

SELECTIVE PUNISHMENT OF INTERRESPONSE TIMES

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Lever pressing by two squirrel monkeys was maintained under a variable-interval 60-second schedule of food presentation. When response-dependent electric shock was made contingent on comparatively long interresponse times, response rate increased, and further increases were obtained when the minimum interresponse-time requirement was decreased. When an equal proportion of responses produced shock without regard to interresponse time, rates decreased. Thus, shock contingent on long interresponse times selectively decreased the relative frequency of those interresponse times, and increased the relative frequency of shorter interresponse times, whereas shock delivered independent of interresponse times decreased the relative frequency of shorter interresponse times while increasing the frequency of longer ones. The results provide preliminary evidence that interresponse times may be differentiated by punishment, further supporting the notion that interresponse times may be considered functional units of behavior.

Key words: interresponse times, punishment, response-contingent electric shock, molecular analyses, squirrel monkey

Current approaches to the analysis of behavior can be classified generally into two broad types on the basis of assumptions about the importance of momentary contingencies in the control of behavior. A "molar" view (e.g., Baum, 1973; Catania & Reynolds, 1968; Herrnstein, 1970; Rachlin & Burkhard, 1978) de-emphasizes momentary contingencies in deference to quantitative analyses of integrated, temporally extensive measures of behavior as controlled by aggregate reinforcement parameters (e.g., rate, magnitude, "value", etc.). Conversely, more "molecular" analyses typically view overall changes in behavior (e.g., average response rate) as alterations in aggre-

gates of smaller sequences of responses which are themselves differentially sensitive to consequent events (e.g., Anger, 1956; Shimp, 1966, 1968, 1973a, 1973b, 1974; Shimp & Hawkes, 1974; Silberberg, Hamilton, Zirix & Casey, 1978; Silberberg & Williams, 1974; Williams, 1968). The latter approach is illustrated by the analysis of behavior in terms of the reinforcement of particular interresponse times (IRTs). (Technically speaking, the IRT is the time between two successive responses; it is the response which terminates the IRT which is followed most directly by reinforcement. However, since the types of behavior required for reinforcement are not all contiguous with the terminating response, it is proper to consider the IRT as a sequence of two responses separated by some period of time.) Relationships between aggregate response and reinforcement measures can be considered, according to these molecular analyses, as by-products of more fundamental relations involving the reinforcement of particular IRTs (e.g., see Morse, 1966).

The validity of this latter type of interpretation depends on the experimental demonstration that IRTs are differentially sensitive to IRT-contingent events. Data attesting to the differential susceptibility of IRTs to rein-

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forcing stimuli abound (see, e.g., Zeiler, 1977) and are especially convincing in the case of $IRT > t$ schedules which provide reinforcement for a response only if it terminates an IRT of t sec or longer. Such arrangements lead to a decrease in the frequency of the terminating response, while at the same time resulting in an increase in the frequency of the reinforced class of IRTs (e.g., see Richardson, 1973).

Additional data which suggest that IRTs act as behavioral units come from studies involving concurrent reinforcement of two or more classes of IRTs, wherein independent schedules of reinforcement for different classes of IRTs operate simultaneously. Such arrangements have been programmed for IRT classes emitted either on separate operanda (Moffitt & Shimp, 1971) or on a single operandum (Hawkes & Shimp, 1974; Shimp, 1968, 1969, 1973a, 1974; Shimp & Hawkes, 1974; Staddon, 1968). Functional relations between relative reinforcement rates or magnitudes and the relative frequency of particular IRT classes (for IRTs between 1 and 6 sec) have been shown to be similar in form to those obtained under situations where reinforcement is not directly IRT-contingent (cf. de Villiers, 1977; Hawkes & Shimp, 1974; Moffitt & Shimp, 1971; Shimp, 1968, 1969, 1973a, 1974; Shimp & Hawkes, 1974; Staddon, 1968). Although some have questioned the interpretation of these results (e.g., Reynolds & McLeod, 1970), IRTs appear to function as units of behavior under a wide variety of positive-reinforcement procedures.

The susceptibility of IRTs to punishing consequences, on the other hand, is still a largely unanswered question. If the IRT can be a behavioral unit, as the results from studies involving differential reinforcement of IRTs suggest, it should be possible to decrease selectively the frequency of particular classes of IRTs through IRT-specific punishment. This means of ascribing functional unity to the IRT has, however, yet to be demonstrated convincingly. When punishment has been arranged specifically for short IRTs, they have indeed decreased in frequency, producing concomitant increases in the relative frequency of longer IRTs (e.g., Ferster, 1958). Although these results are consistent with the effects of punishment of single-response units (i.e., punishment led to a decrease in the frequency of

the punished IRTs), whether this effect was due specifically to differential punishment of IRTs is not clear. The effect of punishing stimuli made contingent on a response irrespective of the time elapsed since the preceding response is to decrease its frequency of occurrence and consequently also to decrease the frequency of short IRTs (e.g., Holz & Azrin, 1963; Holz, Azrin & Ulrich, 1963).

Separation of the effects of IRT-specific punishment from the more general effects of punishment on responding requires that punishment contingencies be arranged so that changes in the frequency of particular IRTs are not confounded by decreases in overall response rate. In the present study, we attempted to do this by presenting brief electric shocks contingent on occurrences of IRTs longer than some criterion value. Punishing only IRTs $> t$ generates opposing predictions about the subsequent effects on behavior, depending on whether the unit of behavior considered is the IRT or the single-response unit. Analyses emphasizing single-response units would predict that overall response rates should be suppressed, since shock presentation is contingent on a response (the one terminating an IRT $> t$). Demonstration of IRT-specific effects of punishment, conversely, would require that only IRTs $> t$ (the punished ones) be suppressed, producing an increase in overall response rate. The present study examined the sensitivity of classes of IRTs to punishment contingencies by comparing response rates and IRT frequency distributions obtained under conditions where responding was maintained by intermittent reinforcement, and where punishment was either 1) absent, 2) programmed only for comparatively long IRTs, or 3) programmed for an equal proportion of responses irrespective of IRT.

METHOD

Subjects

Subjects were two adult male squirrel monkeys (*Saimiri sciureus*) maintained at 85% of their free-feeding body weights (1025 and 800 g, respectively, for M-514 and M-524) by providing supplemental postsession feeding of processed monkey diet. Subjects were housed individually with free access to vitamin-enriched water, and were provided with fresh fruit twice weekly.

Apparatus

Experimental sessions were conducted in a clear Plexiglas restraint unit similar to that described by Hake and Azrin (1963). Subjects were seated approximately 10 cm from the front wall of the unit, and were restrained at the waist by a Plexiglas waist lock that allowed free movement of the head, limbs, and torso. The front wall of the unit contained a response lever (Colbourn Instruments, Model E21-03) and, 7 cm to the left of the lever, a recessed food cup, located in the center of the wall, into which 190-mg banana-flavored food pellets (P. J. Noyes Co.) could be delivered automatically. Two 1.1-W, 28-V dc white stimulus lamps, located 15 cm above the waist plate and behind the transparent front wall, were illuminated continuously during experimental sessions. A downward force to the lever in excess of .4 N operated a "feedback" relay located behind the front wall on the base of the unit and was recorded as a response. Centered on one side at the base of the restraint chair was a Plexiglas stock used to hold a shaved portion of the monkey's tail motionless during experimental sessions. Two brass electrodes resting on the tail allowed delivery of brief (.2-sec), 1.0-mA electric shocks from a BRS/LVE (Model SG-003) constant-current shock generator. Electrode paste (EKG Sol) was applied to the tail to minimize changes in electrical resistance, and a commercially available cream depilatory was employed weekly to maintain the shaved condition of the tail chronically. During sessions the restraint unit was housed inside a ventilated, light- and sound-attenuating chamber located in a room where white masking noise was continuously present. In an adjacent room, a PDP-8/f mini-computer, operating under the SKED (Snapper, Stephens, & Lee, 1974) or SuperSKED (Snapper & Inglis, 1978) software systems, presented stimuli and recorded data. Also, cumulative response records of each session were generated by a Ralph Gerbrands Co. (Model C-3) cumulative recorder.

Procedure

General procedural details. Both subjects had been exposed previously to variable-interval schedules of food presentation, so preliminary magazine and response training were not required. Under all conditions, with the excep-

tion of a short Extinction condition, a constant-probability variable-interval (VI) 60-sec schedule of food presentation was in effect. Thus, the first response after an average interval of 60 sec resulted in the immediate delivery of a food pellet. The VI schedule was composed of 20 randomly ordered intervals, generated using the formula offered by Catania and Reynolds (1968, Appendix II), presented in the same fixed sequence twice during each daily 40-min session. Distributions of IRTs were recorded under all conditions in 24 .25-sec class intervals (bins). A 25th bin recorded IRTs greater than 6 sec. The first response of the session and the first response following each food presentation were not included in the IRT distribution, and also never were followed by shock. One additional restriction was that, under conditions in which both food and shock were programmed, the two were never presented simultaneously. In the event that both were scheduled to occur, shock presentation was cancelled and only food was delivered.

No-Shock condition. This baseline condition consisted merely of the VI 60-sec:food schedule. Shock was never delivered under this condition; however, the subjects' tail was prepared, as described above, in exactly the same way as during procedures which involved shock delivery. The No-Shock condition remained in effect until changes in response rates and IRT distributions across a criterion number of sessions were minimal and showed no systematic trends. The criterion was 10 sessions during the first No-Shock condition and 20 sessions thereafter.

IRT > t:shock condition. Under this condition, responses still produced food according to the VI 60-sec schedule. Conjointly (cf. Catania, 1968), IRTs longer than some criterion value t were also occasionally followed by shock. The value of t was determined in the following manner. Distributions of IRTs from each of the last three sessions of the immediately preceding condition (either a No-Shock or another IRT > t :shock condition) were analysed to determine the IRT value which most closely separated the distribution into two portions such that 90% of the IRTs were shorter than this value (i.e., the 90th percentile). The median value obtained across the three sessions served as the criterion for possible shock delivery. Thus, IRTs comprising the longest 10%

of the IRTs emitted under the preceding condition were eligible for shock. Given that an IRT longer than this value occurred, shock was delivered with a probability equal to .333, i.e., only one out of every three eligible IRTs, on the average, actually produced shock. In traditional schedule terminology (Zeiler, 1977), this condition would be designated as *conjoint* (VI 60-sec:food)(Random Ratio 3 (IRT > t):shock). Since this designation is rather cumbersome, these conditions will hereafter be denoted by the simpler notation IRT > t:shock. (The reader should bear in mind, however, that the VI 60-sec:food schedule always operated, except during one short Extinction condition, and that only one out of three eligible IRTs actually produced shock.)

Monkey M-514 was exposed to two series of IRT > t:shock requirements. The first began after the initial No-Shock condition with IRTs > 3.00-sec eligible for shock. Once responding stabilized for 10 sessions at this value, the IRT requirement was reduced to 2.00 sec for five sessions and then to 1.50 sec. Following a return to the No-Shock condition, IRTs > 1.75, then IRTs > 1.00-sec produced shock according to the random-ratio (RR) 3 schedule. Responding was allowed to stabilize for 20 consecutive sessions at both these IRT values. Monkey M-524 was exposed to IRT > 1.50-sec:shock and IRT > 1.75-sec:shock conditions. Both conditions were preceded and followed by a No-Shock condition, and responding was allowed to stabilize for 10 (IRT > 1.50-sec:shock) or 20 (IRT > 1.75-sec:shock) consecutive sessions at each value.

Extinction condition. During exposure to IRT > 1.50-sec:shock, the VI 60-sec schedule of food presentation was removed while maintaining the punishment contingency. Responses operated the pellet dispenser according to the VI 60-sec schedule, but pellet delivery was blocked by a small steel plate placed above the far end of the tube connecting the dispenser to the food cup. This condition remained in effect until responding ceased for 15 to 20 min, and was followed by reinstatement of the VI 60-sec:food schedule with the IRT > 1.50-sec:shock criterion still in effect.

RR-30:shock condition. The effects of IRT-contingent shock presentation were compared with the effects of an equal initial probability of shock delivery per single response without regard to IRT. Under the IRT > t:shock con-

ditions, the initial probability of shock per response was .033, since 10% of the responses produced shock one-third of the time. Under the RR-30:shock condition, this same probability was used to program shock for responses irrespective of IRT. Thus, on the average, every 30 responses produced a shock, i.e., shock was delivered according to an RR-30 schedule. This condition was preceded and followed by a No-Shock condition, and responding was allowed to stabilize for 20 sessions providing responding was not suppressed below 15 resp/min for 3 consecutive sessions.

Table 1 summarizes the sequence of experimental conditions and gives the number of sessions and the stability criterion under each for the two subjects.

RESULTS

The VI 60-sec schedule of pellet presentation maintained consistent responding in both subjects throughout the course of the experiment. Response rates were fairly constant within sessions, although M-514 did show a pattern of positively accelerated responding across the session during the initial No-Shock condition. This pattern gave way to a more constant rate of responding with the introduction of the first IRT > t:shock contingency, and this new pattern subsequently was maintained for the duration of the experiment.

Figure 1 shows cumulative response records for M-514 taken from the last session of the first No-Shock condition (top record) and the

Table 1

Sequence of experimental conditions with number of sessions of exposure and stability criterion under each.

Condition	Number of Sessions		Stability Criterion (Number of sessions)
	M-514	M-524	
1. No shock	103	93	10
2. IRT > 3.00-sec:shock	34		10
3. IRT > 2.00-sec:shock	5		—
4. IRT > 1.50-sec:shock	26	74	10
5. Extinction	3	2	—
6. IRT > 1.50-sec:shock	20	21	10
7. No Shock	98	244	20
8. IRT > 1.75-sec:shock	64		20
9. IRT > 1.25-sec:shock		27	20
10. IRT > 1.00-sec:shock	75		20
11. No Shock	80	109	20
12. RR-30:shock	17	58	20
13. No Shock	71	68	20

first six sessions following initial introduction of the $IRT > t$:shock contingency (bottom records). The number in parentheses beneath the lower records indicates the number of responses per shock presentation. The initial effect of the $IRT > t$:shock contingency was to suppress responding greatly. Responding remained severely suppressed for the first four sessions under this condition, with a majority of the IRTs emitted eligible for shock. A short period of higher rate responding occurred approximately three-quarters of the way into the

session on Day 4. A more sustained period of higher-rate responding on Day 5 resulted in a decrease in the density of shock delivery when compared to the early part of that session, and a concomitant increase in the number of responses per shock. The last record shows that a period of high-rate responding was initiated earlier and maintained for the duration of the subsequent session, producing a further increase in the number of responses per shock.

Daily response rates and numbers of shocks delivered during Conditions 1 to 7 for both subjects are shown in Figure 2. Responding was suppressed initially in M-524 also, although for a shorter period of time than for M-514. Further exposure to the punishment contingency produced increases in response rate over the course of the next 30 (M-514) or 60 (M-524) sessions. This increase initially increased the number of shocks delivered, but as response rate increased above baseline levels, the number of shocks gradually decreased to approximately 10 per session for both subjects.

The suppression of responding resulting from initial introduction of the $IRT > t$:shock contingency greatly suppressed reinforcement frequency. As responding recovered, the number of pellets delivered per session approached but did not quite reach baseline values. This difference of approximately 3 pellets per session disappeared after about 30 sessions, and both subjects received 39 pellets per session under all subsequent $IRT > t$:shock and No-Shock conditions.

Decreasing the value of t for M-514 first to 2.00 sec then to 1.50 sec produced further increases in response rate. The number of shocks delivered initially increased with each decrease in the IRT criterion. This was rapidly followed by a decrease in shock frequency, as response rate increased even further, to levels comparable to those delivered under the $IRT > 3.00$ -sec:shock condition. Under the $IRT > 1.50$ -sec:shock contingency, response rates stabilized at 70.93 and 95.48 resp/min for M-514 and M-524, respectively, having increased from mean response rates of 29.66 (M-514) and 60.31 (M-524) resp/min observed during the last three sessions of the No-Shock condition.

During Condition 5 (labelled EXT in Figure 2) food presentation was discontinued to determine the degree of control exercised by the VI 60-sec:food schedule in maintaining the performance observed. As can be seen in Fig-

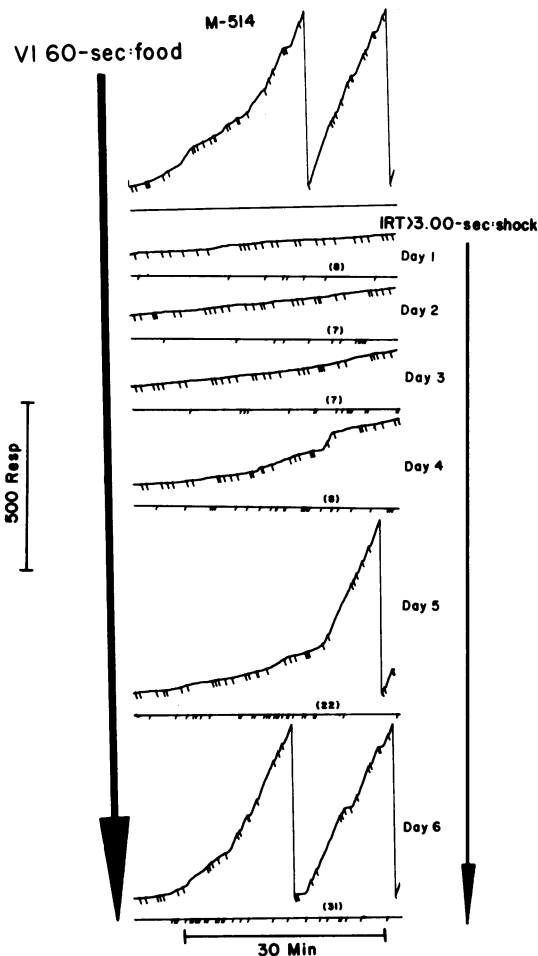


Fig. 1. Cumulative response records of M-514's responding during the last session of the first No-Shock condition (top record) and the first six sessions following introduction of the $IRT > 3.00$ -sec:shock contingency (lower records). In all records, the upper (response) pen stepped vertically with each response and was deflected momentarily with each pellet delivery, whereas deflections of the lower (event) pen denote shock delivery. The number in parentheses beneath each lower record indicates the number of resp/shock.

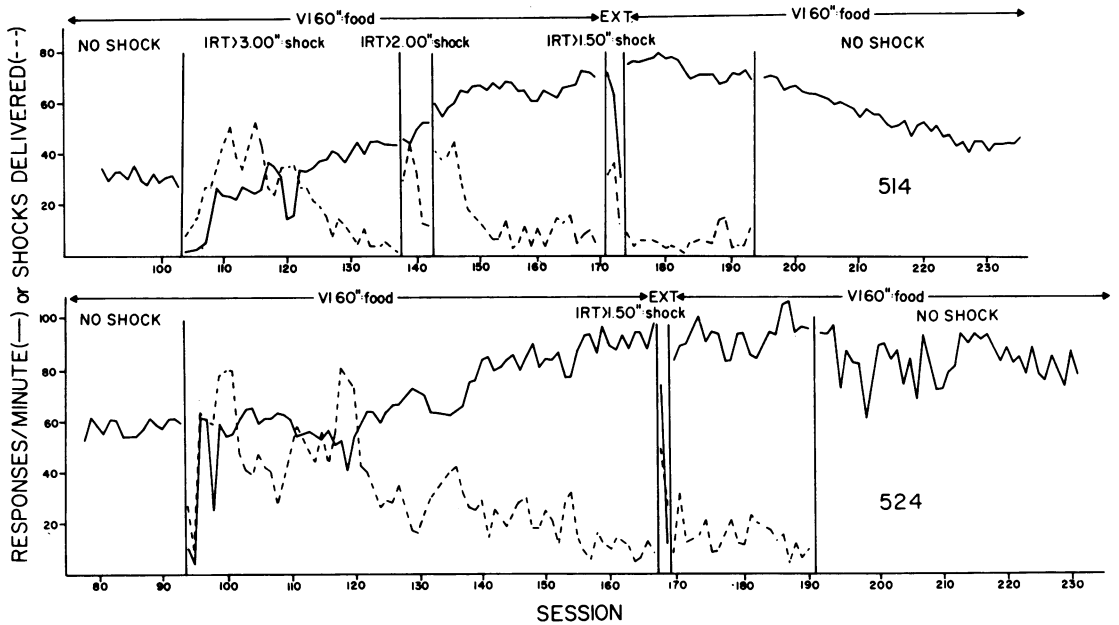


Fig. 2. Daily response rates (solid lines) and numbers of shocks delivered (dashed lines) for M-514 (top panel) and M-524 (lower panel) under Conditions 1 to 7. Vertical lines separate conditions.

ure 2, response rate rapidly decreased under this condition, and within three (M-514) or two (M-524) sessions responding ceased for the 15- to 20-min criterion. Reinstatement of the VI 60-sec:food contingency resulted in rapid recovery of responding to rates comparable to those observed prior to the Extinction condition.

Removal of the IRT > 1.50-sec:shock contingency resulted for M-514 in a gradual transition to a lower rate of responding, which stabilized at a level slightly higher than that observed under the initial No-Shock condition. The decrease in response rate for M-524 was less pronounced and the transition more variable upon removal of the IRT > 1.50-sec:shock contingency, with response rate decreasing only to approximately 80 resp/min after 30 sessions. Responding subsequently decreased to 55.60 resp/min after showing a great deal of variability over 200 sessions.

Figures 3 and 4 display IRT relative frequency distributions for M-514 and M-524, respectively, obtained under the last three sessions of conditions shown in Figure 2 as well as those obtained during the second exposure to the IRT > t :shock contingency (Conditions 7 to 10). The uppermost distributions in both figures were obtained under the immediately preceding No-Shock condition,

those below under the subsequent IRT > t :shock conditions. (Daily plots for the second exposure to the IRT > t :shock contingency are not presented since transitions in responding resembled those obtained upon initial exposure with the exception that they occurred more quickly.) Introduction of the IRT > t :shock contingency (and subsequent decreases in the value of t for M-514) produced substantial shifts in the distribution of IRTs toward shorter IRTs, with relatively few IRTs > t occurring. Only at $t = 2.00$ sec did M-514 exhibit appreciable relative frequencies of IRTs > t . However, it should be remembered that this condition was in effect for only five sessions, and values presented probably do not reflect asymptotic performance. Monkey M-524 generally showed slightly greater relative frequencies of IRTs > t than did M-514. However, the relative frequency of these long IRTs was substantially decreased, and IRTs < t substantially increased over values obtained under No-Shock conditions for both subjects.

The effects on response rate of programming shock with a matched initial probability of occurrence per single response irrespective of IRT are shown in Figure 5. Response rate initially increased slightly for both subjects with introduction of the RR-30:shock contingency, but with further exposure rates de-

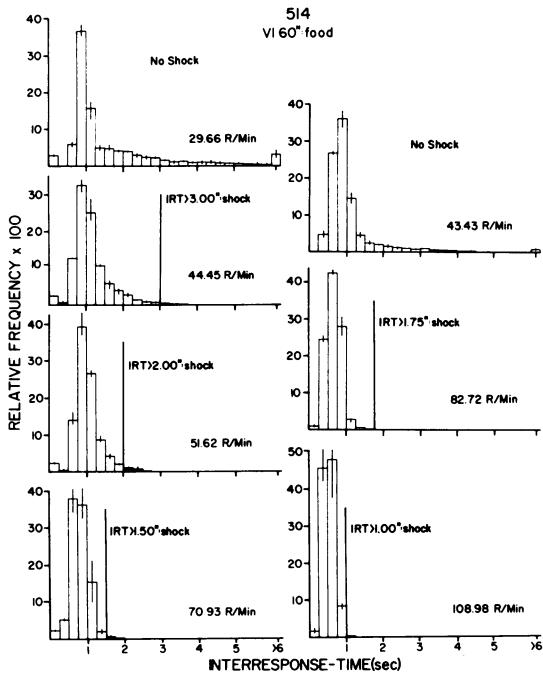


Fig. 3. IRT relative frequency distributions for M-514 obtained under No-Shock (top distributions) and subsequent IRT > t:shock (lower distributions) conditions. Bars to the right of the single vertical lines, which depict the IRT requirements in the lower distributions, have been shaded to denote eligibility for shock. Height of bars and small vertical lines through bars represent means and ranges, respectively, of values observed under the last three sessions of each condition. The mean response rates during these sessions are also presented in each histogram.

creased to levels below baseline values. Again the effect was less pronounced and the transition more variable and slower for M-524 than for M-514, both following introduction of the RR-30:shock contingency and upon its removal. Neither subject, however, showed a sustained increase in response rate like that observed when only IRTs > t were shocked. The decreased rates of responding produced a decrease in number of pellets delivered to M-514 (Range 31 to 38 over the last three sessions), but not to M-524 (39 over the last three sessions).

Figure 6 shows relative frequency histograms for IRTs emitted under the No-Shock (left distributions) and RR-30:shock (right distributions) conditions. Unlike the distributions obtained when only IRTs > t produced shock, delivery of shock irrespective of IRT produced decreases in the relative frequency of short IRTs and increases in the relative frequencies

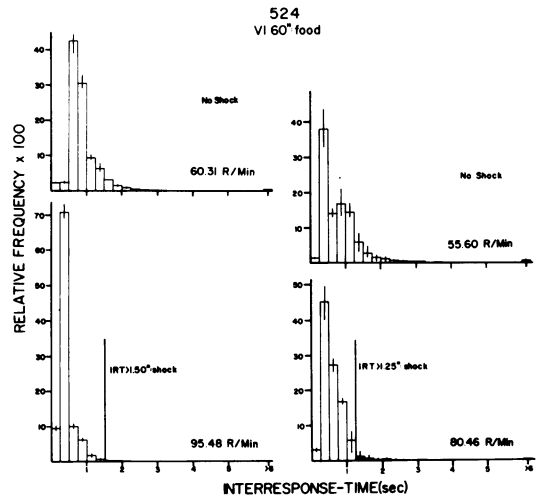


Fig. 4. IRT relative frequency distributions for M-524. Characteristics of this figure are the same as those for Figure 3.

of longer IRTs when compared to distributions obtained under the preceding No-Shock condition.

As noted above, effects for M-524 were often smaller and more variable than those seen with M-514. Consistent with these findings were the results of occasional visual observations of the subjects during sessions. Each shock produced a noticeable reaction in M-514, but no such obvious changes could be detected in M-524.

DISCUSSION

The effect of response-contingent electric shock in the present study depended on whether shock was programmed with or without regard to the time elapsed since the preceding response. When only IRTs > t produced shock, they were suppressed and response rates and the relative frequency of IRTs < t subsequently increased in comparison to baseline values. This effect was reliably produced twice in both subjects, and, furthermore, graded effects were produced in one subject by systematically decreasing the IRT requirement. When an equal initial proportion of responses produced shock independent of IRT, response rates were suppressed. Concomitantly, the relative frequency of shorter IRTs was decreased and longer ones became more prevalent in comparison to relative frequencies observed under the No-Shock baseline conditions.

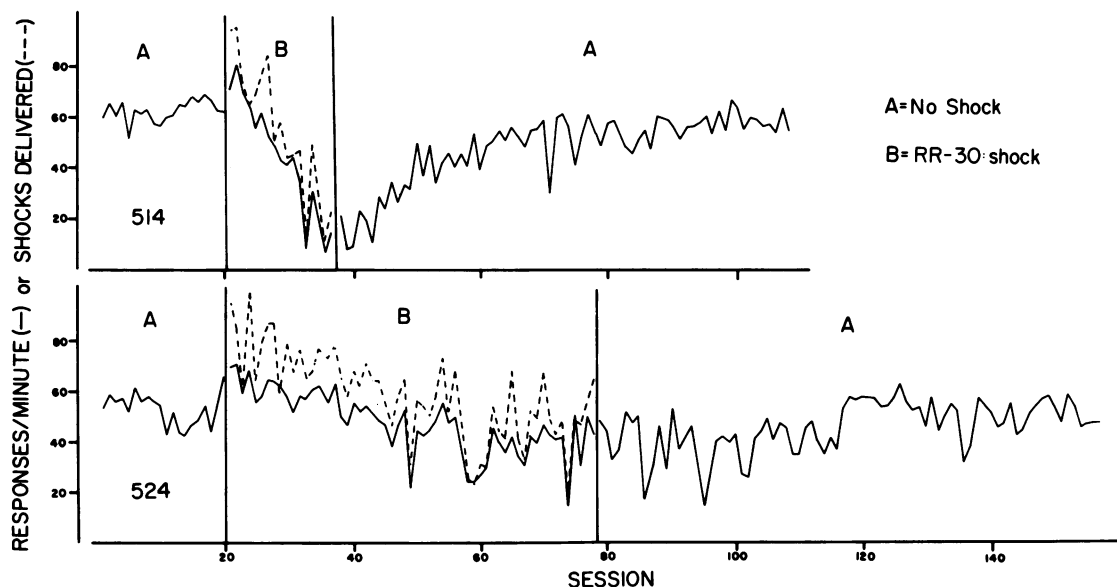


Fig. 5. Daily response rates (solid lines) and numbers of shocks delivered (dashed lines) for M-514 (upper panel) and M-524 (lower panel) under Conditions 11 to 13. Vertical lines separate conditions.

The suppression of responding by IRT-independent shock delivery under the RR-30 schedule is consistent with previously reported effects of punishment programmed under ratio contingencies (e.g., Azrin, Holz, & Hake, 1963; Dardano, 1972), and provides evidence that the intensity and duration of shock used in the present study were indeed sufficient to characterize it as a punishing stimulus (cf. Azrin & Holz, 1966).

Monkey 524 consistently showed smaller effects of shock delivery than M-514, and transitions between conditions for this subject were also more variable and slower to occur. This intersubject difference suggests that M-524's behavior was less sensitive to the parameters of shock employed. The visual observations that revealed little shock-elicited behavior (e.g., muscular contraction, vocalization, chain pulling, etc.) in M-524, whereas M-514 consistently "flinched" with each shock delivery, provide further support for the notion of differential sensitivity to shock in the two subjects. Even so, intersubject differences were, under all conditions, quantitative in nature only. Long-IRT-contingent shock reliably produced response rate increases in both subjects, whereas an equal initial probability of IRT-independent shock suppressed responding in both subjects.

To account for the present results without

reference to IRT-specific effects would require invocation of some other mechanism which would increase response rates only when shock is programmed to follow long IRTs. A number of such possible alternatives exist, including shock-elicited and shock-induced behavior (see Hutchinson, 1977, for a recent review) and reinforcement-like effects of shock delivery that occur under certain temporally defined schedules of presentation (see Morse & Kelleher, 1977, for a recent review). Certain aspects of the present results suggest that such interpretations are probably insufficient, because both alternatives would predict a reduction in response rate as shock frequency decreased across the values observed here (e.g., Hutchinson, 1977; McKearney, 1969). In the present experiment, extended exposure to the $IRT > t$: shock contingency resulted in gradual transitions in response rate to levels above baseline, and this gradual increase in response rate occurred concomitant with a gradual decrease in the frequency of shock delivery. Thus, the highest response rates were observed while minimal numbers of shocks were being delivered. To account for this inverse relation, interpretations based on elicitation or on "reinforcing" effects produced by presentation of electric shock would require the additional specification that less frequent shock produce a greater facilitative effect on responding.

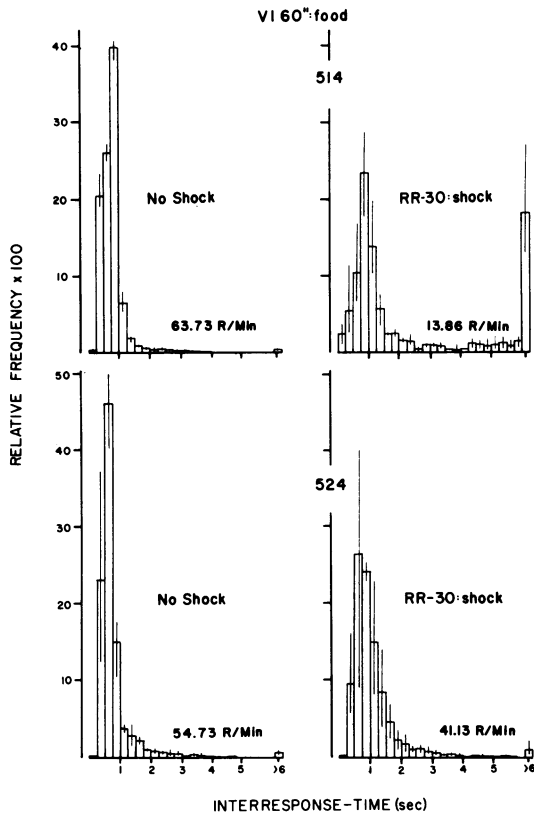


Fig. 6. IRT relative frequency distributions from No-Shock (left distributions) and subsequent RR-30:shock (right distributions) conditions for M-514 (upper distributions) and M-524 (lower distributions). Characteristics of these histograms are the same as those for Figure 3.

However, the parametric data from M-514 provide further difficulties for such interpretations in that, even when terminal frequencies of shock delivery were comparable, shorter IRT requirements produced higher response rates. For example, IRT requirements of 3.00, 2.00, and 1.50 sec resulted in mean response rates of 44.52, 51.62, and 70.93 resp/min, respectively, even though asymptotic shock frequencies under all of these three conditions were between 10 and 15 shocks per session. It therefore seems unlikely that elicitation or reinforcement-like effects of shock can account for the present findings.

One alternative to the notion that the present results demonstrate selective punishment of IRTs that cannot be discounted completely is an alternative to the concept of punishment in general. Specifically, it has been argued that greater parsimony can be achieved by viewing what appear to be punishment effects as the

indirect results of avoidance contingencies (see, e.g., Dinsmoor, 1954, 1977; Skinner, 1953). Avoidance theories of punishment suggest that response suppression produced by response-contingent punishing stimuli occurs as the result of an increase in the frequency of competing responses. These competing responses are said to be maintained by negative reinforcement because engaging in alternative types of behavior decreases the frequency of aversive events. In most cases, however, the nature of the alternative behavior remains unidentified (but, cf. Dunham, 1971). Applied to the present results, it might be argued that long IRTs were not selectively suppressed under the IRT > *t*:shock procedure, but rather that short IRTs predominated since they postponed the next aversive event (i.e., short IRTs avoided shock). Such a notion might allow for a "molar" interpretation of the present results in terms of the positive relation between response and reinforcement rates and the inverse relation between response and shock rates. Undoubtedly, some combinatorial rule governing the interaction of these "feedback functions" (cf. Baum, 1973; Nevin & Baum, 1980) could be devised to describe the data adequately. The results of the present study cannot refute such an argument. Indeed, as Rachlin and Herrnstein (1969) noted, "... it would be difficult to state the conditions for a disproof as long as the free postulation of unobservable behavior is considered acceptable" (p. 103). This almost complete immunity of avoidance theories of punishment from experimental disproof led Rachlin and Herrnstein to argue for the independence of avoidance and punishment as behavioral processes. We tend to agree with this point of view, not only for the reasons cited by Rachlin and Herrnstein but also on the basis of data obtained via pharmacological interventions on avoidance and punished behavior. For example, morphine administration generally produces dose-related decreases in punished responding at doses that do not produce analgesia (e.g., Geller, Bachman, & Seifter, 1963; Holtzman & Villarreal, 1973; Kelleher & Morse, 1964). Such an effect could be attributed to an increase in the frequency of nonspecific, competing avoidance responses. If so, one should thus expect morphine administration to increase the frequency of a specified avoidance response. However, morphine usually only further suppresses

avoidance responding (e.g., Cook & Kelleher, 1963; Heise & Boff, 1962).

The selective decreases in the relative frequency of IRTs $> t$ when shock was made contingent on their occurrence, then, support the notion that IRTs can be punishable units of behavior, and strengthen arguments proposing that such sequences of responses may act as functional units of behavior. Although it may seem paradoxical to explain an increase in response rate in terms of a punishment effect, it is important to bear in mind that the units upon which delivery of the punishing stimulus was made contingent, IRTs $> t$, did decrease in frequency. Of course, the generality of IRTs as punishable units of behavior is at the present time an open question. Boundary conditions involving important variables (e.g., punishment intensity and frequency, percentage of IRTs punished, etc.) remain to be investigated.

Depending on the degree of generality of IRT-specific punishment, the implications of the present results are many. These results may, for example, bear on the analysis of schedules of punishment in much the same way as results from studies involving differential reinforcement of IRTs bear on the analysis of schedules of reinforcement. Responding maintained by various schedules of reinforcement has often been analyzed in terms of the reinforcement provided indirectly to IRT classes (e.g., Morse, 1966). Variable-interval schedules have, for example, repeatedly been demonstrated, both empirically (Anger, 1956; Catania & Reynolds, 1968; Platt, 1979; Shimp, 1969) and mathematically (Reynolds & McLeod, 1970) to reinforce long IRTs differentially (i.e., the probability of reinforcement is a monotonically increasing function of IRT length). Interval schedules of punishment may similarly differentially *punish* long IRTs, providing a situation where effects similar to the ones reported here might be likely to occur. Indeed, some studies have reported increases in response rate over unpunished responding following the introduction of a variable-interval schedule of shock presentation (e.g., Filby & Appel, 1966; Bacotti & McKearney, Note 1). The possibility arises that the response-rate increases observed in these studies were the result of the indirect punishment of long IRTs which interval schedules provide.

It is also interesting to note that experi-

ments reporting the chronic maintenance of responding which results solely in the presentation of electric shock (see Morse & Kelleher, 1977, for a recent review) have by and large demonstrated maintenance only under time-based schedules of shock presentation. Ratio schedules of shock presentation suppress or less readily maintain responding (e.g., McKearney, 1970; Morse & Kelleher, 1970), even when the number of responses per shock is matched to conditions which previously maintained responding (Branch & Dworkin, Note 2). Since interval schedules provide an increasing probability of shock with increases in IRT length, the possibility again arises that long-IRT punishment may play an important role in the maintenance of responding by response-contingent shock. Depending on the schedule of shock delivery, responding may be maintained not because shock assumes reinforcement-like properties under certain schedules, but because shock acts as a punishing stimulus which is differentially allocated to classes of IRTs by different schedules of presentation.

By extending the class of relationships into which IRTs can lawfully enter, the present results provide further support for the acceptance of the IRT as a differentiable unit of behavior. More generally, they suggest that analyses of behavior should take into account the possible importance of extended sequences of responses in determining overall response rate. Although it might be argued that the contingencies arranged in the present study led to the "artificial creation" of a behavioral unit which would not otherwise exist (i.e., sequences of responses may act as units under these contingencies, but they need not act as such under less explicit contingencies), we believe such arguments miss a vital point. It is not the experimental specification of contingencies per se which determines subsequent behavior, but rather how ongoing behavior contacts those contingencies (cf. Morse & Kelleher, 1977). Thus, whenever contingencies provide differential consequences for sequences of responses, either directly or indirectly, analyses which ignore these sequences may possibly obscure important controlling relations. Examination of sequences of responses and their contribution to overall response rate may offer an empirical account of previously unexplained variability, providing the impetus for analyses of increasing precision.

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