Food Quality and Preference 133 (2025) 105646

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Food Neophobia mediates the variety but not the quality of food choices among adolescents☆

Lara Fontana [a,*], Isabella Endrizzi [a], Leonardo Menghi [b,c], Cinzia Franchini [d], Perla Degli Innocenti [d], Luana Bontempo [a], Flavia Gasperi [b,a]

[a] Research and Innovation Centre, Fondazione Edmund Mach, Via E. Mach, 1, 38098 San Michele all'Adige (TN), Italy
[b] Center Agriculture Food Environment, University of Trento, Via E. Mach 1, 38098 San Michele all'Adige (TN), Italy
[c] Department of Green Technology, University of Southern Denmark, Campusvej 55, 5230 Odense, Denmark
[d] Human Nutrition Unit, Department of Food and Drug, University of Parma, 43125 Parma (PR), Italy

ARTICLE INFO

Keywords:
Eating behaviour
Arousal
Food familiarity
Mediterranean diet

ABSTRACT

Eating habits become embedded during adolescence, a developmental stage where individuals increasingly assume responsibility for their dietary choices. Understanding the factors influencing these choices is essential for preventing unhealthy lifestyle patterns in adulthood. Food Neophobia (FN), a trait linked to limited dietary variety and quality as well as specific food preferences, is particularly important to investigate in adolescents. In this study, 200 adolescents (aged 14–17; 35 % girls and 65 % boys) participated in a Food Choice Task designed to evaluate their autonomous food choices across two dimensions: the willingness to select novel or unfamiliar products (reflecting dietary variety) and the inclination to choose healthy options (reflecting dietary quality). Foods depicted in images were categorised as familiar or unfamiliar based on a pilot study and as healthy or unhealthy based on whether they were inspired by the Mediterranean Diet (MD). Findings revealed that adolescents with higher levels of FN were less likely to choose unfamiliar foods. However, no significant differences were observed in the selection frequency between healthy and unhealthy foods based on FN scores. This may be due to the high familiarity and low arousal ratings associated with the foods in these categories, which could mask the effects of FN as no food reached a "warning threshold" that would induce rejection. To promote healthier eating habits among neophobic adolescents, it is recommended to provide simple, familiar food options that evoke minimal arousal, thereby supporting better dietary choices.

1. Introduction

Eating habits seem to consolidate during adolescence, a transitional phase marked by notable shifts in dietary patterns, physical activity levels, and psychological well-being (Sweeting et al., 1994). It is crucial to acknowledge these changes to prevent the adoption of unhealthy lifestyles (Wu et al., 2023), which may result in an increased likelihood of developing conditions such as obesity and non-communicable diseases in adulthood (Ruiz et al., 2020). Eating habits and thus the choice of what to eat, is a complex phenomenon influenced by diverse factors of a physiological, psychological, cultural, and socioeconomic nature (de Andrade Previato & Behrens, 2017). When defining a healthy diet, it refers to a varied and balanced diet that meets individuals' nutritional needs through a combination of foods of high nutrition quality while reducing the intake of foods high in saturated fats (SFAs), sugar, or sodium (FAO & WHO, 2016). Above all, the Mediterranean Diet (MD) has long been considered a pattern in healthy eating, since it is universally recommended as health promoting and disease protective (Dinu et al., 2020; Strisciuglio et al., 2020). The MD recommends the regular use of olive oil as main seasoning and is characterised by high consumption of vegetables, fruits, whole grains, nuts, and pulses (i.e., recommended foods), moderate intake of fish, poultry, eggs, and dairy products and low consumption of red meat and processed meat, as well as sweets (i.e., non-recommended foods) (Willett et al., 1995).

In recent years, the dietary habits of Italians have increasingly been characterised by the consumption of industrial and processed foods, rich

☆ This article is part of a Special issue entitled: 'EuroSense 2024' published in Food Quality and Preference.

* Corresponding author.
E-mail addresses: lara.fontana@fmach.it (L. Fontana), isabella.endrizzi@fmach.it (I. Endrizzi), leom@igt.sdu.dk (L. Menghi), cinzia.franchini@unipr.it (C. Franchini), perla.degliinnocenti@unipr.it (P. Degli Innocenti), luana.bontempo@fmach.it (L. Bontempo), flavia.gasperi@fmach.it (F. Gasperi).

https://doi.org/10.1016/j.foodqual.2025.105646
Received 15 October 2024; Received in revised form 10 June 2025; Accepted 24 July 2025
Available online 25 July 2025

in sugars, SFAs, and sodium, making them even more distant from the traditional MD (Biasini et al., 2021; Ruggiero et al., 2021). Young populations including adolescents are not exempt from this negative trend (Grosso & Galvano, 2016; Rosi et al., 2019).

When considering food variety, food neophobia (FN), namely the reluctance to eat and/or avoidance of different foods (Pliner & Hobden, 1992) is a barrier to achieving a varied diet. The willingness to try unfamiliar foods is essential to have a varied diet (Woo & Lee, 2013) and for ensuring sufficient intake of both macro- and micronutrients (Di Nucci et al., 2023). Broadly, FN is associated with reduced dietary variety (Falciglia et al., 2000; Perry, 2015). There is a paucity of literature investigating correlations between FN and eating behaviours among adolescents (Maiz & Balluerka, 2016; Nicklaus et al., 2005; Rigal et al., 2006; Roßbach et al., 2016) compared to children (for review, see Dovey et al., 2008). A study by Nicklaus et al. (2005) showed that food variety seeking was correlated with low levels of FN (Nicklaus et al., 2005). Moreover, FN also seems to impact the quality of the diet. Children exhibiting higher levels of FN tend to consume fewer vegetables (Galloway et al., 2003; Guzek et al., 2017) and fruits (Cooke et al., 2006) compared to children with lower levels of FN. In contrast, only a few connections between FN and dietary habits were observed in the adolescent cohort of the DONALD study (Roßbach et al., 2016). Maiz and Balluerka (2016) found that neophobic adolescents were less adherent to the MD as indicated by a lower intake of fruits, vegetables, and fish, a higher intake of sweets or candies. This implies that FN might influence food choices by reducing the consumption of beneficial foods such as fruits and vegetables while increasing the intake of sugary foods, as well as SFAs and salt. However, the exact mechanism behind this phenomenon remains unclear (Hazley et al., 2022).

When approaching foods, individuals with high FN scores are more likely to experience negative arousal, a transitory state of heightened alertness, physical tension, and autonomic changes (e.g., shifts in heart rate, skin conductance, and respiration), which is commonly triggered by unexpected or intense sensory input that may amplify discomfort and distress (Prescott & Spinelli, 2024; Raudenbush & Capiola, 2012). Intrinsically, novelty triggers heightened arousal, and this is supported by several evidence suggesting that unfamiliar foods evoke a perception of greater potential danger (Jaeger et al., 2023; Raudenbush & Frank, 1999) and are usually less liked (Tuorila et al., 2001) compared to familiar foods. For instance, in a large-scale study on adults ($n = 7474$) by Jaeger et al. (2023), food names emphasising novelty were rated high in arousal and this strongly influenced overall food acceptability. Moreover, this effect appeared to intensify as familiarity decreased. Indeed, apart from stimulus novelty, heightened arousal also indicates the food complexity and the intensity of flavour elicited by food stimuli, as well as the 'foreignness' of the dish (Jaeger et al., 2023).

While numerous studies have established the influence of FN on dietary habits (e.g., Falciglia et al., 2000; Perry, 2015), research focusing specifically on adolescents is limited. Among the existing studies, some have identified a correlation between FN and reduced dietary variety (Nicklaus et al., 2005), as well as lower consumption of recommended foods and higher intake of non-recommended foods (Maiz & Balluerka, 2016). However, these studies did not explore the role of arousal as a potential mediator in adolescents' food choices—an important factor for understanding how to encourage healthier eating patterns in this demographic. Given that adolescence is a period of significant change, where increasing autonomy in food choices coincides with continued familiar influence on eating habits (Story et al., 2002), it is crucial to investigate these dynamics further. Therefore, it is essential to employ tools designed to mimic real-life decision-making scenarios in food choices, using stimuli that differ in relevant cues (e.g., nutritional quality, familiarity) and potentially reflect the options adolescents are likely to autonomously choose between in their daily lives.

In this context, food frequency questionnaires (FFQ) are one of the most commonly used tools for assessing food consumptions, because they offer several advantages. They are cost-effective, relatively easy to administer and can capture habitual dietary intake over an extended period (Cade et al., 2004). However, their accuracy is limited compared to the weighed food record recognized as the "gold standard" for dietary assessment (Carlsen et al., 2010; Schoeller et al., 2013). Additionally, these instruments are intended to assess general dietary patterns, which limits their capacity to differentiate between familiar and individual influences on adolescent dietary decisions. Indeed, teenagers eat what is offered at home or in the canteen, but they may also already be used to cooking and managing their own meal. Conversely, food choice tasks, employing food-related stimuli, offer a more direct exploration into how individuals decide what to eat. They enable the measurement of decision-making between pairs of food-related stimuli (e.g., pictures, names, real foods) by exploring personal preferences without imposing any learning prerequisites or prescribing right or wrong answers (Foerde et al., 2018). For instance, this type of task is optimal for evaluating the results of interventions aimed at changing eating habits (Foerde et al., 2018), as it is not inflated by reporting biases that could lead to inaccurate results. Additional common uses include the assessment of preferences between healthy and unhealthy foods (Hare et al., 2009) or between foods with varying caloric density and macronutrient content (Foerde et al., 2018; Steinglass et al., 2015). These paradigms have several variations, with the specifics of the chosen task within a study depending on the hypothesis under investigation (Barakchian et al., 2021).

The aim of this study was to investigate the impact of FN on adolescents' food choices, particularly in relation to dietary variety and quality. While the relationship between product familiarity, FN, and food choices in adolescents has been previously explored (Roßbach et al., 2016), this study fills important gaps by focusing specifically on adolescents' autonomous food choices using stimuli based on local traditional foods validated through a pilot study. These stimuli vary in relevant attributes such as nutritional quality and familiarity, reflecting the real-life options adolescents are likely to encounter and choose independently. This culturally relevant and ecologically valid approach advances the field by integrating assessments of FN, arousal, and food choice in a way that potentially captures behaviourally-relevant differences in dietary variety and quality, which are often estimated in common dietary assessments due to their implicit methodological limitations (Bailey, 2021).

The first objective was to confirm the diminished willingness to try unfamiliar foods and consequently the reduced dietary variety, in adolescents with a higher FN score. Secondly, it was examined whether FN contributes to lower intake of recommended foods and higher consumption of non-recommended foods (Proserpio et al., 2020). Recommended foods often elicit low valence (the intrinsic pleasantness or unpleasantness of a stimulus), high arousal, and are less familiar, which may explain FN's impact on dietary quality. Therefore, to minimize potential confounding effects and obtain not inflated results, only familiar and minimally arousing food products were considered. A third objective was to elucidate the role of arousal in mediating food choices among neophobic adolescents. As previously mentioned, FN is associated with higher arousal and lower liking ratings for foods, particularly for unfamiliar foods (Jaeger et al., 2023). Therefore, it was investigated whether arousal ratings could act as a mediator in the relationship between FN and adolescents' food choices, particularly when it comes to unfamiliar foods.

Finally, beyond FN, the potential influence of adolescents' broader dietary habits on their food choices was also explored. Participants' eating behaviours were assessed in terms of their adherence to the MD, daily dietary habits (e.g., skipping breakfast, eating with family), and frequency of consumption of different food groups.

To address these objectives, an experimental task was developed to assess adolescents' food choices using two controlled contrasts. The first contrast measured their willingness to choose novel/unfamiliar products (dietary variety), while the second examined their preference for healthy versus unhealthy food options (dietary quality).

The present study is part of a broader investigation, the Promedlife project (PRIMA 2021, GA n°2132), which aims to reverse the decline in adherence to the MD pattern through a multi-actor approach.

2. Material and methods

2.1. Study design and participant recruitment

In this cross-sectional study, 200 first- and second-year students from

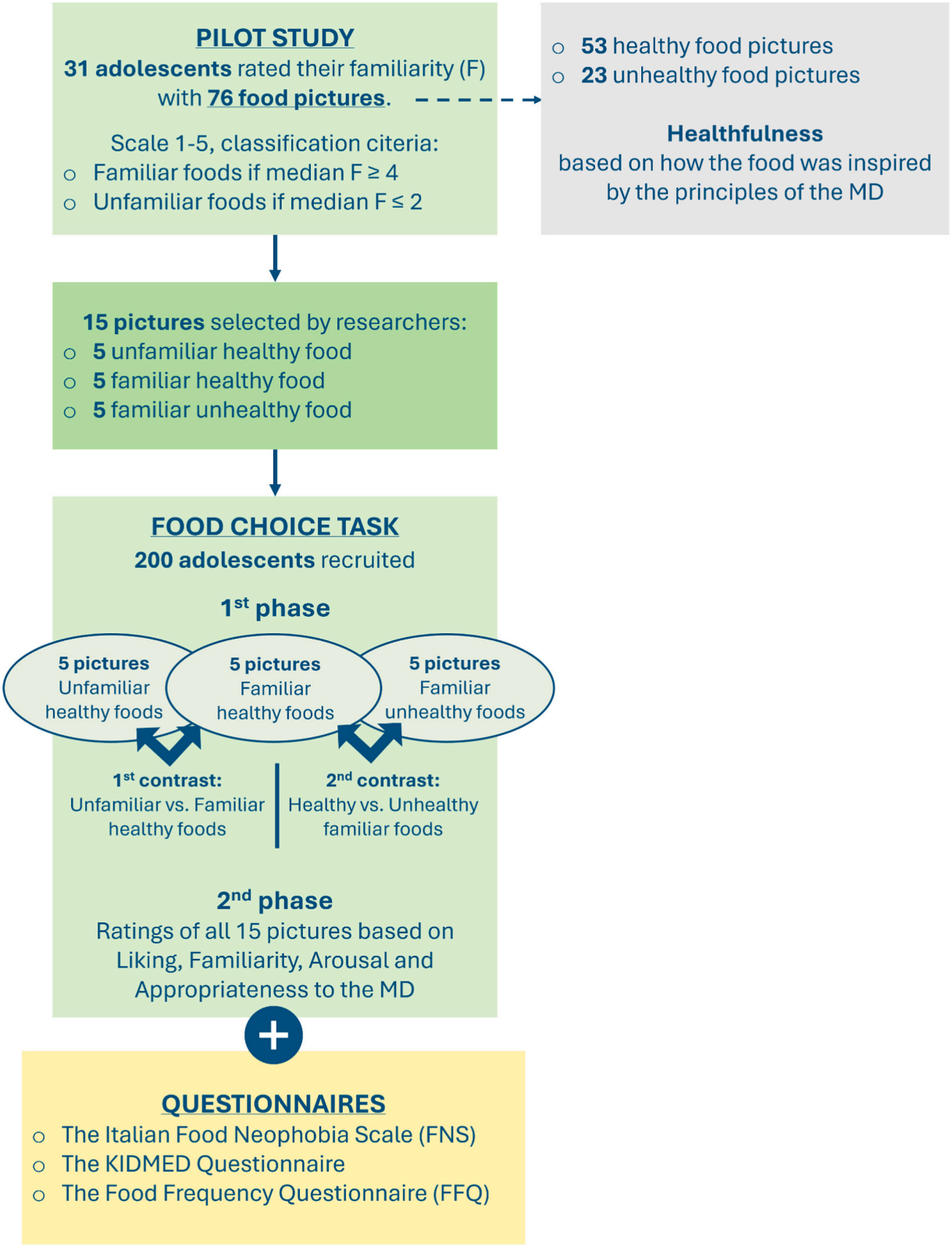

Fig. 1. Flowchart outlining the selection of food images, classification criteria (familiar vs. unfamiliar, healthy vs. unhealthy) and the subsequent Food Choice Task procedure.

a high school in Northern Italy were recruited (mean age ± SD = 14.5 ± 0.6 years old, age range = 14–17 years old, 35 % girls and 65 % boys, BMI ± SD = 21.2 ± 3.7 Kg/m^2, 97 % omnivores). This study was approved by the Research Ethics Committee of the University of Trento, Italy (Protocol 2023–048, approved on September 14, 2023) and conducted according to the Declaration of Helsinki (World Medical Association (World Medical Association, 2013); last amendment in 2013 - Fortaleza, Brasil). Written consent was obtained prior to the study from all the parents of the participants, while written assents were obtained directly from the students. All the participants were invited to the sensory laboratory of the Edmund Mach Foundation (San Michele all'Adige, Trento, Italy), during school days in a time window between 9 and 11 a.m., before the mid-morning snack. Participants were instructed to refrain from smoking, eating, drinking for at least 2 h prior the start of the lab session. During the lab session, participants first completed the Food Choice Task (FCT). Later, they completed a series of questionnaires to gather data on FN, adherence to the MD and dietary habits. The experimental session lasted about 60 min. All data were collected via the Eye Question software (Elst, The Netherlands). Participants accessed the software through a provided tablet.

2.2. Food choice task

2.2.1. Food pictures

Fig. 1 presents the flowchart of the experimental design, from the selection of pictures to the actual task. Food pictures were used as stimuli in the FCT and were selected based on a pilot experiment (see Fig. 1). In the FCT participants selected preferences between familiar and unfamiliar healthy foods and healthy versus unhealthy familiar foods across food pairs. Thus, to classify foods as familiar and unfamiliar, a pilot experiment was conducted with 31 adolescents living in the same geographical area as those involved in the main study (mean age ± SD = 16.7 ± 0.8 years old, age range = 15–18 years old, 32.3 % girls and 67.7 boys). They rated the familiarity level towards 76 pictures showing foods (i.e., single food items, raw or cooked recipes) that were either consistent or inconsistent with the MD. Familiarity ratings were measured by the question "How familiar are you with each of the following foods?" with responses to in five categories: 'I do not recognize it' (1), 'I recognize it, but I have never tasted it' (2), 'I have tasted it, but I don't eat it' (3), 'I occasionally eat it' (4) and 'I regularly eat it' (5) (Tuorila et al., 2001).

Fifteen pictures were then selected, representing ten familiar foods (with a median familiarity rating (Med (F)) ≥ 4 on the 5-point scale described above) and five unfamiliar foods (with a median familiarity rating (Med (F)) ≤ 2). Five out of the ten familiar food pictures were classified as healthy options consistent with MD and five inconsistent. Conversely, the pictures (n = 5) classified as unfamiliar were all representing foods considered healthy alternatives inspired by the MD. Healthfulness was determined by considering how closely each dish was inspired by the principles of the MD. MD-related dishes were characterised by the use of core food groups, such as fruits, vegetables, fish, nuts, and legumes, with preparation methods emphasising the use of extra virgin olive oil, light cooking techniques (e.g., boiling or grilling rather than frying), and a preference for fresh or minimally processed ingredients. In contrast, dishes that deviated from the MD included refined products, sugary foods, and sources of saturated fats (e.g., butter). These dishes were typically prepared using animal fats.

For investigating the contrast between familiar vs. unfamiliar healthy foods, pictures were paired based on different familiarity scores (Med (F) >4 and Med (F) <2), similar estimated nutrient content, and appropriateness for the written context (see Fig. 2, panel A). Likewise, to analyse choices between healthy and unhealthy familiar foods, pictures

Fig. 2. Stimuli example of Food Choice Task for the familiar vs. unfamiliar contrast (panel A) and healthy vs. unhealthy contrast (panel B).

with similar familiarity scores (Med (F) ≥4) but different consistency at MD were paired to fit the context displayed (see Fig. 2, panel B). Moreover, all food pairs were depicted on comparable plates (see Fig. 2).

2.2.2. Responses to food pictures

The FCT consisted of two phases (see Fig. 1): the first phase explored adolescents' food choices when presented with two options in a specific context, while the second phase measured participants' responses, i.e., Liking, Arousal, Familiarity, and Appropriateness to the MD (AMD), towards each previously presented food option. In the first phase, the choice phase, participants were presented with ten pairs of food pictures. Among these pairs, five compared familiar food with unfamiliar ones, while the remaining five contrasted familiar options, comparing healthy versus unhealthy. In each of the five pairs, the familiar healthy food was common between the two contrasts, as well as the written description of the choice context (see Fig. 2 and Table 1). The sequence in which food pairs were presented and the placement of pictures on the screen (right or left) were randomized. The second phase involved evaluating the fifteen pictures that were previously presented during the food choice phase. Participants provided four types of responses for each food picture in sequence. Liking was measured in response to the question, "How much do you like each of the following foods?" using a 9-point labelled hedonic scale ranging from 1 ('dislike extremely') to 9 ('like extremely'). Arousal ratings were collected by inquiring, "When you consider eating each of the following foods, please indicate how it makes you feel", using a 7-point scale, with 'relaxed' (1) and 'anxious' (7) as endpoints (Jaeger et al., 2023). Familiarity was assessed through the question "How familiar are you with each of the following foods?". Participants used a 5-point scale from 1 ('I do not recognize it') to 5 ('I regularly eat it') (Tuorila et al., 2001). Finally, participants rated the extent to which each food was inspired by the MD principles by answering the question "How much each of the following foods are in line with the Mediterranean Diet?", using a 9-point labelled scale ranging from 1 ('Not in line') to 9 ('Extremely in line'). Responses for all fifteen food pictures were collected for one question before moving to the next (see Fig. 1). The presentation order of food pictures was randomized for each response variable. There was no time limit for participants to provide responses during any phase.

Table 1
Descriptions of the food pictures presented considering the two different contrasts in the Food Choice Task.

Written Context	FAMILIAR healthy Picture	UNFAMILAR healthy Picture	Familiar HEALTHY Picture	Familiar UNHEALTHY Picture
"You had a hearty breakfast and now you're at school feeling a bit hungry, what would you choose for a snack?"	Apple	Dragon fruit	Apple	Sweet doughnut
"You're having a snack, what would you drink with it?"	Orange Juice	Tomato Juice	Orange Juice	Carbonated drink
"You're on vacation and need to have a quick lunch, what would you choose?"	Tomato, Mozzarella and Basil Panini	Octopus, Burrata and spinach Panini	Tomato, Mozzarella and Basil Panini	Bratwurst Panini
"You are having lunch and for your first course you had a pasta dish, what would you choose as your second course?"	Dish with salad, tomato and nuts	Dish with kale, walnuts and pomegranate	Dish with salad, tomato and nuts	Roast potatoes
"You're at the restaurant and can only choose one dish to eat for dinner, what would you choose?"	Pasta with salmon and zucchini	Cous cous with vegetables and chickpeas	Pasta with salmon and zucchini	Cheese "canederli" (dumplings) with butter

2.3. Questionnaires

2.3.1. The Italian food Neophobia scale

In this study, the Italian Food Neophobia Scale (FNS) to measure FN (Pliner & Hobden, 1992) was employed, which was translated and validated by Laureati et al. (2018). The FNS consists of 10 items, each rated on a 7-point scale from 1 ('strongly disagree') to 7 ('strongly agree'). Notably, scores from positively keyed items (e.g., 'I will eat almost anything') were reversed (e.g., a score of 7 was transformed into 1), so that higher values always indicated stronger neophobic tendencies. By summing the scores given to all ten items, an individual's FNS score was calculated, ranging from 10 to 70. Higher scores on this scale indicate stronger tendencies towards neophobia regarding food choices. The Italian FNS (Laureati et al. in 2018), underwent validation using data from respondents aged 20 to 60 years. In contrast, the validation process for the scale in Italian children (ICFNS; Laureati et al., 2015) relied on responses from primary school students aged 6 to 9 years old. Neither of these scales encompasses adolescents within the age range of our current study. Consequently, FN was evaluated in our adolescent sample using the Italian FNS, considering its wider adoption among the adolescent population compared to the child version (Appleton et al., 2019; Roßbach et al., 2016; Sorokowska et al., 2022). Cronbach's α of the measure used was acceptable (Cronbach's $\alpha = 0.79$), though somewhat lower than that reported by Laureati et al. (2018) with adults' populations (Cronbach's $\alpha = 0.87$).

2.3.2. The KIDMED questionnaire

The second questionnaire proposed was the validated "KIDMED Test" developed by Serra-Majem et al. (2004), which was used to evaluate adolescent adherence to the MD. The Italian version of this questionnaire (Santomauro et al., 2014) was employed. This questionnaire is specifically designed to evaluate whether adolescents' dietary behaviours align with the principles of the MD pattern. It comprises 16 yes/no questions.

Responses indicating adherence to MD principles, such as using olive oil at home, were scored +1, while those contrary to MD principles, like skipping breakfast, were scored −1. The KIDMED score, which ranges from 0 to 12, is used to categorise adherence levels. A score of ≥8 is indicative of "high" adherence, a score of 4–7 points indicate "medium" adherence and a score ≤ 3 or below denotes "poor" adherence.

2.3.3. Food frequency questionnaire

Eating behaviours was measured by administering the Italian version of the food frequency questionnaire developed by the Health Behaviour in School-aged Children (HBSC) study, as it is one of the largest

international investigations on child and adolescent health and co-operates with the World Health Organization (Rakić et al., 2024). Items were added to the original questionnaire to explore the consumption of other food groups (milk or dairy products, breakfast cereals, cheese, eggs, dried fruit, white meat, red meat, and fish). Participants were asked to rate the frequency of consumption of fifteen food groups (e.g., Vegetables, Fruits, Sweets, Grains, Eggs), by answering the question: "How many times a week do you usually eat or drink …. ?" with the following responses: "Never", "Less than once a week", "Once a week", "2–4 days a week", "5–6 days a week", "Once a day/every day" and "More than once per day".

Moreover, following Liu et al. (2023), the consumption data for four food groups was combined: vegetables, fruits, sweets, and sugary beverages. A score from 0 to 4 was assigned based on the frequency of fruit and vegetable consumption (i.e., higher values indicated more frequent consumption of these recommended food groups). On the contrary, for sweets, and sugary beverages the score was reversed. The total score (Eating behaviour index - EBI) ranged from 0 to 16, with higher scores indicating better dietary quality (Liu et al., 2023).

2.4. Statistical analyses

In the present study, RStudio (version 1.4.1103, Boston, MA, United States; RStudio Team, 2016) was employed as the primary software tool for conducting statistical analyses.

The *lme4* package (Bates et al., 2018) was used to compute linear mixed-effects models (LMEs), for the following dependent variables: Liking, Arousal, Familiarity, and AMD (Likert scales). Generalised linear mixed effect models (GLMMs) were instead employed to investigate choices for unfamiliar vs. familiar foods and healthy vs. unhealthy foods. The binary response variable, indicating whether participants chose the unfamiliar food or the healthy food, was regressed against FN score, KIDMED score, and EBI as the predictors. In these analyses (LMEs, GLMMs), the binary classification of food pictures as familiar or unfamiliar and healthy or unhealthy (hereafter referred to as Food characteristic), the FN, the KIDMED, and the EBI scores were included as independent variables (fixed factors). Moreover, participants were included as a random effect, considering the stochastic variability in the data, to reflect a more general estimate of the fixed effects (Singmann & Kellen, 2019). A model comparison approach (McElreath, 2016) was then employed to contrast the computed LME models via likelihood ratio tests. The model with the lowest Akaike information criterion (AIC) was deemed to be the best fitting to the data. To account for the relative evidence (i.e., likelihood and parsimony) of a given model, the exponent of the difference between the AIC of nested models [$AIC_{RL} = \exp.(\Delta AIC/2)$] was calculated (e.g., Fontana, Albayay, Fernandez-Prieto, & Zampini, 2022). All models were fitted with maximum likelihood estimation. Furthermore, the *piecewiseSEM* package (Lefcheck, 2016) was used to estimate the marginal and conditional R^2 to account for the variance explained by the fixed effects (R^2_m) and by both the fixed and random effects (R^2_c).

Bootstrapping method was used to assess the statistical significance of a mediation effect in order to understand how the independent variables influence the choices of the dependent variables through an intermediary factor (Alfons et al., 2022). The role of two mediators, namely arousal and familiarity, was investigated, thereby revealing the mechanisms underlying these observed relationships.

Data are presented as mean ± standard deviation (SD) where indicated. All tests were conducted as two-tailed and a p value <0.05 was considered statistically significant.

For the sake of openness, transparency and reproducibility of research, all the data reported in this study and the RStudio analysis scripts are available in the Open Science Framework repository accessible at https://osf.io/92e5w/

3. Results

3.1. Food neophobia and responses to healthy food: Familiar vs. unfamiliar options

In Table 2, the results of linear mixed-effects models are reported to investigate the role of FN on the evaluations of different parameters (Liking, Arousal, Familiarity, and AMD) for healthy foods, either familiar and unfamiliar. The main effect of FN on Liking was significant. Specifically, higher FN score was associated with lower liking of both familiar and unfamiliar foods. Additionally, there was a significant effect of the Food characteristic, indicating that participants, regardless of the FN score, preferred familiar foods (6.7 ± 1.8) over unfamiliar ones (3.8 ± 2.1). Furthermore, the first order interaction between FN score and Food characteristic was significant. Specifically, participants with lower FN scores liked unfamiliar foods more than those with higher scores. However, there was a significant difference in Liking also for familiar items across different FN scores, although this difference was less evident than for unfamiliar items (see Fig. 3, Panel A). Similarly, FN score significantly influenced food Arousal, a higher FN score was associated with higher Arousal scores. Unfamiliar foods also triggered higher Arousal (4 ± 1.8) compared to familiar ones (1.9 ± 1.3). The first order interaction between FN score and Food characteristic on Arousal scores was significant, participants with higher FN score showing greater Arousal particularly towards unfamiliar foods as compared to familiar ones (see Fig. 3, Panel B).

Moreover, FN score influenced Familiarity towards foods, a higher FN score was associated with lower Familiarity scores. In line with our expectations, familiar foods were rated as more familiar (4.2 ± 1) than unfamiliar ones (2.1 ± 1.1). The interaction between FN score and Food characteristic was not significant, indicating that participants with high FN systematically rated both familiar and unfamiliar labelled foods as less familiar compared to those with lower FN (see Fig. 3, Panel C). The evaluation of AMD was not influenced by FN score, but familiar foods were overall perceived as more inspired by the MD (7.1 ± 1.6) than unfamiliar ones (5.2 ± 2.2) (see Fig. 3, Panel D). However, there was no significant interaction between FN score and Food characteristic on AMD (see Table 2).

3.2. Food neophobia and responses to familiar foods: Healthy vs. unhealthy food options

In Table 3, the results of linear mixed-effects models were reported to investigate the role of FN on the evaluations of different parameters (Liking, Arousal, Familiarity, and AMD) for familiar foods, either healthy and unhealthy. The main effect of FN and Food characteristic on Liking was significant, showing that lower neophobic adolescents liked more foods as compared to their higher neophobic peers. Moreover, participants preferred unhealthy foods (7.4 ± 1.5) as compared to healthy ones (6.7 ± 1.8). The first order interaction reached significance, indicating that adolescents with lower FN liked more healthy foods as compared to adolescents with higher FN score (see Fig. 4, Panel A), while no difference emerged for unhealthy foods.

The main effect of FN and Food characteristic on Arousal level was significant, indicating that higher FN score was associated with higher Arousal scores, as well as healthy foods produced greater Arousal (1.9 ± 1.3) than unhealthy ones (1.5 ± 1.0). The first order interaction FN score x Food characteristic reached significance, highlighting an increased Arousal towards healthy foods in adolescents with higher FN as compared to lower scores (see Fig. 4, Panel B).

FN score was significant in the evaluation of Familiarity of foods, where participants with lower FN score evaluated foods as more familiar than their peers with higher scores. Moreover, healthy foods were rated as less familiar (4.2 ± 1.0) as compared to unhealthy ones (4.5 ± 0.7). The first order interaction reached significance, indicating that participants with higher FN score evaluated healthy foods as less familiar

Table 2
Results of the mixed-effects modelling of the different parameters (Liking, Arousal, Familiarity, and Appropriateness to the Mediterranean diet) on the Food characteristic (familiar vs. unfamiliar) and Food neophobia score.

Dependent variable	Independent variable	Likelihood ratio test [$\chi^2(1)$]	Estimate	*p* value	AIC_{RL}	R^2_m	R^2_c
Liking	FN score	45.285	−0.025	**<0.001**	>100	0.032	0.068
	Food characteristic	1000.1	−1.440	**<0.001**	>100	0.358	0.465
	FN score x Food characteristic	26.571		**<0.001**	>100	0.398	0.473
	Familiar[a]	10.706	−0.025	**0.001**	77.721	0.017	0.157
	Unfamiliar[b]	54.69	−0.066	**<0.001**	>100	0.095	0.246
Arousal	FN score	46.94	0.031	**<0.001**	>100	0.052	0.164
	Food characteristic	1003.3	1.140	**<0.001**	>100	0.322	0.521
	FN score x Food characteristic	23.611		**<0.001**	>100	0.379	0.528
	Familiar[a]	27.481	0.031	**<0.001**	>100	0.051	0.250
	Unfamiliar[b]	41.268	0.061	**<0.001**	>100	0.102	0.430
Familiarity	FN score	38.637	−0.018	**<0.001**	>100	0.019	0.019
	Food characteristic	1617	−1.926	**<0.001**	>100	0.529	0.596
	FN score x Food characteristic	2.691		0.101	1.413	0.548	0.597
AMD	FN score	2.859	−0.009	0.091	1.537	0.003	0.125
	Food characteristic	543.09	−1.734	**<0.001**	>100	0.205	0.125
	FN score x Food characteristic	0.639		0.424	0.506	0.208	0.353

Note: Bold *p* values denote statistical significance with α = 0.05.
AIC_{RL} = exponent of the difference between the AIC (Akaike information criterion) of the models; R^2_m = marginal effect size; R^2_c = conditional effect size.
[a] Effect of FN for the familiar foods.
[b] Effect of FN for the unfamiliar foods.

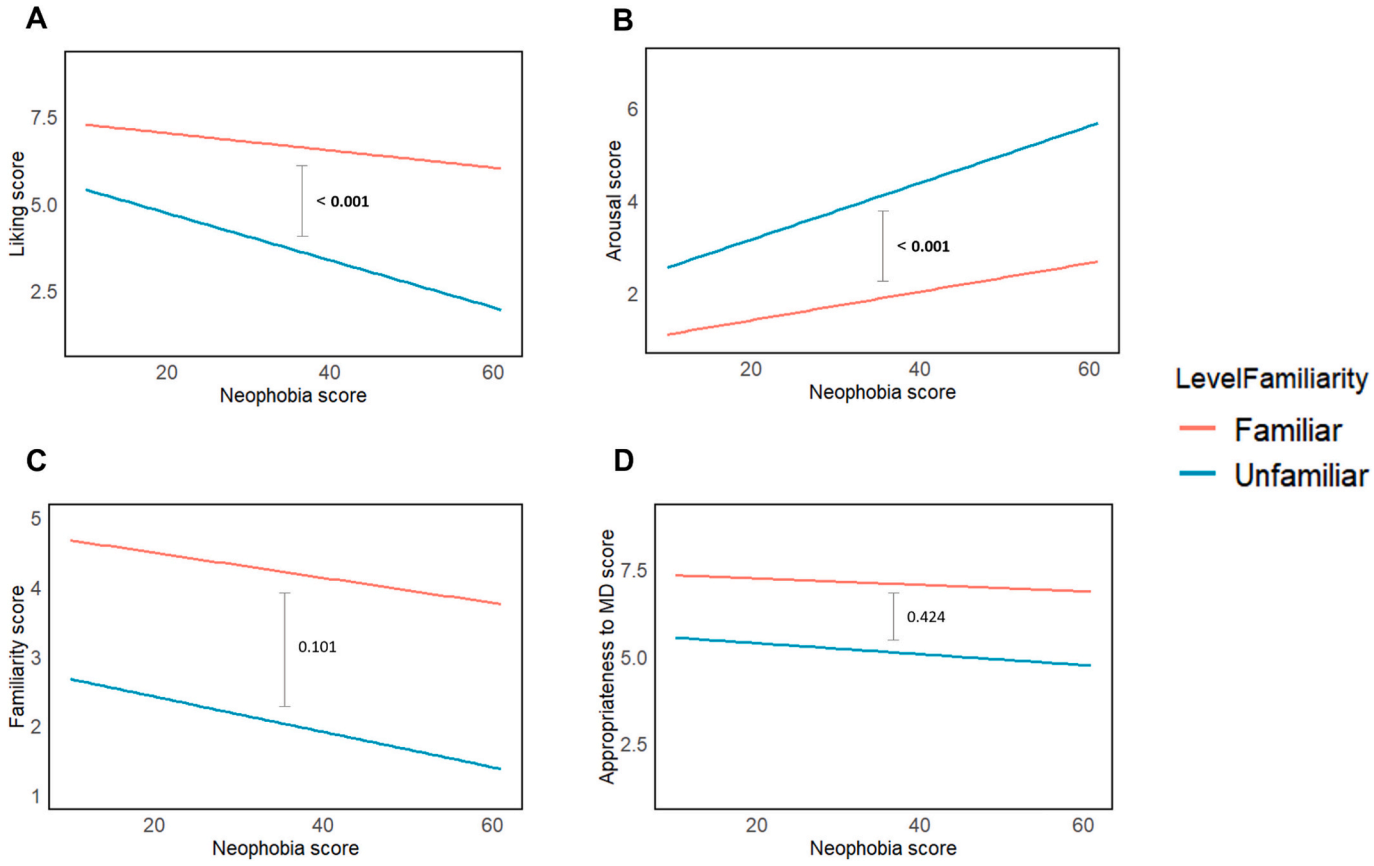

Fig. 3. Liking (Panel A), Arousal (Panel B), Familiarity (Panel C), and Appropriateness to the Mediterranean Diet (Panel D) scores for familiar and unfamiliar healthy foods based on Food neophobia score.

compared to adolescents with lower scores, while no difference emerged for unhealthy foods (see Fig. 4, Panel C).

Concerning AMD evaluation, no differences emerged among FN score (see Fig. 4, Panel D). In line with our expectations, healthy foods were evaluated by all the adolescents as more inspired by the MD (7.1 ± 1.6) than unhealthy ones (4.6 ± 2.3) (see Table 3).

3.3. Food choice preferences for familiar vs. unfamiliar, healthy vs. unhealthy foods based on food neophobia, KIDMED and eating behaviour index

The main effect of FN on preferences for familiar versus unfamiliar foods was found to be statistically significant ($p < 0.05$). Participants with lower FN score showed a higher tendency to choose unfamiliar food

Table 3
Results of the mixed-effects modelling of the different parameters (Liking, Arousal, Familiarity, and Appropriateness to the Mediterranean Diet) on the Food neophobia score and Food characteristic (healthy vs. unhealthy).

Dependent variable	Independent variable	Likelihood ratio test [$\chi^2(1)$]	Estimate	*p* value	AIC_{RL}	R^2_m	R^2_c
Liking	FN score	5.311	−0.025	**0.022**	5.236	0.005	0.021
	Food characteristic	108.92	−0.122	**<0.001**	>100	0.049	0.133
	FN score x Food characteristic	11.667	0.026	**<0.001**	>100	0.058	0.139
	Healthy[a]	10.706	−0.025	**0.001**	77.721	0.017	0.157
	Unhealthy[b]	0.0129	0.001	0.910	0.370	<0.001	0.145
Arousal	FN score	21.668	0.031	**<0.001**	>100	0.033	0.244
	Food characteristic	49.875	0.279	**<0.001**	>100	0.019	0.265
	FN score x Food characteristic	13.693		**<0.001**	>100	0.057	0.270
	Healthy[a]	27.481	0.031	**<0.001**	>100	0.051	0.250
	Unhealthy[b]	6.790	0.014	**0.009**	10.967	0.017	0.378
Familiarity	FN score	21.207	−0.018	**<0.001**	>100	0.016	0.067
	Food characteristic	47.784	−0.195	**<0.001**	>100	0.022	0.091
	FN score x Food characteristic	11.528		**<0.001**	>100	0.043	0.097
	Healthy[a]	24.485	−0.018	**<0.001**	>100	0.029	0.058
	Unhealthy[b]	3.148	−0.005	0.076	1.775	0.005	0.161
AMD	FN score	0.002	−0.009	0.969	0.368	<0.001	0.104
	Food characteristic	758.67	−3.127	**<0.001**	>100	0.277	0.412
	FN score x Food characteristic	5.078		**0.024**	4.661	0.279	0.414
	Healthy[a]	1.506	−0.009	0.220	0.781	0.003	0.267
	Unhealthy[b]	0.693	0.010	0.405	0.520	0.002	0.363

Note: Bold *p* values denote statistical significance with $\alpha = 0.05$.
AIC_{RL} = exponent of the difference between the AIC (Akaike information criterion) of the models; R^2_m = marginal effect size; R^2_c = conditional effect size.
[a] Effect of FN for the healthy foods.
[b] Effect of FN for the unhealthy foods.

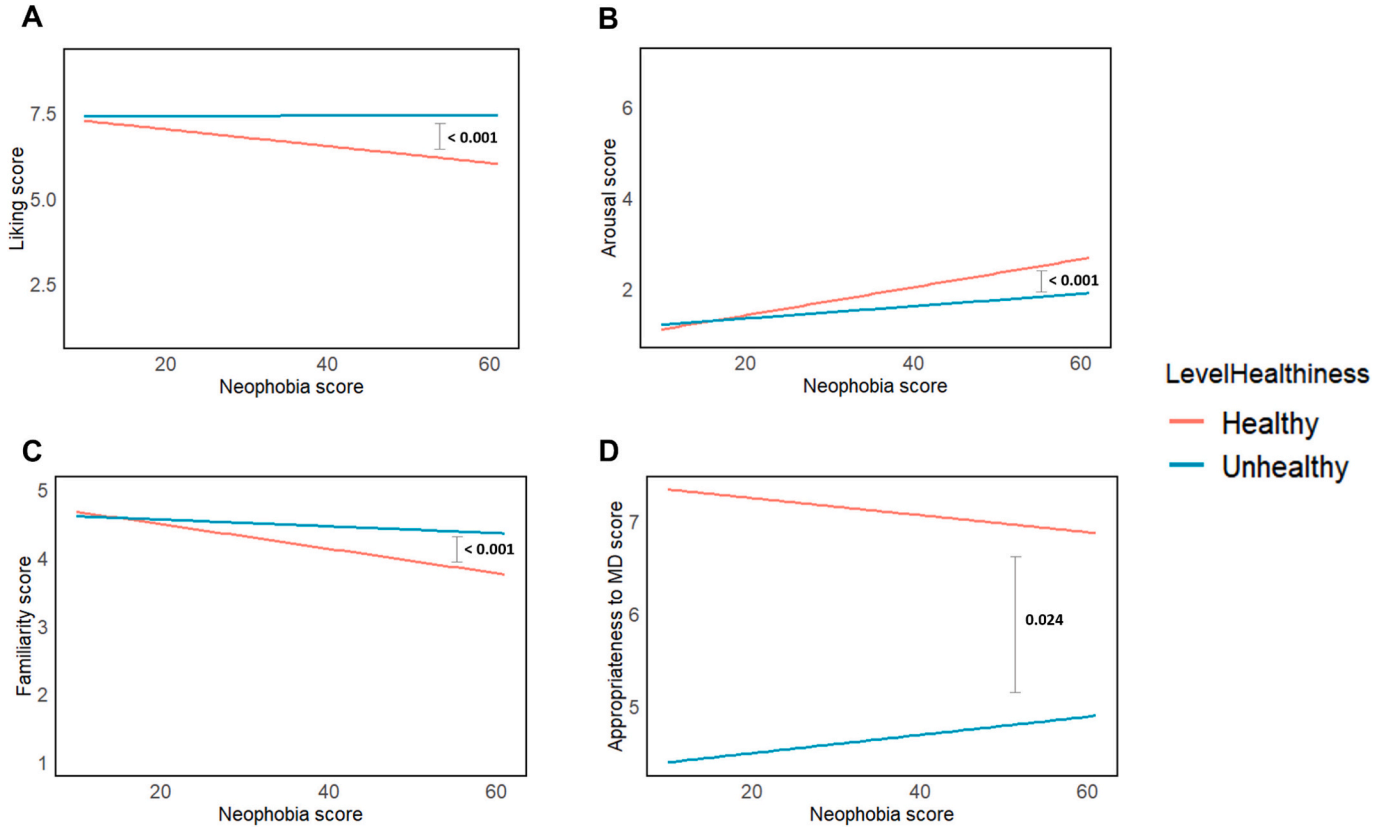

Fig. 4. Liking (Panel A), Arousal (Panel B), Familiarity (Panel C), and Appropriateness to the Mediterranean Diet (Panel D) scores for healthy and unhealthy familiar foods based on Food neophobia score.

pictures compared to those with higher scores (see Fig. 5, Panel A), while no differences emerged considering the scores of KIDMED and EBI. Regarding the choice between healthy and unhealthy foods, neither the FN (see Fig. 5, Panel B) nor the KIDMED scores exhibited a significant effect. EBI had a significant role in modulating the choice of healthy products, where higher scores of EBI led to a higher tendency to choose healthy foods (see Table 4).

Table 5 presents the descriptive analysis of all measurements for the total sample, as well as stratified by class and gender. The table includes summary statistics such as means and standard deviations, providing an

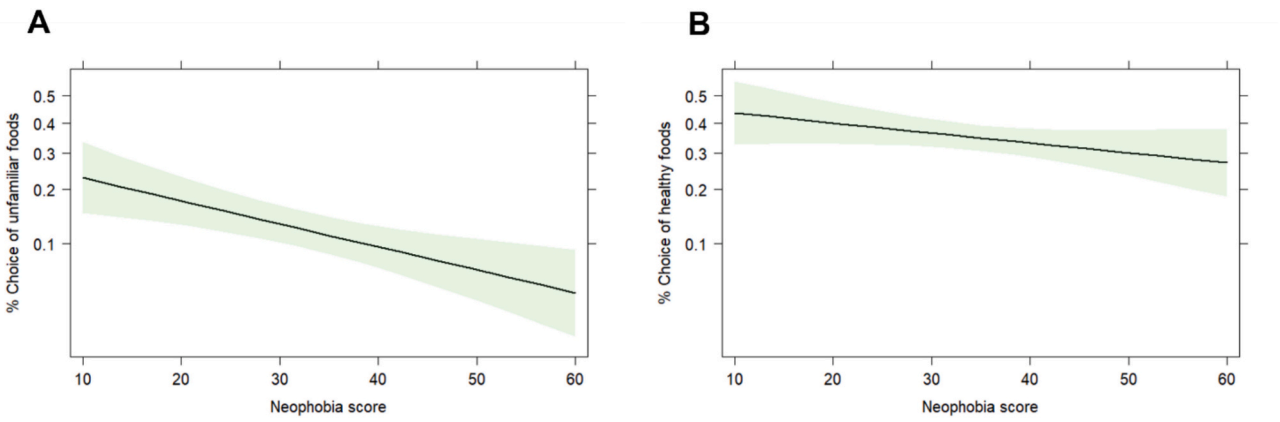

Fig. 5. Frequency of choice preference (Panel A) for unfamiliar foods and frequency of choice preference (Panel B) for healthy foods, based on the Food neophobia score. Green bands indicate the 95 % confidence interval. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Results of the mixed-effects modelling for the choice frequency for familiar vs. unfamiliar and healthy vs. unhealthy foods based on Food neophobia, KIDMED, and Eating behaviour index.

Dependent variable	Independent variable	Likelihood ratio test [$\chi^2(1)$]	*p* value	AIC_{RL}	R^2_m	R^2_c
Choice Preference (Familiar vs. Unfamiliar)	FN	9.974	**0.002**	54.011	0.011	0.029
	KIDMED	0.582	0.446	0.492	<0.001	0.029
	EBI	1.278	0.258	0.697	0.001	0.029
Choice Preference (Healthy vs. Unhealthy)	FN	2.574	0.109	1.332	0.004	0.125
	KIDMED	1.285	0.257	0.670	0.002	0.125
	EBI	6.946	**0.008**	1.857	0.010	0.125

Note: Bold *p* values denote statistical significance with $\alpha = 0.05$. AIC_{RL} = exponent of the difference between the AIC (Akaike information criterion) of the models; R^2_m = marginal effect size; R^2_c = conditional effect size.

overview of the distribution of key variables of this research.

The mechanism through which FN may influence the choice of unfamiliar foods was further explored by examining intervening variables, namely mediators (Fig. 6). Mediation analysis (using the Bootstrapping method) revealed that Arousal scores towards unfamiliar food pictures help explain how FN affects the choice.

The Average Causal Mediated Effect (ACME), which measures how much of FN's influence on food choice goes through Arousal score, was found to be statistically significant (*p* value = 0.028), where 10.7 % of the total effect is mediated by the Arousal score. It is noteworthy that Familiarity score towards unfamiliar food pictures played a smaller role in mediating the above relation. The 5.6 % of the total effect is mediated by the Familiarity score (*p* value = 0.060). Both Arousal scores (prop mediated = 7.9 %; *p* value <0.001) and Familiarity of healthy foods (prop mediated = 8.7 %; *p* value <0.001) were found to mediate the relationship between the EBI and the choices of healthy foods.

4. Discussion

This study aimed to investigate adolescents' autonomous food choices by assessing their preference for novel/unfamiliar foods and their selection of healthy options as indicators of the variety and quality of their food choices, respectively. Adolescence is a critical phase of increased independence in dietary choices, greater exposure to diverse food environments, and stronger peer influence, making it crucial to foster healthy eating habits as food choices become a form of self-expression (Bassett et al., 2008; Daly et al., 2022). Consistent with previous research (e.g., Di Nucci et al., 2023), findings confirm that FN poses a significant barrier to a varied and balanced diet, potentially impacting overall health and development.

Thus, the choice towards unfamiliar foods as compared to familiar ones of Italian adolescents was investigated, reflecting the level of willingness to have a varied diet. The food pictures shown in this contrast included both healthy products and were equally suitable for a given context (i.e., "You're on vacation and need a quick lunch; what would you choose?") to simulate a choice as close to real-life situations as possible. In line with our hypothesis, it was found that a higher score of FN leads to fewer unfamiliar products choices. While this is a defining characteristic of FN, these findings reinforce its impact on dietary variety across different life stages and align with previous research in children (Falciglia et al., 2000), adolescents (Nicklaus et al., 2005), and adults (Hazley et al., 2022). Whether other diet quality indices such as the KIDMED score, and the EBI score influenced the selection of familiar versus unfamiliar products was also investigated. However, no significant effects were observed for these two indices, indicating that the preference for unfamiliar foods, at least the ones tested, is not influenced by adherence to the MD or higher quality in the diet. This underscores that the reluctance to choose novel products is driven by personality traits, such as FN, rather than negative attitudes towards healthy eating behaviour. FN is classically defined as a rejection of food novelty, but it also seems to indicate reluctance to accept foods that differ in aspects beyond familiarity, such as arousal produced by many different aspects (flavour intensity, food complexity, and so on; Jaeger et al., 2023). Despite this evidence, the influence of arousal on food choices among adolescents remains understudied. Therefore, the underlying mechanism by which FN influences the decreased preference for unfamiliar foods was investigated, considering mediating variables like familiarity and arousal towards these food items. As anticipated, it was revealed that arousal towards unfamiliar foods significantly mediated this relationship, while familiarity played a less substantial role. This indicates that food aversion in FN is only partially attributable to familiarity, highlighting that, already as stated by many studies (Karaağaç & Bellikci-Koyu, 2023; Tuorila et al., 2001), FN is not only the unwillingness to taste unfamiliar foods, but also familiar ones. Consequently,

Table 5
Descriptive analysis of all measurements for total sample and by class and gender.

Variable	Total (n = 200)	1° year (mean age ± SD = 14.1 ± 0.3) (n = 116)	2° year (mean age ± SD = 15.1 ± 0.4) (n = 84)	Boys (n = 130)	Girls (n = 70)
FN	34.4 ± 9.5	35.6 ± 9.5	32.7 ± 9.5	34.0 ± 9.2	35.1 ± 10.3
KidMed	6.2 ± 2.4	6.2 ± 2.4	6.3 ± 2.3	6.2 ± 2.5	6.2 ± 2.2
EBI	10.3 ± 2.8	10.2 ± 2.8	10.4 ± 2.7	10.1 ± 2.7	10.8 ± 2.6
Choice of unfamiliar foods	0.6 ± 0.8	0.5 ± 0.7	0.7 ± 0.8	0.7 ± 0.8	0.5 ± 0.7
Choice of healthy foods	1.8 ± 1.3	1.8 ± 1.3	2.0 ± 1.3	1.5 ± 1.2	2.5 ± 1.3
Liking of healthy familiar foods	6.7 ± 1.8	6.7 ± 1.8	6.7 ± 1.8	6.5 ± 1.8	6.9 ± 1.8
Liking of healthy unfamiliar foods	3.8 ± 2.1	3.6 ± 2.1	3.9 ± 2.1	3.9 ± 2.1	3.5 ± 2.1
Liking of unhealthy familiar foods	7.4 ± 1.5	7.4 ± 1.5	7.4 ± 1.5	7.6 ± 1.3	7.2 ± 1.8
Arousal of healthy familiar foods	1.9 ± 1.3	1.9 ± 1.3	1.8 ± 1.3	1.9 ± 1.4	1.7 ± 1.2
Arousal of healthy unfamiliar foods	4.0 ± 1.8	4.2 ± 1.8	3.9 ± 1.8	4.0 ± 1.8	4.2 ± 1.8
Arousal of unhealthy familiar foods	1.5 ± 1.0	1.6 ± 1.0	1.5 ± 1.0	1.5 ± 0.9	1.6 ± 1.2
Familiarity of healthy familiar foods	4.2 ± 1.0	4.2 ± 1.1	4.2 ± 1.0	4.2 ± 1.0	4.3 ± 1.0
Familiarity of healthy unfamiliar foods	2.1 ± 1.0	2.1 ± 1.1	2.1 ± 1.0	2.1 ± 1.1	2.0 ± 1.1
Familiarity of unhealthy familiar foods	4.5 ± 0.7	4.5 ± 0.7	4.5 ± 0.7	4.5 ± 0.7	4.4 ± 0.7
AMD of healthy familiar foods	7.1 ± 1.6	7.1 ± 1.6	7.1 ± 1.6	7.1 ± 1.6	7.2 ± 1.6
AMD of healthy unfamiliar foods	5.2 ± 2.2	5.1 ± 2.2	5.2 ± 2.2	5.1 ± 2.3	5.3 ± 2.2
AMD of unhealthy familiar foods	4.6 ± 2.3	4.9 ± 2.4	4.2 ± 2.3	4.6 ± 2.3	4.6 ± 2.4

Data are presented as mean ± SD. Choice of unfamiliar foods and choice of healthy foods are presented as the numbers of these foods selected in a total of five pairs.

heightened arousal with low valence emerges as a crucial factor contributing to food rejection in FN (Jaeger et al., 2023). Foods elicit this response due to a combination of sensory displeasure, cultural, and personal experiences, such as the fear of the unknown. These factors can trigger feelings of discomfort, anxiety, or disgust when encountering certain foods, usually outside the individual's usual experience. However, intervention studies have shown that educational programs and food-related activities that increase exposure to different foods, while fostering positive attitudes and experiences, can help reduce this heightened state of arousal (Karaağaç & Bellikci-Koyu, 2023).

The second comparison examined focused on selecting between healthy and unhealthy foods. In this instance, both categories displayed high familiarity and low arousal scores. Contrary to the prior contrast analysed (i.e., healthy familiar vs. unfamiliar choice), FN did not influence this decision. These findings contribute to clarifying previous discussions in literature regarding the impact of FN on dietary quality (Hazley et al., 2022; Roßbach et al., 2016). Specifically, in the present FCT, when foods were familiar and elicited low arousal, the preference for healthy or unhealthy options was not influenced by FN. This indicates that when these influential factors are controlled for, neophobic adolescents do not exhibit a tendency to choose more unhealthy items (e.g., sweets, sugary drinks) and fewer healthy options (e.g., fruits, vegetables) compared to neophilic individuals. This preference of neophobic individuals towards fewer healthy options, such as vegetables and fruits, and more unhealthy choices, like sweets and candies, observed in previous studies (Galloway et al., 2003; Guzek et al., 2017; Maiz & Balluerka, 2016) may be attributed to the tendency for recommended foods like vegetables to evoke high arousal with low valence compared to non-recommended items like sweets and sugary drinks. As well as heightened arousal levels are often associated with the complexity of food preparation and ingredients (Berlyne, 1970; Jaeger et al., 2021). Arousal thus emerges as a key determinant in understanding neophobic responses (Jaeger et al., 2021). We speculate that adolescents with a high FN score may tend to restrict their intake of certain recommended foods, such as the pictures of vegetable-based dishes employed here, likely because these items tend to trigger negative reactions stemming from factors like unfamiliarity or sensory complexities. Indeed, previous research has shown that neophobics are less accepting of flavour complexity, in a task where it was requested to rate acceptability for a bland and complex (i.e., with added spices) version of the same dish, both familiar and unfamiliar (Olabi et al., 2015). Conversely, it was highlighted that when healthier options are both familiar and less arousing, even adolescents with high FN can choose them. This underscores the importance, even in everyday life settings, like school canteens, of providing easily recognizable and less complex healthy meal options. This may ensure that neophobic adolescents can opt for healthier choices over less nutritious alternatives.

Furthermore, apart from FN, two other factors were analysed that might depict adolescents' health choices, namely a stated index of adherence to the MD, the KIDMED score, and a calculated index (EBI

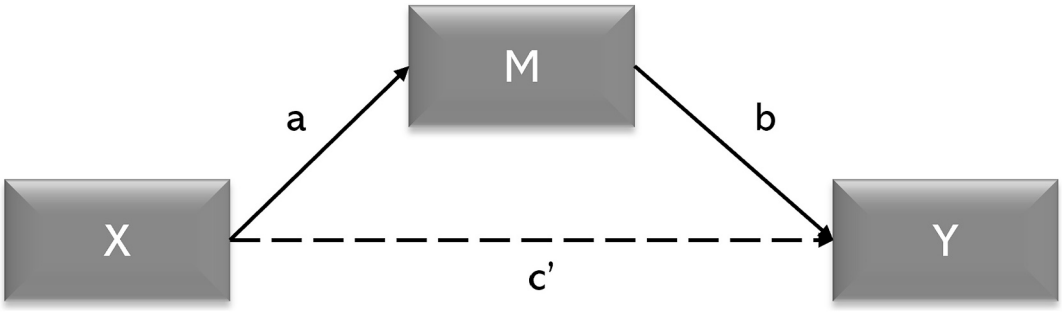

Fig. 6. Results from the mediation analysis. X: Independent variable (Food neophobia); M: Mediator (Arousal); Y: Dependent variable (Choice of unfamiliar foods). Direct Effect (c') → 0.006; $p < 0.001$; Indirect Effect (a*b) → 0.001; $p = 0.024$.

score) derived from a widely used FFQ (Liu et al., 2023). In line with expectations, a higher EBI was found to be associated with a higher tendency of choosing healthy products, in the FCT. This shows how positive eating habits also lead adolescents to prefer healthier foods, even when they are free to choose the less healthy option. Conversely, the KIDMED score, which assesses how closely an adolescent's diet aligns with the principles of the MD pattern, did not play a role in influencing the choice of healthy options. This result may be attributed to the fact that the food pictures chosen in the FCT more closely reflect the categories included in the EBI compared to the items in the KIDMED questionnaire, which also reflect family customs (Sanmarchi et al., 2023) such as skipping breakfast, going out to fast food, utilising olive oil, frequency of fish, and pulses consumption (Serra-Majem et al., 2004).

Lastly, following Jaeger et al. (2023), participants rated each food picture pair used in the FCT along four dimensions: Liking, Familiarity, Arousal, and AMD. The results support the notion that familiarity, arousal, and liking are not independent constructs, but rather interrelated components that shape food responses (Jaeger et al., 2023). In general, being familiar with a food appears to evoke an optimal level of arousal, which may in turn enhance liking. This pattern was observed, for instance, in the familiar versus an unfamiliar version of a healthy dish contrast, where unfamiliar foods triggered higher arousal and lower liking, particularly in adolescents with high FN scores. Conversely, increased familiarity was positively associated with liking, again modulated by FN. Healthy foods were overall perceived as more inspired by the MD than unhealthy ones. However, within the healthy category, unfamiliar options were rated as less MD-inspired compared to their familiar counterparts, likely because these foods were not recognized by most participants. This suggests that familiarity may influence not only affective responses, but also cognitive attributions related to dietary models. Indeed, higher familiarity scores appeared to support more accurate nutritional attribution. The AMD scores were not significantly modulated by FN, suggesting that familiarity with the MD as a dietary model may rely more on cultural knowledge than on FN per se.

In conclusion, foods that adolescents are familiar with tend to be perceived more positively, less arousing and are more likely to be considered healthy compared to unfamiliar foods. In addition, unhealthy foods were perceived as less arousing, and they were more liked as compared to healthy foods. These familiarity and healthy biases, especially when FN increases, can affect food choices and dietary habits. This is evident in the first comparison, where unfamiliar foods are less frequently chosen, especially as FN increases. In the second comparison between healthy and unhealthy options, upon examining these values, it is observed that neophobics report lower liking values and higher arousal values for healthy foods compared to unhealthy foods. Therefore, FN might also be expected to influence healthy choices. However, this doesn't seem to be the case, possibly because, despite relative increases, familiarity with healthy foods remains consistently high, while arousal towards them remains low.

To sum up, FCTs offer a direct exploration into how adolescents decide what to eat (Foerde et al., 2018), exploring personal preferences without considering the imposition given by the eating habits of the family and, more generally, of the home environment. This insight could be valuable for predicting teenagers' future dietary choices and for evaluating the effectiveness of intervention studies aimed at improving eating habits. However, future studies would benefit from a more in-depth investigation of family meal management, either by including specific questions that explore adolescents' independent meal practices or by examining how these practices are shaped by family contexts, such as when parents prepare meals and impose specific dietary patterns. Moreover, a limitation of this study is that it was conducted on an adolescent population with a higher proportion of boys (65 %) compared to girls (35 %) which may affect the generalizability of the findings. Although no differences emerged in our sample, gender differences in FN and dietary behaviours have been previously reported in a large cohort of Italian adults (Predieri et al., 2020), thus suggesting that this imbalance might still be relevant. Additionally, it is worth mentioning that our results are based on a limited number of items in the FCT. Moreover, the pairs of items presented have varying degrees of complexity both in terms of ingredients (from just one such as apple/dragon fruit to many such as pasta with salmon and zucchini) and preparation procedures (some practically little or no processing others a lot such as fried or other cooking processes). Future studies should repeat this research with more choices provided and controlling for the complexity of the dish (i.e., single food items or dishes made with many ingredients). Moreover, it is also worth emphasising that healthy vs. unhealthy foods were described as inspired by the MD. It was not intended to imply that a single dish fully represents the MD. Rather, certain dishes were described as aligned with MD principles based on their nutritional composition, particularly their inclusion of key MD ingredients (e.g., olive oil, vegetables, legumes, fish). Given that it is well known that the MD is not just a collection of specific foods but a holistic dietary pattern encompassing lifestyle, cultural, and social aspects, our focus was solely on the nutritional characteristics of the selected dishes (Guasch-Ferré & Willett, 2021).

Furthermore, the value of including an unfamiliar unhealthy food option is acknowledged to investigate whether, when compared with unfamiliar choices, participants tend to prefer a healthier or less healthy alternative. This also raises the question of whether individuals with varying degrees of FN evaluate the healthiness of unfamiliar foods differently. Additionally, despite efforts to make the task realistic with food pictures and context, it still reflects a decision made in an unrealistic setting. The presented context only reflects a current scenario (e.g., choosing a quick lunch while on vacation) but doesn't consider past or future situations (e.g., what was eaten before or will be eaten after). Furthermore, adolescents were required to make a forced choice, meaning they had to select one option even if they preferred neither. This doesn't accurately mirror real-life scenarios, where food choices are free and influenced by various factors, including dietary restrictions such as vegetarian or vegan diets. However, it is worth noting that 97 % of the adolescents in this study were omnivores. Similar tasks could be done in more ecological settings, where adolescents' choices could be measured in a realistic context, such as a self-service meal with different product categories to assess what choices adolescents would make if they were free to choose for themselves. Future studies could also focus on examining the consistency of these results across different countries to explore the cultural component. It is known that arousal is universally a strong determinant of food preference, and this plays a central role in the rejection of both familiar and novel foods in FN (Jaeger et al., 2023). Other potential limitations to consider include measuring the level of FN among our sample of adolescents using the FNS developed by Laureati et al. (2018), rather than the scale validated for Italian children ICFNS (Laureati et al., 2015). It is worth noting that both scales drew responses from individuals across different age groups than those in our study—specifically, ages 20–60 for the adult scale and 6–9 for the child scale. However, neither of these scales meet the needs of adolescents within the age range of our current research. While validating the use of the FNS scale in adolescents would be necessary, our study suggests that this scale appears to function effectively in Italian adolescents as well. The tool showed an acceptable internal consistency, initial evidence of its convergent and divergent validity was also provided. Indeed, in line with the existing literature, FN score correlated with decreased liking and increased arousal for both familiar and unfamiliar products (Jaeger et al., 2023), as well as reduced choices of unfamiliar items (Tuorila et al., 2001). Additionally, FN score was negatively correlated with adherence to the MD ($\tau = -0.187$, p value <0.001), as previously noted in a cohort ($n = 2449$) of Italian adults (Predieri et al., 2020). Although not the primary aim of the study, this research demonstrates that the scale can be effectively used with Italian adolescents aged 14 to 17.

5. Conclusions

Overall, this study contributes to existing literature by examining the role of FN in food choices, revealing that neophobic adolescents steer clear of novel foods, possibly resulting in a poor dietary variety (Hazley et al., 2022; Nicklaus et al., 2005). It also sheds light into how FN attitudes influence the quality of the diet, thus the preference for healthy versus unhealthy foods. Notably, when foods were familiar and had low arousal scores, FN did not affect the choice between healthy and unhealthy options. While previous studies (Galloway et al., 2003; Guzek et al., 2017; Maiz & Balluerka, 2016) suggest that neophobic individuals tend to consume fewer recommended and more non-recommended products, this behaviour may be attributed to the higher arousal typically associated with some recommended foods like vegetables compared to non-recommended items like sugary snacks. Consequently, to promote healthier eating habits among neophobic adolescents, it is advisable to offer simple, familiar alternatives that evoke minimal arousal, thus discouraging the selection of less healthy options.

Declaration of generative AI in scientific writing

During the preparation of this work the authors used ChatGPT in order to improve grammar and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication. In this paper, we used AI (https://stablediffusionweb.com/) to reproduce the image of the dish featuring pasta with zucchini and salmon.

CRediT authorship contribution statement

Lara Fontana: Writing – original draft, Methodology, Conceptualization, Writing – review & editing, Software, Formal analysis, Visualization, Investigation. **Isabella Endrizzi:** Writing – review & editing, Project administration, Funding acquisition, Resources, Investigation, Supervision, Methodology, Conceptualization. **Leonardo Menghi:** Methodology, Writing – review & editing, Conceptualization, Investigation. **Cinzia Franchini:** Investigation, Methodology, Writing – review & editing, Conceptualization. **Perla Degli Innocenti:** Writing – review & editing, Conceptualization, Investigation, Methodology. **Luana Bontempo:** Resources, Supervision, Funding acquisition, Writing – review & editing, Project administration. **Flavia Gasperi:** Supervision, Methodology, Conceptualization, Writing – review & editing, Project administration, Funding acquisition, Resources, Investigation.

Ethical statement

This study was approved by the Research Ethics Committee of the University of Trento (Protocol 2023–048, approved on September 14, 2023) and was conducted in accordance with the Declaration of Helsinki (World Medical Association; last amendment in 2013). All participants were asked to sign a written consent form to take part in the experiment.

Funding

This work was supported by the PROMEDLIFE (Novel food products for PROmotion of MEDiterranean LIFEstyle and health diet) project, grant agreement nr. 2132 (PRIMA programme supported by the European Union), and by the MUR PNRR project INEST- Interconnected Nord-Est Innovation Ecosystem (ECS00000043) funded by the NextGenerationEU to Leonardo Menghi and Flavia Gasperi.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to express our heartfelt gratitude to all the young volunteers and their families who participated in this study. We extend special thanks to Luana Budano and the teachers from Istituto Tecnico Agrario in San Michele all'Adige (Trento, Italy) for their support in optimising logistics throughout the various phases of the project. We extend our thanks to Jessica Zambanini and Giorgia Mattina for their technical support.

Data availability

All the datasets and R scripts to reproduce the results of this study are available in the Open Science Framework repository accessible at https://osf.io/92e5w/

References

Alfons, A., Ateş, N. Y., & Groenen, P. J. F. (2022). A robust bootstrap test for mediation analysis. *Organizational Research Methods, 25*(3), 591–617. https://doi.org/10.1177/1094428121999096

Appleton, K. M., Dinnella, C., Spinelli, S., Morizet, D., Saulais, L., Hemingway, A., Monteleone, E., Depezay, L., Perez-Cueto, F. J. A., & Hartwell, H. (2019). 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. *Food Quality and Preference, 75*, 179–186. https://doi.org/10.1016/j.foodqual.2019.02.007

Bailey, R. L. (2021). Overview of dietary assessment methods for measuring intakes of foods, beverages, and dietary supplements in research studies. *Current Opinion in Biotechnology, 70*, 91–96. https://doi.org/10.1016/j.copbio.2021.02.007

Barakchian, Z., Beharelle, A. R., & Hare, T. A. (2021). Healthy decisions in the cued-attribute food choice paradigm have high test-retest reliability. *Scientific Reports, 11*(1), Article 12844, 18 https://doi.org/10.1038/s41598-021-91933-6.

Bassett, R., Chapman, G. E., & Beagan, B. L. (2008). Autonomy and control: The co-construction of adolescent food choice. *Appetite, 50*(2–3), 325–332. https://doi.org/10.1016/j.appet.2007.08.009

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., Dai, B., Scheipl, F., Grothendieck, G., Green, P., Fox, J., Bauer, A., & Krivitsky, P. N. (2018) lme4: linear mixed- effects models using 'Eigen' and S4 (R package version 1.1–17). Retrieved from https://cran.r-project.org/web/packages/lme4/.

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception & Psychophysics, 8*, 279–286. https://doi.org/10.3758/BF03212593

Biasini, B., Rosi, A., Menozzi, D., & Scazzina, F. (2021). Adherence to the Mediterranean diet in association with self-perception of diet sustainability, anthropometric and sociodemographic factors: A cross-sectional study in Italian adults. *Nutrients, 13*(9). https://doi.org/10.3390/nu13093282

Cade, J. E., Burley, V. J., Warm, D. L., Thompson, R. L., & Margetts, B. M. (2004). Food-frequency questionnaires: A review of their design, validation and utilisation. *Nutrition Research Reviews, 17*, 5–22. https://doi.org/10.1079/NRR200370

Carlsen, M. H., Lillegaard, I. T., Karlsen, A., Blomhoff, R., Drevon, C. A., & Andersen, L. F. (2010). Evaluation of energy and dietary intake estimates from a food frequency questionnaire using independent energy expenditure measurement and weighed food records. *Nutrition Journal, 9*, 37. https://doi.org/10.1186/1475-2891-9-37

Cooke, L., Carnell, S., & Wardle, J. (2006). Food neophobia and mealtime food consumption in 4-5 year old children. *The International Journal of Behavioral Nutrition and Physical Activity, 3*, 14. https://doi.org/10.1186/1479-5868-3-14

Daly, A. N., O'Sullivan, E. J., & Kearney, J. M. (2022). Considerations for health and food choice in adolescents. *The Proceedings of the Nutrition Society, 81*(1), 75–86. https://doi.org/10.1017/S0029665121003827

de Andrade Previato, H. D. R., & Behrens, J. H. (2017). Taste-related factors and food neophobia: Are they associated with nutritional status and teenagers' food choices? *Nutrition, 42*, 23–29. https://doi.org/10.1016/j.nut.2017.05.006

Di Nucci, A., Pilloni, S., Scognamiglio, U., & Rossi, L. (2023). Adherence to Mediterranean diet and food Neophobia occurrence in children: A study carried out in Italy. *Nutrients, 15*, 5078. https://doi.org/10.3390/nu15245078

Dinu, M., Pagliai, G., Angelino, D., Rosi, A., Dall'Asta, M., Bresciani, L., … Sofi, F. (2020). Effects of popular diets on anthropometric and Cardiometabolic parameters: An umbrella review of Meta-analyses of randomized controlled trials. *Advances in Nutrition, 11*(4), 815–833. https://doi.org/10.1093/advances/nmaa006

Dovey, T. M., Staples, P. A., Gibson, E. L., & Halford, J. C. (2008). Food neophobia and "picky/fussy" eating in children: A review. *Appetite, 50*(2–3), 181–193. https://doi.org/10.1016/j.appet.2007.09.009

Falciglia, G. A., Couch, S. C., Gribble, L. S., Pabst, S. M., & Frank, R. (2000). Food neophobia in childhood affects dietary variety. *Journal of the American Dietetic Association, 100*(12). https://doi.org/10.1016/S0002-8223(00)00412-0

FAO & WHO. (2016). *Second international conference on nutrition (ICN2): Proceedings of the roundtables*. Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/aef90dcf-3aaf-4e5c-b246-2dd1c2345371/content.

Foerde, K., Gianini, L., Wang, Y., Wu, P., Shohamy, D., Walsh, B. T., & Steinglass, J. E. (2018). Assessment of test-retest reliability of a food choice task among healthy individuals. *Appetite, 123*, 352–356. https://doi.org/10.1016/j.appet.2018.01.010

Fontana, L., Albayay, J., Fernandez-Prieto, I., & Zampini, M. (2022). Olfactory habituation to food and non-food odours. *Quarterly Journal of Experimental Psychology*. https://doi.org/10.1177/17470218221115046

Galloway, A. T., Lee, Y., & Birch, L. L. (2003). Predictors and consequences of food neophobia and pickiness in young girls. *Journal of the American Dietetic Association, 103*(6), 692–698. https://doi.org/10.1053/jada.2003.50134

Grosso, G., & Galvano, F. (2016). Mediterranean diet adherence in children and adolescents in southern European countries. *NFS Journal, 3*, 13–19. https://doi.org/10.1016/j.nfs.2016.02.004

Guasch-Ferré, M., & Willett, W. C. (2021). The Mediterranean diet and health: A comprehensive overview. *Journal of Internal Medicine, 290*(3), 549–566. https://doi.org/10.1111/joim.13333

Guzek, D., Głąbska, D., Lange, E., & Jezewska-Zychowicz, M. A. (2017). Polish study on the influence of food Neophobia in children (10–12 years old) on the intake of vegetables and fruits. *Nutrients, 9*, 563. https://doi.org/10.3390/nu9060563

Hare, T. D., Camerer, C. L., & Rangel, A. (2009). Self-control in decision-making involves modulation of the vmPFC valuation system. *Science, 324*, 646–648. https://doi.org/10.1126/science.1168450

Hazley, D., McCarthy, S. N., Stack, M., Walton, J., McNulty, B. A., Flynn, A., & Kearney, J. M. (2022). Food neophobia and its relationship with dietary variety and quality in Irish adults: Findings from a national cross-sectional study. *Appetite, 169*, 1–7. https://doi.org/10.1016/j.appet.2021.105859

Jaeger, S. R., Chheang, S. L., & Prescott, J. (2021). Variations in the strength of association between food Neophobia and food and beverage acceptability: A data-driven exploratory study of an arousal hypothesis. *Nutrients, 13*(10), 1–19. https://doi.org/10.3390/nu13103657

Jaeger, S. R., Hedderley, D., & Prescott, J. (2023). High arousal as the source of food rejection in food neophobia. *Food Research International, 168*. https://doi.org/10.1016/j.foodres.2023.112795

Karaağaç, Y., & Bellikci-Koyu, E. (2023). A narrative review on food neophobia throughout the lifespan: Relationships with dietary behaviours and interventions to reduce it. *The British Journal of Nutrition, 130*(5), 793–826. https://doi.org/10.1017/S0007114522003713

Laureati, M., Bergamaschi, V., & Pagliarini, E. (2015). Assessing childhood food neophobia: Validation of a scale in Italian primary school children. *Food Quality and Preference, 40*, 8–15. https://doi.org/10.1016/j.foodqual.2014.08.003

Laureati, M., Spinelli, S., Monteleone, E., Dinnella, C., Prescott, J., Cattaneo, C., … Pagliarini, E. (2018). Associations between food neophobia and responsiveness to "warning" chemosensory sensations in food products in a large population sample. *Food Quality and Preference, 68*, 113–124. https://doi.org/10.1016/j.foodqual.2018.02.007

Lefcheck, J. S. (2016). PiecewiseSEM: Piecewise structural equation modelling in r for ecology, evolution, and systematics. *Methods in Ecology and Evolution, 7*(5), 573–579. https://doi.org/10.1111/2041-210X.12512

Liu, L., Guo, C., Lang, F., & Yan, Y. (2023). Association of breakfast, total diet quality, and mental health in adolescents: A cross-sectional study of HBSC in Greece. *European Journal of Pediatrics, 182*, 5385–5397. https://doi.org/10.1007/s00431-023-05180-0

Maiz, E., & Balluerka, N. (2016). Nutritional status and Mediterranean diet quality among Spanish chil-dren and adolescents with food neophobia. *Food Quality and Preference, 52*, 133–142. https://doi.org/10.1016/j.foodqual.2016.04.011

McElreath, R. (2016). *Statistical rethinking: A bayesian course with examples in r and stan, 122*. CRC Press.

Nicklaus, S., Boggio, V., Chabanet, C., & Issanchou, S. (2005). A prospective study of food variety seeking in childhood, adolescence and early adult life. *Appetite, 44*, 289–297. https://doi.org/10.1016/j.appet.2005.01.006

Olabi, A., Neuhaus, T., Bustos, R., Cook-Camacho, M., Corvi, T., & Abdouni, L. (2015). An investigation of flavor complexity and food neophobia. *Food Quality and Preference, 42*, 123–129. https://doi.org/10.1016/j.foodqual.2015.01.004

Perry, R. (2015). Food neophobia and its association with diet quality and weight in children aged 24 months: A cross sectional study. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/s12966-015-0184-6

Pliner, P., & Hobden, K. (1992). Development of a scale to measure the trait of food neophobia in humans. *Appetite, 19*(2), 105–120. https://doi.org/10.1016/0195-6663(92)90014-w

Predieri, S., Sinesio, F., Monteleone, E., Spinelli, S., Cianciabella, M., Daniele, G. M., … Laureati, M. (2020). Gender, age, geographical area, food Neophobia and their relationships with the adherence to the Mediterranean diet: New insights from a large population cross-sectional study. *Nutrients, 12*(6). https://doi.org/10.3390/nu12061778

Prescott, J., & Spinelli, S. (2024). Arousal and the modulation of sensory experience: Evidence from food-related emotions. *Philosophical Transactions of the Royal Society, B: Biological Sciences, 379*, Article 20230255. https://doi.org/10.1098/rstb.2023.0255

Proserpio, C., Almli, V. L., Sandvik, P., Sandell, M., Methven, L., Wallner, M., Jilani, H., Zeinstra, G. G., Alfaro, B., & Laureati, M. (2020). Cross-national differences in child food neophobia: A comparison of five European countries. *Food Quality and Preference, 81*. https://doi.org/10.1016/j.foodqual.2019.103861

Rakić, J. G., Hamrik, Z., Dzielska, A., Felder-Puig, R., Oja, L., Bakalár, P., et al. (2024). *A focus on adolescent physical activity, eating behaviours, weight status and body image in Europe, Central Asia and Canada: Health behaviour in school-aged children international report from the 2021/2022 survey*. World Health Organization. Regional Office for Europe. https://iris.who.int/handle/10665/376772.

Raudenbush, B., & Capiola, A. (2012). Physiological responses of food neophobics and food neophilics to food and non-food stimuli. *Appetite, 58*(3), 1106–1108. https://doi.org/10.1016/j.appet.2012.02.042

Raudenbush, B., & Frank, R. A. (1999). Assessing food Neophobia: The role of stimulus familiarity. *Appetite, 32*(2), 261–271. https://doi.org/10.1006/appe.1999.0229

Rigal, N., Frelut, M.-L., Monneuse, M.-O., Hladik, C.-M., Simmen, B., & Pasquet, P. (2006). Food neo-phobia in the context of a varied diet induced by a weight reduction program in massively obese adolescents. *Appetite, 46*(2), 207–214. https://doi.org/10.1016/j.appet.2006.01.001

Rosi, A., Paolella, G., Biasini, B., Scazzina, F., & SINU Working Group on Nutritional Surveillance in Adolescents. (2019). Dietary habits of adolescents living in North America, Europe or Oceania: A review on fruit, vegetable and legume consumption, sodium intake, and adherence to the Mediterranean diet. *Nutrition, Metabolism, and Cardiovascular Diseases, 29*(6), 544–560. https://doi.org/10.1016/j.numecd.2019.03.003

Roßbach, S., Foterek, K., Schmidt, I., Hilbig, A., & Alexy, U. (2016). Food neophobia in German adolescents: Determinants and association with dietary habits. *Appetite, 1*(101), 184–191. https://doi.org/10.1016/j.appet.2016.02.159

RStudio Team. (2016). *RStudio: Integrated development for R*. Boston, MA: RStudio Inc.. http://www.rstudio.com/

Ruggiero, E., Esposito, S., Costanzo, S., Di Castelnuovo, A., Cerletti, C., Donati, M. B., … INHES Study Investigators. (2021). Ultra-processed food consumption and its correlates among Italian children, adolescents and adults from the Italian Nutrition & Health Survey (INHES) cohort study. *Public Health Nutrition, 24*(18), 6258–6271. https://doi.org/10.1017/S1368980021002767

Ruiz, L. D., Zuelch, M. L., Dimitratos, S. M., & Scherr, R. E. (2020). Adolescent obesity: Diet quality, psychosocial health, and Cardiometabolic risk factors. *Nutrients, 12*, 43. https://doi.org/10.3390/nu12010043

Sanmarchi, F., Masini, A., Poli, C., Kawalec, A., Esposito, F., Scrimaglia, S., … Sacchetti, R. (2023). Cross-sectional analysis of family factors associated with lifestyle habits in a sample of Italian primary school children: The I-MOVE project. *International Journal of Environmental Research and Public Health, 20*(5). doi:3390/ijerph20054240.

Santomauro, F., Lorini, C., Tanini, T., Indiani, L., Lastrucci, V., Comodo, N., & Bonaccorsi, G. (2014). Adherence to Mediterranean diet in a sample of Tuscan adolescents. *Nutrition, 30*(11−12), 1379–1383. https://doi.org/10.1016/j.nut.2014.04.008

Schoeller, D. A., Thomas, D., Archer, E., Heymsfield, S. B., Blair, S. N., Goran, M. I., … Allison, D. B. (2013). Self-report-based estimates of energy intake offer an inadequate basis for scientific conclusions. *The American Journal of Clinical Nutrition, 97*(6), 1413–1415. https://doi.org/10.3945/ajcn.113.062125

Serra-Majem, L., Ribas, L., Ngo, J., Ortega, R. M., García, A., Pérez-Rodrigo, C., & Aranceta, J. (2004). Food, youth and the Mediterranean diet in Spain. Development of KIDMED, Mediterranean diet quality index in children and adolescents. *Public Health Nutrition, 7*(7), 931–935. https://doi.org/10.1079/PHN2004556

Singmann, H., & Kellen, D. (2019). An introduction to mixed models for experimental psychology. In *New methods in cognitive psychology* (pp. 4–31). Routledge. https://doi.org/10.4324/9780429318405-2.

Sorokowska, A., Chabin, D., Hummel, T., & Karwowski, M. (2022). Olfactory perception relates to food neophobia in adolescence. *Nutrition, 98*. https://doi.org/10.1016/j.nut.2022.111618

Steinglass, J., Foerde, K., Kostro, K., Shohamy, D., & Walsh, B. T. (2015). Restrictive food intake as a choice-a paradigm for study. *The International Journal of Eating Disorders, 48*(1). https://doi.org/10.1002/eat.22345

Story, M., Neumark-Sztainer, D., & French, S. (2002). Individual and environmental influences on adolescent eating behaviors. *Journal of the American Dietetic Association, 102*(3 Suppl). https://doi.org/10.1016/S0002-8223(02)90421-9

Strisciuglio, C., Cenni, S., Serra, M. R., Dolce, P., Martinelli, M., Staiano, A., & Miele, E. (2020). Effectiveness of mediterranean diet's adherence in children with inflammatory bowel diseases. *Nutrients, 12*. https://doi.org/10.3390/nu12103206

Sweeting, H., Anderson, A., & West, P. (1994). Socio-demographic correlates of dietary habits in mid to late adolescence. *European Journal of Clinical Nutrition, 48*, 736–748.

Tuorila, H., Lähteenmäki, L., Pohjalainen, L., & Lotti, L. (2001). Food neophobia among the Finns and related responses to familiar and unfamiliar foods. *Food Quality and Preference, 12*(1), 29–37. https://doi.org/10.1016/S0950-3293(00)00025-2

Willett, W. C., Sacks, F., Trichopoulou, A., Drescher, G., Ferro-Luzzi, A., Helsing, E. T., & D.. (1995). Mediterranean diet pyramid: A cultural model for healthy eating. *The American Journal of Clinical Nutrition, 61*, 1402S–1406S. https://doi.org/10.1093/ajcn/61.6.1402S

Woo, T., & Lee, K. H. (2013). Effects of sensory education based on classroom activities for lower grade school children. *Nutrition Research and Practice, 7*(4), 336–341. https://doi.org/10.4162/nrp.2013.7.4.336

World Medical Association. (2013). WMA declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA The Journal Of The American Medical Association, 310*(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053

Wu, M., Wu, L., & Ishida, A. (2023). Effect of mid-adolescent dietary practices on eating behaviors and attitudes in adulthood. *Nutrients, 15*, 225. https://doi.org/10.3390/nu15010225