Two-bottle discrimination of equimolar NaCl and LiCl solutions by rats

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In Experiment 1, rats received experience in a two-bottle situation that involved successive discriminations, first between LiCl and sucrose and then between LiCl and distilled water. Following this experience, the rats displayed an immediate discrimination between .15 M LiCl and .15 M NaCl. When rats in Experiment 2 were given no prior LiCl experience, discrimination between .15 M LiCl and .15 M NaCl was not immediate but developed with repeated presentations. With gradual reductions in the molar concentration, it was found that the discrimination between equimolar NaCl and LiCl solutions was lost between .007 and .008 M. Further tests suggested that the discrimination between low concentrations of NaCl and LiCl was based on sensory (oral) rather than on postingestional cues. The exact oral cue used by the rats to discriminate NaCl from LiCl was not an obvious taste factor: Masking of .08 M NaCl and .08 M LiCl with the four basic tastes (sweet, salty, sour, and bitter), either alone or together, failed to disrupt the discrimination. It was concluded that rats could discriminate reliably and efficiently between equimolar NaCl and LiCl solutions throughout a broad range of concentrations. The possible sensory basis of this discrimination is discussed.

Sodium chloride (NaCl) and lithium chloride (LiCl) are two salts that produce different physiological effects in rats. NaCl is a basic physiological requirement, and thirsty rats tend to show a distinct preference for NaCl solutions, within certain concentration limits (Bare, 1949; Braun & Kiefer, 1975; Richter, 1939). On the other hand, LiCl consumption has been shown to produce toxicosis. Nachman and Ashe (1973) have shown that when rats were given a LiCl solution, they quickly learned to avoid drinking the fluid, presumably because of the adverse gastrointestinal consequences.

Despite the difference in physiological effects of ingesting NaCl and LiCl, the tastes of the two salts appear to be similar. The neural discharges produced by these two salts when applied in solution to the tongue have been shown to be alike in the chorda tympani (Beidler, 1953; Fishman, 1957), the solitary nucleus (Doetsch & Erickson, 1970), and the pons (Perrotto & Scott, 1976). Behavioral data have supported the electrophysiological findings by showing that rats appeared to respond similarly to equimolar NaCl and LiCl solutions. Nachman (1963) trained rats to avoid a .12-M LiCl solution, and then found that the rats generalized the aversion almost completely to an equimolar NaCl solution.

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Nachman (1963) also attempted to determine whether normal rats could discriminate between equimolar NaCl and LiCl in a simultaneous, two-bottle discrimination task. In Nachman's experiment, rats were trained first to avoid a .12-M LiCl solution in a one-bottle situation. Following training, they were presented with two bottles, one which contained LiCl and the other an equimolar NaCl solution. The rats did not discriminate obviously between the two salts over five daily presentations; during testing, the rats refused to consume either of the two solutions. Nachman pointed out that: "It is not known at present, whether, with further appropriate training procedures, rats could learn to discriminate the taste of LiCl from that of NaCl. Clearly the tastes appear to be very similar" (p. 348).

In contrast, Rusiniak, Garcia, and Hankins (1976) found that rats could discriminate between equimolar NaCl and LiCl solutions with repeated one-bottle presentations. Over a 14-day period, the rats significantly reduced consumption of LiCl while they maintained a relatively stable level of NaCl consumption. Rusiniak et al. concluded that rats could utilize taste cues effectively to discriminate NaCl from LiCl; this conclusion suggested that the taste of the two salts was not completely indistinguishable.

It appeared from the results of Rusiniak et al. (1976) that rats could discriminate between the tastes of NaCl and LiCl with repeated trials. This posed the question why, in Nachman's (1963) experiment, the rats failed to discriminate between these two salts in the two-bottle test with repeated presentations. To examine this problem, the present experiments first

determined whether rats could discriminate between the two salts in a two-bottle test, i.e., consume NaCl and avoid LiCl, given certain prior experience. Following these tests, several manipulations were performed to determine the limits of the rats' ability to discriminate between equimolar NaCl and LiCl solutions.

EXPERIMENT 1

In the first experiment, rats were tested in a series of two-bottle discriminations that were considered to range in difficulty from easy (a weak sucrose solution vs. .15 M LiCl), to medium (distilled water vs. .15 M LiCl), and finally to difficult (.15 M NaCl vs. .15 M LiCl). It was hypothesized that experience with a two-bottle situation and the taste of LiCl would facilitate the eventual development of a simultaneous discrimination between equimolar NaCl and LiCl solutions.

Method

Subjects

Thirty male Long-Evans hooded rats, 90-100 days old were used as subjects. The rats were housed individually in wire mesh cages and were removed only to be weighed approximately every 3 days.

Procedure

The rats were placed on a restricted drinking schedule of 20 min of fluid access every day at 10:00 a.m. During this 20-min period, two bottles were placed on the front of the cage. The bottles were 50-ml calibrated centrifuge tubes fitted with one-hole rubber stoppers and stainless steel drinking spouts. When attached to the cage, the drinking spouts extended approximately 2 cm into the cage; the spouts were equidistant from the center of the cage, separated from each other by about 8 cm, and approximately 3 cm above the floor of the cage.

After 10 min of each drinking session, the amount of fluid consumed from each bottle was recorded to the nearest .5 ml and bottle position then was reversed for the final 10 min. At the end of the 20-min period, the total amount of fluid consumed from each bottle was recorded and the bottles removed. Distilled water was presented in both bottles for 6 days to adapt the rats to the schedule.

Discrimination testing. Following adaptation to the schedule of restricted fluid access, discrimination testing was begun. On the 7th day and every 3rd day thereafter, distilled water was presented in both bottles. This procedure provided an opportunity for adequate hydration to be maintained over the course of the experiment. Beginning on the 8th day, the rats were presented with a .073-M sucrose solution in one bottle and a .15-M LiCl solution in the second bottle. This discrimination task was thought to be a relatively easy one because it involved a mildly preferred solution (sucrose) and the toxic LiCl solution. These solutions were presented until consumption of sucrose and LiCl reached an asymptote and were significantly different (i.e., the rats consumed sucrose and avoided LiCl). They then were presented with a discrimination between distilled water and .15 M LiCl. The water/LiCl presentations were continued until discrimination between the two was significant and stable. Following the water/LiCl discrimination, the final test between equimolar (.15 M) NaCl and LiCl was conducted. Testing was terminated when it was relatively certain that the rats could or could not discriminate between the two salt solutions. Again, the criterion for discrimination was

when the mean consumption of each salt solution reached an asymptote and differed significantly from each other.

To avoid position biases in the two-bottle situation, several control procedures were used. The starting position of a given solution was arranged according to a double alternation pattern and the positions of the bottles were reversed half way through the drinking period. Because each discrimination was run in 2-day periods separated by a water day, it was possible to collapse the two days' data if position preferences became obvious; a 2-day total balanced for the starting position of each solution. Finally, the discrimination trials were interrupted every 3rd day by two-bottle water presentations, making it more difficult to ascertain the order of starting position for the various taste solutions.

All taste solutions were made fresh daily from reagent grade chemicals and distilled water and presented at room temperature (24°C). Following a watering session, all tubes, stoppers, and glassware were washed in hot Alconox, rinsed thoroughly with tap water, and finally rinsed with distilled water.

Statistical analyses. The data for each discrimination task were analyzed first with a repeated measures analysis of variance with two repeated factors: days and solution type. Where significant overall effects were found, individual comparisons were made using the procedures outlined by Keppel (1973, pp. 425-433); for simplicity, only the results from these comparisons are given.

Results and Discussion

Figure 1 summarizes the results of the first experiment. On the graph, the data from the intervening water days are omitted. Although data were collected in two 10-min periods, only the total amounts consumed for the 20-min period are presented. The rats tended to consume the majority of fluid in the first 10 min, but the differential responding to each of the two solutions did not differ between the two periods.

On the 1st day of discrimination testing, the rats consumed significantly more sucrose than LiCl [$F(1,29) = 62.41, p < .001$]. Thus, given a choice between a mild sucrose solution and a .15-M LiCl solution, most rats selected the sucrose; only 3 out of 30 rats consumed more LiCl than sucrose. The large difference between sucrose and LiCl consumption may have reflected merely the rats' normal preference for sucrose. However, it is believed that the rats' preference for sucrose cannot account com-

Figure 1. Mean milliliters consumed ($\pm$ standard errors) of each solution on successive days of testing in Experiment 1.

pletely for the difference. First, the selected concentration of sucrose was relatively low and it was thought that, from prior tests (Braun & Kiefer, 1975), the preference for sucrose would be weak. Second, assuming that equimolar NaCl and LiCl taste similar to rats (Nachman, 1963) and that normal rats prefer .15 M NaCl to water (Braun & Kiefer, 1975), one would anticipate that the mean consumption of .15 M LiCl during the first discrimination test would have been greater than the 2.9 ml observed. It is suggested that the difference observed between sucrose consumption and LiCl consumption reflected both a preference for sucrose and the rapid development of an aversion for the LiCl solution.

In support of this suggestion, Rusiniak et al. (1976) demonstrated that rats accepted a .12-M LiCl solution during the first 5 min of a drinking session but then decreased consumption of the solution relative to baseline for the remaining time of the test period. These authors suggested that, within the 5 min, the rats probably detected the onset of lithium illness. The low consumption of LiCl in the present experiments suggested a similar rapid detection of the lithium illness. The rats were able to drink little of the lithium chloride solution because an alternative solution was present, a situation that is quite different from that in one-bottle tests (e.g., Nachman, 1963), where rats do not have such an option.

The consumption of sucrose and LiCl on the 2nd day of discrimination testing indicated that the lithium had produced aversive effects the day before. Although the rats still consumed significantly more sucrose than LiCl [$F(1,29) = 97.61$, $p < .001$], the consumption of both fluids was reduced significantly from the day before [$Fs(1,29) \geq 9.79$, $ps < .005$]. On the 3rd and 4th days, the consumption of sucrose returned to its relatively high level while consumption of the LiCl remained at a low mean of approximately .5 ml. This suggested an initial generalization effect followed by an increased discrimination between the sucrose and LiCl solutions.

The discrimination between distilled water and .15 M LiCl was immediate and pronounced. During the 2 days when water and LiCl were presented, the rats consumed significantly more water than LiCl [$Fs(1,29) \geq 488.85$, $ps < .001$].

On the 1st day of the test between NaCl and LiCl, the rats discriminated between the two salt solutions immediately and also consumed significantly more NaCl than LiCl on the 5 remaining test days [$Fs(1,29) \geq 24.30$, $ps < .001$]. Thus the hypothesis that prior experience with a two-bottle situation that involved LiCl would facilitate the eventual discrimination of LiCl and NaCl was supported. The present results are in marked contrast to those of Nachman (1963) in which rats did not evidence the ability to discriminate between equimolar NaCl and LiCl solutions;

the lack of discrimination was shown by the rats' refusing to consume either of the salt solutions over five periods of testing. There were four rats in the present experiment that generalized completely from LiCl to NaCl. Throughout training, these rats consumed less than 1 ml of total fluid on test days, behavior similar to that reported by Nachman (1963).

Differences in prior experience and motivation probably account for the discrepancy between the present results and those of Nachman (1963). In Nachman's study, rats were tested for 10 min a day, followed by a 50-min period of free access to water. They were trained first to avoid the LiCl by repeated presentations of LiCl in a one-bottle situation. After 11 daily trials, the rats were placed in the two-bottle situation with equimolar LiCl and NaCl solutions. During training, the rats may have learned to suppress drinking and to wait for the period of water access that immediately followed. Also, the rats had had no experience with a two-bottle situation prior to being tested in the NaCl/LiCl discrimination.

EXPERIMENT 2

The major result from Experiment 1 was that rats discriminated rapidly between equimolar (.15 M) NaCl and LiCl solutions following prior experience with a two-bottle discrimination that involved LiCl. The present experiment tested whether rats would display a discrimination between equimolar concentrations of NaCl and LiCl without prior LiCl experience. The rats in this experiment were adapted to the two-bottle situation and then presented immediately with the .15-M NaCl and .15-M LiCl solutions.

In addition, this experiment explored the limits of the discrimination between equimolar concentrations of NaCl and LiCl by determining the discrimination threshold between the two salts. This was accomplished by successively reducing the molar concentration of the two solutions until it was apparent that the rats could no longer differentiate between the two. Tests also were conducted to determine if the discrimination between the two salts at near-threshold values was based on postingestional factors or was oral-sensory in nature. And finally, various masking procedures were employed to determine if the discrimination between NaCl and LiCl was based on some obvious taste cue (e.g., sour or bitter). Selective disruption of the NaCl/LiCl discrimination by specific taste stimuli would provide insight to this possibility.

Method

Subjects

Thirty naive rats of the same sex, strain, and approximate age as those rats in Experiment 1 were used as subjects. One rat died during testing and a second rat was eliminated from the experiment when its upper incisors were damaged from biting the cage.

Procedure

The basic procedure was the same as that detailed in Experiment 1. Rats were given access to two bottles of fluid for 20 min a day; bottle position was reversed at the end of 10 min. Distilled water was presented in both bottles for 6 days to adapt the rats to the schedule.

Discrimination testing. Following adaptation, discrimination testing was begun. On the 7th day and every 3rd day thereafter, distilled water was presented to the rats. Beginning on the 8th day, the rats were presented with a .15-M NaCl solution in one bottle and a .15-M LiCl solution in the other bottle. These solutions were presented during the 2-day periods spanned by the water days until the discrimination was apparent (the mean consumption of NaCl and LiCl reached asymptotes and were significantly different from each other).

Threshold measures. Once a discrimination between .15 M NaCl and .15 M LiCl was established, threshold measures were taken to determine at what concentration the discrimination would be lost. On successive 2-day periods, the concentration of the two salts was reduced in the following order: .15, .12, .08, .04, .02, and .01 M, and in .001-M steps thereafter. When threshold was reached, a replication of a near-threshold concentration was conducted to test the stability of the discrimination over time.

NaCl mask. To test whether the discrimination found for low concentrations of NaCl and LiCl was based on oral sensory cues or postingestional cues, a masking procedure was employed. On testing days, rats were presented with .01-M NaCl and .01-M LiCl solutions masked in a .12-M NaCl solution. The .01-M solutions were made up as usual, but the .12-M NaCl solution was used as the solvent instead of distilled water. During these tests, it was necessary to interpose testing periods where the .01-M salt solutions were presented without the masker to check the status of the discrimination. At one point, it was necessary to reinstate the discrimination by presenting .12 M NaCl and .12 M LiCl for one 2-day period.

Position preference test. A further test designed to determine if the discrimination of .01 M NaCl and .01 M LiCl was based on postingestional factors was performed next. For this test, the schedule of fluid presentation was changed slightly. Every other day, the rats were presented with one bottle of distilled water for 20 min. The intervening days were test days. On the 1st test day, .01 M NaCl was presented in two bottles for 20 min (bottle position was not changed for the 20 min on the first day or on subsequent testing days). The amount of fluid consumed from each bottle position was recorded and a side preference was determined based on the bottle from which the rat consumed more fluid (for any rats that consumed equal amounts of fluid from each bottle, a "preferred" side was chosen arbitrarily). On the 2nd test day, .01 M NaCl was presented again in both bottles to determine the stability of the rats' position preferences. Following this, each test day consisted of the presentation of .01 M LiCl in the bottle on the preferred side and .01 M NaCl in the bottle on the nonpreferred side. The rationale for these procedures was that if .01 M LiCl had postingestional consequences that were sufficient to produce illness, then there should be a reversal in side preference so that the majority of fluid consumed would be .01 M NaCl. The NaCl and LiCl solutions were presented over 6 testing days.

Basic tastes mask. The final test involved attempted masking of .08 M NaCl and .08 M LiCl with various solutions that represented the four basic tastes. The masking procedures were conducted to test whether there was a specific taste difference between NaCl and LiCl. Fluid access was returned to the original schedule of 20 min daily access to two bottles of fluid.

On the first 2-day period, the rats were presented with .08 M NaCl in one bottle and .08 M LiCl in the second bottle. The data taken from this test were used as a baseline with which the effectiveness of the various maskers could be compared. During the next four test periods, each consisting of 2 days, .08 M NaCl

and .08 M LiCl were masked with four different taste solutions: .10 M sucrose, .07 M NaCl, .01 M hydrochloric acid (HCl), and 3×10^{-5} M quinine hydrochloride (QHCl). The rats were divided into four equal groups ($n = 7$ for each group) and were presented with the four different masking tests according to a balanced Latin square design.

Following the presentation of each individual masker, a combined-taste masker that included all four tastes was used to mask the .08 M salt solutions. The .08 M NaCl and .08 M LiCl were made up as usual but with the combined masker (.10 M sucrose, .07 M NaCl, .01 M HCl, and 3×10^{-5} M QHCl) as the solvent instead of distilled water.

Results and Discussion

Discrimination Testing

The results from the discrimination test are shown in Figure 2. The rats displayed an initial generalization followed by a clear discrimination between the .15-M NaCl and .15-M LiCl solutions. On the first day of testing, the amount of NaCl consumed was not significantly different from the amount of LiCl consumed [$F(1,29) = 1.20$, $p > .10$]. These data indicated that the immediate discrimination between NaCl and LiCl seen in Experiment 1 was dependent upon prior experience with a two-bottle discrimination that involved LiCl. Without such experience in the present experiment, the rats consumed virtually the same amount of NaCl and LiCl on the first exposure.

On the 2nd day of discrimination testing, both NaCl consumption and LiCl consumption were reduced significantly [$F(1,29) \geq 15.28$, $ps < .001$]. Despite the low consumptions on the 2nd day, the beginning of a discrimination between NaCl and LiCl was evident. On this day, the rats consumed significantly more NaCl than LiCl [$F(1,29) = 12.04$, $p < .005$]. As can be seen in Figure 2, the difference

Figure 2. Mean milliliters consumed ($\pm$ standard errors) of the .15-M NaCl solution and the .15-M LiCl solution during discrimination testing in Experiment 2.

between NaCl consumption and LiCl consumption became greater and stabilized on the remaining days of discrimination testing. Similar to Experiment 1, there were three rats that consistently refused to consume either of the two salt solutions, a result which indicated that a small percentage of rats generalized completely from a LiCl solution to an equimolar NaCl solution.

The present results indicated that rats can discriminate reliably between equimolar NaCl and LiCl solutions. Although the rats in Experiment 2 did not evidence an immediate discrimination between the two salt solutions, the discrimination was established quickly and then maintained across repeated presentations.

Threshold Measures

Figure 3 presents the data obtained during the threshold measurements. Note that each data point is the mean of a 2-day total. Collapsing of the 2 days during which one concentration was run was necessary because several rats began exhibiting position preferences; collapsing the 2 days balanced the starting position of each salt solution.

As can be seen in Figure 3, the mean amount of NaCl consumed approached the mean amount of LiCl consumed as the concentrations were reduced progressively. The rats discriminated between NaCl and LiCl down to the concentration of .008 M, at which the rats still consumed significantly more NaCl than LiCl [$F(1,28) = 7.23, p < .02$]. The amounts of .007 M NaCl and .007 M LiCl consumed did not differ significantly. This differential threshold value is interesting because tests from the present laboratory (Braun & Kiefer, 1975) had indicated that the detection threshold, as determined by preference criteria, for NaCl in normal rats was approximately .01 M. The author is unaware of any similar detection threshold data for LiCl. But as a preliminary conclusion, the combined data suggest that rats can discriminate between NaCl and LiCl down to concentrations that either approach or are the same as the detection threshold for NaCl.

Figure 3. Mean milliliters consumed ($\pm$ standard errors) of NaCl and LiCl as a function of molar concentration in Experiment 2. The logarithmic scale is reversed in this figure to coincide with the order of fluid presentation (descending order).

NaCl Mask

The results from the first masking procedures are presented in Table 1. Each entry presents the mean amount of fluid consumed for the salt solutions over each 2-day period. The first presentation of .01 M was a replication of that concentration run during the threshold measures. As can be seen, the rats consumed significantly more NaCl than LiCl. The mean amounts consumed can be compared with those consumptions recorded during the threshold measures (19.9 ml for NaCl and 11.12 ml for LiCl). These data suggest that little extinction of the discrimination occurred during the presentation of the low salt concentrations; also, the replication indicated that the function shown in Figure 3 was not simply due to extinction.

On the days when the .01 M salt solutions were masked with .12 M NaCl, the discrimination appeared to be disrupted. However, the efficacy of the masker was difficult to determine, because the discrimination between .01 M NaCl and .01 M LiCl

Table 1
Mean Milliliters Consumed ($\pm$ Standard Errors): 2-Day Totals

	.01 M*		Masked .01 M		.01 M		.12 M*		.01 M*	
	NaCl	LiCl	NaCl	LiCl	NaCl	LiCl	NaCl	LiCl	NaCl	LiCl
Mean	20.7	12.3	13.1	11.2	16.5	14.8	33.0	3.2	19.8	12.4
$\pm$ SE	1.5	1.1	1.4	1.4	1.2	1.3	2.5	.7	1.4	1.1
	Masked .01 M		.01 M		.01 M*		.01 M*		.01 M	
	NaCl	LiCl	NaCl	LiCl	NaCl	LiCl	NaCl	LiCl	NaCl	LiCl
Mean	18.3	13.1	17.0	14.6	17.4	11.9	17.3	12.0	14.9	14.1
$\pm$ SE	2.2	1.5	1.1	1.3	.8	1.0	1.1	1.0	.8	.8

* $p < .05$

appeared to extinguish. Despite this, the data do suggest that the discrimination between low concentrations of NaCl and LiCl was based on oral-sensory cues, because the first masking procedure disrupted the discrimination. The results from the second masking test did provide an initial indication that, with further training, the rats would have learned to discriminate between the masked salt solutions.

Position Preference Test

This test was designed to determine further if low concentrations of LiCl had significant adverse effects. The results from this test are shown in Figure 4. The 1st day was used to determine position preferences. The data from the 2nd day indicated that the position preferences were not stable; some rats reversed side preference and consumed more fluid from the unpreferred side on the 2nd day. On the remaining 6 test days, .01 M LiCl was presented on the preferred side to see if changes in consumption from the preferred bottle would occur. As can be seen, the rats did not show any significant change in drinking patterns during the test days. Again, if the discriminations found earlier were based on adverse postingestional cues, one would expect the rats to change bottle position with repeated presentations.

Basic Tastes Mask

The results from the last phase of the experiment are shown in Figure 5. Masking of the .08-M NaCl and .08-M LiCl solutions with the sucrose, quinine,

Figure 4. Mean milliliter consumed ($\pm$ standard errors) of .01 M NaCl and .01 M LiCl during the position preference test in Experiment 2. Dashed line indicates mean milliliters consumed from the bottle on the preferred side; solid line indicates mean milliliters consumed on the nonpreferred side. Note that .01 M NaCl was presented in both bottles on the first 2 days of testing.

Figure 5. The results from the masking tests in Experiment 2. Each bar represents the mean milliliters consumed ($\pm$ standard errors) of .08 M NaCl and .08 M LiCl under each masking condition.

salt, or acid solutions, either alone or together in the combined-taste mask, failed to disrupt the discrimination. In all of the masking tests, the rats consumed significantly more .08 M NaCl than .08 M LiCl [$F(1,27) \geq 48.44$, $p < .001$]. Overall analysis of the data indicated a significant treatment effect [$F(5,135) = 6.143$, $p < .001$]; comparison of each masking condition with the no-mask, control treatment indicated that only the consumption of the combined mask differed significantly from the control condition [Dunnett test, $F(6,135) = 2.50$, $p < .05$]. The significantly lower consumption of the combined masking solutions probably was due to the noxious taste of these solutions.

Taken together, the results of Experiment 2 further attest to the ability of rats to discriminate between equimolar NaCl and LiCl solutions, even under circumstances in which attempts were made to mask the solutions with other taste stimuli. Rusiniak et al. (1976) found that rats could discriminate .12 M NaCl from .12 M LiCl when the solutions were masked with a saccharin taste. When a combined flavor solution (saccharin, acetic acid, and quinine hydrochloride) was used, most rats failed to discriminate between NaCl and LiCl. However, the rats presented with the complex masking solution had no prior experience with NaCl and LiCl, while the rats in the present experiment had extensive experience. This prior experience no doubt facilitated the rats' ability to discriminate NaCl from LiCl when the masking solutions were used.

GENERAL DISCUSSION

Rats can discriminate between equimolar solutions of NaCl and LiCl in two-bottle tests. When given

experience with a two-bottle discrimination that involved LiCl, the rats were able to discriminate immediately between the two salt solutions (Experiment 1). When given no prior experience with LiCl, a discrimination between NaCl and LiCl solutions was not immediately apparent but was established quickly after an initial tendency to generalize from lithium to sodium (Experiment 2). These results therefore support and extend an earlier report of Rusiniak et al. (1976), who demonstrated similar discrimination capabilities in a one-bottle test.

Once the discrimination between .15 M NaCl and .15 M LiCl was established in Experiment 2, the rats proved to be quite proficient at maintaining the discrimination under a variety of conditions. It was found, for example, that they discriminated between equimolar NaCl and LiCl solutions down to a concentration of .008 M. This concentration represented a weak stimulus intensity that was close to detection thresholds for NaCl that have been reported for rats. Richter (1939) found that the detection threshold for NaCl in normal rats was approximately .01 M; in his experiment, rats were given a choice between water and NaCl solutions in a two-bottle test. One-bottle tests from the present laboratory (Braun & Kiefer, 1975) found similar threshold values for normal rats.

The failure to disrupt a discrimination between .08 M NaCl and .08 M LiCl with the masking procedures was another indication of the rats' discrimination capabilities. This discrimination was maintained even when the solutions were masked with the sucrose, salt, quinine, or hydrochloric acid. The complex masking solution that included all four tastes succeeded in reducing the overall fluid consumption a small amount but failed to disrupt the discrimination.

The sensory basis of the discrimination between equimolar NaCl and LiCl solutions could be based on any of several cues. One possibility is that rats use the adverse postingestional effects to determine if the solution is LiCl rather than NaCl. This possibility is deemed unlikely, however, because Rusiniak et al. (1976) showed that rats fitted with intragastric tubes could not use the postingestional cues of LiCl to escape illness. In their experiment, rats were intubated with .12 M LiCl every 3rd day during restricted water access. The amount of LiCl that was intubated was roughly equivalent to the amount of water the rat drank (as measured by lick rate). The rats failed to show differential responding (licking) on the lithium days as opposed to the control days when the rats were intubated with an equimolar NaCl solution. Furthermore, in the present experiment, discrimination of at least the low molar concentrations did not appear to be based on postingestional factors, because: (1) rats that discriminated .01 M NaCl from .01 M LiCl eventually extinguished the

discrimination, a result which indicated that .01 M LiCl did not have significant adverse effects; (2) the rats did not alter obviously their drinking patterns when the .01 M LiCl was put on the side from which they normally consumed the majority of their fluid. Taken together, it would appear that the rats' ability to discriminate NaCl from LiCl is not dependent upon postingestional factors.

Another possibility to account for the rats' ability to discriminate NaCl from LiCl is that these salts enter the bloodstream at the back of the mouth and enter the brain directly (Maller, Kare, Welt, & Behrman, 1967). With such rapid access to areas like the area postrema, LiCl could stimulate certain receptors, thereby indicating that the substance is toxic. However, observation of the rats' behavior once the discrimination was established indicated that many rats needed only a few licks of the LiCl solution before they would switch to the other bottle. But, because these observations were not quantified, the possibility that LiCl does enter the blood and signal central receptors cannot be ruled out.

It is possible that rats can use olfactory cues to discriminate NaCl from LiCl. Miller and Erickson (1966) had shown earlier that rats could discriminate strong NaCl and LiCl solutions from water on the basis of odor alone. However, Harriman, Nance, and Milner (1968) have shown that anosmic, adrenalectomized rats discriminated between NaCl and LiCl as well as adrenalectomized rats with intact olfactory systems. Thus odor would seem to be an unlikely candidate for the sensory basis of the NaCl/LiCl discrimination.

It would appear that subtle sensory differences do exist between NaCl and LiCl. As Rusiniak et al. (1976) already have suggested, it is thought that the sensory difference is based on oral cues. There does not appear to be an obvious taste quality to LiCl (such as, for example, sweet or bitter) differentiating it from NaCl, because the various masking flavors failed to disrupt the discrimination between the two salts. To this experimenter, the LiCl solutions had a metallic sensation that is difficult to describe but which seems distinctly different from any of the four basic tastes. Thus there may be a sensory quality (which may be tactile) about LiCl that could provide enough information to rats so that they could discriminate it from NaCl.

The subtlety of a sensory difference between NaCl and LiCl when the solutions stimulate the oral cavity and tongue might account for why rats did not discriminate immediately between NaCl and LiCl in Experiment 2. The immediate discrimination between NaCl and LiCl in the first experiment was observed probably because the rats had prior experience with the LiCl solution. It seemed reasonable that, once the discrimination was established, the other

cues may have been relied upon. Such a potentiation of a normally weak stimulus cue when combined with a taste cue has already been shown for odors (Braun & Ryugo, 1974) and possibly could be true for other (e.g., tactile) qualities of taste solutions.

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