REINFORCEMENT OF DRINKING BY RUNNING: EFFECT OF FIXED RATIO AND REINFORCEMENT TIME[1]

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Rats were required to complete varying numbers of licks (FR), ranging from 10 to 300, in order to free an activity wheel for predetermined times (CT) ranging from 2 to 20 sec. The reinforcement of drinking by running was shown both by an increased frequency of licking, and by changes in length of the burst of licking relative to operant-level burst length. In log-log coordinates, instrumental licking tended to be a linear increasing function of FR for the range tested, a linear decreasing function of CT for the range tested. Pause time was implicated in both of the above relations, being a generally increasing function of both FR and CT.

The use of drinking and eating as contingent events has been sufficiently consistent throughout the experimental literature to suggest that consummatory responses are unique-reinforcing but not reinforcible. (A notable exception is work by Williams and Teitlebaum (1956) which, however, used licking with negative reinforcement. Hulse's work (1961), though relevant, departs less from convention: licks on an empty tube are reinforced by licks on a filled tube, the consummatory response thus retaining its traditional role.) In the present experiments drinking was used as an instrumental event, rather than as a contingent one, and running was used to reinforce drinking. This arrangement was suggested by a model of reinforcement, the major assumption of which is simply that, for any pair of responses, the independently more probable one will reinforce the less probable one (Premack, 1959, 1961). If there are intervals of time in which drinking is less probable than some nonconsummatory response, then drinking should be reinforcible. Such intervals have been shown in previous work; in the female rat especially, there are a number of parameters which make wheel-running more probable than drinking (e.g., Premack, 1962).

In the present experiments two parameters of reinforcement were studied in the context of drinking to run: the fixed ratio (FR) and the contingent time (CT) or duration for which the reinforcer is available to the subject (S) following completion of the instrumental requirement. The concurrent investigation of these variables is made interesting by the fact that their effects are apt to be largely opposite. Increasing the CT will allow the reinforcing response to habituate increasingly, and should therefore reduce the instrumental output. In contrast, increasing the FR should increase the instrumental output, at least up to a point. If the effects of FR and CT are genuinely opposite, it should be possible to find increments in FR that will equal the effect of decrements in CT.

METHOD

Subjects

Eight female albino rats of the Sprague-Dawley strain, about 160 days old served. Four each were used in two experiments reported here. The Ss were housed individually in Holtge HB-11A rat cages, and were maintained on *ad lib* Purina mash and water.

Apparatus

A modified Wahmann activity wheel was equipped with a braking device and a retractable drinkometer. The wheel was mounted on the rear wall of a refrigerator hull that was sound-deadened, light-tight, ventilated, and illuminated by a 15 w overhead

bulb. The open face of the wheel was enclosed by a stationary aluminum face plate. Located in the face plate were a door through which S was introduced into the wheel, and an aperture that received the drinkometer. The aperture was about 2 in. from the floor of the wheel, and about 1½ in. from center line. The drinkometer consisted of a modified 50 ml burette with a 5 mm inner diameter that was delivered and retracted by a motor driven cam. Each tongue lap closed an electronic switch with a current of about 1 microamp. The braking device on the wheel consisted of a solenoid-operated drag that contacted the rim of the wheel when activated. About 24 in. grams was required to turn the wheel.

A photoelectric cell, activated each time the wheel turned 90 degrees, measured running; a drinkometer counted licks. Both devices could be used to measure duration of running and drinking by arranging that a precision timer operate continuously when receiving seven or more pulses per sec from the drinkometer or four or more pulses per sec from the wheel. The procedure eliminated spurious measures due to wheel-rocking and incidental contacts with the drinkometer, since these occur below the prescribed rates.

Procedure

All Ss were adapted to the wheel until running was stabilized (12 to 20, 30-min sessions), and then given operant-level sessions on running, on drinking, and on running and drinking. On conditioning sessions the drinkometer was inserted, the wheel brake activated, and S was required to complete a prescribed number of licks to free the wheel for a predetermined time. Daily sessions lasted 20 min, operant-level as well as conditioning.

Experiment I: Fixed Ratio. Four Ss were trained to stability on each of eight FRs ranging from 5 to 300; the upper limit of the apparatus. Contingent time (CT)—duration for which the wheel was free following completion of the FR—was the same for all FRs, and equalled 20 sec. Table 1, left side, shows the order in which the FRs were given, as well as the number of sessions given per FR. All Ss were run on a given condition until there was not more than a 5% difference in number of licks per session on four out of five consecutive sessions.

Table 1
Order and Number of FR and CT Sessions

FR		CT	
Value	# of Sessions	Value	# of Sessions
5	24	5	35
15	26	20	11
20	15	2	29
10	20	10	12
40	16	15	22
60	17		
200	15		
300	10		

Experiment II: Contingent Time. Four Ss were trained to stability on each of five CTs ranging from 2 to 20 sec. An FR 10 was used for all CTs, *i.e.*, S was required to complete at least 10 licks to free the wheel for the predetermined time. Table 1, right side, gives the order in which the CTs were given, as well as the number of sessions per CT. The same criterion of stability was used in this study as on FR. General procedure was the same in both studies except that FR was run in the a.m., CT in the p.m., and each by a different experimenter.

RESULTS

Operant-Level. Table 2 shows the duration of operant-level running and drinking for each S averaged over the last four sessions of the eight or more operant-level sessions given. It may be seen that all Ss spent a greater proportion of the session running than drinking. Table 2 also shows the average length of the operant-level drinking burst; it is interesting to compare this burst length with that found when drinking served to release the wheel.

Table 2
Operant-Level Drinking and Running

	Mean Duration (Sec)		Mean Drink Burst
	Run	Drink	Length (Licks)
		FR	
S 1	204	13	64
2	319	17.5	26
3	297	38	56
4	263	9	24
		CT	
S 1	289	19	12
2	186	0	—
3	327	24	27
4	303	28	48

FR and CT Main Effects. The main results for both the FR and CT series are shown in Fig. 1 and 2—group curves in Fig. 1, and curves for individual *S*s in Fig. 2. Instrumental and contingent responding are shown for both the FR and CT series. For example, in Fig. 2, the upper and lower panels show licks/session and runs/session (¼ wheel turns) respectively, as functions of FR and CT, respectively. All points in all figures are based upon the last four sessions given per condition.

Curves drawn by inspection for the group data suggest that, in log-log coordinates, instumental responding is a linear increasing function of FR for the range tested, a linear decreasing function of CT for the range tested. In addition, the curves for contingent responding are approximately linear in log-log coordinates, for both FR and CT. Furthermore, there is a generally inverse relation between instrumental and contingent responding in both the FR and CT series; also, the FR-CT relations are essentially opposite. That is, licks increased and runs decreased as functions of FR, while licks decreased and runs increased as functions of CT.

For the range of FR tested, the absolute rate of change in instrumental and contingent responding appears to be approximately equal;

Fig. 2. Instrumental and contingent responses/session as functions of FR and CT in the left and right panels, respectively. Data are for individual *S*s.

i.e., absolute slope of the lick and run curves is about the same. In addition, if the frequency of licks and runs is added at corresponding magnitudes of the independent variable, the sums approximate a constant (this condition is not entailed by the slope condition, for the latter may hold and the former not). Thus, total mean responses—licks plus runs—was approximately 820 at both FR 5 and FR 300. At FR 5, however, licks comprised only about 25% of the total; at FR 300 they made up over 90% of the total. However, the apparent constancy in the lick-plus-run sum is an artifact—a product of the arbitrary unit of running. The constancy does not hold if, for example, the unit of running is made ½ turn rather than ¼ turn. Revealing here is the fact that total response *duration* (lick-time plus run-time) was not constant, but rather decreased as FR was increased. Hence, although absolute rate of change in instrumental and contingent responding was actually similar, there was no tendency for the lick-plus-run total to be constant over the FR scale.

Contingent time, unlike FR, did not produce proportional changes in instrumental and contingent responding. Rather, the rate of decline in licking was less than the concomitant increase in running. Total duration of responding (lick-time plus run-time) tended to increase with CT, in contrast to FR where it decreased.

The general opposition of the CT and FR effects is shown by the two ways of increasing instrumental responding indicated in Fig. 1.
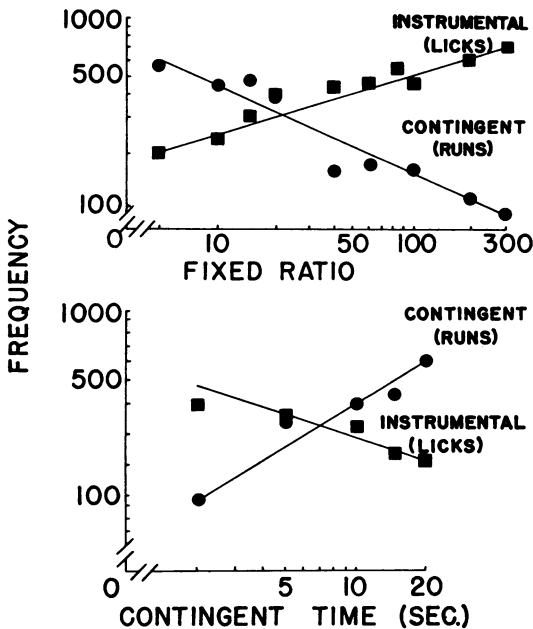

Fig. 1. Instrumental and contingent responses/session as functions of FR and CT in the upper and lower panels, respectively. Curves drawn by inspection.
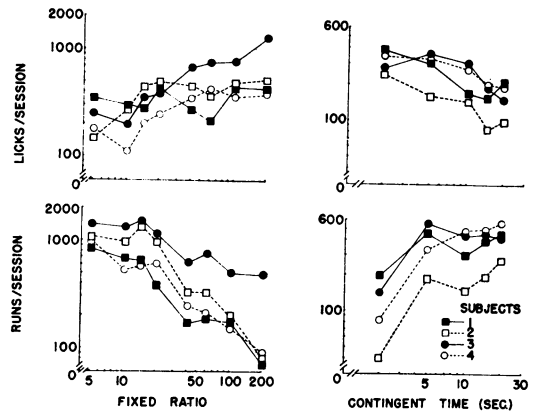
According to the curves in Fig. 1, both reducing CT from 21 to 9 sec and increasing FR from 2 to 5, should have the effect of increasing instrumental licks from 150 to 200. Likewise, an increase in instrumental licks from 200 to 300 should be possible either by reducing CT from 9 to 3.3 sec or by increasing FR from 5 to 20.

There was no tendency for the amount of running per opportunity to run to vary with the FR, nor any tendency for the number of licks made per reinforcement to vary with the CT; both relations are shown in Fig. 3. In the CT case, all Ss may be seen to have made slightly more licks per reinforcement than the 10 required. In the FR case, virtually all of the possible running time was used. This may be seen in the sample Esterline Angus records which are presented in Fig. 4. The records also suggest what is shown more clearly in Fig. 5, which plots pause time as a function of both FR and CT. Upon completing a burst of running, the Ss did not resume licking immediately, but rather, paused between the offset of running and the onset of the next burst of licking. This interval was greater the greater the FR and, to a lesser extent, the

Fig. 3. Runs (¼ wheel turns) per opportunity to run, and licks per reinforcement as functions of FR and CT in the upper and lower panels, respectively. Connected points show group averages.

greater the CT, as may be seen in the group averages shown in Fig. 5. (A few runs shown in Fig. 4 to occur when the wheel was "not available" resulted from brake failure.)

DISCUSSION

For all Ss there was at least one FR value that produced an increased frequency of licking relative to the operant-level; increments ranged from factors of about 1.5 to about 6. In addition, the contingency resulted in notable changes in the burst length of licking. The data suggest this generalization: S did not lick more per burst than was required for running. On the one hand, when the FR demanded fewer licks than normally occurred in the operant-level drinking burst, the contingency produced a burst shorter than that of operant-level drinking. For most Ss this was the case for FRs up to about 20, since for most Ss the operant-level burst length was greater than 20 (see Table 2). On the other hand, when the FR demanded licks in excess of the number typically found in the free drinking burst, the contingency produced a burst substantially greater than that found in free drinking. For example, bursts of 200 or 300 licks substantially exceed those found in free drinking. Thus, the run contingency served not only to increase the frequency of licking, but also to modify the distribution of licking, producing bursts of licking both greater and less than the average operant-level burst. The traditional evidence for reinforcement is contained in the increase in frequency, but, as has been pointed out by others (*e.g.*, Frick, 1952), the change in distributional properties would seem to be no less incisive an indicator.

". . . when a reinforcement depends upon the completion of a number of similar acts, the whole group tends to acquire the status of a single response . . . but with such an organism as the rat . . . a contribution to the reserve commensurate with a large group is probably never achieved. The unity of the group as 'a response' is never fully realized." (Skinner, 1938, p. 300.) In this fashion, Skinner introduced the problem of the response unit in FR, a problem subsequently taken up by Mowrer and Jones (1945) and others (Hearst, 1961). Typically, the problem has been dealt with *vis-a-vis* the extinction function, but this
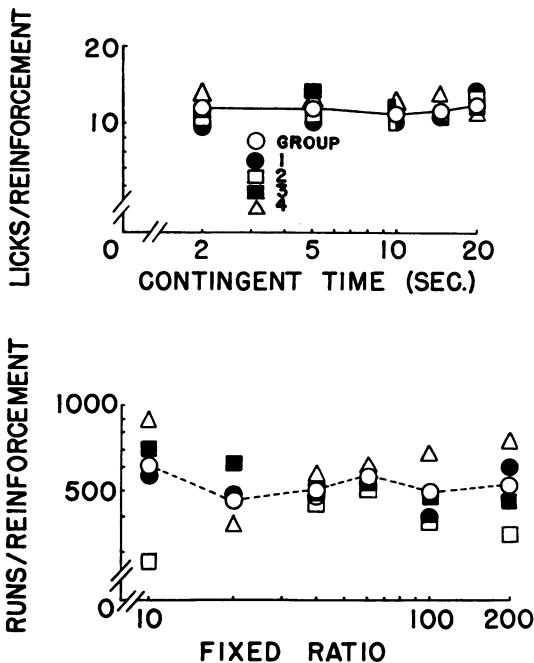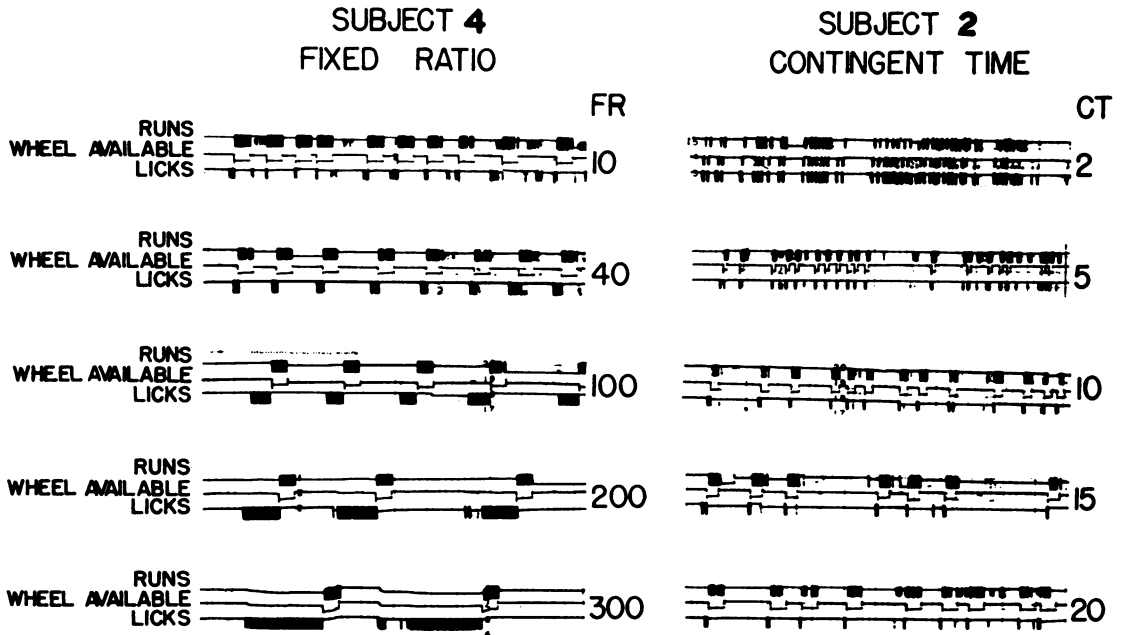
SUBJECT **4**
FIXED RATIO

SUBJECT **2**
CONTINGENT TIME

FR

CT

Fig. 4. Esterline Angus samples for representative *Ss* showing FR and CT effects; all records read from left to right.

seems unduly restrictive. If the "group acquires the status of 'a response' ", then all FR functions, and not only the extinction function, should be linear. Interestingly, that the FR "group" in the present case had the functional unity of a response is rather well supported by the linearity of the present FR relations (see especially Fig. 1). Further, that the linearity is enhanced by log-log coordinates is compatible with Skinner's suggestion that the equivalence or unity breaks down at "large" FRs.

Both the FR and CT effects appear to arise largely from the pause following contingent responding. Sidman and Stebbins (1954) and Collier (1962) have reported food maintenance to exert its effect in the same manner. For example, changes in average response rate, resulting from variation in amount fed prior to test, resulted from pauses between bursts of responding rather than changes in momentary response rate. Special explanations advanced to handle the FR-pause time relation (*e.g.*, Skinner, 1938, p. 298) tend to be ruled out by the fact that three operationally distinct variables—FR, CT, and food maintenance—exert their principal effect in the same manner.

The CT function obtained here is doubtless specific to the (small) size of the FR, and

reflects habituation of the running response. With only 10 licks required between successive bursts of running—approximately 1 sec of licking time—running may be expected to decrease within the session, the decrement being greater the greater the CT. A sufficiently larger FR should permit some recovery between successive bursts of running, and thus a different CT function. Finally, if the FR were large enough, a quite different family of curves may be expected, the small CT now yielding an instrumental output less than that of the large CT. Accounting for the CT function in terms of the probability of running, or, more generally, probability of the contingent response, appeals to at least two processes which can be demonstrated directly, (*a*) response decrement as a function of responding, (*b*) response recovery as a function of rest (*cf.* Premack and Collier, 1962).
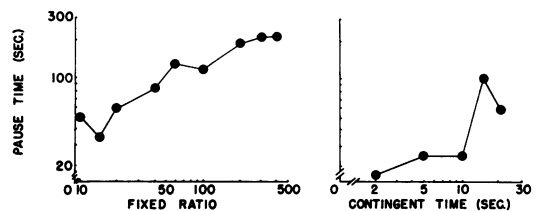

Fig. 5. Pause time as functions of FR and CT in the left and right panels, respectively.

REFERENCES

Collier, G. Consummatory and instrumental responding as a function of deprivation. *J. exp. Psychol.*, 1962, **64**, 410-414.

Frick, F. C. The effect of anxiety—a problem in measurement. *J. comp. physiol. Psychol.*, 1953, **46**, 120-123.

Hearst, E. Resistance-to-extinction functions in the single organism. *J. exp. Anal. Behav.*, 1961, **4**, 133-144.

Hulse, S. H. A precision liquid feeding system controlled by licking behavior. *J. exp. Anal. Behav.*, 1960, **3**, 1-3.

Mowrer, O. H. and Jones, H. Habit strength as a function of the pattern of reinforcement. *J. exp. Psychol.*, 1945, **35**, 293-311.

Premack, D. Toward empirical behavior laws: I. Positive reinforcement. *Psychol Rev.*, 1959, **66**, 219-233.

Premack, D. Predicting instrumental performance from the independent rate of the contingent response. *J. exp. Psychol.*, 1961, **61**, 163-171.

Premack, D. Reversibility of the reinforcement relation. *Science*, 1962, **136**, 255-257.

Premack, D. and Collier, G. Analysis of nonreinforcement variables affecting response probability. *Psychol. Monogr.*, 1962, **76**, 5 (Whole No. 524).

Sidman, M. and Stebbins, W. C. Satiation effects under fixed-ratio schedules of reinforcement. *J. comp. physiol. Psychol.*, 1954, **47**, 114-116.

Skinner, B. F. *The behavior of organisms.* New York: D. Appleton Century Co., 1938.

Williams, D. R. and Teitlebaum, P. Control of drinking behavior by means of an operant conditioning technique. *Science*, 1956, **124**, 1294-1295.