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Research report

The effect of non-caloric sweeteners on cognition, choice, and post-consumption satisfaction ☆

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ABSTRACT

Consumers often turn to non-caloric sweeteners (NCS) as a means of promoting a healthy body weight. However, several studies have now linked their long-term use to increased weight gain, raising the question of whether these products produce unintended psychological, physiological, or behavioral changes that have implications for weight management goals. In the following, we present the results of three experiments bearing on this issue, testing whether NCS-consumption influences how individuals think about and respond to food. Participants in each of our three experiments were randomly assigned to consume a sugar-sweetened beverage, an unsweetened beverage, or a beverage sweetened with NCS. We then measured their cognition (Experiment 1), product choice (Experiment 2), and subjective responses to a sugar-sweetened food (Experiment 3). Results revealed that consuming NCS-sweetened beverages influences psychological processes in ways that – over time – may increase calorie intake.

Introduction

The incidence of overweight and obesity in the U.S. and the rest of the world has steadily increased for more than 30 years (Flegal, 2005, Rigby, Kumanyika, & James, 2004; World Health Organization, 2006). In light of these trends, weight loss products are becoming increasingly popular among consumers seeking to lose weight or prevent weight gain. Among the most popular of these items are products containing non-caloric sweeteners (NCS), which sweeten food and drinks without adding calories. Because these sweeteners are calorie-free, using them as a replacement for sugar should facilitate weight loss. Although some studies have found evidence of this (e.g., de Ruyter, Olthof, Seidell, & Katan, 2012; Raben, Vasilaras, Møller, & Astrup, 2002) – particularly in the short-term – others have found their long-term use associated with weight gain, even after controlling for the fact that heavier people are more likely to use them in the first place (Colditz, Willett, & Stampfer, 1990; Dhingra et al., 2007; Fowler et al., 2008; Lutsey, Steffen, & Stevens, 2008; Nettleton et al., 2009; Stellman & Garfinkel, 1986).

That researchers have failed to establish a reliable association between NCS consumption and weight loss has led some to hypothesize that their consumption might produce unintended physiological, psychological, or behavioral changes that hinder, rather than help, consumers' weight management goals (see e.g., Green & Murphy, 2012; Rudenga & Small, 2012; Smeets, Weijzen, de Graaf, & Viergever, 2011; Swithers & Davidson, 2008). In the following, we present the results of three experiments that examined this possibility, testing the impact of NCS consumption (via a diet soft drink) on food-related cognition, consumer choice, and subjective responses to sugar-sweetened snacks. By measuring the impact of NCSs on processes known to impact food regulation over time, the current research seeks to provide new insights into the ongoing debate about whether NCSs help or hinder consumers' weight loss goals.

Non-caloric sweeteners (NCS) and weight regulation

For most of human history, sweetness has provided a reliable orosensory cue to a food's energy content. Sweet-tasting foods are more calorically dense than less sweet foods, making sweetness a valid predictor of subsequent energy availability. However, when the natural pairing of sweetness and caloric density is decoupled – such as when NCS-sweetened products are consumed – the mismatch between the sweet flavor and energy availability is hypothesized to disrupt the body's natural food-regulation processes, potentially causing changes that discourage rather than promote weight loss (see e.g., Rudenga & Small, 2012; Swithers, Martin, & Davidson, 2010; Wang & Dvorak, 2010). Experimental research conducted using rodent models has found support for this hypothesis (Swithers & Davidson, 2008; Swithers et al., 2010). For example, Swithers and Davidson (2008) found that rats that consumed NCS-sweetened food and drink subsequently ingested a greater number of calories and experienced an increase in body

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weight relative to rats that consumed items sweetened with glucose. Similar experiments in humans, however, have provided more mixed results (see Bellisle & Drewnowski, 2007, for a review). Although a small number of studies have found that consuming non-caloric sweeteners prior to eating a test meal increased subsequent food intake consumption (e.g., King, Appleton, Rogers, & Blundell, 1999; Lavin, French, & Read, 1997), the majority have found no relationship between these variables (e.g., Birch, McPhee, & Sullivan, 1989; Black, Tanaka, Leiter, & Anderson, 1991; Canty & Chan, 1991; Rolls, Kim, & Fedoroff, 1990).

The lack of experimental evidence demonstrating a meaningful causal relationship between consuming NCS-sweetened products and changes in calorie intake has led many to conclude that NCSs do not have a disruptive effect on processes influencing consumers' energy regulation. However, little remains known about the impact of NCS consumption on consumers' food regulation psychology, which guides energy regulation over longer spans of time than can be measured in the laboratory. Because consuming as little as 50 extra calories per day can lead to weight gain of 14–20 pounds over an eight year period (Hill, Wyatt, Reed, & Peters, 2003), even subtle, periodic increases in calorie intake can have implications for weight management goals. Examining the impact of NCSs on the psychological processes that guide consumption over time thus represents the important next step in the ongoing discussion about the impact of NCS-sweetened products on consumers' energy balance. In the following, we present the results of three experiments examining the effect of NCS consumption (via a diet soft drink) on food-related cognition, consumer choice, and subjective response to sugar-sweetened snacks. We predicted that, compared to participants who first consumed a sugar-sweetened or unsweetened drink, those who consumed a beverage sweetened with NCS would demonstrate: (a) increased mental accessibility of the names of high-calorie food items (Study 1), (b) increased likelihood of choosing a sugary snack food item in a consumer choice scenario (Study 2), and (c) decreased satisfaction with a subsequently consumed sweetened snack item (Study 3).

Experiment 1

The goal of our first experiment was to examine the impact of non-caloric sweeteners on the cognitive accessibility of food items with differing levels of caloric density. We predicted that – compared to participants who consumed the sugar-sweetened or unsweetened beverage – those who consumed the beverage sweetened with NCS would have shorter response-time latencies to the names of high-calorie, but not low-calorie, food items.

Method

Participants

Participants who ate or drank anything other than water less than eight hours prior to their session were excluded from all analyses (18 excluded), leaving a total of 116 undergraduates (75 women, 41 men) in our final sample (36 in the Sprite condition, 40 in the Sprite Zero condition, and 40 in the mineral water condition). Participants' ages ranged from 18 to 25 years ($M = 19.81$, $SD = 3.27$) and all received partial course credit in exchange for their participation.

Design and procedure

The design of this study was a 3 (drink condition: Sprite vs. Sprite Zero vs. mineral water, between subjects) × 3 (word type: high calorie vs. low calorie vs. non-word, within subjects) mixed factorial design. During recruitment, all participants were instructed not to eat or drink anything other than water past midnight prior to their testing session. All testing sessions were conducted between 8:00 and 11:00 a.m. After arriving in the laboratory, participants were given a participant ID number that was linked to their testing condition. Upon being seated, participants were given an unmarked, red plastic Solo cup that contained one of three 12 ounce (355 ml) beverages: (1) sugar-sweetened (Sprite), (2) non-calorically sweetened (Sprite Zero), or (3) unsweetened (Kroger brand lemon-lime sparkling mineral water) (Table 1). Participants (all condition-blind) were given five minutes to consume their drink while watching images from the Hubble Telescope on their computer screens. After this time had elapsed, participants were asked to complete a lexical decision task (described below). The study closed with participants being asked to respond to a series of questions about themselves (e.g., sociodemographic questions, height, weight) and about their compliance with the experimental procedure. After the experiment was complete, a hypothesis-blind research assistant used the ID numbers to match participants' computerized data with the drink condition to which they were assigned.

Table 1
Characteristics of the drinks used across all studies.

Drink type	Energy/100 g	Ingredients
Sprite	167 kJ/40 kcal	Carbonated water, sugar, citric acid, malic acid, acidity regulator (sodium gluconate), natural lemon-lime flavorings, sweetener (steviol glycosides).
Sprite Zero	0 kJ/0 kcal	Carbonated water, citric acid, natural lemon and lime flavorings, sweeteners (aspartame, acesulfame-K), preservative (E211), acidity regulator (E331).
Sparkling water	0 kJ/0 kcal	Carbonate water, natural flavors

Cognitive accessibility of high- vs. low-calorie foods

After participants finished their beverages they completed a lexical decision task to measure the cognitive accessibility of high- and low-calorie foods. During this task, participants were presented with 28 letter strings. These letter strings, presented in random order, consisted of seven high-calorie food words (e.g., burger, cookie, pizza), 7 low-calorie food words (e.g., celery, radish, carrot), and 14 non-words (e.g., ebusun, ganeap, tigne). Each letter string flashed on the screen for 250 ms and participants had to indicate whether each letter string was a word or non-word by pressing the "z" or "m" key, respectively. The response latencies (i.e., how long it took for participants to indicate if a string of letters was a word or non-word) served as our dependent variable, with lower response latencies indicating greater cognitive accessibility. To familiarize participants with this task, before completing the experimental trials, participants completed 30 practice trials consisting of 15 neutral words and 15 non-words. A pretest conducted prior to the experiment ($n = 15$) verified that the high-calorie food items were easily recognized as being higher in calories ($M_{high} = 9.73$, $SD = .68$; $M_{low} = 1.97$, $SD = .50$, $F(1, 14) = 923.45$, $p < .001$), more fattening ($M_{high} = 9.84$, $SD = 1.04$; $M_{low} = 1.25$, $SD = .32$, $F(1, 14) = 759.57$, $p < .001$), and more sugary ($M_{high} = 7.28$, $SD = 1.48$; $M_{low} = 1.24$, $SD = .38$, $F(1, 14) = 266.27$, $p < .001$) than the low-calorie food items. Lastly, participants were thanked, debriefed, and dismissed.

To determine whether drink type affected cognitive accessibility of high-calorie food items, we examined participants' response latencies to the names of high- and low-calorie food items. We first calculated the mean reaction time RT for each correct response within each response category (i.e., high-calorie foods, low-calorie foods, and non-words). This measure reflects the average amount of time (in milliseconds) that it took participants to correctly identify a string of letters as being a word (the name of either a high- or low-calorie food item) or a non-word. Because outliers can distort RT measures (Fazio, 1990; Fazio, Sanbonmatsu, Powell,