Journal of Experimental Psychology:
Animal Behavior Processes
1987, Vol. 13, No. 2, 150–155

0097-7403/87/$00.75

Conditioned Flavor Preferences Based on Delayed Caloric Consequences

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In four experiments we showed that rats prefer a flavor associated with a delayed edible consequence if the delayed consequence contains calories; the greater the number of calories, the greater the preference. We obtained conditioned preferences with delayed consequences of dextrose plus quinine, 8% polycose, 8% sucrose, 10 g of high fat mash, and 14 g of lab chow. No conditioned preferences were obtained with delayed consequences of saccharin, 10 g of low fat mash, 1% polycose, or 1% sucrose. Thus, it seems that flavor preferences based on delayed caloric consequences occur only if there are appreciable calories in the consequence.

Taste aversion learning occurs rapidly and is long lasting. A single pairing of food with delayed sickness can produce a lasting aversion to the taste of the food (see Riley & Clarke, 1977, for a bibliography on taste aversion learning). In contrast, the evidence for conditioning of taste preferences based on long-delayed positive consequences is scattered, and when obtained, such preferences are not as robust as those based on aversive consequences. In their well-known article on the role of taste aversion learning in tests of specific hunger, Rozin and Kalat (1971) proposed a useful categorization of foods into "novel," "familiar–safe" or "familiar–aversive." At that time Rozin and Kalat concluded that there was insufficient evidence to postulate a "familiar–positive" category because most demonstrations could be reinterpreted in terms of learned aversion. Since that time some evidence has accumulated substantiating conditioned flavor preferences based on positive consequences. Zahorik, Maier, and Pies (1974) showed enhancement in preference for a food associated with recovery from thiamine deficiency. Others have found conditioned preferences for flavors associated with recovery from symptoms of morphine withdrawal (Parker, Failor, & Weidman, 1973; Ternes, 1975).

There is also suggestive evidence that flavor preferences can be learned on the basis of the long-delayed caloric consequences of eating. Most studies have looked for preferences for flavors that were mixed in foods or liquids varying in calories rather than having a delay between the flavor and the food. With this procedure, although the postingestional effects of the foods are delayed, there are also immediate oral factors that could be the source of the conditioned preference (Bolles, Hayward, & Crandall, 1981).

From this procedure there is evidence that the calories in ethanol can reinforce a flavor preference for a flavor dissolved in ethanol (Mehiel & Bolles, 1984; Sherman, Hickis, Rice, Rusiniak, & Garcia, 1983). In these studies a flavor paired with ethanol was preferred to a flavor paired with an alternative substance only if the ethanol contained more calories than the alternative. Booth and his colleagues in a series of studies have shown that early in a meal, when they are hungry, rats prefer a flavor that has been mixed with a high concentration of starch, whereas later in a meal they prefer a flavor associated with a lower concentration of starch (see review in Booth, 1980). And there is evidence that rats prefer a flavor that was previously mixed in a high-calorie food to one that was previously mixed with a low-calorie food (Bolles et al., 1981; Hayward, 1983). As pointed out by Mehiel and Bolles (1984), these latter studies used chalk as a dilutant, and rats may have been avoiding the chalk-related flavor rather than approaching the calorie-related flavor. More important, as mentioned above, none of these studies involved a controlled delay between the flavor and the caloric consequence.

Other data suggest that flavor preference conditioning based on calories may not be possible if there is a delay between the flavor and the calories. Simbayi, Boakes, and Burton (1985) reported they could produce a conditioned preference for a flavor associated with a nutritive food (glucose) only if the flavor was mixed with the glucose and not if a delay occurred between the flavor and glucose.

The only evidence for a conditioned preference involving an association between a flavor and *delayed* food involves a cross-experiment comparison in an article by Holman (1975). When a flavor is mixed in food for conditioning although the postingestional consequences are delayed, there are immediate oral effects of consumption. When there is a delay between the flavor and food, both oral and postingestional effects are delayed. In Holman's studies using a delay between a flavor and the food, rats learned an association between a flavor and dextrose if a 30-min delay intervened between the flavor and dextrose (Experiment 5), whereas they showed no evidence of learning when a flavor was followed by saccharin with a 30-min delay (Experiment 4). These findings are consistent with the hypothesis that the learned preference obtained in Experiment 5 was based on caloric consequences and therefore occurred with dextrose but not with saccharin. However, because the flavor cues were dissolved in saccharin, an alternative explanation of Holman's data is possible. Perhaps an association over a delay is easier to learn when cue and consequence are different (saccharin–

This research was supported in part by National Institute of Mental Health Grant MH39453 to the first author.

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dextrose) than when they are similar (saccharin–saccharin). There may be interference between the two concentrations of saccharin so that there is confusion between which is cue and which consequence.

Especially because researchers have had such difficulty demonstrating learning based on caloric consequences at a delay (Simbayi et al., 1985), we thought it important to rule out this interpretation of Holman's findings. As will be seen after we review all our findings, it seems that Holman was quite right—flavor preferences can be learned on the basis of caloric consequences experienced after a delay. We will report in the following experiments that an association between a flavor and a delayed consequence occurs only if there are calories in the consequence, with the learning being stronger the greater the number of calories in the consequence.

Experiment 1

Experiment 1 was a replication of two of Holman's groups with the addition of two more. Holman found learning at a delay when a flavor (dissolved in saccharin) was followed by dextrose, but not when the flavor was followed by saccharin. This may have occurred because dextrose contains calories and saccharin doesn't or because learning with a delay is possible when cue and consequence differ but not when they're similar. In Experiment 1 flavors were dissolved in either saccharin or dextrose, and the consequence was either saccharin or dextrose; thus there were four groups. A 30-min interval separated cue and consequence. If flavor preference learning is possible at a delay only when calories are in the consequence, as suggested by Holman, then Groups Saccharin–Dextrose (meaning the flavor cue was dissolved in saccharin and the consequence was dextrose) and Dextrose–Dextrose should learn a flavor preference, whereas Groups Saccharin–Saccharin and Dextrose–Saccharin should not. Alternatively, if learning at a delay is possible only when the cue and consequence are different, Groups Saccharin–Dextrose and Dextrose–Saccharin should learn a flavor preference, whereas Groups Saccharin–Saccharin and Dextrose–Dextrose should not.

In all the experiments reported here, procedures devised by Holman (1975) were used. On half the training days a flavor (say, cinnamon) was dissolved in the cue solution and placed on the front of the home cage for a fixed period. Then a specified interval passed prior to presenting the consequence solution, say, dextrose solution, on the home cage. On the other half of the days, the cue solution was flavored differently (say, with wintergreen) and no consequence followed the cue. Which flavor was and was not followed by the consequence was counterbalanced. A conditioned preference would be demonstrated by a greater preference for the flavor that was paired with the consequence in a later test evaluating preference for cinnamon (C) versus wintergreen (W).

Method

Subjects. Subjects were 40 male albino rats from the Holtzman Co., Madison, Wisconsin. They were 81 days old upon arrival and 154 days old at the beginning of the experiment. They had been previously run in either a radial maze or straight alley runway for Noyes pellets. Groups were counterbalanced for previous experience.

Materials. Solutions were presented in 50-ml Nalgene centrifuge tubes with rubber stoppers and metal spouts. The flavor cues consisted of 1% wintergreen (2% wintergreen oil in 100% ethanol) or 1% cinnamon (2% cinnamon oil in 100% ethanol). The cue solutions were 0.065% saccharin or 1% dextrose; the reinforcement solutions were 0.32% saccharin or 20% dextrose plus 0.01% quinine sulfate. In all experiments, solutions were mixed volume/volume or weight/volume, depending on whether they were liquid or dry. Because all solutions used a water base, and 1 ml of water weighs 1 g, the solutions are independent of this feature.

Procedure. Ad lib water was present throughout the experiment in brown bottles mounted to the right of center on the cage front. On Day 1 all food was removed from the cages. On Days 2–11 a feeding schedule began with 15 g of Wayne Lab Blox every morning at 11:30 for half the animals and every evening at 5:00 for the other half. (The lab is on a 16-hr light/8-hr dark cycle, with dark beginning at 11 p.m.) Beginning on Day 12 all animals were fed in the evening.

Days 13–16 were preexposure days. On Day 13 all animals received 40 ml of the appropriate cue solution in the home cage overnight; on Day 14 they received the same solution but only for a 3-hr exposure. On Day 15 the animals received the appropriate reinforcement solution overnight, and on Day 16 they received the reinforcement solution for 3 hr.

Days 17–34 and Days 36 and 37 were training days. At 4:30 p.m. all animals were given 40 ml of cue solution for 30 min. Groups Saccharin–Saccharin and Saccharin–Dextrose had saccharin as a cue solution, and Groups Dextrose–Dextrose and Dextrose–Saccharin had dextrose as cue. All animals received a wintergreen-flavored cue on half the days and a cinnamon-flavored cue on the other half according to a double alternation pattern. Cue removal was followed 30 min later by placement of 40 ml of reinforcement solution for 30 min. Groups Saccharin–Saccharin and Dextrose–Saccharin received a saccharin consequence, and Groups Dextrose–Dextrose and Saccharin–Dextrose received a dextrose consequence. Half the animals in each group were reinforced on days that they received a wintergreen cue, and the other half were reinforced on days that they received a cinnamon cue. Groups received no consequence on the days on which they were not reinforced. The daily food ration was given 2 hr after removal of the reinforcement tubes.

Testing took place on Days 38–40. A test consisted of a 30-min two-bottle test with a choice between 40 ml of each of cinnamon- and wintergreen-flavored cue solutions. Thus Groups Saccharin–Saccharin and Saccharin–Dextrose received saccharin in test, and Groups Dextrose–Dextrose and Dextrose–Saccharin received dextrose in test. Left and right positions were switched between test days.

Results

Table 1 shows the mean preference for wintergreen during the tests (ml wintergreen consumed/ml of wintergreen + ml of cinnamon) for each group in Experiment 1 separated for rats that had wintergreen followed by reinforcement and those that had cinnamon followed by reinforcement.

A difference in preference for wintergreen between rats for which wintergreen was reinforced and those for which it was not indicates that rats associated the flavors with the consequence. As can be seen in Table 1, groups that received a dextrose consequence learned the flavor–consequence association, whereas groups that received a saccharin consequence did not.

Data were analyzed in a between–within analysis of variance including cue (saccharin vs. dextrose), consequence (saccharin vs. dextrose), reinforcement or nonreinforcement of C or W (termed preference conditioning) as *between* factors and tests as the *within* factor.

Table 1
Mean Preference for Wintergreen for the Groups in Experiment 1

Group & cue consequence	W-reinforced	C-reinforced
Saccharin–saccharin	.58	.58
Saccharin–dextrose	.64	.45
Dextrose–saccharin	.28	.32
Dextrose–dextrose	.33	.19

Note. W = wintergreen; C = cinnamon.

The only variable that affected preference conditioning was the consequence. Preference conditioning was demonstrated when dextrose was the consequence but not when saccharin was the consequence—C vs. W Reinforced × Consequence, $F(1, 32) = 6.52$, $p < .02$. No other interactions involving preference conditioning were significant. Results were the same when absolute consumptions of cinnamon and wintergreen were compared rather than relative consumption of wintergreen, so those results are not reported.

Discussion

Results of Experiment 1 are consistent with the idea that long-delayed flavor preference learning is produced by caloric consequences. Flavor preference learning after a 30-min delay occurred when the consequence was dextrose (40 ml of 20% dextrose, 30.4 calories) but not when the consequence was saccharin. The only significant effect on conditioned preference was that of dextrose versus saccharin consequence. Cue–consequence similarity had no effect, nor did the type of cue (dextrose vs. saccharin) have an effect.

Of course, there may be other than caloric differences between the dextrose and saccharin consequence that account for the results. Perhaps the 20% dextrose + .01% quinine solution tastes better than the 0.32% saccharin solution and therefore is more reinforcing. To establish that the critical component is calories, we decided to repeat Experiment 1 using different consequences that varied calories in a number of different ways. In Experiments 2–4 we varied the calories in the consequence in three different ways.

Experiment 2

In Experiment 2, four groups were employed, with the consequence varying across groups. For all groups the cue flavors were presented in 0.065% saccharin. The consequences were either 1% sucrose, 8% sucrose, 1% polycose, or 8% polycose. Polycose is a minimally sweet glucose polymer, calorically equivalent to sucrose (according to the manufacturer, Ross Laboratories, Columbus, Ohio). If conditioning is stronger the greater the calories in the consequence, then the groups that receive 8% polycose and 8% sucrose should show greater conditioned preferences than the groups that received 1% polycose and 1% sucrose. If, on the other hand, sweetness or other taste qualities are responsible for the conditioned preference, perhaps 8% sucrose will produce a stronger conditioned preference than the minimally sweet 8% polycose, and 1% sucrose may produce a stronger preference than 1% polycose.

Method

Subjects. Subjects were from the same source as Experiment 1. Thirty-one were 79 days old on arrival and 100 days old at the beginning of the experiment; eight rats were 81 days old on arrival and 171 days old at the beginning of the experiment. All subjects were experimentally naive. The 8 older rats were assigned equally among groups. One rat in Group 8% sucrose died during the course of the experiment, and its data were discarded.

Materials. Solutions were the same as in Experiment 1 except the reinforcement solutions were 1% sucrose, 8% sucrose, 1% polycose, or 8% polycose, and all rats received 0.065% saccharin as the cue solution.

Procedure. Procedures were the same as in Experiment 1 except for the following: A 14-g ration was used rather than 15-g (because the rats were generally younger). Half the animals were fed at 9 a.m. and half fed at 5 p.m. on Days 2–16; beginning on Day 17 half the rats were fed at 1:30 p.m. and half at 10 p.m. (These changes were all for the convenience of the experimenter.) The amount of cue solution was reduced to 5 ml, and Days 7–16 were preexposure days. The longer preexposure and smaller cue solution amounts were necessary because rats do not easily consume large amounts of 0.065% saccharin. An overnight exposure to 20 ml of 0.065% saccharin was followed by 3 hr of exposure the next day, which preceded 3 days of 15-min exposure to 5 ml of saccharin and 1 day of 10-min exposure to 5 ml of saccharin. By the end of preexposure all rats were readily consuming the unflavored 0.065% saccharin solution. On Day 13 all rats received 24-hr exposure to 20 ml of their reinforcement solution followed by a 3-hr exposure the next day. This was followed by 2 additional days of 10-min exposure to unflavored 0.065% saccharin.

Days 17–28 were training days. Five ml of the cue solution (now flavored with cinnamon or wintergreen) was presented for 5 min; 5 min later the reinforcement solution was presented (20 ml of the appropriate solution for 10 min). The 14-g daily ration was reduced 1 g for every 10 ml of sucrose or polycose drunk by rats reinforced with 8% polycose or 8% sucrose (20 ml of 8% sucrose or polycose contains 6.4 calories). There were two 50-min tests per day on Days 29–37.

Results

Table 2 shows the mean preference for wintergreen (ml wintergreen consumed/ml wintergreen + ml cinnamon consumed) for each group in Experiment 2. Once again a greater preference for wintergreen when it was reinforced is the measure of conditioned preference. As can be seen in Table 2, groups reinforced with 8% polycose or 8% sucrose formed a conditioned preference, whereas those reinforced with 1% sucrose or 1% polycose did not. The only significant effect on conditioned

Table 2
Mean Preference for Wintergreen for the Groups in Experiment 2

Group	W-reinforced	C-reinforced
1% polycose	.41	.42
8% polycose	.38	.29
1% sucrose	.38	.41
8% sucrose	.38	.25

Note. W = wintergreen; C = cinnamon.

preference was concentration—W vs. C Reinforced × Concentration, $F(1, 31) = 6.46$ $p < .02$. The sucrose versus polycose manipulation had no effect on the conditioned preference ($F < 1$). Results were the same when absolute, rather than relative, consumptions of solutions were analyzed ($p < .04$); thus those data are not reported here.

Discussion

Results of Experiment 2 are consistent with the hypothesis that number of calories is the critical component producing conditioned preferences. Sweetness does not seem to be critical because sweetness had an effect on the conditioned preference only when calories also varied (in the 1% vs. 8% concentration manipulation). When sweetness was varied and calories were constant (the sucrose vs. polycose manipulation), the size of the conditioned preference did not vary.

Experiment 3

Experiment 3 involved a different calorie manipulation—amount of fat in wet mash.

Method

Subjects. Subjects were 19 male albino rats from the same source as the previous experiments. Twelve were naive subjects, 81 days old upon arrival and 92 days old at the beginning of the experiment. The remaining 7 rats were 81 days old upon arrival and 143 days old at the start of the experiment; they had been previously used in a morphine tolerance study.

Materials. The cue flavors were the same as in Experiments 1 and 2. In Experiment 3 they were dissolved in 0.15% saccharin solution.

The reinforcement diets were presented in zinc canning jar lids taped to a metal strip which hung over the side of the cage front and allowed the jar's lid to rest on the cage floor. The lids had a 7.6 cm diameter and were 2.5 cm high. Low-fat mash consisted of 50% water and 50% ground lab blocks (10 g of low-fat mash contains 19.6 calories); the high-fat mash was 50% water, 15% lard, and 35% ground lab blocks (10 g of high fat mash contains 27.2 calories).

Procedure. Ad lib water was present throughout the experiment in brown bottles mounted to the right of center on the cage front. On Day 1 all food was removed from the cages. On Days 2–11 a feeding schedule of 14 g every night at 6 p.m. was begun.

Days 10 and 11 were preexposure days. At 2 p.m. all animals received 5 ml of the appropriate cue solution until all animals had consumed the entire 5 ml, but not for longer than 30 min. Training occurred on Days 12–31 (20 days). All animals received a wintergreen cue on half the days and cinnamon cue on the other half according to a double alternation pattern. A 5-min delay began as soon as an animal's tube was off the cage. Following the delay, reinforcement dishes were placed for those animals receiving mash that day. Half the animals were given low-fat mash (L) as a reinforcer, and the other half received high-fat (H) mash. Dishes were removed as soon as a rat had finished all 10 g of mash. Half of the subjects in each group were reinforced on days that they received a wintergreen cue, and the other half were reinforced on days that they received a cinnamon cue. The daily ration was reduced to 9 g for rats that received low-fat mash that day and 8 g for those that received high-fat mash. All animals were fed their daily ration 2 hr after removal of the reinforcement dishes. One subject in Group L was removed because of an ear infection. The test procedure was the same as in Experiment 1.

Table 3
Mean Preference for Wintergreen for Groups in Experiment 3

Group	W-reinforced	C-reinforced
High fat	.51	.24
Low fat	.42	.43

Note. W = wintergreen; C = cinnamon.

Results

Table 3 shows the proportion of wintergreen consumed by each group separately for those animals for which cinnamon was reinforced and those for which wintergreen was reinforced. As can be seen, the group for which high-fat mash was the reinforcer showed a greater preference for wintergreen when it was reinforced, whereas the group receiving low-fat mash did not. The difference in conditioned preference between the groups was significant—W vs. C Reinforced × Group, $F(1, 15) = 5.47$ $p < .04$. The same significant result occurred when absolute consumptions were analyzed ($p < .02$).

Discussion

Results of Experiment 3 are again consistent with the hypothesis that calories are the source of reinforcement. A conditioned preference was produced by the high-fat mash but not by the low-fat mash. Somewhat surprising is the total lack of conditioned preference for the low-fat mash. Unlike saccharin or 1% sucrose and 1% polycose, the low-fat mash has a fairly large number of calories—5 g of lab chow is slightly over one third of the daily ration when rats are on the 14 g/day deprivation schedule we use. This result may indicate that palatability is playing some role in addition to calories. Perhaps the conditioned preference is produced only when a highly caloric *and* palatable reinforcer is used, such as sucrose, polycose (which rats like very much), or high-fat mash, and not when highly caloric but not particularly tasty reinforcers are used (such as the low-fat mash in Experiment 3). Or perhaps both palatability and calories play a role so that if palatability is low, calories must be higher to produce conditioning than the number needed with high palatability. In Experiment 4 we investigated this hypothesis by increasing the amount of plain food used as the reinforcer to see if we could obtain a conditioned preference.

Experiment 4

In Experiment 4 we used 14 g of plain lab chow as the reinforcer.

Method

Subjects. The subjects were from the same supplier as those used in the previous experiments. Two rats, 1 in each group, had been in previous experiments and were 160 days old at the beginning of the experiment. The remaining 18 rats were experimentally naive and ranged from 83–93 days of age at the beginning of the experiment.

Materials. The materials were the same as in the previous experiments. The cue solution was initially 0.065% saccharin but was later changed to 0.15% to encourage more immediate consumption of the cue solutions.

Procedure. The procedure was generally the same as in the previous experiments. In the 24-hr and 3-hr preexposures we used 0.065% saccharin, as we did on the first 2 days of flavor pairing. Thereafter the cue solution was 0.15% saccharin. On Days 1–10 subjects were adapted to the 14-g per day deprivation schedule, and training occurred on Days 11–30. Five ml of cue solution was placed on the cage front, with the flavor presented being cinnamon or wintergreen according to a double alternation schedule. For Group C the daily 14 g closely followed cinnamon presentation and was delayed 2 hr on days when wintergreen was the cue. For Group W the contingencies were reversed. No subject was given its food until all subjects had consumed their food-paired flavor cue; initially, food followed the food-paired flavor cue by 15 min, but with training this interval decreased to 6–10 min. On Days 31–34 preference testing was given, using the same procedure as in Experiment 1.

Results

The proportion of wintergreen consumed was .50 when wintergreen signaled the daily feeding and .38 when cinnamon signaled the daily feeding. This difference was significant, $F(1, 18) = 4.92, p < .04$. The difference was also significant when we analyzed absolute consumptions ($p < .02$).

Discussion

The results of Experiment 4 are very important. They show that conditioned flavor preferences can be produced by normal daily feeding. The lab chow used as a reinforcer in Experiment 4 was a familiar, not particularly palatable, food. In Experiments 1–3 novel, highly palatable reinforcers were used, and the conditioned flavor preferences obtained might have been limited to those conditions. Experiment 4 shows that the phenomenon is more general than that—a flavor that precedes the daily feeding by 6–15 min is preferred to one that precedes the daily feeding by 2 hr. This result is consistent with our original hypothesis that calories are the source of the reinforcement. What is not clear is if taste or palatability plays any role, or if it is caloric benefit independent of taste that is producing the reinforcement.

General Discussion

We have found that flavor preference learning based on positive consequences can occur when a delay intervenes between the flavor and consequence. Delays ranged from 5 min to 30 min in these experiments. Learning, however, occurred only when there were calories in the consequence, and learning was stronger the more calories there were in the consequence. We obtained conditioned preferences with a delayed consequence of dextrose plus quinine, 8% polycose, 8% sucrose, high-fat mash, or 14 g of lab chow. No conditioned preferences were obtained with a delayed consequence of saccharin, low-fat mash, 1% polycose, or 1% sucrose. Thus, Holman (1975) was quite right: It appears that conditioned flavor preferences can be formed with a delayed consequence only if the consequence contains calories. Actually, we can go farther and say there must be an appreciable number of calories in the consequence for flavor preference learning to occur over a delay. No conditioned preferences occurred with a mash compose of 5 g of lab chow plus 5 g of water, yet a conditioned preference was formed when a 14-g lab chow consequence was used. Failures to obtain conditioned flavor preferences over a delay with caloric consequences may occur, then, if too few calories are given in the consequence.

Number of calories cannot, however, be the whole explanation. We obtained a conditioned flavor preference at a 5-min delay using a consequence of 20 ml of 8% sucrose, which contains 6.4 calories. Yet we failed to obtain a conditioned preference with 5 g of low-fat mash, which contains 19.6 calories.[1] At the same time, calories clearly are an important determiner of the preferences obtained here, given the additional preference we obtained with plain lab chow when enough was given.

The fact that conditioned flavor preferences based on calories can occur even if a delay intervenes between flavor and consequence is important for a number of reasons. First, as mentioned above, although taste aversion learning is robust and well investigated, the evidence for flavor preference learning based on positive consequences is more difficult to obtain. There are no previous data outside of Holman's (1975) report that a flavor can be associated with an explicit positive consequence at a delay as long as 5 min. As we pointed out earlier, though postingestional consequences always occur at a delay, when a flavor is given mixed in a food, oral consequences of the food are not delayed. If a delay occurs between the flavor and the food, both oral and postingestional consequences are delayed. Thus it is important to show that conditioned flavor preferences based on calories can be formed with a delay between the flavor and the caloric outcome. It is also of obvious theoretical importance to determine if learning a flavor–consequence association over a delay is possible only with negative consequences or if such learning is also possible with positive consequences. The experiments reported here show that such learning of a flavor–consequence association at a delay is possible and is dependent on calories in the consequence.

This latter finding suggests, but does not establish, that some internal postingestive consequence is partly responsible for the learning. If the reinforcer involved here were purely oral, it seems that learning would occur with saccharin, a tasty consequence. If, indeed, flavor–consequence learning based on positive consequences is possible at a delay only if a certain internal reaction occurs related to calories, there would be an important parallel with taste aversion learning. Taste aversion also seems to be possible only when a particular internal reaction occurs, specifically nausea (Pelchat & Rozin, 1982).

Lastly, our findings have implications for how animals regulate their weight. It is well known that animals eat less of a high-calorie food and more of a low-calorie food in order to regulate their weight, and in many cases the changes in intake seem to require a number of exposures to the diet (e.g., Snowdon, 1969). This is widely viewed to suggest that rats associate some aspect of the diet with the long-delayed caloric consequence of the diet (e.g., Treit & Spetch, 1986). It is thus important to dem-

[1] The calories in the various consequences producing preferences were as follows: 40 ml of 20% dextrose = 30.4 calories (Experiment 1); 20 ml of 8% sucrose = 6.4 calories (Experiment 2); 10 g of low-fat mash = 19.6 calories and 10 g of high-fat mash = 27.2 calories (Experiment 3); 14 g of plain lab chow = 54.88 calories (Experiment 4).

onstrate that rats can indeed associate a flavor with delayed outcomes varying in calories.

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Received August 1, 1986
Revision received October 14, 1986 ■