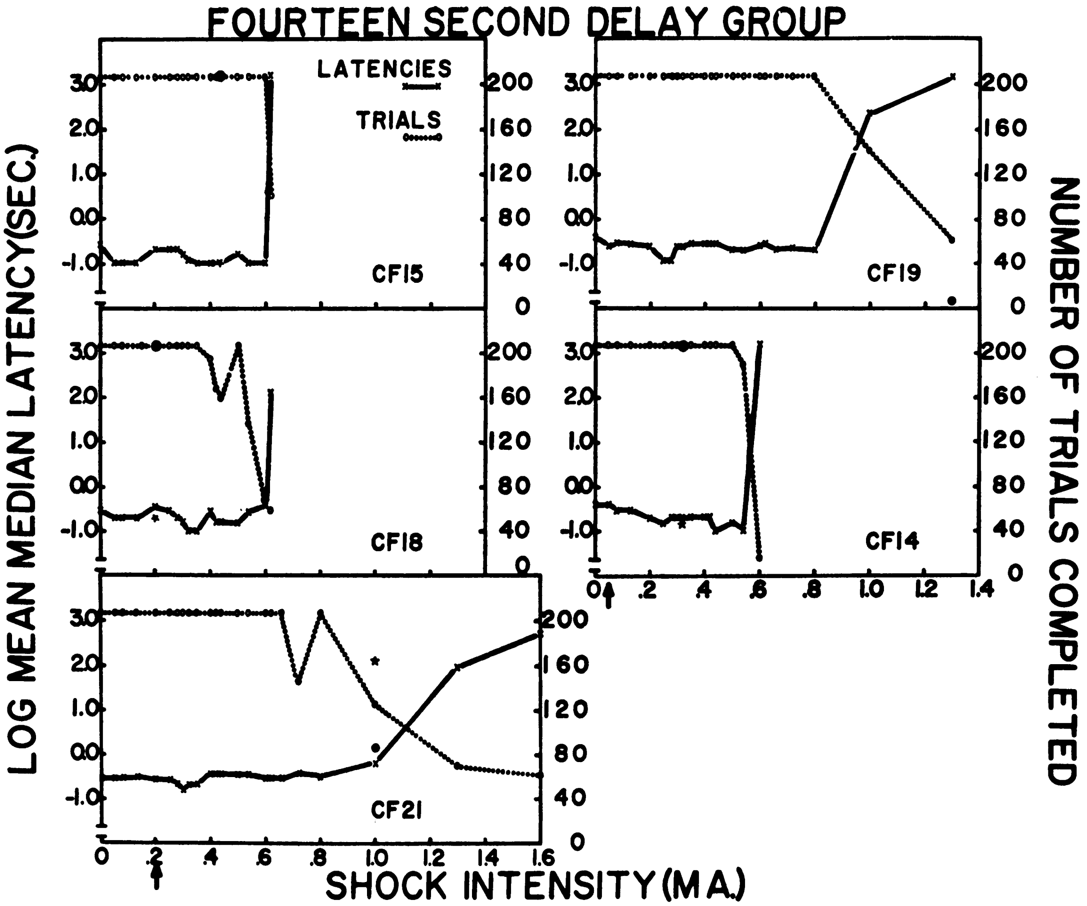

Fig. 4. Intensity of shock functions for five subjects in the 14-sec delay-interval group. See legend of Fig. 2 for additional details.

cessive days to one previously used shock intensity after having met the "punishment criterion". In Fig. 2 to 5, the dark circles correspond to the number of trials completed and the stars correspond to the logarithm of the mean median response latency for this two-day re-exposure period.

Subjects re-exposed to "low" shock intensities, which previously had little or no punishing effect, tended to complete the same number of trials and have the same mean median response latency that they previously had. On the other hand, subjects re-exposed to "high" shock intensities, which previously had moderate or severe punishing effects, tended to complete few trials and have longer mean median response latencies than they previously had. These "low" and "high" shock intensities correspond to values less than and greater than 0.08, 0.28, 0.44, and 0.55 ma for subjects in the 0-, 7-, 14-, and 28-sec delay groups, respectively. This holds for 16 of the 19 subjects re-exposed to a shock intensity.

Figures 2 to 5 show that as the delay interval between a response and shock increased, the shock intensities at the transition from all trials completed with short latencies to few trials completed with long latencies tended also to increase. This finding is summarized in the form of equal-frequency and equal-latency contours (iso-punishment contours) in Fig. 6. From the individual "trials completed" functions plotted in Fig. 2 to 5, the shock intensity (interpolated when necessary) at which each subject completed 120 trials was determined. Similarly, the shock intensity at which each subject exhibited a mean median response latency of 10 sec was also determined. (For cases in which the individual "trials completed" and "latency" functions intersected

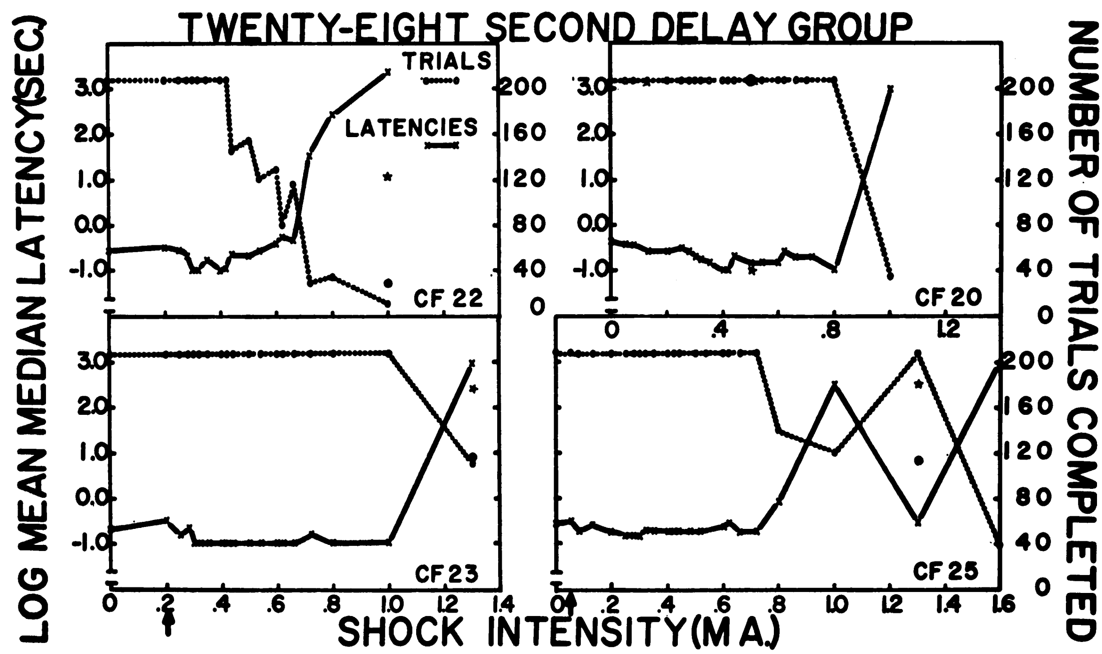

Fig. 5. Intensity of shock functions for four subjects in the 28-sec delay-interval group. See legend of Fig. 2 for additional details.

the 120 completed trials and 10-sec latency criteria at more than one shock value, the highest value was used.) For each delay-interval group, the mean (I_R) and standard deviation of the shock values at which subjects completed 120 trials was computed and is plotted on the lower ordinate of Fig. 6. Likewise, the mean (I_L) and standard deviation of the shock intensities at which subjects in each group had a mean median latency of 10 sec was computed. Mean I_L is plotted on the upper ordinate of Fig. 6. Mean I_R and I_L, in other words, are the mean shock intensities which, under a given delay-interval condition, resulted in 120 completed trials and a mean median latency of 10 sec, respectively. These criteria of 120 completed trials and a mean median response latency of 10 sec were selected to represent a moderate decrease in trials completed and increase in response latency.

The equal-latency and equal-frequency contours in Fig. 6 have two features in common. In both cases, an increase in delay interval from 0 to 14 sec was accompanied by a monotonic increase in mean I_L and I_R from approximately 0.20 ma to 0.80 ma. There were proportionally smaller increments in mean I_L and I_R with a further increase in delay interval from 14 to 28 sec. A Kruskal-Wallis, one-way analysis of variance by ranks indicated that the four data points on the equal-latency contour are statistically different (H: 17.91, df:3, $p < 0.001$) as are the four data points on the equal-response contour (H:7.83, df:3, $p < 0.05$).

A second feature of these contours is that intersubject variability (standard deviation) within the 0-sec delay-interval group was small relative to the intersubject variability within the 7-, 14-, and 28-sec delay-interval groups. In addition, the standard deviation for the 7-, 14-, and 28-sec delay-interval groups was approximately one-third of the respective mean I_L and I_R values.

DISCUSSION

For delay-of-shock intervals of either 0, 7, 14, or 28 sec, there is a range of shock intensities over which the punishing effect of shock is an increasing, monotonic function of shock intensity. Since Appel (1963), Azrin (1960), Gibbon (1967), Hake *et al.* (1967) and others have previously noted this relationship for cases in which a positively reinforced response is immediately punished, the shock intensity functions for subjects in the 0-sec delay group replicate these previous findings. The shock

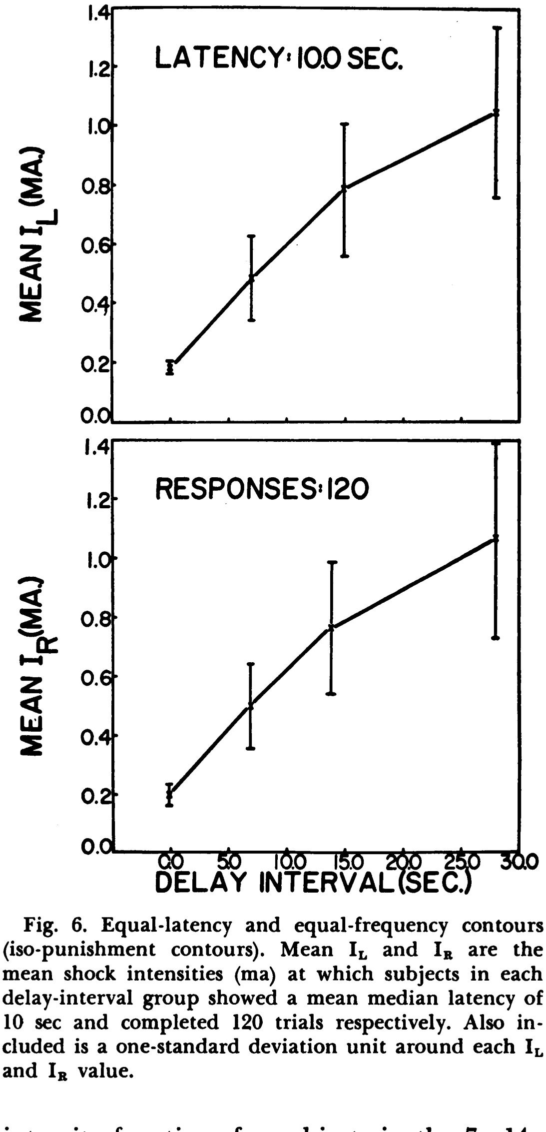

Fig. 6. Equal-latency and equal-frequency contours (iso-punishment contours). Mean I_L and I_R are the mean shock intensities (ma) at which subjects in each delay-interval group showed a mean median latency of 10 sec and completed 120 trials respectively. Also included is a one-standard deviation unit around each I_L and I_R value.

intensity functions for subjects in the 7-, 14-, and 28-sec delay-interval groups extend this rule to the case in which the punished response and punishing stimulus are never temporally contiguous.

For some of the rats in each delay-interval group, the transition from all trials completed with short latencies to few trials completed with long latencies was sudden rather than gradual. The failure to find intermediate punishing effects for Subjects CF 20 and CF 23 may be due to the fact that additional intermediate shock intensities were not used, whereas this is probably not the case for other subjects (CF 9, CF 12, CF 4, CF 5, and CF 15).

Miller (1960) and Karsh (1963) compared the punishing effects of an intense response-contingent shock for rats that were either pretreated or not pretreated with less-intense punishing shocks. The less-intense shocks had a mild punishing effect, partially reducing the speed of a positively reinforced running response. Their data showed that rats pre-exposed to such a mild punishing shock exhibited smaller decrements in running speed when later exposed to a severely punishing shock than subjects not pre-treated. This finding is supported in the present study by the fact that all three subjects in the 0-sec delay group that were initially introduced to a shock intensity with a large punishing effect (0.20 ma) met the "punishment criterion" at lower shock intensities than subjects initially exposed to a shock intensity with little or no punishing effect (0.05 ma).

In contrast, however, subjects in the 7-sec delay group that were initially exposed to a 0.20-ma shock did not meet the "punishment criterion" at lower shock intensities than subjects initially exposed to a 0.05-ma shock. This finding suggests that for subjects in the 7-sec delay group, 0.05- and 0.20-ma shocks functioned similarly as punishing stimuli. Examination of Fig. 3 shows, in fact, that neither a 0.05- nor a 0.20-ma shock functioned as a punishing stimulus for subjects in the 7-sec delay-interval group. One could speculate that a differential effect of "gradual" *versus* "abrupt" introduction to response-contingent shock would have occurred under a 7-sec delay-interval condition if half of the subjects in that group had been introduced to a 0.05-ma shock and the other half to a shock intensity (0.50 ma) that had a moderate punishing effect as determined from the iso-punishment contours (Fig. 6).

Regardless of delay of shock condition, subjects re-exposed, after having met the "punishment criterion", to shock intensities that had had little or no punishing effect tended to complete the same number of trials and have the same response latencies as during their original exposure. On the other hand, subjects re-exposed to shock intensities that had had moderate or severe punishing effects tended to complete fewer trials and have longer response latencies than they did during their original exposure. Hake *et al.* (1967) and Gibbon (1967), using an immediate punishment procedure with monkeys and rats, respectively, re-exposed subjects to response-contingent shock following exposure to more severely punishing shocks. They, likewise, observed that a particular intensity of response-contingent shock can have a greater punishing effect for a subject if that subject is first pre-exposed to a more-intense punishing shock than if it is first pre-exposed to a less-intense punishing shock. As in the present study, Hake *et al.* (1967) also reported that this phenomenon, which they termed "behavioral inertia", did not occur under conditions in which the original shock intensity had little or no punishing effect. The present study provides evidence that "behavioral inertia" occurs with delay-of-shock intervals of 7-, 14-, and 28-sec as well as with the immediate punishment procedure.

Informal observations of each subject in the 7-, 14-, and 28-sec delay groups, indicated that emotional responses such as freezing, urination, and defecation tended to accompany the beginning of trials in which a long latency occurred. These emotional responses, conditioned in this case by avoidable shocks, were similar in form to the emotional responses of rats described by Hunt and Brady (1955), conditioned, in their case, with unavoidable shocks of approximately 1.5 ma. A comparable examination of subjects in the immediate punishment group indicated that a low incidence of these emotional responses and a high incidence of incompleted or abortive lever-pressing accompanied the beginning of trials in which a long response latency occurred. Dinsmoor (1952), as well as Hunt and Brady (1955), also observed abortive lever-pressing under conditions in which a rat's lever-pressing was both positively reinforced and immediately punished with shock. These informal observations of gross behavioral changes suggest that the punishing effects of shock in this experiment were, in large part, mediated by disruptive conditioned emotional responses when the response-shock interval was 7-, 14-, or 28-sec and mediated by these to a lesser degree or not at all when the delay-of-shock interval was 0 sec.

The data from an experiment by Annau and Kamin (1961), as related to the iso-punishment contours in Fig. 6, lend some support to this speculation. These authors, using the Estes-Skinner (1941) CER procedure, parametrically investigated the effects of shock intensity upon the acquisition of conditioned emotional responses to a conditioned stimulus (3-min period of white noise). Annau and Kamin reported that a shock intensity (0.28 ma) strong enough to produce a flinching reaction in a hooded rat, or a punishing effect when made contiguous with a lever-pressing response, was not intense enough to produce conditioned emotional responses that disrupted on-going lever-pressing reinforced on a variable-interval schedule. In addition, these authors demonstrated that, with their CER procedure, a shock intensity of 0.49 ma or greater was required to disrupt lever-pressing. In the present study, a shock intensity of 0.20 ma was intense enough to disrupt lever-pressing when the delay-of-shock interval was 0 sec, but was not intense enough to disrupt lever-pressing when this interval was 7, 14, or 28 sec. In fact, the shock intensities that did effectively disrupt lever-pressing under these long delay-interval conditions (approximately 0.50 ma or greater) were the same shock intensities which, in the Annau and Kamin study, resulted in disruptive conditioned emotional responses.

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