DRUGS AND PUNISHED RESPONDING II: *d*-AMPHETAMINE-INDUCED INCREASES IN PUNISHED RESPONDING¹

D. D. FOREE, F. H. MORETZ, AND D. E. McMILLAN

UNIVERSITY OF NORTH CAROLINA

The effects of *d*-amphetamine on punished responding were studied in two experiments. In Experiment I, pigeons responded under a multiple fixed-ratio 30 response fixed-interval 5-min schedule of food presentation with 60-sec limited holds in both components. Each response was punished with electric shock, the intensity of which was varied systematically. In Experiment II, another group of pigeons responded under a multiple fixed-interval 5-min fixed-interval 5-min schedule of food presentation with 40-sec limited holds. Each response was punished with shock during one component, and every thirtieth response was punished in the other component. *d*-Amphetamine increased overall rates of punished responding only rarely under any of the punishment conditions; however, response rates within the fixed-interval when rates were low were increased by *d*-amphetamine when the shock intensity was low (Experiment I), or when responses produced shock intermittently (Experiment II). The data suggest that the effects of *d*-amphetamine on punished responding depend on the control rate of responding, the punishment intensity, the punishment frequency, and the schedule of food presentation.

In a variety of situations, the effects of the amphetamines on behavior have been shown to depend on the pattern of responding (Dews, 1958a, b; Smith, 1964; Clark and Steele, 1966; McMillan, 1968, 1969). In general, appropriate doses of the amphetamines increase low rates of responding and decrease high rates.

Among several exceptions to the rate-dependent effects of the amphetamines is their effect on punished responding. Although punishing stimuli often reduce responding to very low rates, amphetamine has been reported not to increase rates of punished responding. On the contrary, it has been reported that the amphetamines reduce even further low rates of punished responding. Geller and Seifter (1960) observed the effects of amphetamine (0.5, 1.0, and 1.5 mg/kg) administered to rats working under a multiple schedule in which an unpunished variable-interval 2-min (VI 2-min) component alternated with a component in

which each response was both reinforced with milk and punished with electric shock. Shock intensities ranged from 0.35 to 0.50 mA. In six of seven cases, decreases in the rate of punished responding were produced by *d*-amphetamine. Morrison (1969) used the same schedule as that of Geller and Seifter, but with water as a reinforcer and with a lower range of shock intensities (0.16 to 0.40 mA). At a dose of 0.4 mg/kg of *d*-amphetamine, the rate of punished responding decreased for 11 of 15 rats, but increased for the other rats. Hendry and Van Toller (1964), also using rats as subjects, reinforced each response with water and punished responses at different shock intensities and frequencies (every tenth or every twentieth response). In these experiments, relatively high rates of punished responding were reduced in all six rats by all doses of *d*l-amphetamine (1.0, 2.0, and 3.0 mg/kg). Hanson, Witoslawski, and Campbell (1967), using monkeys as subjects, employed a multiple schedule, in one component of which responses on a lever were concurrently reinforced with milk under a fixed-ratio 10 schedule and shocked under a variable-ratio 15 schedule with a 2-mA, 2-sec shock. Doses of *d*-amphetamine from 0.1 to 0.6 mg/kg decreased the low rate of responding in this component. Responding in another component in which responses were neither reinforced nor

¹These experiments were supported by Grant MH 19440-01 from the USPHS, by a grant from Hoffmann-LaRoche Inc. and by a University of North Carolina Faculty Research Grant. We wish to thank L. S. Harris, V. M. LoLordo, and J. D. Leander for helpful criticism of the manuscript and James Holland and Eugene Goodwin for technical assistance. *d*-Amphetamine was provided by Smith, Kline and French Laboratories. Reprints may be obtained from D. E. McMillan, Dept. of Pharmacology, University of North Carolina, Chapel Hill, N.C. 27514.

punished (S^A) was increased, even though the response rate in the S^A component was higher than the rate in the punishment component.

McMillan (1973) showed that *d*-amphetamine can increase low rates of punished responding by pigeons. In these experiments, responses during one component of a multiple fixed-interval, fixed-interval schedule were punished with electric shock, but responses during the other component were not punished. Within each component, *d*-amphetamine increased low rates of responding but increased higher rates less, or decreased them.

The present experiments were designed to explore some conditions under which amphetamine might increase rates of punished responding. Dose-effect curves for *d*-amphetamine were determined at various intensities of the punishing stimulus, schedules of presentation of the punishing stimulus, and schedules of food presentation maintaining the punished responding.

EXPERIMENT I: EFFECTS OF *d*-AMPHETAMINE ON RESPONDING PUNISHED AT DIFFERENT SHOCK INTENSITIES

Subjects

Three adult male White Carneaux pigeons (3547, 6678, and 5536) weighing between 525 and 563 g under a regimen of free food and water, were maintained at 80% of their free-feeding weights throughout the experiment. Gold wire electrodes were implanted around the pubis bones of each subject and attached to a leather harness worn by the bird at all times (Azrin, 1959). These birds had extensive experience with the multiple fixed-ratio fixed-interval schedule and with various drugs. However, the birds had never been exposed to punishment contingencies.

Apparatus

The experimental chamber (after Ferster and Skinner, 1957) was a sound attenuating box. Centered about 19 cm (7.5 in.) above the floor in one wall was a translucent response key 2 cm (0.75 in.) in diameter that could be illuminated by various colored lights. A force of about 15 g (0.15 N) on the key broke an electrical circuit and defined a response. Response feedback was provided by the sound of a relay operating inside the 28 by 28 by 30.5

cm (11 by 11 by 12 in.) chamber. Below the response key was a square opening through which the pigeon could be given a 4-sec access to grain. On the wall opposite the response key was a mercury swivel to which a phone jack was connected. This jack was plugged into a receptacle on the bird's harness immediately before each session. The chamber was illuminated by a 25-W bulb and white noise was present at all times. Events in the experimental chamber were controlled and recorded by conventional relay apparatus in an adjacent room.

The punishing stimulus was a 110-V ac, 60-Hz electric current delivered through a variable resistance. The 50-msec shocks were varied in intensity from 2.5 to 5.2 mA as described below.

Injections

d-Amphetamine was given as the sulfate and all dose levels were determined for *d*-amphetamine sulfate. Injections were given twice weekly, with distilled water as the injection vehicle. All injections were given into the breast muscle 10 min before the start of a session. Injection volumes were calculated on the basis of 1 ml/kg of the bird's weight as determined immediately before the session. Two birds (3547 and 6678) received the drugs in an ascending series of doses beginning with the injection vehicle; Bird 5536 received the drugs in a descending series of doses terminating with the injection vehicle.

Procedure

The birds had been trained under a multiple fixed-interval 5-min fixed-ratio 30 response schedule with a limited hold of 60 sec applying to each component (*mult* FR 30 LH 60-sec FI 5-min LH 60-sec). In the presence of a red keylight, the first key peck after 5 min resulted in 4 sec access to grain, and in the presence of a blue keylight the thirtieth key peck resulted in 4 sec access to grain. The two schedule components alternated. If 30 responses did not occur within 60 sec in the presence of the blue key, or if no response occurred within 60 sec after the 5 min fixed-interval had elapsed in the presence of the red key, the schedule components alternated without food delivery (60-sec limited hold). The session terminated after six presentations of each schedule component.

Superimposed on this schedule of food presentation was a schedule of shock presentation such that all responses during both components produced electric shock (*mult* FI FR with punishment). The general procedure was to punish responses at a given shock intensity for a number of sessions until responding appeared stable, after which dose-effect curves were determined. Subsequently, the shock intensity was changed to a new value, the behavior allowed to restablize, and the dose-effect curves were redetermined at the new shock intensity. The order in which the shock intensities were studied was 2.5 mA, 4.3 mA, and 5.2 mA. After the 5.2-mA series, the harnesses and electrodes were removed from the birds and the dose-effect curves were determined for behavior under *mult* FR 30 LH 60-sec FI 5-min LH 60-sec without electric-shock punishment (0 mA).

RESULTS

Figure 1 shows the effects of *d*-amphetamine on mean rates of punished responding at three different shock-intensities, as well as the effects of *d*-amphetamine on responding under the multiple schedule at 0 mA. The mean data presented in Figure 1 are representative of all three subjects. With reference to the rate of unpunished responding at 0 mA, 2.5-mA shocks only slightly decreased the rate of responding, with somewhat more marked rate decreases occurring when responding was maintained under the FR component than occurred when responding was maintained under the FI component. However, as can be seen in the lower frames of Figure 1, both 4.3- and 5.2-mA shocks eliminated responding almost entirely.

Doses of 0.3 and 1.0 mg/kg *d*-amphetamine increased the overall rates of responding under the FI component at 0 mA, but not the higher rates under the FR component. These findings are similar to previous reports (Smith, 1964; McMillan, 1968, 1969) which have indicated that in pigeons, amphetamines increase the low overall rates of responding (fewer than one response per second) generated by FI schedules and decrease the high overall rates generated by FR schedules (more than two responses per second).

Figure 1 also shows that *d*-amphetamine did not increase the mean rate of punished responding under either schedule component at

any dose at any shock intensity, even though the rates of punished responding were lower at all shock intensities than the rates of unpunished responding. These results are consistent with previous reports (Geller and Seifter, 1960; Hendry and Van-Toller, 1964; Hanson *et al.*, 1967; Morrison, 1969) that amphetamines do not increase punished responding.

Although overall rates of punished responding were not increased by *d*-amphetamine, the low rates of responding early in the fixed interval may have been increased. To analyze for such effects, each 5-min fixed interval was divided into 30-sec tenths so that response rates in each tenth (local response rates) could be determined. Responses in each tenth of the interval were cumulated for the entire session and mean local response rates were determined for injection days and for days immediately before injection days, which served as control sessions. Drug effects were then plotted on log-log axes as percentage of mean control rate *versus* control rate for each tenth of the fixed interval (see Kelleher and Morse, 1968). Points were not plotted if the injection decreased the rate to less than 1% of the control rate or if the control rate was lower than 0.01 responses per second. Regression lines were fitted to the points by the least squares method. Since very few responses occurred during the entire session when the shock intensity was at 4.3 and 5.2 mA, the analysis was limited to a comparison of 0 and 2.5 mA.

When this type of analysis is performed, effects that depend on mean local control rate of responding appear as positive or negative slope in the regression line. Effects that are not rate dependent appear as vertical displacements of a generally horizontal regression line.

Figure 2 shows log-log plots of per cent of control rate *versus* control rate for the effects of a vehicle injection and the effects of 1.0 and 3.0 mg/kg *d*-amphetamine for the three subjects. The 0.3 mg/kg injection differed little from control and therefore is not shown.

With the exception of Bird 6678, the control injection produced no rate-dependent effects, since the regression lines describing both punished and unpunished responding differ little from the horizontal. For Bird 6678, low rates of unpunished responding tended to be even lower after control injections as evidenced by the positive slope of the line. In contrast, 1.0 mg/kg of *d*-amphetamine pro-

Fig. 1. Effects of *d*-amphetamine on responding punished at different shock intensities. Abscissa: dose of *d*-amphetamine in mg/kg, log scale. Ordinate: mean rate of responding during an entire session in responses per second. The brackets represent the range of control observations based on at least four sessions when injections were not given. The points at zero show the effects of a vehicle injection. Each curve is labelled with the appropriate punishment intensity (●—●, 0 mA or no shock; ○—○, 2.5 mA; ▲—▲, 4.3 mA; ■—■, 5.2 mA). Each point represents the mean of a single observation for each of three birds.

duced clear rate-dependent effects for both punished and unpunished responding for all three birds. As shown by the marked negative slopes of the lines describing the rate-dependent effects of *d*-amphetamine, low rates of responding were increased, while higher rates were increased less, or decreased. The 3.0 mg/kg dose eliminated all responding for Bird 5536 in the unpunished condition and for Bird 6678 in the punished condition. With the

exception of the punished responding in Bird 5536, the 3.0 mg/kg dose of *d*-amphetamine produced the same type of rate dependent effect as noted for the 1.0 mg/kg dose.

Although the effects of *d*-amphetamine on both punished and unpunished responding could be said to be rate dependent, for Birds 6678 and 3547 the punishment and non-punishment functions were separated. Control rates of unpunished responding were increased

more after *d*-amphetamine than were matched rates of punished responding. In addition, the differential drug effect under the two schedules occurred to about the same degree across all control rates. Thus, for these birds the

regression lines representing the drug effect on unpunished and punished responding are nearly parallel, with the line representing unpunished responding above that representing punished responding.

Fig. 2. Log-log plots for the rate-dependent effect of *d*-amphetamine on punished (2.5 mA) and unpunished (0 mA) responding. Abscissa: mean rate of responding (responses per second) during 30-sec segments of the FI 5-min, averaged over non-injection control sessions, log scale. Ordinate: per cent of the mean rate of responding during non-injection control sessions, log scale. The filled symbols are for punished responding and the open symbols are for unpunished responding. The circles represent the ten 30-sec segments of the FI component and the triangles are for the FR components. The broken horizontal line at 100% represents no drug effect. Regression lines were fitted to the points by a solution of a least-squares fit.

It should also be noted that as the dose of *d*-amphetamine increases, a greater proportion of points in the plots in Figure 2 fall below the dashed line representing no effect on control rate. At low doses, only the high control rates are decreased and fall below this line. At higher doses a larger percentage, or even all of the control rates are decreased.

The fixed-ratio (FR) components of the schedule of food presentation generated rates of responding roughly equivalent to the rates of responding observed near the end of the fixed-interval components, (triangles in Figure 2). For unpunished responding, the FR rates fall on or near the function describing the rate-dependent effects of *d*-amphetamine on fixed-interval responding; however, for punished responding, the FR rates of two of the birds (6678 and 3547) fall well below the function describing the rate-dependent effects of 1.0 mg/kg of *d*-amphetamine on fixed-interval responding, while for Bird 3547 the FR rate is far above the function describing the rate-dependent effects of 3.0 mg/kg of *d*-amphetamine. These data suggest that the schedule of food presentation maintaining the behavior can be an important determinant of the effect of a drug on punished behavior.

DISCUSSION

Although *d*-amphetamine did not increase overall rates of responding at any dose level, the low rates of responding near the beginning of the FI component were increased by some doses of *d*-amphetamine when the punishment intensity was low (2.5 mA). Such increases in the rate of punished responding early in an FI component of a multiple schedule have been reported for *d*-amphetamine (McMillan, 1973) when punishment occurred during only one component of a *mult* FI FI schedule. These experiments show that similar increases in punished responding can be produced by *d*-amphetamine when the FI component is one of two components, in both of which responses are punished. Thus, the effects of *d*-amphetamine on punished responding (McMillan, 1973) do not depend on behavioral induction between punished and unpunished responding.

At 2.5 and 0 mA, the effects of *d*-amphetamine depended on the control rate of responding, that is, low rates of punished and

unpunished responding were increased more than were high rates, which often decreased. However, there are at least three indications that other important factors contribute to the effect of *d*-amphetamine besides its rate-dependent effect. First, as previously reported (McMillan, 1973), *d*-amphetamine increases low rates of punished responding much less than it does matched rates of unpunished responding, suggesting that the rate-dependent effects of *d*-amphetamine are modified by punishment. Second, the very low rates of punished responding produced when shock was set at 4.3 and 5.2 mA were not increased by *d*-amphetamine, even though these rates were at least as low as the rates during the early part of the FI with 2.5-mA shock. These data suggest that amphetamines do not increase responding that has been suppressed by severe shocks. Finally, in two birds the moderate rates of punished responding when the shock intensity was 2.5 mA, and when the component of the schedule of food presentation maintaining the behavior was an FR, did not fit the function describing the rate dependent effects of *d*-amphetamine on fixed-interval responding. This observation suggests the importance of a previously ignored factor, the underlying schedule of food presentation maintaining the punished responding.

EXPERIMENT II: EFFECTS OF *d*-AMPHETAMINE ON RESPONDING PUNISHED AT DIFFERENT SHOCK FREQUENCIES

Subjects

Four male White Carneaux pigeons (designated A2943, B3390, C2379, and D2394), with free-feeding weights ranging from 495 to 535 g, were maintained at 75% of their free-feeding weights throughout the experiment. Electrodes were implanted as indicated in the previous experiment. All four birds had histories of key pecking under fixed-interval schedules of food presentation both with and without electric-shock punishment and had received drugs previously.

Apparatus

The experimental chamber differed from that described in Experiment I only in that a 15-W houselight replaced the 25-W bulb.

Procedure

The birds responded under a multiple fixed-interval 5-min, fixed-interval 5-min schedule of food presentation with a limited hold of 40 sec (*mult FI 5-min LH 40-sec FI 5-min LH 40-sec*). Red or green keylight color indicated which component of the multiple schedule was in effect. The two FI components alternated, and each session began with the red keylight on. A 30-sec period in which all lights were turned off (30-sec timeout) followed each food presentation. A session consisted of six presentations of each component.

Superimposed on this schedule of food presentation was a schedule of shock presentation. In the presence of the red keylight, each key peck (FR 1) produced a 2.5-mA, 50-msec shock. In the presence of the green keylight, shock of the same intensity and duration was presented for every thirtieth key peck (FR 30). The ratio requirement was reset at the end of each component so that the shock never was presented until after the first 29 responses in the presence of the green keylight.

Injections

The injection procedure was the same as in the previous experiment, except that data were averaged for two administrations of each of the following doses: 0 mg/kg, 1 mg/kg, 2 mg/kg, 3 mg/kg, and 10 mg/kg. Birds B3390 and D2394 received the doses in the following order: 0, 1, 2, 3, 10, 10, 3, 2, 1, 0 mg/kg. Birds A2943 and C2379 received doses in the following order: 10, 3, 2, 1, 0, 0, 1, 2, 3, 10 mg/kg. In addition, Bird C2379 received two injections of 17.5 mg/kg *d*-amphetamine following the regular series of injections.

RESULTS

For each of the four subjects, the overall rate of responding was lower in the component where each response was punished (FR 1 shock), than in the component where only every thirtieth response was punished (FR 30 shock). Overall rates of responding during the FR 1 shock component ranged from 0.20 to 0.62 responses per second and during the FR 30 shock component, from 0.63 to 1.0 responses per second.

The effect of the various doses of *d*-amphetamine on the overall rate of responding of individual birds can be seen in Figure 3. For

Birds A2943, B3390, and D2394, response rates generally decreased with increasing doses of *d*-amphetamine. In the case of Bird C2379, however, increases in response rate that fell outside the range of control rates occurred for both FR 1 punishment and FR 30 punishment components at the intermediate doses of *d*-amphetamine. For each bird, the effect of *d*-amphetamine at a given dose was about the same under both schedules of punishment. Figure 3 shows that the two curves are generally parallel for individual birds, even though drug effects vary widely across subjects.

Figure 4 shows response rate under drug (as per cent of control response rate) *versus* control response rate for each bird at 0 mg/kg, 1.0 mg/kg, 3.0 mg/kg, and 10.0 mg/kg *d*-amphetamine. These plots were made using the method described in reference to Figure 2 of Experiment I.

The vehicle injection produced very little effect in any of the birds except B3390, which showed a slight rate-dependent effect as evidenced by the negative slope in the regression lines. *d*-Amphetamine, however, produced effects dependent on control rates for all birds at all doses, as evidenced by the negatively sloped regression lines in Figure 4. In addition, a separation of the lines representing effects on responding punished on the FR 1 and the FR 30 is noted in many of the bird-dose combinations. In every case of separation, the line representing the FR 30 punishment was above the line representing FR 1 punishment, indicating that a given rate of responding under FR 30 punishment was increased more or decreased less than a matched rate under FR 1 punishment. All birds but A2943 showed this differential effect for at least one dose of *d*-amphetamine.

Again as in Experiment I, a greater proportion of mean local control rates are decreased rather than increased as the dose of *d*-amphetamine increases. In Figure 4, this is seen as more points falling below the dashed line, and in Figure 3, as lower overall rates at higher doses of *d*-amphetamine.

DISCUSSION

In Experiment II, *d*-amphetamine increased overall rates of responding for only one of four subjects. However, within both FR 1 punishment and FR 30 punishment components of the schedule of reinforcement, *d*-

amphetamine increased the low rates of punished responding that occurred early in

the fixed interval and increased less or decreased the higher rates that occurred late in the interval. The rate-dependent effects of *d*-amphetamine noted in Experiment I were shown to occur for responding punished intermittently as well as responding punished on a continuous reinforcement schedule. It was further shown that *d*-amphetamine was not as effective in elevating low rates of punished responding when each response was punished as it was in elevating intermittently punished responding. This latter finding is consistent with the observation in Experiment I that low rates of punished responding were not elevated as much as low rates of unpunished responding.

GENERAL DISCUSSION

In these experiments, *d*-amphetamine often increased low rates of punished responding, while higher rates were increased less or decreased. This rate-dependent effect of *d*-amphetamine parallels the effect of *d*-amphetamine on unpunished responding.

A number of investigators have reported the failure of the amphetamines to increase rates of punished responding (Geller and Seifter, 1960; Hendry and Van-Toller, 1964; Hanson *et al.*, 1967; Morrison, 1969). The present experiments suggest some conditions under which *d*-amphetamine can increase punished responding. Experiment I showed that *d*-amphetamine increased responding only at the lowest shock intensity. At higher shock intensities, *d*-amphetamine did not increase punished responding, even though the rate was very low. Experiment II extended this finding by showing that *d*-amphetamine increased punished responding more when the punishment frequency was low (FR 30) than when the punishment frequency was high. If both shock intensity and shock frequency can be considered to contribute to the severity of punishment, then it appears that by increasing the severity of punishment the rate-increasing effects of the amphetamines can be attenuated.

The importance of the severity of the punishment can be supported by a close examination of the data from some of the previous experiments that failed to find increases in the rate of punished responding after amphetamine administration. In Morrison's experiments (Morrison, 1969) the shock intensity

Fig. 3. Effect of *d*-amphetamine on responding punished at two different frequencies. Abscissa: dose of *d*-amphetamine in mg/kg, log scale. Ordinate: mean rate of responding in responses per second for an entire session. The brackets at C represent the range of control rates during 10 sessions when injections were not given. The points at P show the effects of an injection of distilled water. Filled circles represent responding under FR 1 punishment. Open circles represent responding under FR 30 punishment.

Fig. 4. Log-log plots for the rate-dependent effect of *d*-amphetamine on responding punished at two different shock intensities. Abscissa: mean rate of responding (responses per second) during 30-sec segments of the FI 5-min averaged over 10 non-injection control sessions, log scale. Ordinate: per cent of the mean rate of responding during non-injection control sessions, log scale. The filled circles are for the FR 1 shock component and the open circles are for the FR 30 shock component. The broken horizontal line at 100% represents no drug effect. Regression lines were fitted to the points by the least-squares method.

varied for different rats. Rats receiving lower shock intensities (1.6 to 2.5 mA) showed increased rates of responding after 0.4 mg/kg of *d*-amphetamine, while this same dose de-

creased rates of punished responding at the higher shock intensities. The rats receiving shock at the very highest intensity were most sensitive to the rate-decreasing effects of am-

phetamine. Geller and Seifter (1960) used a similar procedure but with higher shock levels than those used by Morrison. Thus, the rate-increasing effects of amphetamines on punished responding would not be expected to be observed with these severe shock levels, and they were not. Similarly, Hanson *et al.* (1967) used rather long duration (2-sec) shock, which eliminated responding almost entirely. Under these conditions of severe punishment, *d*-amphetamine did not increase the rate of punished responding.

Another factor that seems to be of some importance in determining the effect of *d*-amphetamine on punished responding is the ongoing rate of responding, which is so widely accepted as a determinant of the effect of amphetamines on unpunished behavior (Dews, 1958*a, b*; Smith, 1964; Clark and Steele, 1966; McMillan, 1968, 1969). In both Experiments I and II, as well as in a previous report in this series (McMillan, 1973), only the low rates of punished responding near the beginning of the FI component were increased by *d*-amphetamine. Thus, it appears that *d*-amphetamine can increase the rate of punished responding only when the rate of punished responding is low, and only when the low rate has not resulted from severe punishment. Hendry and Van-Toller (1964) used an infrequently applied punisher, which resulted in a relatively high control rate of punished responding. The conditions of their experiment did not generate a low rate of punished responding, which seems to be required to see the amphetamine-induced increase in punished responding, and indeed, no increase was observed.

Another factor that seems to influence the effects of *d*-amphetamine on punished responding is the dose of *d*-amphetamine. For a given animal, the control rates at which increases were noted tended to be lower as dose level increased. This resulted in a progressively lower proportion of the control rates that were subject to the rate-increasing effects of *d*-amphetamine, thereby increasing the probability that only overall decreases in rate would occur after high doses of the drug.

Finally, in Experiment I, *d*-amphetamine affected the higher rates of punished responding in some birds in a different manner when the ongoing rate of responding was maintained by a FR schedule of food presentation

than when it was maintained by a FI schedule of food presentation. The schedule of positive reinforcement can thus influence the effect of *d*-amphetamine on punished responding.

Thus, the effects of *d*-amphetamine on punished responding depend on the control rate of responding, the shock intensity, shock frequency, and the schedule of food presentation.

REFERENCES

- Azrin, N. H. A technique for delivering shock to pigeons. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 161-163.
- Clark, F. C. and Steele, B. J. Effects of *d*-amphetamine on performance under a multiple schedule in the rat. *Psychopharmacologia* 1966, 9, 157-169.
- Dews, P. B. Analysis of effects of psychopharmacological agents in behavioral terms. *Federation Proceedings*, 1958, 17, 1024-1030. (a)
- Dews, P. B. Studies on behavior. IV. Stimulant actions of methamphetamine. *Journal of Pharmacology and Experimental Therapeutics*, 1958, 122, 137-147. (b)
- Ferster, C. B. and Skinner, F. B. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Geller, I. and Seifter, J. The effects of meprobamate, barbiturates, *d*-amphetamine and promazine on experimentally induced conflict in the rat. *Psychopharmacologia*, 1960, 1, 482-492.
- Hanson, H. M., Witoslawski, J. J., and Campbell, E. H. Drug effects in squirrel monkeys trained on a multiple schedule with a punishment contingency. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 565-569.
- Hendry, D. P. and Van Toller, C. Fixed-ratio punishment with continuous reinforcement. *Journal of the Experimental Analysis of Behavior*, 1964, 7, 293-300.
- Kelleher, R. T. and Morse, W. H. Determinants of the specificity of behavioral effects of drugs. *Ergebnisse der Physiologie Biologischen Chemie und Experimentellen Pharmakologie*, 1968, 60, 1-56.
- McMillan, D. E. The effects of sympathomimetic amines on schedule-controlled behavior in the pigeon. *Journal of Pharmacology and Experimental Therapeutics*, 1968, 160, 315-325.
- McMillan, D. E. Effects of *d*-amphetamine on performance under several parameters of multiple fixed-ratio, fixed-interval schedules. *Journal of Pharmacology and Experimental Therapeutics*, 1969, 167, 26-33.
- McMillan, D. E. Drugs and punished responding I: Rate-dependent effects under multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1973, 19, 133-145.
- Morrison, C. F. The effects of nicotine on punished behavior. *Psychopharmacologia*, 1969, 14, 221-232.
- Smith, C. B. Effects of *d*-amphetamine upon operant behavior of pigeons: Enhancement by reserpine. *Journal of Pharmacology and Experimental Therapeutics*, 1964, 146, 167-174.

Received 18 May 1972.

(Final Acceptance 26 April 1973.)