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# Psychophysical and Psychohedonic Functions of Four Common Food Flavours in Elderly Subjects

**Cees de Graaf, Wija van Staveren and Jan Burema**

Department of Human Nutrition, Wageningen Agricultural University, Wageningen, The Netherlands

*Correspondence to be sent to: Cees de Graaf, Department of Human Nutrition, Wageningen Agricultural University, PO Box 8129, 6700 EV, Wageningen, The Netherlands*



## Abstract

This study was designed to determine the cause of potential differences in optimal preferred flavour concentrations in four common food items between young and elderly subjects. The main objective was to investigate whether the differences in concentration-pleasantness functions could be attributed to differences in concentration-intensity (psychophysical) functions, or to differences in intensity-pleasantness (psychohedonic) functions. Groups of elderly subjects ($n$ = 31) and young subjects ($n$ = 25) judged four series of food items (bouillon, tomato soup, chocolate custard and orange lemonade), each with five geometrically spaced flavour concentration levels. In addition, all participants judged a series of grey surfaces as a reference series. Stimuli were judged on a 10-point scale with respect to perceived intensity and pleasantness. The results showed that the responses to the various stimuli in the series of grey surfaces were almost equivalent for young and elderly subjects. The older subjects had higher optimal flavour concentrations than young subjects for each of the four food items. The differences could be attributed to differences in both psychophysical and psychohedonic functions for all four flavours. However, changes in psychohedonic functions were less pronounced for the savoury flavours than for the sweet flavours. The higher optimal preferred flavour concentration level for the elderly could be partly explained by the phenomenon that the elderly need higher concentration levels than young subjects in order to obtain a similar perceived intensity level. **Chem. Senses, 21: 293–302, 1996.**

## Introduction

There is an abundance of evidence that the perception of taste substances is less affected by age than the perception of odour substances (cf. Murphy, 1993). Van Toller and Dodd (1987) suggested that there is a 20% decline in olfactory functioning between the ages of 20 and 80 years. There is less information on the changes that occur with age in the sensory pleasantness for food flavours. Results from the studies of Chauhan and Hawrysh (1988) and Zallen *et al.* (1990) did not reveal clear differences between young and elderly subjects in optimal preferred flavour concentrations in foods. However, the research of Murphy (1983), and Murphy and Withee (1986, 1987) suggests that, on average, elderly subjects have higher optimal preferred flavour concentrations than young subjects. Van Toller and Dodd (1987) suggest olfactory compensation should be provided in foods for elderly subjects. A recent study by De Graaf *et al.* (1994) showed that changes in optimal flavour concentrations with age were specific for different flavours.

An important issue concerning age-related changes in the

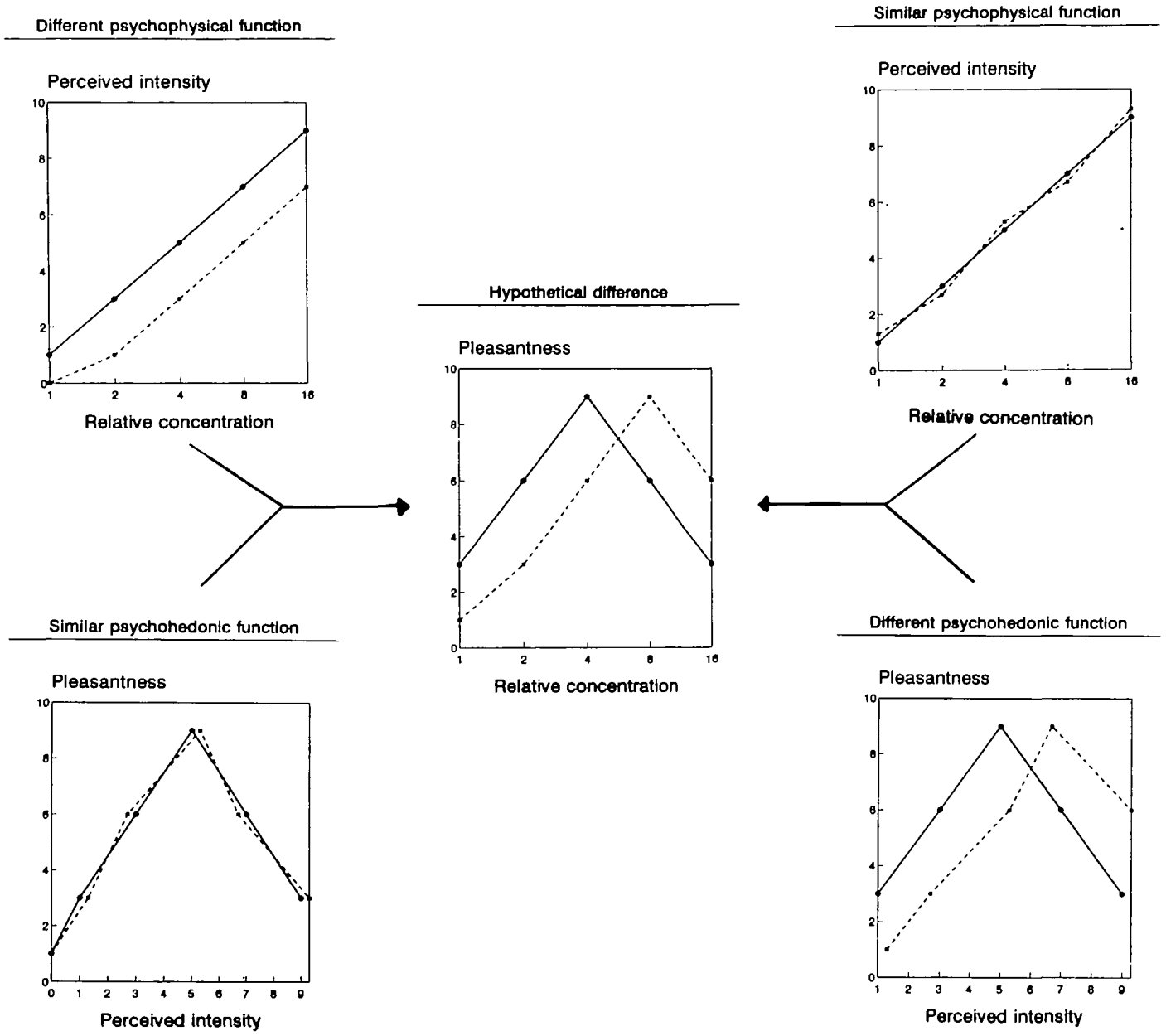


**Figure 1** Hypothetical example of two different causes for a difference in optimal flavour concentration between young and elderly subjects. This difference could be due to differences in the concentration-intensity (psychophysical) function in combination with a similar intensity-pleasantness function. However, the difference can also be caused by a similar psychophysical function in combination with a different intensity-pleasantness function. Possible ranges are from 0 (very weak intensity; very unpleasant) to 10 (very strong intensity, very pleasant).

pleasantness of food flavours is the cause for potential differences in the relationship between concentration and pleasantness. The question to be posed is whether observed differences in the concentration-pleasantness function are caused by changes in the concentration-intensity (psychophysical) functions and/or by changes in the intensity-pleasantness (psychohedonic) function. Figure 1 gives a simple hypothetical example of these two basic possibilities.

Since there is ample evidence of change in psychophysical function with age (cf. Murphy, 1993), it seems more plausible that changes in concentration-pleasantness functions are brought about by changes in psychophysical functions than by changes in psychohedonic functions. This implies that elderly subjects (compared to young subjects) have higher optimal preferred flavour concentrations, since a higher concentration is needed to obtain the same optimal preferred

**Table 1** Selected anthropometric characteristics of young and elderly subjects (mean ± SD)

| Characteristic | Young ($n$ = 35) | Elderly ($n$ = 31) |
|---|---|---|
| Age (years) | 23 (2) | 78 (5) |
| Heigth (cm) | 176 (10)[1] | 169 (8)[1] |
| Weight (kg) | 67 (11)[1] | 69 (10) |
| Men/women ($n$) | 11/24 | 9/22 |

[1]Figures based on ($n$–1) values, due to one missing number.

flavour intensity. The present study is an empirical test for this hypothesis.

## Materials and methods

### Subjects

Subjects were made up of 35 young volunteers with a mean age of 23 years (range 20–30) and 31 elderly subjects with a mean age of 78 years (range 67–86). The young subjects were students from the Agricultural University and the old subjects were residents in service apartments for elderly people. Students were recruited by means of advertisements on posters in university buildings, whereas the elderly subjects were recruited with the help of the management of the service-flat. Subjects were not paid for participation. At the end of the study, the elderly subjects were invited to the university for one morning in which we gave a tour around the Department and presented the results of this study. Table 1 shows selected anthropometric characteristics of the subjects.

### Stimuli

A series of grey surfaces was used as a reference. The series consisted of five grey surfaces of 5.1 by 5.1 cm with reflection percentages of 84, 44, 20, 8 and 4% on a green background of 10.2 by 10.2 cm (cf. Marks *et al.*, 1988).

There were four series of food stimuli, bouillon, tomato soup, chocolate custard and orange lemonade used as commercial sources of taste and smell. The stimuli represented a mixture of taste and odour substances (cf. De Graaf *et al.*, 1994). Commercial sources of taste and smell substances were used because of the higher ecological validity, as opposed to the use of pure taste substances or pure olfactory stimulants. The products used were easy to be manipulated in a realistic sense, since they were well known and represented a variety of products/flavours with different places in the food consumption pattern.

Each series consisted of five geometrically-spaced concentration levels. For the bouillon, tomato soup and chocolate custard, the concentrations between adjacent stimuli differed by a factor two. For the orange lemonade a factor four was used, resulting in a 256-fold ratio between the highest and lowest concentration. The concentrations in the bouillon series were 1.25, 2.5, 5.0, 10.0 and 20.0 g bouillon powder/l water (Maggi of Nestlé, Amsterdam, The Netherlands). The series of tomato soup was made of stimuli with 22.5, 45, 90, 180 and 360 g/l water of a 3.5:1 mixture of tomato concentrate and bouillon powder (tomato concentrate of the Chiara, Veem Tielbeke, Zaandam, and bouillon powder of Maggi of Nestlé, Amsterdam). The orange lemonade series consisted of 12.5, 50, 200, 800 and 3200 g orange lemonade/l water (Loots of Veem Packsystems, Heino). The chocolate custard series had concentrations of 7.5, 15, 30, 60 and 120 g cacao/mixture of 1 l milk, 35 g maize starch and 100 g sugar (cacao of Rademaker, Haarlem; milk: skimmed milk of Albert Heijn, Zaandam; Maize starch of Duryea, Hilversum; sugar of CSM, Diemen). Cooking times to get custards with similar perceived viscosities were 390, 210, 180, 135 and 120 s, with increasing cacao concentrations, respectively.

### Procedure

Subjects were instructed both verbally and in writing to rate the perceived intensity and pleasantness on a 10-point category scale. We chose a 10-point scale, since both young and elderly subjects were familiar with this type of rating from the Dutch school system. Each of the numbers of the pleasantness scale were accompanied by a drawn face with an appropriate expression (De Graaf *et al.*, 1994). The left anchors of the intensity scale (= 1) were described by examples such as a falling needle, the brightness of candlelight and the taste intensity of water. The right anchors of the scale were described by examples such the loudness of a low-flying airplane, the brightness of the shining sun and the taste intensity of pure pepper. The intensity ratings referred to sensory intensity in general, and did not distinguish between taste and smell intensity. For the series of grey surfaces, the intensity scale was anchored on the left-hand side with 'white', on the right-hand side with 'black'.

The young subjects judged the stimuli in carrels used for sensory research. Illumination was provided by two white tubes giving normal daylight. Elderly subjects tasted the stimuli at separate tables in a large room in a service flat for the elderly (Belmonte, Wageningen, The Netherlands).

This space was illuminated by the available light bulbs.

All stimuli had a volume of about 10 ml and were presented in transparent yellow medicine cups. The series of bouillon and tomato soup stimuli were presented at a temperature of about 50°C, the series of chocolate custard and orange lemonade were presented at room temperature. The temperature of the stimuli in the series of bouillon and tomato soup was kept constant at a temperature of 51°C using a water-bath. The stimuli were removed from the water-bath about 15 s before tasting. Each stimulus was handed separately to each subject.

Half of the subjects started with the two savoury flavours and ended with two sweet flavours, whereas the other half of the subjects had the reverse order. The series of grey surfaces was given after the first two series. Within each series, stimuli were presented in a random order, under the condition that neither of the two extreme concentrations or reflection percentages was presented as first stimulus. The time interval between two stimuli was about 90 s and between stimuli subjects rinsed their mouths with water.

## Data analysis

The concentration-intensity and concentration-pleasantness functions were analysed by means of analysis of variance. The age effect (= group) was treated as a fixed between-subjects factor. Concentration was a within-subject factor and subjects were treated as random factor nested within the group effect (Winer, 1971). Potential differences in the shape of concentration-intensity or concentration-pleasantness functions between age groups were analysed by examining the $F$-ratio of the means square (MS) of the (age-group) × (concentration) interaction, and the MS of the (subjects) × (concentration) effect.

The relationships between intensity and pleasantness were judged by visual inspection and by statistical analysis. In this analysis, pleasantness was postulated to be a convex function of the perceived intensity and was modelled as a second degree polynomial, a parabola. The top of the parabola corresponds to the maximum pleasantness, which is reached at a certain perceived intensity. This particular value of intensity is indicated in this paper as 'optimal' intensity. Since the optimal intensity may vary across subjects, an attempt was made to estimate the optimal intensity of each subject from the individual data. As only five pairs of observations of perceived intensity and pleasantness were available for each subject, precautions had to be made in order to stabilize the estimation procedure. Many subjects had scores of pleasantness and intensity that were not consistent with the model of a convex function that has its extreme value of pleasantness at a value of intensity within the range of the scale from 1 to 10. Therefore, a polynomial of the second degree was fitted to the scores of all 66 subjects together using a multiple polynomial regression model. From the least squares solution of this model, predicted scores on pleasantness were calculated for selected values of intensity, i.e. 2, 3, 4, 5, 6, 7, 8 and 9. These eight pairs of values of pleasantness and intensity constituted the 'prior belief evidence' that was combined with the empirical data in order to stabilize the estimation process in the next step. A polynomial was then fitted for each subject separately through the combined evidence of his five pairs of empirical observations and the eight points of the common 'prior belief evidence'.

The optimal intensity was calculated for each individual as the value for which the fitted polynomial reached its maximum, unless this occurred outside the range of 1–10 or if the curve attained a minimum rather than a maximum due to concavity of the estimated polynomial. In those cases, the optimum was set to 10, the end-point of the scale of intensity. It was verified that the estimated slope was always positive at the upper end of the scale in those cases.

Eventually, a two-sample $t$-test was performed to compare the mean estimated optimal intensity in the elderly with the young group. The whole procedure was repeated for fewer prior evidence data, consisting of only 7, 5 or 3 points, respectively, of the same function giving less weight to it in the combined data. This resulted in more concave estimated curves and more convex curves with the top of the parabola outside the range of 1–10. However, the number of prior points used hardly affected the $P$-values of the $t$-test, thus supporting the validity of this heuristic approach.

Data were analysed with the statistical software package SAS (SAS Institute, 1989, 1990).

# Results

## Perceived intensity of grey surfaces

Figure 2 shows that the average responses to the different grey surfaces for the group of young and elderly subjects were similar. There was a slight difference in the shape of the function between the two age groups which was statistically significant [$F(4,256) = 4.4$; $P < 0.002$]. As could be expected, the main effect of reflection percentage was also statistically significant [$F(4,256) = 491.3$; $P < 0.0001$]. On average, elderly had a higher response than young subjects [$F(1,64) = 4.7$; $P < 0.04$].

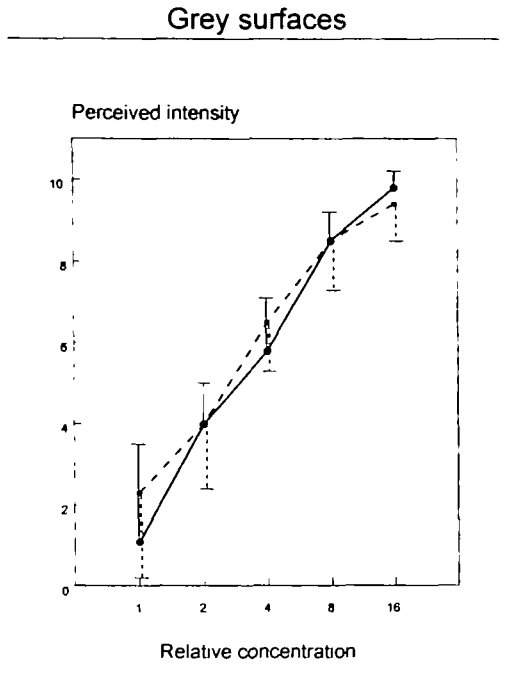


**Figure 2** Mean responses (±SD) on the perceived intensity ('blackness') of grey surfaces judged by a group of 34 elderly subjects (---) and a group of 36 young subjects (—) Possible range is from 1 (white) to 10 (black).

## Concentration-pleasantness functions

Figure 3 shows the concentration-pleasantness functions for each of the four food flavours. Visual inspection suggests that for each of the four flavours elderly subjects have an higher optimal concentration than young subjects. This was reflected in statistically significant (age-group) × (concentration) interaction for the tomato soup flavour [$F(4,256) = 3.4$; $P < 0.01$] and orange lemonade [$F(4,256) = 29.3$; $P < 0.0001$], but not for the bouillon [$F(4,256) = 1.1$; $P = 0.37$] and chocolate custard [$F(4,256) = 1.4$, $P = 0.22$].

Average pleasantness responses for each of the four series (i.e. the responses averaged over the five concentration levels) were not different between the group of young and elderly subjects [all $F(1,64) < 2.9$; $P > 0.05$]. The effect of concentrations was statistically highly significant for each of the flavours [all $F(4,256) = 13.5$; $P < 0.05$].

## Concentration-intensity (psychophysical) functions

Figure 4 shows the psychophysical functions for young and elderly subjects. Visual inspection suggested that the slopes of the psychophysical function were smaller for the elderly than for the young subjects. This was confirmed by statistical analysis for the interaction effect between age group and concentration for tomato soup [$F(4,256) = 4.2$; $P < 0.05$], chocolate custard [$F(4,256) = 4.4$; $P < 0.05$] and orange lemonade [$F(4,256) = 5.0$; $P < 0.05$]. For the bouillon flavour the interaction effect was of borderline significance [$F(4,256) = 2.3$; $P = 0.06$]

The effect of concentration was statistically significant for each of the four flavours [all $F$ (4,256) > 90.9; $P < 0.0001$]. The main effect of age was significant only for the lemonade, where the elderly had a lower average response on perceived intensity than the young subjects [$F(1,64) = 20.6$; $P < 0.0001$]. The other three $F(1,64)$ values were below 3.3 (with $P > 0.05$).

## Intensity-pleasantness (psychohedonic) functions

Figure 5 gives the intensity-pleasantness functions for young and elderly subjects. Visual inspection suggested almost similar psychohedonic functions for the bouillon and tomato soup flavour, but slight differences in the psychohedonic functions of chocolate custard and orange lemonade flavour.

Statistical analysis of the curves did not reinforce the visual inspection completely, as it showed that for each of the four food flavours, elderly subjects had higher optimal preferred perceived intensities than did young subjects (all $t$-values > 3.1; $P < 0.01$). Table 2, which gives the optimal preferred intensities, shows that the differences between young and elderly subjects in optimal intensities were about 0.8 units for the bouillon and tomato soup flavour, compared to 1.1 units for the orange lemonade and chocolate custard flavour.

## Discussion

The results of this study confirm the findings of previous studies that elderly subject have higher optimal preferred flavour concentration in food items than young subjects (Murphy and Withee, 1986, 1987; Van Toller and Dodd, 1987; De Graaf *et al.*, 1994). This study also confirms the notion that these changes are quality specific; the differences are not necessarily equal for various flavours. The differences in optimal preferred orange lemonade concentrations, for example, were much larger than the differences for the bouillon and tomato soup flavour.

For all of the four food flavours investigated, both differences in psychophysical and psychohedonic functions contributed to the differences in the concentration-pleasantness relationship between young and elderly subjects. The differences in optimal preferred concentrations for the two savoury flavours can be predominantly explained by

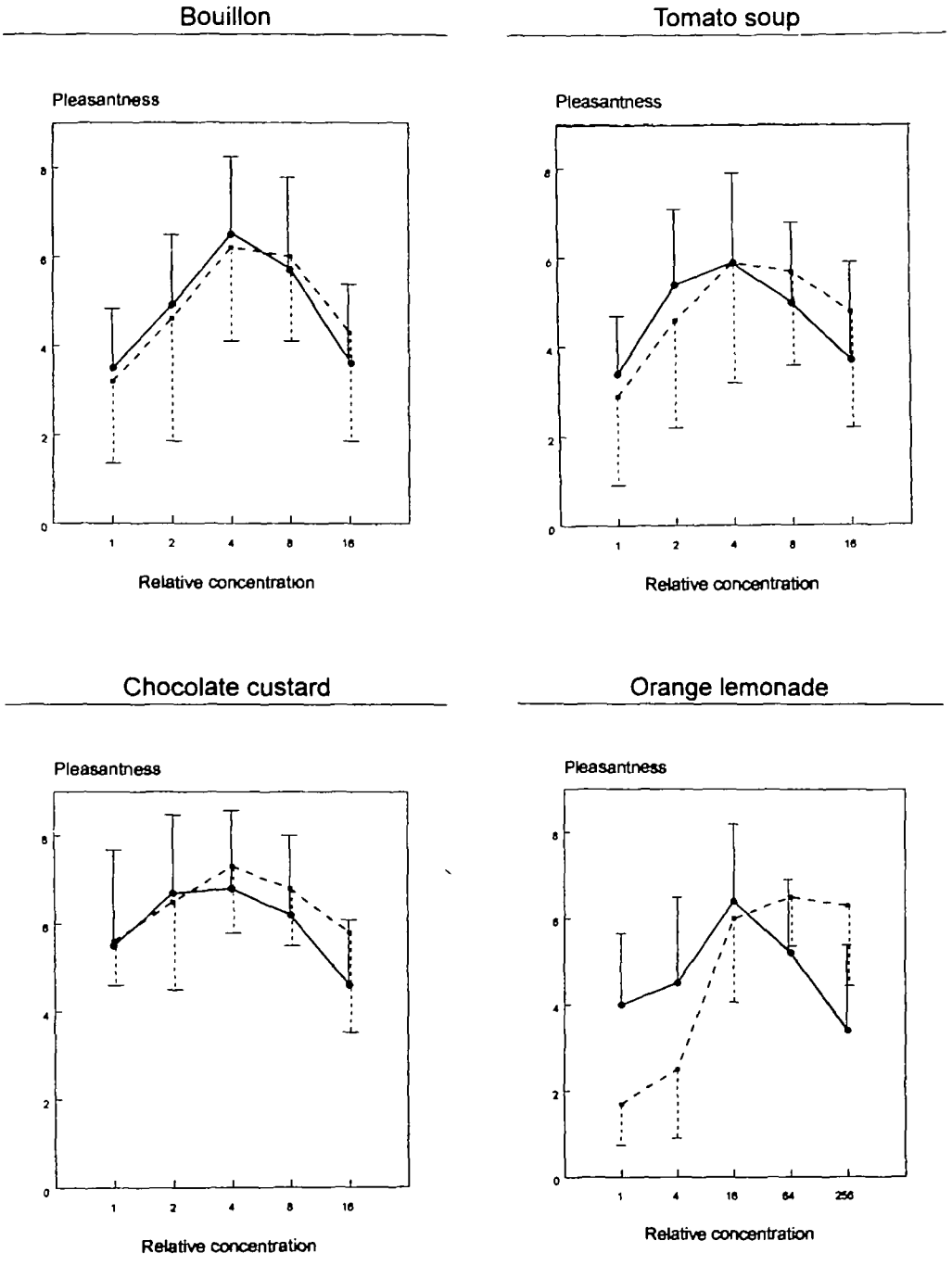


**Figure 3** Mean responses (±SD) on the pleasantness on five series of food stimuli, as a function of relative concentration, judged by a group of 34 elderly subjects (---) and a group of 36 young subjects (—). Panels refer to series of different flavour concentration in bouillon, tomato soup, chocolate-custard and orange lemonade. Actual levels of concentration are given under the head of 'stimuli' in the methods section of this paper. Possible range in responses is from 1 (very unpleasant) to 10 (very pleasant).

the differences in concentration-intensity functions, and to a lesser extent by the differences in intensity-pleasantness functions. Apparently, elderly subjects need a higher concentration of the bouillon or tomato soup flavour to reach a certain perceived intensity than young subjects do. This result is also in line with the studies in which age-related declines in suprathreshold intensities were reported (Murphy, 1983; Stevens *et al.*, 1984; Stevens and Cain, 1985; Marks *et al.*, 1988). This finding may explain why elderly subjects have a higher preference for flavour enhanced food products, reported by Schiffman and Warwick (1993).

Differences between the psychohedonic functions of

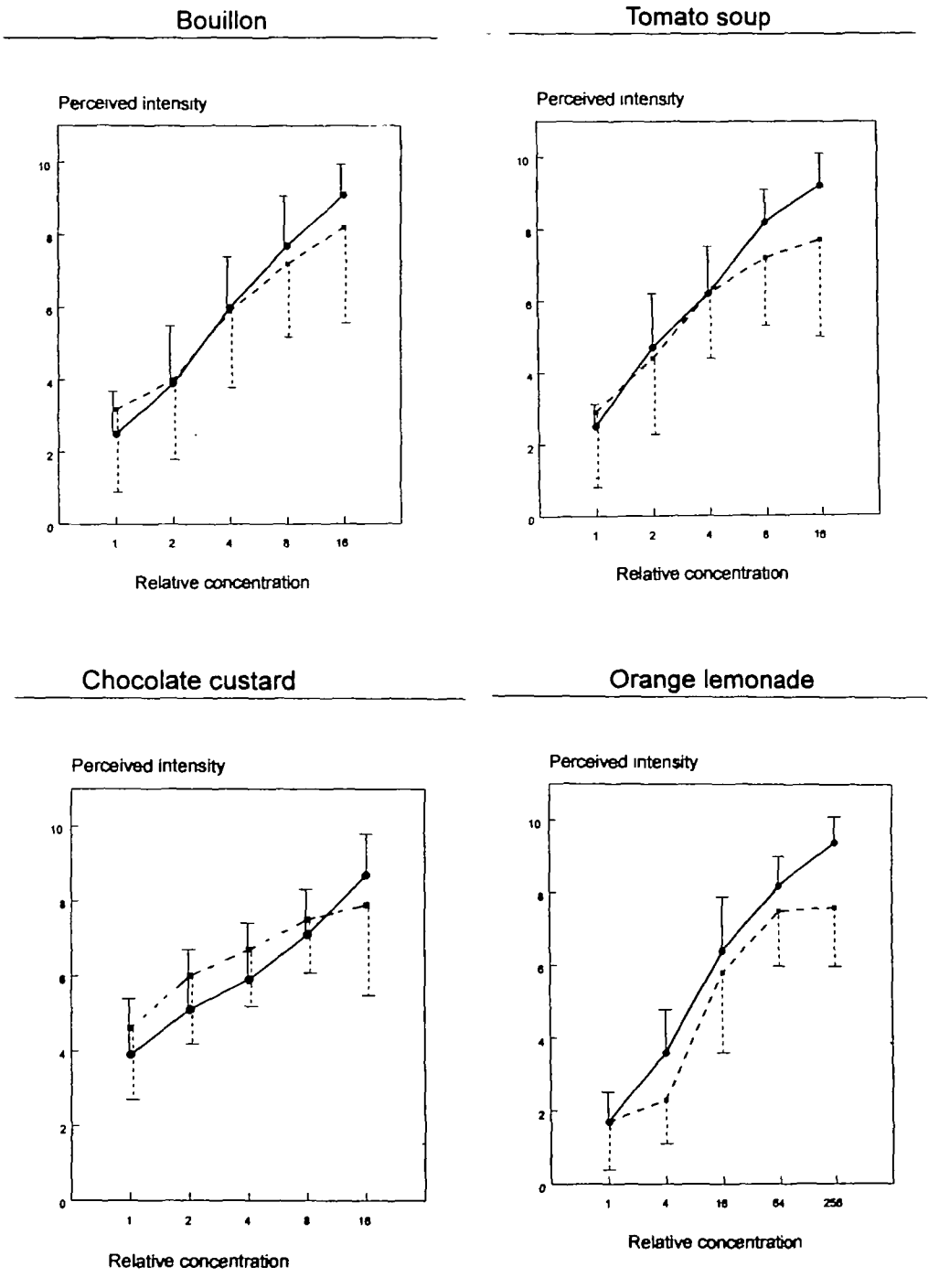


**Figure 4** Mean responses on the perceived intensity (±SD) of five series of food stimuli, as function of relative concentration, judged by a group of 34 elderly subjects (---) and a group of 36 young subjects (—). Panels refer to series of different flavour concentration in bouillon, tomato soup, chocolate-custard and orange lemonade. Actual levels of concentration are given under the head of 'stimuli' in the Methods section of this paper. Possible range in responses is from 1 (very weak intensity) to 10 (very strong intensity).

young and elderly subjects are most clearly shown in the two sweet flavours. The difference in optimal preferred concentration cannot be explained solely by differences in psychophysical functions. Although the psychophysical functions are different between young and elderly subjects, the results shown in Figure 5 clearly suggest that elderly also have higher optimal preferred sweetness intensities compared to young subjects. This finding also applies, although to a lesser extent, to the two savoury flavours. The background for this phenomenon is not clear. It could be

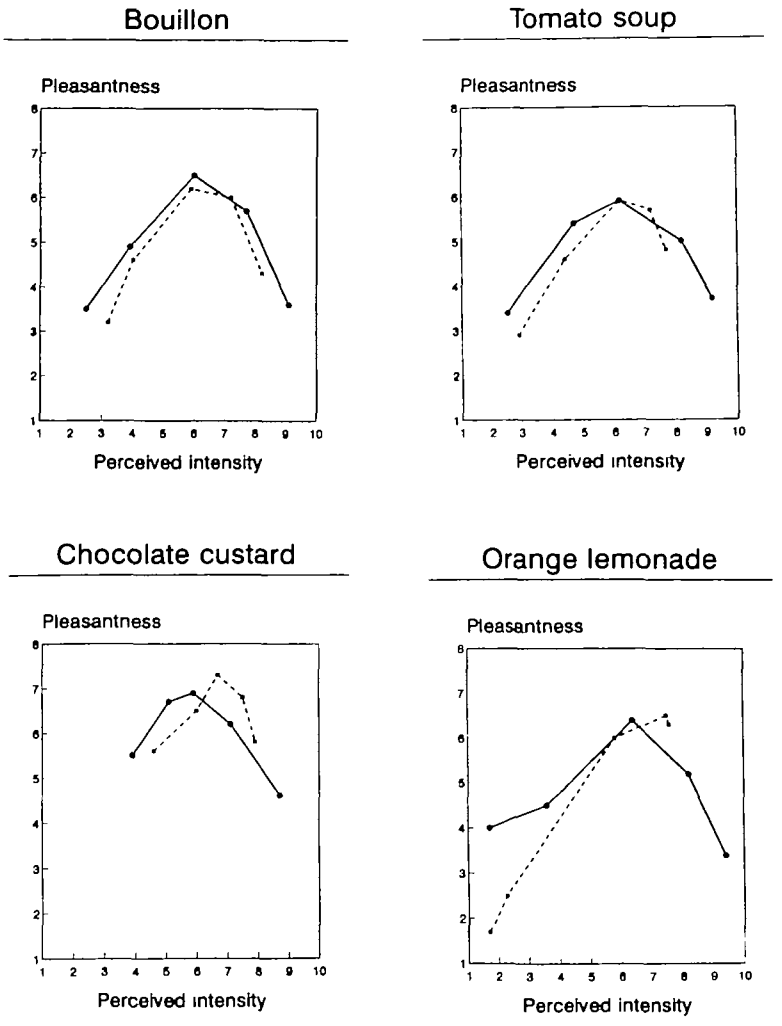


**Figure 5** Mean responses on the pleasantness of five series of food stimuli, as function of perceived intensity, judged by a group of 34 elderly subjects (---) and a group of 36 young subjects (—). Panels refer to series of different flavour concentration in bouillon, tomato soup, chocolate-custard and orange lemonade. Actual levels of concentration are given under the head of 'stimuli' in the methods section of this paper Possible range in responses are from 1 (very weak) to 10 (very strong) for intensity and from 1 (very unpleasant) to 10 (very pleasant) for pleasantness.

that elderly prefer higher sweetness/savoury intensities to compensate for the decreased intensity in other perceptual attributes. It could also be that other non-sensory factors play a role in this phenomenon.

The statistical analyses of the psychohedonic functions focused on the estimation of the optimal preferred perceived intensity of each individual psychohedonic function. This procedure allows for making statistical inference about the difference between two age groups regarding the distribution of a non-directly measurable parameter, yet taking into account its variability across subjects within each group. Following a heuristic approach, the statistical approach resulted in feasible estimates for almost all subjects provided that the 'weight' of the mixed prior distribution was not too light. However, after using different prior distributions with varying weights, the results of the statistical tests were hardly affected by the choice of the weight, thus yielding the same conclusions. We therefore believe to have established a

**Table 2** Estimations of average (± SD) optimal preferred perceived flavour intensities of the group of young and elderly subjects Perceived intensitities were expressed on a 10-point category scale

| Type of flavour | Optimal preferred perceived intensity (mean ± SD) | |
|---|---|---|
| | Young | Elderly |
| Bouillon | 6.2 (0.5) | 7.0 (1.2) |
| Tomato soup | 6.4 (0.9) | 7.2 (1.2) |
| Chocolate dessert | 6.5 (0.9) | 7.5 (1.3) |
| Orange lemonade | 6.2 (1.1) | 7.3 (1.3) |

shift of the psychohedonic curve towards higher values of intensity during the process of ageing. From the quantitative assessment it appears that this shift is greater for sweet than for savoury flavours.

The present finding with respect to orange lemonade, with the very high optimal concentration, is interesting. The highest concentration orange lemonade in the present study, which was rated as rather pleasant by the elderly subjects, contained about 50% w/v sugar. This finding is a replication of a former study, in which the optimal concentration in orange lemonade contained about 50% w/v sugar (De Graaf *et al.*, 1994). The value of 50% w/v sugar for whole drinks is about five times the usual level of 10% w/v sugar in commercial soft-drinks. It is interesting to investigate whether this finding can also be generalized to other types of soft-drinks, or to other types of sweet foods.

In the present study, we used the series of grey surfaces as a reference series. This was done in order to investigate whether or not the elderly subjects attached similar meaning to the same numbers as young subjects did. The results showed that there were small, but statistically significant differences in the responses to the grey surfaces between the groups of young and elderly subjects. The cause of this difference was not known. It could be that the psychophysical function of the grey surfaces was different for the young and elderly subjects, or that this function was the same, but the response behaviour was different. We decided not to adjust the responses to the food stimuli according to the mean responses to the grey surfaces. One of the reasons was that there was not a general tendency in the elderly subjects to give lower responses than the young subjects. The mean response to the grey surfaces was higher for the group of elderly subjects than for the group of young subjects. The mean pleasantness responses were not different between the elderly and young subjects. These findings do not give a clear reason for adjusting the scores of one particular group of subjects and justify the use of uncorrected ratings.

In the present study we used yellow coloured medicine cups for the presentation of the stimuli. This was done to mask some of the differences in colour between the different stimuli with the series. This attempt was not completely successful, because there remained some visual noticeable differences between the stimuli. We do not think that these colour differences were important, since the extent of visual exposure was small and subjects were presented with small quantities in small medicine cups. These differences may have had a 'small' effect on the ratings, but we saw no reason that there would be a differential effect of these visual cues between the young and elderly subjects. On the other hand, it could be argued that the experimental methods for the manipulation of the concentrations of the taste and smell substance concentrations are similar to the way that subjects perform at home. This created a realistic situation with high ecological validity, which was the objective we had wanted to achieve.

Knowledge about optimal preferred flavour concentrations in food is relevant for nutritional issues. One of the first issues to be addressed is, whether or not there exists a relationship between taste and smell perception in elderly people and food consumption behaviour. A recent study by Duffy *et al.* (1995) shows that there is not a simple straightforward relationship between the performance on a particular odour and flavour test, and energy and nutrient intake. However, Duffy *et al.* (1995) reported that elderly with an impaired olfactory performance had a higher intake of low-fat sweet foods. This may be related to the present finding of high optimal sweetness levels in the orange lemonade. This topic needs further investigation.

Another topic that needs further study is whether or not flavour enhancement of foods is useful in changing nutrition behaviour. In theory, it could be that flavour enhancement leads to more preferred foods for people with an impaired flavour perception, which may, in turn, promote the intake of these flavour enhanced food. The work of Schiffman and Warwick (1993) suggest that this is indeed the case, although in their study energy and macronutrient intake was not affected by flavour enhancement.

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