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STIMULUS AND SUBJECT CONTROL OF SCHEDULE-INDUCED DRINKING[1]

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Responding in three food-deprived rats was reinforced on schedules in which reinforcement periods (fixed-ratio 1 or 2 for 1, 3, 6, 9, 14, or 21 reinforcers) alternated with extinction intervals. Schedule-induced drinking occurred and was mostly confined to the onset of extinction intervals. Drink durations were longer after 21-pellet meals but were not reliably different after 1, 3, 6, or 9-pellet meals. When termination of the extinction intervals was response dependent, schedule-induced drinking diminished until minimum extinction intervals of 15, 30, and 60 sec were introduced.

When Falk (1961) reported that rats drink large quantities of water if responding is reinforced intermittently with small pellets of food, he also observed that "shortly after a pellet of food is earned a burst of licking ensues." Several investigators have confirmed this behavioral observation (*e.g.*, Falk, 1969; Keehn, 1970; Segal, 1969; Stein, 1964), but most have taken fluid consumption as the principal datum of interest, not the characteristics of the drinking behavior. Falk (1967, 1969), for example, has shown how fluid consumption is affected by type, size, and spacing of meals, but not how these variables affect occasions and durations of individual drinks.

Studies of schedule-induced post-pellet drink bursts by Colotla, Keehn, and Gardner (1970), Keehn (1970), and Keehn and Colotla (1970*a*, *b*) have suggested that: (a) schedule-induced drink durations are relatively constant for a given schedule of food reinforcement, (b) drink durations vary with inter-reinforcement intervals more than they do with meal size, and (c) schedule-induced drinking, like aggression (Azrin, Hutchinson, and Hake, 1966), is extinction-induced, *i.e.*, it is occasioned not by pellet ingestion but by the onset of nonreinforcement (extinction) intervals. The present paper describes a continuation of the line of investigation that generated these results.

The present study was conducted in two parts: Part A was concerned with the stimulus control of schedule-induced drinking, Part B with subject control of schedule-induced drinking. In Part A, the number of reinforcers per reinforcement period ("meal size") was manipulated. In Part B, subject control of extinction interval duration was permitted. The parts were conducted consecutively without interruption, according to the timetable summarized in Table 1.

METHOD

Subjects

Three experimentally naive male albino rats of the Wistar strain supplied by Woodlyn Farms, Guelph, Ontario, were 130 days old at the beginning of the experiment. They were maintained at 80% of their free-feeding weights at this age for the period of the study, and were individually housed with water always available.

Apparatus

The experimental space was a standard 11.5 by 9.5 by 7.5 in. (29 by 23.5 by 19 cm) Grason-Stadler two-bar rat chamber (Type E3125B) with a pellet magazine that delivered 45-mg Noyes rat pellets. For Part A, the left-hand bar (Bar 2) was removed and its housing covered with a metal plate mounted flush with the wall. A force of 0.19 N (20 g) on Bar 1 (and on Bar 2 when it was used in Part B) was sufficient to activate relay scheduling and recording equipment.

A plastic water bottle was attached to the chamber door such that the glass outlet tube was 1 in. (2.5 cm) above floor level and 3.5 in.

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Table 1
Summary of Experimental Procedures

Subjects	Sessions	Reinforcement Schedule: Bar 1	Reinforcement Schedule: Bar 2*	Schedule Cycles/Session
PART A				
50, 53, 66	1-12	min EXT 30 CRF (1)	-	100
	13-22	min EXT 30 CRF (3)	-	50
	23-32	min EXT 30 CRF (6)	-	40
	33-42	min EXT 30 CRF (9)	-	30
	43-52	min EXT 30 CRF (21)	-	15
	53-62	min EXT 30 CRF (21)	-	15
PART B				
50, 53, 60	63-72	EXT 30 FR 2 (14)	-	20
	73-86	EXT 15 FR 2 (14)	-	20
	87-92	max EXT 15 FR 2 (14)	CRF	20
	93-102	max EXT 30 FR 2 (14)	CRF	20
53	103-122	max EXT 60 FR 2 (14)	CRF	20
50, 66	103-112	max EXT 30 FR 2 (14)	**	20
	113-122	max EXT 30 FR 2 (14)	CRF	20
66	123-152	max EXT 60 FR 2 (14)	CRF	20
50, 53	123-137	max EXT 60 FR 2 (14)	FI15	20
	138-152	max EXT 60 FR 2 (14)	FI30	20
	153-167	max EXT 90 FR 2 (14)	FI60	20
66	153-167	max EXT 60 FR 2 (14)	FI15	20
	168-172	max EXT 90 FR 2 (14)	FI60	20

*During EXT component of schedule on Bar 1.
**Bar 1 and Bar 2 functionally equivalent.

(9 cm) from the wall containing the response bar(s) and food magazine. Licks on this tube were recorded on a Gerbrands cumulative recorder via a Grason-Stadler drinkometer. A Foringer Stimulus Panel (Type 1166-4-M1) was used during selected sessions to generate a tone stimulus of 2400 Hz that raised the noise level in the experimental chamber from 72 to 77 db.

Except for a few early sessions that were conducted with the chamber in the open room for the purpose of videotaping, the chamber was housed in a ventilated chest in a closed closet in the room containing the relay circuitry.

Procedure

Part A. After preliminary adaptation and shaping, reinforcement of bar presses was scheduled such that response-terminated extinction intervals of at least 30 sec (FI 30-sec) alternated with periods during which *n* pellets were delivered under a one-response fixed-ratio schedule (CRF). At various times (*cf.* Table 1), for 62 sessions, the number of pellets (*n*) was either 1, 3, 6, 9, or 21. In Sessions 53 through 62, a 2400-Hz tone that raised the noise level in the experimental chamber from 72 to 77 db was on during extinction intervals.

Part B. During the next 110 sessions, *n* was always 14 and the schedule on Bar 1 was fixed-ratio 2 (FR 2) but different durations of the tone-signalled extinction intervals were studied. In the first 24 of these sessions (Sessions 63 to 86), termination of the extinction intervals was response independent. Beginning with Session 87, two bars were present in the experimental chamber and termination of the extinction interval was made dependent on a response on the second bar. A press on Bar 2 during the extinction interval terminated the interval, which was otherwise limited to the values shown in Table 1.

To facilitate Bar 2 pressing by animals S50 and S66, Bar 1 and Bar 2 were made functionally equivalent by electrical connection for Sessions 103 to 112. Thereafter, this connection was broken and tone-off periods in which 14 pellets were procurable on FR 2 for presses on Bar 1 alternated with tone-off extinction intervals that lasted for the times shown in Table 1, unless terminated by a press on Bar 2. For the final 20 or 30 sessions, presses on Bar 2 terminated extinction inter-

vals only after fixed-intervals of 15, 30, or 60 sec.

RESULTS

Part A. The usual performance of each animal under all the CRF values (1, 3, 6, 9, 21) in the reinforcement schedule was to press the bar and consume pellets as they were delivered, and then drink as soon as bar presses were not reinforced. Typical cumulative licking records are shown in Fig. 1.

Figure 2 shows, for every fifth session, the percentage of occasions on which each animal (a) drank after the last reinforcer in the CRF component of the schedule ("post-meal drinks"), and (b) drank within the CRF component of the schedule ("intra-meal drinks"). Post-meal drinking typically occurred after more than 80% of the CRF cycles, whereas intra-meal drinking occurred in less than 10% of the CRF cycles except in the case of S53 when the CRF component provided 21 pellets of food.

Because most drinks occurred only after a meal, it was possible to compute average water-intake-per-meal by dividing the total amount of water drunk in a session by the number of meals that were actually followed by drinks in that session. These data are also contained in Fig. 2, where it is apparent that there is no consistent relationship between water consumed per meal and size of meal. However, taking all sessions into consideration, more water was consumed after the 21-pellet meals than after the smaller meals. Water intake per meal averaged about 0.4 ml following 1, 3, 6, or 9-pellet meals; it averaged about 0.6 ml following 21-pellet meals.

The effect of the tone in the extinction interval was that the animals often went directly to the drinking tube when the tone came on

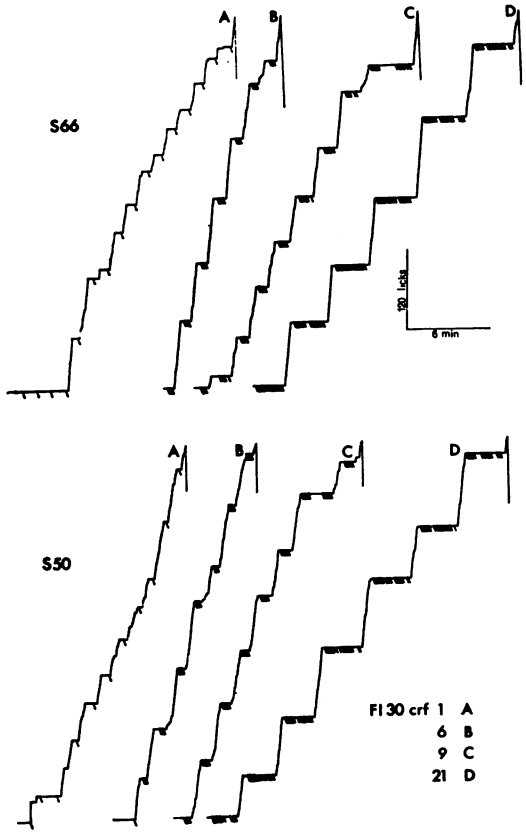

Fig. 1. Typical cumulative records of schedule-induced licking when 1, 6, 9, or 21 successive bar presses were reinforced with 45-mg Noyes pellets at the end of fixed 30-sec intervals. Bar-presses are not shown. Diagonal marks on the records indicate pellet deliveries.

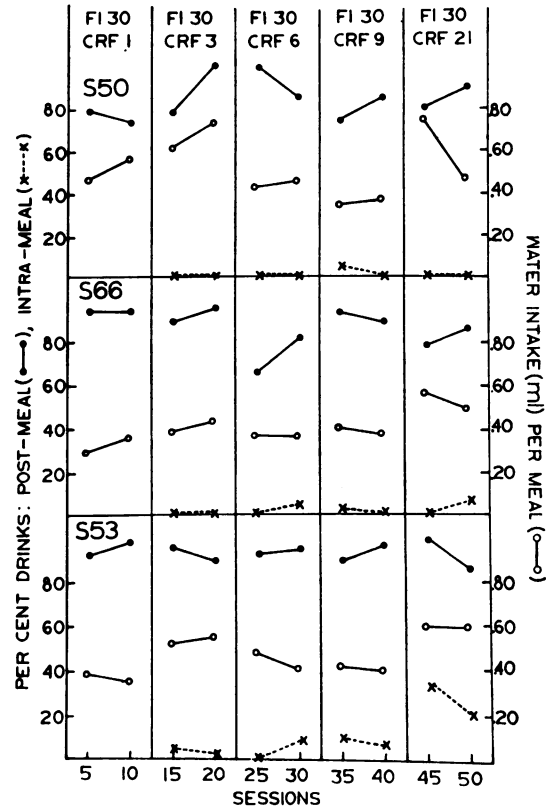

Fig. 2. Per cent post-meal and intra-meal drinks, and mean water intake per meal at five-session intervals under the designated conditions.

after the final (twenty-first) pellet in the CRF component, instead of pressing the bar before drinking. In the 15 cycles of Session 62 (the final session in which the extinction interval was signalled), animals S50, S53 and S66 bar pressed before drinking at the beginning of extinction periods only 5, 3, and 5 times respectively. No other systematic changes from terminal behavior in Session 52 were apparent.

Part B. All three animals learned to press Bar 2, and stopped their regular drinking after meals between Sessions 103 and 122. Figure 3 shows for S53 the number of post-meal (tone on) and intra-meal (tone off) drinks, the number of presses on Bar 2, and the total extinction time (maximum 1200 sec) per session. Before the period covered by the figure, when the extinction interval was limited to 30 sec maximum, the animal pressed Bar 2 no more than four times in a session. Comparison of the upper and lower parts of the figure shows that in 10 of the first 11 sessions, the animal drank in over half of the 20 extinction intervals (post-meal drinks) even though nearly all of these intervals were terminated by a Bar 2-press. By Session 122, S53 terminated most extinction intervals promptly without drinking (Fig. 4). The figure also shows typical terminal performance by S66. Animal S50 did not drink at all by this time. When S53 and S66 did drink, drinking was unpredictable both as to occasion and to duration, as Fig. 4 shows.

The effect of scheduling termination of extinction periods under a fixed-interval schedule was that drinking immediately increased. At first, drinking and responding on Bar 1 and Bar 2 occurred in random sequence in extinction, but eventually all animals typically drank at the beginning of extinction periods (*cf.* Fig. 1) and then pressed the bar (Bar 2) that terminated these periods. Drink durations varied directly with the fixed-interval schedules employed with Bar 2. Average water intakes per meal over the last two sessions for each animal with the 15-, 30-, and 60-sec intervals were: 0.42, 0.85, 1.27 ml (S50); 0.67,

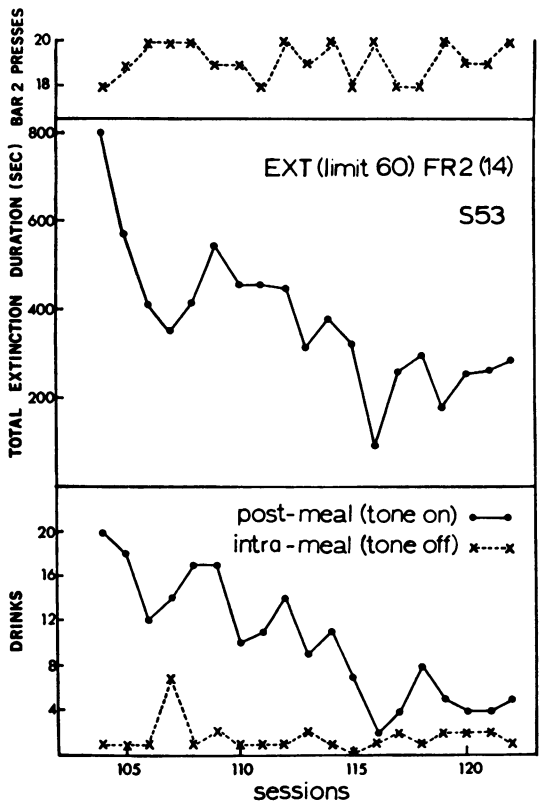

Fig. 3. Total intra-meal and post-meal drinks (max 20), extinction period duration (max 1200 sec) and presses on Bar 2 (max 20) when presses on Bar 1 were reinforced on FR 2 alternating with extinction intervals, and presses on Bar 2 terminated extinction intervals.

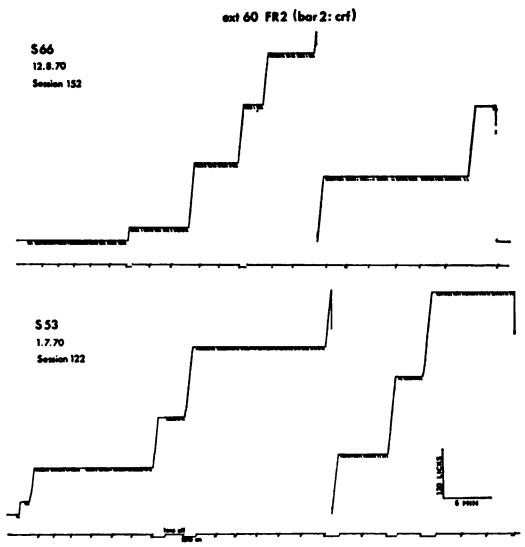

Fig. 4. Typical cumulative records of schedule-induced licking when presses on Bar 1 were reinforced on FR 2 alternating with extinction intervals, and presses on Bar 2 terminated extinction intervals. The lower trace shows the status of the tone: on during extinction, off during FR 2. Diagonal marks on the cumulative records indicate pellet deliveries.

0.66, 0.80 ml (S53); and 0.42, -, 0.60 ml (S60).

When the fixed-interval schedule on Bar 2 was 15 or 30 sec, drinking often occurred for the whole of those times so that the first press on Bar 2 after drinking usually terminated extinction. However, when the fixed-interval duration was 60 sec, drink durations were seldom this long: S50 and S66 typically stopped drinking and pressed Bar 2; S53 more frequently first oscillated between short drinks and presses on Bar 1. Unfortunately, records of bar presses were not obtained.

The extent to which extinction intervals were terminated by presses on Bar 2 is included in Fig. 5, which shows actual durations of extinction intervals in relation to the maximum (limit of extinction intervals) and minimum (FI values on Bar 2) values possible over the last five sessions of S50 and S53, with particular maxima and minima.

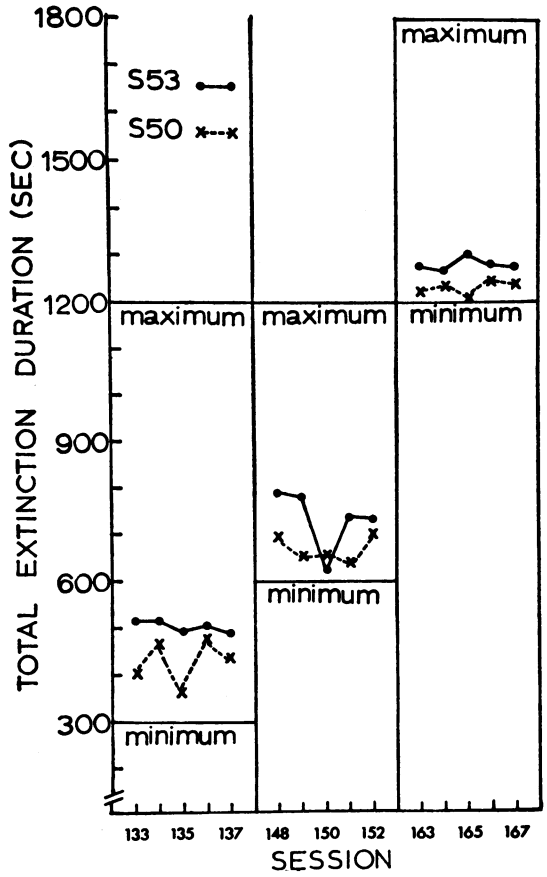

Fig. 5. Total extinction durations when presses on Bar 2 could terminate extinction periods after the designated minimum intervals.

DISCUSSION

The results of Part A confirm the suggestion of Keehn and Colotla (1970*b*) that schedule-induced drinking is occasioned by the absence of food (extinction-induced) rather than by direct stimulus effects of eating. They also confirm that "meal sizes" between one and nine 45-mg Noyes pellets do not systematically affect post-meal drink durations or quantities of water consumed per meal.

When meal size was extended to 21 pellets in the present study, most drinking continued to occur after meals (*i.e.*, in extinction intervals), and drink durations were sometimes longer than those following smaller meals. Thus, it is possible that there is a range over which meal sizes and drink durations co-vary. The upper limit to this range would be set by the maximum number of pellets that could be scheduled per meal without the regularity of post-meal drinking breaking down. There is such a maximum: when pellets are scheduled on continuous reinforcement there is no discernible order in the number of pellets eaten before a drink, or in the duration of drinks when they occur (Keehn and Colotla, 1970*b*).

Beginning with Falk's (1961) original demonstration, induced drinking has been established and maintained by *mixed* schedules of intermittent reinforcement (*e.g.*, FI 30-sec is equivalent to *mixed* EXT 30 FR 1). Our results show that schedule-induced drinking can be maintained by a schedule of reinforcement in which periods of availability and unavailability of food are separately signalled. This excludes "uncertainty" as a factor in the maintenance of schedule-induced drinking, although not necessarily in its establishment.

If schedule-induced drinking is occasioned by unavailability of food, then a response that reinstates the food schedule should gain strength relative to drinking (*cf.* Premack, 1965). The results of Part B show this to be the case, although the induced pattern of regular post-meal drinks of more or less predictable duration was slow to give way to the irregular drinking that occurs with unrestricted feeding. Likewise, if scheduled-induced drink durations are governed by the period of unavailability of food, then drinking should occur when the response that reinstates the feeding schedule is ineffective for

an interval, and should continue longer, the longer the interval. Our results show this to be the case within the limits used in the present study. With intervals of 5 min between reinforcements, reliable post-pellet drinking does not occur (*cf.*, Segal, Oden, and Deadwyler, 1965). Falk (1966*b*, 1969) has discussed the non-monotonic relationship between fixed-interval reinforcement time and quantity of fluid ingested.

Finally, the present study shows that drinking after eating is relative: given the opportunity to eat or drink, subjects acquired a response that enabled them to continue eating. This result complements an earlier one reported by Falk (1966*a*) wherein, given the opportunity to drink or engage in other activity after eating, his subjects acquired a response that enable them to drink. A possible conclusion from Falk's demonstration, that eating generates a need to drink, is not supported by the present results.

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