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Participants with pharmacologically impaired taste function seek out more intense, higher calorie stimuli

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ABSTRACT

Objective: Research suggests a weaker sense of taste in people with obesity, with the assumption that a debilitated taste response increases the desire for more intensely tasting stimuli to compensate for decreased taste input. However, empirical testing of this supposition remains largely absent.
Method: In a randomized, repeated measures design, 51 healthy subjects were treated with varying concentrations of a tea containing *Gymnema sylvestre* (*GS*), to temporarily and selectively diminish sweet taste perception, or a control tea. Following treatment in the four testing sessions, taste intensity ratings for various sweet stimuli were captured on the generalized Labeled Magnitude Scale (gLMS), liking for real foods assessed on the hedonic gLMS, and optimal level of sweetness quantified via an ad-libitum mixing task. Data were analyzed with mixed models assessing both treatment condition and each subject's resultant sweet response with various taste-related outcomes, controlling for covariates.
Results: *GS* treatment diminished sweet intensity perception ($p < 0.001$), reduced liking for sweet foods ($p < 0.001$), and increased the desired sucrose content of these foods ($p < 0.001$). Regression modeling revealed a 1% reduction in sweet taste response was associated with a 0.40 g/L increase in optimal concentration of sucrose ($p < 0.001$).
Discussion: Our results show that an attenuation in the perceived taste intensity of sweeteners correlates with shifted preference and altered hedonic response to select sweet foods. This suggests that those with a diminished sense of taste may desire more intense stimuli to attain a satisfactory level of reward, potentially influencing eating habits to compensate for a lower gustatory input.

1. Introduction

Taste is a sensory gate-keeping mechanism; when we taste foods, we choose to consume or reject them based on their sensory properties. Many reports highlight a weaker sense of taste in people with obesity (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006; Pepino, Finkbeiner, Beauchamp, & Mennella, 2010; Sartor et al., 2011), and that losing weight enhances taste responses (Miras & le Roux, 2010; Scruggs, Buffington, & Cowan, 1994), with taste function also associated with several obesity-linked hormones (Dando, 2010). We consume food not just for nutrition, but also for the positive central reward it offers, with emotions possibly linked to taste (Noel & Dando, 2015). Psychophysicists have noted for many years that appetitive tastes such as sweet follow a psychophysical function resembling an inverted U. Hedonic response increases with stimulus intensity, before reaching a plateau, and decreases when the stimulus becomes unpleasantly strong (Moskowitz, Kluter, Westerling, & Jacobs, 1974). Studies have demonstrated a blunted reward system in rodents with obesity (Berthoud, Zheng, & Shin, 2012), and a lower activity in reward centers of the brains of humans that are obese (G. K. W. Frank et al., 2012; E. Green, Jacobson, Haase, & Murphy, 2011). Therefore, a common assumption is that a person with a weakened sense of taste may desire or habitually consume more intensely tasting foods. These foods would presumably also be higher in calories, since both sweetness and the taste for fat (Running, Craig, & Mattes, 2015) signify caloric content in their common forms. Thus, a depleted taste response in those with obesity may influence diet, and moreover, may represent a form of eating disorder, driving unhealthy eating habits. However, research to support the assumption that decreased gustatory input correlates with an increased desire for more intensely tasting foods remains absent.

Gymnema sylvestre (*GS*) is a plant native to South Asia, known for

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its ability to temporarily suppress sweet tastes (Bone, 2002). Studies suggest this suppression is attributed to a glycoside known as gymnemic acid, which binds to oral receptors activated by sweeteners (Schroeder & Flannery-Schroeder, 2005), reducing the perceived sweetness of a stimulus. When rats were given *GS*, their neural response to sweeteners was significantly reduced when compared to rats consuming the same foods without *GS* treatment (Imoto, Miyasaka, Ishima, & Akasaka, 1991). A relatively low concentration of *GS* is needed to reduce responsiveness to sweeteners in both rats (Imoto et al., 1991) and humans (Bone, 2002), with studies suggesting that concentrated solutions of *GS* can suppress more than 75% of the pre-treatment perceived sweetness of a stimulus (R. A. Frank, Mize, Kennedy, de los Santos, & Green, 1992). *GS* selectively suppresses sweet intensity perception for a prolonged period, making it an intriguing tool to study how a diminished taste response influences a participant's reaction to foods. In a study by Riskey, Desor, and Vellucci (1982), participants were treated with a series of diluted *GS* solutions ranging from 0.03 to 0.50 g/l and reported sweet taste intensity of sucrose solutions at three concentrations. Not surprisingly, with increasing *GS* concentration, the sweetness from sucrose was reported as less intense, reducing suprathreshold sweet intensity ratings between 61% and 68% (Riskey et al., 1982). The group reported only minimal recovery after 20 min, highlighting *GS*'s potential suitability in a sensory study to selectively diminish sweet taste response.

In this study, we pharmacologically impaired the sweet taste signal arising from taste receptors responding to sweeteners in participants over multiple sessions, where participants were asked to complete a series of sensory tests probing the hypothesis that a depleted taste response correlates with a gravitation towards higher calorie stimuli. This hypothesis would further support the notion that the strength of signals arising from the peripheral gustatory system may have consequences that contribute to the ongoing obesity epidemic.

2. Methods

All aspects of this study were reviewed and approved by the Cornell University Institutional Review Board. Healthy, non-smoking participants with a normal sense of taste and smell, without seasonal allergies, and not pregnant or breastfeeding, were recruited with flyers and postings on campus. 51 participants completed all phases of the study, which required attendance at four testing sessions on separate days. The sessions corresponded to three treatment conditions where rinsing with a tea made with *Gymnema sylvestre* (*GS*) solutions of varying concentrations diminished sweet taste perception, and one control condition where rinsing with an equi-bitter control herbal tea maintained sweet taste function. The order that the subjects completed the experimental conditions was randomized and counterbalanced.

Participants were asked to abstain from eating and drinking 30 min prior to testing. Each testing session took place at approximately the same time of day, and took around 30 min to complete. The sessions followed the same schedule: training in scale usage, pre-treatment taste assessment, *GS* or control treatment, post-treatment taste assessment, and finally sensory and hedonic measures of real foods. Upon completion of all four sessions, anthropometric measurements and demographic information were collected, and participants were compensated for their attendance.

2.1. Experimental conditions

Gymnema sylvestre (*GS*) was used to experimentally diminish sweet taste perception, with increasing concentrations of *GS* hypothesized to result in greater reduction in perceived sweet taste (Riskey et al., 1982). Dried and powdered *GS* leaves (Source Naturals, Scotts Valley, CA) were dissolved in deionized water at the following concentrations: 0.0 g/L for the control condition, 1.2 g/L for the lowest *GS* concentration treatment condition (*GS* 1), 3.6 g/L for the medium concentration *GS* treatment condition (*GS* 2), and 10.8 g/L for the highest concentration *GS* treatment condition (*GS* 3). In order to match the bitterness of the solutions containing *GS*, the control solution consisted of a strong herbal tea (judged as equi-bitter in pilot testing), which was also used as a control solution in previous studies using *GS* (Meiselman & Halpern, 1970a,b; Riskey et al., 1982). All solutions were presented at room temperature, identified by a random three-digit code in small opaque cups with lids. Participants were instructed to rinse their mouth with the tea solutions for 60 s (sufficient in pilot testing to inhibit taste response for 40–60 min), and then expectorate.

2.2. Taste intensity scale training and evaluation

Electronic questionnaires on iPads (Apple Inc, Cupertino, CA) captured sweet taste intensity ratings before and after treatment using the sensory software Compusense Cloud (Compusense, Guelph, Canada). Participants received instructions on using the generalized Labeled Magnitude Scale (gLMS), rating a series of broadly varying auditory and visual, real and imagined sensations (Bartoshuk et al., 2004; Green, Shaffer, & Gilmore, 1993). Ratings ranged from 'no sensation' to 'strongest imaginable sensation of any kind'. The scale values were log-transformed: no sensation (0.0), barely detectable (0.14), weak (0.76), moderate (1.21), strong (1.52), very strong (1.70), and strongest imaginable sensation of any kind (1.98). Whole mouth taste intensity ratings were captured using a sip and spit procedure. Sucrose was dissolved in deionized water and presented in a series of three ascending concentrations: 81.0, 243.0 and 729.0 mM/L, denoted as 'low', 'medium', and 'high', with one series presented before treatment and one after. All samples were served in uniform clear plastic cups at room temperature, identified by randomly assigned three-digit codes. Participants rinsed their mouth between each sample and a self-advancing timer ensured that participants were not able to progress through the electronic test without ample rest time, to curtail adaptation, fatigue, and any carry-over effects.

2.3. Quantification of optimal sweetness

Following post-treatment sweet taste assessment, participants performed an ad-libitum mixing task (Pangborn, Braddock, & Stone, 1983), titrating a beverage to their optimal level of sweetness. Participants were given an unsweetened flavored beverage and two additional solutions: one solution of the same flavor labeled 'more sweet', containing a highly sweetened solution (250.0 g/L sucrose), and one flavored solution labeled 'less sweet', containing an unsweetened solution (0.0 g/L sucrose). Participants were instructed to continuously taste and adjust their beverage by adding as much or as little of each of the solutions, until the beverage reached their 'optimal level of sweetness'. This task was completed twice, starting once with the unsweetened beverage (0.0 g/L sucrose), and the other time with a highly sweetened beverage (250.0 g/L sucrose), to avoid context effects (Riskey, Parducci, & Beauchamp, 1979). The final dissolved sugar content was quantified with a refractometer, and the two replicates were averaged as a measure of optimal sweetness (presented here in g/L).