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

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HIGHLIGHTS

- The unappealing sensory properties of vegetables may contribute to low intakes
- Vegetables with more and less appealing sensory properties were compared
- Higher vegetable intakes were associated with higher liking & healthier eating habits
- Liking differed for vegetables with more and less appealing sensory properties
- Liking was linked with food neophobia, sensory and natural food choice motives

ABSTRACT

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

Keywords: vegetables, taste, individual characteristics, demographic characteristics

1. INTRODUCTION

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

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

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

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

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

111 Other studies demonstrate the importance of sensory characteristics in the consumption of vegetables, and
112 demonstrate distinctions between vegetables based on taste properties (Cox et al., 2012; Dinehart et al.,
113 2006; Dinnella et al., 2016; Van Stokkom et al., 2016). Dinnella et al., 2016, for example, find carrots and
114 tomatoes to be characterized by sweet, umami and delicate flavours, while cauliflower and broccoli were
115 characterised by bitter tastes and objectionable flavours. Van Stokkom et al., 2016, find the majority of
116 vegetables in their study to be characterised by a sweet taste, while tomato products were characterized
117 more by umami and sour tastes, and onion and leek juices were more characterized by bitter tastes. Few
118 studies have focussed on adolescents. Focussing on vegetables with differing sensory properties and
119 individual adolescent cognitions may offer opportunities for targeting and increasing adolescent vegetable
120 consumption. Strategies to increase vegetable consumption in adolescents are sorely needed (Appleton et
121 al., 2016), but these strategies should be based on the determinants or barriers to vegetable consumption
122 on a population-wide basis. Interventions that either address challenges or maximise facilitators will have
123 increased chances of success compared to those without a similar theoretical underpinning (Craig, Dieppe,
124 Macintyre, Michie, Nzareth & Petticrew, 2008; Michie, van Stralen & West, 2011). Furthermore,
125 interventions that focus on challenges or facilitators that impact on a large proportion of the population
126 will be of increased impact on a population-wide scale (Craig et al., 2008). This work aimed to investigate
127 the individual characteristics associated with the regular consumption and liking of vegetables with both
128 more appealing and less appealing sensory properties in adolescents from four European countries.
129
130 **2. METHOD**
131 Data were collected as part of the VeggiEAT project, an EU-funded project aiming to understand and
132 increase vegetable intakes in adolescents and older adults from four European countries – from North to
133 South: Denmark, the United Kingdom, France and Italy. These countries represent different European
134 cultures, cuisines and consumption patterns, particularly with respect to vegetables (EFSA, 2008; Pelt,
135 1993). In Italy, for example, raw and salad vegetables are frequently consumed, while the traditional diet in
136 the UK contains more cooked and more root vegetables (EFSA, 2008). The proportion of adolescents eating

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

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

2.1. Questionnaire

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

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

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

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

2.1.3. Liking: Liking was assessed for each of the 11 vegetables above, on an individual basis using a nine-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 a lot' (score 9). Scores were then summed across all 4 vegetables with more appealing sensory properties and all 4 vegetables with less appealing sensory properties for analysis, to provide a score per vegetable type from 4 (very low liking) – 36 (very high liking).

2.1.4. Attitudes: Individual attitudes towards food consumption were assessed using four published questionnaires. The Adolescent Food Habits Checklist (AFHC) (Johnson, Wardle & Griffith, 2002) provides a measure of healthy eating in adolescents based on self-reported food choices using 23 items requesting agreement or disagreement with a number of dietary practices. Response options include true (score 1 for a healthy behavior, 0 for a less healthy behavior), false (score 1 for a healthy behavior, 0 for a less healthy behavior), or not applicable (score 0), and are summed to result in a single score from 0 (less healthy dietary habits) to 23 (more healthy dietary habits). The Restraint Scale of the Dutch Eating Behaviour Questionnaire (DEBQ-R) (van Strien, Frijters, Bergers & Defares, 1986) allows an assessment of restricted eating for weight control using 10 items asking for frequency of several weight control behaviours. Response options range from never (score 1) to very often (score 5), and are averaged across all questions to result in a single score from 1 (low restraint) to 5 (high restraint). The Food Neophobia Scale (FNS) (Pliner & Hobden, 1992) assesses reluctance to try new or unfamiliar foods using 10 items requesting agreement or disagreement with a number of statements on new or unfamiliar foods. Response options range from strongly disagree (score 1) to strongly agree (score 7) on a 7 point scale, and are summed across all questions to result in a single score from 10 (low neophobia) to 70 (high neophobia). The Food Choice Questionnaire (FCQ) (Steptoe, Pollard & Wardle, 1995) measures a range of motivations underlying eating behavior and food choice. Three scales were used – those based on eating for mood-based reasons (6 items), eating for sensory-based reasons (4 items), and concern for eating natural foods / products (3 items). Items requested agreement or disagreement with motivations for eating, using response options ranging from strongly disagree (score 1) to strongly agree (score 7) on a 7 point scale, and are averaged across all questions to result in a single score from 1 (low motivation) to 7 (high motivation). These three scales were chosen to reflect the motivations for food choice over which adolescents aged 12-16 years have control, that were not assessed by the other questionnaires. All questionnaires were demonstrated as reliable and validated at the time of development. Cronbach's alpha's for the responses on questionnaires using continuous scales in this study ranged from 0.80 to 0.88. All questions were translated from English into relevant languages and back translated to ensure accurate translations. All questionnaires are

frequently used to assess eating related attitudes and various studies demonstrate their applicability across countries and cultures (Brunault et al., 2015; Fotopoulos, Krystallis, Vassallo & Pagisaslis, 2009; Januszewska, Pieniak & Verbeke, 2011; Monteleone et al., 2017; Pieniak, Verbeke, Vanhonacker, Guerrero & Hersleth, 2009; Ritchey, Frank, Hursti & Tuorila, 2003).

2.2. Questionnaire Administration

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

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

245

246 **2.3. Analysis**

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

252

253 Study samples were then described and investigated using ANOVA. General characteristics of vegetable
254 consumption and liking were investigated using correlations and ANOVA. Regular consumption of
255 vegetables with more appealing sensory properties and vegetables with less appealing sensory properties
256 and liking for both types of vegetables were then predicted using regression models. Consumption
257 outcomes were predicted using all demographic characteristics (gender, age, affluence (FAS II score), and
258 country of residence), all individual attitudes (AFHC score, DEBQ-R score, FNS score, and FCQ – Mood, FCQ
259 – Sensory and FCQ – Naturalness scores), and liking for both types of vegetables. Country was considered
260 on an individual basis with respect to France. The countries can only be included in the regression models
261 with respect to another country (as we essentially have no zero), so we can not include them all. As a
262 result, France can not be included in the regression models. We chose to consider all countries with respect
263 to France because the sample size from France was the largest. Effects per country should be considered
264 'with respect to France' not as independent effects. Liking outcomes were predicted using the same
265 demographic characteristics and individual attitudes. Correlations were first run to ensure against multi-co-
266 linearity, and no high correlations between predictor variables were found (largest $r=0.46$, $p<0.01$). All
267 analyses were conducted in SPSS, version 23 (IBM, Armonk, NY, USA).

268

269 **3. RESULTS**

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

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

Table 1 about here

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

Table 2 about here

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

higher liking for vegetables with less appealing sensory properties. Liking for vegetables with less appealing sensory properties was higher in females and in Denmark, and was higher in individuals with a lower food neophobia, a higher concern for the consumption of natural foods, and a higher liking for vegetables with more appealing sensory properties.

Table 3 about here

4. DISCUSSION

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

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

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

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

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

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

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

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

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

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

A higher liking and / or consumption of vegetables by females compared to males has previously been found (Baudry et al., 2015; Guzek et al., 2017; Johnson et al., 2002; Kesse-Guyot et al., 2013; Mikkila et al., 2005; Pollard et al., 1998), and has previously been attributed to an increase in healthy eating or attitudes towards healthy eating in females (Johnson et al., 2002; Mikkila et al., 2005, Monteleone et al., 2017).

Country-specific differences are likely to result, at least partly, from different cultures and consumption practices (Pelt, 1993), but differences may also have been found here as a result of differences between the samples based on demographic or individual variables that were not taken into account (e.g. parental education (Mustonen et al., 2012), PROP sensitivity (Sharafi et al., 2013)), or differences between participants in their use or understanding of the rating scales or questionnaire items (Harzing et al., 2009). Particularly, the concept of 'regular' may differ between cultures, resulting in different interpretations of this question. This latter concern may specifically explain the reported higher liking but lower consumption of both types of vegetables by the Danish sample, when other variables were taken into account. This effect was masked when looking at simple group differences, presumably due to other differences between the samples, e.g. in terms of demographic characteristics. This effect however is also reported in broader studies on consumption, where more Northern European countries typically consume less vegetables than more Southern European countries (EFSA, 2008; Vereecken et al., 2015). These effects are largely attributed to culture, climate and agricultural practices (Pelt, 1993), and may suggest an increased need for interventions to increase vegetable consumption in countries that are further North.

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

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

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

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

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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) (Steptoe 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 (1=female, 2=male)	-.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**

781 [1] – Family Affluence Scale II (Boyce and Dallago, 2004)

782 [2] - The Adolescent Food Habits Checklist (AFHC) (Johnson et al, 2002)

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) (Steptoe et al, 1995)

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

	'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**

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

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

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

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

[5] - The Food Choice Questionnaire (FCQ) (Steptoe et al, 1995)