INTRODUCTION

The chemical senses protect us from such environmental hazards as leaking natural gas, spoiled food, and smoke, and provide the primary basis for the perception of the flavor of foods and beverages. Furthermore, these important senses contribute immensely to the overall quality of life and, in dysfunction, serve as a warning for a number of pathologic conditions. Therefore, an understanding of age-related changes in chemosensation is of considerable significance to the layman and medical practitioner alike.

Although advances have been made in documenting the nature of age-related changes in taste and smell perception, causal relations have yet to be demonstrated between the psychophysical alterations and the underlying pathologic mechanisms. Furthermore, because only a fraction of the available stimuli and psychophysical testing procedures have been employed, it is possible that many such changes have yet to be elucidated. Nevertheless, as indicated in this chapter, considerable progress has been made in understanding the anomalies that occur in chemosensory function during the later years. The present monograph reviews this progress and provides a perspective for future research endeavors in this emerging area of geriatric otolaryngology.

OLFACTION

Odor Detection

Impairment in the ability to detect low concentrations of odors is found in later life. An example of the nature of the change in detection thresholds across the age-span is presented in Figure 16-1. Although these curves represent sensitivity to only one odorant (the rose-like smelling compound phenyl ethyl alcohol), their general shape is likely representative of the curves of many compounds since olfactory thresholds typically correlate with one another. It should be noted that, on the average, the decline in sensitivity (i.e., rise in thresholds), while present in both sexes, begins at an earlier age in men than in women.

Figure 16-1 Log phenyl ethyl alcohol odor detection threshold values as a function of age and gender in non-smoking subjects. Numbers by data points indicate sample sizes. Note that concentration values are plotted inversely on the Y axis. * The 7 men over age 79 have been included in the 70 to 79 year age group. Reproduced with permission from Deems DA, Doty RL. Age-related changes in the phenyl ethyl alcohol odor detection threshold. Trans Pa Acad Ophthalmol Otolaryngol 1987; 39:646–650.
Odor Identification

As with odor detection, there is an age-related decrease in the ability to identify or recognize odorants. This decrease, exemplified by scores on the University of Pennsylvania Smell Identification Test (UPSIT, Fig. 16-2), is strikingly similar to that noted for phenyl ethyl alcohol thresholds (see Fig. 16-1), thus suggesting the possibility that the odor identification deficit may be secondary to the odor detection deficit, at least in some cases. As can be observed in Figure 16-2, peak performance in odor identification ability occurs in the third through fifth decades of life and markedly declines after the seventh decade, with women generally outperforming men at all ages. Using the criterion of an UPSIT score of 19 or less as major impairment, more than half of the subjects between the ages of 65 and 80 years, and over three-quarters of those older than 80 years, evidence such impairment. The poor scores in the older age range are likely not attributable to losses in memory as such, since (1) the memory load on the UPSIT does not exceed the span of immediate attention and (2) UPSIT scores of elderly subjects do not significantly correlate with scores on the Wechsler Memory Scale. Interestingly, the sex difference shown in Figure 16-2 is present to the same relative degree in several cultural groups, including American Blacks, American Caucasians, American Koreans, and Native Japanese.

Odor Intensity Perception

Several procedures have been developed for assessing the perceived intensity of odorants at supra-threshold concentrations, including tests of whether odor intensity increases appropriately with increments in odorant concentration. In one procedure (termed magnitude estimation), subjects assign numbers proportionate to the relative intensity of different concentrations of an odorant. In a related...
If threshold and suprathreshold measures of odor detection and perceived intensity are altered by aging processes, then it is likely that the ability to distinguish qualitatively among odorants is also impaired. This is indeed the case, as exemplified by the pioneering study of Shiffman and Pasternak. These investigators had 16 19- to 25-year-olds and 16 72- to 78-year-olds rate 91 pairs of 14 commercial food flavors on a 5-inch “same-different” rating scale. The data were subjected to a statistical procedure (termed multidimensional scaling) that places the responses in two-dimensional space relative to the perceived similarities of the stimuli. The multidimensional spaces obtained for a number of elderly subjects, unlike those obtained for the younger ones, grouped stimuli of different psychological quality in proximate regions, implying that the older persons had difficulty discriminating the qualitative differences.

Stevens et al., using a cross-modal matching procedure, found that the standardized magnitude estimation functions of young (18 to 25 years) and old (65 to 83 years) persons for isoamyl butyrate (which they report is a relatively nonirritating odorant) and carbon dioxide (a trigeminal stimulus with minimal or no odor qualities) did not differ significantly in slope. However, the function of the older subjects for both odorants was displaced downward (i.e., evidenced a lower y-intercept), thus suggesting that older persons have a proportional loss of smell function across a broad range of stimulus concentrations. A similar finding was reported by Stevens and Cain for isoamyl butyrate, benzaldehyde, d-limonene, pyridine, ethanol, and isoamyl alcohol, implying that the deficit is present for odorants ranging widely in chemical structure, psychological quality, and hedonic tone. Interestingly, this age-related decrement in the perceived intensity of odors is present when the odors are presented retronasally (i.e., to the olfactory receptors from inside the oral cavity, as during chewing and swallowing). Since the intensity of retronasal odor perception is influenced by mouth movements that occur during deglutition, some age-related alterations in flavor perception could result from alterations in pressure and/or flow relations within the nasopharynx caused, for example, by changes in the speed and amount of chewing and swallowing.

**Odor Discrimination**

If threshold and suprathreshold measures of odor detection and perceived intensity are altered by aging processes, then it is likely that the ability to distinguish qualitatively among odorants is also impaired. This is indeed the case, as exemplified by the pioneering study of Shiffman and Pasternak. These investigators had 16 19- to 25-year-olds and 16 72- to 78-year-olds rate 91 pairs of 14 commercial food flavors on a 5-inch “same-different” rating scale. The data were subjected to a statistical procedure (termed multidimensional scaling) that places the responses in two-dimensional space relative to the perceived similarities of the stimuli. The multidimensional spaces obtained for a number of elderly subjects, unlike those obtained for the younger ones, grouped stimuli of different psychological quality in proximate regions, implying that the older persons had difficulty discriminating the qualitative differences.

**Odor Hedonics**

Historically, the measurement of the pleasantness or unpleasantness of odorants has been a popular undertaking. This is attributable in part to the fact that humans spontaneously use hedonic descriptors when judging odors (e.g., “good,” “bad,” “pleasant,” “unpleasant”), and conceivably reflects the olfactory system's intimate association with the determination of flavor, the monitoring of foodstuffs, and, at least in the case of many nonhuman animals, sexual behavior. Anatomically, olfactory pathways are closely related to limbic regions and structures known to influence, if not regulate, emotional and pleasurable events.

Albeit limited, there is evidence that elderly subjects do not derive the same degree of enjoyment or displeasure as younger persons from olfactory stimulation. This may be closely related to their decreased smell sensitivity. Thus, if an odorant is perceived as less intense by an elderly person than by a younger one, its perceived pleasantness (or unpleasantness) would also be expected to be correspondingly altered, depending on the form of the intensity/pleasantness relationship for the odorant in question. Therefore, it is not surprising that increases in menthol concentration produce larger increments in estimates of odor pleasantness by
young subjects than by elderly subjects and that diesel fumes are less offensive to older than to younger persons.

Odor Perception in Age-Related Diseases

It is noteworthy that a number of age-related diseases (some of which have been suggested as being models for early aging) are accompanied by alterations in olfactory function. The analysis of the pathologic substrates involved in these diseases may provide clues as to the basis for age-related olfactory deficits. Although there is recent evidence that patients with Down's syndrome and Huntington's chorea suffer decrements in smell function, the most extensive evidence for smell loss in age-related diseases comes from studies of patients with Alzheimer's disease (AD) and parkinsonism. While there is circumstantial evidence that such dysfunction may be related to specific biochemical and structural alterations in olfactory-related brain regions, cause and effect relations have yet to be elucidated.

Alzheimer's disease has been suggested by some as having its genesis within the olfactory system. The basis of such thinking stems primarily from neuropathologic studies that find the distribution of neurofibrillary tangles and neuritic plaques (the neuropathologic hallmarks of this disease) disproportionately present within limbic structures associated with olfactory function. Thus, Pearson et al state,

"The invariable finding of severe and even maximal involvement of the olfactory regions in Alzheimer's disease is in striking contrast to the minimal pathology in the visual and sensorimotor areas of the neocortex and cannot be without significance. In the olfactory system, the sites that are affected—the anterior olfactory nucleus, the uncus, and the medial group of amygdaloid nuclei—all receive fibers directly from the olfactory bulb. These observations at least raise the possibility that the olfactory pathway is the site of initial involvement of the disease."

Such findings gain even more significance in the context of theories that some dementia-related diseases may be related to environmental toxins or viruses and of observations that (1) inoculation of rodents with some viruses results in necrosis of the olfactory neuroepithelium, the olfactory bulbs and tracts, and the prepyriform cortex and that (2) inoculation of such materials into the central nervous system is a major conduit of such materials into the central nervous system and of observations that (1) the olfactory system is a major conduit of such materials into the central nervous system and of observations that (2) inoculation of rodents with some viruses results in necrosis of the olfactory neuroepithelium, the olfactory bulbs and tracts, and the prepyriform cortex.

The evidence for deficits in odor perception in Alzheimer's disease patients is overwhelming; marked decrements in both odor identification and detection ability have been noted in a number of studies (Fig. 16-3), although total anosmia is rarely present. Such alterations appear to occur early in the disease process and to be unrelated to disease stage. Interestingly, most AD patients are initially unaware of an olfactory dysfunction.

Patients with Parkinson's disease (PD), a disorder that shares a number of clinical, neuropathologic, and neurochemical features with AD, also evidence decrements in odor identification, detec-

Age-Related Alterations in Taste and Smell Function

Despite the fact that many studies that explore taste perception in the elderly suffer from methodologic problems (e.g., lack of forced-choice responses, failure to rinse between stimulus presentations), most arrive at the general conclusion that some alterations in taste sensation occur as a function of age. However, as subsequently noted, the magnitude of such effects are small, and few studies have addressed the issue of confounding influences from gender, oral hygiene, cigarette smoking, and other variables. Interestingly, earlier reports that the number of taste buds decrease with age have been recently challenged.

The olfactory dysfunction of parkinsonism appears to be unrelated to the severity of the disease symptoms, and no relationship is apparent between the magnitude of the UPSIT or threshold deficits and the duration of the disease (Figs. 16-5 and 16-6). This lack of an association between disease duration and the degree of the olfactory dysfunction is supported by longitudinal testing; no significant differences in UPSIT test scores were observed in 24 PD patients retested after intervals ranging from 5 months to 3 years.

The olfactory deficit of PD rarely reflects total anosmia. Thus, in the Doty, Deems, and Stellar study, only 13 percent of the 38 patients who received detection threshold testing were unable to detect the highest odorant concentration presented in a threshold test, a figure in close correspondence to a 17 percent anosmia rate reported in an earlier study by Ward et al. This observation is further supported by the finding that all but one of 41 PD patients who were asked whether or not an odor was present on each UPSIT item answered affirmatively to 35 or more of the items, even though the majority were unable to identify most of the odors or felt that the perceived sensation did not correspond to the response alternatives.

Age-related decrements in taste sensitivity, as measured by detection or recognition threshold tests, have been noted for standard sweet, sour, bitter, and salty tastants, as well as for amino acids and artificial sweeteners. In addition, age-related alterations in lingual sensitivity to low electrical current (which is assumed to stimulate taste afferents, rather than trigeminal ones) have also been reported. However, loss of taste function as a result of advancing age appears to be less robust than loss of smell function, and some well-controlled studies fail to document such changes for all tastants.

Most studies indicate that older persons are less sensitive than younger ones to sodium chloride, although the age-related decrements are not large. For example, Grzegorczyk et al. found the mean sodium chloride detection threshold to be 30 mM in a group of 20 subjects ranging in age from 20

Figure 16-4 Mean University of Pennsylvania Smell Identification Test (UPSIT) scores, A, and phenyl ethyl alcohol odor detection threshold values, B, for Parkinson's disease patients and matched normal controls. Reproduced with permission from Doty RL, Deems D, Stellar S. Olfactory dysfunction in Parkinson's disease: a general deficit unrelated to neurologic signs, disease stage, or disease duration. Neurology 1988; 38:1237-1244.
Quinine increase with age, with males exhibiting a greater increase than females. However, in a later study in which only nonsmokers were tested, these authors found no influence of either age or sex on such taste thresholds (n = 268, ages ranging from 16 to 55 years). These investigators concluded:

"...aging within the 16- to 55-year age span did not seem to be associated with a significant deterioration in taste sensitivity unless combined with smoking. The sex difference sometimes observed in population surveys seemed to be an artifact associated with differential smoking habits of men and women."

Of all the classic taste modalities, that of sweet appears to be the most robust. Thus, statistically-significant age-related alterations in sucrose sensitivity have not been observed by every investigator (e.g., Weiffenbach), and those who have observed such alterations report they are small and often occur only in the later years. It is of interest that the magnitude of the age-related effects seen by some investigators is similar (on a molar basis) to those observed for nonsweet tastants. For example, Moore et al. reported a mean sucrose threshold of 3.6 mM in 30 subjects who ranged in age from 20 to 45 years, compared to a mean sucrose threshold of 8.0 mM in 29 subjects who ranged in age from 60 to 88 years. These molar values are similar to those reported by Grzegorczyk et al. for sodium chloride.

In summary, while most studies find age-related changes in taste sensitivity to at least some tastants, the magnitude of such changes is small. Furthermore, the role of variables such as previous smoking history, gender, and oral hygiene is rarely systematically addressed. As noted by Bartoshuk et al., it is conceivable that age-related decreased taste sensitivity at low concentrations reflects the presence of a "masking" background taste or a mild dysgeusia that results in poor discrimination between the water control and the tastant. This hypothesis is supported by observations that improvement of oral hygiene results in the lowering of taste thresholds. Langan and Yarrow found, for example, that elderly persons who received professional oral hygiene therapy three times weekly for 5 weeks evidenced a lowering of thresholds for sucrose and sodium chloride relative to a control group who were similarly visited by an oral hygienist who only inspected and swabbed the teeth. Whether or not improvement of oral hygiene would influence the taste thresholds of cigarette smokers has yet to be determined.
Taste Intensity Perception

Age-related differences in the perceived intensity of suprathreshold concentrations of tastants have been reported. For example, Schiffman et al. and Schiffman and Clark found that, compared to young college students, elderly individuals provided less steep group slopes of magnitude estimates for 10 artificial sweeteners and 23 amino acids. More recently, Bartoshuk et al., using the method of magnitude matching, assessed the perceived intensities of sodium chloride, sucrose, citric acid, and quinine hydrochloride in 18 elderly subjects (16 females and 2 males; mean age = 82.8) and in 18 young controls (16 females and 2 males; mean age = 24.4). Assuming that sounds (the matching modality) were equivalently loud to elderly and to young adults, these authors found that moderate and strong tastes were equivalently strong to these two age groups. However, the lower concentrations were rated as more intense by the elderly subjects, and the highest concentrations as less intense, resulting in a flattening of the psychophysical functions.

In an extensive recent study, Weiffenbach, Cowart, and Baum had 91 men and 79 women between the ages of 23 and 88 years extend a tape measure in proportion to the perceived relative intensity of various suprathreshold concentrations of sucrose, sodium chloride, citric acid, and quinine sulfate. There were no dramatic differences in group functions reflecting taste intensity judgments for any of the age groups or for any taste quality. Nevertheless, other measures did reflect age-related and quality-specific decreases. For example, intraclass correlation coefficients were significantly lower in older, than in younger, subjects for sodium chloride, citric acid, and quinine sulfate, but not for sucrose.

Taste Hedonics

Surprisingly few studies have examined taste hedonics in older subjects. One notable exception is the study by Enns et al., which found no significant differences in hedonic ratings given to a series of sucrose solutions by 21 fifth-grade students, 27 college students, and 12 older persons with an average age of 71 years. Interestingly, the males in each age category gave the most concentrated solution (1.0 M) significantly higher pleasantness ratings than did the females.

GENERAL CONCLUSIONS

It is clear from the aforementioned review that nearly all psychophysical measures of taste and smell perception are altered in elderly individuals. However, the basis of such changes is poorly understood. Thus, it is not presently known whether most cases of decreased taste or smell function in older persons are attributable to aging processes themselves or to phenomena correlated with aging, such as the culmination of repeated insults from viral infections, the onset of age-related diseases, poor oral hygiene, and the use of medications commonly prescribed for the elderly.

Despite these etiologic uncertainties, it is apparent that the age-related deficits observed in olfaction are larger than those observed in taste, and that the majority of elderly persons have significant loss of smell function. Even though older persons have a higher frequency of taste complaints than younger persons (e.g., sour and bitter dysgeusias), it must be kept in mind that many of their reports of "taste loss" are referable to their decrement in olfactory function, which is known to attenuate food flavor. In this regard, it is important to note that xerostomia (which is more prevalent in aged populations) has little influence on human taste thresholds.

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References