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Taste Differences Between Cigarette Smokers and Nonsmokers

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REDINGTON, K. *Taste differences between cigarette smokers and nonsmokers.* PHARMACOL BIOCHEM BEHAV 21(2) 203–208, 1984.—In a series of taste tests, cigarette smokers allowed to smoke, cigarette smokers not allowed to smoke, and nonsmokers, rated the pleasantness and intensity of sugar, salt, and quinine solutions. One taste test was performed before, and three tests were completed after, ingestion of a glucose load. Before the glucose load, there were no significant differences between the groups in rating test solutions. After the glucose load, the smokers allowed to smoke significantly decreased their ratings of the pleasantness of very sweet solutions. In contrast, nonsmokers and smokers-not-smoking did not significantly decrease their ratings of the pleasantness of sweet tastes. None of the subjects significantly changed their intensity ratings after the glucose load, nor did they change their pleasantness and intensity ratings of salt and quinine solutions.

Nicotine Cigarettes Smoking Taste Preference Magnitude estimation Sucrose Salt Glucose preload

A cigarette is the perfect type of a perfect pleasure. It is exquisite, and it leaves one unsatisfied. What more can one want? Oscar Wilde

In spite of this recommendation, the most assertive claim that cigarette smokers now make is that smoking helps them stay thin. Smokers as a group are about 5–10 pounds lighter in body weight than nonsmokers are. Although the amount of the weight difference varies from study to study, it has been demonstrated that smokers are thinner than nonsmokers for both sexes, various age groups, and different occupational groups (e.g., [3, 14, 19, 20, 26, 30]). Not only are smokers thinner than nonsmokers, but those who stop smoking often gain weight (e.g., [4, 8, 12, 15, 36, 39]). After a few years ex-smokers often gain enough weight to close the weight gap between smokers and nonsmokers, so that it is difficult to distinguish between their weights [14, 26, 30]. It seems clear that smokers have a lighter body weight than nonsmokers and that they gain weight when they stop smoking [47].

It is not clear why this occurs. An obvious possibility is that smokers consume less food and ingest fewer calories than nonsmokers do, and that smokers who stop smoking increase their caloric consumption. For instance, ex-smokers may increase their overall food consumption when they stop smoking because food tastes better to them. Taste varies along dimensions of pleasantness and intensity. Some investigators suggest that smoking decreases perception of taste intensity [27,40]. If this were the case, smokers would have a higher threshold for detecting tastes than nonsmokers. Also, when smokers rated the intensity (strength) of above-threshold tastes, their ratings would be expected to be lower than the corresponding ratings of nonsmokers. In support of this claim, some studies have found that smokers have higher taste thresholds than nonsmokers [21,38] and seem to prefer savory as opposed to bland (i.e., less "strong") food. However, the research on taste thresholds has been contradictory, with some investigators finding differences between smokers and nonsmokers, and others not [37,41]; and there have been few comparisons of intensity ratings at above-threshold levels.

Smoking may also change the affective rating of taste: even if smokers and nonsmokers perceive that a taste has the same intensity, the taste may not be equally pleasant to both groups. For instance, a strong taste or a weak taste may be more pleasant to smokers than to nonsmokers. Changes in either the intensity or pleasantness of tastes could lead to increased food consumption.

A related possibility is that smokers who stop smoking increase their consumption of particular types of food. Schachter and Nesbitt (unpublished data, Columbia University, 1970) found that smokers who temporarily abstained from smoking consumed about 25% more food (consisting mainly of sweet and salty foods) than they did in a laboratory session when they smoked. It has been suggested that ex-smokers show an increased preference for sweet food when they stop smoking [24,49]. In a laboratory study where food consumption was studied in both rats and humans, administration of nicotine was associated with a decrease in consumption of sweet foods, while cessation of nicotine was associated with an increased consumption of sweet foods [16]. An epidemiological study revealed a significant inverse correlation between cigarette consumption and sugar consumption in the United States over a 14 year period [17].

In this context, it is interesting to note that some investigators have found that nicotine raises blood sugar level in

animals and/or humans [13, 19, 29, 32]. In addition, Blackburn, Brozek, Taylor, and Keys [2] found that smokers have an elevated fasting blood glucose level. An increased blood sugar level may be related to preference for sweet tastes [31]. These findings suggest that the relationship between nicotine intake and liking for sweets may be of particular interest.

Of course, there are other explanations for the weight differences between smokers and nonsmokers, such as differences in physical activity and metabolic rate [1, 13, 36]. However, this study will focus on the aspects which are related to differences in taste.

The study tested the suggestion that tastes are perceived differently by smokers and nonsmokers. Subjects rated both the pleasantness and the intensity of sweet, salty, and bitter solutions. If smoking changes taste by changing taste perception, every taste should be perceived differently by smokers and nonsmokers. On the other hand, if there is something unique about the consumption of sweets, smokers and nonsmokers should differ only in their response to sugar and all other tastes should be rated the same by both groups. This experiment was also a study of the effect of glucose loading on taste. Since nicotine seems to raise blood sugar level, subjects consumed a glucose load to partially mimic this effect of nicotine. First, subjects rated the taste of all the solutions on an empty stomach to test for initial taste differences between smokers and nonsmokers. After a glucose load, subjects continued to taste and rate solutions. The question was whether calories and increased blood sugar level affected the taste perception of smokers and nonsmokers in the same way.

METHOD

Overview

Each subject came in for two, hour-long tasting sessions. For one experimental session, smokers smoked until the experiment began (smokers smoking condition), and for the other they stopped smoking the night before the experiment (smokers-not-smoking condition). Thus, each subject who was a smoker served in both smoking and non-smoking conditions. Nonsmokers also came in for two sessions, but for them the requirements were the same for both sessions. Overall, there were two groups of subjects: smokers and nonsmokers; and within the smoker group there were two conditions: smoking, and not-smoking. The smokers-not-smoking condition was included to see if taste differences which might be found between smokers and nonsmokers could be eliminated by short-term abstinence from smoking.

Using the sip-and-spit method of tasting [33], each subject rated each of the 14 solutions (6 sucrose, 5 salt, and 3 quinine) used in the experiment. Then subjects consumed a glucose load and tasted the set of 14 solutions three more times. The pleasantness and intensity ratings of the solutions constituted the primary measurements of the study.

Experimental Solutions

Fourteen different solutions were used in the experiment, all made with distilled water. Six were sucrose solutions of the following concentrations: 0.056 molar (1.9%), 0.1 molar (3.4%), 0.18 molar (6.2%), 0.32 molar (10.95%), 0.56 molar (19.2%), and 1.0 molar (34.2%). The five sodium chloride solutions had concentrations of 0.1 molar (0.58%), 0.18 molar (1.05%), 0.32 molar (1.9%), 0.56 molar (3.3%), and 1.0 molar (5.8%). The lowest concentrations of the sucrose and salt solutions were close to threshold, while the highest concentrations were extremely sweet or salty tasting. The concentrations of the three quinine solutions were 0.000025 molar (0.001%), 0.00005 molar (0.002%), and 0.0001 molar (0.003%). The lowest concentration of quinine was not very bitter and even the highest concentration was not extremely bitter. It was thought that a very bitter tasting solution, offered four times during the course of the experiment, would antagonize subjects and make them less likely to return for a second session.

Subjects

Subjects were selected so that age, height, and weight were about the same for smoking and nonsmoking groups. Each subject group was composed of 7 males and 7 females. Smokers were eligible for participation in the study if they had smoked a pack or more of cigarettes a day for at least a year. On the average, they had smoked 23 cigarettes a day for the past 5.5 years.

Subjects were instructed not to eat or drink anything but water after 12:00 a.m. on the day of the experiment. All subjects were run in the afternoon between 12:30 and 4:30. Fifty-seven percent of the subjects were part of a paid subject pool and received $6.25 for participating, and 43% of the subjects were part of a volunteer pool and received two hours of experimental credit for participating in the study. There were equal numbers of paid and volunteer subjects in each group.

Procedure

One or two subjects were run at a time. When subjects were seated in the testing room, they were given specific instructions about the sip-and spit method of tasting: subjects were reminded not to swallow the solutions, to sip the entire contents of each cup (10 ml) and rinse their mouth(s) out with water after every taste. Subjects also rinsed their mouth(s) out before starting to taste. If there were two subjects, they were separated by a curtain, so they could not see each other. The noise of a room fan blocked the sounds of spitting, so neither subject could tell how fast the other subject was tasting. Each subject initially rated each of the 14 solutions used in the experiment (6 sucrose, 5 sodium chloride, and 3 quinine solutions). Solutions were presented in random order. Subjects first rated the pleasantness of a taste on a scale which ranged from −2 (very unpleasant) to +2 (very pleasant). Then they rated the intensity on a magnitude estimation scale. Modified instructions on the magnitude estimation of taste [44] were given: subjects assigned a number of their choice to the first solution they tasted and compared the intensity (strength) of the other solutions to the first one by assigning them proportional numbers. For instance, if a subject assigned the number 10 to the first solution, and thought the second solution was twice as intense, s/he would assign the number "20" to the second solution.

After they had tasted and rated the first 14 solutions, which usually took about 10 or 15 minutes, the subjects consumed a 200 ml sugar drink which consisted of 50 g of glucose dissolved in distilled water (a 25% solution). After 20 minutes of working on filler questionnaires, subjects resumed tasting. Subjects tasted and rated the set of 14 solutions three more times. Blood glucose reaches the maximum level about 30–60 minutes after ingestion [7,10]. Any changes

in taste due to an increase in blood sugar level could be observed in the course of these three taste tests which took place after the glucose load. After completing the taste tests, subjects were given two dishes of yogurt and two milk drinks and allowed to eat freely for 10 minutes.

In addition to the rating scales, the subject also filled out a questionnaire about his or her daily activities, which included questions on what the subject had eaten and what stress he or she was under.

This is a schedule of the subject's activities, with approximate times:

Instructions to subject	0– 5 Minutes
Initial taste test (14 solutions)	5–15 Minutes
Consumption of glucose load	15–17 Minutes
Filler questionnaires	17–37 Minutes
Second taste test (14 solutions)	37–44 Minutes
Third taste test (14 solutions)	44–50 Minutes
Fourth taste test (14 solutions)	50–56 Minutes

All subjects came back for a second tasting session. For nonsmokers, the two sessions were almost identical. For smokers, the two sessions differed only in that they abstained from smoking before one session, but smoked normally before the other session. Sessions were counterbalanced: half the smoking subjects abstained from smoking before the first session, and the other half abstained before the second session. In the second session, all subjects received a shortened version of the instructions, and filled out a smoking questionnaire during the 10 minute eating period. Subjects were debriefed after the second session.

To summarize, in a series of taste tests, cigarette smokers and nonsmokers rated the pleasantness and intensity of sugar, salt, and quinine solutions. One taste test was performed before, and three tests were completed after, ingestion of a glucose load. The manipulated variables were subject group and condition (nonsmoking, smoker smoking, smoker-not-smoking); type and concentration of solution; and time of rating (before or after glucose ingestion). The dependent variables were the subjects' ratings of pleasantness and intensity which were made before and after glucose intake.

RESULTS

It was expected that any initial taste differences between the smoking and nonsmoking groups would be observed in the first taste test, before subjects had consumed the glucose drink. It was also expected that the glucose load would have its maximum effect on taste about 45 minutes after ingestion since this is when maximum blood glucose level occurs [7,10]. Since the fourth (and last) taste test occurred about 40–45 minutes after glucose ingestion, the effect of the glucose load on taste was most visible in this test. For these reasons, the first and the fourth taste tests were the most important to consider in assessing taste differences between smokers and nonsmokers, and the second and third taste tests will only be discussed briefly.

To analyze the pleasantness ratings, the mean rating of each solution for each of the three subject conditions was calculated. A two factor analysis of variance was performed comparing smokers in both smoking conditions to nonsmokers. In addition to a pleasantness rating, every subject gave a magnitude estimation number for the intensity (strength) of every solution. These numbers were standardized after the experiment so that the standardized estimate of the 0.32 M

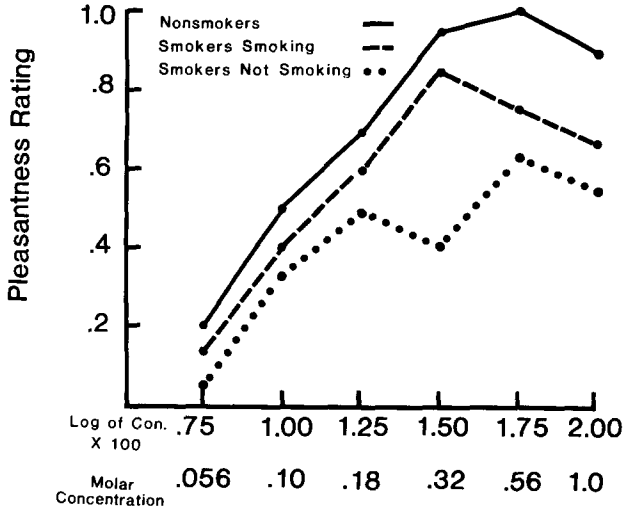

FIG. 1. Pleasantness ratings of sucrose solutions in the first taste test. (In every graph, the curve for the nonsmokers represents the average of the two sessions. Each session was equally weighted, and the data from the two sessions are highly correlated at $p<0.05$ or better.)

salt solution was 100 for each subject. The subject's other intensity estimates were adjusted to make them proportional to the standardized estimate and the median estimate of each group was calculated.

Initial Pleasantness Ratings of Sweet, Salty, and Bitter Tastes

The mean pleasantness rating for the sucrose solutions for each subject condition is graphed in Fig. 1. Although the graph shows that the smokers found the sweet solutions less pleasant than the nonsmokers did, there were no statistically significant differences between the nonsmokers and the smokers smoking, $F(1,26)=0.37$, p=n.s., or between the nonsmokers and the smokers in the not-smoking condition, $F(1,26)=1.89$, p=n.s. Even at the highest concentration levels, there were no significant differences between smokers and nonsmokers.

There were no significant differences between nonsmokers and smokers smoking, $F(1,26)=0.22$, p=n.s., or smokers-not-smoking, $F(1,26)=0.15$, p=n.s., when subjects rated the pleasantness of salt solutions. For all conditions, salty tastes became more unpleasant as the concentration of salt increased.

There were also no significant differences in the way smokers smoking and nonsmokers rated the pleasantness of quinine, $F(1,22)=2.79$, $p<0.1$. (Two subjects in the smoker smoking condition did not rate the pleasantness of the most concentrated quinine solutions. When comparing their data with the nonsmokers (for quinine ratings) these subjects were dropped from the analysis, and data from two randomly chosen nonsmoking subjects was dropped, leaving 12 subjects in each group for this comparison.) When smokers were in the non-smoking condition, results were similar: there were no significant differences in the quinine ratings of smokers and nonsmokers, $F(1,26)=0.04$, p=n.s.

Initial Intensity Ratings of Sweet, Salty, and Bitter Tastes

Both smokers and nonsmokers perceived the intensity of

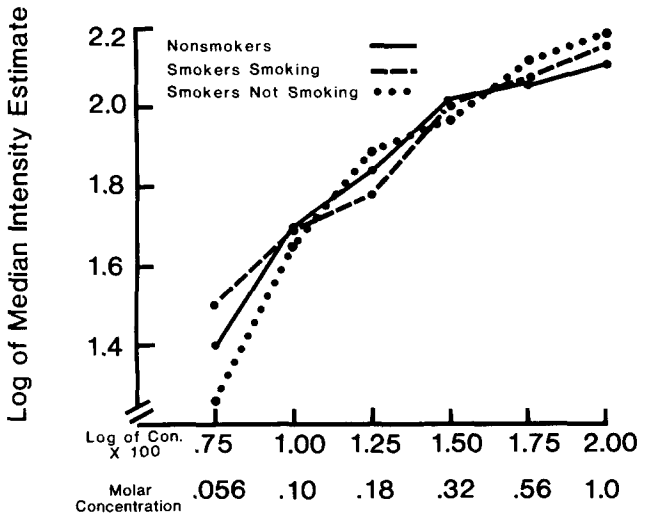

FIG. 2. Intensity ratings of sucrose solutions in the first taste test.

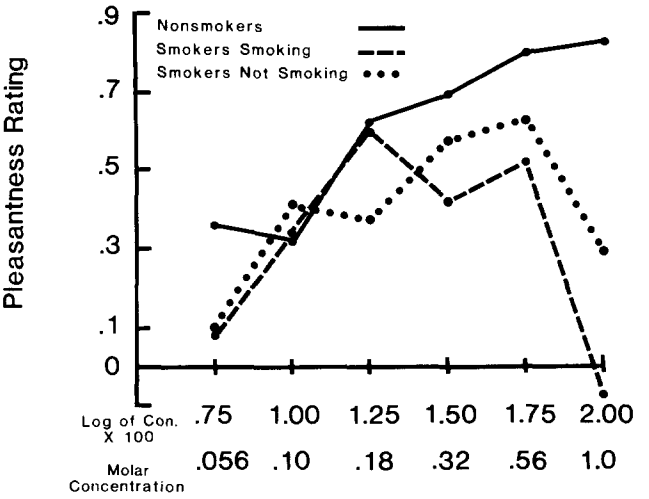

FIG. 3. Pleasantness ratings of sucrose solutions in the last taste test.

the sucrose, salt, and quinine solutions similarly; there were no statistical differences in the intensity ratings. In fact, the curves of the intensity ratings are virtually identical for nonsmokers and smokers in both smoking conditions. Intensity estimates for sucrose are graphed in Fig. 2. The fact that the rated intensities were similar for all conditions is an indication that smoking or nicotine per se does not affect the perceived intensity of sweet, salty, or bitter tastes.

To summarize, there were no significant differences in the way smokers and nonsmokers rated the pleasantness and intensity of sweet, salty, and bitter tastes.

Effect of a Glucose Load on Affective Ratings of Sucrose

Although there was no difference in the way smokers and nonsmokers rated the sweet solutions initially, ingesting the glucose significantly decreased liking for concentrated sweet solutions in the smokers smoking condition (see Fig. 3). The analysis of variance showed a significant group × concentration effect, $F(5,130)=2.36$, which was significant at $p<0.04$. Although the smokers who were smoking significantly decreased their ratings of the sucrose solutions, the nonsmokers continued to rate the sweet tastes as pleasant.

Not only were the ratings of the smokers smoking significantly lower than the ratings of the nonsmokers, but they were also significantly lower than their own ratings of the sweetest solution in the first taste test (matched $t=2.34$, $p<0.05$). Eleven out of 14 subjects in the smokers smoking condition found the 1.0 M sucrose solution less pleasant on the fourth test than on the first test (and one subject's ratings were the same for the first and fourth tests).

In contrast, the glucose load had little effect on the taste ratings of the nonsmokers. The nonsmoking group found the sucrose solutions as pleasant on the last test as they did on the first. In fact, there was a significant correlation between the pleasantness ratings of nonsmokers before and after the glucose drink ($r=.89$, $p<0.05$).

The second and third taste tests showed a consistent and progressive decrease in liking for sweet tastes in the smokers smoking subjects. On the other hand, the nonsmokers maintained their pleasantness ratings at about the same level throughout the second and third taste tests.

When the smokers were in the not-smoking condition,

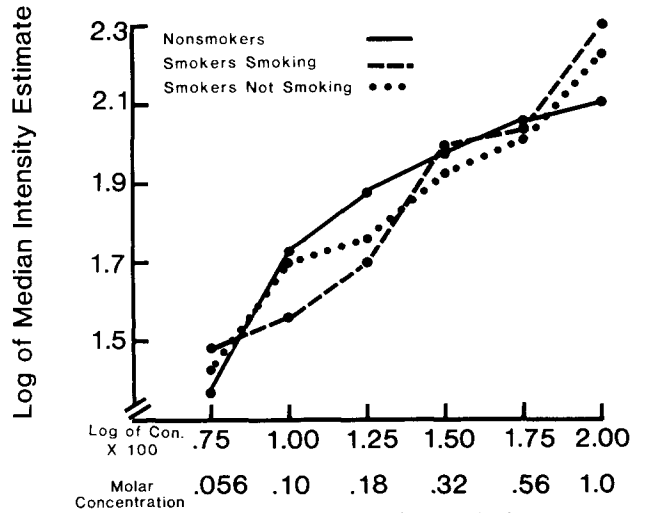

FIG. 4. Intensity ratings of sucrose solutions in the last taste test.

their pleasantness ratings of sweet tastes did not differ significantly from the nonsmokers, $F(1,26)=1.96$, $p=$n.s., even at the highest concentration level. In addition, their ratings of sucrose in the last taste test did not differ significantly from their first test ratings (matched $t=0.87$, $p=$n.s.). Like the nonsmokers, smokers in the not-smoking condition were not significantly affected by the glucose load. However, the ratings of the smokers-not-smoking differed from the ratings in the smoker smoking condition. Smokers liked the 1.0 M sucrose solution significantly less in the smoking condition than they did in the not-smoking condition (matched $t=2.20$, $p<0.05$).

In summary, after the glucose load, smokers in the smoking condition not only found sweet tastes significantly less pleasant than nonsmokers, but also gave the most concentrated sucrose solution a significantly less pleasant rating than they had in the not-smoking condition.

Intensity Ratings of Sucrose After the Glucose Load

Although the rated pleasantness of the sucrose tastes

changed significantly after the glucose drink, the intensity judgements did not. There were still no differences between the intensity ratings of the nonsmokers and smokers in either smoking condition (see Fig. 4), nor were there any significant changes between the intensity ratings before and after glucose ingestion.

For some reason the smokers who were smoking drastically changed their perception of the pleasantness, but not the intensity, of sweet tastes by the fourth taste test of the experiment. The taste perceptions of other subjects were not changed.

Effect of a Glucose Load on Salty and Bitter Tastes

When subjects rated the pleasantness of salty tastes, there were no differences between the nonsmokers and the smokers in either the smoking, $F(1,26)=2.34$, p=n.s., or not-smoking, $F(1,26)=0.27$, p=n.s., conditions.

There were no significant differences between smokers and nonsmokers in rating quinine solutions on the fourth taste test. However, smokers in both smoking conditions found the quinine slightly, but nonsignificantly, more unpleasant than nonsmokers did: nonsmokers and smokers smoking: $F(2,44)=2.53$, $p<0.1$; nonsmokers and smokers-not-smoking: $F(2,52)=3.10$, $p<0.1$. Although neither of these interaction effects are significant, they suggest that there may be a difference in smokers' affective response to quinine, particularly at the higher concentration levels. Since the concentrations tested in this study were rather low, significant differences might be found if higher concentrations were tested. In sum, at the concentration levels tested in this study, no significant difference exists between the quinine ratings of smokers and nonsmokers.

Rated intensity did not seem to change because of glucose intake since all subjects assigned similar intensity ratings to the salt and quinine solutions before and after the glucose drink.

DISCUSSION

The pleasantness and intensity of sucrose, salt, and quinine solutions were rated before and after a glucose drink. Before the glucose load, all subjects gave similar taste ratings to the solutions. After the glucose load, the smokers in the smoking condition decreased their liking for very sweet sucrose solutions. Nonsmokers and smokers in both smoking conditions responded similarly to salty and bitter tastes throughout the experiment: in general, smokers do not rate these tastes differently than nonsmokers do.

From the results, it is clear that there is a relationship between cigarette smoking, glucose consumption, and liking for sweet tastes. It was the combination of smoking and glucose consumption which caused the pleasantness of sweet tastes to dramatically decrease in the smokers smoking condition. Following are some speculations about the characteristics of glucose and nicotine which might be responsible for this change.

It is well established that a glucose load raises the level of sugar in the blood [34]. Previously discussed work indicates that nicotine may also raise blood sugar level. There is evidence to suggest a relationship between high blood sugar level and a decline in liking for sweet foods. For instance, Mayer-Gross and Walker [31] found that the percentage of subjects who preferred a 30% sucrose solution decreased as blood glucose level increased. In addition, ingesting a concentrated glucose solution (which presumably raises blood sugar level) decreases the rated pleasantness of sweet foods in normal weight subjects [5, 43, 46]. Presumably the smokers smoking have a higher blood sugar level than nonsmokers or smokers-not-smoking because both the nicotine and glucose load act to raise their blood sugar. The change in taste would reflect the difference in blood sugar level. Information about the mechanisms by which an elevated blood sugar level affects taste would be of interest.

A glucose load also serves as a source of calories, and may decrease hunger sensations. Some investigators have suggested that nicotine acts through oral or central mechanisms to give smokers a perception of satiety [18, 24, 28], although as yet, there is little more than anecdotal evidence to suggest that smokers actually experience satiety when they smoke [25]. Preference for sweet tastes declines as a function of satiety in normal weight subjects [6, 11, 42]. Again, nicotine and glucose would act in the same direction, and the decreased preference for sweet tastes would reflect the incompatability of satiety and a pleasant sensation for sweets.

There are many other possible mechanisms by which nicotine and a glucose load could act to decrease liking for sweets. Nicotine has numerous physiological effects [9, 22, 23, 35, 45, 48], any one of which could be directly or indirectly responsible for smokers' dislike of sweet tastes. It is also possible that nicotine has some direct effect on glucose receptors or glucose metabolism, or that a third factor affects both nicotine and glucose metabolism. At this point, there is not enough data to choose among alternatives.

Another important finding from this study was that the estimated intensities of tastes were similar for smokers and nonsmokers through the entire experiment. This finding is especially interesting given the common belief that smoking dulls taste perception [40] and the paucity of data about smokers' intensity estimates of suprathreshold tastes. The data suggest that smokers are able to perceive intensity as well as nonsmokers for above-threshold tastes. If the smokers perceived intensity differently than nonsmokers did, it would be difficult to make comparisons between the pleasantness ratings of the groups: it would be as if the two groups were rating two different sets of solutions. In the present study, differences in rated pleasantness are not due to differences in perceived intensity (although it is still possible that taste qualities could be perceived differently by smokers and nonsmokers). As indicated by the data, smoking does not appear to decrease the responsiveness of the taste buds for above-threshold tastes or destroy groups of taste cells.

In conclusion, the smokers who were smoking experienced a decrease in their affective ratings of sweet tastes after a glucose load, although the mechanism by which this occurs is not clear. This difference in taste is especially interesting because it might lead to changes in food consumption: smokers may eat fewer sweets because their affective response to sugar changes when they smoke cigarettes. The change in affective response, together with data which suggests that smokers consume less sweet food than nonsmokers (e.g., [16,17]), may partly account for the lower body weight of smokers.

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