

Food Perception with Age and Its Relationship to Pleasantness

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Abstract

Differences between elderly subjects ($n = 46$, 61–86 years) and young subjects ($n = 36$, 18–25 years) in food perception and food liking were investigated. Intensity and liking ratings were assessed for custard dessert, in which flavor enrichment, textural change, and irritant addition were incorporated as strategies to compensate for sensory losses with increasing age. The sensory acuity (taste, olfaction, irritation, chewing efficiency) of both young and elderly subjects was measured with the help of different sensitivity tests. The elderly perceived the custards differently from the young, mainly as less intense in flavor (cherry/vanilla) and less intense in creaminess/swallowing effort. Several of the observed interaction effects were different for the elderly and the young. The majority of these differences manifested as lower intensity slopes for the elderly. Losses in sensitivity to taste and to olfactory and trigeminal stimuli as well as a reduced chewing efficiency were observed on average for the elderly compared with the young. Furthermore, subgroups of the elderly were observed in which the compensatory strategies flavor enrichment, textural change, and irritant addition led to an increase in food liking. However, these subgroups did not differ in their sensory acuity. The present study does not support the assumption that age-associated changes in food perception—caused by losses in sensory acuity—inevitably reduce the food liking of the elderly.

Key words: compensatory strategies, JND, sensory acuity, sensory interactions

Introduction

Although aging is accompanied by a decreased efficiency in sensory processing in general (Corso 1981), this decrease may not be uniform in all senses. For example, olfaction is more affected than taste (Stevens et al. 1984). Similarly, it has been reported that age-associated decline in sensitivity is more pronounced for olfaction than for nasal irritation (Hummel et al. 1998) and is larger for taste than for oral somatic sensations when determined as thresholds (Fukunaga et al. 2005). Furthermore, there is also a greater variability in sensory acuity within a group of elderly subjects than within a group of young subjects. Whereas some elderly clearly demonstrate impairments in their sensory performance, others maintain performance levels similar to those of younger age groups (Calhoun et al. 1992; Koskinen et al. 2003a; Thomas-Danguin et al. 2003).

While eating or drinking, individuals experience a multifaceted combination of sensations, which will blend into a unitary percept, that is, “gestalt.” This process is known as multimodal sensory integration. It seems likely that declines

in sensory acuity with age might cause changes in this multimodal integration of sensory information. So far, only a few authors have investigated whether or not sensory interactions change with age. In 2 studies on orthonasal smell–taste interactions, no age effect was found (Hornung and Enns 1984; Enns and Hornung 1988). In 2 recent studies, elderly and young subjects differed in their texture–flavor interaction effects for soups but not for waffles (Kremer et al. 2005; Kremer, Mojet, and Kroeze 2007). So, it seems too early to draw general conclusions as the type and degree of interaction may also depend on the type of product and/or ingredients used (Pangborn et al. 1978).

Compensatory strategies, such as adding or increasing certain ingredients (e.g., flavors or irritants) or changing food texture, aim to compensate for age-associated losses in sensory acuity. It is assumed that these sensory losses with age translate into modifications of food pleasantness and food choice, although data in support of this assumption are currently lacking (see review of Mattes 2002). Very limited

support was found recently for the assumption that compensatory strategies are effective in increasing food pleasantness for all elderly (Kremer, Bult, et al. 2007). Only subgroups of elderly were observed, in which applied compensatory strategies—such as flavor enhancement or irritant addition—seemed to be effective. Interestingly, these subgroups did not differ in their olfactory acuity. Nevertheless, it seems too early to draw final conclusions because olfactory acuity was the only sensitivity measure that was taken in this previous study. Finally, although it has been demonstrated that age-associated changes in food perception occur, the influence of these changes on food liking seemed rather limited (Kremer et al. 2005; Kremer, Bult, et al. 2007; Mojet et al. 2005). Consequently, it seems possible that the role sensory compensation strategies may play to increase food liking of the elderly has been overestimated and that nonsensory strategies, taking other age-associated factors into consideration such as loneliness or food wanting, may prove more successful.

The present study investigates whether or not elderly and young differ in their food perception and food liking. Attribute intensities and pleasantness were both assessed in custard desserts, in which flavor enrichment, textural change, and irritant addition were incorporated to compensate for sensory losses. Different sensitivity tests were included as subjects with poor sensory acuity may differ in their food perception and consequently may respond differently to compensatory strategies than those with normal sensory acuity. Finally, additional information on the elderly subjects was collected with the help of a short questionnaire on mainly elderly-specific issues as these nonsensory factors may influence food perception and/or pleasantness of the elderly.

Pretest: intensity discrimination with age

A just noticeable difference (JND) is the amount of change in a physical stimulus necessary to produce a perceptible difference in sensation. The determination of JNDs in food products for both elderly and young subjects yields extra information on their sensory sensitivity because it is a measure of their discriminatory abilities. The pretest had the following objectives. Firstly, it served to determine the thickener, flavor, and trigeminal concentrations to be used in the main experiment, and secondly to indicate whether or not the elderly required a larger increase in stimulus concentration in order to experience a difference than the young.

Materials and methods

Subjects

A group of elderly ($n = 24$, mean age 67, range 61–86 years) and young ($n = 24$, mean age 21, range 18–24 years) subjects, taken from larger groups from the main experiment, participated in the pretest. More detailed information on the subjects can be found in the Materials and Methods of the main experiment.

Stimuli

Custard desserts (Paradies Crème, Dr Oetker KG, Bielefeld, Germany) were used in this pretest together with different concentrations of the cherry flavor (Ducros, Avignon, France) of the thickener (Simplese/Microparticulated whey protein concentrate; Brenntag Specialities B.V., Loosdrecht, the Netherlands) or of the oral irritant (capsaicin, 60% pure solution from the Spanish pepper *Capsicum annum*, IFF B.V., Hilversum, the Netherlands). In a pilot test, a flavor concentration was established by 2-AFC (two alternative forced choice) tests that was significantly perceived as cherry flavor in the custards ($n = 10$, mean age 64, range 61–79 years). This concentration (0.16% w/w cherry flavor embedded in the custard base of 300 g full fat milk and 70 g custard powder) was then chosen as the standard for cherry flavor in the flavor discrimination task. Five comparison stimuli were prepared for this standard, all being more concentrated than the standard (0.23% w/w, 0.35% w/w, 0.53% w/w, 0.78% w/w, 1.18% w/w cherry flavor embedded in 300 g full fat milk and 70 g custard powder). Similarly, a thickener concentration was established by 2-AFC tests for 9 of the elderly (mean age 63, range 61–77 years) that significantly increased the thickness of the custards compared with the custard without any extra thickener addition. This concentration (1.07% w/w thickener embedded in the custard base of 300 g full fat milk and 70 g custard powder) was then chosen as the standard for thickness in the thickness discrimination task. Six comparison stimuli were prepared for this standard, all being more concentrated than the standard (1.49% w/w, 2.06% w/w, 2.86% w/w, 4.00% w/w, 5.49% w/w, 7.52% w/w thickener embedded in the custard base of 300 g full fat milk and 70 g custard powder).

Similarly, a capsaicin concentration was established by 2-AFC tests for 10 elderly (mean age 66, range 63–82 years) that was significantly perceived as prickling in the custards. This concentration ($8.1 \times 10^{-4}\%$ w/w capsaicin solution embedded in the custard base of 300 g full fat milk and 70 g custard powder) was then chosen as the standard for prickling in the irritant discrimination task. Four comparison stimuli were prepared for this standard, all being more concentrated than the standard ($8.9 \times 10^{-4}\%$ w/w, $9.9 \times 10^{-4}\%$ w/w, $1.3 \times 10^{-3}\%$ w/w, $1.5 \times 10^{-3}\%$ w/w capsaicin solution embedded in the custard base of 300 g full fat milk and 70 g custard powder).

Procedure

The JNDs were established with the method of constant stimuli. In each trial, 2 standard stimuli were assessed together with a comparison stimulus by means of a 3-AFC (three alternative forced choice) test. The comparison stimuli were presented in random order. In total, each subject assessed 5 triads in the flavor discrimination task, 6 triads in the thickness discrimination task, and 4 triads in the irritant discrimination task.

Data analysis

The proportion (P) representing the number of times the comparison stimulus was identified correctly was calculated for each of the levels of comparison. The proportions were corrected for chance (P corr), and corresponding z-scores were calculated. We defined the JND as the ratio of 2 stimulus concentrations that results in an z-score of zero (=50% correct discrimination). Therefore, the difference between the standard concentration and the x-intercept of the linear function $z(\text{P corr}) = \log([\text{stimulus}]/[\text{standard}])$ is our estimate for the JND. The Weber ratio (Wr) was determined as the ratio between the JND value and the standard concentration value.

Results

Figure 1a shows the fitted straight lines for the elderly ($Y = 1.57x - 0.79$, $R^2 = 0.94$) and the young ($Y = 1.90x - 0.65$, $R^2 = 0.96$) in the flavor discrimination test. For the elderly, 1 JND equaled a $10^{0.502}$ or 3.17-fold (=Weber ratio) increase in added flavor concentration, whereas for the young, 1 JND equaled a $10^{0.343}$ or 2.20-fold increase in flavor.

Figure 1b shows the fitted straight lines for the elderly ($Y = 3.48x - 1.83$, $R^2 = 0.93$) and the young ($Y = 5.17x - 1.62$, $R^2 = 0.97$) in the texture discrimination test. For the elderly, 1 JND equaled a $10^{0.526}$ or 3.36-fold (=Weber ratio) increase in added thickener concentration, whereas for the young, 1 JND equaled a $10^{0.312}$ or 2.05-fold increase in thickener. Figure 1c shows the fitted straight lines for the elderly ($Y = 7.0x - 1.86$, $R^2 = 0.97$) and the young ($Y = 10.96x - 2.79$, $R^2 = 0.99$) in the irritant discrimination test. For both the elderly and the young, 50% correct discrimination was not even achieved for the highest concentration difference, whereas at the same time, the subjects already described the prickling intensity as extremely intense.

Discussion

In the pretest, the elderly required a larger increase in flavor and thickener concentration in order to experience the same difference as the young. This finding agrees with several other studies. Firstly, the young outperformed the elderly in intensity discrimination of NaCl dissolved in tomato soup (Stevens et al. 1991). Secondly, aging was found to be associated with larger Weber ratios in aqueous solutions of caffeine but not for sucrose (Gilmore and Murphy 1989). Thirdly, Schiffman (1993) reported that the elderly required a concentration increase of 25% in NaCl, KCl, and CaCl_2 dissolved in aqueous solutions to perceive a difference in intensity, whereas the young needed only a 6–12% increase. Finally, in vision and audition/sound, the elderly are also reported to require larger contrasts to discriminate between stimuli (Olsho et al. 1985; Crassini et al. 1988). In contrast to these observations, Mojet et al. (2003) reported that taste intensity discrimination of the elderly was remarkably resistant to the effect of aging, measured both in aqueous solution and in food products.

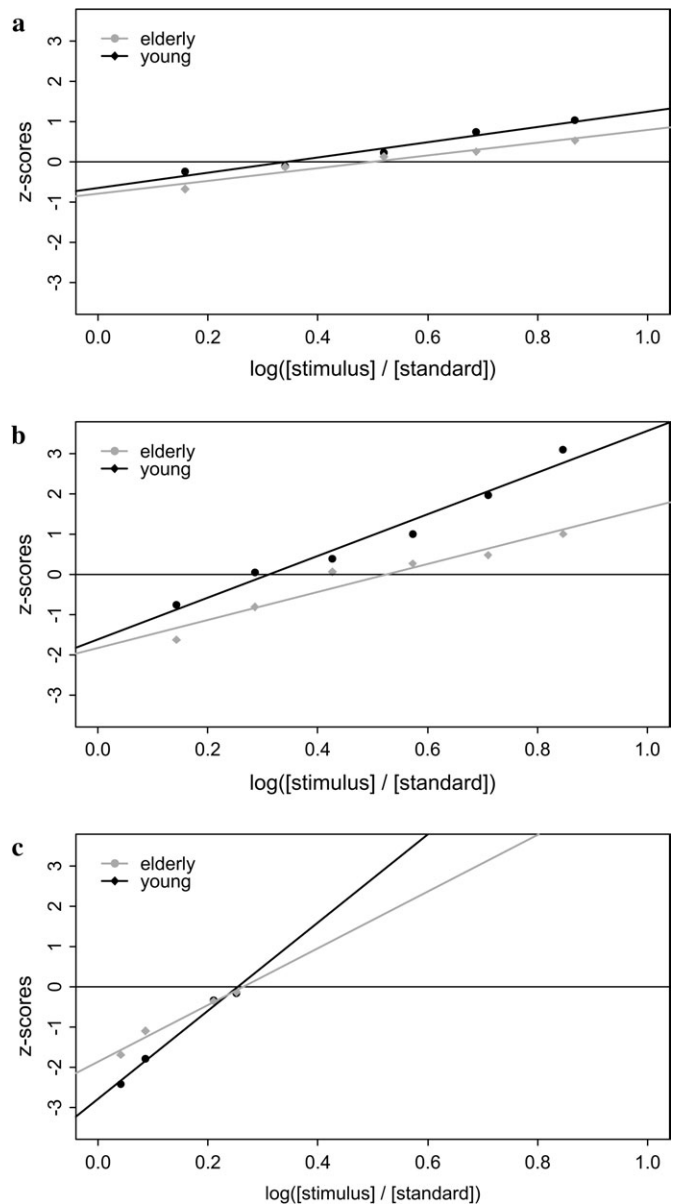


Figure 1 Plot of z-scores for correct discrimination of the elderly and the young subjects against the logarithm of stimulus concentration for (a) flavor, (b) texture, and (c) irritation.

An estimate of irritant JND has not been obtained with the present method because the sensitization properties of capsaicin (Prescott 1999) interfered with the assessment of concentration difference by means of 3-AFC tests. We took no further attempts to establish the JND for capsaicin because the higher capsaicin concentrations used in this pretest were already reported to be highly unpleasant. Therefore, the capsaicin concentrations used in the main experiment were estimated from the results of the pilot 2-AFC tests.

In the present study, the observed impairment of the elderly in texture and flavor discrimination tasks might originate from age-induced changes in sensory performance that

have been reported to affect more or less all the sensory modalities. For example, neuronal responses of the elderly generally slow down accompanied by an increase in stimulus persistence (Salthouse 1996), and this might be accompanied by an increased persistence of the stimulus in the neural representation (Raz et al. 1990). As a result, the neural representation of stimuli arriving in sequence might overlap to the extent that differences might become blurred. Furthermore, it is more difficult for the elderly to divide attention between various sensory inputs or stimuli (Craik and Simon 1980). Thus, irrelevant information processed in conjunction with stimulus information might inhibit the discrimination processes of the elderly.

Conclusions

In the main experiment, we are interested in possible age-associated differences in interaction effects between the different senses. Therefore, it seemed prudent to apply sufficiently large steps in cherry flavor and thickener concentration to ensure that the elderly perceive differences in the flavor and texture of the custards. The flavor and thickener concentration levels chosen for the main experiment were levels at which 75% of the elderly were able to discriminate in this test.

Main Experiment

Materials and methods

Subjects

Initially, a total of 48 young and 48 elderly subjects were recruited. Two of the elderly were unable to complete all experimental sessions as were 12 of the young subjects. As a consequence, their results were excluded from the data analysis. The elderly (33 females and 13 males, mean age 71, range 61–86 years) lived independently either in the area of Zeist or of Wageningen, the Netherlands, and they prepared their daily meals themselves. They were recruited by advertisements in local newspapers. The elderly were screened for cognitive impairment by the translated mini mental state test (Folstein et al. 1975), and they were only accepted into the panel with a 100% correct score. This was done to avoid a study bias caused by diminished cognitive abilities due to neurodegenerative disorders such as dementia or Alzheimer's. The young subjects (24 females and 12 males, mean age 22, range 18–25 years) were students of Wageningen University or members of a sports club in Ede, the Netherlands. The subjects participated in 5 tasting sessions lasting approximately 60 min each and received a fee for participation at the completion of the test.

Samples

The same custard desserts as in the pretest were used in the main experiment. For 1 batch, 70 g of custard powder

(Paradies Crème, Dr Oetker KG, Bielefeld) was mixed with 300 ml of full fat milk and 3 additional ingredients of 1 of 3 levels according to a $3 \times 3 \times 3$ full factorial design. Texture was changed by adding zero, low (1.1% w/w), and high (5.7% w/w) amounts of thickener (Simplese/Microparticulated whey protein concentrate; Brenntag Specialities B.V.). Flavor enrichment was achieved by adding zero, low (0.16% w/w), and high (1.35% w/w) amounts of cherry flavor (Ducros) and irritant addition by adding zero, low (4.1×10^{-4} % w/w), and high (1.2×10^{-3} % w/w) amounts of capsaicin (60% pure solution from the Spanish pepper *Capsicum annum*, IFF B.V.).

All samples were prepared at least 18 h before serving, placed in 50-ml plastic cups with lids, and stored overnight in a food grade chill room at 4 °C. Two hours before serving, all samples were taken out of the chill room, and they were served at room temperature (21 ± 2 °C).

Procedure

The tasting sessions for the young subjects were held in meeting rooms of Wageningen University, and sessions for the elderly were held in clubrooms of the service centers in Zeist and Wageningen. Tests were conducted once a week from 10 AM to 12 AM over a period of 5 weeks. The subjects received randomized subsets of the 27 custard desserts during the first 3 sessions and participated in different sensitivity tests during the last 2 sessions. Per sample, pleasantness was always assessed first on a 100-mm horizontal visual analogue scale. Next, the intensities of the sensory attributes thickness (THI), creaminess (CRE), swallowing effort (SEF), vanilla flavor (VAN), cherry flavor (CHE), sweetness (SWE), and oral prickling (PRI) were rated on visual analogue scales. The verbal anchors were Dutch terms that translate to “very little/weak” and “very much/strong” and were placed at 10% and 90% of the scale, respectively. The samples were coded with random 3-digit numbers and were presented in random order per person. The same randomization scheme was used for the 2 age groups. Panelists were instructed to rinse with water and to eat cream crackers between the samples. The interstimulus interval was 2 min. After the 5-week test cycle, the elderly panelists completed a demographic questionnaire.

Sensory acuity

The sensitivity tests used in the present study were especially developed within the European Union (EU)-funded HealthSense project to assess the sensory acuity of elderly subjects. All these tests were developed and compared in different age groups, and they underwent internal validation processes with combined data sets provided from all HealthSense partners involved. However, until now, publications in peer-reviewed journals are only available with respect to the olfactory sensitivity test (Thomas-Danguin et al. 2003; Koskinen et al. 2004; Koskinen and Tuorila 2005).

Taste sensitivity test. Taste acuity was assessed using aqueous solutions of stimuli of 4 concentrations of the taste qualities sweet (sucrose: 1.1, 3.5, 10.9, and 34.6 g/l), sour (citric acid: 0.13, 0.26, 0.53, and 1.1 g/l), salty (NaCl: 0.19, 0.59, 1.9, and 5.9 g/l), and bitter (quinine: 1.84×10^{-3} , 3.97×10^{-3} , 8.55×10^{-3} , and 1.84×10^{-2} g/l) (Johansson A, Hall G, Bengtzon A, unpublished data). The taste solutions were presented at room temperature in 10-ml portions in 150-ml disposable plastic cups. The sip-and-spit method was used, and the subjects were asked to identify the taste. For each correct taste identification, 1 point was given, resulting in possible scores ranging from 0–16.

Olfactory sensitivity test. The European test of olfactory capabilities (ETOC) was used to measure the olfactory performance in the final session (Thomas-Danguin et al. 2003). Sixteen food and nonfood odors were presented in 16 sets. Each set consisted of 1 odor-filled vial and 3 empty vials. The subjects indicated which of the 4 vials contained an odor (detection), and then, they selected 1 from a list of 4 descriptors (identification). For each correct odor detection, 1 point was given. Only when the odor was detected correctly was another point given for correct identification. This gave scores ranging from 0 to 32.

Trigeminal sensitivity test. The trigeminal sensitivity test (Lähteenmäki et al. 2001) involved compounds representing different trigeminal sensations: oral astringency (tannic acid: 5.0×10^{-4} , 2.0×10^{-3} , 8.0×10^{-3} , and 3.2×10^{-2} g/l), oral cooling (menthol: 5.2×10^{-5} , 2.1×10^{-4} , 8.3×10^{-4} , and 3.3×10^{-3} g/l), nasal burn (ammonia: 2.0×10^{-3} , 8.0×10^{-3} , 3.2×10^{-2} , and 12.8×10^{-2} g/l), and oral burn (piperine: 2.0×10^{-4} , 6.0×10^{-4} , 2.4×10^{-3} , and 9.6×10^{-3} g/l). The aqueous solutions were served at room temperature in 150-ml disposable cups filled with 10-ml of the solutions. The solutions of tannic acid, menthol, and piperine had to be tasted, whereas the solutions of ammonia had to be smelled only. Because the oral trigeminal effect was to be tested, the subjects had to wear a nose clip (except for ammonia) to block the olfactory input. The sip-and-spit method was used. The panelists received set of pairs of samples for paired comparison (blank + stimulus), starting with the lowest concentration. The solutions were assessed according to the ascending 2-AFC-two in a row method. The sensitivity level was defined as the concentration at which 2 correct answers in a row from the same concentration were achieved. The possible range of sensitivity levels varied from 1 to 5, where 1 represented the highest sensitivity and 5 the lowest sensitivity.

Chewing efficiency test. Chewing efficiency was measured using 2-colored chewing gum (Bang Bang cola-lime, Joyco Group, Barcelona, Spain). It was chewed 20 times and then spit out. The degree of mixing was later compared by 3 independent judges to a standard picture scale ranging from score 0 (no mixing) to 8 (fully mixed) (Fillion and Kilcast 2001). The

average of the 3 judgments was taken; the deviation between the 3 judgments was never larger than 2 steps.

Demographic questionnaire

Further insight into the background of the elderly was gained by a short demographic questionnaire. The elderly answered the following 6 questions. First, how many people live in your household? Second, what is your education level (low, medium, high)? Third, do you think that your food intake has changed over the last 5 years (no change, increased, decreased)? Fourth, do you like hot foods (do not like them at all, can tolerate them, really like them)? Fifth, how would you describe your oral health (good, fair, bad)? Sixth, do you still have (some) natural teeth or do you wear complete dentures (natural teeth, dentures)?

Data analysis

Main effects of age (age), added thickener (texture), added cherry flavor (flavor), and added capsaicin (irritation) and their interaction effects with age on attribute intensity and pleasantness were tested by univariate repeated measures analysis of variance (ANOVA) with age as between-subjects factor and texture, flavor, and irritation as within-subjects factors. To correct the model for deviations of sphericity, the degrees of freedom were adjusted with the Huynh–Feldt epsilon, if necessary. Post hoc tests were performed using the least-significant difference method. The ANOVAs were performed using SPSS v. 11.0 (SPSS Inc., Chicago, IL). Only results with an observed power greater than 0.70 and a significance level of alpha of 0.05 or less are reported in the Results.

Conjoint analysis was conducted on pleasantness ratings ranked per person (Hair et al. 1998). Conjoint analysis is a multivariate technique that enables the researcher to obtain information not only on the extent to which the experimentally manipulated factors contributed to the pleasantness ratings of a person (factor importances) but also on how the levels within each factor influence these pleasantness ratings (part-worth estimates); for example, a factor level with a positive part-worth estimate will have influenced the pleasantness ratings positively and the contrary (Hair et al. 1998). Therefore, for each age group, the factor importances for each individual were computed and averaged. In addition, the part-worth estimates were determined within each experimental factor. The frequencies of +/0/– part-worth estimates were collected, and possible differences between the 2 age groups were tested by means of chi-square analysis.

In order to test differences in the performance in the sensitivity tests between the elderly and the young, the data of the different sensitivity tests were analyzed with a 1-way ANOVA. Next, the elderly were divided into 3 subgroups based on their scores in the different sensitivity tests using the 33.3 and 66.6 percentiles as cutoff points. The effect of sensitivity on the attribute and pleasantness ratings were

tested by univariate repeated measures ANOVA with sensitivity as between-subjects factor and the experimentally manipulated factors as within-subjects factors.

Results

Age and intensity ratings

The elderly produced lower scores than the young on 4 out of 7 sensory attributes: creaminess ($F(1, 80) = 10.2, P = 0.002$), swallowing effort ($F(1, 80) = 29.5, P = 0.001$), vanilla flavor ($F(1, 80) = 5.5, P = 0.022$), and cherry flavor ($F(1, 80) = 66.1, P = 0.001$) (Figure 2). No significant main age effect was observed for thickness, sweetness, and prickling.

The F and P values of interaction effects between age and perception or pleasantness are reported in Table 1. In the majority of the observed interaction effects, the addition of 3 different concentrations of thickener, cherry flavor, or capsaicin induced significant changes in perceived intensities for the young but not, or to a significantly lesser extent, for the elderly.

Several complex interaction effects were observed, some involving “age” as a factor. Firstly, an age \times texture \times flavor interaction was found for perceived creaminess ($F(4, 320) = 2.7, P = 0.030$). The young perceived significant differences in creaminess between products with different thickener and/or flavor concentrations, whereas the elderly did not (Figure 3).

Secondly, a texture \times flavor interaction was observed for perceived vanilla flavor ($F(4, 320) = 6.2, P = 0.001$). Adding high concentrations of cherry flavor to custards with high thickener levels decreased the vanilla flavor perception to a lesser extent than when the same high cherry flavor concentration was added to custards with zero or low thickener concentration. No age difference was found for this interaction.

Thirdly, a texture \times flavor \times irritation interaction was found for perceived cherry flavor ($F(8, 640) = 3.0, P = 0.007$). No age difference was found for this interaction. Finally, several complex age \times texture \times flavor \times irritation interactions were observed for thickness ($F(8, 640) = 3.3, P = 0.003$), swallowing effort ($F(8, 640) = 5.1, P = 0.001$), and prickling ($F(8, 640) = 12.9, P = 0.001$). The elderly and young differed in their product perception in the following ways. The 3 texture levels led to significant differences in perceived thickness for the young but not, or to a lesser extent, for the elderly. Compared with the zero and low flavor concentrations, the addition of high flavor concentrations decreased the perceived thickness for the young but not the elderly. The addition of an irritant changed (decreased or increased) the perceived thickness for the young, whereas the thickness perception of the elderly was not influenced by the addition of an irritant. The elderly did not discriminate the products on swallowing effort, whereas the young did. In products with no or low irritant addition, the addition of cherry flavor (low or high) significantly decreased the perceived swallow-

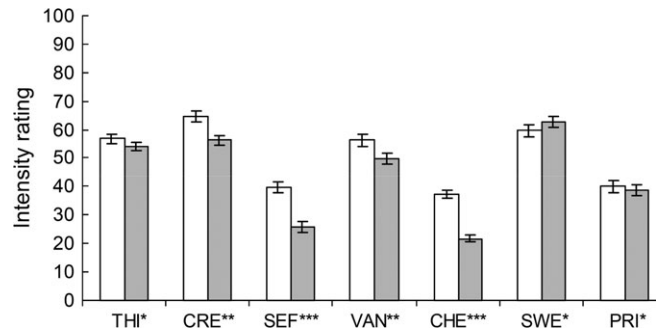


Figure 2 Mean intensity ratings (+SEM) of thickness (THI), creaminess (CRE), swallowing effort (SEF), vanilla flavor (VAN), cherry flavor (CHE), sweetness (SWE), and prickling (PRI) in custard desserts by the elderly (filled bars) and the young (unfilled bars). * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

ing effort for the young. In contrast to the young, the elderly were always able to differentiate between the prickling of products with no or with low irritant addition. The 3 flavor levels led to significant differences in perceived prickling for the young but not, or to a lesser extent, for the elderly. The different texture levels affected the prickling for both the young and the elderly, however, sometimes in the opposite direction.

Age and pleasantness

Adding the thickener to the custard desserts decreased pleasantness ($F(2, 160) = 4.4, P = 0.020$) for zero versus high addition ($P = 0.007$). No significant interaction effect with age was observed (Table 1). Flavor enrichment had no significant effect on pleasantness. The age \times irritant interaction was significant ($F(2, 160) = 5.0, P = 0.008$). The addition of an irritant at low and high concentration both decreased pleasantness ratings for the elderly, whereas pleasantness ratings of the young were not influenced by the presence or absence of trigeminal stimulation (Table 1).

The averages of the individually calculated relative importance of the factors texture, flavor, and irritation on pleasantness ratings and the frequencies of the +/−/0 part-worth estimates are shown in Table 2 for the elderly and the young separately. The contributions of these factors to food pleasantness did not differ between the 2 age groups. All factors contributed almost equally to pleasantness.

Three significant differences in pleasantness between the 2 age groups were observed on the basis of the part-worth frequency estimates. Firstly, flavor enrichment at a low concentration had a positive influence on pleasantness for a significant majority of the elderly but not for the young ($df = 1, \chi^2 = 4.9, P < 0.05$). Secondly, no irritant addition to the custards had a positive influence on pleasantness for a significant majority of the elderly but not for the young ($df = 1, \chi^2 = 13.3, P < 0.001$). Thirdly, the irritant addition at a low concentration had a positive influence on pleasantness for a significant majority of the young but not for the elderly ($df = 1, \chi^2 = 5.8, P < 0.02$).

Table 1 Influence of thickener, flavor, and irritant concentration on the perception of sensory attributes by elderly and young

Attribute	df (2, 160)		Thickener			Flavor			Irritant		
			zero	low	high	zero	low	high	zero	low	high
Thickness		<i>F</i> value		85.55***			11.22***			NS	
	Young	Mean	46.3	54.4	70.0	59.1	58.7	52.8	56.3	57.0	57.3
	Elderly	Mean	51.7	51.6	56.0	53.6	52.7	53.1	52.5	53.6	53.3
Creaminess		<i>F</i> value		24.67***			NS			NS	
	Young	Mean	57.3	63.8	73.2	65.9	66.4	62.0	63.9	65.1	65.3
	Elderly	Mean	54.7	56.9	57.2	55.6	57.9	55.4	57.0	56.2	55.7
Swallowing effort		<i>F</i> value		34.17***			7.58**			NS	
	Young	Mean	33.3	37.3	48.9	41.0	41.3	37.2	40.2	40.1	39.2
	Elderly	Mean	25.0	25.7	26.9	26.9	25.1	25.6	25.8	25.3	26.5
Vanilla flavor		<i>F</i> value		9.90***			32.62***			NS	
	Young	Mean	54.3	55.0	60.0	64.5	61.7	42.8	54.9	58.2	56.0
	Elderly	Mean	50.5	50.4	48.7	51.6	51.4	46.6	50.1	49.8	49.7
Cherry flavor		<i>F</i> value		10.03***			102.89***			NS	
	Young	Mean	38.6	38.8	34.0	22.9	28.7	59.9	38.0	37.1	36.3
	Elderly	Mean	22.4	21.1	21.5	18.9	19.9	26.2	21.9	22.1	21.1
Sweetness		<i>F</i> value		NS			NS			NS	
	Young	Mean	59.4	59.5	60.0	59.3	59.8	60.0	58.2	62.3	58.5
	Elderly	Mean	64.3	64.4	64.6	64.9	64.6	63.9	63.7	65.4	64.3
Pricking		<i>F</i> value		7.23**			4.15*			12.01***	
	Young	Mean	43.8	41.2	41.2	43.3	40.1	42.8	26.5	37.0	62.7
	Elderly	Mean	37.1	40.1	38.9	38.4	39.1	38.6	26.8	38.1	51.2
Pleasantness		<i>F</i> value		NS			NS			4.97**	
	Young	Mean	51.1	52.0	47.7	50.9	51.1	48.8	49.5	52.5	48.9
	Elderly	Mean	52.6	53.0	51.2	51.4	53.7	51.7	54.7	51.4	50.7

* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

Age and sensory acuity

The young subjects outperformed the elderly subjects in the taste sensitivity test ($F(1, 81) = 15.6$, $P = 0.001$). On average, the young identified 12, whereas the elderly only identified 10 out of the 16 taste solutions. The young subjects identified a significantly larger number of the salty ($F(1, 81) = 8.8$, $P = 0.004$) and sour ($F(1, 81) = 8.3$, $P = 0.005$) solutions, whereas no significant age difference was observed in the identification of sweet and bitter solutions.

The young had a higher olfactory sensitivity than the elderly ($F(1, 81) = 23.1$, $P = 0.001$), and the interindividual variation among the elderly was higher than among the young. For the elderly, the mean detection score was 13.7 (standard deviation [SD] = 3.1) and the mean identification score 10.4

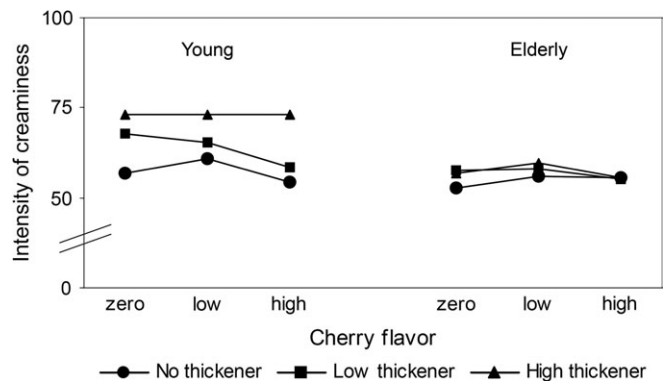


Figure 3 Age \times texture \times flavor interaction for perceived creaminess in custard desserts.

Table 2 Mean factor importance of different compensatory strategies on pleasantness of custard desserts for the young and elderly subjects

Product	Factor	Level	Young (<i>n</i> = 36)				Elderly (<i>n</i> = 46)			
			Part-worth estimates (frequencies)			Factor importance (%)	Part-worth estimates (frequencies)			Factor importance (%)
			+	0	–		+	0	–	
Custard dessert	Texture change	Zero	20	0	16	33.4	20	0	26	
		Low	22	1	13		23	1	22	32.4
		High	15	1	20		19	0	27	
	Flavor enrichment	Zero	19	0	17	37.2	20	2	24	
		Low	15	1	20		31	0	15	33.6
		High	15	0	21		22	1	23	
	Irritant addition	Zero	13	0	23	29.4	35	0	11	
		Low	26	0	10		21	0	25	34.0
		High	15	0	21		15	0	31	

The frequency of the +/–/0 part-worth estimates is cumulated. “+” indicates a positive part-worth estimate, “–” indicates a negative part-worth estimate, and “0” indicates no contribution.

(SD = 3.5), resulting in a cumulative score of 24.2 (SD = 6.3). For the young, the mean detection score was 15.7 (SD = 0.6) and the mean identification score 13.6 (SD = 1.3), resulting in a cumulative score of 29.4 (SD = 1.6).

Overall, the young were significantly more sensitive to trigeminal stimulation than the elderly ($F(1, 81) = 4.1, P = 0.047$) due to the fact that they were more sensitive to ammonia ($F(1, 81) = 5.5, P = 0.021$) and menthol ($F(1, 81) = 7.2, P = 0.009$), whereas they did not differ from the elderly in their sensitivity to piperine and tannic acid.

The chewing efficiency was reduced in the elderly ($F(1, 81) = 38.4, P = 0.001$). On average, the young reached a mixing degree of 6 on a scale ranging from 0 to 8 after 20 chews, whereas the elderly only reached a mixing degree of 4.

Sensory acuity and intensity ratings

Table 3 shows the details of the elderly sensitivity subgroups. No significant differences in intensity responses were found when the elderly were divided into 3 sensitivity subgroups (high, medium, low) according to their performance in the taste sensitivity test.

Dividing the elderly into 3 groups according to their olfactory performance revealed a significant difference in creaminess perception in desserts with different levels of added thickener ($F(4, 86) = 6.3, P = 0.001$). Compared with the desserts with no added thickener, the addition of high amounts of the thickener decreased the perceived creaminess for the elderly in the “high” sensitivity group but increased it for both the “medium” and “low” sensitivity groups.

A division of the elderly according to their trigeminal sensitivity led to the following observation. Elderly with a high sensitivity toward trigeminal stimuli perceived both the

thickness ($F(2, 47) = 4.8, P = 0.013$) and creaminess ($F(2, 47) = 3.4, P = 0.044$) of the products as significantly less intense than elderly in the low sensitivity group.

Dividing the elderly into 3 groups according to their chewing efficiency revealed a significant difference in sweetness perception. Compared with both the elderly with high ($P < 0.040$) and medium ($P < 0.003$) chewing efficiency, the elderly with low chewing efficiency perceived the products to be less sweet.

Sensory acuity and pleasantness

Dividing the elderly into taste, olfactory, trigeminal, or masticatory subgroups according to their performance in the sensitivity tests revealed no significant differences in pleasantness.

Demographics

In the present study, 46% of the elderly lived alone and the remaining lived in households with 2 or more persons. The level of education was low for 39%, medium for 35%, and high for 26%. Of the elderly, 72% reported no change in observed food intake, whereas 22% reported a decreased and 6% an increased food intake over the last 5 years. Regarding spicy foods, 39% stated that they did not like them and tried to avoid them whenever possible, 48% reported that they could tolerate spicy food up to a certain point, and 13% reported that they really like spicy food. The oral health was reported by 61% as good, by 30% as fair, and by 9% as bad. Regarding their dental status, 35% reported that they still had their natural teeth, whereas 65% reported to wear complete or partial dentures.

Table 3 Details of the elderly sensitivity subgroups

Sensitivity tests	Range of outcome	33.3% percentile cutoff point	66.6% percentile cutoff point	Low sensitivity		Medium sensitivity		High sensitivity	
				<i>n</i>	Mean age (\pm SD)	<i>n</i>	Mean age (\pm SD)	<i>n</i>	Mean age (\pm SD)
Taste	0–16	≤ 9	≥ 12	18	69.8 (± 5.8)	18	71.0 (± 6.2)	10	72.0 (± 7.5)
Olfaction	0–32	≤ 24	≥ 28	15	72.7 (± 4.4)	15	71.4 (± 6.2)	16	68.4 (± 7.4)
Trigeminal	20–4	≥ 12	≤ 9	15	69.1 (± 5.1)	19	73.3 (± 6.0)	12	68.8 (± 6.9)
Chewing efficiency	0–8	≤ 3	≥ 5	17	72.2 (± 5.7)	15	70.1 (± 6.0)	14	69.6 (± 7.2)

Demographics and intensity ratings

Elderly with dentures rated the custards less creamy ($F(1, 44) = 4.6, P = 0.037$) and used more swallowing effort ($F(1, 44) = 7.6, P = 0.008$) than elderly with natural teeth. No effect on intensity ratings was observed for household size, education level, or oral health.

Demographics and pleasantness

Elderly who live alone reported the products to be significantly less pleasant than elderly who live together with 2 or more people ($F(1, 44) = 6.0, P = 0.018$). No effect on pleasantness ratings was observed for food intake, hot food liking, oral health, or dentures.

Demographics and sensory acuity

The chewing efficiency was reduced in elderly subjects with dentures compared with elderly subjects with natural teeth ($F(1, 44) = 15.1, P = 0.001$). No effect on sensory acuity was observed for education level, food intake, or oral health.

Discussion

Texture perception with age

According to their performance in the chewing efficiency test, the young were more efficient in their chewing than the elderly. This finding is in accordance with the observations made in previous studies using the same chewing efficiency test (Kälviäinen et al. 2003; Kremer, Mojet, and Kroeze 2007). The elderly differed from the young in their ratings of the texture attributes creaminess and swallowing effort. These findings agree with the results of previous studies on age differences in texture perception (Kremer et al. 2005; Kremer, Mojet, and Kroeze 2007) in which soups were rated less creamy and waffles were rated less fat and easier to swallow by the elderly than by the young. Hence, the perception of fat-related attributes seems to be different in the 2 age groups. Besides the 2 explanations that either impaired olfaction or habituation of the elderly to higher fat levels in their past might cause these differences (Kremer, Mojet, and Kroeze 2007), another explanation seems plausible. In the present study, elderly with dentures rated the custards less

creamy but more difficult to swallow than elderly with natural teeth. This suggests that palatal coverage by dentures interferes with oral perception and that differences in texture perception may be caused by denture-induced changes in chewing and mouth movements rather than by aging per se. All the more plausible is this explanation because the prime regulator of masticatory efficiency is dental integrity (Wayler et al. 1984), and the majority of the elderly in the present study had dentures and proved to be less efficient in mastication than both the elderly with natural dentition and the young.

Flavor perception with age

The elderly perceived the flavor attributes (cherry/vanilla) as being less intense than the young. This finding is in line with earlier studies. The elderly required higher flavor concentrations in order to reach the same intensity rating given by the young (De Graaf et al. 1996), and they consistently gave lower flavor ratings in different foods than the young (Philipsen et al. 1995; Kremer et al. 2005; Kremer, Mojet, and Kroeze 2007). The age differences in olfactory sensitivity measured by the ETOC in the present study are also in line with recent publications (Thomas-Danguin et al. 2003; Koskinen et al. 2003b; Koskinen and Tuorila 2005; Kremer, Bult, et al. 2007): the young outperformed the elderly both in the detection and the identification task. However, no significant differences in reported flavor intensities were found when the elderly were divided into high, medium, and low olfactory sensitivity groups. This finding is not in line with the previously reported lower flavor intensity ratings of the elderly with low olfactory sensitivity (Kremer, Mojet, and Kroeze 2007). Together with earlier reports by Koskinen and Tuorila (2005), it raises considerable doubts as to whether or not orthonasal odor perception may serve as a reliable predictor for retronasal perception intensities in the elderly. Duffy et al. (1999) pointed out that although good olfaction may be necessary for good retronasal flavor perception, it is not sufficient. Other factors, such as chewing, mouth and/or tongue movements, dentition, and oral health, were thought to influence release and retronasal transport of odors from the mouth to the olfactory receptors. Additional support for this notion comes from 2 studies (Burdach and

Doty 1987; De Wijk et al. 2003), in which more complex intraoral food manipulations triggered more intense perceptions of flavor and mouth-feel attributes. Further research is needed to reveal differences in oral food manipulation by the elderly and to investigate whether or not it is possible to improve the perception of sensory attributes by encouraging the elderly to increase their intraoral food manipulations.

Taste perception with age

The age differences in taste solution perception measured by the taste sensitivity test in the present study are in line with the results presented by Koskinen et al. (2003a) using the same test: the young were able to correctly identify a significantly larger number of the 16 taste solutions than the elderly. Interestingly, the elderly and the young did not differ in their sweetness perception neither in the intensity rating nor in the taste sensitivity test. Although this finding is consistent in itself, ambiguous results are reported in the literature. On the one hand, the elderly perceived sweet ingredients in chocolate drinks and vanilla waffles as less intense than the young (Mojet et al. 2003; Kremer, Mojet, and Kroeze 2007). On the other hand, they did not differ from the young in perceived sweetness of pureed fruits and vegetables or dairy products (Stevens and Lawless 1981; Warwick and Schiffman 1990; De Graaf et al. 1994). The present study used commercial-type semisolid foods to study perception in the 2 age groups because it has been demonstrated that suprathreshold perception of tastants dissolved in aqueous solutions is not or barely related to perception of tastants dissolved in foods (Drewnowski et al. 1996; Mojet et al. 2003).

Oral irritation perception with age

The elderly were always able to discriminate between products with zero and low capsaicin levels on prickling sensation, whereas the young were not. Good discriminatory ability of the elderly for capsaicin stimulation in food products has been reported earlier by Forde and Delahunty (2002). In contrast to these observations, the young outperformed the elderly in sensitivity to menthol and ammonia in the trigeminal sensitivity test. This finding is in line with the results reported by Koskinen et al. (2003a) using a subset of the same test (menthol and piperine): the young were more sensitive to menthol than the elderly and at the same time no age difference was observed in the sensitivity to piperine. Nonetheless, it is unclear whether or not the difference in performance between the 2 age groups is caused by a reduction in perception in the oral cavity or in olfactory sensitivity. In contrast to piperine and tannic acid, menthol and ammonia are trigeminal stimuli with a strong olfactory component.

The present study supports the hypothesis that age-associated decline in sensory acuity causes changes in perception of the elderly. Interestingly, the majority of the age differences in perception manifested as lower intensity slopes for the

elderly. This finding agrees with previous observations (De Graaf et al. 1994; Mojet et al. 2003).

Compensatory strategies

No general positive influence of flavor enrichment on the pleasantness of the custard desserts could be observed for the elderly, although a subgroup of the elderly responded positively to the low cherry flavor addition. Again, this demonstrates that flavor enrichment/enhancement may increase the product liking for some elderly people but that this is not true for all elderly (Koskinen et al. 2003b; Mojet et al. 2005; Kremer, Bult, et al. 2007).

The addition of an irritant at near-threshold level has been thought to provide another dimension to the eating experience of the elderly (Laska 2001). However, the vast majority of the elderly in the present study preferred products with no irritant addition, an observation that has been made previously (Koskinen et al. 2003a; Forde and Delahunty 2004; Kremer, Bult, et al. 2007).

In the present study, no direct relationship between poor sensory performance and preference for flavor-enhanced foods was observed. This finding is in agreement with earlier reports of a lack of evidence for this relationship (Koskinen et al. 2003b; Forde and Delahunty 2004; Issanchou 2004; Kremer, Bult, et al. 2007; Kremer, Mojet, and Kroeze 2007).

In sensory and nutrition research, compensatory strategies, in particular flavor enrichment/enhancement, were thought to be beneficial in increasing food liking for the elderly in general and to offer a potential cure for nutritional problems of the elderly such as “anorexia of aging” (Schiffman and Warwick 1993; Griep et al. 1997; Mathey et al. 2001). However, in these earlier studies, poor sensory acuity of the elderly has been assumed but has not been measured. Moreover, in his review challenging old assumptions, Mattes (2002) notes that a causal relationship between age-associated sensory changes and food choice and dietary behavior has yet to be established. Furthermore, it seems unlikely that compensation will ever be practical in product development. The elderly population is known to vary considerably in health status and sensory acuity (Thomas-Danguin et al. 2003; Koskinen et al. 2003a). Thus, whereas some elderly might consider an applied compensatory strategy as a product improvement, others might consider it as an unnecessary and even unwelcome product change.

An interesting observation was made in the present study with respect to possible influences of nonsensory factors on the food appreciation of the elderly. Elderly who lived alone rated the products overall as less pleasant than elderly that lived in a household with 2 or more people. Hence, social facilitation, that is, increase in the amount that is eaten in the presence of other people (De Castro 2002), might not only play a role as a determinant of food intake but also as a determinant of hedonic responses in general. This observation merits further research.

All in all, the results of the present study do not support the assumption that age-associated changes in food perception, caused by losses in sensory acuity, inevitably reduce the food liking of the elderly. Two hypotheses may account for this missing link. Firstly, because normal deterioration of the sensory systems with age starts gradually, people may continuously habituate to their diminished perception and do not experience a decrease in food liking (Wysocki and Pelchat 1993). Secondly, the pathways of sensory and hedonic representations do not converge in the brain and are processed by different areas in the brain (De Araujo et al. 2003; Sedwards 2004; Rolls 2005). As a result, intensity perception of texture or flavor may vary between the elderly and the young, whereas the hedonic aspects remain essentially unchanged with increasing age.

Methodological considerations

Because the present study focuses on age-associated differences in integrated perception in relation to pleasantness, both liking and attribute assessments were asked from the same subjects. To minimize a possible bias in the affective testing, pleasantness was always rated first and both the liking and the intensity assessments were made on the same scale type (see for review Popper et al. 2004).

Only a very limited number of studies have been conducted in this area of research so far, all of them using not only different products but also different procedures and/or subject criteria. For this reason, differences in finding between these studies are noted without an attempt to explain them as this would be highly speculative.

The majority of the sensitivity tests used in the present study are not fully validated yet and research data on them are still rather scarce because only a limited number of studies have used them so far. Furthermore, both the taste and the trigeminal sensitivity tests are based on the assumption that a generalized sensitivity for taste or irritation exists. In the present study, the existence of such a general sensitivity is assumed; however, we acknowledge that this assumption is debatable. Therefore, both the usage of cumulative scores and the division of respondents into sensitivity subgroups with cutoff points 33% and 66% have a more exploratory character. Further research in this area is needed to establish whether or not this procedure is legitimate.

Conclusion

Decreased sensory acuity, although related to changes in perception of some elderly, is obviously not associated with a reduced food liking and thus might not be the predominant reason for a diminished food intake of the elderly.

Acknowledgements

The authors thank Nancy Holthuysen, Mariska Nijenhuis, and Marjan Beetstra for their assistance in preparing and conducting the experiments and Dr Eric Dransfield for his valuable comments

on the manuscript. This work is a part of the “HealthSense” project (Healthy Ageing: How Changes in Sensory Physiology, Sensory Psychology, and Sociocognitive Factors Influence Food Choice) and was carried out with financial support from the EU, Fifth Framework Programme 1998-2002 (QLK1-CT-1999-00010).

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Accepted March 28, 2007