

Differential conditioning as a function of surgical anosmia

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Three groups of anosmic rats served as subjects in a two-stage experiment investigating the effects of surgically produced anosmia on behavior in a differential conditioning situation. Differential responding failed to develop during training (Phase I) for either of the two groups of subjects receiving differential reinforcement (large vs. small) in two straight runways of different brightness. Further, the performance of these two groups did not differ from that of a control group receiving small reward in both runways. Some differential responding was shown during extinction (Phase II), suggesting that a preference for the large reward alternative had been established during Phase I by those subjects experiencing differential reinforcement. Possible mechanisms underlying the behavior of the anosmic subject in this situation are discussed.

Research in the area of differential reward conditioning has been characterized by the concurrent presentation of two reinforcement values. Typically, subjects are given large reward in the presence of one discriminative stimulus (example, a black runway), and a small reward in the presence of a second discriminative stimulus (example, a white runway). Performance to the two alternatives is generally evaluated relative to a control group receiving small reward in the presence of both stimuli, and/or a second control group receiving large reward in the presence of both stimuli. A number of studies (e.g., Bower, 1961; Ludvigson & Gay, 1966; Ludvigson & Gay, 1967; Davis, Gilbert, & Seaver, 1971) have consistently demonstrated that speeds to the small reward alternative (S-) are depressed when subjects concurrently experience large reward in the second alternative (S+). This finding has been termed a "negative contrast effect" (NCE). For reasons to be discussed subsequently, it is worth noting that the above-mentioned studies all employed "normal" rats as subjects.

Recently, Marrero, Davis, and Seago (1973) and Davis, Harper, and Seago (Note 1) have reported studies investigating the effects of surgically produced anosmia on the runway behavior of the rat. Both studies investigated the effects of different reward magnitudes on a between-subject basis. The results of these two studies indicated that reward magnitude effects were not

shown by the anosmic subjects. In fact, there was a tendency (significant in several instances), shown in both studies, for small-reward anosmic subjects to perform better (i.e., faster speeds) than anosmic subjects receiving one large pellet reward. Additionally, the Davis et al. (Note 1) study evaluated the effect of a shift from the large-reward to the small-reward condition. Compared to the abrupt and precipitous drop in performance shown by the normal subjects experiencing the same reduction in incentive, the shift in incentive resulted in a much more gradual decline in the performance of the anosmic subjects. Thus, the results of the Marrero et al. (1973) and the Davis et al. (1975) studies strongly suggest that, in addition to eliminating the sense of smell, surgical anosmic additionally has a pronounced effect on the motivational level of the rat subject.

Combining these two lines of research, the present study was designed to investigate the effects of concurrently exposing anosmic subjects to different levels of reinforcement (i.e., a differential conditioning situation). If, as the Marrero et al. (1973) and Davis et al. (1975) data suggest, the effect of anosmia is to reduce the motivational level, then one might predict that NCEs would not be shown by anosmic subjects in the differential conditioning situation. The concurrent receipt of both large and small rewards on a within-subjects basis would also appear to be an excellent manner by which to ascertain the relative attraction and/or aversion to different reward magnitudes by the anosmic subject.

METHOD

Subjects

Twenty-four male albino rats purchased from the

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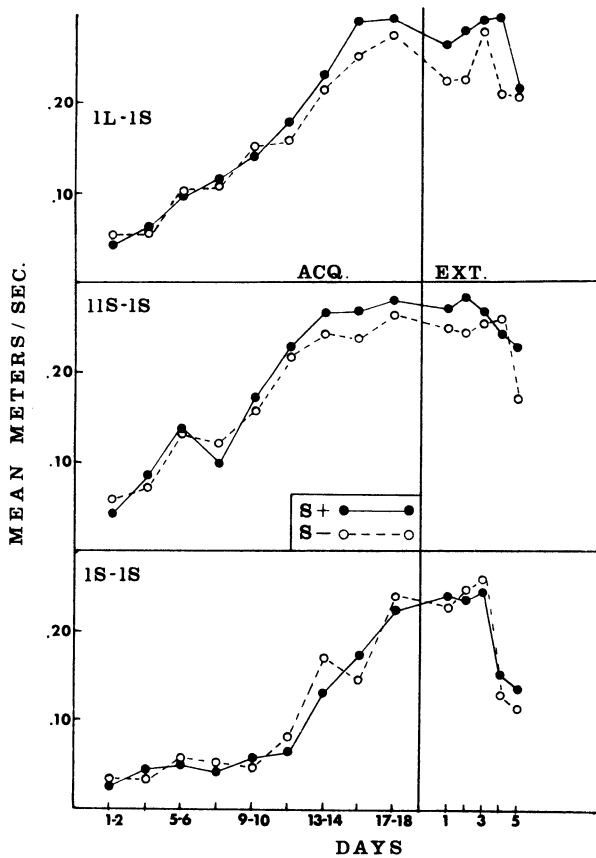


Figure 1. Mean start speeds (meters/second) for Groups 1L-1S, 11S-1S, and 1S-1S during training and extinction.

Sprague-Dawley Laboratories, Madison, Wisconsin served as subjects. All subjects were approximately 110 days old at the inception of the experiment. Prior to experimentation, all subjects were rendered anosmic in the following manner. First, each subject was anesthetized with sodium pentobarbital. Then, using a stereotaxic instrument, trephine openings were placed on each side of the saggital suture above the olfactory bulbs. The olfactory bulbs and connecting tracts were then removed from each subject with an aspirator. Following recovery from surgery (approximately 1 week prior to the start of pretraining), all subjects were placed on food deprivation and were maintained at 85% ad-lib body weight for the duration of the experiment. All subjects were housed in individual cages with water constantly available. Maintenance of the deprivation schedule took place following each experimental session.

Apparatus

The apparatus consisted of two side-by-side runways (11.43 cm wide x 12.70 cm high). The left one was painted white, and the right one was painted black. Each runway was divided into a 91.44-cm run section and a 30.48-cm goal section. Both runways were serviced by a common gray startbox (38.10 cm) that could be positioned in front of either runway. The start- and goalboxes were separated from the run section by masonite guillotine doors. A microswitch located on the startdoor, in conjunction with a series of photoelectric cells, successively activated and stopped electric timers to produce start, run, and goal latencies. Hardware-cloth tops covered the entire apparatus.

Procedure

Prior to pretraining, three equal groups, 1L-1S, 11S-1S, and 1S-1S, were randomly formed. The 5-day pretraining period which immediately preceded the start of the experiment proper consisted of handling and taming (Days 1-2), individual exploration of both runways (Days 3-5), and pellet habituation in the home cage (Days 1-5).

An 18-day acquisition phase was initiated immediately following pretraining. During this phase, all subjects received two S+ and two S- trials per day. Subjects in Group 1L-1S received 1 500-mg pellet on S+ trials and 1 45-mg pellet on S- trials, while subjects in Group 11S-1S received 11 45-mg pellets on S+ trials and 1 45-mg pellet on S- trials. Group 1S-1S served as a small-reward control group and received one 45-mg pellet on both S+ and S- trials. Administration of the four daily trials to each subject was determined by random assignment of one of the six possible sequences of + and - with the restriction that no sequence could occur more than twice in succession. The use of the black and white runways as S+ or S- cues was counterbalanced within each group. On all trials, subjects were confined to the startbox for 5 sec before the startdoor was raised and the trial begun. Subjects were removed from the goalbox as soon as the reward was taken into the mouth. The order for running subjects was randomized daily, with all subjects receiving Trial 1 before Trial 2, and so forth.

A 5-day (20-trial) extinction phase followed acquisition. The same procedures that were used in acquisition also prevailed during extinction, with the exception that all subjects were confined to the empty goalbox for 30 sec on all trials.

Following extinction, the subjects were sacrificed using an overdose of sodium pentobarbital; the animals were then perfused with normal saline in a 10% neutral buffered formalin solution. The entire brain was then removed and stored in a formalin solution. Visual inspection of the brain revealed that the olfactory bulbs and tracts had been successfully removed from all subjects.

RESULTS

Mean start speeds (meters/second) are shown in Figure 1. It should be recalled that previous studies (e.g., Davis et al., 1971; Ludvigson & Gay, 1967) reported finding the most pronounced depression in S- performance in the start measure. Analyses of variance performed on the start, run, and goal speeds from Days 17-18 of acquisition (the point at which differential responding should have been the strongest) yielded no significant effects.

Similar analyses were performed on the start, run, and goal speeds of the extinction phase. The results of these analyses indicated that the trials factor was significant in all three measures [start, $F(4,189) = 11.02, p < .01$; run, $F(4,189) = 9.50, p < .01$; and goal, $F(4,189) = 8.33, p < .01$]. Likewise, the reward alternative (prior S+ vs. prior S-) factor was found to be significant in all three measures [start, $F(1,189) = 7.62, p < .01$; run, $F(1,189) = 22.45, p < .01$; and, goal, $F(1,189) = 4.33, p < .05$]. Thus, the statistical analyses are supportive of the graphical picture that performance declined during extinction, and, further, that the speeds to the former S- alternative were depressed below those to the former S+ alternative. Additionally, the Groups by Trials

interaction was found to be significant, $F(8,189) = 2.47$, $p < .05$, in the start measure, and the Groups by Reward Alternative interaction was found to be significant, $F(2,189) = 6.72$, $p < .01$, in the run measure. Further analyses of the Groups by Trials interaction indicated that significant ($p < .05$) differences occurred on Days 4-5, and that Groups 1L-1S and 11S-1S did not differ but were significantly ($p < .05$) superior to Group 1S-1S. Analyses of the Groups by Reward Alternative interaction indicated that Groups 1L-1S and 11S-1S ran significantly ($p < .01$) faster to the prior S+ than to the prior S-, while Group 1S-1S showed nondifferential performance to the two alternatives. It is interesting to note that the Groups by Reward Alternative interaction showed borderline significance in the start and goal measures during extinction, thus supporting the impression that the significant reward alternative differences were primarily attributable to differential responding by Groups 1L-1S and 11S-1S.

DISCUSSION

Obviously, the most striking feature of the present experiment is the complete absence of differential responding, especially in the start measure, on the part of Groups 1L-1S and 11S-1S during acquisition. Davis and Ludvigson (1974) have recently proposed a two-component model of differential conditioning. According to this model, differential responding may result from: (1) nonemotional processes such as differential habit or incentive formation, and (2) an overlay of frustration that may accompany the basic discrimination. In the later case, the additional frustrative component would be expected to heighten the depression of S- speeds. The data of the present study suggest that rendering the rat subject surgically anosmic has the effect of drastically reducing the first, nonemotional, component. Supportive of this view, both the Marrero et al. (1973) and Davis et al. (1975) studies have suggested that one effect of surgically produced anosmia is to reduce incentive motivation.

Presently, one can only speculate as to the nature of the exact structure or mechanism controlling this behavior. However, it is interesting to note that a number of fibers from the olfactory bulbs terminate in the cortico-medial nuclei of the amygdala, a limbic system structure. Although the exact functions controlled

by the amygdala are not fully delineated at present, amygdalotomy has been shown to interfere with avoidance learning (e.g., Robinson, 1963; Weiskrantz, 1956). If one views the NCE in differential conditioning as a type of avoidance learning, then the case for olfactory system input to the amygdala appears to be strengthened, especially in the rat, with its extremely well-developed olfactory system.

Turning to the extinction data, it can be seen that all groups showed a decline in performance during the course of this phase. However, the fact that the speeds of Groups 1L-1S and 11S-1S were faster (significant in the run measure) to the former S+ alternative suggests that some, although limited, differential incentive formation did take place during training and persisted into the extinction phase. The fact that S+ speeds for Groups 1L-1S and 11S-1S tended to be superior to S- speeds during training is supportive of this view.

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