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Taste Perception with Age: Generic or Specific Losses in Supra-threshold Intensities of Five Taste Qualities?

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Abstract

The influence of ageing on supra-threshold intensity perception of NaCl, KCl, sucrose, aspartame, acetic acid, citric acid, caffeine, quinine HCl, monosodium glutamate (MSG) and inosine 5′-monophosphate (IMP) dissolved in water and in 'regular' product was studied in 21 young (19–33 years) and 21 elderly (60–75 years) persons. While the relative perception (intensity discrimination) seems to be remarkably resistant to the effect of ageing, the absolute perception (intensity rating) decreased with age for all tastants in water, but only for the salty and sweet tastants in product. When assessed while wearing a nose clip, only the perception of salty tastants was diminished with age. The slopes of the psychophysical functions were flatter in the elderly than in the young for the sweet, bitter and umami tastants in water, and for the sour tastants in product only. The age effects found were almost exclusively generic and never compound-specific within a taste. This study indicates that the relevance of determining intensities of tastants dissolved in water for the 'real life' perception of taste in complex food is rather limited.

Key words: intensity matching, perceptual context, psychophysical slopes, taste specificity

Introduction

A variety of studies shows that taste perception diminishes with age. Most of these studies were restricted, either in the number of perceptual aspects (thresholds, supra-threshold intensities or preference) or by the medium in which they were presented or/and in the number of compounds considered. None of them investigated all of these aspects in the same group of people. As a result it is difficult to estimate the relative importance and the structural inter-relationships of differences found between the age groups. An overview of the results of studies on the effect of age on suprathreshold taste intensity perception is given in Table 1. In this overview only studies are mentioned in which one or more taste compounds used are the same as in the present study.

Some authors cited in Table 1 used compounds for four taste qualities but no one used several compounds for each taste quality in a single experiment to study the compound specificity and taste quality specificity of taste losses in the same subjects. In this respect the present study is more complete, even though, in contrast to several of the studies mentioned above, only two age groups were used. For the young, the chosen age group of 19–33 is in line with the other studies. For the elderly, the age group of 60–75 was chosen because it is generally assumed that at 60 a decline in sensitivity occurs, and that up to 75 the probability of major cognitive impairment is still relatively low (Schaie, 1996; La Rue, 1992).

All but one of the studies using salt dissolved in water show no decrease in salt taste intensity perception with age. Half of them found a flattened slope for the elderly. When the perceived saltiness of foods was studied, no effect of age was found but Little and Brinner (Little and Brinner, 1984) found a flattened slope for the elderly which they ascribe to salivary composition. In studies in which a sweet tastant was dissolved either in water or in product, none of the authors found a decreased mean intensity perception for the elderly, although sometimes a flatter slope of the psychophysical function was found for sucrose. In all these cases, the elderly perceived a concentration near threshold level as stronger and relatively high concentrations as weaker than the young did. This phenomenon might be explained for tastants in water by a higher background taste attributed to water by the elderly (Bartoshuk *et al.*, 1986) which, according to Shafar (Shafar, 1965), might reflect mild dysgeusia, a

Table 1 Studies reporting age effects in the supra-threshold perception of taste intensity

Supra-threshold studies	year	method	reps	medium	salty NaCl	sweet sucr/aspart	sour citric	bitter caff/quin	umami msg/imp	age
Enns et al	1979	me	1	water		O				avg10.5/18.8/71.0
Dye and Koziatek	1981	me	1	water		O				40-88
Hyde and Feller	1981	is	3	water	O	O	↓	↓		18-94
Schiffman et al	1981	me	1	water		flatter slope				18-26/74-82
Stevens et al	1984	me	4/2	water	flatter slope					20-25/65-78/80-95
Weiffenbach et al	1986	cmim	3	water	O	O	O	O QS		23-88
Bartoshuk et al	1986	mm	5	water	flatter slope	flatter slope	flatter slope	flatter slope		20-92
Chauhan and Hawrysh	1988	me	3	water			flatter slope			20-29/70-79/80-99
Bartoshuk	1989	mm	5	water	flatter slope	flatter slope	flatter slope	flatter slope QH		20-30/74-93
Cowart	1989	cmim	1	water	↓	O	↓	↓ QS		19-35/45-60/65-80
Murphy and Gilmore	1989	mm	1	water	O	O	↓	↓		18-31/65-83
Weiffenbach et al	1990	cmim	2	water	O	O				25-93
Schiffman et al	1991	me	1	water					↓	25.6 / 86.9
Schiffman et al	1994	me	2	water				↓ C/QS/H		27.4 / 81.3
Drewnowski et al	1996	is	1	water	flatter slope					20-30/60-75
Stevens and Lawless	1981	is	1	fruits/veg.	O	O	O	↓		18-25/36-45/56-65
Little and Brinner	1984	is	>15	tomato juice	flatter slope					20-40/55-69/70-88
Warwick and Schiffman	1990	is	1	dairy products	O	O				avg 22.4/82.3
Chauhan and Hawrysh	1988	me	3	apple drink			flatter slope			20-29/70-79/80-99
Zallen et al	1990	is	1	potatoes/broth	O					20-35/>65
De Graaf et al	1994	is	1	yoghurt		flatter slope				20-25/72-82
Drewnowski et al	1996	is	1	chicken broth	O					20-30/60-75

↓ significant decrease in perception, O no change in perception

me = magnitude estimation, mm = magnitude matching, cmim = cross model intensity matching, is = intensity scaling

chronic taste in the mouth. For citric acid dissolved in water, most authors found differences between the elderly and the young either in mean intensity or steepness of the slope, and most authors found a decrease in the bitterness perception of caffeine or quinine with age. Only one author (Schiffman *et al*., 1991) investigated the age effect on umami perception. Elderly subjects perceived suprathreshold concentrations of monosodium glutamate (MSG) in water as less intense than young subjects did, while the mean slope for the young was steeper than the slope for the elderly. Age effects on umami perception in food have not been reported. Screening for health and medication does not seem to have a large impact on the results, as the studies not mentioning health do not show more age losses than the studies that did report screening for health.

Gender differences are reported in two studies only. Hyde and Feller (Hyde and Feller, 1981) found gender effects for citric acid and caffeine. The gender main effect for citric acid was due to the fact that the young women rated the sourness higher than the elderly men did, and the main effect for caffeine was due to the large difference between young women who perceived the bitterness most, and the elderly men who perceived the bitterness least strongly. The young women differed significantly from the other three groups, the young men differed significantly from the elderly men but not from the elderly women, and both elderly gender groups did not differ. Chauhan and Hawrysh (Chauhan and Hawrysh, 1988) found steeper slopes for women than for men for sour taste intensity, both in water and in apple drink. Other authors did either find no gender differences or did not look for them.

The studies mentioned vary not only in the number of compounds or age ranges of groups but also in the method of measuring intensity, in instructions, concentration ranges, number of repetitions, and in the degree of experience of subjects with the experimental procedure. While in these studies the concentrations of compounds used vary widely, and are in a number of cases far outside the normal range of everyday use, the concentrations chosen in the present studies are chosen around (and include) the concentration found in 'regular' food products.

Several authors not mentioned in Table 1 found that the elderly have a diminished ability to discriminate between ascending concentrations of taste compounds dissolved in water. Gilmore and Murphy (Gilmore and Murphy, 1989) found that ageing was associated with higher Weber ratios at medium and high concentrations, but not at a low concentration, of caffeine, and reported a 74% increase in 0.005 M caffeine to be needed to produce a perceptible difference for the elderly, whereas only a 34% increase was needed for the young. The Weber ratios for sucrose did not differ between the two age groups. For weak and moderate concentrations of NaCl, KCl and $CaCl_2$, Schiffman (Schiffman, 1993) observed that young subjects generally needed only a 6–12% difference in concentration to perceive a change, whereas the elderly subjects required an increment of 25% to distinguish a difference in intensity. In their study on regional sensitivity to three concentrations of NaCl (0.01, 0.1 and 1.0 M), Matsuda and Doty (Matsuda and Doty, 1995) observed that, unlike young subjects, elderly subjects are unable to distinguish among different stimulus concentrations, and were not more sensitive at the tip of the tongue than in a region 3 cm posterior to the tip. Finally, Stevens *et al*. (Stevens *et al*., 1991) showed that the average discrimination score for 10 NaCl 0.25 log concentration steps (0.003–0.56 M) in tomato soup at room temperature, decreases with rather sharply from 79% correct discrimination in young subjects to 56.5% at middle age, and then more slowly to old age (53.8%). When corrected for chance guessing, the performance of the young group exceeded that of the middle and old age groups significantly.

The experiments to be reported here are the second part of a larger study with a fixed group of young and elderly subjects in which the influence of ageing on taste perception has been investigated. In a first paper (Mojet *et al*., 2001), the effects of ageing on threshold sensitivity to the basic tastes were reported. In the present study, pre-tests were carried out first with both elderly and young subjects to ascertain that the concentration ranges to be used in the main experiments were wide enough to perceive concentration differences in distilled water and in product when subjects were wearing a nose clip or not. The subsequent main experiments have been carried out to determine whether age-related taste losses are found when suprathreshold intensities of taste compounds are presented, and if so, to what extent such taste losses are generic, taste-quality-specific, or compound-specific, and furthermore, to investigate the effect of perceptual context on taste intensity perception. Therefore, the subjects were asked to evaluate the intensities in water (single taste perception), in 'regular' products while wearing a nose clip (complex taste–texture perception) and without a nose clip (complex taste–texture–smell perception). This should also help to verify the relevance of determining intensities of taste compounds dissolved in water for the 'real life' perception of taste in complex food products.

Pre-tests: intensity discrimination

The pre-tests have a twofold objective.First, they serve to determine the concentration ranges to be used in the main experiments, and secondly, they indicate whether the acuity for intensity discrimination diminishes with age.

Materials and methods

Subjects

The same 21 older subjects (age 60–75, 10 male, M = 66.0, SD = 3.6, and 11 female, M = 64.6, SD = 4.2) and the same 21 young subjects (age 19–33, 11 male, M = 26.5, SD = 3.6, and 11 female, M = 23.2, SD = 3.3) participated in all experiments described here. They all had taken part in a previous experiment on threshold sensitivity (Mojet *et al*., 2001). All subjects were Caucasian and met the following criteria: healthy, not on a diet, not living in a home for the elderly, not taking any prescribed medicine, non-smoking, not heavy alcohol users, non-pregnant or lactating, not subject to food allergies, good dental hygiene, and not wearing dentures (as it was very difficult to recruit enough elderly persons without dentures, subjects with partial dentures were admitted but they were not allowed to wear these during testing). Furthermore, the subjects had to be within the normal range at hearing sounds of 750 Hz, in view of the use of hearing as a matching modality for taste. A tone audiogramme was made with 500 and 1000 Hz tones of each candidate to screen for normal sensitivity to sounds ~750 Hz. To be admitted, their auditory thresholds should not be higher than 30 dB. Subjects were selected on a volunteer base in response to advertisements in local newspapers and on bulletin boards in senior citizen centres. At the end of all experiments the subjects were paid for their participation.

Stimuli

Five taste qualities were included: saltiness, sweetness, sourness, bitterness and umami taste. For each taste quality, two representative compounds were chosen, which were administered at five concentration levels both in distilled water and in regular products. The compounds were grouped in two sets of five taste qualities each. One set contained NaCl, sucrose, acetic acid, caffeine and MSG, the other set consisted of KCl, aspartame, citric acid, quinine HCl and inosine 5′-monophosphate (IMP). The products were versions of commercially available ice tea, chocolate drink, mayonnaise, tomato soup and bouillon (all five products of Unilever), which were varied by the omission or addition of the taste ingredients to be tested.

To enable the selection of the concentrations of the compounds in water and product for the main experiment, a matching task (paired comparison test) was carried out with 33 members of the descriptive panels at the Unilever sensory laboratory at Vlaardingen. For each compound, the intensities of five ascending concentrations dissolved in water were compared with the intensity of the regular concentration of the compound in the product. The panel members indicated which of the products was respectively saltier, sweeter, etc.

The differences in concentrations in the present study are in 0.1 log steps, which means an increase by a factor of 1.26. For some compounds this increase in concentration is somewhat larger than the Weber ratio found for young subjects in the literature (Schutz and Pilgrim, 1957; Pfaffman *et al*., 1971; Lundgren *et al*., 1976; McBride, 1983) but it is smaller than the Weber ratio found for impaired patients (Fischer *et al*., 1965) and smaller than the highest ratio (2.56) found for the elderly by Gilmore and Murphy (Gilmore and Murphy, 1989). The geometrical midpoint between the highest concentration at which the compound was perceived as weaker in water and the lowest concentration, at which it was perceived as stronger in water, was taken as the matching concentration of the compound in water.

In the pre-tests the concentration in water that matched the concentration of the regular component in product was used as the second concentration step in a series of five steps for each compound dissolved in water. One step down and three steps up completed the range. The difference between two consecutive concentrations in water was 0.1 log step. For the concentration in the products the regular concentration was chosen as the second concentration step in a series of five. One step down and three steps up completed the ranges. Since the bitterness in the chocolate drink could not be left out, a very low concentration was chosen as the first step in the range. Again, the steps in the ranges increased in concentration by a factor of 0.1 log. The concentrations of the non-regular components in these products (KCl, aspartame, citric acid and IMP) where chosen on the basis of their equi-intensity with their regular counterparts in these products. An overview of the concentrations of the compounds used in this discrimination pre-test is given in Table 2.

The solutions of the compounds in water were prepared the day before testing and tested at room temperature the following day. The dry bases for the products (without the specific taste compound) and the compounds to be tested in these products, were weighed beforehand, mixed and prepared on the day of testing, with the exception of the mayonnaise, which was produced in advance at the pilot plant of Unilever Research Vlaardingen. All products were served at room temperature. Per stimulus the subjects received 20 ml in a 50 ml disposable plastic cup.

Procedures

For practical reasons, the sessions for the elderly and the young were conducted separately. More time and a more elaborated instruction were required for the elderly. Throughout the experiments the sip-and-spit method was used. At the start of the session, and before each new trial, the subject rinsed with distilled water and expectorated. The subjects were instructed to eat a piece of cream cracker at the end of a series of samples of a given compound.

The pre-tests were held on three consecutive days. On the first day, the taste compounds were dissolved in water. The subjects had to pick the odd one out of three samples in triangle tests. The next 2 days, the compounds were varied in regular products. In order not to perturb the results of the other conditions, the rather unnatural experimental condition, in which the subjects had to evaluate the stimuli wearing a nose clip, was reserved for the last day. Again, the odd one had to be picked out. Each triad consisted of three

Table 2 Tastant concentrations (in g/l) used for the triangle tests

	Compounds	Dissolved in water		Log steps	Dissolved in product		Log steps
		Lowest	Highest		Lowest	Highest	
Sweet	sucrose	17.062	42.852	0.1	42.854	107.636	0.1
	aspartame	0.116	0.290	0.1	0.290	0.728	0.1
Salt	NaCl	4.512	11.332	0.1	7.150	17.956	0.1
	KCl	7.150	17.956	0.1	11.328	28.452	0.1
Umami	MSG	2.510	6.304	0.1	0.794	1.996	0.1
	IMP	1.584	3.980	0.1	0.502	1.260	0.1
Bitter	caffeine	0.198	0.498	0.1	0.398	0.998	0.1
	quinine	0.002	0.004	0.1	0.003	0.008	0.1
Sour	acetic acid	0.798	2.006	0.1	0.267	0.067	0.1
	citric acid	1.580	3.970	0.1	0.019	0.048	0.1

samples in a row, two samples of the lowest concentration and one sample that was one, two, three or four steps higher in concentration. The place of the odd sample in the row of three samples was randomly chosen. Each triad was assessed once.

To guarantee that order effects equally biased the comparison of the performances of the subjects, the compound presentation order was kept constant for all subjects. The intensities of MSG and IMP were determined last to avoid the risk that these compounds caused an enhancement of the perception of a subsequent taste stimulus. There were short breaks between the tasting of the compounds and there was a larger break between the two series of the five taste qualities.

Statistical analysis

The results were analysed per day by calculating the number of correct responses and comparing them with the critical (minimum) numbers of correct answers to the triangle test at a 0.05 level (Meilgaard *et al.*, 1987). In the results, effects with a significance level of 0.05 are given, while a significance level of 0.10 is only described when it supports a general trend.

Results

The results of the pre-tests are shown in Table 3. For the salty and sweet tastants, both the elderly and the young detected concentration differences at least at a difference level of 0.2 log and higher in all presentation conditions, i.e. in water and in product while wearing or not wearing a nose clip. The elderly and the young detected both sour tastants and the bitter tastant caffeine at least at a difference level of 0.3 log or higher in all presentation conditions. When presented in water, both elderly and young perceived a concentration difference of 0.1 log in quinine HCl, a concentration difference of at least 0.2 log in the umami tastant MSG, and a concentration difference of at least 0.3 log in IMP. The concentration differences of quinine HCl, MSG and IMP dissolved in product were not systematically detected whether subjects were wearing a nose clip or not.

Conclusions

These results show that a maximum concentration difference of 0.4 log is not sufficiently large to ensure that the elderly and the young can perceive the difference for all compounds in all three conditions. Therefore, consecutive 0.2 log concentration steps seemed recommendable for the compounds to be assessed in the main experiments both in water and in product. It is assumed that a maximum increase in concentration of 0.8 log (4 × 0.2 log) will be perceived by all subjects in all compounds. Moreover, larger concentration steps might lead to very 'unrealistic' products.

The results also show that intensity discrimination seems to be remarkably resistant to the effect of ageing, since the elderly and the young produce very similar results and in some cases the elderly even seem to be more acute than the young.

Main experiments: intensities of tastants dissolved in water or in product reported by subjects wearing a nose clip or not

Materials and methods

Subjects and stimuli

The same 42 subjects as in the pre-test experiment took part in these experiments, that were carried out during the 3 weeks following the pre-tests.

Based on the results of the pre-tests, five concentrations (ascending 0.2 log steps) of the same 10 compounds were chosen to be assessed in water and in the same food media as in the pre-tests. An exception was made for mayonnaise (ascending 0.1 log steps), since the total concentration difference could not be larger than 0.4 log for technological

Table 3 Concentration differences in log units perceived as significantly different ($P < 0.05$) by the elderly and young in the three presentation conditions (+ indicates: this and larger concentration differences)

	Compounds	Water		Product (noseclip)		Product	
		Elderly	Young	Elderly	Young	Elderly	Young
Salt	NaCl	0.1+	0.1+	0.2+	0.1+	0.2+	0.2+
	KCl	0.1+	0.2+	0.2+	0.2+	0.2+	0.2+
Sweet	sucrose	0.1+	0.1+	0.1+	0.1+	0.1+	0.2+
	aspartame	0.2+	0.2+	0.2+	0.2+	0.2+	0.2+
Sour	acetic acid	0.1+	0.1+	0.1+	0.1+	0.2+	0.3+
	citric acid	0.1+	0.1+	0.2+	0.2, 0.4	0.1, 0.3, 0.4	0.1+
Bitter	caffeine	0.1+	0.1+	0.1, 0.4	0.3+	0.2+	0.2, 0.4
	quinine HCl	0.1+	0.1+	–	–	0.1	0.1
Umami	MSG	0.2+	0.2+	–	0.2	0.3	0.1, 0.4
	IMP	0.3+	0.2+	–	0.2	–	–

Table 4 Concentrations (in g/l) of the basic tastants used for the intensity measurements

	Compounds	Dissolved in water		Log steps	Dissolved in product		Log steps
		Lowest	Highest		Lowest	Highest	
Sweet	sucrose	8.55	53.95	0.2	53.95	340.38	0.2
	aspartame	0.06	0.37	0.2	0.15	0.92	0.2
Salt	NaCl	3.58	22.61	0.2	5.68	35.83	0.2
	KCl	5.68	35.83	0.2	9.00	56.77	0.2
Umami	MSG	1.99	12.58	0.2	1.58	9.95	0.2
	IMP	1.26	7.94	0.2	1.00	6.28	0.2
Bitter	caffeine	0.16	1.00	0.2	0.63	3.98	0.2
	quinine HCl	0.00	0.01	0.2	0.01	0.00	0.2
Sour	acetic acid	0.63	4.00	0.2	0.27	0.67	0, 1[a]
	citric acid	1.26	7.92	0.2	0.02	0.05	0, 1[a]

[a]For product technical reasons.

reasons. The concentration series are given in Table 4. In most cases, the second step in the range of concentrations corresponded with the regular ('everyday life') concentration of the compound in the selected product. Based on the results of the pre-tests, some adjustments in the concentrations were made but in all cases the regular concentration fitted well within the range of stimuli used. For the assessment of the compounds in water the solutions were prepared the day before testing and tested at room temperature the following day. For the assessment of the compounds in product the compounds were mixed with the dry product beforehand and prepared on the day of testing, and served at room temperature. However, the mayonnaise was prepared beforehand at the Unilever pilot plant at Vlaardingen. Per stimulus the subjects received 20 ml in a disposable 50 ml plastic cup.

In order to serve as control stimuli in cross modal intensity matching of the different sensory modalities, five levels of auditory (loudness), visual (size) and kinaesthetic/tactile (weight) stimuli were presented. For the sounds, a narrow band noise of 750 Hz was recorded. The intensity varied from 45 to 85 dB with intervals of 10 dB. The duration of a sound was kept at 1.5 s. The sounds were delivered by earphones, which the subjects had to wear during the test. Five weights were constructed varying in 0.2 log steps from 33.7 to 212.6 g. The weights were hidden in small black (film) containers of equal size and had to be lifted by the top of the forefinger by means of a ring on a string that was connected to the container. For the visual stimuli, an irregular star figure was multiplied in ascending 0.2 log size steps.

Procedure

The procedure was the same in the three experiments (tastants dissolved in water or in product with subjects wearing a nose clip or not). The stimuli were presented one after the other. Similar to the pre-tests, the sip-and-spit method was used and separate sessions were held for the elderly and the young. At the start of a session and before each new trial the subject rinsed with distilled water and expectorated. The subjects were instructed to eat a piece of cream cracker at the end of a series of samples of a given compound.

The sessions of each experiment took place on three consecutive days, one per day. The 10 taste compounds were presented in a balanced order over the three sessions but within each session the 10 compounds, at five concentration levels each, were presented only once. The last series of stimuli in a session always contained the umami samples to avoid the risk that these compounds caused an enhancement of the perception of a subsequent taste stimulus. In each session the taste stimuli were intermingled with three replications of auditory, visual and weight stimuli at five levels. The presentation order of the compound concentrations and the cross-modal stimuli was the same for all subjects.

In each session, all taste samples had to be judged on liking and on their salt, sweet, sour, bitter and umami intensities, whereas the auditory, visual and weight stimuli had to be rated on intensity only. The intensities were marked on a nine-point scale with the anchors 'very weak' at the left side and 'very strong' at the right side. Liking of the taste stimuli was assessed on a nine-point pleasantness scale with the anchors 'very little' at the left side and 'very much' at the right side. The results of the evaluation of the intensities of the tastes that were not experimentally varied, and the results of the liking, as well as of the comparison of the intensity matching modalities will be reported elsewhere.

Statistical analysis

Methods. The statistical analyses were conducted by means of SAS® and SAS/STAT®. Multivariate analyses of variance (repeated measures analysis and MANOVA) were applied with age and gender as between-subject factors, and taste quality, compound and concentration as within subject factors, in order to investigate the main and interaction effects of age, gender, taste quality, compound and concentration. The same error has been used to test the effects of the mean, age, gender and age by gender per multivariate response (e.g. compound). Data were averaged over replications to compare the older men, older women, young men and young women pair wise, using the LSMeans method. As measures of the intensity and the slope of the psychophysical function, the average of the intensities for the five concentrations and the

$$\beta\_int = (-1*int1 - int2 + int4 + 2*int5)/10$$

were taken, respectively. Separation of variances into variance components (see Results, section on 'General or specific losses') was carried out with Proc Varcomp of SAS/STAT®.

Levels of significance. All effects that have a P-value of 0.05 or lower are reported as 'significant'. Power Analysis shows that, with the number of subjects in our study, an effect with a magnitude of 1.3 standard deviations and a P-value of 0.10 still has a power of 0.90. Therefore a selection of the more interesting effects with a P-value between 0.05 and 0.10 are reported additionally. These effects will be denoted as 'trends' or 'tendencies'.

Cross-modal intensity matching. When people respond differently to a task, they may either perceive the task differently, or they may have an inherent different use of the assessment scale. In this study cross-modal intensity matching (CMIM) is used as a method to overcome this problem. In CMIM, the same scale is offered to the assessors, but now with stimuli from a different sensory modality which are believed to be perceived in the same way by all subjects. If, in this case, differences in intensities are found between groups or individuals, these differences are interpreted as differences in scale usage and can be used to correct the responses to other modalities before any further analysis of the data. The remaining differences are then considered to be 'real'. Cross-modal matching has been described in detail by Marks and Stevens (Marks and Stevens, 1980). In the present study, 'sound' was selected to correct for differences in scale usage, because the sensitivity to low-frequency sound (~750 Hz) is normally not impaired with age and because an analysis of variance of the results for each of the five sound levels did not show an influence of age or gender.

The matrix of the CMIM data consisted of 42 people, 27 replications per individual, and five different levels of loudness per replication. On average, the standard deviation per individual/level of loudness was fairly constant and in the order of 0.9, indicating that the standard error of an individual/level of loudness combination is in the order of 0.17 (0.9/27). The following steps were used in the correction:

1. For each sound level the individual average and the age group average were determined.
2. The (individual minus group) averages (which also have a standard deviation of ~0.17) were regressed against the group averages using polynomial functions of the latter, starting with a polynomial of degree 0 (constant difference from group mean) and ending with a polynomial of degree 4 (complete fit of individual means).
3. For each individual assessor the lowest polynomial with a residual standard deviation of ~0.17 was selected as the assessor's correction formula.
4. Each individual score on the scale was corrected by a value obtained from the individual's correction formula.

All data to be reported here are based on scores that were corrected by means of this method.

Results

Hereafter, the results of the experiment with compounds dissolved in water will be reported first, then the results of the experiment with compounds mixed in product assessed with the nose clip on, and then the results of the experiment with compounds mixed in product evaluated with unblocked noses. Finally the three data sets will be compared.

Overall effects of age and gender

Do age and gender influence taste intensity perception in general? When the tastants were dissolved in water, the elderly perceived the tastants taken overall as significantly less intense than the young [$F(1,38) = 21.16$, $P < 0.0001$]. No overall effect was found for gender or age by gender. When they were dissolved in product and when nose clips were worn to block the retronasal effects of the odour of the products, no overall age, gender or age by gender interaction effect was found. Overall, the elderly perceived the tastants dissolved in product and tasted without wearing a nose clip as significantly less intense than the young subjects [$F(1,38) = 5.88$, $P < 0.03$]. No overall effect was found for gender or age by gender.

Comparison of these results show that when tasted in water and in product without a nose clip, the elderly perceived the tastants overall as less intense than the young. When wearing a nose clip this significant difference disappeared.

Concentration

Are age and gender effects concentration-specific? Taken over all compounds, the ascending concentrations of tastants dissolved in water were perceived as different [$F(4,35) = 471.73$, $P < 0.0001$] as was to be expected, and a concentration by age interaction effect [$F(4,35) = 40.00$, $P < 0.01$] was also found. Overall, for the elderly the intensity increased less with increasing concentration than for the young, i.e. the slope of the psychophysical function was significantly steeper for the young than for the elderly [$F(4,35) = 4.00$, $P < 0.01$] as is illustrated in Figure 1. No significant concentration by gender or concentration by age by gender interaction effects was found.

Whereas overall the ascending concentrations were perceived as different [$F(4,35) = 157.77$, $P < 0.0001$] when the tastants were dissolved in product and assessed with a nose clip on, the slopes of the psychophysical function for quinine HCl, MSG and IMP were rather flat. The slopes of

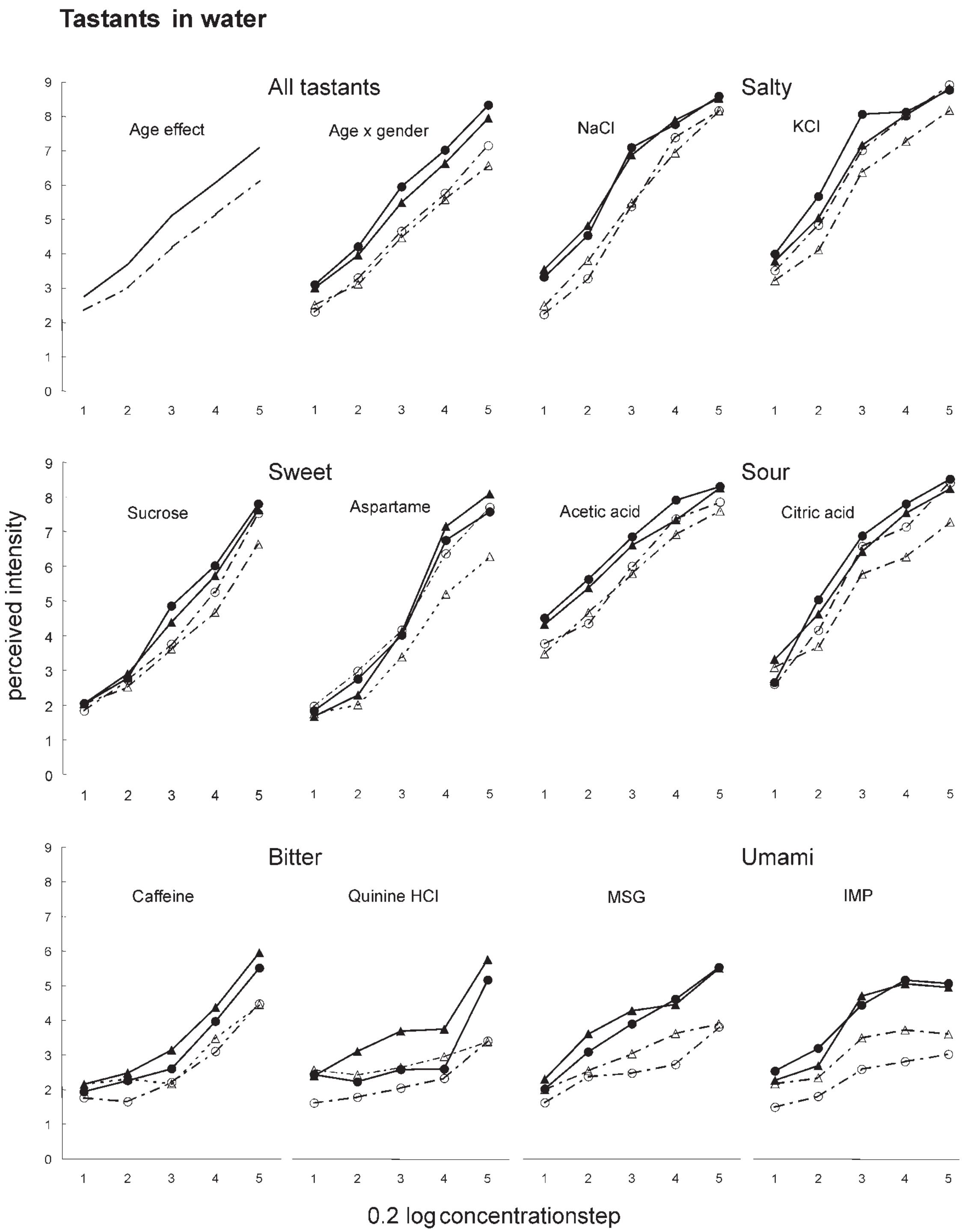

Figure 1 Intensity measurements for 10 taste compounds dissolved in water in young and elderly male and female subjects. Intensity ratings are given in 0.2 log concentration steps. The young subjects are represented by solid lines and filled symbols, the elderly by dotted lines and open symbols. The male subjects are represented by triangles and the female subjects by circles.

the psychophysical function were not different for the elderly and young or for the men and women. Figure 2 shows the results.

Dissolved in product and assessed while not wearing a nose clip, the ascending concentrations were perceived as different [$F(4,35 = 191.81$, $P < 0.0001$] when analysed overall, the slopes of the psychophysical function for quinine HCl, MSG and IMP were rather flat, and all slopes

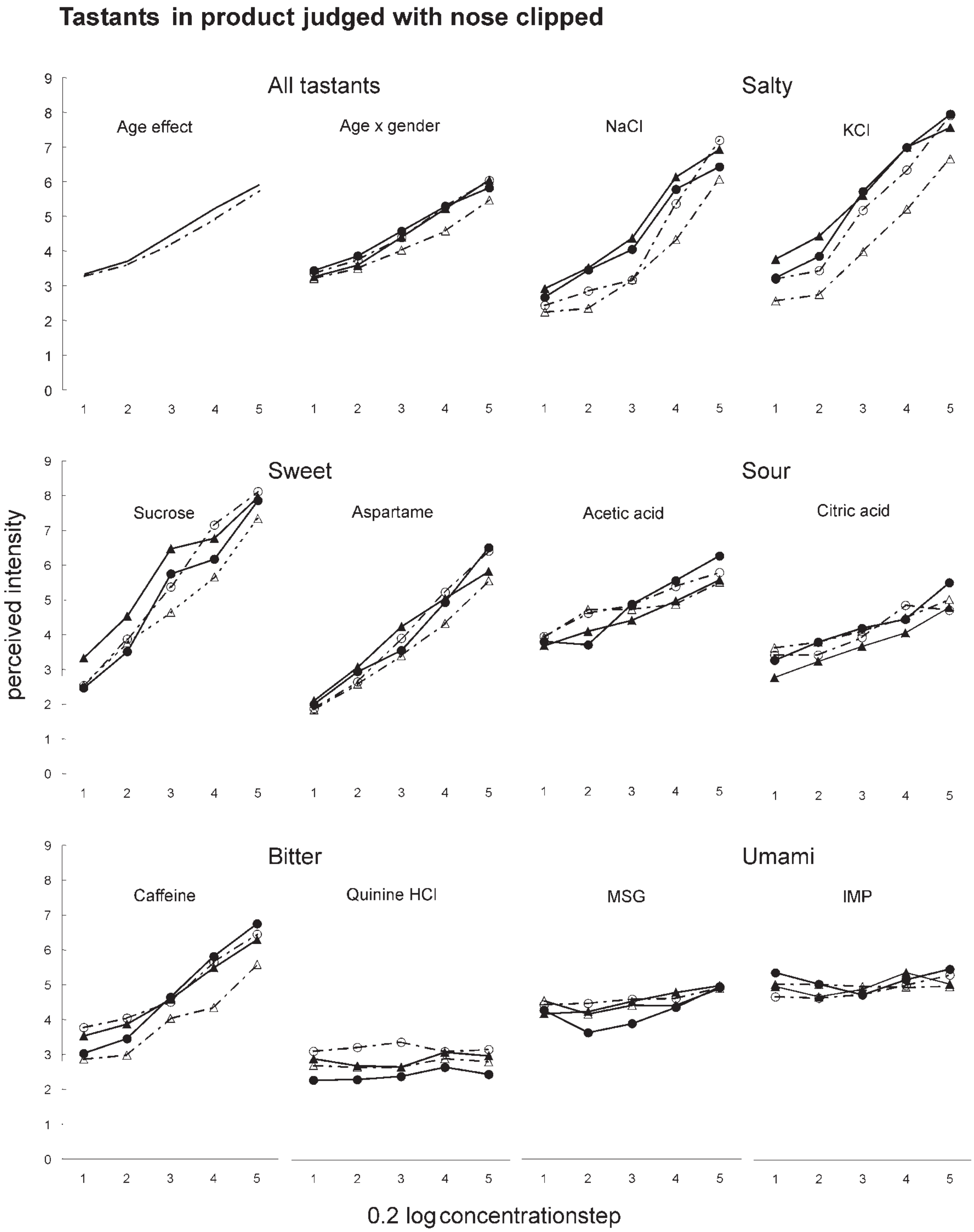

Figure 2 Intensity measurements for 10 taste compounds dissolved in product, assessed by young and elderly male and female subjects while wearing a nose clip. Intensity ratings are given in 0.2 log concentration steps. The young subjects are represented by solid lines and filled symbols, the elderly by dotted lines and open symbols. The male subjects are represented by triangles and the female subjects by circles.

of the psychophysical function were not different for the elderly and young, nor for the men and women. Figure 3 shows the results.

A comparison of the three sets of results shows that in the case of the tastants dissolved in water an age by concentration effect is found, that the slope of the psychophysical function is less steep for the elderly than for the young, and that no such effect is found when the tastants are embedded in product and are assessed with or without a nose clip.

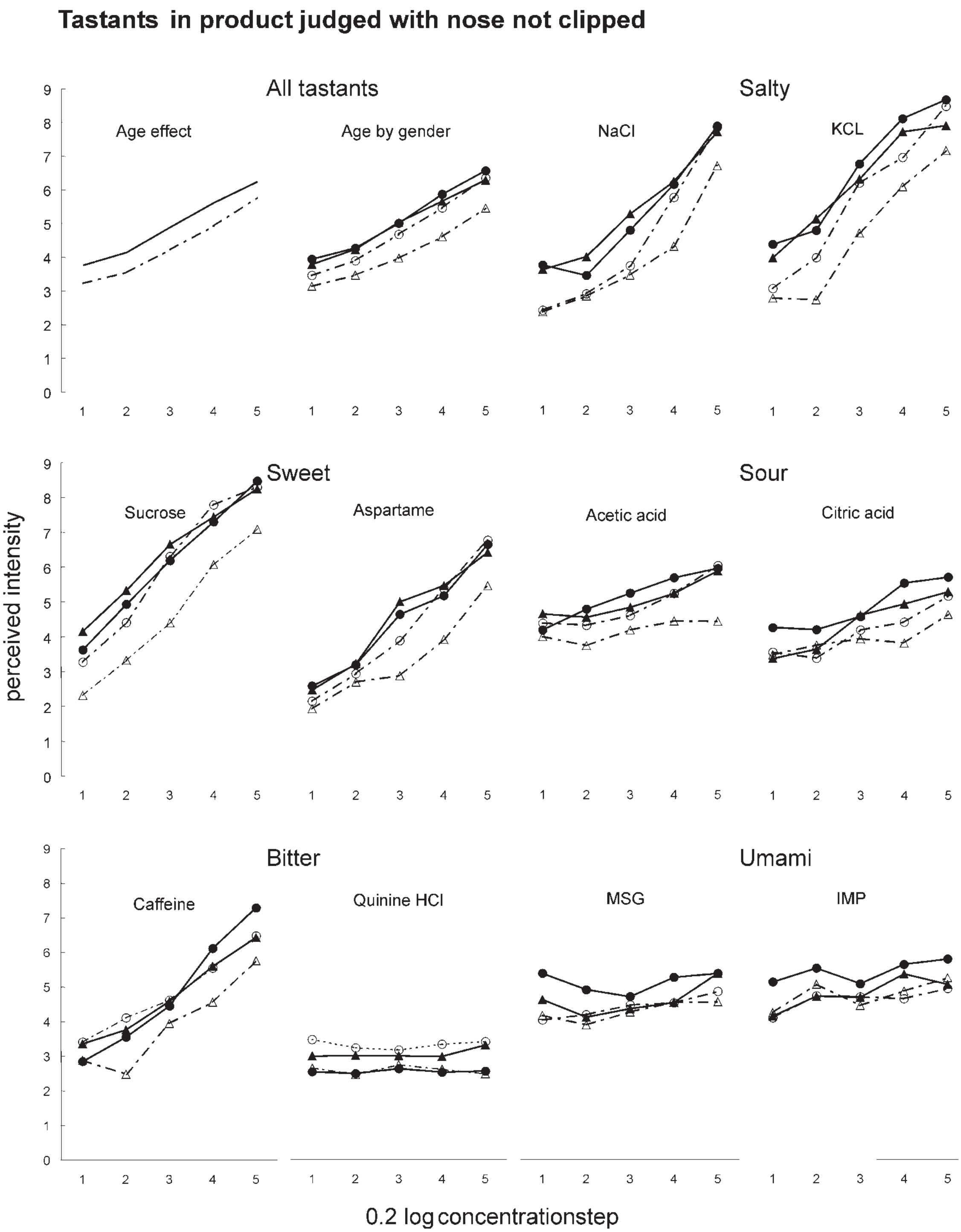

Figure 3 Intensity measurements for 10 taste compounds dissolved in product in young and elderly male and female subjects. Intensity ratings are given in 0.2 log concentration steps. The young subjects are represented by solid lines and filled symbols, the elderly by dotted lines and open symbols. The male subjects are represented by triangles and the female subjects by circles.

Compounds

Are age and gender effects equal for all compounds? When the tastants were dissolved in water, significant age effects on intensity [with all *F*s (1,38) ≥ 4.15 and all *P* values < 0.05 at least] were found for all compounds except aspartame, for which only a trend could be observed [$F(1,38) = 3.53$, $P < 0.07$]. In all cases the young perceived the intensities as stronger than the elderly did. Gender effects on the perceived intensity were observed for aspartame [$F(1,38) = 4.34$, $P < 0.05$] where the women perceived the intensities as stronger than the men, and for quinine [$F(1,38) = 5.52$, $P < 0.03$] where the opposite was found. Age by gender interaction effects on the perceived intensity were observed for aspartame [$F(1,38) = 3.08$, $P < 0.09$] and IMP [$F(1,38) = 2.92$, $P < 0.10$] as a trend only. The elderly men did not perceive the aspartame as intense as the other three groups and they also perceived IMP as weaker than both young groups, whereas the elderly women perceived the IMP even weaker than the elderly men.

An age effect was only found for KCl [$F(1,38) = 4.38$, $P < 0.05$] and NaCl [$F(1,38) = 3.99$, $P < 0.06$] when the tastants were dissolved in product and assessed with a nose clip on. The elderly perceived the salty taste of KCl and NaCl as less intense than the young did. For sucrose an age by gender effect [$F(1,38) = 4.19$, $P < 0.05$] was found. The young men perceived this sweet taste as more intense and the elderly men perceived it as less intense than the other groups.

Assessed without nose clip, significant age effects on intensity [all *F* values (1,38) ≥ 60.00 and all *P* values < 0.02] were found for both salty and for both sweet compounds but not for any of the other compounds. Where differences were found, the elderly perceived the intensities as weaker than the young did. Only for sucrose a gender effect [$F(1,38) = 4.34$, $P < 0.05$] and an age by gender interaction effect [$F(1,38) = 9.41$, $P < 0.004$] on the intensity were observed. Men perceived the intensity of sucrose as weaker than women did and this was especially true for the elderly men.

Comparison of the three sets of results shows that all compounds were perceived as significantly less strong (aspartame trend only) by the elderly than by the young when the tastants were dissolved in water, whereas in product this was only the case for the salty and sweet tastants, and when nose clips were worn the difference between the elderly and young was further restricted to the salty tastants only.

Compounds within taste qualities

Are age and gender effects larger for one compound than for the other within a taste quality? To see if the age effect is similar for the two compounds within a taste quality, the differences between the two compounds within the taste qualities were compared.

Overall, the elderly did not differ from the young in their perception of the differences between the tastants dissolved in water within a taste quality, and men did not differ from women. Also, no age by gender interaction effect was found. A gender by compound within-taste–quality interaction effect was found for the salty taste, where the women perceived a larger difference [$F(1,38) = 4.66$, $P < 0.04$] between the mean intensities of NaCl and KCl concentrations than the men. An age by gender interaction effect was found for the sweet taste [$F(1,38) = 4.55$, $P < 0.04$]. The elderly women perceived the largest and the elderly men perceived the smallest differences in intensity between sucrose and aspartame.

When the tastants were dissolved in product and nose clips were worn, there was no overall age, gender or age by gender interaction effect on the intensity differences between the compounds dissolved in product within a taste quality. When analysed more specifically per compound, there was only an age effect [$F(1,38) = 5.87$, $P < 0.03$] for the bitter taste. The distance in intensity between the two compounds was larger for the young than for the elderly.

Overall, the elderly did not differ from the young and men did not differ from women in the perception of the differences between the two compounds within a taste quality when assessed in product with no nose clip on. Moreover, no overall age by gender interaction effect was found. Univariate analysis per taste quality showed an age effect [$F(1,38) = 6.24$, $P < 0.02$] for the bitter taste, where the young perceived a larger difference between caffeine and quinine than the elderly but no other age differences were found. An age by gender interaction effect was found for the sweet taste [$F(1,38) = 4.61$, $P < 0.04$]. All groups perceived sucrose as stronger than aspartame but the young men perceived this difference as significantly larger than the elderly men did.

A comparison of the three sets of results shows that when the compounds were dissolved in water, the differences in intensity perceived by the elderly and the young remained the same for each given taste quality, regardless of which of the two compounds within that taste was measured. However, when dissolved in product, the perception is differently influenced by age for the bitter taste only. This indicates that the influence of age might be taste-quality-specific but in general is not very specific for compounds within a taste quality.

Taste qualities

Are age and gender effects generic or taste-quality-specific? In other words: does the relation between the intensities of the tastes remain stable or change with age? To see whether this is the case, pairs of taste quality compounds were used as contrasts in the MANOVA. In general, for the intensity contrasts between the taste qualities, an age effect [$F(4,35) = 3.12$, $P < 0.03$] and a gender effect [$F(4,35) = 4.97$, $P < 0.003$] but no overall age by gender interaction effect was found when the tastants were dissolved in water. When the specific combinations of taste qualities were analysed, it appeared that the elderly perceived a larger intensity contrast than the young between umami on the one hand and, respectively, the sweet [$F(1,38) = 12.89$, $P < 0.001$], the sour [$F(1,38) = 4.22$, $P < 0.05$] and the bitter [$F(1,38) = 23.95$, $P < 0.0001$] taste on the other. The elderly perceived both umami tastants as much weaker than the young, whereas the differences between the elderly and the young were much smaller for the sweet, sour and bitter tastes. Gender effects were found for the contrasts between the umami taste and, respectively, the salty [$F(1,38) = 4.61$, $P < 0.04$], sweet [$F(1,38) = 12.28$, $P < 0.002$] and the sour [$F(1,38) = 4.95$, $P < 0.04$] taste, and also between the bitter taste and, respectively, the salty [$F(1,38) = 7.21$, $P < 0.01$], the sweet [$F(1,38) = 9.65$, $P < 0.004$] and the sour [$F(1,38) = 6.13$, $P < 0.02$] tastes. Although all subjects perceived the umami and bitter tastants as weaker than the salty, sweet and sour tastants, in all these cases the women perceived larger contrasts than men. An age by gender interaction effect was found for the contrasts between the umami and the sweet tastants [$F(1,38) = 7.60$, $P < 0.01$]. Here, the elderly women perceived a larger contrast than all other groups.

Between the taste qualities an overall age effect [$F(4,35) = 3.11$, $P < 0.03$] on the intensity contrasts was found when the tastants were dissolved in product and when nose clips were worn by the assessors. There were no gender or age by gender effects. Age effects were found for the contrasts between the salt taste on the one hand and, respectively, the sour [$F(1,38) = 10.69$, $P < 0.003$], the umami [$F(1,38) = 4.70$, $P < 0.04$] and the bitter [$F(1,38) = 6.45$, $P < 0.02$] taste on the other. In the first and the second case, the young perceived the salt tastes as stronger than the other tastes, whereas for the elderly the reverse was true. In the case of salt and bitter, both age groups perceived the salty tastes as more intense but the young did so to a significantly larger extent. There was also an age by gender effect for the contrast between the salt and sour taste. The young men perceived the salt taste as much stronger than the sour taste and the elderly men perceived the sour taste as stronger than the salt taste, while both groups of women occupied a middle position.

Overall, the intensity contrasts between the taste qualities were not equal for the elderly and the young [$F(4,35) = 3.57$, $P < 0.02$] when the tastants were dissolved in product and assessed while not wearing a nose clip. No overall gender effect or age by gender interaction effect was found. When analysed more specifically for the 10 different combinations of taste qualities, only one age effect was found. The elderly perceived the intensity contrast between the salt taste on the one hand and the bitter taste on the other [$F(1,38) = 10.36$, $P < 0.003$] as smaller than the young. No gender effect was found but an age by gender effect [$F(1,38) = 4.66$, $P < 0.04$] was found for the contrast between the umami and the sweet tastants. Here, the young men perceived the intensity of the sweet taste as stronger than that of the umami taste, whereas the older men perceived the umami taste as stronger than the sweet taste.

A comparison of the three sets of results shows that in water as well as in product, the elderly and young wearing a nose clip or not differed in their perception of the intensity contrasts between the taste qualities. This indicates that this overall age effect is dependent on the taste quality involved.

General or specific losses

When the tastants were dissolved in water the total variance due to age could be separated into the following variance components: age 96.4%, age × concentration 1.0%, age × taste quality 1.1%, age × concentration × taste quality 0.8%, age × compound (within taste quality) 0.3%, age × concentration × compound (within taste quality) 0.0% and error 0.4%. This shows that the age effects found can be attributed predominantly to a generic loss in taste perception when tastants were dissolved in water.

When the tastants were dissolved in product and assessed while wearing a nose clip, the total variance due to age could be separated into the following variance components: age 12.1%, age × concentration 0.0%, age × taste quality 60.8%, age × concentration × taste quality 4.8%, age × compound (within taste quality) 12.4%, age × concentration × compound (within taste quality) 0.0% and error 9.9%. This shows that the small age effects found can be attributed predominantly to a taste-quality-specific loss in taste perception when tastants were embedded in food media and were assessed while wearing a nose clip.

When the tastants were dissolved in product and assessed without wearing a nose clip the total variance due to age could be separated into the following variance components: age 92.4%, age × concentration 0.0%, age × taste quality 5.6%, age × concentration × taste quality 0.4%, age × compound (within taste quality) 0.6%, age × concentration × compound (within taste quality) 0.0% and error 1.0%. This shows that the age effects found can be attributed predominantly to a generic loss in taste perception when tastants were embedded in food media and were assessed without wearing a nose clip.

Comparisons of the results described above show that age differences found in the water and product conditions were predominantly generic in nature, while in the condition of product assessed with nose clip the small amount of variance due to age and its interactions is mainly taste quality specific.

Relationships between the taste intensities

In order to reveal possible age differences in the perception of the relationships between the compounds, correlations were calculated per age group for the three conditions: water and product judged with and without nose clip.

A comparison of the results shown in Table 5 demonstrates that the two compounds within a taste quality are correlated in all media, with the one exception of the bitter compounds in water assessed by the young. In all cases the average correlation is higher in product while wearing a nose clip or not than in water and it is higher for the elderly than for the young. In contrast, the intercorrelation is almost similar for the elderly and young in water and in product judged with a nose clip on, whereas in product judged without nose clip the intercorrelation is clearly higher for the elderly than for the young.

Correlations between the results obtained in the three different perceptual contexts

The role of the perceptual context can be derived from the differences between the intensities in water (single taste perception), in 'regular' products while wearing a nose clip (complex taste–texture perception) and not wearing a nose clip (complex taste–texture–smell perception). The correlations between the results obtained in the three presentation conditions are given in Table 6.

As expected, the correlations were highest in the two conditions in which the same media were used (products judged with and without nose clip). At the same time it is remarkable that the elderly showed very high correlations, which in nearly all cases were even substantially higher than those found for the young. The important role of the media in which the tastants are dissolved is further illustrated by the low to very low correlations found for both elderly and young, when the intensities in water were compared with those in product with subjects wearing a nose clip or not. In general, the correlations between these different media were lower for the elderly than for the young and they never reached significance for the elderly, whereas for the young they were in both conditions significant for NaCl and citric acid only.

Table 5 Correlations between the intensities measured for the two compounds of each taste quality, the average correlation for all pairs of compounds and the intercorrelation of all compounds (correlation coefficients *R* are given)

	Tastants dissolved in water		In product assessed with nose clip		In product without nose clip	
	Elderly	Young	Elderly	Young	Elderly	Young
Salty	0.50**	0.55**	0.80***	0.88***	0.69***	0.64**
Sweet	0.89***	0.58**	0.91***	0.60**	0.76***	0.73***
Sour	0.70***	0.65**	0.89***	0.92***	0.85***	0.88***
Bitter	0.72***	0.23	0.87***	0.62**	0.90***	0.73***
Umami	0.75***	0.60**	0.83***	0.88***	0.84***	0.89***
Average	0.71***	0.52*	0.86***	0.78***	0.81***	0.77***
Intercorrelation	0.36	0.32	0.45*	0.43	0.51*	0.34

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 6 Correlations between the intensities measured in the conditions tastant in water and in product with or without nose clip (correlation coefficients *R* are given)

	Water versus product		Water versus product assessed with nose clip		Product assessed with versus without nose clip	
	Elderly	Young	Elderly	Young	Elderly	Young
NaCl	–0.11	0.55**	–0.12	0.46*	0.83***	0.41
KCl	0.26	0.30	0.23	0.24	0.82***	0.57**
Sucrose	0.32	0.30	0.21	0.14	0.76***	0.78***
Aspartame	0.31	0.18	0.24	0.42	0.84***	0.42
Acetic acid	–0.02	0.42	0.05	0.30	0.88***	0.66**
Citric acid	0.20	0.47*	0.18	0.40	0.93***	0.64**
Caffeine	0.11	0.30	0.08	0.26	0.93***	0.72***
Quinine HCl	–0.09	0.19	0.02	0.05	0.84***	0.80***
MSG	0.17	0.15	0.32	0.42	0.85***	0.45*
IMP	0.33	0.08	0.21	0.18	0.88***	0.54*
Average	0.13	0.48*	0.21	0.44*	0.92***	0.67**

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Discussion

Age effects

When supra-threshold intensities of taste compounds are presented in water or in product without wearing a nose clip, the age effects found are almost exclusively generic and never compound-specific. In the product with nose clip condition, there was an indication of some taste-quality specificity.

Furthermore, the perceptual context plays an important role in taste intensity perception by the young and the elderly. When the subjects were asked to evaluate the intensities in water (single taste perception) far more age effects were found than when they were presented in 'regular' products and tasted without a nose clip (complex taste–texture–smell perception). When they were presented in products while wearing a nose clip (complex taste–texture perception) all age effects except for the salty components disappeared. Thus, the relevance of determining intensities of taste compounds dissolved in water for the 'real life' perception of taste in complex food products seems rather limited. This point will be treated more extensively below, but first the present data will be compared with the findings of other authors.

Age effects in water. Age effects, showing a diminished intensity perception of the elderly, have been found for all 10 compounds when dissolved in water. Of the authors, who studied four tastes qualities, the findings of Cowart (Cowart, 1989), who found an age effect for three of the four tastants she tested are most in agreement with the present results. The other authors who studied four taste qualities in water in a single study, found either an age effect for two of the four taste qualities (Hyde and Feller, 1981; Murphy and Gilmore, 1989) or no effect of age at all (Bartoshuk *et al.*, 1986; Weiffenbach *et al.*, 1986; Bartoshuk, 1989). In the last two studies only a flattened slope was found for all tastants in the elderly. To a certain extent, this latter finding is in agreement with the present study in which also flatter slopes were found for the elderly than for the young for all compounds in water except for KCl, acetic acid and citric acid. In the present study however, the average intensities of the young were never lower than those of the elderly, as had been reported by Bartoshuk *et al.* (Bartoshuk *et al.*, 1986; Bartoshuk, 1989) for the lower concentrations. Thus, the present results do not support their hypothesis that, due to poor dental hygiene or to the presence of a mild dysgeusia (Shafar, 1965), the elderly attribute a higher background taste to water, which by summation with the tastes of the stimuli might lead to the heightened intensity perception at lower concentrations. Moreover, this hypothesis seems strange, since it should be assumed that with a higher background taste (Grad, 1954) adaptation would take place, and such adaptation would lead to a diminished rather than an increased intensity perception, especially at the lower concentrations. A more likely explanation for the findings of Bartoshuk *et al.* (Bartoshuk *et al.*, 1986, Bartoshuk, 1989) may be that many of the elderly have difficulty in using very small numbers (smaller than 1) in their magnitude estimations ratings. This explanation is all the more plausible since these authors used a wider range of stimuli and used more extreme concentrations at the lower end of the range than any of the other authors with the exception of Hyde and Feller (Hyde and Feller, 1981) who used similarly low concentrations for salty and sweet.

Age effects for compounds dissolved in product. When the compounds were dissolved in product, an age effect was found only for the salty and sweet tastants in the present experiment. This age difference is in disagreement with the findings of all authors mentioned in Table 1, who found no age effect for these tastants embedded in product (Stevens and Lawless, 1981; Little and Brinner, 1984; Warwick and Schiffman, 1990; Zallen *et al.*, 1990; De Graaf *et al.*, 1994; Drewnowski *et al.*, 1996), although two of them found a flatter slope for the elderly, one for salty (Little and Brinner, 1984) and the other for sweet (De Graaf *et al.*, 1994), a finding that could not be confirmed. The present results are also partially in disagreement with Stevens and Lawless (Stevens and Lawless, 1981) who did find an age effect for bitterness perception in pureed vegetables, whereas in the present study with chocolate milk, such an effect was not found. Only in the sourness perception of products, the present results are in concordance with the results of Stevens and Lawless who showed no effect of age, and are partially in accordance with those of Chauhan and Hawrysh (Chauhan and Hawrysh, 1988) who, for citric acid, found a flatter slope for the elderly, whereas in the present study this was only marginally the case. When nose clips were worn while tasting the products, no differences in intensity perception between elderly and young were found except for the salt taste.

Age effects in different perceptual contexts. From the foregoing comparison of the results with those in the literature, it is evident that far fewer age effects are found when the tastants are tested in product than in water. This casts some doubt on the relevance of experiments with tastants dissolved in water for the 'every day life' situation in which the tastants are almost always embedded in a complex food product. That experiments with tastants dissolved in water have little predictive value for real life situations is further illustrated by the low (young) to very low (elderly) correlations found between the water condition and the two product (with and without nose clip) conditions.

Range effects

Concentration range may also play a crucial role in the division of studies in which age effects were found or not. In the present experiment the concentration range was based on the variation of the tastes in normal everyday products. In the experiments with products, the regular product was enclosed in the concentration range and the steps in the range varied only by a factor of 1.59. This led to a range in which the highest concentration differed only by a factor 6.31 from the lowest one. This was also true for the stimuli in the experiments in water. Thus, even in water the range of the stimuli remained comparable with what subjects would encounter in products in their everyday life. Inspection of the ranges used shows that all authors who did find age effects used concentration ranges that included the range used in the present experiment and did not contain extreme concentrations to either side of it. This is most clear in the study of Cowart (Cowart, 1989) who used ranges with a 10-fold difference between the lowest and the highest concentrations. The two other groups of authors who found an age effect used either a four-fold difference (Murphy and Gilmore, 1989), or a 20-fold (sour) and 40-fold (bitter) difference range (Hyde and Feller, 1981). In total, age effects were found in 17 out of 21 cases for tastants dissolved in water, when a limited range of concentrations was used that included the 'normal' range in everyday products. The only authors who used such a range but did not find an age effect, were Stevens *et al*. (Stevens *et al*., 1984) for salty, Murphy and Gilmore (Murphy and Gilmore, 1989) for salty and sweet and Cowart (Cowart, 1989) for sweet. Authors who used extreme ranges of tastants [(Bartoshuk *et al*., 1986; Bartoshuk, 1989) for salty, sweet, sour and bitter; (Hyde and Feller, 1981) for salty an sweet] found no age effects. That measurements of intensity are subject to range effects is well documented in the psychological literature (Helson, 1964; Parducci, 1974; Poulton, 1979). It seems that in the case of taste perception such range effects easily become stronger than age effects. The use of extreme stimuli (e.g. solutions of more than 600 g of sugar in one litre of water) should perhaps be avoided.

Gender effects

About half of the authors mentioned in Table 1 looked at gender differences, the others did not mention or did not investigate them. Only two papers, dealing with compounds in water, report gender differences. Hyde and Feller (Hyde and Feller, 1981) reported higher intensities for caffeine and citric acid when rated by women than by men, whereas in the present study higher bitterness intensities were found for men than for women in both caffeine and quinine, and no gender difference for citric acid. Chauhan and Hawrysh (Chauhan and Hawrysh, 1988) found steeper slopes for women than for men for citric acid, in water as well as in product. In the present study a steeper slope for women was only found for citric acid in water but when assessed in product without nose clip no such effect was noticed. Main gender and age by gender effects are found for aspartame in water since elderly men rated sweetness as less strong than the other groups. The young men and women perceived the umami taste of IMP in water equally strong, but the older women perceived it as less strong than the young subjects did. Such effects have thus far not been reported. No authors reported gender differences for salty or sweet tastants in products, whereas in the present study such differences were found for KCl (trend only) and sucrose when tasted without nose clips. The gender effect for KCl and the gender and age by gender effect for sucrose were due to lower intensities perceived by the older men.

Relative and absolute sensitivity and the possible role of smell in taste perception

The elderly discriminated the concentration differences both in water and in product, with or without a nose clip, at least as well as the young but nevertheless showed in the main experiment a lower absolute intensity perception of compounds in water and in product judged without a nose clip. In view of the cross-modal intensity matching measures, this difference between the elderly and the young can not be ascribed to differences in scaling behaviour. This is an intriguing finding that may indicate that the young perceive something more than the elderly which does influence their absolute taste intensity perception but does not play a role in the discrimination of taste intensities in a comparative judgement. The fact, that in the condition where the tastants in product were judged with a nose clip, the young loose their advantage over the elderly while the judgement of the elderly remained the same in the conditions with and without nose clip, strongly suggests that the young make use of their sense of smell in rating taste intensities in contrast to the elderly who are less able to do so due to a deterioration in olfactory acuity. Such loss of olfactory sensitivity with age is well-documented (Murphy *et al.*, 1991).

Although the present data do not provide further direct proof for the hypothesis that olfaction plays a role, there are at least two indications that for the young, but not for the elderly, a second factor is indeed involved in the intensity perception of the stimuli in product tasted without nose clips. In order to show this, the correlations between the intensities of the stimuli in products tasted with nose clip and those in product tasted without nose clip were calculated for both groups. The results given in Table 6, last two columns, show that in all cases except for sucrose, the correlations of the elderly are higher (and in most cases even substantially higher) than those of the young. Furthermore, inspection of the scatter plots shows that the lower correlations of the young are almost exclusively due to the fact that they rated the intensities of stimuli without a nose clip higher than with a nose clip. Further careful inspection of the plots showed no additional abnormalities which might explain the differences between the correlations found for the young and the elderly. As an example, Figure 4 is given showing the scatter plots of both groups for the averages per person over all compounds.

If one should accept the hypothesis that smell plays a role, there are two possible ways in which this might take place.

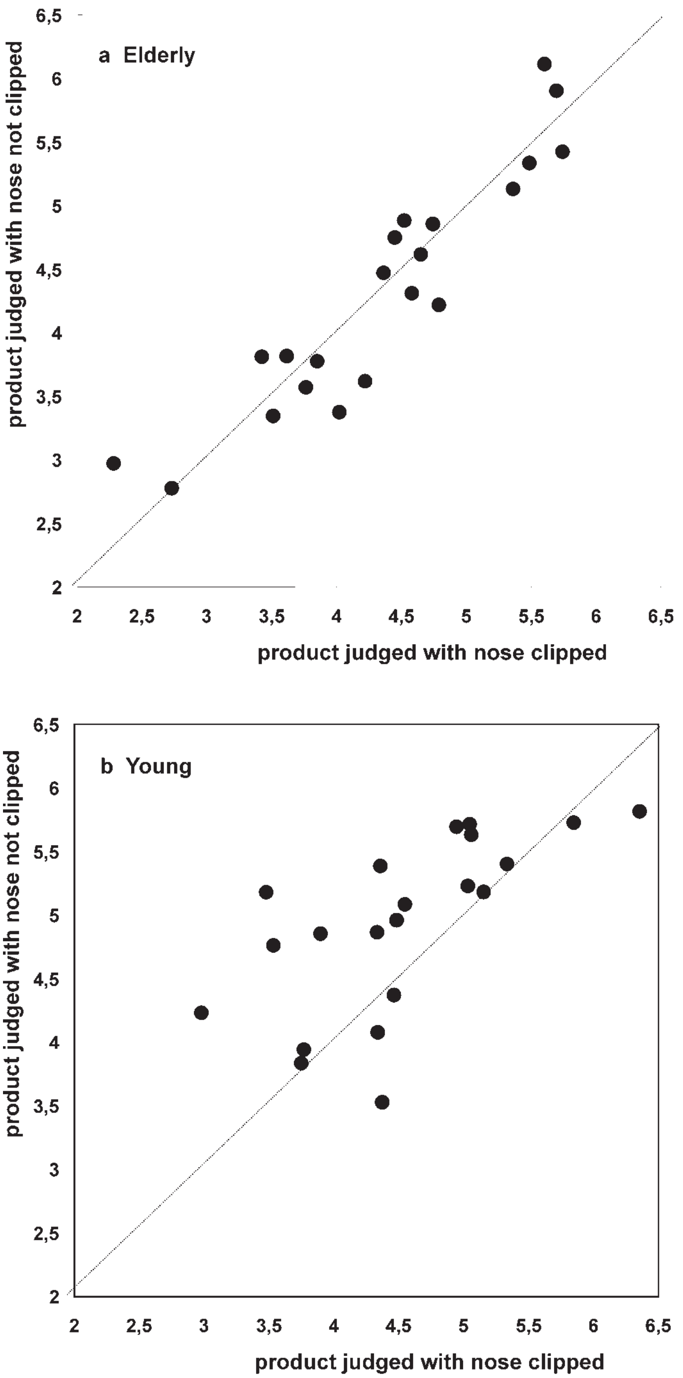

Figure 4 Correlation between intensities of the 10 compounds in product and assessed with and without nose clip for elderly **(a)** and young **(b)** subjects. The intensities are averaged per person over all compounds per condition.

First, the tastants themselves might have a smell. To the knowledge of the present authors, this possibility, unlikely as it seems for most tastants with the possible exception of acetic acid, has never been tested seriously. In the second place, the presence of the tastants might interact with the olfactory perception of the medium in which they are presented. That this latter possibility exists when the tastants are presented in product is evident, since some of them (MSG and IMP) are known flavour enhancers but might this also be true in the case of water? It would suggest that water has a smell of its own which is changed by tastants. Unfortunately, in the present study this has not been tested, since there was no condition in which tastants dissolved in water were assessed with nose clips on. The results of a separate experiment, which is now underway, will have to clarify this matter.

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