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Research report

A preference test for sweet taste that uses edible strips ☆

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ABSTRACT

A novel delivery method is described for the rapid determination of taste preferences for sweet taste in humans. This forced-choice paired comparison approach incorporates the non-caloric sweetener sucralose into a set of one-inch square edible strips for the rapid determination of sweet taste preferences. When compared to aqueous sucrose solutions, significantly lower amounts of sucralose were required to identify the preference for sweet taste. The validity of this approach was determined by comparing sweet taste preferences obtained with five different sucralose-containing edible strips to a set of five intensity-matched sucrose solutions. When compared to the solution test, edible strips required approximately the same number of steps to identify the preferred amount of sweet taste stimulus. Both approaches yielded similar distribution patterns for the preferred amount of sweet taste stimulus. In addition, taste intensity values for the preferred amount of sucralose in strips were similar to that of sucrose in solution. The hedonic values for the preferred amount of sucralose were lower than for sucrose, but the taste quality of the preferred sucralose strip was described as sweet. When taste intensity values between sucralose strips and sucralose solutions containing identical amounts of taste stimulus were compared, sucralose strips produced a greater taste intensity and more positive hedonic response. A preference test that uses edible strips for stimulus delivery should be useful for identifying preferences for sweet taste in young children, and in clinical populations. This test should also be useful for identifying sweet taste preferences outside of the lab or clinic. Finally, edible strips should be useful for developing preference tests for other primary taste stimuli and for taste mixtures.

Introduction

Food preferences in humans are determined by sensory responses to the taste, smell, and texture of foods (Drewnowski & Rock, 1995; Duffy & Bartoshuk, 2000). Of these sensory responses, taste is considered the major determinant of food choice (Asao, Luo, & Herman, 2012). Of the primary taste stimuli, sweet taste generally signals a pleasurable experience (Reed & McDaniel, 2006). Due to this strong hedonic appeal, humans have a strong desire for sweet-tasting foods (Drewnowski, Mennella, Johnson, & Bellisle, 2012), or foods with both sweet and fat taste qualities (Drewnowski, 1993; Drewnowski & Greenwood, 1983). However, this desire for sweet-tasting foods may contribute to metabolic syndrome and obesity (Swithers, 2013), hypertension (Ferder, Ferder, & Inserra, 2010), diabetes (Tepper, Hartfiel, & Schneider, 1996) and dental caries (Binns, 1981; Roberts & Wright, 2012). Nonetheless, no clear association between an increased preference for sweet taste and obesity in humans has been observed (Mattes & Mela, 1986).

Taste preferences for sweetness show age-related differences (Desor & Beauchamp, 1987), and these preferences may be influenced by genetics, race and ethnicity, or nutrient deficiencies (Drewnowski et al., 2012). Changes in preferences for sweet taste are also associated with drug and alcohol use since nicotine (Grunberg, Bowen, Maycock, & Nespor, 1985), cannabinoids (Yoshida et al., 2010), opiods (Langleben, Busch, O'Brien, & Elman, 2012), cocaine (Janowsky, Pucilowski, & Buyinza, 2003), heroin (Picozzi, Dworkin, Leeds, & Nash, 1972), alcohol (Bogucka-Bonikowska et al., 2001; Gosnell & Krahn, 1998), and methadone (Nolan and Scagnelli, 2007), can impact preferences for sweet taste (Turner-McGrievy, Tate, Moore, & Popkin, 2013).

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The preparation, transport, and storage of sucrose solutions for testing outside of the clinic or lab can be laborious. Impregnated filter papers that contain taste stimuli have been prepared that alleviate many of these problems (Landis et al., 2009; Lawless, 1980; Mueller et al., 2003), but the filter paper must be expectorated after each measurement, and disposed as hazardous waste. A third method for delivering stimuli is to prepare edible taste strips that rapidly and completely dissolve in the oral cavity (Smutzer et al., 2008). Sucralose was chosen as the sweet taste stimulus because this molecule is perceived as approximately 600 times sweeter than sugar (Binns, 2003; Friedman, 1998) so that lower amounts of stimulus are required for examining sweet taste. At matched intensities, both sucrose and sucralose exhibit similar taste perception profiles (Binns, 2003), and sucralose does not result in an unpleasant aftertaste in most individuals (Schiffman & Gatlin, 1993; Wells, 1989). Finally, the Venus flytrap domain at the N-terminus of both heteromeric subunits of the mammalian sweet taste receptor binds both sucrose and sucralose, which would suggest a similar transduction mechanism for both sweet taste stimuli (Zhang et al., 2010).

The purpose of this study was to develop edible sucralose strips for rapidly identifying sweet taste preferences in humans. Then, the perception of sucralose strips and solutions in the oral cavity was measured in order to identify which delivery method yielded higher taste intensity and hedonic values.

Materials and methods

All sucrose and sucralose solutions were prepared in water (Deer Park, Stamford, CT.), and warmed to room temperature before use. Edible taste strips were prepared as previously described (Smutzer, Desai, Coldwell, & Griffith, 2013; Smutzer et al., 2008). Briefly, pullulan (α-1,4-; α-1,6-glucan; NutriScience Innovations, LLC, Trumbull, CT), was combined with the polymer hydroxypropyl-methylcellulose (Dow Chemical Co., Midland, MI) at a weight ratio of 11.5:1. Food coloring was added to aid in visualization of taste strips. Sucrose was obtained from Fisher Scientific (Pittsburgh, PA), and sucralose was obtained from Tate & Lyle (MacIntosh, AL). For taste film preparation, a flat casting surface was washed with 70% ethanol, dried, and wiped clean with a paper towel. The clear polymer solution was then poured onto a non-stick surface (Smutzer et al., 2008). The solution was evenly spread over an enclosed area, and allowed to dry for 12 to 18 h at room temperature. After drying, the clear film was removed, cut into one-inch squares, and stored in the dark at 4 °C or −10 °C in an airtight sealable bag for no more than one month.

The maximal amount of sucrose that could be incorporated into a one-inch square edible taste strip was ~80 μmol (Smutzer et al., 2008). This amount of sucrose produces a sweet taste intensity that is well below that of a 36% sucrose solution (Cowart & Beauchamp, 1990). In addition, sucrose amounts greater than ~50 μmol resulted in taste strips that became distorted in shape and possessed diminished tensile strength after their removal from the drying surface. These physical characteristics resulted in taste strips that were unsuitable for a preference test with sucrose as the stimulus.

Test subjects

A total of 50 subjects participated in this project, and included 27 females and 23 males (see Table 1). The mean subject age was 26.5 ± 1.8 years of age, and all subjects were healthy by self-report. The subjects were 54% Asians, 36% Caucasians, 8% African–Americans, and 2% Hispanic. In the sucralose and sucrose comparison study, the subset of subjects included 12 males and 18 females (mean age was 26.8 ± 2.7 years).

All subjects refrained from eating for 30 min prior to the start of the study, and 49 of 50 subjects were non-smokers. Study subjects were recruited through flyers and by word of mouth. All test subjects were trained in the use of the general Labeled Magnitude Scale (gLMS) (Bartoshuk et al., 2004). For taste strips, subjects were instructed to place the strip on the tongue surface, raise their tongue to the roof of their mouth to dissolve the strip, and wait a minimum of 5 s before reporting a response. Subjects were specifically instructed to report a taste intensity response and not a tactile response. Lastly, all subjects rinsed with water after each stimuli presentation. This study protocol was approved by the Institutional Review Board at Temple University, and all study participants were provided written informed consent.

Forced choice paired comparison preference test for sweet taste

For both preference tests, a series of five stimuli with increasing amounts of stimulus were matched in intensities (identified as A, B, C, D, and E, with A containing the lowest amount of stimulus). For a comparison of the two preference tests, sucralose strip intensity was matched to sucrose solution intensity by trial and error. Initially, sucralose strip A was matched in taste intensity to sucrose solution A, and then the intensity of strip E was approximated to that of sucrose solution E. Finally, the amount of sucralose in samples B, C, D, and E were intensity matched to the corresponding sucrose solutions.

In order to more closely match the intensities of all five stimuli in both preference tests, the sucralose preference test used a geometric progression (common ratio = 2) for varying the amount of taste stimulus rather than a modified geometric progression (Cowart & Beauchamp, 1990), where the highest concentration of liquid sucrose was 1.5 times greater than the penultimate concentration.

For edible strips, test subjects were presented with pairs of strips that differed in amounts of sucralose (182.4, 364.8, 730.9, 1460.5, or 2921.1 nmol of sucralose). For the solution test, subjects were presented with pairs of solutions that differed in amounts of sucrose (0.88, 1.75, 3.51, 7.01, or 10.52 μmol of sucrose in 10 ml volumes).

The preference test consisted of two counterbalanced series (see Fig. 1). In both series, trial one consisted of the second lowest stimulus amount (sample B) presented with the penultimate stimulus amount (sample D) according to Cowart and Beauchamp (1990). This protocol allowed the subject to compare his or her preferred stimulus amount from trial one with either the next lower (series one) or next higher (series two) amount of taste stimulus in trial two (see Fig. 1).

For series one, the lower amount of stimulus was presented first in each trial. Then, the preferred amount of stimulus in trial one was always paired with the next lower stimulus amount in trial two. This protocol was repeated until the subject chose the same amount when presented with both the next higher and next lower amount in successive trials, or when the subject chose either the highest or the lowest amount in two consecutive trials (sample A or E) (Mennella, Lukasewycz, Griffith, & Beauchamp, 2011). Each subject rinsed a single time with room temperature water after the first strip of each trial, and rinsed twice between trials.

A 3-min interval occurred between series one and two. For series two, the stronger (higher) amount of stimulus was presented first in all trials. Then, the preferred amount from trial one was always paired with the next higher amount in trial two. As in series one, this process was repeated until the subject chose the same amount when presented with both the next higher and next lower amount of stimulus in consecutive trials, or when the subject chose either the highest (sample E) or the lowest (sample A) amount in two consecutive trials. The preference amount for each subject was estimated by calculating the geometric mean of the amount