Artificial Sweeteners: Outwitting the Wisdom of the Body?

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Obesity, with its correlations to heart disease, diabetes and a multitude of other health problems, is one of our largest public health concerns. It also has a very large behavioral basis. As psychologists, how can we contribute to getting people to eat healthier and exercise more? Behavioral researchers are working on many aspects of this problem, but as a researcher in taste, I gravitate towards understanding why people make the food choices they do. For decades, one choice available to dieters has been to substitute artificial sweeteners for sugar in their diet. But, do artificial sweeteners promote weight loss or weight gain? Although substituting sweeteners for sugar should lead to weight loss, the reality appears to be different. Two psychologists at Purdue have developed an animal model that supports the conclusion that artificial sweeteners lead to weight gain and shows us how it might happen.

The history of artificial sweeteners has been contentious from its beginning. The first artificial sweetener, saccharin, is said to have been accidentally discovered in 1879 when a chemist, Ira Remsen, failed to wash his hands after working with some coal tar derivatives. He noticed a sweet taste to the rolls he was eating for dinner and traced this back to a compound in his lab. He published his discovery with a student, Constantin Fahlberg (Remsen & Fahlberg, 1880). In an early act of academic theft, Fahlberg subsequently patented saccharin, taking sole credit for the discovery (Fahlberg, 1885). Interestingly, Fahlberg justified the importance of “his discovery” to the patent office by arguing that it would be cheaper than sugar. Use of saccharin surged during WWI and WWII because of sugar shortages, but the widespread use of saccharin to aid weight loss was yet to come.

The claim that saccharin could contribute to weight loss seemed like a no-brainer. Sugar has calories; substitute an artificial sweetener for sugar and you consume fewer calories. But this fails to consider other sources of intake (e.g., the classic weight joke: “I’ll have a hot fudge sundae and a diet coke, please”). In fact, Rosenman reviewed the existing literature in 1978 and concluded, “There is no evidence to show that artificial sweeteners are useful in weight reduction.” In 1986, Stellman and Garfinkel analyzed epidemiological data from an American Cancer Society study and found that weight gain was actually significantly greater in those using artificial sweeteners. In another study that same year, John Blundell (an English psychologist who is an expert on appetite and satiety) suggested that artificial sweeteners could intensify appetite (Blundell, 1986). These two papers were met with a barrage of criticism. One of the criticisms of the Stellman and Garfinkel paper noted that the subjects decided themselves whether or not to consume artificial sweeteners; they were not randomly assigned to groups. Thus, one could argue that those who chose to consume artificial sweeteners had weight problems that were the real source of the weight gain. This is one of the problems with observational studies of human behavior and one of the reasons to use animal models to conduct highly controlled studies.

Consumption data for soft drinks come from USDA Economic Research Service. Obesity prevalence
An animal model for weight gain associated with intake of artificial sweeteners is now at hand, and I recently spoke with two researchers developing such a model. Terry Davidson and Susan Swithers are both professors in the Department of Psychological Sciences at Purdue University. Davidson got his PhD in experimental psychology with APS Past President Elizabeth Capaldi and then did a postdoc with APS Fellow and Charter Member Robert Rescorla. Swithers got her PhD and did a postdoc in behavioral neuroscience with Warren G. (Ted) Hall (an expert in the development of controls of feeding). These two investigators have combined their expertise in conditioning to propose a Pavlovian explanation for the possible role of artificial sweeteners in weight gain.

**Bartoshuk:** One of the great puzzles of the rise in obesity is the timing. Why now?

**Swithers & Davidson:** The rate and timing of the increase in obesity suggests environmental causes. Some ideas about environmental causes include increased availability of food, increased intake of fats and increased caloric density of foods. However, there is some evidence for another potential environmental cause. We see the ability to maintain energy balance and body weight as dependent on Pavlovian conditioning. We know that animals (including humans) learn about sensory events that predict the occurrence of “biologically relevant” outcomes and that, more specifically, sensations evoked by foods can come to predict the postingestive consequences of eating. So, sensory input can affect a variety of the body’s responses to food — from salivary and gastric reflexes (the early work of Pavlov) to pancreatic, thermogenic, metabolic, renal, and cardiovascular reactions.

Normal regulation may come to depend on the reliability of the links between sensation and the arrival of nutrients in the gastrointestinal (GI) tract; these links represent what has been called the “wisdom of the body.” If those links are disrupted, the ability to regulate energy intake, use, and body weight is disrupted. The introduction of artificial sweeteners into our diets may represent just such a disruption; the artificial sweeteners outwit the wisdom of the body by breaking the link between the sensation of sweet taste and the arrival of calories in the GI tract (Davidson & Swithers, 2004; Swithers & Davidson, 2005).

**Bartoshuk:** This suggests that the rise of obesity should parallel the introduction of artificial sweeteners into our diets. What do the data show?

**Swithers & Davidson:** Figure 1 shows changes in the consumption of soft drinks, both caloric soft drinks (in blue circles) and soft drinks sweetened with high-intensity, artificial sweeteners (in red triangles) along with changes in the prevalence of obesity in the United States between 1966 and 2000. This shows that consumption of artificially-sweetened beverages and the prevalence of overweight and obesity have both increased during similar time frames. Of course, data such as these are mere correlations, and don’t allow us to make conclusions about which came first. That’s one of the reasons why an experimental animal model is so important to address this issue.

**Bartoshuk:** What is the experimental evidence for weight gain from artificial sweeteners?

**Davidson & Swithers:** Let us describe one of our studies. Rats are fed yogurt along with their usual rat
chow and water. The basic idea is that one group of rats gets a diet in which sweet taste predicts an increase in calories; they get yogurt sweetened with glucose. The other group of rats gets a diet in which sweet taste does not predict an increase in calories; they get yogurt sweetened with saccharin. Even though the saccharin-sweetened yogurt group actually got fewer calories from their yogurt, they gained more weight than the group fed yogurt sweetened with glucose (Swithers & Davidson, 2008; Swithers, Baker, & Davidson, 2009). At the end of 5 weeks of study, the saccharin-fed rats had also gotten significantly fatter than the glucose-fed rats.

**Bartoshuk:** Do we understand the mechanisms responsible for the increased weight and fat associated with saccharin intake?

**Swithers & Davidson:** We have several initial indications of what might lead to these differences. First, the rats fed yogurt and saccharin ate more chow than did those fed yogurt and glucose. In addition, when given a novel sweet tasting food (chocolate Ensure), the rats fed the yogurt and saccharin failed to compensate as well. That is, the yogurt and glucose fed rats ate less at their next meal after a meal of chocolate Ensure than did the yogurt and saccharin fed rats. Our hypothesis is that the rats’ prior experience with sweet taste followed by no additional calories impaired their ability to use sweet taste to anticipate the calories in the chocolate Ensure. Finally, energy balance depends not only on energy intake, but energy expenditure. Energy can be expended in three ways: voluntary activity, basal metabolic rate (the energy required for basic metabolism), and diet-induced-thermogenesis. Diet-induced-thermogenesis means that excess energy (energy not needed for basic metabolism or voluntary activity) can be stored as fat, but it can also be radiated away as heat. When given the same sweet tasting diet to consume, the rats fed saccharin and yogurt produced less heat than did the rats fed glucose and yogurt (Swithers & Davidson, 2008). In sum, the yogurt and saccharin rats not only consumed more calories, they failed to radiate some of those calories away as heat.

**Bartoshuk:** Are the effects of consuming artificial sweeteners reversible?

**Davidson & Swithers:** Based on recent data, the effects of consuming sweet tastes that are poor predictors of calories appear to be relatively persistent, weren’t related to the particular sweetener and didn’t depend on the sweetener being mixed into yogurt (Swithers, Baker, & Davidson, 2009). This suggests that some of the difficulties with addressing these questions in humans may be related to persistent consequences of experience with artificial sweeteners that people may have before they come to participate in experimental studies (e.g., see Appleton, Rogers, & Blundell, 2004). This is another advantage of using an animal model — the previous experience of rats with the diets is not only known, but can be controlled. Among the questions we’re actively pursuing is whether there are ways to re-link sweet tastes to calories after experience with artificial sweeteners, as well as questions related to whether consumption of artificial sweeteners inevitably leads to increased weight gain under all dietary conditions. We are also conducting studies that will further elucidate the mechanisms that underlie the effects of non-nutritive sweeteners on energy and body weight regulation.

**Conclusion**

Artificial sweeteners are big business. Not surprisingly, this big business looks out for its interests. If you would like to see some of this in action, check the Calorie Control Council website (http://www.caloriecontrol.org). The CCC provides citations to studies promoting the use of artificial
sweeteners as an aid to weight loss. As an antidote to the CCC check the webpage of the Center for Science in the Public Interest (CSPI; http://www.cspinet.org) and select “Integrity in Science” for a searchable database on scientists’ ties to industry. Checking the funding sources for the scientists cited by the CCC is an eye-opening activity.

It is important to note that the fact that a given scientist’s work favors the industry that funded the work does not mean there was any quid pro quo. What actually happens may be much more subtle than that. In an area where there is genuine controversy, the industry can differentially fund those scientists whose work favors their interests. Given the shortage of funding, this produces bias in the scientific literature (see also Lesser et al., 2007). I first began to catch on to how the system worked at a conference attended by scientists from government, industry, and academia. At one point there was a lively conversation about how the safety of artificial sweeteners could be evaluated by the companies producing them. I suggested that they use an NIH-like system. The industry would provide the funds, but have an independent panel of experts review applications in order to dissociate the industry from the awarding of the funds. The representative of one company said, “Why would we want to do that?” Why indeed.