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Attentional bias for vegetables is negatively associated with acceptability and is related to sensory properties

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ABSTRACT

Understanding why many individuals dislike vegetables is relevant to develop effective strategies to change food behaviors promoting healthier choices. The influences of sensory properties in the development of food preferences are well known. Attention as well may play a role in this process. Indeed, attention enhances information processing of emotionally salient objects or events by selecting them from the environmental context in which they are embedded.

This study was aimed at investigating the relationship between acceptability of vegetables, food neophobia and taste responsiveness (measured as responsiveness to 6-n- propylthiouracil-PROP) and the attentive responses to vegetables that differ in sensory properties. 120 adults (20–24 years old, 74.2% women) were recruited and characterized for Food Neophobia and PROP responsiveness. To assess the interferences between emotional and attentional processes a food version of the Emotional Stroop Task was used. Attentional bias was measured through reaction times (RTs) to word stimuli, which included 16 vegetables characterized by generally appealing (e.g. ‘sweetness’, ‘mildness’) or unappealing (e.g. ‘bitterness’, ‘astringency’) sensory properties, and 16 emotionally neutral objects presented as control.

A clear association between vegetable liking scores and sensory properties was found in this study, confirming the categorization of appealing and unappealing vegetables.

Furthermore, results showed significantly higher RTs for vegetables than for neutral objects, demonstrating that vegetables were more emotionally salient than objects. Furthermore, the interference scores, computed as the differences between average RTs to unappealing/appealing vegetable words and average RTs to neutral words, for vegetables with unappealing sensory properties were higher than those for vegetables characterized by appealing sensory properties, indicating a greater attentional bias for unappealing vegetables. A strong inverse correlation between liking scores and RTs ($r = -0.83$) was found.

No effect of food neophobia and PROP status was found on interferences scores, while PROP supertasters showed higher RTs for vegetables in general.

The study showed that attention is particularly grabbed by vegetables with unappealing sensory properties, thus indicating that attention play a role in vegetable acceptability.

1. Introduction

The health benefits provided from a high consumption of plant-based foods is well known (Wang et al., 2014; Woodside, Young, & McKinley, 2013). Intake of dark green leafy vegetables have been associated with reduced risk for type II diabetes (Appleton et al., 2016; Cooper et al., 2012; Li, Fan, Zhang, Hou, & Tang, 2014), reduced risk of a number of cancers (Liu et al., 2012; Masala et al., 2012; Takata et al., 2013) and with a reduced depression (Tsai, Chang, & Chi, 2012). Furthermore, beta-carotene-rich, yellow and red-pigmented vegetable consumption is also associated with a reduced risk of cancers (Liu et al., 2012; Masala et al., 2012; Takata et al., 2013).

Although all these benefits, in the last decades a global dietary transition with an increase of animal-based diet was registered at the

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expense of a plant-based diet (Popkin, Adair, & Ng, 2012). Vegetable consumption remains below the World Health Organization recommendations worldwide. According to recommendations, individual consumption of vegetables should be at least 160–240 g or 2–3 portions per day (World Health Organization, 2003; World Health Organization, 2005). However, not every vegetable is consumed with the same frequency. Taste, appearance and texture are important drivers for the acceptability of vegetables (Appleton et al., 2016). In fact, sensory properties which characterize some vegetables, such as bitterness, may constitute a barrier to the consumption of plant-based products (Appleton et al., 2019; Cox, Melo, Zabaras, & Delahunty, 2012; Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006; Dinnella et al., 2016; Krølner et al., 2011).

Cognitive processes, like attention, have a crucial impact on food behaviors (Werthmann et al., 2011) and intake (Overduin, Jansen, & Louwerse, 1995) regulating the processing of what is perceived through the senses, including chemosensory stimuli (White, Thomas-Danguin, Olofsson, Zucco, & Prescott, 2020).

According to the biased competition theory of attention, sensory processing is influenced both by bottom-up factors, such as the physical salience of the stimuli (for instance, determined by its color, shape, etc.) and by top-down mechanisms, such as the incentive salience of stimuli, for example, the goal relevance (Horstmann, 2015); Deco & Rolls, 2005; Garcia-Burgos, Lao, Munsch, & Caldara, 2017; White et al., 2020). In sensory science, the bottom-up mechanisms have been widely considered, especially in studies on product evaluation, while the role of the individual cognitive processes has been only little explored (White et al., 2020).

Food cues are particularly effective at grabbing attention and may induce an attentional bias that is defined as "the tendency for specific types of stimuli (e.g., food-related pictures and words) to capture and/or hold the attention" (Field et al., 2016, p. 768). According to the incentive-sensitization theory, an increased attention to food cues may be the result of repeated associations of reward from food intake and food cues that predict future caloric intake (Berridge, 2009). This suggests that attentional bias may help to establish and maintain eating disorders and other forms of appetitive behaviors (Albery, Michalska, Moss, & Spada, 2020; Harrison, Sullivan, Tchanturia, & Treasure, 2010; Schmitz, Naumann, Trentowska, & Svaldi, 2014). Literature on obese populations and in general on eating-disorder patients, is contradictory, with some studies suggesting that obese and eating-disorders individuals report an increased attentional approach bias to food cues and others not, when compared to healthy-weight participants (Hagan, Alasmar, Exum, Chinn, & Forbush, 2020; Hardman et al., 2021; Johansson, Ghaderi, & Andersson, 2005; Werthmann, Jansen, & Roefs, 2015). Field et al. (2016) proposed that attentional bias should be seen as the expression of momentary motivational evaluation of the stimuli rather than a stable trait, and this may explain why it can be associated both with positive (when the incentive value is high) and negative (when there is a motivation to change the behavior) or can even be ambivalent.

An attentional bias toward foods (both appetizing and less appetizing) was found also in non-clinical samples; even in this case the results are conflicting as an attentional bias was found to be associated with an increased hedonic motivation, but also to negative emotions, such as worry, especially within overweight or restrained samples (Werthmann et al., 2015; Hardman et al., 2021). Selective attention to foods was found in external eaters – people more sensitive to appetitive qualities of foods (Brignell, Griffiths, Bradley, & Mogg, 2009; Hepworth, Mogg, Brignell, & Bradley, 2010; Hou et al., 2011) and overweight restrained eaters (Meule, Vögele, & Kübler, 2012; Veenstra, De Jong, Koster, & Roefs, 2010; Werthmann et al., 2013). It has been reported that attentional resources are preferentially directed to high caloric foods when compared to neutral stimuli even in normal-weight individuals (Harrar, Toepel, Murray, & Spence, 2011; Toepel, Ohla, Hudry, le Coutre, & Murray, 2014). Attentional bias was found to predict future intake even in a non-clinical sample: a longitudinal study with graduated individuals showed that an attentional bias toward healthy or unhealthy foods predicted, respectively, a decrease or increase in BMI (Calitri, Pothos, Tapper, Brunstrom, & Rogers, 2010).

Attention can enhance the information processing of emotionally salient objects or events (Desimone & Duncan, 1995) by selecting them from the environmental context in which they are embedded (Corbetta & Shulman, 2002). The emotional meaning of stimuli can bias the attention: individuals can direct and maintain the attention on objects and events which are congruent to their emotional state (Mathews & MacLeod, 2005). In fact, it is widely confirmed that attentional biases have been associated with stimulus salient/threat, in particular in individuals with high anxiety but also in presence of a phobia (MacLeod, Mathews, & Tata, 1986). In general, phobias have been reported to be associated with avoidance of threat-related stimuli (Cisler & Koster, 2010). From this perspective, it seems that attentional mechanisms are more easily captured by threatening/emotionally negative stimuli than positive ones in those populations (LeDoux, 2003; Maratos, 2011; Maratos & Staples, 2015; Öhman, Lundqvist, & Esteves, 2001; Simione et al., 2014).

One of the most used paradigm to study the attentional bias is the Emotional Stroop Task (Williams, Watts, Macleod, & Mathews, 1997), which is a revised version of the original Stroop Task (Stroop, 1935) based on the assumption that the emotional salience of cues in the environment can affect attentional processes. The emotional Stroop Task is a naming task in which words with different emotional meanings are presented. The task is to identify the color in which the words are presented. The word valence is manipulated: the latency in the identification of the color of a word emotionally salient is compared to the latency in the identification of the color in which a neutral word is presented. Color-identification responses to emotionally salient words are expected to be slower than the one to neutral words because the emotional content of the words draws the attention and distracts the participant from the task (MacLeod, 1991; Williams et al., 1997). The emotionally salient stimulus captures attention and slows down response time due to the emotional relevance of the word for the individual. The attentional bias is computed through longer reaction times: in this kind of paradigm the maintained attention or the delay of attention disengagement from the stimulus is assessed (Field & Cox, 2008).

Beyond the Emotional Stroop Task, other versions of the Stroop Task assume that the valence of food cues draw the attentional system in eating-disorder populations (Ben-Tovim & Walker, 1991; Ben-Tovim, Walker, Fok, & Yap, 1989; Channon, Hemsley, & De Silva, 1988) as well as in normal-weight population (Green & Rogers, 1993; Perpiñá, Hemsley, Treasure, & De Silva, 1993). This suggests that the study of attentional bias through an implicit test like the Stroop Task, is not only appropriate exclusively to detect the presence of a cognitive disorder in clinical populations, but can also be useful in the case of individuals not affected by eating disorders (Johansson et al., 2005). However, studies on attentional bias in normal-weight individuals are still scarce and with mixed results. Indeed, the majority of the studies were aimed at investigating if attention can be grabbed by specific food cues, characterized by high nutritional values and usually identified as unhealthy foods, that were often compared to neutral stimuli like objects, or healthy foods like vegetables (Pothos, Calitri, Tapper, Brunstrom, & Rogers, 2009). To our knowledge, vegetables have not been considered as target stimuli to investigate if selective attention towards them using an Emotional Stroop Task. Furthermore, recent findings suggest that sensory properties may play a role in attentional processes, as an attentional bias was reported in normal-weight subjects for high-calorie sweets, but not for savory (e.g. bacon burger) (Graham, Hoover, Ceballos, & Komogortsev, 2011).

Several studies have shown the influence of individual variations in chemosensory perception and taste responsiveness on acceptability and preference for vegetables. Responsiveness to bitterness of 6-n- propylthiouracil (PROP) compound is considered as a marker of individual differences in oral responsiveness (Bartoshuk, 1991). Those considered as non-tasters (insensitive to the bitterness of PROP) were found to consume more vegetables and particularly more bitter-tasting vegetables, than medium tasters and supertasters. This association was also found with vegetables characterized by astringency (Duffy, Peterson, & Bartoshuk, 2004; Pickering, Simunkova, & DiBattista, 2004). However, results are conflicting as some studies reported no difference between PROP phenotypes in liking (Catanzaro, Chesbro, & Velkey, 2013) and choice of vegetables (De Toffoli et al., 2019). Given these mixed results, further studies are needed to better understand the influence of PROP responsiveness on the acceptability of vegetables taking into account psychological mechanisms, as it has been found that this variable may interact with personality factors such as food adventurousness (Ullrich, Touger-Decker, O'Sullivan-Maillet, & Tepper, 2004).

Several studies have also demonstrated the influence of psychological traits in the development of food preferences since the early ages. Food neophobia is defined as the reluctance to eat, or the avoidance of, novel foods (Pliner & Hobden, 1992). This is a heritable personality trait, preserved during generations, that brings individuals to be extremely selective towards foods (Knaapila et al., 2007), particularly vegetables and fruits but also towards other common foods (Dovey, Staples, Gibson, & Halford, 2008; Jaeger et al., 2017). More recently, Laureati et al. (2018) showed neophobia-related differences in liking for foods, including vegetables, characterized by warning sensations such as bitterness and astringency, in a large sample. The lower liking of vegetables with a strong taste in individuals higher in neophobia could be in part due to their increased perception of strong and disliked oro-sensory characteristics, which often characterize vegetables (Laureati et al., 2018).

Moreover, concerning the role of personality traits on food perception, there is evidence of the role of anxiety as well. In fact, studies have reported that healthy individuals with mild anxiety were more sensitive to sensory inputs, such as bitterness, sweetness and saltiness (Ileri-Gurel, Pehlivanoglu, & Dogan, 2013; Platte, Herbert, Pauli, Breslin, & Behrens, 2013; Wilson, Kumari, Gray, & Corr, 2000).

Attention can be considered as a driver in food perception even in normal-weight individuals. People may have developed an attentional bias that has an impact on food perception, in particular for foods more easily rejected because of their unpleasantness, due to specific sensory properties that are innately disliked (e.g. 'bitter' vegetables). Furthermore, little is known about the interaction of personality traits, taste responsiveness and attention in vegetable perception; in fact, while attentional bias is established at an aggregate level, there are few or no evidence at the individual level (Ben-Haim et al., 2016). Consequently, this study was built on two hypotheses: first, that individuals would show an attentional bias towards vegetables (H_{1a}), especially towards those characterized by generally negative sensory properties such as 'bitterness' and 'astringency' (H_{1b}). In other words, we hypothesized that vegetables (food cues) would be more emotionally salient than the neutral stimuli (no-food cues) and that vegetables characterized by generally unappealing sensory properties such as 'bitter' and 'astringent' would be more emotionally salient than vegetables less 'bitter' and 'sweeter'. Building on previous studies that found an attentional bias associated with cues eliciting worry, we expect a higher attentional bias towards vegetables characterized by sensory "warning" (alarm) sensations, compared to milder vegetables. Emotional salience will be here measured through the Emotional Stroop Task (in terms of reaction times and interference scores) (Ben-Haim et al., 2016), while an explicit measure of acceptability ("liking") will be included to check the explicit emotional valence of the stimuli. We expect emotional salience being negatively correlated to liking. Valence is a building block of emotions (Barrett, 2006) and in the context of food product experience a correlation with liking has been observed (Gutjar et al., 2014; King, Meiselman, & Carr, 2010; Spinelli, 2021).

Secondly, we hypothesized that the attentional bias would be higher in the individuals who have a heightened perception of sensory stimuli and/or that report a lower liking for vegetables. Consequently, we expected the attentional bias being higher in neophobics (H_{2a}) and in subjects more responsive to PROP (H_{2b}). We expected in fact that neophobics and PROP supertasters would show more vigilance for the target stimuli reporting an enhanced attentional bias (measured through higher reaction times) for vegetables, especially for those characterized by bitterness and astringency.

2. Materials and methods

2.1. Participants

A total of 120 young adults (age range 20–24; women: 74.2%) were recruited by means of announcements spread through social networks (Facebook) and emails. Exclusion criteria were food allergies, pregnancy, and breastfeeding at recruiting.

The participants were informed of the general procedure of the study and gave their written consent before taking part. This study was conducted in agreement with the Declaration of Helsinki and the European ethical requirements on research activities and General Data Protection Regulation (GDPR) 2016/679. Individuals were compensated with a token gift for their participation in the study.

2.2. Procedure

Data collection took place from June to October 2019 and ran at the sensory laboratory of the University of Florence. The duration of the study, including the instructions, was one hour. Participants were first informed of the general procedure and the study aim. Tests were conducted individually and social interactions between the participants were not allowed during the test.

Participants first performed the Food Emotional Stroop Task (FEST) then filled in five questionnaires, measuring stated liking of vegetables, perceived sensory properties of vegetables (through a Check-All-That-Apply questionnaire), food neophobia and state and trait anxiety. At the end of the session, responsiveness to PROP was measured (Fig. 1).

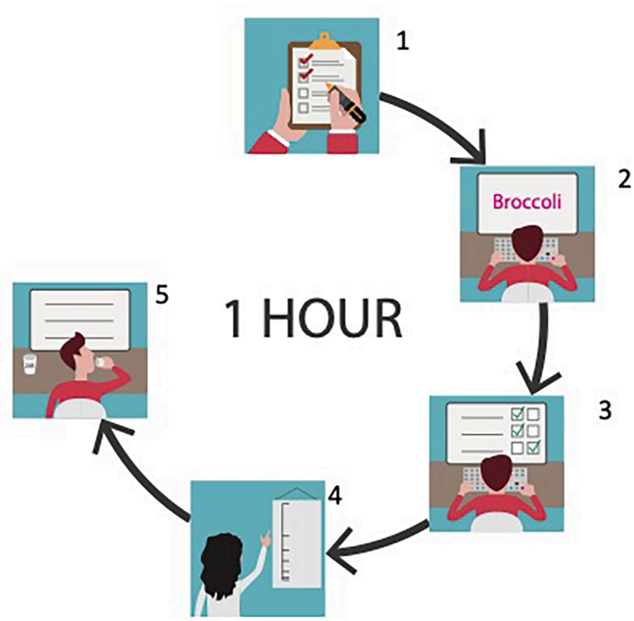

Fig. 1. Overview of data collection and procedure. 1= Instructions and consent form; 2= Emotional Stroop Task Revised (ESTR); 3= In sequence: stated liking, sensory properties, Check All That Apply (CATA) and Food Neophobia Scale; 4= instructions for PROP taste and training to the use of the generalized Labeled Magnitude Scale (gLMS); 5= PROP bitterness intensity evaluation.

2.2.1. The Food Emotional Stroop Task (FEST)

To assess the interferences between emotions and attention a food version of the Emotional Stroop Task (MacLeod et al., 1986) was used (E-prime 3.0 – Psychology Software Tool was used to build the implicit test). Participants were asked to identify the color of the word (either vegetable or neutral object names) appearing on the computer screen by pressing the corresponding key on the keyboard. Selected colors were grey, light blue, pink and black because normally not associated with vegetables (Fig. 2). They were instructed to ignore the meaning of the word and to respond as quickly as possible to the color of the word presented. Individual Reaction Times (RTs) measured in milliseconds to the identification of the color of each stimulus were recorded. The rationale behind the FEST is that the emotional significance of the name slows down the color identification process: slower responses (higher RTs) indicate that the attention is grabbed by an emotionally salient stimulus (MacLeod et al., 1986).

Each stimulus was presented 9 times in a randomized order. The test began with a fixation cross at the center of the screen (for 500 ms), which was presented also between each stimulus. Each word remained visible for 2000 ms; if the subject did not reply in time, the word disappeared, and no response was recorded (Nijs, Franken, & Muris, 2010). During the test, feedback on the accuracy of responses was not given.

Before the test, individuals participated in a practice block, to familiarize themselves with the test procedure. At this stage, the words presented were numbers (from nine to twelve) expressed in letters. Each of the four words was presented in a different color and participants were asked to identify this color using the keyboard: each color was associated with a specific key (Fig. 2). During the familiarization task, a feedback on responses was given ("correct" when the right color was identified; "incorrect" when the right color was not identified; "no answer" when the answer was not given in time) in order to ensure that participants understood the task.

2.2.2. Stimuli

Sixteen names of familiar vegetables for the adult population living in Florence area were selected based on three previous studies (Cliceri, Spinelli, Dinnella, Ares, & Monteleone, 2019; Cliceri, Spinelli, Dinnella, Prescott, & Monteleone, 2018; De Toffoli et al., 2019) (Supplementary material 1). Vegetables were divided into two categories labeled as "appealing" and "unappealing" following the terminology of Appleton et al. (2019) based on their expected sensory properties ('sweet' and 'mild' flavor versus 'bitter', 'astringent' and 'pungent') associated, respectively, to vegetables generally more or less liked. The "appealing" category included *green beans, carrots, lettuce, fennels, zucchini, peas, corn*, and *tomatoes* while the "unappealing" one included *cabbage, artichokes, broccoli, radicchio, rocket, chard, chicory, asparagus*. In addition to vegetable names, sixteen names of neutral objects (office-related) were selected as control: *lamps, window, cans, trash can, table, bag, wardrobe, drawer, binders, pencil, markers, backpack, chair, key, shelf, paper*. These names were selected based on length and lexical similarity to the vegetable names, by considering the Italian lexical.

2.2.3. Stated liking and sensory properties of vegetables

Stated liking of the vegetables, presented in a randomized order, was assessed using a 9-point category scale ('dislike extremely'/ 'like extremely') (Peryam & Pilgrim, 1957).

A Check-all-That-Apply (CATA) questionnaire was used to describe the sensory properties of each vegetable. A list of twelve attributes was presented for each subject and vegetable: 'astringent', 'salty', 'sour', 'bitter', 'sweet', 'crisp', 'pungent', 'hard', 'tender', 'mild', 'tasty', 'juicy'. Attributes were selected based on three studies where CATA questionnaire were used (Cliceri et al., 2018; Cliceri et al., 2019; De Toffoli et al., 2019), in order to discriminate vegetables for their sensory properties. Both attributes and samples were presented in a balanced (Latin square) order. A forced answer (yes/no) was requested.

2.2.4. Food Neophobia

Subjects were asked to fill in the Food Neophobia Scale (Pliner & Hobden, 1992). For each subject food neophobia was quantified as the sum of ratings given to the 10 items using a seven-point Likert scale ('disagree strongly'/'agree strongly'), after reversing the neophilic items. The final score ranged from 10 to 70, with higher scores reflecting higher food neophobia.

2.2.5. State-Trait Anxiety Inventory

Subjects completed the State-Trait Anxiety Inventory (Spielberger,

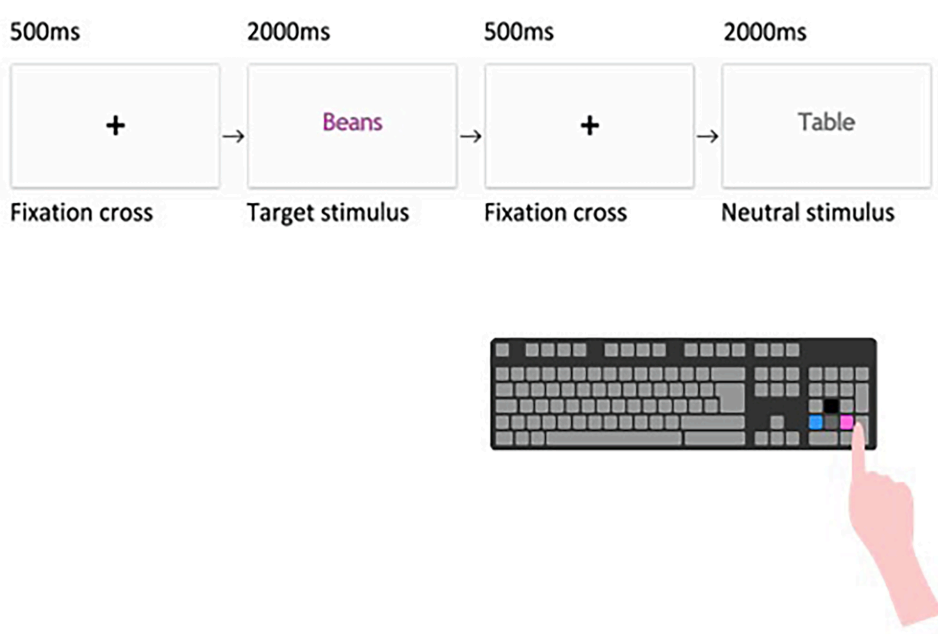

Fig. 2. Food Emotional Stroop Task structure. A fixation cross was presented for 500 ms at the beginning and during interstimulus interval. Examples of target stimulus (word indicating an unappealing vegetable) and neutral stimulus (word indicating an office object), showed for a maximum 2000 ms, are reported. Subjects replied to the stimuli by pressing the key with the corresponding color

Gorsuch, Lushene, Vagg, & Jacobs, 1983). The questionnaire consists of 40-item, divided into two scales: State Anxiety, referring to "how do you feel in this moment" (4-point Likert scale: 'not at all'/ 'strongly') and Trait Anxiety, referring to "how do you generally feel" (4-point Likert scale: 'almost never'/ 'almost always'). Both scales consist of 20 items (Spielberger et al., 1983; Zsido, Teleki, Csokasi, Rozsa, & Bandi, 2020). The final score is counted as the sum of the scores of the items for each scale, with higher scores reflecting higher state and/or trait anxiety.

2.2.6. Taste responsiveness: PROP status

A 3.2 mM PROP solution was prepared by dissolving 0.5447 g/L of 6-n-propyl-2-thiouracil (European Pharmacopoeia Reference Standard, Sigma Aldrich, Milano) into deionized water (Prescott & Swain-Campbell, 2000). To ensure consistency, respondents evaluated the 'bitter' intensity of two identical samples (10 mL), presented monadically in white plastic cups and coded with two different three-digit codes (Masi, Dinnella, Monteleone, & Prescott, 2015). Participants were instructed to hold each sample in their mouth for 10 s, then after expectorating, wait 20 more seconds, and subsequently, evaluate the bitterness using the Generalized Labeled Magnitude Scale (gLMS; from 0= 'no perceived sensation' to 100= 'strongest imaginable sensation of any kind') (Bartoshuk et al., 2004). In order to control for carry-over effect, a break of 90 s was established between the two evaluations; during the break, respondents rinsed their mouth with water (30 s), had a plain cracker (30 s), then rinsed their mouth again. Before the evaluation, participants were instructed on the use of the gLMS scale. Instructions were given that the top of the scale represented the most intense sensation that subjects could ever imagine experiencing. A variety of sensations from different modalities, including loudness and oral pain/irritation, were recalled providing examples (Bajec & Pickering, 2008). To practice the use of the scale, subjects rated intensities of the brightest light they had ever seen following the procedure described in Dinnella et al. (2018). The task was performed individually, and the criterion to conclude that the subjects correctly used the scale was that ratings must have been higher than "very strong", but lower than "strongest imaginable sensation of any kind". In the case of ratings out of this range, a short individual interview was carried out to understand the reason for the ratings, and the use of the scale was clarified.

Individual PROP intensity score was computed using the mean intensity rating across the two evaluations.

All data apart from reaction times were collected using the FIZZ Software (ver.2.51B Biosystèmes, France).

2.3. Data analysis

Normality was tested using the Shapiro-Wilk test and through the visual inspection of P-P and Q-Q plots. In addition, in the ANOVA model the test for homoscedasticity of the residuals was also applied. All data met the requirements for parametric analysis, described below in details. Effect size were estimated using Cohen's d and f, respectively for *t*-test and ANOVA models.

2.3.1. Food Emotional Stroop Task

Reaction times <200 ms and >2000 ms were considered outliers (Nijs et al., 2010) and thus removed from the analysis (0.58%). Color-naming errors (4.70% of the total responses) were also removed from the data analysis. Mean reaction times for each word were computed after the outlier deletion and averaged for each subject. A paired *t*-test was applied to estimate the difference between the reaction times to vegetables and neutral words.

Furthermore, as suggested by Pothos et al. (2009), for each subject the difference between average RTs for trials to unappealing/appealing vegetable words and average RTs for trials with neutral words was computed in order to obtain a measure of unappealing/appealing vegetable interference, respectively. A higher interference score for one of the two vegetable categories (e.g. unappealing) indicated a greater attentional bias toward that category. Finally, an aggregate Stroop interference score to test the presence of a general attentional bias towards vegetables, was computed for each individual by averaging the unappealing and appealing interference scores of each subject. Significant differences between Stroop interference scores for unappealing and appealing vegetables were tested by means of a two-sample paired *t*-test. The relationship between mean liking scores of vegetables and RTs averaged by products (vegetables), was studied by means of a linear regression.

2.3.2. Stated liking and Check-All-That-Apply

Significant differences ($p < 0.05$) between mean liking scores for appealing and unappealing vegetables were tested by means of a paired *t*-test, after that data of the products classified as appealing or unappealing, respectively, were averaged for each subject. A mixed Two-Way ANOVA model was computed on stated liking scores using vegetables (fixed) and subjects (random) as factors. Tuckey Honestly Significant Difference (HSD) test with a confidence interval of 95% was used as post hoc test.

Data from the Check-All-That-Apply questions were treated as dichotomous responses (checked term = 1; unchecked term = 0) for each of the terms presented in the ballot. Cochran Q-Tests (followed by Sheskin multiple pairwise comparison tests) were performed to identify significant differences among vegetables in the frequency of use of each of the terms (Meyners & Castura, 2014). A Correspondence Analysis (CA) based on Chi-square distance was carried out on the contingency table of the frequencies of sensory variables that discriminate significantly among vegetables (Meyners, Castura, & Carr, 2013).

In order to study the relationship between liking and sensory data, a Principal Component Regression (PCR) was computed. PCR can be viewed as a two-step Internal Preference Map (IPM) procedure which first decomposes the liking data matrix (X-matrix) by a PCA (to create an IPM), then fits a Multiple Linear Regression (MLR) model, using the Principal Components instead of the original X-variables as predictors of the sensory data (Y-matrix) represented by the frequencies of significant sensory variables from CATA. Samples were included as dummy variables (down-weighted in the X data matrix) to improve the visual interpretation of the results (Martens & Martens, 2001). The output of the analysis is summarized in a map (correlation loading plot), in which samples, individuals and sensory properties are shown. Moreover, the correlation plot allows the possibility of drawing circles in the plot corresponding to 100% and 50% explained variance for each variable for the two components. A second PCR was calculated considering Reaction Times (RTs) as X-matrix and sensory data as Y-matrix.

2.3.3. Food neophobia scores

Factor analysis and Cronbach α were computed to check the internal reliability of food neophobia scores. Subjects were divided into High and Low Food Neophobia respondents splitting the individual scores on the median (Demattè et al., 2013; Spinelli et al., 2018). Three Two-Way ANOVA models with interaction were computed, after that data were averaged for each subject for the considered category (e.g. neutral stimuli/vegetables; appealing/unappealing vegetables): the first on liking scores to investigate the effect of vegetable category (two levels: unappealing *vs.* appealing vegetables) and food neophobia (two levels: High *vs.* Low); the second on RTs to study the effect of stimuli (two levels: vegetables *vs.* neutral stimuli) and food neophobia (two levels: High *vs.* Low); the third assuming Stroop interference scores as dependent variable and food neophobia (two levels: High *vs.* Low) and vegetable categories (two levels: appealing *vs.* unappealing) as factors.

Furthermore, two One-Way ANOVA models were carried out to test, respectively, the difference between food neophobia levels (High *vs.* Low) on State- and Trait- Anxiety scores.

2.3.4. PROP responsiveness

Respondents were classified in PROP non-taster (NT, gLMS score ≤

17, weak), PROP medium taster (MT, 17> gLMS score <53) and PROP supertaster (ST, gLMS score ≥ 53, very strong) (Fischer et al., 2013; Monteleone et al., 2017). Influences of PROP on RTs were tested similarly to food neophobia: Two-Way ANOVAs with interaction were computed to study the effect of PROP classes (three levels: ST; MT; NT) and stimuli classes (two levels: vegetables *vs.* neutral stimuli) on RTs. A two-way ANOVA on Stroop interference scores was computed to study the effect of PROP and vegetable (appealing and unappealing) classes. In order to investigate the influence of PROP status classes on liking scores, a Two-Way ANOVA (Factors: PROP status and vegetable: appealing and unappealing) with interaction was carried out.

Finally, two One-Way ANOVA models were run to verify the difference between PROP status classes (ST, MT and NT) on State and Trait Anxiety scores.

All the statistical analyzes were computed with XLSTAT 22.1.1, Addinsoft (France) software, except for Principal Component Regression, computed with Unscrambler version 10.3-Camo software and effect sizes, calculated using WebPower (Zhang & Yuan, 2018).

3. Results

3.1. Validation of stimuli selection: appealing and unappealing vegetables

Results from the mixed ANOVA model computed on liking scores showed a significant effect of product ($F_{15,1785} = 27.63$; $p < 0.0001$, effect size: Cohen's $f = 0.42$) and of the random factor subject ($F_{15,1785} = 4.387$; $p < 0.0001$). Vegetables largely differed in liking (Fig. 3). Mean scores ranged from 4.99 (SE = 0.17), corresponding to the central point of the scale "neither liked nor disliked" reported for *chicory*, to 8.07 (SE = 0.17) "very liked" reported for *tomatoes*. There was a clear decrease in liking when passing from vegetables categorized as appealing to the unappealing ones. In fact, vegetables categorized as appealing were on average more liked (M = 7.31; SE = 0.08) than vegetables categorized as unappealing (M = 5.98; SE = 0.08) ($t_{119} = 10.82$; $p < 0.0001$, Cohen's $d = 1.13$). Following the ranking order of the decreasing liking reported in Fig. 3, it is possible to note that only one vegetable was not falling in the expected category, *asparagus,* that based on its sensory properties was classified as 'unappealing'. However, looking at the significant differences among mean liking scores of vegetables in the central part of the distribution the discrepancy is minimal and did not affect the goodness of the categorization.

Results from the Cochran Q-Tests computed on CATA data showed that all the selected sensory terms significantly discriminated between vegetables (p-values < 0.0001). Frequencies of selection of these attributes by product were submitted to a Correspondence Analysis (Fig. 4). The first two dimensions accounted for 45.34% and 28.45% of variance, respectively. Along the first dimension of the biplot from the right to the left, the opposition *tomatoes/green beans/peas/zucchini/corn* versus *rocket/chicory/artichoke/radicchio* is represented by contrasting the descriptors 'sweet' and 'mild', to 'bitter', 'astringent' and 'pungent'. The first group of products included the most liked ("appealing") vegetables while the latter the least liked ("unappealing") ones. Visual inspection of the second dimension, from the bottom to the top of the map, indicated that *carrots* and *fennels* are separated from the rest by contrasting 'hard' and 'crisp' to 'juicy' and 'tender'.

In order to identify the sensory drivers of liking and disliking that influence the appealing and unappealing characteristics of vegetables, the frequencies of selection by product for each sensory descriptor that discriminated significantly among products were regressed on the multidimensional configuration of vegetables based on individual liking scores. The first two components explained 41% of the variance. Most respondents are located on the right of the first component of preference map (Fig. 5), and their liking is mainly driven by 'sweet' and 'mild' . 'Bitter' 'astringent' and 'pungent' tastes drive respondents disliking. The perceptual map clearly shows that the main sensory opposition between appealing and unappealing vegetables is represented by the contrast between 'sweet' and 'mild' versus 'bitter', 'astringent' and 'pungent'.

Overall, sensory and hedonic responses of subjects confirmed the classification of the selected vegetables into "appealing" and "unappealing".

The PCR on RTs accounted for 15% and 17% on the first and second dimension of the X and for 11% and 3% on the Y. Reaction times were higher for vegetables characterized by bitterness, astringency and saltiness, and thus that are generally disliked, while they were lower for

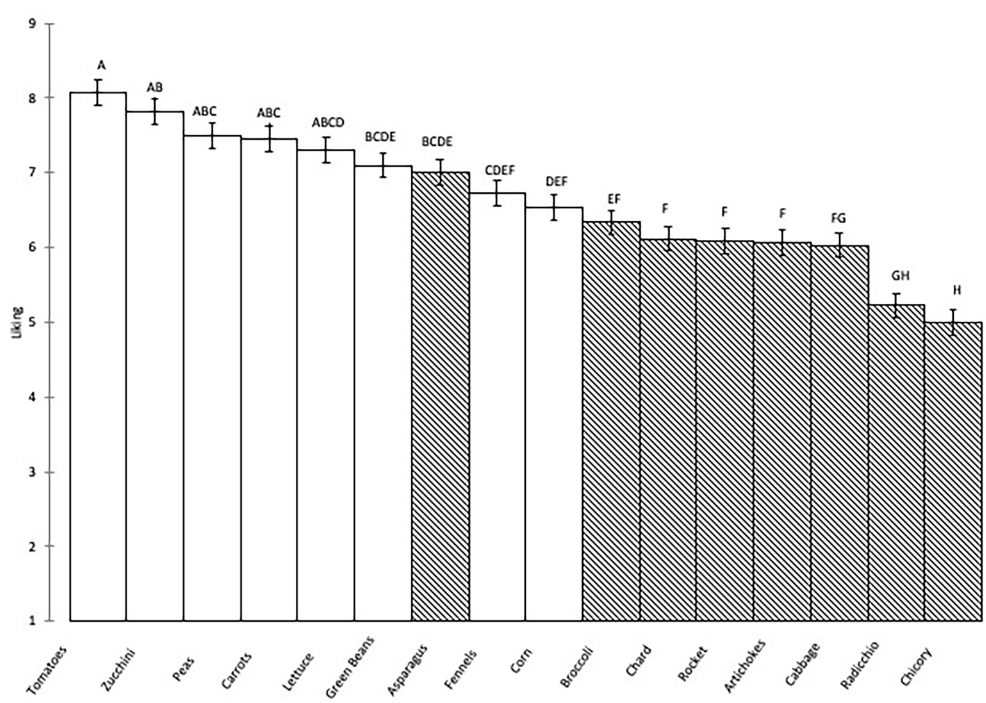

Fig. 3. Mean and standard error of liking scores for vegetables. White bars indicate vegetables categorized as "appealing" while filled bars indicate vegetables categorized as "unappealing". Different letters indicate significant differences according to Tuckey HSD post hoc test (p < 0.05)

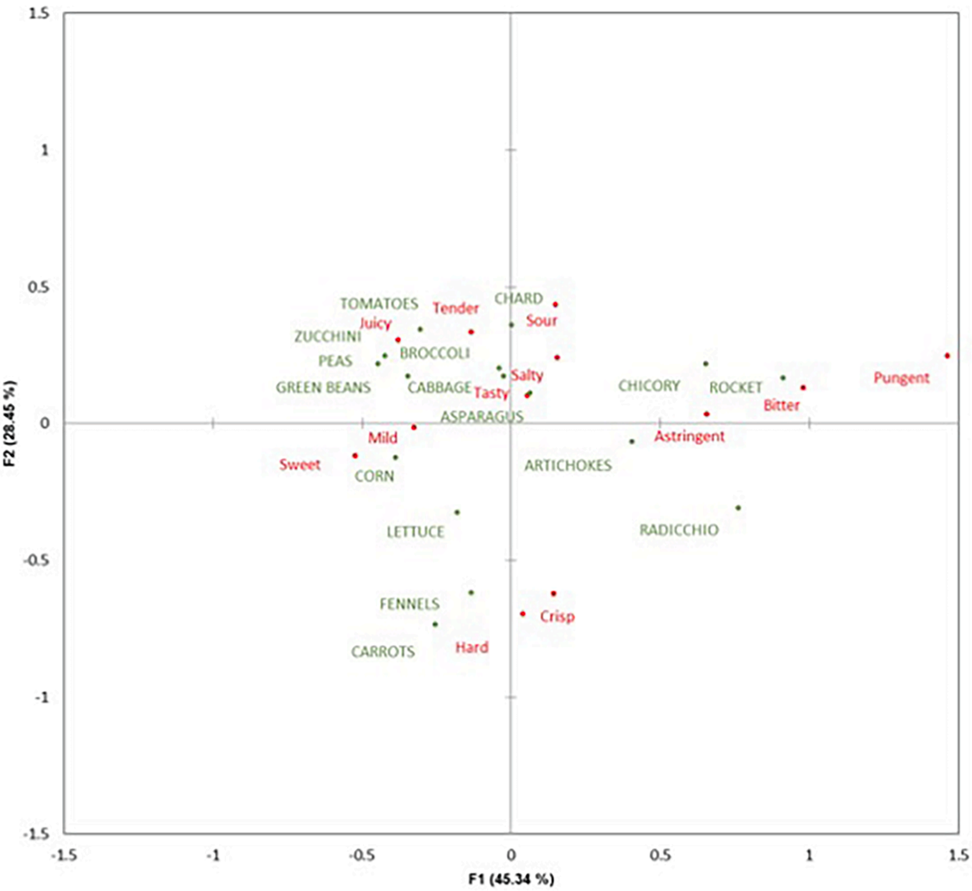

Fig. 4. Representation of vegetables (green) and sensory properties (red) in the first and second dimensions of the correspondence analysis of the CATA.

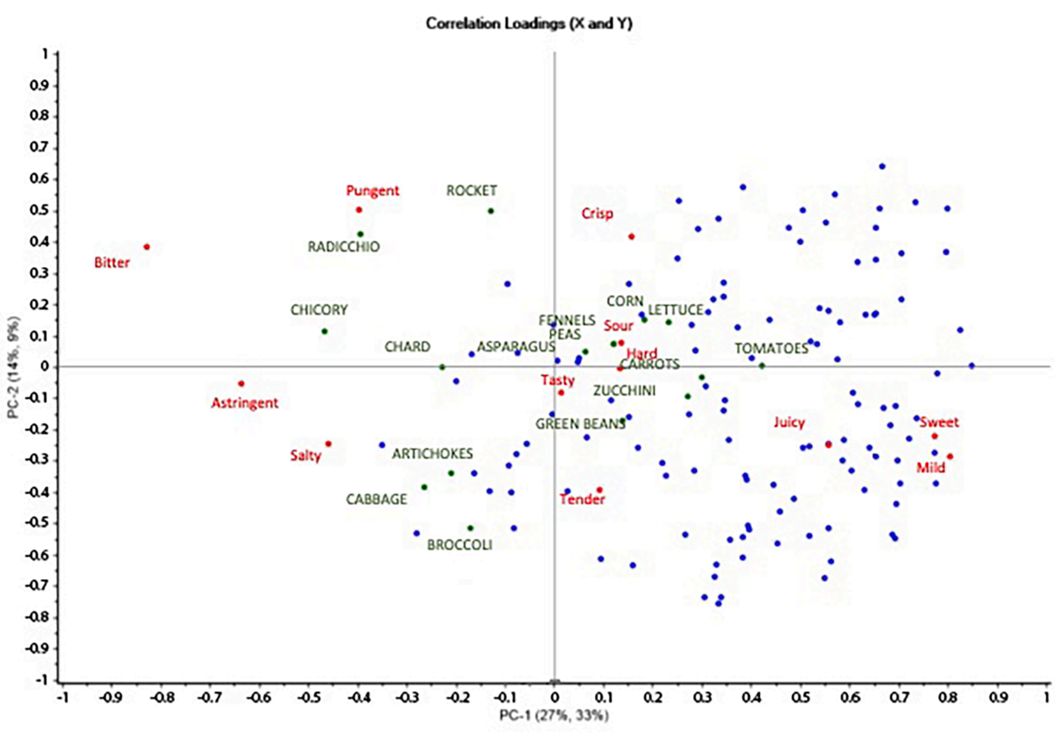

Fig. 5. Internal preference mapping (correlation loading plot) resulted from Principal Component Regression (PCR) in the first two dimensions (PCs 1 and 2): subjects correlation loadings (blue); product coordinates (green) liking data (X) and correlation loadings of frequencies of use of sensory descriptors (red) from the CATA test (Y).

vegetables characterized by a sweet and mild flavor (Fig. 6).

3.2. Food emotional Stroop Task (FEST)

Increased response latencies were displayed for vegetables as compared to neutral words ($t_{119} = 8.70$, $p < 0.0001$, Cohen's d = 0.27). RTs to neutral category (M = 696.85 ms; SE = 2.02) were lower than RTs to vegetables (M = 726.24 ms; SE = 2.02) indicating that subjects were slower in reporting the color of words referred to vegetables rather than office-related words (Fig. 7). Furthermore, a significant difference between aggregate Stroop interference scores for appealing and unappealing vegetables was found ($t_{119} = 7.265$, $p < 0.0001$, Cohen's d = 0.77) as reported in Fig. 8. The higher score for unappealing vegetables indicated a greater attentional bias towards that product category.

Mean RTs to each vegetable resulted strongly related to mean liking scores. The linear regression indicated that the two variables were negatively and significantly correlated (r = -0.83) with an explained variance (R^2) of 67% ($p < 0.0001$).

3.3. Influences of food neophobia on RTs and liking score of vegetables

The internal reliability of the FNS was satisfactory, with Cronbach α of 0.9. All items were strongly positively related to PC1, which accounted for the 47.79% of variability. These results are in line with the evidence reported from Laureati et al. (2018) with a larger sample of Italian adults (n = 1225), and a Cronbach α of 0.87. The overall mean reached in this study was lower (M = 24.27; SD = 11.58) compared to the results of the study above mentioned (M = 27.10; SD = 10.80), probably due to the lower age of the participants in our study.

The population was divided into individuals High (HN) and Low (LN) in neophobia based on the median of the total score (Me = 22). Two-Way ANOVA model on liking scores for the two vegetable categories (unappealing and appealing) and FN groups (HN and LN) showed a significant effect of vegetable category ($F_{1:230} = 78.454$; $p < 0.0001$, Cohen's f = 0.50) and food neophobia ($F_{1:230} = 27.253$; $p < 0.0001$,

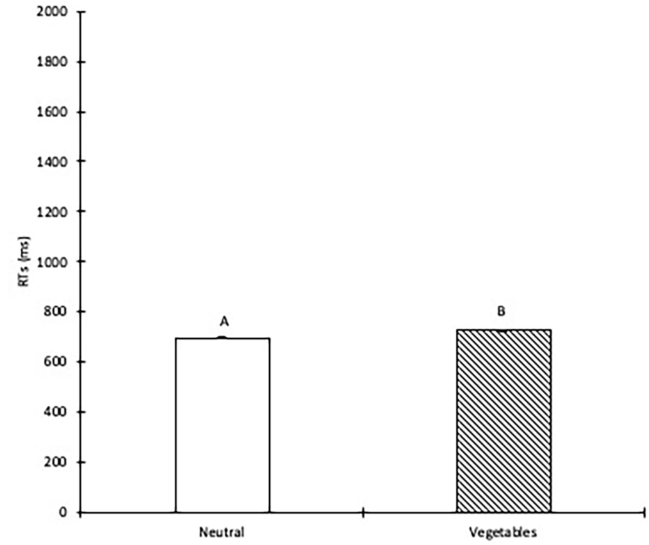

Fig. 7. Mean and standard error of reaction times (RTs) to neutral stimuli (white bar) and to vegetable stimuli (filled bar). A,B Different letters indicate a significant difference ($p < 0.05$).

Cohen's f = 0.27) but not of their interaction ($F_{1:230} = 2.353$; $p = 0.127$). LN subjects reported to like vegetables, in general, more than HN. Both groups liked more appealing vegetables than the unappealing ones, but the mean liking scores for both categories of vegetables were higher in low neophobic (LN) subjects compared to the more neophobic one (HN) (Fig. 9).

The Two-Way ANOVA model computed to test the effect of both FN groups (HN and LN) and stimulus categories (neutral objects and vegetables) on RTs showed a significant effect of the stimulus category ($F_{1:220} = 4.395$; $p = 0.037$, Cohen's f = 0.13), but not of food neophobia

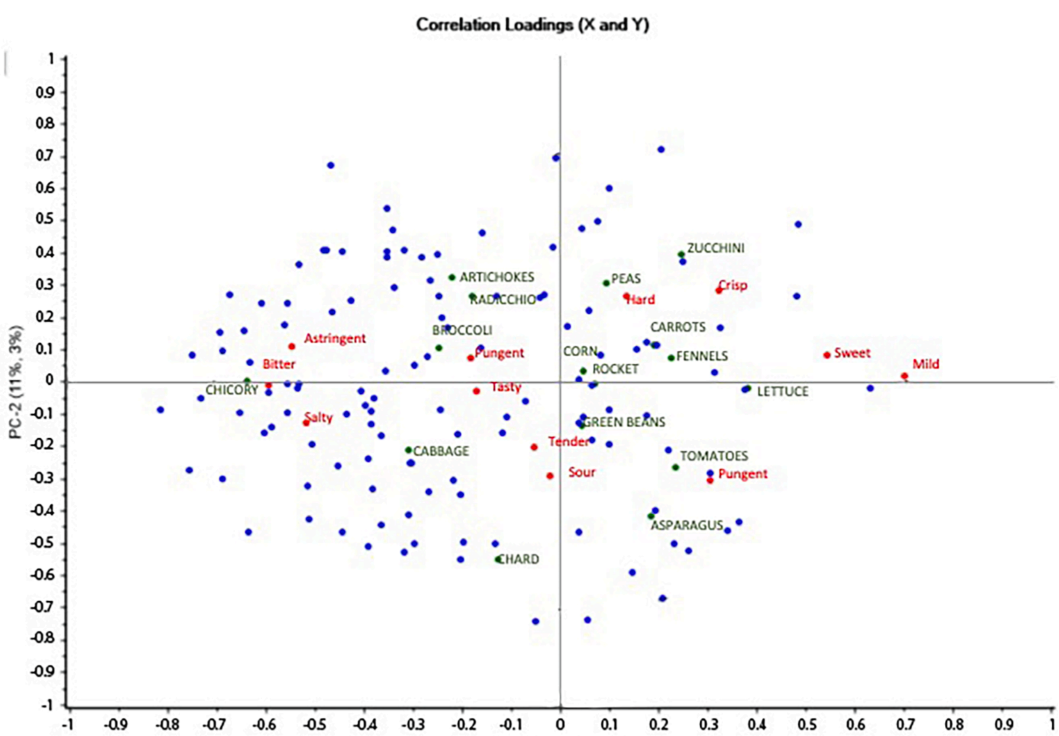

Fig. 6. Principal Component Regression (PCR) in the first two dimensions (PCs 1 and 2): subjects reaction times (blue); product coordinates (green) of reaction time (RT) data (X) and correlation loadings of frequencies of use of sensory descriptors (red) from the CATA test (Y).

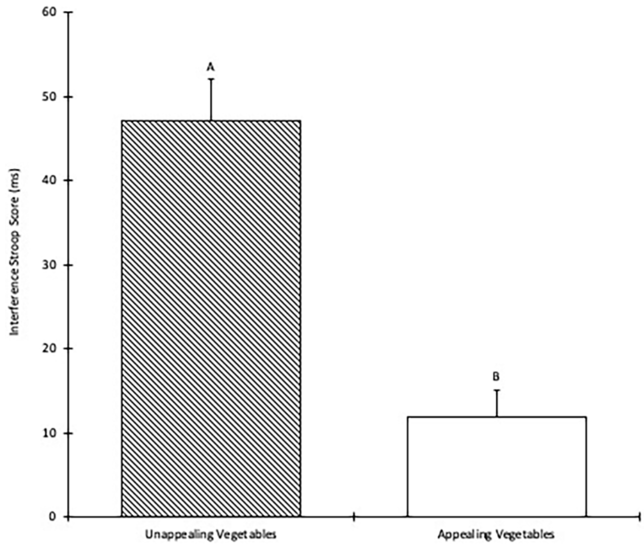

Fig. 8. Mean and standard error of Stroop interference scores for appealing vegetables (white bar) and unappealing vegetables (filled bar). [A,B]Different letters indicate a significant difference ($p < 0.0001$).

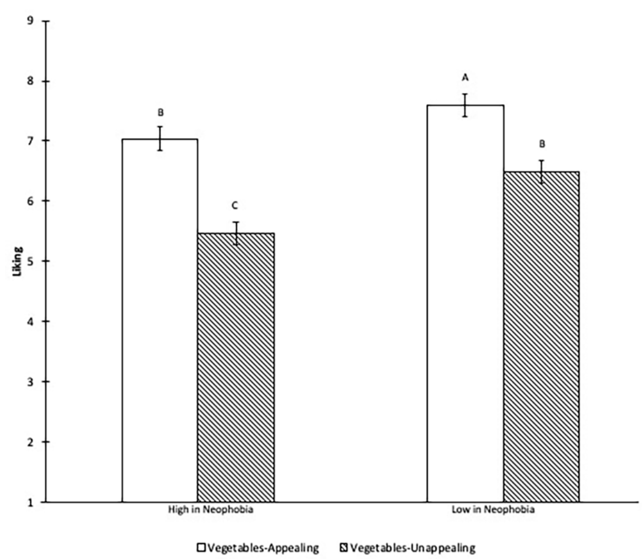

Fig. 9. Mean and standard error of liking scores for appealing and unappealing vegetables in individuals high and low in food neophobia. Filled bars indicate unappealing vegetables and white bars indicate appealing vegetables. [A,B,C]Different letters indicate a significant difference ($p < 0.05$).

($F_{1:220} = 0.867$; $p = 0.353$) and of their interaction ($F_{1:220} = 0.166$; $p = 0.68$).

Finally, the two-way ANOVA ran to test the effect of FN on the Stroop Interference scores for appealing and unappealing vegetables showed a significant effect of the vegetable variable only ($F_{1:220} = 37.702$; $p < 0.0001$, Cohen's $d = 0.39$), while a trend was observed for the FN variable ($F_{1:220} = 3.735$; $p = 0.055$, Cohen's $d = 0.12$) and between the two main factors ($F_{1:220} = 1.551$; $p = 0.214$). The interference score tended to be lower in individuals higher in neophobia ($M = 24.21$; $SE = 4{,}38$), than the ones lower in neophobia ($M = 35.98$; $SE = 4.23$).

3.3.1. Influence of food neophobia on State and Trait Anxiety scores

A significant effect of food neophobia on State Anxiety was found ($F_{1:110} = 5.926p = 0.017$, Cohen's $f = 0.6$), with individuals higher in food neophobia that reported significantly higher scores on State Anxiety (HN; $M = 36.33$, $SE = 0.22$) than subjects classified al lower in food neophobia (LN; $M = 33.24$, $SE = 0.23$).

No significance was reach for the Trat Anxiety scores ($F_{1:110} = 3.889$, $p = 0.051$). However, even in this case, HN respondents tended to show higher scores on Trait Anxiety ($M = 47.70$; $SE = 0.32$) than LN respondents ($M = 42.93$; $SE = 0.31$).

3.4. Influences of PROP status on RTs from FEST

The Two-Way ANOVA model computed to test the effect of PROP groups (NT, MT and ST) and stimulus categories (vegetables and neutral objects) on RTs showed a trend to significant effect of the two main factors (PROP status: $F_{2:232} = 2.99$; $p < 0.052$, Cohen's $f = 0.16$; stimulus category: $F_{1:232} = 4.509$; $p = 0.035$; Cohen's $f = 0.10$). No significant effect of the interaction PROP status × stimulus category was found ($F_{2:232} = 0.082$; $p = 0.921$). Participants classified as PROP supertasters were significantly slower than PROP medium tasters, and these were slower than PROP non-tasters.

Two-Way ANOVA (PROP status and vegetable categories) with interaction computed on Stroop interference scores for appealing and unappealing vegetables showed a significant effect of the vegetable category only ($F_{1:232} = 34.883$; $p < 0.0001$, Cohen's $f = 0.27$), with higher reaction times for unappealing vegetables. No significant effect of PROP status ($F_{2:232} = 1.763$; $p = 0.174$) nor of the interaction of the two factors ($F_{2:232} = 0.278$; $p = 0.757$) was found.

3.4.1. Influence of PROP status on liking scores

The Two-Way ANOVA model on liking scores for the two vegetable categories (unappealing and appealing) and PROP status classes (ST, MT and NT) showed a significant effect of vegetables ($F_{1:232} = 78.366$; $p < 0.0001$, Cohen's $f = 0.35$), while no significance was reached by PROP status category ($F_{2:232} = 0.798$; $p = 0.452$) nor of the interaction between vegetables category and PROP status groups ($F_{2:232} = 2.756$; $p = 0.066$).

3.4.2. Influence of PROP status on State and Trait Anxiety scores

The two One-Way ANOVA of PROP status groups on State Anxiety scores and Trait Anxiety, did not showed significant effects ($F_{2:116} = 0.329$; $p = 0.720$; $F_{2:116=0.712,}$ $p = 0.493$).

4. Discussion

Our findings support the hypothesis that individuals show an attentional bias towards vegetables (H_{1a}): reaction time scores for vegetable cues were significantly longer than the ones in response to neutral objects. These results are consistent with Nijs et al. (2010) and Castellanos et al. (2009), which found longer reaction times for food-cues compared to neutral stimuli in normal-weight and overweight individuals. In this study only vegetables were used as food stimuli, while in the two studies above mentioned, the food target stimuli were represented by high-caloric food products (e.g. cake, pasta, kebab, chocolate, ice cream, etc…). The results of this study support the hypothesis that the food in itself, independently from the caloric content, elicits a greater attentional bias than non-food (neutral) stimuli.

The hypothesized classification of the selected vegetables into "appealing" and "unappealing" was confirmed in this study, both in terms of acceptability and sensory properties. As expected, we report that vegetables characterized by bitterness and astringency were less liked, while sweeter and milder vegetables were more liked, confirming previous findings (Appleton et al., 2019; Cox et al., 2012; Dinehart et al., 2006; Dinnella et al., 2016; Krølner et al., 2011). In fact, vegetables classified as "appealing" (such as *tomatoes, green beans, peas, zucchini,* and *corn*) were mainly described by 'sweet' and 'mild', while vegetables classified as "unappealing" (such as *rocket, chicory, artichokes*, and *radicchio*) were mainly described by 'bitter', 'pungent' and 'astringent' attributes. Our classification of vegetables into "appealing" and "unappealing" was corroborated by the data except for *asparagus*, which in terms of mean data resulted to be slightly more liked than the other vegetables classified as "unappealing". This can be explained by its intermediate sensory profile (described as not 'sweet', not 'bitter') and by the high familiarity with the product, which is well known and frequently consumed in the region in which the test was performed. Furthermore, asparagus is perceived as a "gourmet" vegetable appropriate for special occasions and it is included in many refined dishes in the Italian and Tuscan cooking, differently from other vegetables.

We also hypothesized that vegetables characterized by innately disliked sensory properties such as 'bitter' and 'astringent' may be more disliked and possibly elicit more negative emotions, thus requiring more attention in their processing (H_{1b}). Our hypothesis was confirmed as we found that the interference scores for vegetables classified as "unappealing" were significantly greater than the interference scores for the "appealing" ones. This means that when the word presented indicated a less liked vegetable, characterized by a less 'sweet' and 'mild' and more 'bitter' taste, for the participants it took more time to identify the color of the word. This indicates that vegetables characterized by unappealing sensory properties determine a greater attentional bias as compared to vegetables connoted by more appealing sensations. This new finding is strongly supported by the strong effect size and by the significant inverse correlation between RTs and liking scores, that further highlights that sensory properties associated with less liked sensations, such as 'bitter', 'astringent' and 'pungent', are associated with a greater attentional bias compared to more innately liked sensations (such as 'sweet'). This could reflect the delay to disengage the attention (Field & Cox, 2008; Pothos et al., 2009) from those vegetables connoted by warning sensations. Our results are consistent with previous studies that reported in non-clinical populations longer color-naming latencies for undesirable than desirable traits (e.g., honest, sadistic) (Pratto & John, 1991; Wentura, Rothermund, & Bak, 2000).

These results indicate, for the first time, that sensory properties and not only the caloric content or the healthiness of a food product are able to induce an attentional bias. This means that specific sensory properties, innately aversive such as bitterness and astringency, may act as a concern-related environmental cue that grabs attention.

The experiment does not allow to explain the causal mechanism, and it can be hypothesized both that an attentional bias may contribute to lower acceptability, but also that lower acceptability, due to sensory properties, may induce an attentional bias. This second hypothesis could be supported, for example, by a lower familiarity that usually is associated with a lower acceptability. However, we did not measure the frequency of consumption and familiarity of food items selected in this study. When familiarity with the products selected was controlled, reported differences on hedonic responses were found to be related to it (Laureati et al., 2018). We recommend including this variable in future studies in order to disentangle its role in attentional mechanism in food perception.

Our second hypothesis was that the attentional bias for vegetables, and particularly for those characterized by astringency and bitterness, was greater in individuals higher in neophobia (H_{2a}) and more responsive to PROP (H_{2b}). We expected in fact that neophobics and supertasters individuals were more vigilant for the target stimuli showing thus a greater attentional bias (measured through reaction times) for vegetables, especially for the vegetables characterized by bitterness and astringency. The rationale behind this hypothesis is that earlier studies have shown that biases are greater when the emotional stimuli match the specific concerns of the subjects (Williams, Mathews, MacLeod 1996). Our hypothesis was not confirmed in the case of neophobia (H_{2a}) and partially confirmed in the case of PROP responsiveness (H_{2b}). Our results showed that individuals higher in neophobia like less all the vegetables when compared to individuals lower in neophobia. Similarly, previous studies highlighted that food neophobia was negatively associated with the choice of vegetables (De Toffoli et al., 2019), confirming other evidences that food neophobia in adults is associated with a reduced dietary variety, leading to lower acceptability and intake of this food category (Jaeger, Rasmussen, & Prescott, 2017; Laureati et al., 2018; Spinelli et al., 2018). Therefore, we would have expected to find higher interferences scores for neophobics while this was not the case. In particular, this was due to the fact that neophobics had lower reactions times in response to the neutral stimuli. We may hypothesize that anxiety, that was associated to neophobia may interfere with the perception of neutral stimuli, consistently with previous studies that reported that "Social Anxiety Disorder is associated with a tendency to interpret ambiguous social stimuli (such as neutral faces) in a threatening manner" (Cooney, Atlas, Joormann, Eugène, & Gotlib, 2006, p. 55).

Our study showed that participants classified as supertasters were slower than medium and non-tasters in response to vegetables and no difference in the interference score by PROP status was reported, thus only partially confirming H_{2b}. However, this was not found to be associated with specific sensory properties but rather with the whole vegetable category. This finding could be explained by the lower acceptability of vegetables in general of supertasters reported in some studies (e.g. Bell & Tepper, 2006), which may explain why for these individuals vegetables in general, and not only the ones characterized by "warning" sensory properties, are emotionally salient in a negative way. However, in our study we did not report a lower acceptability of vegetables in supertasters. We may hypothesize that further variable may contribute to this result, for example frequency of consumption. It has also been reported that PROP responsiveness interacts with other variable, such as personality traits in modulating responses to foods (Ullrich et al., 2004).

Our hypothesis that for supertasters and individuals higher in neophobia, 'bitter' and 'astringent' vegetables are more emotionally salient and thus induce an attentional bias because they perceive these sensations as more intensely or as aversive sensations was not confirmed. In fact, this was true for all the subjects, independently from their responsiveness to PROP or food neophobia.

Given the specific age group considered (20–24 years old) in this study, further studies are needed to expand these results including different age groups. Caution should be thus adopted before generalizing the results. Furthermore, it should be noted that the sample was not well balanced in terms of gender, due to the higher presence of women (74.2%) and this could have affected the results as well.

Attention is a complex process to investigate and, in the literature, it is widely reported that using different methods can lead to diverging results. This suggests that different task designs could measure different mechanisms of attention. In order to overcome those limits, implicit behavioral tasks such as Emotional Stroop Task could be combined with other tools, like event-related potential (ERP) or eye-tracking (Franken, Gootjes, & Van Strien, 2009; Nijs et al., 2010). In this way, data collected from the behavioral task can be supported by brain activity recordings or gaze movements.

5. Conclusion

This study showed for the first time that vegetables grab attention inducing an attentional bias, and that "unappealing" vegetables induce a higher attentional bias, due to their sensory characteristics, independently from food neophobia level or sensory acuity. Taken together, these results indicate that acceptability for vegetables is negatively related to attentional bias in healthy non-clinical subjects, and that innately aversive sensory characteristics, and not only caloric content or degree of healthiness of a product, induce an attentional bias as they act as emotionally salient stimuli.

These results support the finding that negative sensory properties such as bitterness can act as barriers to the acceptability of vegetables and suggest that attentional and emotional processes contribute to this phenomenon. This suggests that sensory properties should be always considered in the development of strategies to increase vegetable consumption, for example modifying the product in order to mask or counterbalance potentially "negative" sensory properties. Furthermore, these strategies may take advantage of attentional mechanisms appropriately modeling them.

Responsiveness to PROP, but not food neophobia, was found to be a factor significantly associated with a stronger attentional bias in the evaluation of all vegetables, independently from their sensory properties. Future studies are needed to investigate more in depth the attentional bias at an individual level.

CRediT authorship contribution statement

Herdis Agovi: Writing – original draft, Conceptualization, Investigation, Formal analysis, Software, Methodology. **Lapo Pierguidi:** Writing – review & editing. **Caterina Dinnella:** Writing – review & editing. **Maria Pia Viggiano:** Writing – review & editing. **Erminio Monteleone:** Writing – review & editing, Conceptualization, Supervision, Project administration, Funding acquisition. **Sara Spinelli:** Writing – original draft, Conceptualization, Formal analysis, Methodology, Validation, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2021.104429.

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