JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1984, 41, 291-308 NUMBER 3 (MAY)

INTERRESPONSE-TIME PUNISHMENT: A BASIS FOR SHOCK-MAINTAINED BEHAVIOR

GREGORY GALBICKA AND JOHN R. PLATT

MCMASTER UNIVERSITY

Lever pressing of squirrel monkeys postponed brief electric shock according to a free-operant shock-postponement procedure. Pressing also produced shock with a probability proportional to the duration of the current interresponse time in some conditions, or to the fifth ordinally-preceding interresponse time in others. These conditions provided equal frequencies and temporal distributions of response-produced shocks either contingent on or independent of the current interresponse-time duration, respectively. Shock delivered contingent on the current interresponse-time duration resulted in shorter mean interresponse times and higher overall response rates than shock delivered independent of the current interresponse time. In subsequent conditions, response-produced shocks were sufficient to maintain responding following suspension of the postponement procedure only when those shocks were contingent on the current interresponse time. Presenting shock independent of the current interresponse time, conversely, suppressed response rate and ultimately led to cessation of responding in the absence of a conjoint shock-postponement procedure. These results demonstrate interresponse-time punishment in the absence of any indirect avoidance contingencies based on overall shock-frequency reduction, and strongly support similar interpretation at the more local level of shock-frequency reduction correlated with particular interresponse times. Differential punishment of long interresponse times also provides both an a priori basis for predicting whether a schedule of shock presentation will maintain or suppress responding and a framework for interpreting many of the functional relations between overall response rate and parameters of consequent shock presentation. Finally, these results and others indicate the importance of response-consequence contiguity above and beyond any notion of noncontiguous contingency in the control of behavior.

Key words: interresponse times, punishment, response-produced shock, avoidance theories of punishment, contiguity, contingency, lever press, squirrel monkeys

Galbicka and Branch (1981) presented response-dependent food at varying intervals to squirrel monkeys, and conjointly delivered brief electric shock following interresponse times (IRTs) that exceeded a specified duration. The frequency of those IRTs decreased, thus decreasing mean IRT duration and increasing overall response rate. Because the IRT criterion for shock delivery was fixed, the frequency of shock delivered under this procedure decreased as supercriterion IRTs were suppressed. In interpreting this result, Galbicka and Branch suggested that the decreased frequency of supercriterion IRTs reflected a direct IRT-punishment effect. Such an interpretation is entirely consistent with the literature on punishment of other operants (see Azrin & Holz, 1966). However, Galbicka and Branch noted a possible alternative interpretation emphasizing negative reinforcement of noncriterion IRTs. Specifically, the shock-frequency reduction provided by emitting IRTs shorter than the criterion may have increased the frequency of "short"

This work was supported by National Research Service Award Postdoctoral Fellowship 5 F32 MH08696 from NIMH (USA) to Gregory Galbicka, and by Natural Sciences and Engineering Research Council (Canada) Grant A8269 to John R. Platt. Portions of these data were presented at the ninth annual meeting of the Association for Behavior Analysis, Milwaukee, May,1983. Thanks are extended to M. N. Branch and S. Siegel for graciously providing some needed apparatus, and to G. J. Weatherill for his more than competent technical assistance. The McMaster Psychology Department secretarial staff expertly prepared the manuscript for submission. As always, the conceptual input of the New Wave Behaviorists is taken as self-evident. Reprints may be obtained from Gregory Galbicka at McMaster University, Department of Psychology, Hamilton, Ontario, Canada L8S 4K1.

IRTs, only indirectly decreasing the frequency of "long" IRTs. This is an extension of more general "avoidance theories of punishment" (Skinner, 1953). Demonstrating IRT punishment independent of such indirect negative reinforcement requires that overall shock frequency remain fixed, a condition not met in the Galbicka and Branch study.

Independent of the above considerations, relationships between IRT duration and shock presentation may provide an alternative account of responding maintained under procedures in which the consequence of responding is shock presentation. Following response acquisition under response-contingent schedules of food presentation (e.g., Kelleher & Morse, 1968), shock postponement (e.g., McKearney, 1969), or response induction by periodic response-independent shock (e.g., Morse, Mead, & Kelleher, 1967; see Hutchinson, 1977, for a review), lever pressing of squirrel monkeys can be maintained by shock presentation under interval schedules, which present shock following the first response after a specified temporal interval (see Morse & Kelleher, 1977, for a review). But when shock is delivered under ratio schedules, that is, following a specified number of responses, pressing typically is suppressed, even when the number of responses per shock is matched to a preceding condition in which responding was maintained under an interval schedule (Branch & Dworkin, 1981). Current conceptualizations of "shock-maintained behavior" hold that the schedule of shock presentation is fundamental in determining the consequent stimulus function of shock (Morse & Kelleher, 1977) — presented under interval schedules, shock functions to reinforce responding; under ratio schedules, it serves to punish responding.

Shock presentation is contingent on responding under both ratio and interval schedules, but it is a differential consequence of IRT duration only under interval schedules. Under interval schedules, shock availability depends on the passage of time. Hence, the longer the interval between successive responses (i.e., the longer the IRT duration), the more likely the response terminating the IRT will be followed by shock. Under ratio schedules, in which shock delivery depends only on the number of responses emitted and not on the passage of time, shock probability is independent of IRT duration. That is, the probability of shock presentation does not change systematically with changes in IRT duration under ratio schedules, but remains roughly constant for all IRTs. Thus, shock delivery under interval schedules is a differential consequence of responding and of IRT duration; under ratio schedules it is a differential consequence only of responding.

An IRT-punishment account of shock-maintained behavior would emphasize these differences in consequent relations under interval and ratio schedules. Under the former, two punishment relations operate — one between shock presentation and responding, and one between shock and IRT duration. (In the present context, "response-punishment relations" refer to relations between lever pressing and shock presentation, whereas "IRT-punishment relations" involve relations between IRT duration and shock presentation. "IRT punishment" is used occasionally instead of the ambiguous "long-IRT punishment" and always denotes a positive relation between IRT duration and shock frequency.) The response-shock relation acts to suppress responding; the IRT-shock relation suppresses shocked long IRTs differentially. With respect to overall response rate these two relations are functionally opposite, the former decreasing and the latter increasing response rate. Provided the latter is greater than the former, response rates will increase and responding may be maintained chronically by interval schedules of consequent shock presentation. Under ratio schedules, conversely, only the response-shock relation operates, and responding is suppressed.

The present experiment examined responding under IRT-based schedules of consequent shock presentation arranged so as to control the overall frequency and temporal distribution of shock. Under some conditions, response-produced shock delivery was a differential consequence of IRT duration; under others, response-produced shock was delivered independent of the current IRT. The resulting procedure thus addressed both issues raised above: (1) assessment of IRT punishment in the absence of indirect negative reinforcement based on shock-frequency reduction, and (2) the importance of differential-IRT punishment in the maintenance of responding by consequent shock presentation.

The procedure was identical in most respects to that used by Platt (1979) to assess differential reinforcement of IRTs in the absence of changes in the overall frequency of food presentation. Brief electric shocks were delivered according to what previously has been termed a stochastic-reinforcement-of-waiting schedule (Weiss, 1970). Because one of the goals of the present study was to distinguish reinforcing from punishing functions, we shall use the less connotive term "linear-IRT schedule" in referring to this procedure. Under a linear-IRT schedule, the probability of a consequent event is an increasing, linear function of IRT duration. That is, consequent events are delivered with a probability proportional to IRT duration, specifically with a probability equal to the IRT duration divided by T, an experimentally defined temporal parameter expressed in the same units as IRT duration. Provided IRT durations are short relative to T, consequent events are delivered under linear-IRT schedules at varying intervals geometrically distributed around a mean interval equal to T, much like the intervals generated by constant-probability variable-interval (VI) schedules.

Events thus arranged contingent on IRT duration need not simultaneously be contiguous with it. Event presentation can be postponed from the contingent IRT by imposing a "Lag" of some fixed number of IRTs. For any ordinal sequence of IRTs, a linear-IRT schedule with Lag = L specifies a probability of event presentation following the Nth IRT, $\Pr(E_N)$, equal to

$$\Pr(E_N) = \frac{\mathrm{IRT}_{N-L}}{T}. \qquad (1)$$

The numerator of the fraction is the contingent IRT, which always precedes the IRT contiguous with event presentation by L IRTs. Thus, if Lag = 0, the contingent and contiguous IRTs are one and the same. As Platt (1979) indicated, the resulting hazard function between IRT durations and consequent events under such a procedure is similar to that indirectly provided by constant-probability VI schedules across the range of IRTs typically observed in free-operant situations. For Lags greater than zero, events are delivered independent of the contiguous IRT, contingent instead on the Lth-preceding IRT (and hence contingent on the contiguous IRT only to the degree that Lth-order sequential dependencies develop in IRT durations). Because events always are delivered contingent on some IRT duration, a Lag manipulation will not greatly alter either the overall frequency or temporal distribution of consequent events. Equal-duration IRTs always produce consequent events with equal probabilities under a Lag = 0 and a Lag>0, only at different times — under the former, when that IRT occurs; under the latter, L IRTs later.

Thus, events may be delivered contingent on (under a Lag = 0) or independent of (under a Lag>0) the current IRT duration without changing the overall frequency or temporal distribution of event presentation. If the "punishment" effect reported by Galbicka and Branch (1981) depends on negaive reinforcement arising from shock-frequency reduction, responding should not be affected by the Lag manipulation, because the frequency and temporal distribution of shocks remains constant. If, conversely, long IRTs are suppressed directly by IRT-consequent shock presentation, differentially punishing long IRTs under the Lag = 0 procedure should generate shorter IRTs and higher rates of responding than comparable IRT-independent punishment.

This latter prediction is also directly opposite to results obtained under linear-IRT schedules of food presentation. Platt (1979) compared key-pecking rates and IRTs of pigeons under such schedules with Lag = 0 or Lag = 5 across a range of T values from 10 to 120 s. Lag = 5 consistently maintained higher rates of responding and shorter mean IRTs than the comparable Lag = 0 procedure. Such results evidence the shaping of long IRTs by the differential-IRT reinforcement provided under the Lag = 0 procedure. Similar results might be predicted under linear-IRT schedules of shock presentation if response maintenance reflects reinforcing properties of shock as has been proposed by Morse and Kelleher (1977) and others. Conversely, if responding is maintained by punishing longer IRTs differentially, suspending this relation under Lag = 5 by presenting a similar overall frequency and temporal distribution of shock independent of IRT duration should suppress responding.

The latter prediction, if correct, raises a methodological problem. Branch and Dworkin (1981) reported repeated failures to reestablish responding under interval schedules of shock presentation once responding ceased. The response suppression predicted under Lag = 5 in the present study may be sufficient to generate similar problems of irreversibility. To guard against this and to allow evaluation of responding under Lag = 0, Lag = 5, and a return to Lag = 0, these conditions originally were programmed conjointly with a shock-postponement procedure (see Sidman, 1953). This ensured continued responding but allowed evaluation only of the direction of change in response rate following a Lag manipulation. Absolute rates of responding under Lag = 0 and Lag = 5 were assessed by subsequently removing the postponement contingency and comparing the two Lags.

METHOD

Subjects

Three adult squirrel monkeys (*Saimiri sciureus*), designated M-601, M-602, and M-603, served as subjects. They were housed individually in a colony room, where they were provided continuous access to Purina Monkey Chow and vitamin-enriched water.

Apparatus

During experimental sessions subjects were seated in a Plexiglas restraint unit similar to that described by Hake and Azrin (1963). They were restrained by a Plexiglas waist lock that allowed free movement of the head, limbs, and torso. Two 1.1-W white stimulus lamps, mounted behind the front wall 15 cm above the waist plate, were illuminated during experimental sessions. A response lever (Coulbourn Instruments, Model E21-03) was mounted on the front wall of the unit 0.4 cm above the waist plate, 10 cm directly in front of the monkey. A downward force on the lever in excess of 0.4 N produced a "click" from a feedback relay mounted behind the front wall, darkened the houselights for 0.1 s and recorded a response. A Plexiglas stock located at the base of the chamber held the subject's tail motionless. Two brass electrodes resting on a shaved portion of the tail allowed delivery of 200-ms, 8.0-mA electric shocks from a BRS/LVE (Model SG-003) constant-current shock generator. Electrode paste, comprised of 3 parts Unibase (a neutral cream base) and 2 parts 0.9% NaCl solution mixed volume/volume, was applied to the tail to minimize changes in electrical resistance. Weekly application of a cream depilatory maintained the shaved condition of the tail.

During experimental sessions the unit was enclosed in a light- and sound-attenuating chamber located in a room where white noise was continuously present. This, along with noise from a ventilation fan mounted on the side wall of the enclosure, helped mask extraneous sounds. An LSI 11 computer, which resolved real time to 0.02 s, programmed stimuli and recorded data.

Procedure

All subjects had prior histories of lever pressing under shock-postponement and response-produced shock procedures, and so were exposed directly to the first experimental condition. Table 1 lists experimental conditions and the number of sessions exposure

Table 1
List of Experimental Conditions and Number of Sessions Exposure for each Subject

Condition	Lag	RS (sec)	SS (sec)	Number of Sessions M-601 T = 60	M-602 T = 120	M-603 T = 240
1	0	20	5	25	15	55
2	5	20	5	40	32	29
3	0	20	5	30	40	30
			In Conditions 4 through 7, T = 240 s for all subjects			
4	0	20	5	10	10	-[a]
5	0	--	-	22	24	26
6	5	--	-	24	21	22
7	0	240	240	3	1	1

[a]Conditions 3 and 4 are identical for this subject.

for each subject.

Each daily 1-hr session began with a response-independent shock and illumination of the white houselights. During Conditions 1 through 4, a free-operant shock-postponement procedure (Sidman, 1953) was in effect, with a response-shock (RS) interval of 20 s and a shock-shock (SS) interval of 5 s. The RS interval specified the delay between the most recent response and the next shock delivery; the SS interval specified the time between successive shocks if no response occurred. Thus, if the subject responded once but did not respond again within 20 s, a shock was delivered and was followed 5 s later by a second shock unless a response occurred within the 5-s period.

Response-dependent shocks were delivered during all conditions according to the linear-IRT schedule. IRTs were timed in 0.02 s class intervals and were stored individually in sequence. Depending on the value of the Lag, either the current IRT (Lag = 0) or the fifth-preceding IRT (Lag = 5) was divided by the value of *T*, and this value then determined shock probability for the current IRT. Under Lag = 5, IRTs from the previous session did not determine shock probability for the first five IRTs of each session. Rather, a restriction was imposed such that the first 10 responses of each session were never shocked. This allowed accumulation of IRTs sufficient to meet the requirements of the programmed Lag. The same restriction was imposed under Lag = 0 to control differences in the number of "early-session shocks" that might otherwise have arisen. The first response immediately following a response-dependent shock was not considered an IRT. Such responses were never shocked and never entered into calculating the probability of response-produced shocks.

All subjects were exposed initially to Lag = 0, then Lag = 5, and finally Lag = 0 again (Conditions 1 through 3, respectively). The values of *T* used throughout these conditions were 60, 120, and 240 s for M-601, M-602, and M-603, respectively. The first two conditions remained in effect until response rates and IRT distributions appeared stable. Stability was defined throughout this study as 10 consecutive sessions showing minimal variability and no consistent ascending or descending trends as determined by visual examination of dependent measures. Condition 3 remained in effect until response measures stabilized or until the mean rate observed over a 10-session period was equal to or greater than that obtained under initial exposure to Lag = 0.

All subjects subsequently were exposed to a linear-IRT schedule of shock presentation with *T* = 240 s:Lag = 0 and the shock-postponement procedure conjointly in effect (Condition 4). After 10 sessions the postponement contingency was removed, and responding was maintained subsequently during Condition 5 for a minimum of 30 consecutive sessions during which the postponement contingency was effectively inoperative (i.e., for 30 consecutive sessions since the last shock delivered according to the postponement contingency during Condition 4) and until responding stabilized. Then Lag = 5 was programmed during Condition 6, again without a postponement contingency. This condition continued for a minimum of 30 sessions and until responding stabilized, unless responding ceased for 30 min or more during a session, at which point the condition was terminated.

Finally, subjects were reexposed to Lag = 0 and $T = 240$ s with a shock-postponement procedure conjointly programmed such that RS = SS = 240 s. The final condition remained in effect until responding stabilized or ceased for more than 30 min.

RESULTS

In the analysis of results, response and shock rates included postshock pauses and responses; IRT measures did not. Figure 1 shows mean IRT durations and overall response rates during the first three conditions. Lag = 5 generated longer mean IRTs and lower overall rates of responding than the initial Lag = 0 condition. Subsequent reexposure to Lag = 0 reversed these effects, decreasing mean IRT duration and increasing response rate. Subjects M-601 and M-603 did not quite recover initial values of these measures, but M-602 showed complete recovery during exposure to this condition. Response rate may ultimately have been even higher and mean IRT shorter for this subject, as such trends were clearly evident in behavior at the end of this condition.

Interresponse-time distributions generated by the Lag = 0 and Lag = 5 procedures (Conditions 1 and 2) are shown in Figure 2. Two points are noteworthy. First, the distribution of shocked IRTs was necessarily displaced to the right of the overall IRT distribution under Lag = 0, but not under Lag = 5. Second, the relative frequency of long IRTs was lower under Lag = 0 than under Lag = 5. Monkey-601's modal IRT class shifted to the next-longer class interval; the other subjects maintained the same modal class while the distributions skewed more towards longer IRTs.

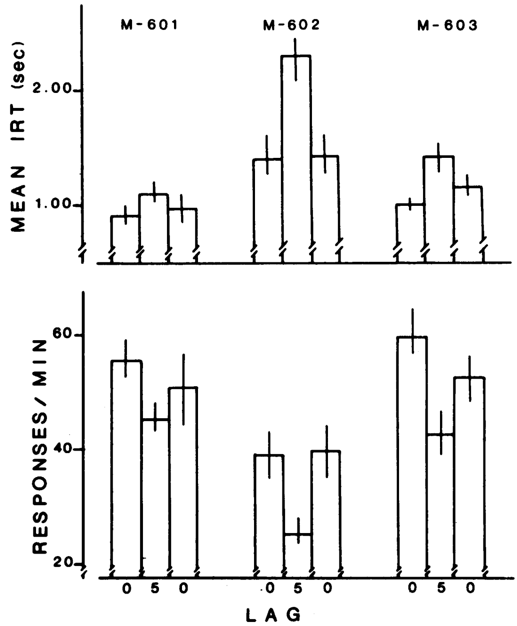

Fig. 1. Response rate and mean IRT duration obtained with each subject during the final 10 sessions of each of the first three conditions. Values and vertical bars represent the means and ranges of values observed during this period, respectively.

Daily session response rates and numbers of shocks during these conditions (see Figure 3) suggest that the behavioral effects of the Lag = 5 procedure were attenuated to some degree by the increased frequency of shocks delivered by the postponement contingency as response rates decreased. The frequency of such shocks was low for M-601 and M-602 under Lag = 0. Without exception, these shocks were delivered during pauses following response-dependent shock delivery (i.e., pauses occasionally exceeded 20 s). Monkey-603 did not pause appreciably after shock delivery at any time during the course of the experiment. Prior to introduction of Lag = 5, this subject had responded for over 50 sessions under the Lag = 0 procedure without delivery of a postponement-schedule shock.

Introduction of the Lag = 5 procedure ultimately led to an increase in the frequency of postponement-schedule shocks delivered to each subject. This apparently halted any further decrease in response rate and, in the

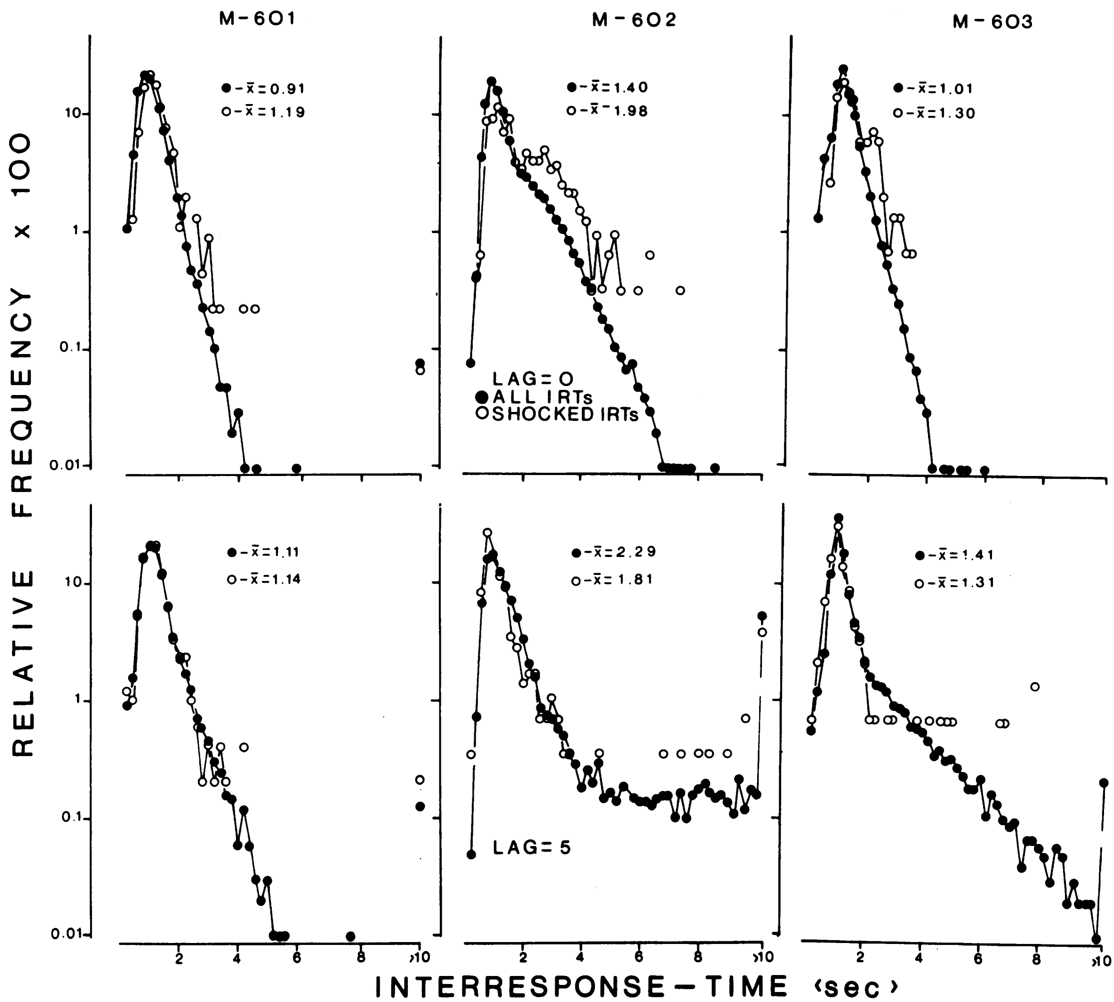

Fig. 2. Relative frequency distributions of IRTs obtained with each subject during initial exposure to Lag = 0 (upper panels) and Lag = 5 (lower panels). Relative frequencies are the accumulated number of IRTs within each class interval normalized across the cumulated number of IRTs during the final 10 sessions of each condition. The mean of the distribution of all IRTs (filled symbols) and of the distribution of IRTs followed by shock (unfilled symbols) is also presented in each panel. Each class interval is 0.2 s wide with the exception of the last, which includes all IRTs greater than 10 s. Note that, given the semilogarithmic axes, values lower than 0.01 have not been plotted.

case of M-603, engendered a pronounced oscillatory pattern in response rates. Rates decreased across sessions until shocks were delivered by the postponement procedure, then increased for a few sessions, followed by a subsequent cycle of response-rate decreases and postponement-schedule shock delivery.

As Figure 3 reveals, the frequency of response-dependent shock remained roughly constant across the Lag manipulation. This result is further evident in intershock-interval distributions obtained under the two Lag values, as shown in Figure 4. As with overall frequency, temporal distributions of shock delivery were not systematically affected by the Lag value, but remained geometrically distributed much like distributions generated under constant-probability VI schedules.

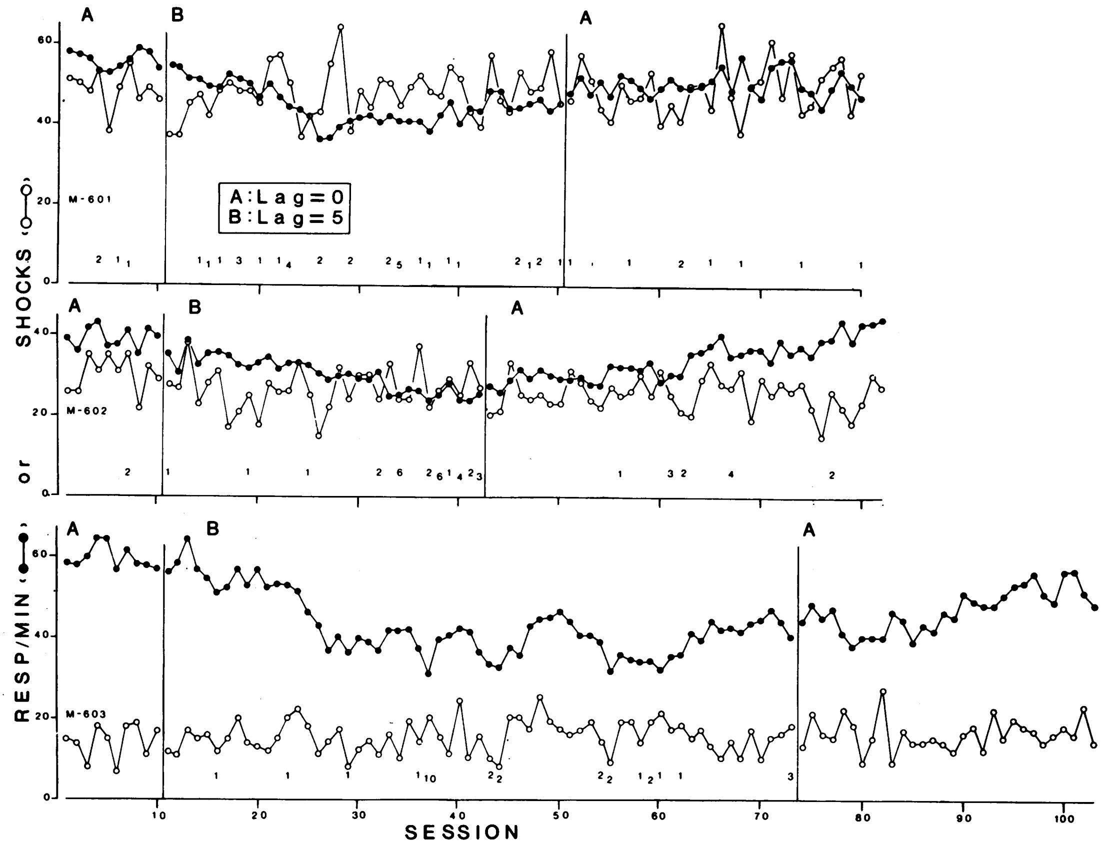

Fig. 3. Daily session response rates (filled symbols) and numbers of shocks delivered (unfilled symbols) for each subject under initial exposure to Lag = 0 (left panels), Lag = 5 (middle panels), and reexposure to Lag = 0 (right panels). Numbers appearing just above each abcissa denote the number of shocks delivered by the conjoint shock-postponement schedule during the session whenever that number was greater than 0. Numbers for successive sessions have been offset to increase clarity.

Response rates and mean IRTs obtained for each subject under subsequent exposure to linear-IRT = 240 s:Lag = 0, with and without the postponement procedure (Conditions 4 and 5, respectively), are presented in Table 2. Removing the postponement contingency decreased response rates and increased mean IRT durations slightly for each subject. Differences in response rate were more pronounced than differences in mean IRT duration for M-601 and M-602 due to a slight increase in postshock pausing. Otherwise, patterns of responding under both conditions were comparable to previous Lag = 0 conditions.

Figure 5 shows response rates and shocks delivered during the last 10 sessions of Condition 5 and during subsequent exposure to

Table 2

Overall response rates and mean IRTs for each subject during Conditions 4 and 5[a]

Subject	*Condition*	*R/min*	*IRT (sec)*
M-601	4	43.9	1.34
		(40.0–46.5)	(1.24–1.48)
	5	40.4	1.43
		(38.0–42.6)	(1.35–1.52)
M-602	4	40.1	1.43
		(36.5–42.1)	(1.37–1.56)
	5	34.1	1.63
		(30.2–36.2)	(1.39–1.86)
M-603	4	52.5	1.15
		(48.8–56.4)	(1.07–1.25)
	5	51.5	1.17
		(46.8–55.5)	(1.08–1.29)

[a]Values are means across the final 10-session means of each condition. Ranges of session means during this period are presented in parentheses.

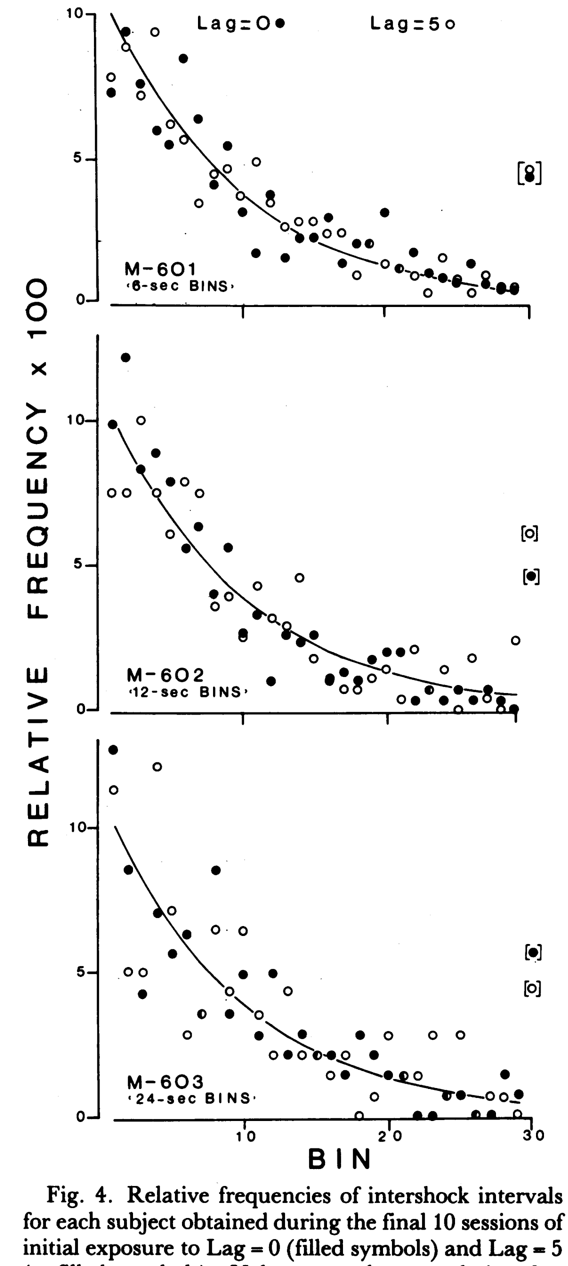

Fig. 4. Relative frequencies of intershock intervals for each subject obtained during the final 10 sessions of initial exposure to Lag = 0 (filled symbols) and Lag = 5 (unfilled symbols). Values are the cumulative frequency of intershock intervals within each bin normalized by the cumulative number of shocks during the final 10 sessions under that condition. Each distribution is comprised of 30 bins, with each but the overflow bin (Bin 30) spanning one-tenth of the programmed intershock interval. The fitted curve is an exponential approximation [$f(t) = \lambda e{-}\lambda t$] to the geometric distribution, with a rate parameter (λ) of 0.1 and t equal to the bin number minus one.

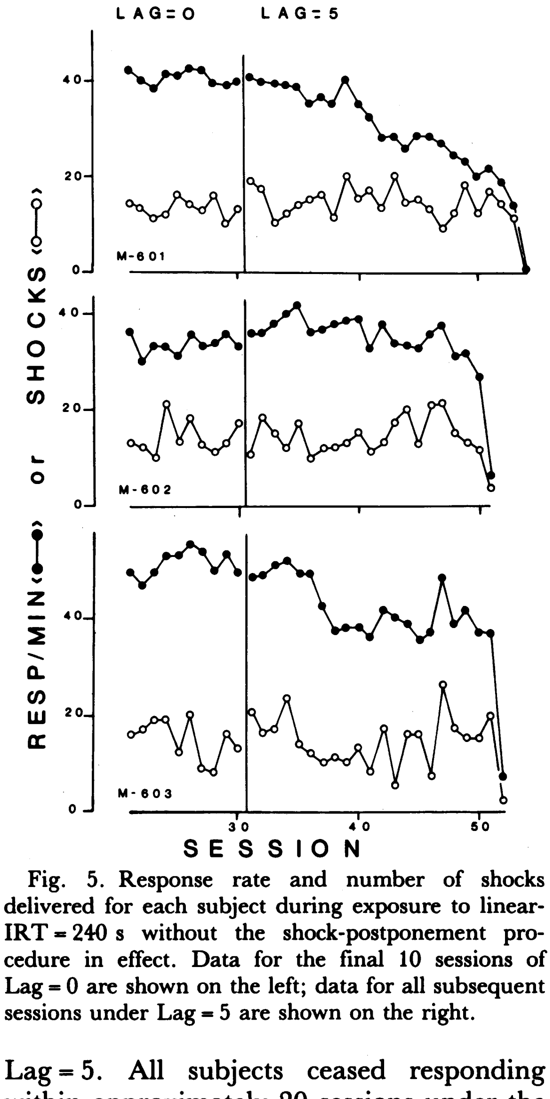

Fig. 5. Response rate and number of shocks delivered for each subject during exposure to linear-IRT = 240 s without the shock-postponement procedure in effect. Data for the final 10 sessions of Lag = 0 are shown on the left; data for all subsequent sessions under Lag = 5 are shown on the right.

Lag = 5. All subjects ceased responding within approximately 20 sessions under the latter condition. Note that the frequency of shock was not appreciably decreased until the final session of Lag = 5 for each subject. Other dependent measures are not presented because of their similarity to the results of the initial Lag manipulation.

Subjects were exposed next to a linear-IRT 240 s:Lag = 0 procedure with a conjointly programmed postponement procedure of RS = SS = 240 s. The postponement schedule ensured a rate of shock in the absence of responding comparable to that arranged under the linear-IRT schedule. Responding was not reestablished in any subject. Monkey-601 responded at a low rate for two sessions before responding ceased altogether during the third. The other subjects did not respond appreciably during the single session of exposure to this condition.

DISCUSSION

Comparable frequencies and temporal distributions of shock delivered as a consequence of responding in the present study produced substantially different behavioral effects depending on whether shock was simultaneously a differential consequence of longer IRTs. When longer IRTs were shocked differentially (i.e., Lag = 0 conditions), mean IRT durations were shorter and overall response rates were higher than under Lag = 5 conditions, in which shock presentation was a differential consequence of lever pressing but not of the current IRT duration. In addition, responding was maintained solely by consequent shock presentation only when both lever presses and longer IRTs were shocked differentially, not when shock was delivered independent of the current IRT. These results are opposite in all respects to those obtained by Platt (1979) with linear-IRT schedules of food presentation. Platt's results evidence the differential reinforcement of longer IRTs under Lag = 0 conditions but not under Lag = 5. The present results demonstrate differential punishment of longer IRTs under Lag = 0 but not under Lag = 5. In so doing, they prompt discussion of three largely independent conceptual issues in the analysis of behavior: (1) the function of shock under schedules of response-consequent shock presentation, (2) the importance of (indirect) negative reinforcement in the suppression of responding by punishment, and (3) the relative importance of response-consequence contiguity versus contingency in the control of behavior.

Shock-Maintained Behavior

Responding was maintained by consequent shock presentation in the present study only when longer IRTs were followed differentially by shock presentation; comparable frequencies and temporal distributions of response-consequent shock delivered independent of the current IRT duration suppressed responding. These results, along with the previously noted maintenance of responding under interval but not under ratio schedules of shock presentation, are compatible with the notion that shock presentation consistently functions as a punishing stimulus. The Lag value in the present study and the schedule of presentation in previous studies need not change the consequent stimulus function of shock presentation, but rather can be viewed as changing the behavioral unit(s) of which shock is a consequence. When longer IRTs are followed differentially by shock, they are punished selectively, leading to a decrease in mean IRT duration and thus an increase in overall response rate. Selective punishment of longer IRTs opposes response suppression resulting from simultaneous presentation of shock as a consequence of lever pressing, and the interaction of these two punishment relations determines whether responding ultimately is maintained or suppressed by consequent shock presentation. When the dependency of shock delivery upon IRT duration is weakened, as in the current Lag = 5 procedure or under ratio schedules, only lever pressing is punished differentially and is subsequently suppressed. When delivered differentially and contiguously with respect to responding and longer IRTs, the functional effect of shock is determined by the efficacy of the response-punishment relation relative to the IRT-punishment relation.

Differential punishment of longer IRTs is apparently a neccessary, but not sufficient, condition for predicting whether consequent shock will maintain or suppress responding. Note that no subject resumed responding under Lag = 0 in the present study once responding was all but eliminated during the final Lag = 5 condition. During the final Lag = 0 condition, an avoidance contingency ensured a frequency of shock comparable to the programmed frequency of response-consequent shock (i.e., 1 shock/4 min). Thus, the failure to reestablish responding under Lag = 0 cannot be ascribed to a decrease in shock frequency correlated with "not responding" without attributing differential status to response-consequent versus postponable shock.

Although such an attribution may be justified, the above discussion suggests a possible alternative interpretation. A Lag = 0 procedure, imposed on a preexisting moderate rate of responding, generated response maintenance, but the same procedure imposed on a preexisting low rate of responding did not. The IRT-punishment relation under the two Lag = 0 conditions was unchanged and hence provides no basis for predicting maintenance of responding in the first case and suppression in the second. The response-punishment relation, however, did change, at least when measured with respect to the probability of shock per response. Given a constant overall rate of shock presentation, the probability of shock per response is inversely related to the overall rate of responding: the higher the response rate, the less probable a particular response will be followed by shock. Research on punishment has demonstrated the degree of response suppression to be inversely related to punishment probability (e.g., Azrin, Holz, & Hake, 1963; Snapper, Schoenfeld, & Locke, 1966). To the extent Lag = 0 suppresses pressing to a lesser degree when implemented in the presence of a moderate rate of responding than in the presence of a lower rate, the relative efficacy of the IRT-punishment relation may be greater in the former than in the latter case. Further, any effect of the IRT-punishment relation will additionally reduce the efficacy of the response-punishment relation (i.e., decreases in mean IRT length and the correlated increase in overall response rate will further decrease the probability of shock per response).

IRT punishment and acquisition of shock-maintained behavior. These results may also help clarify the role of pretraining procedures used in all investigations of shock-maintained behavior. Responding has never been maintained with consequent shock presentation in subjects without some previous training to establish a moderate rate of responding. The manner in which responding is engendered does not appear critically important, varying from prior histories of response-consequent food presentation (e.g., Kelleher & Morse, 1968) or shock postponement (e.g., McKearney, 1969) to periodic response-independent shock presentation (e.g., Morse et al., 1967). Some preliminary responding is required, however, at least under the procedures investigated to date. Such training may function to decrease the initial response suppression generated by introduction of response-consequent shock, thus allowing the IRT-punishment relation to predominate, shaping higher response rates and ultimately leading to response maintenance.

This need not reflect some "inherent" primacy of response punishment over IRT punishment, however. The stochastic nature of the IRT-punishment relation arranged under linear-IRT schedules ensures only that longer IRTs will on the average be followed differentially by shock. As such, no absolute relation is established between a particular IRT (or IRT class) and shock presentation, except that IRTs longer than T always are shocked. Only within the context of a large sample of IRT durations does the differential IRT-punishment relation emerge. For any fixed number of IRTs, the punishment relation becomes more variable as the sample size decreases. In any finite sample, even the longest IRT emitted may go unshocked, provided it is less than T, whereas the shortest IRT has some nonzero probability of being followed by shock. Thus, the IRT-punishment relation, although effective in controlling behavior, locally is weak in linear-IRT schedules. To the degree that such schedules mimic relations provided indirectly by interval schedules, the same situation holds.

The response-punishment relation is, conversely, relatively "stronger" under both linear-IRT and interval schedules, in that shock is presented only following responses. Hence, across a wide variety of responses and species, response suppression might be likely to predominate under these arrangements, as indeed it does. With the exception of a single report of responding in cats (Byrd, 1969), only monkeys demonstrate response maintenance under schedules of response-consequent shock presentation. Given the perplexing nature of shock-maintained behavior, it is difficult to believe that other species have not been investigated. Hence, the absence of reports involving other species can only be taken as an indication of failure to maintain responding.

Such interspecies differences are of little heuristic value to the analysis of behavior unless the variables of which they are a function can be delineated (Sidman, 1960). One such variable relevant to the present discussion is the "induction" of lever pressing in squirrel monkeys by (periodic) response-independent shock presentation (see Hutchinson, 1977, for a review). Such induced responding may counteract response suppression generated by response-consequent shock presentation, continuing to generate responding that is then differentiated by IRT-punishment contingencies. Selection of an equally shock-induced response of another species may increase the probability of response maintenance in that species.

Alternatively, programming a more robust IRT-punishment relation may more effectively counteract response suppression generated by shock presentation. Laurence (in press) recently demonstrated that IRT>T requirements do indeed generate substantial decreases in mean IRT duration and concomitant increases in overall response rate with squirrel monkeys. Although maximally relating IRT duration to shock presentation, such a procedure is severely handicapped by the inevitable decrease in shock frequency as IRT durations are shaped below the criterion value.

This limitation can be overcome by defining IRTs with respect to estimated percentiles of the distribution of IRTs comprising the subject's most recent IRTs. Such "percentile schedules" (see Platt, 1973, for an extended discussion) control the overall probability or rate of event presentation while simultaneously delivering events to extreme IRTs. Such an arrangement might successfully engender shock-maintained responding in subjects other than monkeys. Further, the relationship between IRT duration and shock presentation may be graded by interspersing various frequencies of IRT-independent shocks with those shocks arranged by the percentile schedule. Demonstrating a systematic functional relation between IRT duration and the degree to which shock presentation is related to IRT duration would add credence to the notion that shock-maintained behavior reflects differential punishment of long IRTs.

IRT punishment and parameters of response-produced shock. Although a quantification of the IRT-punishment relation is not provided by the present experiment, the maintenance of responding itself is prima facie evidence that the IRT-punishment relation exerts relatively more control than the response-punishment relation. This relatively greater control most likely reflects the synergic interaction of these two relations. That is, IRT punishment directly suppresses long IRTs, opposing any response punishment and increasing response rate. Increasing response rate, however, decreases the probability of shock per response under linear-IRT and interval schedules. This decrease in shock probability would lead to less effective suppression of responding, increasing response rate further and incorporating even shorter IRTs into the IRT-punishment relation. Hence the amount of opposing response suppression decreases as shorter and shorter IRTs are differentially shaped.

The limit of this shaping presumably reflects the limit of the IRT-punishment relation. That is, IRT durations will become progressively shorter until the probability of shock per a particular IRT class is sufficiently low to no longer suppress its occurrence. The absolute duration of the limiting

IRT class depends on the parameters of punishment. More effective IRT punishment, either by more intense or more frequent shock presentation, should decrease the duration of the modal IRT, increasing response rate. Extending punishment relations to IRTs thus provides an interpretive framework consistent with observed functional relations between overall response rate and the frequency (e.g., McKearney, 1969) and intensity (e.g., Barrett & Spealman, 1978) of shock delivered consequent on responding under interval schedules.

IRT punishment and drug effects on shock-maintained behavior. Results from pharmacological investigations involving responding maintained by response-consequent shock presentation are also largely compatible with the notion of differential IRT punishment. Drugs such as amphetamine, cocaine, and morphine tend to increase the rate of responding maintained by shock (e.g., Branch, 1979; McKearney, 1974) while further decreasing responding suppressed by punishment (e.g., Holtzman & Villarreal, 1973; Wilson, 1977). Conversely, the benzodiazepines and barbiturates, distinguished by their facilitative effect on punished responding (e.g., Cook & Davidson, 1973), typically decrease the rate of shock-maintained behavior (e.g., Barrett, 1976). Such complementarity in effects is predicted by the present account in that different behavioral units are punished under the different procedures. That is, punishment procedures differentially suppress responding; shock-maintenance procedures differentially suppress long IRTs. Hence, drugs that decrease punished responding should decrease longer IRTs and increase response rate under shock-maintenance procedures. Conversely, drug-induced increases in punished responding would be reflected by increases in the rate of differentially punished longer IRTs under schedules of response-consequent shock presentation, leading to a decrease in overall response rate.

Differential punishment of longer IRTs provides an interpretive framework consistent with a majority of data pertaining to shock-maintained behavior. As such, attention should be paid to the existence of such relations in situations involving responding maintained by consequent shock presentation. It must be emphasized that such behavior is multiply determined, however, with IRT punishment playing a primary but not exclusive role in controlling such responding. Other factors not touched on here (e.g., previous experimental histories, temporal control exerted by periodic shock presentation under some arrangements) must be incorporated prior to a complete understanding of the phenomenon.

Punishment versus Indirect Negative Reinforcement

The changes in behavior as a function of the Lag value in the present study were generated, with the exception of the final session under the second Lag = 5 condition, without changing the overall frequency or temporal distribution of shock presentation. As such, the present results cannot be attributed to indirect negative reinforcement based on overall shock-frequency reduction. Under both Lag conditions, the frequency of shock presentation averaged 1 per 4 min regardless of the rate of responding or the distribution of IRTs. Hence, changes in the overall frequency of shock cannot account for the present results.

Further, appeals to negative reinforcement operating at the level of IRT duration are incapable of accounting for the present results. Recall that the linear-IRT probability function specifies shock probability by normalizing IRT duration with respect to the average expected intershock interval, *T*. The probability thus derived specifies an average intershock interval for each IRT class of *T* s. The linear contingency between IRT duration and shock probability equates the frequency of shock for different duration IRTs through complementary changes of shock probability with IRT duration. For example, an IRT twice the duration of another will be shocked with twice the probability, and hence with equal numbers of shocks per unit time. Control of the overall shock frequency arises as a by-product of controlling the frequency of shock within each IRT class.

Under the Lag = 0 procedure, the normalized IRT and the current IRT are one and the same. Hence, the frequency of shock for all IRT classes is equal to $1/T$, where T is expressed in the same units as IRTs. Under the Lag = 5 procedure, the normalized IRT and the current IRT differ, hence the frequency of shock for different IRT classes will not be equal. Rather, the overall probability of shock for all IRTs should be roughly constant and equal to the probability of shock for the mean IRT. With an equal probability of shock for all IRTs, shock frequency will be higher for shorter than for longer IRTs, because less time is involved in emitting short IRTs.

An avoidance account could point to this difference, attributing the decrease in response rate under Lag = 5 procedures to the decreased shock frequency for longer IRTs. Such an interpretation, however, would require some other mechanism to maintain behavior under the Lag = 0 condition, inasmuch as no IRT-correlated shock-frequency reduction is available. Obviously, this mechanism cannot be the above proposed account of response maintenance through differential punishment of longer IRTs, as this is precisely what such an account would hope to avoid. Although appeals to other response-generating mechanisms might be possible, the parsimony afforded by accepting punishment as an independent process responsible for responding under both Lag conditions strongly opposes such an endeavor.

Unlike the difficulties faced by an avoidance theory of the present results in terms of shock-frequency reduction, an account in terms of shock-probability reduction is entirely consistent with the present results. Under Lag = 0, the probability of shock increases as a function of IRT duration; under Lag = 5, the probability remains constant independent of IRT duration. Hence, it might be argued that shorter IRTs under Lag = 0 decrease the probability of shock and thus increase directly as a function of this negative reinforcement, only indirectly decreasing the frequency of longer IRTs. This argument would entail substantial reinterpretation of the controlling variables in negative-reinforcement procedures, which currently are presented almost exclusively in terms of rates of aversive stimulation (Hineline, 1977)—that is, shocks per unit time rather than shocks per response. Such an undertaking again would seem highly unparsimonious given that the present results can readily be incorporated into the extant literature on punishment. Even if accomplished, the mirror-image correspondence between punishment of longer IRTs and negative reinforcement of shorter IRTs would appear so indistinguishable as to be of no practical, and little if any theoretical, utility.

The relative simplicity of interpreting the present results as direct effects of punishment, as well as Galbicka and Branch's (1981) argument based on the results of pharmacological interventions, strongly supports acceptance of punishment as a behavioral process independent of indirect negative reinforcement. Although negative reinforcement may modify the degree or rate of response suppression associated with a punishment procedure, it need not be present for suppression to occur.

Contingency as Differential Contiguity

Contiguity has been emphasized repeatedly as a primary controlling variable in the analysis of both respondent (e.g., Pavlov, 1927) and operant (e.g., Skinner, 1938; Thorndike, 1911) behavior. Recent experimental results questioning the adequacy of a simple contiguity account of behavior in both domains (e.g., Rescorla, 1972; Staddon & Simmelhag, 1971) have occasioned a variety of alternative formulations attempting to quantify the degree of association or "contingency" between conditional and unconditional stimuli in respondent paradigms or between responses and consequent events in operant ones. However, the increased prediction and control of behavior afforded by contingency analyses need not necessitate abandoning contiguity as a controlling variable. On the contrary, the present results, and those of Platt (1979), suggest that contingency measures reflect behavior only to the extent they track changes in differential contiguity. The arguments for this position differ, depending upon whether probability- or frequency-based measures of contingency are employed and whether the lever press or the IRT is considered the functional operant. Hence, these will be treated in turn.

Contingency as response:shock probability. Probability-based measures of operant contingency (see Gibbon, Berryman, & Thompson, 1974) typically specify some relation between the probability of a consequent event in the presence versus absence of a response. Under the linear-IRT arrangement, the Lag does not change contingency as measured with respect to shock probability given response versus "no-response," because all events are contiguous with lever presses.

Contingency as IRT:shock probability. Neither does the contingency relation with respect to IRT duration change as a function of the Lag, because the same probability function is used to program consequent events. The Lag does not change this relation, but rather determines when a contingent event will be delivered. That is, the Lag functions to separate contiguity and contingency by holding the contingency relation constant while allowing variation in the IRT contiguous with event presentation. A contingency relation simultaneously specifying differential contiguity (i.e., Lag = 0) engenders different response rates and IRT distributions than the same contingency programmed noncontiguously (Figures 1 and 2). Hence, contiguity controls responding independent of a change in contingency. Distinguishing "experienced" from "programmed" contingencies does little to affect the argument, because experienced contingency and differential contiguity then become isomorphic. To argue that only non-lagged contingencies control responding is to remove any feature distinguishing contingency from differential contiguity.

Contingency as response:shock rates. Notions of contingency based on overall response and shock rates (e.g., Baum, 1973; Nevin & Baum, 1980) typically assume that behavior involves a continuous organism-environment interaction. This usually leads to a reliance on rates of responding and consequent event presentation as independent and dependent variables, respectively. It is the correlation of these rates that partially defines the degree of contingency and controls behavior. This correlation is generally specified as a simple regression of lever-press rates on consequent-event rates and is termed a "feedback function." This function only partially controls responding because, although behavior constitutes a continuous interaction between the organism and environment, it is recognized that at any point in time only a finite sample of the interaction is functional. That is, past correlation controls response rate, but more recent correlation exercizes relatively greater control than more remote correlation. Hence, the subject never experiences the ideal correlation, but rather, only discrete samples estimating points along the feedback function. Because these samples are finite, they are subject to error.

Contingency, according to this view, is multiply determined by the slope of the feedback function and the variance of sample correlations around the function. All else equal, contingency varies directly with the former and inversely with the latter. The function of contiguity in this formulation is to ensure that sample variance is minimized. Because sampled intervals are of finite duration, the closer the contiguity the greater the temporal grouping of lever presses and consequent events. Delaying consequent events increases the frequency of correlating event rates with a response rate other than that responsible for its production, leading to greater variance around the feedback function and consequently lower contingency.

The key to a contingency analysis of the present results revolves around definition of the sample duration. The feedback function does not change as a function of Lag value; for all response rates observed here the expected rate of event presentation remains relatively constant at $1/T$. (Because linear-IRT schedules are based on IRT durations, it is impossible to specify a single feedback function, because the same overall response rate can be achieved with different component IRTs. However, given IRT durations short relative to T and a unimodal distribution, the feedback function should resemble that for a constant-probability VI schedule; that is, it should increase in a negatively accelerated fashion, approaching an asymptotic shock frequency.)

Because the slope of the feedback function remains stable across Lags, a rate-based contingency analysis requires sample variance around the regression function to change with Lag value. Under the present conditions, Lag = 5 procedures must occasion larger sample variances than comparable Lag = 0 conditions. The difference in the associated variances, however, is inversely related to the duration of the aggregate sample. If entire sessions are considered as the appropriate aggregate, only the last five responses of each session are treated differentially under the different Lags. As the aggregate samples decrease in duration, relatively more consequent events will be correlated with the response rate prevailing during a subsequent aggregate sample under Lag = 5 than under Lag = 0. Thus, contingency decreases more rapidly under Lag = 5 than under Lag = 0 as the aggregate sample is arbitrarily dimished.

The present results, however, should not be ascribed to changes in contingency, for two reasons. First, defining smaller aggregates to achieve greater variance under Lag = 5 than under Lag = 0 demands that the variance under both conditions increase drastically. The stochastic relation arranged by the linear-IRT schedule itself becomes more variable as the sample size decreases. Samples comprised of entire sessions accommodate a fair amount of variability, as shown in the number of shocks delivered across daily sessions (see Figure 3). Smaller samples still, required to produce substantial differences between Lag conditions, would generate such variable samples under both Lags that questions should more readily arise as to how the correlation under either condition controls responding than as to how differences in the experienced variances control responding.

Even if the argument presented above were refuted empirically, the proposed difference between Lag conditions is opposite that required for shock to function as a punishing stimulus with respect to responding in the present study, or for food presentation to function as a reinforcing stimulus in Platt's (1979) study. That is, response rates in the present study were higher under Lag = 0 than under Lag = 5. If Lag = 5 decreases contingency, it should decrease the effectiveness of the consequent stimulus in controlling responding. Response-contingent shock presentation could not then function as a punishing stimulus, because the decrease in response-shock contingency would require less effective response suppression under Lag = 5 than under Lag = 0. Instead, the opposite was observed. A complementary argument involving Platt's results is as easily made. Response rates there were higher under Lag = 5 than under Lag = 0. If food presentation functions as a reinforcer, weakening the contingency under Lag = 5 should then decrease response rate under that condition, not generate the observed increased rates of responding.

Contingency as IRT:shock rates. A correlation-based law of effect might successfully overcome the problem described in the previous paragraph by adopting the IRT as the behavioral unit and then correlating across classes of IRTs. Although theoretically possible, the requirements of such an endeavor are considerable. First, IRT and consequent-event rates would have to be aggregated and correlated uniquely for each subject-defined IRT class. Second, it is unclear whether the subject-defined period of aggregation would involve a single interval of real time or multiple intervals of time spent in each IRT class. The former would yield poor information about infrequent IRT classes; the latter represents yet another level of complexity attributed to the subject. In addition, the number of sample variances associated with the various subject-defined IRT classes around their associated correlations (across the subject-defined period of aggregation) not only stretches the sensibilities but undermines an adequate analysis by placing two important variables within the organism.

The analysis presented here requires simply that the IRT be considered a functional unit of behavior controlled by its local consequences. No hypothetical aggregates are needed to provide an adequate account of either the present results or previous results in studies involving responding maintained by response-consequent shock presentation. It would seem, therefore, that an analysis of "contingency" in the present procedure and in Platt's (1979) is most parsimoniously achieved by considering it to reflect the long-term effects of varying degrees of differential contiguity.

Acceptance of the IRT as a functional operant allows interpretation of the otherwise perplexing phenomenon of shock-maintained behavior in terms of previously established properties of punishment. No appeal need be made to indirect avoidance contingencies in accounting for this punishment effect, and no derivative notion of associative contingency need be established a priori. The view that contiguity is of primary importance in the control of behavior does not refute the established primacy of contingency measures under certain paradigms, as these paradigms are precisely those that provide consequent events contiguous with more than one operant class. In such situations, contingency may more economically describe the long-term effects of differential contiguity. Such contiguities should not be disregarded, however, as changes in contingency can be interpreted parsimoniously as reflecting changes in the degree to which events are differentially contiguous. The former may always be derived from the latter; however, the converse need not be the case.

REFERENCES

Azrin, N. H., & Holz, W. C. (1966). Punishment. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 380-447). New York: Appleton-Century-Crofts.

Azrin, N. H., Holz, W. C., & Hake, D. F. (1963). Fixed-ratio punishment. *Journal of the Experimental Analysis of Behavior,* **6,** 141-148.

Barrett, J. E. (1976). Effects of alcohol, chlordiazepoxide, cocaine and pentobarbital on responding maintained under fixed-interval schedules of food or shock presentation. *Journal of Pharmacology and Experimental Therapeutics,* **196,** 605-615.

Barrett, J. E., & Spealman, R. D. (1978). Behavior simultaneously maintained by both presentation and termination of noxious stimuli. *Journal of the Experimental Analysis of Behavior,* **29,** 375-383.

Baum, W. H. (1973). The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior,* **20,** 137-153.

Branch, M. N. (1979). Consequent events as determinants of drug effects on schedule-controlled behavior: Modification of effects of cocaine and *d*-amphetamine following chronic amphetamine administration. *Journal of Pharmacology and Experimental Therapeutics,* **210,** 354-360.

Branch, M. N., & Dworkin, S. I. (1981). Effects of ratio contingencies on responding maintained by schedules of electric-shock presentation (response-produced shock). *Journal of the Experimental Analysis of Behavior,* **36,** 191-205.

Byrd, L. D. (1969). Responding in the cat maintained under response-independent electric shock and response-produced electric shock. *Journal of the Experimental Analysis of Behavior,* **12,** 1-10.

Cook, L., & Davidson, A. B. (1973). Effects of behaviorally active drugs in a conflict-punishment procedure in rats. In S. Garattini, E. Mussini, & L. O. Randall (Eds.), *The benzodiazepines* (pp.327-345). New York: Raven Press.

Galbicka, G., & Branch, M. N. (1981). Selective punishment of interresponse times. *Journal of the Experimental Analysis of Behavior,* **35,** 311-322.

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

Hake, D. F., & Azrin, N. H. (1963). An apparatus for delivering pain shock to monkeys. *Journal of the Experimental Analysis of Behavior,* **6,** 297-298.

Hineline, P. N. (1977). Negative reinforcement and avoidance. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 364-414). Englewood Cliffs, NJ: Prentice-Hall.

Holtzman, S. G., & Villarreal, J. E. (1973). Operant behavior in the morphine-dependent rhesus monkey. *Journal of Pharmacology and Experimental Therapeutics,* **184,** 528-541.

Hutchinson, R. R. (1977). By-products of aversive control. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 415-431). Englewood Cliffs, NJ: Prentice-Hall.

Kelleher, R. T., & Morse, W. H. (1968). Schedules using noxious stimuli. III: Responding maintained with response-produced electric shocks. *Journal of the Experimental Analysis of Behavior,* **11,** 819-838.

Laurence, M. T. (in press). Discriminative processes in the maintenance of responding on schedules of response-produced shock. *Journal of the Experimental Analysis of Behavior.*

McKearney, J. W. (1969). Fixed-interval schedules of electric shock presentation: Extinction and recovery of performance under different shock intensities and fixed-interval durations. *Journal of the Experimental Analysis of Behavior,* **12,** 301-313.

McKearney, J. W. (1972). Maintenance and suppression of responding under schedules of electric shock presentation. *Journal of the Experimental Analysis of Behavior,* **17,** 425-432.

McKearney, J. W. (1974). Effects of *d*-amphetamine, morphine and chlorpromazine on responding under fixed-interval schedules of food presentation or electric shock presentation. *Journal of Pharmacology and Experimental Therapeutics,* **190,** 141-153.

Morse, W. H., & Kelleher, R. T. (1977). Determinants of reinforcement and punishment. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 174-200). Englewood Cliffs, NJ: Prentice-Hall.

Morse, W. H., Mead, R. N., & Kelleher, R. T. (1967). Modulation of elicited behavior by a fixed-interval schedule of electric shock presentation. *Science,* **157,** 215-217.

Nevin, J. A., & Baum, W. M. (1980). Feedback functions for variable-interval reinforcement. *Journal of the Experimental Analysis of Behavior,* **34,** 207-217.

Pavlov, I. P. (1927). *Conditioned reflexes* (G. V. Anrep, Trans.). London: Oxford University Press.

Platt, J. R. (1973). Percentile reinforcement: Paradigms for experimental analysis of response shaping. In G. H. Bower (Ed.), *Psychology of learning and motivation: Advances in research and theory* (Vol. 7, pp. 271-296). New York: Academic Press.

Platt, J. R. (1979). Interresponse-time shaping by variable-interval-like interresponse-time reinforcement contingencies. *Journal of the Experimental Analysis of Behavior,* **31,** 3-14.

Rescorla, R. A. (1972). Informational variables in Pavolvian conditioning. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 6, pp. 1-46). New York: Academic Press.

Sidman, M. (1953). Two temporal parameters of the maintenance of avoidance behavior by the white rat. *Journal of Comparative & Physiological Psychology,* **46,** 253-261.

Sidman, M. (1960). *Tactics of scientific research: Evaluating experimental data in psychology.* New York: Basic Books.

Skinner, B. F. (1938). *The behavior of organisms.* New York: Appleton-Century.

Skinner, B. F. (1953). *Science and human behavior.* New York: Macmillan.

Snapper, A. G., Schoenfeld, W. N., & Locke, B. (1966). Adrenal and thymus weight loss in the food-deprived rat produced by random ratio punishment schedules. *Journal of Comparative & Physiological Psychology,* **62,** 65-70.

Staddon, J. E. R., & Simmelhag, V. L. (1971). The "superstition" experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review,* **78,** 3-43.

Thorndike, E. L. (1911). *Animal intellegence.* New York: Macmillan.

Weiss, B. (1970). The fine structure of operant behavior during transition states. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules* (pp. 277-311). New York: Appleton-Century-Crofts.

Wilson, M. C. (1977). The effect of cocaine and *d*-amphetamine on punished responding. *Archives internationales de Pharmacodynamie et de Therapie,* **227,** 98-105.

Received September 13, 1983
Final acceptance January 10, 1984