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Conditioned flavor preferences based on hunger level during original flavor exposure

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In five experiments, rats' preference for a flavor was greater if the flavor had previously been consumed under low rather than high deprivation. This preference was conditioned in as few as three flavor-deprivation pairings (Experiment 1), and persisted through 28 test days, half under each deprivation level (Experiment 2). Rats never preferred the flavor associated with high deprivation even when calories were increased by giving 40 ml of 8% sucrose or when caloric density was increased to the equivalent of 20% sucrose. The preference for the low-deprivation flavor was greater when saccharin solutions were used rather than sucrose solutions, but the preference did emerge when sucrose solutions were used as testing proceeded and when a lower concentration of sucrose was used. We suggest that these preferences may be a result of flavor-taste associations rather than associations between flavors and postingestive consequences, and that the taste of the solutions under low deprivation is preferred to the taste under high deprivation.

We recently found that rats' preference for a flavor was greater if they had previously consumed it under low rather than high hunger when flavors were given separately from the daily feeding (Capaldi & Myers, 1982). Given the widespread assumption that the incentive value of food increases with increased hunger (e.g., Kurtz & Jarka, 1968; Revusky, 1967), this finding is surprising. Our aim in the first two of the present experiments was to establish the reliability of this effect and the range of conditions under which it occurs. Experiment 1 looked for the effect with minimal training, and Experiment 2 measured the persistence of the effect.

EXPERIMENT 1

Experiment 1 used 6 training days. In all our previous experiments, we have used 20 training days. However, taste aversions based on illness can be conditioned rapidly (Logue, 1979), so it was of interest to determine if taste preferences[1] based on hunger level were also learned rapidly.

Method

Subjects. The subjects were 24 male albino rats, 174 days old at the beginning of the experiment. They were 78 days old on arrival from the Holtzman Co., Madison, Wisconsin, and had been employed in a straight alley instrumental learning experiment in which they had received 14 g of food per day for 69 days. New groups were formed by evenly redistributing the rats from the old groups.

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Materials. Flavored solutions were presented in 50-ml Nalgene centrifuge tubes with rubber stoppers and metal spouts. Flavor cues consisted of 1% cinnamon (2% imitation cinnamon flavoring mixed with 100% ethanol) or 1% wintergreen (2% imitation wintergreen flavoring mixed with 100% ethanol) dissolved in a saccharin solution with water (.15% saccharin) or a sucrose-water solution (8% sucrose).

Procedure. All training and testing occurred in the rats' home cages. Ad-lib water was available throughout the experiment in 350-ml brown bottles mounted in the center of the cage front. The rats were fed 35 g of Wayne Lab Blox on even-numbered days at 5:30 p.m. and nothing on odd-numbered days. Training began on Day 9. All training began at 9:30 a.m., and low- and high-deprivation training occurred 16 and 40 h, respectively, after food was given. On a low-deprivation day, if any food remained from the preceding night's feeding it was removed before the solutions were administered. On each of 6 training days, the rats were given 5 ml of a solution which remained on the cage until the next morning, when the amount of any residual was recorded. For half of the rats, the flavors were given in sucrose solution; for the other half, they were given in saccharin solution. For half of each of these conditions, cinnamon (C) was the high-deprivation flavor and wintergreen (W) was the low-deprivation flavor; for the other half the reverse applied. The tubes were placed adjacent to the water bottle so that the spout was about 2 cm from the floor of the cage and 5 cm from the side. Position of the tubes was double-alternated over days, beginning with left for two or three rats within each subgroup and right for the rest.

On each of 2 test days, the rats received two consecutive 10-min two-bottle choice tests between 40 ml of each of their training cues. The tests began at 9:00 a.m. and were spaced 30 min apart. On the first test, the positions of the cues were W on the left and C on the right for two or three rats of each subgroup, and the reverse for the rest on Days 1, 4, 5, and 8. These initial positions were reversed for all rats on Days 2, 3, 6, and 7. All rats began their second test with the cues in positions opposite to those on the initial test. Also, positions were reversed after 5 min within each 10-min test. If a rat was drinking at reversal time within each test, that tube was removed first and the other tube was put in its place. When drinking resumed, the first tube was placed in its opposite position. If the rat was not drinking, the tube with the least solution was removed first, and the position of the two tubes was reversed irrespective of the rat's behavior. Presentation of the tubes occurred at 1-min intervals from cage to cage.

Results

Rats consumed all the solution on training days. The mean preferences for wintergreen (W) (ml wintergreen consumed/total ml consumed) for rats given saccharin solutions were: W/low-deprivation cue in training, .443; W/high-deprivation cue, .252. For rats given sucrose, they were: W/low-deprivation cue in training, .451; W/high-deprivation cue, .443. Analysis of variance showed that the preference for wintergreen was greater for rats that had wintergreen under low deprivation than for those that had wintergreen under high deprivation [$F(1,16) = 7.66$, $p < .02$], and that this preference was stronger for rats that had saccharin solutions rather than sucrose solutions [$F(1,16) = 6.58$, $p < .02$]. This preference did not vary with test deprivation level, and no other interactions were significant.

Analysis of absolute consumption produced the same pattern of significant differences. In addition, rats drank significantly more on the first 10-min test than on the second [$F(1,16) = 109.77$, $p < .001$], and this was more so for rats given sucrose solution [$F(1,16) = 11.77$, $p < .01$]. Sucrose groups decreased from a mean of 14.5 ml consumed on the first test to a mean of 8.1 on the second; saccharin groups decreased from 11.6 to 8.4 ml. Also, rats consumed more on their high-deprivation test day than on their low-deprivation test day [$F(1,16) = 52.11$, $p < .001$].

Discussion

Experiment 1 showed that the preference for a flavor previously consumed under low hunger can be established in as few as three pairings of each flavor/deprivation-level combination. The preference occurred only for rats given flavors dissolved in saccharin rather than sucrose. Capaldi and Myers (1982) also reported that rats given saccharin solutions developed a stronger preference than did those given sucrose solutions, but this interaction was not significant in their experiment.

EXPERIMENT 2

Experiment 2 sought to determine how long preferences based on hunger level during original flavor consumption persist and also if the preference would occur in naive rats. All our previous experiments employed rats that had been in other experiments in which they had been on food deprivation schedules for 30 to 93 days. In Experiment 2, the rats had had no previous experience with food deprivation.

Method

Subjects. The subjects were 20 naive male albino rats, 78 days old upon arrival from the Holtzman Co. and 100 days old on Day 1 of the experiment. They received ad-lib food and water prior to Day 1 of this experiment.

Materials. The solutions were the same as in Experiment 1, except that 10 ml of solution were given on each training day.

Procedure. The procedure was the same as in Experiment 1, with the following exceptions. Food was removed on the day preceding Day 1, and subsequently, on odd-numbered days, the rats were fed 35 g of Wayne Lab Blox at 3 p.m. and training began at 9:30 a.m. There were 20 training days. In training, the water bottle was mounted on the right of the cage front, the tubes containing solutions were placed on the left of the cage front so that the tip of the spout was about 2 cm from the cage floor and 4-5 cm from the left wall. On each test, the two tubes were inserted simultaneously in the grids adjacent to the training grid. After one solution was sampled, that spout was withdrawn. After the alternative solution was sampled, that spout was withdrawn for 1 sec before both spouts were reinserted. Presentation of the tubes occurred at 30-sec intervals from cage to cage, and the second 10-min test began 30 sec after the last tube was removed in the first 10-min test. There were breaks of 10 and 4 days, respectively, between Days 16 and 17 and Days 26 and 27 of testing during which the rats were maintained on the deprivation schedule.

Immediately following testing, all rats received 10 more training days identical to prior training except that, for all rats, the flavor-deprivation pairings were reversed (e.g., if a rat initially received C under high deprivation and W under low deprivation, it now received W under high deprivation and C under low deprivation). There was a 4-day break between Days 7 and 8 of reversal training. Testing lasted 12 days, during which the procedure was identical to that of prior testing except for a 20-min break between the two 10-min tests. In postreversal testing, there were 2-day breaks between Days 2 and 3 and Days 8 and 9.

Results

In training, the rats drank all 10 ml of solution offered.

In previous experiments, we had presented the mean preference for wintergreen when it was the low-deprivation flavor and when it was the high-deprivation flavor. In Experiment 2 there were 28 days of testing, making this presentation unwieldy. Accordingly, Figure 1 simply shows the difference between the mean preference for wintergreen when it was the low-deprivation cue and when it was the high-deprivation cue (a positive number means the preference for wintergreen was greater when it was the low-deprivation cue). As can be seen in the figure, for groups given saccharin, preference for wintergreen was greater when it was the low-deprivation flavor, from the beginning of testing to the end, except for an inexplicable lack of difference on Block 6. For the groups given sucrose, there was no preference on the first block, and then, when wintergreen had been the low-deprivation cue, a greater preference for it developed and remained stable over the 14 test blocks.

Analysis of variance showed a significantly greater preference for wintergreen when it was the low-deprivation flavor [$F(1,16) = 11.92$, $p < .01$]. This preference did not interact significantly with saccharin vs. sucrose [$F(1,16) = 1.45$, $p < .20$] or with deprivation level in testing ($F < 1$). And no inter-

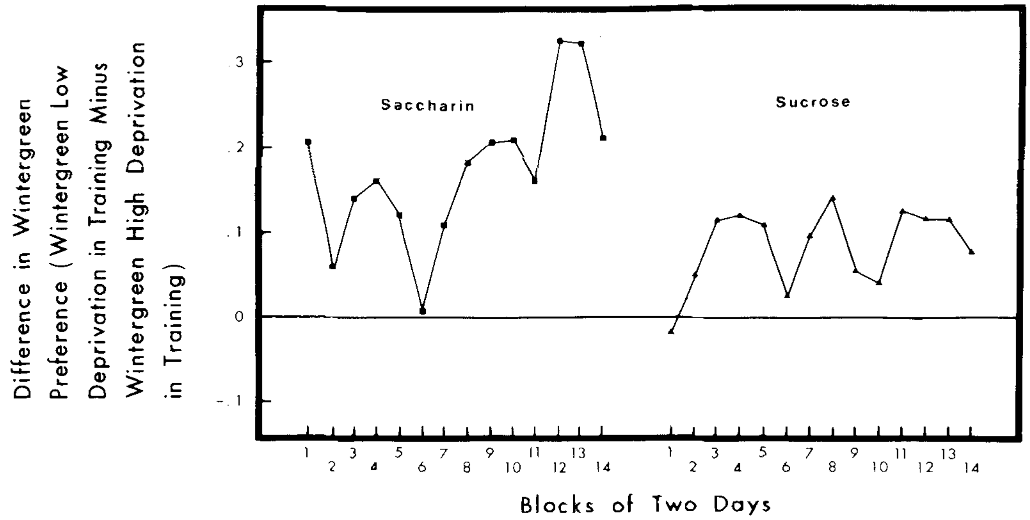

Figure 1. Difference in mean preference for wintergreen when it was associated with low deprivation and when it was associated with high deprivation (Wintergreen low-deprivation cue minus Wintergreen high-deprivation cue) for rats given a saccharin solution (left panel) and rats given a sucrose solution (right panel) on each block of test days.

actions with blocks were significant, although the main effect of blocks was significant [$F(13,208) = 2.68$, $p < .01$]. For purposes of comparison with Experiment 1, the mean preferences for wintergreen for groups given the saccharin solution were: W/low-deprivation cue in training, .787; W/high-deprivation cue in training, .613. For groups given the sucrose solution, the mean preferences were: W/low-deprivation cue in training, .453; W/high-deprivation cue in training, .369. These are means over the 28 test days.

Analysis of absolute consumption showed the same pattern of results. In addition, rats given sucrose drank significantly more than did rats given saccharin [$F(1,16) = 34.83$, $p < .001$], and they drank more on the first 10-min test than on the second 10-min test [$F(1,16) = 97.25$, $p < .001$] and on high-deprivation test days than on low-deprivation test days [$F(1,16) = 73.07$, $p < .001$]. The amount consumed first increased over test days and then decreased, producing a significant blocks effect [$F(13,208) = 5.35$, $p < .001$].

Reversal training reduced these preferences. After reversal training, there was no significant preference [$F(1,16) = 2.58$, $p < .10$], although the direction of preference was the same as that shown in original testing. For saccharin groups: W/low-deprivation cue in original training., .64; W/high-deprivation cue in original training, .52. For sucrose groups: W/low-deprivation cue in original training, .40; W/high-deprivation cue in original training, .37.

Discussion

The preference for a flavor previously consumed under low deprivation is incredibly persistent. This preference persisted throughout 28 days of testing with no sign of diminishing in Experiment 2. This is striking, since during testing each flavor was consumed repeatedly under each deprivation level. Because the test results did not differ as a function of deprivation level in test, this persistence cannot be attributed to the rats' behavior in maintaining the original flavor-deprivation contingencies. They did not drink more of their low-deprivation flavor only on low-deprivation test days; they did so also on high-deprivation test days. It is possible to eliminate the preference, however. Reverse flavor-deprivation pairings reduced the preference to nonsignificance, although it was still in the same direction. Whatever the reason, it is clear that flavor preferences based on hunger level during original flavor consumption are extremely persistent.

Other flavor preferences are also quite persistent. Revusky (1974) found flavor preferences based on thirst during original flavor consumption to persist throughout 10 days of testing, after which they were not significant and taste aversions based on illness are often very resistant to extinction (Logue, 1979). The persistence of the taste preferences obtained here, however, is not resistance to extinction. Normally extinction involves presenting the CS with no US, but with the taste preference under study extinction in this sense is not possible. The rat is always under some hunger level (including satiation as one point on the continuum). Thus, when the CS (the flavor) is presented, the rat will of necessity consume it under some deprivation level and will experience some US. In Experiment 2, we showed that when the contingency between flavor and the original deprivation level is broken by having both flavors consumed under both high and low deprivation, the original preference continues undiminished. An analogous procedure in an experiment measuring taste aversions based on illness would be to have one flavor associated with illness and another not, and then give both flavors associated with both the presence and absence of illness. Perhaps, if this were done, the aversion to the original poisoned flavor would persist as long as the taste preference based on original flavor-deprivation pairing persisted here.

EXPERIMENT 3

We have established that the preference for a flavor previously consumed under low hunger over one previously consumed under high hunger occurs in naive rats, can be conditioned in as few as three pairings of each flavor-deprivation combination, and is very persistent. Thus, the finding is robust and the question of interest becomes why does this preference occur? The next three experiments sought to provide information relevant to this question.

The hypothesis suggested by Capaldi and Myers (1982) was that the taste of a small amount of food is unpleasant and that the unpleasantness is greater the higher the hunger level during consumption because the responses of digestion (e.g., insulin release) that are elicited by the taste are unsatisfied. This mechanism could explain the tendency to find a greater preference when saccharin solutions are used rather than sucrose solutions, although the preference for the low-deprivation flavor does occur with sucrose (Experiment 2). Sucrose has calories and saccharin does not, so perhaps, to some minimal extent, responses of digestion elicited by a small taste of flavor are more satisfied by sucrose, and thus consuming a small amount of sucrose under high deprivation is less aversive than consuming a small amount of saccharin. If this reasoning is correct, giving flavors in a large amount of sucrose might reduce or eliminate the preference for the flavor consumed under low deprivation. In Experiment 3, 40 ml of 8% sucrose solution were given with the different flavors under each deprivation level. This amount of solution contains about 13 calories, about the number in 4½ g of Wayne Lab Blox. Perhaps, with this caloric content, animals might associate the long-delayed beneficial effects of consumption with the flavors, and if these beneficial effects are greater under high deprivation than under low (Revusky, 1967; Revusky & Garcia, 1970), rats may prefer the flavor given under high deprivation over that given under low deprivation.

Method

Subjects. The subjects were 24 male albino rats, 78 days old upon arrival at the laboratory from the Holtzman Co. and 140 days old at the beginning of the experiment. They had previously been used in an escape-avoidance experiment (44 days on 14 g of food per day) or in a straight alley instrumental learning experiment (66 days on 14 g of food per day). They were assigned to new groups, which were formed by evenly redistributing the rats from the groups in the previous experiment.

Materials. The solutions were the same as in the previous experiment, except that 40 ml of solution were given.

Procedure. The procedure was the same as in Experiment 1, except for steps taken to equalize the calories consumed by each group. The rats were each fed 35 g of Wayne Lab Blox on even-numbered days at 4 p.m. for 10 days prior to the beginning of training. On each of 20 training days, the rats were given 40 ml of one flavored solution at 9:30 a.m. The tube remained on the cage until 4 p.m., when the amount of any residual was recorded. To equate caloric intake across groups on odd-numbered days (nonfeeding days) rats received, at 4 p.m., 40 ml of unflavored saccharin (for groups receiving flavored sucrose in the morning) or of sucrose (for groups receiving flavored saccharin in the morning). Unflavored solutions remained on the cages until the next morning, when the amounts of any residuals were recorded. In this way, all groups drank 40 ml of sucrose (and thus consumed about 13 calories) on nonfeeding days. At 4:00 p.m. on feeding days, the groups given flavored saccharin in the morning received 35 g of food and the groups given flavored sucrose in the morning were given 30.5 g of food (compensating for the 13 calories consumed in sucrose in the morning). Throughout training, body weights on even-numbered days were approximately 8.6% below weights on odd-numbered days and did not differ systematically between groups given flavored saccharin and those given flavored sucrose.

Positions of the flavored solutions were double-alternated over days, beginning with left for half the rats and right for the other half. Positions of the unflavored solutions were single-alternated over the odd-numbered days, beginning with right for half the rats and left for the other half, such that the unflavored solution was always received on the side opposite to that of the flavored solution received earlier in the day. There were two consecutive 10-min tests spaced 40 min apart on each of 4 test days. The testing procedure was the same as in Experiment 1. On even-numbered test days, all rats received 35 g of food at 4 p.m.

Results

The mean amount consumed of the 40 ml offered to rats given sucrose was 39.96 ml on high-deprivation days and 39.69 ml on low-deprivation days; for rats given saccharin, it was 39.73 ml on high-deprivation days and 35.5 ml on low-deprivation days. The lower consumption of saccharin on low-deprivation days produced significant differences associated with deprivation [$F(1,20) = 16.5$, $p < .001$], saccharin vs. sucrose [$F(1,20) = 17.5$, $p < .001$], and the interaction of deprivation level with saccharin vs. sucrose [$F(1,20) = 12.74$, $p < .001$].

The mean preferences for wintergreen were greater when wintergreen had been consumed under low rather than high deprivation. For rats given saccharin, these preferences were: W/low-deprivation cue in training, .702; W/high-deprivation cue in training, .146. For rats given sucrose, they were: W/low-deprivation cue in training, .460; W/high-deprivation cue in training, .381. Analysis of variance showed that the preference for wintergreen was greater for rats that had consumed wintergreen under low deprivation than for those that had consumed it under high deprivation [$F(1,20) = 30.09$, $p < .001$]. This difference was significantly larger for groups that had had saccharin solution than for those that had had sucrose solutions [$F(1,20) = 16.87$, $p < .001$]. Newman-Keuls tests showed that the difference in preference for wintergreen as a function of deprivation level associated with wintergreen in training was significant for rats given saccharin, but not for those given sucrose.

There were no significant effects or interactions involving test deprivation level (Fs < 1). However, differences were larger in the second 10-min test than in the first. Table 1 shows the data for each test set separately. As can be seen in Table 1, a greater preference for wintergreen when it was the low-deprivation cue occurred for the saccharin groups on both test sets, but occurred for the sucrose groups only on the second 10-min test, producing a test × saccharin vs. sucrose × wintergreen preference interaction [$F(1,20) = 9.81$, $p < .01$].

Analysis of absolute consumption produced the same pattern of significant differences. In addition, the rats given sucrose consumed more than the rats given saccharin [$F(1,20) = 4.72$, $p < .04$], rats drank more in the first 10-min test than in the second [$F(1,20) = 17.19$, $p < .001$] and more when tested under high hunger than when tested under low hunger [$F(1,20) = 16.87$, $p < .001$].

Discussion

When 40 ml of flavored solutions were consumed, the results were much the same as those in our previous experiments when 5 or 10 ml were consumed. Rats preferred wintergreen more if it was associated with low rather than high deprivation, and this preference was stronger for rats given saccharin solutions than for those given sucrose solutions. If anything, the preferences shown in Experiment 3 were stronger than when a smaller amount of solution was given. Therefore, it does not seem that these preferences occur because a small taste of flavor elicits responses of digestion which are then unsatisfied because too few calories are given. Nor does it appear that our failure to find a greater preference for a flavor previously consumed under high deprivation is a result of our providing too few calories. It could be argued that giving even more calories would produce a preference for the high-deprivation flavor. However, 13 calories are more than are contained in the usual reinforcer for instrumental performance when responding is faster under high deprivation than under low deprivation (e.g., in a straight alley, rats run faster for a .045-g pellet under high deprivation than under low deprivation, e.g., Ehrenfreund, 1971). If this greater responding is attributed to the reinforcer's having greater value under high than under low deprivation (e.g., Kurtz & Jarka, 1968), then 13 calories should be more than enough for food to have higher value under high hunger than under low hunger.

Table 1
Mean Preference for Wintergreen as a Function of Which Deprivation Level It was Associated With in Training for Each Group in Experiment 3 Using 40 ml of Solution Shown Separately for Each 10-min Test

	First 10-min Test		Second 10-min Test	
	Low	High	Low	High
Saccharin	.695	.122	.709	.170
Sucrose	.393	.395	.527	.365

EXPERIMENT 4

Although increasing the degree of long-delayed caloric restoration did not change the preference we are finding, Bolles, Hayward, and Crandall (1981) recently showed that, in part, the preference for high-calorie food is related to the density of calories. For example, rats prefer a flavor associated with 1.5 g of a 4-calorie diet to a flavor associated with 3 g of a 2-calorie diet (Bolles et al., 1981). If rats are sensitive to the density of calories rather than or in addition to the total amount, perhaps if we used a higher concentration of calories in our solutions, rats would prefer the flavor received under high deprivation. The purpose of Experiment 4 was to test this hypothesis by varying concentration of calories in the solution.

In Experiment 4, flavors were given in a solution with .15% saccharin plus polycose. Polycose is a glucose polymer that is minimally sweet, but has basically the same caloric and metabolic effects as glucose and sucrose. Rats received flavors dissolved in either .15% saccharin plus 1% polycose or .15% saccharin plus 20% polycose under high and low deprivation. The same amount of solution (5 ml) was given whether 1% or 20% polycose solutions were given. Thus, the groups differed not only in density of calories, but also in total caloric restoration. If caloric density is sensed by the rat and calories are more valuable under high than under low deprivation, the group given 20% polycose might show a greater preference for wintergreen if it was received under high rather than low deprivation.

Method

Subjects. The subjects were 20 naive male albino rats, 100 days old at the beginning of the experiment and 75 days old on arrival at the laboratory from Holtzman Co.

Materials. The materials were the same as those in the previous experiments, except that the .15% saccharin was in solution with either 20% or 1% polycose.

Procedure. The procedure was the same as that in previous experiments, with feeding occurring at 4:30 p.m. and training and testing beginning at 8:00 a.m. There were 20 training days and 12 test days. The training and test procedures were the same as in Experiment 2. There was a 15-min interval between tests.

Results

Regardless of polycose concentration, the preference for wintergreen was greater when it was the low-deprivation cue. For rats given .15% saccharin plus 1% polycose, the mean preference for wintergreen was .489 when it was the low-deprivation cue and .286 when it was the high-deprivation cue; for rats given .15% saccharin plus 20% polycose, the mean preference for wintergreen was .538 when it was the low-deprivation cue and .417 when it was the high-deprivation cue. The greater preference for wintergreen when it was the low-deprivation cue was significant [$F(1,16)=10.66$, $p < .01$], and although this preference was numerically larger for rats given 1% polycose than for those given 20% polycose, the interaction of concentration and preference was not significant ($F < 1$). The greater preference for wintergreen when it had been the low-deprivation flavor did not interact with any other variable (days, first vs. second test, or test deprivation level), although numerically the preference was greater on later tests and later days. For example, on the last test day, the preferences of rats given 1% polycose were: W/low-deprivation cue, .555; W/high-deprivation cue, .244. For rats given 20% polycose, they were: W/low-deprivation cue, .600; W/high-deprivation cue, .339.

Discussion

In Experiment 4, rats' preference for wintergreen was greater when they had previously received it under low deprivation rather than high deprivation, even when the caloric density was increased. Also, increasing the concentration of polycose did not change the direction of the preference or reduce it significantly in size (although it was numerically smaller with the higher concentration). Thus, it does not appear that our failure to find a greater preference for a flavor given under high rather than low deprivation is a matter of not using a high enough caloric density. Of course, sweet tastes may, indeed, elicit responses of digestion which, when unsatisfied (i.e., not followed by great enough caloric restoration), are aversive and increasingly so the higher the deprivation level. The results of Experiment 4 show, however, that the greater preference for a flavor given under low rather than high deprivation is not limited to sweet solutions of low caloric density. And Experiment 3 showed that increasing the degree of caloric restoration did not change the preference. Thus, it seems likely that some process in addition to unsatisfied digestive responses elicited by sweet tastes may be contributing to these results.

One hypothesis suggested by Davidson-Codjoe and Holman (1982) is that flavors may be associated with the deprivation state itself, rather than any consequences of consumption under the deprivation state. This idea, together with the reasonable assumption that high deprivation is more aversive than low deprivation, might explain why rats prefer a flavor consumed under low deprivation over one consumed under high deprivation. However, this hypothesis implies that the solution the flavors are dissolved in should be irrelevant, and this is clearly not so. The flavor consumed under low deprivation is preferred more if the flavors are ground in a saccharin rather than a sucrose solution. Thus, one cannot account for these preferences on the basis of associations between flavors and deprivation state alone. Some factor makes this preference greater for saccharin than for sucrose solutions, and that factor does not seem to be calories.

In addition to calories, saccharin and sucrose also differ in taste—saccharin is sweeter than sucrose and, at least for some humans, has a bitter aftertaste. Perhaps what is being associated with these flavors are some aspects of their tastes as a function of deprivation, rather than the deprivation state itself, or of the consequences of their consumption under different levels of deprivation. Flavor-flavor associations have been demonstrated (e.g., Bolles et al., 1981; Fanselow & Birk, 1982; Holman, 1975a, 1980; Lavin, 1976; Rescorla & Cunningham, 1978), so it is certainly possible for the flavor cues to be associated with the taste of the solutions.

If the taste of a solution varies with deprivation level, and the rats prefer the low-deprivation taste, then the preferences we are obtaining can be explained. The sucrose-saccharin difference could be accounted for if the taste differences produced by deprivation levels are greater with saccharin than with sucrose. Perhaps this is because sucrose is more palatable than saccharin. In these experiments, rats given sucrose solutions in test always drank more than did rats given saccharin, independent of any other variables we investigated. This greater palatability of sucrose could mask measurement of conditioned preferences based on deprivation during original consumption; perhaps the rats like sucrose so much that they drink a lot of it in the test regardless of previous hunger level associated with the flavor. Alternatively, perhaps the palatability of sucrose is so high that there are no noticeable taste differences as a function of deprivation level during training, so no differential taste preferences were conditioned to the flavors. If either of these ideas is correct, reducing the palatability of sucrose might recruit a greater preference for the flavor consumed previously under low hunger. In Experiment 5, this was attempted by using a low concentration of sucrose. In Experiment 5a, different groups were given 5 ml of either 1% or 8% sucrose. Equating amount of solution means that different groups received different degrees of caloric restoration. In Experiment 5b, caloric restoration was equated so the group given 1% sucrose was given 40 ml while the group given 8% sucrose was given 5 ml.

EXPERIMENT 5

Method

Subjects. In Experiment 5a, the subjects were 24 male albino rats, 78 days old upon arrival from the Holtzman Co. and 149 days old at the beginning of the experiment. They had previously been used in instrumental learning experiments and were assigned to new groups formed by redistributing the rats as evenly as possible from the previous groups. They had received 14 g of Wayne Lab Blox for 47 days and then ad-lib food for 15 days prior to Day 1 of this experiment. In Experiment 5b, the subjects were 20 naive male albino rats, 60 days old on arrival from the Holtzman Co. and 74 days old at the beginning of the experiment.

Materials. The materials were the same as in previous experiments except that the solutions were composed of 1% sucrose or 8% sucrose.

Procedure. In Experiment 5a, the procedure was the same as in Experiment 1, except the 35 g was fed on odd-numbered days at 3 p.m. and training was given at 10:30 a.m., beginning on Day 11. In Experiment 5b, feeding was at 3:30 p.m. and training at 8:30 a.m. There were 20 days of training. In Experiment 5a, 5 ml of solution were given each day; in Experiment 5b, the 8% sucrose group was given 5 ml each day, and the 1% sucrose group was given 40 ml each day. Test days (16 in Experiment 5a and 12 in Experiment 5b) followed the procedure used in Experiment 2, except that the second 10-min test followed 30 sec after the first test ended. In Experiment 5a, there were 2-day breaks between Days 5 and 6 of training and between Days 15 and 16 of testing, when rats were maintained on the deprivation schedule. One rat in Group 1% W-high died, and its data were discarded. In Experiment 5b, one rat in Group 8% W-high became ill and its data were discarded.

Results

Experiment 5a. All rats consumed 5 ml of the solution in training.

For rats given 8% sucrose, there were no differences in preference for wintergreen as a function of the deprivation level under which it had been experienced previously, while for rats given 1% sucrose there was a greater preference for wintergreen when it was the low-deprivation flavor. The mean preferences for wintergreen of rats given 8% sucrose were: W/low-deprivation cue in training, .537; W/high-deprivation cue in training, .517. For rats given 1% sucrose, they were: W/low-deprivation cue, .457; W/high-deprivation cue, .366. However, these differences were not significant when both 10-min tests were analyzed together. As in Experiment 3, differences in preferences grew larger in the second 10-min test. Table 2 shows the data for each 10-min test separately.

As can be seen in Table 2, for all groups, the greater preference for wintergreen when it was the low-deprivation flavor was more evident on the second test. This was particularly so in the later test blocks and on the high-deprivation tests, although

Table 2
Mean Preference for Wintergreen as a Function of Which Deprivation Level It was Associated With in Training for Each Group in Experiment 5a Using 40 ml Solution Shown Separately for Each 10-min Test

	First 10-min Test		Second 10-min Test	
	Low	High	Low	High
8% Sucrose	.536	.550	.539	.484
1% Sucrose	.440	.394	.474	.338

the data are not shown broken down by these variables. There were significant interactions of preference for wintergreen [test × concentration × deprivation level, $F(1,19) = 7.67$, $p < .02$, and test × concentration × block, $F(7,133) = 2.69$, $p < .02$]. Newman-Keuls tests showed that the only significant difference in preference for wintergreen as a function of deprivation level associated with wintergreen occurred for the 1% sucrose groups on the second test set ($p < .05$).

Absolute consumption showed the same pattern of results as did preference data. In addition, rats given 8% sucrose drank more than rats given 1% sucrose [$F(1,19) = 23.84$, $p < .001$], rats drank more on the first 10-min test than on the second 10-min test [$F(1,19) = 69.33$, $p < .001$] and more on tests under high hunger than under low hunger [$F(1,19) = 19.27$, $p < .001$].

Experiment 5b. By the end of training, all rats were consuming all of the solution offered. For rats given 40 ml of 1% sucrose, six failed to consume all 40 ml, with failures occurring once for two rats, twice for two rats, and five times for two rats. All rats were consuming all the solution by Day 10 of training.

On the first 2 days of testing for rats given 1% sucrose, the preference for wintergreen was greater if it had been the low-deprivation cue, while for rats given 8% sucrose, the reverse was true. The mean preferences for wintergreen of rats given 8% sucrose were: W/low-deprivation cue in training, .367; W/high-deprivation cue in training, .432. For rats given 1% sucrose, they were: W/low-deprivation cue in training, .616; W/high-deprivation cue in training, .355. The interaction of group with preference for wintergreen as a function of deprivation was significant [$F(1,15) = 6.25$, $p < .03$]. Newman-Keuls tests showed that the difference in preference for wintergreen as function of deprivation level associated with wintergreen was significant for rats given 1% sucrose but not for those given 8% sucrose.

Over days, the greater preference for wintergreen when it had been the low-deprivation cue grew larger, as in previous experiments, and remained larger for rats given 1% sucrose than for those given 8% sucrose. Over the 12 days of testing, the preferences for wintergreen of rats given 8% sucrose were: W/

low-deprivation cue in training, .519; W/high-deprivation cue in training, .408. For rats given 1% sucrose, they were: W/low-deprivation cue in training, .571; W/high-deprivation cue in training, .287. The interaction between group and these preferences was no longer significant [$F(1,15) = 1.58$, $p > .20$], but the main effect of preference for wintergreen as a function of deprivation level was significant [$F(1,15) = 10.89$, $p < .01$]. Absolute consumption showed the same pattern of results as the preference data, and the same differences that were significant in Experiment 5a for absolute consumption were also significant in Experiment 5b.

Discussion

The greater preference for a flavor previously consumed under low deprivation was greater when the flavor was given in 1% sucrose rather than an 8% sucrose solution, whether the amount of solution was equated with caloric restoration varying (Experiment 5a) or with caloric restoration equated and amount of solution varying (Experiment 5b). The results are consistent with the notion that the high palatability of sucrose may be masking the greater preference for a flavor previously consumed under low deprivation rather than high deprivation.

GENERAL DISCUSSION

The present experiments clearly establish that rats' preference for a flavor is greater if the flavor was previously consumed under low rather than high hunger, and that this is a robust effect, at least when .15% saccharin solutions are used to deliver the flavors with or without polycose added. With sucrose solutions, the preference is in the same direction as with saccharin and polycose, but smaller, although the preference was significant with 8% sucrose solution in Experiment 2 when 28 test days were given and with 1% sucrose solution in Experiments 5a and 5b.

These preferences can be viewed within either a classical conditioning or an instrumental learning paradigm. In a classical conditioning framework, the flavors are CSs and they are being associated with some US that is being produced by consumption under the different deprivation levels. In an instrumental learning paradigm, the flavors are S^Ds signaling the reinforcement produced by the instrumental response of consumption under the different deprivation levels. Within either paradigm, the puzzle is what the US or reinforcer is.

It does not seem likely that the US is the deprivation state itself (Davidson-Codjoe & Holman, 1982), because this hypothesis cannot account for why preferences as a function of deprivation level under which the flavor was consumed are greater for saccharin solutions than for sucrose solutions and greater with 1% sucrose than with 8% sucrose solutions. Nor does it seem likely that the US is the aversive effects of unsatisfied digestive responses elicited by a sweet taste, as suggested by Capaldi and Myers (1982). Increasing, by a factor of 8, the amount of sucrose consumed, and thereby providing 13 calories (equivalent to about 4½ g of lab chow), did not change the direction of the preference for the low-deprivation flavor in Experiment 3. And increasing, by a factor of 20, the caloric density in Experiment 4 did not change the direction of preference. It is, of course, possible that simultaneously increasing density of calories and amount by giving a large quantity of high calorie solution could change the preference. It is also possible that the digestive responses elicited by a sweet taste are aversive whether or not calories follow. However, it does not seem that sweetness itself is aversive under high deprivation (saccharin is sweeter than sucrose). Eight percent sucrose is sweeter than 1%, yet preference differences were greater with 1% sucrose. Also, Myers (1982) showed a stronger preference for the low-deprivation flavor when .015% or .05% saccharin solutions were used rather than a sweeter .05% saccharin plus 4% sucrose solution.

An alternative hypothesis is that the tastes of the solutions themselves vary as a function of deprivation level, and that these tastes are the USs. Perhaps, in general, the taste of solutions (foods) is better under low deprivation than under high deprivation, but, with a highly palatable and preferred substance such as sucrose, it is not possible to measure different preferences as a function of hunger level. With less palatable saccharin or saccharin plus polycose solutions, it is possible to measure different preferences as a function of hunger level.

Consistent with this hypothesis, reducing the palatability of sucrose by using a 1% rather than 8% solution increased the preference for the low-deprivation flavor in Experiment 5. There are two ways in which a highly palatable solution such as sucrose could mask taste preferences as a function of training level. Using sucrose in training could make any taste difference associated with deprivation not noticeable, so that no taste preference is conditioned with sucrose. Or a taste preference may be conditioned, but the use of sucrose in testing may make it impossible to measure this preference. Perhaps sucrose is so palatable that rats drink large amounts of it in the test regardless of conditioned preferences. Data in the present experiments support the latter alternative. The preference for the low-deprivation flavor was larger on the second 10-min test, suggesting that, when the palatability of sucrose was reduced by "satiation" on sucrose (e.g., Davidson-Codjoe & Holman, 1982; Holman, 1980), the flavor preference based on previous conditioning emerged. Also, giving repeated tests in Experiment 2 allowed the greater preference for the low-deprivation flavor to emerge with sucrose solutions. Both of these findings suggest that a preference for the low-deprivation flavor is conditioned when sucrose solutions are used but is not measurable when highly palatable sucrose is given in the test. This hypothesis also explains why Myers (1982) found that adding 4% sucrose to saccharin reduces the preference for the low-deprivation flavor. It does not seem that this effect can be attributed to the calories in sucrose (Myers gave 10 ml of solution), because Experiments 3 and 4 showed that increasing caloric restoration or caloric density to a degree greater than that done by Myers when he added 4% sucrose to saccharin did not change the preference. This finding can be explained on the basis of sucrose's increasing the palatability of the solution so that taste preferences produced by varying deprivation were not measurable.

Regardless of interpretation, in the present experiments preferences, when obtained, were always greater for the flavor associated with low deprivation rather than high. There was no tendency under any conditions for rats to prefer the flavor associated with high deprivation. These results thus suggest that some aspect of the consumption of these solutions was more reinforcing under low deprivation or more aversive under high deprivation. In contrast, rate of instrumental responding has been found to be higher, the higher the deprivation level when either saccharin or sucrose is the reinforcer (e.g., Collier, 1962; Collier & Bolles, 1968), suggesting perhaps that the reinforcement produced by saccharin and sucrose is higher, the higher the deprivation level. It is possible that some parametric difference is responsible for this difference. For example, the amount of solution given in an instrumental learning situation is typically small, and we have given from 5 to 40 ml in training in our flavor-preference studies. If parametric variations are not responsible for the different effects of deprivation level in the two situations, it is clearly not possible to explain both the present flavor preference data and the instrumental performance data with some single construct of incentive value. In one case, value appears to be higher, the higher the deprivation level, while in the other, value appears to be lower, the higher the deprivation level. Perhaps there are multiple dimensions of value, with some aspects of value increasing with increasing deprivation and others decreasing, and perhaps consummatory and instrumental performance are affected more strongly by different aspects of value. Or perhaps there are multiple motivational determinants of performance (with value only one possible determinant), and instrumental and consummatory behavior depend on different motivational factors (e.g., Holman, 1975b).

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NOTE

1. The word "preference" is intended as a neutral term accommodating either a learned aversion for the flavor associated with high deprivation, a learned liking for the flavor associated with low deprivation, or both.

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