Effects of d-amphetamine on the "breaking point" of progressive-ratio performance *

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When d-amphetamine was administered intramuscularly to pigeons 30 min pre-session, the "breaking point" of their progressive-ratio performance increased as the dose increased from 0.5 to 2 mg/kg and then decreased to below control values at the largest dose (4 mg/kg). The maximum increase in breaking point induced by d-amphetamine was substantially less than that found with the optimal dose of phenobarbital (40 mg/kg). An attempt to mimic the large disruptive effect of the 4-mg/kg dose of d-amphetamine by prefeeding the Ss 60 g of grain produced only a small decrease in breaking point compared to the drug condition.

Thompson (1972) described a technique for assessing the behavioral effects of drugs in a free operant situation without reference to rate of responding. The keypecking of pigeons was reinforced with food on a progressive-ratio (PR) schedule, which required an increasing number of responses for each successive reinforcement: 8, 16, 24, 32, etc. When the S failed to complete the next ratio in the sequence within 60 min, the session terminated. The number of responses in the final completed ratio was defined as the "breaking point" (cf. Hodos, 1961). After the breaking point had stabilized, it served as a baseline to assess the effects of varying doses (5-80 mg/kg) of chlordiazepoxide and phenobarbital, administered intramuscularly 30 min before the sessions. Both drugs increased the breaking point. The dose-effect curves were inverted U-shaped, with maximum enhancement of performance occurring at 20 mg/kg for chlordiazepoxide and at 40 mg/kg for phenobarbital.

The main objective of the present research was to obtain dose-effect data for d-amphetamine, using the PR breaking point as the behavioral baseline. To permit a direct comparison in terms of maximum enhancement of performance, the effect of phenobarbital (40 mg/kg) was redetermined. Finally, an attempt was made to mimic the effect of the largest dose of d-amphetamine by prefeeding the Ss before the sessions.

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SUBJECTS

Two adult male White Carneaux pigeons, with an extensive history of fixed-ratio and variable-ratio reinforcement, were maintained within 10 g of 80% of their free-feeding weights throughout the baseline and drug conditions by food presented during the sessions and by postsession supplemental feeding. Water and grit were always available in the home cages.

APPARATUS

The experimental chamber was a single-key box designed to provide a food reinforcer. A 12 x 12 x 12 in. (30 x 30 x 30 cm) aluminum enclosure with a Plexiglas door was housed in a commercial ice chest, which was fitted with an exhaust fan and a one-way observation window. The translucent response key (Gerbrands Model B) was centered on the front wall, 8 in. (20 cm) above the wire-mesh floor. The key could be illuminated from behind by two green 7.5-W bulbs. A white 7.5-W houselight was mounted on the back wall near the ceiling. A minimum force of 15 g (0.14 N) was required to operate the response key. Located 4 in. (10 cm) below the key was a 2 x 2 in. (5 x 5 cm) opening through which a solenoid-operated hopper containing mixed grain was made available as the reinforcer. White noise was continuously present in the chamber to mask extraneous sounds. The automatic scheduling and recording equipment was located in a separate room.

PROCEDURE

Throughout the following procedures, the reinforcer was 5 sec access to grain. Presentation of the food magazine was accompanied by the offset of the keylight and houselight and the onset of the magazine light. A "blackout" (all

lights off) of variable duration preceded and followed each session. With few exceptions, there were six daily sessions a week.

Baseline Training

The Ss were exposed to the PR schedule for 60 sessions to allow the breaking points to stabilize. The ratio increment was 8, i.e., at the start of each session, 8 responses were required for the first reinforcement, 16 responses for the second, 24 for the third, etc. There was no option available to the S to reset the PR during a session (cf. Hurwitz & Harzem, 1968). The criterion for the breaking point was reached when the S failed to complete the next ratio in the sequence within 60 min, at which time the session was terminated.

Drug Testing

After Baseline Session 60, the next 10 weeks were used to test the drugs, d-amphetamine sulfate and phenobarbital sodium. Four doses of d-amphetamine (0.5, 1, 2, and 4 mg/kg) and one dose of phenobarbital (40 mg/kg) were tested, and two determinations of each dose were taken with each S. The drug testing followed the design APAP, where A represents a block of the four doses of d-amphetamine (within each block, the doses were tested in a random order) and P represents the single dose of phenobarbital. The drugs were dissolved in saline and injected into the pectoral muscles 30 min before the test sessions, which took place once a week. Another session in each week was preceded by the administration of saline. The volume of each injection was 0.1 ml/100 g body weight.

Prefeeding Probe

After drug testing, the degree of food deprivation was temporarily decreased to see whether a "motivational" interpretation of the effect of the largest dose of d-amphetamine could be ruled out. This probe involved prefeeding the Ss 60 g of grain in their home cages 30 min before the start of the session. This amount of grain was roughly four times the amount ordinarily required each day to maintain the Ss' body weights at approximately 80% of their free-feeding weights. Following the probe, the daily sessions were discontinued for a few days to allow the body weights to return to the 80% value. Then, after several baseline sessions, a second determination of the effect of the prefeeding probe was taken with each S.

RESULTS AND DISCUSSION

The dose-effect data for individual Ss were analyzed by comparing the breaking point (the number of responses in the last completed ratio) for a given drug session with the

Fig. 1. Effects of d-amphetamine, phenobarbital, and prefeeding on the breaking point (the number of responses in the last completed ratio of a session) of two pigeons' progressive-ratio performance. Drug administration (intramuscularly once a week) and prefeeding occurred 30 min pre-session. The brackets and shaded area indicate the ranges of the breaking points for the baseline (B) and saline (S) sessions.

breaking points for the saline sessions and all of the baseline sessions during drug testing except the one after the drug session. The main results are shown in Fig. 1. The brackets indicate the ranges of variability for the baseline (B) and saline (S) sessions. A drug was considered to have an overall effect on the breaking point to the extent that the dose data fell outside of both ranges (shaded area). Figure 1 shows that the effect of d-amphetamine, except at the largest dose, was to increase the breaking point. This enhancement of performance was dose-related, with the maximum facilitation occurring at 2 mg/kg. Although this maximum facilitation was considerable when compared to baseline performance, it was relatively small when compared to the increased breaking point produced by the optimal dose (40 mg/kg) of phenobarbital (note triangles at the far right in each graph in Fig. 1).

One interpretation of the enhanced PR performance with phenobarbital is that the drug increased the pigeons' "motivation" to work. Since previous research (e.g., Bainbridge, 1968) has shown that this drug can increase food intake of rats in their home cages, it would not be unreasonable to argue that the enhanced PR performance of the pigeons occurred because the food maintaining the performance was more reinforcing under the drug condition. Dews (1956) suggested that if a drug affects food-reinforced responding by modifying the deprivation conditions ("hunger," "appetite," etc.), then the effect of the drug should be mimicked by manipulation of the deprivation conditions by other means. This was the rationale for the deprivation probe that followed drug testing in the

Thompson (1972) experiment. When the pigeons' body weights were reduced from 80% to 70% of their free-feeding weights by increasing the food deprivation, the breaking point did increase for one of the two Ss, but the amount of increase was relatively small compared to the maximum effect seen with phenobarbital. These results suggest that the "motivational" interpretation is not a sufficient account of the drug-induced enhancement of performance.

Fig. 2. Cumulative response records of one S for a saline session and for the sessions in which the maximum effects on breaking point were obtained under the drug and prefeeding conditions. The response pen reset after each reinforcement. Eight responses were required for the first reinforcement in each session, 16 responses for the second reinforcement, 24 responses for the third, etc. The number of responses in the last completed ratio (breaking point) is indicated for each session.

The present results indicate that increased "motivation" is not a necessary condition for obtaining a drug-induced enhancement of PR performance. The breaking point was increased by d-amphetamine (except at the largest dose), despite the fact that this drug has the well-known "anorexic" effect of decreasing food intake in a variety of situations (Costa & Garattini, 1970). This may be another example of "...the predominance of schedule contingencies over other controlling variables, such as motivation, in determining the modification of behavior by drugs [Dews & Morse, 1961, p. 166]."

In a review of the experimental effects of amphetamine, Cole (1967) concluded that "the depressant action of amphetamine on food-motivated performance is, apparently, a reflection of the anorexic properties of the drug [p. 82]." Applied to the present experiment, this would mean that the "anorexic" effect of d-amphetamine could account for the decreased breaking point found at the 4 mg/kg dose. However, the attempt to mimic this effect by prefeeding the Ss produced only a small decrease in breaking point compared to the drug condition (Fig. 1). The possibility exists that the drug effect could have been mimicked if the Ss had been prefed even more, but this seems improbable considering the fact that one of the Ss (P-2) actually stopped

eating before the end of the 30-min prefeeding period (2-4 g of grain remained of the 60 g made available during both determinations). Thus, Cole's explanation does not apply to the present results. Empirically ruling out one plausible interpretation (decreased "motivation") brings us one step closer to isolating the "behavioral mechanism(s)" (cf. Laties & Weiss, 1969) involved when PR performance is "depressed" by a large dose of d-amphetamine.

Figure 2 shows the cumulative response records of one S (P-1) for a saline session and for the sessions in which the maximum effects on breaking point were obtained under the drug and prefeeding conditions. Note that as the breaking point increased with the optimal dose of each drug (d-amphetamine 2 mg/kg; phenobarbital 40 mg/kg), there was a decrease in the postreinforcement pausing associated with the larger ratios. A similar effect has been reported with fixed-ratio schedules. Moderate doses of amphetamines (Dews, 1958) and barbiturates (Morse, 1962) have been found to increase the output of behavior of pigeons working on large fixed ratios by reducing the postreinforcement pause. Inspection

of these records also indicates that the high running rates of responding remained intact under the drug conditions, except during the larger ratios near the end of a session. Although the breaking point decreased when the S was administered 4 mg/kg of d-amphetamine or was prefed 60 g, the cumulative records show that when responding did occur, the rate was high and usually not disrupted. These within-session characteristics of PR performance were also observed with the other S under the same drug and prefeeding conditions. No attempt was made to examine the PR performance more closely (e.g., interresponse time distributions), since the major focus was on the simpler measure of breaking point. However, such a "microanalysis" of the drug effects may prove fruitful, as it has in the case of fixed-ratio performance (cf. Weiss & Gott, 1972).

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