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Effects of d-Amphetamine on Schedule-Induced Escape[1]

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SLIFER, B. E. *Effects of d-amphetamine on schedule-induced escape*. PHARMAC. BIOCHEM. BEHAV. 9(5) 609–614, 1978.—Pigeons were trained to respond on a fixed-ratio schedule during which 90 responses produced 3 sec of grain reinforcement (FR 90). Concurrently, a separate key was available on which a response initiated a time-out from the FR schedule and turned off the discriminative stimuli associated with the FR. A second response on the same key terminated the time-out and reinstated the fixed ratio. The pigeons demonstrated a pattern of escape responding immediately following the grain reinforcement. d-Amphetamine (0.5, 1.0, 3.0 mg/kg) was administered 30 min before a probe session. During the probe sessions grain presentation was decreased to 2 sec to generate maximum escape responding. The FR response rate showed a dose related increase with doses of 0.5–1.0 mg/kg, while the same doses produced a dose related decrease in the rate of schedule-induced escape. The highest dose of 3.0 mg/kg of d-amphetamine eliminated FR and schedule-induced escape responding in all but one animal. The drug effects on a topographically similar response from the same animal during the same session suggests differential effects on schedule-controlled and schedule-induced behavior.

Adjunctive behavior Schedule-induced escape Schedule-controlled behavior d-Amphetamine

SCHEDULE-INDUCED, or adjunctive, behaviors are difficult to explain by present, simple operant conditioning theory, since these behaviors do not temporally precede the reinforcer or punisher. While schedule controlled behavior follows the law of effects by immediately preceding reinforcement or punishment, adjunctive behaviors are most prevalent immediately following reinforcement or punishment. Even so, they are considered induced by the controlling schedule because: first, the behaviors are not usually present during the initial sessions and appear only gradually over a period of repeated exposures to the schedule [33]; and, second, the parameters of the schedule controlling the conditioned behavior affect the adjunctive behavior as well [8, 11, 15]. These parameters include the interreinforcement or punishment interval and the magnitude and type of reinforcer [18] or punisher [21].

The first schedule-induced behavior reported was polydipsia, the consumption of large quantities of water. Falk [13] noticed this phenomenon in rats maintained on a variable interval of food reinforcement. Polydipsia has also been demonstrated in monkeys on an unavoidable shock schedule [20]. Several other types of adjunctive responses have been reported. These include such behaviors as wheel running [26], air licking [29] and attack responses [6, 15, 22]. Escape from a schedule of positive reinforcement is also a schedule-induced behavior. An organism will respond to initiate a timeout from a schedule or stimulus associated with positive reinforcement [2,37].

Azrin [2] first examined schedule-induced escape in pigeons during a fixed ratio schedule. He reported that the escape responses occurred during the post reinforcement pause, and the animal controlled duration of the timeout was a function of the ratio value. This is consistent with the findings that the pause duration following reinforcement in operant responding is a function of the ratio requirement [3,14]. Other investigators, while failing to find a similar relationship to ratio size report that the degree of stimulus change within the operant chamber is a controlling factor in the rate and duration of the escapes [38]. This observation is supported by the fact that few if any responses are made on the fixed ratio key during the timeout which suggests that the removal of the contingency has no effect or is not important.

Another variable which has reciprocal effects on schedule-controlled and schedule-induced behaviors is the magnitude of the reinforcer. In operant responding an increase in reinforcement size results in an increase in response rate [5,32]. Similar results are seen in schedule-induced polydipsia [1, 18, 34]. This relationship has not been examined with many other adjunctive behaviors; however, there is an indication of an inverse function between reinforcer size and escape responses based on pilot studies conducted by the author.

If it is possible to measure escape behavior while maintaining reinforced responding within the same session, then there is the opportunity to examine drug effects upon two types and rates of behaviors maintained by the same discriminative stimulus. The fixed interval schedule is often used in behavioral pharmacological studies to generate

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different rates of responding. One can then measure the rate increasing effects of amphetamines on low baseline rates and the rate decreasing effects on high baseline rates within a single component. However, it is assumed that this schedule generates differing rates of the same operant response.

Amphetamine has been found to increase operant, while decreasing adjunctive behaviors such as polydipsia [4,35] and induced biting [9]. The different drug effects, however, might be attributed to the dissimilar physical topography of the operant response and adjunctive behaviors as suggested by DeWeese [9].

This study examines the effects of d-amphetamine on the two response categories during a schedule of positive reinforcement: schedule-controlled, positively reinforced responses and schedule-induced escape responses. The two responses with the same topography but differing rates and consequences provide the opportunity to study the effects of d-amphetamine on the different behaviors.

METHOD

Animals

The four animals were adult, male, White Carneaux pigeons obtained from the Palmetto Pigeon Plant, Sumter, SC. Three of the birds had previous experience with the schedule. The pigeons were maintained at 70–80% of their free feeding weight by supplemental feedings after each session. Water and grit were continuously available in their individual cages.

Apparatus

The sessions were conducted in a three-key pigeon chamber (30×25×27 cm) within a ventilated, sound attenuation enclosure. The three response keys were on the front panel, 18 cm off the grid floor and 4 cm apart. The keys were illuminated by 7 W bulbs. The grain reinforcement magazine was presented through an opening 4 cm from the floor and 14 cm below the center key. During presentation, the grain magazine was illuminated. A 28 W houselight was centered above the front panel. Events within the chamber were controlled and recorded by electromechanical equipment located in a separate room. White masking noise, immediately outside the operant chamber, was added approximately halfway through the study.

Behavioral Procedure

The naive bird (P-1096) was trained to peck the red center key by presenting food after each key peck. The number of responses required for reinforcement was gradually incremented over a number of sessions from one response (FR 1) to a fixed ratio of 90 (FR 90). Pigeon P-4274 had been previously trained on an FR 60 and was brought up to an FR 90 over 6 sessions. The remaining two animals (P-3403 and P-9163) were run on an FR 90 during the training of the other birds. Sessions were run daily except when the animals weights were above 80% of their free feeding weight. Reinforcement during training consisted of 3 sec access to grain and the sessions lasted until 50 reinforcements had been obtained.

The key on the right side of the center key was the escape key. It was illuminated with a green light. A single response on this key was required to initiate the session. This response turned on the red center key light, the houselight, and instituted the fixed ratio on the center key. This contingency was in effect from the initial sessions for all animals except P-1096. For this bird the green key contingency began at FR 25. Within the session a response on the green escape key turned off the red FR key light and houselight. During this period responses on the dark center key had no effect. A second response on the green escape key again illuminated the red FR key and houselight, and reinstated the fixed ratio schedule. Thus, the timeouts were animal initiated, and the duration animal controlled.

The key to the left of the center key was a noncontingent, white key. The only effect a response on this key had was to operate a counter. Table 1 summarizes the stimulus configurations during a session.

TABLE 1

STIMULUS CONFIGURATION DURING FR-ESCAPE SESSIONS

	Fixed Ratio	Escape Timeout
Green Escape Keylight	ON	ON
White Noncontingent Keylight	ON	ON
Red Fixed Ratio Keylight	ON	OFF
Houselight	ON	OFF

As the fixed ratio behavior stabilized the number of escapes (responses on the green key) per session declined to a low rate. Occasionally the only response on the green key was the response to begin the session. To provide more baseline behavior, probe sessions were inserted every four days unless prohibited by the animal's weight [12,18]. The probes consisted of the fixed ratio-escape schedule, however, reinforcement duration was decreased to 2 sec. A preliminary study by the author indicated an increase in escape response rate when the reinforcement magnitude (measured as duration of presentation) was decreased. A 2 sec duration demonstrated maximum increases in escapes.

The probe sessions served as test and control days. It was necessary to use the probes rather than continuous sessions of 2 sec reinforcement to prevent extinction of the response. While the pigeons usually received all 50 reinforcements, an occasional probe session had to be terminated after approximately 90 min.

Pharmacological Procedure

The drug was administered 30 min prior to the probe sessions, which never occurred less than four days apart. The d-amphetamine sulfate was injected into the pectoral muscle in a volume of 1 ml/kg body weight. Two injections of each of the following doses (salt weight) were given in ascending, then descending order: 0.5, 1.0, 3.0 mg/kg. Saline was administered two times to each animal.

RESULTS

All animals demonstrated a typical fixed ratio pattern of responding under the schedule. Reinforcement was followed by a period of not responding. Once responding was initiated a high, steady rate continued until food presentation. Within a session, the post reinforcement pause duration was variable with reinforcement being followed by short and relatively long pauses characteristic of a large ratio value. Figure 1 illustrates these patterns showing the high running rate and

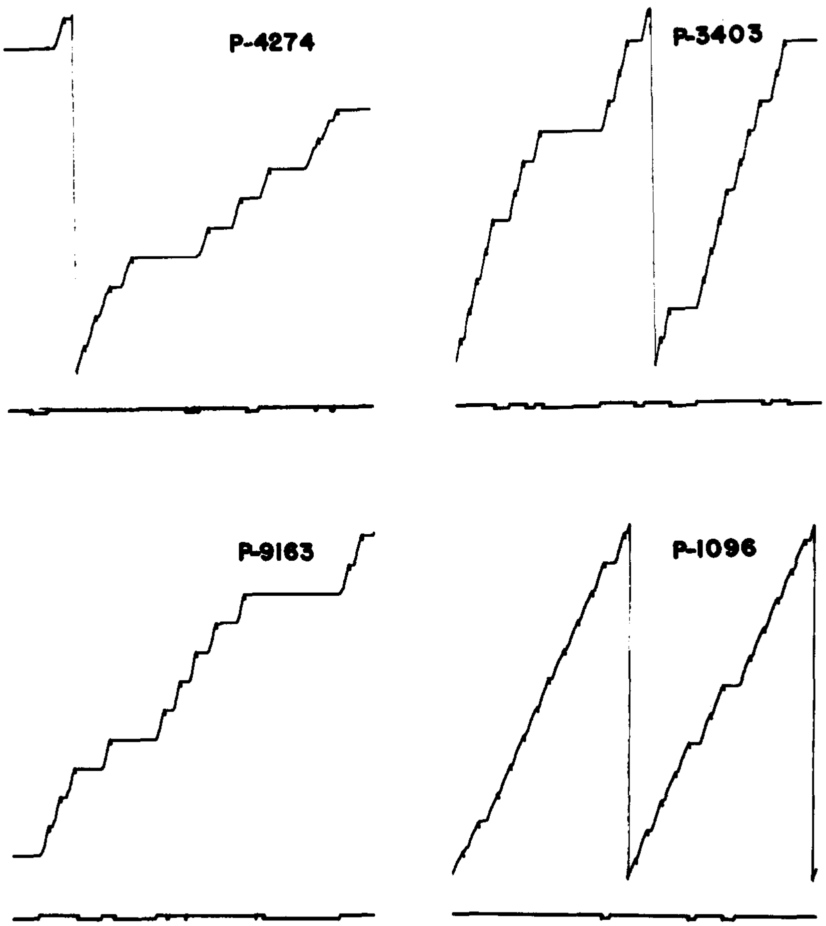

FIG. 1. Cumulative records for key pecking on a FR-Escape schedule. The timeout is shown when the event pen is down.

post reinforcement pauses interspersed with long pauses. The escape responses are seen immediately following the reinforcements. This was found to be the case in the majority of sessions. Although an escape response was seldom seen further into the post reinforcement pause, and never observed after initiation of the rapid responding, an occasional response occurred following one or two spaced responses.

Amphetamine Effects

Mean response rates, calculated as responses/minute, are shown for all treatments in Fig. 2. The amphetamine effects on response rate are obvious. The rate increasing effect is seen with 0.5 mg/kg and 1.0 mg/kg, while the largest dose of 3.0 mg/kg produced a substantial decrease in the rate of responding. Representative cumulative records (Fig. 3) show the elimination of responding in three pigeons while responding was maintained in P-4274, although it did not begin until late into the session. Analysis of variance revealed highly significant dose effects, $F(3,21)=7.93$, $p<0.001$. A post hoc Dunnett test showed that the three doses significantly differed from the saline control ($p<0.05$).

The number of escape responses for each control and drug dose was calculated for each animal using the ratio: $ESC/ESC+S^R$, where ESC is the number of escape responses and S^R is the number of food reinforcements obtained [37]. This ratio minimizes the effects of extreme values. The percentage of escapes for all animals is shown in Fig. 4. It can be seen that d-amphetamine produced a dose related decrease in the percent of escapes at all three dosage levels. The dose effects were significant, $F(3,21)=7.29$, $p<0.005$. A post hoc Dunnett test comparing control and drug means at each amphetamine dose revealed significant effects ($p<0.05$) for the 3.0 mg/kg dose.

Duration of the escape time-outs was calculated for all animals as the mean of the minutes per time-out during the sessions for each treatment. An increase at the 1.0 mg/kg dose was followed by a decrease to zero at the 3.0 mg/kg dose. These effects, however, were not significant, $F(3,21)=0.9705$.

Responses to the noncontingent key showed increases in mean rate at 0.5 mg/kg and 3.0 mg/kg, however, the dose effect was not significant, $F(3,21)=0.3541$.

The analysis of variance for all measures revealed no significant effects due to the order of the drug administration, indicating that there was no increased sensitivity to the drug.

DISCUSSION

The fixed-ratio escape schedule in the present study pro-

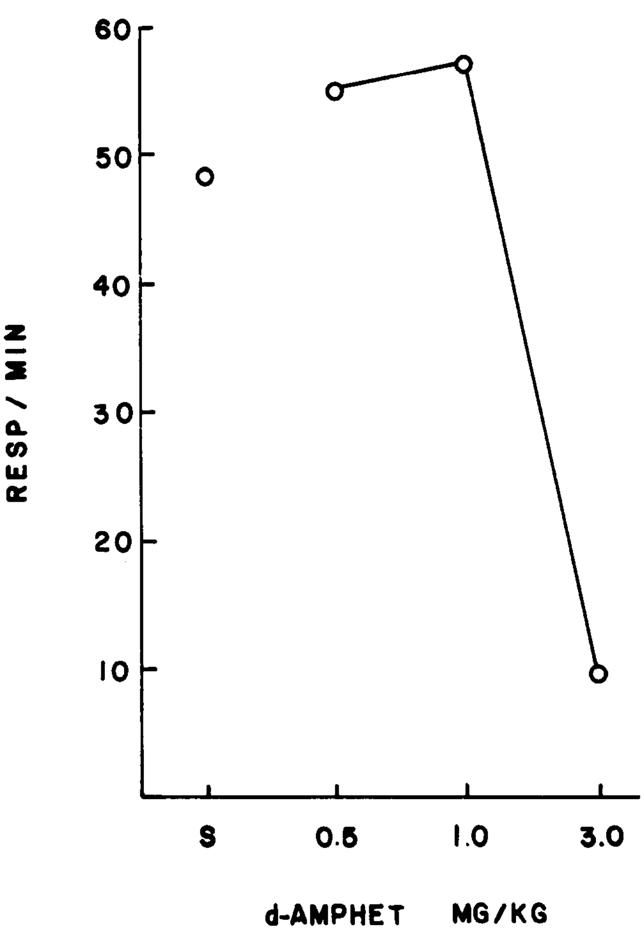

FIG. 2. Effects of *d*-amphetamine on mean FR response rates for all 4 birds. The mean of two saline control sessions is indicated at point S. Data for each dose is based on two administrations.

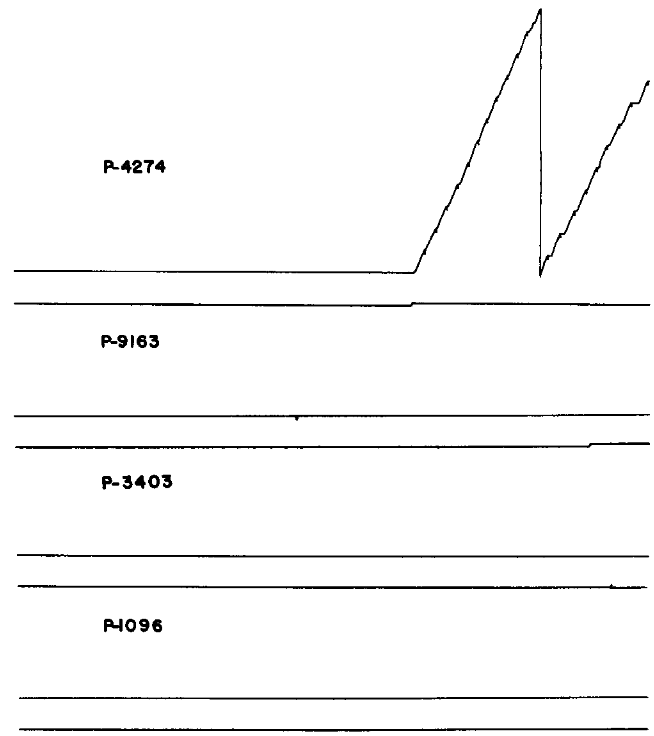

FIG. 3. Representative cumulative records showing the elimination of responding in three birds at 3.0 mg/kg d-amphetamine. Pigeon P-4274 began responding after a long initial pause.

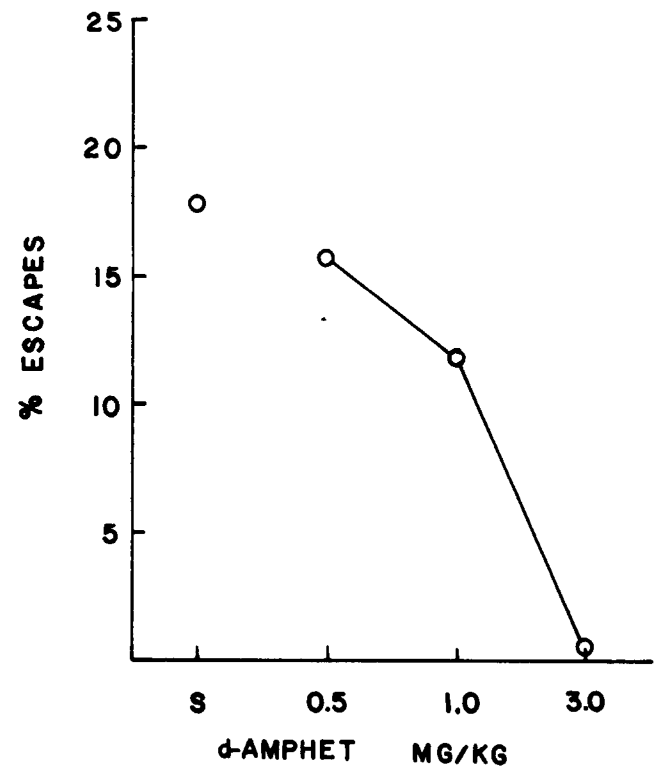

FIG. 4. The effects of d-amphetamine on the percentage of escapes for the four birds, percentage is calculated as ESC/ESC+S^R. The mean of the two saline control sessions is indicated at point S. Data for each dose is based on two administrations.

duced a pattern of FR responding to food reinforcement followed by an escape response during the post reinforcement pause which initiated a time-out. This pattern is consistent with previous studies of fixed-ratio induced escape [2,37], and aggression [6, 15, 16] in pigeons and rats. Unlike the earlier reports, however, the birds in this study consistently made escape responses immediately following food presentation rather than just prior to fixed-ratio responding as reported by Azrin [2].

The fixed-ratio response rate showed a dose related increase with the low and intermediate doses of d-amphetamine, while the highest dose of 3.0 mg/kg eliminated responding in three animals (Fig. 3). The fourth bird (P-4274) responded at a high rate only after a long initial pause. This resulted in a low overall rate for the session. While the fixed-ratio operant rate was increased by the lower doses of d-amphetamine, the rate of schedule-induced escapes was decreased in a dose related manner. Such differential effects of amphetamine on schedule-controlled and schedule-induced behaviors have been reported with polydipsia [35] and induced biting [9]. In these studies, however, the schedule-induced response was topographically different from the schedule-controlled operant. DeWeese [9] suggested that the difference in topography may have accounted for the different drug effects. Segal and Oden [36] used a single operandum to measure amphetamine effects on food reinforced and polydipsic drinking. They reported an increase in the schedule-controlled and a decrease in the schedule-induced behaviors. The present study parallels these results with a common response for the operant and induced behaviors, further suggesting that it is unlikely that response topography is the important variable in the differential effects of amphetamine.

Dews [10] first proposed a rate-dependency hypothesis for drug effects. This hypothesis states that the effects of a drug on a behavior can be best described in relation to the ongoing rate of behavior. He observed that methamphetamine increased rates when the ongoing rate was low but decreased rates when the behavior was at a high baseline rate. This observation has since been reported by other investigators and for other drugs [7, 24, 25]. While the increase in the intermediate operant rate in the current study is compatible with the findings by others who have related control rates to amphetamine effects [17,28], the decrease in the low baseline rate of escape responses is not. According to the rate-dependency hypothesis, amphetamine should produce an increase in the low rate of responding. Although studies using low rates of operant responding occasionally report no significant increases with amphetamines [19,27], the decreases found in this study are surprising. The failure of the escape rate to increase was not due to a ceiling on the escape response rate. While establishing a baseline for the present study, the escape rate occasionally reached values two-fold the final steady baseline indicating that the response could be emitted at a higher rate.

Dews [10] suggested that amphetamine produces a rate increase in a fixed-ratio by reducing the duration of periods of not responding. Though amphetamine decreased the percentage of escapes in the present work, the average duration of the timeouts was increased by doses of 0.5 mg/kg and 1.0 mg/kg. So, while the birds were responding more rapidly on the fixed ratio and making fewer escape responses under amphetamine, when they did escape the duration of the timeout was longer.

The noncontingent key was added as a control to establish whether pecks on the escape key were maintained by the contingency on the key or if they were random responses. The mean number of responses to the noncontingent key were not significantly changed by amphetamine.

The schedule-induced escape responses are probably an escape from the stimulus associated with the fixed ratio, as suggested by Thompson [37], because there were no responses on the center FR key during the timeout. Thus, the fixed-ratio responses are schedule-controlled by a food reinforcer while the schedule-induced responses to the escape key result in the removal of a discriminative stimulus. The different consequences of the responses probably do not account for the different effects of amphetamine. Kelleher and Morse [23] found identical amphetamine effects on response rates whether the behavior was maintained by food reinforcement or escape from a conditioned aversive stimulus.

The findings that two topographically similar responses from one animal within the same session are differentially affected by d-amphetamine, and that this difference cannot be explained by the rate-dependency hypothesis nor the differing consequence of the responses, suggests that the difference may be due to the fact that the one response is schedule-controlled by contingent reinforcement while the other is a schedule-induced behavior.

Recently, Moore, Tychsen and Thompson [31] and Moore and Thompson [30] reported that in pigeons chlordiazepoxide and cocaine reduced schedule-induced mirror responding at doses which did not change operant responding. Although they interpreted these results as a selective effect on an aggressive behavior, the results of the current study suggest that the decrease may have been due to the schedule-induced character of the response.

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