A second factor is that of the measurement interval. A number of studies have shown that the measurement interval used may significantly affect the results obtained (e.g., Wagner, 1968; Wagner, Green, & Manley, 1965). The effects of measurement intervals are most clearly seen in the results of the second study of this paper. Figure 3 indicates a number of order-effect reversals as a function of the measurement interval.

The previous studies by these authors (Marks et al, 1969) indicated differential effects on the motivated performance of anosmic and normal rats as a function of previous experience. In that study, three groups of rats (anosmic, sham-operated, and normal) were trained in an active avoidance task; another three groups were trained in a passive avoidance task. The anosmic and normal rats from both studies were then used in an operant task. Normal rats did not differ as a function of previous experience. Passive-avoidance-trained anosmic rats responded reliably more than anosmic rats used in the active avoidance experiment, probably as a function of the familiarity with the food pellets used in both the reward training preceding passive avoidance and in the operant task. Neither of the present experiments was able to evaluate the possibility of differential effects of previous experience, but its possible contribution to the observed effects should not be ignored.

It would undoubtedly be possible to attribute some portion of the anosmic animal's performance to the loss of olfactory cues. Miller & Erickson (1966) have shown taste solutions to have discriminable odors and have suggested that anosmia would affect preference by the elimination of these odors. The loss of olfactory cues

would not, however, explain a difference in relative preference between anosmic and normal animals as a function of different types of deprivation.

Since the olfactory bulbs project fibers to numerous parts of the limbic system and the limbic system is intimately connected with food and water regulation, the authors speculate that it is not merely the loss of olfactory cues, but primarily the loss of olfactory bulb input that may be the major factor accounting for the differences between anosmic and normal animals. Further research is clearly needed to determine the relationships among olfactory bulb input, limbic system function, and preference behavior.

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Fishman, 1957) and subjective reports of humans (Hanlon, Romaine, Gilroy, & Deitrich, 1949). Several studies have since employed LiCl poisoning and have utilized equimolar NaCl as a control solution (Garcia & Koelling, 1966) or have alluded to salt taste generalization effects (Kalat & Rozin, 1970). Thus, there has appeared to be a growing acceptance of taste equivalence for these salts in rats. However, Nachman clearly indicated that 10-min test periods may have been too brief to clearly reveal a discrimination between NaCl and LiCl. He noted that during the last half of the test period there appeared to be some beginning signs of a preference for NaCl over LiCl. This possible preference was attributed to "learning based upon the position of the tubes within each daily 10-min test [Nachman, 1963, p. 347]." Since the toxic effects of LiCl are fast acting, it is possible that aversion responses could develop in less than 10 min. However, Barnett (1963) and Garcia & Koelling (1966) report that poisoning-aversion learning for very distinctive environments is extremely difficult, if not impossible, to obtain in the rat. In the following experiments, rats were confronted with the problem of having only NaCl and LiCl available to drink. If the animals were to avoid the toxic aftereffects of LiCl, they must learn either the difficult taste discrimination or the difficult place discrimination. After discrimination learning had occurred, it was possible, by manipulating bottle position and test duration, to determine the utilization of place or taste cues in the choice of solutions.

METHOD

Throughout the first experiment the nine male 300- to 450-g Sprague-Dawley rats were housed in their individual home cages and had ad lib access to Purina Lab Chow. Animals were adapted to the cages for 7 days prior to being given the salt solutions. During the adaptation period each cage had two standard water bottles attached. Water intake was recorded daily at 12:00 noon. At the end of the seventh adaptation day, two Ss were eliminated for displaying a water-bottle side preference of more than 5:1 on at least 1 day. Of the remaining seven Ss, four had mean left preferences of up to 75%, one had no side preference, and two had mean right preferences of up to 70%. The 0.12-M solutions were prepared with distilled water. LiCl bottles were located on the preferred side for half of the Ss and on the nonpreferred side for the other half. Identical bottles, stoppers, and drinking tubes were used on each cage. Ss had continuous access

Intake differentiation by rats of equimolar sodium chloride and lithium chloride solutions

RONALD G. SMITH*

Wright State University, Dayton, Ohio 45431

Sodium chloride solutions have been frequently used in taste-aversion and bait-shyness experiments as taste equivalents or control solutions for lithium chloride toxin. It was demonstrated that rats can readily discriminate between 0.12 M NaCl and equimolar LiCl when both solutions are continuously available in their home cages. Additional work indicated that the learned discrimination was based primarily upon taste cues but that place cues could also be utilized.

Nachman (1963) established in rats a learned aversion to the taste of lithium chloride that could be

extinguished by repeated exposures to equimolar sodium chloride. The similarity of taste of these two salts is further supported by the similarity of nerve firing patterns recorded from the chorda tympani (Beidler, 1953;

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to the bottles, except for measurement and refilling time. Measurements of LiCl and NaCl intake to the nearest 1.0 ml were taken daily at 12:00 noon for an 8-day period. Both bottles were refilled with 200 ml of solution following readings.

RESULTS AND DISCUSSION

Figure 1 shows that rapid LiCl aversion learning occurred on the first day and continued to develop on the second day. Stabilized performance levels appeared to be achieved beyond the fourth day of trials when the means generally paralleled the estimated spillage/evaporation value. This value was estimated by sham operation of two empty cages during the experiment; therefore, it does not also estimate spillage occurring during actual drinking. The three Ss whose LiCl bottles had been placed on their preferred H₂O sides had the highest intake of LiCl on Day 1. On all subsequent test days, these three Ss consistently ranked in the lower half of the group. In fact, there was only 1 test day in which one of the three did not obtain the lowest LiCl percentage intake of the whole group.

The clear-cut learned aversion to LiCl was established with surprising speed, considering that (1) no forced trials were run, (2) no time periods were allowed for unambiguous toxic feedback, and (3) high similarity of tastes have been reported. The obtained results indicated that rats were capable of functionally avoiding the toxic material. It then remained to determine the basis upon which the rats were performing this discrimination, i.e., taste vs place.

One additional factor that might have aided the discrimination was a possible cumulative influence of LiCl. That is, the threshold of aversive feedback to the intake of the toxic material might have shifted due to a buildup of the material or sensitization in the system. Such a cumulative effect may be reduced by allowing recovery time between test days.

To investigate these effects, an additional 10 male 300- to 450-g Sprague-Dawley rats were adapted to the cages and water bottles as previously described. Two groups of five Ss were created by matching for water-bottle side preference and total intake over a 7-day adaptation period. One group had LiCl and NaCl bottle positions alternated each test day; the other group had LiCl and NaCl always on the same side until the eighth and last test day, when the LiCl was shifted to the opposite side. One recovery day was interposed between each test day. These different exposures to LiCl on the home cages produced no differences in intakes, except on the last test day, when one of the groups had its LiCl bottle reversed for the first time. This reversal yielded the highest LiCl intakes of the whole test period. The increase occurred in three of the five Ss in the group. The remaining two Ss continued to avoid the toxic salt. In the second study the onset of the illness states should have been more easily discriminated, as a result of the interposed recovery days. Therefore, on the basis of discriminability of the illness state, one would have predicted a lesser percent intake of LiCl.

However, both groups in the second study displayed a higher percent of LiCl intake than the original group, suggesting that cumulative toxic effects sensitized the original group.

After the eighth recovery day, all 10 Ss were placed on 23-h water deprivation. The Ss were then given two 3-min NaCl-LiCl choice tests, spaced 1 h apart. Two different test cages were used, one with LiCl to the left and the other with NaCl to the left. Order of testing in the cages was balanced. Only one of the Ss drank more LiCl than NaCl in the two short tests. Mean intake of LiCl on the second short test was more than double that of the first test, suggesting that rapid development of place cues had also taken place in the first cage.

The primary finding that rats can discriminate between 0.12-M solutions of LiCl and NaCl has been replicated in three different ways. Evidence that the discrimination is primarily gustatory was seen in (1) the stable low intake in the group that had the LiCl bottle position alternated daily on their home cages and (2) the low LiCl intakes on the first of the 3-min tests. That animals may also utilize place cues to avoid the LiCl was indicated by (1) the greatly increased LiCl intake of several Ss whose home cage LiCl bottle position was shifted for the first time on the eighth test day and (2) the increased LiCl intake on the reversal of bottle positions on the second short test. Regardless of what mechanism is used in the discrimination, Es should consider that rats are fully capable of differentiating between equimolar NaCl and LiCl when both are simultaneously available. This intake differentiation, once established, will also be evident in brief tests that have minimal opportunity for toxic feedback.

Fig. 1. Home cage intake of 0.12 M lithium chloride with only equimolar sodium chloride as an alternative. Ss of Experiment 2 had a 24-h recovery period between each test day. Cross hatched area is the spillage/evaporation value estimated from sham cages.

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