# Motivational specificity of the signal value of odor cues

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The performance of the laboratory rat in the enclosed maze apparatus is profoundly influenced by subject-generated cues that seem to be olfactory. The present experiment investigated the specificity of these cues. Odor cues produced by odor-donor rats placed in the startbox were ineffective determinants of the behavior of runway-trained rats when the deprivation states of these two groups differed. However, when the deprivation states of these two groups coincided, the odor cues produced by the odor-donor rats became effective determinants of performance. Thus, it would appear that even though odor cues are influential in determining the runway performance of the rat subject, their effectiveness may well be drive-state dependent.

Recently, a large body of data has been accumulated (e.g., Bloom & Phillips, 1973; Ludvigson, 1969; Ludvigson & Sytsma, 1967; Mellgren, Fouts, & Martin, 1973; Pitt, Davis, & Brown, 1973; Prytula & Colbert, 1975; Prytula & Davis, 1974; Prytula, Lawler, & Davis, 1975; Seago, Ludvigson, & Remley, 1970, etc.) indicating that the rat exudes an odor on frustrative or nonreward trials which (a) can be utilized by subsequent subjects as a discriminative cue, or (b) can produce an avoidance response. Having established the existence and potential use of such odor cues, several intriguing questions concerning their limits have also surfaced.

For example, a recent three-phase study by Davis, Prytula, Harper, Tucker, Lewis, & Flood (1974) investigated the motivational specificity of odor cues. Both runway-trained (Run) and startbox-placed odor-donor subjects were employed. During the first two phases, the deprivation states of the two groups differed (i.e., the runway-trained subjects were water deprived, while the odor-donor subjects were food deprived). During the first phase, the daily eight-trial double-alternation reward(R)-nonreward(N) schedules for the two groups were the same (i.e., both groups received their trials in an RRNNRRNN sequence). During Phase 2, the odor-donor schedule was shifted to become the converse of the run-

subject schedule (i.e., run = RRNNRRNN; odor-donor = NNRRNNRR). Significant double-alternation patterning (i.e., fast to reward, slow to nonreward) was shown by the run subjects *only in the goal measure* during Phases 1 and 2. These results suggested that the run subjects were affected only by odor cues generated *at the goal* by run-subjects and not by odor cues from donor rats. The frustration-generated cues from donor rats in the startbox apparently had no effect on the run subjects under different motivational conditions. In the third phase, the double-alternation schedules were once again identical for the two groups and the run subjects were shifted to food deprivation (i.e., the deprivation states of donor and run rats were now the same). Somewhat to our surprise, during Phase 3 the run subjects displayed significant double-alternation patterning in *all* measures, indicating that the donor-odor cues were used by the run subjects when both were under the same deprivational state.

To the extent that deprivation states were manipulated and a similar research design employed, the present study is a replication of Davis et al. (1974). However, unlike our previous experiment, the run subjects were food deprived and the odor-donor subjects water deprived in the first two phases of the experiment. During the final phase, all subjects were water deprived. If the utilization of odor cues is linked to the deprivation state, then one would expect appropriate double-alternation patterning to be shown by the run subjects only in the goal measure when these states differed (i.e., Phases 1

and 2). However, double-alternation patterning should be displayed in all measures during Phase 3 when the deprivation states of the two groups coincided. The present study differed from Davis et al. in one additional respect. During Phase 2 of the present study, the double-alternation schedules of the run and odor-donor subjects remained positively correlated but were reversed from the Phase 1 sequence (NNRRNNRR). It was felt that this modification would yield information concerning (1) the reaction of the run subjects to a shift in the startbox-produced odor-donor cues, and (2) the potency of the odor cues exuded by the run subjects themselves in controlling behavior.

## METHOD

### Subjects
Twenty male albino rats, purchased from the Holtzman Company, Madison, Wisconsin, and approximately 90 days old at the beginning of the experiment, served as subjects. Upon arrival, the subjects were assigned randomly to two equal groups: odor-donor and run. Seven days before the start of the experiment, the odor-donor subjects were placed on a 23-h water-deprivation schedule while the run subjects were placed on a food-deprivation schedule that maintained them at 85% free-feeding body weight. These deprivation schedules continued in effect during Phases 1 and 2. During Phase 3, *all* subjects were maintained on the water-deprivation schedule. Maintenance of the deprivation schedule took place following the daily experimental session.

### Apparatus
The apparatus was a single straight alley (11.43 cm wide, 12.70 cm high), divided into a gray startbox (38.10 cm), a black run section (91.44 cm), and a black goalbox (30.48 cm). A plastic receptacle mounted into the end wall of the goalbox served as the goal cup. During Phase 3, the goal cup was modified to allow the external attachment of a ½-pint water bottle. The sipper tube of the water bottle projected into the receptacle when the bottle was in place, thus allowing the subject easy access but preventing water from dripping onto the goalbox floor. During all three phases, a water bottle, attached externally to the side of the startbox with the sipper tube extending slightly into the startbox, was employed. Start, run, and goal latencies were recorded on all trials.

### Procedure
The experiment proper was preceded by a 5-day pretraining phase. At the beginning of pretraining, each subject was assigned a number (1 to 10) within its respective group. On Pretraining Days 1-3, all rats were handled and tamed. On the fourth and fifth days of pretraining, each run subject received a 5-min exploration period in the unbaited apparatus. The odor-donor subjects received additional handling and taming on these days. During all 5 pretraining days, the run subjects received pellet-habituation to the 500-mg Noyes reward pellets in the home cage.

During all three phases of the experiment, all subjects received 8 trials per day—4 reward (R) and 4 nonreward (N)—with all subjects completing Trial 1 before Trial 2 was begun, etc. During Phase 1 (96 trials) and Phase 3 (88 trials), both the run subjects and the odor-donor subjects received their 8 daily trials in an RRNNRRNN sequence. In Phase 2 (24 trials), both groups received their 8 daily trials in an NNRRNNRR sequence (i.e., sequence reversed). Hence, the schedules were the same for donor and run subjects during all three phases of the experiment,

but deprivation states were the same (both groups were water deprived) *only* in Phase 3.

Running a trial during Phases 1 and 2 involved placing the proper odor-donor subject (i.e., Odor-Donor 1 was used when Run Subject 1 was to be run, etc.) directly into the startbox. A full water bottle was in place on an R trial, and an empty bottle was in place on an N trial. After a 30-sec confinement period, the odor-donor subject was removed, and the appropriate run subject placed immediately into the startbox. Following a 10-sec confinement period, the run subject was allowed to traverse the runway. On R trials, the run subject received a 500-mg Noyes pellet. On N trials, the run subject was confined to the goalbox for 30 sec.

A 5-day interval separated Phases 2 and 3. At the end of Phase 2, the run subjects were shifted from food deprivation to water deprivation. As in Phases 1 and 2, the odor-donor subjects were confined to the startbox for 30 sec with a full water bottle on R trials and an empty bottle on N trials. The same procedures were employed with the run subjects in the goalbox during Phase 3. As in Phases 1 and 2, the run subjects were confined for 10 sec in the startbox prior to traversing the runway. The order for running subject pairs was randomized daily during all phases of the study.

It should be noted that the tops of the apparatus were covered by a thin sheet of transparent plastic to prevent odors from dissipating. To avoid providing differential water cues, the start-box was swabbed with a damp sponge following the running of each subject pair during all phases of the experiment. Also, the sipper-tube access hole in the startbox was plugged following an odor-donor trial to prevent odors from dissipating.

## RESULTS

The start, run, and goal latencies for each run subject for each trial were transformed to reciprocals and, when multiplied by the appropriate constant, yielded speed scores in meters per second. For purposes of statistical analysis and graphing, the speed scores for each run subject for each block of eight daily trials were combined in the following manner. The two adjacent trials of the same nature (e.g., the first two R trials, the first two N trials, etc.) were combined and averaged thus yielding composite $R_1$, $R_2$ $N_1$, and $N_2$ scores. Figure 1 presents the mean start, run, and goal speeds for the run subjects during Phases 1 and 2. The transformed scores for Phases 1-3 were subjected to a Subjects by Treatments (R vs. N) by Days analysis of variance. Tukey's procedure was used for all significant contrasts.

The Phase 1 analyses were performed on the data from Days 10 to 12 (the point in training at which patterning appeared to have been established in the goal measure and asymptotic behavior shown in the start and run measures). The results of these analyses indicated that the R vs. N factor was significant, $F(1,45) = 9.76$, $p < .01$, in the goal measure. No other significant effects were found. Thus, the statistical analyses were supportive of the graphical impression that this patterning developed during Phase 1, and that it was limited to the goal measure.

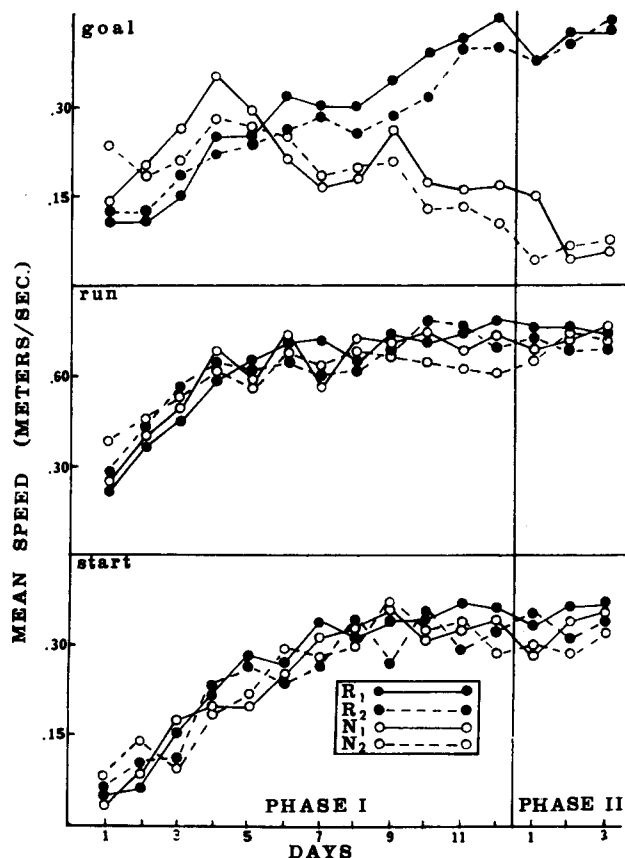Analyses of the Phase 2 data indicated that the

Figure 1. Mean speeds (meters per second) during Phases 1 and 2.

alternation schedules were reversed (i.e., Phase 2); and (c) the development of double-alternation patterning in the start and run measures during Phase 3 (see Figure 2). These findings indicate that (a) odors produced by the donor subjects in the startbox were not used by the run subjects during the first two phases; (b) odors exuded by previous run subjects were the only effective determinants of performance in Phase 2; and (c) donor-subject odors were used in Phase 3 when the deprivation regimens were the same across groups.

Even though these results seem clear, and are compatible with our earlier data (Davis et al., 1974), some problems do arise in interpreting them. For instance, it could be argued that donor odors were not used as predictive cues by the run subjects when the deprivation states differed (Phases 1 and 2), but were used in this manner during Phase 3 when both groups were water deprived. Consistent with this interpretation, Figure 2 shows that patterning developed over trials during Phase 3. Since the donor odors must be present in the startbox in *all* phases of the experiment, the predictive-cue argument is that odors serve as cues under one deprivation condition but not under another. Along these lines, differential conditioning studies (e.g., Davis, Gilbert, & Seaver, 1971; Ludvigson & Gay, 1967) which

R vs. N factor was significant, $F(1,45) = 11.23$, $p < .01$, and that this effect was limited to the goal measure. No other significant effects were produced by the Phase 2 analyses.

Mean start, run, and goal speeds (meters per second) for the run subjects during Phase 3 are shown in Figure 2. Analyses were performed on the speed data from Days 7-10 (the point at which double-alternation patterning appeared to have been established in all three measures). These analyses indicated that the R vs. N factor achieved significance in all three measures [start, $F(1,63) = 5.96$, $p < .05$; run, $F(1,63) = 8.80$, $p < .01$; and goal, $F(1,63) = 18.14$, $p < .01$]. Additionally, the R vs. N by Days interaction was found to be significant, $F(3,63) = 4.53$, $p < .05$, in the start measure. Further analyses of this interaction indicated that the R vs. N speeds did not differ significantly on Day 7, but were significantly different ($p < .05$) on Days 8 to 10.

## DISCUSSION

The striking features of the results are: (a) the development in Phases 1 and 2 of significant double-alternation patterning by the run subjects in the goal measure *only*; (b) the lack of behavioral change on the part of the run subjects when the double-
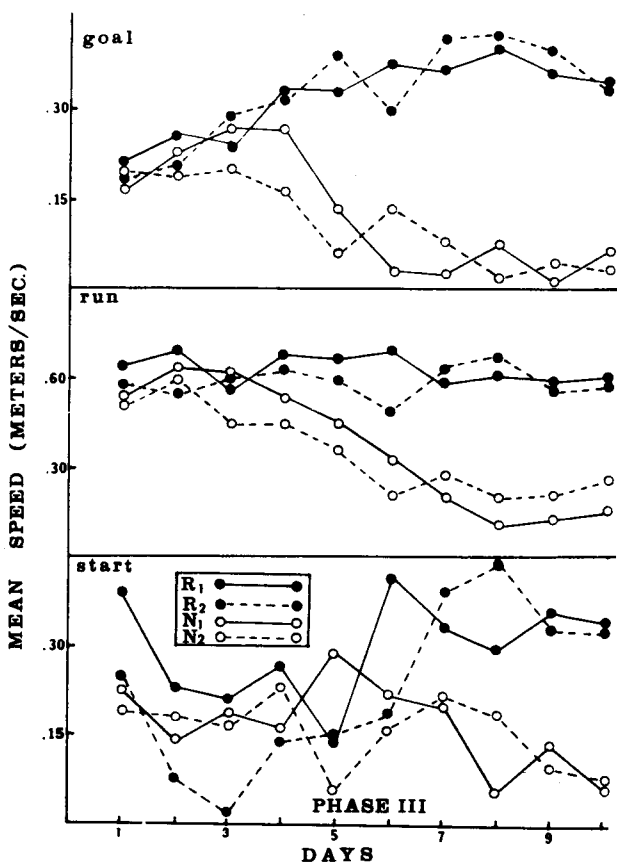


Figure 2. Mean speeds (meters per second) during Phase 3.

manipulated startbox stimuli have shown that these stimuli can serve as cues for differential responding even though not linked to deprivational states. Thus, a cue interpretation of the present data assigns rather specal properties to exuded odors as stimuli.

Alternatively, it might be suggested that the patterning shown in Phase 3 represents avoidance of N odors. This option offers some possible advantages over the discriminative cue interpretation. First, it permits us to reason that even though nonreward donor odors had been present throughout the experiment, they were not aversive until the deprivation states of both groups coincided (Phase 3). Accordingly, the odor of nonreward would be functioning as a pheremone (Reynierse, 1974). In view of the large body of literature on pheremones and the specificity of such stimuli that has been accumulated (e.g., Gleason & Reynierse, 1969), such an assumption would appear to be warranted. Second, the development of patterning over trials is also compatible with this interpretation. Similar results have been reported by Ludvigson, McNeese, and Collerain (1973). Neither of the above alternatives is ruled out on the basis of the present data. The procedure of giving all subjects the same R-N sequence from trial to trial does not allow one to choose between them.

### REFERENCE NOTE

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