Food Quality and Preference 60 (2017) 154–164

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Bitter mouth-rinse affects emotions

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ARTICLE INFO

Keywords:
Taste
Bitter
Sweet
Mood
Emotions
Decision-making
Hedonic acceptance

ABSTRACT

The sense of taste enables evaluation of food and is an important regulator of food consumption. In general, sweet is an attractive taste modality that leads to ingestion of nutritive food, while sour and bitter are aversive taste modalities that lead to avoidance of spoiled and toxic food. Recent studies suggest inter-connections between taste, emotion and cognition. Here we test the potential effects of two prototypical taste modalities, bitter and sweet, on emotions and on generalized avoidance behaviors, such as risk aversion and mistrust.

Three experiments included over 250 participants who tasted, without swallowing, one of the following stimuli: water control, quinine solution, sucrose solution, quinine-sucrose mixture solution, or propylthiouracil (PROP) solution. The participants had to identify the taste, rank its intensity, perform seemingly unrelated behavioral tasks, and fill a PANAS mood questionnaire.

Our results indicate that oral exposure to bitter compounds negatively correlates with mood scores; that the effect depends on perceiving the solution as bitter; that bitter mouth rinse can lower PANAS mood score and that there is a potential asymmetry in the effects of bitter and sweet taste modalities on mood.

1. Introduction

The sense of taste is essential for translating chemical cues into food rejection and ingestion choices (Chandrashekar, Hoon, Ryba, & Zuker, 2006; Hayes, Feeney, & Allen, 2013; Lindemann, 2001; Yarmolinsky, Zuker, & Ryba, 2009). Preferences for different taste modalities have a strong innate component: sweet (carbohydrates) and umami (amino acid) substances are innately preferred, bitter and many sour substances are innately rejected, while salty substances are innately preferred in low concentrations and innately rejected in high concentrations (Berridge, Robinson, & Aldridge, 2009; Steiner, Glaser, Hawilo, & Berridge, 2001). The recognition of these taste modalities is mediated by sets of chemosensory receptors and channels expressed in separate taste cells on the tongue (Chaudhari & Roper, 2010); different taste modalities are also represented by topographically segregated sub-regions in the gustatory cortex (Chen, Gabitto, Peng, Ryba, & Zuker, 2011). In mammals, bitter substances are detected by taste receptors type 2 (TAS2Rs), and sweet and umami compounds are detected by heterodimers consisting of two subtypes of taste receptor type 1 (TAS1Rs) (Drayna, 2005). Taste receptors belong to the large super-family of G-protein coupled receptors (GPCRs). There are considerably more receptors dedicated to detecting bitter taste than receptors for other taste modalities, with 25 TAS2Rs subtypes in human and 30 in rodents (Bachmanov et al., 2014). TAS2Rs have important genetic variations, with the best studied example of TAS2R38. Various bitter compounds are detected by other TAS2R subtypes (Di Pizio & Niv, 2015; Meyerhof et al., 2010), while for many additional bitter compounds (Wiener, Shudler, Levit, & Niv, 2012), cognate receptors are still unknown.

The canonical taste modalities are detected by animals as diverse as fruit flies and humans, suggesting a near-universal drive to consume fundamental nutrients and to avoid toxins or other harmful compounds (Kim, Breslin, Reed, & Drayna, 2004). The nutritionally beneficial sweet substances have innately pleasant taste (Steiner et al., 2001), and in general may relate to positive experience and emotions. Bitter taste, which signals toxicity, poison and thus danger, is innately aversive (Steiner et al., 2001) and may be more generally associated with unpleasant and difficult situations.

Indeed, in humans, additional layers of connection between the basic tastes and verbal, emotional and behavioral responses have been reported (Chen & Chang, 2012). Sweet drinks were found to evoke interest in interpersonal relationship (Ren, Tan, Arriaga, & Chan, 2014). Bitter taste, on the other hand, was found to promote hostility (Sagioglou & Greitemeyer, 2014), and to induce negative effects on

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http://dx.doi.org/10.1016/j.foodqual.2017.04.007
Received 15 December 2016; Received in revised form 20 March 2017; Accepted 12 April 2017
Available online 26 April 2017
0950-3293/

general mood (Yang, Baad-Hansen, Wang, Xie, & Svensson, 2014), although the robustness of this finding was questioned (Horjales-Araujo, Finnerup, Jensen, & Svensson, 2013). In addition, bitter taste was shown to elicit disgust responses similar to responses to immoral behavior (Chapman, Kim, Susskind, & Anderson, 2009), and to promote moral disgust (Eskine, Kacinik, & Prinz, 2011).

Another implication of the intrinsic value of prototypical taste modalities is the potential effect of taste on risk behavior: Since taste has a central role in signaling of both threats (represented by bitter taste) and benefits (represented by sweet taste), and since risk judgments are focused on the assessment of threats against benefits, taste, as other oral sensations (Byrnes & Hayes, 2016), is likely to play a role in risk assessment. Specifically, if bitter taste induces avoidance of threats, then its tasters might avoid taking risks. Similarly, if sweet taste induces responsiveness to benefits, then its tasters might be open to taking risks. In line with this reasoning, it was found that bitter taste induces self-protecting intentions and increases motivation for survival (Chen & Chang, 2012). This focus on self-protection was found to affect the weighting of gains and losses (Li, Kenrick, Griskevicius, & Neuberg, 2012), a core aspect in risk taking (Ert & Erev, 2013; Kahneman & Tversky, 1979). Thus, while the relation between taste and risk taking has yet to be tested directly, it is plausible that such relation exists.

Here we test the two hypotheses suggested above: (a) that bitter taste affects mood negatively while sweet taste affects it positively, and (b) that bitter taste enhances risk avoidance, while sweet taste increases risk taking. In our study, we used bitter (quinine and PROP) and sweet (sucrose) compounds. Quinine is aversive to many species, including humans and primates (Masi et al., 2013; Mennella & Bobowski, 2015; Steiner et al., 2001), insects (Avargues-Weber, de Brito Sanchez, Giurfa, & Dyer, 2010; de Brito Sanchez, Serre, Avargues-Weber, Dyer, & Giurfa, 2015), and avians (Behrens, Korsching, & Meyerhof, 2014; Cheled-Shoval, Behrens, Meyerhof, Niv, & Uni, 2014). PROP is a well-studied bitter substance, which is aversive to humans (Duffy et al., 2004) and mice (Nelson, Munger, & Boughter, 2003). Taste sensitivity to PROP is genetically determined and allows tapping into interpersonal variability in bitter taste perception (Duffy et al., 2004). Sucrose is attractive to many species, including primates, humans and rats (Berridge, 1991; Brining, Belecky, & Smith, 1991; Grill & Norgren, 1978; Steiner et al., 2001).

The hypothesis that the taste has an effect on emotion is evaluated using a widely used mood questionnaire (PANAS) (Yang et al., 2014). The hypothesis that taste may affect risk-taking is explored by behavioral tasks: a common risky-choice task that involves choice between a sure amount of money and a lottery (Lopes, 1983), and several measures of risk associated with trusting another person (Bohnet & Zeckhauser, 2004). Those include the common trust-game (Berg, Dickhaut, & McCabe, 1995), a simple trust question (Kawachi, Kennedy, Lochner, & Prothrow-Stith, 1997), and trust ratings based on face photographs (Ert, Fleischer, & Magen, 2016; Loewenstein, Weber, Hsee, & Welch, 2001). The first two measures (risky-choice and trust game) involve more thinking and reasoning than the latter two, but are still subjective to intuition, automatic processing and affect (Loewenstein et al., 2001).

The solutions in all experiments are not swallowed, in order to decouple the effects of taste from possible post-oral effects, which can include sensation of nutrients such as amino acids and sweeteners in the gut (Iwatsuki et al., 2012), absorption of the compounds that reach the intestine (Jeon, Zhu, Larson, & Osborne, 2008; Rozengurt, 2006), changing blood glucose levels (Wang & Dvorak, 2010) or inducing the release of incretin hormones (GIP, GLP1) (Sclafani & Ackroff, 2012). Furthermore, pure chemical compounds at a known concentration are used here to rule out effects of color, smell or carbonation, and to allow for a maximally controlled set-up. Behavioral experiments have been criticized for their dependence on college students in laboratory settings. Moreover, differences between students and an older population, in terms of interpersonal relationships, cognitive skills and personality characteristics, might lead to biased results (Sears, 1986). Hence, we examined the effect of bitter taste on two different age groups, young (age range: 18–40) and seniors (age range: 59–88) .Finally, the participants are unaware of the connection between the taste test and the mood scoring and the behavioral tasks.

2. Materials and methods

2.1. Participants

Experiment I: 190 volunteers (125 women and 65 men) were recruited from two major campuses (The Faculty of Agriculture, Food and Environment of the Hebrew University and The Weizmann Institute of Science) in Rehovot, Israel. The age of the participants ranged from 18 to 40, and their Body Mass Index (BMI) ranged from 16.0 to 31.6.

Experiment II: 25 volunteers (13 women and 12 men) were recruited from attendants of lecture series for seniors in Rehovot (age range: 59–88; BMI range: 22.1–34.6).

Experiment III: participants were 25 genotyped subjects (16 women and 9 men, age range: 23–35, BMI range: 18.8–31.0), who did not participate in Experiment I. Participants were either students or staff at The Faculty of Agriculture, Food and Environment of the Hebrew University, who were paid for a routine participation in taste trainings and in experiments. TA2R38 genotype was detected by collecting saliva samples from the panel members, using OG-500 Saliva collection kits (Pronto Diagnostics Ltd). Nucleotides and amino acid codons for two alleles of each panelist were carried out in Monell Chemical Senses Center (Knaapila et al., 2012). Seven members were PAV/PAV, 13 were AVI/PAV, and 5 were AVI/AVI. The most common TAS2R38 variant, PAV (Proline, Alanine and Valine residues in positions 49, 262 and 296, respectively), is activated by 6-n-propylthiouracil (PROP) and other compounds containing the N—C═S moiety. Another common TAS2R38 variant is AVI (Alanine, Valine, Isoleucine in same positions as above), which is not activated by these or any other known compounds in cell-based assays. PAV/PAV homozygotes have high sensitivity to PROP compound, PAV/AVI heterozygotes have intermediate sensitivity, while AVI/AVI homozygotes are PROP non-tasters (Bufe et al., 2005; Duffy et al., 2004). Members of the genotyped panel were trained to ensure that they understand and distinguish the four taste modalities (sweet, bitter, sour and salty), and can use the “Labeled Magnitude Scale” (LMS) (Green et al., 1996) and the “Labeled Hedonic Scale” (LHS) (Lim, Wood, & Green, 2009).

2.2. Compounds and solutions

Quinine-sulfate and PROP were purchased from SIGMA (CAS Numbers: 207671-44-1 and 51-52-5, respectively) and sucrose was bought from a local supermarket (table sugar). The compounds were dissolved in doubly distilled water (TREION column), or in “San Benedetto” water (differences between doubly distilled water and “San Benedetto” water, in terms of taste perception and hedonic acceptance, were not significant, results not shown).

Quinine concentration was aimed to be supra-threshold, but lower than strong intensity range. The reported detection threshold is 0.0083 mM (Keast & Roper, 2007), while the strong intensity values are around 0.5 mM (Green et al., 1996). We aimed for a moderate intensity, to ensure, on the one hand, that a bitter sensation is obtained, and on the other hand, that the concentration does not stimulate extreme responses (Chapman et al., 2009). Accordingly we chose 0.055 mM concentration for Experiment I. In Experiment II, quinine concentration of 0.55 mM was used to ensure that most participants perceive its bitterness, since it was shown that a decrease in taste sensitivity is common in the elderly (Schiffman, 1997). The higher concentration of quinine, 0.55 mM, was kept also in Experiment III.

For sucrose, the reported detection threshold is in the range of