Food-based timing behavior sharpened by the selective punishment of short interresponse times¹

ALFRED BRUNER

AUTONOMICS DIVISION, NATIONAL PHYSICAL LABORATORY

Following training on a DRL schedule three rats were punished for short interresponse times and a limited hold applied to the period of opportunity for food reinforcement. As a result the interresponse time distributions peaked sharply at the interval of reinforcement, and in one rat this time discrimination was shown to be strongly dependent upon punishment.

The basic procedure for establishing timing behavior has been to reward S for responses which are spaced some minimum length of time following the preceding response. This schedule is called the differential reinforcement of low rates (DRL; Ferster & Skinner, 1957). The resulting response rate becomes low and steady, tending to maximize reinforcement frequency. The frequency and probability distributions of interresponse times (IRTs) tend to peak near the time interval when reinforcement is available, particularly when a limited hold (LH) is also in force, i.e., when the availability of reinforcement expires after a predetermined time has elapsed. This finding has been demonstrated repeatedly in both animals (Anger, 1956; Kelleher, Fry, & Cook, 1959; Sidman, 1955; Wilson & Keller, 1953) and humans (Bruner & Revusky, 1961).

The present study was undertaken as an attempt to further sharpen food-based timing behavior by the selective punishment of short IRTs, operating upon the assumption that highly efficient behavior can be most readily established by an effective combination of reward and punishment.

Subjects

The Ss were three male naive hooded rats about 120 days old, at ad lib weight determination. They were reduced to and maintained at 80% of their ad lib weight. Two of the Ss died during the course of the experiment at points indicated in the procedure section.

Apparatus

A "Skinner Box" similar to that described by Dinsmoor & Lyon (1961) was used, having a lever adjusted to operate at about 20 g force. An audible relay click accompanied each press, while reinforcements (Noyes 97 mg pellets) were accompanied by a magazine solenoid sound. Shock was delivered through the grid floor, walls, and lever by a commercial shock generator and scrambler set at .3 mA intensity and .5 sec duration. The box was enclosed in a ventilated ice chest illuminated by a 7 W red lamp.

IRTs were recorded in 3-sec bins on a bank of electri-

cal counters, while response rates were drawn on a cumulative recorder.

Procedure

The Ss were usually run in 2-h daily sessions, with all changes in schedules being made mid-session. Following magazine training the rats were continuously reinforced for IRTs of 6 sec or longer for two sessions (4 h). Reinforced IRTs were then gradually lengthened over the next 10 h until an 18-sec pause had to intervene between reinforced responses (DRL 18). After 40 h of DRL 18, when behavior had stabilized, a punishment contingency for short IRTs was introduced, i.e., responses which followed the preceding response by too brief an interval were shocked. Over the next 10 h shock was given for increasingly long IRTs until the end of the shocked IRT period coincided with the beginning of the food-reinforced period, at 18 sec.

After 18 h of the punishment schedule the first rat died and an LH procedure was added for the remaining two. Here the interval following an 18-sec IRT, during which reinforcement was available, was gradually reduced to 3 sec (LH 3). That is, only responses spaced by between 18-21 sec were reinforced; IRTs briefer than 18 sec were punished, while IRTs longer than 21 sec simply reset the IRT timer. After 208 h of this LH contraction phase, the second rat expired, having attained LH 6. The surviving rat attained LH 3 after 348 h of the contraction phase. Then an additional 116 h at LH 3 were run, including various test sessions wherein the effects of extinction or punishment omission were examined.

Results and Discussion

Figure 1 presents the IRT probability distributions

Fig. 1. IRT probability distributions plotted over 3-sec bins (0-3, 3-6, etc.) after DRL 18, and after DRL 18 plus shock for IRTs up to 18 sec for all three rats.

Fig. 2. IRT probability distributions as a function of LH interval and shock contingency and a cumulative record showing the effect of the punishment contingency. The LH 9 and 6 distributions are based on two rats while the LH 3 and shock-off distributions are based on one. The oblique pips on the cumulative record indicate reinforcements while those on the baseline indicate shocks.

($\Sigma \text{IRTs} / \Sigma \text{IRT opportunities}$; Anger, 1956) after 39 h of DRL 18 (before shock), and after 17 h of DRL 18 plus shock for IRTs up to 18 sec. The development of typical DRL behavior is apparent in the before-shock curve of Fig. 1 in that the IRT probability distribution tends to show depression among the early, nonreinforced bins, while rising and flattening over the reinforced bins. The after-shock curve of Fig. 1 shows the pronounced effect of punishing IRTs of up to 18 sec. This distribution is greatly depressed during the punished interval and much inflated over the reinforced bins. Bursts (brief IRTs) are virtually nonexistent here in contrast to the before-shock condition.

The influence of the LH contraction procedure is shown in three of the IRT probability distributions of Fig. 2. As the LH interval is contracted from LH 9 to LH 3 the peak of the distribution grows higher and sharper within the reinforced period. The LH 3 curve was obtained after 66 h at LH 3 and reflects very precise timing behavior for the surviving rat. The last few points of the LH 3 distribution are based on a small number of responses and would most likely drop off more sharply were the sample larger.

The importance of the presence of the punishment contingency was investigated in the surviving rat during the final hours of the LH 3 phase. When punishment was withheld for short IRTs, timing behavior deteriorated markedly, as shown in the shock-off distribution of Fig. 2. This distribution manifests inflated response probabilities over the short IRT bins and a general flattening over the reinforced and longer IRT bins, in contrast to the LH 3 distribution obtained when the punishment contingency was in effect. Also shown is a representative

cumulative record showing the effect of removing the punishment contingency. The record reveals a relatively high, erratic rate with very few reinforcements during the shock-off period, followed by a quick recovery of accurately spaced responding after the punishment contingency was reinstated. The same effect resulted when the shock-off period occurred later in a session.

Food extinction tests likewise resulted in the deterioration of timing accuracy in this rat, manifested by a generalized flattening of the IRT distribution accompanied by a rapid overall decrease in response rate when the punishment contingency was in force, and a transient increase when it was not.

Under ordinary DRL the ability to space responses accurately is thought to depend upon cues arising from the preceding reinforced response and from collateral mediating behaviors (Bruner & Revusky, 1961; Wilson & Keller, 1953). While in the present procedure it is apparent that the short-IRT punishment contingency acquired an additional cueing function which aided the rat's tendency to maximize reinforcement frequency by reducing bursting and sharpening timing accuracy, and upon which the rat's timing behavior became highly dependent.² The apparent importance of punishment in maintaining the highly efficient behavior observed here suggests that the cue value of an acceptable degree of punishment might be preferred over no punishment by a suitably motivated animal seeking to maximize reinforcement.

References

- Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *J. exp. Psychol.*, 1956, 52, 145-161.
- Bruner, A., & Revusky, S. H. Collateral behavior in humans. *J. exp. Anal. Behav.*, 1961, 4, 349-350.
- Dinsmoor, J. A., & Lyon, D. O. The selective action of chlorpromazine on behavior suppressed by punishment. *Psychopharmacology*, 1961, 2, 456-460.
- Ferster, C. B., & Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Holz, W. C., Azrin, N. H., & Ulrich, R. E. Punishment of temporally spaced responding. *J. exp. Anal. Behav.*, 1963, 6, 115-122.
- Kelleher, R. T., Fry, W., & Cook, L. Inter-response time distribution as a function of differential reinforcement of temporally spaced responses. *J. exp. Anal. Behav.*, 1959, 2, 91-106.
- Sidman, M. Time discrimination and behavioral interaction in a free operant situation. *J. comp. physiol. Psychol.*, 1956, 49, 469-473.
- Wilson, M. P., & Keller, F. S. On the selective reinforcement of spaced responses. *J. comp. physiol. Psychol.*, 1953, 46, 190-193.

Notes

1. This research was performed at Indiana University. The author is grateful for the support of J. A. Dinsmoor and the assistance of Wm. Mead. Address reprint requests to the author, Autonomics Division, National Physical Laboratory, Teddington, Middlesex, England.
2. Holz, Azrin & Ulrich (1963) nonselectively punished all the responses of pigeons on a DRL schedule thereby reducing response rate and increasing reinforcement frequency, but the punishment effect was not interpreted as aiding timing behaviour per se.