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The Effects of Chlordiazepoxide and *d*-Amphetamine during a Three-Component Multiple Schedule

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Abstract

Multiple schedules have been used in behavioral pharmacology research to show that a drug's effect on behavior can be a function of the schedule of reinforcement that supports that behavior. However, less research has examined whether the context of the schedule of reinforcement in a multiple schedule can change the drug's effect on behavior. We examined the effects of acute chlordiazepoxide and *d*-amphetamine injections on the behavior of two groups of pigeons trained on a three-component multiple schedule with identical schedules of reinforcement in the first and last components. For one group of pigeons reinforcement was unavailable during the middle component (decreased-middle-component). For the second group reinforcement rate was higher during the middle component than during the first or third components (increased-middle-component). In the decreased-middle-component group, chlordiazepoxide (3.2-32 mg/kg) decreased third-component response rates less than it decreased responding in the first component. Conversely, in the increased-middle-component group, chlordiazepoxide (3.2-10 mg/kg) decreased third-component response rates more than in the first component. In both groups, *d*-amphetamine did not differentially affect response rates across components. These results are consistent with previous research showing that drugs can differentially affect responding to two different schedules of reinforcement during the same session, and suggest that pharmacological preparations may be helpful in elucidating the mechanisms that control multiple schedule interactions.

Keywords

amphetamine; benzodiazepines; response strength; stimulants; value; key-peck; pigeons

Multiple schedules have been used successfully to study drug effects on behavior (Barrett, 2002). Initial studies in behavioral pharmacology showed that a drug's effect on behavior can be influenced by the schedule of reinforcement that maintains that behavior. For example, when pentobarbital was administered to pigeons trained on either a fixed-interval (FI) 15-min or fixed-ratio (FR) 50 schedule of reinforcement, FI-maintained behavior was changed much more than FR-maintained responding (Dews, 1955). Similar changes in behavior have been observed under multiple schedules of reinforcement (Leander & McMillan, 1974; McMillan, 1969); that is, when the reinforcement schedule alternates between two or more components and a unique schedule-correlated stimulus is presented

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during each component. Thus, to characterize a drug's effect, one must take into account the schedule of reinforcement supporting that behavior.

In behavior analysis, multiple schedules have been used for research in areas such as stimulus control and contrast. Specifically, Reynolds' (1961a, b, c, d) initial experiments with multiple schedules stimulated an extensive area of research on how factors outside a particular schedule of reinforcement influence responding during that schedule of reinforcement. At least two main contextual effects have been noted. Contrast is said to occur when changes in the reinforcement rate during one component of a multiple schedule changes responding during an unchanged component in the *opposite* direction. Conversely, induction is said to occur when changes in the reinforcement rate during one component of a multiple schedule changes the organism's responding during the unchanged component in the *same* direction (Reynolds, 1963).

More complex interactions have been observed with a three-component multiple schedule of reinforcement, in which reinforcement rates during the first and last components are equal, while reinforcement rates during the middle component are varied (Williams, 1979; Williams, 1981; Williams & Wixted, 1986). Typically, an asymmetry in response rates develops whereby responding during the two identical schedules of reinforcement diverges. This effect has been termed both *anticipatory contrast* and *the following-schedule effect* because the response rates most affected by the change in reinforcement rates during the middle component are those that temporally precede that change. Thus, the rate of responding on a given schedule of reinforcement can be modified by the context in which it is occurring; in particular, by the relative rate of reinforcement in the next schedule component.

The present research was conducted to evaluate the effects of chlordiazepoxide and *d*-amphetamine on one type of reinforcement context effect: anticipatory contrast. Multiple schedules allow a way to separate the effects of reinforcement context from history effects and have been used extensively in behavioral pharmacology (Barrett, 2002). The three-component AXB procedure was chosen over a two-component procedure so the effects of context (i.e., the schedule arranged in the X component) could be examined by comparing responding in the A and B components, where reinforcement schedule is held constant. We chose to test chlordiazepoxide because it has consistently been shown to attenuate contrast-like effects in procedures like successive negative contrast (Flaherty, Grigson & Rowan, 1986; Flaherty & Rowan, 1988). Because previous studies have shown that *d*-amphetamine does not influence contrast with a two-component multiple schedule of reinforcement (Hearst & Vane, 1967; Spealman, Katz & Witkin, 1978), we tested it as a negative control. We examined the effects of these two drugs on multiple schedule performance when reinforcement was either eliminated or increased during the middle component.

Method

Subjects

Two separate groups of pigeons were used. In the decreased-middle-component reinforcement group, six adult male White Carneau pigeons (Palmetto Pigeon Plant, Sumter, South Carolina, USA) with extensive multiple schedule experience (e.g., Lamb & Ginsburg, 2005; Pinkston, Ginsburg & Lamb, 2009) were used. In the increased-middle-component reinforcement group, six experimentally naive adult male White Carneau pigeons (Palmetto Pigeon Plant, Sumter, South Carolina, USA) were used. All pigeons were maintained at 80% of their free-feeding weights with the food obtained during the experimental sessions and additional postsession feedings, if necessary. All pigeons had free access to water and grit outside of the experimental sessions. All pigeons were housed under a 12 h light/12 h dark

cycle of illumination, and were tested during the light phase. All experimental procedures were approved by the Institutional Animal Care and Use Committee of the University of Texas Health Science Center, San Antonio.

Apparatus

Experimental sessions were conducted in Gerbrands G7410S test chambers (Alderston, Massachusetts, USA). Chambers measured $27.5 \times 26.4 \times 27.5$ cm and were constructed of Plexiglas and aluminum, with a grid floor. Three response keys were distributed across one wall, 18 cm above the floor. Only the center key was used. It could be transilluminated either white, red, or green, and required a force of at least 0.1 N for operation. Below the center key was a hopper in which pigeon chow (Purina Checkers; Purina Mills, St Louis, Missouri, USA) could be presented. Test chambers were enclosed within Gerbrands G7211 sound- and light-attenuating chambers, equipped with an exhaust fan. Experimental contingencies were controlled, and data were collected by a computer running Med-PC software (Med Associates, Georgia, Vermont, USA).

Procedure

Decreased-middle-component reinforcement group—Because of their extensive histories with multiple schedules, pigeons in this group began the experiment on a three-component multiple schedule with identical VI 15-s schedules of reinforcement in each component. Individual intervals comprising each VI schedule were determined using the equation by Fleshler and Hoffman (1962), and were composed of 30 unique intervals without replacement. The interval timer was reset after each component terminated. The first response to the center key after the VI timer elapsed resulted in 3 s access to pigeon chow from the food hopper. The color of the center key alternated across components in a fixed sequence of Green-White-Red throughout the session with no between-component blackouts. Each multiple-schedule component lasted 30 s (hopper time excluded) and was repeated 20 times during the session (i.e., 60 components per session). Each session lasted approximately 30 min. This procedure was in effect until subjects responded reliably during all three components and received at least 30 food presentations per component, across sessions. The reinforcement schedule was then gradually increased to a VI 30-s schedule, while the component duration was gradually decreased to 10 s for each component (see Williams, 1981 for data illustrating reliable anticipatory contrast effects at this component duration). The number of times each component was repeated during the session was increased to 90. Thus, pigeons had 900 s of exposure to each component of the multiple schedule during each session.

Because 21 of 30 of the individual intervals generated by the Fleshler and Hoffman (1962) equation for a VI 30-s schedule were longer than the 10-s multiple-schedule component duration, approximately two-thirds of the components were functionally equivalent to extinction. Therefore, *at least* one reinforcer could be obtained in the other nine components. This was functionally equivalent to one reinforcer approximately every 30 s in the presence of each keylight color.

These parameters were in effect for 10 sessions, each lasting approximately 45 min. Following this, extinction (EXT) was programmed in the middle component (white stimulus) while the schedules in the first and third components were unchanged. We will refer to this as a recycling three-component AXB schedule, where reinforcement rates during the A and B components are identical and constant, while the reinforcement rate during the X component is varied (Williams, 2002). Following 25 sessions under the AXB schedule, we visually evaluated if responding during the EXT component had decreased and response rates had stabilized in the A and B components. When these conditions were met

(or 80 sessions were conducted without achieving stability), injections of either chlordiazepoxide or *d*-amphetamine were administered.

Increased-middle-component reinforcement group—Following magazine training and autoshaping (Brown & Jenkins, 1968) the requirement to peck the center key was gradually increased to a fixed ratio (FR) 5. When responding was maintained under this schedule, the three-component multiple schedule was programmed as it had been for the other group of pigeons with the exception that the first schedule programmed (in all three components) was a VI 10-s schedule. After subjects responded reliably during each component, the VI schedules programmed in all three components were gradually increased to VI 150 s while the component duration was gradually decreased to 10 s. The number of times each component was repeated during the session was increased to 75.

Similar to the interval progression for the decreased-middle-component group, 28 of the 30 individual intervals comprising the VI 150 s were longer than the 10 s component duration. Because the two remaining intervals were less than 10 s, a reinforcer could be obtained in approximately 1 in 15 components (i.e., a VI 150-s schedule). These parameters were in effect for five sessions, which lasted approximately 40 min each.

Following this, the VI schedule of reinforcement in the middle component (white stimulus) was changed to a VI 15-s schedule of reinforcement; the other components were unchanged. Once response rates stabilized in all three components, injections of either chlordiazepoxide or *d*-amphetamine were administered. All pigeons were first tested with chlordiazepoxide and then with *d*-amphetamine.

Drugs

Chlordiazepoxide and *d*-amphetamine were purchased from Sigma Chemicals (St Louis, Missouri, USA), and dissolved in 0.9% saline to provide an injection volume of 1.0 ml/kg. Six doses of chlordiazepoxide (1.8, 3.2, 5.6, 10, 17.8, & 32 mg/kg) were used. Chlordiazepoxide was injected into the pectoral muscle 15 min before the sessions. Six doses of *d*-amphetamine (0.1, 0.3, 0.56, 1.0, 1.8, & 3.0 mg/kg) were used in the decreased-middle-component group. The increased-middle-component group received additional *d*-amphetamine doses of 5.6 mg/kg, as response rates for five of the six pigeons were still maintained following doses of 3.0 mg/kg. *D*-amphetamine was injected into the pectoral muscle 10 min prior to the session. During the waiting periods, pigeons remained in their home cage. Either chlordiazepoxide or *d*-amphetamine was administered on Tuesdays and Fridays, and saline was injected on Thursdays. Injections of saline were also given on some Tuesdays and Fridays to serve as control values. For both chlordiazepoxide and *d*-amphetamine, each drug dose was assessed at least twice, and at most three times in each pigeon. Dose order was counterbalanced across pigeons. That is, no more than two pigeons received the same dose during a given injection session. In addition, a given pigeon did not receive the same dose two injection sessions in a row.

Data Analysis

Response rates for each component were calculated by dividing the number of responses on the center key by the total time each component was available during the session (excluding reinforcer presentations). Group ED₅₀ values (the dose required to reduce responding by 50%) for doses of chlordiazepoxide and *d*-amphetamine were calculated with the method described by Tallarida and Murray (1987). The effects of chlordiazepoxide and *d*-amphetamine on response rates were expressed as a percentage of each subject's Tuesday/Friday saline control values. Unless necessary to define the linear portion of the curve at 50%, doses that produced less than 20% or greater than 80% of the maximal response were

excluded from the group ED_{50} regression. For chlordiazepoxide, doses contained in the linear portion of the curve were 5.6 – 32 mg/kg and 5.6 - 17.8 mg/kg for the decreased-middle-component reinforcement groups and increased-middle-component reinforcement group, respectively. For *d*-amphetamine, doses contained in the linear portion of the curve were 1.0 - 3.0 mg/kg and 0.56 - 5.6 mg/kg for the decreased-middle-component reinforcement groups and increased-middle-component reinforcement group, respectively. We computed the group ED_{50} by regressing the descending portion of the function against the $\log_{10}$ of the dose. The linear equation from the fit was solved for the x-value yielding a 50% reduction in response rate. This x-value was then exponentiated to obtain the dose. Confidence intervals corresponded to points within two standard deviations around the ED_{50} , as calculated from the individual subject data. ED_{50} values were examined with paired *t*-tests between components A and B.

Results

Decreased-Middle-Component Group

Chlordiazepoxide testing—Table 1 shows the mean reinforcer and response rates from each component following saline (standard deviation [*SD*]) and chlordiazepoxide injections for pigeons in the decreased-middle-component group. In saline sessions, pigeons 26, 28, 31 and 10 consistently had higher response rates in component A than in B; the opposite was true for pigeons 13 and 30. With the exception of pigeon 26, the mean number of reinforcers obtained in the saline sessions was undifferentiated across components A and B. Pigeon 26 obtained more reinforcers per session during component A relative to the component B¹. Response rates were consistently lower during component X (EXT).

Figure 1 (top panel) shows the across-subjects mean chlordiazepoxide dose response curve for the decreased-middle-component group. Response rates during component B were less sensitive (i.e., decreased relatively less) to increasing doses of chlordiazepoxide relative to response rates during component A. The ED_{50} for chlordiazepoxide effects on mean response rate during component B was 30.9 mg/kg (95% confidence interval [CI]: 20.1-47.7), and 16.6 mg/kg (95% CI: 12.9-21.3) for component A ($p < .05$). Relative response rates for responding during component X were omitted due to the influence of the three pigeons (26, 28, and 31) that showed very low response rates during EXT. In this case, even small changes in responding would be exaggerated out of proportion to any real effect. For example, increasing from 0.01 to 0.03 responses per second would be a 300% increase in control rate responding.

Individual pigeon's data are shown in Figure 2. Increasing doses of chlordiazepoxide decreased component A responding more than component B responding for pigeons 26, 31 and 13. By contrast, pigeons 28, 10 and 30 did not show reliable differences in relative changes in responding as a function of increasing doses of chlordiazepoxide. The effects of chlordiazepoxide were not systematically related to control response rates in components A and B.

***d*-amphetamine testing**—Table 2 shows response and reinforcement rates for control, saline and *d*-amphetamine sessions. With the exception of pigeon 13 (now responding at a relatively higher rate in component A), the response and reinforcement rates in components A and B were similar to those observed during chlordiazepoxide testing (Table 1). The

¹It is unlikely that the difference in reinforcements obtained between sessions caused a MULT schedule interaction in pigeon 26. The difference in response rates between components A and B was already present and relatively stable with pigeon 26 before saline injections were begun. Here, reinforcers obtained were similar between components A and B. It is more likely that progressively decreasing rates of responding during component B led to more 'missed' reinforcements during component B.

bottom panel of Figure 1 shows that increasing doses of *d*-amphetamine decreased mean response rates and this was undifferentiated between components A and B. This is reflected in comparable ED₅₀ values in component A (2.5 mg/kg; 95% CI: 1.8-3.5) and B (2.1 mg/kg; 95% CI: 1.5-3.2). The ED₅₀ for response rates during component A was not significantly different than the ED₅₀ for response rates during component B.

Increased-Middle-Component Group

Chlordiazepoxide testing—As shown in Table 3, during the saline sessions, all six pigeons emitted higher mean response rates during component A relative to component B. However, the mean number of reinforcers obtained during these components was not different. Figure 3 (top panel) shows that on average pigeons' response rates during component B were more sensitive to increasing doses of chlordiazepoxide relative to response rates during component A. This is reflected in significantly lower ED₅₀ values in component B (9.3 mg/kg; 95% CI: 8.1-10.8) than in component A (12.3 mg/kg; 95% CI: 10.5-14.5) ($p < .05$). As shown in Figure 4, this effect was due to three pigeons (5296, 7607, and 9770) for which low and moderate doses of chlordiazepoxide increased responding above saline levels during component B. The ED₅₀ for chlordiazepoxide effects on mean response rate during component X was 10.9 mg/kg (95% CI: 9.3-12.9). The ED₅₀ for response rates during component X was significantly higher than component B ($p < .05$), but not higher than component A.

***d*-amphetamine testing**—Table 4 shows that in the saline sessions that were intermixed with *d*-amphetamine testing, all six pigeons in the increased-middle-component group had higher mean response rates during component A relative to component B. These rates were similar to those obtained during chlordiazepoxide testing (Table 3). Additionally, the mean number of reinforcers obtained during components A and B of saline testing for five of the six pigeons showed no differences.²

Figure 3 (bottom panel) shows that the effects of increasing doses of *d*-amphetamine on mean response rate did not differ between components A and B. This is reflected in the approximately equivalent ED₅₀ values for *d*-amphetamine's effect during component A (3.1 mg/kg; 95% CI: 0.3-5.9) and B (2.3 mg/kg; 0.9-3.7). The ED₅₀ for *d*-amphetamine's effect on mean response rate during component X was 3.4 mg/kg (95% CI: 1.2-5.7). The ED₅₀ for response rates during component X was not significantly different than either component A or B.

Discussion

Chlordiazepoxide was differentially effective in attenuating response rates during components supported by identical reinforcement rates, whereas *d*-amphetamine was not. That chlordiazepoxide affects contrast-like behavior, whereas *d*-amphetamine does not is consistent with studies on successive negative contrast (Flaherty, 1996). On average, pigeons' response rates during component B in the decreased-middle-component group were less sensitive (decreased more slowly) to increasing doses of chlordiazepoxide relative to response rates during component A. For pigeons in the increased-middle-component group, we obtained the opposite result. Response rates during component B were more sensitive (decreased more quickly) to increasing doses of chlordiazepoxide relative to response rates during component A. In both groups of pigeons, *d*-amphetamine had similar response rate

²Pigeon 3940 obtained a significantly higher (paired *t*-test; $p < .05$) mean number of reinforcers during component A relative to component B. However, the mean difference was only 2.5 more reinforcers obtained during component A, while the response rate during component A (0.96 responses/s) was more than triple that during component B (0.31 responses/s).

decreasing effects on components with identical reinforcer rates. Thus, the context of reinforcement change (i.e., component X) altered the effect of chlordiazepoxide, but not *d*-amphetamine.

Whether response rates during component A or component B were more sensitive to increasing doses of chlordiazepoxide seemed to depend on the relative rate of reinforcement in component X. However, it is difficult to compare results across groups because of the different schedules of reinforcement used during the A and B components for the decreased-middle-component groups (VI 30 s) and the increased-middle-component group (VI 150 s). In addition, pigeons in the decreased-middle-component group had extensive experimental experience with three-component multiple reinforcement schedules prior to the current experiment. Therefore, any firm conclusions about between-group comparisons should be made with caution.

Response rates were more variable between subjects for components A and B during drug testing. This was especially true for subjects in the decreased-middle-component group. The statistically significant difference between components A and B during chlordiazepoxide testing for this group was primarily driven by pigeons 26, 31, and 13 (see Figure 2). However, pigeon 13 showed the opposite saline response rate pattern between components A and B, relative to pigeons 26 and 31. In addition, pigeon 13's pattern of saline response rates between components A and B switched after chlordiazepoxide testing. Thus, providing a meaningful interpretation of the decreased-middle-component group results is more difficult in lieu of no uniform, and in one case, shifting response rates after saline injections. By contrast, pigeons in the increased-middle-component group all showed a systematic pattern of saline responding across both drug tests. When increasing doses of chlordiazepoxide had a differential effect on response rates during components A and B, component B always decreased faster than component A.

We used a recycling three-component AXB schedule to establish anticipatory contrast response patterns. However, this was not successful. Table 5 shows how response rates changed across components as a result of changing the X component to either EXT or a VI 15 s for the decreased-reinforcement and increased-reinforcement groups, respectively. The data represent the mean of the five sessions immediately before and after the change to component X (i.e., when the X component was changed from VI 30 s to EXT). Changing the middle component to EXT (left panel) largely eliminated responding during the middle component for three birds (26, 28 and 31), while substantial reductions in responding occurred in the other three birds (13, 10 and 30). Most pigeons showed stable response rates during this five-session post-EXT period. However, there was no evidence of anticipatory contrast developing after the middle component was changed to EXT, whereby response rates during component A increased more than component B. Rather, the trend was for responding to decrease in both components and, in four pigeons (26, 28, 31 and 13) responding decreased as much or more during the B component, relative to component A. As described above, three (26, 31 and 13) of these pigeons' response rates during component B were less sensitive (decreased more slowly) to increasing doses of chlordiazepoxide relative to response rates during component A. Thus, relative changes in response rate between the A and B components as a consequence of a changing X component may be predictive of relative sensitivity to chlordiazepoxide.

For pigeons in the increased-middle-component group, response rates were similar across components before the X-component was changed to a VI 15 s schedule (third column of the right-hand panel of Table 5). Changing the middle component increased responding in that component for all six pigeons. After component X was changed to a VI 15-s schedule, response rates during the A component increased (or decreased less; pigeon 9770) more than

during the B component for all six pigeons. Given the uniform pattern of responding across pigeons in this group, perhaps it is not surprising that when chlordiazepoxide had a differential effect on component A and B response rates, it was always in the same direction. That is, component B always decreased faster than component A. By contrast, there was no uniform pattern of responding across pigeons in the decreased-middle-component group. Perhaps as a result, the effects of increasing doses of chlordiazepoxide on component A and B response rates were not as consistent across pigeons.

It is possible that the results of the decreased-middle-component group could be attributed to the rate-dependent effects of chlordiazepoxide, which tends to decrease higher rates of responding more than lower rates of responding (Barrett, Dworkin & Zuccarelli, 1977). Following doses of chlordiazepoxide, pigeons in the decreased-middle-component reinforcement group showed the largest decreases in responding during component A, which also had the highest rates of responding during saline injections (see Figure 1, top panel; Table 1). However, a rate-dependency interpretation is not consistent with pigeons in the increased-middle-component group. The middle component (VI 15 s) had the highest rates of responding, followed by component A. Component B had the lowest rate of responding. Chlordiazepoxide decreased response rates the most in component B, followed by component X (see Figure 4, top panel; Table 2). Chlordiazepoxide had the least effect on response rates during component A. Thus, rate-dependency does not provide a comprehensive explanation for the effects of chlordiazepoxide that we observed with a three-component multiple schedules of reinforcement.

The current results are not without limitations. Comparing across-subjects responding on different schedules of reinforcement with different histories of reinforcement has previously been mentioned. It is unknown how this prior experience impacted these pigeons' responding during the current experiment. These different histories of reinforcement can also result in stimulus preference and between-subject variability. It has been previously noted that "there [is] considerable variability among subjects, much of which was associated with stimulus preferences" (Williams, 1981; p. 303) during experiments using a three-component multiple schedule of reinforcement. Future research should focus on targeting and controlling for stimulus preference in subjects to reduce variability between subjects by randomizing stimuli color and using equivalent schedules of reinforcement across experiments.

Finally, the relative instability of interactions in the decreased-middle-component group after both chlordiazepoxide and *d*-amphetamine was administered is also a limitation. This was reflected in both the response rates during periods of reinforcement (components A and B) as well as during extinction. Comparing saline response rates from Table 1 and Table 2 (column 5) shows increased response rates during component X for four of the six pigeons (31, 10, 13, and 30) when *d*-amphetamine was being administered, relative to chlordiazepoxide. This relative lack of stimulus control over the course of the experiment may have contributed to the negative finding with *d*-amphetamine. Similar to the previous limitation, one way to control for this would be to use a within-subject reversal design.

In conclusion, the results of the current experiment show that responding to identical schedules of reinforcement can be differently affected by a drug during the same session. This is consistent with previous research that has shown that drugs can differentially affect responding to two different schedules of reinforcement during the same session (Barrett, 2002). In addition, the results suggest that pharmacological preparations may be able to elucidate mechanisms for behavioral phenomena, such as contrast.

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Fig. 1.

Mean dose-response curves for pigeons in the decreased-middle-component reinforcement group during chlordiazepoxide (top panel) and *d*-amphetamine (bottom panel) testing. Data points represent mean $\pm$ SEM. Vertical axis is the percent of control response rates during component A (filled triangles connected by solid line) and component B (open squares connected by dotted line). Horizontal axis is the drug dose (mg/kg) plotted on a log scale. S represents saline injections on scheduled drug-injection days (Tuesday/Friday).

Fig. 2.

Chlordiazepoxide dose-response curves for pigeons in the decreased-middle-component reinforcement group. Vertical axis is the percent of control response rates during component A (filled triangles) and component B (open squares). Mean determinations for component A and B response rates are represented by solid and dotted lines, respectively. Horizontal axis is the dose of chlordiazepoxide (mg/kg) plotted on a log scale. S represents saline injections on scheduled drug-injection days (Tuesday/Friday).

Fig. 3.

Mean dose-response curves for pigeons in the increased-middle-component reinforcement group during chlordiazepoxide (top panel) and *d*-amphetamine (bottom panel) testing. Data points represent mean $\pm$ SEM. Vertical axis is the percent of control response rates during component A (filled triangles connected by solid line) and component B (open squares connected by dotted line). Horizontal axis is the drug dose (mg/kg) plotted on a log scale. S represents saline injections on scheduled drug-injection days (Tuesday/Friday).

Fig. 4.

Chlordiazepoxide dose-response curves for pigeons in the increased-middle-component reinforcement group. Vertical axis is the percent of control response rates during component A (filled triangles) and component B (open squares). Mean determinations for component A and B response rates are represented by solid and dotted lines, respectively. Horizontal axis is the dose of chlordiazepoxide (mg/kg) plotted on a log scale. S represents saline injections on scheduled drug-injection days (Tuesday/Friday).

Table 1

Mean Saline Reinforcer and Response Rates (Standard Deviation in Parentheses) across Components as a Function of Different Doses of Chlordiazepoxide in the Decreased-Middle-Component Reinforcement Group

Pigson	Component	Schedule	S ^{R+} /session	Saline	Control	Responses per Second					
						Chlordiazepoxide dose (mg/kg)					
						1.8	3.2	5.6	10	17.8	32
26	A	V130 s	27.90	0.64 (0.09)	0.59	0.55	0.76	0.51	0.26	0.19	0
	X	EXT	0	0.01 (0.01)	0.02	0.01	0.03	0.01	0.03	0.01	0
	B	V130 s	22.90	0.23 (0.05)	0.19	0.17	0.16	0.29	0.23	0.10	0
28	A	V130 s	29.00	1.12 (0.14)	0.97	0.95	1.20	0.99	1.14	0.61	0.22
	X	EXT	0	0.01 (0.01)	0.01	0.01	0.02	0.01	0.02	0.01	0.01
	B	V130 s	27.78	0.67 (0.09)	0.61	0.67	0.84	0.53	0.74	0.31	0.20
31	A	V130 s	28.80	0.63 (0.15)	0.62	0.52	0.63	0.55	0.63	0.43	0.23
	X	EXT	0	0.04 (0.02)	0.02	0.03	0.05	0.08	0.11	0.09	0.06
	B	V130 s	27.90	0.43 (0.07)	0.42	0.49	0.60	0.64	0.65	0.70	0.63
13	A	V130 s	26.45	0.60 (0.06)	0.51	0.56	0.79	0.71	0.54	0.51	0.32
	X	EXT	0	0.18 (0.17)	0.10	0.04	0.43	0.11	0.07	0.07	0.13
	B	V130 s	27.55	0.71 (0.14)	0.51	0.55	1.26	1.04	0.80	0.82	0.64
10	A	V130 s	26.56	1.11 (0.26)	1.06	1.17	0.80	0.84	0.48	0	0
	X	EXT	0	0.31 (0.17)	0.25	0.58	0.49	0.38	0.25	0	0
	B	V130 s	28.22	0.83 (0.18)	0.78	0.73	0.79	0.65	0.48	0	0
30	A	V130 s	27.63	1.25 (0.17)	1.38	1.19	1.33	1.26	1.33	0.64	0.03
	X	EXT	0	0.55 (0.16)	0.68	0.72	0.61	0.86	0.20	0.26	0.02
	B	V130 s	30.13	1.74 (0.08)	1.85	1.74	2.02	1.78	1.63	1.09	0.06
Mean	A	V130 s	27.70	0.85 (0.31)	0.86	0.82	0.92	0.81	0.73	0.40	0.13
	X	EXT	0	0.17 (0.22)	0.18	0.23	0.27	0.24	0.11	0.07	0.03
	B	V130 s	27.60	0.72 (0.49)	0.73	0.73	0.94	0.82	0.75	0.50	0.26

Table 2

Mean Saline Reinforcer and Response Rates (Standard Deviation in Parentheses) across Components as a Function of Different Doses of D-amphetamine in the Decreased-Middle-Component Reinforcement Group.

Pigson	Component	Schedule	S ^{R+} /session	Saline	Control	Responses per Second					
						<i>d</i> -Amphetamine dose (mg/kg)					
						0.1	0.3	0.6	1.0	1.8	3.0
26	A	VI 30 s	26.43	0.49 (0.21)	0.64	0.42	0.41	0.21	0.46	0.50	0.01
	X	EXT	0	0.01 (0.01)	0.01	0.01	0	0.01	0.01	0.01	0
	B	VI 30 s	23.07	0.24 (0.09)	0.27	0.29	0.23	0.30	0.33	0.29	0.01
28	A	VI 30 s	28.57	1.14 (0.15)	1.19	0.98	1.14	0.99	0.71	0.05	0
	X	EXT	0	0.02 (0.01)	0.02	0.01	0.02	0.01	0.01	0	0
	B	VI 30 s	28.14	0.64 (0.07)	0.61	0.54	0.60	0.48	0.31	0	0
31	A	VI 30 s	27.63	0.93 (0.21)	0.81	0.96	0.71	0.96	0.83	0.81	0.58
	X	EXT	0	0.19 (0.09)	0.36	0.26	0.42	0.23	0.64	0.59	0.77
	B	VI 30 s	28.63	0.86 (0.31)	0.86	0.77	0.68	0.76	0.60	0.65	0.59
13	A	VI 30 s	28.13	0.83 (0.17)	0.86	1.05	0.74	0.86	0.68	0.69	0.56
	X	EXT	0	0.27 (0.12)	0.37	0.43	0.22	0.22	0.11	0.02	0.02
	B	VI 30 s	26.00	0.76 (0.19)	0.89	0.94	0.60	0.62	0.47	0.48	0.39
10	A	VI 30 s	28.00	1.84 (0.19)	2.07	1.95	1.81	1.77	1.53	1.53	0.91
	X	EXT	0	0.47 (0.08)	0.62	0.80	0.57	0.45	0.60	0.58	0.39
	B	VI 30 s	27.25	1.04 (0.15)	1.16	1.07	0.86	1.09	0.86	1.03	0.61
30	A	VI 30 s	29.00	1.24 (0.09)	1.28	1.27	1.41	1.05	0.79	0.87	0.33
	X	EXT	0	1.15 (0.24)	1.17	1.11	1.01	0.75	0.42	0.58	0.14
	B	VI 30 s	28.33	2.06 (0.11)	1.96	1.81	2.08	1.21	0.78	1.00	0.15
Mean	A	VI 30 s	27.96	1.01 (0.47)	1.14	1.10	1.04	0.97	0.83	0.74	0.40
	X	EXT	0	0.29 (0.36)	0.43	0.44	0.37	0.28	0.30	0.30	0.22
	B	VI 30 s	26.90	0.84 (0.56)	0.96	0.90	0.84	0.74	0.56	0.58	0.29

Table 3

Mean Saline Reinforcer and Response Rates (Standard Deviation in Parentheses) across Components as a Function of Different Doses of Chlordiazepoxide in the Increased-Middle-Component Reinforcement Group

Pigron	Component	Schedule	S ^{R+} /session	Saline	Control	Responses per Second					
						Chlordiazepoxide dose (mg/kg)					
						1.8	3.2	5.6	10	17.8	32
3940	A	VI 150 s	7.13	0.94 (0.10)	0.89	0.92	1.19	1.09	0.57	0.08	0
	X	VI 15 s	45.88	1.15 (0.19)	1.35	1.20	1.15	1.17	0.76	0.07	0
	B	VI 150 s	5.88	0.26 (0.03)	0.34	0.41	0.29	0.22	0.11	0.01	0
4732	A	VI 150 s	6.63	1.63 (0.14)	1.55	1.80	1.85	1.43	0.73	0.26	0
	X	VI 15 s	44.63	1.18 (0.35)	0.95	1.48	1.52	1.28	0.66	0.23	0
	B	VI 150 s	7.25	0.50 (0.13)	0.45	0.52	0.55	0.38	0.14	0.05	0
9005	A	VI 150 s	7.25	1.68 (0.16)	1.55	1.66	1.42	1.91	1.31	0.41	0.02
	X	VI 15 s	45.13	1.71 (0.18)	1.80	1.67	1.62	1.83	0.94	0.25	0.04
	B	VI 150 s	6.50	0.55 (0.10)	0.55	0.52	0.50	0.59	0.22	0.06	0.01
5296	A	VI 150 s	6.88	0.95 (0.12)	1.07	1.11	1.14	1.04	0.62	0	0
	X	VI 15 s	47.63	1.05 (0.12)	1.09	1.19	1.13	0.99	0.60	0	0.02
	B	VI 150 s	7.13	0.31 (0.08)	0.31	0.28	0.25	0.27	0.09	0	0
7607	A	VI 150 s	8.00	1.99 (0.35)	1.99	1.86	1.85	1.52	1.34	0.01	0.36
	X	VI 15 s	46.75	2.14 (0.09)	2.16	2.00	1.74	1.69	1.40	0.05	0.44
	B	VI 150 s	7.38	1.24 (0.08)	1.14	1.06	0.81	0.53	0.41	0	0.08
9770	A	VI 150 s	6.50	0.37 (0.09)	0.38	0.39	0.53	0.51	0.54	0.19	0
	X	VI 15 s	43.50	1.25 (0.17)	1.21	1.19	1.36	1.02	1.06	0.24	0
	B	VI 150 s	5.25	0.23 (0.07)	0.18	0.23	0.17	0.24	0.23	0.04	0
Mean	A	VI 150 s	7.07	1.26 (0.59)	1.24	1.29	1.33	1.25	0.85	0.16	0.06
	X	VI 15 s	45.59	1.41 (0.43)	1.42	1.45	1.42	1.33	0.90	0.14	0.09
	B	VI 150 s	6.57	0.52 (0.36)	0.49	0.50	0.43	0.37	0.20	0.02	0.01

Table 4

Mean Saline Reinforcer and Response Rates (Standard Deviation in Parentheses) across Components as a Function of Different Doses of D-amphetamine in the Increased-Middle-Component Reinforcement Group

Pigeon	Component	Schedule	S ^{R+} /session	Saline	Control	Responses per Second						
						d -Amphetamine dose (mg/kg)						
						0.1	0.3	0.56	1	1.8	3	5.6
3940	A	VI 150 s	8.60	0.96 (0.11)	0.65	0.80	0.61	0.61	0.64	0.59	0.46	0.10
	X	VI 15 s	46.90	1.12 (0.21)	1.26	1.08	0.99	1.06	1.16	1.12	0.87	0.23
	B	VI 150 s	6.10	0.31 (0.09)	0.28	0.31	0.33	0.34	0.23	0.22	0.13	0.01
4732	A	VI 150 s	7.40	1.56 (0.14)	1.47	1.69	1.46	1.32	0.82	1.20	0.10	0
	X	VI 15 s	45.70	1.19 (0.16)	1.05	1.66	1.00	0.97	0.72	0.72	0.10	0
	B	VI 150 s	6.40	0.29 (0.09)	0.29	0.31	0.25	0.23	0.11	0.10	0	0
9005	A	VI 150 s	7.40	1.53 (0.25)	1.63	1.35	1.42	1.02	0.97	0.65	0.32	0.04
	X	VI 15 s	46.50	1.49 (0.34)	1.68	1.55	1.58	1.33	1.24	0.71	0.53	0.07
	B	VI 150 s	6.70	0.45 (0.11)	0.53	0.43	0.38	0.41	0.23	0.23	0.20	0.03
5296	A	VI 150 s	7.10	1.05 (0.13)	1.02	1.15	1.14	1.10	1.15	0.98	0.58	1.03
	X	VI 15 s	45.80	1.03 (0.13)	1.08	1.07	1.14	1.16	1.15	1.15	0.77	0.93
	B	VI 150 s	6.80	0.30 (0.06)	0.27	0.32	0.33	0.31	0.27	0.22	0.16	0.09
7607	A	VI 150 s	7.70	1.79 (0.17)	1.81	1.57	1.78	1.32	1.37	1.56	0.33	0
	X	VI 15 s	46.40	2.27 (0.15)	2.19	2.14	2.15	1.81	2.18	1.83	0.56	0
	B	VI 150 s	6.60	1.04 (0.14)	0.96	0.87	0.98	0.37	0.70	0.38	0.07	0
9770	A	VI 150 s	6.10	0.58 (0.28)	0.44	0.44	0.45	0.64	0.34	0.29	0.17	0.04
	X	VI 15 s	46.60	1.35 (0.12)	1.24	1.31	1.20	1.35	1.24	0.70	0.76	0.19
	B	VI 150 s	5.70	0.31 (0.11)	0.23	0.25	0.25	0.26	0.26	0.07	0.15	0.01
Mean	A	VI 150 s	7.38	1.21 (0.49)	1.17	1.17	1.14	1.00	0.88	0.88	0.33	0.20
	X	VI 15 s	46.32	1.41 (0.45)	1.42	1.47	1.34	1.28	1.28	1.04	0.60	0.24
	B	VI 150 s	6.38	0.45 (0.29)	0.43	0.42	0.42	0.32	0.30	0.20	0.12	0.02

Table 5

Decreased Middle-Component Reinforcement Group					Increased Middle-Component Reinforcement Group				
Pigeon	Component	Responses per Second			Pigeon	Component	Responses per Second		
		Before EXT	After EXT	Change			Before $\uparrow$ S ^{R+}	After $\uparrow$ S ^{R+}	Change
26	A	0.58	0.64	0.06	3940	A	0.75	0.94	0.19
	X	0.36	0.01	-0.35		X	0.45	1.15	0.70
	B	0.58	0.23	-0.35		B	0.65	0.26	-0.39
28	A	1.13	1.12	-0.01	4732	A	1.46	1.63	0.17
	X	1.30	0.01	-1.29		X	1.06	1.18	0.12
	B	1.53	0.67	-0.86		B	0.78	0.50	-0.28
31	A	0.80	0.63	-0.17	9005	A	1.20	1.68	0.48
	X	1.24	0.04	-1.20		X	0.84	1.71	0.87
	B	0.96	0.43	-0.53		B	0.90	0.55	-0.35
13	A	0.99	0.60	-0.39	5296	A	0.62	0.95	0.33
	X	0.81	0.18	-0.63		X	0.46	1.05	0.59
	B	1.08	0.71	-0.37		B	0.45	0.31	-0.14
10	A	0.57	1.11	0.54	7607	A	1.35	1.99	0.64
	X	0.45	0.31	-0.14		X	0.88	2.14	1.26
	B	0.36	0.83	0.47		B	1.27	1.24	-0.03
30	A	1.62	1.25	-0.37	9770	A	0.46	0.37	-0.09
	X	1.07	0.55	-0.52		X	0.68	1.25	0.57
	B	1.82	1.75	-0.07		B	0.49	0.23	-0.26
Mean	A	0.95	0.85	-0.10	Mean	A	0.97	1.26	0.29
	X	0.87	0.17	-0.70		X	0.73	1.41	0.68
	B	1.06	0.72	-0.34		B	0.76	0.52	-0.24