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Higher sensitivity to sweet and salty taste in obese compared to lean individuals

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A B S T R A C T

Although putatively taste has been associated with obesity as one of the factors governing food intake, previous studies have failed to find a consistent link between taste perception and Body Mass Index (BMI). A comprehensive comparison of both thresholds and hedonics for four basic taste modalities (sweet, salty, sour, and bitter) has only been carried out with a very small sample size in adults. In the present exploratory study, we compared 23 obese (OB; BMI > 30), and 31 lean (LN; BMI < 25) individuals on three dimensions of taste perception – recognition thresholds, intensity, and pleasantness – using different concentrations of sucrose (sweet), sodium chloride (NaCl; salty), citric acid (sour), and quinine hydrochloride (bitter) dissolved in water. Recognition thresholds were estimated with an adaptive Bayesian staircase procedure (QUEST). Intensity and pleasantness ratings were acquired using visual analogue scales (VAS). It was found that OB had lower thresholds than LN for sucrose and NaCl, indicating a higher sensitivity to sweet and salty tastes. This effect was also reflected in ratings of intensity, which were significantly higher in the OB group for the lower concentrations of sweet, salty, and sour. Calculation of Bayes factors further corroborated the differences observed with null-hypothesis significance testing (NHST). Overall, the results suggest that OB are more sensitive to sweet and salty, and perceive sweet, salty, and sour more intensely than LN.

1. Introduction

The sense of taste is important to detect nutrients and toxins in our foods. According to this notion, sweet indicates carbohydrates, salty indicates sodium, sour indicates acids and potentially spoiled foods, and bitter acts as a warning sign for potentially toxic ingredients (but also healthy compounds found in green vegetables). Impairments in taste perception and/or hedonic experience of taste can cause deviant eating behaviour, which can lead to mal- or super-nutrition, both representing major public health issues.

Overweight and obesity are defined as abnormal or excessive accumulation of body fat to an extent that may lead to negative effects on health. Body Mass Index (BMI, kg/m^2) is a simple and commonly used measure for classifying weight status (underweight, normal weight, overweight, obese etc.). According to the latest global estimates from the World Health Organisation (WHO), worldwide, prevalence of obesity has more than doubled since 1980 (WHO, 2015). WHO has also reported that an increased BMI is a major risk factor for several non-communicable diseases such as type 2 diabetes, heart disease, stroke, and some forms of cancer. Considering that obesity is preventable, it is important to understand the causes and effects of obesity in order to devise prevention and treatment strategies.

The large part of the obesity research in recent years has concentrated on 'eating behaviour', and the reward response to food or food cues (e.g. food pictures) rather than the sensory aspects of food intake, i.e. taste sensitivity and preference. Consequently, the link between taste perception and BMI is unclear (Donaldson, Bennett, Baic, & Melichar, 2009). Studies looking at BMI related sensitivity or threshold differences for sweet, salty, sour and bitter tastes have either found no effect (Malcolm, O'Neil, Hirsch, Currey, & Moskowitz, 1980; Martinez-Cordero, Malacara-Hernandez, & Martinez-Cordero, 2015), lower taste sensitivity in obesity (Proserpio, Laureati, Bertoli, Battezzati, & Pagliarini, 2015)

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or higher taste sensitivity in obesity in some or all tastes in children, adolescents, and older adults (Overberg, Hummel, Krude, & Wiegand, 2012; Pasquet, Frelut, Simmen, Hladik, & Monneuse, 2007; Simchen, Koebnick, Hoyer, Issanchou, & Zunft, 2006). A comprehensive investigation of taste experience in adults, measured with taste thresholds as well as supra-threshold hedonic ratings for the four basic tastes, found no differences between adult-onset obese, juvenile-onset obese, and never-obese women (Malcolm et al., 1980). However, the small sample sizes may have hindered the authors from detecting small differences between groups.

Research on taste perception and weight status has primarily focused on sweet taste (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006; Grinker, Hirsch, & Smith, 1972; Pepino, Finkbeiner, Beauchamp, & Mennella, 2010; Rodin, Moskowitz, & Bray, 1976; Thompson, Moskowitz, & Campbell, 1976); while bitter taste has also been investigated, studies have focused on Phenylthiocarbamide (PTC) and 6-*n*-propylthiouracil (PROP) (Goldstein, Daun, & Tepper, 2005; Tepper et al., 2008), bitter compounds that are not commonly found in foods. Salty and sour taste perception has remained largely unexplored (Donaldson et al., 2009). The combined results from these studies are inconclusive. For instance, in spite of the widespread belief that sweet foods contribute greatly to excess weight gain, no clear difference in sweet sensitivity had been seen between obese and lean individuals (Grinker et al., 1972; Rodin et al., 1976; Thompson et al., 1976). A lower sweet intensity perception was first reported in people with obesity when general Labelled Magnitude Scales (gLMS) were used instead of traditional visual analogue scales (VAS), combined with a higher sweet preference (Bartoshuk et al., 2006). GLMS are designed to be more valid than traditional VAS when comparing inter-individual subjective ratings. However, in a later study, no difference was shown between obese and normal weight groups in detection thresholds, preference, discrimination performance or supra-threshold intensity ratings, even when intensity ratings were acquired using a gLMS (Pepino et al., 2010).

An unambiguous interpretation of the literature on nutritional status and taste is further complicated by the heterogeneity of methods across studies. First of all, the current WHO definitions of weight status are: 'normal weight' = 18.5–25 kg/m^2, 'overweight' = 25–30 kg/m^2, and 'obese' $\geq$ 30 kg/m^2. But the classification for obese and non-obese groups in studies does not always adhere to these criteria (e.g. Simchen et al., 2006). Secondly, a comparison of thresholds may refer to absolute or detection thresholds, recognition thresholds, or identification thresholds, which may, in turn, be estimated in a variety of ways (Snyder, Sims, & Bartoshuk, 2015). Taste stimuli may be applied in the form of water-based taste solutions, or taste infused paper strips, cotton swabs, or discs (for an overview, see Hummel, Hummel, & Welge-Luessen, 2014). Liquid stimuli can be administered to the tongue as sprays or drops, or as larger aliquots that participants are asked to sip. There is also variability in the chemical compounds (e.g. citric acid or acetic acid for 'sour', caffeine or quinine for 'bitter')', concentration ranges, and stimulus amounts used for taste assessment. Sets of taste infused paper often use very few concentration steps (e.g. 4 for taste strips; Mueller et al., 2003) that do not readily allow detection of small differences between groups or across time. It is worth taking into account that differences in taste thresholds do not necessarily reflect differences in supra-threshold sensitivity (Bartoshuk, 1978; Webb, Bolhuis, Cicerale, Hayes, & Keast, 2015). Consequently, it is important to independently estimate supra-threshold sensitivity and preferences for taste, as human food intake generally takes place at a supra-threshold taste level. To date, measures of taste sensitivity and subjective supra-threshold perception have not been systematically assessed and compared between lean and obese individuals.

In the present study, we compared taste perception in lean and obese participants on three dimensions: recognition thresholds as an objective measure of taste sensitivity, as well as subjective intensity and pleasantness for different supra-threshold concentrations of four basic tastes.

2. Materials and methods

2.1. Participants

54 healthy participants between 18 and 35 years of age were recruited into the lean (LN) or obese (OB) group based on BMI of <25 and >30, respectively. The LN group consisted of 31 participants (Mean BMI = 21.88, range = 18.73 to 24.49; 14 women), and the OB group included 23 participants (Mean BMI = 33.8, range = 30.47 to 38.96; 12 women). All women used hormonal contraceptives. Self-report based exclusion criteria were: taste and smell disorders, smoking, substance abuse and other addictions, current or recent oral, nasal or sinus infections, pregnancy, recent (in the last 6 months) childbirth, thyroid disorders, diabetes, or weight loss of more than 10 kg in the last 3 months. All participants gave written informed consent prior to the experiment.

2.2. Stimuli

Tastants were sucrose (Sigma-Aldrich, CAS number: 57-50-1), sodium chloride (NaCl; Sigma-Aldrich, CAS number: 7647-14-5), citric acid (Sigma-Aldrich, CAS number: 77-92-9), and quinine hydrochloride (quinine; Sigma-Aldrich, CAS number: 6119-47-7) dissolved in mineral water (Volvic) creating 'sweet', 'salty', 'sour', and 'bitter' taste, respectively. Each stimulus was a 0.2 mL bolus of the tastant administered to the anterior part of the tongue. For threshold estimation, 12 dilution steps, evenly spaced on a decadic logarithmic scale, were prepared for each taste quality. The concentration ranges (Table 1) were derived from the literature, and adjusted according to preliminary testing. Tastants were stored in individual glass bottles with a spray dispenser, presented at room temperature, and kept at 5 °C in the dark for a maximum of three days when not in use.

2.3. Recognition thresholds

Recognition thresholds were estimated for each of the four taste qualities independently through an adaptive staircase procedure based on QUEST (Watson & Pelli, 1983), implemented via PsychoPy 1.80.03 (Peirce, 2007). The procedure assumed the relationship between log-transformed stimulus concentrations and perceived taste intensities to follow the shape of a Weibull function with a slope of 3.5, and the threshold as free parameter. Pilot testing showed that participants were highly unlikely to report a stimulus at very low concentrations or when pure water was presented (low false-alarm rate; FAR), and, likewise, would only rarely report not perceiving a stimulus at high concentrations (low lapsing rate). Therefore, we assumed both false-alarm and lapsing rates to be fixed at 0.01. A starting concentration and its standard deviation were provided to QUEST as a prior. These concentrations were chosen after pilot testing in such a way that they would be clearly perceptible to most participants (sucrose: 5.022 g/100 mL, NaCl: 1.615 g/100 mL, citric acid: 0.285 g/100 mL, quinine: 0.0092 g/100 mL) and presented on the first trial of threshold estimation for the respective taste quality. After each response given by the participant, QUEST updates the posterior probability density function for the threshold, and proposes the next concentration to be presented. Since we only had a limited number of stimuli