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Individual differences in oral thermosensation

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Abstract

Although oral thermosensation is critical to the perception of food and drinks, little information is available on the organization of individual differences in these abilities. We examined the relationship between measures of cooling and warming on the tongue and lip and the association of these measures to taste sensitivity in a sample of 76 healthy subjects. Thermal abilities were assessed with a computer-controlled, 1.5 cm^2 peltier plate that was placed on the anterior dorsal surface of the tongue or the lower lip. Thermal testing consisted of both cooling and warming threshold detection, and intensity ratings of warm and cool suprathreshold temperatures. Intensity ratings of different temperatures were highly correlated, especially for temperatures in the same class. Similarly, warming and cooling thresholds were highly correlated. In contrast, thermal detection abilities were largely dissociable from suprathreshold intensity ratings, especially in the cooling direction. Suprathreshold ratings of cooling on the tongue were also modestly associated with ratings of the taste intensity of 6-*n*-propylthiouracil (PROP). However, a similar association was observed for the lower lip, indicating that the effect does not reflect an isolated characteristic of lingual physiology. Unexpectedly, two subjects with no history of oral trauma demonstrated abnormally deficient (4 S.D. below the mean) cool threshold detection abilities for the tongue, suggesting that there may exist subjects in the population who have profoundly poor lingual temperature processing.
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1. Introduction

The pleasantness of foods and drinks is strongly influenced by their thermal properties [1]. Thermosensory information from the anterior two-thirds of the tongue is primarily carried through the lingual branch of the trigeminal nerve [2,3]. These nerve endings are found in the perigemmal and extragemmal regions of fungiform papillae surrounding taste buds and in tissues in the core of filiform papillae [4,5]. Thermal information appears to be primarily coded by activation of ion channels belonging to the transient receptor potential (TRP) family [6]. Each member of this family–namely ANKTM1, TRPM8, TRPV1, TRPV2, TRPV3, and TRPV4–activates in response to specific ranges of thermal stimuli [7–14]. Of particular note, TRPV3 and TRPV4 show responses within the innocuous warming range, while TRPM8 shows responses in the innocuous cooling range, whereas the other receptors appear more related to nociceptive responses. Although this basic physiology is well described, the literature on oral thermal abilities is limited [15–17], and little information is available regarding the organization of individual differences on different thermosensory measures. Given that different TRP receptors selectively code for different temperatures, it is not clear whether thermosensory abilities in a given temperature range are necessarily predictive of abilities in ranges coded by different TRP receptors. Similarly, although threshold detection and suprathreshold magnitude estimation are often used to index thermal sensitivity, the relationship between these two types of measures has not been detailed. In order to address these issues, we performed tests of oral thermosensory detection and suprathreshold magnitude estimation in a group of healthy subjects.

In addition, we sought to test whether thermosensory abilities were associated with individual differences in taste sensitivity for 6-*n*-propylthiouracil (PROP). Temperature has long been known to alter the intensity of sweet perception [18], and indeed roughly half of adults perceive a sweet taste during rapid warming of the tongue [19]. Moreover, subjects who perceive

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thermal tastes appear to have both higher oral perception of temperature and heightened taste sensitivity [20]. Individuals differ dramatically in their ability to taste PROP, ranging from individuals who cannot detect it at all (nontasters) to those who perceive it as extremely intense (often referred to as supertasters) [21]. Because these differences have been found to covary with individual differences in the sensitivity for other tastants, it has been suggested that PROP sensitivity underlies broader individual differences in gustatory sensitivity [22], although the literature also makes clear that significant aspects of taste sensitivity are independent of PROP sensitivity (see for instance [23]).

Physiologically, the ability to taste PROP is related to the density of fungiform papillae on the tongue surface, with fungiform papillae count increasing as sensitivity to PROP increases [21,24,25]. Approximately 75% of fungiform papillae innervation arises from the lingual nerve [26]. Not surprisingly, data from hamsters [4] indicates a proportional relation between the number of papillae and the number of trigeminal fibers. Taken together, these findings suggest that there are more trigeminal nerve endings on the tongues of individuals with heightened sensitivity to PROP relative those with lower sensitivity to PROP. Behavioral data supports this hypothesis, indicating that trigeminally-mediated processes increase with increasing PROP sensitivity. For instance, PROP taster status has been observed to influence lingual texture perception [27–29] and lingual tactile acuity [30]. Similarly, lingual sensitivity to a number of chemical irritants including capsaicin has been repeatedly associated with PROP taster status [31–34]. Given that capsaicin is coded by a heat activated TRP receptor (TRPV1), such data raise the possibility that PROP taste sensitivity might be associated with oral thermal perception. However, in considering this possibility, it must be noted that the overall association between PROP taste sensitivity and lingual irritation is at best modest, and that in most of the published literature the association is either weak or sensitive to the specific concentrations, methods or stimuli utilized (see [35] for a review of this literature). Given such weak effects, empirical data is clearly needed before assuming a relationship between PROP taste sensitivity and thermosensation. In order to test for such an association, we assessed lingual thermal perception and PROP taster status in a group of healthy subjects. We additionally examined thermal sensitivity on the lower lip. Recent studies have raised the possibility that aspects of PROP taste sensitivity might reflect perceptual or rating factors that are not specific to lingual sensations (see for instance [20]). Inclusion of a lip control site allowed us to determine if any observed associations between PROP and thermal sensitivity specifically reflect lingual processing or instead reflect a more generalized pattern of association.

2. Materials and methods

2.1. Participants

76 young adults (54 females and 22 males) participated in this study. Participants completed written informed consent approved by the Vanderbilt University Institutional Review Board and received research credit for psychology courses. Enrollment was open to participants regardless of PROP taster status.

2.2. Stimuli

2.2.1. Thermosensory testing

All thermal stimuli were presented with a computer controlled thermal probe (Medoc Thermosensory Analyzer: TSA-2001, Medoc LTD, Israel). The thermal probe consisted of a 1.5 cm^2 peltier plate connected to the end of a curved plastic housing, which allowed the participants to comfortably place the plate on the dorsal surface of their anterior tongue. For tongue testing, subjects were instructed to place the plate at the midline of the tongue, just behind the tip of the tongue.

Participants also completed trials where the plate was placed on their lower lip. The lip served as a nonlingual control site in order to examine the specificity of the effects. For lip trials, the subject was asked to lightly press the thermal probe down at the midline of the dorsal surface of their lower lip. For sanitary purposes, the probe's surface was covered with a clean piece of plastic wrap. Pilot testing indicated that the plastic wrap produces a mild slowing of thermal conduction from the probe to the tongue, raising the amount of deviation necessary to detect a change by roughly 0.2–0.3 °C. Thus our measurements slightly overestimate the absolute deviations necessary for threshold detection. However, since the same type of plastic wrap was used in all studies, it should affect all subjects equally, and therefore does not limit the ability to analyze the association between thermal measures, or their relationship to PROP taster status.

Participants were tested for both thermal threshold detection and magnitude estimates of suprathreshold temperatures. Threshold detection was assessed with the method of limits. After an adaptation period at 35 °C (which is close to the basal temperature of the dorsal surface of the tongue), the temperature of the probe rose or declined at a predefined rate 0.5 °C/s until the participants pressed a response button indicating that they had detected warming or cooling. Participants received five trials for warming followed by five trials for cooling.

For suprathreshold testing, the thermal probe was placed on the participants' tongue after it had already been set to a predetermined temperature of 21, 24, 27, 39, 41, or 43 °C. The participants were asked to place and hold the probe on their tongue at the selected destination temperature for approximately 5 s, and then were told to remove the probe. Participants rated the intensity of the temperature using a paper format of a pseudo-logarithmic labeled-magnitude scale [36] with the highest point labeled as "strongest imaginable sensation". The instructions were modality specific, in that subjects were not asked to compare their intensity across different modalities (as is sometimes done with labeled magnitude scales). Note, although the relative scaling of the LMS was identical to that of original LMS, the scale was shrunk in reproduction to 17.1 cm instead of the original 23 cm. Thus the resultant numbers (expressed in cm) would need to be multiplied by 1.345 in order to be directly compared to a 23 cm LMS. All of the temperatures were presented in random order three times each for a total of eighteen trials.

A methodological limitation of the present paradigm is that it is not possible to attach the plate to the surface of the tongue with adhesive, and participants would have become uncomfortable if

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