M.W. Heft[1]* and M.E. Robinson[2]

[1]Department of Oral & Maxillofacial Surgery and Claude D. Pepper Center, University of Florida, Box 100416, HSC, Gainesville, FL 32610-0416, USA; and [2]Department of Clinical & Health Psychology, College of Public Health and Health Professions, University of Florida; *corresponding author, mwheft@ufl.edu

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Age Differences in Orofacial Sensory Thresholds

ABSTRACT

Declines in sensory functioning with aging are evident for many of the senses. In the present study, thresholds were determined for somatosensory (warming and cooling temperature, pain, touch, and two-point discrimination) and taste stimuli in 178 healthy individuals aged 20-89 yrs. Somatosensory stimuli were applied to the upper lip (glabrous skin) and the chin (hairy skin). The sample was divided into two groups, based on a bimodal split "< 45 yrs" and "≥ 65 yrs". In all instances, there were elevations in thresholds for the older individuals. Further, males were less sensitive than females for cool at the chin site, for touch, and for sour taste. We conclude that there are elevations in sensory thresholds with age for multimodal somatosensory and gustatory senses.

KEY WORDS: aging, thresholds, touch, temperature, taste.

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INTRODUCTION

Decreased sensory functioning with age is evident for many of the sensory systems. Declines are most apparent in the visual and auditory systems, where clinical complaints are buttressed by findings in the controlled laboratory setting (Fozard *et al*., 1990).

Evidence from studies of other senses is not so clear. In studies of temperature sensitivity, several investigators have suggested that there is diminished sensitivity to both non-painful warming and cooling thermal stimuli (Kenshalo, 1986; Stevens and Choo, 1998; Heft *et al*., 1996; Lin *et al*., 2005) and painful thermal stimuli (Procacci *et al*., 1970; Edwards and Fillingim, 2001). However, Harkins *et al*. (1986) have suggested that there is no decline in the judged painfulness of noxious thermal stimuli. These disparate findings are derived from studies with methodological differences. While both Procacci *et al*. and Kenshalo assessed thresholds for pain, Harkins *et al*. assessed suprathreshold ratings of painful stimuli. In addition, threshold values can be influenced by the method by which the threshold is derived (Guilford, 1954; Nunnally, 1978; Stevens and Choo, 1998; Stevens *et al*., 1998). Finally, these findings may have been influenced by stimulus type. For example, while Procacci *et al*. applied radiant heat to blackened skin (to maximize heat absorption for radiant heat) of the volar forearm and found elevations in pain threshold with age, Kenshalo applied the heat stimulus *via* a Peltier contact thermal device to the arm and foot and found no age differences for pain at either site. The contact thermode offers greater control of stimulus conditions, because both the ambient skin temperature and the stimuli (stimulus temperature and duration) can be controlled more reliably.

In the present investigation, we determined sensory thresholds for thermal, tactile, and taste stimuli to address whether there are: (1) age differences for each of the sensory domains, and (2) consistent patterns in differences of thresholds for the somatosensory thermal and tactile stimuli at the lip and chin sites.

MATERIALS & METHODS

Participants

One hundred and seventy-eight community-dwelling, healthy individuals aged 20-89 yrs participated in the sensory testing sessions. We purposively recruited individuals for each of four age categories (20-29 yrs, 35-44 yrs, 65-74 yrs, and ≥ 75 yrs) to ensure at least 20 males and 20 females *per* group. The study was approved by the Institutional Review Board of the University of Florida. Prior to their acceptance into the study, participants underwent a neurological screening examination to exclude potential factors other than aging (*e.g.*, systemic disease or trauma) that might contribute to the sensory testing results.

Stimuli

Cooling, Warming, and Painful Thermal Stimuli

The thermal stimuli were delivered *via* a three-layer Peltier thermode (Model LTS, Thermal Devices, Golden Valley, MN, USA) that delivered warming stimuli at a rate of 10°C/sec and cooling temperatures at 4.0°C/sec (Wilcox and Giesler, 1984).

Tactile Stimuli

The pressure stimuli were delivered with Semmes-Weinstein filaments, calibrated nylon monofilaments that, when force is applied at a 90° angle to the skin and distended, reliably provide a standard force to the skin (Weinstein, 1962). The set of filaments delivered forces that ranged from 0.078 mN to 58.8 mN.

Two-point Discrimination Stimuli

The two-point aesthesiometer consisted of two vinyl tips mounted on a quantifiable caliper. Step size differences between successive stimuli were 0.8 mm.

Gustatory Stimuli

Stimuli were prepared for the assessment of salt (sodium chloride) and sour (citric acid). Stimulus concentrations were prepared and stored prior to testing sessions and ranged from 0.00001-0.56 M for sodium chloride and 0.000001-0.01 M for citric acid, with 0.25 logarithmic steps between successive stimulus concentrations.

Stimulation Sites

The warming, cooling, and painful thermal stimuli and the tactile stimuli were each delivered to two sites on the face, the upper lip (glabrous skin) and chin (hairy skin), for independent assessments of thresholds. Taste stimuli were applied to the dorsal surface of the tongue.

Procedure

The order of the four testing sessions—(1) tactile and two-point discrimination, (2) salt and sour taste, (3) warming and cooling temperature, and (4) pain—was randomized across participants. Sensory thresholds for (1) each stimulus set and (2) site for the thermal and tactile stimuli were determined independently by the ascending (aMoL) and descending (dMoL) Method of Limits (Gescheider, 1976). In the aMoL, the initial presentation was at a stimulus level below perception. With each successive stimulus presentation, the stimulus magnitude was raised in standard increments for each modality. Participants were alerted prior to the delivery of each stimulus trial. Stimulus levels were increased until the participant reported feeling a sensation or tasting a solution on two successive trials. The aMoL sequence was then completed, and this transition point value was recorded. For the dMoL, the initial presentation was several steps above the aMoL threshold. Stimulus increments were now decreased sequentially similarly, but in the reverse direction as for the aMoL until the participant did not feel or taste the stimulus on two successive trials, and that dMoL sequence was completed. The aMoL and dMoL procedures were repeated, and the two aMoL and two dMoL transition points were averaged to determine the threshold.

For the warming, cooling, and pain thermal assessment procedures, the temperature probe was clamped to a test tube holder that was attached to a vertical rod and mounted on the desktop. The height of the thermode was adjusted so that it was roughly level with the participant's mouth. For each stimulus trial, the participant was instructed to place his/her upper lip or chin firmly on the contact thermode. Stimuli sites were alternated between lip and chin for each stimulus presentation after random choice of the initial stimulation site. For the thermal conditions, the thermode was applied to the test site (either lip or chin) at an adapting temperature of 33°C for a period of 30 sec prior to the initiation of trials (Kenshalo, 1986). Temperature change increments were ± 1°C for each successive trial. Stimuli were presented every 20 sec and lasted 5 sec (Heft *et al*., 1996). Only the aMoL procedure was used to establish the pain threshold, because repeated application of a painful stimulus might sensitize the test site and change the subsequent threshold ratings (Price, 1988).

For the tactile assessments, the research assistant applied the filaments and the two-point aesthesiometer to the upper lip and at the chin mid-face. Participants were requested to close their eyes during these assessments so they would not be able to distinguish the different thicknesses of the filaments or distances between the vinyl tips of the aesthesiometer. Tactile force increments were 0.3 log steps. The vinyl tips of the aesthesiometer were applied at a 90° angle with the skin to minimize surface contact. The caliper gap was changed in 0.8-mm steps for the MoL.

Each taste stimulus trial consisted of three separate presentations: (1) 1 cc of taste (either sodium chloride or citric acid) or distilled water, (2) 10 cc distilled water rinse from a disposable cup before the next (3) 1 cc distilled water presentation or taste solution. The research assistant delivered the 1-cc fluid trials to the dorsal surface of the tongue with disposable pipettes. After each trial, participants were instructed to rinse their mouths with 10 cc of distilled water. Whether the order was taste, rinse, water or water, rinse, taste was randomly determined. Participants indicated (1) whether they tasted the solution and (2) whether it was the first 1-cc presentation or the second. Taste-stimulus concentrations were increased or decreased in 0.25-M steps. Participants needed to correctly identify as sour or salty a taste that was presented within the correct interval on two successive trials before completing an aMoL or dMoL sequence.

Statistical Analyses

The sample was divided into two groups, "< 45 yrs" and "≥ 65 yrs", to yield 92 younger and 86 older adults (100 female, 78 male).

Threshold levels were determined independently for both lip and chin sites (for the somatosensory stimuli) and for each of the two taste stimuli. Each participant's values were computed as the average of the crossover points (last stimuli felt and last stimuli not felt from the MoL procedures) for all but the pain procedure, which was determined solely by the aMoL.

Table. Mean Thresholds (standard deviations) for Stimulus Site and Location by Age Group and Sex

	Younger Participants		Older Participants	
Sensation	Female	Male	Female	Male
Cool lip[1]	32.3 (0.27)	32.4 (0.21)	32.0 (1.0)	31.9 (0.71)
Cool chin[1]	31.6 (0.67)	31.4 (0.74)	31.2 (1.2)	30.6 (1.5)
Warm lip[1]	33.7 (0.4)	33.7 (0.59)	34 (0.72)	34 (1.1)
Warm chin[1]	34.6 (1.5)	34.5 (1.2)	35.8 (2.4)	36.8 (2.7)
Pain lip[1]	43.13 (2.95)	43.3 (2.08)	45.1 (2.55)	46.02 (2.52)
Pain chin[1]	44.1 (3.2)	43.7 (2.3)	46.3 (2.9)	47.1 (2.9)
Touch lip[2]	0.147 (0.09)	0.19 (0.11)	0.23 (0.13)	0.4 (0.22)
Touch chin[2]	0.23 (0.28)	0.34 (0.17)	0.42 (0.45)	0.87 (0.73)
Two-point lip[3]	2.1 (0.84)	2.3 (1.8)	2.9 (1.1)	2.7 (0.97)
Two-point chin[3]	6.1 (2.8)	5.8 (3.5)	7.6 (2.7)	7.8 (3.7)
Sour[4]	0.0004 (0.0003)	0.0004 (0.0003)	0.0007 (0.0005)	0.0012 (0.0013)
Salt[4]	0.007 (0.009)	0.0068 (0.0068)	0.017 (0.034)	0.019 (0.027)

1 = °C; 2 = mN; 3 = mm; 4 = M.

Each sensory domain was tested in a separate Analysis of Variance (ANOVA). We calculated thresholds by averaging the aMoL and dMoL transition levels across the trials, and the thresholds were used as the dependent variables in each analysis. In each ANOVA, age category and sex served as between-participants effects, resulting in 2 (age) by 2 (sex) ANOVAs.

RESULTS

Mean threshold levels are listed in the Table (by age group, sex, modality, and site).

Cool: Older adults showed significantly higher cool thresholds (lower temperatures) at both lip and chin sites [$F(1,163) = 13.7$, $p < 0.001$, $eta^2 = 0.08$, and $F(1, 173) = 14.5$, $p < 0.001$, $eta^2 = 0.08$]. Males had higher cool thresholds at the chin site [$F(1,173) = 5.0$, $p = 0.027$, $eta^2 = 0.03$]. There were no age-by-sex interactions at either stimulation site ($p > 0.1$).

Warm: At both lip and chin sites, older adults showed significantly higher warm thresholds than younger adults [$F(1,173) = 16.7$, $p < 0.001$, $eta^2 = 0.09$, and $F(1,173) = 32.7$, $p < 0.001$, $eta^2 = 0.16$]. There were no significant sex or age-by-sex interaction effects for either lip or chin stimulation $p > 0.05$.

Pain: Results of the ANOVAs for pain thresholds at the lip and chin sites indicated a significant main effect for age [$F(1,171) = 35.6$, $p < 0.001$, $eta^2 = 0.17$, and $F(1,171) = 39.7$, $p < 0.001$, $eta^2 = 0.2$]. The main effects of sex and the age-by-sex interactions were all nonsignificant ($p > 0.1$) for both lip and chin stimulation. At both sites, older adults showed significantly higher thresholds.

Touch: For lip stimulation, older adults had higher touch thresholds at both lip and chin sites [$F(1,175) = 25.6$, $p < 0.001$, $eta^2 = 0.13$ and $F(1,175) = 36.2$, $p < 0.001$, $eta^2 = 0.17$], men had higher thresholds than women at both lip and chin sites [$F(1, 175) = 18.3$, $p < 0.001$, $eta^2 = 0.1$ and $F(1,175) = 36.2$, $p < 0.001$, $eta^2 = 0.17$], and there were no sex-by-age interactions ($p > 0.1$).

Two-point Discrimination: Older adults had higher two-point discrimination thresholds at the chin [$F1,175) = 13.1$, $p < 0.001$, $eta^2 = 0.07$], and lip sites [$F1,175) = 9.6$, $p < 0.001$, $eta^2 = 0.05$]. There were no significant sex effects for lip stimulation or chin stimulation, $p > 0.1$, and no age-by-sex interactions for either site ($p > 0.1$).

Sour: ANOVA results indicated significant main effects for age [$F(1,170) = 2.8$, $p < 0.001$, $eta^2 = 0.12$], sex [$F(1,170) = 6.9$, $p = 0.01$, $eta^2 = 0.04$], and a sex-by-age interaction [$F(1, 170) = 4.5$, $p = 0.035$, $eta^2 = 0.026$]. These results suggest that older adults have higher sour thresholds, with older men having the highest sour threshold.

Salt: Results indicate that older adults have a higher salt threshold [$F(1,170) = 9.9$, $p < 0.001$, $eta^2 = 0.055$] than younger adults. There was no significant sex or age-by-sex interaction ($p > 0.1$).

To test the hypothesis that lip stimulation would be more sensitive than chin stimulation, we conducted a multivariate analysis of variance (MANOVA) using all types of stimulation as dependent variables (pain, warm, cool, touch, two-point discrimination) and site (lip *vs*. chin) as a within-participants factor.

Results indicated that the lip site of stimulation had lower thresholds [$F(1,164) = 265.8$, $p < 0.001$, $eta^2 = 0.62$] than the chin.

DISCUSSION

The findings provide evidence that sensory thresholds increase in older adults. A major strength of the approach in this study was that thresholds were determined for multiple somatosensory and taste domains using the same MoL testing paradigm. These improvements over previous work point to a more global sensory-perceptual difference between older and younger individuals than was possible with single-modality studies. The observed greater sensitivity of the upper lip compared with the chin site is consistent with previous reports (Rath and Essick, 1990; Jacobs *et al*., 2002) and offers a measure of task validity. The observed elevation in thresholds of both the somatosensory and gustatory stimuli with increasing age is consistent with reported findings, for taste (Grzegorcyk *et al*., 1979; Schiffman, 1979; Cowart, 1981; Weiffenbach *et al*., 1982), smell (Schiffman, 1979; Murphy, 1983; Cain and Stevens, 1989), mechanoreception (Kenshalo, 1979, 1986; Lautenbacher *et al*., 2005), and pain (Harkins *et al*., 1984). It is unclear whether these findings reflect changes in the sensory systems or cognitive processes. For example, it has been suggested that reported age-related changes in detection thresholds may reflect differences in attention or responding tendencies (response biases) as well as changes in the sensory systems (Stevens and Choo, 1998). While perception of stimuli at threshold would appear to be more susceptible to loss of attention, the presence of warning cues, as used in this study, prior to the stimulus presentations would seem to preclude this in healthy individuals. With regard to responding tendencies, Botwinick (1984) has reported that older individuals are more cautious in identifying the perception of low-intensity stimuli. The MoL paradigm for determining sensory thresholds, in which stimulus intensities are changed in a predictable manner, is potentially subject to this type of response bias (Cornsweet, 1962). To control for potential responding tendencies of individuals for stimuli of either increasing or decreasing intensities, we used both aMoL and dMoL strategies for all modalities except for pain, and consistently found elevation in thresholds among the older participants. Further, for taste thresholds, participants were required to identify in which of the two intervals the tastant was present, which controls for guessing. It is unclear whether these findings can predict individuals' abilities to assess suprathreshold stimuli.

The results of this study suggest that sensory thresholds are elevated with age for multiple sensory somatosensory and taste modalities. Additional studies should address potential contributions of more conservative responses among older adults to this finding. Further, while thresholds provide a relatively stable measure of sensory detection, future studies should address age and sex differences in the perception of suprathreshold sensory stimuli.

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