The effects of d- and l-amphetamine upon hoarding behavior and feeding in the Mongolian gerbil (*Meriones unguiculatus*)*

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D-amphetamine was found to be more potent than l-amphetamine in suppressing both food hoarding and feeding behavior in the gerbil. The implications of these findings for a physiological explanation of rodent food hoarding are discussed.

A number of findings suggest that the physiological control of rodent food hoarding may be very similar to that of feeding. For example, rats both eat and hoard more when food deprived (Wolfe, 1939; Morgan, Stellar, & Johnson, 1943), when placed at a low temperature (McCleary & Morgan, 1946), when given a preferred food (Bindra, 1948), when frustrated (Hunt, 1941; McCord, 1941), and when electrically stimulated in the lateral hypothalamus (Herberg & Blundell, 1967). Furthermore, rats neither eat nor hoard very much in a strange situation (Miller & Viek, 1944). Finally, estrogen in the female rat (Herberg, Pye, & Blundell, 1972; Pye & Herberg, 1972) and androgen in the male gerbil (Nyby, 1974) suppress both hoarding and weight gain.

However, while amphetamine clearly suppresses feeding behavior in the rat (Cole, 1968; 1973) conflicting data exist for its effect upon food hoarding. Zucker and Milner (1964) found that amphetamine increased hoarding at the two lower dosages (1 & 2.5 mg/kg) while only the highest dosage (5 mg/kg) suppressed hoarding. It was speculated that amphetamine exerted a nonspecific disruption of hoarding at the highest dosage by causing stereotyped repetitive motor movements. The effects of amphetamine upon feeding were not measured in this experiment.

In a more recent study, Blundell (1971), using exactly the same dosages of amphetamine as Zucker and Milner, found that all three dosages suppressed both feeding and hoarding in a dose-dependent fashion. Furthermore, Blundell found that two additional anorexic agents, fenfluramine and chlorphentermine, which do not affect motor activity, also showed similar dose-dependent depressions of both feeding and hoarding. Blundell's results strongly suggest that anorexic agents affect feeding and hoarding in a similar fashion.

One possible explanation for the discrepant hoarding results is that Zucker and Milner used racemic

amphetamine sulfate (a combination of d- and l-isomers) while Blundell used dextroamphetamine sulfate (only the d-isomer). It is known that the d-isomer is a more potent anorexic agent than the l-isomer in rats (Hajos & Garattini, 1973). Thus, it is possible that the effectiveness of the two isomers in suppressing hoarding parallels their effects upon feeding.

The predominant use of the domesticated rat to study hoarding behavior has been criticized because rats are not prolific hoarders in the wild (Beach, 1950) and because domestication tends to genetically disrupt species-specific behaviors such as hoarding (Lockard, 1968). For these reasons, we chose to use a less domesticated laboratory animal, the Mongolian gerbil. The gerbil is a prolific hoarder in its natural environment (Bannikov, 1954; Kasuga, 1966) and has also been observed to hoard in seminatural and laboratory situations (Nyby, Wallace, Owen, & Thiessen, 1973). In the present experiment, the effects of d- and l-amphetamine isomers upon both feeding and hoarding by Mongolian gerbils were assessed.

METHOD

Animals and Apparatus

Fifteen adult female gerbils (*Meriones unguiculatus*) approximately 400 days of age, that had been bilaterally ovariectomized 2 months earlier, were used. These animals were purchased at 150 days of age from Tumblebrook Farms in West Brookfield, Massachusetts. While ovariectomy might increase hoarding during ad lib food availability, this manipulation probably has no effect upon the deprivation-induced hoarding utilized in this experiment (Herberg et al, 1972; Pye & Herberg, 1972).

All animals were housed individually in white plastic home cages 30 x 35 x 17 cm. A stainless steel shelter 25 x 13 x 10 cm for nesting was placed inside each home cage. Nesting material and ad lib water were always present. Each home cage had a hole in one side, 5 cm in diam, which was normally kept closed. During the hoarding trials, a food bin 17 x 28 x 13 cm could be connected to the home cage by placing a Plexiglas tube, 35 cm long and 5 cm in diam, into the hole of the home cage.

Procedure

The food bin contained 20 Purina Lab Chow food pellets

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weighing approximately 2 g each. Hoarding behavior was quantified by counting the number of pellets carried to the home cage from the food bin during a 30-min test period. Possible scores ranged from 0 to 20 food pellets hoarded per trial.

All females were given 3 weeks to adapt to housing conditions. The animals were then deprived of food for 22 ½ h/day for 10 consecutive days. On Days 8-10, daily hoarding trials were given in the light part of a 12-h/12-h light-dark cycle. For these 3 days, animals were allowed to eat only during the hour immediately preceding the trial plus the 30 min of the hoarding trial. Upon completion of the hoarding trial, the tube leading to the food bin was disconnected and all food was removed from the animals' home cages. On the basis of hoarding scores on Days 9 and 10, the animals were placed into three matched treatment groups of five animals each.

The next day after matching the three groups, both food consumption and hoarding were measured after subcutaneously injecting each group with either 12 mg/kg l-amphetamine sulfate, 12 mg/kg d-amphetamine sulfate, or the saline vehicle used to dissolve the two isomers. (The two stereoisomers were kindly provided by Smith, Kline, and French Laboratories.) Pilot work had suggested that gerbils require more amphetamine than rats to achieve similar effects and also that subcutaneous injections were less disturbing to gerbils than intraperitoneal injections. The animals were deprived of food on the day of these feeding and hoarding trials.

Thirty minutes after injection, a preweighed food pellet of approximately 6 g was placed in each animal's home cage. The pellet was removed after 30 min, reweighed, and food consumption determined. Immediately after removing the food pellet, each animal was given a 30-min hoarding trial.

The animals were tested two more times for the effects of amphetamine upon feeding and hoarding, but each group received a different drug treatment each time. Thus, all animals received all three drug treatments although the order of treatment was different for each group. Three days of ad lib feeding followed by several days of deprivation intervened between the three testing periods. Animals were tested for hoarding during these deprivation periods to ensure that hoarding levels were roughly comparable across trials.

After completing the three tests, all animals were allowed 3 weeks of ad lib feeding. The animals were then again deprived of food for 10 days and rematched into three groups as before. The remaining procedure was identical to that already described, with the exception that animals received a lower dose of amphetamine isomers (5 mg/kg).

The hoarding and feeding data were computer analyzed using a matched groups analysis of variance (ANOVAR) designed by Veldman (1967). Selected contrasts were performed using orthogonal comparisons.

RESULTS

The effects of different dosages of d- and l-amphetamine upon both feeding and hoarding are shown in Fig. 1.

The high dose of amphetamine clearly affected hoarding behavior [$F(2,28) = 17.2$, $p = .0001$]. Orthogonal comparisons indicated that both isomers suppressed hoarding below control levels [$F(1,28) = 25.27$, $p < .001$] while the d-isomer was more effective than the l-isomer [$F(1,28) = 9.13$, $p < .01$]. Hoarded food was almost invariably transported inside the shelter of the home cage.

The effects of the high dose of amphetamine upon

Fig. 1. The effects of two doses of d- and l-amphetamine (5 mg/kg and 12 mg/kg) upon the mean number of pellets hoarded and mean food consumption, in grams, during 30-min tests.

feeding behavior were similar to the effects upon hoarding behavior. The drug-treatment effect was again highly significant [$F(2,28) = 185.931$, $p < .0001$]. Orthogonal comparisons indicated that much of the treatment difference was due to the anorexic properties of both of the amphetamine isomers. However, at this dosage, there did not appear to be a difference in the anorexic properties of the d- and l-isomers [$F(1,28) = 0.1$, n.s.]. This lack of difference between isomers was probably due to a ceiling (or basement) effect, since feeding was almost totally eliminated by both isomers.

The drug treatment also significantly affected hoarding at the lower dosages [$F(2,28) = 7.3$, $p = .0031$]. Again, orthogonal comparisons indicated that both isomers suppressed hoarding below control levels [$F(1,28) = 7.00$, $p < .05$] while d-amphetamine suppressed hoarding to a significantly greater degree than l-amphetamine [$F(1,28) = 7.65$, $p < .01$].

Feeding behavior was also significantly depressed by the lower-dosage treatment [$F(2,28) = 26.812$, $p < .0001$]. Orthogonal comparisons indicated that both amphetamine treatments resulted in significantly less food consumption than the control treatment [$F(1,28) = 41.82$, $p < .001$] while d-amphetamine suppressed feeding more than l-amphetamine [$F(1,28) = 11.06$, $p < .01$]. Thus, d-amphetamine was more effective than l-amphetamine in suppressing both hoarding and feeding.

DISCUSSION

The present experiment clearly demonstrates that, at the dosages administered, both d- and l-amphetamine

suppress both feeding and hoarding behavior in the gerbil. The d-isomer, however, appears to be more potent than its racemate in suppressing both behaviors, particularly at the lower dosage. Subjectively, the l-isomer appeared to have less of a transient soporific effect than the d-isomer. In all cases, this soporific effect had disappeared by the time of behavioral testing.

The underlying mechanisms by which amphetamine affects feeding and hoarding are not altogether clear. However, the bulk of the evidence supports a central effect of this drug upon feeding and there is some evidence that the lateral hypothalamus (LH) and/or the ventromedial hypothalamus is the site of action (Cole, 1968; 1973). Blundell (1971) suggests that the LH is the center which responds to amphetamine for both feeding and hoarding.

There is also evidence that amphetamine depresses feeding by affecting catecholamine-dependent mechanisms (Randrup & Munkvard, 1966; Carr & Moore, 1969). However, hypothalamic injections of norepinephrine that increased feeding had no effect upon hoarding (Blundell & Herberg, 1970). Nevertheless, the present study does suggest catecholamine mediation of both behaviors. The d-isomer has been reported to be much more potent in inhibiting the reuptake of norepinephrine *in vitro* than the l-isomer, while both isomers are approximately equipotent in inhibiting the reuptake of dopamine (Taylor & Snyder, 1971). If the inhibition of reuptake is the main mechanism by which amphetamines produce their behavioral effects, as is often suggested (Snyder, 1972), then our results suggest a role for noradrenergic neurons in the amphetamine-induced suppression of both feeding and hoarding. This speculation is consistent with the hypothesis that hoarding and feeding may share some of the same underlying neural control mechanisms.

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