JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1985, 44, 367-376 NUMBER 3 (NOVEMBER)

COMPARISON OF DRUG EFFECTS ON FIXED-RATIO PERFORMANCE AND CHAIN PERFORMANCE MAINTAINED UNDER A SECOND-ORDER FIXED-RATIO SCHEDULE

PETER J. WINSAUER, DONALD M. THOMPSON, AND JOSEPH M. MOERSCHBAECHER

GEORGETOWN UNIVERSITY SCHOOLS OF MEDICINE AND DENTISTRY AND LOUISIANA STATE UNIVERSITY MEDICAL CENTER

In one component of a multiple schedule, pigeons were required to complete the same four-response chain each session by responding sequentially on three identically lighted keys in the presence of four successively presented colors (chain performance). Food presentation occurred after five completions of the chain (i.e., after 20 correct responses). Errors, such as responding on the center or right key when the left was designated correct, produced a brief timeout but did not reset the chain. In the other component, responding on a single key (lighted white) was maintained by food presentation under a fixed-ratio 20 schedule. In general, phencyclidine and *d*-amphetamine produced dose-dependent decreases in the overall response rates in both components. With pentobarbital, overall rate in each component generally increased at intermediate doses and decreased at higher doses. All three drugs produced dose-dependent disruptive effects on chain-performance accuracy. Phencyclidine and pentobarbital increased percent errors at doses that had little or no rate-decreasing effects, whereas *d*-amphetamine generally increased percent errors only at doses that substantially decreased overall rate. At high doses, all three drugs produced greater disruption of chain performance than of fixed-ratio performance, as indicated by a slower return to control responding, although the effects of *d*-amphetamine were less selective than those of phencyclidine or pentobarbital.

Key words: response chain, second-order schedule, fixed-ratio schedule, phencyclidine, pentobarbital, *d*-amphetamine, key peck, pigeons

In a previous study of drug effects on complex operant behavior (Moerschbaecher, Boren, Schrot, & Simoes Fontes, 1979), pigeons acquired a different chain of conditional discriminations each session. This repeated-acquisition procedure constituted one component of a multiple schedule. In the other component, the chain of conditional discriminations remained the same from session to session (performance). Although increasing doses of *d*-amphetamine were found to decrease the overall response rate and increase the percent errors in both schedule components, these disruptive effects tended to occur at lower doses in the acquisition component. It was suggested that the greater sensitivity of the acquisition component may be related to the relatively weak stimulus control and/or the lower rate of reinforcement in that component.

The generality of the finding that pigeons' acquisition and performance in a conditional discrimination task were differentially sensitive to the effects of *d*-amphetamine (Moerschbaecher et al., 1979) was extended in two experiments with patas monkeys responding in a task more closely related to that used in the present study (Thompson & Moerschbaecher, 1979). In one component of a multiple schedule, the monkeys acquired a different four-response chain each session by responding sequentially on three keys in the presence of four geometric forms. In the other component, the four-response chain was the same each session (performance). The response chain in each component was maintained by food presentation under a second-order fixed-ratio (FR) schedule. In the first experiment, as the dose of *d*-amphetamine was increased, the percent errors in the repeated-acquisition component tended to increase progressively, whereas accuracy in the perfor-

This work was supported by U.S. Public Health Service Grants DA 01528, DA 03573, and DA 02679. Reprints may be obtained from P. J. Winsauer or D. M. Thompson, Department of Pharmacology, Georgetown University Schools of Medicine and Dentistry, Washington, DC 20007, or from J. M. Moerschbaecher, Department of Pharmacology and Experimental Therapeutics, Louisiana State University Medical Center, 1901 Perdido Street, New Orleans, Louisiana 70112-1393.

mance component was generally unaffected. Although there were individual differences in the effects on overall response rate in each schedule component, low to intermediate doses were more likely to produce rate-increasing effects in the performance component, and higher doses typically produced greater rate-decreasing effects in the acquisition component.

The second experiment examined some of the possible "behavioral mechanisms" (cf. Laties & Weiss, 1969) for the drug effects obtained. As a probe, a high dose of *d*-amphetamine was administered during the session after the four-response chain had already been acquired (i.e., after strong stimulus control had been established as indicated by near-zero error levels). Compared to presession administration of the same dose, the rate-decreasing and error-increasing effects were greatly attenuated. The results of this probe suggest that the differential effects of *d*-amphetamine on acquisition and performance are related to differential stimulus control. However, because errors produced timeouts, which decreased the frequency of reinforcement per unit time during acquisition, the procedure could not rule out the possibility that differential rate of reinforcement was a determinant of the differential drug effect.

Given the finding that the acquisition of a response chain was more readily disrupted by *d*-amphetamine than was the performance of an established response chain (Thompson & Moerschbaecher, 1979), the question arose as to whether this type of performance baseline would differ from less complex schedule-controlled performance in terms of sensitivity to drug effects. Accordingly, in the present research a multiple schedule was used to compare drug effects on well established simple and complex operant performance in pigeons. More specifically, responding on a single key under a simple FR schedule (FR performance) was compared with sequential responding on three keys under a second-order FR schedule (chain performance). Although there are several procedural differences between these two conditions, a simple FR schedule was chosen for comparison because it is used frequently in behavioral pharmacology research. The multiple schedule of FR and chain performance served as a baseline to assess the effects of *d*-amphetamine, pentobarbital, and phencyclidine because these three drugs have frequently been compared in previous research involving schedule-controlled behavior (e.g., Segal, Moerschbaecher, & Thompson, 1981; Thompson, Moerschbaecher, & Winsauer, 1983).

METHOD

Subjects

Three adult male White Carneaux pigeons were maintained at approximately 80% of their free-feeding body weights by food presented during the sessions and by postsession supplemental feeding. The 80% values were 454 g, 440 g, and 455 g for P-3799, P-2617, and P-6835, respectively. Water and grit were always available in the home cages. Each subject had an extensive history of repeated acquisition of four-response chains under FR schedules.

Apparatus

The experimental space was a standard three-key pigeon chamber (BRS/Foringer, Model PH-001). Each translucent response key required a minimum force of 0.18 N for activation. An in-line projector (BRS/LVE, Model IC 901-696), mounted behind each key, could project colors onto the key. A fan ventilated the chamber and masked extraneous noise. Solid-state programming and recording equipment, located in an adjacent room, was used.

Procedure

Baseline. In one component of a multiple schedule, the pigeons were required to complete the same four-response chain each session by responding sequentially on three identically lighted keys in the presence of four colors (chain performance). During this component, all three response keys were simultaneously illuminated by a single color—yellow, green, red, or blue. A different key was designated as correct in the presence of each color: keys yellow–left correct; keys green–center correct; keys red–left correct; keys blue–right correct (reinforcement). This type of sequential responding is procedurally defined as a "chain" because each response except the last produces a discriminative stimulus controlling the response that follows (Kelleher, 1966; Thompson, 1975). Responding was

maintained by food presentation under a second-order FR schedule (an FR 5 schedule with FR 4 components). Thus, every fifth completion of the four-response chain (or 20 correct responses) was followed by 5-s access to mixed grain. Presentation of the grain magazine was accompanied by offset of the keylights and onset of the magazine light. All other completions of the four-response chain produced a 0.5-s flash of the magazine light, which was accompanied by the offset of the keylights. When the pigeon pecked an incorrect key (e.g., the center or right key when the left key was correct), the error was followed by a 6-s timeout. During the timeout, the keys were dark and responses were ineffective. An error did not reset the sequence; that is, the keylights after the timeout were the same color as before the timeout.

In the other component of the multiple schedule, only the center key was illuminated (white), and responding on this key was maintained by food presentation under an FR 20 schedule. As in the chain component, food presentation was accompanied by the offset of the keylight and onset of the magazine light. Sessions began in the chain component, which then alternated with the FR component after five reinforcements or 15 min, whichever occurred first. Each session was terminated after 50 reinforcements or 2 hr, whichever occurred first. A "blackout" (all lights off) of variable duration preceded and followed each session. Sessions were conducted daily, Monday through Friday.

For each session, the data in the chain component were analyzed in terms of (1) the overall response rate (total responses/s, excluding timeouts) and (2) the overall accuracy or percent errors [(errors/total responses) × 100]. In the FR component, the data were analyzed in terms of overall rate (responses/s). In addition to these measures based on session totals, within-session changes in responding were monitored by a cumulative recorder.

Drug testing. Before the drug testing began, the multiple-schedule baseline was stabilized. The baseline was considered stable when the response rates and percent errors no longer showed systematic change from session to session. After baseline stabilization (15 to 20 sessions), dose-effect data were obtained for *d*-amphetamine sulfate, phencyclidine hydrochloride, and pentobarbital sodium, in that order. The drugs were dissolved in saline (0.9%) and injected intramuscularly, either 10 min (phencyclidine and pentobarbital) or 15 min (*d*-amphetamine) before the start of the session. The doses of each drug were tested in a mixed order and there were two or three determinations for all of the effective doses.

Throughout testing, drug sessions were usually conducted on Tuesdays and Fridays, with control sessions (saline alone injected intramuscularly, 10 or 15 min presession) occurring on Thursdays, and baseline sessions (no injections) on Mondays and Wednesdays. Approximately 10 days of baseline sessions intervened between the end of a series of injections with one drug and the start of a series with another. The volume of each injection was 0.1 mL/100 g body weight. All doses are expressed in terms of the salt of each drug.

RESULTS

Figure 1 shows the effects of varying doses of phencyclidine on response rate for both components of the multiple schedule, and on percent errors for the chain component. In five of six cases, phencyclidine produced dose-dependent decreases in overall response rate in both components. The only exception was an increase in response rate in the FR component at intermediate doses in P-3799. In the chain component, the rate-decreasing effects were accompanied by an increase in percent errors in all 3 subjects. Note that percent errors also increased at doses that had little or no effect on response rate in the chain component (e.g., at 0.56 mg/kg in P-3799 and at 0.32 mg/kg in P-2617). In other words, accuracy tended to be more sensitive than response rate in the chain component in detecting the disruptive effects of phencyclidine. It should be pointed out, however, that there was one clear instance in which response rate in the FR component was decreased at a dose of phencyclidine that did not affect either response rate or accuracy in the chain component (P-6835, 0.32 mg/kg).

The dose-effect curves for pentobarbital are shown in Figure 2. Overall response rate in each component increased at intermediate doses and decreased at higher doses in five of six cases, the only exception being P-6835 in the FR component, where the control rate was relatively high. In this regard, pentobarbital

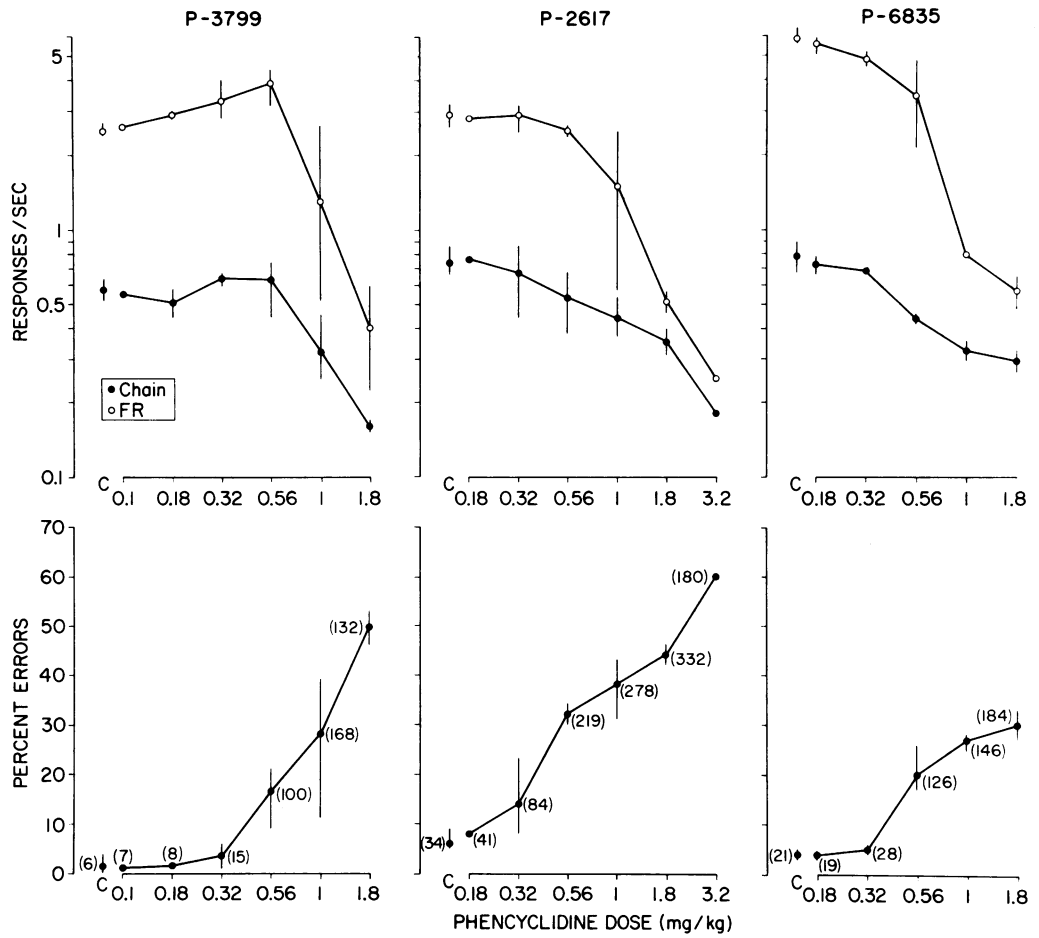

Fig. 1. Effects of varied doses of phencyclidine on overall response rates in the chain and FR components of a multiple schedule (top panels) and on overall accuracy (percent errors) in the chain component (lower panels) for each subject. The points and vertical lines at C indicate the means and ranges for eight or nine control (saline) sessions. The points with vertical lines in the dose-effect data indicate the means and ranges for either two determinations (identified by the mean bisecting the range) or three determinations (other points). The points without vertical lines indicate either single determinations (at ineffective doses) or instances in which the range is encompassed by the point. In the top panels, a constant (0.1) was added to each response rate to facilitate the plotting of the data on a logarithmic scale. In the lower panels, the values in parentheses indicate the absolute number of errors (rounded means) from which the mean percent values were derived.

differed from phencyclidine, which generally decreased overall response rate in both components at intermediate doses (Figure 1). However, with regard to accuracy in the chain component, pentobarbital was similar to phencyclidine in producing dose-related increases in percent errors. Also, like phencyclidine, pentobarbital increased percent errors at doses that did not decrease overall response rate in the chain component. This can be seen at the 10-mg/kg dose in P-3799 and P-6835, and at the 5.6-mg/kg dose in P-2617.

Figure 3 shows the dose-effect curves for *d*-amphetamine. In general, *d*-amphetamine produced dose-dependent decreases in the overall response rate in both components. The only exception was P-3799 in the chain component, where small but reliable increases in rate occurred (relative to control levels) at the lower doses. With regard to the dose-effect curves for rate, *d*-amphetamine was similar to phencyclidine (Figure 1) but differed from pentobarbital (Figure 2). With regard to accuracy in the chain component, the higher doses of *d*-amphetamine increased percent errors, but these increases were relatively small

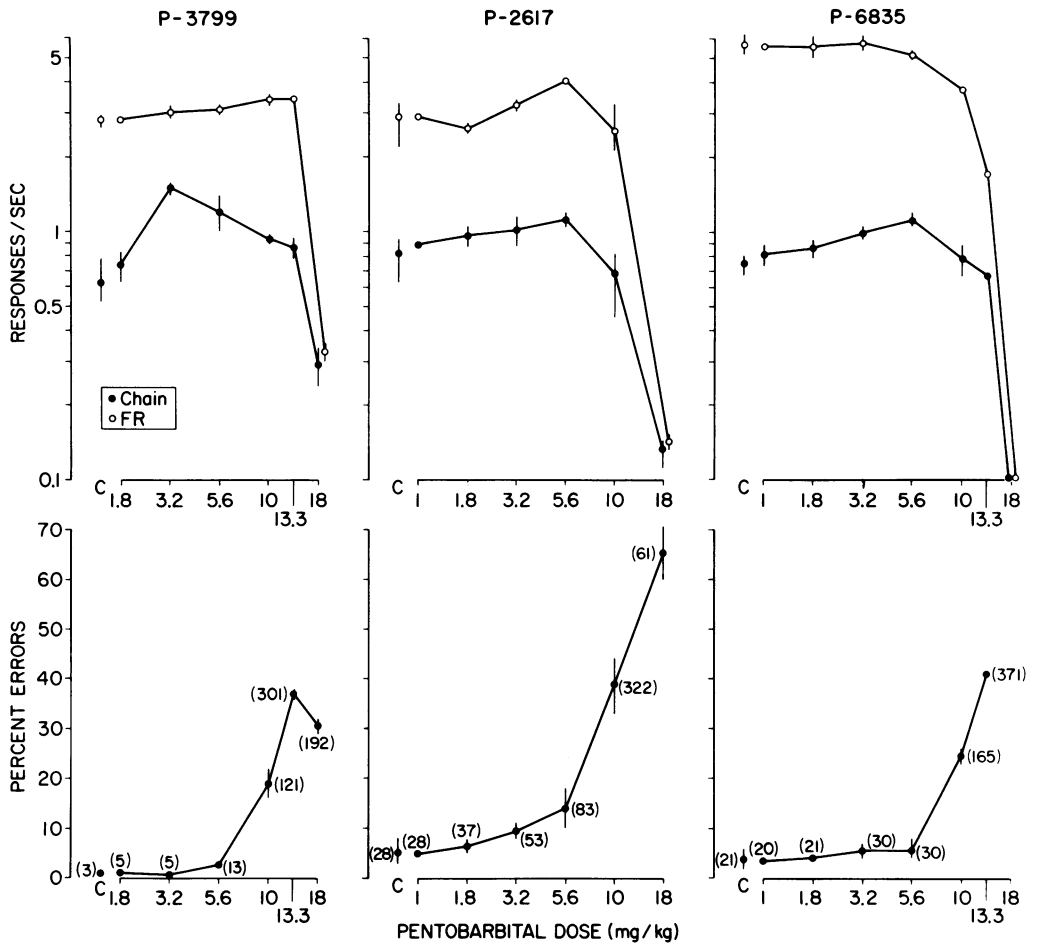

Fig. 2. Effects of varied doses of pentobarbital on overall response rates in the chain and FR components of a multiple schedule (top panels) and on overall accuracy (percent errors) in the chain component (lower panels) for each subject. The points and vertical lines at C indicate the means and ranges for 9 or 10 control (saline) sessions. Points for percent errors in the dose-effect data have been omitted in cases where the overall response rate was virtually zero. For other details, see caption for Figure 1.

in 2 subjects, in comparison to phencyclidine and pentobarbital. In addition, unlike phencyclidine and pentobarbital, in 2 subjects (P-2617 and P-6835) *d*-amphetamine increased percent errors only at doses that substantially decreased overall response rate.

The cumulative records in Figure 4 illustrate some within-session effects of the three drugs in P-2617. The top record shows the pattern and rates of responding during a representative control session. As can be seen, the overall response rate in the FR component was greater than the overall rate of correct responding in the chain component, and errors in the chain component were distributed quite evenly throughout the session (about six errors per component). After a high dose of phencyclidine (3.2 mg/kg), there was a long period of no responding in both components. When responding resumed, chain performance was disrupted substantially, as indicated by a large increase in errors and pausing, but FR performance was relatively unaffected. In general, the within-session effects of a high dose of pentobarbital (18 mg/kg) were similar to those of phencyclidine (i.e., a long initial pause, followed by a greater disruption of chain performance than of FR performance). Although a high dose of *d*-amphetamine (1.8 mg/kg) also produced greater disruption of chain performance than of FR performance, the effects of *d*-amphetamine were less selective than with

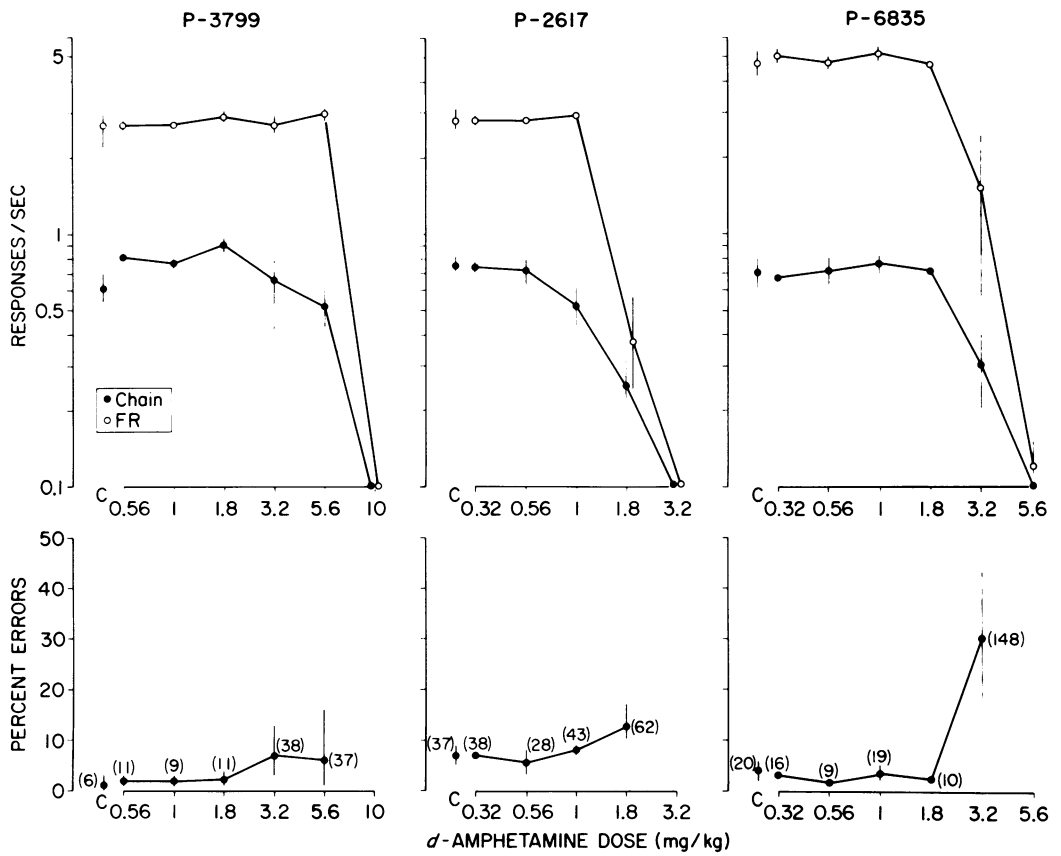

Fig. 3. Effects of varied doses of *d*-amphetamine on overall response rates in the chain and FR components of a multiple schedule (top panels) and on overall accuracy (percent errors) in the chain component (lower panels) for each subject. The points and vertical lines at C indicate the means and ranges for 10 to 12 control (saline) sessions. Points for percent errors in the dose-effect data have been omitted in cases where the overall response rate was virtually zero. For other details, see caption for Figure 1.

the other two drugs. With *d*-amphetamine, after the initial pause, there were more cycles of the multiple schedule with disruption in both components. In general, the within-session effects of phencyclidine, pentobarbital, and *d*-amphetamine in P-2617 (Figure 4) were replicated with the other 2 subjects, although the particular doses and the magnitude of the effects varied.

DISCUSSION

Under baseline conditions, the chain component of the multiple schedule generated a lower overall response rate than did the FR component. This finding is in agreement with the results of previous studies in pigeons comparing chain FR schedules with simple FR schedules. For example, Thomas (1964) found that the overall response rate was lower under a chain FR 20 FR 20 FR 20 schedule than under an FR 60 schedule; the lower overall rate was due primarily to pausing during the initial component of the chain schedule. Jwaideh (1973) obtained similar results at different FR values, and suggested that the pausing could be attributed to a discriminative effect of the initial chain stimulus (cf. Ferster & Peele, 1980; Ferster & Skinner, 1957, p. 113). Although the amount of pausing was not recorded separately in the present study, the cumulative records (e.g., Figure 4, top) clearly indicate that more pausing occurred in the chain component than in the FR component. The relatively low overall response rate in the chain component may also be related to the

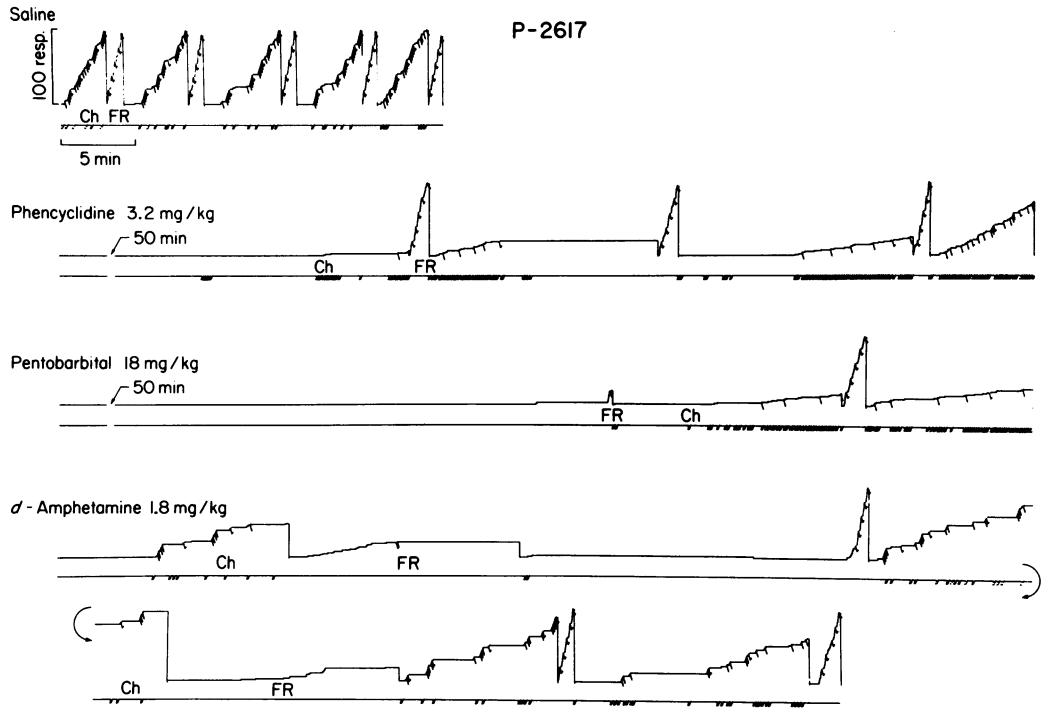

Fig. 4. Cumulative records for Subject P-2617 showing the within-session effects of high doses of phencyclidine, pentobarbital, and *d*-amphetamine on responding under a multiple schedule with chain (Ch) and FR components. In the chain component, the response pen stepped upward with each correct response and was deflected downward each time the four-response chain was completed. Errors are indicated by the event pen (below each record), which was held down during each timeout. In the FR component, the response pen stepped upward with each response and was deflected and held down during reinforcement. Sessions began in the chain component, which then alternated with the FR component after five reinforcements or 15 min, whichever occurred first. A change in components of the multiple schedule reset the stepping pen. Complete sessions are shown, except for the omission of periods of no responding (50 min, indicated by arrows).

fact that the chain involved responding on three keys; switching between keys would probably require more time than responding on a single key.

In general, both phencyclidine and *d*-amphetamine produced dose-dependent decreases in the overall rates of responding in both components of the multiple schedule. This finding is consistent with previous studies of the effects of these drugs on responding under simple FR schedules of food presentation in pigeons (e.g., Leander, 1982; Wenger, 1976). Moreover, the generality of this finding can be extended to pigeons responding in a repeated-acquisition task, where a four-response chain maintained under a second-order FR schedule of food presentation was changed from session to session (Thompson et al., 1983). The only notable exception to this general finding was the rate-increasing effect in the FR component at intermediate doses of phencyclidine in Subject P-3799 (Figure 1). Such biphasic effects with phencyclidine, although unusual under FR schedules, have been reported in two other species. Segal et al. (1981) found rate-increasing effects on FR responding with intermediate doses of phencyclidine in rats, and Slifer, Balster, and Woolverton (1984) found such effects during chronic phencyclidine administration in rhesus monkeys.

Pentobarbital, on the other hand, before decreasing responding at higher doses, generally increased the overall rates of responding in both components in all 3 subjects (Figure 2). That intermediate doses of pentobarbital can increase response rate under simple FR schedules in pigeons is a well established finding (e.g., Dews, 1955; Waller & Morse, 1963). Although these increases are not as consistent

under second-order FR schedules (Thompson et al., 1983), Harting and McMillan (1976) have reported rate increases with pentobarbital in pigeons responding under such schedules in a repeated-acquisition task.

The error-increasing effects of phencyclidine and pentobarbital in the chain component were predictable on the basis of previous research showing that these drugs produce similar dose-related disruptive effects on behavior in various discrimination tasks. For example, Brown and Bass (1967) found that both drugs disrupted the performance of rhesus monkeys in an oddity-discrimination task; each drug decreased the rate of correct responding in a dose-dependent manner and, at higher doses, increased errors. More recently, McMillan (1981) reported that both phencyclidine and pentobarbital disrupted the performance of pigeons in a delayed matching-to-sample task; the higher doses of each drug decreased matching accuracy. Finally, in research more closely related to the present study, it was found that both phencyclidine and pentobarbital disrupted the behavior of pigeons in a repeated-acquisition task involving four-response chains; each drug increased percent errors at doses that had little or no rate-decreasing effects (Thompson et al., 1983).

The error-increasing effects of *d*-amphetamine in the chain component are in accord with most of the results obtained with other discrimination techniques, such as matching to sample, fixed consecutive number, and related procedures (see review in Thompson & Moerschbaecher, 1984). With these techniques, it has been shown that performance accuracy generally decreases with increasing doses of *d*-amphetamine in pigeons, rats, and monkeys. Although the higher doses of *d*-amphetamine disrupted chain-performance accuracy in the present study, the disruptive effects were relatively small in 2 of 3 subjects, in comparison to phencyclidine and pentobarbital. This finding is in contrast to large error-increasing effects previously obtained with *d*-amphetamine in a repeated-acquisition task, where pigeons acquired a different four-response chain each session (Thompson & Moerschbaecher, 1980; Thompson et al., 1983). This apparent discrepancy may be accounted for in terms of differential stimulus control. It has been shown in a variety of situations that behavior under strong stimulus control is more resistant to disruption by amphetamine than is behavior under weak stimulus control (Thompson, 1978). That the behavior in the chain-performance condition was under relatively strong stimulus control is indicated by the fact that the baseline error levels were lower in performance than in repeated acquisition. This explanation may also apply to other cases in which *d*-amphetamine produced little or no effect on performance accuracy in discrimination tasks (e.g., Katz, 1982; McMillan, 1981).

At high doses, all three drugs produced greater disruption of chain performance than of FR performance, as indicated by slower returns to control rates and patterns of responding, although the effects of *d*-amphetamine were less selective than those of phencyclidine or pentobarbital (Figure 4). On the basis of previous studies of "rate-dependent" drug effects (e.g., MacPhail & Gollub, 1975), the greater disruption of chain performance was unexpected inasmuch as the control rate of responding was lower in the chain component than in the FR component. Alternatively, there is reason to believe that the control rate of reinforcement was an important determinant of the differential drug effects (cf. Moerschbaecher et al., 1979). Components of a multiple schedule with different rates of reinforcement have been shown to be differentially sensitive to nonpharmacological variables. For example, Blackman (1968, Experiment II) found that, when response rates were equated, suppression of food-reinforced responding in the presence of a stimulus preceding unavoidable shock was greater in the component with the lower rate of reinforcement. During the control sessions in the present study, the rate of reinforcement was lower in the chain component than in the FR component (e.g., see Figure 4, top), and this may account for the greater sensitivity of the chain component to disruptive drug effects. Although the importance of the control rate of reinforcement as a determinant of the behavioral effects of drugs has been questioned (e.g., MacPhail & Gollub, 1975), there is a substantial amount of nonpharmacological research, in addition to the Blackman study, indicating that "resistance to change" in behavior (i.e., sensitivity) depends on the rate of reinforcement across a wide variety of

experimental manipulations (Nevin, Mandell, & Atak, 1983). The present results suggest that the generality of this conclusion can also be extended to certain behavioral effects of drugs.

On the other hand, one could argue that there are too many differences between the FR schedule and the chain procedure to allow a meaningful comparison even though both conditions required 20 responses per reinforcement. In addition to the differential rate of reinforcement, the two conditions differed with respect to schedules (simple FR vs. second-order FR), the number of response keys (one vs. three), the number of discriminative stimuli (one vs. four), etc. Although such differences make it difficult to isolate the critical variable(s) involved, this was not the objective of the present research. Rather, the intent was to find sufficient conditions for demonstrating a clear difference in drug effects on simple and complex operant performance, such as that shown in Figure 4. The data in Figure 4 are reminiscent of the classic differential drug effects on FR versus FI performance (e.g., Dews, 1955). As Branch (1984) has pointed out, however, such effects still remain unanalyzed: "The roles played by rate of reinforcement, response topography, differentiation of interresponse times (IRTs), type of reinforcer, and many other variables have yet to be determined" (p. 516). This is also true for the data shown in Figure 4, and further time-consuming studies will be required to identify the "behavioral mechanism(s)" underlying the drug effects. Nevertheless, in regard to research strategy, it seems worthwhile to demonstrate a difference in sensitivity to drug effects between two behavioral conditions (e.g., FR vs. chain performance, FR vs. FI, repeated acquisition vs. matching to sample) before the difference is explained. This same approach (i.e., generating sufficient conditions prior to finding necessary conditions) has also proved useful in the experimental analysis of behavior involving nonpharmacological variables (e.g., Ferster & Hammer, 1965).

In summary, with regard to the effects on overall response rate in each component of the multiple schedule, phencyclidine was more similar to *d*-amphetamine than to pentobarbital. In contrast to these effects are the effects on accuracy in the chain-performance component, where phencyclidine was more similar to pentobarbital than to *d*-amphetamine. The accuracy measure, therefore, provides new information that would be difficult to predict from the effects on response rate. An important implication of the present results is related to the fact that the chain-performance component was studied in a context where it alternated with a simple FR schedule. The drug effects on the chain-performance baseline were similar to those previously seen when this type of complex performance alternated with a repeated-acquisition condition (e.g., Thompson & Moerschbaecher, 1979); there seems to be little evidence, therefore, of a context dependency.

REFERENCES

Blackman, D. (1968). Response rate, reinforcement frequency, and conditioned suppression. *Journal of the Experimental Analysis of Behavior,* **11,** 503–516.

Branch, M. N. (1984). Rate dependency, behavioral mechanisms, and behavioral pharmacology. *Journal of the Experimental Analysis of Behavior,* **42,** 511–522.

Brown, H., & Bass, W. C. (1967). Effect of drugs on visually controlled avoidance behavior in rhesus monkeys: A psychophysical analysis. *Psychopharmacologia,* **11,** 143–153.

Dews, P. B. (1955). Studies on behavior. I. Differential sensitivity to pentobarbital of pecking performance in pigeons depending on the schedule of reward. *Journal of Pharmacology and Experimental Therapeutics,* **113,** 393–401.

Ferster, C. B., & Hammer, C. (1965). Variables determining the effects of delay in reinforcement. *Journal of the Experimental Analysis of Behavior,* **8,** 243–254.

Ferster, C. B., & Peele, D. B. (1980). The contribution of an added counter to a fixed-ratio schedule. *Journal of the Experimental Analysis of Behavior,* **34,** 93–105.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Harting, J., & McMillan, D. E. (1976). Effects of pentobarbital and *d*-amphetamine on the repeated acquisition of response sequences by pigeons. *Psychopharmacology,* **49,** 245–248.

Jwaideh, A. R. (1973). Responding under chained and tandem fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior,* **19,** 259–267.

Katz, J. L. (1982). Effects of drugs on stimulus control of behavior. I. Independent assessment of effects on response rates and stimulus control. *Journal of Pharmacology and Experimental Therapeutics,* **223,** 617–623.

Kelleher, R. T. (1966). Chaining and conditioned reinforcement. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 160–212). New York: Appleton-Century-Crofts.

Laties, V. G., & Weiss, B. (1969). Behavioral mechanisms of drug action. In P. Black (Ed.), *Drugs and the brain* (pp. 115–133). Baltimore: Johns Hopkins Press.

Leander, J. D. (1982). Comparison of phencyclidine, etoxadrol and dexoxadrol in the pigeon. *Substance and Alcohol Actions/Misuse,* **2,** 197–203.

MacPhail, R. C., & Gollub, L. R. (1975). Separating the effects of response rate and reinforcement frequency in the rate-dependent effects of amphetamine and scopolamine on the schedule-controlled performance of rats and pigeons. *Journal of Pharmacology and Experimental Therapeutics,* **194,** 332–342.

McMillan, D. E. (1981). Effects of chemicals on delayed matching behavior in pigeons I: Acute effects of drugs. *Neurotoxicology,* **2,** 485–498.

Moerschbaecher, J. M., Boren, J. J., Schrot, J., & Simoes Fontes, J. C. (1979). Effects of cocaine and *d*-amphetamine on the repeated acquisition and performance of conditional discriminations. *Journal of the Experimental Analysis of Behavior,* **31,** 127–140.

Nevin, J. A., Mandell, C., & Atak, J. R. (1983). The analysis of behavioral momentum. *Journal of the Experimental Analysis of Behavior,* **39,** 49–59.

Segal, S. A., Moerschbaecher, J. M., & Thompson, D. M. (1981). Effects of phencyclidine, *d*-amphetamine and pentobarbital on schedule-controlled behavior in rats. *Pharmacology, Biochemistry and Behavior,* **15,** 807–812.

Slifer, B. L., Balster, R. L., & Woolverton, W. L. (1984). Behavioral dependence produced by continuous phencyclidine infusion in rhesus monkeys. *Journal of Pharmacology and Experimental Therapeutics,* **230,** 399–406.

Thomas, J. R. (1964). Multiple baseline investigation of stimulus functions in an FR chained schedule. *Journal of the Experimental Analysis of Behavior,* **7,** 241–245.

Thompson, D. M. (1975). Repeated acquisition of response sequences: Stimulus control and drugs. *Journal of the Experimental Analysis of Behavior,* **23,** 429–436.

Thompson, D. M. (1978). Stimulus control and drug effects. In D. E. Blackman & D. J. Sanger (Eds.), *Contemporary research in behavioral pharmacology* (pp. 159–207). New York: Plenum Press.

Thompson, D. M., & Moerschbaecher, J. M. (1979). An experimental analysis of the effects of *d*-amphetamine and cocaine on the acquisition and performance of response chains in monkeys. *Journal of the Experimental Analysis of Behavior,* **32,** 433–444.

Thompson, D. M., & Moerschbaecher, J. M. (1980). Effects of *d*-amphetamine and cocaine on strained ratio behavior in a repeated-acquisition task. *Journal of the Experimental Analysis of Behavior,* **33,** 141–148.

Thompson, D. M., & Moerschbaecher, J. M. (1984). Phencyclidine in combination with *d*-amphetamine: Differential effects on acquisition and performance of response chains in monkeys. *Pharmacology, Biochemistry and Behavior,* **20,** 619–627.

Thompson, D. M., Moerschbaecher, J. M., & Winsauer, P. J. (1983). Drug effects on repeated acquisition: Comparison of cumulative and non-cumulative dosing. *Journal of the Experimental Analysis of Behavior,* **39,** 175–184.

Waller, M. B., & Morse, W. H. (1963). Effects of pentobarbital on fixed-ratio reinforcement. *Journal of the Experimental Analysis of Behavior,* **6,** 125–130.

Wenger, G. R. (1976). The effect of phencyclidine and ketamine on schedule-controlled behavior in the pigeon. *Journal of Pharmacology and Experimental Therapeutics,* **196,** 172–179.

Received October 11, 1984
Final acceptance July 17, 1985