Aging is associated with increased Weber ratios for caffeine, but not for sucrose

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To investigate whether age-associated changes in the human taste system are quality-specific, we compared young and elderly subjects' suprathreshold discrimination abilities for caffeine and sucrose. The method of constant stimuli was used to obtain just noticeable differences and Weber ratios. The elderly generated larger Weber ratios than did the young for both the medium and high concentrations of caffeine, but not for the low concentration. For example, a 74% increase in .005 M caffeine was required to obtain a perceptible difference for the elderly, whereas a 34% increase produced a perceptible difference for the young. The Weber ratios for sucrose did not differ for the two age groups. The results of this study indicate that age-associated changes in the taste system are quality-specific.

We wished to know whether impairment in the ability to discriminate just noticeable differences (JNDs) in suprathreshold taste stimuli is associated with aging. To our knowledge, no systematic study has been made of JNDs for sweet and bitter stimuli that has demonstrated differences in young adults and elderly persons. We hypothesized that more stimulation would be required for an elderly person than for a young person to detect a perceptible difference in sensation.

There is sparse literature on gustatory JNDs or Weber ratios (Wrs), the ratios of JNDs to standard concentrations. Pfaffmann, Bartoshuk, and McBurney, who reviewed the known ratios in 1971, reported a median ratio of .20 for sweet, .25 for bitter, .15 for salty, and .21 for sour. Schutz and Pilgrim (1957), after conducting a systematic study of gustatory sensitivity, determined Wrs for the four basic tastants, sweet (.17), bitter (.30), salty (.15), and sour (.22). Recently, McBride (1983) revised the methodology used in past studies and reported JNDs for sucrose of approximately .02 for a .15 M solution, and .04 for a .30 M solution, or Wrs of approximately .13. In none of these studies were the effects of aging on the JND investigated.

Investigations of psychophysical functions, recognition thresholds, and detection thresholds for taste in the elderly demonstrate age-associated impairment (see Murphy, 1986, in press, and Schiffman, 1986, for reviews) and suggest the additional hypothesis that the effects of aging on the taste system may be quality-specific (Bartoshuk,

Rifkin, Marks, & Bars, 1986; Cowart, 1983, in press; Hyde & Feller, 1981; Murphy & Gilmore, 1989; Spitzer, 1988; Weiffenbach, Baum, & Burghauer, 1982; Weiffenbach, Cowart, & Baum, 1986). When we determined psychophysical functions for stimuli representative of the four basic taste qualities in a previous study (Murphy & Gilmore, 1989), the elderly's intensity estimates of bitter were the most depressed relative to young people's estimates, and their intensity estimates of sweet were the least depressed. Therefore, tastants representative of these two taste qualities were examined in the present study, and we hypothesized that larger age differences would be found in the discrimination of bitter, as opposed to sweet, stimuli.

Thus, the present study addressed two questions. First, do elderly individuals require a greater increase in the concentration of a suprathreshold stimulus in order to experience a perceptible difference in taste sensation than young subjects do? Second, does the size of the Weber ratio depend not only on age, but also on the stimulus tested?

METHOD

Subjects

The participants were 12 females, 67-77 years of age ($M = 72.42$, $SD = 3.20$), and 12 females, 18-25 years of age ($M = 22.92$, $SD = 1.51$). All of the elderly subjects were active, community-dwelling individuals who were able to drive themselves to the laboratory and had not been hospitalized within the previous year. All were members of a university-based education and enrichment program. All reported good to excellent health, and only 3 smoked. All but 1 of the young subjects were upper division or graduate students majoring in psychology, and 1 young subject smoked.

The cognitive status of the subjects was assessed with the Raven progressive matrices (Raven, 1956) and the digit-span portion of the Wechsler Adult Intelligence Scale (Wechsler, 1955). The cognitive testing indicated that all subjects were intellectually capable of performing the task. The mean Raven and digit-span scores,

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respectively, were 43.42 (95th percentile for age group) and 16.0 for the elderly, and 55.17 (95th percentile for age group) and 18.08 for the young. All subjects were paid \$5.00 per hour for participating.

Stimuli

The stimuli were reagent grade sucrose and Baker grade caffeine, dissolved in deionized water. For the discrimination task, the standards for sucrose were .15 M, .30 M, and .60 M sucrose. The standards for caffeine were .0025 M, .005 M, and .01 M. Six comparison stimuli were prepared for each standard, three being more concentrated than the standard and three less concentrated. The six comparison stimuli for each standard were .70%, .82%, .94%, 1.06%, 1.18%, and 1.30% of the standard concentration (see McBride, 1983). The levels selected for the discrimination task were determined by pretesting with a recognition task, to be sure that the stimuli to be presented in the JND experiment were actually perceptible.

Procedure

The discrimination task was run according to the method of constant stimuli. For most subjects, a total of four sessions were run, usually on separate days. During each single session, the subject was presented with stimuli of only one taste quality, sweet or bitter. (One elderly and 1 young subject participated in a session in which sweet and bitter stimuli were both presented.) Half the subjects received bitter stimuli first, and half received sweet first. The subjects set their own pace, and a session lasted approximately 1 h for the young subjects and 1-2 h for the elderly subjects.

A session consisted of the tasting of 60 pairs of stimuli: the stimuli associated with two standards. (Two elderly and 1 young subject opted for three sets of 30 pairs in one session with intermittent breaks.) One stipulation was that of the 60 pairs presented, the subject first taste the 30 pairs in which the standard was lower in concentration. Each subject tasted 30 pairs of stimuli associated with each of the standards.

Within one set of 30 pairs were the six comparison stimuli, each paired with the standard. These six pairs were administered five times and randomly distributed. Within a pair, the stimuli were randomly placed so that each subject had an equal probability of tasting the standard first or second.

The experimenter instructed the subject where to begin, to always taste the left cup first, to taste both cups in the pair, and subsequently to choose the stronger of the two by placing a small piece of paper in the cup. The subjects were allowed to rest at any time, and they were encouraged to rinse thoroughly between pairs. The experimenter recorded the number of times the comparisons were judged to be stronger than the standards.

Data Analysis

The proportion representing the number of times a comparison stimulus was judged stronger than a standard was calculated for each of the six levels of comparison, for each of the standards. These proportions were then converted to z-scores, according to Reference Table 1 in Engen (1971). The least squares regression method described by Engen (1971) was used to determine JNDs by fitting normal deviates against concentrations. The JND was defined as the increment judged correctly 75% of the time. The point of subjective equality (PSE, the point at which the comparison stimulus is perceived as being equal to the standard) was also determined, and the ratio of the JND to the PSE yielded the Weber ratio.

A few values fell outside the distribution. These were replaced with data points three standard deviations from the mean of the distribution (Tabachnick & Fidell, 1983).

One-way analyses of variance were used to compare results for the two age groups.

RESULTS

PSEs at each concentration level were compared, to ensure that the young and elderly subjects' perceptions of the standard were equivalent. Table 1 presents mean PSE values associated with the three sweet standards and the three bitter standards, for both age groups. For each concentration, the PSEs were equivalent for the two age groups.

Mean Wrs for each age group were compared separately at each concentration level. Figure 1 presents the mean Wrs for the elderly and young subjects, as a function of sucrose concentration. The mean Wrs for sweet did not differ in the two age groups (see Figure 1). Figure 2 shows the elderly and young subjects' mean Wrs for bitter, as a function of caffeine concentration. As illustrated in Figure 2, the elderly subjects generated significantly larger mean Wrs for the medium [$F(1,22) = 4.48, p < .05, \eta^2 = .17$] and the high [$F(1,22) = 4.41, p < .05, \eta^2 = .17$] concentrations of caffeine, but not for the low concentration.

DISCUSSION

The results of the present study support the hypothesis of quality-specific effects of aging on the human taste system. Elderly subjects generated larger Weber ratios for suprathreshold bitter stimuli than young subjects did. The η^2 value indicated that age accounted for approximately 17% of the variance associated with the ability to discriminate among bitter stimuli. Discrimination among sweet stimuli was not different for the two age groups.

The mean Wrs for sweet stimuli, .13 (young) and .16 (elderly), were somewhat smaller than the value of .20 reported by Pfaffmann, Bartoshuk, and McBurney (1971), but larger than the values of .10 and .08 reported by Lundgren, Pangborn, Barylko-Pikeilna, and Daget (1976). The Wrs in the present study were consistent with the value of .17 reported by Schutz and Pilgrim (1957), and the value of .13 calculated from McBride (1983). The average bitter Wrs of .40 (young subjects) and 1.27 (elderly subjects) were higher than those previously reported, although the young subjects generated ratios close to that reported by Schutz and Pilgrim (.30). The elderly subjects' highest Weber ratio (2.56) was consistent with that

Table 1
Mean Values of Point of Subjective Equality
for Both Young and Elderly Subjects

Stimulus	Mean PSE	
	Young	Elderly
Sucrose .15 M	.149	.141
Sucrose .30 M	.316	.308
Sucrose .60 M	.615	.603
Caffeine .0025 M	.003	.003
Caffeine .005 M	.005	.004
Caffeine .01 M	.01	.009

Figure 1. Mean Weber ratios as a function of sucrose concentration. Open circles represent means for young subjects, and closed circles represent means for elderly subjects.

reported by Fischer, Griffin, Archer, Zinsmeister, and Jastram (1965) for patients with impairment, demonstrating that when the ability to discriminate becomes depressed, the size of the Weber ratio increases. The Wrs in the present study, as is typical of Weber functions, approximated linearity in the midranges of concentration. The elderly's Wrs tended to rise at high concentrations of sucrose and especially at high concentrations of caffeine.

As hypothesized, elderly subjects required a larger increase in stimulus concentration than young subjects did to attain a just noticeable difference in sensation. For example, to experience a perceptible difference in sensation for the .005 M concentration of caffeine, elderly subjects required a 74% increase in concentration, whereas young subjects required a 34% increase in concentration. These percentages increased at the higher concentration.

Discriminability was more difficult for bitter than for sweet for both age groups, and especially difficult at the high concentrations of both tastants. At the .01 M concentration of caffeine, 42% of the elderly sample showed severe performance decrements.

It is certainly possible that age-associated effects on central mechanisms could mediate the quality specificity of the effects seen in the present study (e.g., age may

differentially affect fibers of different diameter and, thus, fibers carrying information about different taste qualities). It is also logically possible that one or more peripheral factors are involved. Past anatomical studies of the aging taste system have produced conflicting data regarding declining numbers of taste buds and papillae in old age (see Schiffman, 1986, for a review). Since human taste papillae can respond to more than one taste quality (Cardello, 1981), a peripheral site for quality-specific age effects would have to be at the level of individual taste buds or cells. The results of the present study further support the idea that in the pursuit of the underlying mechanism for age effects on the human taste system, attention should be given to membrane function and transduction in aging cells (Murphy & Gilmore, 1989). It will be of interest to determine whether age effects are stimulus-specific within the bitter taste quality, since more than one mechanism may encode the bitter taste quality.

Murphy and Gilmore (1989) demonstrated greater age-related loss of suprathreshold intensity for some taste stimuli (e.g., caffeine and citric acid) than for others (e.g., sodium chloride and sucrose). This was true whether single stimuli or binary mixtures were considered. In that study, we used the method of magnitude matching with the kinesthetic continuum acting as the calibration con-

Figure 2. Mean Weber ratios as a function of caffeine concentration. Open triangles represent means for young subjects, and closed triangles represent means for elderly subjects.

tinuum. Bartoshuk et al. (1986) also reported larger age-related effects on suprathreshold intensity estimates for bitter than for other taste qualities, using single tastants (quinine hydrochloride, citric acid, sodium chloride, and sucrose) and loudness as the matching continuum. The fact that the slope of the psychophysical function for bitter was flatter in the elderly they attributed to dysgeusia, adding tastes near threshold and flattening the overall function. This hypothesis needs to be tested.

Magnitude matching is currently the method of choice for investigating differences between two groups in perceived magnitude of suprathreshold stimulation (see Marks & Stevens, 1980, and Stevens & Marks, 1980, for comprehensive descriptions). Subjects rate the intensity of stimuli from two separate sensory systems using one common scale. One sensory system serves as the calibration continuum, or anchor. The groups being compared must function equally well on the calibration continuum to ensure that any differences in the two groups' intensity estimates on the continuum of interest actually reflect differences in sensory function. Finding a sensory system that functions equally well for both the young and the elderly is difficult at best (Bartoshuk et al., 1986). Auditory or kinesthetic stimuli are currently used as calibration continua in studies comparing different age groups.

Marks (1988) has recently pointed out the limitations of magnitude matching that result from contextual effects. In a series of experiments, he observed that judgments of perceived intensity of qualitatively different stimuli do not always obey the principle that equal sensations yield equal responses. He concluded that matches obtained by scaling procedures like magnitude estimation may depend markedly on the choice of stimulus levels and the qualitative similarity of stimuli. To minimize contextual effects, experiments in which scaling methods are used to generate matches should be done to compare stimuli whose levels of subjective magnitude are roughly the same.

Contextual bias would be expected to play a particularly large role in magnitude-matching experiments in which the sensory systems of young and elderly persons are compared, since subjective magnitude may vary with age. Several studies have suggested that the olfactory system shows greater age-associated losses than the taste system does (Murphy, 1982, 1985; Stevens, Bartoshuk, & Cain, 1984). Thus, when presented with a series of tastants and odorants, young subjects will perceive greater intensities of odors than will elderly subjects, relative to taste. Because odor levels are different for the two age groups, the context for any given stimulus will be different for young and old, and magnitude estimates of intensity will be affected by the differences in context. Under these circumstances, magnitude matching will underestimate the effects of age on suprathreshold intensity perception (Marks et al., 1988). Similarly, perceptual context probably had some influence on elderly and young persons' judgments of the intensity of bitter and sweet in the magnitude-matching experiment described above

(Murphy & Gilmore, 1989). As we noted in our discussion of those results, because the contextual worlds of the elderly and young were probably different, the differences between the two groups may have been even larger than described. The agreement of the present results with the conclusion drawn from that study—that there is greater age-related impairment in judgments of bitter than in judgments of sweet—illustrates the complementary nature of the data to be obtained from the two methods.

Magnitude matching with elderly subjects has other limitations. We do not yet know the mechanisms underlying the effects of the aging process on sensory systems. If the effects of aging on a sensory system of interest derive, in part, from a process that affects all sensory systems, then to exclude individuals who show impairment on the calibration continuum will rule out important subjects and bias the results. For example, if hearing impairment is among the exclusionary criteria for participation in a magnitude-matching taste experiment in which audition is used as the calibration continuum, an interesting subset of the elderly population will be excluded. To ensure the validity of the results obtained when using the method of magnitude matching, one must also be absolutely certain that subjects are using a unitary scale. This is a cognitively demanding task that may be difficult for some elderly subjects. A further problem is the tendency for the elderly to produce more false positives, perhaps because these subjects "tend to be conservative in making judgments and setting criteria" (Marks & Stevens, 1980, p. 593). The procedure for obtaining just noticeable differences is not subject to the contextual bias that can influence the results of magnitude matching, and it controls for criterion bias with a forced-choice task in which the subject's only requirement is to choose the strongest of two stimuli. In situations in which sensory or cognitive impairment in subjects of interest limits the use of magnitude matching to assess sensory function, the JND may prove to be one useful measure of age-associated impairment.

CONCLUSIONS

The results of the present study support the hypothesis of quality-specific effects of aging on the human taste system. The resulting Wrs demonstrate that elderly subjects do not discriminate bitter stimuli as well as young subjects do, whereas elderly subjects do discriminate sweet stimuli as well as young subjects do. To determine Wrs may assist the evaluation of decrements in the taste system, since Wrs provide information regarding taste function for suprathreshold stimuli that differs from what can be obtained from scaling intensity. In general, the measurement of Wrs should be thought of as supplementary to magnitude matching, since the two techniques provide different types of information. Wrs may be particularly useful when one assesses chemosensory function in individuals with impaired cognitive status (e.g., Alzheimer's

Disease) or known or suspected impaired function in another sensory system (e.g., audition) that would prevent them from performing magnitude-matching tasks.

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