Odor cues in a maze discrimination

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Rats were found capable of making the choice in a T-maze using the odor from only one 45-mg Noyes food pellet as a discriminative stimulus. This finding points to the need for controlling odor stimuli in the traditional food-reinforcement situation, and especially in studies concerned with the magnitude of reward.

Early naturalists considered the olfactory system to be a highly sensitive sensory system, and therefore, important in the daily life of subprimate mammals. Support for this position was obtained from naturalistic observations and later from comparative studies of forebrain anatomy. However, when these inferences were subjected to behavioral studies conducted in a controlled laboratory environment, a different picture emerged. Behavioral research failed to confirm the importance of odor stimuli in directing the behavior of rats (Watson, 1907; Liggett, 1928) except when other sensory modalities were compromised (Honzik, 1936). These empirical findings led to the conclusion that olfaction plays only a small part in maze learning by rats, and largely as a result of such findings, odor stimuli have been and continue to be ignored in the majority of behavioral studies.

A radical shift in these conclusions has become apparent recently as evidence has accumulated that the sense of smell may be playing a much more important role in behavioral measures than previously thought. Recently, Miller & Erickson (1966) demonstrated that rats can successfully make a discrimination between salt solutions using only olfactory cues. Additional support has come from studies suggesting that animals may even be able to respond to odor trails laid down by preceding animals (Ludvigson & Sytsma, 1967). These findings clearly demonstrate that olfactory sensitivity far surpasses the findings of the early research.

In our own laboratory, several attempts to measure olfactory thresholds in a T-maze led to the conclusion that the rats were responding to some stimulus other than the odor being used as the independent variable. The present study reports a systematic exploration of these uncontrolled stimuli.

PROCEDURE

The apparatus consisted of a black opaque Plexiglas T-maze which was made reasonably air-tight by a clear hinged Plexiglas top. An exhaust fan attached to the start box pulled the background air through a silica gel and activated charcoal filter. This air was then pulled simultaneously into each arm at equal rates, through the maze, and was exhausted outside the room.

Odorized air serving as the discriminative stimulus was produced by passing compressed air through filters, and then bubbling it through a bottle containing the odor substance diluted with di-ethyl phthalate. The apparatus for odor presentation was similar to the one described by Long & Tapp (1968). Odorized air was injected at the rate of 50 ml/min into the much larger volume of background air which flowed at an average velocity of 47 ft/min. Mixing of air from these two sources occurred in a plenum located just outside of each arm of the T-maze. An odor gradient was thus established at the junction of the stem and the arms of the T-maze.

Initially, 24 naive male Sprague-Dawley rats, 140 days old, were trained by massed trials, randomized according to Fellows' series, to discriminate the correct goal box by utilizing an odor gradient established in the T-maze. The reinforcement, consisting of four 45-mg Noyes food pellets, was presented in retractable food cups. For each trial, the appropriate food cup was baited, inserted, and the odor stimulus was introduced on the corresponding side. Each rat was placed in the start box for 12 sec. After making a choice, the animals were confined to the goal box for 15 sec before being returned to a closed transfer cage. Auditory cues resulting from preparations for the next trial were masked by white noise delivered through a speaker placed above the transfer cages.

RESULTS AND DISCUSSION

During the first phase of training, the odor from a 20% solution of amyl acetate was used as the discriminative stimulus for one-half of the animals, and the odor of a 20% solution of butyric acid was used for the other half. All but 3 of the 24 rats reached a criterion of 10 consecutive correct responses within 100 trials, these 3 animals making seven correct responses in 10 trials. To provide the time necessary to control for extraneous odors, only two animals, randomly selected from each group, were used in the remaining procedures.

On subsequent days, when animals were given 12 trials per day with a 20% concentration of amyl acetate serving as the discriminative stimulus, they continued to perform at a consistent, near-perfect level. Reversal of the odors for the two groups on the fourth training day did not reduce the animals' performance. Thereafter, only the odor of amyl acetate was used as the discriminative stimulus. After 6 days, a stepwise decrease in odorant concentration was instituted, with no significant loss in discrimination occurring for concentrations as low as 0.06%. A control day where only the solvent-bubbled air and food reward were presented resulted in performance at the chance level. Upon replication, however, there was no deviation to a chance level of performance for any of the animals. Clearly, the animals were using other cues, possibly odor from the food reward, the solvent, or both, to make the discrimination.

Several manipulations of the food odor and solvent-bubbled air were made to determine whether the animals were responding to one or both of these stimuli. When the presentations of food and solvent-bubbled air were randomly presented three of the animals made the discrimination significantly above chance, suggesting that the food was serving as the discriminative stimulus (Fig. 1A). Since the solvent did not appear to be contributing an

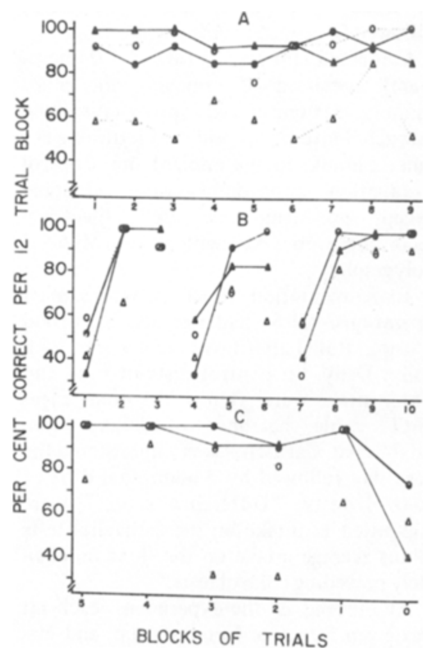

Fig. 1. Per cent correct choice of each of four rats for blocks of 12 trials. (A) Solvent-bubbled air was presented on both sides while four-pellet rewards were randomly presented. (B) Comparison of results over 12-trial blocks where odor cues from the food reward were absent (Blocks 1, 4, and 7) with trials where food odor cues were present. (C) Depicts reduction in number of food pellets from 6 to 0 over blocks of trials.

odor which could be reliably used as the discriminative stimulus by these animals, the solvent was eliminated and only the food-odor stimulus was evaluated.

The intensity of the food-odor stimulus was increased by increasing the pellet reward from four to six to determine if more stable performance might be obtained from the fourth animal. This increase resulted in significant discrimination by all animals. Also, the six-pellet reward resulted in a clearer differentiation between performances, with and without the food odor cues, than did the four-pellet reward. As can be seen from Fig. 1B, a dramatic shift in performance occurs when the odor stimuli are controlled by baiting both cups but only pushing in the appropriate one after the animal has made the correct choice (pellets absent) as compared with blocks of trials where only the correct cup was baited and inserted (odor stimulus present). This effect was easily replicated with the additional finding that the rat with the poor performance on early trials was now able to consistently perform at a significant level. Finally, when the reward size was reduced by one pellet for each succeeding 12-trial block (Fig. 1C), three animals continued their good performances with only a single-pellet reward. A fourth animal was unable to discriminate with fewer than four pellets.

This study demonstrates, contrary to most earlier findings, that rats can learn to make the correct discrimination in a T-maze to odor cues. Once the animals learn this discrimination it easily generalizes to other olfactory stimuli. Further, it is apparent from this study that the rat is capable of performing a discrimination task successfully with the odor from only a very small quantity (45 mg) of dried food contained in a single Noyes pellet.

Studies concerned with the manipulation of the amount of reward should be seriously concerned with the control of odor stimuli. In many of these experiments, manipulations in reward magnitude result in concomitant manipulations in the intensity of food odor which may then serve as a discriminative stimulus. The fact that rats can perform at a significant level with only the odor of one dry 45-mg food pellet diluted with a large volume of background air serving as a discriminative stimulus clearly shows that odor controls are necessary. With this degree of sensitivity it is not enough to assume that the presence of extraneous food particles and the lack of an established odor gradient are sufficient to minimize the effects of odor stimuli serving as discriminative stimuli.

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Social dominance in gerbils and hamsters

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Dominance orders in four groups of gerbils (Meriones unguiculates) *and four groups of hamsters* (Mesocricetus auratus) *were measured in two conventional tests. Both species evidenced reliable rank orders in a majority of group-test combinations. Water competition rankings were associated with obvious aggression and were positively correlated with body weight. In the gerbils, tunnel competition rankings were not accompanied by overt aggression and were negatively correlated with body weight and uncorrelated with water dominance orders. In the hamsters, tunnel dominance orders were mediated by overt aggression and were positively correlated with both body weight and water dominance orders.*

Social dominance is typically defined in terms of stable orders of precedence within animal groups (e.g., Allee, 1951). Because precedence orders are reflected in diverse behaviors such as food-getting and copulation, different tests of dominance may not be measures of the same general trait. For example, Lindzey et al (1966) found a negative correlation between tunnel dominance and food competition in *Mus*. Similarly, one species may show reliable hierarchies in a measure which does not produce stable rankings in another species (Candland & Bloomquist, 1965). The present study compared dominance in possession of a water spout and in removing a competitor from a tunnel in two genera of the family *Cricetidae*. One rodent, the gerbil, is unusually nonaggressive in comparison to the second, the hamster.

The selection of dominance tests was influenced by specific characteristics of the rodents. Spontaneous aggression (Baenninger, 1966) was excluded because gerbil groups established for more than 3 days showed overt aggression only when thirsty or hungry and in pursuit of water or food. Water competition was substituted for the more conventional test of food competition (Becker & Flaherty, 1968) since hamsters are less likely to persist in competition to fill their food pouches than to drink water. Gerbils do consume drinking water with apparent avidity (Boice & Arledge, 1968).

SUBJECTS

Sixteen male gerbils *(Meriones unguiculates)* were obtained from Tumblebrook Farms and 16 male golden hamsters *(Mesocricetus auratus)* were obtained from E. G. Steinhilber & Co. All were maintained in plastic cages (33 x 45 x 30 cm) with wire tops and substrates consisting of two parts dried wood chips and one dried clay. Water was presented, when appropriate, from inverted cylinders with metal drinking spouts. Maintenance food was Wayne Breeder Blox.

PROCEDURE

Original assignment to intraspecific experimental groups of four was made on the basis of age. Groups 1, 2, and 3 for each species consisted of males of 71, 98, 126, and 200 days of age at the start of testing. Group 4 consisted of four immature males of 36 days of age. The occurrence of respiratory ailments in the youngest hamsters following shipment arrival forced the substitution of a heterogeneous age group for the young-hamster group.

Testing began with 7 days of tunnel pretraining in which the gerbils learned to run from one endbox of a tunnel (45 x 3-6 cm, according to girth of the Ss) to the opposite end to obtain 5-min access to unshelled sunflower seeds. Two such pretraining trials were run daily with goal sites and start sites switched randomly between ends. Water but not food was available in home cages on days of tunnel experimentation.