Effects of formalin-induced Na deficiency on CaCl_2 and KCl acceptability*

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A study by Kriekhaus and Wolf found that following formalin-induced sodium deficiency resistance to extinction was much stronger in animals who had been trained to barpress for sodium salts than in those trained for potassium or calcium. However, a significant difference exists between the latter two groups in the opposite direction from what would be expected, a result apparently overlooked by the authors. The present study replicated this result and concludes that the difference is, in fact, due to the formalin injection treatment.

Since it has been suggested that sodium deficiency produces an altered appetite that is highly specific to sodium-containing solutions (for example, Wolf, 1969), it is of some interest that one of the studies on which this argument is based actually contains a result, apparently overlooked by the authors, that contraindicates this conclusion (Kriekhaus & Wolf, 1968).

In Experiment 3 of this study, five groups of animals were trained to barpress under water deprivation on a 1-min VI schedule. Three of these groups were responding for sodium salts, the remaining two control groups for CaCl_2 or KCl. Sodium deficiency was then induced by subcutaneous formalin injection, and following this the animals were tested with a 1-h extinction session.

The main result is clear: the sodium-trained animals do substantially more responding to extinction than the controls. However, the authors conclude, "there were no significant differences . . . between the two groups trained without sodium." It is this conclusion that is at variance with the results. The mean number of responses, taking the data from Table 2 (p. 199), for the CaCl_2 trained animals was 78 and for the KCl trained animals, 46, the difference between these being significant ($p < .05$, two-tailed t or Mann-Whitney U).

This is not a question of the particular level of significance one is willing to accept, since for this particular case the null hypothesis of no difference between means, and consequently the obtained p value, is a very conservative one. If Na deprivation is not affecting the two groups differentially, one would predict a significant difference between the means in the opposite direction from the obtained one, since

it would be reasonable to assume that rate of responding to be positively related to the palatability of the reinforcement. At the concentrations used, 0.15 Molar, KCl is much more acceptable to the rat than CaCl_2 . Based on a 1-h two-bottle intake test, the authors give the palatability of KCl to be 33% of CaCl_2 , 1% where these figures represent: 100 x salt solution intake/total fluid intake.

The following experiment is an attempt to determine whether or not this finding can, in fact, be attributed to the formalin injection treatment by eliminating some of the other possible causes.

Three other possibilities that arise out of the Kriekhaus and Wolf design are the following: (1) Although KCl is preferred to CaCl_2 using intake as a measure, this might be reversed in a brief exposure test. Barpress rates during acquisition might be higher for CaCl_2 than for KCl. These data are not given for the previous study. (2) An extinction test per se without Na depletion might, for some reason, give a reversal in response rate. (3) Their animals were trained under water

deprivation, but the extinction test was run following ad lib water but with food (and Na) deprivation. Relative palatability for the two salts may reverse with food deprivation or the absence of water deprivation.

METHOD

Twenty-four naive male hooded rats were pre-trained to barpress for water in six identical Skinner boxes and then given one session on a 1-min VI schedule for water. They were then divided into two groups which were matched for mean response rate on this final pretraining day. Group Ca were then given .15 Molar CaCl_2 as their reinforcement in subsequent sessions and Group K, .15 M KCl. Except where noted, the animals were tested under 22-h water deprivation with 1-h test sessions using a 1-min VI reinforcement schedule. The sequence of testing was: (1) 2 days reinforced responding; (2) extinction test, water deprived; (3) 2 days reinforced responding; (4) extinction test, food deprived, no water deprivation; (5) 3 days reinforced responding, subcutaneous injection of 2.5 ml, 1.5% formalin following the test session on third day; (6) extinction test, food (and Na) deprivation, no water deprivation, followed 4 h later by a final reinforced session.

RESULTS

Reinforced responding

The two groups were equated on the basis of their response rates to water, the mean number of responses in this session being 738 for Group Ca and 754 for Group K. On the first session with the salt solutions, the rate declined to 212 in the former and increased to 804 in the latter. Throughout the remainder of the reinforced sessions, with the exception of the final one following formalin injection, the rates in both groups increased, with Group K always

Table 1
Number of Responses Made in 1-H Test Sessions by Groups Ca and K Animals

	Water-Deprived Extinction		Food-Deprived Extinction		Food- and Na-Deprived Extinction		Food- and Na-Deprived Reinforced	
	Ca	K	Ca	K	Ca	K	Ca	K
	410	494	16	54	31	8	95	14
	151	359	7	99	45	23	161	42
	116	224	23	19	35	12	150	84
	180	290	30	42	17	11	5	11
	123	284	58	46	10	8	4	1
	152	221	68	44	10	37	118	37
	180	317	43	72	13	8	143	36
	108	82	8	7	29	8	19	9
	161	565	10	28	2	2	19	3
	88	136	25	75	5	12	10	149
	11	527	5	87	13	17	14	20
	103	217	26	73	26	11	1	10
Mean	137	287	27	54	20	13	62	35
t	3.11		2.72		-1.41		-1.18	
p	< .01		< .02		< .10		< .15	
	two-tailed		two-tailed		one-tailed		one-tailed	

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Table 2
Summary of a Two-Way Analysis of Variance Combining Kriekhaus and Wolf's Results
With Those of the First Extinction Test. The deprivation conditions are Na (K and W)
vs water (M), reinforcement conditions KCl vs CaCl₂.

Source	Mean Square	df	F	p
Deprivation	336,508	1	38.71	< .001
Reinforcement	49,988	1	5.75	< .025
Interaction	111,843	1	12.86	< .001
Error	8,694	44		

responding at a rate slightly less than double that of Group Ca. Mean rate over all these sessions was 504 for Group CA and 928 for Group K.

From these results it is apparent that the Kriekhaus and Wolf result is not due to a reversal in relative palatability under conditions of brief exposure.

Extinction Responding

Table 1 shows the number of responses under the three extinction conditions and the final acquisition session following formalin injection.

Under water or food deprivation, Group K again made approximately twice as many responses as Group Ca, with the differences significant in both cases. Following formalin injection, this difference is reversed, the Group Ca animals responding more than the Group K ones both in extinction and acquisition. Although these differences do not reach statistical significance on the basis of a null hypothesis of no difference, they do represent a significant reversal from all previous conditions.

A possibly more appropriate statistical analysis would be to compare the results of the first extinction test, under water deprivation, with Kriekhaus and Wolf's results. The animals at this

point have had similar pretest training and are on extinction for the first time. The emphasis here would be on the existence of a Deprivation Condition by Reinforcement interaction. Table 2 gives the results of this analysis.

It appears, therefore, that the effect is dependent on the formalin injection or at least is not attributable to the other possible causes listed above. The results also suggest that while the relative reinforcing properties of KCl and CaCl₂ are reversed, neither of these is a particularly strong reinforcer for Na-deficient rats.

DISCUSSION

Formalin injection is a commonly used technique for inducing sodium need. The question, of course, can be raised as to whether the present results are due to this sodium need or to some other effect of the injection. It is unlikely that they can be attributed to a generalization effect from the taste of sodium, since both neural data (Erickson, 1967) and behavioral data (Morrison, 1967, 1969) indicate that, qualitatively, KCl is more similar to NaCl than is CaCl₂.

A variety of other methods have been used to induce sodium need, and in general the conclusions have been that the resulting appetite is specific to

sodium. However, Falk (1965) has shown that when the solutions are equated for palatability, intraperitoneal dialysis also increases KCl acceptability, and Jalowiec, Crapanzano, & Stricker (1966) find increased KCl but not CaCl₂ intake following polyethylene glycol injection. Combined with the present results, these facts, particularly the latter ones, suggest that, depending on the technique used to invoke it, mechanisms other than Na need may be called into play which affect the relative palatability of salts. Clearly, however, the degree of appetite specificity resulting from sodium deprivation remains open to further investigation.

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