Information processing of olfactory stimuli by the dog: I. The acquisition and retention of four odor-pair discriminations*

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Three dogs were tested in a two-choice olfactory discrimination situation. There was a progressive decrease in the number of trials to learn four successive odor discriminations. Extinction and reacquisition measures of retention were highly correlated and indicated that retention was still maintained after 69 days.

The literature is rich in anecdotal stories about the marvelous olfactory capability of the dog (e.g., Droscher, 1971). The apparently successful use of the dog in a variety of olfactory tasks that would be most difficult, if not impossible, for man (such as mine detection, tracking of prisoners, detection of marijuana, etc.) attests to the validity of this claim. Yet, with few exceptions (e.g., King, Becker, & Markee, 1964), there have been no controlled laboratory studies with the dog using odorous stimuli; and, with the exception of the work of Lubow and his associates (Behavior Systems, 1970; Carr-Harris & Thal, 1969; Carr-Harris & Siebert, 1969), who developed the procedures for the mine, booby-trap, and tunnel detecting dogs used in Viet-Nam and Israel, even the training procedures have remained obscure.

The purpose of the present series of studies is twofold: The first purpose is to study the dog as an information processing system in discrimination studies, using olfactory stimuli in order to fill a gap in the comparative psychology literature, and to ascertain whether there are any special characteristics of the dog in the discrimination process as a result of the supposedly exquisitely developed sensory acuity. The second purpose is to provide some useful hard data to those who employ dogs as components in biosensor systems.

METHOD

Subjects

Three Ss were drawn from the Bar-Ilan University compound. They were mongrel dogs about ½ to 2 years of age at the beginning of training, weighing between 7 and 12 kg: a male poodle-type (A), a male German shepherd-type (B), and a female pointer-type (D). All Ss were given the normal prophylactic veterinary care and put on a diet of Gaines meal.

Apparatus

The apparatus for discrimination training consisted of two discrimination stations about 90 cm center to center. Each station was an open-front wooden box, 22 x 22 x 46 cm, lined with Formica. A Lehigh Valley omnidirectional manipulandum was vertically suspended from the top of the box, so that its lowest point was 12 cm from the box floor.

The stimuli were placed in open 250-ml beakers beneath the manipulanda. Reinforcement, 190-mg Noyes dog-food pellets, was delivered from a Lehigh Valley pellet dispenser, placed between the two discrimination stations. A 4000-Hz Sonalert tone source, which served as an end of trial signal, was located above the food dispenser.

A startcage, constructed of wire mesh but having an opaque guillotine-type door, was located 3 m in front of the feeder. The perimeter, from startcage to discrimination stations, was surrounded by wooden partitions 0.6 m high. Reinforcement contingencies and other programming were controlled by Massey Dickenson logic modules.

Four pairs of odorous stimuli were employed. Training pairs, in their order of presentation, are shown in Table 1. All were laboratory grade and were chosen on the basis of having distinctive odor qualities to E. Only the acetic acid was diluted. For Dog A the positive stimuli (S^D) were acetone, ethanol, propylene glycol, and heptane; for Dog B, acetone, butanol, propanol, and 1-octanol; for Dog D, acetone, butanol, propylene glycol, and heptane. The other member of each stimulus pair served as the negative stimulus (S^Δ).

Procedure

Preliminary Training

During Days 1-9, each S was allowed ½ h to explore the experimental area. On Days 10-15, each S was fed in the experimental area. While feeding on the Gaines meal, the feeder was remotely operated but without dispensing pellets. Following this stage, S was allowed to eat pellets from the foodcup. The

Table 1
Odor Pairs Used in Training and Their Reinforcement Status for Each Dog

Pair	Stimulus	Reinforcement Status for Each Dog		
		A	B	D
W	Acetone	+	+	+
	Acetic Acid	–	–	–
X	Butanol	–	+	+
	Ethanol	+	–	–
Y	2-Propanol	–	+	–
	Propylene-glycol	+	–	+
Z	Heptane	+	–	+
	1-Octanol	–	+	–

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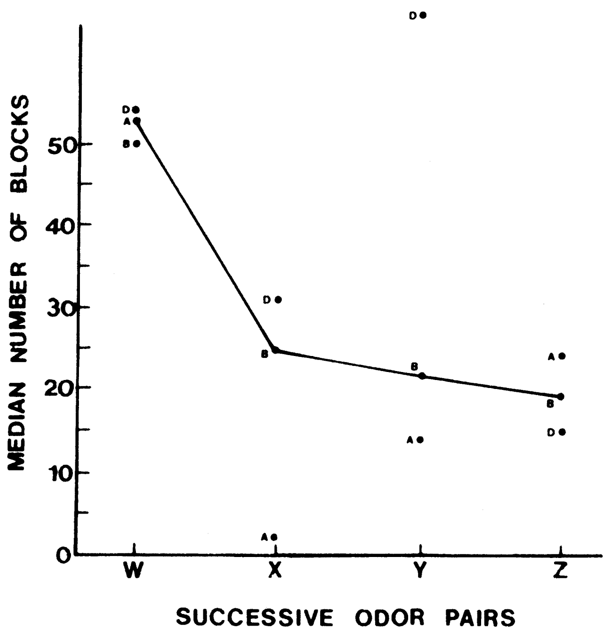

Fig. 1.

pellets were then delivered from the magazine. When a rapid reliable approach response to the dropping of the pellet was achieved, response shaping was started. This was accomplished using a single lever with the usual methods of approximation. After a stable response rate was achieved, a contingency training procedure was employed, such that no reinforcement could be delivered during the presence of the tone. After several days of training to S^D and S^Δ, with durations being 20 sec and 4 sec, respectively, and with contiguous presentations of 20 complete cycles per session, the tone was extended for 8 sec from the last response made during S^Δ. Thus, a minimum of 8 sec of tone without any response always preceded S's return to the startcage. Gradually the S^D/S^Δ time ratio was reduced to 5 sec/5 sec, and the number of trials per block increased to 50. Typically, two blocks per day were run. This phase lasted about 10 days, depending on S's performance. At the end of this stage, there was excellent inhibitory control of responding by S^Δ.

Odor Discrimination Training

Preliminary odor discrimination training began with acetone as S^D and acetic acid as S^Δ for all dogs. During this and all subsequent stages, the basic units of analysis were blocks of 10 trials. The order of presentation was such that equal numbers of S^D and S^Δ were presented to the right and to the left in each block and such that S^D and S^Δ did not appear on the same side on more than two consecutive trials.

Each trial began with release of the dog from the startcage. Latency was measured from the opening of the start door to the first response. Reinforcement was available for each correct response during a 12-sec period starting from the first correct response. At the end of this period, the trial terminated. An incorrect response immediately terminated the trial. Any trial in which a response was not given within 10 sec was counted as an error and terminated manually.[1] The end of the trial was indicated by a 4000-cps tone which continued until S reentered the startcage.

Five blocks per day were run. This was continued for each stimulus odor pair until a criterion of 9 out of 10 correct responses was reached on two consecutive blocks.

RESULTS AND DISCUSSION

The progressive decrease in number of blocks to reach criterion on successive odor discrimination pairs is shown in Fig. 1. It should be noted that, although the median block to criterion exhibits an orderly decrease and there is little variance for the first and last odor pairs, there is considerable variance between Ss for the second and third pairs, with Dog A showing complete positive transfer from Pair W to Pair X and Dog D showing virtually complete negative transfer from Pair X to Pair Y. Because of the small number of Ss, the inability to use a completely counterbalanced design, and the absence of knowledge concerning the specification of the stimulus dimension that is controlling behavior, it is difficult to evaluate these transfer effects with confidence. However, it would appear that ethanol and acetone, both S^D for Dog A, have a common stimulus property to which A is responding. Likewise for Dog D, where butanol was S^D for Pair Y and 2-propanol S^Δ for Pair W, there may be a common stimulus property that accounts for the negative transfer. These hypotheses assume that the dogs' responding is under the control of S^D and not S^Δ.

The second stage of this program was concerned with determining the ability of the same dogs to retain the four odor discriminations over fairly long periods of time. A fixed temporal interval between last acquisition to a pair and testing for retention was not employed, since Ss reached acquisition criteria at different times. In addition, as a result of a complete absence of information about the retention function, it was desirable to sample a number of values on the temporal continuum.

METHOD

Subjects and Apparatus

The Ss and apparatus were exactly the same as in the acquisition stage.

Procedure

The procedure for testing retention consisted of two parts. Part 1 was run under conditions of extinction. One block of 10 trials for Odor Pair W was given. Scoring was in terms of whether S responded to S^D, S^Δ, or made no response. The latency of the responses to S^D and S^Δ was also recorded. Immediately following the testing under extinction, a reacquisition procedure identical to the one employed in original acquisition was instituted. This continued, five blocks per day, until S reached the criterion of 9 out of 10 correct responses on two consecutive blocks. The order of testing under extinction and then reacquisition was the same for all Ss–Odor Pairs W, X, Y, and Z.

The two indices of retention were calculated as follows: extinction score equals correct responses divided by total responses; savings score equals the number of blocks to reach criterion on original acquisition minus the number of blocks to reach criterion on the relearning divided by the number of blocks to reach the criterion on the original acquisition minus two.

RESULTS AND DISCUSSION

The extinction score and savings score retention data, together with the temporal interval between last exposure to an odor pair and the retention tests, are presented in Table 2.

Table 2
Measures of Retention for Each Dog as a Function of Time Since Last Exposure to the Odor Pair

Dog	Stimulus Pair	Days Since Last Exposure	Extinction	Savings Score (Percent)
A	W	31	100	100
	X	30	100	–[2]
	Y	26	100	100
	Z	7	–[3]	35
B	W	46	100	100
	X	38	80	100
	Y	24	80	45
	Z	14	75	77
D	W	69	77	100
	X	53	63	95
	Y	20	60	–
	Z	25	60	17

It should be noted that the extinction scores are based on relatively small numbers because the maximum correct was 10, and on a number of trials S did not respond. As a result, these scores would appear to be relatively unstable. In spite of this, the two retention scores are significantly correlated. Using each complete pair of scores from the two indices of retention as a single observation, the two indices were found to have a correlation of .68 (Kendal rho), $p < .01$. In general, it can be seen that, although there are considerable individual differences between dogs, retention was fairly good, with Dog A exhibiting almost perfect retention for all pairs, while retention for B and D was present but less than perfect. In addition, it would appear that the earlier learning was retained better than the later learning. Of course, from the design one cannot determine whether this is some function of the particular odor pairs used, since the same order of presentation was employed for all Ss, or simply because there was more exposure to the earlier pairs as a result of their requiring more trials to reach criterion.

Also of interest is the fact that the Ss developed a stable search pattern. Almost invariably, Ss first inspected the left stimulus, and then, if they did not respond to the left, switched to the right side. This pattern was observed on most trials and is reflected in the latency data. On the criteria blocks for acquisition and reacquisition, the group mean of the median latency for each dog for correct responses to the left was 2.40 sec and for correct responses to the right, 3.89 sec. Using as paired scores the median response to the right and the median response to the left for each of the dogs and odor pairs yields a significant left-right difference ($T = 2$, $p < .005$, $df = 24$, Wilcoxon matched-pair signed-rank test). Whether this left-then-right search pattern is a function of some cerebral dominance factor or an artifact of the training procedure remains to be determined.

In summary then, it was found that dogs exhibited a progressive decrease in the number of trials to learn four successive odor discriminations. Although a complete learning set phenomenon was not achieved, i.e., learning after a single information trial, it is assumed that such a level could be approached with the addition of a considerable number of odor discrimination problems. In addition, it was found that dogs exhibited excellent long-term retention of these discriminations, with some evidence that early learning was retained better than later learning.

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NOTES

1. Of the total 4,528 possible responses during the acquisition phase, only 68 were terminated manually: .026 of Dog A's responses, .020 of Dog B's, and .007 of Dog D's. Likewise, during the reacquisition phase, with a total of 681 trials, 16 were terminated manually: .059, .043, and .000 of the responses for Dogs A, B, and D, respectively.

2. Not calculable, since A reached the original learning criterion in the minimum number of blocks (two). On the relearning test, he reached criterion in three blocks.

3. Not calculable because of E's error. 2-octanol was accidentally used instead of 1-octanol.

4. Not calculable because D did not reach criterion in original learning. In the relearning he also did not reach criterion after 73 blocks.

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