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EFFECTS OF CHLORPROMAZINE ON FIXED-RATIO RESPONDING: MODIFICATION BY FIXED-INTERVAL DISCRIMINATIVE STIMULI

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Effects of chlorpromazine (1 to 100 mg/kg) were assessed on two pigeons' responding under various modifications of a multiple schedule of food delivery. During a fixed-interval component, the first response after 5 min produced food; during the subsequent, fixed-ratio component, the 30th response produced food. Modifications of the schedule entailed changes in stimulus conditions imposed during the fixed-ratio component that did not systematically alter characteristics of performance under nondrug conditions. In the first phase of the experiment, distinctive visual stimuli were correlated with each schedule component (conventional multiple schedule); chlorpromazine produced small decreases in fixed-ratio responding (20% at 30 mg/kg). When each response during the fixed-ratio component produced the stimulus correlated with the fixed-interval schedule (fixed-interval discriminative stimulus) for 1.2 s, effects of chlorpromazine were not different from those under the conventional multiple schedule. Chlorpromazine produced greater decreases in fixed-ratio responding (55% at 30 mg/kg) when either the first response of each fixed ratio changed the stimulus correlated with the fixed-ratio schedule to the fixed-interval discriminative stimulus for the remainder of the fixed-ratio component, or when the fixed-interval discriminative stimulus was presented independently of responding according to a matched temporal sequence. When the fixed-interval discriminative stimulus was present continuously during the fixed-ratio component (mixed schedule), chlorpromazine produced even more substantial decreases in fixed-ratio responding (greater than 80% at 30 mg/kg). Effects of chlorpromazine on fixed-interval responding were also modified by the schedules of fixed-interval discriminative stimulus presentation. The effects of chlorpromazine were a joint function of the stimuli prevailing during the multiple schedule and the degree to which responding influenced these stimuli.

Key words: chlorpromazine, fixed-ratio schedules, fixed-interval schedules, multiple schedules, mixed schedules, stimulus control, discriminative stimuli, pigeons

Behavioral effects of drugs can be altered by the stimuli prevailing at the time of drug administration (cf. Laties, 1975; Thompson, 1978). For example, in pigeons, chlorpromazine produces very little change in fixed-ratio responding under a multiple fixed-interval fixed-ratio (multiple FI FR) schedule across a range of doses that markedly decrease FR responding under a comparable mixed FI FR schedule (Leander & McMillan, 1974), even when performances under the two conditions are made quite similar (Leander, 1981a). Under a multiple FI FR schedule, distinctive stimuli are correlated with each schedule component. A mixed FI FR schedule provides reinforcement according to the identical response contingencies as a multiple FI FR schedule, but the same stimulus is present during both FI and FR components (Ferster & Skinner, 1957).

The present study was initiated when it was observed that chlorpromazine only marginally decreased FR responding under a multiple FI FR schedule modified so that stimulus conditions more closely resembled a mixed schedule. Under the modified schedule, each FR response produced a 1.2-s change from the stimulus present during the FR component (FR–discriminative stimulus; FR–S^D) to the stimulus present during the FI component (FI–discriminative stimulus; FI–S^D). In contrast to a mixed schedule, however, absence of FR responding under the modified schedule for more than 1.2 s produced the FR–S^D, thus reinstating the original multiple schedule condition. This provision for the reinstatement of the multiple schedule stimuli may have limited the rate-decreasing effects of chlorprom-

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azine that are so prominent under a mixed schedule.

In order to identify the stimulus conditions influencing the effects of chlorpromazine, the schedules under which the FI–S^D was presented during the FR schedule component were manipulated in the present study. The experiment evaluated the role of response-dependent and response-independent changes in discriminative stimuli on the behavioral effects of chlorpromazine. Specifically, it was of interest to determine whether chlorpromazine would produce more substantial behavioral effects when the degree of control over discriminative stimuli by responding was more limited and when behavioral control of stimulus presentations was eliminated. Across all phases of the study, rates and temporal patterns of responding under nondrug conditions were either unchanged or not systematically altered; thus, any variations in the effects of chlorpromazine could not be attributed to these potentially important variables (Kelleher & Morse, 1968; McKearney & Barrett, 1978).

METHOD

Subjects

Two adult male White Carneaux pigeons were maintained at 80% (425 and 455 g) of their free-feeding body weights. Both pigeons had prior exposure to fixed-interval schedules with a red keylight, and to multiple FI FR schedules as described below. They were housed individually in a temperature-controlled vivarium with constant illumination and had continuous access to fresh water and oyster-shell grit.

Apparatus

The experimental chamber was similar to that described by Ferster and Skinner (1957). A translucent response key (Gerbrands) was mounted behind a 2-cm-diameter opening in the front panel of the chamber and could be transilluminated with blue or red light. A minimum force of 0.15 N applied to the key was recorded as a response and produced the audible click of a relay. Mixed grain could be presented for 3.5 s to an opening 12 cm below the response key by a solenoid-operated feeder. When grain was presented, the grain magazine was illuminated and the keylight was extinguished. The experimental chamber was located within a ventilated, sound- and light-attenuating enclosure that provided diffuse white illumination of the chamber and white noise to mask extraneous sounds.

Behavioral Procedure

Table 1 lists the experimental conditions in the order in which they were studied. In all conditions, responding was maintained by contingent food delivery under compound schedules whose component schedules were FR 30 and FI 5 min. In the FR 30 component, the 30th response produced food; the first response after 5 min produced food in the FI component. If the FR 30 response requirement was not completed within 60 s, or if no response occurred within 60 s of the lapse of the FI, components alternated without food delivery (60-s limited hold). Schedule components alternated after each food delivery or the lapse of the limited hold. Experimental sessions consisted of 11 presentations of each schedule component, started with the FR 30 and, under nondrug conditions, lasted about 60 min.

Under all experimental conditions, the FI 5-min schedule was always correlated with a red keylight, the FI discriminative stimulus (FI–S^D). Stimuli correlated with the FR 30 schedule were varied across Conditions 1 through 6. However, in all cases the 30th response during the FR 30 component produced food regardless of the keylight color prevailing during that component. In the first condition, a blue keylight was correlated with the FR 30. In Condition 2 (FR–each schedule), each response changed the keylight color from blue (FR–S^D) to red (FI–S^D) for 1.2 s, an arbitrary value selected on the basis of the interreinforcement intervals obtained under the FR component of the multiple FI FR schedule (7 to 15 s). If a response did not occur during this 1.2-s interval, the FR–S^D was reinstated. Responses during the FI–S^D prolonged the presentation of the FI–S^D for additional 1.2-s periods. Thus, interresponse times less than 1.2 s resulted in continuous presentation of the FI–S^D. In Condition 3 (FR–first schedule), the first response in the FR changed the keylight color from blue to red, which remained until the 30th response produced food. In Condition 4 (prime–FR schedule), the keylight color changed from blue to red, independently of responding, t s after the onset of the

FR–S^D. The values of t are given in Table 1 and were based on the mean pause durations (i.e., the duration of the FR–S^D) established under the preceding condition (FR–first schedule). Thus, the stimulus conditions during the FR component were comparable under the FR–first and prime–FR schedules; however, in the FR–first condition, changes in the stimuli were determined by the behavior of the pigeon, whereas under the prime–FR schedule, stimulus changes occurred independently of responding. During the fifth condition (mixed schedule), the red keylight (FI–S^D) was present continuously during both FI and FR schedule components. The final condition was a replication of Condition 1 (multiple schedule) in which separate blue and red keylights were correlated with the FR and FI schedule components, respectively.

Experimental events were scheduled by electromechanical switching circuitry located in a separate room. Data were recorded on digital counters, elapsed-time meters, and a cumulative response recorder. Experiments were conducted 6 days per week, Sunday through Friday.

Table 1

Experimental conditions in the order in which they were studied. Numbers of sessions per condition are shown in parentheses for Pigeons 659 and 660, respectively.

Schedule of reinforcement	Stimulus conditions	
	FI	FR
1. Multiple FI 5-min FR 30 (50, 56)	Red	Blue
2. Multiple FI 5-min FR 30–each (78, 91)	Red	Blue, but each response produced red for 1.2 s
3. Multiple FI 5-min FR 30–first (82, 75)	Red	Blue, but first response produced red for remainder of component
4. Multiple FI 5-min prime–FR 30 (54, 51)	Red	Blue, but red occurred independently of responding at time t where t equals mean pause time in condition 3 (t = 2.1 s for P-659 and 3.4 s for P-660)
5. Mixed FI 5-min FR 30 (68, 74)	Red	Red
6. Multiple FI 5-min FR 30 (50, 56)	Red	Blue

Pharmacological Procedure

Drug experiments began after at least 14 sessions of each experimental condition and when no session-to-session trends were present in the data over 5 consecutive days. For every condition, entire dose-effect functions were determined before proceeding to the next condition. Each dose, expressed as the salt, was studied at least twice in each pigeon and doses were given in a mixed order. Solutions of chlorpromazine hydrochloride (donated by Smith, Kline and French) were made fresh with distilled water. Injections (1.0 mL/kg) were given into the pectoral muscle immediately before the experimental session. Drug or saline injections were typically given on sessions conducted on Tuesdays and Fridays; data from the preceding day served as noninjection control values against which the effects of injections were assessed.

Data Analysis

Four measures of performance were obtained separately during the FI and FR schedule components. Mean pause time, the time from component onset to the first response, was assessed by dividing the cumulative elapsed time from component onset to the first response of the component by 11 (the number of individual FI and FR schedule components). Overall response rates were calculated by dividing the total number of responses in the FI or FR components by the corresponding total elapsed time. Running response rates were calculated by dividing the total number of responses by the total elapsed time in the components excluding pause time. After the first response in the FR component, momentary pauses in responding for more than 1.2 s activated a timer that was turned off with the next response. This value was divided by 11 to determine the mean amount of time per component during which the FR–S^D would have been reinstated under the FR–each schedule. Also counted were the numbers of schedule components per session that terminated without food delivery (elapsed limited holds).

RESULTS

Performances under the compound FR 30 FI 5-min schedules were generally similar regardless of whether the FI–S^D was presented during the FR schedule component and irre-

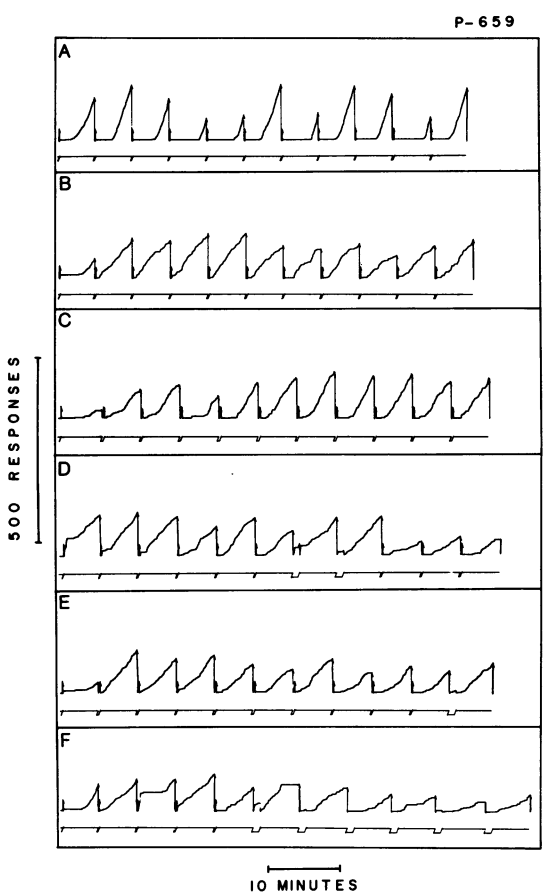

Fig. 1. Cumulative response records for Bird P-659 showing control performance under the mixed FI FR schedule (Panel A) and effects of 30 mg/kg chlorpromazine under various conditions of FI-S^D presentation during the FR schedule component (Panels B to F). Each response incremented the response pen. The lower event pen of each record was displaced during the FR schedule component. The response pen reset at the end of each schedule component. Panel B: multiple schedule; Panel C: FR-each schedule; Panel D: FR-first schedule; Panel E: prime-FR schedule; Panel F: mixed schedule. Performance under the mixed FI FR schedule shown in Panel A was representative of control performance across all experimental conditions. Experimental conditions are defined in Table 1 and in the Methods section.

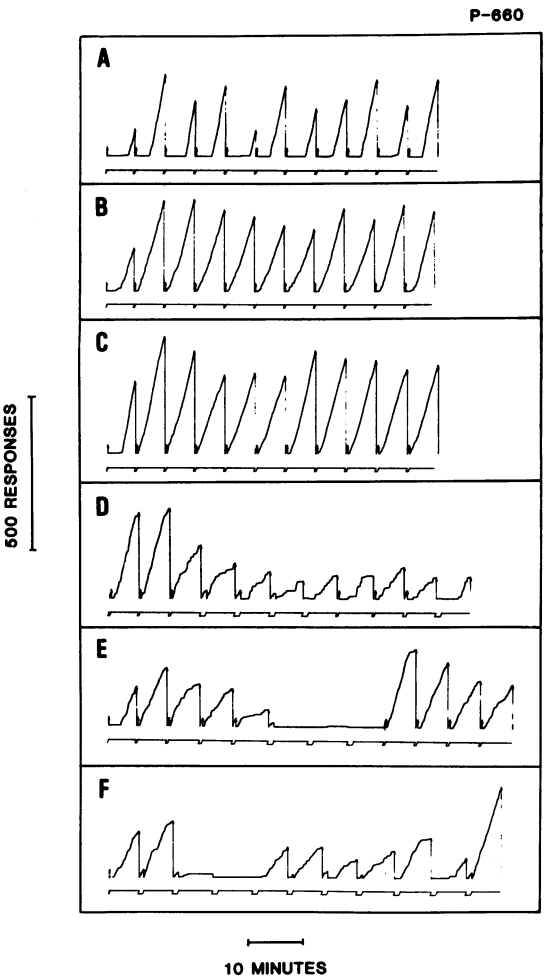

Fig. 2. Cumulative response records for Bird P-660 showing control performance under the mixed FI FR schedule (Panel A) and effects of 30 mg/kg chlorpromazine under various conditions of FI-S^D presentation during the FR schedule component (Panels B to F). Panel B: multiple schedule; Panel C: FR-each schedule; Panel D: FR-first schedule; Panel E: prime-FR schedule; Panel F: mixed schedule. Other details as in Figure 1.

spective of whether the FI-S^D was presented contingently. Representative performances under the mixed FR 30 FI 5-min schedule (Condition 5) are shown for the two pigeons in the top panels of Figures 1 and 2, respectively. During the FR 30 schedule, a brief period of no responding was followed by a high rate of responding that prevailed until food delivery. Under the FI 5-min schedule, a period of little or no responding was followed by a moderate rate of responding until food presentation. Control rates of responding were relatively invariant across the six experimental conditions for P-659 and showed no systematic trends across conditions for P-660 (Table 2). Other aspects of performance under the FR schedule (reinforcers per session, pause duration, and momentary pause times) also were not systematically affected by the various stimulus conditions imposed (Tables 3, 4, and 5, considered in detail later).

Table 2

Control rates of responding (responses per second ± *SD*) for the FR and FI schedule components under the six experimental conditions. For details see Table 1 and Methods section.

	Experimental conditions					
	1 Multiple	2 FR–each	3 FR–first	4 Prime–FR	5 Mixed	6 Multiple
Overall rate–FR						
P-659	3.79 ± 0.45	3.99 ± 0.52	3.67 ± 0.35	4.14 ± 0.26	3.90 ± 0.17	3.62 ± 0.28
P-660	2.92 ± 0.48	2.21 ± 0.26	2.21 ± 0.48	2.72 ± 0.48	1.72 ± 0.14	2.63 ± 0.35
Running rate–FR						
P-659	5.15 ± 0.66	5.57 ± 0.75	4.90 ± 0.38	5.53 ± 0.69	5.25 ± 0.38	4.82 ± 0.38
P-660	3.88 ± 0.73	2.71 ± 0.49	2.96 ± 0.55	3.31 ± 0.62	2.25 ± 0.24	3.39 ± 0.52
Overall rate–FI						
P-659	0.31 ± 0.07	0.34 ± 0.07	0.32 ± 0.03	0.39 ± 0.03	0.39 ± 0.03	0.38 ± 0.07
P-660	0.78 ± 0.10	0.71 ± 0.11	0.70 ± 0.14	0.67 ± 0.10	0.64 ± 0.11	0.57 ± 0.10
Running rate–FI						
P-659	0.49 ± 0.14	0.57 ± 0.07	0.55 ± 0.10	0.69 ± 0.10	0.71 ± 0.14	0.69 ± 0.10
P-660	1.35 ± 0.17	1.27 ± 0.15	1.41 ± 0.31	1.18 ± 0.21	1.25 ± 0.14	1.13 ± 0.14

Effects of chlorpromazine on overall rates of responding under the FR 30 schedule are shown in Figure 3 for each pigeon. Across a wide range of doses (1 to 30 mg/kg), chlorpromazine had little effect on overall FR rates under the multiple schedule (open and filled circles); a dose of 30 mg/kg produced less than a 20% decrease in rate. When each response during the FR component produced the FI–S^D (squares; FR–each schedule), there was little change in the effects of chlorpromazine. At 30 mg/kg, responding was decreased only 20% for P-660 and 30% for P-659. Under the FR–first schedule (triangles), the first response during the FR component produced the FI–S^D; under the prime–FR schedule (inverted triangles), the FI–S^D was presented independently of responding. Dose-effect functions for chlorpromazine obtained during these two conditions were very similar and were steeper than those obtained under the multiple or FR–each condition. For example, under both FR–first and prime–FR schedules, the 30-mg/kg dose of chlorpromazine decreased FR responding by about 55%, an effect almost three times greater than under the multiple schedule (Conditions 1 and 6). Under the mixed schedule in which the FI–S^D was present continuously (diamonds), effects of chlorpromazine were even more pronounced. Chlorpromazine produced substantial decreases across a wider range of doses than under the earlier conditions. At 30 mg/kg, FR responding was almost completely eliminated for P-659 and was decreased by 80% in P-660. Effects of chlorpromazine on FR responding under the multiple schedule (Condition 1) were replicated (Condition 6) after the four intervening conditions. The relation among dose-effect curves across conditions was generally the same for running rates of FR responding (Figure 4) as it was for overall rates.

The reliability of differences between dose-effect functions can be assessed by the degree of overlap in the observations (2 to 3 determinations of each dose per condition) across experimental conditions. For example, the range of values obtained after 30 mg/kg chlorpromazine did not overlap between FR–each and FR–first or prime–FR schedules, nor did the ranges overlap between prime–FR and the mixed schedule. Additional confirmation of data reliability comes from the cross-subject consistency in drug effects across experimental conditions and the replicability of the results upon return to the multiple schedule.

Figures 1 and 2 demonstrate that 30 mg/kg of chlorpromazine produced disruptions in FR responding that generally increased in magnitude from Conditions 1 through 5 (Panels B through F). Instances occurred in which the high steady rate of FR responding was interrupted under chlorpromazine by pauses in responding. These effects were most prominent under the FR–first, prime–FR, and

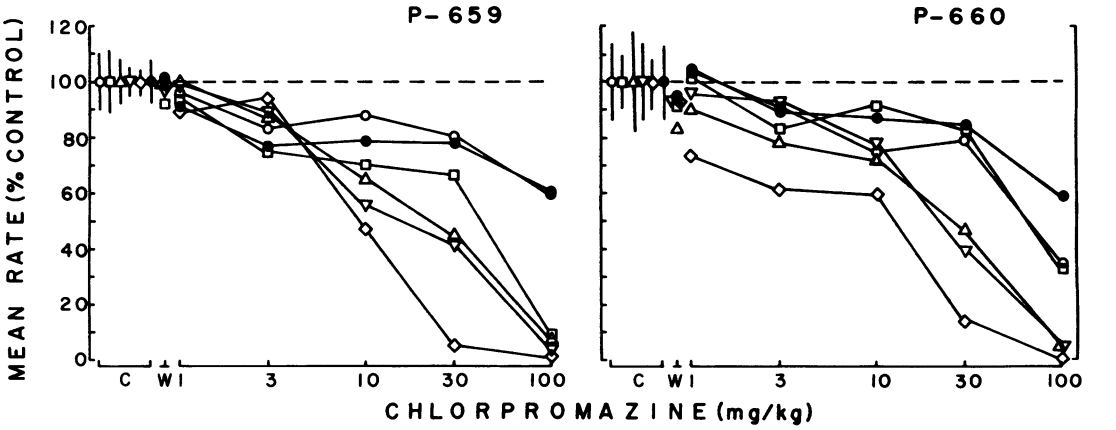

Fig. 3. Effects of chlorpromazine on overall rates of responding during the FR schedule component for each of six experimental conditions in which the stimuli prevailing during the FR component were varied (see Table 1). Above C (on the abscissa) are shown the control means (n = 12 to 14), along with ±3 *SE*. Unconnected points above W represent the effects of vehicle control injections. O multiple schedule; □ FR–each schedule; △ FR–first schedule; ▽ prime–FR schedule; ◇ mixed schedule; ● multiple schedule (replication). Drug effects are means of two or three determinations.

mixed schedules (Panels D, E, and F, respectively); under those conditions, reinforcers sometimes were not obtained.

Under the FR–each schedule, momentary pauses of greater than 1.2 s resulted in the reinstatement of the FR–S^D. When chlorpromazine (up to and including 30 mg/kg) was studied in this condition, reinstatement of the FR–S^D always resulted in a resumption of responding and the FR requirement was always completed. In contrast, under the FR–first, prime–FR, and mixed schedules (Conditions 3, 4, and 5), momentary pauses greater than 1.2 s did not reinstate the FR–S^D and, under chlorpromazine, decreases in responding often resulted in the termination of the schedule component without food delivery. Table 3 shows the number of scheduled reinforcers not obtained after 30 mg/kg chlorpromazine due to the lapse of the FR limited

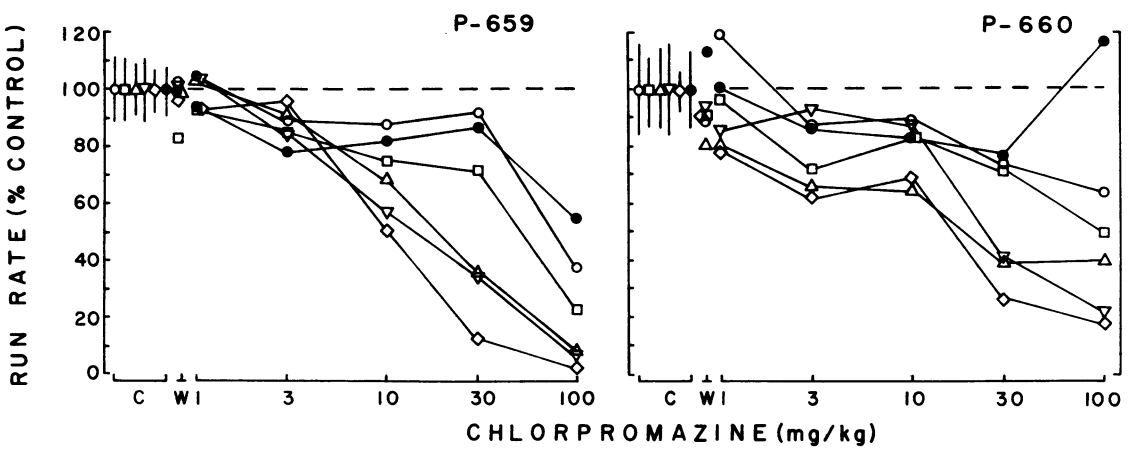

Fig. 4. Effects of chlorpromazine on running rates of responding under the FR schedule component for each of six experimental conditions in which the stimuli prevailing during the FR component were varied (see Table 1). Above C (on the abscissa) are shown control means (n = 12 to 14), along with ±3 *SE*. Unconnected points above W represent the effects of vehicle control injections. O multiple schedule; □ FR–each schedule; △ FR–first schedule; ▽ prime–FR schedule; ◇ mixed schedule; ● multiple schedule (replication). Drug effects represent means of two or three determinations.

Table 3

Mean number of FR components in which food was not presented under control conditions and after 30 mg/kg chlorpromazine under the six experimental conditions. For details see Table 1 and Methods section.

	Experimental conditions					
	1 Multiple	2 FR–each	3 FR–first	4 Prime–FR	5 Mixed	6 Multiple
P-659						
Control	0	0	0	0	0	0
30 mg/kg[a]	0	0	1.5	1.0	9.0	0
P-660						
Control	0	0	0	0	0	0
30 mg/kg[a]	0	0	2.0	2.0	7.5	0

[a] Means of two or three determinations.

hold. The relative disruption occurring across conditions paralleled the relative difference in rates of responding (Figures 3 and 4). Qualitatively similar effects occurred at doses of 10 and 100 mg/kg chlorpromazine (data not shown).

Control pause duration under the FR 30 schedule was relatively invariant across experimental conditions and showed no systematic trends (Table 4). Chlorpromazine (3 to 100 mg/kg) increased pause duration for P-659 but often decreased pause duration for P-660 (3 to 30 mg/kg). As shown in Table 4, 30 mg/kg chlorpromazine increased pause duration across all conditions for P-659 but increases were 10-fold greater under the mixed schedule. For P-660, pause duration increased only under the prime–FR and mixed schedules. Qualitatively similar observations were made at 3 and 10 mg/kg. Pause durations substantially increased in both birds at 100 mg/kg (data not shown).

Table 5 presents data on momentary pauses (times cumulating with interresponse times greater than 1.2 s) in FR responding that occurred after the initial postreinforcement pause. This measure showed no systematic trends across conditions and for P-659 was quite constant. Chlorpromazine (30 mg/kg) had little effect on momentary pauses under the multiple schedule (Condition 1). Increases occurred after 30 mg/kg under the FR–each schedule, but more substantial increases were obtained under the FR–first, prime–FR, and mixed schedules. Effects of chlorpromazine on momentary pauses declined again when the multiple schedule was reinstated in Condition 6, although original effects were not completely replicated for P-659. Qualitatively similar results occurred after 3 and 10 mg/kg chlorpromazine (data not presented).

Figure 5 presents chlorpromazine dose-effect curves for overall rates of FI responding under each of the experimental conditions. Under the conventional multiple schedule (open and filled circles, Conditions 1 and 6), chlorpromazine (3 to 30 mg/kg) produced only modest decreases in FI responding for P-659. For P-660, increases in FI responding occurred with chlorpromazine (3 to 30 mg/kg). Interestingly, increases in FI responding at doses of 3 and 10 mg/kg did not occur when chlorpromazine was first studied under the multiple schedule; however, these doses consistently increased FI rates for P-660 under all subsequent phases of the study. A striking

Table 4

Mean pause time (seconds ± *SD*) for the FR schedule component during control sessions and after 30 mg/kg chlorpromazine under the six experimental conditions. For details see Table 1 and Methods section.

	Experimental conditions					
	1 Multiple	2 FR–each	3 FR–first	4 Prime–FR	5 Mixed	6 Multiple
P-659						
Control	2.12 ± 0.97	2.12 ± 0.52	2.12 ± 0.62	1.80 ± 0.35	2.01 ± 0.31	2.02 ± 0.35
30 mg/kg[a]	3.41	3.67	3.18	2.95	32.60	3.33
P-660						
Control	2.88 ± 0.07	3.39 ± 0.79	3.39 ± 2.08	2.00 ± 0.42	3.39 ± 0.97	2.93 ± 0.83
30 mg/kg[a]	3.02	1.66	2.27	7.28	18.95	2.02

[a] Means of two or three determinations.

Table 5

Momentary pause time (mean in seconds ± *SD*) for the FR schedule component during control sessions and after 30 mg/kg chlorpromazine under the six experimental conditions. For details see Table 1 and Methods section.

	Experimental conditions					
	1 Multiple	2 FR–each	3 FR–first	4 Prime–FR	5 Mixed	6 Multiple
P-659						
Control	0.26 ± 0.28	0.17 ± 0.11	0.15 ± 0.14	0.12 ± 0.17	0.13 ± 0.10	0.22 ± 0.14
30 mg/kg[a]	0.23	0.50	7.73	3.37	11.01	0.50
P-660						
Control	0.09 ± 0.10	0.41 ± 0.52	0.34 ± 0.35	0.10 ± 0.14	0.82 ± 0.31	0.21 ± 0.14
30 mg/kg[a]	0.14	0.86	13.33	5.42	15.78	0.21

[a] Means of two or three determinations.

consequence of the experimental manipulations was the reversal of the rate-increasing effects of 30 mg/kg chlorpromazine (P-660) under the FR–first (triangles), prime–FR (inverted triangles), and mixed (diamonds) schedules. Fixed-interval responding under the mixed schedule (diamonds) was decreased by chlorpromazine (30 and 100 mg/kg) for P-660; under the mixed schedule, FI responding was decreased more than under the other conditions for P-659. Running rates of FI responding were not increased in either pigeon with chlorpromazine (data not presented). As with overall rates (Figure 5), 30 mg/kg decreased responding to a much greater extent under the mixed schedule than under the other conditions.

The tendency for the rate-decreasing effects of chlorpromazine to become progressively more pronounced across conditions did not correlate precisely with the effects of the drug on FR responding (compare Figures 3 and 5). Chlorpromazine generally decreased FR responding at doses that either increased responding or that produced smaller decreases in rates of FI responding. In addition, although chlorpromazine decreased FR responding in a graded fashion across conditions, it did not do so to FI responding.

The temporal pattern of responding under the FI schedules was markedly disrupted after 30 mg/kg chlorpromazine (Figures 1 and 2). Under all conditions, the pause in responding usually present during the early periods of the FI was shortened or eliminated. In records D, E, and F, FI responding was frequently negatively accelerated toward the end of the interval. The rate increases in FI responding produced by chlorpromazine were attenuated in these latter conditions. These records also indicate that the negatively accelerated responding and the reduced rate-increasing effects of chlorpromazine were not correlated precisely with the loss of reinforcers under the FR schedule, inasmuch as these changes in FI responding also occurred at points in the session where reinforcers were obtained under the FR component (e.g., Figure 2, Panels D and E). Also apparent in the FI records is the occurrence of brief bursts of high-rate responding separated by pauses. These effects were most notable under the mixed schedule (Panel F) and, at least for P-660, did not occur at all under the multiple or FR–each conditions (Figure 2, Panels B and C).

DISCUSSION

The principal finding of the present study was that the effects of chlorpromazine on responding under a multiple FI FR schedule were substantially altered by the presentation of FI discriminative stimuli during the FR component. Leander (1981a) also compared performances under a multiple FI FR schedule with those occurring under a mixed FI FR schedule in which component schedules alternated successively. As in the present study, Leander found marked decreases in FR responding under the mixed schedule at doses of chlorpromazine that had no effect on rates of responding under the multiple schedule. Similar differences in the effects of chlorpromazine on performances under multiple

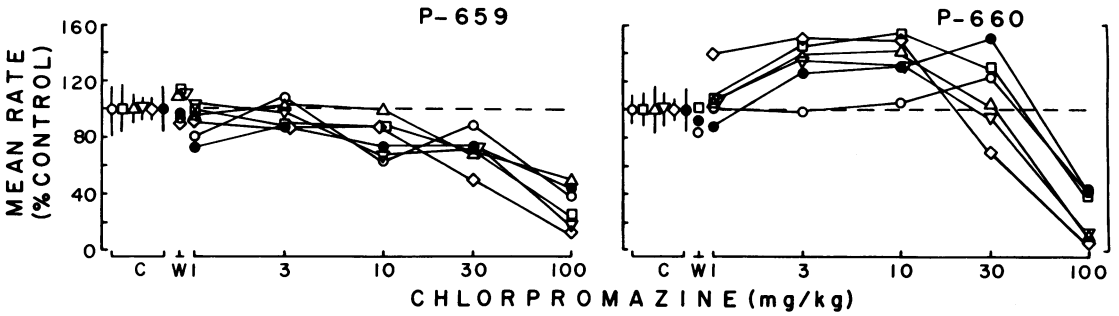

Fig. 5. Effects of chlorpromazine on overall rates of responding under the FI schedule component for each of six experimental conditions in which the stimuli prevailing during the FR component were varied (see Table 1). Points above C show control means (n = 12) and ±3 *SE*. Unconnected points above W represent the effects of vehicle control injections. O multiple schedule; □ FR-each schedule; △ FR-first schedule; ▽ prime-FR schedule; ◇ mixed schedule; ● multiple schedule (replication). Drug effects are means of two or three determinations.

and mixed schedules have been reported under conditions in which schedule components alternate in a quasi-random sequence (Leander & McMillan, 1974).

Ksir and McKearney (1978) compared effects of the related compound, promazine, under a multiple FI FR schedule with drug effects obtained under a primed FI FR schedule (Ferster & Skinner, 1957). Under the primed schedule, the FI–S^D or the FR–S^D was present for the first 6 s of each component, after which time a third stimulus, common to both schedules, was present. No differences in effects of promazine across these conditions were noted. In contrast, under the prime–FR schedule of the present study, chlorpromazine decreased FR responding more than under a comparable multiple FI FR schedule. The discrepancy between the results of these studies may be due to procedural differences. The relatively long duration of the priming stimulus used by Ksir and McKearney probably allowed a substantial number of FR responses to be completed during the FR–S^D. In addition, Ksir and McKearney used priming stimuli in both FI and FR components, whereas the FI–S^D was in effect during the entire FI cycle of the prime–FR condition used in the current study. The additional FI priming stimulus in their study provided a basis for discrimination between FI and FR components not available in the prime–FR schedule reported here.

In the present study, stimulus presentations were manipulated across experimental conditions during which control rates and temporal patterns of responding were relatively constant or not systematically affected. This fact, combined with the observed between-subjects consistency of effects across conditions, demonstrates that slight differences in control rates or temporal patterns of responding did not contribute importantly to the differences in effects of chlorpromazine. Although not varying along a single dimension, the experimental conditions imposed can be viewed as a continuum (in terms of stimulus similarity between components as well as the degree to which responding affected stimulus presentation) with the conditions varying between a multiple and a mixed schedule. Changes in the effects of chlorpromazine across this continuum revealed that discriminative stimuli can profoundly modify the effects of this drug. Compared to the mixed schedule, presentation of a brief priming stimulus mitigated the rate-decreasing effects of chlorpromazine on FR responding. When FI- and FR-discriminative stimuli were perfectly correlated with their respective schedules of reinforcement (multiple FI FR), the rate-decreasing effects of chlorpromazine were modest or absent across a wide dose range.

The relationship between responding and discriminative-stimulus presentation was an important determinant of the behavioral effects of chlorpromazine. Although the discriminative stimuli were virtually identical under the FR–each, FR–first, and prime–FR schedules under control conditions, differences in effects of chlorpromazine across these conditions were observed. For example, rates of FR responding under the FR–each schedule were not different from those under the multiple schedule. However, chlorpromazine pro-

duced larger increases in momentary pause times under the FR–each condition than under the multiple schedule. Following momentary pauses of greater than 1.2 s under the FR–each schedule, the FR–S^D was reinstated. This reinstatement of the FR–S^D resulted in a resumption of responding and completion of the FR requirement (Tables 3 and 5). Unlike in the FR–each schedule, reinstatement of the FR–S^D did not occur under the FR–first condition; once the FI–S^D was produced under the FR–first schedule, it remained regardless of performance. This absence of reinstatement of the FR–S^D under the FR–first and prime–FR schedules may have been responsible for the greater decreases in FR responding observed in these conditions than under the FR–each schedule. Thus the effect of chlorpromazine on FR responding under the FR–each schedule may have been at times similar to that occurring under the FR–first and prime–FR schedule conditions, but prolonged decreases in responding were opposed by reinstatement of the FR–S^D after momentary pauses.

Chlorpromazine had similar effects on FR responding when the first response in the FR produced the FI–S^D (FR–first schedule) and when the FI–S^D was presented independently of responding (prime–FR schedule). Thus, regardless of whether responding controlled the initial duration of the FR–S^D, FR responding was decreased by chlorpromazine to a greater extent than when each response controlled the occurrence of the discriminative stimuli (FR–each schedule). This result indicates that the control of FR responding by currently available stimuli is more powerful than by stimuli more temporally remote from responding.

Fixed-interval responding was also modified by the schedules of FI–S^D presentation occurring in the FR component. Increases in FI responding of P-660 were reduced or eliminated, and response-rate decreases were exacerbated when FI–discriminative stimuli were presented during the FR component. Behavioral interactions between FI and FR components of the multiple schedules may have contributed to the differences in effects of chlorpromazine on FI responding observed across experimental conditions. Waller (1961) also noted changes in effects of chlorpromazine on FI performances when conditions during the FR component were manipulated. Barrett and Stanley (1980) demonstrated a comparable phenomenon with ethanol. In these earlier experiments, the effects of drugs on FI responding were modified by the FR response requirement. Schedule component interactions were apparently facilitated in the present study by making component discriminative stimuli more similar to one another. Inasmuch as effects of chlorpromazine on FI responding did not correlate precisely with effects on FR responding, subtle drug-behavior interactions may have had more influence on drug effects than did response-induction between FI and FR schedule components.

Whereas effects of chlorpromazine on overall rates of FR responding were comparable, effects on FI responding differed between subjects (see also Branch, 1975; Dews, 1958; Leander, 1981a; Leander & McMillan, 1974, for reports of both rate-increasing and rate-decreasing effects of chlorpromazine on FI responding of pigeons); this provides evidence for increased generality of the effects of chlorpromazine on FR responding described here.

By measuring indices of stimulus control that are independent of performance (cf. Appel & Dykstra, 1977; Katz, 1982), the degree of stimulus control has been shown to modify the behavioral effects of chlorpromazine and promazine (Altman, Appel, & McGowan, 1979; Dykstra, 1979; Hernandez & Appel, 1979; Katz, 1983; Ksir & Slifer, 1982). For example, Katz (1983) showed that promazine did not affect stimulus control when responding was under control of an intense stimulus light but that it decreased stimulus control when responding was controlled by a relatively weak stimulus light. These data are consistent with our finding that responding controlled by temporally remote stimuli was more readily disrupted by chlorpromazine than was responding controlled by temporally contiguous stimuli. In contrast, other findings have indicated that the effects of chlorpromazine are relatively immune to modification by discriminative stimuli (e.g., Laties, 1972; Laties & Weiss, 1966). Laties and Weiss showed that chlorpromazine produced comparable increases in FI responding regardless of whether responding early in the interval was suppressed by stimuli correlated with nonreinforcement. The discrepancy among these reports may be related to differences in

reinforcement contingencies across studies. Drug effects on the stimulus control of behavior depend critically upon the conditions under which they are studied (cf. Katz, 1982). For example, conditions that maintain low rates of responding bring into play the powerful tendency of the phenothiazines to increase responding in pigeons (Leander, 1981b), and such conditions may have led previous authors to conclude that chlorpromazine's behavioral effects are relatively insensitive to the presence of exteroceptive discriminative stimuli (e.g., Laties & Weiss, 1966).

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