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DIVERSITY AND SUBSTITUTABILITY OF ADJUNCTIVE ACTIVITIES UNDER FIXED-INTERVAL SCHEDULES OF FOOD REINFORCEMENT

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Six rats received food contingent on pressing a lever on fixed-ratio 1, fixed-interval 30-second, and fixed-interval 60-second schedules, with concurrent access to a drinking spout, a running wheel, and a block of wood. Drinking, running, and chewing were monitored automatically, and these and other activities were observed directly during selected sessions. Because all sessions ended after delivery of 60 pellets, total time available for activities other than eating increased over the three schedules. Time spent contacting the lever and visiting the food tray increased in proportion to total available time, whereas the time spent in other activities changed in a complex manner such that drinking was the dominant adjunctive behavior in the 30-second condition, and running or chewing the dominant adjunctive behavior in five of six rats in the 60-second condition. General activity and grooming also occupied significant amounts of time. In a subsequent part of the experiment, running and chewing were prevented, and the majority of other activities, especially drinking and grooming, increased. The results show that (a) FI schedules of food reinforcement are accompanied by a wide variety of adjunctive activities; (b) the preferred activity differs according to the schedule duration; and (c) the extent to which activities substitute for one another is limited by the tendency for different activities to occupy different parts of the interreinforcement interval.

Key words: adjunctive behavior, food reinforcement, drinking, running, chewing, grooming, fixed-interval schedule, lever press, rat

There is good evidence that a variety of interreinforcement activities can occur under periodic schedules of food reinforcement. These "adjunctive" activities (Falk, 1971) include drinking, running in a wheel, licking at a stream of air, gnawing, tail-nibbling, grooming, head and body movements, manipulating and shredding paper, and attacking a conspecific (see reviews by Falk, 1971; Segal, 1972; Staddon, 1977). This raises the question of what determines the identity of the activity that develops in any particular case, and whether different adjunctive activities can substitute for one another. One possibility is that any activity within the animal's repertoire can expand to occupy the spare time made available by intermittent schedules of reinforcement, and that any activity can substitute for any other. Alternatively, certain activities may be preferentially linked to certain schedules, reinforcers, or species (see Hogan and Roper, *in press*), and substitutability may be limited by the nature of the activities in question.

Scarcely any consideration has been given to the problem of how adjunctive behavior is selected, but a few studies provide information relevant to the question of substitutability. Levitsky and Collier (1968) found that drinking and running, both of which occurred under a variable-interval schedule of food reinforcement, did not interact with one another, in the sense that neither increased when the other was removed. In a similar experiment, Segal, (1969) found that preventing running perhaps caused a slight increase in drinking, whereas preventing drinking did not affect running. Knutson and Schrader (1975) failed to find any interaction between drinking and aggres-

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sion, under fixed-interval schedules of food reinforcement.

On the other hand, cases of complete or almost complete substitutability have been reported anecdotally by Laties, Weiss, and Weiss (1969), and by Freed and Hymowitz (1969). Laties *et al.* found that tail-nibbling and gnawing on a block of wood were to a large extent substitutable in two rats tested on a differential-reinforcement-of-low-rate schedule; Freed and Hymowitz observed that two rats gave up drinking altogether under an FI 60-sec schedule of food reinforcement, and instead shredded the litter sheet with which the cage floor was lined. Drinking reappeared when the litter sheet was removed. In addition, several studies have shown that preventing the occurrence of adjunctive behavior can increase the frequency of operant responding (*e.g.*, Levitsky and Collier, 1968; Skuban and Richardson, 1975).

This survey suggests that some pairs of activities are more substitutable than others. One explanation for differences is that different activities tend to occur in different parts of the interreinforcement interval (*e.g.*, drinking usually occurs immediately after eating, whereas running and grooming are delayed with respect to eating), and two activities would not be expected to substitute for one another if their temporal distributions within the interval did not overlap (see Staddon, 1977). This idea accounts for at least some of the results cited above, but in most cases, detailed information about the temporal properties of the activities is lacking.

The present experiment was intended to obtain precise quantitative information about (a) the selection of particular adjunctive activities from the total behavioral repertoire; (b) the temporal distribution of different activities within the interreinforcement interval; and (c) the substitutability of different activities for one another. My hypothesis about selection was that, following Luce's Choice Axiom (Luce, 1959), behavior would develop adjunctively under intermittent schedules in proportion to its probability of occurrence in association with unconstrained consummatory behavior (*cf.* Hogan and Roper, *in press*). Accordingly, rats were allowed to obtain food first on a fixed-ratio 1 schedule (a baseline condition which involved relatively little constraint on the rate of eating), and then on FI 30-sec and 60-sec schedules, so that the probabilities of occurrence of different activities could be compared. The test chamber was fitted with a drinking spout, a running wheel, and a block of wood for chewing, and behaviors such as grooming and locomotor activity were recorded by an observer. The procedure of observing behavior directly also allowed calculation of the probabilities of occurrence of all possible activities as a function of time since reinforcement. Finally, the question of substitutability was addressed by removing the wheel and wood, to see which activities would substitute for running and chewing.

METHOD

Subjects

Twelve female hooded Lister rats, of mean weight 140 g (range 130 to 155 g), aged eight to nine weeks, were obtained from a commercial supplier. They were caged in four groups of three, of equal mean initial weight, in wire cages measuring 38 by 24 by 18 cm. Two groups (six rats in all) served as experimental subjects, the others as weight controls.

Apparatus

The operant chamber measured 22 by 20 by 19 cm, and was constructed of aluminum except for a clear Plexiglas front door, a Plexiglas rear wall, and a stainless-steel floor grid. A stainless-steel lever (3.8 by 1.8 by 1.4 cm) and a recessed food tray (5.3 by 6.0 by 3.5 cm), manufactured by Campden Instruments Ltd., were mounted on one side wall. Access to the food tray was gained by pushing open a Plexiglas flap (5.3 by 6.0 cm), which operated a microswitch. Food pellets (P. J. Noyes Co., Formula "A", 45 mg) were delivered to the tray by an automatic dispenser. The lever, mounted 11.0 cm to the right of the food tray, and 5.0 cm above floor level, operated a sealed-reed switch when depressed with a force of 0.15 N. A stimulus light was mounted above the lever, and another light inside the food-tray recess.

Mounted on the other two walls and the door of the chamber were, respectively, a running wheel, a block of wood, and a calibrated water bottle. (When the rat faced the food tray, the water was to its left, the wheel to its right, and the wood behind it.) The wheel (25.0 cm in diameter by 8.0 cm wide) was mounted outside the chamber on the rear wall, and could be entered through a circular hole in the wall (7.5 cm in diameter) just above floor level. Each revolution of the wheel closed a sealed-reed switch. The block of wood (3.0 by 2.5 by 1.3 cm) was screwed onto the face of a pigeon key (Campden Instruments Ltd.) mounted on the side wall of the chamber, and it protruded into the chamber at a height of 4.0 cm. Horizontal or vertical pressure on the wood caused the key to swing back, operating a sealed-reed switch. Extensive observations made during the experiment verified that the switch operated reliably when rats chewed the wood block, and only rarely in other circumstances (see Results). The water bottle was mounted on the door of the chamber, with a stainless-steel ball-valve spout projecting into the chamber at a height of 4.5 cm. Contact with the tip of the spout operated a drinkometer circuit, the rest of the spout being insulated by a Plexiglas sleeve. The water spout, the block of wood and the entrance to the wheel were approximately equidistant from the food tray (18, 22, and 18 cm away, respectively).

The chamber was continuously illuminated by a houselight in the center of the ceiling, and was placed in a sound-attenuating chest fitted with a one-way observation window. The chest was located in an air-conditioned room, and extraneous sounds were masked by background noise. Activities were monitored and schedules controlled by equipment located in a nearby room.

Procedure

Food deprivation. All rats were allowed free access to food and water and were weighed daily for 10 days. Thereafter, the six experimental rats were fed for about 1 hr per day, to keep their weights at a constant 75% to 80% compared with those of the control rats.

Pretraining. On Days 1 to 7, each rat was allowed to run for 20 min per day in a wheel similar to the one attached to the operant chamber. All rats learned to run, and the number of revolutions per 20 min averaged about 200 on Days 6 and 7.

On Day 8, each rat was placed in the operant chamber for 20 min, with the food-tray flap wedged open and 60 pellets in the tray. During this and succeeding pretraining sessions, access to the wheel was blocked, and the water spout and wood block were absent. On Day 9, the rats were magazine trained, and on Day 10 the lever-pressing response was shaped. On Days 11 to 13, each lever press resulted in delivery of a food pellet, *i.e.,* fixed ratio 1 (FR 1) schedule, and in offset of the stimulus light and onset of the tray light for 2.5 sec. The session was terminated after delivery of the sixtieth pellet by switching off the recording apparatus and withdrawing the lever.

Experimental testing. The experiment proper consisted of four conditions, designated FR 1, FI 30-, FI 60-, and FI 60-sec *water only,* respectively. In the first condition, food was delivered according to an FR 1 schedule, as in the last stage of pretraining, but with the running wheel, water spout, and wood block concurrently available. In the second condition the schedule was FI 30-sec, and in the third it was FI 60-sec, with the full range of alternative activities still available. In the FI 60-sec *water only* condition, the schedule remained the same as in the third condition, but the entrance to the wheel was closed and the wood block was removed, thereby preventing running and chewing. The FR 1 and FI 30-sec conditions each lasted for 15 sessions, but it proved necessary to continue the other conditions for 30 sessions to obtain stable behavior in all rats.

In order to compare the behavior directly associated with eating under different schedules and comparable degrees of satiation, all sessions were terminated after delivery of the sixtieth pellet. Hence, session duration increased from about 10 min in the FR 1 condition to about 30 min in the FI 30-sec condition, and about 60 min in the two FI 60-sec conditions. It follows that the total amount of time available for activities other than eating increased over the first three conditions. To allow for these differences in absolute amount of available time, the data on amount of time devoted to adjunctive behavior were analyzed in terms of percentages of session length, as well as in terms of absolute values.

Observation and recording of behavior. Lever presses, food-tray entries, water-spout contacts, wood-block displacements, wheel turns, and food-pellet deliveries were counted automatically and recorded on a cumulative recorder fitted with extra event pens. The level of water in the bottle was recorded at the beginning and end of each session.

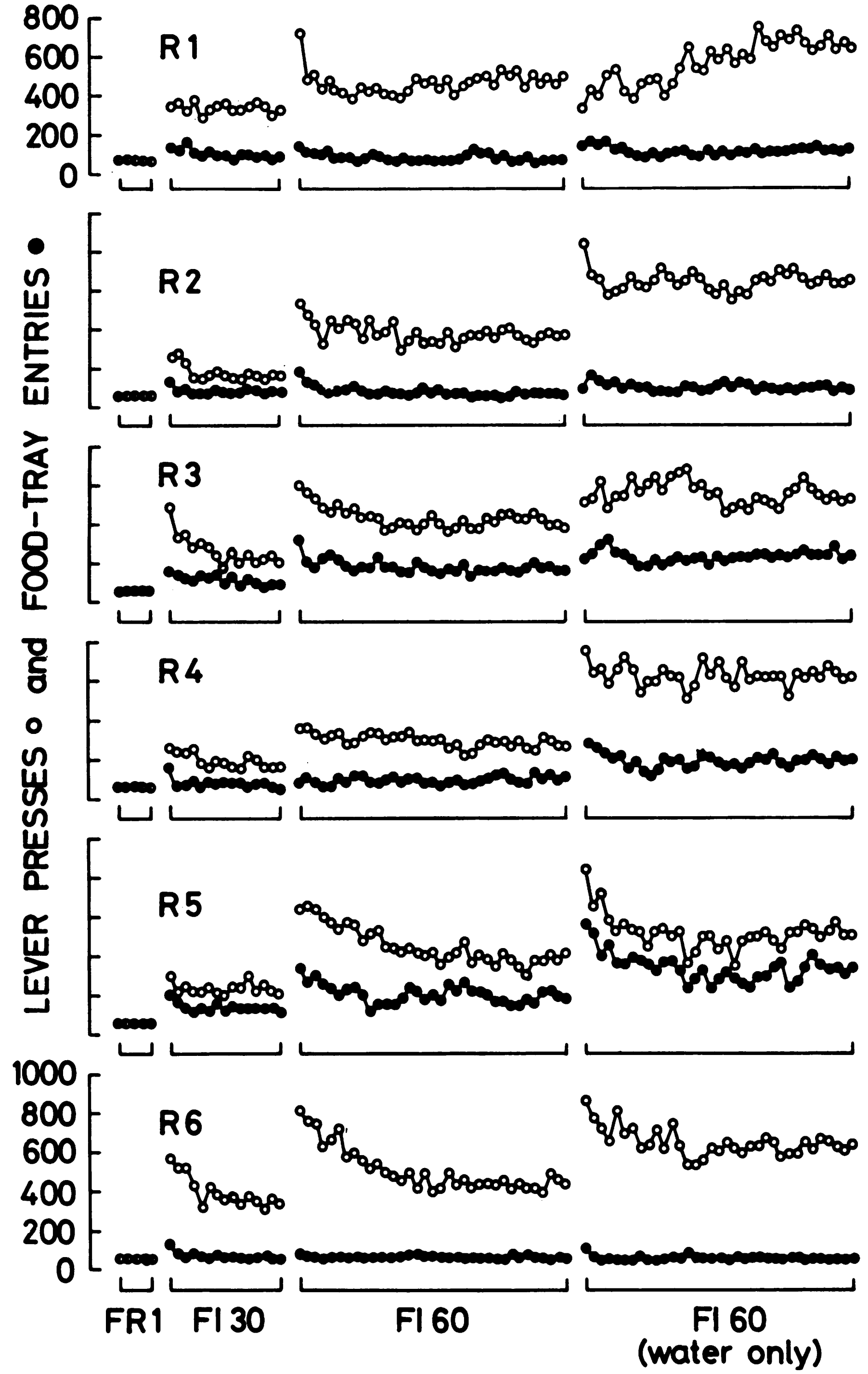

Fig. 1. Number of lever presses and food-tray entries per session, for each rat on each day of the experiment, excluding the first 10 days of the FR 1 condition.

Behavior was observed directly by the experimenter during the last five sessions of the FR 1 condition, and the last four sessions of each subsequent condition. The following activities were recorded on magnetic tape for subsequent computer analysis (White, 1971), via a manually operated keyboard: contacting the lever, eating, drinking, chewing the wood block, having at least head, shoulders, and both front paws in the running wheel, grooming, visiting the food tray at times other than to collect a food pellet (since only such visits could be considered adjunctive), and general activity, which consisted of rearing, sniffing, and moving about the chamber in an apparently undirected manner. These behavioral categories were, for all practical purposes, mutually exclusive and exhaustive. Observation did not seem to disrupt the rats' behavior, and scores monitored automatically during observation sessions did not differ consistently from those obtained in preceding sessions.

RESULTS

Figure 1 shows number of lever presses and food-tray entries per session for each rat on each day of the experiment (excluding Days 1 to 10 of the FR 1 condition, when the data were very similar to those obtained on Days 11 to 15). Asymptotic number of lever presses and tray entries increased in all rats from each condition to the next, but the increases in number of tray entries were relatively small, especially in Rats 2 and 6. A change from one condition to the next usually produced an abrupt increase in both scores, followed by a gradual decline to the new asymptotic level, but there were individual exceptions for both activities.

Figure 2 (Rats 1, 2, and 3) and Figure 3 (Rats 4, 5, and 6) show number of wheel turns, number of wood-block displacements, and volume of water consumed by each rat in each session. Water consumption increased in all six rats as the schedule changed from FR 1 to FI 30-sec, and declined in five of six rats (Rat 3 was the exception) during the FI 60-sec condition. When the wheel and wood block were removed (FI 60-sec *water only* condition), drinking recovered in the same five rats, to at least the level of the FI 30-sec condition. Scores for running and chewing were generally low during the FR 1 and FI 30-sec conditions, but increased markedly during the FI 60-sec condition. Again, Rat 3 was an exception to the general trend, in that its wheel-running score (which is not shown in Figure 2) was zero throughout. This is because Rat 3 avoided the wheel after catching its tail in it early in training.

Except in the FI 60-sec condition, drinking usually increased in a negatively accelerated manner within each condition. The same was generally true of running and chewing in the FI 30-sec and FI 60-sec conditions, but Figures 2 and 3 show clear exceptions. The asymptotic level of all three activities varied markedly among individual rats, and from day to day.

The asymptotic levels of different activities can be directly compared using the measures of time spent obtained from direct observation. Table 1 shows the absolute amount of time spent in each activity, as well as the session duration, for each rat on the last day of each condition. Figure 4 is derived from the same data, but shows time spent as a percentage of session duration.

Figure 4 shows that in the FR 1 condition eating was the preponderant activity in all rats, while contacting the lever and drinking accounted for most of the remaining time. In the FI 30-sec and FI 60-sec conditions, the percentage of time spent eating was progressively less (because number of food pellets remained constant while session duration increased), so that additional time was available for other activities. Figure 4 shows that none of this extra time was spent contacting the lever or visiting the food tray, because the percentage of time spent in these activities did not vary consistently over the first three conditions (*i.e.,* absolute time spent increased in proportion to session duration). In the FI 30-sec condition, all six rats spent most of the extra time drinking, but there were also increases in the percentage of time spent in the wheel, chewing, grooming, and engaging in general activity (*i.e.,* absolute time spent in these activities increased more than did session duration). In the FI 60-sec condition, the percentage of time spent drinking decreased in all six rats, and there were further increases in the remaining four activities. Of the latter, being in the wheel accounted for the largest proportion of the extra time in all rats except Rat 2 (which spent most time chewing), and Rat 3 (which continued to drink at a high rate). When the wheel and wood were removed (FI 60-sec *water only* condition), drinking again became the dominant activity in all rats. The percentage of time spent grooming also increased conspicuously, and there were small increases in contacting

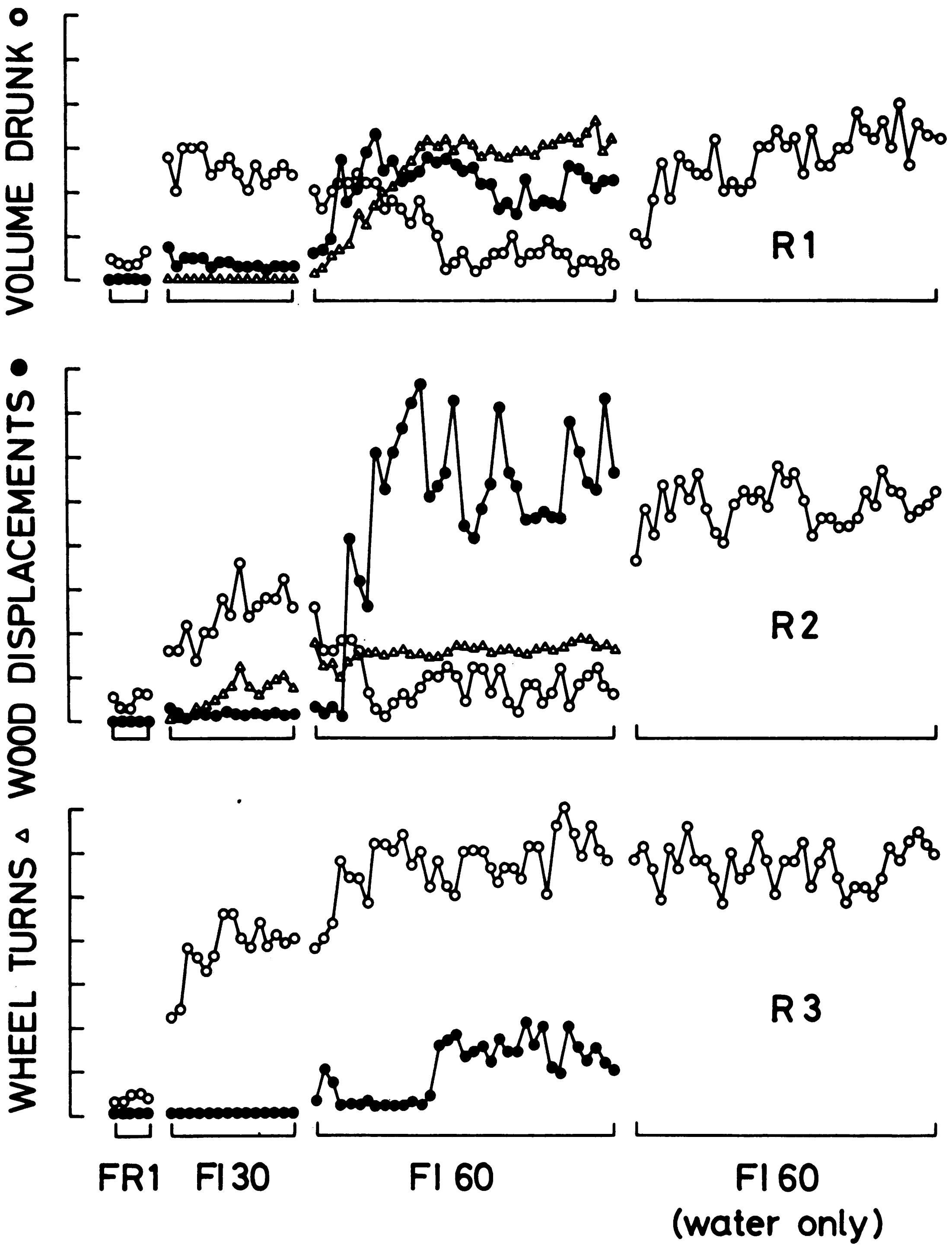

Fig. 2. Number of wheel turns (triangles), number of wood-block displacements (filled circles), and volume of water consumed (open circles) per session. Each division on the vertical axis corresponds to 200 wheel turns, 100 wood-block displacements, and 5 ml of water. Results are shown for Rats 1, 2, and 3, on each day of each condition, excluding the first 10 days of the FR 1 condition.

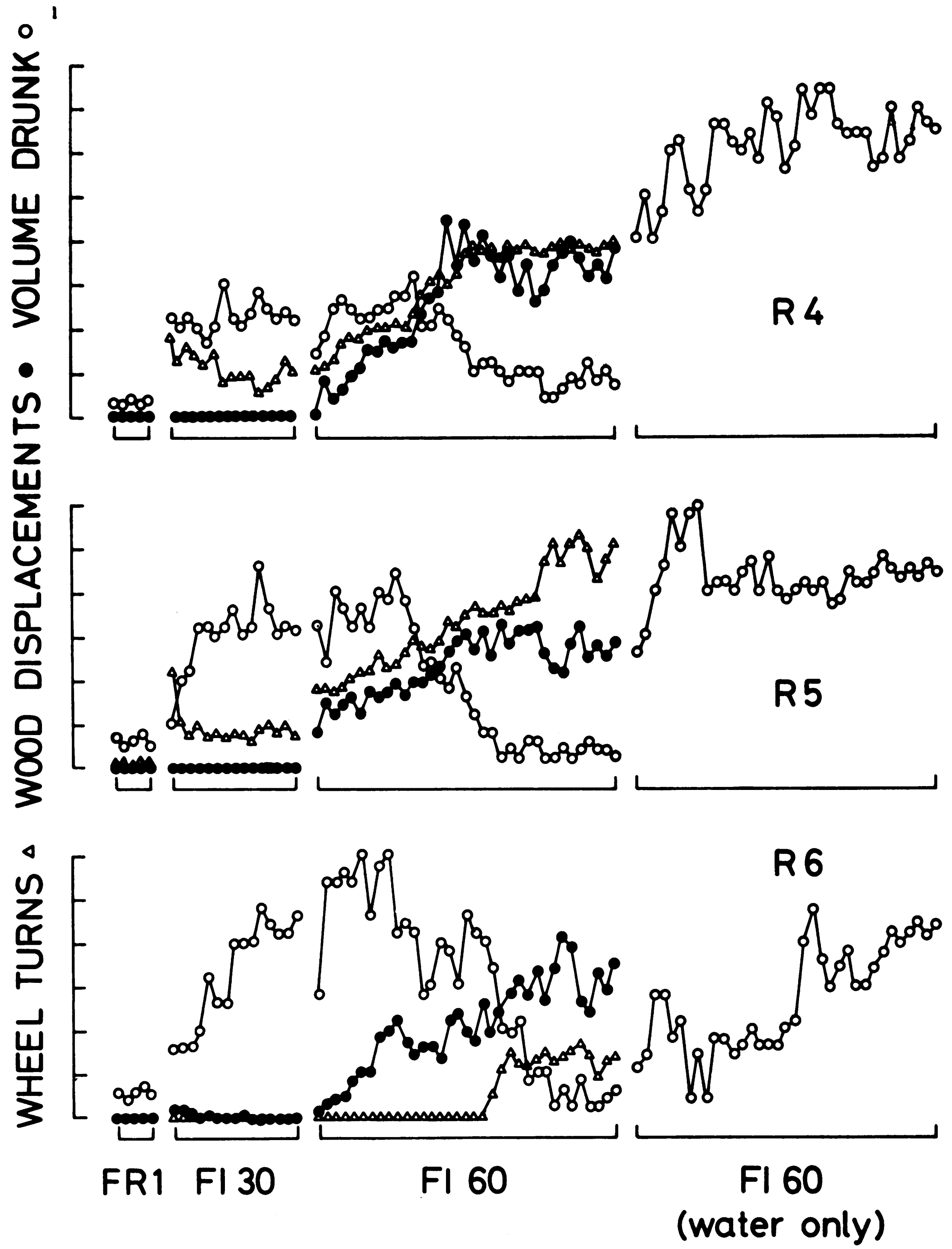

Fig. 3. Number of wheel turns (triangles), number of wood-block displacements (filled circles), and volume of water consumed (open circles) for Rats 4, 5, and 6. Other details as in Figure 2.

Table 1

Absolute time spent in each activity (seconds), and total session duration for each rat on the last day of each experimental condition.

		Behavior								
Condition	*Rat*	*Eat*	*Lever*	*Tray*	*Drink*	*Wheel*	*Chew*	*General Activity*	*Groom*	*Session Length*
FR 1	1	506	77	12	0	21	0	11	1	617
	2	429	90	7	128	26	0	24	6	723
	3	345	78	6	123	2	0	13	7	586
	4	272	99	0	85	11	0	3	1	486
	5	576	74	8	146	48	0	21	2	769
	6	409	88	1	34	6	0	5	2	553
FI 30-sec	1	567	300	30	521	152	16	399	107	1891
	2	532	203	22	747	508	0	137	81	2251
	3	423	166	26	1132	0	0	72	84	1905
	4	409	198	32	587	583	0	93	43	1953
	5	606	264	14	482	301	0	99	36	1894
	6	524	260	28	887	36	2	74	62	1965
FI 60-sec	1	563	397	50	25	1193	368	931	165	3690
	2	588	417	62	258	441	1982	297	304	4287
	3	449	490	109	1181	0	364	685	145	3664
	4	543	419	84	350	1145	282	516	226	3625
	5	543	398	55	43	1066	275	601	187	3666
	6	455	668	58	167	709	396	548	279	3820
FI 60-sec *water only*	1	523	525	67	874	NA*	NA*	445	770	3655
	2	542	380	65	1320			507	895	3782
	3	482	536	261	1299			457	600	3714
	4	513	502	180	1045			712	560	3756
	5	541	425	91	1206			609	593	3708
	6	543	919	139	807			555	669	3725

*NA = Not applicable.

the lever and visiting the food tray. There was no consistent difference in general activity between the FI 60-sec and FI 60-sec *water only* conditions.

In summary, the observational results show that the additional time, which was made available first by the schedule-related increases in session duration and then by removing the wheel and wood, was distributed widely but unevenly among the various possible activities. Furthermore, the changes in time spent that resulted from these manipulations were not simply proportionate increases in the frequencies of all available activities, according to the amount of extra time available for them. For example, time spent contacting the lever was, on average, slightly greater than time spent drinking in the FR 1 condition; when more time was made available for these activities by introducing an FI 30-sec schedule, drinking increased, but contacting the lever did not. Similarly, time spent in general activity exceeded time spent grooming in five of six rats in the FI 60-sec condition; when more time was made available for these activities by preventing running and chewing, grooming increased, but general activity did not.

Figure 5 shows a direct record of asymptotic performance in each condition, for one representative subject (Rat 4). Postreinforcement drinking occurred throughout the session in the FI 30-sec and FI 60-sec *water only* conditions, but only at the beginning of the session in the FI 60-sec condition. Wheel running occurred fairly consistently in the FI 30-sec and FI 60-sec conditions, while chewing occurred only in the FI 60-sec condition, and was at best sporadic. In this rat, chewing and running often occurred within the same fixed interval in the FI 60-sec condition, whereas in some animals, only one of these activities occurred in any one interval, and the subject alternated between activities throughout the session.

To assess consistent within-session changes in behavior, time spent in each activity was computed for successive 5-sec intervals through-

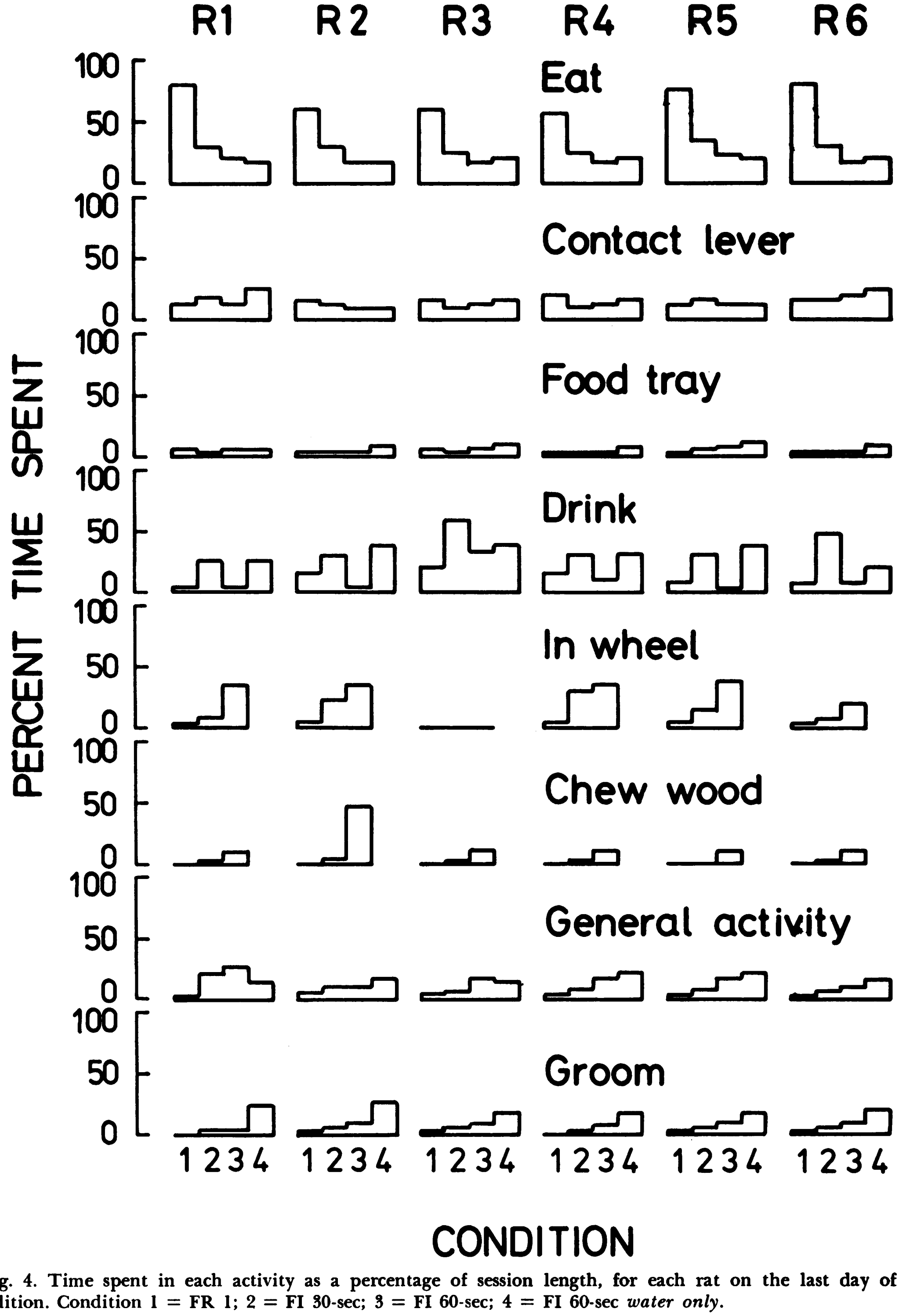

Fig. 4. Time spent in each activity as a percentage of session length, for each rat on the last day of each condition. Condition 1 = FR 1; 2 = FI 30-sec; 3 = FI 60-sec; 4 = FI 60-sec *water only*.

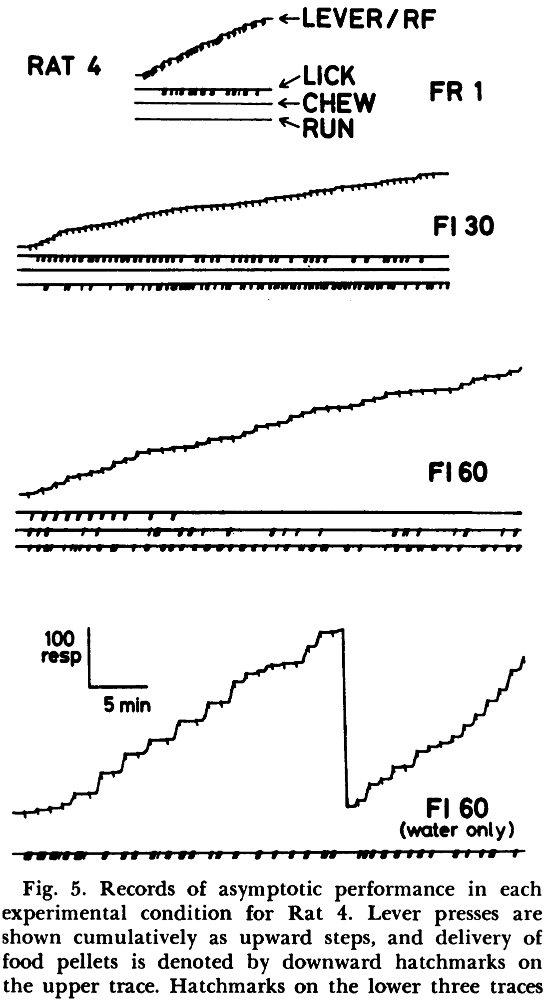

Fig. 5. Records of asymptotic performance in each experimental condition for Rat 4. Lever presses are shown cumulatively as upward steps, and delivery of food pellets is denoted by downward hatchmarks on the upper trace. Hatchmarks on the lower three traces show, respectively, water-spout contacts, wood-block displacements, and wheel turns. A complete session is shown in the FR 1 and FI 30-sec conditions, and the first two thirds of a session in the FI 60-sec and FI 60-sec *water-only* conditions.

out the last session in each condition. The only consistent effect was that drinking declined within the session in all six rats in the FI 60-sec and FI 60-sec *water only* conditions.

The sequence of events occurring during the interreinforcement intervals is shown more clearly in Figure 6, where the frequency of occurrence of each activity is plotted at 1-sec intervals from the time at which a food pellet was delivered. Results are shown for two representative subjects (Rats 1 and 4) from the last session in each of the three FI conditions. In the FI 30-sec condition, the bout of eating (E) at the end of the fixed interval was followed immediately by drinking (D); then by running in the wheel (W) and general activity (A); and finally by contacting the lever (L). In the FI 60-sec condition, the postreinforcement time made available by the complete (Rat 1) or partial (Rat 4) cessation of drinking was filled by general activity (A), not by running (W) or chewing (C). However, running did occur later in the interval in both rats, and chewing occurred later still in Rat 1. In the FI 60-sec *water only* condition, drinking consistently followed eating, and was itself followed first by general activity, and then by grooming (G). Thus, the results show that general activity could occur at almost any time after eating, whereas other activities occurred only in particular parts of the interreinforcement interval. The latter conclusions were also consistent with the results of the other four subjects, not shown in Figure 6.

All rats did run during most of the time that they were in the wheel. Drinking involved ingestion of water in the normal manner, though some rats occasionally chewed or pawed at the spout as well. Wood-block displacements reflected sustained and vigorous gnawing, as a consequence of which the block had to be replaced from time to time in the FI 60-sec condition. (The block was also occasionally displaced by "accidental" contacts, especially during rearing, but these were too rare to alter the results significantly). None of the activities developed a stereotyped appearance.

DISCUSSION

One aim of the present experiment was to compare quantitatively the activities that accompany eating under an FR 1 schedule with those that develop as adjunctive behavior under fixed-interval schedules. Sessions were terminated on receipt of 60 food pellets in each schedule condition, so that session length increased from about 10 min in the FR 1 condition to about 30 min in the FI 30-sec condition, and about 60 min in the FI 60-sec conditions. Thus, the imposition of successively longer FI schedules increased the total amount of time available for activities other than eating, as well as introducing successively longer interreinforcement intervals. This dual effect of the procedure means that care must be taken in ascribing the results to changes in schedule *per se*.

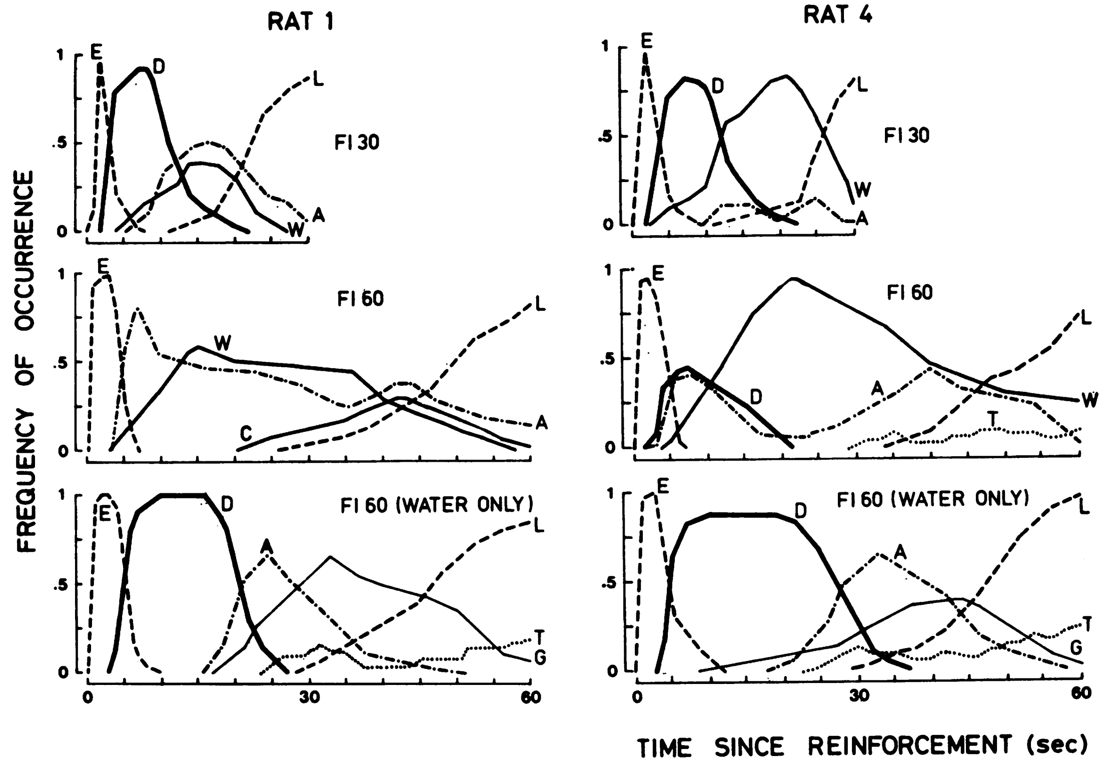

Fig. 6. Frequency of occurrence of each activity as a function of time since delivery of a food pellet, for Rats 1 and 4 in each of the three FI conditions. E = eat; D = drink; A = general activity; W = in running wheel; G = groom; T = visit food tray; C = chew wood; L = contact lever. Activities in which frequency of occurrence failed to exceed 0.05 have been omitted in the interests of clarity.

Given successive increases in the total time available for activities other than eating, the absolute time spent in these activities could have changed in four alternative ways: (1) only one or a few of the activities observed in the FR 1 condition might have increased to fill the extra time; (2) all activities observed in the FR 1 condition might have increased, in proportion to their initial levels of occurrence; (3) all activities observed in the FR 1 condition might have increased, but not in proportion to their initial levels of occurrence; or (4) activities might have appeared that were not observed at all in the FR 1 condition. A result of the first type is implied by the theory that adjunctive behavior is induced by "thirst" (*e.g.*, Stein, 1964), because this theory predicts an especially large increase in drinking, whereas a result of the second or third type is predicted by the theory that adjunctive behavior is induced by a more general motivational state such as "arousal", "emotion", or "frustration", because these states would be expected to have a nonspecific facilitating effect on behavior (see Killeen, 1975). A result of the second type is also specifically predicted by Luce's Choice Axiom (Luce, 1959), and results of this type have been obtained in practice by Jacobson and Premack (1970) and Dunham (1972). These authors measured the extent to which clockwise running would substitute for anticlockwise running, and drinking for running, respectively, when one or other of each pair of activities was prevented from occurring in a relatively restricted environment. There is no definite precedent in the literature for a result of the fourth type, but aggression may be an example of an activity that can be induced by intermittent schedules of reinforcement despite a very low level of occurrence in association with unconstrained eating.

In fact, the present results were of the third type. In the FI 30-sec and FI 60-sec conditions, the absolute time spent in all observed alternatives to eating (except for drinking, which is discussed below) increased progressively in comparison to the scores in the FR 1 condition, but the increases were not in direct proportion to the frequencies of occurrence of the same activities in the FR 1 condition. No activity appeared that was never observed in the FR 1 condition, though the frequency of occurrence of chewing in the FR 1 condition was extremely low. Hence, if adjunctive behavior is defined as behavior that occurs systematically in association with intermittent schedules of reinforcement, the results show that adjunctive behavior in the rat can consist of many different activities. However, the results do not provide any simple quantitative rule for predicting the extent to which particular activities will develop in any one case, using behavior under an FR 1 schedule as a baseline.

On the other hand, the results do not allow the conclusion that the interreinforcement activities were "schedule-induced" or "schedule-dependent", because changes in the schedule were confounded with changes in session duration. Hence, if schedule-induction or schedule-dependence are considered to be defining characteristics of adjunctive behavior (as implied by Falk, 1971), we must reserve judgement about the true status of the activities, such as running, grooming and chewing, that occurred in the present experiment. Staddon (1977) pointed out that running may not be schedule-induced, because it has a very high frequency of occurrence even in the complete absence of food; but this view requires confirmation by means of an experiment in which total time available for running is held constant, while schedule is systematically varied.

When time spent in each activity was calculated as a proportion of session length over the first three conditions, all activities except contacting the lever and visiting the food tray changed consistently. In other words, the absolute time spent contacting the lever and visiting the food tray increased in direct proportion to session duration, whereas the other alternatives to eating (except for drinking in the FI 60-sec condition) increased in excess of session duration. Lever pressing and tray visiting were also anomalous, in that they tended to decline over the first few sessions of each new condition, whereas other activities tended to increase (see Figures 1, 2, and 3). These results support the view that activities occurring at the end of the interreinforcement interval (including operant responses) are controlled by different factors from activities occurring earlier in the interval, and hence suggest that the latter activities do not occur because they are adventitiously reinforced by food (*cf.* Staddon, 1977, pp. 127-128). In the present experiment, tray visits occurred almost exclusively between bouts of lever pressing, and they may well have been "superstitious", since the response of pushing open the food-tray flap was a necessary precursor of obtaining food.

Staddon (1977) not only distinguished "terminal" responses (*i.e.*, those occurring at the end of the interval) from truly "adjunctive" activities, but also divided the latter into two subclasses. These are "interim" activities, such as drinking, that occur immediately after delivery of the reinforcer, and "facultative" activities, such as running and grooming, which occur later in the interval. The present results provide confirming evidence that different activities consistently occupy different parts of the interval, but at the moment there is little independent evidence for Staddon's claim that these activities constitute different classes of behavior. However, the results do show that Staddon's hypothetical classes of behavior do not contain exclusive sets of activities, because general activity was able to occur both in the "interim" and in the "facultative" part of the interval.

In the present experiment, drinking increased between the FR 1 and FI 30-sec conditions, but declined in five of the six rats in the FI 60-sec condition. This result conflicts with numerous studies showing that drinking persists with interreinforcement intervals in excess of 1 min (see Falk, 1971; Staddon, 1977). The obvious explanation of the discrepancy is that running and/or chewing competed with drinking in the present study, and this explanation is confirmed by the fact that drinking recovered in the FI 60-sec *water only* condition, when running and chewing were prevented. Running seems to have been the primary competitor in four of the five rats, and chewing in the fifth rat (*i.e.*, Rat 2; see Figures 2, 3, and 4).

The question remains as to why running or chewing successfully displaced drinking in the FI 60-sec condition, but not in the FI 30-sec condition. One possibility is that because drinking is subject to short- and long-term satiation effects, it becomes less attractive relative to running or chewing at long interval durations. Short-term satiation of drinking (*i.e.,* satiation within a single interreinforcement interval) is suggested by evidence that bout-lengths of air-licking exceed those of normal drinking under comparable schedules (Mendelson and Chillag, 1970), and that normal drinking can be elicited at any point in the interval if access to water is restricted to that point (*e.g.,* Daniel and King, 1975). Long-term satiation (*i.e.,* satiation within the session) is suggested by the results of the present experiment in the FI 60-sec and FI 60-sec *water only* conditions, in which drinking declined as the session progressed. Thus, it may be the case that the rat will tolerate grossly excessive drinking only if no suitable alternative activity is available. But then it remains to be shown why running or chewing are "suitable" alternatives, whereas grooming and general activity, which could have displaced drinking, are not.

An alternative approach is to account for differences in substitutability in terms of the temporal distributions of the relevant activities. For some reason, running is always delayed with respect to eating (*e.g.,* Levitsky and Collier, 1968), even when there is no competition from drinking (Skinner and Morse, 1957). Drinking typically occupies the part of the interval immediately after eating, but it extends further into the interval due to increases in its bout length at moderate to long interval durations (*e.g.,* Hawkins, Schrot, Githens, and Everett, 1972). Consequently, drinking and running would not be expected to overlap if the interreinforcement interval is short, whereas they would be expected to overlap if the interval is moderately long. It follows that drinking and running would be expected to compete with one another only in the latter case. This interpretation is consistent with the results shown in Figure 6, which show substantial overlap between the distributions of running and drinking in the two FI conditions; the same argument can be applied to the interaction between chewing and drinking.

However, this "temporal competition" hypothesis fails to explain why drinking was virtually abolished in the FI 60-sec condition, rather than merely being confined to the first 10 to 15 sec of the interval (as in the FI 30-sec condition), since running never occupied the period immediately after eating. It is therefore necessary to postulate that the rat prefers not to drink at all, rather than to drink in shorter bouts than would occur if no alternative activity were available.

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