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Immediate and Delayed Reinforcers for Flavor Preferences in Rats

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When rats received, on alternate days, one flavored saccharin solution for 5 min and a differently-flavored saccharin solution for 60 min, they showed no consistent preference between the flavors. On the other hand, when they received one flavor in a concentrated saccharin solution and a different flavor in a dilute one, they preferred the first flavor in tests with saccharin concentration held constant; also, rats learned to prefer a flavor immediately followed by a concentrated saccharin solution to one followed by nothing. They showed no consistent preference, however, between a flavor followed 30 min later by a concentrated saccharin solution and one followed by nothing; but they learned to prefer a flavor followed 30 min later by a dextrose solution to one followed by nothing. In other words, consummatory responding did not reinforce flavor preference, sweet taste did so with immediate but not delayed reinforcement, and nutrition did so even with delayed reinforcement.

Traditional questions about theoretical conditions for reinforcement have become more complicated since Garcia and Koelling (1966) showed that the effectiveness of reinforcers depends upon the cues with which they are associated. For visual and auditory cues, Kimble (1961) cites numerous studies contradicting Hull's (1943) original hypothesis that positive and negative reinforcement depend respectively upon reduction and augmentation of bodily need. For gustatory cues, however, the evidence reviewed by Revusky and Garcia (1970) and Rozin and Kalat (1971) shows no such counter-examples: known reinforcers for taste aversions include X-rays, various drugs, and dietary deficiencies, while known reinforcers for taste preferences include recovery from drugs or deficiencies, and food or water for hungry or thirsty animals. The present experiments associated other possible reinforcers with gustatory cues, in order to investigate whether and under what conditions need reduction is necessary for the reinforcement of flavor preferences.

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EXPERIMENT 1

Sheffield and Roby (1950) and Sheffield, Roby, and Campbell (1954) found that saccharin solution reinforced instrumental running in rats; they attributed this reinforcement to the consummatory response of drinking elicited by the saccharin. The first experiment therefore tested whether a flavor preference could also be reinforced by consummatory responding for saccharin or by the volume of saccharin solution consumed. Rats received, on alternate days of training, one flavored saccharin solution for 5 min and a differently flavored saccharin solution for 60 min. Since the rats consumed much more in 60 min than in 5 min, they had the opportunity to associate the 60-min flavor with more drinking and with more saccharin solution drunk. Subsequent two-bottle tests ascertained whether these differences had any effect on flavor preference.

Method

Subjects. The subjects were 16 naive female Sprague–Dawley rats obtained at the age of about 90 days from Simonson Laboratories, Gilroy, CA.

Materials. The two solutions contained 0.16% sodium saccharin dissolved in water and flavored with 1.5% Crown Colony almond or banana extract. The solutions were provided to the rats in graduated test tubes with drinking spouts, which were attached to the rats' home cages in place of the water bottles.

Procedure. The rats lived in individual cages with constant temperature and illumination; they had continuous access to water, except when offered the solutions instead. For 2 wk before the experiment, they were handled and then fed 10 g of laboratory chow daily. During the experiment, they were handled immediately before the solution was offered, and fed 10 g of Purina Lab Chow 1 hr after the solution was removed.

The experiment consisted of 20 days of training followed by a test day, then 4 more training days followed by another test day. All the rats were offered 40 ml of the almond solution on odd-numbered training days and 40 ml of the banana solution on even-numbered days. During training, the rats were divided into two equal groups; Group A received the almond solution for 60 min and the banana solution for 5 min; Group B received the almond solution for 5 min and the banana solution for 60 min. On each test day, all the rats were offered 40 ml of each solution side by side for 30 min.

Results

Table 1 gives the mean daily consumption of the almond (A) and banana (B) solutions by the two groups during training and tests. In

TABLE 1
MEAN DAILY CONSUMPTION (ml) IN EXPT 1

	Training solutions		First test solutions		Second test solutions	
	A	B	A	B	A	B
Group A	21.8	5.5	11.9	8.9	9.5	13.1
Group B	5.0	25.7	10.4	12.2	11.1	13.2

training, each rat drank more of the 60-min flavor than of the 5-min flavor. This difference vanished, however, in the tests: consumption of the two flavors did not differ significantly ($F(1,14) = 0.4$).[1] In each test, only 9 of the 16 rats drank more of the 60-min flavor than of the 5-min flavor. Consequently, even a sizeable difference in consummatory responding and volume consumed failed to cause a flavor preference.

EXPERIMENT 2

Young (1949) has suggested that saccharin is reinforcing because of the hedonic effects of its sweet taste. The second experiment therefore tested whether preference for a neutral flavor could be influenced by the sweetness of a substance associated with it. Rats received, on alternate days of training, a concentrated saccharin solution mixed with one flavor and a dilute saccharin solution mixed with another flavor. Subsequent two-bottle tests offered the rats a choice between the two flavors mixed with the same concentration of saccharin.

Method

Subjects. The subjects were 18 naive female rats of the same age, strain, and origin as in Expt 1.

Materials. The concentrated and dilute saccharin solutions contained respectively 0.32 and 0.065% sodium saccharin dissolved in water; the flavors were again 1.5% Crown Colony almond and banana extracts. In pilot experiments, rats drank more 0.32% saccharin than solutions of either higher or lower concentrations in 30-min two-bottle tests; 0.32% was also close to the most preferred saccharin concentrations in the experiments of Collier and Novell (1967) and Young and Greene (1953).

Procedure. The rats were housed, handled, watered, and fed as in Expt 1. The experiment again consisted of 20 training days followed by

[1] Since the rats' consumption was approximately normally distributed, all statistical tests in this paper are mixed-design analyses of variance, with flavors, training groups, and (in Expts 1 and 2 only) test days as factors; the significance level is .05 throughout.

a test day, then 4 more training days followed by another test day. On each training day, the rats were offered 20 ml of solution for 60 min; they all received an almond solution on odd-numbered training days and a banana solution on even-numbered training days. The rats were divided into two equal groups: for Group A, the almond solution contained the concentrated saccharin and the banana solution contained the dilute saccharin; for Group B, the almond solution was dilute and the banana solution concentrated. On each test day, all the rats were offered 40 ml of almond and banana solutions side by side for 30 min. Both solutions contained dilute saccharin on the first test day and concentrated saccharin on the second test day.

Results

Table 2 gives the mean daily consumption of the almond (A) and banana (B) solutions by the two groups during training and tests. In training, each rat drank more of the concentrated solution than of the dilute one. Because of the limitation on the amount offered, however, the difference between the two solutions was not nearly as great as in Expt 1.

In the tests, the rats drank significantly more of the flavor previously mixed with the concentrated saccharin than of the flavor previously mixed with the dilute saccharin ($F(1/16) = 20.3$). Of the 18 rats, 17 showed this preference in the first test, and 13 showed it in the second test. Consequently, saccharin can reinforce a flavor preference. Not surprisingly, total consumption was also significantly greater in the second test, with concentrated solutions, than in the first test, with dilute solutions ($F(1/16) = 141.2$).

Discussion

Since this experiment used the same flavors as the previous one, the negative result in the previous experiment cannot be attributed to a lack of discrimination between the flavors. Thus, consummatory responding does not seem to be an important factor in the reinforcement of flavor

TABLE 2
MEAN DAILY CONSUMPTION (ml) IN EXPT 2

	Training solutions		First test solutions		Second test solutions	
	A	B	A	B	A	B
Group A	16.5	10.6	11.4	4.6	22.7	9.7
Group B	11.7	16.8	2.1	15.8	15.0	19.2

preferences. The most obvious reinforcing factor in the present experiment was the greater sweetness of the more concentrated solution, although postingestive effects of the sort described by Deutsch (1974) and Valenstein and Weber (1965) may also be relevant. In any case, flavor preferences, like responses to visual and auditory cues, can be reinforced without need reduction.

EXPERIMENT 3

In most conditioning experiments, the cue and the reinforcer are presented in temporal succession rather than in a physical mixture. To investigate saccharin reinforcement with a more typical procedure, therefore, the next experiment tested whether rats could learn to prefer a flavor immediately followed by concentrated saccharin solution to another flavor followed by nothing.

Method

Subjects. The subjects were 18 naive female rats of the same age, strain, and origin as in the previous experiments.

Materials. Flavor extracts were made of 2% of cinnamon or oil of wintergreen (methyl salicylate) dissolved in ethanol. The two cue solutions contained 0.065% sodium saccharin and 1% cinnamon or wintergreen flavor extract dissolved in water. The reinforcing solution contained 0.32% sodium saccharin dissolved in water without additional flavor.

Procedure. The rats were housed, handled, watered, and fed as in the previous experiments, except that they received their food 1½ hr after removal of the cue solution during training. In order to familiarize the rats with the reinforcement solution, they were given 20 ml of the solution overnight on the second day before training, and another 20 ml for 3 hr on the day before training; water was continuously available during familiarization.

The experiment consisted of 20 training days followed by one test day. On each training day, the rats were offered 20 ml of cue solution for 30 sec. The flavor of the cue solution followed a double-alternation schedule: cinnamon the first day, wintergreen the next two days, cinnamon the next two days, and so on. The rats were divided into two equal groups; Group C was offered 40 ml of reinforcement solution for 30 min immediately after the cinnamon cue solution, and nothing after the wintergreen cue solution; Group W was offered the reinforcement solution after wintergreen and nothing after cinnamon. On the test day, all the rats were offered 40 ml of each cue solution side by side for 30 min.

TABLE 3
MEAN DAILY CONSUMPTION (ml) IN EXPT 3

	Training solutions			Test solutions	
	C	W	R	C	W
Group C	1.3	1.3	27.9	10.2	4.7
Group W	1.3	1.4	25.5	5.6	9.6

Results

Table 3 gives the mean daily consumption of the cinnamon (C), wintergreen (W), and reinforcement (R) solutions during training and test. In training, the rats generally drank the cue solution steadily throughout the short period it was available; consequently, there was no significant difference in intake between the flavor followed by the reinforcement solution and the flavor followed by nothing ($F(1/16) = 1.1$), although 12 of the 18 rats drank more of the reinforced flavor. The rats generally started drinking the reinforcement solution as soon as it was presented; thus, the interval between cue and reinforcement was usually only a few seconds.

In the test, the rats drank significantly more of the formerly reinforced flavor than of the formerly nonreinforced flavor ($F(1/16) = 11.0$). This preference was shown by 14 of the 18 rats. Consequently, saccharin can reinforce a flavor preference when presented immediately after the cue in a typical differential conditioning procedure.

EXPERIMENT 4

In contrast to visual and auditory cues, gustatory cues are easily associated with long-delayed reinforcement. Flavor aversions can be reinforced by X-rays delayed 6–12 hr according to Revusky (1968) and Smith and Roll (1967), by lithium chloride delayed 12 hr according to Nachman (1970), and by cyclophosphamide delayed 24 hr according to Etscorn and Stephens (1973). Flavor preferences can be reinforced by food delayed 3 hr according to LeMagnen (1957a,b). Lavin (1972), however, has recently placed an important limit on the generality of delayed gustatory conditioning. Lavin's rats were able to associate two flavors in a sensory preconditioning procedure if and only if the flavors were separated by an interval of at most a few seconds. Since Lavin's procedure differed in several respects from the previous studies that used long delays, the last two experiments of the present series explored intermediate procedures in order to determine the boundary conditions for long-delayed reinforcement. The first of these experiments investigated whether rats can learn to prefer a flavor followed 30 min later by concentrated saccharin solution to another flavor followed by nothing. This study thus involved primary reinforcement rather than sensory preconditioning, but used a reinforcer that did not change bodily need.

Method

Subjects. The subjects were 18 naive female rats of the same age, strain, and origin as in the previous experiments.

Materials. The cue and reinforcement solutions were exactly the same as in Expt 3.

Procedure. Familiarization, training, and testing were the same as in Expt 3, except for the following parametric changes during training. The rats were offered 40 ml of cue solution for 30 min. Then, 30 min after removal of the cue solution, the appropriate group was offered 40 ml of reinforcement solution for 30 min. Finally, 2 hr after removal of the cue solution, all the rats received their daily food ration.

Results

Table 4 gives the mean daily consumption of the cinnamon (C), wintergreen (W), and reinforcement (R) solutions by the two groups during training and test. In training, the rats drank less of the reinforcement solution than in the previous experiment, perhaps because they had already drunk considerably more of the cue solutions during the longer period that these were offered. In neither training nor test was there any significant difference in intake between the reinforced and nonreinforced flavors ($F(1/16) = 1.5$ and 0.4 respectively). Of the 18 rats, 9 drank more of the reinforced flavor during training, and 10 drank more of it in the test. Like sensory preconditioning, therefore, saccharin reinforcement did not influence flavor preference when delayed by a period at which X-rays, lithium chloride, cyclophosphamide, and food are still effective.

TABLE 4
MEAN DAILY CONSUMPTION (ml) IN EXPT 4

	Training solutions			Test solutions	
	C	W	R	C	W
Group C	9.1	9.6	17.0	8.8	8.6
Group W	9.2	10.4	21.4	11.3	7.8

EXPERIMENT 5

Since saccharin is an effective reinforcer immediately but not after a long delay, need reduction may be more important for delayed than for immediate reinforcement of flavor preferences. The next experiment tested this possibility more directly, by repeating the previous experiment with dextrose solution instead of saccharin solution as the reinforcer.

Method

Subjects The subjects were 16 naive female rats of the same age, strain, and origin as in the previous experiments.

Materials. The cue solutions were the same as in Expts 3 and 4. The reinforcement solution, however, contained 20% dextrose and 0.01% quinine sulfate dissolved in water. In pilot experiments rats drank less of this dextrose-quinine solution than of 0.32% solium saccharin solution in a 30-min two-bottle test.

Procedure. Because of the difference between the cue and reinforcement solutions, both were offered for familiarization before training. The rats first received 20 ml of unflavored saccharin cue solution overnight and another 20 ml for 3 hr on the next day, then 20 ml of dextrose reinforcement solution overnight and another 20 ml for 3 hr on the next day. Otherwise, the procedure was the same as in Expt 4, except for the change of reinforcement solution.

Results

Table 5 gives the mean daily consumption of the cinnamon (C), wintergreen (W), and reinforcement (R) solutions by the two groups during training and test. In training, the rats drank even more of the cue solutions and less of the reinforcement solution than in the previous experiment. In both training and test, the rats drank significantly more of the reinforced flavor than of the nonreinforced flavor ($F(1/14) = 14.4$ and 5.6 respectively). Of the 16 rats, 14 showed this preference during training, and 12 showed it in the test. Consequently, dextrose can reinforce a flavor preference even when presented 30 min after the cue.

TABLE 5
MEAN DAILY CONSUMPTION (ml) IN EXPT 5

	Training solutions			Test solutions	
	C	W	R	C	W
Group C	18.7	17.6	14.7	9.1	7.1
Group W	16.8	18.4	15.2	5.4	12.0

Discussion

Since this experiment used the same flavors as the previous one, the negative result in the previous experiment cannot be attributed to lack of memory for the flavors. The delayed reinforcement in the present experiment was probably not caused by sweetness, since the added quinine made the dextrose solution less preferred than the saccharin solution that was ineffective in the previous experiment. Instead, the reinforcement can be attributed to the postingestive effects of the dextrose; but further research will be necessary to determine whether the crucial factor is caloric, osmotic, or some other effect. Thus, need reduction may be necessary for delayed but not immediate reinforcement of flavor preferences.

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