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Variation in thermally induced taste response across thermal tasters

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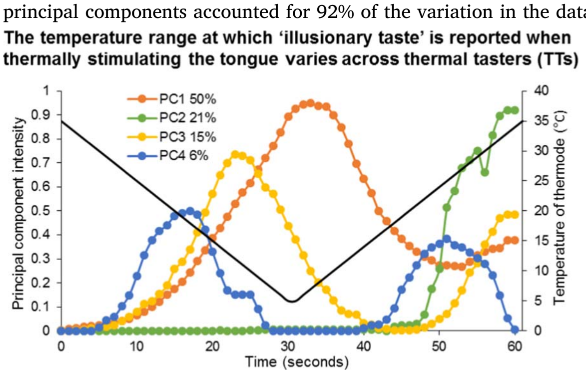
GRAPHICAL ABSTRACT

Principal component analysis was performed on the average temporal taste intensity ratings from 10 replicates of thermal stimulation reported by 36 TTS. Four principal components accounted for 92% of the variation in the data associated temporal responses shown.



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ABSTRACT

Thermal tasters (TTs) perceive thermally induced taste (thermal taste) sensations when the tongue is stimulated with temperature in the absence of gustatory stimuli, while thermal non tasters (TnTs) only perceive temperature. This is the first study to explore detailed differences in thermal taste responses across TTs. Using thermal taster status phenotyping, 37 TTs were recruited, and the temporal characteristics of thermal taste responses collected during repeat exposure to temperature stimulation. Phenotyping found sweet most frequently reported during warming stimulation, and bitter and sour when cooling, but a range of other sensations were stated. The taste quality, intensity, and number of tastes reported greatly varied. Furthermore, the temperature range when thermal taste was perceived differed across TTs and taste qualities, with some TTs perceiving a taste for a small temperature range, and others the whole trial. The onset of thermal sweet taste ranged between 22 and 38 °C during temperature increase. This supports the hypothesis that TRPM5 may be involved in thermal sweet taste perception as TRPM5 is temperature activated between 15 and 35 °C, and involved in sweet taste transduction. These findings also raised questions concerning the phenotyping protocol and classification currently used, thus indicating the need to review practices for future testing. This study has highlighted the hitherto unknown variation that exists in thermal taste response across TTs, provides some insights into possible mechanisms, and importantly emphasises the need for more research into this sensory phenomenon.

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1. Introduction

Multiple factors contribute to individual differences in orosensory perception, which in turn influence food choice, nutritional status, health and disease outcomes [10]. Factors influencing variation in taste/orosensory perception are vast, and include taste phenotype, such as the well-evidenced 6-n-propylthiouracil (PROP) taster status [5] and the more recently discovered thermal taster status [8]. Thermal tasters (TTs) perceive thermally induced taste sensations (thermal taste) when the tongue is temperature stimulated using a temperature thermode, in the absence of any gustatory stimuli, while those who only perceive temperature are termed thermal non-tasters (TnTs). The prevalence of TT has been reported to be between 20% [1] and 50% [8] of participants.

TTs are observed to report higher intensity ratings to chemical taste stimuli delivered at suprathreshold concentrations [1,13,15,30], as well as sucrose at detection threshold [30] and difference threshold for tartaric acid [21], when compared to TnTs. Observed intensity ratings for astringency, metallic [1] and temperature [1,15,16] are higher for TTs than TnTs, whilst an advantage is not reported for capsaicin and menthol [13,30]. Evidence for altered responsiveness to olfactory stimulation is contradictory [15,30]. TTs perceptual advantage has been supported in a recent study showing increased cortical activation in multiple brain regions in response to gustatory-trigeminal stimuli in TTs compared to TnTs [16]. Some evidence suggests thermal taster status may also influence food preference [22]. However, the heightened oral responsiveness that TTs exhibit to attributes in alcohol and some food products does not always translate to a difference in overall preference [19,20,22,23].

Little is understood about the mechanism responsible for thermal taste phenotype. One hypothesis is whether the variation in temperature sensitivity of gustatory neurons in the chorda tympani and glossopharyngeal nerves results in some individuals encoding a taste in response to thermal stimulation, thus resulting in a thermal taste response [8]. A genetic mechanism is possible, and Transient Receptor Potential (TRP) cation channels involved in the transduction of chemical stimuli into taste, temperature, irritant and pungent sensations may be involved. The TRPM5 cation channel is a potential candidate for thermal taste as it is involved in the taste transduction of sweet, umami and bitter chemical tastes, and has been found to be temperature sensitive and activated between 15 and 35 °C in the absence of gustatory stimuli [28]. Other cation channels associated with taste transduction may be involved in the perception of other thermal tastes (sour, salt, bitter) [27] and oral sensations (metallic, spicy, mint).

An alternative theory is that TTs have a central nervous system gain mechanism which results in increased excitability in sensory integration areas where trigeminal, gustatory and olfactory inputs merge to produce a flavour perception [1,15].

The most recent hypothesis is that there is variation in the physiology of fungiform papillae and co-innervation of the gustatory and trigeminal nerve fibres that innervate them, and cross wiring allows them to activate one another in TTs [7]. This would explain the lack of difference in the perceived intensity of aroma across thermal taste phenotypes which was reported by Yang et al. [30].

Research to date has focussed on the differences in orosensory perception between TTs and TnTs, while little attention has been given to exploring individual differences in thermal taste responses between TTs alone. Variable sensations are perceived by TTs, with sweet, sour, salty, bitter [8], metallic, mint, [16] and spicy [30] having been reported. The number of tastes experienced, and the temperature at which a taste is elicited appears to vary. For example, sweet taste is more frequently reported when warming the tongue between 20 and 40 °C, whilst cooling the tongue from 35 to 10 °C evokes sourness, and saltiness as the temperature decreases from 10 to 5 °C [8]. However, the specific temperature range for which tastes are perceived has not been quantified, nor how this varies across TTs. The tongue area which is thermally stimulated has also been shown to influence taste perception, with sweet more frequently reported on the anterior tip, bitter at the posterior, and sour on the lateral edges of the tongue [8].

The overall aim of this study was to explore differences in thermally induced taste (thermal taste) responses across TTs. The first objective was to investigate the variability in taste qualities reported whilst warming/cooling the tongue tip using traditional thermal taster status phenotyping protocols, where a range of different thermal tastes were expected. As limited evidence details the temperature at which taste is perceived by TTs [8], the second objective was to explore the temporal thermal taste response to thermally stimulating the tongue, identify the taste quality, intensity, and temporal profile of perceived tastes within and across TTs, and identify the temperature at which taste was perceived. If the TRPM5 channel is the mechanism responsible for thermal sweet taste, it should be perceived between 15 and 35 °C [28].

2. Materials and method

An initial phenotyping session was conducted to identify TTs. These individuals were then invited to attend two further study sessions. During session one (90 min), TTs were trained to use the general Labeled Magnitude Scale (gLMS), rated their temporal response to taste perceived in response to thermal stimulation, and identified the associated taste qualities. During session two (60 min), reproducibility of the temporal taste response to thermal stimulation was measured during 10 replicates of each temperature trial.

2.1. Participants

The study had ethical approval from the University of Nottingham Medical Ethics Committee. Participants gave written informed consent and an inconvenience allowance for participating was provided. Eighty five individuals were phenotyped for thermal taster status. All participants were healthy non-smokers, age 19–40 years, with no known taste or smell abnormalities or tongue piercings. Participants were instructed not to consume anything other than water for at least 1 h prior to all test sessions, which were individually conducted with each participant.

2.2. Phenotyping thermal taster status

Thermal taster status phenotyping was based on methods described by Bajec and Pickering [1]. A intra-oral ATS (Advanced Thermal Stimulator) peltier thermode (16 × 16 mm square surface) (Medoc, Israel) was used to deliver temperature stimulation on the tip of the tongue, as this has the highest fungiform papillae density [25] and has been shown to be most responsive to thermal taste [8,29]. Before testing each participant the thermode was cleaned with 99% ethanol (Fischer Scientific, UK) and covered with a fresh piece of tasteless plastic wrap (Tesco, UK). The researcher instructed participants to position the thermode firmly in contact with the tongue [15] prior to thermal stimulation. The warming trial started at 35 °C, was reduced to 15 °C, and then re-warmed to 40 °C and held for 1 s (Fig. 1a). The cooling trial started at 35 °C, was reduced to 5 °C and held for 10 s (Fig. 1b). All temperature changes occurred at a rate of 1 °C/s. Participants were instructed to 'attend' to the temperature increasing from 15 to 40 °C during the warming trial, and to the whole of the cooling trial. At the end of each trial, the participant rated the intensity of the temperature when it reached its maximum on a gLMS. If a taste/s was perceived, a second gLMS was presented so each of the perceived taste qualities could be rated. Six categories of taste were listed for selection, the prototypical tastes (sweet, sour, salty, bitter, umami) and 'other (please state)' as other sensations (metallic, minty, spicy) have previously been associated with taste perception [16,30]. Metallic has been proposed as a taste in the past [4], and some evidence indicates it may have a taste component [9,17,18,26]. Mint is typically considered to occur as a result of chemesthesis and aroma stimulation [24]. However,