Runway performance of normal, sham, and anosmic rats as a function of magnitude of reward and magnitude shift

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A two-phase experiment was designed to yield information concerning the effects of magnitude of reward and magnitude shifts on the runway performance of normal, sham-operated, and surgically anosmic rats. Three squads of normal, sham, and anosmic subjects were each divided into three subgroups that received small, multiple-pellet large and single-pellet large reward, respectively, during the first phase (51 trials). During Phase II (30 trials), all subjects received the small reward. Reward magnitude effects developed during Phase I but were shown only by the normal and sham subjects. Significant depression effects were shown during Phase II by all subjects shifted from large to small reward. However, the form of the performance decrements shown during Phase II differed considerably between the normal and sham subjects and the anosmic subjects.

Recent studies reported by Marrero, Davis, and Seago (1973) and Davis and Seago (1975) have been concerned with delineating the behavioral effects of rendering the rat subject anosmic. In both instances, the straight-runway apparatus was employed for testing purposes. The results of the Marrero et al. (1973) study in which reward magnitude (single-pellet large vs. single-pellet small) was manipulated indicated that magnitude effects were not shown by the anosmic subjects and further that the performance of the large-reward anosmic subjects was somewhat inferior (significantly so in the start measure) to that of the small-reward anosmic subjects.

On the other hand, the Davis and Seago (1975) experiment studied the effects of anosmia on behavior in the differential conditioning situation. The results of this study indicated that differential responding failed to develop, thus suggesting, as did the Marrero et al. (1973) study, that one effect of anosmia is to reduce incentive motivation. It is interesting to note that when the anosmic subjects were concurrently exposed to different reward magnitudes, as in the Davis and Seago (1975)

study, inferior performance to the large reward alternative (see Marrero et al., 1973) did not develop.

Thus, the present experiment was designed to yield additional, and hopefully more complete, information on the effects of reward magnitude and reward magnitude reduction upon the runway performance of surgically anosmic subjects. During the first phase of the experiment, a factorial design employing three levels of reward magnitude (small, single-pellet large, and multiple-pellet large) and three olfactory states (normal, sham-operated, and surgically anosmic) was used. During the second phase of the study, *all* subjects received additional trials with the small-reward magnitude. Thus, the second phase constituted an incentive reduction phase for those subjects initially trained on large reward and was included to yield information concerning the effects of a *successive*, as compared with the simultaneous procedure employed by Davis and Seago (1975), shift in reinforcement.

METHOD

Subjects

The subjects were 81 male albino rats purchased from the Sprague-Dawley Company, Madison, Wisconsin. Twenty-seven of the subjects were rendered surgically anosmic in the following manner. First, the subject was anesthetized with sodium pentobarbital. Then, utilizing a stereotaxic instrument, trephine openings were placed on each side of the sagittal suture above the olfactory bulbs. The olfactory bulbs and connecting tracts were removed from each subject with an aspirator. Twenty-seven additional animals (sham-operated subjects) received identical surgical treatment with the exception that their olfactory bulbs were not removed. A third set of 27 animals (normal subjects)

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Figure 1. Mean goal speeds (meters per second) for the normal subjects during Phases I and II.

were not subjected to surgical procedures. All subjects were approximately 120 days old at the beginning of the experiment. The subjects were housed in individual cages with water always available. Two weeks preceding the experiment, the subjects were placed on food deprivation and maintained at 85% ad-lib body weight during the experiment. All subjects were fed at the completion of each day's session.

Apparatus

The apparatus consisted of a single straight runway (11.43 cm wide, 12.70 cm high) made from 12.7-mm-thick pine lumber. The runway was divided into a 38.10-cm gray startbox, a 91.44-cm black run section, and a 30.48-cm black goalbox. The start- and goalboxes were separated from the run section by guillotine doors. Raising the start door activated a Standard Electric Timer (start time). When a rat passed through a photoelectric beam, located 15.24 cm beyond the start door, the first timer stopped and a second timer started (run time). When a second beam, located 76.20 cm beyond the first beam, was broken, the second timer stopped and a third timer started (goal time). When a third beam, located 5.08 cm in front of the goal cup, was broken, the third timer stopped. The plastic goalcup, recessed into the back wall of the goalbox, was 4.0 cm high, 4.0 cm wide, and 3.40 cm deep. Hardware-cloth tops, covered by a thin sheet of transparent plastic, covered the entire apparatus.

Procedure

At the beginning of deprivation, the normal, sham, and anosmic squads were randomly divided into three equal subgroups: 11L (multiple-pellet large reward), 1L (single-pellet large reward), and S (small reward). All subjects received 5 days of pretraining prior to the beginning of the experiment proper. During pretraining, all subjects were handled and tamed (Days 1-2), allowed to individually explore the runway (Days 3-5), and habituated to the appropriate reward pellet in the home cage (Days 1-5). A 51-trial acquisition phase (Phase I) followed pretraining. During this, Group 11L received 11 45-mg Noyes pellets per trial, Group 1L received 1 500-mg Noyes pellet per trial, and Group S received 1 45-mg Noyes pellet per trial. Phase II (30 trials) immediately followed Phase I. During this phase, all subjects received 1 45-mg Noyes pellet per trial.

Trials were administered at the rate of 3 per day with the sham, normal, and anosmic subjects being run as three separate squads. Both the order for running squads and the order for running subjects within a squad were randomized daily. All members of a squad received their three daily trials before the next squad was run. The intertrial interval was approximately 7 min during both phases of the experiment.

Following the general testing procedure, each of the 54 anosmic and sham subjects was sacrificed, using an overdose of

Figure 2. Mean goal speeds (meters per second) for the anosmic subjects during Phases I and II.

sodium pentobarbital; the animals were then perfused with normal saline and a 10% neutral buffered Formalin solution. The entire brain was then removed and stored in the Formalin solution. Visual inspection of the brains revealed that the olfactory bulbs and tracts had been successfully removed from all of the anosmic animals.

RESULTS

Since the results of the start, run, and goal measures were quite similar, only those of the goal measure will be presented. Figures 1 and 2 show the mean goal speeds (meters per second) for the normal and anosmic subjects during Phases I and II. As the performance of the normal and sham subjects was virtually indistinguishable, only the graphical results for the normal subjects are presented. Analyses of variance were performed on the speed data from the last 5 days of Phase I since this appeared to be the point in training at which reward magnitude effects had developed most strongly. The results of the Phase I analyses yielded a significant, $F(2,72) = 5.88$, $p < .01$, reward magnitude effect. However, the form of this effect differed significantly ($p < .01$) between the respective olfactory-condition squads. Subsequent Newman-Keuls analyses indicated that the normal and sham large-reward subjects (i.e., Groups 1L and 11L) were significantly ($p < .01$) superior to the respective small-reward subjects (i.e., Group S) but did not differ between themselves. However, anosmic Groups S and 11L did not differ significantly between themselves, but were significantly ($p < .05$) superior to Group 1L.

Turning to the results of Phase II, it can be seen from Figures 1 and 2 that the shift from large to small reward had pronounced behavioral effects. Analyses indicated that the incentive reduction [$F(2,72) = 6.77$, $p < .01$], olfactory state [$F(2,72) = 4.98$, $p < .01$], trials [$F(9,648) = 87.36$, $p < .01$], Incentive Reduction by Trials interaction [$F(18,648) = 27.30$, $p < .01$], Olfactory State by Trials interaction [$F(18,648) = 32.12$, $p < .01$], and the Incentive Reduction by Olfactory State by Trials interaction

[$F(36,648) = 17.36$, $p < .01$] factors were significant. Subsequent Newman-Keuls tests indicated that: (1) the small-reward subjects were approaching the goal faster than the subjects that had experienced incentive reduction, and (2) the anosmic subjects were approaching the goal faster than the normal or sham subjects. Further investigation of the significant Incentive Reduction by Olfactory State by Trials interaction corroborated the graphical impressions that significant differences between the 11L, 1L, and S subjects within the three olfactory states were often influenced by large variations in the performance of Group S within both the sham and normal squads.

DISCUSSION

Regarding conclusions to be derived from this study, several points would appear to merit consideration. First, the traditional assumption concerning the effectiveness of reward magnitude was supported, at least in the case of the normal and sham subjects, in that the performance of both 11L and 1L subjects in these squads was superior to that of the respective small-reward subjects at the conclusion of the 51 trials of Phase I. It should be noted that these results are not necessarily inconsistent with those reported by McCain (1969, 1970, 1971). The data reported by McCain (1969, 1970; McCain, Dyleski, & McElvain, 1971) showed that reward magnitude effects did develop but were limited to the early stages of acquisition and had dissipated appreciably as training progressed, with virtually no differences being shown between large- and small-reward subjects after approximately 50 trials. Had Phase I of the present study been extended beyond 51 trials, it is quite possible that the observed magnitude effects would have eventually dissipated.

A somewhat different picture emerges when one considers the Phase I performance of the anosmic subjects. During this phase, the performances of the 11L and S anosmic subjects were highly similar (i.e., no reward magnitude effects) and were superior to that of the 1L anosmic subjects. This finding corroborates the data reported by Marrero et al. (1973). However, the depressed performance to the single-pellet large reward on the part of the

anosmic subject would appear to be limited to the situation in which this is the *only* reward value received by the subject (see Davis & Seago, 1975).

Turning to the Phase II data, it can be seen that when the 11L and 1L subjects were shifted to small reward, their performance fell significantly below that of their respective small reward control groups (i.e., depression effects developed: see Crespi, 1942). However, as Figures 1 and 2 indicate, the depression effects shown by the normal subjects differed considerably from those shown by the anosmic subjects. Thus, the large and precipitous drops in performance shown by the shifted normal subjects are to be contrasted with the gradual decline shown by the shifted anosmic subjects. Hence, another striking effect of rendering the rat subject anosmic is to greatly attenuate performance decrements, possibly through a reduction in incentive motivation (see Davis & Seago, 1975), typically shown during incentive reduction.

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