JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1975, 23, 437-450 NUMBER 3 (MAY)

PARTIAL AVOIDANCE CONTINGENCIES[1]

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Rats were trained in a discrete-trial paradigm with no intertrial interval. The first response changed an auditory stimulus for the remainder of the trial. Shocks were delivered only at the end of the trial cycle. Avoidance contingencies were defined by the conditional probability of shock, given no response (P_0), and the conditional probability of shock given a response (P_1). The maximal avoidance contingency was $P_0 = 1.0$, $P_1 = 0$, and noncontingent conditions were those for which $P_0 = P_1$. In Experiment I, after training on the maximal contingency, three groups of subjects experienced either $P_0 = P_1 = 0$, $P_0 = P_1 = 0.5$, or $P_0 = P_1 = 1.0$. Eight of 10 subjects stopped responding under the noncontingent conditions. Experiment II studied partial contingencies by varying P_0 and P_1. For one group, P_0 was reduced holding $P_1 = 0$. Responding decreased to zero as P_0 approached zero. A second group was studied under $P_1 > 0$, holding $P_0 = 1.0$. For three of the six rats in this group, responding decreased to zero with increasing P_1. The other three maintained responding as P_1 was increased up to the noncontingent, $P_1 = P_0 = 1.0$ value. The P_0 group was also studied with $P_0 = P_1 > 0$, and half of these subjects responded. The results demonstrated two modes of response to weakening or eliminating the avoidance contingency. Some subjects were sensitive to contingency only, and insensitive to changes in shock density. Approximately one half of the subjects were sensitive to both contingency and shock density. This shared control was observed only when $P_1 > 0$.

Instrumental training paradigms establish a dependency or contingency between a specified response class and a stimulus "consequence". A traditional focus of attention in the study of contingencies has been variation in the delivery of the stimulus after a response has occurred. In the study of avoidance, this emphasis on response consequences led naturally to the study of whether the response must be effective in eliminating shock (Brogden, Lipman, and Culler, 1938), whether the response must be effective in terminating a warning signal (Kamin, 1956; Mowrer and Lamareaux, 1942), and whether an escape contingency once shock was present was important in conjunction with these factors (Bolles, Stokes, and Younger, 1966). The consequence of not responding has been less frequently manipulated. An exception in a free-operant context is Boren and Sidman's (1957) study of probabilistic shock delivery. Generally, however, instances of no responding invariably resulted in shock, and experimental interest centered on the response consequence.

The present experiments defined avoidance contingencies in terms of conditional probabilities of shock delivery at the end of a trial, and investigated the parallels between contingencies established on the response and nonresponse classes separately. Possible procedures varying these conditional probabilities are shown in the orthogonal plot in Figure 1 (Catania 1971; Church 1969; Gibbon, Berryman, and Thompson, 1970, 1974; Seligman, Maier, and Solomon, 1971). The probability of shock, given a response, $P_1 = P(S|R)$, is on the y-axis and the probability of shock, given no response, $P_0 = P(S|\sim R)$, is on the x-axis. The traditional avoidance procedure is one in which shock is always delivered in the absence of a response ($P_0 = 1.0$) and never delivered after a response ($P_1 = 0$). Thus, the maximal avoidance contingency is represented by the point at the lower-right corner. Similarly, the strict punishment contingency is represented in the upper-left corner. The diagonal passing

[1]This report is based on a dissertation submitted to the Graduate Faculties, Columbia University, by G.G.N. in partial fulfillment of the requirements for the Ph.D. degree. The research was supported by a NIMH Predoctoral Fellowship to G.G.N., and by NSF Grant GB 34095 to the N.Y.S. Psychiatric Institute. Reprints may be obtained from J. Gibbon, N.Y.S. Psychiatric Institute, 722 West 168th Street, New York, New York 10032.

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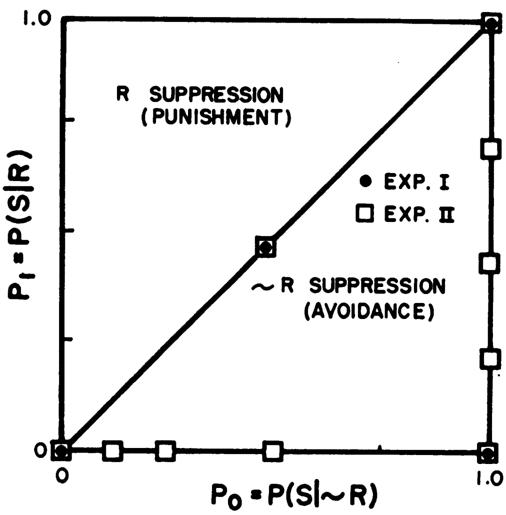

Fig. 1. Instrumental training space for possible procedures varying the conditional probability of shock given responding or not responding. The strict punishment and strict avoidance cases are represented by the upper-left and lower-right corners, respectively, and noncontingent procedures are located on the diagonal through the origin.

through the origin is the locus of all noncontingent procedures, in which the two conditional probabilities are equal. This definition of noncontingent corresponds to no statistical relationship between a response and its consequences: response alternatives are equally predictive of reinforcement. The lower-left corner is the traditional extinction or operant-level condition in which shock is never delivered, and in the upper-right corner shock is delivered on every trial irrespective of whether or not a response occurs.

The bottom edge represents partial reinforcement of failure to respond. Here, nonresponse occurrences are the only ones that produce shock ($P_1 = 0$), but not all nonresponse trials are shocked ($P_0 < 1.0$). The right edge represents partial punishment of avoidance. Here, nonresponse trials continue to be shocked, but response trials may be shocked as well.

The present experiments examined the effects on avoidance responding of procedures represented by the right vertical and bottom horizontal edges, and the noncontingent diagonal. The importance of their study arises from the possibility of varying contingency independently of shock density. The analysis parallels contingency investigations in classical conditioning (Rescorla, 1968, 1969), and is developed in more detail in Gibbon, Berryman, and Thompson (1974). Briefly, one may think of increasing shock density with little change in contingency by moving from lower left to upper right in Figure 1, and of changing contingency by moving orthogonal to that diagonal. The contingency between responding and shock omission increases with the difference between P_0 and P_1, while the frequency of shock increases with their sum.

EXPERIMENT I

Experiment I investigated responding at three noncontingent values along the diagonal in Figure 1 after training at the maximal avoidance contingency ($P_0 = 1.0$, $P_1 = 0$). This experiment asked whether breaking the strict avoidance contingency reduced responding independently of the frequency of shock.

Method

Subjects

Ten naive male hooded (Long-Evans) rats selected from a larger pool served. The selection procedure is described below. The rats were eight to nine weeks of age at the start of experimentation and were housed in pairs with food and water continuously available.

Apparatus

Four operant-conditioning chambers (Grayson Stadler E3125D) with sound-attenuating enclosures (E3125A-3) were modified for these experiments. A right-angled Plexiglas partition was inserted into each chamber so that it abutted the front metal wall and the Plexiglas side-access panel. This partitioning resulted in a square chamber measuring 12.7 by 12.7 by 29.2 cm, which occupied the front outside quadrant of the original chamber. The floor consisted of nine stainless-steel bars, 0.16 cm in diameter, spaced 1.27 cm apart. A stainless-steel rat lever, 5.08 cm wide, was mounted centrally on the front wall of the chamber, 8.9 cm above the floor, and extended 1.6 cm into the chamber. The force required to operate the lever was approximately 0.3 N and an audible click accompanied operation. A white jewelled lamp was located immediately above and to the left of the lever. A speaker was mounted below the floor behind the front panel. An auditory stimulus used in both experiments was a 1000 ±10-Hz tone generated by Foringer Multiple Stimulus Panels (1166-4-11). The tone intensity was set so that the sound-pressure level within the chamber and inside the inner enclosure was 20 dB above the chamber's ambient noise level of approximately 60 dB. A houselight provided dim illumination. Scrambled shock was delivered to each bar of the floor by a Grayson Stadler shock generator (E1064GS). Throughout both experiments the intensity was 0.8 mA, and the duration was 0.5 sec.

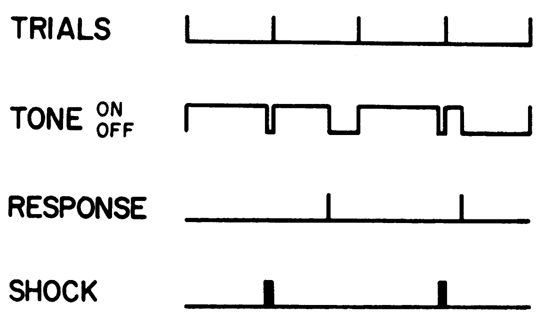

Fig. 2. Experimental paradigm. A discrete-trial procedure is represented with no intertrial interval. Trial onsets are indicated on the top line. In this example, shocks are delivered at the end of the first and third trial cycles that did not contain a response.

P_0 and P_1 were scheduled independently and individually for each of the experimental chambers by randomized probability sequences punched into 16-mm film loops 40 units long. The starting position in the loop was varied over sessions.

Procedure

Paradigm. The paradigm used in both experiments is shown in Figure 2. It is similar to a procedure devised by Hineline and Herrnstein (1970) and represents a discrete-trial procedure with no intertrial interval. Trials were 20-sec cycles, consisting of a 19.5-sec "response" period, during which a response might occur, followed by a 0.5-sec "consequence" or reinforcement period in which shock could be presented. Shock was never presented at any other point in the cycle. Trials began with a tone, and at the end of the response period the tone was turned off for the reinforcement period. When a response occurred during the response period, the white jewelled lamp over the lever was briefly illuminated, and the tone was terminated for the remainder of the trial cycle. Responses following the first in a trial had no experimental consequences and are not reported.

Subject selection. A screening procedure was used to select subjects that evinced reasonably rapid avoidance acquisition. Rats were exposed to 180, 20-sec trials for three consecutive days with the maximal avoidance contingency ($P_0 = 1.0$, $P_1 = 0$). Animals that had not made at least three avoidance responses were then eliminated. The remaining animals were continued for another six days. At that point, all animals that had not attained a response probability exceeding 0.8 were discarded. Screening was continued until 10 animals were available. The original subject pool was 35 rats; the attrition rate under this procedure was thus approximately 70%.

Contingency training. After their selection in the screening process, subjects were continued under the maximal avoidance contingency for 27 successive daily sessions. With one exception, described below, each session consisted of 360 trials and lasted 2 hr. At the end of the twenty-seventh session, the animals were divided into three groups matched approximately for response-probability levels. Group 0 was assigned the traditional extinction condition ($P_0 = P_1 = 0$). Group 100 was assigned $P_0 = P_1 = 1.0$, and Group 50 was assigned $P_0 = P_1 = 0.5$. Groups 0 and 100 contained three animals and Group 50 contained four.

The session in which the change in contingency was introduced was a double session. The first 360 trials were conducted under the maximal avoidance contingency. An additional 360 trials, which followed immediately, were conducted at the new noncontingent condition. Fourteen more consecutive daily sessions were conducted for each animal under its respective condition. Thus, each animal experienced 28 sessions under the maximal avoidance contingency, followed by 15 sessions under a noncontingent condition.

Two animals were subsequently studied at additional points on the noncontingent diagonal for one session each. The values were, in sequence: $P_0 = P_1 = 0$, 1.0, 0.75, 0.5, 0.25, and 0.

The first 60 trials of each session were deleted to eliminate warm-up effects. The data presented below were computed on the basis of the last 300 trials of a session.

RESULTS

Figure 3 presents the response probability of each subject for the last nine days under the maximal avoidance contingency, pooled over three-session blocks, followed by the 15 individual sessions under the noncontingent procedures. The top panel shows Group 0 (no shock), the middle panel shows Group 50 (shock on 50% of the trials), and the lower panel shows Group 100 (shock on every trial). The three Group 0 subjects in the traditional avoidance-extinction procedure eventually stopped responding, as did most of the rats in the other two groups. The 100 and 50 groups contained one subject each (hereafter called a "Class II" subject) that maintained responding in the face of considerable (50%) or inevitable (100%) shock at the end of each response trial. For the subjects that did cease responding (Class I subjects), the change to zero-response level was relatively rapid.

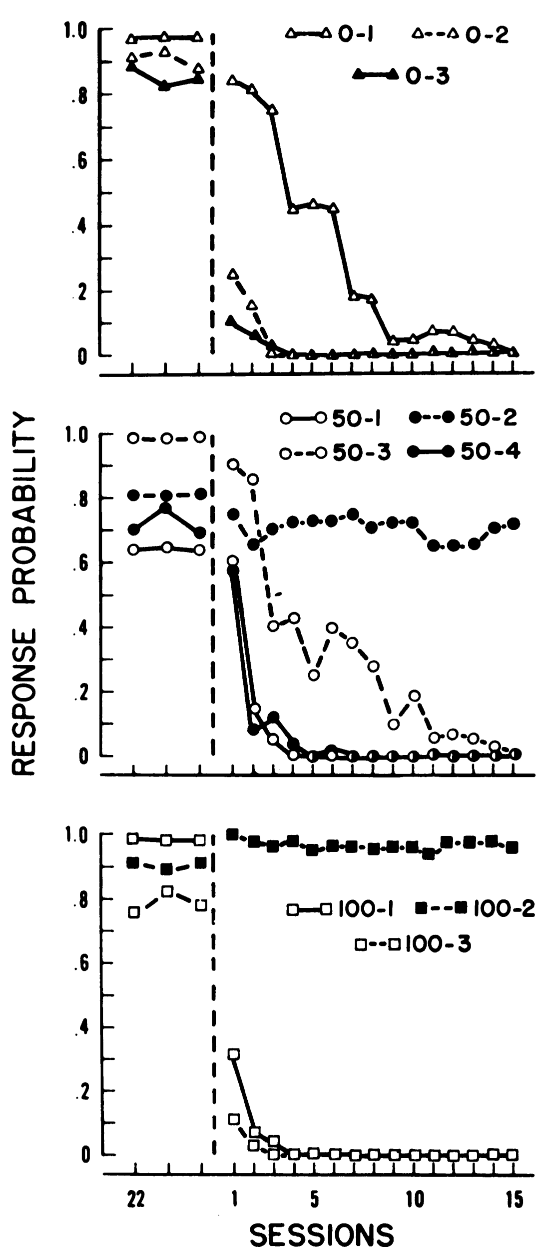

Fig. 3. Response probability before and after the change to noncontingent conditions for three groups (left and right of dashed line respectively). Group 0 received no shock, Group 50 received 50% shock, and Group 100 received 100% shock in the noncontingent treatments.

All subjects during the later portion of maximal avoidance training evinced a temporal discrimination, indicated by an increasing tendency to respond as shock-delivery time approached. Latency distributions pooled over the last nine days of avoidance training and the first nine days of the noncontingent schedules have been calculated in "per-opportunity" form, and are shown in the upper and lower panels respectively of Figure 4. The functions represent the conditional probability of a response falling in successive tenths (1.95-sec interval) of the response period, given an opportunity for such a response to occur—that is, given a latency at least that long. The functions were computed for response trials only, and thus the tenth category, which is necessarily 1.0, is not shown. Also, the functions were not plotted beyond values for which opportunities did not exceed 20.

During baseline training (upper panel), response probability for all subjects showed a nearly linear increase as shock-delivery time approached. This pattern differed from that observed in free-operant avoidance, which typically shows a high frequency of short-latency responses (Boren, 1961; Hineline and Herrnstein, 1970). The noncontingent conditions (lower panel) produced virtually no change in this pattern for the seven Class I animals. These rats continued to show a temporal discrimination, evident in their rising conditional-probability functions, even when, for some subjects, response trials reliably ended in shock. In fact, two subjects in the 100% shock group (100-1 and 100-3) showed the sharpest temporal discrimination.

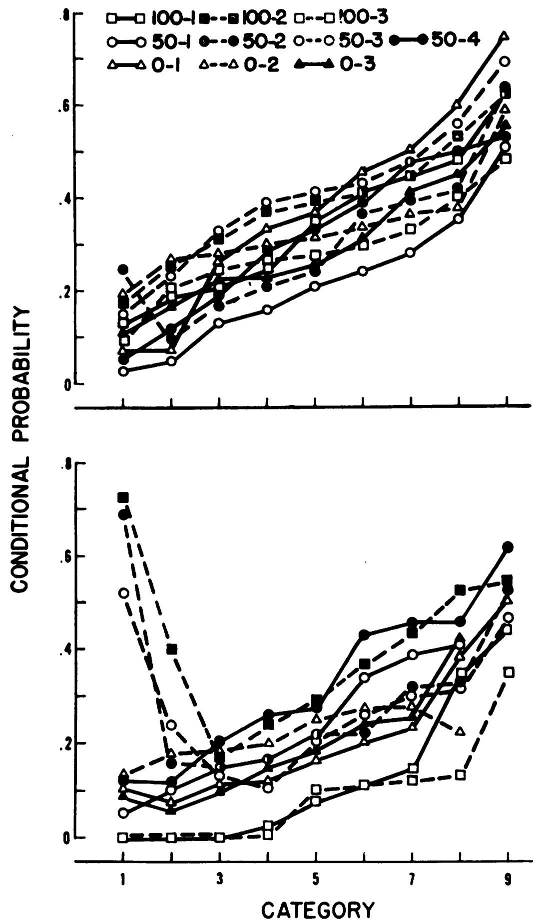

Fig. 4. Conditional probability of a response falling in successive tenths of the trial cycle for all animals in Experiment I. The top panel represents latencies averaged point by point over the last nine days of training on the maximal avoidance contingency. The bottom panel represents the subsequent nine sessions of training on the noncontingent schedules. The measure is the conditional probability of latency, given a wait of at least the abscissa value (latency-per-opportunity).

The Class II animals showed a different latency pattern. For these subjects (50-2 and 100-2), a high frequency of short latencies was evident. The remainder of their functions, however, were similar to those of the other subjects. The difference between Class I and Class II animals appeared in short-latency responding. Something like this pattern, though not as pronounced, was shown by one other subject in Group 50 (50-3). This animal did eventually cease responding, though behavior remained at intermediate levels over a longer time than for the other subjects. Class II subjects differed from Class I animals also with respect to an increased response probability after shocked, as opposed to nonshocked, trials. These sequential data are analyzed later in the context of similar findings from Experiment II.

The two Class II subjects were subsequently studied at a variety of values along the noncontingent diagonal for one session each. These data are shown in Figure 5. The control exerted by the noncontingent schedule is striking. Responding varied between close to 100% and 0% at the two extremes, and exceeded the diagonal at intermediate shock probabilities. This means that the shock schedule was not simply eliciting a response after each shock, since behavior at least 20 sec away from a preceding shock was reliably maintained at intermediate values. The responding of these subjects when shock probability was less than 1.0 occurred both after shock trials and nonshock trials, though to a lesser extent. On the 100% schedule, however, responding decreased somewhat below the one-per-shock level.

EXPERIMENT II

Experiment I revealed two patterns of responding by subjects exposed to noncontingent shock. Class I subjects were sensitive to the break in contingency between responding and shock omission, and were not sensitive to changes in shock density *per se*. The Class II

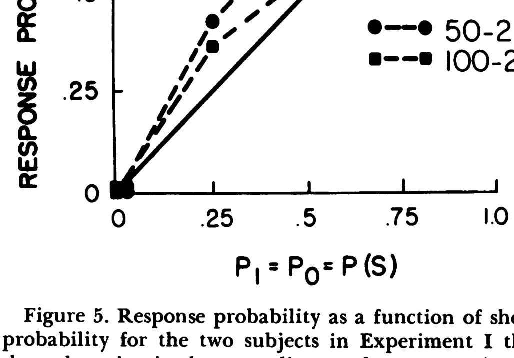

Figure 5. Response probability as a function of shock probability for the two subjects in Experiment I that showed maintained responding under noncontingent shock.

pattern showed sensitivity to both contingency and shock density. In these subjects, the effect of shock density on responding was revealed when they were exposed to the noncontingent schedules. Their behavior under the maximal avoidance contingency was as efficient as their Class I counterparts. Experiment II examined contingencies intermediate between the extremes observed in Experiment I. The partial contingency values examined are those shown on the horizontal and vertical edges of Figure 1. These partial contingencies allowed an assessment of whether the consequences for responding and not responding operated symmetrically on behavior, and whether the abrupt break in contingency studied in Experiment I was necessary for the emergence of the Class II pattern.

Method

Subjects

Twelve naive male hooded rats, obtained from the same supplier, were selected from a pool of 40 rats according to the method described in Experiment I.

Apparatus

The apparatus was the same as that used in Experiment I.

Procedure

Immediately following their selection, the 12 animals were exposed to the maximal avoidance contingency ($P_0 = 1.0$, $P_1 = 0$) for 12 daily sessions. They were then divided into two groups roughly matched for response-probability levels. Group H was studied at points along the horizontal edge and Group V at points along the vertical edge of the P_0, P_1 space (Figure 1). Partial contingencies were studied for nine consecutive sessions, and baseline recovery under the maximal avoidance contingency was interpolated between each partial contingency value. Baseline recovery was generally conducted for nine sessions also, with an occasional extended exposure when subjects did not recover their previous baseline levels within that time period.

The sequence of conditions may be divided into three phases as shown in Table 1. Phase 1 was an initial exposure to a range of values, Phase 2 was a replication and extension, and Phase 3 consisted of exposure to noncontingent conditions. In combination with the last value

Table 1

P_0,P_1 Values for Successive Phases of Experiment II

Phase	*Group*	*(P_0,P_1) in order of presentation*
1	V	(1.0, 0.25), (1.0, 0.5), (1.0, 0.75)
	H	(0.5, 0), (0.25, 0.), (0, 0)
2	V	(1.0, 0.25), (1.0, 0.5), (1.0, 0.75), (1.0, 1.0)
	H	(0.5, 0), (0.25, 0), (0.125, 0), (0, 0)
3	V	(0.5, 0.5), (0, 0)
	H	(0.5, 0.5), (1.0, 1.0)

in Phase 2, Phase 3 provided a set of three noncontingent conditions that were the same for both groups and the same as for the three groups studied in Experiment I.

Results

A sample of response-probability data for an animal from each group for Phase 1 is presented in three-session blocks in Figure 6. For both subjects, successive partial contingencies produced increasing response decrements. Recovery between partial contingency determinations was generally somewhat protracted after large response decrements (as in the last recovery sessions).

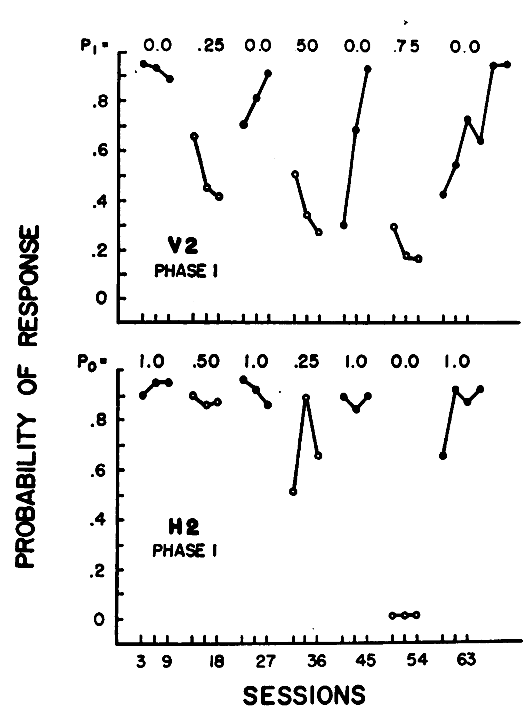

Fig. 6. Response probability under successive conditions for an animal from Group V and Group H. Data are pooled over three-session blocks. Recovery data at the maximal avoidance contingency are represented by filled points.

Summary data for all subjects of Group H are presented in Figure 7. The data are presented from left to right in the order that the determinations were actually made. Thus, the x-axis values read from $P_0 = 1.0$ (avoidance recovery) to $P_0 = 0$ (traditional extinction) for Phases 1 (left-most panel) and 2 (middle panel). For Phase 3, the noncontingent values are presented in the order studied ($P_0 = P_1 = 0.5, 1.0$). The data represent the last three days of each condition, except that the recovery data are the mean of all the last three-day blocks at successive recovery conditions within each phase. In Phases 1 and 2, responding showed an orderly monotonic decrease with decreasing shock probability. For four subjects in both Phases 1 and 2, the drop in responding was relatively steep. For the other two subjects (H_3, H_4), the decline was more gradual and appeared to be related to their lower response probabilities at the maximal avoidance contingency. All animals stopped responding under the traditional extinction condition.

In Phase 3, three of the six animals revealed substantial responding under the noncontingent values. These subjects thus qualified for the Class II designation, while the other three that showed no responding under these probabilities were classified Class I animals. The Class II *versus* Class I distinction has been represented by the filled *versus* open circles in Figure 7. There was no evident difference between these subjects in Phases 1 and 2. The Class II pattern was seen only when subjects were studied under noncontingent schedules.

Summary data for Group V are shown in Figure 8. The x-axis represents P_1 values and the y-axis shows response probability over the last three days at each determination. In Phase 1, three subjects (open points) showed decreasing response probability with increasing punishment probability. The other three subjects showed an initial decrement and then little change in responding as punishment probability increased up to $P_1 = 0.75$.

In Phase 2, the three subjects that showed graded response reductions in Phase 1 again showed a decrement, though two subjects showed a different function form. The other three subjects showed little change in respond-

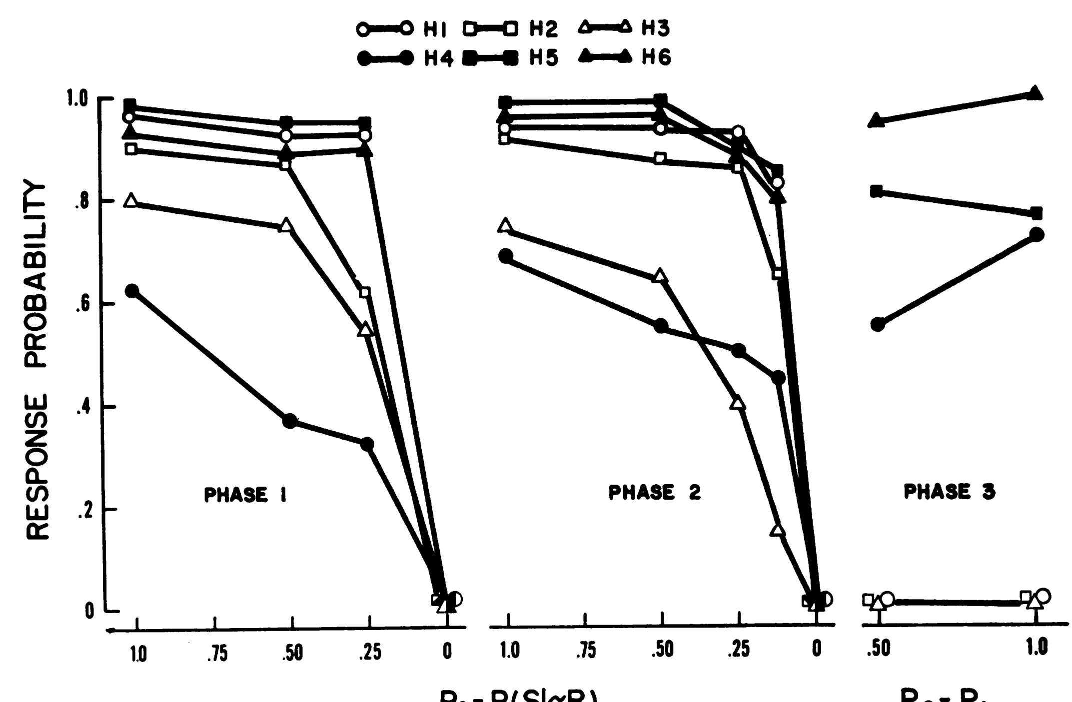

Fig. 7. Response probability as a function of the conditional probability of shock given a nonresponse trial for the Group H subjects. Data are taken from the final three days of exposure to the schedule values, and the functions are plotted from left to right in the order in which the probability values were studied in successive phases. In Phase 3, shock probability for responding and not responding was equal.

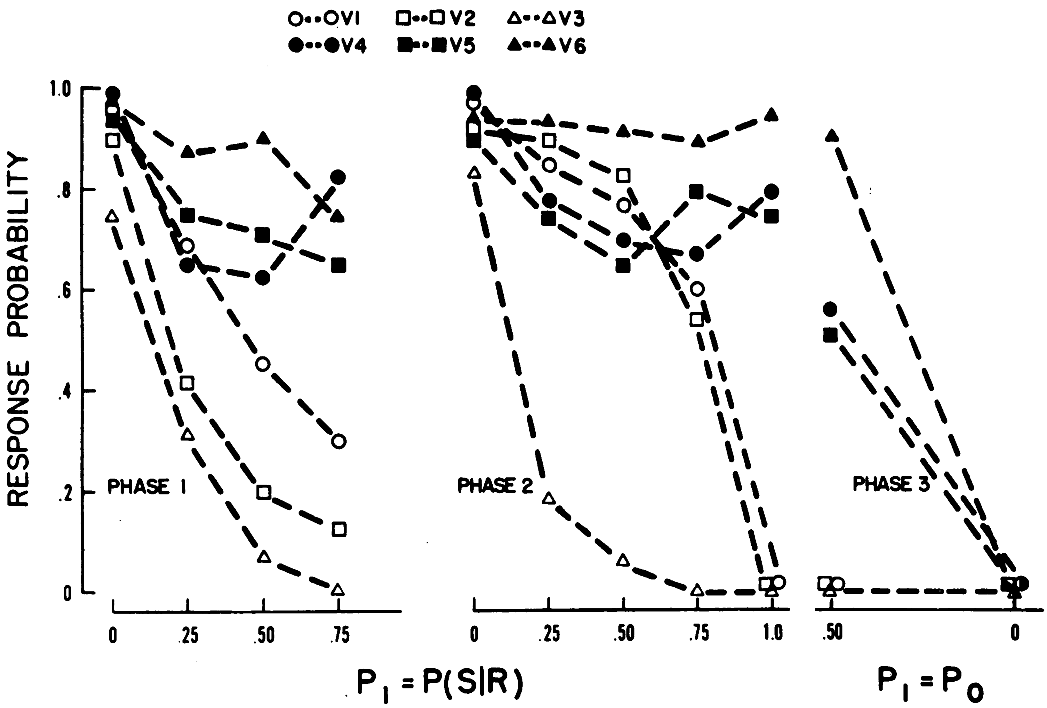

Fig. 8. Response probability as a function of the conditional probability of shock, given a response trial for Group V subjects. Data are taken from the final three days at each schedule value, and the functions are plotted from left to right in the order in which the probability values were studied in successive phases. In Phase 3, shock probability was equal for response and nonresponse trials.

ing as punishment probability increased to 1.0. The maintained responding of these subjects under the noncontingent point, $P_0 = P_1 = 1$, qualified them as Class II subjects. In Phase 3, as would be expected from Experiment I, the 50% noncontingent schedule reduced response strength somewhat, and responding stopped for all subjects when shock was omitted ($P_0 = P_1 = 0$). The control over responding exerted by shock density for the Class II subjects was striking in Experiment I, and was replicated here. When the contingency was eliminated, response probability decreased with decreasing shock probability. Again, also, response probability was above 0.5 at 50% shock and below 1.0 at 100% shock.

In contrast with the omission variable, shocks on response trials produced some early differences between the Class I and Class II subjects. After an initial decrease when punishment was introduced, Class II subjects showed no subsequent change with increases in punishment probability. This is especially noteworthy because sensitivity to the shock-density variable under the noncontingent treatments in Phase 3 was evidenced by a decrease with decreasing shock probability. This means that the Class II pattern that emerged early in the punishment determinations shared control with the contingency-sensitive behavior shown by these subjects at the maximal avoidance contingency.

Latency data for Groups H and V are presented on the left and right respectively of Figure 9. The data are median latencies to respond during the last three days at each partial-contingency value in Phase 2 and under the subsequent noncontingent determinations of Phase 3. The Group H subjects showed virtually no change in median latency until P_0 reached quite low values, at which point a slight increase was observed for all subjects. Two of the Class II subjects of this group (filled points) showed a drop in median latency in the Phase 3 noncontingent determinations. For the third, a decrease was evident only relative to the last contingent point ($P_0 = 0.125$).

The Class I subjects in the V group (open points) showed unchanged or longer latencies under the partial-contingency treatments. However, the Class II subjects of this group showed a progressive drop in latency to levels

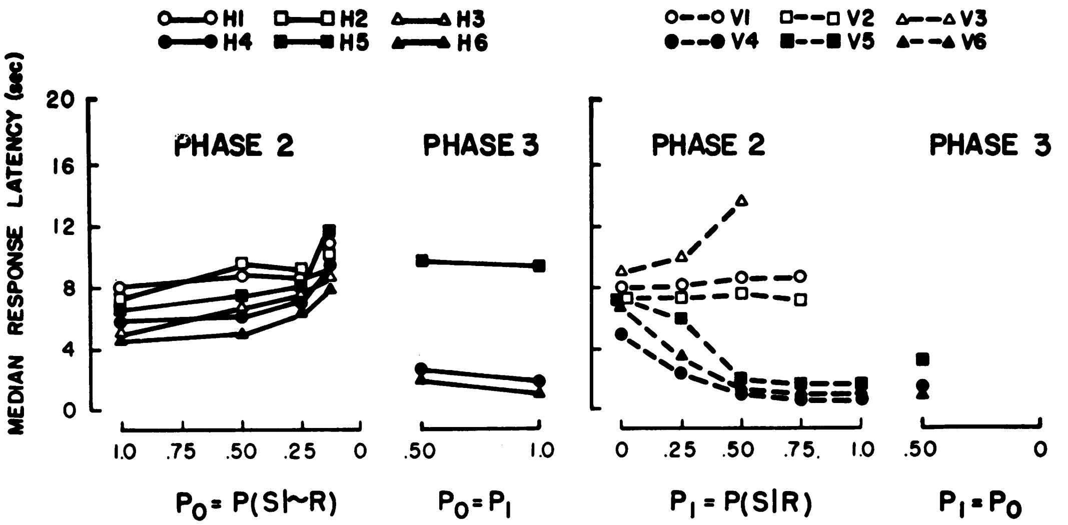

Fig. 9. Median response latency as a function of schedule value for Group H (left panel) and Group V (right panel) in Phases 2 and 3. Data are taken from the last three days of exposure to the schedule value.

that persisted under the noncontingent points. Responding occurred progressively earlier in the trial as punishment probability increased.

The decrease in median latency reflected an increase in the frequency of short latencies similar to that observed for the Class II subjects in Experiment I. This effect is clearest in Figure 10, which shows conditional-probability distributions during recovery phases between noncontingent points in Phase 3 (top two panels), along with distributions obtained during the noncontingent 50% shock schedule for the Class II subjects (bottom panel). The Class I subjects (top panel) showed the same rising latency-per-opportunity functions observed for all subjects under the maximal avoidance contingency in Experiment I. The Class II subjects, except for H4, showed this pattern during the recovery sessions in Phase 3 (middle panel). There is more scatter in these data than in those for the Class I animals, but all subjects showed a steady increase in

Table 2

Response probability under the maximal avoidance contingency after unshocked and shocked trials.

Experiment I				Experiment II			
Subject	$P(R_n\|{\sim}S_{n-1})$	$P(R_n\|S_{n-1})$	*Diff.*	*Subject*	$P(R_n\|{\sim}S_{n-1})$	$P(R_n\|S_{n-1})$	*Diff.*
			Class I				
0-1	0.97	1.0	−0.03	H1	0.97	1.0	−0.03
0-2	0.94	0.66	0.28	H2	0.95	0.65	0.30
0-3	0.87	0.73	0.14	H3	0.82	0.55	0.27
50-1	0.81	0.42	−0.04	V1	0.98	1.0	−0.02
50-3	0.96	1.0	−0.04	V2	0.97	0.91	0.06
50-4	0.74	0.75	−0.01	V3	0.93	0.15	0.78
100-1	0.97	1.0	−0.03				
100-3	0.88	0.61	0.27				
			Class II				
50-2	0.75	1.0	−0.25	H4	0.59	0.85	−0.26
100-2	0.90	1.0	−0.10	H5	0.96	1.0	−0.04
				H6	0.99	1.0	−0.01
				V4	0.97	1.0	−0.03
				V5	0.89	1.0	−0.11
				V6	0.98	1.0	−0.02

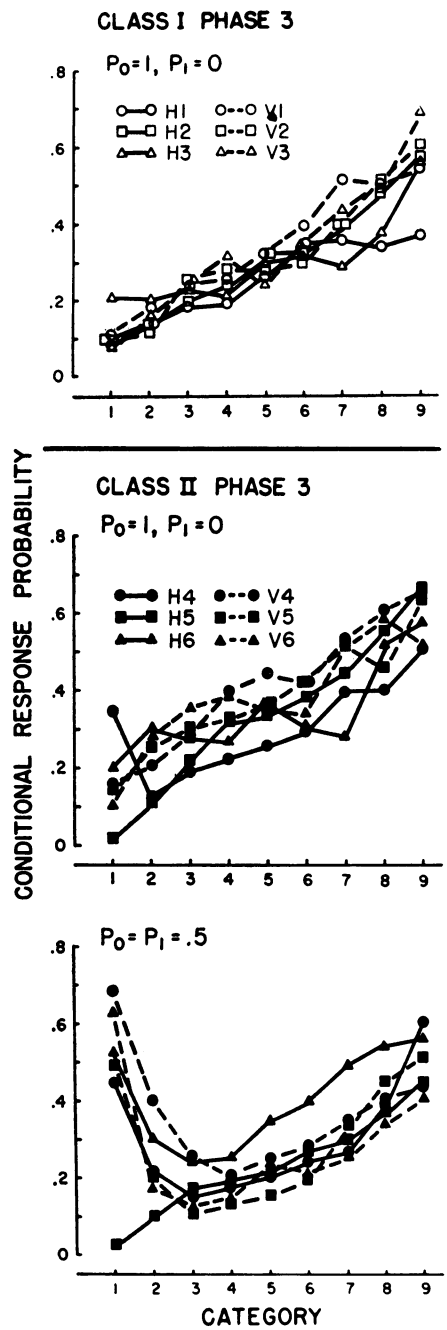

Fig. 10. Latency-per-opportunity functions for all subjects during Phase 3. The top panel represents latency distributions for Class I subjects during recovery periods. These subjects did not respond on the noncontingent schedules. The middle panel represents latency during recovery periods for Class II subjects that responded under noncontingent treatments. Latency distributions for these same subjects under the 50% noncontingent shock schedule are shown in the bottom panel.

response probability as shock-delivery time approached. In contrast, the Class II subjects showed the characteristic short-latency pattern under the noncontingent 50% delivery schedule (bottom panel). With one exception, the Class II subjects showed a high early response probability, followed by decline to low values in the middle of the trial period, followed in turn by an increase as the end of the trial approached. Thus, both the temporal discrimination and the short-latency pattern remained features of Class II responding during noncontingent shock. The one subject that did not show the short-latency pattern (H5) was the subject that was deviant from the other Class II animals in response probability. Its response-probability data did not show the rise with increasing shock density characteristic of the other subjects (Figure 7, Phase 3). Since this subject was an H Group subject, it received its first exposure to shocks following response trials on the 50% schedule in Phase 3.

In Experiment I, it was noted that the two Class II subjects tended to respond immediately after shock and with a somewhat lower probability after nonshock trials. A sequential analysis was performed on the maximal avoidance data of all subjects from both experiments, in which response probability after shock and nonshock trials was calculated separately. The data are presented in Table 2. Entries represent the last three sessions before the noncontingent treatment in Experiment I and the baseline recovery sessions in Phase 2 of Experiment II. The third column under each experiment is the difference between the preceding two. The Class II subjects are clearly negative in this difference, indicating that responding after a nonresponse-plus-shock trial is higher in these subjects than responding after a response-plus-no-shock trial. The Class I subjects were generally less negative or positive in this difference, indicating a greater tendency toward long response runs. The difference scores were analyzed by a Wald-Wolfowitz runs test and found to distinguish Class I and Class II subjects at the 0.05 level. Of course, the distinction is statistical and not all Class II subjects are strongly negative on the difference measure, just as not all Class I subjects are positive. Also, this analysis is complicated by the fact that subjects in Group 0 in Experiment I never experienced shock following a response trial. Since some Group

H subjects in Experiment II did show the Class II pattern when exposed later to noncontingent schedules, it is not clear whether, for example, 0-1 might not also show this pattern. In any case, very high values for postshock responding appear to be good predictors of the Class II pattern, which subjects may later demonstrate when exposed to noncontingent shock schedules.

GENERAL DISCUSSION

Experiment I demonstrated and Experiment II elaborated two modes of response to a break in contingency between responding and shock. Class I subjects stopped responding when the contingency between their behavior and shock omission was eliminated, regardless of whether shocks continued to be delivered. Class II subjects maintained responding under noncontingent shock delivery when response and nonresponse alternatives were no longer associated with differential outcomes.

Class I

The defining feature of our description of the Class I pattern was the cessation of responding when the response-shock contingency was eliminated ($P_0 = P_1$). The manner in which responding dropped out under partial contingencies as the noncontingent condition was approached, differed for the two partial contingency dimensions studied here. However, one feature of the behavior that remained the same in both Experiment I, in which the contingency was abruptly eliminated, and Experiment II, in which the contingency was gradually degraded, was the pattern of timing behavior exhibited by all subjects. Timing can be expected as a feature of maintained avoidance behavior (Gibbon 1971), but Experiment I showed that timing was also maintained throughout extinction when overall response probability was decreasing to zero. Experiment II showed that this independence of response probability and response latency was maintained under the partial-contingency conditions for Class I subjects. These animals showed very little change in latency of response during partial-contingency treatments under either the punishment or omission schedules until responding was very close to zero. Evidently, the timing component of the Class I response pattern remained virtually unchanged after it was established under the maximal avoidance contingency. Such a view is consonant with earlier accounts (Gibbon, 1972; Hineline and Herrnstein, 1970).

The decrease in response probability with increasing omission of shock delivery for not responding (as P_0 approached zero), was relatively abrupt at values near the traditional, noncontingent extinction condition. This finding is consonant with Boren and Sidman's (1957) data, and is consonant also with a shock-density-discrimination hypothesis.

For the subjects studied here, those that had high response probabilities under the maximal avoidance contingency showed the steepest functional relationship with decreasing P_0. Subjects with lower avoidance efficiency when $P_0 = 1.0$, showed more gradual reduction in responding with decreasing shock delivery. Such ordering of initial response strength and rate of decline is what would be expected if the decline was produced by the difficulty of discriminating between shock densities associated with responding and not responding. The discrimination hypothesis is elaborated in more detail elsewhere (Gibbon, 1972), but on a qualitative basis it may be described as follows: subjects with a high response probability produce a very low shock density when responding under the maximal avoidance contingency. For these subjects, shock density associated with not responding cannot approach the shock density associated with responding until omission probabilities are very high, that is until P_0 is close to zero. Then, shock densities associated with not responding begin to approach shock densities associated with responding, as both shock frequencies are quite low. Under these circumstances, the discrimination between the value of working *versus* the alternative, becomes less clear and subjects accordingly respond less frequently. Conversely, for a subject with an inefficient performance on the maximal avoidance contingency, which results in more frequent shock, the omission schedule need not reduce shock frequency as drastically to approximate the shock density associated with responding. Thus, for these subjects, P_0 takes effect at more intermediate values.

The form of the function relating decrements for Class I subjects to punishment probabilities is not clear from these data. One subject showed a relatively early decrease in response strength when shock was introduced at the end of response trials, while two subjects showed this pattern for their first determination but later (Phase 2) were relatively resistant to the effects of punishment until punishment probability was close to 1.0. Thus, the form of the function relating response strength to P_1 for the Class I subjects will require further study.

However, one qualitative detail for the relation between these data and a discrimination hypothesis of the contingency effect is of interest. When the avoidance contingency is weakened by the introduction of shocks after response trials, the rate at which behavior might be expected to reflect "confusability" between the shock densities associated with the two response alternatives is less dependent on initial response strength. For the omission variable, this dependence was the result of the fact that P_0 omission probabilities must approximately match shock-omission probabilities produced by responding before the discrimination of improvement in shock density becomes difficult. For the punishment variable, however, given an initial response probability greater than approximately $\frac{3}{4}$, punishment probabilities of as little as $\frac{1}{4}$ should affect the discriminability of the shock rates associated with responding and not responding. This means that the rate at which response levels decline with increasing punishment should be less dependent on initial response strengths under the maximal avoidance contingency. While the functions are not definitive, as noted above, this prediction is consonant with the data.

Class II

The Class II pattern is defined by continued responding under the elimination of contingency between behavior and shock, when shocks are delivered at some nonzero rate. Subjects exhibiting the Class II pattern showed a response probability somewhat higher than shock probability under the noncontingent procedures, and their behavior was also characterized by a high frequency of short-latency responding.

This pattern was not observed under the partial contingencies produced by the omission schedule. Under the $P_0 < 1.0$ schedules, as well as under the maximal avoidance contingency, Class II subjects were sensitive to the contingency between responding and shock. The P_0 functions for these animals were indiscriminable from those of their Class I counterparts.

The P_1 functions for these subjects, in contrast, showed an early decrease when shock was introduced on response trials, followed by little change as punishment probability increased toward the noncontingent value of 1.0. Evidently, shock density and contingency shared control under the partial-punishment contingencies. The dependence of the Class II pattern on shock density suggested that for the punishment variable, control by contingency decreased as control by shock density was increasing with increasing P_1. The result was that these factors balanced each other and responding remained relatively high.

Evidently, the two conditional probabilities define asymmetrical contingency dimensions. For subjects that are sensitive to contingency without being sensitive to shock-density increments, as well as for the Class II subjects for which control is shared, the P_1 dimension appears more complex. For Class II subjects, punishment seems to invoke additional control by shock density over responding. This control is absent on the P_0 dimension, where Class II subjects look precisely like their Class I counterparts. Lack of shock-density control was particularly clear at low P_0 values where the shock densities subjects experienced were much too low to support any substantial proportion of their behavior. Thus, it seems that the omission variable exerts a different kind of control, in some qualitative sense, than the punishment variable.

Shared control over responding in the Class II pattern was evident in the latency distributions for these subjects as well. Timing behavior, developed under the maximal avoidance contingency, was maintained under the noncontingent conditions. The high frequency of short latencies represented slightly more than 50% of the behavior of these subjects on noncontingent schedules. The remainder of their responses were well timed, and thereby occurred in close temporal contiguity to subsequent shock. Class I subjects also showed maintained timing as response levels decreased (Experiment I). Thus, timing behavior, once established, appeared to be invariant with changes in the *level* of response, independently of how such changes were produced.

It is tempting to speculate that the shock-density control in the Class II pattern is related to a species-specific defense repertoire (*e.g.*, Bolles, 1970; Hutchinson, Renfrew, and Young, 1971) and that responding of this type may be a hidden feature of much avoidance behavior previously thought to be solely under control of the shock-omission contingency. Certainly the "bursting" pattern commonly observed in free-operant avoidance is similar to the Class II pattern observed here. An important feature of the present results is that a short-latency burst is not the only characteristic of this pattern that may be nonassociative with respect to the contingency between behavior and shock. Well-timed behavior occurs also under shock-density control.

Finally, we wish to offer two speculations suggested by these findings. First, the Class I and Class II patterns may result in part from our screening procedures. Subjects appear to divide into these two patterns fairly cleanly, though three (of 22) had less-clear designations. It seems possible that the two patterns may be rooted in the biology of the rat, and that our screening procedure may have selected for two extremes from the subject pool. Subjects whose initial species-specific response to aversive stimulation was immobility, were eliminated by the screening procedures *unless* they were also very sensitive to the shock-omission contingency. That is, subjects that froze frequently under a high frequency of shock had to be very sensitive to one or two shock omissions for responding to develop. These subjects may constitute our Class I group. On the other hand, subjects that responded with "aggressive-like" behavior toward the lever did not require as great a sensitivity to contingency to acquire avoidance responding. If these subjects responded under a high density of shock, they had a greater opportunity to learn the avoidance task because they made contact with the shock-omission contingency more frequently. Such subjects may constitute our shared-control, Class II group. Evidently, the response task, coupled with the screening procedure, selected for extremes of both patterns. Different response tasks that result in more rapid acquisition (Bolles 1970) may well show less differentiation between these two patterns of responding.

A second speculation stems from the finding of maintained timing under a variety of conditions. Timing was observed in both the Class I and Class II subjects when responding was declining during extinction (Experiment I), and was also observed for Class II subjects under noncontingent schedules. This means that there is a substantial dissociation between *whether* an avoidance response will occur and *when* in the preshock interval it will occur. This dissociation with other features of the performance makes it unlikely that timing is critically important in the maintenance of avoidance behavior. Certainly, spaced responding under the noncontingent schedules places responses in closer proximity to a following shock. Possibly, timing behavior is more collateral than causal in avoidance behavior, and reflects coincident temporal regularities present in most avoidance training paradigms.

REFERENCES

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

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

Boren, J. J. Isolation of post-shock responding in a free-operant avoidance procedure. *Psychological Reports*, 1961, **9**, 265-266.

Boren, J. J. and Sidman, M. Maintenance of avoidance behavior with intermittent shocks. *Canadian Journal of Psychology*, 1957, **11**, 185-192.

Brogden, W. J., Lipman, E. A., and Culler, E. The role of incentive in conditioning and extinction. *American Journal of Psychology*, 1938, **51**, 109-117.

Catania, A. C. Elicitation, reinforcement, and stimulus control. In R. Glaser (Ed.), *The nature of reinforcement*. New York and London: Academic Press, 1971. Pp. 196-220.

Church, R. M. Response suppression. In B. A. Campbell and R. M. Church (Eds.), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 111-156.

Gibbon, J. Scalar timing and semi-Markov chains in free-operant avoidance. *Journal of Mathematical Psychology*, 1971, **8**, 109-138.

Gibbon, J. Timing and discrimination of shock density in avoidance. *Psychological Review*, 1972, **79**, 68-92.

Gibbon, J., Berryman, R., and Thompson, R. L. *Contingency spaces and random controls in classical and instrumental conditioning*. Paper presented at the 41st meeting of the Eastern Psychological Association, Atlantic City, 1970.

Gibbon, J., Berryman, R., and Thompson, R. L. Contingency spaces and measures in classical and instrumental conditioning. *Journal of the Experimental Analysis of Behavior*, 1974, **21**, 585-605.

Hineline, P. N. and Herrnstein, R. J. Timing in free-operant and discrete-trial avoidance. *Journal of the Experimental Analysis of Behavior,* 1970, **13,** 113-126.

Hutchinson, R. R., Renfrew, J. W., and Young, G. A. Effects of long-term shock and associated stimuli on aggressive and manual responses. *Journal of the Experimental Analysis of Behavior,* 1971, **15,** 141-166.

Kamin, L. J. The effects of termination of the CS and avoidance of the US on avoidance learning. *Journal of Comparative and Physiological Psychology,* 1956, **49,** 420-424.

Mowrer, O. H. and Lamareaux, R. R. Avoidance conditioning and signal duration—a study of secondary motivation and reward. *Psychological Monographs,* 1942, **54,** (Whole No. 247).

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

Rescorla, R. A. Probability of shock in the presence and absence of CS in fear conditioning. *Journal of Comparative and Physiological Psychology,* 1969, **67,** 504-509.

Seligman, M. E. P., Maier, S. F., and Solomon, R. L. Unpredictable and uncontrollable aversive events. In F. Robert Brush (Ed.), *Aversive conditioning and learning.* New York and London: Academic Press, 1971. Pp. 347-400.

Received 30 July 1973.
(Final Acceptance 3 December 1974.)