WITHIN-SESSION CHANGES IN RESPONDING DURING SEVERAL SIMPLE SCHEDULES

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Pigeons' key pecking was reinforced by food delivered by several fixed-interval, variable-ratio, and differential-reinforcement-of-low-rate schedules. Rate of responding, number of responses per reinforcer, length of postreinforcement pause, running response rate, and the time required to collect an available reinforcer changed systematically within sessions when the schedules provided high rates of reinforcement, but usually not when they provided low rates. These results suggest that the factors that produce within-session changes in responding are generally similar for different schedules of reinforcement. However, a separate factor may also contribute during variable-ratio schedules. The results question explanations for within-session changes that are related solely to the passage of time, to responding, and to one interpretation of attention. They support the idea that one or more factors related to reinforcement play a role.

Key words: within-session responding, fixed-interval schedule, variable-ratio schedule, differential reinforcement of low rates of responding, response rate, postreinforcement pause, responses per reinforcer, key peck, pigeon

Responding may change systematically within experimental sessions, often increasing to a peak and then decreasing (McSweeney, Hatfield, & Allen, 1990). These within-session changes deserve further study for several reasons. First, they are as large as, or larger than, those usually studied by operant psychologists. For example, Catania and Reynolds (1968, Experiment 1) observed only a doubling of overall response rate when they changed the programmed rate of reinforcement from 8.4 to 300 reinforcers per hour. The rate of key pressing reported by McSweeney et al. (1990) changed by an average of 450% within the session. Second, within-session changes are reliable, usually occurring for each individual subject responding during each session (McSweeney & Hinson, 1992). Third, the changes are orderly. The changes peak at the same time in the session regardless of whether subjects press levers for Noyes pellets or keys for sweetened condensed milk. Finally, as discussed elsewhere, within-session changes may have important implications for theory and methodology in operant psychology (McSweeney & Roll, 1993).

The present experiments examined within-session changes in responding during several fixed-interval (FI, Experiment 1), variable-ratio (VR, Experiment 2), and differential-reinforcement-of-low-rate (DRL, Experiment 3) schedules. Responding on these schedules was examined to help to determine the generality of within-session changes. If these changes occur only under limited conditions, then they reflect processes peculiar to those conditions. If they occur more generally, they may have fundamental implications for theory and methodology (McSweeney & Roll, 1993). These particular schedules were selected because they provide different feedback functions between responding and reinforcement (Morse, 1966). Finding within-session changes for schedules with different properties will extend their generality more than finding changes under relatively similar schedules.

The experiments examined responding on each schedule at several different parameters. This was done to determine whether the same factors produced within-session changes for each of the different schedules. If within-session patterns of responding change in similar ways with changes in the obtained rates of reinforcement for all of the schedules, then similar variables may produce the changes for all of these schedules. If responding changes in different ways for different schedules, then different factors may be involved.

The present experiments examined how several different measures of responding

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changed within sessions. Studying changes in measures such as the length of the postreinforcement pause, running response rate, number of responses per reinforcer, and the time required to collect an available reinforcer can help to clarify the nature of the dynamic changes that occur within sessions. For example, Collier (1962a) reported that the rate of sucrose-reinforced lever pressing was relatively constant within the session when the subject was responding (running response rate). The within-session decreases in lever pressing that he observed occurred mainly because the length of the postreinforcement pause increased.

Finally, as will be discussed later, these experiments may help to determine the factors that produce within-session changes in responding. Research on within-session changes in responding has often confounded the effects of responding, reinforcement and the passage of time. That is, as time has passed in the session, the subjects have responded and they have received reinforcement. The present experiments may help to clarify which of these factors contribute to producing within-session changes. If factors related to the passage of time produce these changes, then the changes should be relatively independent of the choice of schedule when plotted in constant time units. If factors related to responding produce the changes, then these changes should occur differently for schedules that support different rates of responding (e.g., VR and DRL). If factors related to reinforcement contribute, then within-session patterns should be altered by changes in the obtained rates of reinforcement.

EXPERIMENT 1

Method

Subjects. The subjects were 4 experimentally experienced pigeons maintained at approximately 85% of their free-feeding weights by postsession feedings.

Apparatus. The experiment was conducted in a three-key operant conditioning chamber for pigeons. The chamber measured 30 cm by 35.5 cm by 27 cm and was contained in a sound-attenuating enclosure. Response keys (2.5 cm diameter) were Plexiglas panels, located 7 cm apart and 3 cm from the ceiling. The left and right keys were 6.5 cm from the

side walls. They were operated by a force of approximately 0.25 N. An opening (5 cm by 4 cm), directly below the center key and 8 cm above the floor, allowed access to the food hopper. A light behind a Plexiglas panel (4 cm diameter, 1 cm below the ceiling and 0.5 cm from the right side), served as a houselight. (A treadle was located on the floor directly below the left and right keys. The treadles will not be described because they were not used in this experiment.) An exhaust fan mounted on the outside wall of the chamber masked extraneous noises. A SYM[®] microcomputer, located in another room, controlled the experimental events and recorded the data.

Procedure. The subjects had pecked keys in previous experiments. Therefore, they were immediately exposed to the experimental procedure. During the first condition, pecking the left key produced reinforcers (5 s of access to mixed grain) according to an FI 30-s schedule. The response key was illuminated with red light throughout the 60-min sessions. The houselight was also illuminated, and both lights were extinguished when the magazine was presented. Sessions were conducted five to six times per week. When subjects had responded on the FI 30-s schedule for 30 sessions, they were placed on FI 120-s, FI 240-s, FI 15-s, and FI 60-s schedules, in that order. Each parameter was presented for 30 sessions.

Results and Discussion

Table 1 presents the mean rates of responding (responses per minute) and the mean obtained rates of reinforcement (reinforcers per hour) for each subject responding on each schedule. Rates were calculated by dividing the total number of responses emitted, or the number of reinforcers obtained, during a session by the total session time (excluding the time of magazine presentation). The means presented in Table 1, as well as the rest of the data presented in this paper, are the averages of the results obtained during the last five sessions for which each schedule was available. Table 1 shows that the rates of responding generally decreased and the obtained rates of reinforcement increased with increases in the programmed rates of reinforcement.

Figure 1 presents the cumulative records for the first 10 min of individual sessions for Subject 101 responding on the FI 30-s, FI 60-s, and FI 120-s schedules. (Data generated by

Fig. 1. Cumulative records of responding during the first 10 min of an individual session for Subject 101 responding on the FI 30-s, FI 60-s, and FI 120-s schedules.

Table 1

Mean rate of key pecking (R) (pecks per minute) and mean obtained rates of reinforcement (SR) (reinforcers per hour) for each subject responding on each of the FI schedules. Rates were calculated over the last five sessions for which that schedule was available in Experiment 1.

Subject		Schedule				
		FI 15	FI 30	FI 60	FI 120	FI 240
10	R	16.1	15.4	28.0	48.2	28.2
	SR	132.2	87.0	57.8	29.2	14.0
20	R	10.8	13.0	11.7	25.1	34.9
	SR	130.8	77.4	46.4	28.6	13.8
101	R	24.5	26.5	48.9	64.5	67.0
	SR	211.6	98.8	58.6	29.0	14.0
2560	R	36.2	17.6	58.7	47.7	63.7
	SR	196.8	111.3	59.0	29.0	14.0
<i>M</i>	R	21.9	18.2	36.9	46.4	48.5
	SR	167.9	93.6	55.5	29.0	14.0

Subject 101 on these schedules were arbitrarily selected for presentation.) The cumulative records in Figure 1 are similar to those reported by other authors when subjects respond on FI schedules (e.g., Ferster & Skinner, 1957).

Figure 2 presents the rates of responding during successive 5-min intervals for each subject and for the mean of all subjects responding on the FI 15-s and FI 30-s schedules. A standard format is used in this and most of the following figures. The left axes present the results for the mean or median of all subjects. The right axes present the results for individual subjects. Different scales are sometimes used on the ordinates of the left and right axes because of the greater variability in the data from individual subjects. For the temporal measures of behavior to be presented later (e.g., postreinforcement pauses), medians and non-parametric statistics were used because these measures may not be normally distributed. For all other measures, including the response rates presented in Figure 2, means and parametric statistics are used. To make the presentation of the data more manageable, results are presented only when the measure of behavior changed significantly and systematically within sessions. Results for the other schedules appear

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Each set of axes presents the results for a single schedule. Results have been taken from the 26th session for which the schedule was presented.

Fig. 2. Rates of responding (responses per minute) during successive 5-min intervals for the FI 15-s and FI 30-s schedules. Results for the mean of all subjects appear on the left axes. Those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Note that an S precedes each subject's identifying number.)

in the Appendix, which contains the results for the mean or median of all subjects responding on all schedules.

Responding mainly decreased within sessions for the FI 15-s and FI 30-s schedules. One-way within-subject analyses of variance applied to the rates of responding by individual subjects during successive 5-min intervals were significant for the FI 15-s schedule, $F(11, 33) = 19.38, p < .001$, and the FI 30-s schedule, $F(11, 33) = 9.64, p < .001$, but not for the FI 60-s schedule, $F(11, 33) = 0.46, p < .91$, or the FI 120-s schedule, $F(11, 33) = 1.82, p < .09$. Rates of responding also changed statistically significantly for the FI 240-s sched-

ule, $F(11, 33) = 2.15, p < .044$, but these results are not presented here because the changes were not systematic or consistent across subjects. Throughout this paper, results will be considered to be statistically significant when $p < .05$.

Figure 3 presents the running response rates during successive 5-min intervals for the FI 15-s and the FI 30-s schedules. Running rate is the rate at which subjects responded when they were responding. It was calculated by dividing the number of pecks during an inter-reinforcer interval by the time from the first to the last peck in that interval. Running rates increased briefly and then decreased within the

Fig. 3. Running response rates (responses per minute) during successive 5-min intervals for the FI 15-s and FI 30-s schedules. Results for the mean of all subjects appear on the left axes; those for individual subjects appear on the right. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

session for the mean of all subjects responding on the FI 15-s and the FI 30-s schedules. One-way within-subject analyses of variance applied to the rates for individual subjects responding during successive 5-min intervals were significant for the FI 15-s schedule, $F(11, 33) = 4.15, p < .001$, and the FI 30-s schedule, $F(11, 33) = 10.13, p < .001$, but not for the other schedules, $F(11, 33) = 0.21, p < .995$; $F(11, 33) = 0.64, p < .784$; and $F(11, 33) = 1.60, p < .144$ for the FI 60-s, FI 120-s, and FI 240-s schedules, respectively.

Figure 4 presents the length of the postreinforcement pause during successive 5-min intervals for the FI 15-s and FI 30-s schedules.

The postreinforcement pause was the time that elapsed between the end of the last reinforcer and the first response in the next interreinforcer interval. Median postreinforcement pauses generally increased within the session for the FI 15-s and FI 30-s schedules, but the median results disguise some variability from interval to interval for individual subjects. Friedman analyses of variance by ranks applied to the postreinforcement pauses during successive 5-min intervals for individual subjects showed that these pauses changed significantly within the session for the FI 15-s schedule (Friedman test statistic = 29.12, $df = 11, p < .002$) and FI 30-s schedule (Friedman

Fig. 4. Length of postreinforcement pauses (seconds) during successive 5-min intervals for the FI 15-s and FI 30-s schedules. Results for the median of all subjects appear on the left axes; those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S).

test statistic = 24.92, $df = 11$, $p < .009$), but not for the other schedules (Friedman test statistic = 16.96, $df = 11$, $p < .109$ for the FI 60-s schedule; Friedman test statistic = 12.92, $df = 11$, $p < .298$ for the FI 120-s schedule; Friedman test statistic = 13.96, $df = 11$, $p < .235$ for the FI 240-s schedule).

Figure 5 presents the time taken to collect an available reinforcer during successive 5-min intervals for the FI 15-s and FI 30-s schedules. Collection time was measured by the difference between the time at which a reinforcer became available and the time at which it was collected. Collection time was longer at the end of the session than at the beginning. However,

again, the results for the median mask variability from interval to interval for individual subjects. Friedman analyses of variance by ranks applied to the median collection times for individual subjects in successive 5-min intervals showed that these times changed significantly within the session for the FI 15-s schedule (Friedman test statistic = 26.35, $df = 11$, $p < .006$) and FI 30-s schedule (Friedman test statistic = 33.64, $df = 11$, $p < .001$), but not for the FI 60-s schedule (Friedman test statistic = 16.64, $df = 11$, $p < .119$), FI 120-s schedule (Friedman test statistic = 15.92, $df = 11$, $p < .144$) or the FI 240-s schedule (Friedman test statistic = 5.74, $df = 11$, $p < .890$).

Fig. 5. The time required to collect an available reinforcer (seconds) during successive 5-min intervals for the FI 15-s and FI 30-s schedules. Results for the median of all subjects appear on the left axes; those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S).

Figure 6 presents the number of responses per reinforcer during successive 5-min intervals for the FI 15-s and FI 30-s schedules. The number of responses per reinforcer decreased within the session for these schedules. One-way within-subject analyses of variance applied to the number of responses per reinforcer by individual subjects during successive 5-min intervals were significant for the FI 15-s schedule, $F(11, 33) = 32.42$, $p < .001$, and the FI 30-s schedule, $F(11, 33) = 7.52$, $p < .001$. Responding also changed statistically significantly within sessions for the FI 120-s schedule, $F(11, 33) = 6.29$, $p < .001$, and the FI 240-s schedule, $F(11, 33) = 6.12$, $p < .001$;

these changes have not been plotted because they were fluctuations in responding from 5-min interval to 5-min interval rather than a systematic change in responding within the session (see Appendix). Responding did not change significantly for the FI 60-s schedule, $F(11, 33) = 1.62$, $p < .140$.

All of the preceding results were plotted in terms of 5-min intervals. This choice of interval might have contributed to the failure to find significant within-session changes for the schedules that provided lower rates of reinforcement. Many studies have reported that responding is faster later in the interreinforcer interval than it is earlier when subjects respond

Fig. 6. Responses per reinforcer during successive 5-min intervals for the FI 15-s and FI 30-s schedules. Results for the mean of all subjects appear to the left of those for individual subjects. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

on FI schedules (e.g., Schneider, 1969). Such changes in responding are readily apparent in the present data (see Figure 1). These changes should not create problems for the schedules that provide high rates of reinforcement. Each 5-min interval will contain many interreinforcer intervals and therefore will sample both the low rate of responding after reinforcement and the high rate before reinforcement. This method of analysis might add variance to the data for the schedules that provide low rates of reinforcement. For example, different 5-min intervals might sample predominantly high or low rates of responding when subjects respond on FI 240-s schedules. If the same 5-min interval sampled high rates for some subjects and

low rates for other subjects, then enough variance might be added to the data so that the within-session changes in responding would not be significant when plotted in terms of 5-min intervals, even though they would be significant when plotted in terms of number of reinforcers.

To test this idea, all of the measures of responding reported above were reanalyzed in terms of successive reinforcers for the schedules that provided low rates of reinforcement. Results were analyzed in terms of four-, two-, and one-reinforcer bins for the FI 60-s, FI 120-s, and FI 240-s schedules, respectively. This was done to yield a manageable number of bins (approximately 15 per session) for each

schedule. The conclusions reached above were not changed by this reanalysis. For example, one-way within-subject analyses of variance applied to the response rates of individual subjects during successive blocks of reinforcers showed that response rates did not change significantly as a function of successive reinforcers for subjects responding on the FI 60-s schedule, $F(12, 36) = 0.846, p < .606$, the FI 120-s schedule, $F(13, 39) = 0.637, p < .808$, or the FI 240-s schedule, $F(12, 36) = 1.564, p < .147$. Different degrees of freedom appear for the different tests because the tests could be applied only to intervals in which all subjects obtained the full number of reinforcers, and different subjects obtained different numbers of reinforcers during different sessions.

All data in this paper are reported in terms of 5-min intervals, instead of in terms of obtained reinforcers, for several reasons. First, the data are somewhat more orderly when plotted in terms of time than in terms of reinforcers. This method also allows the present results to be compared directly to past data that were reported in terms of time (e.g., McSweeney, 1992).

EXPERIMENT 2

Method

Subjects. The subjects were 4 experimentally experienced pigeons maintained at approximately 85% of their free-feeding body weights by postsession feedings.

Apparatus and procedure. The apparatus was a two-key, two-treadle experimental chamber, measuring 27 cm by 30 cm by 29.5 cm. The two keys were Plexiglas panels (2.5 cm diameter) located 4 cm below the ceiling and 12.5 cm from each other. The left key was 6.0 cm from the left wall; the right key was 6.5 cm from the right wall. The keys were operated by a force of approximately 0.25 N. An opening (5 cm by 4 cm) allowed access to a magazine that contained mixed grain. The opening was 12.5 cm from the right wall and 3 cm above the floor. A houselight (1 cm diameter, located 0.5 cm from the left wall and 0.5 cm from the ceiling) illuminated the chamber throughout the session. (A treadle was located 15.5 cm below each of the response keys. The treadles will not be described because they were not used in this experiment.) The experimental chamber was located in a sound-

Table 2

Mean rates of key pecking (R) (pecks per minute) and mean obtained rates of reinforcement (SR) (reinforcers per hour) for each subject responding on each schedule over the last five sessions for which the schedule was available in Experiment 2.

Subject		Schedule				
		VR 5	VR 15	VR 30	VR 60	VR 120
83001	R	14.5	26.6	31.3	34.1	88.7
	SR	174.0	106.4	62.6	34.1	44.4
63	R	12.9	23.4	40.1	45.0	74.3
	SR	154.8	93.6	80.2	45.0	37.2
33	R	8.5	10.4	15.2	32.1	1.2
	SR	102.0	41.6	30.4	32.1	0.6
6	R	15.0	30.5	32.6	65.8	0.7
	SR	180.0	122.0	65.2	65.8	0.4
M	R	12.7	22.7	29.8	44.3	41.2
	SR	152.4	90.8	59.6	44.3	20.6

attenuating enclosure. A ventilating fan masked noises from outside. Experimental events were controlled and data were recorded by a SYM® microcomputer located in another room.

All procedural details were identical to those of Experiment 1 except that subjects pecked the right key, illuminated with blue light, to obtain reinforcers. They responded on the following schedules presented in the following order: VR 30, VR 120, VR 15, VR 60, and VR 5. Reinforcers (5 s of access to mixed grain) were scheduled according to a 25-interval Fleshler and Hoffman (1962) series. Again, subjects responded on each schedule for 30 sessions. These VR schedules were selected to provide a range of obtained rates of reinforcement similar to that provided in Experiment 1 for FI schedules.

Results and Discussion

Table 2 presents the mean rates of responding by each subject on each schedule. Rates are reported in responses per minute, and were calculated as in Table 1. The obtained rates of reinforcement are multiples of the rates of responding because the subjects responded on ratio schedules. These rates are presented for convenience and are reported in reinforcers per hour.

Figure 7 presents the cumulative record of responding during the first 10 min of individual sessions. As in Figure 1, results are presented for an arbitrarily selected subject (63) responding during an arbitrarily selected ses-

Fig. 7. Cumulative records of responding during the first 10 min of an arbitrarily selected individual session for Subject 63 responding on the VR 15, VR 30, and VR

sion for each of three VR schedules. The procedure exerted good control over behavior. The steady responding reported in Figure 7 is similar to that reported by other authors when subjects respond on VR schedules (e.g., Ferster & Skinner, 1957). Table 2 shows that average rates of responding changed as an orderly function of the ratio requirement. Rates of responding generally decreased with decreases in the ratio requirement and with increases in the obtained rates of reinforcement. Subjects 33 and 6 almost stopped responding at the highest ratio requirement (VR 120).

Figure 8 presents group-average rates of responding during successive 5-min intervals for each VR schedule. Figure 9 presents similar results for individual subjects. Mean rates of responding mainly decreased within the session for all schedules. However, these decreases were not always observed for individual subjects responding during the schedules with the higher ratio requirements (VR 30, VR 60, and VR 120). One-way within-subject analyses of variance applied to the rates of responding by individual subjects during successive 5-min intervals were significant for all of the schedules, $F(11, 33) = 10.28, p < .001$; $F(11, 33) = 5.94, p < .001$; $F(11, 33) = 2.41, p < .025$; $F(11, 33) = 3.77, p < .002$; $F(11, 33) = 2.26, p < .035$ for the VR 5, VR 15, VR 30, VR 60, and VR 120 schedules, respectively.

Several of the measures of behavior that were reported for interval schedules are not informative for ratio schedules. The average number of responses per reinforcer cannot change because it is fixed by the schedule. Reinforcers are also collected as soon as they become available because they depend on responding, not the passage of time. The postreinforcement pause and running response rate are potentially meaningful but could not be calculated because of limitations on the present data-recording equipment.

EXPERIMENT 3

Method

Subjects. The subjects were 4 experimentally experienced pigeons maintained at ap-

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120 schedules. Each set of axes presents the results for a different schedule.

Fig. 8. Rates of responding (responses per minute) during successive 5-min intervals for the mean of all subjects responding on each of the VR schedules. Each set of axes presents the results for one schedule. All results have been taken from the last five sessions for which that schedule was available.

Fig. 9. Rates of responding (responses per minute) during successive 5-min intervals for individual subjects responding on each of the VR schedules. Each set of axes presents the results for one schedule. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

Fig. 10. Relative frequency of interresponse times for an arbitrarily selected subject (5504) responding during an arbitrarily selected session for the DRL 2-s, DRL 10-s, and DRL 20-s schedules. Results are presented in terms

Table 3

Mean rates of key pecking (R) (pecks per minute) and mean obtained rates of reinforcement (SR) (reinforcers per hour) for each subject responding on each schedule over the last five sessions for which that schedule was available in Experiment 3.

Subject		Schedule				
		DRL 2	DRL 5	DRL 10	DRL 15	DRL 20
5501	R	6.3	2.7	7.0	15.0	24.5
	SR	183.0	98.2	96.4	9.4	2.0
5502	R	6.9	4.0	6.2	16.7	17.7
	SR	168.6	124.2	66.4	7.8	10.0
5503	R	5.6	5.0	3.4	2.7	10.9
	SR	259.0	158.4	98.8	84.2	9.0
5504	R	4.3	2.3	6.8	2.2	22.6
	SR	143.8	98.4	91.6	88.0	8.9
<i>M</i>	R	5.8	3.5	5.9	9.2	15.5
	SR	188.6	119.8	88.3	47.3	8.7

proximately 85% of their free-feeding body weights by postsession feedings.

Apparatus and procedure. The apparatus was a three-key experimental chamber for pigeons, measuring 32.5 cm by 30.5 cm by 35.5 cm. Three response keys (2.5 cm diameter) appeared 23.5 cm above the floor and 7.5 cm apart. The left and right keys were 6.5 cm from the left and right walls, respectively. The keys were operated by a force of approximately 0.25 N. Two openings (6.5 cm by 4 cm) allowed access to magazines that contained mixed grain. The magazines were 9.5 cm below the left and right keys. The experimental panel was housed in a sound-attenuating enclosure. A ventilating fan masked noises from outside the chamber. Experimental events were programmed by a SYM® microcomputer located in another room.

The procedure was identical to that used in Experiments 1 and 2 for FI and VR schedules except that subjects pecked the left key, illuminated with white light, to obtain reinforcers presented by the left magazine. Subjects responded on the following DRL schedules in the following order: DRL 10 s, DRL 20 s, DRL 2 s, DRL 5 s, and DRL 15 s. Again, each schedule was presented for 30 sessions.

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of 2-s bins. Each set of axes presents the results for a different schedule.

Fig. 11. Rates of responding (responses per minute) during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Results for the mean of all subjects appear on the left axes; those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

The values of the DRL schedules were selected to provide a range of obtained rates of reinforcement similar to the ranges provided in Experiments 1 and 2.

Results and Discussion

Table 3 presents the mean rates of responding emitted, and the mean rates of reinforcement obtained, by each subject responding on each schedule. Rates were calculated and reported as in Table 1. Figure 10 presents the relative frequency of interresponse times (IRTs) for a single arbitrarily selected subject (5504) responding during a single arbitrarily

selected session for each of three DRL schedules. IRTs are classified into 2-s bins.

The schedules exerted good control over behavior. Figure 10 shows that many responses occurred at short IRTs regardless of the schedule requirement. These results are similar to those reported by other authors when pigeons respond on DRL schedules (e.g., Staddon, 1965). Table 3 shows that rates of responding changed systematically with changes in the DRL requirement. In particular, rates of responding generally increased, and obtained rates of reinforcement decreased, as the DRL requirement lengthened.

Fig. 12. Running response rates (responses per minute) during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Results for the mean of all subjects appear on the left axes; those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

Figure 11 presents the rate of responding during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Rate of responding mainly decreased within sessions. One-way within-subject analyses of variance applied to the rates of responding by individual subjects during successive 5-min intervals were significant for the DRL 2-s schedule, $F(11, 33) = 10.66$, $p < .001$, and the DRL 5-s schedule, $F(11, 33) = 4.95$, $p < .001$, but not for the DRL 10-s schedule, $F(11, 33) = 1.66$, $p < .126$, the DRL 15-s schedule, $F(11, 33) = 1.29$, $p < .271$, or the DRL 20-s schedule, $F(11, 33) = 0.89$, $p < .559$.

Figure 12 presents the running response rates during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Running rates were calculated by dividing the number of pecks during an interreinforcer interval by the time from the first to the last peck in that interval. Different scales were used for different schedules because of the large differences in running rates among them. Running rates increased briefly and then decreased within the session. One-way within-subject analyses of variance applied to the rates by individual subjects during successive 5-min intervals were significant for the DRL 2-s schedule, $F(11,$

Fig. 13. Length of postreinforcement pause (seconds) during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Results for the median of all subjects appear on the left axes; those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

33) = 2.48, $p < .021$, and the DRL 5-s schedule, $F(11, 33) = 2.89$, $p < .009$, but not for the other schedules, $F(11, 33) = 0.53$, $p < .872$; $F(11, 33) = 0.41$, $p < .941$; and $F(11, 33) = 1.17$, $p < .342$ for the DRL 10-s, DRL 15-s, and DRL 20-s schedules, respectively. Figure 13 presents the length of the postreinforcement pause as a function of successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Pauses were the time that elapsed between the end of the last reinforcer and the first response in the next interreinforcer interval. When no reinforcer was collected during an interval, the postreinforcement pause

was 300 s (because it occupied the entire 5 min). Postreinforcement pauses increased within the session, although the smooth changes for the medians mask variability from interval to interval for individual subjects. Friedman analyses of variance by ranks showed that postreinforcement pauses changed significantly within sessions for the DRL 2-s schedule (Friedman test statistic = 29.21, $df = 11$, $p < .002$) and the DRL 5-s schedule (Friedman test statistic = 32.89, $df = 11$, $p < .001$). Pauses did not change significantly for the DRL 10-s schedule (Friedman test statistic = 14.77, $df = 11$, $p < .193$), the DRL 15-s schedule (Fried-

Fig. 14. The time required to collect an available reinforcer (seconds) during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Results for the mean of all subjects appear on the left axes; those for individual subjects appear on the right axes. All results have been taken from the last five sessions for which that schedule was available. (Subject numbers are preceded by an S.)

man test statistic = 8.50, $df = 11$, $p < .668$) or the DRL 20-s schedule (Friedman test statistic = 5.86, $df = 11$, $p < .883$).

Figure 14 presents the time required to collect an available reinforcer during successive 5-min intervals for the DRL 2-s and DRL 5-s schedules. Collection times were calculated by determining the length of the interresponse time that produced each reinforcer. The reported times are the median times by which that interresponse time exceeded the DRL requirement. When no reinforcer was collected in a 5-min interval, collection time was set equal to 300 s (5 min) minus the DRL re-

quirement. The median time required to collect an available reinforcer was generally longer at the end of the session than at the beginning. Again, however, the medians mask variability from interval to interval for individual subjects. Friedman analyses of variance by ranks applied to the results for individual subjects showed that collection time changed significantly within sessions for the DRL 2-s schedule (Friedman test statistic = 22.55, $p < .020$) and the DRL 5-s schedule (Friedman test statistic = 29.05, $p < .002$). They did not change significantly for the other schedules (Friedman test statistic = 18.77, $p < .065$;

Friedman test statistic = 13.50, $p < .262$; and Friedman test statistic = 11.33, $p < .416$ for the DRL 10-s, DRL 15-s, and DRL 20-s schedules, respectively; in all cases, $df = 11$).

The number of responses per reinforcer was not plotted because it did not change significantly within sessions for any schedule for which a statistical test could be calculated, $F(11, 33) = 1.12$, $p < .390$; $F(11, 33) = 1.28$, $p < .281$; $F(11, 33) = 2.03$, $p < .057$; $F(11, 33) = 1.03$, $p < .453$ for the DRL 2-s, DRL 5-s, DRL 10-s, and DRL 15-s schedules, respectively. Subjects failed to receive any reinforcers during several 5-min intervals when responding on the DRL 20-s schedules. Therefore a statistical test could not be performed for this schedule.

GENERAL DISCUSSION

The Generality of Within-Session Changes in Responding

The present results extend the generality of within-session changes in response rates to several FI, VR, and DRL schedules. Responding mainly decreased within sessions when subjects responded on the FI 15-s, FI 30-s, VR 5, VR 15, VR 30, VR 60, VR 120, DRL 2-s, and DRL 5-s schedules. These within-session changes were large (see below) as well as systematic.

Other measures of behavior also changed systematically within sessions for the FI and DRL schedules. The running response rate increased briefly and then decreased for subjects responding on the FI 15-s, FI 30-s, DRL 2-s, and DRL 5-s schedules. Postreinforcement pauses increased for subjects responding on the FI 15-s, FI 30-s, DRL 2-s, and DRL 5-s schedules. The time required to collect an available reinforcer increased for the FI 15-s, FI 30-s, DRL 2-s, and DRL 5-s schedules. Finally, the number of responses per reinforcer decreased for the FI 15-s and FI 30-s schedules. These behavioral measures were not reported for the VR schedules either because they were held constant by the schedule or because equipment limitations prevented their calculation.

The present results are compatible with past results reported in the literature about within-session changes in responding. Relatively constant response rates (Palya, 1992) and running response rates (Collier, 1962a) were reported

for FI schedules that provided low rates of reinforcement. The length of the postreinforcement pause increased (Collier, 1962a; Collier & Myers, 1961) or remained constant (Palya, 1992) for FI schedules. Decreases in response rates and increases in postreinforcement pauses were also reported for DRL schedules (Palya, 1992).

The present results may help to explain why within-session changes in responding have been relatively ignored (but see McSweeney & Roll, 1993). The changes consistently reached significance only for schedules that provided high rates of reinforcement. The changes were occasionally statistically significant for schedules that provided lower rates of reinforcement, but these changes were unsystematic for the FI 240-s schedule and were not observed consistently for individual subjects during the VR 30, VR 60, and VR 120 schedules. Therefore, systematic within-session changes in responding may not have been observed during past studies of simple-schedule responding that delivered relatively low rates of reinforcement.

Within-Session Changes for Simple Schedules

The within-session changes in responding shared several common properties for the FI, VR, and DRL schedules. First, as indicated in the summary of the results provided above, the same within-session change was reported for each behavioral measure, regardless of the schedule. For example, response rates always decreased within sessions at higher rates of reinforcement. The only exception occurred for the number of responses per reinforcer. This measure decreased for the FI schedules but did not change significantly for the DRL schedules.

Second, changes in the obtained rates of reinforcement produced similar changes in the within-session patterns of responding for all schedules. To begin with, the within-session functions became flatter as the obtained rates of reinforcement decreased. Dividing the mean rate of responding during the highest 5-min interval by the rate during the lowest 5-min interval showed that responding changed by a factor of approximately 7, 5, 1, 1, and 2 for the FI 15-s, FI 30-s, FI 60-s, FI 120-s, and FI 240-s schedules, respectively. It changed by a factor of approximately 92, 48, 6, 5, and 9 for the VR 5, VR 15, VR 30, VR 60, and VR

120 schedules, respectively. It changed by a factor of approximately 17, 10, 3, 1, and 1 for the DRL 2-s, DRL 5-s, DRL 10-s, DRL 15-s, and DRL 20-s schedules, respectively.

Responding was distributed more symmetrically around the middle of the session for lower than for higher rates of reinforcement. Subjects emitted an average of 74%, 69%, 50%, 53%, and 52% of their total-session responses during the first half of the session for the FI 15-s, FI 30-s, FI 60-s, FI 120-s, and FI 240-s schedules, respectively. Subjects emitted an average of 90%, 87%, 70%, 69%, and 79% of their total-session responses during the first half of the session for the VR 5, VR 15, VR 30, VR 60, and VR 120 schedules, respectively. Subjects emitted an average of 89%, 77%, 81%, 50%, and 52% of their total-session responses during the first half of the session for the DRL 2-s, DRL 5-s, DRL 10-s, DRL 15-s, and DRL 20-s schedules, respectively.

Finally, the peak rate of responding occurred somewhat later in the session for lower than for higher rates of reinforcement. The highest rate of responding for the mean of all subjects was observed during the second, second, first, second, and fourth 5-min intervals for the FI 15-s, FI 30-s, FI 60-s, FI 120-s, and FI 240-s schedules, respectively. The peak rate of responding occurred during the first, first, second, second, and second 5-min intervals for the mean of all subjects responding on the VR 5, VR 15, VR 30, VR 60, and VR 120 schedules, respectively. The peak rate of responding occurred during the first, second, third, first, and sixth 5-min intervals for the mean of all subjects responding on the DRL 2-s, DRL 5-s, DRL 10-s, DRL 15-s, and DRL 20-s schedules, respectively.

These similarities suggest that, for the most part, similar factors produced the within-session changes for the FI, VR, and DRL schedules. However, one difference also appeared. Within-session changes in response rates were consistently larger for the VR than for the other schedules, even when the obtained rates of reinforcement were similar. For example, the FI 30-s, DRL 10-s, and VR 15 schedules all provided approximately 90 reinforcers per hour (see Tables 1 to 3), but the ratio of the highest to the lowest rate of responding within the session was approximately 5 for the FI 30-s schedule, 3 for the DRL 10-s schedule, and 48 for the VR 15 schedule. As a result of

their larger size, within-session changes in responding were significant even for VR schedules that provided lower rates of reinforcement. Future experiments should determine the factors that produce this difference.

Within-Session Changes During Simple and Multiple Schedules

Many aspects of the present results are similar to those reported for multiple variable-interval (VI) VI schedules. As just mentioned, the within-session changes in responding for simple schedules were flatter, more symmetrical around the middle of the session, and peaked later for lower than for higher rates of reinforcement. McSweeney (1992) reported similar results when subjects responded on multiple VI VI schedules.

The present results also differed in at least one way from those reported for multiple schedules. The increases in responding early in the session that were reported for multiple schedules (e.g., McSweeney et al., 1990) were small or absent for the present simple schedules. Instead, response rates primarily decreased within sessions for simple schedules.

Future experiments should determine the factors that produced this difference between multiple and simple schedules. It may have been produced by any one of several procedural differences between the studies (e.g., the presence or absence of discriminative stimuli, the choice of simple schedules, etc.). The difference may also prove to be quantitative rather than qualitative. The early-session increases in responding are smaller for multiple schedules that provide higher rates of reinforcement than they are for those that provide lower rates (McSweeney, 1992). Therefore, the early-session increases in responding may have been small for the present simple schedules because these changes were reported only for schedules that provided high rates of reinforcement. The results presented in Figures 8 and 9 support this reasoning. The early-session increases in responding were larger for VR schedules that provided lower rates of reinforcement (higher ratio requirements), just as they were for multiple schedules.

The Factors That Produce Within-Session Changes

As mentioned earlier, past studies of within-session changes in responding have con-

founded the act of responding with the receipt of reinforcement and the passage of time. Therefore, factors related to any one of these variables may have produced the within-session changes.

Finding that the within-session patterns of responding changed with changes in the rates of reinforcement rules out the idea that factors related to the passage of time alone are responsible for these changes. For example, early-session responding might increase as subjects recover from the handling routine, or late-session responding might decrease in anticipation of the end of the session (which may involve handling and the possibility of postsession feedings; e.g., Timberlake, Gawley, & Lucas, 1987). If, however, factors related to the passage of time were solely responsible for within-session changes, then similar within-session changes should have been reported for all schedules. Instead, responding changed systematically with changes in the obtained rates of reinforcement.

The idea that the act of responding changes future responding (i.e., muscular warm-up, fatigue) has a long history in research with human and nonhuman animals (e.g., Mosso, 1906). For example, Hull (1943) argued that the act of responding creates reactive inhibition that decreases the probability of repeating the response. Finding that within-session changes were larger for the VR than for the FI and DRL schedules challenges explanations for these changes based on factors related solely to responding. Subjects emitted similar rates of responding on the VR ($M = 30.1$ responses per minute) and FI schedules ($M = 34.4$ responses per minute). They responded more slowly on the DRL schedules ($M = 8.0$ responses per minute). If the decreases in responding occurred because of fatigue, then the changes in responding should have occurred similarly for the FI and VR schedules and more slowly for the DRL schedules. Instead, responding declined more steeply for the VR than for either the FI or DRL schedules. To explain these results in terms of fatigue, it would be necessary to argue that responding on the VR schedule was somehow more effortful than responding on the other schedules, even though the force required to peck each of the response keys was similar.

Two results suggest that factors related to reinforcement (e.g., satiation) contributed to the within-session changes in responding. First,

within-session changes were larger for the schedules that provided higher rates of reinforcement. Second, the peak rates of responding occurred earlier for higher than for lower rates of reinforcement. If the presentation of reinforcers produced the changes in responding, then these changes would be more likely to occur during schedules that provided more reinforcers, and responding should reach its peak earlier and decline more steeply for schedules that present reinforcers more quickly.

Future experiments should specify the nature of this reinforcement-related factor. It is unlikely that the decreases in responding seen here were produced by a simple interpretation of satiation. To begin with, Collier (1962b) reported that responding decreased within sessions when saccharin served as the reinforcer, indicating that the presence of calories is not necessary to produce these decreases. Second, the present decreases began in either the first 5 or 10 min of the session. Although it is possible, it does not seem likely that subjects, maintained at 85% of their free-feeding weights, would become satiated after consuming only a limited number of reinforcers. Third, McSweeney and Johnson (in press) found that responding increased early in the second of two consecutive sessions, rather than continuing the decreasing trend observed at the end of the first session. This occurred regardless of whether 2 to 3, 10, or 30 min elapsed between sessions and regardless of whether subjects spent the time between sessions inside or outside the experimental enclosure. It seems unlikely that satiation could have dissipated over the short intervals that separated these two consecutive sessions. Finally, McSweeney, Roll, and Cannon (in press) reported that the decreases in responding were similar regardless of whether rats' lever pressing was maintained by Noyes pellets or their key pressing was maintained by sweetened condensed milk delivered by multiple VI VI schedules. The similarities were especially strong at high rates of reinforcement. It is unclear why satiation would occur at the same rate for Noyes pellets and sweetened condensed milk.

Several authors have argued that cognitive factors may contribute to operant performance. For example, Spear (1973) argued that reinstatement of "memory" produces the early increases in responding that are found on tasks such as operant avoidance. Richardson and Campbell (1992) argued that unfamiliar en-

vironments evoke an "information overload" that engages all of the animal's limited resources. As the animal adapts to the environment, more of these resources become available for such tasks as processing stimuli. Blough (1983) argued that variables related to "attention" may be involved in performance of some operant tasks.

The present results question one potential interpretation of the idea that attention changes systematically within sessions. If attention changes, then subjects might be differentially sensitive to the contingencies of reinforcement that govern their behavior at different times in the session. This should result in opposite within-session changes in responding for the VR and DRL schedules. For example, if sensitivity to the stimulus-response-reinforcer contingency declines within experimental sessions, then subjects should respond slower on VR and faster on DRL schedules as the session progresses. Slower responding indicates greater sensitivity to a DRL contingency. Faster responding shows greater sensitivity to a VR contingency. This is not what happened. Instead, rates of responding decreased within the session for both types of schedules.

Future experiments should test other potential interpretations of changes in attention. For example, such a hypothesis might imply that the degree to which responding is under the control of stimuli associated with the instrumental response changes within the session. In that case, the subject's susceptibility to distraction by other stimuli might change systematically as the session progresses.

The Relation Between Responding and Reinforcement

The present experiments were not primarily directed at examining the relation between overall rates of reinforcement and overall rates of responding. However, all of the present experiments found an inverse relation between the two variables (see Tables 1 to 3). These results are consistent with the most commonly reported past results for VR schedules. A direct relation between response rates and ratio size is usually found at least over moderate ratio sizes (Timberlake, 1977). In contrast, the present results differ from the most common findings for FI and DRL schedules. Response rates usually decrease with increases in the size of the FI interval (Lowe, Harzem, & Spencer, 1979) and with increases in the DRL require-

ment (Staddon, 1965). It should be noted, however, that the present study differed in many ways from these studies. It should also be noted that these most common results are not universally found. For example, some studies have reported either no relation (Catania & Reynolds, 1968, Experiment 4) or a direct relation (Staddon, 1967, for cyclic, but not for simple, FI schedules) between the overall rate of responding and the length of the FI interval.

The differences in the relation between rates of responding and rates of reinforcement found in different studies, as well as the fact that rate of responding usually varies inversely with rate of reinforcement during ratio schedules (Timberlake, 1977) but directly with rate of reinforcement during interval schedules (Herrnstein, 1970), have led several authors to question whether rate of reinforcement exerts a fundamental control over rate of responding. As an alternative, rate of reinforcement may control running response rate (Baum, 1993). For example, Timberlake (1977) showed that running response rate usually varies directly with rate of reinforcement during ratio schedules. Catania and Reynolds (1968, Experiment 4) reported that the response rate just before reinforcement increased with increases in rate of reinforcement, even though the overall response rate was unrelated to rate of reinforcement.

The results of the present experiments are compatible with the idea that running response rate varies directly with rate of reinforcement. The mean running rate, averaged across the session and across all subjects, was 75.0, 49.7, 63.8, 54.4, and 45.6 responses per minute for the FI 15-s, FI 30-s, FI 60-s, FI 120-s, and FI 240-s schedules, respectively. Running rate was 26.7, 16.6, 12.5, 11.8, and 14.0 responses per minute for the DRL 2-s, DRL 5-s, DRL 10-s, DRL 15-s, and DRL 20-s schedules, respectively. The relation between running response rate and rate of reinforcement should be examined more carefully in future studies. Running rate may eventually prove to be more directly controlled by rate of reinforcement than overall response rate.

Summary

Large and systematic within-session decreases in response rates were reported when subjects responded on FI, VR, or DRL schedules that provided high rates of reinforcement.

They were also found during VR schedules that provided lower rates of reinforcement. These changes in response rates were accompanied by changes in other measures of behavior such as running response rate, postreinforcement pause, time required to collect an available reinforcer, and number of responses per reinforcer. The similarities of the changes in these measures for the different schedules suggested that they were mainly produced by similar factors, although a separate factor may also contribute to the changes for VR schedules. At least one of these factors is related to the presentation of reinforcers. Future experiments should clarify the nature of this variable, as well as examine within-session changes in responding in more detail.

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APPENDIX

Columns represent data from successive 5-min intervals.

Schedule parameter												
FI schedules												
Mean rates of responding (responses per minute)												
15 s	36.2	43.0	37.6	32.8	27.3	21.1	18.3	14.5	10.5	9.3	6.2	6.3
30 s	27.7	32.0	27.4	22.7	22.7	16.5	15.3	13.6	11.0	12.0	9.8	7.0
60 s	43.7	36.7	35.7	36.9	36.1	36.4	33.9	37.8	33.9	35.3	38.6	37.2
120 s	44.5	54.7	47.0	53.6	44.5	49.0	40.9	48.0	40.7	48.1	42.1	43.8
240 s	41.1	50.9	54.8	59.3	52.7	47.6	45.1	50.7	38.1	45.9	48.9	46.5
Mean running response rate (responses per minute)												
15 s	68.7	112.0	104.4	90.1	81.6	91.0	64.7	68.1	50.5	75.8	65.0	28.3
30 s	48.8	79.1	75.1	70.9	67.6	55.1	53.7	43.5	32.1	26.1	24.0	20.3
60 s	57.7	62.3	62.8	66.1	63.8	63.4	64.2	68.2	63.6	64.7	68.3	60.8
120 s	53.0	55.5	51.7	59.1	55.6	51.1	54.0	54.1	53.9	59.7	53.3	51.4
240 s	37.1	49.5	52.8	52.3	51.3	41.0	45.3	45.6	42.7	43.0	41.0	46.2
Median postreinforcement pause (seconds)												
15 s	9.4	9.9	11.9	11.1	12.1	11.0	13.0	24.3	22.4	14.7	22.9	28.8
30 s	13.3	18.0	16.2	19.3	19.7	19.4	18.8	20.2	23.3	22.8	17.5	33.8
60 s	19.1	20.5	28.0	25.2	27.0	28.3	30.1	30.9	30.2	29.2	26.3	29.1
120 s	14.9	14.8	18.2	22.1	20.1	22.2	18.9	24.5	19.3	17.9	16.9	21.2
240 s	8.3	38.1	20.3	22.8	22.4	17.3	17.0	25.5	22.8	24.1	25.8	17.5
Median time to collect an available reinforcer (seconds)												
15 s	2.0	0.3	0.5	1.2	1.2	1.6	4.1	11.6	11.4	5.7	17.5	20.2
30 s	1.2	0.2	0.3	0.9	1.6	2.5	2.5	7.2	6.5	8.3	14.7	17.9
60 s	3.1	0.3	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.1	0.2	0.3
120 s	0.7	0.8	0.5	0.0	0.1	0.2	0.2	0.2	0.8	0.2	0.2	0.5
240 s	0.8	0.9	0.3	0.6	0.8	0.6	0.8	0.3	0.3	0.2	0.6	0.3
Mean responses per reinforcer												
15 s	10.4	11.0	10.1	9.5	8.9	6.7	5.1	4.6	3.7	3.8	3.3	3.5
30 s	18.9	18.9	16.6	13.9	15.7	11.5	10.8	9.9	8.1	8.1	7.2	6.6
60 s	57.6	38.0	36.3	37.2	36.8	36.6	34.1	38.0	34.4	35.8	38.5	38.1
120 s	115.0	131.7	69.3	122.9	72.6	104.9	70.4	115.3	71.4	126.0	75.5	113.2
240 s	181.7	244.4	248.2	245.0	108.5	190.4	200.5	209.5	90.7	190.6	185.7	215.2
VR schedules												
Mean rates of responding (responses per minute)												
VR 5	64.2	46.9	13.3	2.5	3.2	6.4	3.7	0.7	1.8	3.1	4.9	2.2
VR 15	82.2	62.8	36.5	21.8	22.5	13.6	7.8	6.2	7.6	5.5	1.7	4.3
VR 30	52.4	74.5	56.7	32.7	18.5	13.3	16.3	26.6	20.7	18.7	15.1	12.3
VR 60	67.2	73.9	67.6	53.5	53.4	49.4	38.3	34.1	30.7	27.2	21.3	14.7
VR 120	53.3	82.5	72.2	66.7	63.4	49.8	27.6	20.6	22.4	14.1	12.3	9.6
DRL schedules												
Mean rates of responding (responses per minute)												
2 s	17.2	17.0	11.7	7.6	4.1	3.2	2.0	1.2	1.5	1.0	1.7	1.3
5 s	7.2	7.6	5.8	5.3	3.8	2.7	2.4	2.1	1.9	1.5	1.3	0.8
10 s	7.2	8.3	8.6	7.2	6.2	5.6	5.9	5.0	4.9	4.7	3.7	3.1
15 s	10.3	9.6	9.3	8.1	8.1	9.2	8.5	9.0	9.4	8.7	9.8	9.4
20 s	14.3	16.3	16.2	14.7	14.5	18.4	15.7	15.5	15.8	14.0	14.4	16.1
Mean running response rates (responses per minute)												
2 s	26.2	47.8	54.8	32.9	68.9	22.4	12.9	18.3	12.2	8.3	10.6	5.7
5 s	13.2	26.8	23.0	22.0	21.9	20.6	18.5	14.7	10.7	13.9	8.9	5.3
10 s	9.0	13.5	13.7	14.8	13.5	13.5	13.9	9.9	13.1	13.5	9.6	11.5
15 s	10.8	11.7	13.3	11.8	10.7	11.6	11.0	10.7	14.5	12.1	12.0	10.9
20 s	11.3	13.8	16.0	13.3	13.1	13.3	13.0	14.3	14.9	14.0	15.2	15.7

APPENDIX (*Continued*)

Schedule parameter												
Median postreinforcement pause (seconds)												
2 s	3.6	3.8	7.3	14.8	68.3	240.0	284.4	300.0	300.0	300.0	300.0	300.0
5 s	5.8	6.1	6.7	6.4	9.9	22.8	17.9	48.6	39.4	163.5	167.1	155.8
10 s	10.0	8.8	9.1	10.6	9.9	11.3	11.1	11.4	12.5	14.2	84.9	12.7
15 s	20.4	18.0	13.4	160.8	19.2	20.8	165.2	19.3	23.6	20.9	21.8	166.7
20 s	168.7	88.5	159.6	84.9	85.6	155.8	159.5	300.0	229.3	158.6	300.0	225.8
Median time taken to obtain an available reinforcer (seconds)												
2 s	6.4	2.3	5.4	12.6	52.4	224.8	298.0	298.0	298.0	298.0	161.7	215.7
5 s	13.7	2.1	2.7	2.9	6.4	4.4	15.8	17.9	9.3	15.5	87.8	102.1
10 s	21.0	3.5	3.0	2.6	2.5	2.7	3.2	3.5	4.3	5.2	75.4	78.0
15 s	67.0	15.8	8.5	146.4	3.6	10.1	8.8	10.0	9.2	7.2	6.3	15.6
20 s	193.9	82.2	142.3	72.9	73.5	140.9	142.7	280.0	210.5	144.2	280.0	280.0
Mean responses per reinforcer ^a												
2 s	2.5	1.9	1.5	1.7	2.1	1.5	1.6	1.7	1.4	2.0	2.6	1.9
5 s	1.9	1.8	1.9	1.7	1.7	1.8	1.7	1.6	1.4	1.4	1.6	1.4
10 s	7.5	9.5	7.6	4.8	3.9	3.0	3.4	3.2	2.8	3.3	2.7	2.6
15 s	156.2	21.8	56.9	86.2	21.4	50.3	50.4	68.6	39.0	62.4	41.8	24.1
20 s	132.0	291.2	255.2	218.4	227.1	168.5	45.8	22.2	84.9	87.7	350.8	181.4

^a In some cases, a subject did not receive a reinforcer during a 5-min interval. In that case, the results have been averaged only for the other subject.