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Some effects of rotation and centrifugally produced high gravity on taste aversion in rats

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Rats were exposed to a single pairing of grape juice and rotation or rotation plus high gravity (5 g or 10 g). They were then tested separately for grape juice consumption over the next several days. High gravity did not reduce the amount of grape juice consumed, and nonrotated controls drank significantly more throughout testing. A high resistance to extinction was evidenced by the fact that drinking suppression was maintained for the experimental groups throughout five tests.

It has long been known that toxic chemicals and radiation are effective as US in producing taste aversion learning in rats (e.g., Garcia & Koelling, 1966). More recently, rotational stimulation has been shown to produce similar aversions to novel gustatory stimuli, such as those arising from saccharin solutions (Green & Rachlin, 1973, 1976; Haroutunian & Riccio, 1975). Some have speculated that the gastrointestinal consequences of rotation are similar to those of toxic chemical agents and irradiation, and that this is possibly the mechanism underlying rotation-produced taste aversion learning (Braun & McIntosh, 1973). In all of these studies, the subjects experienced rotational stimulation while positioned directly over the axis of rotation in order to minimize any centrifugal effects.

The present investigation sought to manipulate these centrifugal effects and explore yet another aspect of rotation, gravity, as it affects taste aversion learning. Centrifugation is the only method by which increased gravities can be produced for prolonged periods of time. Centrifugal acceleration or "artificial gravity" (McCoy, Love, & Miller, 1971) is a function of two variables, angular velocity and radial distance. Increases in either of these factors during rotation will produce increases in gravity. Since increasing gravity by changing rotational speed alone confounds these two variables, it is often desirable and necessary to change gravity by holding rotational speed constant while manipulating radius only (McCoy et al., 1971). More important with regard to the present issue, increased gravity has been shown to be aversive when produced by either of these methods (Clark, Martin, Lange, & Belleville, 1969; McCoy & Jankovich, 1972).

The present investigation examined whether exposure to high gravity, with rotational speed held constant, would increase the aversive aspects of the rotation experience as reflected in taste aversion learning. In addition, the rate and degree of recovery of drinking were examined during subsequent extinction tests.

METHOD

Subjects

Sixty Sprague-Dawley rats (32 males and 28 females) were housed in standard laboratory cages. All were between 150 and 180 days of age at the beginning of the experiment. The animals had free access to food but were maintained on a 15-min/day drinking schedule throughout the experiment.

Apparatus

Experimental treatments were administered on a fixed-speed constant-radius centrifuge. The centrifuge contained two opposed radial arms measuring 91.44 cm in length. The unit was driven by a dc motor that rotated at a speed of 107 rpm. Three experimental cages were mounted on the centrifuge: one over the axis of rotation, one at a radial distance of 39 cm on one of the arms, and one 78 cm from the rotational axis on the other arm. At a speed of 107 rpm, 5 g and 10 g were produced in the shorter and longer radius cages, respectively. Each of the radially positioned cages was free to pivot, so that the effective weight during rotation (i.e., the resultant vector of earth gravity and centrifugal force) was always transmitted dorsoventrally, just as it is for any quadruped in the normal 1-g environment. The center cage was fixed so that the animal's head remained over the axis of rotation. Each of the experimental cages measured 20.3 x 10.2 x 10.2 cm. They were intentionally small so as to minimize movement during rotation and to thereby prevent tangential or "Coriolis" accelerations, also known to produce motion sickness (e.g., Broderson, 1969). The entire centrifuge was surrounded with a 61-cm-high sheet metal fence intended to minimize visual stimulation during rotation.

Procedure

The animals were randomly assigned to four groups with the restriction that eight females and seven males compose each group. They were then adapted to a water-deprivation schedule over the next 5 days, in which water was available for a 15-min period each day. On the day on which rotation treatments were administered, each animal received a 15-min exposure to grape juice followed 15 min later by the appropriate treatment. Group 10 g received a 10-min exposure to 10 g in the longer radius capsule. At the same time, a subject from the 5-g group

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was rotated in the shorter radius capsule. Finally, one animal from the rotate group was placed in the center cage and rotated over the axis for the same time duration. The controls remained in the home cage after drinking grape juice.

All subjects were given 15 min access to water during the next 2 days following rotation. On the 3rd day, they were given a 15-min one-bottle test with grape juice. They were then given water for the next 2 days, followed by grape juice on the 3rd. This pattern was maintained until five tests with grape juice had been administered, each separated by 2 days of water. All tests were one-bottle tests, and all drinking occurred in the home cage. For each animal, the amount of water or grape juice was measured before and after each drinking period.

RESULTS AND DISCUSSION

Upon return to the home cage following centrifugation, the experimental animals were observed to huddle in the corner of the cage, becoming quiescent, and never engaging in eating. Similar observations were reported by Braun and McIntosh (1973), who noted the parallel between these symptoms and those produced by toxic drug or irradiation treatments.

More quantitative analyses indicated that the groups did not differ in terms of the amount of water consumed during the 5-day adaptation period. Neither did they differ significantly in terms of the amount of grape juice consumed during the 15-min "baseline" period prior to rotation. The latter analysis approached significance, however [$F(3,56) = 2.58$, $p > .05$ (F of 2.76 required)], presumably because of the relatively small amount of grape juice consumed by the control group during this baseline exposure. An explanation for this reduced drinking by the controls does not present itself, since it is not at all clear why these animals should have reacted to the novel solution any differently from the experimental groups at this time. These baseline values, along with the group means for the five tests, appear in Table 1.

The tendency of the control animals to consume less grape juice during the baseline session carried over to Test 1, and this presumably accounts for the fact that an overall analysis of the test data yielded an F for the groups factor that approached, but did not attain, significance [$F(3,56) = 2.70$, $p > .05$ (F of 2.76 required)]. The apparent recovery of all groups in Test 2 probably accounts for the significant tests effect [$F(4,224) = 2.87$, $p < .05$], although this trend was not maintained. The Groups by Tests interaction was not significant.

Table 1
Mean Amount of Grape Juice Consumed (in Milliliters) by Experimental and Control Groups During Baseline and Five Test Exposures

	Treatment			
Condition	Control	Rotate	5 g	10 g
Baseline	14.8	17.4	16.8	16.7
Test 1	14.1	12.3	12.8	10.9
Test 2	15.7	13.8	13.8	12.7
Test 3	15.8	14.0	13.1	12.4
Test 4	15.4	13.6	12.1	10.9
Test 5	15.8	14.0	13.0	11.2

The failure to find a significant groups effect suggests that not only did high gravity fail to magnify the aversion for grape juice, but also rotation per se did not produce a significant difference in the amount of the test solution consumed. Therefore, the data at this point seem to be at odds with the many reports of rotation-produced taste aversion in rats (e.g., Braun & McIntosh, 1973; Green & Rachlin, 1973).

Within-groups analyses tended to clarify the situation, since it seems clear from Table 1 that differences did exist between grape juice consumption during baseline and Test 1 for the experimental groups. One-tailed t tests for related measures confirmed this impression: The rotate group, the 5-g group, and the 10-g group drank significantly less in Test 1 than in the baseline session [$ts(14) = 4.07$, 3.23, and 4.05, respectively; $ps < .05$ in all cases]. The control group, on the other hand, drank nearly equivalent amounts under both conditions ($t < 1$).

Considering the present pattern of results, within-groups analyses seemed more appropriate and sensitive. Accordingly, the raw data for each animal were calculated as a percentage of the score for that subject during the baseline session. Expressed in this manner, the transformed data appear in Figure 1. The suppressed consumption by the experimental groups relative to the controls is quite evident here. The controls, on the other hand, drank increasing amounts of grape juice over the five tests, consuming more than baseline amounts during Tests 2-5. This increased consumption by the controls did not seem to be a result of the prolonged water-deprivation condition, since water consumption during the 2-day intervals separating tests did not increase. A two-way analysis of the relative amount of grape juice consumed by the groups over the course of testing yielded a significant effect for groups [$F(3,56) = 9.27$, $p < .01$], but neither the tests factor nor the Groups by Tests interaction was significant. The latter results indicate that drinking suppression was maintained, and about equally so, for all experimental groups over the five test sessions. Further analyses of the group differences using the Newman-Keuls test ($p < .05$) confirmed the impression one might receive from inspection of Figure 1: The control group drank significantly more than did the three experimental groups throughout testing. The experimental groups did not differ among themselves. Furthermore, the apparent difference between the 5-g and 10-g groups on Test 1 was not significant, nor was that between the 10-g and rotation groups on Test 5.

The relative consistency of grape juice consumption by the experimental groups over the course of testing is of interest because it indicates that a sustained suppression of drinking was produced by a single pairing with rotation. While the retention of taste aversion has

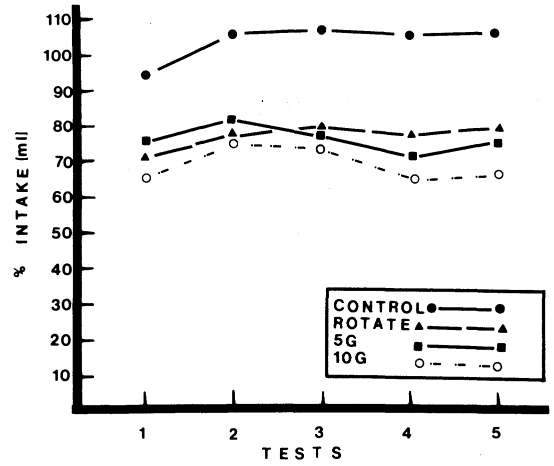

Figure 1. Mean percent of grape juice consumed during five test exposures.

been reported to be complete after a 24-h interval (Braun & McIntosh, 1973) and "reasonably good" (about a 10% loss) after a 30-day interval (Haroutunian & Riccio, 1975), the present data also suggest that such aversions are, in addition, highly resistant to extinction. Further research is needed to explicate this finding.

The present rotational data can be incorporated with earlier reports of rotation-produced taste aversion by considering the important features of the situation, namely, length of the interstimulus interval, number of pairings of gustatory stimulation with rotation, and rotational speed and duration. Our results indicate that relative suppression of drinking can be achieved in a single pairing of drinking with rotation when the interstimulus interval is 15 min. Haroutunian and Riccio (1975) reported that a single stimulus pairing was capable of producing reliable suppression of drinking only with a short (.5-min) delay. A 15-min interval required three such pairings to produce the effect. However, in this context, it is also important to consider the parameters of the rotational stimulus per se. Green and Rachlin (1976) showed that degree of aversion is positively related to speed and duration of rotation. More specifically, if speed and duration of rotation are multiplied, degree of aversion can be expressed as a positive function of the number of rotations experienced. In the present experiment, this value is calculated to be 1,070 revolutions (107 rpm X 10 min), whereas Haroutunian and Riccio used 70 rpm at 10 min, a total of 700 revolutions. The considerable difference in number of revolutions in these two experiments might explain the apparent discrepancy in number of pairings needed to produce an aversion. The relatively high number of revolutions used here might also account for the marked resistance to extinction.

Finally, it must be noted that, although there is a slight suggestion in terms of the final ordering of the groups that high gravity might have added to the aversiveness of the rotational experience, this has in no way been demonstrated. This does not mean, however, that high gravity is not an aversive stimulus. As indicated earlier, there are several reports that demonstrate clearly that rats, along with other species, will produce operant responses that remove, reduce, or postpone programmed increases in gravity (e.g., Clark et al., 1969). It may indicate, however, that in the present situation the rotational stimulation necessary to produce increased gravity overrides the effect of weight (i.e., gravity) stimuli. This is not too surprising inasmuch as the malaise or motion sickness produced by rotation has been compared to the illness produced by toxic chemicals or irradiation (e.g., Braun & McIntosh, 1973). Nevertheless, it may also be true that a single exposure to the rotation-gravity stimulus was not sufficient to allow the effect of gravity to materialize. Future research will deal with this issue.

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