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SHORT COMMUNICATION

A Pavlovian approach to the problem of obesity

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During the past 15–20 y, the incidence of overweight and obesity in the United States has grown rapidly. The processes that underlie this alarming trend remain largely unspecified. We hypothesize that degradation of the ability to use certain orosensory cues to predict the caloric consequences of intake may contribute to overeating and excessive weight gain. The results of two preliminary studies with rats are consistent with this hypothesis. In one study, the ability of rat pups to regulate their caloric intake after consuming a novel high-calorie, sweet food was disrupted if they had received prior training with sweet tastes that failed to predict the caloric consequences of eating. Another study found that altering the normal predictive relationship between food viscosity and calories led to increased body weight in adult rats. Dietary factors that degrade the relationship between sweet tastes, food viscosity and calories may contribute to overeating and weight gain.
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It is not unusual for people to indulge in large, energy-rich meals that provide calories well in excess of their short-term needs, eat smaller more 'calorie conscious' meals on other occasions, and skip meals altogether at other times. The fact that many people maintain normal body weight over the long-term despite such wide fluctuations in energy intake points to the existence of regulatory control mechanisms that enable people to compensate ultimately for shorter-term excesses (or deficits) with periods of decreased (or increased) caloric consumption. Unfortunately, it appears that this compensatory system is becoming increasingly ineffective as data from several sources indicate that the proportion of the population classified as overweight or obese has climbed steadily since the mid-1980s.[1] Concerns about the public health consequences of obesity make it critical to identify factors that contribute to the widespread decline in the ability to regulate intake.

A hallmark of modern theories of Pavlovian conditioning is that animals, including humans, learn about sensory events that predict biologically significant outcomes. [2] Recent studies on the control of ingestion show that the orosensory properties of foods can serve as conditioned stimuli to predict the caloric consequences of eating. [3] It may be that the ability to predict the caloric consequences of eating influences the precision of caloric intake regulation. Accordingly, factors that disrupt or degrade this ability could lead to imprecise caloric compensation and increased incidence of obesity.

To consider this hypothesis within a Pavlovian conditioning framework one must: (a) identify stimuli that are used by animals to predict the caloric consequences of intake; (b) specify events or conditions that could degrade this predictive relationship; and (c) provide evidence that increases in the incidence of obesity are related to the occurrence of these events or conditions. One good predictor of calories, especially when encountered in early childhood, is the sweetness of food. Thus, early experience provides a basis for learning that very sweet foods are associated with more calories than less sweet foods. Exposure to a largely direct relationship between food viscosity and caloric content is also common with, for example, the viscosity and caloric density of human breast milk appearing to vary together.[4] Thus, breast-feeding may provide an important initial exposure to a general rule that thicker substances contain more calories than thinner substances. Accordingly, among the experiences that could degrade the ability of animals to anticipate the caloric consequences of eating would be intermittent consumption of (a) sweet substances that are calorie-free or (b) low-viscosity foods or beverages that are relatively high in calories.

It seems that since the mid-1980s, consumption of these types of substances has increased dramatically. For example, according to the Calorie Control Council,[5] the number of Americans consuming sugar-free products increased from

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less than 70 million in 1987 to over 160 million by 2000. Similarly, consumption of low-viscosity, but relatively high-calorie, soft drinks increased by more than 15 gallons per capita, over roughly the same time frame.[6] A question of interest is whether or not the intake of sweet, low-calorie substances, and low-viscosity, high-calorie beverages might be causally related to increases in obesity that have occurred over the same time period. Such a link has been suggested in children, with high levels of fruit juice consumption associated with increased adiposity and short stature.[7]

The results of two preliminary experiments suggest that further investigation of this potential causal link is warranted. In one study, two groups of 23-day-old weanling rats ($n = 10$/group) were given overnight access to 50 ml of flavored (grape or cherry) sweet solutions along with *adlib* lab chow. For Group Consistent, 10% sucrose sweetened one solution and 10% glucose sweetened the other. For Group Inconsistent, the flavored solutions were sweetened with noncaloric 0.3% saccharin and 10% glucose. Thus, sweet taste was a reliable predictor of calories for Group Consistent, but not for Group Inconsistent. Following 10 days of this training, all rats were given 1 day with just lab chow before testing began. Next, the animals were food deprived overnight, before being offered 4 g of a sweet, high-calorie, chocolate-flavored pre-meal. After consuming the pre-meal, rats were given lab chow for 1 h. If the predictive relationship between sweet taste and calories that was experienced during training affected the ability of the rat pups to compensate for the calories consumed in the pre-meal, then intake of lab chow during testing should differ for the two groups.

Figure 1 shows that although intake of the pre-meal did not differ between the groups, Group Consistent subsequently ate significantly less lab chow than Group Inconsistent during testing. This outcome agrees with the hypothesis that Group Consistent was better able than Group Inconsistent to anticipate the caloric consequences of eating the sweet pre-meal and thus was better able to compensate for the calories contained in that meal by reducing subsequent intake of lab chow.

In a second study, two groups of adult rats ($N = 8$/group) were given 15 g daily of a relatively high-calorie (1.3 kcal/g) dietary supplement along with *adlib* lab chow. For Group Low, 3% water was added so that the viscosity of the supplement was similar to chocolate milk. For Group High, adding 3% nonmetabolizable guar produced a supplement with viscosity similar to thick chocolate pudding. Thus, for the two groups the supplements were equated in terms of caloric and nutritive content, but differed markedly in viscosity. Figure 2 shows that over a 30-day period, Group Low gained significantly more weight than did Group High. This outcome indicates that rats are less able to compensate for calories contained in low-viscosity compared to high-viscosity foods (also see DiMeglio and Mattes[8]).

The results of both of these preliminary studies suggest that manipulating the ability of sweet tastes and food viscosity to predict the caloric consequences of eating may produce increased intake and body weight. The extent to which degradation of such predictive relationships, by dietary and other factors, contributes to the societal problem of obesity merits further research attention.

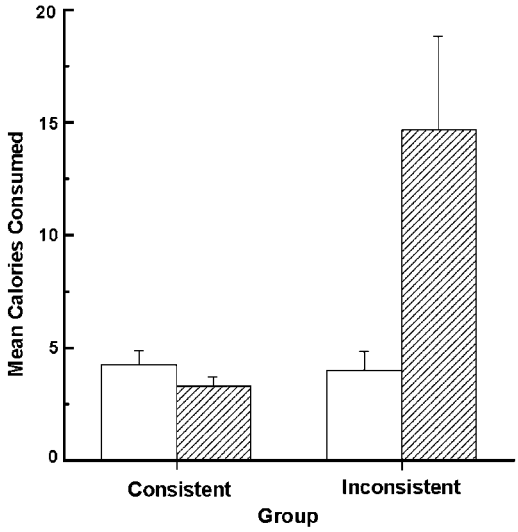

Figure 1 Mean calories consumed of a sweet, chocolate-flavored pre-meal (open bars) and of a subsequent lab chow test meal (cross-hatched bars) for rats that were given prior training with different sweet tastes that were consistently paired with calories (Group Consistent) and for rats that were trained with sweet tastes that were inconsistently paired with calories (Group Inconsistent). Error bars depict standard error of the mean (s.e.m.).

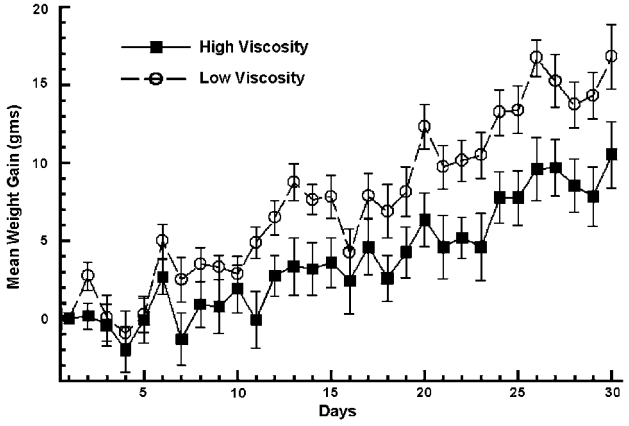

Figure 2 Mean weight gain of rats given 15 g daily of an equicaloric (1.34 kcal/g) low-viscosity (>100 cP; open circles) or high-viscosity (~55 000 cP; solid squares) dietary supplement. Error bars depict standard error of the mean (s.e.m.).

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