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# Food Quality and Preference

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## Sex differences in the genetic and environmental underpinnings of meat and plant preferences

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### ABSTRACT

People vary in the degree to which they enjoy eating meats versus plants. This paper examines the genetic and environmental roots of this variation, as well as the genetic and environmental roots of meat neophobia, plant neophobia, and vegetarianism/veganism. Using data from 9319 adult Finnish twins and siblings of twins (551 MZ, 861 DZ complete; 783 MZ, 2692 DZ incomplete twin pairs), we examine the degree to which recalled childhood exposure to meats and plants relates to adult preferences for the same meats and plants. We also investigate sex differences in the heritability of 1) meat and plant preferences, 2) childhood meat and plant consumption, 3) meat and plant neophobia, and the heritability of 4) vegetarianism/veganism. For both men and women, recalled childhood meat consumption correlated more strongly with current meat preferences than current plant preferences, and recalled childhood plant consumption correlated more strongly with current plant preferences than current meat preferences. We detected sex differences in the heritability of childhood meat consumption ( $h^2_{\text{men}} = 0.31$ ,  $h^2_{\text{women}} = 0.11$ ) and current meat preferences ( $h^2_{\text{men}} = 0.26$ ,  $h^2_{\text{women}} = 0.51$ ), but not childhood plant consumption ( $h^2_{\text{men}} = 0.41$ ,  $h^2_{\text{women}} = 0.17$ ), current plant preferences ( $h^2_{\text{men}} = 0.45$ ,  $h^2_{\text{women}} = 0.53$ ), meat neophobia ( $h^2_{\text{men}} = 0.48$ ,  $h^2_{\text{women}} = 0.55$ ) or plant neophobia ( $h^2_{\text{men}} = 0.56$ ,  $h^2_{\text{women}} = 0.54$ ). Further, different genes undergirded men's and women's meat preferences. Abstention from meat (i.e., vegetarianism/veganism) was 76% heritable. These results have implications for hypotheses of the developmental origins of dietary patterns and hypotheses for sex differences in meat consumption.

Unlike many species, humans consume a wide range of foods. The vast array of dietary choices – which include both meats and plants – leads to the so-called omnivore's dilemma: identifying and selecting nutritious foods and avoiding harmful ones (Rozin & Todd, 2015). These tasks are facilitated by socially-transmitted information such as recipes that contain combinations of available ingredients that are consumable and protect against ecologically-specific food risks (Billing & Sherman, 1998). For example, Aboriginal Australians use various food processing techniques (e.g., grinding, exposing to ashes and mussel shells) to render nardoo (a plant with high thiaminase levels that are toxic) non-toxic and edible (Earl & McCleary, 1994). Such techniques are unknown to foreigners who have not been exposed to this information. Similar processes are ubiquitous across cultures. Naturally, in addition to ranging across cultures, dietary preferences and choices also vary within cultures. One notable dimension of variation concerns preferences for meats versus plants. For example, women, on average, consume more

plants and less meats than men, and they are more likely to completely abstain from eating meat (Fessler, Arguello, Mekdara, & Macias, 2003). Why do individuals within a society – and, specifically, men and women – vary in such preferences for meats and plants? Here, we outline current knowledge regarding the nature and causes of variation in food preferences. Next, we review the degree to which twin methods – which are uniquely suited to evaluating sources of variation in phenotypes, including food preferences – support or refute these proposals. Then we present findings from a novel twin study designed to inform why people vary in their meat and plant preferences.

### 1. Understanding why people vary in food preferences

A wealth of evidence suggests that life experiences affect food preferences. For example, at a proximate level, nausea or vomiting after eating a specific food leads to an acquired aversion of that food (Rozin,

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1986). A food's familiarity also influences its appeal (Aldridge, Dovey, & Halford, 2009). Hence, food preferences might partially arise from mere exposure – especially exposure early in development. Cashdan (1994, 1998) proposes a function for this phenomenon, and further argues that such exposure effects occur most strongly in early childhood during a sensitive period. Specifically, children are especially attentive to foods and are more willing to try new foods at earlier ages, when parents are especially attentive and steer dietary choices away from foods that are toxic, have low nutrient quality, etc. As a result, children's diet during these putative sensitive periods is mostly determined by what their parents feed them (Cashdan, 1994). These set food preferences continue steering children away from harmful foods as they become less dependent on their parents.

People also vary in their preferences for novel foods – that is, they vary in food neophobia. Greater neophobia reduces the consumption of unfamiliar foods and reduces dietary breadth (Jaeger, Rasmussen, & Prescott, 2017; Russell & Worsley, 2008). Importantly, the processes that underlie variation in preferences for familiar or normative foods (e.g., past experience, familiarity, exposure during a critical developmental window) should not underlie variation in food neophobia, since novel foods, by definition, are unfamiliar.

## 2. Differences in preferences for meats versus plants

Over human evolution, meat consumption increased after the advent of cooking and the transition from foraging to hunting (Wrangham, 2010). Meats provide essential nutrients and calories that are more difficult to obtain from plants, though they also present greater pathogen and parasite threats than plants (Billing & Sherman, 1998; Bryan, 1988; Higgs, 2000; Pereira & Vicente, 2013; Sherman & Hash, 2001; Sockett, 1995; Williams, 2007). Natural selection has shaped multiple adaptations that guide food preferences. For example, bitter tastes, an indicator of toxic compounds, are universally rejected by infants (Steiner, 1977). Children also learn whether to avoid certain plants based on reactions from other adults (Wertz & Wynn, 2014). At the same time, meat taboos universally outnumber plant taboos (Fessler & Navarrete, 2003), and spices that inhibit microbial growth are usually used in meat dishes (Sherman & Hash, 2001). Further, people are more meat neophobic than plant neophobic; that is, they are less willing to eat novel meats than they are to eat novel plants (Çınar, Karinen, & Tybur, 2021).

Notably, across cultures, men consume more meat than women do (Berbesque & Marlowe, 2009; Daniel, Cross, Koebnick, & Sinha, 2011; Fessler et al., 2003; Prattala et al., 2007). Abstention from meat (i.e., being vegetarian) also differs across the sexes, with women more likely to be vegetarian than men (Fessler et al., 2003; Neumark-Sztainer, Story, Resnick, & Blum, 1997; Worsley & Skrzypiec, 1998). Researchers have forwarded biological arguments to explain sex differences in meat preferences and consumption. For example, Fessler (2002a, 2002b) argues that women's immune defenses are suppressed when progesterone levels are especially high - during pregnancy and during the luteal phase of the menstrual cycle. Given that the immune system can attack zygotes, immune defenses might be lowered during these periods. In such a state, women are putatively more vulnerable to pathogen risks, and hence might consume less meat, which poses more of a pathogen risk than plants. Consistent with this idea, evidence suggests that food aversions during pregnancy mostly concern animal-based foods such as meats, poultry, fish, and eggs (Fessler, 2002b; Flaxman & Sherman, 2000). Women's meat consumption is also sometimes socially regulated, as exemplified by culturally-evolved Fijian food taboos, which limit pregnant women's consumption of toxic compounds found in certain marine life (Henrich & Henrich, 2010).

In sum, both biological and social explanations have been forwarded as explanations for meat and plant preferences, from having the PROP bitter taste phenotype (Bell & Tepper, 2006) to avoiding socially prohibited foods. Despite different plausible roots for preferences for meats

versus plants (e.g., childhood exposure) – as well as different potential roots for men's and women's preferences for these foods – little work has evaluated the genetic and environmental roots of meat and plant preferences. Twin studies provide an opportunity to examine the etiology of these different types of food preferences.

## 3. Genetic and environmental influences on food preferences

Classical twin studies compare monozygotic (MZ) twins and dizygotic (DZ) twins to decompose phenotypic (i.e., observed) variance into heritable and environmental components. MZ twins share ~ 100% of their segregating genes (i.e., the DNA sequences) and 100% of their shared environment (e.g., rearing family environment, neighborhood), whereas DZ twins share ~ 50% of their segregating genes and 100% of their shared environment. Finding that MZ twin pairs are more similar than are DZ twin pairs suggests that phenotypic variance has a genetic component. For example, MZ versus DZ correlations of 1.00 versus 0.50, respectively, would indicate 100% heritability, since MZ twins are twice as similar to each other in the observed trait as DZ twins, just as they are twice as genetically similar. MZ correlations more than double the DZ correlations indicate the presence of non-additive genetic effects. MZ correlations less than double the DZ correlations indicate the presence of shared environmental effects. Any variance that is not explained by heritable and shared environmental components (i.e., dissimilarity between MZ twins) reflects unique environmental influences and includes measurement error.

Food preferences are doubtlessly shaped by environment, though the precise nature of environmental factors that shape food preferences is unclear. For example, in parallel to Cashdan (1994), introduction to foods in early childhood might increase children's later dietary breadth. Hence, children raised by the same parents (especially at the same time) – and presumably, given the same foods by those parents – should have similar dietary preferences as adults. If childhood frequency of meat and plant consumption influences adult meat and plant preferences, then twin methods should reveal shared environmental effects (denoted as "C") on these preferences. That is, if both dizygotic (DZ) and monozygotic (MZ) twin pairs are fed the same foods as children this exposure would cause similarities in food preferences in both types of twins. Yet, twin studies on food preferences have found only small or non-existent shared environmental components (or "C") in adulthood (Smith et al., 2016; Vink, van Hooijdonk, Willemsen, Feskens, & Boomsma, 2020; see Table 1). These same studies suggest that food preferences are heritable, and that heritability might differ across food types, across the life span, and across the sexes. For example, one study detected higher heritability in men for processed meat consumption than women (see coefficients and CI in Table 1). However, most behavioral genetics studies of food consumption and preferences have not reported separate heritability estimates for men and women. Additionally, different genes might underlie men's and women's food preferences (so-called qualitative sex differences), especially concerning meats. Such differences might reflect greater costs of meat consumption to women due to immunosuppression (e.g., possible pleiotropy, with genes that affect immune function also affecting women's meat preferences but not men's). The only study to have reported qualitative sex differences did not detect any qualitative sex differences on food preferences as measured by a hedonic liking and disliking scale (Vink et al., 2020). Furthermore, even though men's and women's dietary patterns include asymmetries in abstaining from meat, none of these earlier studies reported possible genetic and environmental influences on vegetarianism/veganism.

Much of the variation in food neophobia is heritable as well. One of two studies assessing heritability in adults reported a broad sense heritability of 0.67 in British twins (Knaapila et al., 2007); the other, which enrolled a Finnish sample, reported heritability of 0.61 for women but zero for men (Knaapila et al., 2011). In this latter study, about half (0.45) of the variation in men's food neophobia was attributed to shared environment. However, both studies assessed food neophobia with the

**Table 1**  
Summary table for genetic (A), shared environmental (C), additive genetic estimates (D), and unique environment (E) reported in food preferences for men and women (if applicable) across different meat and plant categories.

Article	Dependent variable	Food categories	A		D		C		E		Sample
			Male	Female	Male	Female	Male	Female	Male	Female	
(Keskitalo et al., 2008)	food consumption frequency	Meats	0.39 (0.30–0.48)	0.44 (0.36–0.51)	–	–	–	–	0.39 (0.30–0.48)	0.56 (0.49–0.64)	Finnish twins (adult)
		Healthy foods	0.49 (0.40–0.56)	0.54 (0.47–0.60)	–	–	–	–	0.51 (0.44–0.60)	0.54 (0.47–0.60)	
(Hasselbalch, Heitmann, Kyvik, & Sørensen, 2008)	food consumption frequency	Red meat	0.34 (0.19–0.48)	0.33 (0.17–0.47)	–	–	–	–	0.66 (0.52–0.81)	0.67 (0.53–0.83)	Danish Twin Registry (adult)
		Processed meats	0.47 (0.31–0.59)	0.29 (0.14–0.43)	–	–	–	–	0.53 (0.41–0.69)	0.71 (0.57–0.86)	
		Vegetables	0.24 (0.01–0.53)	0.14 (0.00–0.41)	–	–	0.40 (0.13–0.59)	0.46 (0.22–0.61)	0.37 (0.29–0.46)	0.40 (0.32–0.49)	
(Teucher et al., 2007)	food consumption frequency	Red meat	–	0.39 (0.32–0.45)	–	–	–	–	–	0.61 (0.55–0.68)	UK Twins (adult)
		Fruit - vegetable	–	0.49 (0.43–0.54)	–	–	–	–	–	0.51 (0.46–0.57)	
(Vink et al., 2020)	food liking	Meats	0.41 (0.33–0.49)	0.51 (0.47–0.55)	–	–	–	–	0.59 (0.51–0.67)	0.49 (0.45–0.53)	Twins in the NL (adult)
		Vegetables	0.51 (0.48–0.55)	–	–	–	–	–	0.49 (0.45–0.52)	–	
		Fruits	0.02 (0.00–0.26)	–	0.41 (0.17–0.47)	–	–	–	0.57 (0.53–0.61)	–	
(Smith et al., 2016)	food liking	Vegetables	0.54 (0.47–0.59)	–	–	–	–	–	0.46 (0.41–0.53)	–	UK Twins (adult)
		Fruit	0.49 (0.43–0.55)	–	–	–	–	–	0.51 (0.45–0.57)	–	
		Meat/Fish	0.44 (0.38–0.51)	–	–	–	–	–	0.56 (0.49–0.62)	–	
(Pallister et al., 2015)	food liking	Meats	0.44 (0.35–0.51)	–	–	–	–	–	0.56 (0.49–0.64)	–	TwinsUK (adult)
		Fruit- vegetable	0.36 (0.28–0.44)	–	–	–	–	–	0.64 (0.56–0.72)	–	
(Keskitalo et al., 2008)	food liking (responses by parents)	Vegetables	0.54 (0.47–0.63)	–	–	–	0.35 (0.27–0.42)	–	0.11 (0.10–0.13)	–	Gemini UK (child)
		Fruit	0.53 (0.45–0.61)	–	–	–	0.35 (0.26–0.43)	–	0.13 (0.11–0.15)	–	
		Meat and fish	0.48 (0.40–0.57)	–	–	–	0.37 (0.27–0.45)	–	0.15 (0.13–0.17)	–	
(Faith, Heo, Keller, & Pietrobelli, 2013)	dietary intake recall	Fruit	0.26	–	–	–	0.62	0.8	0.12	0.2	same-sex Coloradoborn (child)
		Red meat/pork/lamb	0.57	–	–	–	0.32	0.74	0.11	0.23	
(Breen, Plomin, & Wardle, 2006)	food liking	Vegetables	–	–	–	–	0.79	0.85	0.21	0.15	TEDS UK (child)
		Vegetables	0.37 (0.20–0.58)	–	–	–	0.51 (0.30–0.66)	–	0.13 (0.09–0.17)	–	
		Meat and fish	0.78 (0.63–0.92)	–	–	–	0.12 (0.00–0.27)	–	0.10 (0.08–0.12)	–	
		Fruit	0.51 (0.37–0.68)	–	–	–	0.32 (0.16–0.46)	–	0.17 (0.14–0.20)	–	
(Pimpin et al., 2013)	food consumption frequency	Meat and fish	–	–	–	–	0.91 (0.89–0.94)	–	0.09 (0.06–0.11)	–	Gemini UK (child)
		Vegetables	0.15 (0.12–0.18)	–	–	–	0.81 (0.78–0.83)	–	0.05 (0.04–0.05)	–	
		Fruit	0.10 (0.06–0.13)	–	–	–	0.82 (0.79–0.85)	–	0.09 (0.07–0.10)	–	

\*Keskitalo et al., 2008 includes fruits vegetables chicken as healthy foods

Food Neophobia Scale (Pliner & Hobden, 1992), an instrument that does not differentiate between meats and plants. Recent research suggests that men and women differ in meat neophobia but not in plant neophobia (Çınar et al., 2021). Hence, these earlier findings on the (sex-specific) heritability of food neophobia have not been equipped to assess dimensions of neophobia in which the largest sex differences might exist.

Based on hypotheses of critical developmental windows that influence food preferences, shared environment effects should be stronger for food preferences rather than for willingness to try novel foods. Yet, studies have generally reported no shared environmental effect on food preferences, but a non-zero contribution to food neophobia, at least in men (for food preferences see, Table 1; for food neophobia see, Knaapila et al., 2011). While puzzling, these findings have generally arisen via studies with small sample sizes. For example, only 936 and 1176 individual twins were included in the two food neophobia studies (Knaapila et al., 2007, 2011). Further, the study that reported sex differences in food neophobia was likely underpowered to test for sex differences too with only 82 MZ, 79 DZ male and 124 MZ and 92 DZ female twin pairs in the sample (Knaapila et al., 2011).

#### 4. The present research

The current study aims to test for 1) phenotypic relations between childhood consumption of meats and plants and adult preferences for meats and plants; 2) whether these relations differ for meats versus plants; 3) genetic and environmental factors underlying meat and plant preferences and neophobia; and 4) sex differences in genetic and environmental influences in meat and plant preferences and neophobia.

To achieve these aims, we assessed relations between recalled meat and plant consumption during childhood, current meat and plant preferences, meat and plant neophobia, and abstention from meats (i.e., vegetarianism or veganism). Using univariate twin modeling, we assessed the genetic and environmental components underlying these variables, and we further tested for quantitative and qualitative sex differences in genetic and environmental components. Finally, using bivariate twin modeling, we estimated the degree to which overlapping genetic and shared environmental factors influence childhood meat and plant consumption and adulthood meat and plant preferences.

### 5. Method

#### 5.1. Participants

Twins and siblings of twins older than 18 and registered in the Central Population Registry in Finland were invited if their mother tongue was listed as Finnish and if they were residents of Finland. 33,390 twins and siblings of twins, some of whom had participated in previous studies of the same research group and indicated interest in participating in future studies ( $n = 7716$ ; see, Johansson et al., 2013) were invited to participate. Excluding individuals who were not in Finland at the time of the study resulted in 33,211 potential participants who were invited with posted letters in November 2018 (for further details, see Tybur et al., 2020).

Participants received a link to an online survey, with a unique eight-character code for matching twin pairs and siblings, and the chance to participate in a raffle for one of 40 vouchers each worth €100.

In the first week of January 2019, data collection was completed, resulting in responses from 9564 individuals (6965 twins, 2592 siblings, and 7 unknown) with a response rate of 29%. Of the 9319 (97%) participants who gave consent for using their data on scientific research, 3475 twin singletons, 898 siblings of twins, 2824 members of complete twin pairs from 4887 families provided data on the variables examined here (see Table 3 for the sample sizes per zygosity). The age range of the sample was 18–58.

#### 5.2. Ethical review

The research was reviewed and approved by The Ethics Review Board of Åbo Akademi University in Turku, Finland. All participants consented prior to completing the study. This form followed the Declaration of Helsinki, and informed the participants about the voluntary nature of the study and that they could terminate their participation at any time.

#### 5.3. Materials

Items were first written in English and then translated to Finnish by a native Finnish speaker fluent in English. Another person who was a native Finnish, fluent English speaker and blind to the original items back-translated the scales. A native English speaker compared the original and back-translated versions of the scales. The original translator solved any discrepancies highlighted by the native English speaker and finalized the items. All items were then checked by two other Finnish speakers for any grammatical or comprehension issues.

*Current meat and plant preferences.* We aimed to assess preferences for meats and plants that are widely consumed in the population from which we sampled (Finland). To generate a list of these foods, we conducted a pilot study in which 36 Finns answered the following four open-ended questions: (1) “Which plant-based foods do you not like? List as many plant-based foods as you want to.” (2) “Which plant-based foods do you like, but you believe many others would not like? List as many plant-based foods as you want to.” (3) “Which meat-based foods do you not like? List as many meat-based foods as you want to.”, and (4) “Which meat-based foods do you like, but believe that many others would not like? List as many meat-based foods as you want to”. We chose six plants (olive, radish, asparagus, paprika, cabbage, cauliflower) and six meats (liver, sausage, reindeer, moose, bacon, sheep) that were mentioned at least twice in the answers to these questions. Participants responded to the item “How much do you like to eat this?” (1 = not at all to 7 = very much) for each of these 12 foods. We computed the mean of responses to the six meat items and the mean of the responses to the six plant items ( $\alpha = 0.88$  for meats;  $\alpha = 0.78$  for plants).

*Childhood consumption of meats and plants.* Participants reported the frequency with which their parents served them these same six meats and same six plants during their childhood (0 = never or less than once a year, 1 = at least once a year, 2 = monthly, 3 = weekly, 4 = daily). We computed the mean of the responses to the six meat items and the mean of the responses to the six plant items ( $\alpha = 0.64$  for meats;  $\alpha = 0.79$  for plants).

*Meat and plant neophobia.* A picture-based instrument was used to measure participants’ willingness to eat novel meats and novel plants (see Çınar et al., 2021, and Perone et al., 2021). Images of twelve meats (e.g., frog legs, chicken feet) and twelve plants (e.g., rambutan, Buddha’s hand) that are generally not consumed in Finland, but are consumed in other cultures, were presented individually with the name of the food/dish. Participants responded to the question “Would you be willing to eat this?” on a 4-point Likert scale (1 = absolutely not, 2 = probably not, 3 = probably yes, 4 = absolutely yes). Separate composite scores were created for meats and plants ( $\alpha = 0.95$  for meats,  $\alpha = 0.96$  for plants), and these composites were reverse coded so that higher scores represent less willingness to try novel meats and plants.

*Vegetarianism/veganism.* Participants answered the question “Are you a vegetarian or vegan?” by responding “Yes/No”.

#### 5.3. Statistical analyses

*Classical twin modelling* enables estimates of the additive genetic (A), non-additive (dominant) genetic (D), shared environmental (C), and non-shared environmental (E) effects on the variation of trait of interest. Variation of a trait is attributed to: 1) A, if twin-pair correlations are higher in MZ twins (who share ~ 100% of their genetic material) than in

DZ twins (who share ~ 50% of their genetic material); 2) C, if twin-pair correlations are more than half as large in DZ twins as in MZ twins; and 3) D, if twin-pair correlations are less than half as large in DZ twins as in MZ twins. C and D have opposing effects on DZ twin correlations and cannot be estimated simultaneously. Hence, either an ACE or ADE model is selected based on a visual inspection of the MZ and DZ twin correlations. After estimating A and C or D components, any remaining variance forms E, which reflects components that make twins different, including the non-shared environmental influences and measurement error. This approach also allows for estimates of the A, C or D, and E components of relationships between variables via the examination of cross-twin-cross-trait correlations. Additionally, genetic and environmental correlations between the traits can be estimated, with the former being the overlap of the genetic factors underlying the traits of interest and the latter being the overlap of environmental factors underlying the traits of interest. A genetic or environmental correlation of 1 shows a perfect overlap, indicating the traits of interest are influenced by the same genetic or environmental factors, whereas a correlation of 0 indicates no overlap, suggesting that independent genetic or environmental factors underlie the traits of interest.

Before fitting the twin models, we retrieved phenotypic correlations (i.e., observed correlations), means and standard deviations, and within twin-pair correlations per zygosity-by-sex groups for 1) childhood recall of meat and plant consumption, 2) current preferences of meats and plants, 3) meat neophobia and plant neophobia, and 4) vegetarianism/veganism (with analyses using polychoric within twin-pair correlations for this dichotomous variable). Next, using classical twin modelling, we fitted ACE or ADE models to estimate genetic and environmental effects for variation in 1) childhood recall of meat and plant consumption, 2) current preferences of meats and plants, 3) meat neophobia and plant neophobia, and 4) vegetarianism/veganism.

We used independent sample t-tests to test for significant mean differences between males and females. Models estimating genetic and environmental influences separately for male and female twins and likelihood ratio tests were used to test for further sex differences (the saturated model). The negative log-likelihood (-2LL) of a constrained model was subtracted from the -2LL of the overall/ saturated model. A  $\chi^2$  of the difference in log-likelihoods (with degrees of freedom equal to the number of constrains) was used to select the most parsimonious

model using an alpha of 0.01. To test whether contributions of A, C or D, and E differ across the sexes (*quantitative sex differences*), we constrained A, C or D and E to be equal across the sexes. To test whether the genes underlying variation of the traits of interest differ across the sexes (*qualitative sex differences*), we constrained the genetic correlation between DZ same-sex twins ( $r = 0.50$ ) to be equal to the genetic correlation in opposite-sex (DOS) twins.

Lastly, we fitted two bivariate ACE models to estimate the genetic and environmental correlations between 1) childhood recall of meat consumption and current meat preferences; 2) childhood recall of plant consumption and current plant preferences.

All analyses were done in R with the OpenMx package (Boker et al., 2011).

## 6. Results

### 6.1. Phenotypic sex differences

Women and men showed different dietary patterns in preferences, childhood consumption, and food neophobia (see Table 2). Men reported much greater preferences for culturally-normative meat than women ( $M_{men} = 5.52, SD_{men} = 1.14; M_{women} = 4.34, SD_{women} = 1.59; t(7,200) = 32.58, p < .001, d = 0.85$ ), and they reported much greater willingness to try novel meats than women (i.e., less neophobia;  $M_{men} = 2.55, SD_{men} = 0.69; M_{women} = 3.16, SD_{women} = 0.69; t(7,208) = 35.42, p < .001, d = 0.88$ ). Men also reported consuming more meat in their childhood than women ( $M_{men} = 2.33, SD_{men} = 0.52; M_{women} = 2.10, SD_{women} = 0.47; t(7,200) = 19.31, p < .001, d = 0.46$ ). Women reported greater preferences for plants than men, though the sex difference was smaller than that for meat preferences ( $M_{men} = 4.72, SD_{men} = 1.23; M_{women} = 5.11, SD_{women} = 1.18; t(7,200) = -13.03, p < .001, d = 0.32$ ). Sex differences in childhood plant consumption ( $M_{men} = 2.62, SD_{men} = 0.64; M_{women} = 2.55, SD_{women} = 0.65; t(7,200) = 4.24, p < .001, d = 0.11$ ), and willingness to try novel plants ( $M_{men} = 1.94, SD_{men} = 0.64; M_{women} = 1.87, SD_{women} = 0.67; t(7,208) = -4.23, p < .001, d = 0.11$ ) were both small, with men scoring slightly higher on both measures.

**Table 2**

Phenotypic correlations for men (below the diagonal) and women (above the diagonal) between childhood recall of meat and plant consumption, preferences for meat and plant consumption and neophobia of meat and plants. At the bottom means are depicted for males and females, all significantly differ with a  $p$ -value < 0.001. All correlations are significant with a  $p$ -value of < 0.001 with the exception of the correlation between meat childhood consumption and plant neophobia for men. Significant differences ( $\alpha = 0.01$ ) between male and female correlations using a Fisher Z-transformation are indicated with an asterisk.

		Correlations					
		Childhood consumption		Preferences		Neophobia	
		Meat	Plants	Meat	Plants	Meat	Plants
Childhood consumption	Meat	-	0.33 (0.30–0.35)	0.32 (0.29–0.34)	0.14 (0.11–0.17)*	-0.21 (-0.24–0.18)	-0.10 (-0.13–0.07)*
	Plants	0.34 (0.39–0.38)	-	0.05 (0.02–0.08)	0.39 (0.37–0.42)	-0.10 (-0.13–0.07)	-0.20 (-0.23–0.17)
Preferences	Meat	0.29 (0.25–0.33)	0.10 (0.06–0.14)	-	0.18 (0.15–0.21)	-0.57 (-0.58–0.55)*	-0.15 (-0.17–0.12)
	Plants	0.07 (0.03–0.11)	0.39 (0.35–0.43)	0.21 (0.17–0.25)	-	-0.28 (-0.31–0.26)	-0.51 (-0.53–0.48)
Neophobia	Meat	-0.18 (-0.22–0.14)	-0.14 (-0.18–0.10)	-0.52 (-0.55–0.49)*	-0.30 (-0.34–0.26)	-	-0.47 (-0.49–0.45)
	Plants	-0.03 (-0.07–0.01)*	-0.23 (-0.27–0.18)	-0.14 (-0.18–0.10)	-0.50 (-0.53–0.47)	-0.50 (-0.53–0.46)	-
		<b>Mean (SD)</b>					
Males		2.33 (0.52)	2.62 (0.64)	5.52 (1.14)	4.72 (1.23)	2.55 (0.69)	1.94 (0.64)
Females		2.10 (0.47)	2.55 (0.65)	4.34 (1.59)	5.11 (1.18)	3.16 (0.69)	1.87 (0.67)

\*\* $p < .001$

### 6.2. Phenotypic correlations

Childhood meat consumption related more strongly to current meat preferences ( $r$ 's = 0.29 and 0.32 for men and women, respectively) than to current plant preferences ( $r$ 's = 0.07 and 0.14 for men and women, respectively). In parallel, childhood plant consumption related more strongly to current plant preferences, ( $r$ 's = 0.39 for men and women) than to current meat preferences ( $r$ 's = 0.10 and 0.05 for men and women, respectively; see Table 2).

A similar pattern existed for childhood consumption and neophobia, such that childhood meat consumption related more negatively to meat neophobia ( $r$ 's = -0.18 and -0.21 for men and women) as compared to plant neophobia ( $r$ 's = -0.03 and -0.10), and childhood plant consumption related more negatively to plant neophobia ( $r$ 's = -0.23 and -0.20 for men and women) than to meat neophobia ( $r$ 's = -0.14 and -0.10).

The effect sizes for the relationships between meat preferences and meat neophobia ( $r$ 's = -0.52 and -0.57 for men and women) and plant preferences and plant neophobia ( $r$ 's = -0.50 and -0.51 for men and women) were substantial. Though smaller in size, meat preferences also related to plant neophobia ( $r$ 's = -0.14 and -0.15 for men and women), and plant preferences also related to meat neophobia ( $r$ 's = -0.30 and -0.28 for men and women).

The correlations between 1) childhood meat consumption and plant preferences, 2) childhood plant consumption and meat preferences, 3) childhood meat consumption and plant neophobia differed for men and women (see Table 2).

### 6.3. Twin modeling

*Childhood consumption and current preferences for meats and plants.* We detected quantitative sex differences in the heritability of men's and women's childhood meat consumption, with men's consumption being explained by additive genetic effects (31%) to a higher extent than women's consumption (11%) (Table 4). We also detected quantitative sex differences in the heritability of men's and women's current meat preferences, though here the genetic component was stronger for women (51%) than for men (26%). Though there was a discrepancy in the heritability estimates of men's and women's childhood plant consumption (41% and 17%, respectively), the difference did not reach significance ( $p = .03$ ). we concluded there were no sex differences due to  $p = .03$ . Further, we detected no quantitative sex differences in the

heritability of men's and women's current plant preferences (45% and 53%, respectively). Lastly, qualitative sex differences (i.e., different genes operating between men and women) were detected only for current meat preferences. This finding indicates that different genes account for meat preferences in men and women.

Inspection of ACE components revealed a substantial shared environmental ("C") component for both men's and women's recalled childhood plant and meat consumption (ranging between 15% and 40%). However, for current preferences, we detected a non-zero C parameter only for men's meat preferences (20%, 95% CI 1–34).

The two bivariate ACE models testing relations between childhood consumption and current preferences showed genetic overlap of  $r_g = 0.38$  for meats and  $r_g = 0.42$  for plants. The shared environmental factors that influence childhood consumption and adulthood preferences had an almost perfect overlap, with a correlation of 0.99. Note, though, that shared environmental influences on current preferences were negligible. Unique environmental components correlated 0.10 and 0.18 for meats and plants respectively (Table 6).

*Food neophobia.* We detected neither quantitative nor qualitative sex differences in meat or plant neophobia (see Table 5). That is, genetic components of meat neophobia were similar for men and women (48% and 55%, respectively), as were genetic components of plant neophobia (56% and 54%, respectively) (Table 4). Shared environmental components were non-significant for plant and meat neophobia in both men and women. Non-shared components were similar for both sexes ranging between 44% and 47% for meat and plant neophobia.

*Vegetarianism/veganism.* Vegetarianism/veganism was more common in women (15%) than in men (5%). Due to the small number of male vegetarians/vegans, it was not possible to estimate sex-specific A, C, E components. Collapsing across the sexes, results indicated that vegetarianism/veganism is 76% heritable and unique environmental influences account for the remaining variation (see Table 7).

## 7. Discussion

The current results shed new light on the sources of variation in preferences for meats versus plants. The key takeaways include: 1) Childhood consumption of meats and plants was more strongly related to current preferences for those meats and plants than to neophobia for both meats and plants; 2) Childhood meat consumption related more strongly to current meat preferences and to meat neophobia than to plant preferences and plant neophobia, and childhood plant

**Table 3**

Sample sizes, within twin pair correlations per zygosity-by-sex group (monozygotic male (MZm), dizygotic male (DZm), monozygotic female (MZf), dizygotic female (DZf), dizygotic opposite sex (DOS) twins), as well as correlation estimates constrained to be the same across sex (for MZ and DZ pairs). Sibling with twin member correlations, as well as correlation estimates constrained to be the same across siblings and DZ and siblings.

	N		Correlations					
	Complete pairs	Incomplete pairs	Childhood consumption		Preferences		Neophobia	
			Meat	Plants	Meat	Plants	Meat	Plants
MZm	135	304	0.41 (0.29–0.52)	0.59 (0.48–0.67)	0.65 (0.53–0.73)	0.52 (0.40–0.62)	0.53 (0.42–0.63)	0.59 (0.48–0.68)
DZm	120	527	0.34 (0.19–0.47)	0.40 (0.25–0.53)	0.43 (0.34–0.66)	0.28 (0.13–0.41)	0.36 (0.18–0.51)	0.32 (0.14–0.47)
MZf	416	479	0.55 (0.48–0.61)	0.55 (0.48–0.61)	0.52 (0.45–0.58)	0.59 (0.52–0.64)	0.57 (0.51–0.63)	0.57 (0.50–0.62)
DZf	371	749	0.52 (0.44–0.59)	0.51 (0.42–0.57)	0.30 (0.22–0.38)	0.37 (0.28–0.45)	0.32 (0.22–0.40)	0.24 (0.14–0.34)
DOS	370	1416	0.28 (0.18–0.37)	0.38 (0.28–0.46)	0.18 (0.06–0.28)	0.32 (0.23–0.40)	0.25 (0.15–0.34)	0.28 (0.17–0.38)
MZ	551	783	0.50 (0.44–0.56)	0.56 (0.50–0.61)	0.54 (0.48–0.60)	0.57 (0.51–0.62)	0.56 (0.51–0.61)	0.57 (0.51–0.62)
DZ/DOS	861	2692	0.38 (0.32–0.44)	0.44 (0.38–0.49)	0.27 (0.20–0.33)	0.34 (0.27–0.39)	0.29 (0.22–0.35)	0.27 (0.20–0.33)
Siblings								
Brothers		277						
With male twin			0.34 (0.12–0.50)	0.44 (0.21–0.59)	0.41 (-0.11–0.58)	0.38 (0.18–0.53)	0.21 (-0.07–0.43)	0.04 (-0.22–0.30)
With female twin			0.29 (0.17–0.39)	0.40 (0.30–0.49)	0.23 (0.08–0.36)	0.38 (0.27–0.47)	0.25 (0.13–0.36)	0.28 (0.15–0.39)
Sisters		620						
With male twin			0.42 (0.34–0.49)	0.42 (0.34–0.49)	0.25 (0.16–0.34)	0.19 (0.09–0.28)	0.18 (0.09–0.27)	0.21 (0.11–0.31)
With female twin			0.45 (0.35–0.53)	0.46 (0.38–0.54)	0.15 (0.06–0.24)	0.40 (0.23–0.43)	0.31 (0.22–0.40)	0.24 (0.12–0.34)
Total siblings			0.39 (0.34–0.44)	0.43 (0.38–0.48)	0.21 (0.15–0.27)	0.29 (0.23–0.34)	0.24 (0.18–0.30)	0.23 (0.16–0.29)
Total DZ + siblings			0.39 (0.35–0.43)	0.43 (0.39–0.47)	0.23 (0.19–0.28)	0.31 (0.26–0.35)	0.26 (0.22–0.31)	0.25 (0.20–0.29)

**Table 4**  
Standardized estimates of additive genetic (A), and common and unique environmental (C and E) influences and their 95% confidence intervals (CI).

	A		C		E	
	Males	Females	Males	Females	Males	Females
<b>Childhood consumption</b>						
<i>Meat</i>	31 (8–51)	11 (0–27)	15 (1–31)	40 (28–50)	54 (44–66)	49 (42–56)
<i>Plants</i>	41 (6–56)	17 (2–32)	18 (6–42)	37 (26–48)	41 (33–54)	45 (39–52)
<b>Preferences</b>						
<i>Meat</i>	26 (5–52)	51 (41–60)	20 (1–34)	5 (0–11)	54 (43–66)	44 (38–51)
<i>Plants</i>	45 (18–62)	53 (40–59)	8 (0–28)	1 (0–11)	47 (38–58)	46 (40–53)
<b>Neophobia</b>						
<i>Meat</i>	48 (22–62)	55 (43–61)	5 (0–23)	0 (0–1)	47 (38–59)	44 (39–51)
<i>Plants</i>	56 (36–64)	54 (46–60)	0 (0–14)	0 (0–6)	44 (35–54)	46 (40–54)

**Table 5**  
Testing for qualitative and quantitative sex differences.

		Model	–2LL	df	Compared to model	$\chi^2$ (df)	p-value
<b>Childhood consumption</b>	<i>Meat</i>	1 Full model	9488.00	7187	–	–	–
		2 Qualitative sex differences	9588.47	7188	1	0.46 (1)	0.50
		3 Quantitative sex differences	9547.31	7191	2	58.85 (3)	<0.001
	<i>Plants</i>	1 Full model	13504.81	7188	–	–	–
		2 Qualitative sex differences	13504.81	7188	1	0 (1)	0
		3 Quantitative sex differences	13509.19	7191	2	4.38 (3)	0.22
<b>Preferences</b>	<i>Meat</i>	1 Full model	25099.96	7187	–	–	–
		2 Qualitative sex differences	25133.94	7188	1	33.98 (1)	<0.001
		3 Quantitative sex differences	25389.33	7190	1	289.37 (3)	<0.001
	<i>Plants</i>	1 Full model	22215.13	7187	–	–	–
		2 Qualitative sex differences	22215.134	7188	1	0.09 (1)	0.77
		3 Quantitative sex differences	22224.30	7191	2	9.17 (3)	0.03
<b>Neophobia</b>	<i>Meat</i>	1 Full model	14635.96	7187	–	–	–
		2 Qualitative sex differences	14637.90	7188	1	1.94 (1)	0.16
		3 Quantitative sex differences	14638.85	7191	2	0.94 (3)	0.81
	<i>Plants</i>	1 Full model	13861.32	7187	–	–	–
		2 Qualitative sex differences	13863.05	7188	1	1.74 (1)	0.19
		3 Quantitative sex differences	13867.82	7191	2	4.76 (3)	0.19

**Table 6**  
Genetic (*rA*) and environmental correlations (*rC* for familial factors and *rE* for unique environmental factors) between childhood consumption and food preferences in adulthood for males and females taken together.

	<i>rA</i>	<i>rC</i>	<i>rE</i>
<i>Meat</i>	0.38	0.99	0.10
<i>Plants</i>	0.42	0.99	0.18

consumption related more strongly to current plant preferences and plant neophobia than to meat preferences and meat neophobia; 3) Approximately half of the variation in plant preferences was accounted for by genetic factors for both men and women. Childhood plant consumption had both genetic and shared environmental components, which did not differ across the sexes. Half of the variation in both meat neophobia and plant neophobia was accounted for by genetic factors for both men and women. Across the sexes, approximately three-quarters of variation in vegetarianism/veganism was explained by genetic factors; 4) Whereas about half of the variation in women’s current meat preferences was accounted for by genetic factors, only about a quarter of men’s current meat preferences were. In contrast, men’s childhood meat consumption was more heritable than women’s, and women’s childhood meat consumption was influenced more by the shared environment than men’s.

### 7.1. Theoretical implications

*The relation between childhood consumption and current preferences.* Researchers have argued that dietary preferences are shaped by the foods consumed in early childhood (e.g., Cashdan, 1994). We extended this hypothesis to test whether greater exposure to meats (versus plants) in childhood related to greater preferences for meats (versus plants) in adulthood. At the phenotypic level, we indeed found that current preferences for meats related to recalled consumption of meats during childhood, and that current preferences for plants related to recalled consumption of plants in childhood. Twin modeling revealed that, as expected, childhood meat and plant consumption were influenced by shared environmental factors. However, twin modeling also detected little influence of the shared environment on adult meat and plant preferences. The lack of a shared environment effect runs counter to expectations gleaned from the critical window perspective, since this perspective suggests that individuals raised in the same household (and, presumably, exposed to the same foods during childhood) should have similar food preferences after accounting for genetic similarities. Importantly, these results do not necessarily cast doubt on the existence of critical developmental windows in food learning; they simply suggest that broad preferences for meats versus plants likely do not arise from such critical windows (or that our assessment of childhood consumption did not precisely cover this window).

**Table 7**

Vegetarianism. Within twin pair polychoric correlations per zygosity-by-sex group (monozygotic male (MZm), dizygotic male (DZm), monozygotic female (MZf), dizygotic female (DZf), dizygotic opposite sex (DOS) twins), correlation estimates constrained to be the same across sex (for MZ and DZ pairs). Sibling with twin member correlations, as well as correlation estimates constrained to be the same across siblings and DZ and siblings. Male and female ratios for vegetarianism (yes or no vegetarian) are depicted at the bottom of the Table. Standardized estimates of additive genetic (A), non-additive genetic (D) and unique environmental (E) influences are shown on the right. In brackets 95% confidence intervals (CI).

Within twin pair polychoric correlations	
MZm	0.75 (0.39–0.93)
DZm	0.14 (0.00–0.89)
MZf	0.76 (0.61–0.86)
DZf	0.53 (0.32–0.70)
DOS	0.01 (0.00–0.36)
MZ	0.76 (0.63–0.85)
DZ/DOS	0.38 (0.19–0.54)
Total siblings	0.35(0.20–0.48)
Total DZ + siblings	0.36 (0.24–0.47)
	<b>yes/no</b>
Men	109/ 2,294 (5%)
Women	615/ 4,179 (15%)
Standardized genetic and environmental estimates	
A	57 (13–83)
D	19 (12–65)
E	24 (14–36)

Twin modeling also revealed that the sexes differ not only in their meat preferences, but also in the extent to which genetic and environmental factors underlie these preferences. Specifically, we detected evidence that genetic factors account for less variance in men's meat preferences than women's meat preferences. Importantly, the heritability for women's meat preferences was approximately equal to the heritability of both sexes' plant preferences (around 0.50); the heritability of men's meat preferences was lower (approximately 0.25). And, notably, the male variation not accounted for by genetic factors was accounted for by shared environmental factors. We offer some speculative thoughts on this pattern. Meat consumption is widely viewed as masculine (perhaps as early as age four; [Graziani, Guidetti, & Cavazza, 2021](#)), and men's dietary choices are influenced by desires to be viewed as masculine, either for intrasexual competition or intersexual attraction purposes ([Cavazza, Guidetti, & Butera, 2015](#); [Gal & Wilkie, 2010](#); [Heinz & Lee, 1998](#); [Rozin, Hormes, Faith, & Wansink, 2012](#); [Vartanian, 2015](#)). Indeed, in at least some cultures, vegetarian men are viewed as less attractive than non-vegetarian men ([Timeo & Suitner, 2018](#)). The larger shared environmental influences on meat preferences in men could reflect the influence of household- or neighborhood-specific endorsements of these types of norms. That is, men (but not women) reared in environments that either especially value masculinity and/or especially associate meat with masculinity might prefer meat more. Designs that assess specific aspects of the shared environment would be needed to evaluate this hypothesis. Naturally, these results could reflect a Type I error. Given the width of the 95% confidence interval for the heritability of men's meat preferences (0.05–0.52), replicating this finding would be valuable. Interestingly, the sex difference in heritability in childhood exposure to meat showed the opposite pattern, with men's heritability higher than women's. This result might reflect boys having a greater influence on the degree to which their preferred meats are served at home. Naturally, this hypothesis would also need to be evaluated in future research. And, again, given the wide confidence intervals around the heritability estimates for men's childhood exposure (0.8–0.51) replicating this finding would also be valuable.

Findings also indicated that the genes underlying meat (but not plant) preferences varied across the sexes. This pattern is consistent with [Fessler's \(2002a, 2002b\)](#) argument that women's meat preferences are

shaped by factors different from men's meat preferences – specifically, hormonally-mediated immunosuppression during the luteal phase of the menstrual cycle and during pregnancy. This immunosuppression putatively leads to greater acquired meat aversions in women relative to men. Hormonal changes and fecundity also vary across women, and much of this variation is heritable. Hence, if the immunosuppression hypothesis is correct, then part of the heritability in women's meat preferences might reflect pleiotropic effects with the genes underlying between-woman hormonal variation – i.e., the same genes influencing both meat preferences and hormonal variation.

**Food neophobia.** In line with previous findings, women and men were similarly plant neophobic, but women were much more meat neophobic than men ([Çınar et al., 2021](#); [Perone et al., 2021](#)). In contrast to general meat preferences, though, we detected no differences in the heritability of meat neophobia (nor plant neophobia) across the sexes. We also detected no shared environment effect on meat or plant neophobia. At first blush, this result might seem to contrast with earlier findings from another study (notably, a study sampling from Finland, the same country sampled from here), which reported the shared environment accounts for about half of the variation in men's food neophobia ([Knaapila et al., 2011](#)) (though, not in women's food neophobia). However, this earlier, sex-specific finding should be taken as inconclusive given the wide confidence interval around the C estimate for men (0 to 0.56), and the lack of a detected C component for women in the same sample. Notably, the assessment of food neophobia varied across these studies as well. Whereas [Knaapila et al. \(2007\)](#), [Knaapila et al. \(2011\)](#) administered the Food Neophobia Scale ([Pliner & Hobden, 1992](#)), which includes items such as, "I like to try new ethnic food restaurants" and "At dinner parties, I'll try new foods," we asked participants how willing they would be to eat individual foods (either meats or plants) displayed in images. Although these assessments are highly correlated ([Perone et al., 2021](#)), we cannot rule out that the constructs they reflect are differentially shaped by environmental and genetic factors.

Social learning experiments indicate that children are attentive to social cues of others when they come across a novel plant as compared to other novel artifacts ([Wertz & Wynn, 2014](#)). Even though this work does not examine the social learning of meats, our twin data illustrates that social learning (as part of the shared environmental influence which includes parental influence) might not be differentially influential on neophobia in either sex and in either of the food categories. Though, we would like to caution interpretation of these outcomes as existing research concerns specific plants being modeled to infants at an early developmental stage and takes interaction with the plant into account (for a review of similar research, see [Wertz & Moya, 2019](#)), whereas the current data represents a sample at a later developmental stage on a general openness to novel meat and plant products.

**Vegetarianism/veganism.** Perhaps the most striking of our findings revealed that vegetarianism/veganism is 76% heritable in this population. People might abstain from meat for a number of reasons (e.g., health reasons, animal welfare concerns, environmental concerns, disgust, distaste; [Fessler et al., 2003](#)). While the current study did not assess motivations to become vegetarian/vegan, meat attitudes seem more prone to change if concerns over animal welfare or disgust-eliciting information about meat is highlighted ([Palomo-Vélez, Tybur, & van Vugt, 2018](#)). Given that worldviews and ideologies are heritable ([Eaves & Hatemi, 2008](#); [Verweij et al., 2008](#)), the heritable components of becoming vegetarian (concerning environment or animal rights) could overlap with those underlying values, ideologies, or empathy. A complete abstinence from meats might also be related to specific taste receptors that makes meat consumption more or less enjoyable. Future Genome-Wide Association Studies (GWAS) making use of measured DNA data could shed light on the specific genetic variants associated with vegetarianism/veganism choices. Moreover, such results can be extended to see if those genes underlying vegetarianism/veganism overlap with those underlying other individual difference variables.

## 8. Limitations and future directions

The current study used a limited number of food items for measuring meat and plant preferences and childhood consumption of meats and plants. The specificity of the food items used might have consequences on the generalizability of the findings. Future studies can see if results replicate with a wider assessment of meat and plant preferences. The measurement of childhood consumption was also imperfect, for a few reasons. First, the response scale for childhood consumption included non-equal intervals (0 = never or less than once a year, 1 = at least once a year, 2 = monthly, 3 = weekly, 4 = daily), and hence the composites of childhood meat and childhood plant consumption were averages of ordinal variables. While we are not aware of a directional bias caused by this measurement strategy, assumptions underlying parametric tests may have been violated. Further, childhood consumption was assessed via recall of a timeframe of consumption was labeled as “childhood” rather than a specific developmental stage. Therefore, it does not allow for finer-grain distinctions between exposure to meats and plants in infancy versus later in childhood. The accuracy of the childhood consumption measure could also be limited by recall biases. However, earlier studies that count for memory bias in retrospective reports of food intake reports reveal effects of childhood diet on portion sizes in adulthood (e.g., Brunstrom, Mitchell, & Baguley, 2005), and they have found a high correspondence between self-reports of childhood consumption and parents’ reports of the same variable (Wadhera, Capaldi Phillips, Wilkie, & Boggess, 2015). Longitudinal twin studies that collect data from infancy to adulthood would close both the gap for consumption in different developmental stages as well as any memory biases that might occur.

Limitations of classical twin designs apply here (Verweij, Mosing, Zietsch, & Medland, 2012). Importantly, the classical twin designs (so as the one used here) can underestimate shared environment components if certain assumptions are violated. For example, the equal environment assumption requires that MZ twins and DZ twins are exposed to shared environmental factors in similar degrees. Additionally, DZ twins are assumed to share, on average, 50% of their segregating genes. This assumption can be violated if mating does not occur at random with respect to the phenotype being investigated. Interactions or correlations between genetic variants and environmental influences can also distort C (as well as A or E) estimates. Because C and D cannot be estimated simultaneously, only A and C or A and D can be modeled – a limitation that can lead to inflated A estimates. Lastly, while the current study had between 80% and 90% power to detect a shared environment component of  $C = 0.20$  for current meat and plant preferences and meat and plant neophobia, depending on the strength of the additive genetic component (Verhulst, 2017; see also Tybur, Wesseldijk, & Jern, 2020), it was not well powered to detect smaller shared environmental components. Hence, even larger future studies could reveal shared environment components of these variables. And, naturally, findings are limited to the population currently sampled from. Of all the environmental conditions possible in the world, our population experienced only those present in Finland in the time period sampled from. Different shared environmental effects might arise in populations that experience different environmental conditions (Uchiyama, Spicer, & Muthukrishna, 2020).

## 9. Concluding remarks

People require a particular diet to obtain the calories and nutrients necessary to support metabolic functions (for reviews, see, Cena & Calder, 2020; Liu, Tuvblad, Raine, & Baker, 2013; Biesalski, 2005). Yet, individuals do not always follow guidelines for diversifying their meals and they vary in their dietary preferences for the number of consumed meats and plants. Better understanding why individuals vary in food preferences can improve our understanding of factors that lead to various positive and negative health consequences of dietary decisions

(Bendall et al., 2018; Sinha, Cross, Graubard, Leitzmann, & Schatzkin, 2009). Using twin modelling, we showed that within-population meat and plant preferences are heritable, but minimally arise from shared environmental effects (e.g., the degree to which people were exposed to meats and plants as children). Additionally, we showed that men and women differ in the extent to which genetic factors undergird meat preferences. Further, even though women are less willing to try novel meats than men, the extent to which genetic versus environmental factors explain meat neophobia do not differ for the sexes. Future studies can build upon these findings to better understand the sex differences and sex similarities in these food preferences.

## 10. Transparency statement

Study materials, data, and analysis scripts can be found online at <https://osf.io/zrg9j/>.

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## CRediT authorship contribution statement

Ç. Çınar: Writing – original draft, Conceptualization, Methodology, Visualization. L.W. Wesseldijk: Formal analysis, Data curation, Writing – review & editing. A.K. Karinen: Methodology, Writing – review & editing. P. Jern: Project administration, Investigation, Funding acquisition, Writing – review & editing. J.M. Tybur: Funding acquisition, Supervision, Project administration, Methodology, Writing – review & editing.

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