EFFECTS OF CHLORPROMAZINE IN THE PIGEON UNDER A SECOND-ORDER SCHEDULE OF FOOD PRESENTATION¹

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Chlorpromazine was studied for its effects on responding under a second-order schedule in which food was presented following a sequence of 20 one-minute fixed-interval components. A brief visual stimulus occurred at the completion of each fixed interval including the one that terminated with food presentation. Chlorpromazine showed rate-dependent effects in that it increased low rates in the early components of the second-order schedule and, to a lesser extent, decreased high rates in the later components. Chlorpromazine also increased rates in the early quarters within the 1-min fixed-interval components and to a smaller extent decreased rates in the final quarter. The alteration in the patterns of responding within 1-min fixed-interval components terminating in a brief stimulus presentation was substantially less than that which occurred throughout the succession of 1-min fixed-interval components terminating in food presentation, thus suggesting that the presentation of the brief stimulus exerted more control over responding within components than did food presentation over the sequence of components. This result and others suggest that studies using drugs may be useful in elucidating the factors controlling patterns of responding in second-order schedules.

Under one class of second-order schedules, a stimulus, usually of brief duration, is presented under a schedule and the behavior engendered by this schedule component is treated as a unitary response that is reinforced according to some schedule of food presentation (Findley, 1962; Findley and Brady, 1965; Kelleher, 1966a,b; deLorge, 1967; Thomas and Stubbs, 1967; Byrd and Marr, 1969, Marr, 1969). The brief stimulus may or may not be temporally paired with food presentation and responses in its presence have no scheduled consequences. The performance under this type of second-order schedule can generally be characterized by two principal features: the temporal distribution of responses within components, *i.e.*, the pattern of responding generated between presentations of the brief stimulus; and the temporal distribution of responses over components, *i.e.*, the pattern of responding throughout a succession of schedule components between presentations of food. These two patterns are effected by (1) the com-

ponent schedule under which the brief stimulus is presented, (2) the schedule of components under which food is presented, and (3) the temporal relation of the brief stimulus to food presentation (Kelleher, 1966a,b; deLorge, 1967; Byrd and Marr, 1969, Marr, 1969).

When the brief stimulus immediately precedes or accompanies the presentation of food, the component schedule performance can be similar to that generated by the presentation of food under the same schedule. For example, if a brief stimulus, paired with food presentation, is presented under a fixed-interval schedule, responding terminating in the brief stimulus presentation is often positively accelerated. The pattern of responding over successive schedule components leading to the presentation of food results from an interaction between the component schedule under which the brief stimulus is presented, and the schedule of components under which food is presented. These effects are illustrated in a schedule of the form FR n (FI- t :S) which Kelleher (1966b) has investigated. Under this schedule a brief stimulus, paired with food presentation, terminates each FI t -min component and food follows the n th presentation of the stimulus. Responding within the fixed-interval components is frequently positively accelerated, particularly during those components temporally close to food presentation. This within-com-

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ponent pattern results largely from the conditioned reinforcing properties of the brief stimulus that are established by virtue of the ultimate pairing of the stimulus with the presentation of food (Kelleher, 1966b). The average rate of responding tends to increase throughout the succession of n fixed-interval components terminating in food presentation.

It is of interest for several reasons to investigate the effects of drugs in altering the patterns of responding generated by second-order schedules. First, little research has been reported concerning the effects of drugs on second-order schedule performance (Thomas, 1966) and none on schedules of the form FR n (FI- t :S). Second, such schedules allow the investigation of lengthy sequences of behavior maintained, in part, by a conditioned reinforcer; the effects of drugs on responding maintained by conditioned reinforcement can thus begin to be compared with that maintained by unconditioned reinforcement. Third, schedules of the form FR n (FI- t :S) generate complex but fairly regular patterns of responding encompassing a wide range of rates, and thus provide interesting baselines for studying the manner in which drugs interact with rates of responding.

Studies of the effects of many drugs on patterns of responding engendered by various schedules of reinforcement have shown that the change in rate of responding effected by a drug is very often inversely related to the rate (Kelleher and Morse, 1968). The concept of rate dependency is pervasive, applying to a wide variety of drugs over many schedule patterns maintained by several types of reinforcers, although there are notable exceptions; *e.g.*, neither chlorpromazine nor the amphetamines will increase responding suppressed by punishment, while the barbiturates and certain minor tranquilizers will (Geller and Seifter, 1960; Cook and Catania, 1964; Kelleher and Morse, 1964). The present experiment showed that the notion of rate dependency can be extended to a second-order schedule of the type discussed above, but that the dependency functions characterizing the rate changes within the second-order schedule components terminating in the presentation of a paired brief stimulus may differ from those characterizing the rate changes over successive components terminating in food presentation.

METHOD

Subjects

Two White Carneaux pigeons with no previous drug experience but with long experimental histories under various schedules of food reinforcement, including second-order schedules, were maintained at 80% of their free-feeding weight. Water and grit were available at all times in their home cages.

Apparatus

The experimental chamber was similar to that described by Ferster and Skinner (1957). It contained a single response key that could be transilluminated by either blue or red 6-w lamps and that required a minimum force of 12 g (0.118N) to operate. White noise was present at all times. The experiment was arranged by relay switching circuitry and data were recorded by digital counters, elapsed time meters, and a Gerbrands cumulative recorder. Mixed grain was used as a reinforcer.

Procedure

Experimental sessions were conducted Monday through Friday. Each session ended when eight food presentations had occurred, and each food presentation comprised six 3-sec operations of the feeder.

The second-order schedule studied was FR 20 (FI-1:R). Under this schedule food presentation occurred upon the completion of 20 consecutive FI 1-min components. A blue keylight was present during the FI 1-min components, but in components 1 to 19 a response at the end of 1 min produced a 0.75-sec presentation of a red (R) keylight. At the termination of the twentieth FI 1-min component a response produced the 0.75-sec red keylight followed by food presentation. The red keylight flashed only at the beginning of the 18-sec food presentation period. During the operation of the feeder the food hopper was illuminated by two white 6-w bulbs.

Examination of the cumulative records and numerical data indicated that a stable performance had developed during 25 sessions, at which time drug investigations began. Chlorpromazine HCl (CPZ) was dissolved in distilled water for injections. The birds were drugged once per week on the same day (Thursday) but only if preceded by a normally executed standard session. Each bird was in-

Fig. 1. Representative cumulative records showing control and drug performances of Birds 287 and 289 under FR 20 (FI-1:R). The diagonal pips of the response pen denote the 0.75-sec presentation of the red keylight. The response pen reset after 1000 responses or at food presentation.

jected in the breast muscle 30 min before the start of the session. The doses studied were 1.0, 3.0, 10.0, and 17.0 mg/kg. Doses were in terms of the salt and the injected volume was always less than 0.5 cc. No systematic order of doses was followed but at least three replications were carried out at each dose.

RESULTS

Figure 1 shows cumulative records of performance of Birds 287 and 289 under control and drug conditions. The control performances are very similar to those described by Kelleher (1966b) and were characterized by low rates of responding in the early FI 1-min components followed by variable but generally increasing rates in the later FI 1-min components. Positively accelerated responding occurred rarely in those FI 1-min components early in the sequence but was seen frequently within those components temporally close to food presentation.

Increasing doses of chlorpromazine up to 10 mg/kg resulted in an increased overall rate of responding, while at 17 mg/kg the rate was less than at 10 mg/kg, but still greater than control (Fig. 2).

Accelerated responding occurred within components at 1 and 3 mg/kg but at 10 mg/kg, re-

Fig. 2. The effect of chlorpromazine on the overall rate of responding under FR 20 (FI-1:R). The isolated points represent the means of 12 control (distilled water) sessions for each bird. The vertical bars represent ± 2 S.E. Each drug point represents the mean of three determinations. The abscissa is a log scale.

sponding tended to be at a relatively constant rate within the FI 1-min components. At 17 mg/kg Bird 287 exhibited some accelerated responding within components, although Bird 289 did not. Chlorpromazine, particularly at the lower doses, altered the pattern of responding within the early components from one characterized by very low rates with infrequent instances of accelerated responding to one in which accelerated responding was the rule. At the same time, but apparently to a much lesser extent, the pattern of responding within the later components changed from one of accelerated responding to that characterized by a more constant rate throughout the components.

Figure 3 shows the response rate distribution over successive FI 1-min components for the two subjects. Under control conditions responding tended to increase throughout the sequence of FI 1-min components. Chlorpromazine increased response rates in the early components and, to a lesser extent, decreased rates in the later components, resulting in a

more uniform distribution of response rates over the sequence of components.

Figure 4 shows the distribution of response rates within the FI 1-min components. Control responding increased within the components and chlorpromazine again tended to produce a more uniform distribution of response rates, largely by increasing the low rates in the initial portion of the interval. This leveling effect, particularly at the low doses, appeared to be much less than that exerted on the distribution of response rates throughout the series of FI 1-min components as seen in Fig. 3.

Because of the wide range of response rates it is difficult to compare directly rate changes under chlorpromazine within and over components by simple perusal of Fig. 3 and 4. A comparison of the effects of chlorpromazine on response rates over the FI 1-min components with those within components can be made by a log-log plot of per cent change in control rate against control rate at each dose level (Dews, 1964) as shown in Fig. 5. For

Fig. 3. The rates of responding of Birds 287 and 289 over the 20 FI 1-min components under control (distilled water) conditions and at each dose of chlorpromazine. The components have been grouped in units of five and the mean rate over these successive units was plotted. Each control point represents the mean of 12 sessions and each drug point represents the mean of three determinations.

Fig. 4. The mean rates of responding of Birds 287 and 289 within successive quarters of the FI 1-min components. Data points were computed from the same sessions represented in Fig. 3.

both birds at 1 and 3 mg/kg doses of chlorpromazine, two separate regression lines, *i.e.*, lines whose slopes differed significantly ($P < 0.01$), could be plotted for the change in within and over component rates. Increasing the dose from 1 to 10 mg/kg resulted in an increase in the slope of the within-component regression lines toward equality with the over-component regression lines. At 10 and 17 mg/kg the lines did not differ in slope significantly at the 0.01 level and a single regression line was plotted. Bird 287 at 17 mg/kg showed a tendency of reseparation of regression lines, but this was not significant at the 0.01 level. The slopes of the over-component regression lines were at or near unity, while the within-component regression lines were consistently less than unity (Table 1).

DISCUSSION

This experiment explicitly confirmed the results of several previous studies indicating

Table 1

Slopes of the over- and within-component regression lines at each dose for the two subjects. All slopes are negative. The t values marked with an asterisk are significant at the 0.01 level. The t -test for differences in slopes of linear regression lines can be found in Goldstein (1964).

Bird CPZ (mg/kg)	287			289		
	over	within	t 4df	over	within	t 4df
1.0	1.03	0.25	6.24*	1.00	0.25	9.30*
3.0	1.21	0.47	5.88*	1.01	0.60	6.42*
10.0	0.88	0.70	2.84	0.96	0.95	0.06
17.0	0.95	0.56	2.87	0.96	0.86	2.36

rate-dependent effects of chlorpromazine in the pigeon under other schedules of reinforcement (Dews, 1958a,b, 1962, 1965; Fry, Kelleher, and Cook, 1960; Kelleher, Riddle, and Cook, 1962). The rate-dependency function may be written $P = kR^a$ ($a < 0$) where P is the proportional change in the control rate of responding under the drug, R

Fig. 5. Log-log plots showing the relationship between the mean rates of responding over and within FI 1-min components under controlled conditions and the per cent change in rate after chlorpromazine. The points are from the same sessions depicted in Fig. 3 and 4 and were fitted by the method of least squares. At 10.0 and 17.0 mg/kg the least-square regression lines did not differ significantly in slope at the 0.01 level and both the over and within points were used in calculating a single regression line. The slopes of the lines correspond to the exponent of the power function relating the change in the control rate under chlorpromazine and the control rate.

is the control rate, a is the slope of the log-log regression line, and k is a constant. The slopes of the over-component regression lines generally remained near unity independently of the dose of chlorpromazine, implying a strict inverse proportionality between the drug rate and control rate, *i.e.*, $P = k/R$. Rate-dependency functions of the type shown in Fig. 5 have not previously been reported for chlorpromazine in studying its effects on other schedules of reinforcement. However, a study of Dews (1965) provides data from which regression lines describing the effect of chlorpromazine in the pigeon under a complex multiple schedule can be computed. The rate-dependency relations at several doses are shown in Fig. 6. The slopes increased with the dose but remained considerably less than unity. A similar relationship has been shown by Dews (1964) for amobarbital in the pigeon under a fixed-interval schedule composed of alternating S^A and S^D periods. Slopes near unity have been observed however, for d -amphetamine in the squirrel monkey under a multiple fixed-ratio fixed-interval schedule of electric shock termination (Kelleher and Morse, 1968).

Rate-dependency effects were also observed within the FI 1-min components. However, at 1 and 3 mg/kg the slopes of the within-component regression lines were significantly less than those of the over-component regression lines. This reflects the small proportional changes produced by chlorpromazine on the within-component responding, particularly at the lower rates. The properties of the rate-dependency function are such that below the intersection of the two regression lines, the difference in the proportional change in the two drug rates becomes very large as the control rate becomes less. Above the point of intersection this difference increases very slowly.

If it can be assumed that the extent of change in rate produced by a drug is inversely related to the degree of schedule control, then these results suggest that the schedule control exerted by the presentation of food under the FR 20 (FI-1:R) schedule was considerably less than that exerted by the presentation of the brief stimulus under the FI 1-min schedule. It does seem plausible that the brief stimulus as an effective conditioned reinforcer might exert more moment-to-moment control over

responding under this schedule than the terminal, food reinforcer.

Another possibility is that the differences in the effects of chlorpromazine on the over- and within-component responding resulted from some other property of the two schedules, *e.g.*, parameter value. The data in Fig. 6 from the study by Dews (1965) provide some indirect evidence to indicate that the difference in rate-dependency functions at the low doses may not have occurred as a result of differences in parameter value. These plots clearly show that although the fixed-interval para-

Fig. 6. Log-log plots computed from rate data provided by a study of Dews (1965) on the effects of chlorpromazine in the pigeon under a multiple schedule composed of FI 3, FI 6, FI 9, and FI 10-min schedules. The filled points were derived from rates in the initial 3 min of each fixed-interval schedule, and the open points were derived from the remaining portion of the interval. The regression lines were calculated by the method of least squares.

meter values and the response rates generated by them vary widely, at the doses investigated all points appear to lie on a single regression line. This indicates that under this complex schedule chlorpromazine resulted in a rate-dependency function independent of the schedule parameter values that generated the rates. Such evidence is only suggestive, however.

The functions describing the change in the within-component rates correspond closely to those derived from the study of Dews, as shown in Fig. 6. As the dose of chlorpromazine was increased the slope of the within-component regression line increased. This provides evidence to indicate that under chlorpromazine, the changes in responding under a fixed-interval schedule of conditioned reinforcement can be very similar to those under a fixed-interval schedule of food.

The slopes of the regression lines describing the changes in rates over components showed little change over the range of doses studied. Perhaps because of the substantial minimum interval (20 min) between food presentations this second-order schedule shows a certain similarity to a fixed-interval schedule, *i.e.*, a pattern of increased responding between food presentations. However, the schedule of food presentation is actually a *fixed-ratio* of fixed intervals. Analyses of schedules of the form FR n (FI- t :S) and VR n (FI- t :S) have indicated that these schedules have some of the properties of ordinary ratio schedules (Kelleher, 1966*b*; Byrd and Marr, 1969). For example, Kelleher (1966*b*) pointed out a relationship between the rates within components of a second-order schedule of the form FR n (FI- t :S) and the interresponse time distribution in an ordinary fixed-ratio schedule. Rate-dependency functions have not previously been calculated for ordinary fixed-ratios so that comparisons with earlier work are not possible; however, one can speculate that the relatively stable slope of the over-component rate dependency functions may be, in part, due to a ratio characteristic of this second-order schedule.

An additional factor responsible for the pattern of increased responding throughout the succession of fixed-interval components might be an increase in the conditioned reinforcing strength of the brief stimulus as the terminal reinforcer is approached. The experi-

ments of Kelleher (1958) on token reinforcement lend some support for this notion. However, low doses of chlorpromazine not only increased responding throughout the early fixed-interval components but resulted in an increased frequency of fixed-interval patterning between brief stimulus presentations in these early components. Thus, the brief stimuli presented early in the sequence can be shown to exert as much control over the within-component response pattern as those presented at the termination of components later in the sequence. Assuming that the drug had no influence on the reinforcing strength of the brief stimulus, but only interacted with the ongoing rate, it appears that the significant factor controlling the low rate in the early components is that involving the minimum interval between food presentations concomitant with the fixed-ratio schedule of components.

The results of this experiment indicate that studies of second-order schedules involving drugs may be very useful in elucidating the factors controlling the complex patterns of responding generated under these schedules.

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