The multidimensional nature of food neophobia

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ABSTRACT

People vary in their willingness to try new foods. This variation, which is most frequently measured using the Food Neophobia Scale (FNS; Pliner & Hobden, 1992), has been interpreted as unidimensional. In four studies (N’s = 210, 306, 160, and 161), we 1) demonstrate that food neophobia varies across meat and plant dimensions, 2) explore the validity of a measure of meat and plant neophobia, and 3) test whether these food neophobia dimensions predict decisions to eat a novel food item (i.e., a snack bar that contains insects). Mixed-effects models across the four studies indicated that the two dimensions differentially relate to a number of variables, including disgust sensitivity, animal empathy, and masculinity. Women scored higher on meat neophobia than men, but the sexes did not differ on plant neophobia. Only meat neophobia uniquely predicted eating a novel insect-based snack bar. Overall, these results extend knowledge regarding orientations toward novel foods.

1. Introduction

Food neophobia – the aversion to unfamiliar foods – has been widely regarded as unidimensional, and is typically measured with the Food Neophobia Scale (FNS; Pliner & Hobden, 1992), which asks respondents to indicate their agreement with statements such as 'I am constantly sampling new and different foods’, 'I don’t trust new foods’, and 'I like foods from different cultures.’. Should we expect food neophobia to be unidimensional, though? Here, we propose that meat and plant neophobia might be distinct given the relative risks and benefits offered by foods within these categories.

1.1. Relative costs and benefits of foods across meats and plants

Novel foods present new flavors, textures, and smells. They also present unknown nutritional outcomes, including (on the positive side) calories and nutrients and (on the negative side) somatic damage. Having a varied diet increases the likelihood of consuming health-promoting macro- and micro-nutrients and simultaneously allows for smaller portions from any individual food, which reduce the risk of damage incurred from consuming large amounts of a single food with low levels of toxins (Remick et al., 2009; Rozin & Vollmecke, 1986). Therefore, sampling novel foods can lead to a more balanced and safer diet. However, some people lack the enzymes to digest certain compounds, which novel foods can contain. For example, individuals who do not have the enzyme lactase are unable to break down lactose molecules found in dairy products (Swagerty et al., 2002). Further, some foods (e.g., milk, eggs, fish, peanuts, and wheat) can trigger allergic reactions with consequences ranging from mild (e.g., contact dermatitis) to severe (e.g., anaphylaxis) (Decker et al., 2008; Sicherer & Sampson, 2006; 2009). Additionally, some plants have evolved toxic defenses against insects, microorganisms, and competing plants (Wink, 2009); these toxins can harm humans, especially small children (Eddleston & Persson, 2003). Foods, regardless of their novelty, can also house pathogens, which are not produced by the food (a la plant toxins) but are instead housed within animals or on the surface of plants that are contaminated via contact (e.g., soil that contains parasites) (Schantz & McCauley, 1991). Recent estimates suggest that pathogens cause more than 9 million foodborne illnesses each year in the U.S. alone (Scallan et al., 2011).

Such risks vary across food categories, however. Meats deteriorate faster than plants (Billing & Sherman, 1998; Bryan, 1988; Sherman & Hash, 2001; Sackett, 1995; Tybur et al., 2016), and some threats posed by plants (e.g., thorns, toxins) are more readily detectable via taste or visual inspection (Fallon & Rozin, 1983; Tybur et al., 2016; Wertz & Wynn, 2014). Most importantly, meats are more likely than plants to harbor bacteria and microparasites harmful to humans (Fessler & Navarrete, 2003). Evidence illustrates the relatively greater pathogen risk that meats have as compared with plants. According to one estimate, far more deaths resulting from foodborne illnesses from 1998 to 2008 were...
attributed to animal products (43%) than to plant products (25%) (Painter et al., 2013). These asymmetric costs presumably underlie the fact that, on average, societies have about six times more meat taboos than non-meat food taboos (Fessler & Navarrete, 2003).

1.2. How do people manage food risks?

Our ancestors have had to navigate the food risks inherent to an omnivorous, generalist diet for millions of years (Bunn, 1981; Domínguez-Rodrigo, 1997; Eaton & Konner, 1985). The availability of possible food options with wide ranging nutritional consequences likely afforded the evolution of various food-learning adaptations, some of which are broadly learning about negative consequences of behaviors (e.g., humans quickly acquire dislike towards a food after having a one-time bad experience with it such as feeling sick after consumption; Rozin, 1986), and some of which concern specific food categories and time periods. For example, infants and children are more vulnerable to the effects of plant toxins, and children appear to be more neophobic toward plants (Cashdan, 1998).

To solve plant-specific risks, selection might have also favored social learning over individual learning because of the costs of individual learning via trial-and-error (Wertz, 2019; Wertz & Moya, 2019). Infants, who are especially vulnerable to toxins, attend to social cues (e.g., looking at adults interact with a plant) especially when they are given real plants compared to when they are given other type of artifacts (Elsner & Wertz, 2019) and generalize the edibility information of a plant that they obtain from other individuals to other plants with similar appearances (Wertz & Wynn, 2019). Wertz and Moya (2019) further propose that cognitive designs for solving plant risks might also be functional for other food items and that social learning is only a piece of the big picture in food learning mechanisms.

Distinct learning mechanisms might be used to navigate meat-specific risks as well. Self-report data shows that the majority of food aversions comes from foods of animal origin (Batsell Jr. & Brown, 1998; Rozin & Fallon, 1987). Further, initial evidence indicates that people more readily learn to associate pathogen cues with meats than with plants or beverages (Tybur et al., 2016).

Food neophobia reduces the number of potentially harmful foods ingested. Given evidence that learning mechanisms show some specificity for meats and plants, might food neophobia show similar distinctions across these categories? To this point, research in this area has largely assumed that food neophobia is unidimensional. Although people can be neophobic toward both meat and plants, neophobia might vary across these categories in important ways. And, indeed, some data suggest that cognitive designs for solving plant risks might also be functional for other food items and that social learning is only a piece of the big picture in food learning mechanisms.

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1.3. Interpreting novel food avoidance

We conducted factor analyses on items measuring neophobia toward a variety of specific foods, some of which are meats, and some of which are plants. Guided by theory and previous findings, we also tested how food neophobia relates to: 1) participant sex, 2) openness to experience, 3) pathogen-avoidance motivations, 4) broader dietary behavior orientations that encompasses overall tendencies of eating meats and plants, and 5) situational characteristics such as hunger. We briefly describe work on food neophobia and these variables below.

Sex differences. Existing works suggests that the sexes do not differ in unidimensional measures of food neophobia (Alley et al., 2006; Nordin et al., 2004; Pliner & Hobden, 1992; though see Tuorila et al., 2001). However, men eat more meat (especially red meat) than women across cultures (Barbesque & Marlowe, 2009; Daniel et al., 2011; Fessler et al., 2003; Prátilaá, 2006). Women are also more likely than men to be vegans or vegetarians (Beardsworth & Bryman, 1999; Fessler et al., 2003; Neumark-Sztainer et al., 1997; Worsley & Skrzypiec, 1998). In parallel to the differential preference in meats, women might be more meat neophobic than men, but not necessarily more plant neophobic.

Openness to experience. Openness to experience encompasses intellecual curiosity, appreciation in beauty of art, and acceptance of unconventionality (Lee & Ashton, 2008) and is related to sensation-seeking and risk-taking (De Vries et al., 2009). Phenomenologically, novel foods offer new textures and flavors, and hence might be experienced as especially rewarding for individuals higher on openness. Further, the risks associated with sampling new foods might be especially aversive for individuals low on openness. Existing work suggest that openness is negatively correlated with unidimensional food neophobia (Knaapila et al., 2011; Pliner & Hobden, 1992). Given that both plants and meats offer risks and novel phenomenological experiences, openness might be equally related to both potential dimensions of food neophobia.

Neutralizing risks. Disgust (and, specifically, pathogen disgust; see Tybur et al., 2013) functions to neutralize infectious microbes by motivating avoidance responses. Pathogen disgust sensitivity appears to relate to unidimensional food neophobia (Al-Shawaf et al., 2015). As meats are more likely to house pathogens than plants, disgust sensitivity might relate more strongly to meat neophobia than to plant neophobia.

Dietary behavior. Individuals differ in their broader meat and vegetable intake. First, meat has masculine connotations in the social environments, such as in advertisements and other visual and linguistic associations (Heinz & Lee, 1998), and therefore might be consumed more by individuals who define themselves as masculine. The masculinity-meat association is illustrated by findings that people who eat meat (versus vegetables) are perceived as more masculine (Rozin et al., 2012). Second, individuals might differ on how empathetic they are towards animals, leading to a greater meat avoidance for animal-based foods products. One study reports that attachment to pets predicts meat avoidance, but that empathy toward animals fully mediates this relationship (Rothgerber & Mican, 2014). Hence, if meat neophobia arises from factors similar to those governing meat consumption, masculinity and empathy towards animals would be expected to also relate more strongly to meat than to plant neophobia. In parallel, willingness to eat novel meats and plants might be a by-product of how much people like eating meat (plant) products. Familiarity with flavor, texture, and appearance increases likelihood to try a novel food (Hwang & Lin, 2016; Pliner & Stallberg-White, 2000), so greater exposure to food from a specific category might predict willingness to eat novel food aligned with the predominantly consumed food categories.

To test these three hypotheses, we measured gender roles, empathy towards animals, and meat and plant eating frequency, as these would predict individuals’ liking of these food products and act as a precursor of willingness to eat novel meats and plants.

Hunger. Because hunger indicates a greater need for calories when not satiated, it might correspond with an increased willingness to eat foods with unknown costs (Tybur et al., 2018). In parallel, hunger increases how well one discriminates smells as well as the reward value of the food (Cameron et al., 2012). However, studies examining effects of experimentally-manipulated hunger on food neophobia have reported conflicting results, with one study suggesting that hunger might increase, rather than decrease, food neophobia (Pliner et al., 1995), and another study reporting that hunger decreases food neophobia (Perone et al., 2021). We therefore included a measure of hunger to examine whether hunger would increase or decrease food neophobia.

1.4. How does meat and plant neophobia translate into behavior?

In addition to examining the dimensionality of food neophobia, we also examined how meat versus plant neophobia predict behavior. Specifically, we tested how meat and plant neophobia relate to decisions
to eat insects, which are a novel food to the Western population we sample from (Hartmann et al., 2015). Unidimensional measures of food neophobia are negatively related to intentions to eat insect-based foods (Hartmann et al., 2015; Sogari et al., 2018; Verbeke, 2015). Positive attitudes toward meat (e.g., weighing more importance of meat taste, and being more convinced on the health and nutritional aspects of meat) appear to negatively relate to the likelihood of integrating insects as the protein source to one’s diet (Verbeke, 2015). Although studies have reported that food neophobia relates to attitudes toward eating insects (Hartmann et al., 2015; Sogari et al., 2018; Verbeke, 2015), the only study we are aware of to examine how food neophobia relates to insect eating behavior found no association between the two (Jensen & Lieberoth, 2019). Further, they were unable to assess if willingness to eat insects relates more to meat versus plant neophobia.

1.5. Overview of studies

Across four studies, we tested the validity of a picture-based instrument, similar to that of the Food Disgust Scale (Ammann et al., 2018), using novel meat and plant images for measuring food neophobia. Using factor analyses, we investigated whether meat and plant neophobia varied across distinct dimensions. Studies 1–4 also tested how participants sex and pathogen disgust sensitivity relate to meat and plant neophobia. Studies 2–4 tested how masculine gender roles, germ aversion, frequency of eating meats and plants, animal empathy, and openness to experience relate to meat and plant neophobia. Studies 3 and 4 further examined the test-retest reliability of meat and plant neophobia. Study 4 examined how liking of familiar meats and plants relates to meat and plant neophobia, and Study 3 tested how food neophobia relates to decisions to eat a snack bar partly made of insects1 (for sample and study characteristics, see Table 1).

2. Methods

2.1. Participants

In Studies 1 and 2, we recruited 223 and 387 U.S. residents via Amazon Mechanical Turk. Given that vegetarians are not open to eating meats, novel or otherwise, and given that we aimed to test for sex differences in food neophobia, we excluded participants reporting being vegetarian (NStudy1 = 11, NStudy2 = 43), being neither male nor female (NStudy1 = 2), or having completed instruments in an inaccurate or dishonest manner (NStudy2 = 3), and those who completed the survey in less than 297 s (NStudy2 = 45). The latter exclusion criterion was based on excluding participants who take less than 3 s to complete a question and was used as a proxy for attention. Studies 3 and 4 were conducted in the Social Psychology labs at Vrije Universiteit Amsterdam. Participants were mainly students participating for course credits. Participants who declared being vegetarian or vegan (N = 1) and participants who did not complete the study (N = 6) from Study 3 or indicated being neither male nor female (N = 1) from Study 4 were excluded. Further in both Studies 3 and 4, only participants who completed both sessions were included. Table 1 describes the final samples from all four studies.2

2.2. Procedure

Study 1. After providing informed consent, participants reported their sex and age and answered whether they are vegetarian or vegan. Participants then viewed images of 35 exotic meats (e.g., chicken feet) and 35 plants (e.g., Buddha’s hand) and responded to the question ‘Would you be willing to eat this?’ on a four-point scale labeled ‘1 – definitely not,’ ‘2 – probably not,’ ‘3 – probably yes,’ or ‘4 – definitely yes.’ They also completed the Food Neophobia Scale (FNS; Pliner & Hobden, 1992) and the pathogen domain of the Three Domain Disgust Scale (Tybur et al., 2009). Finally, they reported how hungry they were (‘1 – not hungry at all,’ ‘7 – extremely hungry’).

Study 2. After providing informed consent, participants first reported their sex, age, hunger level, and the last time they ate a meal. They then completed the Empathy Towards Animals Scale (Paul, 2000), Traditional Masculinity-Femininity Scale (Kachel et al., 2016), the Openness to Experience factor of the HEXACO-60 (Ashton & Lee, 2009), the Germ Aversion factor of Perceived Vulnerability to Disease Scale (Duncan et al., 2009), the Pathogen Disgust factor of the Three Domains of Disgust Scale (Tybur et al., 2009), and the Food Neophobia Scale (FNS; Pliner & Hobden, 1992), and they reported the number of meals that contained at least one meat and at least one plant for the last 9 meals. These measures were presented in randomized order. Further, participants answered either the original FNS or one of the two modified versions of FNS (meat-specific FNS or plant-specific FNS), which replaced original scale items such as ‘I am constantly sampling new and different foods’ with ‘I am constantly sampling new and different meats (or plants in plant-specific FNS).’ After completing these measures, participants reported their willingness to eat 12 exotic meats and 12 exotic plants selected based on results from Study 1 (‘1 – definitely not,’ ‘2 – probably not,’ ‘3 – probably yes,’ or ‘4 – definitely yes’). The food picture ratings were fixed in the end of the questionnaire to reduce potential carry-over effects of the food pictures onto the food neophobia scales.

Study 3. Data collection was conducted in tandem with another project in which participants came to the lab twice. We took this as an opportunity to present the meat and plant neophobia items in both sessions, with the aim of testing the measures’ test-retest reliability across a one-week span. In the first session, participants signed a consent form and responded to the same measures described in Study 2, except that the modified versions of the Food Neophobia Scale were omitted, and all participant responded to the original version of the Food Neophobia Scale. During the second session, participants completed the meat and plant neophobia items again and received a chocolate-orange flavored Bugbar, a commercially available snack bar that contains 5% meal worm flour (though one participant received the same bar in another flavor). For this task, participants read the ingredients of the snack bar first and chose to eat it or not. Those who ate the Bugbar rated it on taste and texture and reported their likelihood of buying the product in the future and the amount of money they would be willing to pay for it. All participants wrote a brief explanation for trying the Bugbar (or not).

Study 4. Similar to Study 3, data collection was done in tandem with another project in which the participants came to the lab twice where they completed the meat and plant neophobia scales both times. In the first session participants also completed all measures described in Study 3. In the second session, unlike in Study 3 there was no behavioral measure; instead, participants reported how much they like 12 foods that are commonly consumed in the local population, six of which were meats (chicken, steak, hamburger (prepared with ground meat), turkey, ham, sausages), and six of which were plants (zucchini, carrots, tomatoes, spinach, bananas, apples), on a seven-point scale (1 – ‘not at all’, 7 – ‘very much’). Each food appeared with a corresponding image. Participants also reported their frequency of eating meats and plants again in Session 2. These two tasks appeared in random order. Participants were debriefed at the end of each study.

Pre-registration. Hypotheses, exclusion criteria, methods, and analysis plan for Studies 2–4 were pre-registered on Open Science Framework. After data collection, we decided to aggregate results across studies, and departed from our pre-registered analyses regarding hunger

1 We did not pre-register any hypotheses regarding the variables and mainly aimed to explore how these variables translate into behavior.
2 Exclusion criteria were pre-registered on OSF for Studies 2, 3, and 4.
3 The frequency measures were averaged over two sessions for the analyses.
as a control variable (see below for further details).

Selection of food neophobia items. To reduce the likelihood that differences between our measures of meat neophobia and plant neophobia might reflect biases in our selection of meat and plant images (e.g., selecting more exotic looking meats than plants), we had a separate sample of 202 Mechanical Turk participants rate the food images on either "weirdness," "strangeness," "exoticness," "unusualness," "foreignness," or "unfamiliarity," ("1 – not at all, "7 – extremely"). Ratings for each of these six characteristics were internally reliable (all α's above 0.94), and the six characteristics also formed internally reliable composites (α = 0.98). We refer to this composite as strangeness. Fifteen meat items were rated as stranger than the strangest plant item (mean scores of these meats varying between 6.29 and 5.12 as compared to the strangest plant item Rambutan with a mean score of 4.97). We thus selected 12 meats and 12 plants that were matched for rated strangeness and loaded above 0.60 on the factor solution. All meat items loaded most strongly (and all above 0.61) on the first factor, and all of the plant items loaded most strongly (and all above 0.56) on the second factor. Investigations of scree plots in Studies 1 and 2 suggested a two-factor solution. All predictors were standardized prior to the analysis.

Behavioral outcome

In Study 1, the highest eigenvalues were 10.60 and 3.75, and the scree plot suggested a two-factor solution. All meat items loaded most strongly (and all above 0.61) on the first factor, and all of the plant items loaded most strongly (and all above 0.56) on the second factor. Investigations of scree plots in Studies 2–4 similarly indicated the presence of two factors (see online supplement for more details). In Studies 3 and 4, meat and plant neophobia scores in Session 1 were almost identical with Session 2 (rfood = 0.94, 0.94, rplant = 0.86, 0.88 respectively). Hence composite scores averaging

3. Analytic approach

First, we investigated the dimensionality of food neophobia by conducting principal axis factor analyses with oblimin rotation in each study. Afterwards, we tested for the relationship between Food Neophobia Scale (FNS), meat neophobia, and plant neophobia. In Study 2, the Food Neophobia Scale was modified to represent plant-specific food neophobia and meat-specific food neophobia. Therefore, we additionally tested how meat and plant specific modified version of Food Neophobia Scale related to the developed picture-based meat and plant neophobia. In Studies 3 and 4, we examined the correlation between the meat and plant neophobia scores across the two session assessments.

In order to better understand meat and plant neophobia, we tested multiple hypotheses, which are described below in five main sections. First, we predicted that women might be more meat neophobic than men. Second, we hypothesized that openness to experience would relate negatively to meat and plant neophobia. Third, we hypothesized that masculinity and animal empathy would relate to meat neophobia but not to plant neophobia, and that meat-eating frequency would negatively relate to meat neophobia and plant eating frequency would negatively relate to plant neophobia. Fourth, due to the asymmetrical pathogen risks that meats and plants pose, we hypothesized that higher disgust sensitivity would relate more strongly to meat neophobia than to plant neophobia. Finally, we explored how hunger related to meat and plant neophobia.

To test these hypotheses, we ran random-effects models in R (R Core Team, 2012) using the lme4 package (Bates et al., 2012). We entered neophobia as the dependent measure, and modeled participant and study numbers as random intercepts, and participant sex and food type (meat versus plant) as random effects. Each predictor was tested in a separate model, which contained a main effect of that predictor and an interaction between that predictor and food type. We additionally tested for post-hoc pairwise comparisons of these interactions using emmeans (Lenth, 2019) and retrieved p-values with the package immetTest (Kuznetsova et al., 2017). All predictors were standardized prior to the analyses. We further meta-analyzed effect sizes from all studies to represent an overview using the metafor package (Viechtbauer, 2010).

4. Results

Dimensionality of food neophobia. In Study 1, the highest eigenvalues were 10.60 and 3.75, and the scree plot suggested a two-factor solution. All meat items loaded most strongly (and all above 0.61) on the first factor, and all of the plant items loaded most strongly (and all above 0.56) on the second factor. Investigations of scree plots in Studies 2–4 similarly indicated the presence of two factors (see online supplement for more details). In Studies 3 and 4, meat and plant neophobia scores in Session 1 were almost identical with Session 2 (rfood = 0.94, 0.94, rplant = 0.86, 0.88 respectively). Hence composite scores averaging

4 A linear mixed model testing the effect of hunger on meat and plant neophobia also included session number as a random intercept.
across the two sessions were calculated.

### Relationship between food neophobia, meat neophobia, and plant neophobia

Mean FNS scores ranged from 2.77 to 3.55 across studies (see Table 2; for means and standard deviations). In all four studies, the FNS was related to both meat neophobia, \( r's > 0.40 \), and plant neophobia, \( r's > 0.46 \) (all \( p's < 0.01 \)). In Study 2, the meat-specific FNS was positively correlated with meat neophobia, \( r = 0.70, p < .01 \) and plant neophobia, \( r = 0.58, p < .01 \), and the plant-specific FNS was positively correlated with meat neophobia, \( r = 0.24, p = .007 \), and plant neophobia, \( r = 0.78, p < .01 \). In all four studies, meat and plant neophobia were moderately correlated, \( r's > 0.32 \), \( p's < 0.05 \). Meat neophobia was consistently greater than plant neophobia, \( d's = 1.48, 1.49, 1.92, 2.15 \) (see Fig. 1).

### Sex differences

The difference between meat and plant neophobia was moderated by participant sex, \( F (1, 835) = 80.20, p < .001 \). Across four studies, women were more meat neophobic than men, \( B = 0.41, p < .001 \), but the sexes did not differ in plant neophobia, \( B = -0.04, p = .46 \) (also see Fig. 1, for effect sizes in each study). Notably, sex differences on the FNS were small and similar to those for plant neophobia (\( d's = 0.27, 0.34, 0.05, 0.17 \)).

**Openness to experience.** Openness to experience was negatively related to both meat and plant neophobia, but not differentially so (interaction \( B = -0.03, F (1, 625) = 3.59, p = .058 \); main effect \( B = -0.16, F (1, 623) = 49.72, p < .001 \); see Tables 3 and 5 for simple effects).

### Dietary behavior

Tests of moderation by food type indicated that masculinity, \( B = -0.13, F (1, 625) = 92.20, p < .001 \), animal empathy, \( B = 0.10, F (1, 625) = 50.81, p < .001 \), meat eating frequency, \( B = -0.09, F (1, 625) = 37.69, p < .001 \), and plant eating frequency, \( B = 0.07, F (1, 625) = 25.02, p < .001 \), differently related to meat and plant neophobia. Meat neophobia negatively related to masculinity, meat eating frequency, plant eating frequency, and positively to animal empathy, while plant neophobia negatively related to plant eating frequency and animal empathy. Masculinity and meat-eating frequency did not relate to plant neophobia (see Table 4). Animal empathy and plant eating frequency were more strongly related to meat (versus meat) neophobia.

### Pathogen avoidance motives

Tests of moderation by food type indicated that meat and plant neophobia differentially related to both germ aversion and pathogen disgust sensitivity, \( B = 0.04, F (1, 625) = 5.64, p = .02 \) and \( B = 0.06, F (1, 835) = 21.65, p < .001 \), respectively. While both dimensions of neophobia related to both germ aversion and pathogen disgust sensitivity, relations were stronger for meat neophobia (see Table 4).

### Hunger

Hunger had a main effect on neophobia ratings, \( B = 0.03, F (1, 2159) = 4.04, p = .04 \). This effect did not differ for food type, \( B = 0.01, F (1, 1448) = 1.23, p = .27 \). However, hunger related to neophobia only in Study 1, in which it was measured after the neophobia ratings, but not in Studies 2-4, when it was measured before neophobia. We speculate that viewing the novel foods decreased hunger (e.g., by eliciting mild disgust). A similar pattern emerged for FNS.

Notably, hunger was related to pathogen disgust sensitivity only in one of the four studies (\( r's = -0.01, 0.06, -0.07, -0.16 \) and \( p's = 0.86, 0.29, 0.39, 0.047 \)). An internal meta-analysis over the four bivariate correlations indicated that the overall effect was non-significant, \( r = -0.04, p = .46 \). These null results run counter to the only published study reporting a relationship between self-reported hunger and disgust sensitivity (Al-Shawaf & Lewis, 2013).

### Predicting eating behavior

The majority of the participants (78.6%) ate at least part of the Bugbar. Regressing participants’ binary decisions (yes or no) on hunger, the FNS, meat neophobia, and plant neophobia revealed that only meat neophobia uniquely predicted (not) eating the Bugbar (see Table 6).

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5. **Discussion**

Across four studies, factor analyses suggested that meat and plant neophobia form distinct dimensions. Participants were more meat neophobic than plant neophobic, even when items were equated for strangeness of appearance. While plant neophobia did not differ across the sexes, women were more meat neophobic than men. We also observed that, 1) openness to experience negatively related both to plant and meat neophobia similarly, 2) pathogen disgust sensitivity and germ aversion positively related both to meat and plant neophobia (though more strongly to plant neophobia), 3) masculinity negatively related to meat neophobia but not plant neophobia, 4) meat eating frequency negatively related to meat neophobia but not plant neophobia, 5) plant eating frequency negatively related to both plant and meat neophobia (though more strongly to plant neophobia), 6) animal empathy related both to meat and plant neophobia (though more strongly to plant neophobia), and 7) meat neophobia uniquely predicted participants eating a snack bar made of insects. We interpret these findings below.

Whereas sex differences in plant neophobia were small and similar to those on the Food Neophobia Scale, women were more meat neophobic than men. Disgust sensitivity and masculinity (the former being consistently higher in women in past studies (Sparks et al., 2018), and the latter expected to be more prevalent in men) would potentially explain the sex differences in meat neophobia. However, in each model testing for pathogen avoidance motives and empathy towards animals, participant sex still had a unique effect on neophobia (\( p's < 0.05 \)). Therefore, the costs and benefits of being meat neophobic and plant neophobic seem different for men and women. Al-Shawaf et al. (2015) previously explored the relationship between mating strategy and food neophobia and showed that men with a more unrestricted sociosexual orientation exhibit higher levels of food neophilia, while this effect was not observed for women (\( r's = -0.26 \) and \(-0.09 \) respectively). Noting that the current studies, contrary to Al-Shawaf et al. (2015), did not show a sex difference in food neophobia as measured with the Food Neophobia Scale, our data cannot rule out the possibility that men’s more unrestricted sociosexual orientation explains the sex differences observed in meat neophobia. Future studies can test whether being low on meat neophobia, and thus exposing oneself to more risks than by being low on plant neophobia, is a candidate for better immunocompetence display, and therefore observed more in men with less restricted sociosexuality.

Openness to experience related similarly to both meat and plant neophobia, and hence captures an aspect in food neophobia that generalizes across food categories. Even though the risks meats and plants pose are different, they are both non-zero. Further, both food categories offer a new experience opportunity (whether it will have an undesirable end or not) when eaten, again due to the unknown nature of a novel food.

Contrary to predictions, animal empathy related more strongly to plant neophobia compared to meat neophobia. This discrepancy might reflect greater awareness over dietary choices among individuals more empathic toward animals. However, data indicates no relationship between animal empathy and meat or plant eating frequency (see supplementary materials).

Overall, these results suggest that assumptions of unidimensionality in food neophobia (e.g., the FNS; Pliner & Holden, 1992) might have masked important differences between meat and plant neophobia in past research.

6. **Theoretical implications**

Food neophobia is relevant to food learning and the development of food aversions. Humans develop aversions to foods that have produced illness (e.g., stomach ache, diarrhea, etc.) (Logue et al., 1981; Rozin, 1986). However, learning about the harmful effects of a food would prove to be difficult if multiple novel foods were consumed in close succession. A greater number of the unknown foods eaten would create...
Table 2
Mean (M), standard deviation (SD), and sample size (n) of food neophobia as measured by the original (FNS–O) and the meat and plant specific versions of the Food Neophobia Scale (FNS–M; FNS–P).

| Study | Food Neophobia (FNS–O) | Food Neophobia (FNS–M) | Food Neophobia (FNS–P) |
|-------|------------------------|------------------------|------------------------|
|       | M  | SD  | n   | M  | SD  | n   | M  | SD  | n   |
| 1     | 3.55 | 1.35 | 210 | –  | –   | –   | –  | –   | –   |
| 2     | 2.83 | 1.23 | 102 | 3.58 | 1.48 | 103 | 2.78 | 1.23 | 101 |
| 3     | 2.78 | 1.14 | 160 | –  | –   | –   | –  | –   | –   |
| 4     | 2.77 | 1.11 | 161 | –  | –   | –   | –  | –   | –   |

Note. Food neophobia represent the food neophobia variable derived from the Food Neophobia Scale (Pliner & Hobden, 1992) on a 7-point Likert scale. Study 2 includes mean and standard deviations computed for the original Food Neophobia Scale (FNS–O) as well as the meat-specific and plant-specific versions of the Food Neophobia Scale.

Fig. 1. Sex differences in meat and plant neophobia. Note. Meat and plant neophobia scores derived from willingness to eat foods displayed in pictures. The scores were reverse-coded so that higher scores indicate less willingness eating the foods. Purple bars represent female participants, and orange bars represent responses of male participants. Error bars represent standard errors. Cohen’s d was calculated using lsr package’s cohensD function with non-paired method (Navarro, 2015). Therefore, the graph does not account for errors derived from mixed model analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 3
Main effect and interaction effect of the variables in interpreting novel food avoidance on neophobia scores.

| Predictors                          | Estimate | t statistic | p      | df  |
|-------------------------------------|----------|------------|--------|-----|
| Participant sex                     | 0.09     | 4.25       | <.001  | 827 |
| Food Type × Participant sex          | –0.11    | 9.96       | <.001  | 835 |
| Openness                            | –0.16    | –7.05      | <.001  | 822 |
| Food Type × Openness                | 0.03     | 1.89       | 0.06   | 625 |
| Pathogen disgust                    | 0.15     | 7.35       | <.001  | 831 |
| Food Type × Pathogen disgust        | 0.06     | 4.65       | <.001  | 835 |
| Germ aversion                       | 0.17     | 7.18       | <.001  | 572 |
| Food Type × Germ aversion           | 0.04     | 2.37       | 0.02   | 625 |
| Animal empathy                      | –0.03    | –1.18      | 0.24   | 623 |
| Food Type × Animal empathy          | 0.10     | 7.13       | <.001  | 625 |
| Masculinity                         | –0.12    | –3.04      | <.01   | 624 |
| Food Type × Masculinity             | –0.13    | –6.60      | <.001  | 625 |
| Plant frequency                     | –0.18    | –8.10      | <.001  | 623 |
| Food Type × Plant frequency         | 0.07     | 5.00       | <.001  | 625 |
| Meat frequency                      | –0.02    | –0.77      | 0.44   | 526 |
| Food Type × Meat frequency          | –0.09    | –6.14      | <.001  | 625 |
| Hunger                              | –0.03    | –2.01      | 0.04   | 2159|
| Food Type × Hunger                  | –0.01    | –1.11      | 0.27   | 1448|

Note. Neophobia scores represent responses given to the meat and plant neophobia derived from the images. Separate models were run by each predictor on the dependent variable, food neophobia. Each model included study number and participant id as random intercepts and participant sex, food type, the predictor of interest, and the interaction between food type and the predictor of interest (of which the table includes information from the latter two) as fixed effects. In the model with hunger session number is also included as a random intercept.

more noise as well as uncertainty in knowing which food poses the threat (Rozin & Vollmecke, 1986). It is therefore adaptive to take steps in learning while reducing chances of putting oneself at risk.

Food neophobia reduces the probability of ingesting foods with unknown costs, including those resulting from toxins and pathogens. In line with the greater threats posed by meats, results from four studies indicated greater meat neophobia than plant neophobia. Further, individual differences in pathogen-avoidance motives (e.g., germ aversion and pathogen disgust) were more strongly related to meat neophobia than to plant neophobia.

Some learning mechanisms are specialized to detect the types of dangers present in the evolutionary past. The aversive learning literature indicates that people more readily learn to associate shocks or noises with animals that threatened the survival of human ancestors (i.e., snakes or spiders) compared to fear-irrelevant stimuli (i.e., flowers) (Cook & Mineka, 1989; Haselton & Nettle, 2006; Seligman, 1971). In parallel to the dangers posed by animals, in the domain of nutrients, meat is more likely to lead to illness. Tybur et al. (2016) reported a similar learning specialization for meat products (versus vegetables and beverages), results here show that pathogen avoidance motives (i.e., pathogen disgust sensitivity and germ aversion) relate to food neophobia, and this effect is stronger for novel meats compared to novel plants. Hence, individuals who are more motivated to avoid pathogens are also less willing to try new foods – especially new meats.

Children tend to be high in food neophobia (Dovey et al., 2008), especially in the case for novel “greens” (Cashdan, 1998). This greater food neophobia might result from children’s lower ability to handle the toxins present in plants (Cashdan, 1998). Better understanding the developmental trajectory of plant and meat neophobia can provide a
more thorough picture of the adaptations that address the unique risks posed by different types of foods. Understanding how food neophobia progresses longitudinally can aid interventions compensating possible malnutrition and further introduce diets specific to solving food neophobia relevant to the children’s developmental window.

7. Practical implications

Replacing livestock protein with food innovations with smaller footprints (e.g., insects) would reduce greenhouse gas emissions and conserve water while providing substantial amounts of protein (Alexander et al., 2017; Herrero et al., 2016; Lokeshwari & Shantibala, 2010; Oonincx & De Boer, 2012), yet insects or other technologies such as recycled water remain unpopular (Hartmann et al., 2015; Rozin et al., 2015). Hence, better understanding the psychological barriers to implement novel technologies can yield dividends to environmental sustainability. Previous studies revealed greater food neophobia to be related with lower readiness to include insects as a meat substitute (Verbeke, 2015). Limited studies (Jensen & Lieberoth, 2019) testing behavioral outcomes found no evidence of food neophobia relating to insect tasting behavior. Results here suggest that meat neophobia uniquely relates to willingness to eat insects.

This study demonstrates that meat neophobia is a larger barrier to this sustainable food option than are plant neophobia or unidimensional food neophobia. Future research can focus on ways to reduce the perception of insects as animals. We used snack bars that did not have any visual resemblance to insects and yet we found that meat neophobia uniquely relates to willingness to eat insects. We used snack bars that did not have any visual resemblance to insects and yet we found that meat neophobia uniquely relates to willingness to eat insects.

Table 4
Relations between meat – plant neophobia and multiple predictors.

| Predictor          | Study 1 | Study 2 | Study 3 | Study 4 | Estimate [95%CI] |
|--------------------|---------|---------|---------|---------|-----------------|
| Masculinity        | 0.15    | 0.14    | 0.13    | 0.12    | -0.04 to 0.17   |
| Germ Aversion      | 0.27    | 0.25    | 0.23    | 0.22    | 0.15 to 0.26    |
| Pathogen Disgust   | 0.10    | 0.09    | 0.08    | 0.07    | -0.05 to 0.14   |
| Frequency (Meat)   | 0.16    | 0.15    | 0.14    | 0.13    | -0.08 to 0.20   |
| Frequency (Plant)  | 0.16    | 0.15    | 0.14    | 0.13    | -0.08 to 0.20   |
| Openness           | 0.11    | 0.10    | 0.09    | 0.08    | -0.06 to 0.22   |
| Hunger             | -0.11   | -0.10   | -0.09   | -0.08   | -0.06 to 0.24   |

Note. Food neophobia scores were derived from mean willingness to eat novel meats and plants neophobia displayed in images. Partial correlations controlling for participant sex for Studies 1, 2, and 4 followed by an internal meta-analysis estimate with [95% CI]. Partial correlations were calculated using the prep function from the ppcor package (Kim, 2015). Values in bold, p < .05. Study 3 and Study 4 hunger – neophobia correlations are from Session 1 and Session 2, respectively.

Table 5
Simple effects from mixed models.

| Predictor          | Study 1 | Study 2 | Study 3 | Study 4 | Estimate [95%CI] |
|--------------------|---------|---------|---------|---------|-----------------|
| Masculinity        | 0.15    | 0.14    | 0.13    | 0.12    | -0.04 to 0.17   |
| Germ Aversion      | 0.27    | 0.25    | 0.23    | 0.22    | 0.15 to 0.26    |
| Pathogen Disgust   | 0.10    | 0.09    | 0.08    | 0.07    | -0.05 to 0.14   |
| Frequency (Meat)   | 0.16    | 0.15    | 0.14    | 0.13    | -0.08 to 0.20   |
| Frequency (Plant)  | 0.16    | 0.15    | 0.14    | 0.13    | -0.08 to 0.20   |
| Openness           | 0.11    | 0.10    | 0.09    | 0.08    | -0.06 to 0.22   |
| Hunger             | -0.11   | -0.10   | -0.09   | -0.08   | -0.06 to 0.24   |

Note. Food neophobia scores were derived from mean willingness to eat the novel meats and plants neophobia displayed in images. Separate models were run for each predictor. Each model includes study number and participant id as random intercepts and participant sex, food type, the predictor of interest, and the interaction between food type and the predictor of interest as fixed effects. In the model with hunger, session number is also included as a random intercept. Simple effect estimates were retrieved from each mixed model using emtrends function from emmeans package in R and are given in this table with the SE, and confidence intervals (lower CL, upper CL).

Table 6
Summary table of the logistic regression predicting willingness to eat an insect-based snack bar, with the estimate (β), SE of the estimate, odds ratio (exp(β)), and p-values.

| Predictor          | β     | SE β  | exp(β) | p     | CI lower bound | CI upper bound |
|--------------------|-------|-------|--------|-------|---------------|---------------|
| Food neophobia     | -0.39 | 0.25  | 0.67   | 0.11  | -0.88         | 0.10          |
| Meat neophobia     | -1.14 | 0.44  | 0.55   | 0.01  | -2.00         | -0.29         |
| Plant neophobia    | -0.59 | 0.54  | 0.32   | 0.27  | -1.65         | 0.46          |
| Hunger             | -0.008| 0.15  | 0.99   | 0.96  | -0.29         | 0.27          |

Note. Logistic regression was used to test how meat and plant neophobia, as assessed via mean willingness to eat novel meats and plants neophobia displayed in images, and general food neophobia, as assessed via the Food Neophobia Scale (FNS), relate to willingness to eat an insect-based snack bar. The dependent variable includes binary responses for tasting (tasted versus did not taste). Hunger was entered as a control variable.
8. Concluding remarks

Until now, food neophobia has been measured using unidimensional scales that are unable to make fine-grained distinctions between food categories. The current work suggests that food neophobia is multidimensional in nature, with meat and plant neophobia underpinned by different psychological variables. Better understanding the nature of these different dimensions can yield future benefits, such as increasing consumption of sustainable meat alternatives.

Ethical and funding statement

This research project was approved by the Scientific and Ethical Review Board of the Vrije Universiteit Amsterdam, and preregistered at Open Science Framework (https://osf.io/3jy9s/; data, as well as the R code for the analyses can also be found on this page). We report all measures, data exclusions, and the sample size determination rule.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105177.

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