

*EFFECTS OF REINFORCEMENT RATE AND
DELAY ON THE ACQUISITION OF
LEVER PRESSING BY RATS*

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The acquisition of lever pressing by naive rats, in the absence of shaping, was studied as a function of different rates and unsignaled delays of reinforcement. Groups of 3 rats were each exposed to tandem schedules that differed in either the first or the second component. First-component schedules were either continuous reinforcement or random-interval 15, 30, 60, or 120 s; second-component schedules were fixed-time 0, 1, 3, 6, 12, or 24 s. Rate of responding was low under continuous immediate reinforcement and higher under random-interval 15 s. Random interval 30-s and 60-s schedules produced lower rates that were similar to each other. Random-interval 120 s controlled the lowest rate in the immediate-reinforcement condition. Adding a constant 12-s delay to each of the first-component schedule parameters controlled lower response rates that did not vary systematically with reinforcement rate. The continuous and random-interval 60-s schedules of immediate reinforcement controlled higher global and first-component response rates than did the same schedules combined with longer delays, and first-component rates showed some graded effects of delay duration. In addition, the same schedules controlled higher second-component response rates in combination with a 1-s delay than in combination with longer delays. These results were related to those from previous studies on acquisition with delayed reinforcement as well as to those from similar reinforcement procedures used during steady-state responding.

Key words: response acquisition, reinforcement rate, reinforcement delay, lever press, rats

Response shaping by differential reinforcement of successive approximations to the target behavior is the procedure most commonly used to establish a new response (e.g., Ferster & Skinner, 1957; Gleeson, 1991). Once the target response occurs, conventional wisdom recommends immediately reinforcing every instance of the desired behavior to increase its rate. However a few studies have explored variations on this method. Lattal and Gleeson (1990) studied the acquisition of lever pressing by rats and key pecking by pigeons without response shaping, simply exposing their subjects to continuous or intermittent schedules of unsignaled delayed reinforcement. In each of their procedures, response rates increased relative to those of control groups that were exposed to either extinction or response-independent rein-

forcement. Other, related studies have used unsignaled delayed reinforcement for the acquisition of light-beam interruptions by rats (Critchfield & Lattal, 1993) and swimming through a ring by Siamese fighting fish (Lattal & Metzger, 1994).

The present research studied the acquisition of lever pressing by rats, in the absence of response shaping, as a function of different rates and unsignaled delays of reinforcement. Rate of reinforcement has not been studied systematically in the acquisition of new responses. The only information on the effect of reinforcement rate during acquisition comes from the study by Lattal and Gleeson (1990), in which a variable-interval (VI) 30-s schedule of reinforcement with a 10-s delay to each reinforcer was as effective for acquisition as a continuous fixed-ratio (FR) 1 schedule of reinforcement with a 30-s delay to each reinforcer (Experiments 1 through 6). Several studies have been conducted to investigate the effect of different rates of immediate reinforcement on steady-state responding, mainly by pigeons, using interval schedules. The results suggest that, in general, higher rates of reinforcement control higher response rates (cf. Catania & Reyn-

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olds, 1968). There is evidence, however, that FR 1 schedules of immediate reinforcement may yield lower response rates than do schedules that moderately lower reinforcement rate (Sidley & Schoenfeld, 1964). Given that intermittent schedules have proved to be effective for the acquisition of new responses, the present investigation attempted to determine whether varying the rate of reinforcement during acquisition would produce response-rate functions similar to those obtained during steady-state responding. In the present study, different reinforcement rates were combined parametrically with immediate reinforcement and with a 12-s unsignaled delay.

The effects of different durations of unsignaled delays of reinforcement on acquisition have received some research attention; however, the work to date has revealed mixed results. Wilkenfield, Nickel, Blakely, and Poling (1992) found that FR 1 differential-reinforcement-of-other-behavior (DRO) schedules with durations ranging from 4 to 32 s produced lower response rates under longer DRO durations in rats. Their finding, however, is difficult to integrate with other delay effects because the delivery of reinforcement was contingent on pauses in responding, and rates of responding necessarily covaried with the specified delay duration (i.e., otherwise reinforcement would not occur). Thus, delay and contingency effects were confounded. In contrast to their DRO condition, Wilkenfield *et al.* also found that when similar nominal delays of reinforcement were programmed according to a fixed-time (FT) interval (i.e., in which responses that occur during the delay do not reset the delay period), there was no systematic relation between delay duration and rate of responding. This finding differs from the more common outcome obtained under conditions of response maintenance, in which longer FT delays control lower response rates (i.e., a delay gradient; e.g., Dews, 1960; Richards, 1981; Sizemore & Lattal, 1978). An intriguing possibility is that Wilkenfield *et al.* may not have obtained a delay gradient for their FT condition due to the FR 1 schedule present in the first component of their tandem schedules (FR 1 FT x). Bruner, Avila, and Gallardo (1994) found that an intermittent schedule of delayed reinforcement using an FT interval (a tandem random-in-

terval [RI] 30 s FT 6 s, 12 s, or 24 s) produced the expected higher response rates under shorter delay intervals during the acquisition of lever pressing in rats. This finding was taken to suggest that, compared to the more commonly used schedule of continuous reinforcement, an intermittent schedule might produce the familiar delay gradient using unsignaled FT delays. The present research also examined this possibility, combining different FT delays with different reinforcement rates provided by an FR 1 schedule and by an RI 60-s schedule.

METHOD

Subjects

Fifty-four male rats of Wistar descent were bred at the vivarium of the School of Psychology of the National University of Mexico. The rats were 4 months old, had no experimental history, and were maintained at 80% of their free-feeding weights. Each subject was housed individually, with free access to water.

Apparatus

A standard rat box (BRS/LVE Model RTC-020) was used for all subjects. The box was 24 cm wide by 26 cm high by 30.5 cm long and was equipped with a pellet dispenser (BRS/LVE Model PDH-020) and a tray located at the center of the front panel, 5 cm above the grid floor. The response lever (BRS/LVE Model RRL-015), located 5 cm to the left of the food tray and 5 cm above the grid, was 2.5 cm wide and protruded 2 cm into the chamber. The lever was sensitive to 0.15 N. The box was placed inside a sound-attenuating cubicle (BRS/LVE Model SEC-002), in a room separate from the main laboratory and programming equipment.

Pulverized rat food (Nutricubes by Purina) was remolded into 0.25-mg pellets and used as reinforcers. The experiment was controlled by a Radio Shack TRS-80 computer coupled to an LVB interface.

Procedure

During the first session, with the lever removed from the box, the rats were given response-independent reinforcement at arbitrary irregular intervals until the experimenter judged that each rat approached the tray re-

liably and ate the pellet upon operation of the dispenser for 50 successive deliveries.

Beginning with the second session, the lever was installed in the box, and with no further training, each of 18 groups of rats (3 in each group) was exposed to tandem schedules of reinforcement that differed in reinforcement frequency or the duration of an unsignaled nonresetting delay to pellet presentation. Different reinforcement rates were arranged by including either an FR 1 or an RI schedule in the first component of the tandem schedules. Random-interval schedules were derived by applying a fixed probability of reinforcement (p) to the first response in each time cycle of fixed duration (T) (Farmer, 1963). In the present study p was constant at .10, and T was 1.5, 3, 6, and 12 s. Thus, T/p yielded RIs of 15, 30, 60, and 120 s. Although FR 1 schedules can be viewed as the limiting case of RI schedules (i.e., where $T < \text{IRT}$ and $p = 1.0$), in this research the FR 1 schedule was not strictly related to the RI schedules and therefore was described as a qualitatively different manipulation. Delays between the completion of the response requirement and the reinforcer delivery were arranged by FT intervals during the second component. Hereafter, these schedule combinations will be referred to as tandem FR 1 RI x FT x . Each of five groups of rats was exposed to a tandem schedule that consisted of either FR 1, RI 15 s, RI 30 s, RI 60 s, or RI 120 s in the first component and no reinforcement delay (hereafter described as FT 0 s) in the second component. Five additional groups were exposed to tandem schedules that consisted of either FR 1, RI 15 s, RI 30 s, RI 60 s, or RI 120 s in the first component and a constant FT 12 s in the second component. Four other groups were exposed to FT durations of either 1 s, 3 s, 6 s, or 24 s in the second component while an FR 1 schedule was held constant in the first component. The last four groups were exposed to FT durations of either 1 s, 3 s, 6 s, or 24 s in the second component while an RI 60-s schedule was held constant in the first component.

The course of acquisition was observed across 20 daily sessions, conducted 7 days per week. This period was chosen to be consistent with a majority of the published reports on response acquisition with delayed reinforcement, in which similar limits on observations

have been imposed (e.g., Bruner et al., 1994; Lattal & Gleeson, 1990; Lattal & Metzger, 1994). Each session lasted 1 hr or the time necessary to earn 30 reinforcers, with the exception of tandem RI 120 s FT 0 s and 12 s. In the latter cases, sessions lasted 2 hr or 30 reinforcers, to compensate for the longer interreinforcement interval.

RESULTS

Figure 1 shows the response rates of the individual subjects during each of the 20 sessions across the different reinforcement rates, with the constant 0-s or 12-s delays. These response rates, hereafter designated as global rates, represent responding across the two components of the different tandem schedules.

The first column shows the effect of different rates of immediate reinforcement (0-s delay). With the exception of Rat T26, which responded substantially during the first session, the subjects pressed the lever at very low rates on the first session. However, the response rates of the subjects exposed to the tandem FR 1 FT 0-s and tandem RI 15-s FT 0-s schedules increased steadily across the 20 sessions. The global response rates of the rats exposed to the tandem schedules in the range from tandem RI 30 s FT 0 s to tandem RI 120 s FT 0 s also increased above their initial level by the second or third session, but after a transitory increase during the next three or four sessions, their response rates remained unchanged for the rest of the experiment.

The second column of graphs in Figure 1 shows the effect of different reinforcement rates combined with a constant 12-s delay. Again, global response rates were very low in the first session, but in most cases, after two or three sessions of exposure to the schedules, lever pressing occurred at low but sustained rates. The global response rates of the rats exposed to tandem FR 1 FT 12 s, tandem RI 15 s FT 12 s, and tandem RI 30 s FT 12 s increased slightly throughout the 20-session exposure period, whereas the rats exposed to tandem RI 60 s FT 12 s and tandem RI 120 s FT 12 s stabilized at very low rates of responding from the onset of the experiment.

Figure 2 also shows the effect of different delays of reinforcement combined with rein-

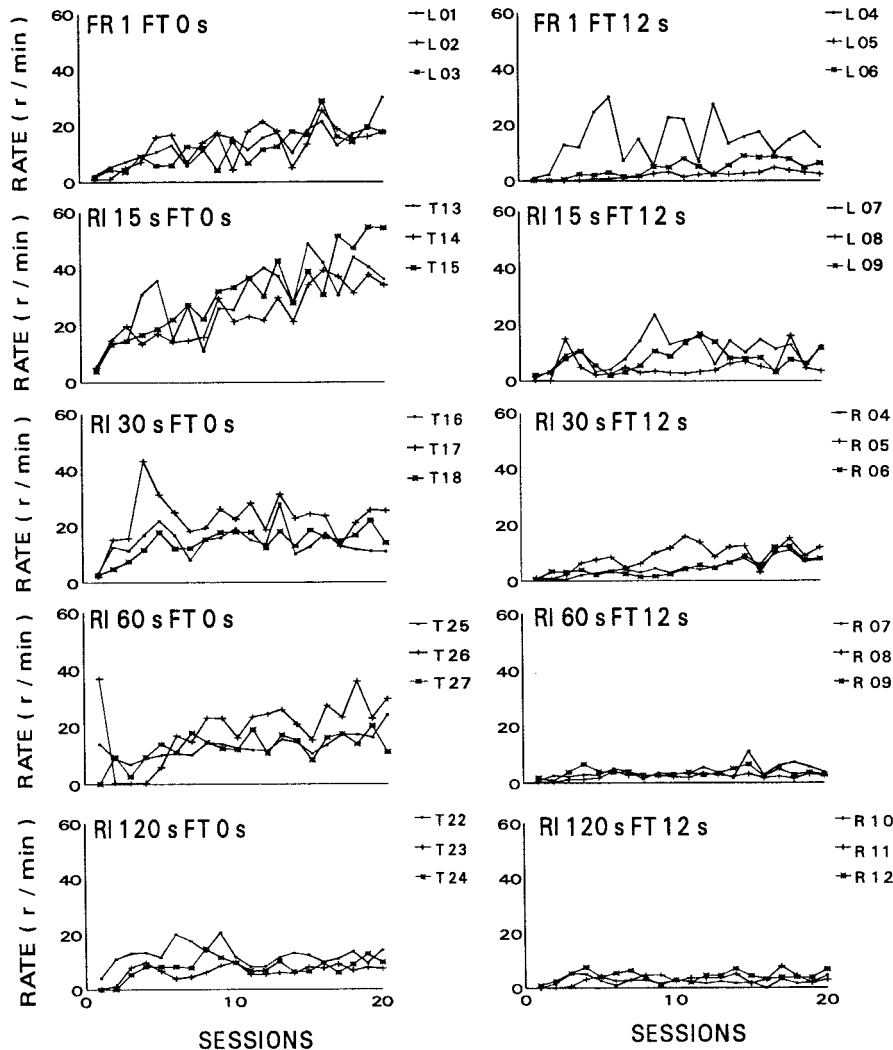


Fig. 1. Effects of varying reinforcement rate across constant schedules of immediate (0-s delay) and delayed (12-s delay) reinforcement. Each plot shows rate of responding over the 20 sessions for an individual rat.

forcement rates that were constant at either FR 1 or RI 60 s. The graphs of tandem FR 1 FT 0 s, tandem FR 1 FT 12 s, tandem RI 60 s FT 0 s, and tandem RI 60 s FT 12 s, shown in Figure 1, are repeated here to allow convenient visual comparison. The continuous schedule of immediate reinforcement produced response rates that increased steadily over the 20 sessions of the experiment. The subjects exposed to the FR 1 schedule with delays in the range between 1 s and 12 s responded at rates that increased from the first to the second or third session and then either continued to increase very slightly (e.g., rats

T34, T35, T36, L05, and L06) or remained more or less constant. The rats exposed to tandem FR 1 FT 24 s responded with very low global rates that did not increase during the 20-session observation period.

Figure 2 also shows the effect of the different delays of reinforcement combined with a constant RI 60 s. Under tandem RI 60-s FT 0-s conditions, Rat T26 emitted a burst of responses on the first session, then stopped lever pressing during the next three sessions and afterwards responded again at rates that increased steadily during the remaining sessions. The other rats exposed to tandem RI

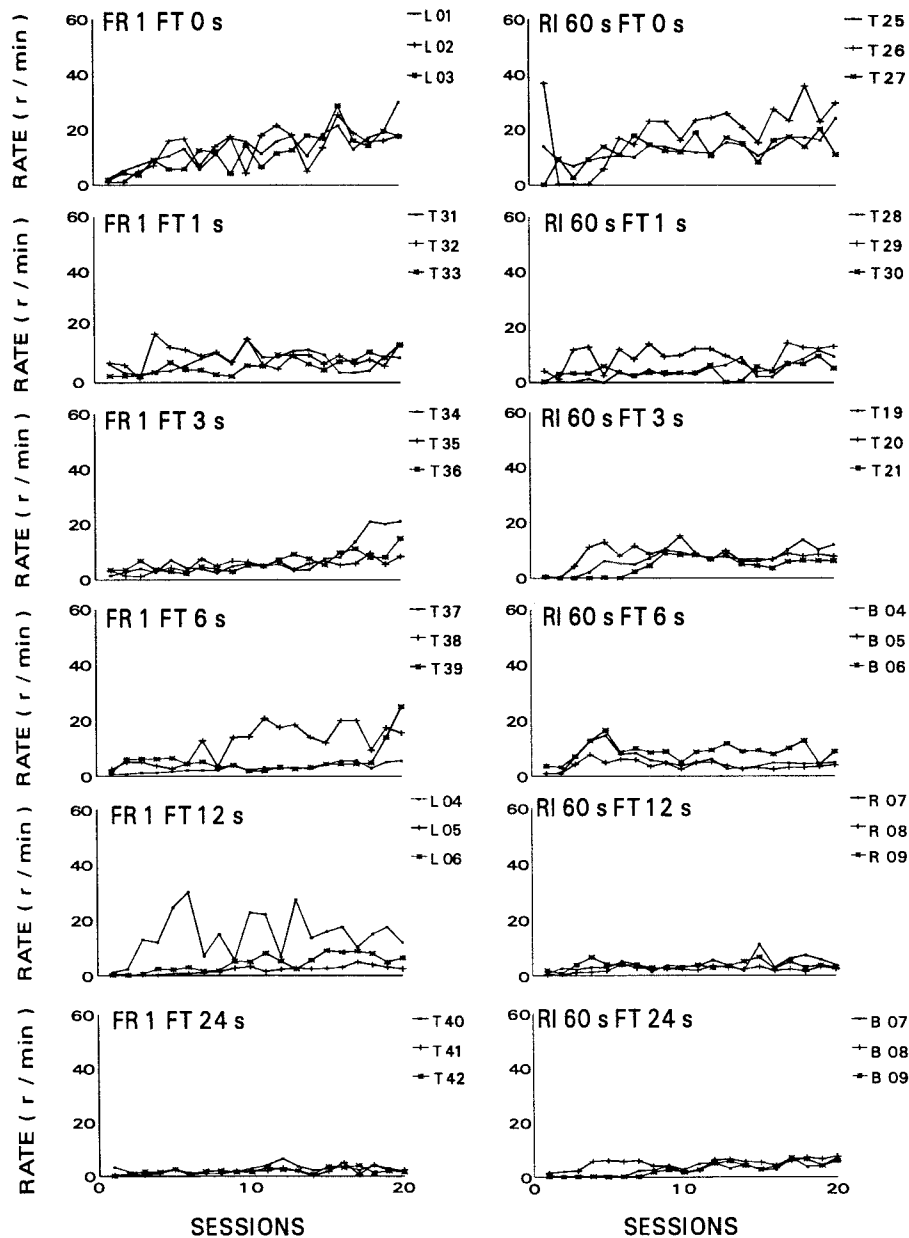


Fig. 2. Effects of varying reinforcement delay across constant schedules of continuous (FR 1) and intermittent (RI 60-s) reinforcement. Each plot shows rate of responding over the 20 sessions for an individual rat.

60 s FT 0 s began lever pressing on the first or second session at substantial rates that remained more or less constant during the experiment. The global response rates of the rats that were exposed to delays in the range from 1 to 24 s followed the more common pattern observed: an initial increase relative to the near-zero response rates in the first ses-

sion, followed by stability from about the 10th session until the end of the experiment.

Figure 3 summarizes the results of the present study, ordered over the experimental domain defined by the parameters of rate and delay of reinforcement. The two graphs at the top show global response rates as the mean for the 3 rats that were exposed to each com-

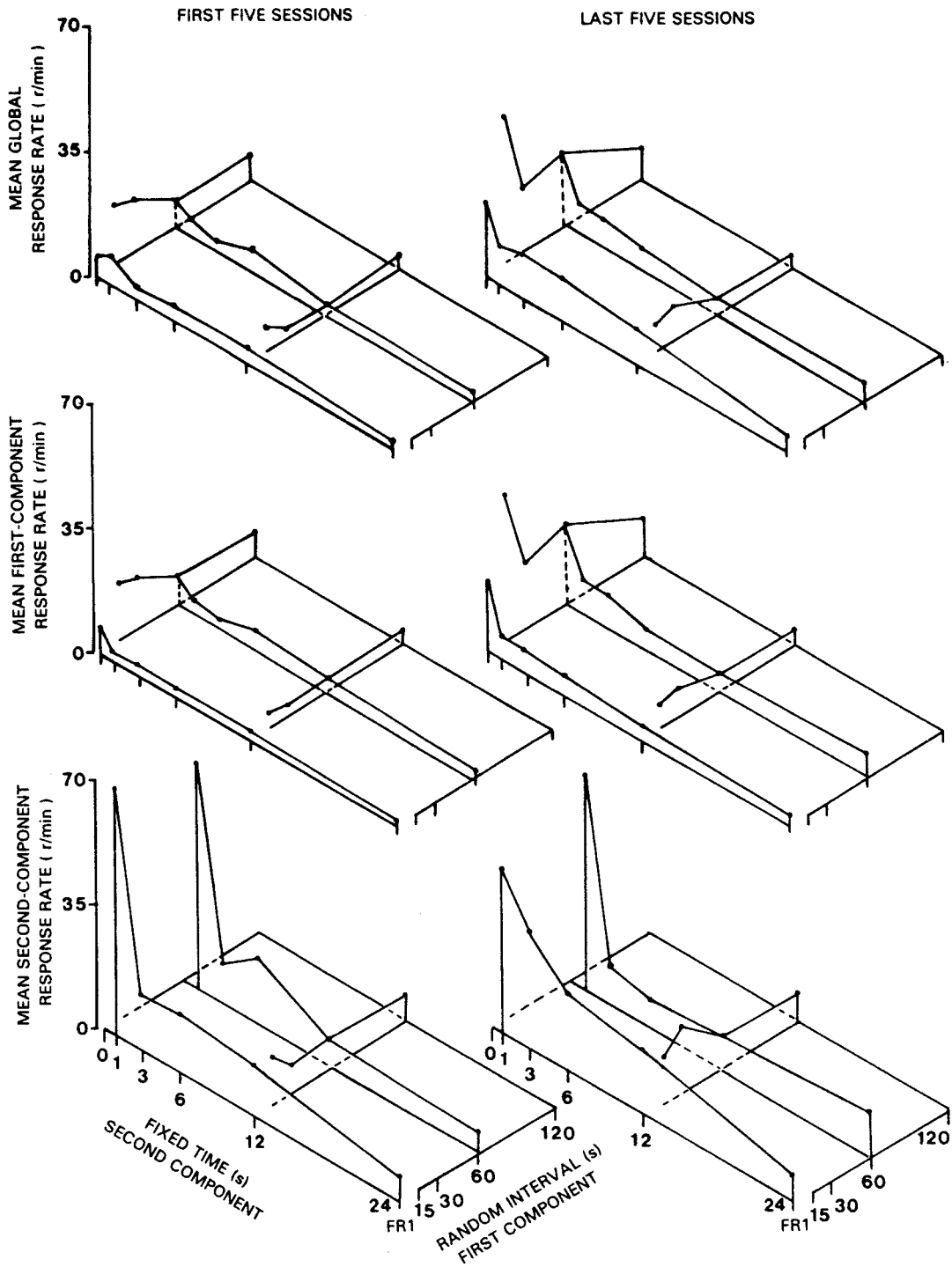


Fig. 3. Mean global response rates (top graphs), mean first-component response rates (middle), and mean second-component response rates (bottom) as a function of rate and delay of reinforcement. The graphs on the left show these measures across the first five sessions of the experiment, and the graphs on the right show the same data across the last five sessions.

bination of the parameters across the first five and last five sessions of each condition. The two graphs in the middle show the mean rates of responding in the first component of the tandem schedules. Of course, when the different rates of reinforcement were combined with FT 0 s, the mean global rates of responding and the mean rates of responding in the first component were identical. Nevertheless, because the global rate and the rate of responding in the first component under the different reinforcement rates combined with FT 12 s were free to vary, the response functions under FT 0 s are repeated in the two sets of graphs to allow convenient visual comparison. The rates of responding in the second component of the tandem schedules are shown in the two graphs at the bottom of Figure 3.

The data shown in Figure 3 were subjected to statistical analyses that will be described shortly. However, visual inspection of Figure 3 shows some relations that are worth mentioning. First, the shape of the functions for the mean response rates in the first and second components of the tandem schedules did not change much from the first to fourth, or last, five-session block. Global response-rate functions did not change much either from the first to the fourth block of sessions. A second salient characteristic of Figure 3 is that the absolute response rates in the second component were consistently higher than the absolute response rate in the first component of the tandem schedules.

To analyze the effects of the different rates of reinforcement combined with 0-s and 12-s delays on global and first-component response rates, a two-way 5×2 ANOVA (5 rates of reinforcement: FR 1, RI 15 s, RI 30 s, RI 60 s, and RI 120 s \times 2 delays: FT 0 s and FT 12 s) was performed separately for both the first and fourth blocks of five sessions. Although first-component and global response rates were identical under the different rates of immediate reinforcement, these two dependent variables were free to vary independently when the same reinforcement rates were combined with FT 12 s. Given that the fixed-effects ANOVAs used here collapse the response functions obtained under the different reinforcement rates combined with FT 0 s and FT 12 s, separate analyses were conducted for the first-component and the glob-

al response rates. Response rates in the second component of the tandem schedules were analyzed by a one-way ANOVA to test for the effects of the different reinforcement rates (FR 1, RI 15 s, RI 30 s, RI 60 s, and RI 120 s) combined with a single FT 12-s delay. Table 1 shows the F coefficients from the ANOVAs and from the post hoc tests from each analysis.

As Table 1 shows, the parameters of the study had consistent effects within the first and fourth blocks of sessions for first- and second-component response rates as well as for the global rates of responding. That is, when a main effect or an interaction appeared within the first block of sessions, the same effect also appeared within the fourth block. In addition, Table 1 shows that, in general, the results of the post hoc tests were also consistent from the first to the fourth block of sessions. Given such consistency in statistical results and for economy, the description that follows will be based only on the fourth block of sessions. Also for brevity, the similarities between pairs of means will be ignored and only the significant differences will be noted.

For the first-component and the global response rates, the five rates of reinforcement had a significant main effect. The two delays of reinforcement also had a reliable main effect. In addition, the interaction between the rates of reinforcement and the delay parameters was significant. Given the interaction between parameters a test for simple effects was performed (Keppel, 1991). Simple effects showed that the combination of the five reinforcement rates with FT 0 s resulted in significant differences, whereas the same reinforcement rates combined with FT 12 s did not. Multiple comparisons showed that when combined with FT 0 s, the RI 15-s schedule controlled higher first-component and global response rates than did the FR 1, RI 30-s, RI 60-s, and RI 120-s schedules. The RI 120-s schedule controlled first-component and global response rates lower than any other schedule of immediate reinforcement. Although first-component and global response rates were identical when the different reinforcement schedules were combined with FT 0 s, the F coefficients in Table 1 are not identical, because when each of these measures was collapsed in the two-way ANOVAs, each test had its own error term, which in turn was

Table 1
F ratios from the ANOVAs for the different rates of reinforcement (FR 1, RI 15 s, RI 30 s, RI 60 s, and RI 120 s) \times constant FT 0-s or FT 12-s delay.

First five-session block					Fourth five-session block				
Mean global rate									
Two-way ANOVA					Two-way ANOVA				
S ^R rate	$F(4, 20) = 3.40, p < .05$				S ^R rate	$F(4, 20) = 18.22, p < .01$			
Delay	$F(1, 20) = 33.40, p < .01$				Delay	$F(1, 20) = 115.74, p < .01$			
S ^R rate \times Delay	$F(4, 20) = 2.80, p < .05$				S ^R rate \times Delay	$F(4, 20) = 12.71, p < .01$			
Simple effects					Simple effects				
S ^R rate \times Delay 0 s	$F(4, 20) = 5.95, p < .01$				S ^R rate \times Delay 0 s	$F(4, 20) = 29.36, p < .01$			
S ^R rate \times Delay 12 s	$F(4, 20) = 0.26, p > .05$				S ^R rate \times Delay 12 s	$F(4, 20) = 1.58, p > .05$			
Multiple comparisons for					Multiple comparisons for				
S ^R rate \times Delay 0 s (<i>df</i> 1, 20)					S ^R rate \times Delay 0 s (<i>df</i> 1, 20)				
	RI 15 s	RI 30 s	RI 60 s	RI 120 s		RI 15 s	RI 30 s	RI 60 s	RI 120 s
FR 1	13.57**	10.12**	0.51	0.09	FR 1	51.58**	0.32	0.00	9.37**
RI 15 s		0.25	8.84**	11.48**	RI 15 s		59.58**	51.39**	104.91**
RI 30 s			6.10*	8.33**	RI 30 s			0.33	6.24*
RI 60 s				0.17	RI 60 s				9.45**
Mean first-component rate									
Two-way ANOVA					Two-way ANOVA				
S ^R rate	$F(4, 20) = 5.17, p < .01$				S ^R rate	$F(4, 20) = 19.82, p < .01$			
Delay	$F(1, 20) = 67.62, p < .01$				Delay	$F(1, 20) = 191.82, p < .01$			
S ^R rate \times Delay	$F(4, 20) = 3.77, p < .05$				S ^R rate \times Delay	$F(4, 20) = 16.00, p < .01$			
Simple effects					Simple effects				
S ^R rate \times Delay 0 s	$F(4, 20) = 8.72, p < .01$				S ^R rate \times Delay 0 s	$F(4, 20) = 35.03, p < .01$			
S ^R rate \times Delay 12 s	$F(4, 20) = 0.21, p > .05$				S ^R rate \times Delay 12 s	$F(4, 20) = 0.79, p > .05$			
Multiple comparisons for					Multiple comparisons for				
S ^R rate \times Delay 0 s (<i>df</i> 1, 20)					S ^R rate \times Delay 0 s (<i>df</i> 1, 20)				
	RI 15 s	RI 30 s	RI 60 s	RI 120 s		RI 15 s	RI 30 s	RI 60 s	RI 120 s
FR 1	19.89**	14.84**	0.74	0.13	FR 1	59.85**	0.71	0.15	12.22**
RI 15 s		0.37	12.96**	16.84**	RI 15 s		73.57**	54.05**	126.16**
RI 30 s			8.96**	12.23**	RI 30 s			1.50	7.05**
RI 60 s				0.25	RI 60 s				15.06**
Mean second-component rate									
One-way ANOVA					One-way ANOVA				
S ^R rate	$F(4, 10) = 0.39, p > .05$				S ^R rate	$F(4, 10) = 1.69, p > .05$			

* $p < .05$, ** $p < .01$.

also used for the analyses of simple effects and for the multiple comparisons. The different rates of reinforcement in combination with FT 12 s did not have a reliable effect on second-component response rates, as revealed by the one-way ANOVA. This latter finding is consistent with the results of the previous analyses for the same parameter combination on first-component and global response rates.

To analyze the effects of the different delays of reinforcement combined with FR 1 or RI 60 s, two separate fixed-effects two-way ANOVAs were performed, one for each block of

sessions. With the exception of rates of responding in the second component of the tandem schedules, for which there was obviously no response rate under FT 0 s, the ANOVAs for first-component and global response rates were 6×2 (6 delays: FT 0 s, FT 1 s, FT 3 s, FT 6 s, FT 12 s, and FT 24 s \times 2 reinforcement rates: FR 1 and RI 60 s). It should be noted that again when the FR 1 and the RI 60-s schedules were combined with immediate reinforcement (FT 0 s), the data points for the first-component and the global response rates were identical. However, for the reasons given above, the same data

were included in the separate ANOVAs performed on the first-component and the global response rates. Again, given that the statistical tests yielded results that were usually consistent within the first and fourth blocks of sessions for first-component and global response rates, only the results from the fourth block of sessions will be described. Because rates of responding in the second component did not vary consistently across blocks of sessions, these will be described further below. Again, for brevity, the similarities between pairs of means will be ignored, and only the significant differences will be noted. Table 2 shows the *F* coefficients from the ANOVAs and from the post hoc tests.

For first-component and global response rates, the ANOVAs revealed that delay of reinforcement had a significant main effect. Multiple comparisons between pairs of means showed that FT 0 s controlled higher first-component and global response rates than did any other longer delay. The FT 1-s and FT 3-s schedules each controlled higher first-component response rates than the FT 12-s and FT 24-s schedules did. The interaction between the delay and reinforcement rate parameters was not significant for either first-component or global response rates. The effect of the two reinforcement rates (FR 1 and RI 60 s) on global rates of responding did not differ significantly. However, the RI 60-s schedule controlled reliably higher first-component response rates ($M = 8.26$) than did FR 1 ($M = 6.60$). For rate of responding in the second component of the tandem schedules a significant main effect for delay was found in both blocks of sessions. Within the first block, FT 1 s controlled higher second-component response rates than did any longer delay. Comparison of the two reinforcement rates (FR 1 and RI 60 s) revealed no significant main effect in either block of sessions. Although in the first block of sessions second-component response rates showed no interaction between the parameters of delay and rate of reinforcement, in the second block of sessions such interaction was significant. Simple effects of the different reinforcement delays combined with the FR 1 schedule within the fourth block of sessions showed a reliable effect on second-component response rates. Multiple comparisons between pairs of means showed that FT 1 s controlled

higher second-component response rates than FT 6 s, FT 12 s, and FT 24 s did and that FT 3 s controlled higher second-component response rates than FT 12 s and FT 24 s did. The different delays of reinforcement combined with RI 60 s also had a significant effect. The comparisons between means showed that FT 1 s controlled higher second-component response rates than did any other longer delay.

Table 3 shows the mean obtained rates of reinforcement for each subject over the first and fourth blocks of five sessions of exposure to the different reinforcement rates (FR 1 and RI schedules) while delay of reinforcement was held constant at either FT 0 s or FT 12 s. For both blocks of sessions as well as under both delay parameters, reinforcement rates decreased gradually as the programmed interreinforcement interval was lengthened. Also, for both blocks of sessions reinforcement rates were usually higher under immediate reinforcement than under reinforcement delayed 12 s. In addition, reinforcement rates varied among subjects in the same condition, usually being higher for those that responded more. Table 3 shows that mean rates of reinforcement increased proportionally more, from the first to the fourth block of sessions, for the subjects that were exposed to the tandem FR 1 FT 0 s, and increased proportionally less for the subjects that were exposed to tandem FR 1 FT 12 s and tandem RI 15 s FT 0 s. For the subjects that were exposed to tandem RI 15 s FT 12 s, mean obtained rate of reinforcement also increased slightly, but not as much as for the subjects in the conditions mentioned above. Obtained reinforcement rates for the rats that were exposed to leaner reinforcement rates combined with FT 0 s and FT 12 s did not vary much from the first to the fourth block of sessions.

Table 4 shows the mean obtained rate of reinforcement for each subject over the first and fourth blocks of five sessions of exposure to the different delays of reinforcement (i.e., FT intervals) while the schedule of reinforcement was held constant at either FR 1 or RI 60 s. Again, for the sake of continuity, the data from the tandem FR 1 FT 0-s, tandem FR 1 FT 12-s, tandem RI 60-s FT 0-s, and tandem RI 60-s FT 12-s conditions shown in Table 3 are repeated in Table 4. Reinforcement

Table 2

F ratios from the ANOVAs for the different delays of reinforcement (FT 0 s, FT 1 s, FT 3 s, FT 6 s, FT 12 s, and FT 24 s) × constant FR 1 or RI 60-s reinforcement rates.

First five-session block						Fourth five-session block					
Mean global rate											
Two-way ANOVA						Two-way ANOVA					
Delay	$F(5, 24) = 2.85, p < .05$					Delay	$F(5, 24) = 13.61, p < .01$				
S ^R rate	$F(1, 24) = 0.00, p > .05$					S ^R rate	$F(1, 24) = 1.80, p > .05$				
Delay × S ^R rate	$F(5, 24) = 0.84, p > .05$					Delay × S ^R rate	$F(5, 24) = 1.05, p > .05$				
Multiple comparisons for the main effect for delay (<i>df</i> 1, 24)						Multiple comparisons for the main effect for delay (<i>df</i> 1, 24)					
	FT 1 s	FT 3 s	FT 6 s	FT 12 s	FT 24 s	FT 1 s	FT 3 s	FT 6 s	FT 12 s	FT 24 s	
FT 0 s	0.94	5.38*	1.36	5.39*	11.06**	FT 0 s	31.10**	24.42**	31.89**	40.74**	56.58**
FT 1 s		1.82	0.04	1.83	5.55*	FT 1 s		0.40	0.00	0.65	3.78
FT 3 s			1.33	0.00	1.01	FT 3 s			0.50	2.08	6.65*
FT 6 s				1.34	4.67*	FT 6 s				0.54	3.51
FT 12 s					1.01	FT 12 s					1.30
Mean first-component rate											
Two-way ANOVA						Two-way ANOVA					
Delay	$F(5, 24) = 9.91, p < .01$					Delay	$F(5, 24) = 41.41, p < .01$				
S ^R rate	$F(1, 24) = 5.52, p < .01$					S ^R rate	$F(1, 24) = 4.19, p < .05$				
Delay × S ^R rate	$F(5, 24) = 1.16, p > .05$					Delay × S ^R rate	$F(5, 24) = 0.63, p > .05$				
Multiple comparisons for the main effect for delay (<i>df</i> 1, 24)						Multiple comparisons for the main effect for delay (<i>df</i> 1, 24)					
	FT 1 s	FT 3 s	FT 6 s	FT 12 s	FT 24 s	FT 1 s	FT 3 s	FT 6 s	FT 12 s	FT 24 s	
FT 0 s	13.02**	20.61**	10.30**	31.41**	39.52**	FT 0 s	92.50**	89.09**	111.27**	142.95**	151.05**
FT 1 s		0.87	0.16	3.98	7.17*	FT 1 s		0.03	0.87	5.47*	7.14**
FT 3 s			1.77	1.13	3.05	FT 3 s			1.23	6.34*	8.13**
FT 6 s				5.74*	9.47**	FT 6 s				1.98	3.04
FT 12 s					0.46	FT 12 s					0.11
Mean second-component rate											
Two-way ANOVA						Two-way ANOVA					
Delay	$F(4, 20) = 15.73, p < .01$					Delay	$F(4, 20) = 22.95, p < .01$				
S ^R rate	$F(1, 20) = 0.09, p > .05$					S ^R rate	$F(1, 20) = 2.65, p > .05$				
Delay × S ^R rate	$F(5, 24) = 0.07, p > .05$					Delay × S ^R rate	$F(5, 24) = 3.45, p < .05$				
Multiple comparisons for the main effect for delay (<i>df</i> 1, 24)						Simple effects					
	FT 3 s	FT 6 s	FT 12 s	FT 24 s		Delay × S ^R rate FR 1	$F(4, 20) = 8.04, p < .01$				
FT 1 s	37.56**	31.34**	40.90**	44.90**		Delay × S ^R rate RI 60 s	$F(4, 20) = 18.37, p < .01$				
FT 3 s		0.28	0.07	0.33							
FT 6 s			0.64	1.22							
FT 12 s				0.09							
Multiple comparisons for the main effect for delay × S ^R rate FR 1 (<i>df</i> 1, 24)						Multiple comparisons for delay × S ^R rate RI 60 s (<i>df</i> 1, 24)					
	FT 3 s	FT 6 s	FT 12 s	FT 24 s		FT 3 s	FT 6 s	FT 12 s	FT 24 s		
FT 1 s	3.49	11.51**	16.34**	26.51**		FT 1 s	44.28**	46.58**	49.49**	42.74**	
FT 3 s		2.32	4.72*	10.76**		FT 3 s		0.03	0.15	0.01	
FT 6 s			0.42	3.09		FT 6 s			0.04	0.08	
FT 12 s				1.23		FT 12 s				0.25	

* $p < .05$, ** $p < .01$.

Table 3

Mean obtained rate of reinforcement and its respective standard deviation, for each subject during the conditions in which rate of reinforcement was varied. The top two rows are means from the first five-session block and the two bottom rows are means from the fourth five-session block.

	FR 1			RI 15 s			RI 30 s			RI 60 s			RI 120 s		
	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD
First five-session block															
FT 0 s	L1	6.86	(3.18)	T13	2.84	(1.15)	T16	1.43	(0.36)	T25	0.67	(0.29)	T22	0.43	(0.05)
	L2	5.99	(6.11)	T14	2.60	(0.90)	T17	1.45	(0.62)	T26	0.25	(0.25)	T23	0.35	(0.21)
	L3	4.19	(3.55)	T15	2.23	(0.84)	T18	1.29	(0.37)	T27	0.67	(0.41)	T24	0.30	(0.23)
FT 12 s	L4	1.32	(0.81)	L7	0.85	(0.50)	R4	0.37	(0.26)	R7	0.45	(0.19)	R10	0.29	(0.14)
	L5	0.20	(0.16)	L8	0.49	(0.45)	R5	0.52	(0.26)	R8	0.21	(0.12)	R11	0.15	(0.16)
	L6	0.44	(0.44)	L9	1.07	(0.32)	R6	0.72	(0.24)	R9	0.57	(0.23)	R12	0.33	(0.10)
Fourth five-session block															
FT 0 s	L1	20.23	(6.78)	T13	3.44	(0.78)	T16	1.73	(0.24)	T25	0.94	(0.10)	T22	0.48	(0.06)
	L2	18.87	(3.77)	T14	3.83	(0.42)	T17	1.69	(0.24)	T26	0.90	(0.18)	T23	0.51	(0.09)
	L3	19.18	(5.62)	T15	3.18	(0.29)	T18	1.60	(0.20)	T27	0.82	(0.10)	T24	0.47	(0.09)
FT 12 s	L4	2.02	(0.15)	L7	1.59	(0.34)	R4	0.83	(0.06)	R7	0.65	(0.10)	R10	0.25	(0.14)
	L5	1.67	(0.23)	L8	1.07	(0.33)	R5	0.86	(0.15)	R8	0.53	(0.06)	R11	0.33	(0.04)
	L6	2.33	(0.25)	L9	1.37	(0.22)	R6	1.00	(0.16)	R9	0.71	(0.08)	R12	0.36	(0.03)

rates were variable among the subjects in a given condition, and the rats that responded more frequently also earned more reinforcers. Typically, lengthening the delay interval resulted in corresponding decreases in mean obtained rates of reinforcement for both blocks of sessions. Also for both blocks of sessions, obtained reinforcement rates were usu-

ally higher under FR 1 than under RI 60 s. Mean obtained reinforcement rates increased from the first to the fourth block of sessions, but for the subjects that were exposed to tandem FR 1 FT 0 s, these increased proportionally more than for the subjects in any other condition in the study.

Obtained response–reinforcer intervals

Table 4

Mean obtained rate of reinforcement and its respective standard deviation, for each subject during the conditions in which delay of reinforcement was varied. The top two rows are means from the first five-session block, and the two bottom rows are means from the fourth five-session block.

	FT 0 s			FT 1 s			FT 3 s			FT 6 s			FT 12 s			FT 24 s		
	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD	Rat	S ^R /min	SD
First five-session block																		
FR 1	L1	6.86	(3.18)	T31	2.16	(0.42)	T34	2.16	(1.04)	T37	0.61	(0.29)	L4	1.32	(0.81)	T40	0.37	(0.10)
	L2	5.99	(6.11)	T32	4.06	(1.30)	T35	1.69	(0.77)	T38	1.33	(0.61)	L5	0.20	(0.16)	T41	0.26	(0.09)
	L3	4.19	(3.55)	T33	2.20	(1.15)	T36	2.14	(0.41)	T39	1.94	(0.67)	L6	0.44	(0.44)	T42	0.41	(0.26)
RI 60 s	T25	0.67	(0.29)	T28	0.07	(0.02)	T19	0.27	(0.28)	B4	0.53	(0.26)	R7	0.45	(0.19)	B7	0.10	(0.03)
	T26	0.25	(0.25)	T29	0.69	(0.20)	T20	0.52	(0.38)	B5	0.60	(0.29)	R8	0.21	(0.12)	B8	0.35	(0.07)
	T27	0.67	(0.41)	T30	0.47	(0.22)	T21	0.05	(0.05)	B6	0.64	(0.11)	R9	0.57	(0.23)	B9	0.03	(0.01)
Fourth five-session block																		
FR 1	L1	20.23	(6.78)	T31	2.94	(1.05)	T34	5.12	(0.92)	T37	2.71	(0.74)	L4	2.02	(0.15)	T40	0.68	(0.14)
	L2	18.87	(3.77)	T32	5.37	(1.06)	T35	3.72	(0.49)	T38	3.89	(0.64)	L5	1.67	(0.23)	T41	0.61	(0.27)
	L3	19.18	(5.62)	T33	5.66	(0.58)	T36	3.98	(0.41)	T39	3.13	(1.27)	L6	2.33	(0.25)	T42	0.73	(0.29)
RI 60 s	T25	0.94	(0.10)	T28	0.73	(0.18)	T19	0.91	(0.15)	B4	0.75	(0.04)	R7	0.65	(0.57)	B7	0.57	(0.10)
	T26	0.90	(0.18)	T29	0.89	(0.11)	T20	0.91	(0.16)	B5	0.71	(0.14)	R8	0.53	(0.49)	B8	0.49	(0.04)
	T27	0.82	(0.10)	T30	0.66	(0.15)	T21	0.88	(0.16)	B6	0.80	(0.11)	R9	0.71	(0.56)	B9	0.56	(0.08)

Table 5

Mean interresponse time (IRT in seconds) and its respective standard deviation during the second component of the tandem schedules, for each subject in the conditions in which rate of reinforcement was varied under a constant 12-s delay. The top rows are means from the first block of five sessions, and the bottom rows are means from the fourth block of five sessions.

	FR 1			RI 15 s			RI 30 s			RI 60 s			RI 120 s		
	Rat	IRT	SD	Rat	IRT	SD	Rat	IRT	SD	Rat	IRT	SD	Rat	IRT	SD
First five-session block															
FT 12 s	L4	1.89	(0.28)	L7	2.94	(0.08)	R4	5.88	(0.05)	R7	4.00	(0.06)	R10	5.56	(0.03)
	L5	7.14	(0.07)	L8	5.00	(0.05)	R5	3.33	(0.08)	R8	4.55	(0.04)	R11	6.25	(0.09)
	L6	5.88	(0.05)	L9	3.13	(0.08)	R6	5.88	(0.03)	R9	4.76	(0.05)	R12	4.17	(0.07)
Fourth five-session block															
FT 12 s	L4	1.69	(0.11)	L7	2.70	(0.07)	R4	3.33	(0.08)	R7	4.17	(0.05)	R10	6.25	(0.06)
	L5	5.88	(0.03)	L8	5.26	(0.02)	R5	2.00	(0.18)	R8	6.25	(0.02)	R11	5.00	(0.02)
	L6	3.85	(0.04)	L9	3.23	(0.12)	R6	2.70	(0.10)	R9	5.88	(0.05)	R12	5.00	(0.03)

were not recorded directly in the present study. However, one way to assess obtained delays, albeit indirectly, is to calculate individual average interresponse times (IRTs) as the reciprocal of individual mean response rates during the second component of the tandem schedules. For a variety of response patterns, the average IRT should be positively correlated with the average response-reinforcer delay. Under the (probably unrealistic) assumption that responses during the delay are emitted at a constant rate, the average (or estimated) response-reinforcer delay should be about half of the average IRT. Table 5 shows individual mean IRTs during the 12-s delay interval for the conditions that differed in reinforcement rate. The means of each block of five sessions are shown separately. As Table 5 shows the mean IRTs were different among subjects, but nevertheless were remarkably similar from the first to the fourth block of sessions for each individual rat. Also, although the average IRTs (and thus the estimated obtained delays) were shorter than the nominal 12-s interval, there was no consistent trend, either to increase or decrease IRT duration, as a function of the different rates of reinforcement.

Table 6 shows the individual mean IRTs during the delay for the conditions that combined a different FT interval with the continuous (FR 1) and RI 60-s schedules. The means for each block of sessions are also shown separately. Table 6 shows a general correspondence in the order of the respective magnitudes between nominal FT delays and

average IRTs (and thus the estimated response-reinforcement delays). The mean IRTs from the first to the fourth block of sessions were quite consistent within individual subjects but were variable between rats. No consistent change in IRT duration was observed from one block of sessions to the other.

DISCUSSION

In operant conditioning experiments, the response-reinforcer dependency has the potential of introducing differences between the prescribed and the obtained values of the independent variables. For this reason, obtained reinforcement rates and delays were somewhat different from their nominal values in the present study. However, in keeping with the design of the present investigation, obtained reinforcement rate varied more in the prescribed direction as a function of the different reinforcement schedules that were present in the first component of the tandem schedules than as a function of the different delay intervals that were present in the second component. Also, although somewhat different from the nominal durations, estimated obtained delays varied generally in the same order of magnitudes.

The results of the present study can be summarized by referring to Figure 3, which allows systematic consideration of the data. For each of the two components of the tandem schedules, response rates were higher in the second than in the first component. With

Table 6

Mean interresponse time (IRT in seconds) and its respective standard deviation during the second component of the tandem schedules, for each subject in the conditions in which delay of reinforcement was varied under a constant FR 1 and RI 60 s. The top rows are means from the first block of five sessions, and the bottom rows are means from the fourth block of five sessions.

	FT 1 s			FT 3 s			FT 6 s			FT 12 s			FT 24 s		
	Rat	IRT	SD	Rat	IRT	SD	Rat	IRT	SD	Rat	IRT	SD	Rat	IRT	SD
First five-session block															
FR 1	T31	0.52	(0.45)	T34	1.85	(0.06)	T37	3.23	(0.05)	L4	1.89	(0.28)	T40	4.35	(0.12)
	T32	0.35	(0.25)	T35	1.89	(0.09)	T38	1.96	(0.13)	L5	7.14	(0.07)	T41	6.67	(0.06)
	T33	0.61	(0.25)	T36	1.59	(0.11)	T39	2.27	(0.09)	L6	5.88	(0.05)	T42	9.09	(0.07)
RI 60 s	T28	0.51	(0.48)	T19	1.96	(0.37)	B4	1.96	(0.16)	R7	4.00	(0.06)	B7	7.69	(0.03)
	T29	0.40	(0.30)	T20	1.85	(0.14)	B5	2.56	(0.12)	R8	4.55	(0.04)	B8	4.00	(0.08)
	T30	0.58	(0.35)	T21	2.44	(0.11)	B6	1.92	(0.12)	R9	4.76	(0.05)	B9	7.69	(0.13)
Fourth five-session block															
FR 1	T31	0.52	(0.30)	T34	0.92	(0.31)	T37	3.23	(0.05)	L4	1.69	(0.11)	T40	5.88	(0.02)
	T32	0.61	(0.45)	T35	1.61	(0.11)	T38	1.43	(0.10)	L5	5.88	(0.03)	T41	5.56	(0.06)
	T33	0.58	(0.33)	T36	1.15	(0.20)	T39	1.96	(0.27)	L6	3.85	(0.04)	T42	7.69	(0.02)
RI 60 s	T28	0.46	(0.35)	T19	1.67	(0.06)	B4	3.85	(0.02)	R7	4.17	(0.05)	B7	5.56	(0.06)
	T29	0.50	(0.49)	T20	2.04	(0.09)	B5	4.17	(0.05)	R8	6.25	(0.02)	B8	3.57	(0.06)
	T30	0.56	(0.13)	T21	2.63	(0.02)	B6	2.50	(0.10)	R9	5.88	(0.05)	B9	5.56	(0.05)

respect to the effect of the parameters during the first and fourth blocks of sessions, the shape of the functions for the global response rates, as well as for the response rates separated by component, did not change much between the two blocks of sessions. Given that the reinforcement rate and delay parameters had a clear effect during the first block of five sessions, a description of their effects could be based on either of the two blocks. However, to be consistent with the Results section, the following description will be based on the fourth block of sessions.

Concerning the effects of the different reinforcement rates in combination with FT 0 s, the RI 15-s schedule controlled higher first-component (and of course, global) response rates than did the FR 1, RI 30-s, and RI 60-s schedules, which controlled response rates similar to each other. The latter schedules however, controlled higher response rates than did the RI 120-s schedule. In combination with FT 12 s, the different schedules of reinforcement controlled first-component and global response rates that were uniformly lower than in combination with FT 0 s, but were no different from each other. Concerning the effect of the different FT intervals combined with the FR 1 and RI 60-s schedules, FT 0 s controlled higher first-compo-

nent and global response rates than did any other longer delay. Delays of FT 1 s and FT 3 s controlled first-component response rates lower than FT 0 s but higher than FT 12 s and FT 24 s. The FT 1-s delay interval controlled higher second-component response rates than did any other delay duration. The two schedules of delayed reinforcement, FR 1 and RI 60 s, had mixed effects; although the RI 60-s schedule controlled higher first-component response rates than did the FR 1 schedule, global or second-component response rates did not differ.

To facilitate their discussion, these results will be treated in the same order as in the summary above. The finding that second-component response rates were consistently higher than first-component response rates under all schedules of delayed reinforcement is congruent with the results of the study by Critchfield and Lattal (1993). In one condition of their experiment, a beam-interruption response was acquired by rats that were exposed to a tandem FR 1 DRO 30-s schedule of unsignaled delayed reinforcement. The rates of beam interruptions were higher in their delay component (DRO 30 s) than in their first component (FR 1). Response rates that are higher in the second component than in the first component of tandem sched-

ules of unsignaled delayed reinforcement suggest a pattern of positively accelerated responding during the interreinforcement interval. Given that Critchfield and Lattal used a DRO delay, such a response pattern may be general to FT delays, such as those used in the present study.

The shape of the functions that relate first- and second-component response rates, as well as global response rates, to the parameters under investigation was similar for the first and fourth blocks of five sessions. However, first-component and global response rates increased from the first to the fourth block, and this increase was larger for those conditions that involved either richer schedules in the first component or shorter delays in the second component. The fact that some measures of responding changed progressively with duration of exposure to different schedules of delayed reinforcement is relatively consistent with previous research on the effect of introducing a reinforcement delay after a baseline with immediate reinforcement. Sizemore and Lattal (1977) studied the effect of adding an FT 3-s unsignaled delay to a variable-interval (VI) 60-s schedule, using pigeons. As sessions progressed under the tandem VI 60 s FT 3 s, the global rates of key pecking, initially disturbed by the shift from immediate to delayed reinforcement, stabilized at a lower level than under the schedule of immediate reinforcement. Although in the present investigation none of the response-rate measures decreased as a function of duration of exposure to the different schedules, delays in the range between 0 and 12 s increased global and first-component response rates more than the 24-s delays did. A related finding was that the richer of the intermittent schedules of reinforcement, RI 15 s, showed a similar differential increase in response rate relative to leaner schedules. Sizemore and Lattal (1978) shifted pigeons from immediate-reinforcement baselines to tandem VI 60-s FT 0.5-s to 10-s schedules, and also found that the stable level of global response rate was a function of the FT value, with shorter delays controlling higher rates than longer delays did.

The effect of different reinforcement rates combined with a constant FT 0-s and FT 12-s delay will be discussed next. The continuous schedule of immediate reinforcement (tan-

dem FR 1 FT 0 s) produced lower first-component (and global) rates of responding than did the tandem RI 15 s FT 0 s, which moderately lowered reinforcement rates. This finding agrees with the results of Sidley and Schoenfeld (1964), who also observed that relative to leaner intermittent schedules of reinforcement, FR 1 produced lower rates of steady-state responding. The likely reason for this is that under FR 1, subjects tend to alternate between responding and collecting reinforcement, thus limiting response rates (see also Baum, 1993; Brandauer, 1958). In the present study, rates of immediate reinforcement lower than tandem RI 15 s FT 0 s (i.e., tandem RI 30 s FT 0 s, tandem RI 60 s FT 0 s, and tandem RI 120 s FT 0 s) also controlled lower first-component rates of responding. Although the rates of responding controlled by tandem RI 30 s FT 0 s and tandem RI 60 s FT 0 s were not different from each other, the tandem RI 120 s FT 0 s controlled the lowest response rates. This generally decreasing function between rates of responding and rates of immediate reinforcement during acquisition is similar to functions obtained under comparable conditions in investigations of steady-state responding (cf. Catania & Reynolds, 1968). Thus, these results suggest that delivering immediate reinforcement at different rates has the same effect during the acquisition of a new response and during its subsequent maintenance.

The combination of different reinforcement rates with a constant unsignaled delay, FT 12 s in the present investigation, controlled response rates that, although lower than those obtained under FT 0, were not statistically different from each other. This outcome suggests that the positive correlation between rates of responding and rates of reinforcement, frequently reported in the response-maintenance literature, can be attenuated by response-reinforcer delays, at least for response acquisition. This finding awaits follow-up because such parameter combinations have not been explored previously with either response acquisition or steady-state maintenance of behavior. However, an interesting comparison can be made to research involving two-component chain schedules. In general, such experiments show that rate of responding in the initial component decreases

es as a function of both lengthening the duration of the terminal component and decreasing the rate of primary reinforcement (Findley, 1962; Gollub, 1977). The results of the present study agree with those on chain schedules in that adding a 12-s delay to the different reinforcement schedules produced lower first-component response rates than using immediate reinforcement. However, the effects of varying the rate of the 12-s delayed reinforcement were not statistically significant and thus differed from the more common finding in the literature on chain schedules. Findley (1962), for example, varied the overall rate of reinforcement using different VI schedules in the first component of a two-component chain schedule, and a constant fixed-interval 1 min (an analogue of a delay interval) comprised the second component. Rates of responding in the first component decreased as the mean duration of the first component was lengthened, hence decreasing reinforcement rate. In spite of the fact that the present research found no similar statistically significant effect, visual inspection of Figure 3 suggests that first- and second-component rates as well as global rates of responding under tandem RI 15 s FT 12 s and tandem RI 30 s FT 12 s were consistently higher than they were under the other schedules with longer interreinforcement intervals.

The effects of different reinforcement delays combined with constant reinforcement rates, FR 1 and RI 60 s, will be discussed next. The results produced by combining several FT intervals with a constant FR 1 schedule can be compared to those of a study by Dews (1960) that involved steady-state responding by pigeons under tandem FR 1 FT x schedules. During steady-state responding, delays of 10 and 30 s controlled similar global rates of key pecking, whereas a 100-s delay resulted in lower response rates. In the present study, it was also found that global and first-component rates of lever pressing were statistically similar under delays of 12 and 24 s when combined with FR 1 (and lower than rates with shorter delays).

Another comparison can be made with the study by Wilkenfield et al. (1992) that involved acquisition of lever pressing by rats. In their study no systematic relation was found between global rate of responding and unsignaled reinforcement delays (either FT 0-, 4-,

8-, or 16-s delays) when combined with an FR 1 schedule. The present investigation also revealed that FT delays in the range from 3 to 24 s were not reliably related to global response rates. However, in contrast to the results of Wilkenfield et al., in the present study, FT 0 s combined with the FR 1 schedule controlled global response rates reliably higher than any other longer delay.

Also relative to the study by Wilkenfield et al. (1992), one of the questions asked by this investigation was whether the effect of different delays of reinforcement on the acquisition of a new response would be the same when superimposed on continuous (FR 1) and intermittent RI 60-s schedules. As noted previously, Bruner et al. (1994) found a typical delay gradient during the acquisition of lever pressing using tandem RI 30-s FT 6-s to 24-s schedules. Thus, one possibility was that the different findings of Wilkenfield et al. and Bruner et al. were due to the use of an intermittent schedule of delayed reinforcement in the latter study versus an FR 1 schedule in the earlier study. Because no delay gradient was found in the present investigation for global response rates, the present results contrast with both previous studies. Wilkenfield et al. acknowledge that a possible explanation for their having obtained similar global response rates under immediate reinforcement and under several delays of reinforcement may be that these conditions were tested in a single, very long (500-min) session. Unlimited reinforcer availability could have produced faster satiation under immediate reinforcement than in their other delay conditions, thus artificially lowering response rate in the former condition. In contrast, in the present research the number of food pellets available in any given session was restricted to 30 for all animals; therefore, differential satiation was unlikely. Keeping motivation constant across all conditions in the present experiment may have been responsible for the higher rates of responding under immediate reinforcement than under any delay duration. In the previous study by Bruner et al., in which global response rates decreased uniformly as a function of delay duration, global response rates were considerably higher than those obtained in the present investigation. Such higher response rates may have been due to the use of an RI

30-s schedule in the first component of their tandem schedules, which, by providing a higher rate of reinforcement than the present RI 60-s schedule, may have in turn avoided a floor effect. That is, higher response rates in the previous study may have been more sensitive to the effects of longer response-reinforcer intervals. Although the FR 1 schedule used in the present investigation provided a still higher rate of reinforcement than the RI 30-s schedule used in the study by Bruner *et al.*, the present data show that rates of responding controlled by FR 1 are as low as those controlled by the RI 60-s schedule. Also worth noting in the present research is that although global response rates were not reliably related to delays in the range between 1 and 24 s, first-component rates did show a graded effect, being highest under immediate reinforcement, intermediate under 1-, 3-, and 6-s delays, and lowest under delays of 12 and 24 s.

The combination of different delays of reinforcement with a constant RI 60-s schedule can also be compared with the results of studies that have explored the effects of intermittent delayed reinforcement in steady-state conditions. Williams (1976) used tandem VI 2-min FT 3-s to 15-s schedules and found that the global rate of pecking by pigeons decreased after a shift from immediate reinforcement to 3-s delay, although further increases in the delay interval produced unsystematic effects on global response rates. Sizemore and Lattal (1978) also used pigeons to vary the delay interval from 0.5 to 10 s using tandem VI x FT x schedules, in which the VI interval varied as the complement of FT duration so as to yield a constant 60-s interreinforcement interval. They found that lengthening delay produced corresponding decreases in the global response rate and that the largest decrease occurred after the change from 0.5-s to 1-s delay. Richards (1981) also used pigeons and tandem VI 60-s FT 1-s to 10-s schedules. Response rates in the first component of the tandem schedules dropped sharply with FT values in the range from 0 to 5 s and leveled off in the range from 5 to 10 s. Relative to these studies that have used intermittent schedules to examine the effects of different delay durations on the steady-state responding of pigeons, the present investigation, involving the acquisition of

lever pressing by rats, revealed two similar findings. First, the largest difference in first-component and global response rates occurred between immediate reinforcement and the first condition of noncontiguity (i.e., 1-s delay), and the 1-s delay controlled second-component response rates that were much higher than delays in the range from 3 to 24 s. Second, delays in the range from 3 to 24 s did not produce significant differences for global response rate.

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