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1 **LIKING AND CONSUMPTION OF VEGETABLES WITH MORE APPEALING AND LESS APPEALING SENSORY**
2 **PROPERTIES: ASSOCIATIONS WITH ATTITUDES, FOOD NEOPHOBIA AND FOOD CHOICE MOTIVATIONS IN**
3 **EUROPEAN ADOLESCENTS**

4

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25

26 **Declaration of Interests:** None

27

28 **HIGHLIGHTS**

29 The unappealing sensory properties of vegetables may contribute to low intakes

30 Vegetables with more and less appealing sensory properties were compared

31 Higher vegetable intakes were associated with higher liking & healthier eating habits

32 Liking differed for vegetables with more and less appealing sensory properties

33 Strategies to increase intakes may benefit from focussing liking & healthy eating

34

35 **ABSTRACT**

36 Vegetable consumption in adolescents is reported to be low, at least in part, due to the unappealing
37 sensory properties of vegetables, such as bitter tastes, but not all vegetables have unappealing sensory
38 properties, and strategies to improve consumption may benefit from wider consideration. This work aimed
39 to understand the individual characteristics in adolescents from four European countries associated with
40 the regular consumption and liking of vegetables with more appealing and less appealing sensory
41 properties. Adolescents from Denmark (N=178), the UK (N=155), France (N=206) and Italy (N=197)
42 completed self-report questionnaires to assess all variables. We found higher self-reported consumption
43 and liking of vegetables with more appealing than less appealing sensory properties. Regular consumption
44 of both types of vegetable was associated with healthier eating habits and a higher liking for each vegetable
45 type. Liking for vegetables with more appealing sensory properties was higher in individuals with lower
46 food neophobia, healthier eating habits, higher interest in consuming foods for sensory reasons and higher
47 liking for vegetables with less appealing properties. Liking for vegetables with less appealing sensory
48 properties was higher in individuals with lower food neophobia, higher concern for the consumption of
49 natural foods, and higher liking for vegetables with more appealing properties. Some gender and country-
50 specific differences were also found. Our findings suggest that strategies to increase vegetable
51 consumption in adolescents should focus on increasing healthy eating in general, increasing vegetable
52 liking, and may benefit from reducing food neophobia and enhancing the positive sensory and natural
53 aspects of vegetables.

54

55 **Keywords:** vegetables, taste, individual characteristics, demographic characteristics

56

57

58 **1. INTRODUCTION**

59 A high vegetable consumption is associated with many health benefits (Appleton, Hemingway, Saulais, et
60 al., 2016; Aune, Giovannucci, Boffetta, et al., 2017; Oyedobe, Gordon-Dseagu, Walker & Mindell, 2014;
61 Wang, Ouyang, Liu, et al., 2014; Woodside, Young & McKinley, 2013), yet vegetable consumption across
62 Europe and the world remain lower than recommended for health reasons (EFSA, Vereecken, Pedersen,
63 Ojala, et al., 2015).

64

65 Vegetable consumption is reported to be particularly low in adolescence (EFSA, 2008; Vereecken et al.,
66 2015). EFSA report mean intakes across 25 European countries that range from 26g/day in Sweden to
67 227g/day in Poland, and Vereecken et al., 2015 report daily vegetable intakes in between only 20%
68 (Estonia) and 54% adolescents (Belgium) in 33 European countries. Dietary intakes in adolescence are
69 important. Adolescence is a period of rapid development, from physical, cognitive and social perspectives,
70 when food choice also becomes under more individual control (Mikkila, Rasanen, Raitakari, Pietinen &
71 Viikari, 2005; Nu, MacLeod & Barthelemy, 1996; Story, Neumark-Sztainer & French, 2002), and when the
72 development of eating habits can become established and sustained (Larson, Neumark-Sztainer, Harnack,
73 Wall, Story & Eisenberg, 2008; Li & Wang 2008; Mikkila et al, 2005; Von Post-Skagegard, Samuelson,
74 Karlstrom, Mohsen, Berglund & Bratteby, 2002).

75

76 Many reasons have previously been given for low vegetable consumption in adolescence. Environmental
77 and societal factors continue to impact considerably on adolescents, as is found for children (Gebremariam,
78 Henjum, Terragni & Torheim, 2016; Giskes, Turrell, Patterson & Newman, 2002; Larson et al., 2008;
79 Middlestadt et al., 2013; Trude, Kharmats, Hurley, Anderson Steeves, Talegawkar & Gittelsohn, 2016). Low
80 vegetable consumption in adolescents has been associated with low parental education and socio-
81 economic status (Gebremariam et al, 2016; Giskes et al, 2002; Middlestadt et al, 2013), low vegetable
82 consumption by the parents (Gebremariam et al, 2016; Middlestadt et al, 2013), low availability in the
83 home and a family environment that is unsupportive of vegetable consumption (Gebremariam et al, 2016;
84 Larson et al, 2008; Middlestadt et al, 2013; Trude et al, 2016).

85

86 Taste, texture, and liking can also be important in adolescents, as is found for children (Cox, Melo, Zabaraz,
87 Delahunty, 2012; Dinehart, Hayes, Bartoshuk, Lanier & Duffy, 2006; Dinnella et al., 2016; Krolner,
88 Rasmussen, Burg, Klepp, Wind & Due, 2011; Larson et al., 2008; Middlestadt et al., 2013). Vegetables are
89 often reported to be poorly liked and so poorly consumed due to unappealing tastes, such as bitter and
90 sour (Cox et al., 2012; Dinehart et al., 2006; Dinnella et al., 2016; Krolner et al., 2011), and unappealing
91 textures, such as slimy, granular and hard / hard-skinned (Dinnella et al., 2016; Krolner et al., 2011;
92 Zeinstra, Koelen, Kok & de Graaf, 2010). Not all vegetables however have unappealing tastes and textures.
93 Many vegetables are considered more sweet-tasting than bitter-tasting by both trained and consumer
94 panels (Cox et al., 2012; Martin, Visalli, Lange, Schlich & Issanchou, 2014; van Stokkom, Teo, Mars, de
95 Graaf, van Kooten & Stieger, 2016), and some vegetables have pleasant textures and bright colourful visual
96 appeal (Dinnella et al., 2016; Poelman, Delahunty & de Graaf, 2017). Vegetables with more appealing
97 properties offer micronutrients and so health benefits, although the health benefits of different vegetables
98 are known to differ (Appleton et al, 2016). There is some suggestion that less appealing dark leafy green
99 vegetables have greater health benefits in general, but ideally a range of vegetables and so a combination
100 of vegetables with more appealing and less appealing sensory properties should be consumed for health
101 benefits (Appleton et al., 2016; Aune et al., 2017; Oyedobe et al., 2014; Wang et al., 2014; Woodside et al.,
102 2013).

103

104 Individual cognitions, such as attitudes, beliefs and understanding, also gain increasing importance in the
105 eating habits of adolescents. Vegetable consumption in adolescents has been associated with an awareness
106 of food knowledge and the importance of vegetables for health (Middlestadt et al., 2013; Trude et al.,
107 2016), increased self-efficacy for healthy eating (Gebremariam et al., 2016; Trude et al., 2016) and a
108 willingness and ability to ask for vegetables from parents (Middlestadt et al., 2013). The data by Vereecken
109 et al., 2015, however show lower vegetable intakes in 15 year olds compared to 13 years olds, and lower
110 intakes in 13 year olds compared to 11 year olds (Vereecken et al., 2015).

111

112 Other studies demonstrate the importance of sensory characteristics in the consumption of vegetables, and
113 demonstrate distinctions between vegetables based on taste properties (Cox et al., 2012; Dinehart et al.,
114 2006; Dinnella et al., 2016). Dinnella et al., 2016, for example, find carrots, tomatoes and green salad to be
115 characterized by sweet, umami and delicate flavours, while cauliflower and broccoli were characterised by
116 bitter tastes and objectionable flavours. Van Stokkom et al., 2016, find the majority of vegetables in their
117 study to be characterised by a sweet taste, while tomato products were characterized more by umami and
118 sour tastes, and onion and leek juices were more characterized by bitter tastes. Few studies have focussed
119 on adolescents. Focussing on vegetables of differing sensory properties and individual adolescent
120 cognitions may offer opportunities for targeting and increasing adolescent vegetable consumption.
121 Strategies to increase vegetable consumption in adolescents are sorely needed (Appleton et al., 2016), but
122 these strategies should be based on the determinants or barriers to vegetable consumption on a
123 population-wide basis. Interventions that either address challenges or maximise facilitators will have
124 increased chances of success compared to those without a similar theoretical underpinning (Craig, Dieppe,
125 Macintyre, Michie, Nzareth & Petticrew, 2008; Michie, van Stralen & West, 2011). Furthermore,
126 interventions that focus on challenges or facilitators that impact on a large proportion of the population
127 will be of increased impact on a population-wide scale (Craig et al., 2008). This work aimed to investigate
128 the individual characteristics associated with the regular consumption and liking of vegetables with both
129 more appealing and less appealing sensory properties in adolescents from four European countries.

130

131 2. METHOD

132 Data were collected as part of the VeggiEAT project, an EU-funded project aiming to understand and
133 increase vegetable intakes in adolescents and older adults from four European countries – from North to
134 South: Denmark, the United Kingdom, France and Italy. These countries represent different European
135 cultures, cuisines and consumption patterns, particularly with respect to vegetables (EFSA, 2008; Pelt,
136 1993). In Italy, for example, raw and salad vegetables are frequently consumed, while the traditional diet in
137 the UK contains more cooked and more root vegetables (EFSA, 2008). The proportion of adolescents eating

138 vegetables daily are also reported to be low in these countries. Figures range from 45% in France, 42% in
139 Denmark, 38% in England to only 25% in Italy (Vereecken et al., 2015).

140

141 Data to assess the regular consumption of a number of vegetables, liking for vegetables and various
142 individual characteristics that may impact on vegetable consumption were assessed using self-report
143 questionnaires.

144

145 **2.1. Questionnaire**

146 The questionnaire assessed various demographic characteristics, self-reported regular consumption of
147 various vegetables, liking for various vegetables, and individual attitudes to food consumption, in that
148 order.

149

150 **2.1.1. Demographic characteristics:** The demographic characteristics assessed were gender, age, country of
151 residence, and social affluence. Social affluence was assessed using the four questions and scoring system
152 of the Family Affluence Scale (FAS II) developed by Boyce and Dallago (2004): 'Does your family own a car,
153 van or truck?', answers 'no' (score 0), 'yes, one car or van' (score 1), 'yes, more than one car or van' (score
154 2); 'Do you have your own bedroom for yourself?', answers 'no' (score 0), 'yes' (score 1); 'How many
155 computers does your family own? (Do not include playstations or other computers that can only be used
156 for games)', answers 'none' (score 0), 'one' (score 1), 'two' (score 2), 'more than two' (score 3); 'During the
157 past 12 months, how many times did you travel away on holiday with your family?' answers 'not at all'
158 (score 0), 'once' (score 1), 'twice' (score 2), 'more than twice' (score 3). Answers to all questions were
159 summed to result in a score from 0 (low affluence) to 9 (high affluence).

160

161 **2.1.2. Regular vegetable consumption:** Regular vegetable consumption was assessed by asking for
162 consumption of 11 vegetables that are used in all four European countries (EFSA, 2008): 'broccoli', 'carrots',
163 'cauliflower', 'green beans', 'green salad', 'peas', 'spinach', 'sweetcorn', 'tomatoes', 'courgettes', and
164 'beans, other than green beans'. These 11 vegetables were chosen due to differences in a number of

165 sensory properties (Poelman et al., 2017; Zeinstra et al., 2010), different uses in the different cuisines of the
166 four European countries (EFSA, 2008; Pelt, 1993), and with consideration for other aspects of the larger
167 VeggiEAT project. Vegetables were classified into two groups according to their sensory properties, based
168 on the ratings of consumer and trained panels (Baxter, Schroder & Bower, 2000; Engel, Martin & Issanchou,
169 2006; Poelman et al., 2017; Zeinstra, Koelen, Kok & de Graaf, 2007). Of the 11 vegetables, 'carrots', 'peas',
170 'sweetcorn', and 'tomatoes' were classified as vegetables with more appealing sensory properties, due to
171 the presence of a sweet taste, delicate flavour and bright appealing colour, while 'broccoli', 'cauliflower',
172 'green salad', and 'spinach' were classified as vegetables with less appealing sensory properties. These
173 vegetables are typically characterized by generally disliked sensory properties such as bitter taste,
174 astringent sensation, objectionable flavour and dark unattractive colour. Three vegetables - 'courgettes',
175 'green beans' and 'beans, other than green beans' typically receive similar ratings for sweet and bitter taste
176 and neutral ratings for visual appeal, so were not assigned to either group. The question on consumption
177 was included as part of a measure asking individuals to report their combined knowledge and frequency of
178 consumption for all 11 vegetables developed by Backstrom, Pirttila-Backman & Tuorila (2004). This
179 questionnaire describes combined knowledge and frequency of consumption increasing from lexical / visual
180 knowledge, to a taste experience not associated with consumption, to frequency of consumption using the
181 categories: 'I do not recognize the product'; 'I recognize the product, but I have not tasted it'; 'I have
182 tasted, but I do not use the product'; 'I occasionally eat the product'; and 'I regularly eat the product'
183 (Backstrom et al., 2004). Responses to the option 'I regularly eat this' were summed to provide number of
184 vegetables with more appealing sensory properties (of 4) and number of vegetables with less appealing
185 sensory properties (of 4) that were regularly consumed.

186

187 **2.1.3. Liking:** Liking was assessed for each of the 11 vegetables above, on an individual basis using a nine-
188 point scale ranging from 'I don't like it at all' (score 1) to 'I neither like it nor don't like it' (score 5) to 'I like it
189 a lot' (score 9). Scores were then summed across all 4 vegetables with more appealing sensory properties
190 and all 4 vegetables with less appealing sensory properties for analysis, to provide a score per vegetable
191 type from 4 (very low liking) – 36 (very high liking).

192

193 **2.1.4. Attitudes:** Individual attitudes towards food consumption were assessed using four published
194 questionnaires. The Adolescent Food Habits Checklist (AFHC) (Johnson, Wardle & Griffith, 2002) provides a
195 measure of healthy eating in adolescents based on self-reported food choices using 23 items requesting
196 agreement or disagreement with a number of dietary practices. Response options include true (score 1 for
197 a healthy behavior, 0 for a less healthy behavior), false (score 1 for a healthy behavior, 0 for a less healthy
198 behavior), or not applicable (score 0), and are summed to result in a single score from 0 (less healthy
199 dietary habits) to 23 (more healthy dietary habits). The Restraint Scale of the Dutch Eating Behaviour
200 Questionnaire (DEBQ-R) (van Strien, Frijters, Bergers & Defares, 1986) allows an assessment of restricted
201 eating for weight control using 10 items asking for frequency of several weight control behaviours.
202 Response options range from never (score 1) to very often (score 5), and are averaged across all questions
203 to result in a single score from 1 (low restraint) to 5 (high restraint). The Food Neophobia Scale (FNS) (Pliner
204 & Hobden, 1992) assesses reluctance to try new or unfamiliar foods using 10 items requesting agreement
205 or disagreement with a number of statements on new or unfamiliar foods. Response options range from
206 strongly disagree (score 1) to strongly agree (score 7) on a 7 point scale, and are summed across all
207 questions to result in a single score from 10 (low neophobia) to 70 (high neophobia). The Food Choice
208 Questionnaire (FCQ) (Steptoe, Pollard & Wardle, 1995) measures a range of motivations underlying eating
209 behavior and food choice. Three scales were used – those based on eating for mood-based reasons (6
210 items), eating for sensory-based reasons (4 items), and concern for eating natural foods / products (3
211 items). Items requested agreement or disagreement with a number of motivations for eating, using
212 response options ranging from strongly disagree (score 1) to strongly agree (score 7) on a 7 point scale, and
213 are averaged across all questions to result in a single score from 1 (low motivation) to 7 (high motivation).
214 These three scales were chosen to reflect the motivations for food choice over which adolescents aged 12-
215 16 years have control, that were not assessed with the other questionnaires. All questionnaires were
216 demonstrated as reliable and validated at the time of development. Cronbach's alpha's for the responses in
217 this study ranged from xx to xx. All questions were translated from English into relevant languages and back
218 translated to ensure accurate translations. All questionnaires are frequently used to assess eating related

219 attitudes and various studies demonstrate their applicability across countries and cultures (Brunault et al.,
220 2015; Fotopoulos, Krystallis, Vassallo & Pagisalis, 2009; Januszewska, Pieniak & Verbeke, 2011;
221 Monteleone et al., 2017; Pieniak, Verbeke, Vanhonacker, Guerrero & Hersleth, 2009; Ritchey, Frank, Hursti
222 & Tuorila, 2003).

223

224 **2.2. Questionnaire Administration**

225 Questionnaires were administered in paper form either following a separate task assessing the sensory
226 characteristics of several different pea and sweetcorn samples (see Dinnella et al., 2016), or via teachers
227 and researchers as an independent study. Where tasks were undertaken, these were undertaken
228 separately from completing the questionnaire, and are very unlikely to have had any impact on
229 questionnaire responses. Using both types of recruitment, for inclusion in the study, individuals were
230 required to be aged 12 – 16 years, and able to fully understand and complete the consent procedures and
231 questionnaires. This age range was selected to typify adolescents as individuals with some choice over their
232 food intake, but where the choice remains limited for various reasons, such as the home environment,
233 parental expectations, and limited incomes. Individuals over the age of 16 years, who are no longer living at
234 home may demonstrate food choices more similar to those of adults resulting in a less distinctive sample
235 and less informative investigation. No other inclusion / exclusion criteria were used to enhance the
236 generalisability of the study findings. All participants provided written informed consent from themselves
237 and from a parent / guardian prior to taking part. Researchers were available to answer questions if
238 requested. The study was approved by the Research Ethics Committees of the University of Copenhagen,
239 Denmark, Bournemouth University, UK, Institut Paul Bocuse, France, and the University of Florence, Italy,
240 prior to commencement.

241

242 Questionnaires were administered until a sample size of at least 150 participants was gained per country,
243 as required for the analyses we wished to conduct (Cohen, 1998). A minimum of 150 participants would
244 allow the detection of an effect size of 0.15 in a regression analysis using 14 predictors, at a power of 0.80,
245 for a significance level of 0.05.

246

247 **2.3. Analysis**

248 Questionnaires with 10% missing data or more were discarded. Where less than 10% data per respondent
249 were missing, missing data were imputed using mid-scale point values where scales were used (e.g. for
250 attitudes) or means for the country sample where no scale was used, e.g. age. Less than 3% of all data
251 points were imputed, thus data imputation is likely to have had a minimal impact on our results while
252 allowing use of more of the available data.

253

254 Study samples were then described and investigated using ANOVA. General characteristics of vegetable
255 consumption and liking were investigated using correlations and ANOVA. Regular consumption of
256 vegetables with more appealing sensory properties and vegetables with less appealing sensory properties
257 and liking for both types of vegetables were then predicted using regression models. Consumption
258 outcomes were predicted using all demographic characteristics (gender, age, affluence (FAS II score), and
259 country of residence), all individual attitudes (AFHC score, DEBQ-R score, FNS score, and FCQ – Mood, FCQ
260 – Sensory and FCQ – Naturalness scores), and liking for both types of vegetables. Country was considered
261 on an individual basis with respect to France. As a result, France can not be included in the regression
262 models. We chose to consider all countries with respect to France because the sample size from France was
263 the largest. Effects per country should be considered 'with respect to France' not as independent effects.

264 Liking outcomes were predicted using the same demographic characteristics and individual attitudes.

265 Correlations were first run to ensure against multi-co-linearity, and no high correlations between predictor
266 variables were found (largest $r=0.46$, $p<0.01$). All analyses were conducted in SPSS, version 23 (IBM,
267 Armonk, NY, USA).

268

269 **3. RESULTS**

270 Descriptive statistics for all individual characteristics and attitudes, and for vegetable consumption and
271 liking for each country sample are provided in Table 1. Significant differences between countries were
272 found in all individual characteristics and attitudes (smallest $F(3,735)=6.96$, $p<0.01$).

273

274 Taking all countries together, adolescents reported regularly consuming significantly more vegetables with
275 more appealing sensory properties than vegetables with less appealing sensory properties
276 ($F(1,732)=388.12, p<0.01$), and consumption of both types of vegetables was higher in France > Denmark >
277 UK and Italy ($F(3,732)=9.55, p<0.01$). Adolescents also reported liking vegetables with more appealing
278 sensory properties more than vegetables with less appealing sensory properties ($F(1,732)=374.15, p<0.01$),
279 and liking for both types of vegetables was higher in Denmark > France > UK > Italy ($F(3,732)=38.19,$
280 $p<0.01$). Liking for both types of vegetables were also correlated with each other ($r=0.46, p<0.01$).

281

282 Table 1 about here

283

284 Individual characteristics and attitudes associated with the regular consumption of both types of vegetables
285 are given in Table 2. **Taking other variables into account**, regular consumption of vegetables with more
286 appealing sensory properties was lower in Denmark, and higher in individuals with healthier eating habits
287 and with a higher liking for vegetables with less appealing sensory properties. A regular consumption of
288 vegetables with less appealing sensory properties was also lower in Denmark, and was higher in individuals
289 with healthier eating habits, and with a higher liking for vegetables with more appealing sensory properties.

290

291 Table 2 about here

292

293 Individual characteristics and attitudes associated with liking both types of vegetables are given in Table 3.
294 **Taking other variables into account**, liking for vegetables with more appealing sensory properties was
295 higher in males, and in Denmark and Italy, and was higher in individuals with a lower food neophobia,
296 healthier eating habits, a higher interest in consuming foods for sensory reasons and in individuals with a
297 higher liking for vegetables with less appealing sensory properties. Liking for vegetables with less appealing
298 sensory properties was higher in females and in Denmark, and was higher in individuals with a lower food

299 neophobia, a higher concern for the consumption of natural foods, and a higher liking for vegetables with
300 more appealing sensory properties.

301

302 Table 3 about here

303

304 **4. DISCUSSION**

305 Adolescents reported regularly consuming more vegetables with more appealing sensory properties, than
306 with less appealing sensory properties. This finding has been demonstrated previously (Cox et al., 2012;
307 Dinehart et al., 2006; Dinnella et al., 2016; Krolner et al., 2011). However, for both types of vegetables,
308 regular consumption was lower in Denmark, and was higher in individuals with healthier eating habits, and
309 in individuals with a higher liking for each type of vegetable respectively.

310

311 While consumption was higher for vegetables with more appealing sensory properties, the comparability
312 between vegetable types in the associations is interesting, and suggests associations with vegetable
313 consumption in general as opposed to with the consumption of specific vegetables. Associations between a
314 higher vegetable consumption, healthier eating habits in general and a higher liking for other vegetables
315 have been demonstrated across the lifespan (e.g. Glasson, Chapman & James, 2011; Mikkila et al., 2005),
316 and our study confirms these associations in adolescents from across Europe (Gebremarian et al., 2016;
317 Johnson et al., 2002; Krolner et al., 2011; Larson et al., 2008; Middlestadt et al., 2013), and suggests that
318 regular vegetable consumption is part of a healthy diet, even in adolescents. Liking is also a well-known
319 predictor of food consumption across the lifespan (Appleton, 2006; Appleton, McGill, Neville & Woodside,
320 2010; Appleton et al., 2017; Brug, Tak, te Velde, Bere & de Bourdeudhuij, 2008; Glasson et al., 2011;
321 Mingioni et al., 2016), and some work has previously suggested a likely increased importance of liking for
322 food consumption in young individuals, such as adolescents (Appleton et al., 2016, Cox et al., 2012;
323 Dinehart et al., 2006; Krolner et al., 2011).

324

325 Importantly also, these factors - liking and healthy eating habits are potentially malleable. Several studies
326 demonstrate the value of a number of strategies for increasing vegetable liking (Appleton et al, 2016).
327 Repeated exposure, the use of rewards and the provision of positive education or experiences have all
328 been found to increase liking for vegetables (Appleton, Hemingway, Rajska & Hartwell, 2018; Appleton et
329 al, 2016; Nicklaus, 2016; Wadhwa, Capaldi-Philips & Wilkie, 2015). Furthermore, while many studies have
330 so far been conducted in children, success using these techniques for increasing liking and preferences for
331 foods in other age-groups has also been demonstrated (Appleton, 2013; Appleton, Gentry & Shepherd,
332 2006; Mobini, Chambers & Yeomans, 2007), including in adolescents (Ratcliffe, Merrigan, Rogers &
333 Goldberg, 2011). The clustering of healthy eating habits to include the consumption of vegetables among a
334 diet of other more healthy food items, also testifies to the benefit of strategies to increase healthy eating in
335 general. Studies again demonstrate the value of interventions that focus not just on increasing vegetable
336 preferences and consumption, but also on increasing preferences and the consumption of other healthy
337 foods, and a general interest in a healthy diet (e.g. deCosta et al., 2017; Maderuelo-Fernandez et al., 2015;
338 Savoie-Roskos, Wengreen & Durward, 2017; Zhou et al., 2018).

339

340 Adolescents also reported higher liking for vegetables with more appealing sensory properties than for
341 those with less appealing sensory properties, as has again been demonstrated previously (Cox et al., 2012;
342 Dinehart et al., 2006; Dinnella et al., 2016; Krolner et al., 2011). Comparability was again found between
343 the vegetable types. Liking for both types of vegetables was associated with a lower food neophobia, and a
344 higher liking for the other vegetables. Lower food neophobia has been repeatedly reported in association
345 with increased vegetable liking and consumption (Guzek, Glabska, Lange & Jewewska-Zychomicz, 2017;
346 Laureati et al., 2018; Mielby, Norgaard, Edelenbos & Thybo, 2012; Mustonen, Oerlemans & Tuorila, 2012;
347 Russell & Worsley, 2008). Lower food neophobia has also been linked to increased variety within the diet
348 (Falciglia, Couch, Gribble, Pabst & Frank, 2000), and increased preferences for and an increased
349 consumption of different foods and different tastes (Flight, Leppard & Cox, 2003; Mielby et al., 2012).
350 These findings suggest that strategies to increase vegetable liking may benefit from decreasing food
351 neophobia. Lower food neophobia has been found to be associated with a higher exposure to different

352 cuisines and cultural diversity (Flight et al., 2003; Mustonen et al., 2012), and there is some evidence that
353 educational interventions can reduce food neophobia to some degree (e.g. Park & Cho, 2016). The
354 associations between vegetable types also suggest that adolescents who like vegetables with both more
355 and less appealing sensory properties typically like a range of vegetable tastes, and again may suggest a
356 liking for vegetables in general and a clustering of healthy eating preferences.

357

358 Differences in liking for vegetables based on their sensory characteristics were also found. Liking for
359 vegetables with more appealing sensory properties was associated again with healthier eating habits, and
360 with higher food choice motivations based on sensory reasons, and liking for vegetables with less appealing
361 sensory properties was associated with higher interests in the consumption of natural foods. The
362 association with healthier eating habits suggests again an interest in healthy eating in general, but it is
363 interesting that this was found only for the vegetables with more appealing sensory properties. This may
364 suggest a greater tolerance for the inclusion of vegetables with more appealing sensory properties into a
365 healthy diet, and may suggest greater chances of increasing healthy diets by focussing on foods with more
366 appealing sensory properties. Furthermore, the sensory component of the Food Choice Questionnaire
367 involves smell, taste and appearance (Steptoe et al, 1995), and characteristics other than taste may be
368 contributing to the higher liking for the more appealing vegetables in this study. Preferences have been
369 found for foods with bright appealing colours (Dinnella, Torri, Caporale & Monteleone, 2014; Salles,
370 Nicklaus & Septier, 2003; Varming et al., 2004), and for foods that are highly familiar through widespread
371 use and consumption (Dinnella et al, 2016; Poelman & Delahunty, 2011; Poelman, Delahunty & de Graaf,
372 2015). The taste intensities of vegetables have also been reported as low compared to those for other
373 foods (van Stokkom et al., 2016). Sensory food choice motives have previously been linked positively to
374 improved personal health (Steptoe et al, 1995). Our findings suggest that strategies to promote liking for
375 vegetables with more appealing sensory properties may benefit from a focus on (all) sensory properties, or
376 from enhancement of these properties. Studies that enhance taste, through the addition of salt and/or
377 sweet compounds are demonstrating some success (Bouhlal et al., 2013; Sharafi, Hayes & Duffy, 2013),

378 although complete dietary profiles also need to be considered. Studies that enhance visual appearance
379 however have also demonstrated increases in intakes (Correia, O'Connell, Irwin & Henderson, 2014).

380

381 An interest in consuming natural foods has previously been linked to increased fruit and vegetable
382 consumption (Pollard, Steptoe & Wardle, 1998), and organic food consumers typically consume more plant-
383 based foods (Baudry et al., 2015; Kesse-Guyot et al., 2013) and are more likely to be vegetarian (Baudry et
384 al., 2015). Natural and organic food consumption has previously been found to be highly correlated with
385 healthy eating (Steptoe et al., 1995; Kesse-Guyot et al., 2013). Based on our findings, strategies to increase
386 preferences for vegetables with less appealing sensory properties may benefit from a focus on the natural
387 aspects of these foods. Promotion of the natural aspects of vegetables will apply to all vegetables, and may
388 be beneficial for all vegetable consumption, but associations here suggest specific benefit for vegetables
389 with less appealing sensory properties. Considering the increased health benefits from consuming a range
390 of vegetables, promotion of vegetables with less appealing sensory properties, that may be less likely
391 consumed by choice, may be particularly valuable for health (Appleton et al. 2016; Aune et al. 2017;
392 Oyedobe et al. 2014; Wang et al. 2014; Woodside et al. 2013).

393

394 A suggestion to focus on the sensory aspects of foods with more preferred sensory profiles and to focus on
395 other positive aspects of foods with less appealing sensory profiles is a direct novel result of this work. This
396 finding adds weight to previous arguments for a multitude of reasons for food choice (Steptoe et al., 1995),
397 and suggests the need for a variety of strategies to increase healthy food intakes.

398

399 Demographic differences were also found in our study. Liking for vegetables with more appealing sensory
400 properties was higher in males, and in Denmark and Italy, and liking for vegetables with less appealing
401 sensory properties was higher in females and in Denmark. Higher preferences in males for vegetables with
402 more appealing sensory properties is a novel finding. These findings suggest that the promotion of
403 vegetables with more appealing sensory properties - with sweeter tastes, more delicate flavours and
404 brighter colours may be a more promising route for increasing vegetable consumption in males particularly.

405 A higher liking and / or consumption of vegetables by females compared to males has previously been
406 found (Baudry et al., 2015; Guzek et al., 2017; Johnson et al., 2002; Kesse-Guyot et al., 2013; Mikkila et al.,
407 2005; Pollard et al., 1998), and has previously been attributed to an increase in healthy eating or attitudes
408 towards healthy eating in females (Johnson et al., 2002; Mikkila et al., 2005, Monteleone et al., 2017).
409
410 Country-specific differences are likely to result, at least partly, from different cultures and consumption
411 practices (Pelt, 1993), but differences may also have been found here as a result of differences between the
412 samples based on demographic or individual variables that were not taken into account (e.g. parental
413 education (Mustonen et al., 2012), PROP sensitivity (Sharafi et al., 2013)), or differences between
414 participants in their use or understanding of the rating scales or questionnaire items (Harzing et al., 2009).
415 Particularly, the concept of 'regular' may differ between cultures, resulting in different interpretations of
416 this question. This latter concern may specifically explain the reported higher liking but lower consumption
417 of both types of vegetables by the Danish sample, when other variables were taken into account. This
418 effect was masked when looking at simple group differences, presumably due to other differences between
419 the samples, e.g. in terms of demographic characteristics. This effect however is also reported in broader
420 studies on consumption, where more Northern European countries typically consume less vegetables than
421 more Southern European countries (EFSA, 2008; Vereecken et al., 2015). These effects are largely
422 attributed to culture, climate and agricultural practices (Pelt, 1993), and may suggest an increased need for
423 interventions to increase vegetable consumption in countries that are further North.

424
425 The strengths of the study include the consideration of a large sample size in each of the four European
426 countries, the use of validated work to describe our vegetables based on sensory properties, and the use of
427 validated questionnaires for all individual characteristics. The study is limited by the use of self-report
428 questionnaires, and the use of rating scales that may not have been used in a comparable manner between
429 countries (Harzing et al., 2009). Although self-report measures are commonly used in questionnaire studies
430 of dietary behaviours, and brief measures have been reported as valid methods for measuring vegetable
431 intake (Mainvil, Horwath, McKenzie & Lawson, 2011; Wolfe, Frongillo & Cassano, 2001), these measures

432 can be prone to inaccuracies and biases such as social desirability bias (Bingham, 1987). We also assessed
433 liking for and consumption of only four vegetables with more appealing sensory properties and four
434 vegetables with less appealing sensory properties, and although these vegetables were selected as those
435 consumed in the four European countries, and were intended to allow comparisons between countries, we
436 do recognize that different vegetables taste different (Dinnella et al., 2016; van Stokkom et al., 2016), thus
437 different findings may have occurred had we used different specific vegetables. Tastes can differ also
438 dependent on agricultural practices and preparation styles (Poelman & Delahunty 2011; Poelman et al.,
439 2015; van Stokkom et al., 2016), thus differences between countries may genuinely arise. While these
440 differences may have resulted in slight differences in absolute ratings, however, there is no reason to
441 suspect any systematic bias in the associations between vegetable liking or consumption and individual
442 attitudes based on our measures. The low comparability between country samples also limits the cross-
443 country conclusions that can be made. This variability between samples however, does not reduce the
444 value of the findings from our main analyses. Importantly however, while this work was conducted to
445 suggest strategies to increase vegetable intakes, it must be recognised that our data are cross-sectional
446 only and thus relationships may be bidirectional or may be influenced by additional variables. High
447 vegetable intake may result in high vegetable liking as a result of exposure to positive experiences, or high
448 vegetable availability may result in both high vegetable liking and high vegetable intakes through
449 familiarity. Our suggested strategies are suggestions only – any intervention would need full testing before
450 it can be recommended.

451
452 In conclusion, our findings demonstrate higher consumption of and liking for vegetables with more
453 appealing sensory properties than for vegetables with less appealing sensory properties in European
454 adolescents. Greater regular consumption of both types of vegetables was found in individuals with
455 healthier eating habits, and in individuals with a higher liking for each type of vegetable. Liking for both
456 types of vegetables was associated with lower food neophobia and higher liking for other vegetable tastes,
457 and liking for vegetables with more appealing sensory properties specifically was associated with healthier
458 eating habits in general and a higher interest in consuming foods for sensory reasons and liking for

459 vegetables with less appealing sensory properties specifically was associated with a higher interest in the
460 consumption of natural foods. Our findings suggest that strategies to increase vegetable consumption in
461 adolescents may benefit from focusing on increasing healthy eating in general, and increasing vegetable
462 liking. Increasing liking may benefit from strategies that reduce food neophobia, focus on sensory
463 properties, or focus on the natural properties of vegetables.

464

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767 Table 1: Descriptive statistics (mean value (standard deviation)) for all individual characteristics, attitudes,
 768 vegetable consumption and vegetable liking for each country sample.
 769

	Denmark (N=178)	UK (N=155)	France (N=206)	Italy (N=197)	Total (N=736)
Gender (% female:male)	58:42 ^a	43:57 ^b	59:41 ^a	44:56 ^b	51:49
Age (years)	15.4 (1.3) ^a	13.3 (1.4) ^b	13.1 (1.0) ^b	15.1 (1.2) ^c	14.3 (1.6)
FAS II ¹ score (0-9)	6.5 (1.4) ^a	6.2 (1.9) ^a	7.1 (1.5) ^b	5.8 (1.6) ^c	6.4 (1.7)
AFHC ² Index (0-23)	12.1 (4.4) ^a	11.0 (4.4) ^b	13.1 (4.2) ^c	11.0 (4.6) ^b	11.9 (4.5)
DEBQ-R ³ score (1-5)	2.3 (0.9) ^a	2.2 (0.9) ^a	2.4 (0.9) ^{a,c}	2.6 (0.9) ^{b,c}	2.4 (0.9)
FNS ⁴ Neophobia score (10-70)	26.6 (11.2) ^a	36.5 (8.4) ^b	31.9 (11.7) ^c	32.7 (11.0) ^c	31.8 (11.3)
FCQ ⁵ – Mood (1-7)	4.5 (1.2) ^a	4.1 (1.2) ^b	3.6 (1.4) ^c	4.2 (1.4) ^{b,d}	4.1 (1.4)
FCQ ⁵ – Sensory (1-7)	5.5 (1.1) ^a	5.4 (1.1) ^a	5.1 (1.4) ^b	4.2 (2.1) ^c	5.0 (1.6)
FCQ ⁵ – Natural (1-7)	4.7 (1.4) ^a	4.3 (1.2) ^b	4.5 (1.5) ^{a,b}	4.1 (1.6) ^{b,c}	4.4 (1.5)
Number of 'more appealing' vegetables consumed regularly (0-4)	1.9 (1.2) ^a	1.9 (1.1) ^a	2.4 (1.2) ^b	1.6 (1.2) ^c	1.9 (1.2)
Number of 'less appealing' vegetables consumed regularly (0-4)	1.2 (1.0) ^a	0.9 (0.9) ^b	1.2 (0.9) ^{a,c}	1.1 (1.0) ^{a,c}	1.1 (1.0)
Liking for 'more appealing' vegetables (1-9)	6.9 (1.5) ^a	6.2 (1.4) ^b	7.2 (1.4) ^{a,c}	5.8 (1.8) ^d	6.5 (1.6)
Liking for 'less appealing' vegetables (1-9)	6.2 (1.6) ^a	4.9 (1.6) ^b	5.3 (1.9) ^c	4.6 (1.8) ^{b,d}	5.2 (1.9)

770 ¹ – Family Affluence Scale II (Boyce and Dallago, 2004)

771 ² - The Adolescent Food Habits Checklist (AFHC) (Johnson et al, 2002)

772 ³ - The Dutch Eating Behaviour Questionnaire - Restraint Scale (DEBQ-R) (van Strien et al, 1986)

773 ⁴ - The Food Neophobia Scale (FNS) (Pliner & Hobden, 1992)

774 ⁵ - The Food Choice Questionnaire (FCQ) (Stephoe et al, 1995)

775 Superscripts denote differences between countries – different letters reflect significant differences

776 between countries.

777

778 Table 2: Characteristics and attitudes associated with the regular consumption of 'more appealing' and 'less
 779 appealing' vegetables (N=736). Significant predictors (p<0.05) are highlighted in bold.
 780

	'More appealing' vegetables		'Less appealing' vegetables	
	R=0.60, R ² =0.36, adj. R ² =0.35, F(14,735)=28.86, p<0.01		R=0.56, R ² =0.31, adj. R ² =0.30, F(14,735)=23.23, p<0.01	
	Beta	p	Beta	p
Gender	-.04	.22	-.05	.15
Age	-.01	.96	.06	.15
Denmark	-.10	.03	-.12	.01
UK	.01	.79	-.04	.28
Italy	-.04	.38	.07	.14
FAS II ¹ score	.05	.15	.06	.08
AFHC ² Index	.13	<.01	.10	.01
DEBQ-R ³ score	-.01	.79	.01	.79
FNS ⁴ Neophobia score	-.05	.16	-.03	.38
FCQ ⁵ – Mood	-.01	.90	-.01	.71
FCQ ⁵ – Sensory	.00	.99	.02	.57
FCQ ⁵ – Natural	-.04	.32	.01	.85
Liking for 'more appealing' vegetables	.54	<.01	.01	.73
Liking for 'less appealing' vegetables	-.02	.60	.50	<.01

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783 ³ - The Dutch Eating Behaviour Questionnaire - Restraint Scale (DEBQ-R) (van Strien et al, 1986)

784 ⁴ - The Food Neophobia Scale (FNS) (Pliner & Hobden, 1992)

785 ⁵ - The Food Choice Questionnaire (FCQ) (Stephoe et al, 1995)

786

787 Table 3: Characteristics and attitudes associated with liking for 'more appealing' and 'less appealing'
 788 vegetables (N=736). Significant predictors (p<0.05) are highlighted in bold.
 789

	'More appealing' vegetables		'Less appealing' vegetables	
	R=0.57, R ² =0.32, adj. R ² =0.31, F(13,735)=26.62, p<0.01		R=0.61, R ² =0.37, adj. R ² =0.36, F(13,735)=33.08, p<0.01	
	Beta	p	Beta	p
Gender (1=female, 2=male)	.07	.03	-.09	<.01
Age	.04	.40	.06	.15
Denmark	.09	.02	.15	<.01
UK	.08	.07	.07	.08
Italy	.31	<.01	-.02	.67
FAS II ¹ score	-.03	.45	.03	.42
AFHC ² Index	.10	<.01	.07	.06
DEBQ-R ³ score	.02	.50	-.03	.36
FNS ⁴ Neophobia score	-.11	<.01	-.25	<.01
FCQ ⁵ – Mood	-.01	.86	.07	.06
FCQ ⁵ – Sensory	.12	<.01	.02	.62
FCQ ⁵ – Natural	.02	.61	.09	<.01
Liking for 'less appealing' / 'more appealing' vegetables	.35	<.01	.33	<.01

790 ¹ – Family Affluence Scale II (Boyce and Dallago, 2004)

791 ² - The Adolescent Food Habits Checklist (AFHC) (Johnson et al, 2002)

792 ³ - The Dutch Eating Behaviour Questionnaire - Restraint Scale (DEBQ-R) (van Strien et al, 1986)

793 ⁴ - The Food Neophobia Scale (FNS) (Pliner & Hobden, 1992)

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