SELECTIVE PUNISHMENT OF INTERRESPONSE TIMES: THE ROLES OF SHOCK INTENSITY AND SCHEDULING

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Two experiments investigated the roles of shock intensity and scheduling in selective punishment of interresponse times. In each experiment the punishment contingencies were imposed on a background of rats' responding maintained by a variable-interval schedule of food presentation. In Experiment 1 all interresponse times greater than 8 seconds produced shock. In Experiment 2 all interresponse times greater than 8 seconds but less than 12 seconds produced shock. In each experiment shock intensity was initially 0.3 milliamperes (mA) and then was varied through an ascending sequence ranging from 0.1 mA to 0.4 mA, in 0.1-mA increments. Experiment 1 produced response-rate increases at low intensities (0.1 and 0.2 mA) but eliminated responding at the remaining intensities. Experiment 2 produced response-rate increases only with 0.1-mA shock, although responding was maintained at all shock parameters investigated. Analysis of the interresponse times per opportunity showed differential suppression of the targeted responses in all cases except the high-intensity shock phases of Experiment 1. The current data support and extend previous studies of selective interresponse-time-dependent shock schedules but suggest that response-rate increases are not a necessary outcome of this type of procedure. The view that variable-interval schedules of shock presentation selectively target long interresponse times was also supported.

Key words: interresponse times, punishment, punishment intensity, variable-interval punishment, shock-maintained behavior, shock-elicited behavior, bar pressing, rats

It has been demonstrated repeatedly that interresponse times (IRTs) are sensitive to selective reinforcement (e.g., Millenson, 1966; Shimp, 1968, 1969). Recently, Galbicka and Branch (1981) demonstrated that IRTs are also sensitive to punishment contingencies. They initially maintained squirrel monkeys' bar pressing by means of a variable-interval (VI) schedule of food presentation. The monkeys were then exposed to an additional contingency whereby shocks were delivered dependent upon and contiguous with the emission of an IRT greater than t s in duration. During this condition, one third of the criterion IRTs produced shock. Subsequent shock conditions investigated the effect of parametric changes in t . In each case the frequency of the targeted IRTs decreased and was accompanied by an increase in overall response rate.

As Galbicka and Branch (1981) note, it seems paradoxical to account for response-rate increases by appealing to punishment, because a key defining feature of the response

that produced shock (bar pressing) also defines the one that increased in rate. The targeted response in their study was not the bar press, per se, but rather a more complex response-pause-response unit. Indeed, in their study the frequency of the targeted unit declined in each case. At present it is unclear how decreases in the targeted unit are related to increases in the remaining units. This type of finding is not confined to selective IRT shock schedules. Sizemore and Maxwell (1983) delivered pause-dependent shock and observed a similar outcome. That is, decreases in the targeted pauses were accompanied by reliable increases in overall response rate. That finding is not paradoxical inasmuch as response-shock contiguity was not possible, but it remains unclear how the punishment contingency produced rate increases. One obvious explanation for both studies is that the punishment procedures indirectly arranged negative reinforcement of increases in response rate. However, recent work by Galbicka and Platt (1984) does not support such a position because IRT-specific suppression and response-rate increases were observed without a concomitant decrease in overall shock frequency.

One issue that neither of the previous IRT-

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shock studies addressed was the role of shock intensity. Two disparate intensities (1.0 and 8.0 mA) were employed by Galbicka and Branch (1981) and Galbicka and Platt (1984), but these studies employed two different behavior-maintenance procedures, which precludes their use for assessing shock intensity as an independent variable. Second, in both IRT-dependent shock studies conducted to date, the shock-delivery procedures arranged probabilities of punishment such that members of the targeted class were not always shocked. In addition, the targeted classes were defined by a single temporal boundary (i.e., the longer members of the IRT distributions). Finally, IRT-selective shock procedures have been employed only with monkeys as subjects.

The purpose of the present experiments was to investigate the roles of shock scheduling and intensity using rats as subjects. Experiment 1 arranged shock contingent upon all IRTs greater than 8 s in duration (punishment of "long" IRTs). Experiment 2 arranged shock contingent upon all IRTs greater than 8 s but less than 12 s in duration (punishment of "intermediate" IRTs). In both experiments, bar pressing was initially maintained with a VI schedule of food presentation; shock intensity was varied systematically in both studies.

EXPERIMENT 1

METHOD

Subjects

The subjects were 3 female Holtzman albino rats maintained at 80% (± 10 g) of their free-feeding weights. The subjects were experimentally naive and approximately 120 days old at the onset of training. All subjects were individually housed with water freely available in their home cages. Colony lighting was automatically controlled to provide 12-hr illumination/12-hr darkness daily.

Apparatus

The experimental space was a Coulbourn Instruments (E10-10) modular test cage. A lever was mounted 7 cm above the floor in the center of the work panel. A force of approximately 0.18 N was required to operate the lever. A 6-W light, located in the center of the work panel, 27 cm above the floor, illuminated the cage continuously during experimental sessions. The experimental cage was

located in a ventilated, sound-attenuating enclosure.

Reinforcers consisted of 45-mg Noyes pellets delivered by a Gerbrands pellet dispenser. Punishers consisted of foot-shock delivered via stainless steel rods, spaced 1.7 cm center to center (the floor of the test cage). A Coulbourn Instruments (E13-35) solid-state shocker delivered scrambled shocks. Solid-state programming and recording equipment were in a separate room. An Apple® II microcomputer recorded data and arranged event presentations. Real time was resolved to the nearest 0.001 s using a Mountain Hardware clock and user-developed machine-language routines.

Procedure

Following initial bar-press shaping, the schedule of food availability was gradually changed until it reached a VI value of 40 s. An arithmetic VI of the type described by Catania and Reynolds (1968) was employed, consisting of 16 intervals that ranged from 0.0 s to 80.0 s. This schedule remained in effect for all subsequent experimental sessions. Each session lasted 40 min. During the punishment phases, all IRTs greater than 8 s were followed immediately by shock. (IRT timing was initiated by the start of the session.) In the event food and shock were scheduled for the same response, the shock was delivered. Food was delivered following the next response, provided another shock had not been scheduled. Each food availability was retained until the pellet was delivered. The VI scheduling program was halted between the time of availability and delivery.

Once stable schedule control was established by the VI food deliveries, the first shock contingency was introduced. The targeted IRTs produced 0.3-mA shocks that were 400 ms in duration. Following the development of stable performance, the punishment contingency was removed and behavior was allowed to recover. Subjects were then reexposed to the punishment contingency and shock intensity was systematically increased, across blocks of sessions, from 0.1 mA to 0.4 mA in 0.1-mA steps. Shock was not removed until all four shock levels had been investigated. All subjects were exposed to the different shock levels in an ascending sequence. Rat T6 was not exposed to the 0.2-mA condition.

Stability was defined as the occurrence of a

Fig. 1. Response rates for Rats T4, T5, and T6. Solid lines separate experimental conditions and dashed lines separate the first and last six sessions of each condition. Open circles represent sessions in which no responses were emitted. A VI 40-s schedule of reinforcement was in effect throughout. All IRTs greater than 8 s were punished during the shock conditions. The labels at the top of the graph indicate shock and no-shock conditions. Shock intensity is shown where appropriate.

six-session block in which the mean response rate of the first and last three-session blocks did not differ by more than $\pm 2.5\%$ of the six-session mean. Stability was not assessed until a subject had been exposed to a condition for at least 12 sessions. These criteria were employed for all phases of the current experiment.

RESULTS AND DISCUSSION

Figure 1 shows responses per minute for Rats T4, T5, and T6 for the last six sessions

of baseline and the first and last six sessions of all subsequent conditions. Solid lines separate experimental conditions and dashed lines separate the first and last six sessions within each condition. Sessions in which no responses occurred are designated by an open circle. Although all rats were "exposed" to the 0.4-mA condition, no data are presented. Because of the low level of responding produced with 0.3-mA shock, it can be argued that subjects were not functionally exposed to this condition. That is, the rats were typically emitting only one

Fig. 2. Interresponse-time probabilities per opportunity (IRT/OP) for Rats T4, T5, and T6. The vertical line denotes the boundary of the targeted IRT classes. IRT/OP probabilities were not included for IRTs greater than 16 s (see text).

response per three or four sessions during the last six sessions of the 0.3-mA shock condition, and this pattern continued or declined during the 0.4-mA condition. As a result, the change from 0.3 mA to 0.4 mA was considered inconsequential.

Initial exposure to the 0.3-mA condition resulted in virtual elimination of responding for all 3 rats. Discontinuation of the shock procedure resulted in resumption of responding within three sessions for 2 of the 3 rats. Rat T4 had not yet responded at that point so the bar-press response was reshaped. Following

shaping, the response rate for Rat T4 returned to approximately the same level observed before introduction of shock, as was the case for the other 2 rats.

Exposure to 0.1-mA shock produced increased response rates for all 3 rats. For Rat T4 the increase was small but stood in marked contrast to this rat's performance during the previous exposure to shock. For Rats T5 and T6 this level of shock produced larger response-rate increases. Changing shock intensity to 0.2 mA produced small decreases in response rates for Rats T4 and T5 relative to

the previous condition. Rat T6 was not exposed to this parameter of shock. Exposure to 0.3-mA shock produced response rates similar to those observed during the first exposure to this shock intensity. That is, rates dropped precipitously for all 3 rats, although responding did continue at a very low rate. Removal of the shock contingency resulted in gradual recovery of responding for all rats, and in each case the level of responding was higher than that observed during either of the previous no-shock conditions.

Figure 2 shows the probability of each 1-s IRT class as a function of the opportunity for responding in each class. Anger (1963) termed this an IRT/OP analysis and argued that the IRT/OP is a more sensitive measure of responding than are the typically reported relative frequencies of IRTs. For a detailed discussion of how to calculate IRT/OP and the reasons for using that analysis, the reader is directed to Anger (1963) or Sidman (1966). In the current study, data were pooled over the last six sessions of each condition when probabilities were calculated. Two aspects of the current analyses should be noted. First, data regarding the 17th response class (IRTs greater than 16 s) are not included inasmuch as the value for the longest class is always equal to one in an IRT/OP analysis. Second, data from the 0.3- and 0.4-mA shock conditions are not shown because an IRT/OP analysis based on such small numbers would be of questionable value. For ease of comparison, data from the first VI baseline have also been excluded.

The upper panels of Figure 2 show the IRT/OP distributions during the preceding baseline condition and the two shock conditions. The lower panels show the baseline and recovery conditions (VI without shock). The data were separated in this manner to enhance clarity. The vertical line denotes the boundary of the targeted IRTs. Introduction of shock reduced the probability of the targeted IRTs with few exceptions. For Rat T4, responses in the 8- to 9-s class did not change, and for Rat T6, introduction of shock seemed to alter only the first two classes of the targeted IRTs. All 3 rats also showed changes in the nontargeted classes. In general, those IRTs shorter than 5 to 6 s increased in probability and the remainder of the distribution decreased. This pattern was also evident when

shock was increased to 0.2 mA. Discontinuation of shock (shown in the lower panels) did not result in distributions such as those observed prior to shock introduction. For Rats T4 and T6, the targeted IRTs were more probable during recovery than during baseline. For Rat T5, the opposite was observed. This finding is particularly difficult to understand in view of the consistent response-rate changes observed following shock removal. Inspection of the daily IRT/OP distributions for each of the conditions indicated that the observed differences were the result of systematic changes in responding and were not produced by a few aberrant data points.

Table 1 provides additional data for the conditions shown in Figure 2. This table includes response rates, absolute numbers of targeted IRTs (which is equivalent to number of shocks during the shock condition), absolute numbers of IRTs in the largest IRT class (bin 17), number of food pellets earned per 40-min session, and number of sessions each condition was in effect. Of particular interest here is the absolute number of IRTs in bin 17. This number can be used in conjunction with the data from Figure 2 to construct the distribution of relative IRT frequencies, if desired.¹ Note also that absolute rather than relative frequencies of targeted IRTs are shown. Finally, data for the 0.3- and 0.4-mA conditions were excluded because the table would have contained zeros or undefined numbers in nearly all categories.

The data demonstrate that selective IRT shock is an effective punishment procedure for rats, and extend the previous studies that had shown this effect only in monkeys. The current findings, however, show differential IRT suppression only at low shock levels (i.e., 0.1 and 0.2 mA). This differential effect was accompanied by response rates similar to or in excess of the no-shock baseline. The two

¹ To calculate relative frequency of IRTs, divide the number of responses in bin 17 by total responses (rate $\times$ session length). To obtain the relative frequency of the remaining IRT classes, beginning with bin 16 and working in decreasing order, multiply the IRT/OP probability by the cumulative frequency of the previously calculated IRT classes. Thus, the relative frequencies are added together prior to multiplying the next IRT/OP probability. The relative frequency and IRT/OP probability of the shortest IRT class are the same. Due to rounding error, the total cumulative frequency may not equal one.

Table 1

Response rate, absolute number of targeted IRTs per session, number of IRTs > 16 s per session, number of pellets per session, and number of sessions each condition was in effect for Rats T4, T5, and T6. With the exception of number of sessions, all figures are the averages of the last six sessions of the condition indicated. Dashed lines indicate that a subject was not exposed to that condition.

	T4					T5					T6				
	Rate	Trgted IRTs	Bin 17	Rein-forcers	Ses-sions	Rate	Trgted IRTs	Bin 17	Rein-forcers	Ses-sions	Rate	Trgted IRTs	Bin 17	Rein-forcers	Ses-sions
VI 40-s No shock	38.8	28.7	15.5	58.3	16	15.0	79.8	13.8	55.6	22	24.0	62.5	25.7	51.6	13
VI 40-s Shock = 0.1 mA	43.6	17.5	13.2	56.0	15	47.3	25.3	9.0	55.3	17	38.6	53.7	24.2	51.7	13
VI 40-s Shock = 0.2 mA	35.8	6.3	6.0	37.5	15	46.2	24.5	15.0	55.0	15	—	—	—	—	—
VI 40-s No shock	45.8	20.8	4.3	56.8	17	38.0	29.0	7.0	57.3	15	34.2	51.7	10.5	55.0	14

higher levels of shock employed here (0.3 and 0.4 mA) produced a nondifferential effect upon behavior and resulted in near-complete elimination of bar pressing. Although response cessation as a result of punishment is not remarkable, the paradoxical elevation and elimination of response rates by a common stimulus prompts several questions.

One could speculate, for example, that shock functions as a reinforcer at low levels but as a punisher at higher levels. This would seem reasonable if the targeted IRTs had not been suppressed in all shock conditions. Note, however, in those cases in which a differential effect upon the IRT distribution was observed, the suppression was not confined to the targeted IRT class but was observed also in a few classes outside the target area. The observed effect may represent a systematic change in the number of nontargeted classes that are altered by shock as the shock intensity increases.

A different approach, not incompatible with the previous one, might suggest that behavior elicited by shock interfered with bar pressing. As shock level increases, the elicited behavior patterns interfere to a greater extent until bar pressing is eliminated. Additionally, such an effect could functionally alter the shock contingency. For example, following the delivery of a 0.3-mA shock, the rat might engage in an aggressive behavior pattern (as studied by Hutchinson, Azrin, & Renfrew, 1968) or defensive freezing (as suggested by Bolles, 1970).

Since bar pressing has been followed by shock, that activity should, at least momentarily, be suppressed. Unless shock is particularly intense (e.g., see Azrin, 1960), bar pressing would eventually resume. If the *t* parameter has been exceeded prior to resumption of responding, however, another shock would be scheduled. A bar press would then produce another shock, another bout of aggression or freezing, and a high probability of another shock delivery. A response repertoire altered in this manner could produce the functional equivalent of a continuous punishment schedule rather than a differential one. With the current experimental arrangement, this scenario would also result in few opportunities for food delivery.

Experiment 2 was conducted in an attempt to circumvent the aforementioned problem by targeting a band of intermediate-duration IRTs. Thus, shock-eligible IRTs were limited to those greater than 8 s but less than 12 s in duration. The features of presenting shock for all IRTs within the targeted class and giving shock presentation priority over food delivery were retained in Experiment 2.

EXPERIMENT 2 METHOD

Subjects

The subjects were 3 female Holtzman albino rats maintained at 80% (± 10 g) of their free-feeding weights. The subjects were ex-

Fig. 3. Response rates for Rats B7, B8, and B9. Solid lines separate experimental conditions and dashed lines separate the first and last six sessions of each condition. A VI 40-s schedule of reinforcement with food was in effect throughout. All IRTs greater than 8 s but less than 12 s were punished during the shock conditions. The labels at the top of the graph indicate shock and no-shock conditions. Shock intensity is shown where appropriate.

perimentally naive and approximately 120 days old at the onset of training. These subjects were housed in the same colony under the same conditions as those in Experiment 1.

Apparatus and Procedure

The apparatus and procedures were identical to those in Experiment 1 with one exception: Only those IRTs greater than 8 s and less than 12 s in duration were shocked. As in Experiment 1, shock delivery was given priority over food delivery. Stability was assessed in the manner described previously.

RESULTS AND DISCUSSION

Figure 3 shows responses per minute for Rats B7, B8, and B9 for the last six sessions

of baseline and the first and last six sessions of all subsequent conditions. Solid lines separate experimental conditions and dashed lines separate the first and last six sessions within each condition. Sessions in which no responses occurred are designated by open circles.

Initial exposure to the 0.3-mA shock condition produced marked suppression of responding. The levels of responding were quite low, but compared with Experiment 1, they suggest that the present experimental arrangement sustains higher response rates. Discontinuation of shock resulted in prompt increases in rate for Rats B7 and B8, while B9 continued at the previous levels for several sessions. It was not necessary to reshape Rat B9's lever pressing as had been the case with Rat T4 in Experiment 1.

Exposure to 0.1-mA shock produced response-rate increases for all 3 rats. These changes are not large but, as in Experiment 1, stand in marked contrast to those observed following introduction of 0.3-mA shock. Increasing shock intensity to 0.2 mA resulted in response-rate decreases relative to 0.1-mA shock and also relative to the previous no-shock condition. Further increases in shock intensity suppressed response rates to levels similar to those observed during the first exposure to 0.3 mA. Although Rat B9 was not exposed to the 0.4-mA condition, the other 2 rats did continue to respond at a very low rate. Discontinuation of the shock procedure resulted in gradual recovery of responding for all rats, but in each case the level of responding was lower than that observed during either of the previous no-shock conditions.

Figure 4 shows the probability of each 1-s IRT class as a function of the opportunity for responding in each class. These data were derived and arranged in the manner outlined in Experiment 1 (Figure 2) except that data for the second exposure to 0.3-mA shock and the only exposure to 0.4-mA shock are also included here. For each rat, introduction of shock decreased the probability of the targeted IRTs. As shock intensity was increased, a graded decline in probability of the targeted IRTs was obtained. This relationship was observed for each of the 3 rats regardless of the initial level of the targeted IRTs. Changes in the distribution were not confined to the targeted portion of the IRT distribution. Instead, decreases were observed from approximately the 2- to 3-s class to the end of the distribution. Introduction of shock and increasing shock intensity tended to be accompanied by increases in those IRT classes of less than 2 s in duration.

Discontinuing the shock procedure did not produce such consistent findings. For 2 rats (B7 and B8), the targeted IRTs did not return to the level observed during baseline; for the third (B9), the targeted IRTs exceeded their no-shock baseline. Again, this shift in the no-shock IRT distributions is difficult to understand in view of the consistent changes in response rate that were observed. Further, inspection of the daily IRT/OP distributions indicated that the differences observed here, as in Experiment 1, were not produced by a

few aberrant data points but were the result of consistent changes in responding.

Data regarding changes in the longest IRT class are shown in Table 2 (arranged in the same manner as in Table 1). Introduction of shock and increasing shock intensity were usually accompanied by increases in the absolute number of IRTs in the longest class, and the relative frequency of IRTs in the longest class was always above the level observed during baseline.

Figure 5 shows responses per minute averaged across the 3 rats in Experiments 1 and 2. The left panel presents data from the ascending shock-intensity condition and the previous and subsequent no-shock conditions (labeled BLN and RCV) for the 3 rats in Experiment 1. The right panel shows the corresponding conditions for the 3 rats in Experiment 2. Range bars have been included for all data points in both panels. The procedure used in Experiment 1 (punishment of "long" IRTs) produced a substantial increase in response rates at the two lower shock intensities but failed to sustain responding at the two higher intensities. Discontinuation of shock resulted in response rates that were elevated relative to the previous baseline. The procedure used in Experiment 2 (punishment of "intermediate" IRTs) generated only a slight increase in response rate at the lowest shock level, yet responding persisted at all shock parameters investigated. Discontinuation of shock resulted in response rates that were considerably lower than those observed during the previous no-shock condition. Although these two punishment contingencies consistently suppressed the targeted IRTs, they differ markedly in their effects upon overall response rate.

GENERAL DISCUSSION

The current studies employed two selective IRT punishment contingencies and four parameters of shock intensity. These contingencies were termed differential punishment of "long" IRTs (Experiment 1) and differential punishment of "intermediate" IRTs (Experiment 2). With 0.1-mA shock, both procedures enhanced response rates and decreased the absolute numbers of targeted IRTs. An IRT/OP analysis revealed that the condition-

Fig. 4. Interresponse-time probabilities per opportunity (IRT/OP) for Rats B7, B8, and B9. The two vertical lines denote the boundaries of the targeted classes for the shock contingency. IRT/OP probabilities were not included for IRTs greater than 16 s (see text).

al probability of the targeted IRTs also decreased. Increasing the intensity of shock to 0.2 mA produced slight decreases in response rate if "long" IRTs were shocked, but rates dropped precipitously at higher levels of shock intensity. In contrast, punishment of "intermediate" IRTs produced small rate increases with the lowest level of shock and decreases at all other levels. Responding was, however, maintained at all parameters investigated. The IRT/OP analyses for Experiment 2 showed decreases in probability of the targeted IRTs

with increasing shock level. These changes were not confined to the targeted classes but included a few classes of IRTs shorter than the targeted ones. Alternatively, inspection of the shortest IRT classes typically showed increased probabilities. Selective punishment of IRTs produced a differential effect upon the targeted response classes in Experiment 2 and not merely a general suppression of responding, even in those cases where overall response rate declined.

Discontinuation of the shock procedure re-

Table 2

Response rate, absolute number of targeted IRTs per session, number of IRTs > 16 s per session, number of pellets per session, and number of sessions each condition was in effect for Rats B7, B8, and B9. With the exception of number of sessions, all figures are the averages of the last six sessions of the condition indicated. Dashed lines indicate that a subject was not exposed to that condition.

	B7					B8					B9				
	Rate	Trgtd IRTs	Bin 17	Rein-forcers	Ses-sions	Rate	Trgtd IRTs	Bin 17	Rein-forcers	Ses-sions	Rate	Trgtd IRTs	Bin 17	Rein-forcers	Ses-sions
VI 40-s															
No shock	19.0	50.2	14.3	53.2	18	18.8	34.2	21.3	52.2	18	34.0	10.5	42.7	53.5	19
VI 40-s															
Shock = 0.1 mA	22.0	35.7	25.8	51.3	21	25.0	15.0	44.8	50.8	32	44.6	7.0	47.7	53.2	23
VI 40-s															
Shock = 0.2 mA	16.9	24.8	43.8	48.2	19	11.0	5.8	54.0	44.0	19	8.5	4.0	67.0	42.2	21
VI 40-s															
Shock = 0.3 mA	6.2	6.2	53.7	38.8	20	3.8	2.3	57.7	38.7	18	1.6	1.0	40.3	30.5	22
VI 40-s															
Shock = 0.4 mA	2.9	1.2	53.7	36.0	14	2.9	1.2	57.0	38.3	13	—	—	—	—	—
VI 40-s															
No shock	10.8	42.0	34.5	49.5	17	6.8	40.0	45.0	47.6	31	18.8	29.8	52.8	51.0	24

sulted in increased response rates and probabilities of the targeted IRTs for all subjects relative to the most recent shock condition. Comparison with the preceding no-shock baseline did not reveal this consistency. Following punishment of "intermediate" IRTs, response rates during VI recovery were lower than those observed during the previous no-shock condition. Following punishment of "long" IRTs, response rates were enhanced relative to the no-shock condition. Inspection of the baseline and recovery data reported by Galbicka and Branch (1981) also shows enhanced rates following selective IRT punishment. Although the significance of these baseline shifts is currently unclear, such systematic effects seem noteworthy.

The current data bear remarkable similarity to those reported by Filby and Appel (1966, Figure 2, p. 523). Filby and Appel, however, used variable-interval schedules of shock presentation to investigate several parameters of shock intensity. Two of the three VI schedules they employed produced increases in response rate with low levels of shock but failed to maintain responding at higher levels. The similarity in these two sets of data supports the argument (Galbicka & Branch, 1981;

Howell, Byrd, & Marr, 1983) that variable-interval shock schedules functionally target long IRTs. Further, the data of Filby and Appel, in conjunction with the current data, raise questions about the generality of response-rate increases produced by selective IRT shock schedules.

Galbicka and Platt (1984) suggest, "Differential punishment of longer IRTs is apparently a necessary, but not sufficient, condition for predicting whether consequent shock will maintain or suppress responding" (p. 300). They further suggest that the level of responding prior to introduction of the IRT shock procedure will also contribute to predictions of whether the response-punishment or IRT-punishment relation will control behavior (i.e., "lower" rates would yield response-punishment and thus suppression; "moderate" rates would yield IRT-punishment and thus rate increases or maintenance). The current data appear to contradict this position—or at least suggest that other factors must also be considered. For example, introduction of 0.3-mA shock in Experiment 1 produced response-punishment whether it followed the "moderate" levels of responding during initial VI training or the higher levels

produced by the 0.2-mA shock condition. Alternatively, in Experiment 2 the 0.4-mA condition had little impact on response rate and further differentiated the IRT distribution even though it was introduced while responding was at a low level.

In discussing shock-maintained behavior, Galbicka and Platt (1984) indirectly offer another factor that might require consideration in predicting the effect of IRT-shock schedules on response rate. They argue that the types of responses elicited or "induced" by shock presentation can contribute to or interfere with shock-maintained behavior. That is, shock-produced, lever-directed aggression by monkeys "may counteract response suppression generated by response-consequent shock presentation" (p. 302) and thereby sustain a distribution of IRTs that can be altered by the IRT-shock schedule. Thus, reports of shock-maintained behavior in organisms such as rats, which might freeze or attempt to escape as a result of shock presentation (Bolles, 1970), are noticeably absent from the literature. These arguments would seem to bear directly on the current studies. As outlined in Experiment 1, production of response-incompatible behavior might vary with shock intensity and functionally alter the shock schedule. At low intensities, therefore, the IRT-punishment relation would predominate, but at higher intensities, the response-punishment relation would predominate.

With Experiment 2 we attempted to circumvent a functional change in the IRT-shock schedule by not arranging shock for those IRTs greater than 12 s. In this way elicited responses that momentarily interfered with lever pressing would not result in the scheduling of another shock. Although responding was maintained and the IRT distributions were differentially altered, only the lowest shock intensity increased response rate. This suggests that shock-maintained behavior may be observed in rats if low levels of shock are employed and if shock is scheduled so that shock-elicited behavior does not functionally alter the shock contingency. An interesting manipulation in the current studies would have involved removal of the food-reinforcement contingencies (either by gradually altering the schedule value or deprivation level) during the 0.1-mA shock condition.

It is important to note that the response-

Fig. 5. Average response rate (responses per minute) as a function of shock intensity. The left panel shows the ascending shock-intensity conditions and the preceding and subsequent baselines for all rats in Experiment 1. The right panel shows the corresponding conditions for the rats in Experiment 2.

rate decreases observed in the current studies may not be attributable solely to the intrusion of shock-produced behavior. Sizemore and Maxwell (1983) were able to increase response rates by delivering *pause-dependent* shocks that were 0.3 mA in intensity. That procedure, termed differential-punishment-of-other-behavior (DPO), differs from an IRT > t schedule in only one respect. Technically, shock is pause-dependent with both procedures; with DPO, shock delivery follows immediately upon completion of the pause (t) parameter and, thus, shocks are never contiguous with responses; with IRT-shock schedules, shock delivery is made available by the pause component of the IRT but is not delivered until the next bar-press response is emitted. Presumably, the latter feature is necessary for the suppression seen in the current experiments, because the same shock intensity did not suppress bar pressing in the DPO study.

It is tempting to suggest that Galbicka and Branch (1981) would have found response suppression had they employed a higher intensity of shock. In their study, shocks were 1.0 mA in intensity and 200 ms in duration. Compared with other studies using monkeys as subjects and using 6.0-mA shock (e.g., Branch & Dworkin, 1981; Gardner & Malagodi, 1981; Howell et al., 1983; Malagodi, Gardner, Ward, & Magyar, 1981), this intensity seems "low." In none of these studies

was response suppression observed with schedules that functionally shocked long IRTs. Perhaps, as Galbicka and Platt (1984) argue, the shock-induced lever pressing found with monkeys would preclude ever observing response suppression with $IRT > t$ shock schedules. Differences between the current experimental arrangements and those mentioned above are not limited to subject species. For example, studies employing monkeys typically use restraint chairs, which could limit alternatives to lever pressing and thereby maintain higher response rates. Further, Galbicka and Branch (1981) delivered shock contingently upon only one third of the targeted IRTs, and Galbicka and Platt (1984) never shocked two successive responses even if the criterion value of t had been exceeded. Thus, a variety of procedural differences could be responsible for the observed rate differences in the three IRT-shock studies.

At this juncture, it is clear that IRT-shock schedules can differentially alter the distribution of IRTs in monkeys and rats, and that, at least in rats, these changes can occur independently of response-rate changes. The data from Experiment 2, in particular, demonstrate a parametric relationship between shock intensity and suppression of the targeted IRTs. The relation between shock intensity and response rate, however, is not straightforward and seems to depend in part upon the manner in which shocks are scheduled. Clarification of the relation between changes in targeted and nontargeted IRTs would appear to be crucial.

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