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The effects of d-amphetamine on prey killing and prey eating in the rat and mouse

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d-Amphetamine inhibited mouse, frog, and cricket killing in the rat and cricket killing in the laboratory mouse. Feeding on the same prey was also inhibited, but required a lower dose of the drug. While the anoxeric effects of d-amphetamine may contribute to the drug's inhibition of prey killing, other actions of the drug also appear to be involved.

d-Amphetamine, at moderate doses, blocks mouse killing by rats (Barnes, Cunningham, Penberthy, & Goberty, 1967; Barnett, Taber, & Roth, 1969; Horovitz, Piala, High, Burke, & Leaf, 1966; Karli, 1958; Kulkarni, 1968; Leaf, Lerner, & Horovitz, 1969). This inhibitory effect appears to be due to a direct pharmacological action on central target sites involved in predatory aggression and not to an indirect action on other perceptual or motivational systems (Gay, Leaf, & Arble, 1975; Leaf et al., 1969). For example, the drug effect does not appear to be due to anorexia (Gay et al., 1975), because pilocarpine, which induces mouse killing, also produces decreased consumption of laboratory chow. This conclusion, however, has not been evaluated by studies of the anorexic properties of d-amphetamine on prey eating.

The following studies had two purposes: (1) to extend the generality of the d-amphetamine inhibitory effect to other prey and another predator and (2) to explore further the relationship of d-amphetamine inhibition of prey killing to anorexia.

EXPERIMENT 1

In the first experiment, mouse killing and mouse eating were studied in the rat. Prey eating was studied in rats which killed their own prey.

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Method

Subjects. The subjects were 12 male Holtzman rats (331-620 g), selected from a larger population of approximately 160 because they killed mice on a 1-h pretest. The prey were adult mice of both sexes, bred in our laboratory from original ICR stock (ICR-derived mice).

Procedure. Following selection, each rat was given four additional tests for mouse killing, once each with 0, .75, 1.5, or 3.0 mg/kg i.p. d-amphetamine SO_4 in 1 cc/kg .9% NaCl (d-amphetamine). The order of doses was latinized. Tests for mouse-killing were given every second day.

On test days, each rat was administered its scheduled dose of drug. Forty-five minutes later, each rat had a 1-h opportunity to kill and eat a single mouse placed in its home cage. All rats were maintained on ad-lib Purina Rat Chow and water, except that food and water were removed during the mouse-killing tests. For each test, latency (in minutes), success of kill (kill, no kill) and the amount of mouse consumed (weight of mouse prior to test minus weight of mouse remains) were measured.

Results

d-Amphetamine significantly decreased the number of rats killing mice (Cochran Q test: $Q = 9.82$, $df = 3$, $p < .05$) and significantly increased the latency to kill (Friedman 2-way analysis of variance: $\chi_r^2 = 10.68$, $df = 3$, $p < .02$). Prey consumption was also significantly reduced (analysis of variance: $F = 25.68$, $df = 3/33$, $p < .01$). As can be seen in Figure 1, the dose-response function for inhibition of killing had an ED_{50} of approximately 2.1 mg/kg. On the other hand, at a dose of .75 mg/kg the rats had reduced their prey consumption by about half. Although food intake was not significantly related to within-group latency to kill at any drug dose ($r = -.05$ to $-.31$) and observation suggested that rats likely to eat their prey begin eating soon after the kill, it is possible that the decreased time allowed for prey consumption when drugged accounted for this decrease. Thus, the data only suggest that amphetamine may inhibit prey eating at lower doses than it inhibits prey killing.

EXPERIMENT 2

In Experiment 2, an attempt was made to obtain a

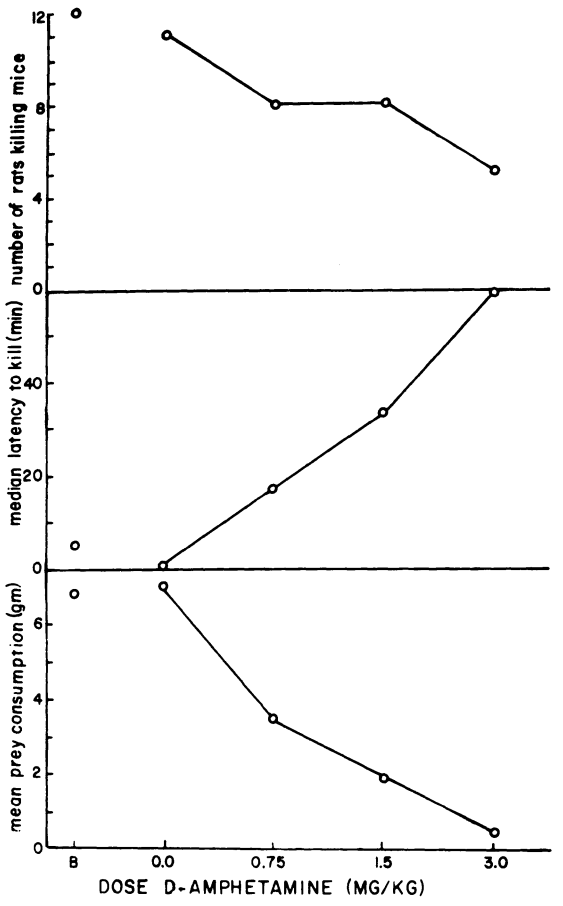

Figure 1. Number of rats killing mice, median latency to kill, and mean mouse consumption under baseline (B) conditions and four doses of amphetamine.

dose-response function for d-amphetamine's affects on prey eating that was not contaminated by the act of prey killing. Rats were fed mice killed by other animals while drugged with one of four doses of d-amphetamine.

Method

Subjects. The subjects were seven adult male Holtzman rats (400-562 g), selected because they killed mice on a 1-h pretest. The prey were ICR-derived mice of both sexes.

Procedure. Each rat was given four 1-h opportunities to eat a mouse killed by another animal. All animals received one test with each of the following doses of d-amphetamine: 0, .75, 1.5, and 3.0 mg/kg. The order of doses was randomized separately for each rat and tests were separated by at least 2 days.

On test days, each rat was injected i.p. with the appropriate dose of d-amphetamine. At this time, food and water bottles were removed. Forty-five minutes later, a freshly killed mouse was placed in the animal's home cage. Mice were weighed before placement in the home cage and immediately after removal and the weight difference recorded. None of the rats in this study was allowed to kill mice after the initial screen.

Results

d-Amphetamine significantly reduced prey eating at all doses [$F(3,18) = 5.47$, $p < .01$]. As can be seen in Table 1, consumption was considerably suppressed even following the .75-mg/kg d-amphetamine dose. These

Table 1
Mean Mouse Consumption With Three Doses of d-Amphetamine

Dose (mg/kg)	.0	.75	1.5	3.0
Mean Consumption (g)	5.0	.57	.29	.29

data compare favorably with those for randomly selected rats fed laboratory chow (see review by Cole, 1972) in that d-amphetamine suppressed feeding at low doses. Prey eating in this study was suppressed at a dose (< .75 mg/kg) considerably less than that required to inhibit mouse killing (approximately 2.1 mg/kg) in Experiment 1. Taken together, these data suggest prey eating is inhibited by lower doses of d-amphetamine than is prey killing. Thus, the primary mechanism of action by which d-amphetamine inhibits mouse killing does not appear to be anorexia.

In this study, prey consumption was lower, at all doses, than in Experiment 1, where animals were required to kill their own prey. This was true in spite of the uniform eating time in Experiment 2. While the results of these two studies cannot be statistically compared, they do appear to support the contention that the act of killing facilitates that of eating, even in drugged animals.

EXPERIMENT 3

Experiment 3 explored the effects of d-amphetamine on frog killing and eating in the rat.

Method

Subjects. The subjects were 12 male Holtzman rats (302-408 g), selected from a larger population of 20 because they killed frogs on a 1-h pretest. Due to illness, only 10 rats completed the entire study. The prey were small grass frogs *(Rana pipiens)*.

Procedure. The procedure was identical to that of Experiment 1, except that (1) frogs, instead of mice, were used as prey; (2) latency to kill was measured only to the nearest 15 min; and (3) the weight of the frog consumed was not directly measured. Instead, consumption was rated on a 4-point scale by examining the remaining carcass.

Results

As in Experiment 1, d-amphetamine significantly decreased the number of rats killing frogs ($Q = 9.00$, $df = 3$, $p < .05$) and increased the latency to kill ($\chi_r^2 = 46.23$, $df = 3$, $p < .001$). Rated prey consumption also decreased significantly ($Q = 14.40$, $df = 3$, $p < .01$) when the ratings were dichotomized to compare those animals that ate some significant portion of the frog (usually brain or legs) with those that failed to eat at all, or ate only minimally around the wound. As can be seen in Figure 2, the dose-response function for total inhibition of prey killing had an ED_{50} of approximately 1.1 mg/kg, while the function for feeding had an ED_{50} of approximately .75 mg/kg. As in the previous studies, there appeared to be d-amphetamine doses which suppressed prey consumption, but still permitted prey killing in some animals.

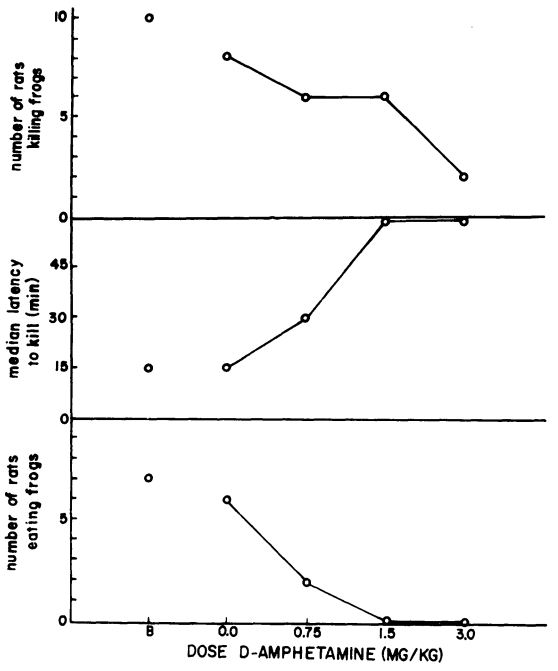

Figure 2. Number of rats killing frogs, median latency to kill, and number of rats eating frogs under baseline (B) conditions and four doses of d-amphetamine.

EXPERIMENT 4

Experiment 4 explored the effects of d-amphetamine on cricket killing and eating in the rat.

Method

Subjects. The subjects were 12 male Holtzman rats (353-518 g), selected from a larger population of 59 because they killed and ate crickets on both of two 30-min pretests. The prey were large brooder crickets (Selph's Cricket Ranch, Memphis, Tennessee).

Procedure. Following selection, each rat was given four additional tests for cricket killing, once each with 0, .75, 1.5, or 3.0 mg/kg i.p. d-amphetamine. The order of doses was latinized. Tests for cricket killing were given every second day.

On test days, each rat was administered its scheduled dose of drug and returned to its home cage. Forty-five minutes later, the rat was placed in a 2½-gallon aquarium and given 30 min to kill and eat a single cricket. For each test, latency and success of kill, as well as the parts of the cricket eaten, were measured.

Results

As in the two previous studies, d-amphetamine significantly decreased the number of rats killing crickets ($Q = 20.35$, $df = 3$, $p < .001$) and increased the latency to kill ($\chi_r^2 = 18.45$, $df = 3$, $p < .001$). Prey consumption could not be separately evaluated because it proved difficult to determine if a cricket was dead before it was consumed. Unlike mouse and frog killing, cricket killing was not a stereotyped response. The rats tended to "play" with the insect until death occurred either by maiming or by gradual dismemberment. d-Amphetamine, however, did block cricket-killing, with an ED_{50} of approximately 1.00 mg/kg (see Figure 3). The log dose-response function had a steeper slope than those for mouse or frog killing, suggesting that the d-amphetamine inhibition of cricket killing may be due to different actions of the drug than those that produce inhibition of mouse and frog killing.

EXPERIMENT 5

Experiment 5 explored the effects of d-amphetamine on cricket killing in the laboratory mouse *(Mus musculus)*. While the laboratory mouse is not generally considered predatory, many of this species will kill and consume small insects.

Method

Subjects. The subjects were 24 male and 27 female ICR-derived mice (16-49 g), selected from a larger population of 112 because they killed and ate crickets in a 30-min pretest. Animals were group housed prior to selection, but were housed singly in No. 10 tin cans containing food, water, and bedding and covered with wire mesh for 1 day after selection. The prey were large brooder crickets, as described in Experiment 4.

Procedure. On the day following selection, the mice were randomly assigned to one of four d-amphetamine groups (0, .75, 1.5, and 3.0 mg/kg d-amphetamine). This created four independent groups of approximately 13 (6 males, 7 females) animals each. Animals were injected i.p. with the appropriate dose (1 cc/100 g) of drug 30 min prior to a 30-min opportunity to kill a single cricket. Testing took place in a bare, clean, No. 10 tin can covered with mesh screen. Success of kill and latency to kill (to the nearest 5 min) were recorded.

Results

The results of this study are shown in Table 2. As in the previous experiments, d-amphetamine significantly reduced the number of mice killing crickets ($\chi_r^2 = 19.0$, $df = 3$, $p < .01$) and significantly increased the latency

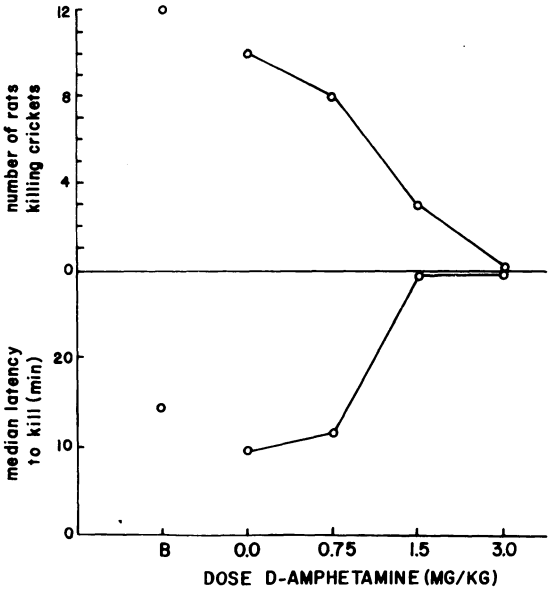

Figure 3. Number of rats killing crickets and median latency to kill under baseline (B) conditions and four doses of d-amphetamine.

Table 2
Number of Mice Killing Crickets With Three Doses of d-Amphetamine

Dose (mg/kg)	Male	Female	Dose (mg/kg)	Male	Female
.0	5/6	6/7	1.5	4/6	4/7
.75	4/6	2/7	3.0	0/6	0/6

to kill (Kruskal-Wallis H = 16.32, $p < .01$). There were no evident effects of sex, so variables were collapsed across sex prior to analysis. ED_{50} for inhibition of killing was estimated at 1.0 mg/kg, a figure comparable to that calculated for the rat in Experiment 4.

As in Experiment 4 with rats, it was difficult to determine death of the insect, separate from ingestion. Unlike the predatory mouse, *Onychomys*, which nearly always kills insects with a stereotyped bite to the back of the head (McCarty & Whitesides, 1976), the laboratory mouse will often kill by gradual dismemberment. Occasionally, however, a directed pattern of attack to the head, involving prior pouncing and pinning of the insect, was observed.

GENERAL DISCUSSION

d-Amphetamine inhibited mouse, frog, and cricket killing by rats, although ED_{50}s varied somewhat between prey. This variation, however, was not related to the population tendency to kill the various prey (present studies, Bandler & Moyer, 1970), nor to reported preferences for eating the various prey once they were killed (Bandler & Moyer, 1970). d-Amphetamine also inhibited cricket killing in the laboratory mouse. These results, as well as those of McCarty & Whitesides (1976) for cricket killing by *Onychomys*, suggest that, at least in rodents, d-amphetamine is a potent blocker of predatory aggression in general, and its effects are not restricted to either a particular predator or a particular prey.

d-Amphetamine inhibited both prey killing and prey eating. However, prey eating was blocked at lower doses than those which inhibited prey killing, suggesting that, even if the anorexic actions of d-amphetamine account for its inhibitory effects on prey killing, they do not account for the entire phenomenon. This is not surprising, because other studies have suggested at least some independence of feeding and predatory killing (Gay et al., 1975; Paul & Posner, 1973). Other drugs which inhibit mouse killing [e.g., monoamine oxidase inhibitors (Leaf et al., 1969)] are not potent anorexic agents (Goodman & Gilman, 1970) nor do all drugs which facilitate killing [e.g., pilocarpine, chlordiazepoxide (Leaf, Wnek, Gay, Corcia, & Lamon, 1975; Vogel & Leaf, 1972)] increase feeding behavior. For example, pilocarpine decreases feeding (Gay et al., 1975), while chlordiazepoxide increases it (Randall, Schallek, Heise, Keith, & Bagdon, 1960). Thus, a constant relationship between pharmacological inhibition of prey killing and anorexia is not found. Moreover, available evidence suggests that tolerance to amphetamine anorexia may develop more quickly than tolerance to the inhibition of mouse killing (Barr, Gibbons, Garelick, & Bridger, Note 1), perhaps because the two behaviors are controlled by two separate physiological systems. Taken together, these pieces of evidence suggest that the primary mode of action by which d-amphetamine inhibits prey killing is not anorexia.

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