Rat's aversion to flavors following induced illness*

GEORGE E. HARGRAVE and ROBERT C. BOLLES
University of Washington, Seattle, Wash. 98105

This study confirms previous reports that rats can learn from a single induced illness to avoid a novel food encountered just prior to becoming ill and points to the relative specificity of the adequate stimulus. Rats appear to avoid the taste of the illness-associated food but not its smell or its location.

When a rat ingests a novel food substance and is then made sick, it subsequently tends to avoid that food (Garcia, Kimeldorf, & Hunt, 1961). Such food aversions have been found for foods varying from lab chow (Garcia et al., 1961) to grape juice (Revusky & Bedarf, 1966) and have been produced by methods of inducing sickness ranging from X-irradiation (Garcia et al., 1961) to injection of insulin (Lovett, Goodchild, & Booth, 1968) and lithium chloride (Nachman, 1968). One remarkable feature of this aversion of food associated with illness is that the aversion can be learned even when the sickness is induced as much as 12 h after ingestion (Smith & Roll, 1967). Garcia & Koelling (1966) have suggested that the possibility for learning with such extremely long delays depends upon the existence of certain specific channels in which learning can take place with unusual facility. These writers propose that, in the case of the rat, there is such a channel for the association of the sensory qualities of food substances and the long-delayed beneficial or noxious aftereffects of injections. Garcia and Koelling support their argument with the dramatic demonstration that the drinking of "tasty" water could be suppressed by a subsequent internal event (sickness) but not by an external event (shock). By contrast, they found that the drinking of "bright, noisy" water was suppressed by shock but not by sickness. Evidently, for the rat, the visual and auditory dimensions of a novel food are not readily associated with a subsequent illness, whereas the taste of the food is. The species-specific nature of these readily made associations is illustrated by the recent report that, for the quail, *Colinus virginianus*, visual aspects of the food are more important in a learned aversion than its taste (Wilcoxon, Dragoin, & Kral, 1968; see also, Capretta, 1961).

The present study suggests that taste is the only relevant sensory dimension for the rat. The rat does not

seem to avoid the smell of the substance or the place where ingestion has been followed by illness. Additionally, we demonstrate that a food aversion resulting from induced illness can be established with a single "trial," i.e., with a single association of a novel food with illness.

METHOD

Twenty-four male Long-Evans rats were used in a procedure where ingestion of a specific food was followed by sickness. The rats were housed in individual cages and were given 3 days adaption to a once-a-day 1-h feeding schedule. Then an initial preference test between chocolate and strawberry Metrecal was conducted by simultaneously placing bottles of the two flavors in the cages for the 1-h feeding period. Metrecal was used because it equates all dietary qualities except flavor. Kaopectate was added to prevent diarrhea. Preference for one flavor of Metrecal over the other was determined for each S, and the nonpreferred flavor was then presented as the S's only food for 1 h a day for 3 days. Each S was fed during this hour in a distinctive unpainted wooden box that was 35 cm long, 35 cm high, and 10 cm wide. On the fourth day, all animals were given their originally preferred flavor of Metrecal for 30 min in one of two novel environments. To control for any possible bias due to the experimental situation, one-half of the animals received this food in a distinctive box with painted stripes, while the other half received the food in a painted gray box. Thirty minutes later, one-half of the Ss in each environmental group (striped box and gray) were made ill by an intraperitoneal injection of 15% saline solution (3 ml/kg body weight); the other half were given comparable injections of isotonic saline. All animals were then returned to their home cages.

All animals were tested on the next day, 23.5 h after the single induction of illness. To test for an association of the place of feeding and later illness, a Y-maze was constructed so that the empty striped feeding box was on one arm and the empty gray box was on

the other. If place were important, the Ss in the group that was made sick should avoid the box where the "bad" food was eaten. Following the place test, all Ss were tested for a possible association of a distinct odor with subsequent sickness. Two such tests were run. The first was an avoidance test where neutral boxes were placed on the arms of the Y-maze and the smell of the "bad" food presented in one of the arms. The second was a preference test where the neutral boxes were used with a chocolate odor in one arm and a strawberry odor in the other. Finally, a test for the association of taste with illness was conducted by measuring food consumed for the two flavors when they were simultaneously presented in the home cages for 30 min. The home cages were used for the taste test to eliminate any possible residual environmental effects.

RESULTS AND DISCUSSION

The results showed that the environment in which the animal ate prior to illness and the smell of the food in a neutral environment were not avoided. Choices between arms of the Y-maze for the place test, as well as both tests for smell, were apparently random in both cases and did not approach statistical significance. Clear differences in the taste test were found, however. Those animals which were made sick after eating their previously preferred flavor (on the pretest) changed their preference and consumed, instead, predominantly their formerly nonpreferred flavor. By contrast, the control animals maintained their original preferences. The magnitude of this effect is shown in Table 1.

These results indicate that rats can avoid a food that has been associated with illness after a single experience. One-trial acquisition has been reported before by several Es using irradiation techniques, so its occurrence with other illness-inducing techniques should not be surprising. Indeed, such rapid acquisition might be expected from ethological considerations. The rat (even the laboratory variety) is an omnivorous scavenger and so has probably survived strong selection pressure to evolve a mechanism to "remember" and avoid novel foods that result in illness. Such a selection

Table 1
Consumption of the Initially Nonpreferred Food as a Percentage of Total Consumption (Means and Standard Errors)

	N	
Pretest	24	33.5 ± 4.7
Posttest		
Experimental	12	72.3 ± 9.3
Control	12	30.5 ± 8.4

*Supported by NSF Grant GB-8035.

pressure operates on a variety of animals, of course, but we may expect adaptations to it to be most evident among omnivorous feeders. Alcock (1971) has compared learned food aversions in black-capped chickadees, which are relatively wide-ranging eaters, and white-crowned sparrows, which are more conservative eaters. He found that the chickadees developed more generalized and more persistent aversions to noxious mealworms than did the sparrows. We would generalize these findings to predict that learned food aversions would be quite difficult to demonstrate in highly specialized feeders.

The present results indicate that the environmental cue which is most instrumental for the rat in producing aversion for illness-producing foods appears to be the flavor of the food, with visual and olfactory cues playing much less of a role. However, it would be wrong to conclude that the rat cannot acquire a food aversion based upon the sight or smell of a substance. For one thing, there is no reason to suppose that the different test procedures used here for the different sense modalities had the same sensitivity, so that we could not have gotten location- or olfactory-based aversion by using other procedures. For another thing, food aversions cued by other sense modalities have been reported in the rat (Garcia et al, 1961; Lovett et al, 1968). But when we turn to dimensions other than taste or to behaviors other than ingestion (Garcia, Kovner, & Green, 1970), we find much less impressive and less rapid learning. What should be concluded, then, is that the rat has a remarkable ability to learn a particular kind of highly specific association, namely, the avoidance of a taste that has preceded illness.

REFERENCES

- ALCOCK, J. Interspecific differences in avian feeding behavior and the evaluation of Batesian mimicry. *Animal Behaviour*, 1971, in press.
- CAPRETTA, P. J. An experimental modification of food preference in chickens. *Journal of Comparative & Physiological Psychology*, 1961, 54, 238-242.
- GARCIA, J., KIMELDORF, D. J., & HUNT, E. L. The use of ionizing radiation as a motivating stimulus. *Psychological Review*, 1961, 68, 383-395.
- GARCIA, J., & KOELLING, R. A. Relation of cue to consequence in avoidance learning. *Psychonomic Science*, 1966, 4, 123-124.
- GARCIA, J., KOVNER, R., & GREEN, K. F. Cue properties vs palatability of flavors in avoidance learning. *Psychonomic Science*, 1970, 20, 313-314.
- LOVETT, D., GOODCHILD, P., & BOOTHE, D. A. Depression of intake and nutriment by association of its odor with effects of insulin. *Psychonomic Science*, 1968, 11, 27-28.
- NACHMAN, M. Some stimulus conditions affecting learned aversions produced by illness. Paper presented at the Third International Conference on the Regulation of Food and Water Intake, Haverford, 1968.
- REVUSKY, S. H., & BEDARF, E. W. Association of illness with prior ingestion of novel foods. *Science*, 1967, 155, 219-220.
- SMITH, J. C., & ROLL, D. L. Trace conditioning with X-rays as the aversive stimulus. *Psychonomic Science*, 1967, 9, 11-12.
- WILCOXON, H. C., DRAGOIN, W. B., & KRAL, P. A. Differential conditioning to visual and gustatory cues in quail and rat: Illness-induced aversions. Paper presented at the Tenth Meeting of the Psychonomic Society, St. Louis, 1969.

Extinction in a straight alley as a function of varied quality and quantity of reward sequence

WILLIAM N. BOYER, RAYMOND RUSSIN, and HENRY A. CROSS
Colorado State University, Fort Collins, Colo. 80521

Six groups of albino rats were extinguished in a straight alley after receiving two daily trials on one of the following varied quality and/or quantity of reward sequences: 1 regular pellet followed by 1 regular pellet, 1 regular pellet followed by 1 sucrose pellet, 1 sucrose pellet followed by 1 regular pellet, 1 regular pellet followed by 16 sucrose pellets, 1 sucrose pellet followed by 16 sucrose pellets, and 16 sucrose pellets followed by 1 sucrose pellet. Further evidence for an extension of the sequential hypothesis to include quality of reward was provided by showing that greater resistance to extinction results when a high-quality reward follows a low-quality reward than when the opposite sequence occurs. In addition, variations in both quantity and quality of reward produced more resistance to extinction than variations in quantity of reward alone.

In a varied magnitude-of-reward experiment, Leonard (1969) reported that Ss receiving two trials a day with a small reward on Trial 1 and a large reward on Trial 2 (SL) were more resistant to extinction than Ss receiving the opposite sequence (LS). Recently, Russin, Boyer, & Cross (1970) demonstrated that quality of reward operates similarly to quantity of reward in a two-trial sequence. While this study suggested that a "high-quality" reward following a "low-quality" reward¹ produced more resistance to extinction than a low-quality reward following a high-quality reward, a much stronger effect was observed by varying both quality and quantity of reward than quantity alone.

These results have been interpreted within a sequential framework (Capaldi, 1967) which states that different magnitudes of reward vary along a continuum, large reward to no reward, and that a small reward on Trial 1 produces a stimulus aftereffect which is very similar to the aftereffect of nonreward experienced in extinction. The Trial 2 reward conditions this aftereffect strongly or weakly depending upon its size.

Resistance to extinction can thus be increased by using a second reward greater in magnitude than the first reward. The present experiment represented an attempt to verify the Russin et al findings and to test more completely the effect of varied quality and combinations of varied quality and quantity of sequenced rewards upon extinction.

Six groups of rats were given two trials each day on one of the following reward sequences: Group R1-R1 received 1 regular pellet on the first daily trial, followed by 1 regular pellet on the second daily trial; Group R1-S1, a single regular pellet followed by a single sucrose pellet; Group S1-R1, 1 sucrose pellet followed by 1 regular pellet; Group R1-S16, a single regular pellet on Trial 1 followed by 16 sucrose pellets on Trial 2; Group S1-S16, a single sucrose pellet followed by 16 sucrose pellets; and Group S16-S1, 16 sucrose pellets on the first trial followed by 1 sucrose pellet on the second trial. The sequential hypothesis, in combination with the Russin et al findings, would allow the prediction that the rank ordering of groups from most resistant to least would be as follows: R1-S16, S1-S16,