Predictors and correlates of taste preferences in European children: the IDEFICS study

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Abstract

The present study investigated taste preferences in a sample of 1,705 children aged 6-9 years from survey centres in Italy, Estonia, Cyprus, Belgium, Sweden, Germany, Hungary, and Spain and aimed to identify factors correlated with taste preference. Children's preferences for varying levels of sucrose (sweet) in apple juice and fat, NaCl (salt) and monosodium glutamate (umami) in crackers were assessed using paired-comparison tests. Socio-demographics (age, sex, parental education), early feeding practices (breastfeeding, introduction of fruits), parenting behaviour (TV viewing, using food as a reward) and taste threshold sensitivity for sucrose (sweet), NaCl (salt), caffeine (bitter) and monosodium glutamate (umami) were investigated as possible correlates of taste preferences. Parents reported on socio-demographics, early feeding and parenting behaviour. Taste thresholds were determined via a paired-comparison staircase method. Country of residence was the strongest factor related to preferences for all four tastes. Taste preferences also differed by age. Preference for sugar and NaCl increased between 6 and 9 years of age while preference for monosodium glutamate decreased. The age differences were independent of sex, country of residence, parental education and early feeding habits. Sex, parental education, early feeding habits, TV viewing, using food as a reward and taste thresholds were not consistently related to taste preferences among the survey centres. In summary, the results highlight the importance of culture and age in taste preferences in children younger than 10 years of age.

Introduction

Consumer studies show that the taste of a food is one of the most important drivers of food choice (Glanz, Basil, Maibach, Goldberg, & Snyder, 1998). Because of this prominent role in nutrition, taste and food preferences have been proposed to be related to health outcomes, mainly to overweight and obesity (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006; Drewnowski, Brunzell, Sande, Iverius, & Greenwood, 1985; Mela & Sacchetti, 1991; Ricketts, 1997). In fact, we previously demonstrated that a preference for fat and sweet taste was related to overweight in 6-9-year-olds from 8 European countries (Lanfer et al., 2012). Detecting a relationship between taste preferences in children and a health outcome calls for further investigations into taste preferences in children. However, not only the fact that taste preference is related to weight status underscores the necessity of further studies. Dietary habits develop early in childhood and remain stable throughout adolescence and into young adulthood, therefore exerting an impact on immediate as well as future health of children (Kelder, Perry, Klepp, & Lytle, 1994; Tabacchi, Giammanco, La Guardia, & Giammanco, 2007). Additionally, in-depth studies into differential taste preferences in children can help in designing contextualized prevention programs that aim to improve eating habits. Designing these measures will require a profound understanding of the predictors and correlates of taste preferences and of groups most at risk of having taste preferences that might lead to detrimental eating habits.

Factors that possibly influence taste preferences are numerous. The development of food and taste preference is linked to the food environment provided by the parents. Previous studies showed that the mother's diet can influence infants' taste preferences already during pregnancy and lactation (Mennella, Jagnow, & Beauchamp, 2001), as children experience flavours of their mother's diet through amniotic fluid and breast milk. In accordance with this, it was found that early feeding habits such as breastfeeding versus formula-feeding influences acceptance of novel foods during weaning (Sullivan & Birch, 1994) and consumption of fruits and vegetables in older children (Cooke et al., 2004; Skinner, Carruth, Bounds, Ziegler, & Reidy, 2002). In rats, the offspring of mothers that had access to a 'junk food' diet during pregnancy and lactation showed a stronger preference for sugar, fat and salt compared to offspring of mothers that received a normal chow (Bayol, Farrington, & Stickland, 2007). Parents' influence on children's taste and food preferences does not only comprise early feeding but other factors under their control such as dietary rules, food availability or media use. For example, children have shown to develop a preference for foods that have been used as a reward by their parents for approved behaviour (Birch, 1999) and investigations on TV viewing indicated that the observed relationship between TV viewing and unhealthy dietary choices are mediated partially through taste preferences (Harris & Bargh, 2009) that are mainly influenced by food advertisement and marketing (Cornwell & McAlister, 2011).

It is a common notion that taste sensitivity i.e. the capability to perceive a taste, is a determinant of taste preference. However, the literature on this association is ambiguous. Most studies have focused on genetically determined sensitivity towards the bitter substance propylthiouracil (PROP) and showed that it is linked to an increased preference of sweet taste in children although results for fat preference are inconclusive (Tepper, 2008). Studies on taste qualities other than PROP have found no or ambiguous associations between taste sensitivity and preferences (Coldwell, Oswald, & Reed, 2009; Mojet, Christ-Hazelhof, & Heidema, 2005). The latter studies, however, differ in their design and were conducted in adolescents or adults. Whether taste sensitivity influences preference in younger children still needs investigation.

Parental and physiological factors may be useful in understanding underlying processes in the development of taste preference. Demographic determinants of taste indicate subgroups of the population that are prone to taste preferences that might lead to less favourable eating habits. Gender and socio-economic status have both been previously linked to taste preferences, with females and high socioeconomic groups generally having food and taste preferences that are associated with healthier food choices (Brug, Tak, te Velde, Bere, & de Bourdeaudhuij, 2008; Cooke & Wardle, 2005; Monneuse, Bellisle, & Louis-Sylvestre, 1991; Wright, Nancarrow, & Kwok, 2001). Previous studies have also found effects of age such that the preference for sweet and salty tastes declines from childhood through adolescence to adulthood (De Graaf & Zandstra, 1999; Desor & Beauchamp, 1987; Desor, Greene, & Maller, 1975; Enns, Van Itallie, & Grinker, 1979; Mennella, Lukasewycz, Griffith, & Beauchamp, 2011). Finally, studies have shown that taste preferences are probably influenced by cultural factors and differ between countries (Prescott & Bell, 1995; Rozin & Vollmecke, 1986).

Sensory studies usually limit their investigations to one or two of the mentioned factors and are normally conducted with small convenience samples in laboratory settings. Epidemiological studies are still lacking, especially in children. However, using population-based data provides the opportunity to confirm hypotheses from laboratory studies and allows for investigation of the influence of several factors simultaneously and therefore taking account of their possible interdependence.

Against this background, the present study aims to describe taste preferences in children from eight European countries. It also aims to map predictors and correlates of taste preferences that comprise socio-demographics, early feeding, parenting behaviour and taste sensitivity.

Methods

Study design and participants

The study is based on data of the baseline survey of the IDEFICS study which is a European epidemiological multi-centre study that focuses on investigating the aetiology of overweight and obesity in children and on the development of effective intervention strategies. The design, study population, and data collection have been described in detail previously (Ahrens et al., 2011). A baseline survey was conducted from September 2007 until May 2008 and included 2- to 9-year-old children from survey centres in Italy, Estonia, Cyprus, Belgium, Sweden, Germany, Hungary and Spain. It had a response rate of 51% and comprised 16,220 children for which full information on sex, age, weight and height were available and therefore fulfilled inclusion criteria. A random subsample of 1,839 (20.8%) IDEFICS schoolchildren (6-9 year-old) from the baseline sample were asked to participate in taste preference and sensitivity tests during the baseline survey. Our analyses include children that participated in at least one preference test for sweet, fat, salty or umami taste. This was the case for 1,705 children of the subsample. The other children either only conducted other sensory tests (128 children) or were excluded because of known food allergies or last minute refusal (6 children).

In each country, the participating centres obtained ethical approval from their responsible authority. Parents or legal guardians provided written informed consent for all examinations and/or the collection of samples, subsequent analysis, and storage of personal data and collected samples. Standardized instruments and procedures were applied in data collection that was further guaranteed by central and subsequent local trainings of field staff.

Taste preference tests

Sensory testing was performed in schools usually on the same day as the other examinations in a separate section of the general examination room. A standardised sensory test battery for taste preference, developed for epidemiological studies, was employed. A detailed description of the taste preference tests has been provided in a previous report (Knof, Lanfer, Bildstein, Buchecker, & Hilz, 2011).

Taste preference for varying content of sucrose (sweet) in apple juice as well as fat, sodium chloride (salt) and monosodium glutamate (umami) in crackers was assessed using paired-comparison preference tests. The taste preference test procedure also included a test for the preference for apple flavour but its results were not analysed in the present study.

During the taste preference tests the children had to choose their preferred food sample out of a pair that consisted of a reference sample and a corresponding modification with added sucrose (sweet), fat, sodium chloride (salt) or monosodium glutamate (umami). The two food samples were identical except for the component under investigation. For sweet preference, apple juice was chosen as food medium, while for fat, salt and umami preference the same basic cracker recipe was used. The participants tasted each food pair, non-modified food sample first, decided which sample was preferred, and subsequently rinsed their mouth with water before continuing with the next sample pair. A preference for the added ingredient was assumed when the modified food sample was chosen over the basic sample. The sequence of testing was: sweet before fat, salt and umami. The preference tests were subject to pre-testing (Suling et al., 2011) and have yielded reliable results in a separate reproducibility study in children (Knof, et al., 2011). Cracker-based preference tests were conducted in all eight survey centres. Sweet preference tests were not performed with the Cypriot children as the majority was unfamiliar with apple juice. All food samples were centrally produced and then shipped to the corresponding survey centres.

Taste sensitivity tests

In the present study, taste sensitivity was assessed to investigate whether it was a predictor of taste preferences in young children. It was measured in the same session before assessment of taste preferences by determining the detection thresholds for sucrose (sweet), sodium chloride (salt), caffeine (bitter) and monosodium glutamate (umami). A paired-comparison staircase method was used where children tasted five watery solutions with increasing concentrations of the taste substance. Each solution was compared to the taste of the same plain deionised water that had been used to prepare the solutions. The lowest concentration at which the child tasted a difference to the water sample was considered as the threshold concentration. The sequence of testing was: sweet, salt, bitter, umami. Based on the threshold distribution for each tastant, all children with a lower threshold concentration than the median of the full sample were classified as sensitive for the respective taste. Tastants for the solutions were centrally purchased, weighed in, packed and then shipped to survey centres. Test solutions were prepared locally in the survey centres prior to testing. A detailed description of the taste threshold tests can be obtained from a previous report (Knof, et al., 2011).

Questionnaires

Next to taste sensitivity, also age, sex, country of residence, parental education and parental feeding practices including breastfeeding, first introduction of fruit, TV exposure and using food as a reward or punishment were considered to be possible correlates of taste preferences. Information on these factors was obtained from a parental questionnaire and the Children's Eating Habits Questionnaire (Huybrechts et al., 2011; Lanfer et al., 2011) that were filled in by a parent or guardian living with the child. Country of residence was defined by the country where the respective IDEFICS survey centre was located. The educational level of father and mother was reported. The maximum was chosen to represent parental education. To allow cross-country comparability, the educational levels were categorised according to the International Standard Classification of Education (ISCED) (UNESCO, 2006). We created a dichotomous variable where the ISCED levels 1, 2 and 3 were categorised as low and level 4, 5 and 6 as high educational attainment.

In the parental questionnaire mothers were asked to report which kind of early feeding they used: exclusive breastfeeding, combination feeding or formula feeding. Based on the answer to this question children were classified as either ever breastfed if the parents used exclusive or combination feeding or never breastfed if the parents reported formula feeding. Additionally, mothers indicated at what age they first introduced fruits in the diet of the child.

The question "How long does your child usually watch TV / video / DVD per day?" posed separately for weekdays and weekends was used to describe television exposure. The variable was dichotomised as less than 60 minutes for weekdays or weekend days versus at least 60 minutes on weekends and/or weekdays.

Parental use of foods as a reward or punishment was assessed by asking parents if they agreed to the following statements: ”A good way to get a child to finish a chore is to promise a snack when he/she is finished.", "Children should have dessert only after everything on the plate has been eaten.", and ”It is alright to tell a child he/she can't have dessert because he/she misbehaved”. Parents that agreed to any of these statements were classified as using food as a reward or punishment.

Statistical analyses

Chi^2- tests were used to analyse differences in taste preferences by survey centre. In order to assess whether taste preferences were associated with each other, odds ratios were calculated for each taste preference pair.

Odds ratios and their 95% confidence intervals were calculated by means of logistic regressions to identify predictors and correlates of a preference for sweet, fat, salty and umami taste. Due to the cross-sectional design of the study, two types of independent factors had to be distinguished. The first type of variables was defined as possible causal predictors of taste preferences. They comprised age, sex, parental education, survey centre, breastfeeding and age at introduction of fruits. In case an association is detected between such a factor and taste preference, the only plausible direction of the association is that the factor influenced taste preference and not the other way round. For the second type of factors the direction of an association with taste preferences would not be clear. These possible correlates included TV use, using food as a reward and taste sensitivity. For instance, it is possible that taste sensitivity impacts taste preferences when taste sensitivity is assumed to be purely genetically determined. However, it cannot be ruled out that taste sensitivity can be learned and thus changed by dietary experience which is also related to taste preferences.

Based on these considerations the following analysis scheme was developed. First, crude odds ratios were calculated based on models that included one of the predictors or correlates as independent variable and taste preference as dependent variable. In a second step a basic logistic model was fit that included only the possible predictors (model 1). Then, a model for each of the second type of factors, the correlates, was fit. Each of these models was adjusted for all variables in model 1 (Type 2 models). Additionally, analyses were repeated stratified by survey centre. Odds ratios from these analyses were only adjusted for age, sex and parental education to avoid model over-fitting.

All analyses were performed using SAS 9.2 (SAS Institute, Cary, NC, USA).

Results

Participant characteristics

The proportion of boys and girls (ranging from 45.8% to 57.7% girls) was well balanced between the survey centres. Mean age was highest in Estonia and Hungary (7.9 years) and lowest in Cyprus (7.0 years). Further information on the sample characteristics are provided in Table 1. It also includes information on the distribution of the other possible predictors and correlates of taste preference in the sample.

Table 1: Sample characteristics

	N	ITA 16.0%	EST 17.8%	CYP 6.5%	BEL 9.9%	SWE 9.4%	GER 14.1%	HUN 14.4%	ESP 11.8%	All N=1705
Socio-demographic factors										
Age (years, mean)	1705	7.6	7.9	7.0	7.2	7.6	7.7	7.9	7.1	7.6
Girls (%)	1705	46.2	55.9	53.6	50.9	49.1	57.7	50.8	45.8	51.4
High parental education (%)	1649	17.3	60.1	89.8	72.1	77.6	37.6	55.0	66.2	54.6
Early feeding practices										
Child was breastfed (%)	1560	83.4	94.4	69.6	60.1	92.0	75.1	93.6	89.4	84.1
Introduction of fruit (months, mean)	1461	5.6	5.8	6.3	4.2	5.4	6.5	5.3	5.5	5.6
Parenting behaviour										
TV ≥ 60min per day (%)	1632	51.7	64.7	55.1	38.6	54.3	42.4	35.2	32.0	47.1
Food used as reward (%)	1635	57.9	37.1	33.7	52.5	36.3	25.8	46.9	22.8	39.9
Taste sensitivity										
Sweet sensitive (%)	1520	87.6	84.4	39.1	76.9	58.4	64.0	78.1	70.5	72.0
Bitter sensitive (%)	1530	59.7	44.0	36.4	31.4	49.7	49.4	73.6	66.5	53.9
Salt sensitive (%)	1538	57.9	61.0	26.4	24.3	62.7	47.7	56.1	57.8	50.9
Umami sensitive (%)	1524	62.6	55.7	26.4	46.8	62.0	38.4	71.5	53.6	54.1

ITA=Italy N=273, EST=Estonia N=304, CYP=Cyprus N=110, BEL=Belgium N=169, SWE=Sweden N=161, GER=Germany N=241, HUN=Hungary N=246, ESP=Spain N=201

Taste preference patterns

For sweet, fat and salt preference the majority of children in the overall sample preferred the food sample with the added ingredient (Figure 1). In contrast, only 34% of the children liked the cracker with added monosodium glutamate better than the natural cracker. Taste preferences also varied among the survey centres (Figure 1). Differences were especially pronounced for fat and umami for which the difference between the survey centres with the highest (Germany and Spain) and the lowest (Cyprus and Belgium) preference prevalence was more than twofold. Centre differences were somewhat similar for fat, salt and umami preference: prevalence of a preference for the added ingredient was always relatively high in the Hungarian, Spanish and Estonian sample.

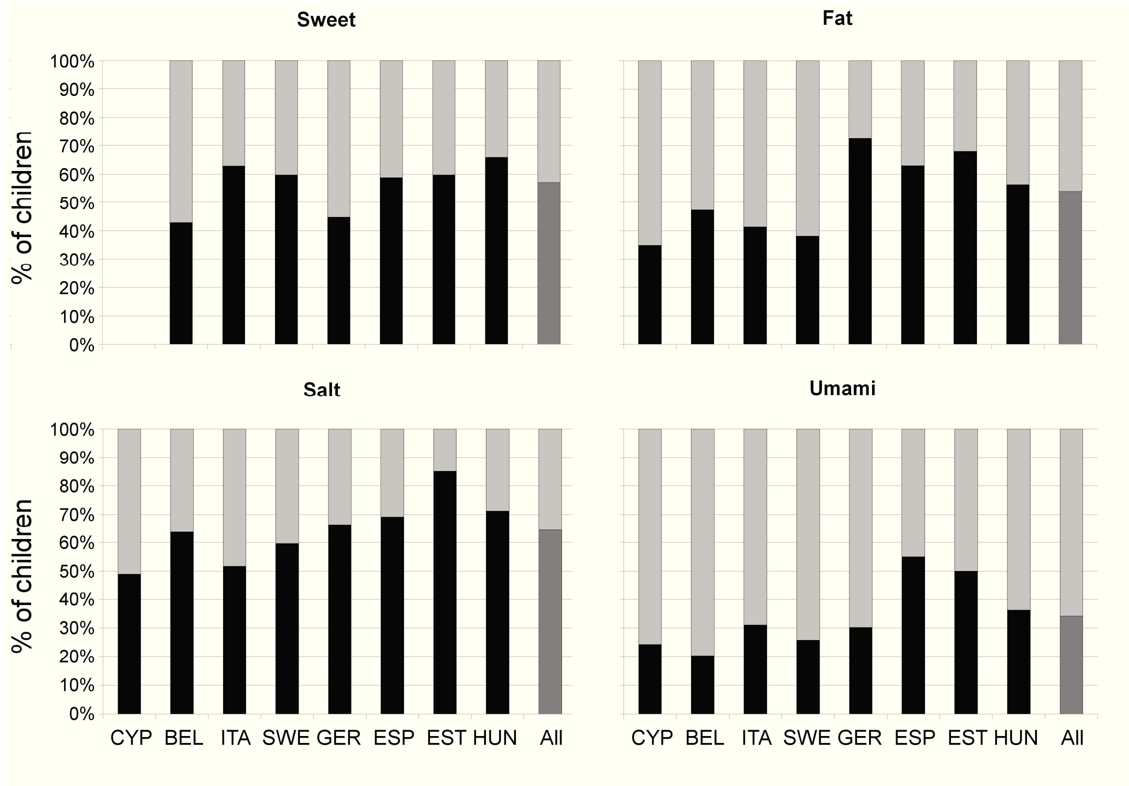

Figure 1: Taste preferences by survey center. Black and dark grey bars = preference for the food sample with the added ingredient. Light grey bars = preference for the basic food sample. Difference in preference prevalence between the survey centers was highly significant for each taste (Chi^2_{sweet}=40.9, p=<0.0001; Chi^2_{fat}=94.2, p=<0.0001; Chi^2_{salt} 51.9, p=<0.0001; Chi^2_{umami}=75.9, p=<0.0001). CYP=Cyprus, BEL=Belgium, ITA=Italy, SWE=Sweden, GER=Germany, ESP=Spain, EST= Estonia, HUN=Hungary.

Except for fat and umami preference, which were significantly positively associated with each other, taste preferences were not significantly related (Table 2). Children that preferred the fatty cracker also had a tendency to prefer sweet, however the results did not reach statistical significance. So, although there is some indication that fat preference is associated with a preference for umami, the correlations of preference ratings for sweet, fat, salt and umami taste were overall weak and hence, all further analyses were conducted separately for the four taste qualities.

Factors associated with taste preferences

<u>Socio-demographic factors</u>

Results of univariate and multivariate logistic models are provided in Table 3a for sweet and fat preference and in Table 3b for salt and umami preference. As already seen in Figure 1, preferences for all four taste qualities differed significantly between survey centres. Adjusted analyses showed that the centre-specific differences could not be explained by any of the other variables in model 1. Of all investigated factors, survey centre showed the strongest association with taste preference.

The logistic models also revealed a relation between taste preferences and age. Increasing age was associated with a higher probability of a preference for sweet and salt. Each additional year of age resulted in a 34% increase in the odds for sweet and a 29% increase in the odds for salt preference in adjusted analyses. In contrast, the probability of a child having a preference for umami taste decreased with increasing age. Also these associations were independent of the other investigated factors and could not be explained by them.

Sex and parental education were not related to preference for any of the four tastes (Table 3a and 3b).

Table 2: Taste-taste associations

	Sweet preference	**Fat preference**	**Salt preference**
		Odds ratio (95% confidence Interval)	
Fat preference	1.23 (0.98 - 1.54)		
Salt preference	1.08 (0.86 - 1.36)	0.85 (0.68 - 1.07)	
Umami preference	1.15 (0.91 - 1.45)	1.35 (1.08 - 1.70)	1.06 (0.84 - 1.33)

The full sample included children from Italy (16.0%), Estonia (17.8%), Cyprus (6.5%), Belgium (9.9%), Sweden (9.4%), Germany (14.1%) , Hungary (14.4%) and Spain (11.8%) (see also Table 1).

<u>Early feeding practices, parenting behaviour, taste sensitivity</u>

Early feeding practices and parenting behaviour variables were not associated with taste preferences in crude or adjusted analyses in the overall sample. In unadjusted analyses, a high umami and salt sensitivity was positively associated with sweet taste preference. However, adjustment for covariates attenuated the relationship (Table 3a and 3b).

Table 3a: Logistic regression models to identify factors related to sweet and fat preference. Results are presented in odds ratios (OR) for the probability of having a preference for sweet or fat

Variable	Sweet preference				Fat preference			
	Univariate Analysis		Model 1[a]		Univariate Analyses		Model 1[a]	
	OR (95%CI)	p[b]	OR (95% CI)	p[b]	OR (95%CI)	p[b]	OR (95%CI)	p[b]
Socio-demographic factors								
Age	**1.33 (1.16 - 1.53)**	**<0.001**	**1.34 (1.14 - 1.58)**	**0.001**	0.89 (0.77 - 1.03)	0.115	0.86 (0.72 - 1.03)	0.102
Girl	0.89 (0.73 - 1.09)	0.244	0.95 (0.77 - 1.19)	0.679	0.95 (0.77 - 1.17)	0.614	0.84 (0.66 - 1.07)	0.167
High parental education	0.82 (0.67 - 1.00)	0.050	0.84 (0.66 - 1.07)	0.157	0.98 (0.79 - 1.22)	0.885	1.08 (0.83 - 1.42)	0.558
Centre[c]		**<0.001**		**0.001**		**<0.001**		**<0.001**
Italy	1.14 (0.76 - 1.70)		1.00 (0.64 - 1.57)		1.15 (0.75 - 1.75)		1.21 (0.75 - 1.94)	
Estonia	1.00 (0.68 - 1.48)		0.89 (0.58 - 1.37)		**3.45 (2.04 - 5.85)**		**3.53 (2.01 - 6.20)**	
Cyprus	-		-		0.87 (0.52 - 1.46)		0.91 (0.49 - 1.69)	
Belgium	**0.51 (0.33 - 0.79)**		**0.55 (0.34 - 0.90)**		1.46 (0.93 - 2.29)		1.15 (0.69 - 1.92)	
Sweden	ref.		ref.		ref.		ref.	
Germany	**0.55 (0.36 - 0.82)**		**0.55 (0.35 - 0.87)**		**4.29 (2.79 - 6.59)**		**5.85 (3.54 - 9.67)**	
Hungary	1.30 (0.86 - 1.96)		1.17 (0.75 - 1.82)		**2.10 (1.39 - 3.17)**		**2.21 (1.42 - 3.44)**	
Spain	0.96 (0.63 - 1.47)		1.11 (0.70 - 1.77)		**2.76 (1.80 - 4.24)**		**2.48 (1.56 - 3.96)**	
Early feeding practices								
Child was breastfed	1.24 (0.93 - 1.67)	0.146	1.01 (0.72 - 1.40)	0.975	1.14 (0.85 - 1.52)	0.393	1.06 (0.75 - 1.49)	0.756
Age at introduction of fruit	1.00 (0.96 - 1.04)	0.827	1.00 (0.95 - 1.04)	0.864	0.97 (0.63 - 1.49)	0.875	0.70 (0.43 - 1.13)	0.148
			Type 2 Models[d]				**Type 2 Models[d]**	
Parenting behaviour								
TV ≥ 60min per day	1.16 (0.94 - 1.42)	0.159	1.11 (0.88 - 1.39)	0.386	0.89 (0.72 - 1.10)	0.288	1.01 (0.79 - 1.30)	0.922
Food used as reward	1.03 (0.84 - 1.26)	0.796	1.10 (0.87 - 1.39)	0.421	0.89 (0.71 - 1.11)	0.299	1.11 (0.86 - 1.43)	0.422
Taste sensitivity								
Sweet sensitive	0.90 (0.70 - 1.15)	0.383	0.80 (0.61 - 1.06)	0.125	1.24 (0.98 - 1.57)	0.073	1.30 (0.98 - 1.72)	0.067
Bitter sensitive	1.23 (1.00 - 1.52)	0.055	1.11 (0.87 - 1.42)	0.405	1.19 (0.96 - 1.47)	0.110	1.10 (0.85 - 1.42)	0.485
Salt sensitive	**1.29 (1.05 - 1.60)**	**0.018**	1.17 (0.92 - 1.48)	0.209	1.03 (0.84 - 1.28)	0.757	1.03 (0.80 - 1.32)	0.815
Umami sensitive	**1.31 (1.06 - 1.63)**	**0.012**	1.08 (0.85 - 1.38)	0.511	0.94 (0.76 - 1.16)	0.548	1.10 (0.85 - 1.41)	0.479

[a] Model1: socio-demographic factors and early feeding behaviour variables mutually adjusted
[b] p-value for estimator derived from Wald Chi-square test
[c] The distribution in the full sample was: Italy 16.0%, Estonia 17.8%, Cyprus 6.5%, Belgium 9.9%, Sweden 9.4%, Germany 14.1%, Hungary 14.4%, Spain 11.8% (see also Table 1).
[d] Type 2 Models: Parenting behaviour or taste sensitivity variable + adjustment for variables of Model1
OR: odds ratio; CI: confidence interval

Table 3b: Logistic regression models to identify factors related to salt and umami preferences. Results are presented in odds ratios (OR) for the probability of having a preference for salt or umami

Variable	**Salt preference**				**Umami preference**			
	Univariate Analyses		**Model 1[a]**		**Univariate Analyses**		**Model 1[a]**	
	OR (95%CI)	**p[b]**	**OR (95%CI)**	**p[b]**	**OR (95% CI)**	**p[b]**	**OR (95%CI)**	**p[b]**
Socio-demographic factors								
Age	**1.19 (1.02 - 1.38)**	**0.024**	**1.29 (1.08 - 1.54)**	**0.006**	**0.78 (0.67 - 0.90)**	**0.001**	**0.75 (0.62 - 0.90)**	**0.002**
Girl	0.92 (0.74 - 1.15)	0.481	0.91 (0.71 - 1.16)	0.439	0.91 (0.73 - 1.14)	0.412	0.91 (0.71 - 1.17)	0.451
High parental education	1.14 (0.91 - 1.42)	0.257	1.19 (0.90 - 1.56)	0.222	0.86 (0.69 - 1.08)	0.196	0.81 (0.62 - 1.07)	0.145
Centre[c]		**<0.001**		**<0.001**		**<0.001**		**<0.001**
Italy	0.73 (0.48 - 1.10)		0.82 (0.51 - 1.31)		1.29 (0.81 - 2.06)		1.17 (0.70 - 1.97)	
Estonia	**3.84 (2.04 - 7.22)**		**4.38 (2.22 - 8.62)**		**2.88 (1.70 - 4.89)**		**2.78 (1.59 - 4.89)**	
Cyprus	0.65 (0.39 - 1.08)		0.68 (0.37 - 1.25)		0.92 (0.52 - 1.65)		0.79 (0.40 - 1.57)	
Belgium	1.19 (0.76 - 1.85)		1.35 (0.82 - 2.23)		0.74 (0.44 - 1.24)		0.60 (0.34 - 1.08)	
Sweden	ref.		ref.		ref.		ref.	
Germany	1.34 (0.88 - 2.03)		1.44 (0.90 - 2.31)		1.24 (0.79 - 1.96)		1.08 (0.65 - 1.79)	
Hungary	**1.68 (1.10 - 2.56)**		**1.63 (1.04 - 2.56)**		**1.63 (1.05 - 2.55)**		**1.75 (1.09 - 2.83)**	
Spain	1.52 (0.98 - 2.34)		**1.91 (1.19 - 3.07)**		**3.53 (2.24 - 5.54)**		**2.79 (1.71 - 4.56)**	
Early feeding practices								
Child was breastfed	1.05 (0.78 - 1.42)	0.751	0.95 (0.67 - 1.33)	0.753	1.14 (0.83 - 1.55)	0.421	0.88 (0.61 - 1.25)	0.464
Age at introduction of fruit	1.18 (0.75 - 1.86)	0.481	1.36 (0.83 - 2.24)	0.218	1.22 (0.78 - 1.89)	0.382	1.12 (0.70 - 1.79)	0.643
			Type 2 Models[d]				**Type 2 Models[d]**	
Parenting behaviour								
TV ≥ 60min per day	0.93 (0.75 - 1.17)	0.548	0.94 (0.73 - 1.20)	0.603	1.01 (0.80 - 1.26)	0.959	1.14 (0.88 - 1.48)	0.338
Food used as reward	0.95 (0.76 - 1.20)	0.674	1.07 (0.83 - 1.38)	0.625	0.93 (0.73 - 1.17)	0.507	1.05 (0.81 - 1.37)	0.701
Taste sensitivity								
Sweet sensitive	0.99 (0.78 - 1.27)	0.846	0.96 (0.73 - 1.28)	0.790	0.93 (0.73 - 1.19)	0.585	0.83 (0.62 - 1.10)	0.191
Bitter sensitive	0.96 (0.77 - 1.20)	0.733	0.90 (0.69 - 1.16)	0.401	1.05 (0.84 - 1.32)	0.650	0.92 (0.71 - 1.20)	0.541
Salt sensitive	0.84 (0.68 - 1.05)	0.126	0.85 (0.66 - 1.09)	0.195	1.21 (0.97 - 1.51)	0.097	1.02 (0.79 - 1.32)	0.886
Umami sensitive	1.06 (0.85 - 1.32)	0.637	0.96 (0.75 - 1.25)	0.782	1.04 (0.83 - 1.31)	0.719	0.99 (0.76 - 1.29)	0.965

[a] Model1: socio-demographic factors and early feeding behaviour variables mutually adjusted
[b] p-value of Wald Chi-square test
[c] The distribution in the full sample was: Italy 16.0%, Estonia 17.8%, Cyprus 6.5%, Belgium 9.9%, Sweden 9.4%, Germany 14.1%, Hungary 14.4%, Spain 11.8% (see also Table 1).
[d] Type 2 Models: Parenting behaviour or taste sensitivity variable + adjustment for variables of Model1
OR: odds ratio; CI: confidence interval

Stratified analyses

To account for the striking differences found by age and survey centre, we examined the age-taste relationship in each country sample separately (Figure 2). For sweet and salt preference the positive overall association with age could be found consistently in all samples except for salt preference in Germany where the odds ratio was 1. However, the estimates did only reach statistical significance for sweet preference in the Spanish sample. For umami preference, centre-specific analyses revealed a more heterogeneous picture. In the Estonian and Spanish children, odds ratio estimates of higher than 1 indicating a positive association between age and umami preference were found. For the other survey centres, odds ratio estimates pointed towards an inverse association between age and umami preference which was in line with the results of the full sample.

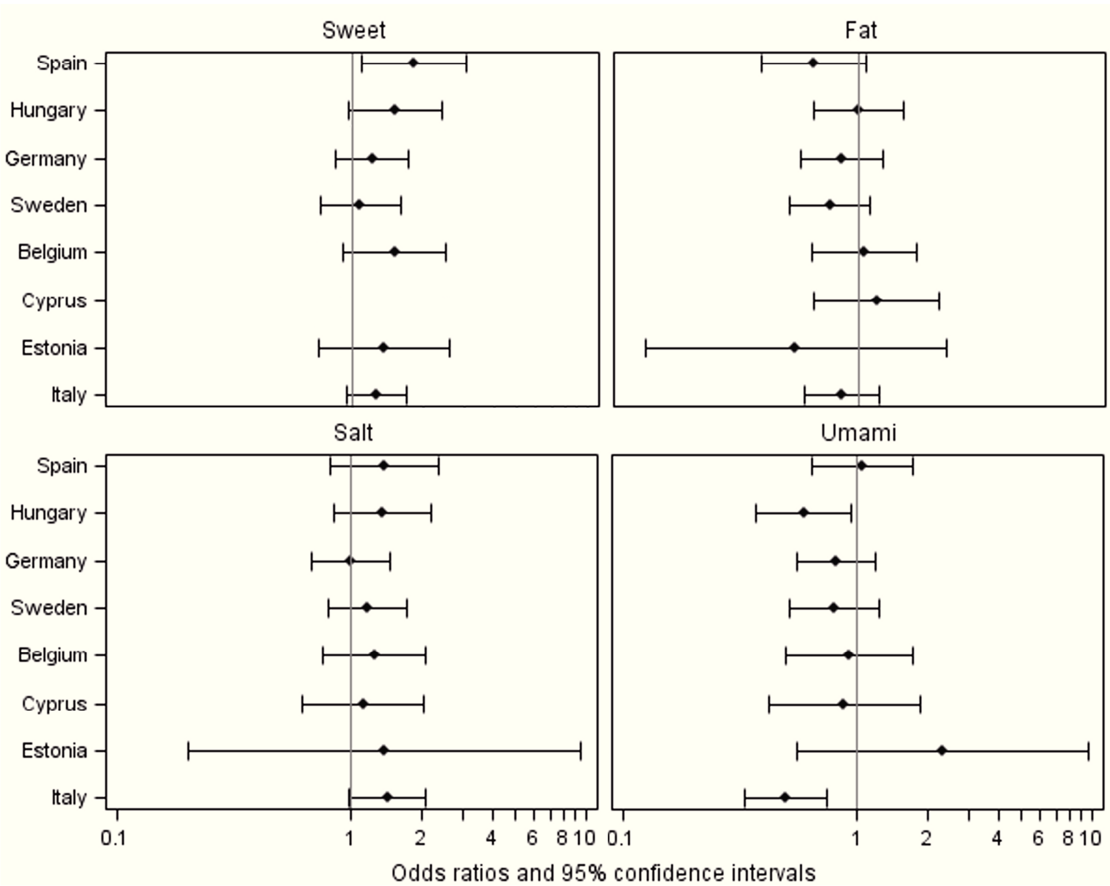

Figure 2: Association between age and preference for sweet, fat, salt and umami in 8 survey centers. Odds ratios (OR) indicate the change in odds for having a preference for the respective taste by one year increase in age. An OR >1 indicates a positive association between age and taste preference and an OR<1 an inverse association. ORs are adjusted for sex and parental education.

Stratified analyses by survey centre were also performed for all other investigated factors. They provided a heterogeneous picture. Factors associated with taste preferences varied largely between the survey centres and for none of them a consistent pattern of positive or negative associations with taste preference among all centres was found (data not shown).

Discussion

The present study provided the unique possibility to examine taste preferences in a population-based sample of over 1,700 children from eight different European countries. To our knowledge, this constitutes the largest study on taste preferences in children to date.

One part of our analyses comprised investigations into taste preference patterns. They revealed that generally taste preferences were not correlated. Only for fat and umami preference we found that children with a preference for fat had a tendency to also prefer added monosodium glutamate in crackers. This implies that fat and umami preference could – at least partially - be driven by the same underlying mechanism. Given the fact that fat and monosodium glutamate both act as flavour enhancers in food, this underlying factor could be preference (or rejection) for flavour enhancing components in general. Apart from this, our results show that taste preferences for fat, salt, sweet and umami are independent from each other which means that no general pattern of taste preferences for or against added components in foods exists in children. These findings are the basis for future studies that aim to identify preference patterns in subgroups of children and investigate whether they have the capacity to predict dietary habits and health outcomes.

The second set of analyses aimed at mapping factors that are related to taste preferences in children. Our results showed large differences in preferences between countries. From all examined possible factors, country of residence, i.e. survey centre, was the strongest predictor of taste preferences. Age was also related to preference for sweet, salt and umami taste in crude and adjusted analyses despite the fact that we only covered a quite narrow age range. It is known that humans have an innate preference for sweet and an early developed preference for salt (Birch, 1999; Schwartz, Scholtens, Lalanne, Weenen, & Nicklaus, 2011) which is also known to decline during adolescence leading to a lower sweet and salt preference in adults than children (De Graaf & Zandstra, 1999; Desor & Beauchamp, 1987; Desor, et al., 1975; Enns, et al., 1979; Mennella, et al., 2011). Up to now, age related differences in taste preferences have not been studied in children between 2 and 9 years of age. Our results indicate that sweet and salt preference in children might increase in childhood before it starts to drop with the onset of adolescence. This hypothesis is supported by a study on food preferences in 4-16-year-old children that found that liking for fruits and sweet & fatty foods peaked at 8-11 years (Cooke & Wardle, 2005). Our result on age effects on umami taste preference is also new and requires confirmation from future studies.

In crude analyses, sweet preference was related to taste sensitivity determined by taste threshold. Children with low thresholds for detecting salt and umami taste had a higher probability to prefer the sweetened apple juice in crude analyses. However, controlling for other covariates attenuated the relationship. One possible explanation of our and previous findings could be that taste threshold, i.e. the lowest concentration of a tastant that can be detected, is not relevant in everyday taste sensation in a major way. We live in a sensory world where our hedonic evaluations are usually based on perceptions above the detection threshold. Therefore it is possible that suprathreshold intensity ratings of basic taste would show a closer link to taste preferences in food. These considerations are supported by results from previous studies in adolescents and adults. While they did not find a relationship between taste threshold for basic taste qualities and preference, some indications for a possible link between suprathreshold sensitivity and preference was found (Coldwell, et al., 2009; Mojet, et al., 2005).

Apart from age, we did not find any other common factor underlying taste preferences independent of cultural background. Culture – usually defined as country of residence - has previously been discussed to be the most important determinant of food preferences which overrides other determinants (Rozin & Vollmecke, 1986). Our results imply that the same could be true for taste preferences. We also found that none of the other factors could explain the cross-country differences in taste preferences. This could imply either that we did not assess an important mediator of the association between preference and country of residence or that determinants of taste preferences vary along with the cross-country differences in preference. In fact, for some of the investigated factors we found associations with taste preferences in some, but not all, survey centres and never in the same direction in all survey centres. This implies that a factor might be a determinant of taste preference in one country but not in another. There are some indications that cross-country differences in the determinants of preferences exist. For instance, Cervellon & Dubé found that reasons for food likes and dislikes differed between Chinese and French citizens and motives for food choice varied significantly across countries in a study of consumers from four Asian countries and New Zealand (Cervellon & Dubé, 2005; Prescott, Young, O'Neill, Yau, & Stevens, 2002). Our results suggest that similar differences in determinants of taste preferences also exist at early ages and between food cultures that are much more related.

Our study has some limitations. First, we used cross-sectional data. Although some of the factors are more likely to influence taste preference than vice versa, the design does not allow us to draw causal conclusions from the observed associations. Second, we tested taste preferences in only one food medium for each taste quality. Preference for a food component highly depends on the food medium and it can be argued that assessing taste preferences with a variety of food samples could have been beneficial to the validity of assessments. However, due to the comprehensive assessment protocol of the IDEFICS study that required children to undergo examinations for many hours, taste tests had to be short comprising only a limited number of foods. Additionally, we used a non-randomised sequence of sample presentation where the basic food sample was always tasted first. This decision was taken to minimise measurement error by field personnel due to complex test instructions. A simple testing procedure is crucial in multi-centre cross-cultural studies where a large number of different trained field personnel conduct the experiments. Still, the non-random stimulus presentation creates the risk of some position bias. However, the fact that taste preference ratings in the four tests were mostly not associated with each other implies that there was no general tendency to always choose the first or second food sample in our sample of children. Finally, some additional information on the children themselves and their parents (e.g. food neophobia, picky eating or dietary restraints) would have been interesting in order to investigate their relationship with taste preferences.

Despite some limitations, our study also has several strengths. Our method to assess taste preferences in children – albeit using a limited number of foods and a non-randomised set-up – applied a quasi-experimental design that was feasible in an epidemiological study, required minimal verbal skills and was based on standardised, centrally produced food samples. This kind of standardisation was crucial in order to avoid inter-cultural bias that self- or parental-reported food preferences without tasting standardised food samples could have implied. For instance, the same food when purchased in a food store can have different sugar contents in different countries and could thus be rated differently by children that in reality have similar preferences for sugar. Also all other data were assessed in a strictly standardised way that was guaranteed by quality control measures such as central trainings and site visits by a quality control team. Therefore, our data ensured a high level of cross-country comparability. Furthermore, the large population-based sample that comprises children of eight European countries adds value to our results.

In summary, our results reveal for the first time the crucial importance of culture and age in taste preferences in children younger than 10 years of age. In terms of public health implications, these results underscore the necessity to design diet intervention programs which are adapted to or even make use of the cultural context of their target group. Our age results also imply that children cannot be seen as a homogeneous target group and that different measures might be necessary for different age groups even in childhood.

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