Age-Associated Changes in Taste and Odor Sensation, Perception, and Preference

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When an elderly person observes that food simply doesn't taste the way it used to, he or she is referring to food flavor. The chemical senses (taste, smell, and trigeminal sensitivity) all contribute to the perception of food flavor. The sense of taste provides the individual with information about sweet, sour, bitter, and salty stimuli. The sense of smell is extremely important for the perception of food flavor, since the olfactory system carries the information about the many volatile substances in food that add the nuances that transform, for example, a bittersweet substance into a truffle, and a sweet and sour substance into a tangerine. The trigeminal system provides the sensations of warmth, coolness, and pungency important to the perception of, for example, food flavored with chili peppers or mint.

Thus, in considering the effects of aging on "taste" or, more correctly, flavor, it is essential to consider the effects of aging on olfaction and the trigeminal sense, both for their own effects on appetite and dietary selection and for their contribution to the overall constellation of food flavor.

TASTE

Many studies have reported that threshold sensitivity to taste stimuli declines with age (see refs. 1–3 for reviews). Still to be definitively settled are the magnitude and rate of the decline, the degree to which various taste qualities are differentially affected by age, and the role of threshold sensitivity in perception of real-world stimuli.

Suprathreshold taste intensity perception also shows a decline in the elderly, although the picture is less clear-cut (see ref. 1 for a review). Several investigators have examined the psychophysical function for taste, that is, the function that relates psychological intensities to the physical concentrations of a series of taste stimuli. Enns et al. (4) found no alteration in the slope of the psychophysical function for taste, that is, intensity grew with increases in concentration at the same rate, from young adulthood to old age, although slopes for adults were less steep than for children. Bartoshuk et al. (5) reported general stability of slopes in the elderly, and
attributed flatter slopes at threshold to lack of dental hygiene. Several other studies have reported some flattening of the slopes with age, further suggesting a decline in the ability of the elderly to track increases in a stimulus concentration (see ref. 2 for review). Most recently, Murphy and Gilmore (6) reported quality-specific age-related losses at the suprathreshold level. In a magnitude matching paradigm where subjects rated taste intensity against an outside standard, we found bitter to be the taste quality most affected by age, and sweet the least.

Because assessing taste intensity above threshold can be problematic in elderly subjects, we studied discrimination of suprathreshold taste stimuli using the Weber Ratio technique (7) and found the same pattern: older people showed greater impairment in discriminating bitter than in discriminating sweet.

**OLFACTION**

As mentioned above, perception of food involves not only taste information (i.e., information about sweet, sour, bitter, and salty), but also olfactory and trigeminal information from the myriad volatile components of foods and beverages. Independent of changes in sweet, sour, bitter, and salty perception, age-related differences in the constellation of volatile accompaniments to a taste may influence its perception, particularly its pleasantness.

Threshold sensitivity clearly declines with age, both for stimuli that are largely olfactory, and for stimuli that are largely trigeminal (see refs. 1–3 for reviews). Of importance for those working with food delivery to the elderly, those older persons who have developed Alzheimer's disease show significantly greater impairment in olfaction than the normal elderly, and the degree of impairment, at least at threshold, is related to the degree of dementia exhibited by the Alzheimer's patient (8). That this is a neurologically based phenomenon and not due simply to increases in nasal disease in the Alzheimer's population is quite clear (9).

Several studies have reported that suprathreshold intensity perception of olfactory and trigeminal stimuli is also significantly reduced in old age (10–12). In most cases the intercept of the psychophysical function was affected, in others the slope of the function.

Identification of odors is severely affected by aging (13,14), suggesting alterations in the overall quality perception of an odor. Furthermore, recent work in our laboratory shows significant age-associated loss of odor memory ability that is related to the sensitivity to, the familiarity of, and the identifiability of the odors (15).

**FLAVOR PREFERENCE**

Changes in flavor preference would be suggested by the changes in smell and taste function in the elderly. Several studies have addressed this issue. Laird and Breen (16) reported increased preference for tartness over sweetness in older subjects. Although Desor et al. (17) reported that 9- to 15-year-olds preferred greater sweetness
and saltiness than did adults; they found no differences among adults up to 64 years old. Lack of information about the numbers of subjects falling into different adult age groups makes this result difficult to interpret.

Enns et al. (4) reported that college students had higher sucrose preferences (in aqueous solution) than children or elderly subjects. Dye and Koziatcek (18) found that in older (65–88 years) nondiabetic subjects aqueous sucrose solutions became increasingly pleasant as concentrations increased over the range of 0.125M to 1M. Younger nondiabetic subjects rated 0.25M as the most pleasant and decreased their pleasantness ratings with each subsequent concentration. In adding salt to taste to chicken broth, older (36- to 66-year-old) subjects have shown higher salt preferences than younger (17- to 32-year-old) subjects (19).

Moncrieff (20) reported age-related shifts in preference for some odors. Simply being exposed to an odor (21) or to olfactory-taste mixtures (22) presented orally can produce shifts in pleasantness. Murphy (22) also demonstrated effects of context on the pleasantness of chemosensory stimuli. Since over the course of life the elderly have had significantly greater exposure than young subjects to both individual tastes and odors and to food and beverage systems, one might expect altered food and odor preferences in the elderly simply on the basis of exposure.

In addition, age-related changes in chemosensory perception also have the potential to alter preferred concentrations and hedonic judgments, since intensity is a powerful predictor of hedonic tone (23). For example, since the bitter function flattens with age, a stimulus which is too bitter for a young person might be less bitter, and thus more or less pleasant, for an elderly person.

The distinction between preference and pleasantness is an important one. Two useful measures of hedonics are the peak preferred concentration (i.e., the one concentration in a series that is chosen as the most preferred) and the pleasantness judgment (i.e., a kind of magnitude estimate of the pleasantness or unpleasantness of a given stimulus). These two measures provide different types of information concerning the hedonic quality of a stimulus. The former identifies the most preferred stimulus concentration in a series and the latter provides information about the pleasantness of each stimulus in the series. Both measures are important in assessing changes with age in pleasantness of tastes, smells, and flavors. For example, in a series of four concentrations of salt in a sample of vegetable juice, both young and old might choose the third concentration as the most preferred. However, the elderly might rate the fourth and highest concentration as pleasant whereas the young subjects might rate the saltiest stimulus as unpleasant. For this reason we have employed both of these measures in our studies of chemosensory hedonics over the life span.

We investigated the existence of age-related changes in preference in a sample of 300 people: 100 young adults, 100 middle-aged adults, and 100 older adults (24). We considered (i) whether the concentration most preferred in a series differs over the life span for salt, sugar, or citric acid stimuli; (ii) whether there are age-associated changes in pleasantness judgments for various concentrations of salt, sugar, or citric acid; and (iii) whether the background in which a stimulus is presented significantly affects the pleasantness of that stimulus.
The stimuli were sucrose, citric acid, and NaCl, each presented in four concentrations in deionized water and the same four concentrations in appropriate beverage bases. Degree of pleasantness or unpleasantness was measured on a bipolar line scale (22).

Pleasantness depended on age, background (beverage base or water), stimulus type, and concentration. Pleasantness ratings were less negative for elderly participants than for either young or middle-aged participants. Stimuli were judged less pleasant overall in water than in a beverage base, and concentration significantly affected ratings. Young and middle-aged participants found salt less pleasant than did elderly subjects. Overall, pleasantness ratings for sugar were higher for older subjects than for middle-aged, but not young subjects. High concentrations of sugar were also rated as more pleasant by the elderly participants than by the younger participants. Citric acid was less pleasant than NaCl for elderly subjects, but the reverse was true for young and middle-aged subjects.

Pleasantness judgments of all three stimuli were significantly affected by the background base in which they were presented. Sucrose and NaCl were both rated more pleasant in the beverage base, but the background produced greater differences in the pleasantness of NaCl than in the pleasantness of sucrose. The elderly rated salt higher than other participants did, regardless of its background. For all age groups, salt in water grew increasingly unpleasant when presented in increasing concentrations in deionized water. However, when presented in vegetable juice, both middle-aged and elderly raters preferred midrange salt concentrations. Ratings for sucrose produced inverted U-shaped functions. The elderly found the two highest concentrations of sucrose significantly more pleasant than the younger subjects did.

When peak preferred concentration was considered, analysis of variance showed significant differences as a function of background and of stimulus. Higher concentrations were preferred in beverage base than in water, suggesting the importance of studying stimuli in food and beverage systems.

This study has implications for dietary intake in elderly people, particularly those who must restrict their intake of salt and sugar. As a group, the elderly have an increased incidence of hypertension and diabetes. The elderly have decreased energy requirements because of lower energy expenditure. As a result, reduced intake is necessary to maintain energy balance. For older people who must restrict intake of salt and sugar for medical reasons, taste preference for these stimuli can have health consequences.

High concentrations of sucrose and NaCl were rated as more pleasant by elderly than by younger participants. The most obvious possible explanation for this effect is sensory, although this study was not designed to address the etiology of preferences. Older people may, for example, rate higher concentrations of salt as more pleasant simply because these concentrations are less salty to them than to younger subjects, who generally rate very high concentrations of salt as unpleasant. This sensory hypothesis follows from studies demonstrating some loss of suprathreshold intensity with aging for some of the simple tastants (6) and for amino acids (3). The results of the present study suggest that an experiment designed to test directly the
ability of intensity to predict chemosensory hedonics across the life span would be worthwhile.

As with any cross-sectional aging study, the question of cohort differences in the present study arises. Environmental influences may have interacted with sensory influences on perception of flavor. The significant age effects on pleasantness ratings in the present study suggest the importance of longitudinal investigation.

Differential pleasantness depending on the background in which stimuli are presented suggests the importance of chemosensory elements other than taste in determining pleasantness. Age-associated changes in smell may be partially responsible for the differences in pleasantness judgments made by the young, middle-aged, and elderly subjects in our experiments. Previous experiments considering the ability of elderly and young subjects to identify blended food, with and without the sense of smell, clearly demonstrated that smell was more affected by the aging process than taste. An older person might, for instance, rate a stronger concentration of sugar in the beverage base as more pleasant, not necessarily because he desired more sweetness per se, but because he desired an overall stronger flavor. He or she could compensate for reduced sensory input from volatile components by increasing sweetness.

High concentrations of salt and sugar are more pleasant for older people than for younger people. The reasons for this may be cultural, contextual, or sensory.

Significant nutritional deficits in samples of elderly people have been reported (25). Whether these nutritional deficiencies result from decreased nutrient intake, from lowered rates of absorption and utilization (26), or from a combination of factors, is yet to be determined. We do know that up to 41% of elderly participants show deficient levels of serum protein, and 20% show deficiency in serum albumin (26).

RELATION BETWEEN SENSORY PERCEPTION AND NUTRITIONAL STATUS

Many of the recent studies of the chemical senses in aged people have been conducted with the implicit or explicit assumption that age-associated changes in chemosensory perception are related to health and nutritional status in elderly persons. Evidence to back this assumption is lacking. We sought this evidence in a series of experiments (27) in which we operationally defined nutritional status as the biochemical indices of total protein, albumin, and blood urea nitrogen (BUN).

We first investigated the effects of aging and biochemical status on preference for casein hydrolysate. We hypothesized that (i) older participants would find high concentrations of the amino acid mixture more pleasant than young participants would, and that (ii) participants with poorer biochemical status would prefer higher concentrations of casein hydrolysate than would those with better biochemical status.

To address these hypotheses, we tested 10 young adult and 10 elderly persons with a series of concentrations of casein hydrolysate: 0, 1, 2, 3, 4, and 5% w/v in
an amino-acid-deficient soup base. Participants rated pleasantness or unpleasantness of the stimuli on the bipolar line scale described above. Venipuncture was performed on each person for assays of protein, albumin, and BUN.

Elderly participants had lower protein and albumin, and higher BUN values than young adults. The majority of the elderly, but only one young subject had low serum protein levels (defined as less than 6.5 g/dl). Analysis of variance (ANOVA) on peak preferred concentration (i.e., the concentration of casein hydrolysate most preferred by each participant) showed that elderly subjects preferred significantly higher concentrations of casein hydrolysate than did the young.

Similarly, ANOVAs examining the effects of the three blood measures (grouped above and below the median) on peak preferred concentration indicated that higher concentrations of casein hydrolysate were preferred by those with higher values of BUN and those with lower serum albumin.

Since these results suggested an influence of age and biochemical status on the perceived pleasantness of casein hydrolysate, a major experiment was designed to investigate these variables further, as well as to determine the effect of perceived intensity on preference for casein hydrolysate. We hypothesized that higher concentrations of the amino acid mixture would be preferred by older participants and those of lower biochemical status, and that perceived intensity would be predictive of preference.

Twenty young adults and 20 elderly persons performed magnitude matching to rate the intensity of the same six chemosensory stimuli used in the first experiment as well as of six auditory stimuli, included for matching purposes. The 40 participants also rated pleasantness of both auditory and chemosensory stimuli using the bipolar line scale described above. Blood was drawn and assayed as in the first study.

All three biochemical measures showed significant age effects. Compared to the young, elderly participants showed lower levels of serum protein and albumin, and increased levels of BUN. None of the young participants had low or deficient levels of protein, whereas a full 20% of the elderly had low serum protein levels (below 6.5 g/dl).

Elderly participants rated the amino acids as tasting significantly less strong than did young participants. Age group differences in intensity were similar at all concentrations of casein hydrolysate: there were no differences in slopes of the psychophysical functions. Biochemical status was not significantly related to perceived intensity.

Age and blood status (as measured by the biochemical index described above) were significantly related to peak preferred concentration, but perceived intensity was not. Elderly participants preferred higher concentrations of casein hydrolysate than did young participants. Across age, participants with lower composite biochemical indices also preferred higher concentrations of amino acids. Thus, both older participants and participants with poorer biochemical status preferred higher concentrations of the amino acid mixture.
AGE-ASSOCIATED CHANGES IN TASTE AND SMELL

CONCLUSION

Because there is evidence to show age-related increases in olfactory and taste thresholds, one could argue that older peoples’ preferences for higher concentrations of amino acids reflect impaired sensitivity. The present study suggests that the elderly participants’ higher preferred concentration of casein hydrolysate is not simply due to generally lower perceived intensity. However, at lower concentrations, the individual flavor components of casein hydrolysate may fall below a person’s odor or taste threshold and thus also alter its pleasantness. The importance of considering the complex chemosensory mixture when studying the effects of aging on taste perception should be clear.

ACKNOWLEDGMENT

The author’s research and the preparation of this chapter have been supported by NIH grant No AG04085 from the National Institute on Aging.

REFERENCES

DISCUSSION

**Dr. Chen:** Could the effects you showed be related to zinc deficiency?

**Dr. Murphy:** It was reported in the early 1970s that patients with loss of taste sensation could be improved by treatment with zinc (1). However, this finding was not confirmed in a double-blind study (2). Nevertheless, the notion that taking zinc will improve your taste has persisted in popular culture. In our taste and smell clinic we see many patients who have taken zinc for this reason but of the maybe 400 patients whom I have seen in the past few years, only two or three have reported that they improved on zinc. Thus, I think the chances that we are seeing an effect of zinc deficiency are very small.

**Dr. Mertz:** The connection between trace elements and taste function was first discovered in patients who were under copper therapy. The very first attempts to correct disturbed taste and smell thresholds were not made with zinc but with copper, which is just as effective as zinc. This strongly suggests that if trace elements are indeed involved in taste and smell function, certainly more than one is involved.

**Dr. Meredith:** In premenopausal women olfaction changes according to the estrogen status within the cycle. What happens after the menopause?

**Dr. Murphy:** The studies showing an effect of estrogen on olfaction only found the effect for certain kinds of odors. The cyclical effect was only captured by very complicated statistical analysis and it is certainly not a very large one. So far as postmenopausal effects go, the only studies that have separated men and women have shown that women preserve their sense of smell better than men.

**Dr. Hallfrisch:** Were your subjects screened for cognitive impairment or for smoking?

**Dr. Murphy:** We tested for cognitive function and it was well above average in the group as a whole. No one had cognitive impairment. So far as smoking is concerned, it is worth sketching in some of the background here. There have been two studies on aging and smoking
that have to do with perception of bitter taste with advancing age (3,4). These showed that bitterness perception is compromised in older men more than in women, and this appears to be related to the fact that men smoke more. If this is a causal relationship it seems to be a cumulative one because acute studies in young smokers and nonsmokers show no difference in taste sensation unless a cigarette was smoked within 1 h of the test. The problem of retrospective analysis of smoking in a study such as ours is that it is difficult to define the problem among elderly individuals, some of whom may have smoked for 40 years but stopped 20 years ago, whereas others are current smokers but have only smoked for 10 years. In Southern California, defining smokers for these various studies has proved to be very difficult.

Dr. Guesry: You told us that there was no change in the sweetness threshold with advancing age. I assume your test was done using sucrose. Do you find the same with artificial sweeteners?

Dr. Schiffman: There is a big difference between natural and artificial sweeteners. The perception of the latter is considerably impaired in the elderly.

Dr. Glick: Did you find a correlation between impaired sense of taste and nutritional status?

Dr. Murphy: The results have been inconclusive. No one was overtly malnourished in our study population and among hundreds of people whom I have tested I can only think of a couple who had lost weight as a result of the problem.

Dr. Edwardson: Is there any evidence that old people use more added flavorings than young people?

Dr. Murphy: Yes, there is. One study done in 1983 (5) showed that older people added more salt to chicken than younger people. I have done similar studies and can confirm this, at least with respect to salt.

Dr. Edwardson: There is also the alternative possibility that adaptations occur over time. If you stop putting sugar on your cereal, after a few months the thought of eating cereal with sugar becomes unpleasant. Presumably such adaptations can occur in old age as well.

REFERENCES