

Responses to sweetness

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8 Affective responses to sweet products and sweet solution in British and Finnish adults

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Responses to sweetness

24 Abstract

25 Responses to sweetness are reported in two populations, one segmented by gender and age, and
26 the other one by gender only. The strength of the association between liking for specific sweet
27 foods and liking for an aqueous sucrose solution (20% w/v) is also tested, and health attitudes
28 examined. British adults (n = 1855, age 17-82, mean 55 years, 90% women) and Finnish young
29 adults (n=1292, age 20-25, mean 22 years, 54% women) rated their liking of ten sweet foods and
30 beverages based on names of products, and completed questionnaires on Craving for Sweet Foods
31 (CSF) and General Health Interest (GHI). One-half of Brits and a third of Finns rated liking and
32 intensity of sucrose solution. In factor analysis, identical categories of liking for sweet products
33 were formed in each population, one consisting of five *processed sweets* ("Goodies"), and the
34 other of *naturally sweet fruits and berries* ("Fruits"). *Sugared and sugar-free soft drinks and fruit*
35 *juice* loaded on the third factor. After age 50, British men scored higher than British women in CSF
36 and liking for several sweet products; Finnish women scored higher than Finnish men in CSF and
37 liking for most sweet products. GHI was positively associated with liking for Fruits and negatively
38 with liking for sugared soft drinks. Sucrose solution was better liked by British men than women,
39 with no gender difference in Finns. Liking for sucrose solution was only weakly associated with
40 liking for sweet products based on product names. In two demographically different European
41 populations, attraction to sweet gathered in similar product categories, but manifested differently
42 at different ages and gender.

43 KEYWORDS: sweet, liking, craving, gender, age

44

45 1. Introduction

46 Abundant sugar intake is a health concern worldwide (WHO, 2015). High consumption of mono-
47 and disaccharides added to foods is associated with higher body weight, and high consumption of
48 sugar-sweetened beverages is associated with overweight and obesity in children (Te Morenga,
49 Mallard, & Mann, 2013; Cox, Hendrie, & Carty, 2016). High sugar intake is also associated with
50 increased incidence of dental caries (Moynihan, & Kelly, 2014).

51 The flip side of the concern is the deeply rooted position of sweetness in our biology and culture
52 (Rozin, 1982). Inclination to enjoy sweetness is inherent and evolutionarily well founded due to
53 energy and nutrients associated with it (Drewnowski, Mennella, Johnson, & Bellisle, 2012).
54 Technologies to refine sugar from canes and beets, to produce a great variety of fine-tuned
55 commercial sweet products, have been generated to satisfy the indulgence for sweetness. Further
56 technological development has introduced intense sweeteners to the market to satisfy the need
57 without calorie load and caries risk (Spillane, 2006).

58 Data from Finnish families (Keskitalo et al., 2007a) and British and Finnish twins (Keskitalo et al.,
59 2007b, 2008) suggest that part of the predilection for sweetness (“sweet tooth”) is inherited and
60 thus, it runs in families. Evidence for some genetic influence was also found in 3-year-old twins
61 whose parents rated their preference for snacks that were primarily sweet (Fildes et al., 2014).
62 Studying genetic variations in the perception of sweetness in children and adults, Mennella,
63 Pepino, and Reed (2005) concluded that in adults, cultural forces override genetic effects. Thus,
64 genetic architecture defines the basis on which the cultural supply of products builds individual
65 profiles of sweet preferences and inclinations.

66 The data of the present study were originally collected for the purpose of research on genetics of
67 sweetness preferences. We measured sweetness perception using a sweet aqueous solution of
68 sucrose - a simple and universal stimulus which is easy to present to large populations (Keskitalo
69 et al., 2007b, 2008). For getting a wider perspective to sweetness perceptions we developed a
70 questionnaire in which liking responses to sweet products and craving for sweet foods were
71 recorded from British and Finnish twins (Keskitalo et al., 2007b, 2008; Knaapila et al. 2011). These
72 data were used in the search of genetic roots in sweetness preferences using a twin paradigm
73 (Keskitalo et al, 2007b, 2008; Knaapila et al., 2011), and of specific trait locus of genetic linkage
74 analysis (Keskitalo et al., 2007a). Because of the long term data collection expanding over years,

75 and the focus of the reports, only a part of the outcome data have been incorporated into the
76 published papers.

77 The data contain unique and as yet unused information of the attraction to sweetness in two
78 large, separate populations at three levels: 1) hedonic and intensity ratings of a simple aqueous
79 solution of sucrose, 2) reported liking and use frequency of a range of everyday sweet foods and
80 beverages, and 3) craving for sweet foods, measured by a six-item validated instrument
81 (CSF)(Roininen, Lähteenmäki, & Tuorila, 1999). Analyzing the data fills a gap in knowledge of
82 general sweetness preferences, as the published literature tends to focus on specific sensory
83 stimuli in specific experimental conditions (an exception is the large web-based study with French
84 consumers, Urbano et al., 2016). The British respondents covered a wide age range, thus enabling
85 the analysis of responses to sweetness across age groups. Both the British and Finnish data
86 contained responses from both genders, thus gender differences could be analyzed. By reporting
87 on two data sets that share the methodology in the same paper, we seek to identify characteristics
88 of sweetness responses that are not bound to a specific age group, gender or cultural setting. The
89 members of twin pairs are here treated as individuals, but their data are not statistically
90 independent observations, which is taken into account in statistical analyses (see Section 2.3
91 Statistical analysis).

92 The data also allow to examine the prediction of liking for sweet products from responses to an
93 aqueous sucrose solution, a stimulus that is widely and universally used in the measurement of
94 sweetness attraction (e.g., Esses, & Herman, 1984; Desor, & Beauchamp, 1987; Mennella et al.,
95 2005; Keskitalo et al., 2007a, 2007b, 2008; Mennella, Finkbeiner, & Reed, 2012; Pepino, &
96 Mennella, 2012; Mennella, Finkbeiner, Lipchock, Hwang, & Reed, 2014; Thai, Tan, Tan, Tey, Kaur,
97 & Say, 2011). The present analysis adds to research comparing liking for aqueous solutions with
98 ratings of liking for sweet products based on their names (Kim, Prescott, & Kim, 2014).

99 The General Health Interest (GHI) (Roininen et al., 1999) was used to examine the potentially
100 controlling role of health attitudes in responses to sweetness. If powerful in this context, GHI
101 should be negatively correlated with liking for sweet items that are perceived as unhealthful.

102 Thus, the objective of the present study was to describe demographic variations in affective
103 responses to a range of sweet foods and beverages in two populations of which one (British)
104 allowed the examination of variation by gender and age, and the other (Finnish) by gender only.
105 Besides ratings of liking of sweet products based on product names, also craving for sweet foods

106 (CSF) was measured. The secondary aim was to describe the demographic variations in responses
107 to an aqueous sweet solution in the same populations and to examine the extent to which liking
108 for the very sweet solution could predict the rated liking of sweet products based on product
109 names. Finally, the capability of health attitude (GHI) to control the responses to sweetness was
110 tested by correlational analysis.

111 2. Respondents and methods

112 2.1 Respondents

113 The present data were collected in British (UK) and Finnish twin research units in years 2005-2007,
114 British data in English and Finnish data in Finnish language. **Table 1** presents the distribution of
115 participants by gender and age group, as used in the subsequent analyses. For brevity, we refer to
116 British respondents as Brits and the Finnish respondents as Finns.

117 The British respondents (n=1855 individuals) were twins in the UK Adult Twin Registry (Spector &
118 Williams, 2006). A minority (n=188, 10.1%) were men. The age range of the respondents was 17-
119 82 y (mean \pm SD: 54.9 \pm 12.7; for men 54.9 \pm 14.1, for women 54.9 \pm 12.6). The present study was
120 approved by the Guy's and St Thomas's Hospital Ethics Committee.

121 The Finnish data (n=1292 individuals) were collected during the fourth wave assessment of the
122 FinnTwin12 study (Kaprio, Pulkkinen, & Rose, 2002), which is based on five consecutive and
123 complete year cohorts of Finnish twins born in 1983-87. Close to half (n=594, 46.0%) were men,
124 and the age range was 20-25 y (mean \pm SD: 22.4 \pm 0.7, for men and women identical). The present
125 study was approved by the Coordinating Ethics Committee of Helsinki University Hospital and the
126 IRB of Indiana University, Bloomington, IN.

127 Data on weight and height were available from 98.3% (n= 1823) of the British and 99.0% (n=1279)
128 of Finnish respondents. Of the Brits, 44% were normal-weight (BMI \leq 25), 36% overweight (BMI >
129 25...30), and 20% obese (BMI > 30). The corresponding figures for the young adult Finns were 75%,
130 20%, and 5%.

131 2.2 In person testing procedure

132 The respondents visited the clinic after overnight fasting, and rated the sweet aqueous solution of
133 sucrose (20% w/v) as described by Keskitalo et al. (2007b). This concentration of sucrose was
134 chosen as it yielded highest heritability estimates and best differentiated between respondents.

135 Thus it was expected to best reflect the underlying preference for sweet taste in Keskitalo et al.
136 (2007a) study, in which also lower sucrose concentrations were rated. After rinsing their mouths
137 with tap water, the respondents received the solution (20mL) at room temperature. They were
138 instructed to take it into the mouth and swirl around 5-10 s, and expectorate. The degree of liking
139 was then rated using a 120 mm Labeled Affective Magnitude scale (LAM) (Schutz & Cardello, 2001)
140 and the intensity using 120 mm Labeled Magnitude Scale (LMS) (Green et al., 1996). The verbal
141 anchors of LAM scale ranged from “greatest imaginable dislike” (- 60) to “greatest imaginable like”
142 (+60), with “like slightly” at +5 (dislike -5), “like moderately” at +20 (dislike -20) and “like very
143 much” at +32 (dislike -32). The verbal anchors of LMS scale were at +2 (“barely detectable”), +5
144 (“weak”), +19 (“moderate”), +40 (“strong”), +60 (“very strong”), and +120 (“strongest imaginable
145 sensation”). Of the Brits, 53% (n=987) and of the Finns, 36% (n=468) participated in the sensory
146 rating task (see **Table 1**). The partial attendance in the tasting session was due to procedures: in
147 the UK, the questionnaires were filled out from the year 2005 to 2007, but the collection of
148 sensory data was finished earlier (in 2006); and the participation in the sensory test was not
149 requested of diabetics. In Finland, part of the participants did not visit the clinic and thus did not
150 rate the solution, but completed the questionnaire at home and then mailed it to the clinic.

151 The respondents completed an extensive questionnaire prior to visiting the clinic. In the
152 questionnaire, also aspects of their preferences and use of sweet items were queried. They rated
153 their degree of liking for 34 (British) or 38 (Finnish) sweet or non-sweet foods and eight sweet or
154 non-sweet beverages. Ten of these were sweet items to which the present study focuses: five
155 (chocolate, ice cream, sweet desserts, sweet pastry, and other sweets “candy”) were solid,
156 typically sugar-sweetened processed products; three were sweet beverages (fruit juice; sugared
157 soft drinks; “unsugared” (British questionnaire) or “sugar-free” (Finnish questionnaire) soft drinks,
158 in the present text they are called sugar-free); and two were naturally sweet solid products (fruits
159 and berries). The foods and beverages were rated from 1 = dislike very much to 7 = like very much
160 (British) or 1 = very unpleasant to 7 = very pleasant (Finnish), thus the value 4 equaled neutral. The
161 Finnish language lacks the word “dislike”, and to allow bipolar evaluations, pleasantness was rated
162 by Finns instead of ratings of liking (for the comparison and use of scales anchored by
163 pleasantness and liking, see Tuorila et al., 2008). In the following, the ratings will be referred to as
164 liking. Use frequencies of the same foods were rated from 1 = never to 6 = several times a day (see
165 Keskitalo et al. 2007b), but due to our focus on hedonics and to relatively high positive

166 correlations with ratings of liking of the ten products ($r = 0.50 - 0.68$, Brits; and $r = 0.35 - 0.58$,
167 Finns), the use frequency data will not be reported in detail.

168 Two subscales of internationally validated (Roininen et al., 2001) Health and Taste Attitude Scales
169 (Roininen et al., 1999) were completed: six statements quantifying Craving for Sweet Foods (CSF),
170 and eight statements quantifying the General Health Interest (GHI). Rated statements for CSF
171 were, for example: "I often have cravings for sweets" (positive) and "In my opinion it is strange
172 that some people have cravings for chocolate (negative). Rated statements for GHI were, for
173 example: "I am very particular about the healthiness of food I eat" (positive), and "I eat what I like
174 and I do not worry much about the healthiness of food" (negative). Statements were rated from 1
175 = strongly disagree to 7 = strongly agree.

176 2.3 Statistical analysis

177 The British and Finnish data were analyzed separately. Data analysis was conducted using SPSS
178 statistical software, version 21 (SPSS Inc., Chicago, IL) and Stata version 13 (Stata Corp, College
179 Station, TX).

180 Correlations between ratings of sweetness and responses to sweet products were computed as
181 the Pearson's product moment coefficients. Factor analysis was applied to find groupings of liking
182 responses to ten sweet products.

183 CSF and GHI were constructed as described by Roininen et al. (1999, 2001). Thus, after reversal of
184 ratings of statements that were negative to the target, individual means were calculated to
185 indicate the strength of GHI ($\alpha = 0.77$, Brits, and 0.90 , Finns) and CSF ($\alpha = 0.70$, Brits, and
186 0.84 , Finns). Both subscales could theoretically range from 1 to 7.

187 One-way analysis of variance was used to reveal gender differences in ratings of liking in each
188 population, and age differences in liking and intensity of sucrose solution in the British
189 respondents. Two-way analysis of variance was used to examine the effects of age and gender
190 and their interactions, on ratings of liking in the British respondents. Post hoc comparisons of
191 liking and intensity ratings of the sweet solution in different age groups were conducted with
192 Tukey test.

193 The effect of the design (ratings from twin pairs) was taken into account by using statistical models
194 for complex survey data. The twins have been sampled as pairs and so the individual twins are not

195 statistically independent observations. The “svy” option or cluster-correction in Stata was used to
196 derive proper standard errors and p-values (Williams, 2000).

197 Statistically significant ($p < 0.05$) values are reported below.

198 3. Results

199 3.1 Categories of sweet products and responses to sweetness

200 Factor analysis on ratings of liking for 10 sweet products resulted in similar structures in British
201 and Finnish data (**Table 2**). Five semi-solid and solid sweet products (desserts, pastry, sweets,
202 chocolate, ice cream, called by a common name “Goodies”) loaded strongest on the first factor
203 (variations explained 31 and 33%). Liking for Goodie scale formed based on this factor had
204 Cronbach’s alpha = 0.85 and 0.88, for Brits and Finns, respectively. Naturally sweet products (fruits
205 and berries, called by a common name “Fruits”) loaded on the second factor (18% of variation
206 explained in both data sets). The corresponding liking for Fruits scale had alpha 0.76 in Brits and
207 0.82 in Finns. Liking for beverages loaded mainly on the third factor (16% in both data sets), but
208 their mutual associations were low for which reason no common group was formed. The
209 subsequent analyses were mainly (apart from the final correlations) conducted on each individual
210 product to preserve the product-specific information unique in the present data. However, it is
211 noteworthy that the two demographically different European populations rated their liking for 10
212 sweet items in a way that resulted in similar factor structures and almost identical proportions of
213 variation explained.

214 Factor analysis on use frequencies of sweet products followed the patterns observed for liking
215 data, confirming the close association of liking and reported use.

216 3.2 Gender and age associations of responses to sweetness

217 Sweet products were generally well-liked: except for the sugared soft drinks in the British
218 respondents, mean ratings were well above the neutral (value 4) for both populations and all
219 products (**Figure 1**). British men rated ice cream and sugared soft drinks higher ($p < 0.001$), but
220 fruits ($p = 0.005$) and berries ($p = 0.002$) lower than did women. Among British respondents, no
221 gender differences were seen for the remaining six sweet products (chocolate, sweet desserts,
222 sweet pastry, sweets, sugar-free soft drinks and fruit juice) (**Figure 1A**). Finnish men rated sugared
223 soft drinks ($p < 0.001$) and fruit juice ($p = 0.007$) higher, but rated the remaining eight sweet items
224 lower than women (**Figure 1B**).

225 In **Figure 2**, the mean ratings of products by age groups in Brits are shown for genders separately.
226 Given the limited age variability among Finns, the analysis of age effects was not meaningful.
227 Significant U-shaped main effects of age were observed for sweet desserts and for sweet pastry
228 (**Figure 2C and 2D**), with the youngest and oldest age groups rating them highest (F [4, 953] = 6.0,
229 $p < 0.001$ for desserts and 5.0, $p = 0.005$ for pastry). An age effect was also found for soft drinks
230 (**Figure 2F and 2G**) such that older participants had lower liking ratings (F [4, 950] = 15.9, $p <$
231 0.001 for sugared and 8.3, $p < 0.001$ for sugar-free soft drinks). Older subjects reported higher
232 liking of fruits and berries (**Figure 2I and 2J**) (F [4, 953] = 3.4, $p = 0.01$ for fruits and 5.8, $p < 0.001$,
233 for berries).

234 Two significant age by gender interactions were found. With increasing age, ratings of chocolate
235 (**Figure 2A**) and sweets (**Figure 2E**) were higher for men, but lower for women (F [4, 1732] = 4.1, p
236 = 0.0013 for chocolate and 2.9, $p = 0.023$ for sweets). A similar tendency for interaction was
237 observed for the remaining processed sweets.

238 Mean craving (CSF) was higher in Finnish women than in Finnish men (mean ratings 4.7 and 3.6,
239 respectively, F[1, 1290] = 209, $p < 0.001$). In the British data, CFS varied by gender and age (**Figure**
240 **3**). On average, the British women scored higher for craving than men (mean values 4.2 and 3.9,
241 respectively) (F [1, 1845] = 8.3, $p = 0.004$), but a significant gender by age interaction (F [4, 1845] =
242 5.0, $p = 0.001$) indicated that craving was less in older women, but greater in older men.

243 Mean health interest (GHI) was higher in British women (mean 5.1, SD 1.1) than in men (mean 4.6,
244 SD 1.2). The corresponding mean for the Finnish women was 4.5 (SD 1.3) and for men 3.7 (SD 1.3).

245 To provide a context for the ratings of liking of sweet foods, we computed mean ratings of non-
246 sweet products (**Table 3**), including those 26 foods and beverages that, in the questionnaires, were
247 identically defined to Brits and Finns (e.g., some fish dishes and cereals were defined in culture
248 specific ways and therefore excluded). The mean ratings of 26 foods were 5.2 (Brits) and 5.4
249 (Finns), suggesting on average fairly positive and similar ratings of food likes/dislikes in both
250 countries. With the exception of sugared and sugar-free soft drinks, the sweet products were
251 rated higher than these averages, supporting the notion that sweetness plays an important role in
252 making products attractive.

253 3.3 Responses to the aqueous sucrose solution and their relationship to other ratings

254 In both populations, mean hedonic ratings of the sweet solution were above neutral, although on
255 average much below the verbal anchor “like moderately” (**Figure 4**). British men rated their liking
256 higher than did British women ($F [1, 508] = 6.3, p = 0.012$), whereas no gender difference was
257 observed between Finnish men and women. Hedonic ratings varied widely, from -60 to +54 in Brits
258 and from -44 to +55 in Finns. The share of non-likers of sweet solution (ratings below 0) was 42.1%
259 and 24.4% in Brits and Finns, respectively. Both genders rated the intensity of sweetness similarly
260 in both countries. Brits had higher ratings of liking after age 50 years. This finding is however
261 tempered by the fact that intensity ratings decreased with increasing age (**Table 4**).

262 Correlations between sweetness related measurements are presented in **Table 5**. In both
263 populations, liking for the sweet sucrose solution was significantly, but weakly, related to liking for
264 Goodies and sugared soft drinks; in Brits, it was very weakly related to craving (CSF). CSF was
265 strongly associated with liking for Goodies and significantly also with other sweet items. GHI was
266 positively related to liking for Fruits and negatively to liking for sugared soft drinks.

267 4. Discussion

268 The two demographically different populations, Brits and Finns, rated their liking (and also
269 frequency of use) of 10 sweet items such that in factor analyses, similar factor structures and
270 identical proportions of explained variation emerged from the analyses. This implies that in spite
271 of different food cultures, major categories of sweet foods are similar in the minds of these
272 respondents representing two European food cultures. In more detailed scrutiny including the
273 variations by gender and age, responses to sweetness at the three levels of measurement (liking of
274 sweet foods based on food name, craving, and ratings of aqueous sucrose solution) show a more
275 complex picture of sweetness preferences.

276 4.1 Gender, age and sweetness

277 Gender differences in liking for sweet foods, based on food names, were only a few in the Brits,
278 but clear and consistent in the young adult Finns: Finnish women scored higher than men for all
279 sweet items except sugared soft drinks and fruit juices. Note however that the British age group
280 17-39 years (closest to the age of Finnish respondents, 20-25 years), was similar to the Finns in
281 that women rated chocolate, sweets and fruits higher than men, and men rated the sugared soft
282 drinks higher than women. Contrary to the young adult Finns, the youngest British adult men and
283 women did not differ in their responses to ice cream, sweet desserts, and sweet pastry. Early

284 literature on young adult Finns (n=224) found that posed to food names, Finnish women rated
285 sweet foods higher than men did (Tuorila-Ollikainen, & Mahlamäki-Kultanen, 1985). This
286 corresponds to the present results with young Finnish adults and, partly, younger Brits. We could
287 tentatively conclude that gender differences in sweet product preferences are seen clearly in
288 young adulthood and diminish or disappear when people get older.

289 However, the present British data suggest that, when men grow older (>50 years), their
290 attachment to sweetness grows (displayed by heightened CSF) and they show heightened liking
291 for processed sweet foods. Such gender by age interaction in responses to sweetness has not been
292 reported earlier. It could either mean that for a physiological, psychological or psychosocial
293 reason, men develop heightened liking for sweetness in older age, or it may possibly derive from a
294 specific cohort effect. In the large web-based survey (n >40000), French men rated their liking for
295 sweet foods, added sugar, and natural sweetness higher than women did (Deglaire et al., 2015),
296 but both genders showed decreased liking for sweetness with older age (Lampure et al., 2015). In
297 their literature review, Issanchou and Nicklaus (2006) conclude that men, compared to women,
298 generally seem to prefer sweetness. The present gender by age interaction suggests a somewhat
299 more complex view.

300 In a cross-national data (Roininen et al., 2001), gender had a main effect on craving for sweet such
301 that Finnish and British women rated higher than Finnish and British men in CSF; that study did not
302 analyze the effect of age nor the gender by age interaction on CSF. The lower values of CSF at
303 older age were observed in a Finnish representative cross-sectional data (Roininen et al., 1999).
304 The extent to which craving for sweet (intense desire, see e.g., Pelchat, 1997) parallels or merges
305 liking for sweet can be questioned. However, the composite six-item instrument CSF used in the
306 operationalization of craving appears to capture liking for sweet items, as demonstrated by
307 relatively high correlations (0.44 for Brits, 0.52 for Finns) between CSF and liking for Goodies.

308 Culture was suggested as a possible explanation for differences in Japanese and Australian
309 responses to sweetness (Laing et al., 1994). Likewise there are major cultural, historical and
310 societal differences between European countries in the role and position of foods and meals
311 (Meiselman, 2009). For example, sweet confectionery has long been an intimate part of the British
312 food culture (James, 1990), while the Finnish food culture is rather characterized by powerful
313 nutrition policies (Prättälä, 2003). We may speculate that such differences affect the exposure and
314 attitudes towards sweet foods in gender specific ways. At this point of time and available

315 information from two European populations, we conclude that inclination to like sweetness or
316 sweet items is not strongly tied to biological sex or cultural gender. Rather, preference for sweet
317 may vary due to a complex interplay between inputs from biology and culture. Biology includes
318 factors such as genetics (“sweet tooth”) and physiological state, and culture includes e.g.,
319 availability of sweet items, affluence of society, and parenting practices.

320 Naturally sweet products (fruits, berries, and fruit juice) were highly liked by all respondents. In
321 both populations, women liked fruits and berries more than men did. Liking for fruits and berries
322 was unrelated to liking for sweet solution, and rather weakly associated with CSF (the association
323 was found in the Finnish data only). Furthermore, in the factor analysis naturally sweet items
324 formed their own, separated factor. Although sweet, fruits may not primarily be considered as
325 sweet items, or they form their own specific sub-category among sweet items. This view is
326 supported by the British analysis of responses to sweetness (Conner, & Booth, 1988), in which
327 factor scores of liking for sweet snacks were not correlated with those of liking for sweet
328 vegetables and fruit. Sweet fruits and vegetables are preferred foods for most primates
329 (Beauchamp, 2016), while industrially processed sweet foods are a very recent development and
330 hence the attraction to them is bound to be more culturally dependent.

331 British men rated their liking for aqueous sucrose solution higher than British women. No gender
332 differences in the corresponding ratings were observed in the Finns. Liking of the aqueous sweet
333 solution increased with age, but was accompanied by decreased perception of sweetness
334 intensity. A similar trend was found when elderly subjects rated orange drinks containing 8 to
335 23.5% sucrose (Zandstra, & De Graaf, 1998). In the course of age, Malaysian respondents rated
336 both the intensity and pleasantness of cola drinks lower (Thai et al., 2011). Decreasing sweetness
337 preference from the teenage to the adult age has been shown in a longitudinal study (Desor, &
338 Beauchamp, 1987), and 6-10-year old children preferred higher sweetness than their mothers
339 (Mennella et al., 2005). An earlier British study with an age range from childhood to 67 years
340 (Conner, & Booth, 1988) suggested less liking for a sweet drink the older the respondent; that
341 study did not examine gender by age effects. Taken together, sweetness in simple solutions (water
342 or beverage) attracts teenagers and younger more than adults, but sweetness may again be
343 attractive in older age, if the intensity is perceived weaker. Desor and Beauchamp (1987) propose
344 that this makes sense evolutionarily, as adolescents and young adults need energy for growth and
345 reproduction.

346 4.2 Do ratings of an aqueous sucrose solution predict liking for sweet foods?

347 Ratings of liking for the 20% aqueous solution of sucrose were only weakly correlated with liking
348 (based on product names) for Goodies and sugared soft drinks in both populations ($r = 0.13 -$
349 0.19). Among the Finns, they were also correlated with liking for juice, but again very weakly ($r =$
350 0.10). Although traditionally used in the measurement of sweetness preference (e.g., Esses, &
351 Herman, 1984; Desor, & Beauchamp, 1987; Mennella et al., 2005; Pepino, & Mennella, 2012;
352 Keskitalo et al., 2007a, 2008) and successfully used as a component of such measurements
353 (Keskitalo et al., 2007b), the aqueous sucrose solutions do not appear to be adequate surrogates
354 for sweet products in studies aiming to broadly define “sweet tooth”. Even when two sets of
355 sensory stimuli, water solution and jellies, were compared for the most preferred concentration of
356 sucrose, the correlation was only $r = 0.19$ (Mennella et al. 2014), and in case of water and pudding,
357 correlation was in adults $r = 0.23$ (Mennella et al., 2012). The advantage of sugar solutions,
358 compared to specific sweet foods and beverages, is their relative independence from the cultural
359 context which shapes preferences by repeated exposures to sweet foods (Rozin, 1982; Laing et al.,
360 1994; Prescott et al., 1997).

361 In a recent study, respondents tasted sucrose solutions and beverages and were clustered based
362 on hedonic rating patterns (Kim et al., 2014). In a cluster of respondents that particularly favored
363 high sweetness, ratings of the aqueous sweet solutions closely corresponded ratings of flavored
364 beverages; in two other clusters the associations were less clear (Kim et al., 2014). Furthermore,
365 these authors found only a few associations between each cluster and rated liking of sweet
366 products based on product names. Within the realm of sweetness there is a wide range of
367 different and unique products that appear to evoke consumer responses that are specific to each
368 product.

369 4.3 General Health Interest as a gatekeeper

370 GHI acted similarly in British and Finnish populations, being positively correlated with liking for
371 fruits and berries and negatively correlated with liking for sugared soft drinks. The correlations of
372 GHI with liking for Goodies, juice and sugar-free soft drinks were none or negligible. Thus, only
373 responses to products that have strong health-related connotations, positive (fruits) or negative
374 (sugared soft drinks) (Roininen, Lähteenmäki, & Tuorila, 2000), were influenced by GHI. In keeping
375 with the theory on attitude activation (Fazio, Sanbonmatsu, Powell, & Kardes, 1986), liking for
376 products with weaker health connotations was not controlled by GHI. We conclude that health

377 attitudes, here quantified by GHI, are capable of regulating the appeal to sweet products in
378 modern consumers.

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Kentän koodi muuttunut

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499 FIGURE LEGENDS

500 **Figure 1.** Mean (\pm SD) liking for sweet products by A. British men and women (n= 188 and 1667,
501 respectively) and B. Finnish men and women (n=594 and 698, respectively). Statistical difference
502 between genders: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

503 **Figure 2.** Mean liking for sweet products by age group (x-axis, 5 age groups) in British men and
504 women (n = 188 and 1667, respectively). "M" refers to grand mean for each product. A. Chocolate,
505 B. Ice cream, C. Sweet desserts, D. Sweet pastry, E. Sweets, F. Sugared soft drinks, G.
506 Unsugared/sugar-free soft drinks, H. Fruit juice, I. Fruits, J. Berries. SDs of individual data points
507 varied from 0.8 – 2.2.

508 **Figure 3.** Craving for Sweet Foods (means and SDs) by age group in British men (n=188) and
509 women (n=1667).

510 **Figure 4.** Liking (A) and intensity (B) ratings (mean \pm SD) of the sweet solution (20% sucrose) in
511 British men (n=102) and women (n=885), and in Finnish men (n = 186) and women (n = 282). LAM
512 scale is shown from dislike very much (DVM) to like very much (LVM) with neutral (not like nor
513 dislike = L/D) in the center. LMS scale is shown from zero to very strong intensity (W = weak, M =
514 moderate, S = strong, VS = very strong). Ratings are presented as arithmetic means (\pm SD).

515 Statistical difference between genders: ** $p < 0.01$.

516

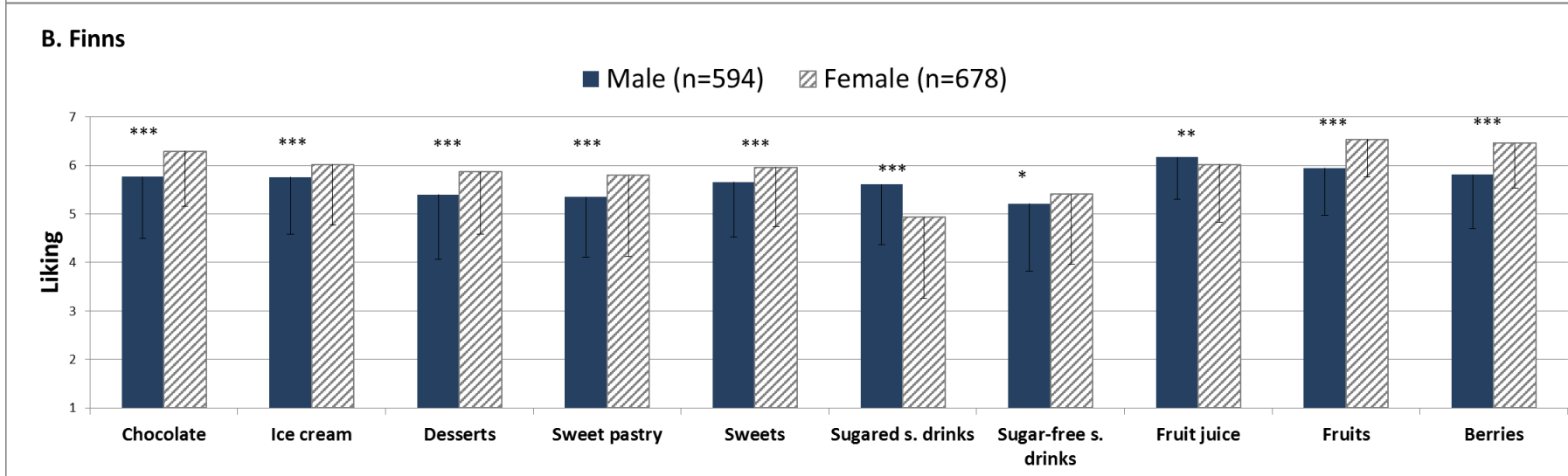
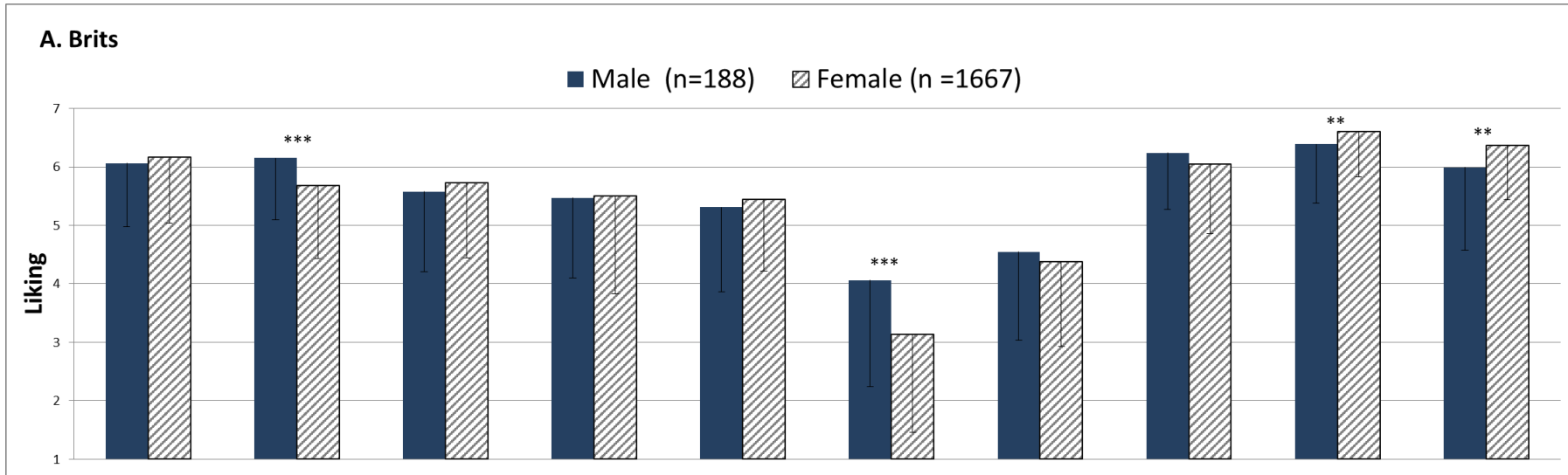


Figure 2

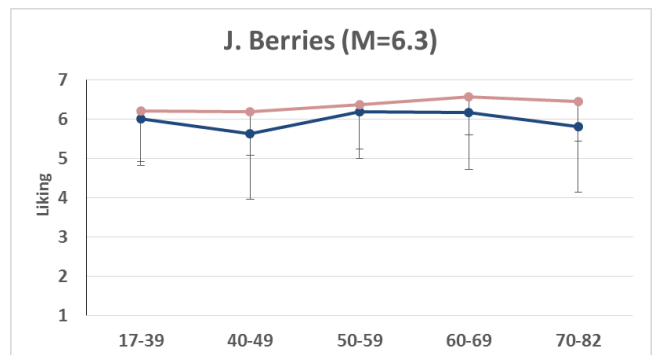
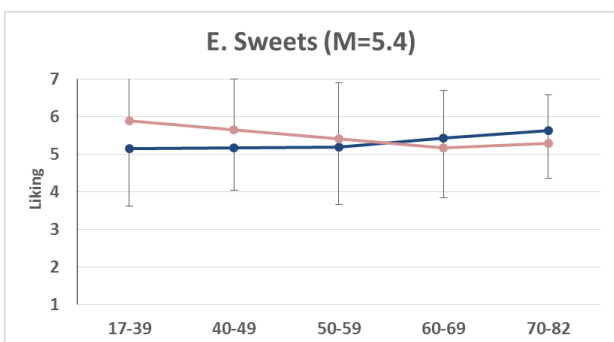
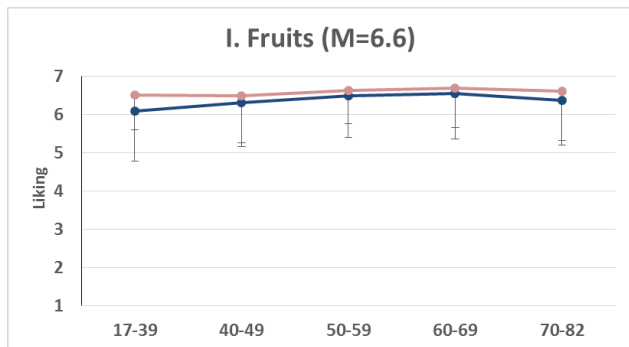
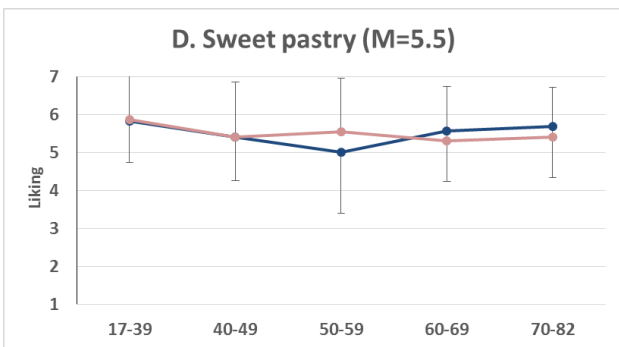
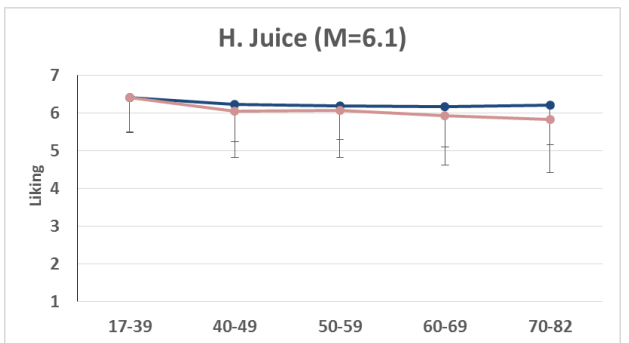
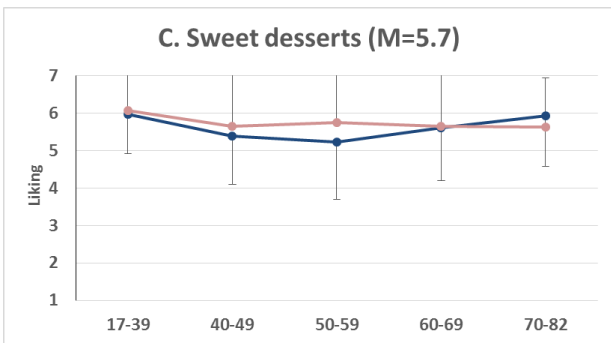
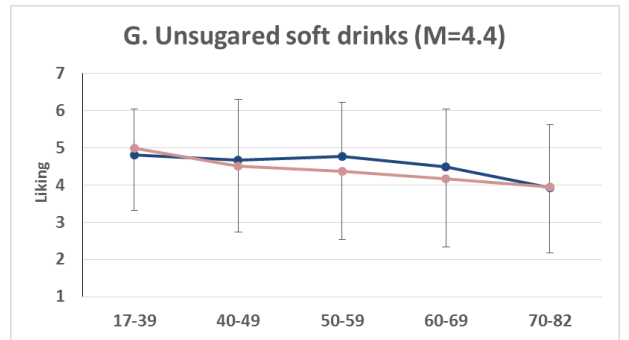
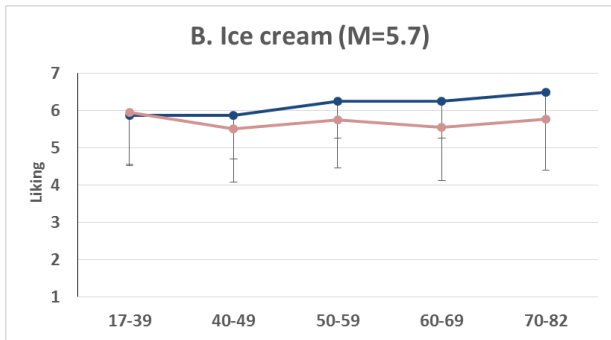
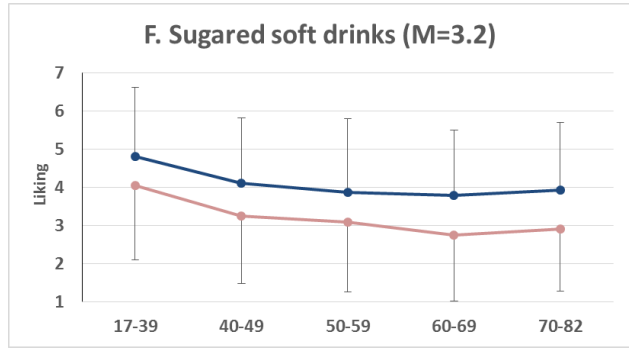
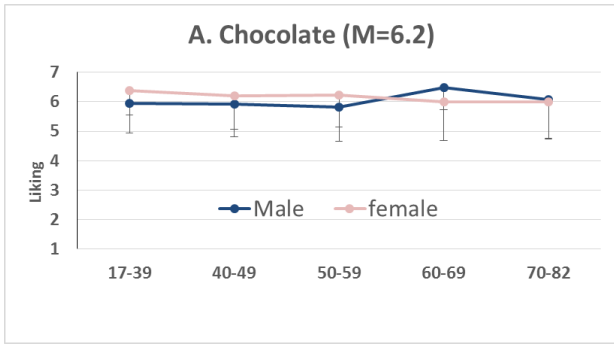


Figure 3

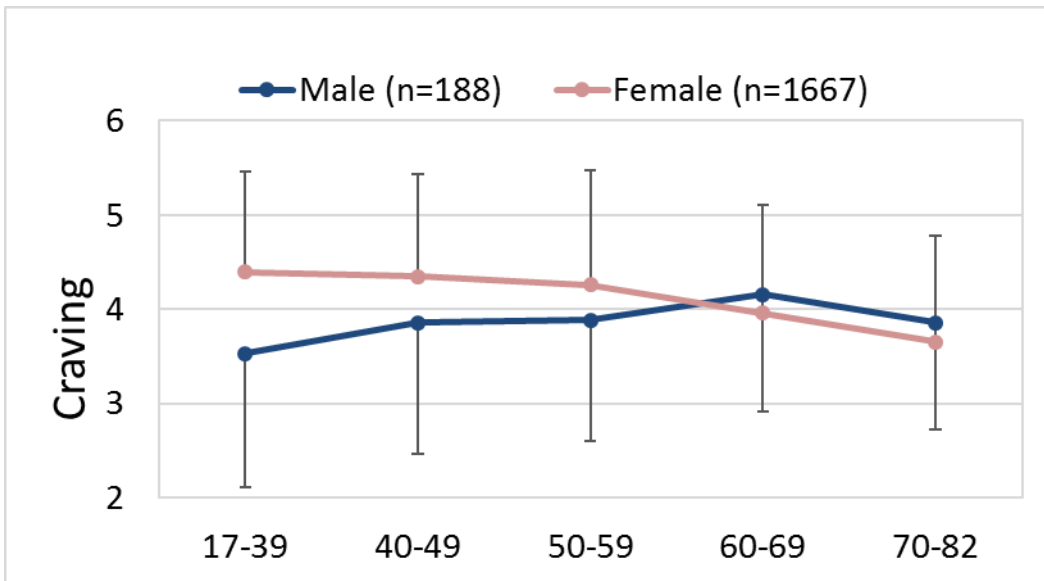


Figure 4

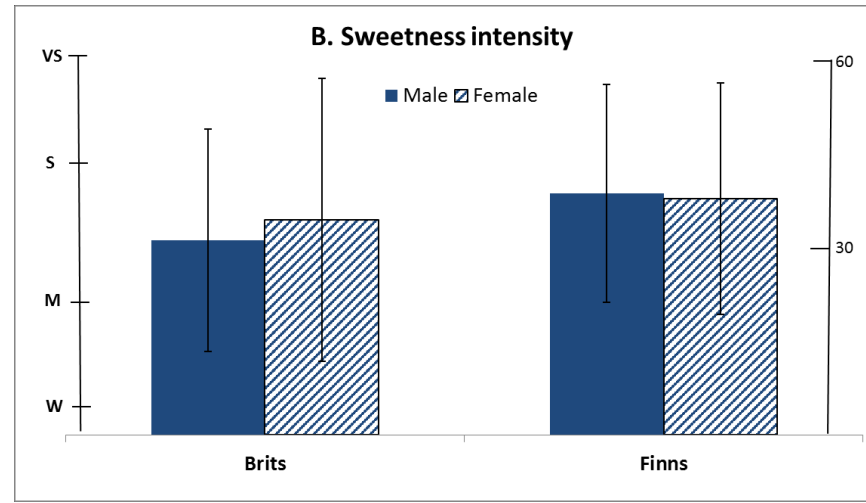
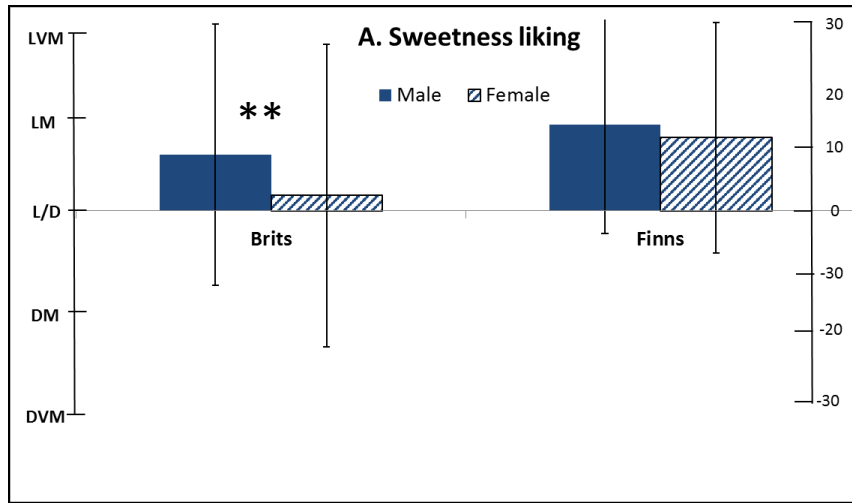


Table 1. Profiles of British and Finnish respondents. M+F refers to the number of males + females.

Background		Brits		Finns	
Characteristic	Categories	Questionnaire n = 1855 (M+F) (%)	Subgroup tasting sweet solution n =987 (M+F)	Questionnaire n = 1292	Subgroup tasting sweet solution n = 468
Sex	Male	188 <i>(10.1%)</i>	102 <i>(10.3%)</i>	594 <i>(46.0%)</i>	186 <i>(39.7%)</i>
	Female	1667 <i>(89.9%)</i>	885 <i>(89.7%)</i>	698 <i>(54.0%)</i>	282 <i>(60.3%)</i>
Age group (years)	17-39	242 (33+209) <i>(13.0%)</i>	122 (13+109) <i>(12.4%)</i>	1292 <i>(100%)</i>	468 <i>(100%)</i>
	40-49	306 (29+277) <i>(16.5%)</i>	149 (12+137) <i>(15.1%)</i>		
	50-59	623 (49+574) <i>(33.6%)</i>	332 (28+304) <i>(33.6%)</i>		
	60-69	501 (45+456) <i>(38.6%)</i>	279 (33+246) <i>(28.3%)</i>		
	70-82	183 (32+151) <i>(9.9%)</i>	105 (16+89) <i>(10.6%)</i>		

Table 2. Liking and use of sweet products grouped in factor analyses, varimax rotation, three factors F1 – F3; the variance of liking ratings explained at 65.2% in British (n=1855) and at 67.1% in Finnish (n=1255) data, and variance of use frequency explained 53.4% in British and 53.6% in Finnish data. The sweet items within a factor are organized by the order of magnitude in loadings of liking in the British data. Values >0.30 marked as **bold**.

	Liking for products						Use frequency of products					
	Brits			Finns			Brits			Finns		
<i>Factors</i>	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
<i>% variance explained</i>	31.2	17.9	16.0	32.9	17.9	16.3	23.7	15.7	14.0	25.6	14.0	13.9
Sweet desserts	0.89	0.08	0.09	0.88	0.11	0.16	0.82	0.10	0.03	0.76	0.15	0.15
Sweet pastry	0.84	0.07	0.09	0.88	0.09	0.14	0.74	0.08	0.02	0.77	0.09	0.09
Other sweets	0.76	-0.01	0.26	0.74	0.03	0.19	0.60	-0.23	0.24	0.72	0.10	-0.08
Chocolate	0.75	0.06	0.02	0.76	0.10	0.08	0.65	-0.12	0.02	0.71	-0.01	0.01
Ice cream	0.61	0.14	0.26	0.71	0.19	0.21	0.53	0.20	0.21	0.56	0.07	0.05
Berries	0.07	0.88	-0.00	0.18	0.89	0.01	0.03	0.80	0.01	0.14	0.06	0.77
Fruits	0.10	0.88	0.04	0.12	0.90	0.11	0.01	0.79	0.03	0.01	0.06	0.76
Sugar-free soft drinks	0.07	0.06	0.80	0.18	0.07	0.58	0.02	-0.02	0.73	0.08	0.46	0.19
Sugared soft drinks	0.29	-0.22	0.70	0.23	-0.21	0.76	0.29	-0.31	0.60	0.21	0.68	-0.37
Juice	0.12	0.41	0.57	0.06	0.25	0.76	0.07	0.31	0.64	0.01	0.82	0.10

Table 3. Mean (SD) ratings of liking for “other” (non-sweet) 26 foods rated by British (n=1855) and Finnish (n=1292) respondents, listed according to descending mean rating of liking of Brits.

Product	Brits (n = 1855)		Finns (n = 1292)	
	Mean	<i>SD</i>	Mean	<i>SD</i>
Fresh vegetables	6.6	0.8	5.9	1.2
Cooked vegetables	6.6	0.9	5.2	1.6
Chicken or turkey	6.4	1.2	6.2	1.7
Cooked or smashed potatoes	6.1	1.2	6.2	1.8
Meat dishes	6.1	1.4	6.2	2.6
Eggs	6.0	2.1	5.5	1.9
Rice or pasta	6.0	1.3	6.1	2.1
Tea	5.9	1.7	5.2	1.6
Fried potatoes or French fries	5.8	1.3	5.7	1.3
Yoghurt	5.8	1.6	5.8	1.3
Semi-skimmed milk	5.7	1.6	5.4	1.6
Salmon or rainbow trout	5.6	1.9	5.9	1.6
Coffee	5.4	1.8	5.2	2.0
Salty snacks	5.4	1.5	5.9	1.2
Salad dressings	5.1	1.6	5.0	1.5
Other cheeses	5.1	2.0	5.9	1.9
Pizza	5.0	1.6	6.2	1.0
Liquorice	4.9	1.9	5.7	1.3
Creamy foods	4.7	1.6	5.3	1.4
Reduced-fat cheeses	4.4	1.7	5.1	1.5
Fried foods	4.2	1.8	4.9	1.8
Skimmed milk	4.1	2.1	5.6	1.7
Blue cheese	4.0	2.4	4.2	3.4
Full fat milk	3.7	2.2	3.5	1.9
Hamburgers	3.7	1.9	5.8	1.3
Pickled herring	2.8	2.1	3.1	2.2
Mean	5.2	1.0	5.4	0.8

Table 4. Ratings of liking and intensity of sweet solution by age groups in the British respondents, means and standard deviations (SD) are shown. Liking ratings (LAM scale) from -60 to +60, -60 = greatest imaginable dislike, 0 = don't dislike nor like, +60 = greatest imaginable like; intensity ratings (LMS scale) from 0 to 120, 60 = very strong, 120 = greatest imaginable sensation. Within a column, letters a, b, or c shared by cells denote that values are not statistically different.

Age group (years)	n	Liking		Intensity	
		Mean	<i>SD</i>	Mean	<i>SD</i>
17-39	121	3.1ab	25.9	41.4a	23.6
40-49	148	-2.6a	24.9	35.4ab	22.1
50-59	330	2.2ab	22.7	32.9abc	22.0
60-69	278	4.9b	23.4	31.6bc	20.0
70-82	105	8.9b	20.6	28.1c	21.7

Table 5. Correlations (Pearson's r) of responses to sweetness with a) liking for sucrose solution, b) Craving for Sweet Foods (CSF), and c) General Health interest (GHI) in British and Finnish respondents. Values significant at $p < 0.05$, $p < 0.01$, and $p < 0.001$ marked with *, **, and ***, respectively.

Variable	Liking for sucrose solution		Craving for Sweet Foods		General Health Interest	
	Brits (n = 987)	Finns (n = 468)	Brits (n = 1855)	Finns (n = 1292)	Brits (n = 1855)	Finns (n = 1292)
Craving for Sweet Foods	0.07*	0.06				
General Health Interest	- 0.05	-0.03	0.02	0.08**		
Goodies	0.19***	0.13*	0.44***	0.52***	-0.04	0.04
Fruits	0.05	0.01	0.03	0.16*	0.29***	0.33***
Juice	0.04	0.10**	0.12**	0.07*	0.03	- 0.07*
Sugared soft drinks	0.16***	0.15**	0.13**	0.09**	-0.27***	-0.31***
Sugar-free soft drinks	0.05	0.08	0.15***	0.16***	0.02	0.08*