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Influences of age, tongue region, and chorda tympani nerve sectioning on signal detection measures of lingual taste sensitivity

Richard L. Doty *, Julie M. Heidt, Michael R. MacGillivray, Merle Dsouza, Elisabeth H. Tracey, Natasha Mirza, Douglas Bigelow

Smell and Taste Center, Department of Otorhinolaryngology: Head and Neck Surgery, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA

HIGHLIGHTS

- Criterion-free signal detection analysis applied to regional taste testing.
- Age differentially influences taste in different tongue regions.
- Chorda tympani damage differentially alters taste function in different tongue regions.
- Tongue tip less affected by chorda tympani lesions than other tongue regions.
- Posterior to anterior, and medial to lateral, gradients of taste sensitivity noted.

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ABSTRACT

Although the ability to taste is critical for ingestion, nutrition, and quality of life, a clear understanding of the influences of age, sex, and chorda tympani (CT) resection on taste function in different regions of the anterior tongue is generally lacking. In this study we employed criterion-free signal detection analysis to assess electric and chemical taste function on multiple tongue regions in normal individuals varying in age and sex and in patients with unilateral CT resections. The subjects were 33 healthy volunteers, ranging from 18 to 87 years of age, and 9 persons, 27 to 77 years of age, with unilateral CT lesions. The influences of age, sex, tongue region, and chorda tympani resections on signal detection sensitivity (d′) and response bias (β) measures was assessed in 16 tongue regions to weak electric currents and solutions of sucrose, sodium chloride, and caffeine. Significant age-related decrements in d′ were found for sucrose ($p = 0.012$), sodium chloride ($p = 0.002$), caffeine ($p = 0.006$), and electric current (EC) ($p = 0.0001$). Significant posterior to anterior, and medial to lateral, gradients of increasing performance were present for most stimuli. β was larger on the anterior than the posterior tongue for the electrical stimulus in the youngest subjects, whereas the opposite was true for sucrose in the oldest subjects. No sex differences were apparent. d′ was depressed ipsilateral to the CT lesion side to varying degrees in all tongue regions, with the weakest influences occurring on the medial and anterior tongue. CT did not meaningfully influence β. This study is the first to employ signal detection analysis to assess the regional sensitivity of the tongue to chemical and electrical stimuli. It clearly demonstrates that tongue regions differ from one another in terms of their age-related sensitivity and their susceptibility to CT lesions.

1. Introduction

Ever since Claudius Galen (129–201 AD) described the major nerves innervating the tongue, the ontology, development, and innervation of the taste buds has been debated [1,2]. To this day a clear picture of the differential sensitivity of localized regions of the tongue to basic taste qualities remains controversial. It is generally accepted that the glossopharyngeal nerve (CN IX) innervates taste buds on the posterior third of the tongue and the chorda tympani (CT) division of the facial nerve (CN VII) on the anterior two thirds of the tongue, including sectors of the foliate papillae on the tongue's lateral posterior margins and the large fungiform papillae located just anterior to the sulcus terminalis [1,3]. However, there is evidence that small branches of CN IX may extend into the anterior two-thirds of the tongue and may even anastomose with segments of the lingual nerve (CN V) [4]. It is unknown whether these fine nerve fibers influence taste function or innervate taste buds.

* Corresponding author at: Smell and Taste Center, Hospital of the University of Pennsylvania, 5 Ravdin Pavilion, 3400 Spruce Street, Philadelphia, PA 19104.
E-mail address: doty@mail.med.upenn.edu (R.L. Doty).

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In accord with the latter observation is evidence that the anterior/posterior CN VII/CN IX lingual border may not be absolute in regards to taste function. Thus, several studies have reported normal taste function on sectors of the anterior tongue in some persons following CT severance. For example, Leung et al. [5] reported that 4 of 8 of children who had undergone a modified radical mastoidectomy that sacrificed the CT nerve exhibited normal electric current (EC) thresholds on the anterior side of the tongue ipsilateral to the operation. Similarly, Schwartz and Weddell [2] described two cases in which radical mastoidectomy was performed where chemical taste function remained on the ipsilateral anterior tongue. Importantly, Tomita et al. [6] have presented evidence that considerable variability exists regarding the extent of the anterior tongue that remains functioning after lesions of the CT nerve. Moreover, Tomita and Ikeda [7] found that anesthetizing the lingual branch of the CN IX appeared to result in taste loss over a tongue region more anterior than expected on the basis of the classical anatomy of this nerve, congruent with the concept that the neural distribution of CN IX may extend, at least in some cases, beyond its classical posterior boundaries [4]. Less-than-total deterioration of fungiform taste buds occurs in a number of rodent species following interruption of CN VII; in rats, only interruption of both CN VII and IX leads to complete disappearance of vallate and foliate taste buds [8]. In humans, fungiform papillae decline by about a third following CT transection, but do not disappear altogether [9].

The literature is not in agreement regarding the influence of age on taste function, both in terms of the involved taste qualities and associations with tongue regions [10]. For example, one study found, using a sophisticated magnitude matching procedure, that all four major taste qualities were not affected by age [11], whereas others have reported that suprathreshold deficits occur for some taste qualities but not others [12,13]. In a recent meta-analysis, whole-mouth identification thresholds were found to be higher for older adults in 17 of the 18 studies evaluated (94%) [14]. Somewhat fewer age-related deficits were noted in studies that assessed suprathreshold intensity functions (16/25; 64%), suggesting that age may preferentially alter the perception of low concentrations of taste stimuli. With rare exception [15], few studies have addressed age-related deficits on localized regions of the tongue. Those that have done so have examined only one or two lingual sites on each side of the tongue [9], typically with single stimuli (sodium chloride [16,17], quinine sulfate [18]), or EC) [9,19–23]. Only a minority of studies has employed forced-choice or signal detection psychophysical procedures that are criterion free, i.e., do not confound the sensitivity measure with response biases.

The purpose of this study was to quantify, using a criterion-free signal detection procedure, the ability of young, middle aged, and older subjects to identify sweet, salty, and bitter tasting stimuli at 16 different locations on the anterior tongue. Sour tasting stimuli were not presented to minimize variance and confounding from the well-known sour/bitter confusion on identification tasks [24]. The main question was to what degree different regions of the tongue vary in sensitivity to such stimuli and whether age uniformly or differentially influences taste function in such tongue regions. The ability of the subjects to discern subtle differences in low currents of electrical stimulation was also determined, as was the influence of unilateral transection of the CT nerve on taste function in patients who had middle ear operations for otosclerosis. The latter was done to answer the question as to whether taste function is spared, at least to some degree, in sectors of the anterior tongue ipsilateral to the lesion, as suggested by earlier work [2,5,7].

2. Methods

2.1. Subjects

In the age-related element of the study, 33 healthy non-smoking subjects were tested with the sweet (sucrose), salty (sodium chloride) and electric stimuli (17 men, 16 women). Twenty five were tested with the bitter (caffeine) stimulus (12 men, 13 women). They were largely students and workers at the University of Pennsylvania. The group was divided into 18–27, 39–50, and 52–87 year age categories. For the sweet, salty, and electrical stimuli, 15 were in the first of these groups [mean (SD) age = 21.29 (2.64)], 5 in the second [mean (SD) age = 45.60 (4.28)], and 13 in the third [mean (SD) age = 64.21 (11.23)]. For the bitter stimulus, these respective numbers were 11 [mean (SD) age = 21.36 (2.77], 5 [mean (SD) age = 45.60 (4.28)], and 9 [mean (SD) age = 57.44 (5.57)]. In the CT lesion element of the study, 9 subjects (4 men, 5 women) who had unilateral CT nerve transections in middle ear operations for otosclerosis were tested with sucrose, sodium chloride and EC [6 left and 3 right transections; mean (SD) age = 43.33 (17.73)]. Only four subjects were tested with caffeine. The subjects were patients within the department who had undergone middle ear surgery for otosclerosis. All subjects provided written informed consent and the study protocol was approved by the University of Pennsylvania's Office of Regulatory Affairs.

2.2. Test procedures

Prior to testing, 16 loci between the circumvallate papillae and the tip of the tongue were identified. The midline of the tongue was marked using an indelible marker. Five equal anteroposterior sections were drawn anterior to the circumvallate papillae. The three middle anteroposterior sections were then divided into four even sections mediolaterally (Fig. 1). Midpoints within the indicated regions were marked using a dental color transfer applicator (Great Plains Dental Products, Kingman, KS) to indicate where the stimuli would be applied. Chemical and electrical testing of each tongue region was then performed, as described below.

2.3. Chemogustometry

Whatman® type 1 filter paper disks (6 mm dia) served as the tastant transfer medium. On the day before testing, the disks were soaked for 10 min in aqueous (distilled/deionized) solutions of sodium chloride (1.25% v/v), sucrose (12%), and caffeine (0.7%). Blank disks were similarly soaked in the distilled/deionized water. With the exception of

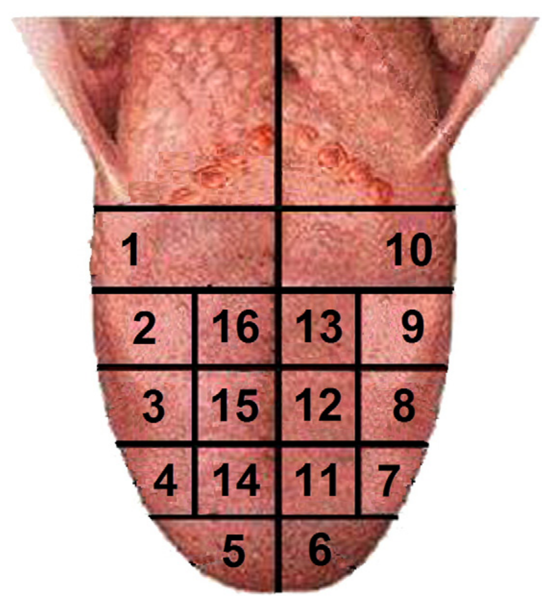

Fig. 1. Anterior tongue regions tested in this study for the final analyses, these regions were divided into four categories, namely anterior tongue (regions 5 & 6), medial lateral tongue (regions 2, 3, 4, 7, 8 & 9), medial central tongue (regions 11, 12, 13, 14, 15 & 16), and posterior tongue (regions 1 & 10).