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We vary in what we choose to eat and what we choose not to eat. The current dissertation sheds light on the psychological factors that underlie food learning and discusses social, emotional, and genetic foundations of food preferences. In four empirical chapters I apply concepts and methods from the literatures on (specialized) learning and learning strategies (e.g., social information, previous food experiences, associative learning) on meat and plant preferences. Our empirical research illustrates the relevance of disease avoidance systems to food selection as well as new insights in the ways the unfamiliarity of a food interacts with decision-making or learning processes.

ADAPTING FOOD PREFERENCES

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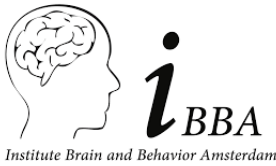


ADAPTING FOOD PREFERENCES:
THE SOCIAL, EMOTIONAL, AND GENETIC
ROOTS OF PREFERENCES FOR MEATS
VERSUS PLANTS

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ADAPTING FOOD PREFERENCES:
THE SOCIAL, EMOTIONAL, AND GENETIC ROOTS OF
PREFERENCES FOR MEATS VERSUS PLANTS

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Chapter 1

Introduction

Understanding food choice

Every living being requires food for sustenance and survival: unicellular organisms eat each other, dung beetles munch on feces, and newborn mammals drink breastmilk. But why does a dung beetle find a pile of feces appetizing while we are revolted by the mere thought of having a nibble of it? Relatedly, how do humans, as omnivores that can eat many options available in their environment, choose among a vast array of possible foods?

Despite the importance of food to support and maintain nutrition and energy, food choice remains an underexplored area in the behavioral sciences (Rozin, 2020). Food choice by definition requires people to first separately categorize non-food items (e.g., rocks with no nutritional benefits) versus foods. Foods that are spoiled should also be avoided as should foods with toxic properties (e.g., leaves containing cyanogenic glucosides; Mithöfer & Boland, 2012) unless consumed purposefully. People consume toxic plants for rituals (e.g., participants of Ayahuasca ceremonies who drink *Banisteriopsis caapi* or *Kamarampi* in Peru, Baer & Snell, 1974), medication (e.g., the Kichwa community using various plants for different medicinal purposes such as bites, menstrual cramps, muscular pain, Doyle et al., 2017; tobacco and cannabis consumption to reduce worm infection in Congo Basin hunter gatherers; Roulette et al., 2014; 2016), or recreation (e.g., millions of tourists who flock over to Amsterdam to smoke cannabis in coffeeshops – or, more pertinent to diet, eat it in baked goods). Considering the abundance of information required in the process of food selection, how does one come to decide what to eat?

Food has multiple cues (visual, olfactory, and gustatory) that enable an initial assessment of its quality, taste, and freshness. The brain receives information at the sensory level and assesses the appetizing or threatening characteristics of these sensory cues. This process might lead to different outcomes, such

as the food being deemed safe to eat, or disgusting and hence to be avoided (Fallon & Rozin, 1983; for more on information processing see, Tooby & Cosmides, 2015; Tybur et al., 2013; Tybur & Lieberman, 2016). The facial expression of disgust (gaping, tongue extraction, raising the upper lip, wrinkling the nose) functions to physically repel food from the mouth, constricts airflow through the nose, or minimizes surface area of the eye opening (Rozin, Lowery et al., 1994; Susskind et al., 2008). Due to this function, disgust has been important in battling against germs. Therefore, certain expressions related to disgust such as mouth gaping is shown as early as infancy as a response to foods that has certain qualities such as bitterness and sourness that cue for a possible food threat (Rosenstein & Oster; 1988), and further the expression is universally present across different cultures (Sawchuk, 2009).

Disgust functions to motivate an individual to avoid an immediate pathogen source (e.g., at the presence of vomit) influencing a “reactive” response. It also plays a role in so-called “proactive” responses in which immediate cues to pathogens need not be present (Schaller, 2016). In the latter function, disgust aids various learning forms and supports persisting memories and information transmission; therefore, promoting learning to avoid contact with pathogen sources in the future. Exposure to a food that was previously consumed before illness (e.g., vomiting after drinking a bottle of tequila) triggers disgust (Rozin, 1986). For this association formation to happen between the food and disgust, the food does not need to directly cause the feelings of sickness. This phenomenon is present in multiple species. Garcia and Koelling (1966) found that rats, who have a similar diet to humans, learn to separate negative gustatory experiences from negative physical experiences. In their experiments, rats were given either flavored water or unflavored water. Afterwards, some rats received shocks to their feet and

some received radiation; the former caused physical pain whereas the latter caused nausea. The rats that received the foot shock continued drinking flavored water whereas the nauseated rats avoided the flavored water, showing that the nauseated rats associated their negative outcome with the specific flavor of the drink, whereas the shocked rats did not. Cancer patients similarly associate nausea with particular foods after receiving chemotherapy that triggers nausea (Christensen et al., 2022; Jacobsen et al., 1993). Moreover, such associations with disgust are especially persistent and difficult to “unlearn” (Rozin, 1986; Olatunji et al., 2007).

Overcoming food-borne threats

Some cognitive biases guide humans to avoid dangers. Error management theory (Haselton et al., 2016) posits that cognitive biases are strategic in the sense that they reduce the possibility of making errors when errors are especially costly (e.g., resulting in death, injury, or sickness). In other words, these cognitive biases are tendencies to react in a manner that is “better safe than sorry”. From this perspective, disgust reactions might be given in response to situations that do not carry a definitive threat to the individual (e.g., avoiding a piece of cheddar cheese with a mold on it despite that the moldy part can be cut and thrown away while the remaining part is edible). In parallel to this phenomenon, and also the experiments by Garcia and Koelling (1966) on rats, humans can develop food aversions even when they know that the nausea is not caused by the food (e.g., chemotherapy or motion sickness; Nesse et al., 1980; Arwas et al., 1989). Formation of such associations does not only need to be experienced viscerally per se. Information about a food being in contact with a pathogen source is enough to evoke disgust and motivate avoidance. For example, adults are less likely to drink milk after learning that that the milk container was in contact

with a contaminating substance (e.g., dog feces) even if they know that the container had been disinfected (Fallon et al., 1984).

Food familiarity also influence food preferences and rejections. Individuals find unfamiliar foods more dangerous than familiar ones, which in turn negatively affects willingness to eat the foods (Pliner and Hobden, 1992). Learned safety is an important concept for food selection (Kalat & Rozin, 1973). Animals limit their exposure to novel foods and add the novel food to their diet only if sampling this food did not have negative consequences. For example, sheep tend to avoid the novel food when nausea is induced after exposure to one novel and four familiar food products (Burritt & Provenza, 1991). Similarly, rats that are exposed to both novel and familiar foods prior to experiencing effects of radiation, develop greater aversion to the novel tastes as compared to the familiar ones (Revusky & Bedarf, 1967). Humans also acquire stronger food aversions if a novel flavor, compared to a familiar had a negative effect. Inducing motion sickness in humans reduces consumption of a novel drink more than a familiar tasting one (Arwas, et al., 1989). These examples illustrate the specificity in food aversion learning in relation to novel foods, hence indicating an adaptation that decreases future food-related risks.

Adding more to the complexity of food preferences and food aversions is the fact that humans are omnivores, meaning that they eat both plants and animals. While an omnivorous diet allows humans to survive in a wide array of environments, it also brings more risks on allergens, foodborne pathogens, and toxins (Rozin, 1976). Primary allergens in Europe and the US include eggs, milk, nuts, wheat, and fish for children and nuts, fish, and shellfish for adults (Burks et al., 2001; Monaci et al., 2020). Further, plants might have chemical (e.g., toxins) or physical properties (e.g., thorns) that are harmful (e.g., poisoning, injury) – properties that evolved to keep the herbivores away (Mithöfer

& Maffei, 2016). Foods also carry a pathogen risks. All of these threats can contribute to sickness, discomfort, and death. People use different approaches to minimize food risks – approaches that can vary across the type of food or the risk in question. Below approaches to minimize each risk is outlined per food risk with a focus in relation to different learning strategies.

Allergen risks

Allergens and food intolerances can be avoided based on individual learning experiences (Rozin, 1986). Trial-and-error is particularly effective as allergens are mostly specific to individuals. Even though some allergies cause serious immediate reactions (e.g., anaphylactic shock; Sampson, 2013), for some food allergies the cause is not that obvious. Therefore, individuals need to use different trial-and-error methods. For example, *elimination methods* help to see whether eliminating a particular food helps in alleviating symptoms or *oral food challenges* (in which patients are provided foods thought to cause allergies in varying portions) helps in ruling out or confirming foods that are suspected to cause an allergic reaction (Sicherer, 2014).

Toxin risks

Plants pose two risks: physical and toxin. Their physical defenses such as thorns can be visually detected and avoided. Toxic defenses, which are not always visible, are often neutralized by the liver, or their costs are mitigated by the blood brain barrier (Cheeke, 1994; Hagen & Tushingham, 2019). Some plant toxins can be reduced for safe consumption after using complex procedures that are learned throughout generations (e.g., nardoo, a commonly found plant in Australia that can cause thiamine deficiency and even beriberi disease if eaten without any processing; Earl & McLeary, 1994). Even with such defenses, plant consumption can cause serious damage. Inhaling ricin, a

toxin found in castor oil plant can cause respiratory failure in humans (Lord et al., 2003; Audi et al., 2005). Consumption of tutu plant's berries has caused poisoning in the past and previously consuming honey made from tutu plant's pollens have resulted in a poisoning outbreak in New Zealand (Beasley et al., 2018; Belcher & Morton, 2013). Children are especially vulnerable to plant toxins (Eddleston & Persson, 2003). Therefore, this vulnerability brings a food decision risk specific to plants. Studies show functional specialization in children for plant avoidance. First, infants are especially reluctant to touch plants and plant foods (Wertz & Wynn, 2014a; Rioux & Wertz, 2021) and are especially sensitive to cues from adults in understanding whether or not a plant is safe to touch (Wertz & Wynn, 2014b). Earlier studies also show that children are more plant neophobic than adults (Cashdan, 1998).

Pathogen risks

Solving problems related to pathogen growth on foods can be more difficult than toxins and allergens. Even though pathogens can contaminate both plant and animal products, humans are especially vulnerable to pathogens that infest other animal tissues (Taylor et al., 2001). Foodborne illnesses that lead to death are mostly caused by animal products rather than plant products (Painter et al., 2013). This pattern partially arises because meats decay quicker than plants, and the harmful microbes that have already grown on meats might not always be apparent with obvious cues such as foul smells or discoloration. For example, some bacteria like *E.coli* or *salmonella* do not always cause signs of illness in their hosts, and they can go undetected in slaughterhouses (Corry & Hinton, 1997). Similarly, the zoonotic parasite *Trichinella's* larvae is usually hidden in meat muscle therefore the parasite can grow in intestines after consumption (Corry & Hinton, 1997). Lastly, plants contaminated via contact

with soil or animal feces can be washed, for example with vinegar (Sengun & Karapinar, 2005; Woldetsadik et al., 2017; Karapinar & Gönül, 1992). Cleaning is less effective for meats, and doing so can increase contamination instead of eliminating it. For example, whereas salmonella activity in plants decreases after vinegar dipping (Sengun & Karapinar, 2005), the risk for foodborne illnesses increases after cleaning raw chicken in a similar procedure (Henley et al., 2018). Further, most approaches to cleaning are not viable for some meats (e.g., ground meat). Heat is another option to get rid of germs. Meats require contact with fire at high temperature in order for any pathogenic activity to be neutralized (e.g., 70 Celsius degrees for Salmonella; Nørrung et al., 2009) and even this is sometimes not enough to decrease the odds of microbial growth below detection levels (Langsrud et al., 2020).

Secondary characteristics of plants come in handy to decrease pathogenic activities as well. Hotter climates that provide an environment for quicker reproduction of germs also use more spices in their recipes (Billing & Sherman, 1998; though see, Bromham et al., 2021) and spices are used especially in meat recipes (Sherman & Hash, 2001). In a similar vein, taboos are more common for meat products across the globe in comparison to other types of food taboos combined (Fessler & Navarrete, 2003). Specialization in formation of meat aversion also happens in other learning types and in varying contexts. For example, having experienced a foodborne illness once and avoiding the same food later is particularly the case for meat products than for other foods (Rozin, 1986). Further, pregnant women who are especially prone to illnesses due to decreased immunologic reactivity during first trimester, show an elevation in meat aversion (Flaxman & Sherman, 2000; Fessler, 2002b; though see Placek et al., 2017); or taboos against pregnant women that mostly target meat consumption (Iradukunda, 2020).

The theoretical overview above shows varying strategies that humans use to mitigate the risks posed by meats and plants. Despite the importance of food choice to every person on the planet – and its relevance for health and well-being – the psychology of food choice remains underexplored, especially relative to the focus on caloric intake (Rozin, 2020). Better understanding how people learn to avoid meat and embrace unfamiliar meat alternatives is critical for behavioral changes targeting meat consumption and is especially timely given the current data on the carbon footprint of livestock production.

Practical relevance

Eating patterns, preferences, and behaviors have significant effects on not only the consumers of the foods but also the broader population through their influence on the future vitality of our environment. Meats not only pose greater pathogen risks compared to plants but also are contributors to various diseases. For example, recent meta-analyses indicate a 9-18% increase in ischemic heart disease risk due to red meat and processed meat consumption (Papier et al., 2023). Furthermore, simulations indicate an increase in life expectancy with a reduction in red and processed meats and an increase legumes, fruits, and vegetables (Fadnes et al., 2022). Therefore, reducing meat consumption and increasing plant consumption are key behavioral changes that could be targeted for healthier societies.

In addition to the health consequences brought by (red) meat consumption, a significant proportion of greenhouse gas emissions and loss in biodiversity is due to livestock production to meet the global consumption of red meat (Reisinger & Clark, 2018; Machovina et al., 2015; Parlasca & Qaim, 2022). The carbon footprint of beef and sheep consumption is estimated to be 19-48 times more than protein-rich plants (Ripple et al., 2014). Hence, a global effort for transitioning towards diets that include less

meats and more plants is argued to be an effective tool against climate change (Machovina et al., 2015; Schiermeier, 2019). For example, mealworms, crickets, and migratory locusts are edible insects that are high in protein with smaller carbon footprint as compared to cattle (Rumpold & Schlüter, 2015; Oonincx et al., 2010; Dobermann et al., 2017). Although sustainable meat alternatives have become more and more available in Western markets, the availability of these foods (or a willingness to incorporate meat alternatives to one's diet) does not necessarily result in change (Naranjo-Guevara et al., 2020).

Adhering to a change in diet pertaining to eating less meat and more meat alternatives (e.g., insects or cultured meat) might be difficult to implement mainly because of the unfamiliarity of these new food technologies and food sources (Orsi et al., 2019; cultured meat, Verbeke et al., 2015). Better understanding the psychological barriers against adopting a low-meat diet as well as attitudes towards different types of novel foods could help reduce traditional approaches to meat and possibly increase the consumption for meat alternatives. To achieve this, human food choices, learning mechanisms, as well as food aversions should be examined with a specific focus on meats and plants.

Current dissertation

This dissertation examines the similarities and differences in preferences for foods with animal origins versus plant origins. Across four empirical chapters, we approached to meat and plant preferences using a broad array of methods.

In **Chapter 2**, the focus is on attitudes towards unfamiliar foods. To better distinguish neophobia towards meats and plants, we developed an image-based instrument that assesses neophobia towards two food categories: meats and plants. This chapter further investigates how meat neophobia

and plant neophobia relates to other different individual differences variables such as disgust sensitivity, animal empathy, and masculinity. In **Chapter 3**, genetic and environmental factors that contribute to meat and plant choices are investigated. Here, we assessed three types of variables in a sample of adult twins from Finland: (1) childhood plant and meat consumption; (2) current preferences for meats and plants; (3) willingness to eat novel meats and plants. We look at the sex differences as well as the overlap in childhood consumption and adult preferences to answer if exposure in childhood extends to meat and plant preferences in adulthood. Twin modelling allows for estimates of variance in these traits attributed to environmental factors (which can include learning via parent, peers, and individual experiences) and a variance attributed to genes. In **Chapter 4**, we use an evaluative conditioning procedure to test for specialized learning towards foods using pathogenic and non-pathogenic depictions of negative stimuli. Here, both in laboratory and online samples, participants saw meat and plant images along with negative and positive or neutral images and reported their willingness to eat foods shown with these emotion-laden imagery as well as foods that were not shown before. We then test if pathogen-relevant (versus pathogen-irrelevant) content has a greater impact on willingness to eat foods than non-foods, and meats than plants. In **Chapter 5**, we investigate how social learning impacts novel and familiar meat and plant preferences. Here, in two online samples, participants read other individuals' positive and negative experiences for various meat and plant products. We then test how different experiences from social counterparts affect their expected enjoyments eating these food products. We additionally test for accuracy and biases in memory retention for food-related negative (versus positive) outcome information. Again, we test for these biases for food type (meats and plants) as well as food novelty (familiar versus unfamiliar).

In **Chapter 6**, the results from the four empirical chapters are reviewed and discussed from a broader perspective with implications on eating disorder pathologies as well as on sustainable behaviors such as introducing consumption of meat alternatives.

A note on open science

As researchers we should support transparent research and open science practices in order to produce replicable results. Having this in mind, all three of the four chapters were pre-registered. In cases of any departure from analysis plans, we explicitly note where and justify why we depart from pre-registered analysis plans. Materials, analysis scripts, and data is all available for all empirical chapters on OSF.

Chapter 2: <https://osf.io/5jv9s>

Chapter 3: <https://osf.io/zrg9j>

Chapter 4: <https://osf.io/8jzkh/>

Chapter 5: <https://osf.io/gnqy6/>

The background is a light sage green color. It features several large, overlapping, organic shapes in a darker shade of green. These shapes are rounded and fluid, resembling leaves or abstract organic forms. They are positioned in the top-left, top-right, and bottom-right areas of the page, leaving a clear space in the center for the text.

Chapter 2

The multidimensional nature of food neophobia

This chapter is based on:

Çınar, Ç., Karinen, A.K., Tybur, J.M. (2021). The multidimensional nature of food neophobia. *Appetite*, 162, 105177

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 model 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.

Keywords: food neophobia; sex differences; entomophagy; food preferences; disgust

Food neophobia – the aversion to unfamiliar foods – has been widely regarded as unidimensional and is typically measured with the Food Neophobia Scale (Pliner & Hobden, 1992; Ritchey et al., 2003), 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.

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 & McAuley, 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; Sockett, 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, 2014a). 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).

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 indicate

that people are less open to animal-based novel foods than to plant-based novel foods (Pliner & Pelchat, 1991; Pliner & Salvy, 2006). To our knowledge, though, no work has yet tested whether food neophobia varies along these two dimensions. With distinct risks coming from these two predominantly consumed food categories, we propose that food neophobia is multidimensional.

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 (Berbesque, & Marlowe, 2009; Daniel et al., 2011; Fessler et al., 2003; Prättälä et al., 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 intellectual 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 general 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 (-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, 2010; 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.

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.

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 participant 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 2.1).

Methods

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 ($N_{\text{Study1}} = 11$, $N_{\text{Study2}} = 43$), being neither male nor female ($N_{\text{Study1}} = 2$), or having completed instruments in an inaccurate or dishonest manner ($N_{\text{Study2}} = 3$), and those who completed the survey in less than 297 seconds ($N_{\text{Study2}} = 45$). The latter exclusion criterion was based on excluding participants who take less than 3 seconds 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

¹We did not pre-register any hypotheses regarding the variables and mainly aimed to explore how these variables translate into behavior.

included. Table 2.1 describes the final samples from all four studies.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

² Exclusion criteria were pre-registered on OSF for Studies 2, 3, and 4.

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 participants 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).

Table 2.1
Sample and study characteristics

	Study 1	Study 2	Study 3	Study 4
Number of sessions	1	1	2	2
N_{final}	210	306	160	161
$M_{\text{age}} (SD_{\text{age}})$	36.74 (11.48)	36.19 (10.82)	20.46 (2.25)	20.7(2.54)
Age range	19-71	18-70	18-31	17-32
% Female	44	45	77	80
Study setting	Online (MTurk)	Online (MTurk)	University Lab	University Lab
Data collection time frame	September (2017)	December (2017)	February - May (2019)	January-February (2020)
Testing for dimensionality	✓	✓	✓	✓
Behavioral outcome	X	X	✓	X
Food Neophobia Scale	original	original, modified	original	original
Predictors of meat and plant neophobia				
Sex differences	✓	✓	✓	✓
Hunger	✓	✓	✓	✓
Openness to experience	X	✓	✓	✓
Neutralizing pathogen risks	PD	PD+GA	PD+GA	PD+GA
		masculinity, animal	masculinity, animal	masculinity, animal
Dietary behavior	X	empathy, frequency eating meats/plants	empathy, frequency eating meats/plants	empathy, frequency eating meats/plants

Note. The table shows participant and study characteristics, including age (mean, standard deviation, and range), percentage of female participants, and study settings (if the study took place online or in a lab). It also provides methodological information, the variables assessed, whether or not a factor analysis was conducted to test for the dimensionality of the meat and plant neophobia picture scales, and whether the survey included the original or modified versions of the food neophobia scale. Under the predictors, pathogen avoidance motives were measured with pathogen disgust subscale of the Three Domains of Disgust Scale (PD) or/and germ aversion subscale of the perceived vulnerability of disease scales (GA).

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 2³. 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 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

³ The frequency measures were averaged over two sessions for the analyses.

“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 .94), and the six characteristics also formed internally reliable composites ($\alpha = .98$). 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 removed these items. We then selected 12 meats and 12 plants that were matched for rated strangeness and loaded above .60 on the factor analysis of the 35 exotics meats and 35 exotic plants used in Study 1. The average strangeness rating for these 12 meats was 4.44, and the average rating for the 12 plants was 4.43.

In returning to the initial dataset from Study 1, the 12 meats formed an internally reliable composite, as did the 12 plants (α 's = .94 and .93, respectively). In all four studies, we used this set of images and reverse scored composite averages so that higher scores indicate less willingness to eat the foods.

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 effects⁴. 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 *lmerTest* (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 A linear mixed model testing the effect of hunger on meat and plant neophobia also included session number as a random intercept.

Results

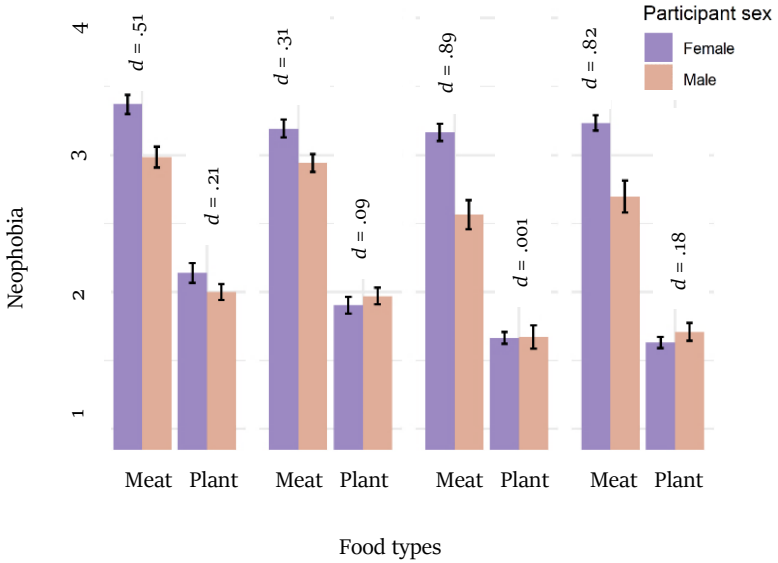
Dimensionality of food neophobia

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 .61) on the first factor, and all of the plant items loaded most strongly (and all above .56) on the second factor. Investigations of scree plots in Studies 2-4 similarly indicated the presence of two factors (see supplementary materials for more details). In Studies 3 and 4, meat and plant neophobia scores in Session 1 were almost identical with Session 2 ($r_{\text{meat}} = 0.94, 0.94, r_{\text{plant}} = 0.86, 0.88$ respectively). Hence composite scores averaging across the two sessions were calculated.

Relationship between food neophobia, meat neophobia, and plant neophobia

Mean FNS scores ranged from 2.77 and 3.55 across studies (see Table 2.2; for means and standard deviations). In all four studies, the FNS was related to both meat neophobia, r 's $> .40$, and plant neophobia, r 's $> .46$ (all p 's $< .01$). In Study 2, the meat-specific FNS was positively correlated with meat neophobia, $r = .70, p < .01$ and plant neophobia, $r = .58, p < .01$, and the plant-specific FNS was positively correlated with meat neophobia, $r = .24, p = .007$, and plant neophobia, $r = .78, p < .01$. In all four studies, meat and plant neophobia were moderately correlated, r 's $> .32$, p 's $< .05$. Meat neophobia was consistently greater than plant neophobia, d 's = 1.48, 1.49, 1.92, 2.15 (see Figure 2.1).

Figure 2.1. 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.

Chapter 2

Table 2.2. 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)		
	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>
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.

Table 2.3. Main effect and interaction effect of the variables in interpreting novel food avoidance on neophobia scores

Predictors	Estimate	<i>t</i> statistic	<i>p</i>	df
Participant sex	0.09	4.25	<.001	827
Food Type × Participant sex	0.11	8.96	<.001	835
Openness	-0.16	-7.05	<.001	622
Food Type × Openness	0.03	1.89	0.06	625
Pathogen disgust	0.15	7.35	<.001	831
Food Type × Pathogen	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	0.1	7.13	<0.001	625
Masculinity	-0.12	-3.04	<0.01	624
Food Type × Masculinity	-0.13	-9.6	<0.001	625
Plant frequency	-0.18	-8.1	<0.001	623
Food Type × Plant	0.07	5	<0.001	625
Meat frequency	-0.02	-0.77	0.44	526
Food Type × Meat	-0.09	-6.14	<0.001	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.

Table 2.4. Relations between meat – plant neophobia and multiple predictors

	Meat neophobia				Plant neophobia				Estimate [95%CI]	
	Study 1	Study 2	Study 3	Study 4	Study 1	Study 2	Study 3	Study 4		
Masculinity	-	-0.13	-0.32	-0.19	-0.21 [-0.32, -0.10]	-	-0.04	-0.14	0.13	-0.02 [-0.16, 0.13]
Germ Aversion	-	0.25	0.21	0.3	0.26 [0.18, 0.33]	-	0.25	0.08	0.15	0.17 [0.07, 0.28]
Pathogen Disgust	0.09	0.29	0.32	0.38	0.27 [0.15, 0.39]	0.04	0.24	0.12	0.3	0.18 [0.06, 0.29]
Animal Empathy	-	0.06	0.08	0.12	0.08 [0.001, 0.16]	-	-0.23	-0.07	-0.08	-0.14 [-0.25, -0.03]
Frequency (Meat)	-	-0.05	-0.1	-0.15	-0.09[-0.17, -0.01]	-	-0.01	0.09	0.16	0.07[-0.04, 0.17]
Frequency (Plant)	-	-0.23	-0.14	-0.05	-0.15[-0.26, -0.05]	-	-0.39	-0.43	-0.28	-0.38[-0.44, -0.31]
Openness	-	-0.14	-0.24	-0.16	-0.17[-0.25, -0.09]	-	-0.33	-0.29	-0.26	-0.30[-0.38, -0.23]
Hunger	-0.24	0.07	-0.05, -0.07	-0.16 , -0.08	-0.06[-0.17, 0.04]	-0.17	0.02	0.04, -0.05	-0.13, <.001	-0.05[-0.12, 0.03]

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, 3, and 4 followed by an internal meta-analysis estimate with [95% CI]. Partial correlations were calculated using the pcor 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.

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, $B = -0.04, p = 0.46$ (also see Figure 2.1, for effect sizes in each study). Notably, sex differences on the FNS were small and similar to those for plant neophobia (d 's = .27, .34, .05, .17).

Openness to experience

Openness to experience was negatively related to both meat and plant neophobia, but not differentially so (interaction $B = .03, F(1, 625) = 3.59, p = .058$; main effect $B = -0.16, F(1, 623) = 49.72, p < .001$; see Tables 2.3 and 2.5 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 2.4). Animal empathy and plant eating frequency were more strongly related to plant (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 2.4).

Hunger⁵

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, $B = 0.01$, $F(1, 1448) = 1.23$, $p = 0.27$. 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 = $-.01$, $.06$, $-.07$, $-.016$ and p 's = $.86$, $.29$, $.39$, $.047$). An internal meta-analysis over the four bivariate correlations indicated that the overall effect was non-significant, $r = -0.04$, $p = 0.46$. 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

⁵ We departed from our pre-registered analysis plan and did not control for hunger across our analyses.

that only meat neophobia uniquely predicted (not) eating the Bugbar (see Table 2.6).

Table 2.5. *Simple effects from mixed models*

	Meat Neophobia				Plant Neophobia			
	<i>Estimate</i>	<i>SE</i>	<i>lower CL</i>	<i>upper CL</i>	<i>Estimate</i>	<i>SE</i>	<i>lower CL</i>	<i>upper CL</i>
Sex	0.41	0.05	NA	NA	-0.04	0.05	NA	NA
Masculinity	-0.25	0.04	-0.33	-0.17	0.01	0.04	-0.07	0.1
Germ Aversion	0.2	0.03	0.15	0.26	0.13	0.03	0.08	0.19
Pathogen Disgust	0.21	0.02	0.16	0.26	0.09	0.02	0.04	0.14
Animal Empathy	0.07	0.03	0.02	0.13	-0.13	0.03	-0.19	-0.07
Frequency (Meat)	-0.11	0.03	-0.17	-0.05	0.07	0.03	0.01	0.13
Frequency (Plant)	-0.11	0.03	-0.16	-0.06	-0.26	0.03	-0.31	-0.2
Openness	-0.13	0.03	-0.19	-0.08	-0.19	0.03	-0.24	-0.13
Hunger	-0.04	0.02	-0.08	0.006	-0.02	0.02	-0.06	0.02

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 2.6. *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 (e^β), and p-values*

<i>Predictor</i>	β	<i>SE β</i>	e^β	<i>p</i>	<i>CI lower</i>	<i>CI upper</i>
Food	-0.39	0.25	0.67	0.11	-0.88	0.1
Meat	-1.14	0.44	0.55	0.01	-2	-0.29
Plant	-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.

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 meat 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 < .05). Therefore, the costs and benefits of being meat neophobic and plant neophobic seem different for men and women. Al-Shawaf and colleagues (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 .26 and -.09 respectively). Noting that the current studies, contrary to Al-Shawaf and colleagues (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 & Hobden, 1992) might have masked important differences between meat and plant neophobia in past research.

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., stomachache, diarrhea, etc.) (Rozin, 1986;

Logue et al., 1981). 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 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 and colleagues (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.

Practical Implications

Replacing livestock protein with food innovations with smaller footprint (e.g., insects) would reduce greenhouse gas emissions and conserve water while providing substantial amount 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 general 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 reduced the chances of eating a Bugbar. So how well does reducing visible animalistic properties

(e.g., having a face, locomotion, etc.) affect the perception of insects as animals? Could there be interventions that change this perception? Although individuals who like eating Western meats might be less likely to replace their beef with bugs (Verbeke, 2015), effects of increasing environmental awareness and decreasing meat neophobia might be worth studying in the future as well. Previous studies also show that under certain social environments, individuals tend to be more open to eating insects (Jensen & Lieberoth, 2019). Future studies can test whether the social contexts affect one's level of meat neophobia or test if one's perception of insects as food products mediate this relationship.

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.

Chapter 3

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

This chapter is based on:

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Abstract

People vary in the degree to which they enjoy eating meats versus plants. This chapter examines the genetic and environmental roots of this variation, as well as the genetic and environmental roots of meat neophobia, plant neophobia, and vegetarianism or veganism. Using data from 9,319 adult Finnish twins and siblings of twins (551 MZ, 861 DZ complete; 783 MZ, 2,692 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 ($h^2_{\text{men}} = .31$, $h^2_{\text{women}} = .11$) and current meat preferences ($h^2_{\text{men}} = .26$, $h^2_{\text{women}} = .51$), but not childhood plant consumption ($h^2_{\text{men}} = .41$, $h^2_{\text{women}} = .17$), current plant preferences ($h^2_{\text{men}} = .45$, $h^2_{\text{women}} = .53$), meat neophobia ($h^2_{\text{men}} = .48$, $h^2_{\text{women}} = .55$) or plant neophobia ($h^2_{\text{men}} = .56$, $h^2_{\text{women}} = .54$). Further, different genes undergirded men's and women's meat preferences. Abstention from meat (i.e., vegetarianism or 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.

Keywords: food preferences, food neophobia, vegetarianism, genetics, twins

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 & McLeary, 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 et al., 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.

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, 1986). A food's familiarity also influences its appeal (Aldridge et al., 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 et al., 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.

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, 2014b). 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 et al., 2021).

Notably, across cultures, men consume more meat than women do (Berbesque & Marlowe, 2009; Daniel et al., 2011; Fessler et al., 2003; Prättälä 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 et al., 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.

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 .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 et al., 2020; see Table 3.1). 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 3.1). 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 .67 in British twins (Knaapila et al., 2007); the other, which enrolled a Finnish sample, reported heritability of .61 for women but zero for men (Knaapila et al., 2011). In this latter study, about half (.45) of the variation in men's food neophobia was attributed to shared environment. However, both studies assessed food neophobia with the 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 3.1; 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

Chapter 3

Table 3.1. Summary table for genetic (A), shared environmental (C), additive genetic women (if applicable) across different meat and plant categories.

Article	DV	Food categories	A	
			Male	Female
(Keskitalo et al., 2008)	food consumption	Meats	0.39 (.30 - .48)	0.44 (.36 - .51)
	frequency	Healthy foods	0.49 (.40 - .56)	0.54 (.47 - .60)
(Hasselbalch et al., 2008)	food consumption	Red meat	0.34 (0.19 - .48)	0.33 (.17 - .47)
		Processed meats	0.47 (.31 - .59)	0.29 (0.14 - .43)
	frequency	Vegetables	0.24 (0.01 - 0.53)	0.14 (.00 - .41)
(Teucher et al., 2007)	food consumption	Red meat	-	0.39 (.32 - .45)
	frequency	Fruit - vegetable	-	0.49 (.43 - .54)
(Vink et al., 2020)	food liking	Meats	0.41 (.33 - .49)	0.51 (.47 - .55)
		Vegetables	.51 (.48 - .55)	
		Fruits	.02(.00 - .26)	
(Smith et al., 2016)	food liking	Vegetables	.54(.47 - .59)	
		Fruit	.49(.43 - .55)	
		Meat/Fish	.44(.38 - .51)	
(Pallister et al., 2015)	food liking	Meats	0.44 (0.35 - 0.51)	
		Fruit- vegetable	0.36 (0.28 - 0.44)	
(Keskitalo et al., 2008)	food liking (responses by parents)	Vegetables	.54 (.47 - .63)	
		Fruit	.53(.45 - .61)	
		Meat and fish	.48(.40 - .57)	
(Faith et al., 2013)	dietary intake recall	Fruit	0.26	
		Red meat/pork/lamb	0.57	
(Breen et al., 2006)	food liking	Vegetables	.37(.20 - .58)	
		Meat and fish	.78(.63 - .92)	
		Fruit	.51(.37 - .68)	
(Pimpin et al., 2013)	food consumption frequency	Meat and fish	-	-
		Vegetables	.15(.12 - .18)	
		Fruit	.10(.06 - .13)	

estimates (D), and unique environment (E) reported in food preferences for men and

D		C		E		Sample
Male	Female	Male	Female	Male	Female	
-	-	-	-	0.39 (0.30 - 0.48)	0.56 (0.49 - 0.64)	Finnish twins (adult)
-	-	-	-	0.51 (0.44 - 0.60)	0.54 (0.47 - 0.60)	
-	-	-	-	0.66 (0.52-0.81)	0.67 (0.53-0.83)	Danish Twin Registry (adult)
-	-	-	-	0.53 (0.41-0.69)	0.71 (0.57-0.86)	
-	-	0.4 (0.13-0.59)	0.46 (0.22-0.61)	0.37 (0.29-0.46)	0.4 (0.32-0.49)	
-	-	-	-	-	.61(.55 - .68)	UK Twins (adult)
-	-	-	-	-	.51(.46 - .57)	
-	-	-	-	0.59 (.51-.67)	0.49 (.45-.53)	Twins in the NL (adult)
-	-	-	-	.49(.45- .52)	.57(.53 - .61)	
.41(.17 - .47)						
-	-	-	-	.46(.41 - .53)		UK Twins (adult)
-	-	-	-	.51(.45 - .57)		
-	-	-	-	.56(.49 - .62)		
-	-	-	-	0.56 (0.49 - 0.64)		TwinsUK
-	-	-	-	0.64 (0.56 - 0.72)		
-	-	.35(.27 - .42)		.11(.10 - .13)		Gemini UK (child)
-	-	.35(.26 - .43)		.13(.11 - .15)		
-	-	.37(.27 - .45)		.15(.13 - .17)		
-	-	0.62	0.8	0.12	0.2	same-sex
-	-	0.32	0.74	0.11	0.23	Colorado
-	-	0.79	0.85	0.21	0.15	born (child)
-	-	.51(.30 - .66)		.13(.09 - .17)		TEDS UK (child)
-	-	.12(.00 - .27)		.10(.08 - .12)		
-	-	.32(.16 - .46)		.17(.14 - .20)		
-	-	.91(.89 - .94)		.09(.06 - .11)		Gemini UK (child)
-	-	.81(.78 - .83)		.05(.04 - .05)		
-	-	.82(.79 - .85)		.09(.07 - .10)		

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

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).

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.

Method

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 ($n = 7,716$; 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 9,564 individuals (6,965 twins, 2,592 siblings, and 7 unknown) with a response rate of 29%. Of the 9,319 (97%) participants who gave consent for using their data on scientific research, 3,475 twin singletons, 898 siblings of twins, 2,824 members of complete twin pairs from 4,887 families provided data on the variables examined here (see Table 3.3 for the sample sizes per zygosity). The age range of the sample was 18-58.

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.

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 ($\alpha = .88$ for meats; $\alpha = .78$ 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 ($\alpha = .64$ for meats; $\alpha = .79$ 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 ($\alpha = .95$ for meats, $\alpha = .96$ 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".

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 χ^2 of the difference in log-likelihoods (with degrees of freedom equal to the number of constraints) was used to select the most parsimonious model using an alpha of .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., 2012).

Results

Phenotypic sex differences

Women and men showed different dietary patterns in preferences, childhood consumption, and food neophobia (see Table 3.2). Men reported much greater preferences for culturally-normative meat than women ($M_{men} = 5.52$, $SD_{men} = 1.14$; $M_{women} = 4.34$, $SD_{women} = 1.59$; $t(7,200) = 32.58$, $p < .001$, $d = .85$), and they reported much greater willingness to try novel meats than women (i.e., less neophobia; $M_{men} = 2.55$, $SD_{men} = .69$; $M_{women} =$

3.16, $SD_{women} = .69$; $t(7,208) = 35.42$, $p < .001$, $d = .88$). Men also reported consuming more meat in their childhood than women ($M_{men} = 2.33$, $SD_{men} = .52$; $M_{women} = 2.10$, $SD_{women} = .47$; $t(7,200) = 19.31$, $p < .001$, $d = .46$). Women reported greater preferences for plants than men, though the sex difference was smaller than that for meat preferences ($M_{men} = 4.72$, $SD_{men} = 1.23$; $M_{women} = 5.11$, $SD_{women} = 1.18$; $t(7,200) = -13.03$, $p < .001$, $d = .32$). Sex differences in childhood plant consumption ($M_{men} = 2.62$, $SD_{men} = .64$; $M_{women} = 2.55$, $SD_{women} = .65$; $t(7,200) = 4.24$, $p < .001$, $d = .11$), and willingness to try novel plants ($M_{men} = 1.94$, $SD_{men} = .64$; $M_{women} = 1.87$, $SD_{women} = .67$; $t(7,208) = -4.23$, $p < .001$, $d = .11$) were both small, with men scoring slightly higher on both measures.

Phenotypic correlations

Childhood meat consumption related more strongly to current meat preferences (r 's = .29 and .32 for men and women, respectively) than to current plant preferences (r 's = .07 and .14 for men and women, respectively). In parallel, childhood plant consumption related more strongly to current plant preferences (r 's = .39 for men and women) than to current meat preferences (r 's = .10 and .05 for men and women, respectively; see Table 3.2).

A similar pattern existed for childhood consumption and neophobia, such that childhood meat consumption related more negatively to meat neophobia (r 's = -.18 and -.21 for men and women) as compared to plant neophobia (r 's = -.03 and -.10), and childhood plant consumption related more negatively to plant neophobia (r 's = -.23 and -.20 for men and women) than to meat neophobia (r 's = -.14 and -.10).

The effect sizes for the relationships between meat preferences and meat neophobia (r 's = -.52 and -.57 for men and women) and plant preferences and plant neophobia (r 's = -.50

and $-.51$ for men and women) were substantial. Though smaller in size, meat preferences also related to plant neophobia (r 's = $-.14$ and $-.15$ for men and women), and plant preferences also related to meat neophobia (r 's = $-.30$ and $-.28$ 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 3.2).

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 3.4). 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 $r_g = .38$ for meats and $r_g = .42$ for plants. The shared environmental factors that influence childhood consumption and adulthood preferences had an almost perfect overlap, with a correlation of .99. Note, though, that shared environmental influences on current preferences were negligible. Unique environmental components correlated .10 and .18 for meats and plants respectively (Table 3.6).

Food neophobia

We detected neither quantitative nor qualitative sex differences in meat or plant neophobia (see Table 3.5). 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 3.4). 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 44-47% for meat and plant neophobia.

Table 3.2. 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 $< .001$. All correlations are significant with a p -value of $< .001$ with the exception of the correlation between meat childhood consumption and plant neophobia for men. Significant differences ($\alpha = .01$) between male and female correlations using a Fisher Z -transformation are indicated with an asterisk. ** $p < .001$

	Childhood consumption		Preferences		Neophobia	
	Meat	Plants	Meat	Plants	Meat	Plants
Childhood consumption	Meat	0.33 (.30 ^{***} -.35)	0.32 (.29 ^{***} -.34)	0.14 (.11 ^{***} -.17)*	-0.21 (-.24 ^{***} -.18)	-0.1 (-.13 ^{***} -.07)*
	Plants	0.34 (.39 ^{***} -.38)	0.05 (.02 ^{***} -.08)	0.39 (.37 ^{***} -.42)	-0.1 (-.13 ^{***} -.07)	-0.2 (-.23 ^{***} -.17)
Preferences	Meat	0.29 (.25 ^{***} -.33)	0.1 (.06 ^{***} -.14)	0.18 (.15 ^{***} -.21)	-0.57 (-.58 ^{***} -.55)*	-0.15 (-.17 ^{***} -.12)
	Plants	0.07 (.03 ^{***} -.11)	0.39 (.35 ^{***} -.43)	0.21 (.17 ^{***} -.25)	-0.28 (-.31 ^{***} -.26)	-0.51 (-.53 ^{***} -.48)
Neophobia	Meat	-0.18 (-.22 ^{***} -.14)	-0.14 (-.18 ^{***} -.10)	-0.52 (-.55 ^{***} -.49)*	-0.3 (-.34 ^{***} -.26)	-0.47 (-.49 ^{***} -.45)
	Plants	-0.03 (-.07 ^{***} -.01)*	-0.23 (-.27 ^{***} -.18)	-0.14 (-.18 ^{***} -.10)	-0.5 (-.53 ^{***} -.47)	-
Mean (SD)						
Males	2.33 (.52)	2.62 (.64)	5.52 (1.14)	4.72 (1.23)	2.55 (.69)	1.94 (.64)
Females	2.10 (.47)	2.55 (.65)	4.34 (1.59)	5.11 (1.18)	3.16 (.69)	1.87 (.67)

Table 3.3. 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. Sex-specific mean and standard deviations are depicted at the bottom of the Table.

N		Correlations										
		Childhood consumption				Preferences				Neophobia		
	Complete pairs	Incomplete pairs	Meat	Plants	Meat	Plants	Meat	Plants	Meat	Plants	Meat	Plants
MZm	135	304	.41 (.29-.53)	.59 (.48-.67)	.65 (.53-.73)	.52 (.40-.62)	.53 (.42-.63)	.59 (.48-.68)				
DZm	120	527	.34 (.19-.47)	.40 (.25-.53)	.43 (.34-.66)	.28 (.13-.41)	.36 (.18-.51)	.32 (.14-.47)				
MZf	416	479	.55 (.48-.61)	.55 (.48-.61)	.52 (.45-.58)	.59 (.52-.64)	.57 (.51-.63)	.57 (.50-.62)				
DZf	371	749	.52 (.44-.59)	.51 (.42-.57)	.30 (.22-.38)	.37 (.28-.45)	.32 (.22-.40)	.24 (.14-.34)				
DOS	370	1416	.28 (.18-.37)	.38 (.28-.46)	.18 (.06-.28)	.32 (.23-.40)	.25 (.15-.34)	.28 (.17-.38)				
MZ	551	783	.50 (.44-.56)	.56 (.50-.61)	.54 (.48-.60)	.57 (.51-.62)	.56 (.51-.61)	.57 (.51-.62)				
DZ/DOS	861	2692	.38 (.32-.44)	.44 (.38-.49)	.27 (.20-.33)	.34 (.27-.39)	.29 (.22-.35)	.27 (.20-.33)				
Siblings												
Brothers		277										
With male twin			.34 (.12-.50)	.44 (.21-.59)	.41 (.11-.58)	.38 (.18-.53)	.21 (-.07-.43)	.04 (-.22-.30)				
With female twin			.29 (.17-.39)	.40 (.30-.49)	.23 (.08-.36)	.38 (.27-.47)	.25 (.13-.36)	.28 (.15-.39)				
Sisters		620										
With male twin			.42 (.34-.49)	.42 (.34-.49)	.25 (.16-.34)	.19 (.09-.28)	.18 (.09-.27)	.21 (.11-.31)				
With female twin			.45 (.35-.53)	.46 (.38-.54)	.15 (.06-.24)	.40 (.23-.43)	.31 (.22-.40)	.24 (.12-.34)				
Total siblings			.39 (.34-.44)	.43 (.38-.48)	.21 (.15-.27)	.29 (.23-.34)	.24 (.18-.30)	.23 (.16-.29)				
Total DZ + siblings			.39 (.35-.43)	.43 (.39-.47)	.23 (.19-.28)	.31 (.26-.35)	.26 (.22-.31)	.25 (.20-.29)				

Table 3.4. 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
Childhood						
<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)
Preferences						
<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)
Neophobia						
<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 3.6. 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.

	rA	rC	rE
<i>Meat</i>	.38	.99	.10
<i>Plants</i>	.42	.99	.18

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 3.7).

Table 3.5. Testing for qualitative and quantitative sex differences.

	Model	-2LL	df	Compared to model	χ^2 (df)	p-value
Childhood	1 Full model	9488	7187	-	-	-
	2 Qualitative sex	9588.47	7188	1	0.46 (1)	0.5
	3 Quantitative sex	9547.31	7191	2	58.85 (3)	<.001
<i>Plants</i>	1 Full model	13504.81	7188	-	-	-
	2 Qualitative sex	13504.81	7188	1	0 (1)	0
	3 Quantitative sex	13509.19	7191	2	4.38 (3)	0.22
Preferences	1 Full model	25099.96	7187	-	-	-
	2 Qualitative sex	25133.94	7188	1	33.98 (1)	<.001
	3 Quantitative sex	25389.33	7190	1	289.37 (3)	<.001
<i>Plants</i>	1 Full model	22215.13	7187	-	-	-
	2 Qualitative sex	22215.13	7188	1	.09 (1)	0.77
	3 Quantitative sex	22224.3	7191	2	9.17 (3)	0.03
Neophobia	1 Full model	14635.96	7187	-	-	-
	2 Qualitative sex	14637.9	7188	1	1.94 (1)	0.16
	3 Quantitative sex	14638.85	7191	2	0.94 (3)	0.81
<i>Plants</i>	1 Full model	13861.32	7187	-	-	-
	2 Qualitative sex	13863.05	7188	1	1.74 (1)	0.19
	3 Quantitative sex	13867.82	7191	2	4.76 (3)	0.19

Table 3.7. 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	
<i>MZm</i>	.75 (.39-.93)
<i>DZm</i>	.14 (.00-.89)
<i>MZf</i>	.76 (.61-.86)
<i>DZf</i>	.53 (.32-.70)
<i>DOS</i>	.01 (.00-.36)
<i>MZ</i>	.76 (.63-.85)
<i>DZ/DOS</i>	.38 (.19-.54)
<i>Total siblings</i>	.35 (.20-.48)
<i>Total DZ + siblings</i>	.36 (.24-.47)
	yes/no
<i>Men</i>	109/ 2,294 (5%)
<i>Women</i>	615/ 4,179 (15%)
Standardized genetic and environmental estimates	
<i>A</i>	57 (13-83)
<i>D</i>	19 (12-65)
<i>E</i>	24 (14-36)

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 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.

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).

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 .50); the heritability of men's meat preferences was lower (approximately .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 et al.,

2021), and men's dietary choices are influenced by desires to be viewed as masculine, either for intrasexual competition or intersexual attraction purposes (Cavazza et al., 2015; Gal & Wilkie, 2010; Heinz & Lee, 1998; Rozin et al., 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 (.05-.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 (.08-.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 .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 and colleagues (2007, 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, 2014b). 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 and 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 et al., 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.

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 et al., 2005), and they have found a high

correspondence between self-reports of childhood consumption and parents' reports of the same variable (Wadhera et al., 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 et al., 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 $C = .20$ 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 et al., 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 et al., 2020).

Concluding remarks

People require a particular diet to obtain the calories and nutrients necessary to support metabolic functions (for reviews, see, Biesalski, 2005; Cena & Calder, 2020; Liu et al., 2013). 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 et al., 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.

Chapter 4

Four studies yield limited evidence for prepared (disgust) learning via evaluative conditioning

This chapter is based on:

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Abstract

Prepared learning accounts suggest that specialized learning mechanisms increase the retention of associations linked to ancestrally-prevalent threats. Few studies have investigated specialized aversion learning for pathogen threats. In four pre-registered studies (N 's = 515, 495, 164, 175), we employed an evaluative conditioning procedure to test whether foods (versus non-foods) are more readily associated with negative content associated with pathogens than negative content not associated with pathogens. Participants saw negatively valenced (either pathogen-relevant or -irrelevant), neutral or positively-valenced stimuli paired with meats and plants (in Studies 1 and 2) and with meats and abstract shapes (in Studies 3 and 4). They then evaluated each stimulus explicitly via self-reports (Studies 1-4) and implicitly via an Affect Misattribution Procedure (Studies 3 and 4). Linear mixed models revealed general evaluative conditioning effects, but inconsistent evidence for specialized (implicit or explicit) learning for a food-pathogen association. However, results from a mega-analysis across studies revealed stronger conditioning effects for meats paired with pathogen-relevant negative stimuli than pathogen-irrelevant negative stimuli.

Keywords: evaluative conditioning, preparedness, learning, disgust, food evaluations

From moldy food to lunging snakes, humans have long encountered risks that can be neutralized via physical avoidance. Sensory associations (e.g., feeling pain after touching a hot stove) facilitate learning what is safe and what is dangerous, and this learning in turn motivates the approach versus avoidance that can be the difference between life and death (for an overview see, Öhman & Mineka, 2001). Across many species, animals putatively learn about the threatening properties of objects more readily if this threat was recurrent in their ancestral past. This phenomenon is known as prepared learning (Seligman, 1970; 1971). Consistent with prepared learning, the human aversive learning literature shows that when participants experience a shock immediately after seeing images of objects that connote physical threat (e.g., snakes) and those that do not (e.g., flowers), they more readily associate the shocks with the former than the latter (Öhman et al., 1975; Seligman, 1970). Similar findings have emerged when comparing effects of aversive conditioning (via electric shocks) on responses to outgroup members relative to ingroup members (Olsson et al., 2005) and especially male outgroup members relative to ingroup members and female outgroup members (Navarrete et al., 2009). However, it is worth noting contradictory findings from recent systematic reviews (i.e., 69% of papers did not find preparedness in conditioning studies using fear-relevant stimuli; Åhs et al., 2018).

Our ancestors were threatened not only by snakes, spiders, and male out-groups; they also had to cope with ubiquitous infectious disease threats. In contrast to the large body of work conducted on fear conditioning, little work has tested prepared learning of pathogen threats. In this chapter, we test pathogen-relevant aversive learning using evaluative conditioning (EC), a phenomenon in which the valence of a positive or a negative unconditioned stimulus (US) crosses over to a neutral stimulus (CS), causing the neutral stimulus to be

perceived as more positive or more negative (De Houwer et al., 2001).

EC is used in many fields, including social psychology (Walther, 2002), marketing (e.g., Sweldens et al., 2010), and moral psychology (David & Olatunji, 2011; Rozin, Markwith, et al., 1994). Emotion researchers have conducted EC studies using disgust eliciting US, with findings suggesting that disgust conditioning reduces sexual arousal response to erotic films (Pawłowska et al., 2020) and is especially resistant to extinction (e.g., Engelhard et al., 2014; Olatunji et al., 2007). Yet, EC with disgust stimuli has only been used to test prepared learning in a small set of studies (e.g., Tybur et al., 2016) and has never compared conditioning effects of disgust-eliciting stimuli with those of other negative stimuli (e.g., fear-eliciting). Stimuli used to test fear-relevant prepared learning include physical threats, such as snakes, angry faces, or out-group members. In parallel, disgust-based learning might be strongest for stimuli that have posed pathogen risks over human evolutionary history, such as foods.

Solving food-specific risks

Omnivores obtain nutrients from a variety of foods, including both plants and meats. Such breadth provides a number of options for obtaining calories and nutrients, but it also increases the possibility of ingesting allergens, toxins, and pathogens. When ingested in large quantities, toxins such as cyanide can result in neurological problems, e.g., Parkinsonism or dystonia (Carella et al., 1988; Uitti et al., 1985); allergens can cause severe reactions including eczema and diarrhea, and may result in death due to anaphylactic shocks upon ingestion (Bock et al., 1978; Sampson et al., 1992); and pathogens can lead to vomiting, diarrhea, and death (Painter et al., 2013; Thielman & Guerrant, 2004). Omnivorous species have developed adaptations for

navigating such food-specific risks, including food neophobia (Pliner & Salvy, 2006; Çınar et al., 2021), social/cultural learning (Rozin, 1996; Meyer-Rochow, 2009), and individual learning (e.g., mere exposure or conditioned taste aversions; Stevenson & Yeomans, 1995; Garcia et al., 1974).

Garcia and Koelling (1966) demonstrated differential prepared learning for nausea and pain in rats, who received flavored water while being exposed to an audiovisual stimulus (i.e., lights flashing while a noise occurs). In one condition, rats then received radiation, which caused them to feel nauseated. Those in the other condition received a shock to the foot. Rats later received flavored water with no audiovisual stimulus and plain water in concert with an audiovisual stimulus. In the radiation condition, flavored water was avoided, whereas in the pain condition, plain water with the audiovisual stimulus was avoided. This experiment showed that rats had differential associative learning mechanisms in response to different aversive stimuli; learning to avoid gustatory stimuli followed from induced nausea whereas learning to avoid visual (i.e., flashing lights) and auditory stimuli (i.e., a noise) followed from pain.

Some evidence suggests that conditioned taste aversion might also occur in humans. Food that are recalled to previously have caused nausea and/or vomiting trigger disgust (Rozin, 1986). Such learned aversions seem to occur even when one is aware that the nausea is caused by something other than the food (e.g., chemotherapy, or motion sickness; Arwas et al., 1989; Nesse et al., 1980, Boudreaux, 1995). Although these examples suggest that nausea and relatedly disgust seem to drive the avoidance process in food choices, they are mostly based on recall methods and lack experimental control. We are aware of no research that experimentally manipulates both conditioned stimulus (CS) type and emotion content of a negative US to test prepared learning. In four studies, we used an EC procedure to condition food

images and non-food images with different types of aversive stimuli (pathogen-relevant and pathogen-irrelevant), with the expectation that foods paired with pathogen-relevant negative images would be evaluated more negatively than foods paired with pathogen-irrelevant negative images, and non-foods paired with pathogen-relevant negative images would not be evaluated more negatively than non-foods paired with pathogen-irrelevant negative images.

Overview of studies and hypotheses

In each of four studies, participants saw two images simultaneously or in close succession per trial. One of these images acted as the CS (i.e., an image that should adopt the valence of the image it is shown together with, i.e., the US), and the other acted as the US. In all studies, some or all CSs were foods, but USs varied in the emotion they were intended to elicit. US valence was negative (and either pathogen-relevant or pathogen-irrelevant), neutral, or positive. Liking of the CSs and anticipated enjoyment of eating the foods were measured as the dependent variable. Across studies, we tested whether food evaluations change more strongly when associated with pathogen-relevant USs compared to pathogen-irrelevant USs. Below we describe hypotheses with respect to different levels of conditioning specificity, which range from general evaluative conditioning effects to those consistent with prepared learning.

General evaluative conditioning effects

At a most general level, and consistent with the evaluative conditioning literature, CSs paired with a negative US should be liked less than CSs paired with neutral or positive USs, and CSs paired with a positive US should be liked more than CSs paired with neutral or negative USs.

Differences in the effect of US emotion content across meat versus non-food CSs

In two laboratory studies, we used meats and abstract geometric shapes as CSs and paired them with negative (either pathogen-relevant or pathogen-irrelevant, which was manipulated between subjects) and positive stimuli. If prepared learning holds, conditioning effects on food evaluations (versus abstract shapes) should be stronger when paired with pathogen-relevant cues – that is, there should be an interaction between the emotion content of the negative stimulus and the type of CS (meat versus geometric shapes).

Differences in the effect of US emotion content across meat versus non-meat food CSs

In two online studies, participants saw foods (some of which were meats and some of which were plants) paired with negative (either pathogen-relevant or pathogen-irrelevant) and neutral stimuli. Self-reported desires to eat the pictured foods served as the dependent variable. If prepared learning holds, food evaluations should be lower following pairings with pathogen-relevant USs than with pathogen-irrelevant USs. Further, in line with earlier work (Tybur et al., 2016), this effect might be further specialized for meats (versus plants), because of meats' greater pathogen risk compared to plants (Navarrete & Fessler, 2003; Çınar et al., 2021).

Moderation by whether the food is raw or cooked

Hypothesis 3 might be further moderated by the food being raw versus cooked, either because cooking kills infectious microbes housed in foods or because foods are more recognizable in raw form. Both arguments might be especially true for meats relative to plants, since meats are more likely than plants to contain

infectious microbes, and since meats arguably change more in color and texture after cooking than do plants.

Open science statement

We pre-registered all four studies at Open Science Framework (all pre-registrations are available under the registrations section on <https://osf.io/8jzkh>). On the project page, we report all measures, data exclusions, and the sample size determination rules. The data, as well as the R code for the analyses can also be found on this page. For transparency we also note that, we had minor departures from our pre-registered analysis (e.g., using R packages to compare contrasts instead of dummy coding variables and entering them into our models, or modeling random slopes differently and keeping the slopes if the model had a better fit regardless of their final status in convergence) and based on the recommendations during the review process, we provide a mega-analysis at the end of the chapter, which was not pre-registered.

Study 1

Method

Participants

The targeted sample size was 480 with $N = 120$ per between-subjects condition. Upon anticipating an exclusion of 8% based on diet and sex, and an 8% based on failure to pass attention checks, we pre-registered enrolling 560 participants. Participants were recruited through Amazon Mechanical Turk (MTurk) ($N = 560$) in exchange for \$1.85. All participants indicated being either male or female, therefore there was no exclusion based on sex. After excluding vegetarians and pescatarians ($N = 34$), participants who failed either of the attention check questions on a pass or fail basis (see below; $N = 12$) and participants who did not meet the English comprehension criteria assessed by two

raters (see below; $N = 5$), the final sample consisted of 515 participants (212 female, $M_{\text{age}} = 36.31$, $SD_{\text{age}} = 10.83$).

Design

The study followed a 3 (US pairing, within: CS+ vs. CS- vs. CS-None) \times 2 (food type, within: meat vs. plants) \times 2 (negative emotion content, between: pathogen-relevant vs. pathogen-irrelevant) \times 2 (food form, between: raw vs. cooked) design. Forty-eight stimuli served as CSs. Each participant saw 18 of these stimuli, 6 of which were CS+ (i.e., paired with an emotionally-valenced US), 6 of which were CS- (i.e., paired with a neutral US), and 6 of which were CS-none (i.e., unpaired with a US). The CSs that the participants saw were semi-randomized (more information can be found on the project's OSF page).

Conditioned stimuli

The conditioned stimuli consisted of two food categories (meats and plants) in two different food forms (raw and cooked), such as raw broccoli, raw pumpkin, raw meatball, raw sausages, raw chicken leg, cooked brussels sprouts, cooked zucchini, cooked steak, cooked turkey legs. Raw foods were photographed on a black background. Images of cooked foods were retrieved from the internet and were cropped so that the image focus was on the product and not on the decorations or side dishes. Participants were randomly assigned to either a raw or cooked condition, in which they saw both meats and plants.

Unconditioned stimuli

There were three categories of unconditioned stimuli: (1) neutral (e.g., a chair); (2) pathogen-irrelevant negative (e.g., a man holding a gun to someone); and (3) pathogen-relevant negative (e.g., a man throwing up in a toilet). Each US category consisted of 5 images, which were chosen according to valence ratings

estimated in a pilot study. Pathogen-relevant and pathogen-irrelevant USs were selected based on similarities in valence in this pilot study (though two pathogen-relevant images were taken from Tybur et al., 2016). Neutral USs were chosen based on having a neutral valence (rated around 4 on a 7-point Likert scale) whereas the pathogen-relevant and pathogen-irrelevant negative USs were chosen from stimuli with lowest valence ratings on the same 7-point Likert scale. Most of the USs were retrieved from the IAPS database (Lang et al., 1997).

Procedure

After providing consent, participants answered an attention check question before the main study began. The question showed a moon and 6 stars with numbers next to them and asked participants to select the number that is not next to a star. Participants were informed that the study aimed to assess individual differences in perception of image similarities. Participants saw CSs and USs next to each other in a random order. The location of CSs and USs were semi-randomized with approximately half of the CSs on the left and half of the CSs on the right. Participants rated each pair's color and content similarity on a 6-point Likert scale (1 = Not at all, 6 = Extremely). Participants could not proceed to the next question before 3 seconds had passed. After this procedure, participants were asked to imagine eating each of 18 foods depicted in the images, and they rated their anticipated eating enjoyment one by one (1 = Not at all, 7 = Extremely). These images consisted of the 12 foods they saw during the conditioning procedure and 6 new foods consistent with the condition they are in (e.g., 3 raw meats and 3 raw plants if in raw condition) that they had not previously seen, and hence had not been paired with any USs. Finally, they answered a second Likert-scale attention check question which showed an image of actors from the show *Friends* and asked how

many of them are women, three demographics questions (dietary preferences, gender, and age), and an open-ended question (“Please describe your thoughts on the negative images that you have seen in this study.”) that targeted meaningless responses to detect bots and participants who were either inattentive or had poor English ability. Participants were then debriefed.

Analytic approach

A linear mixed-model analysis was conducted on the food evaluations (see Supplementary Materials for the model). We tested fixed effects of the food type (meat vs. plant), food form (raw vs. cooked), US pairing (CS+, CS-, and CS-None), and the emotion content of the negative US (pathogen relevant vs. pathogen irrelevant negative). We additionally tested interactions between these variables. We controlled for participant sex because (1) women are more disgust sensitive than men (Sparks et al., 2018), and hence might show stronger disgust conditioning responses, and (2) women on average eat less meat than men (Beardsworth & Bryman, 1999; Fessler et al., 2003) and meat eating frequencies are negatively related to willingness eating various meats (Çınar et al., 2021) and hence men might overall show more willingness to eat meat. Given our stimulus-sampling approach, we modelled random intercepts for participants and the CS (see Judd et al., 2012; Wells & Windschitl, 1999). We also modelled random slopes within CS for negative emotion content of US, participant sex, and US pairing, and we modeled random slopes within participants for food type, food form, and US pairing.

We used *lme4* (Bates et al., 2012) in R (R Core Team, 2012) to use linear mixed models in our analysis. To retrieve *p* values, we used the *lmerTest* package (Kuznetsova et al., 2017). The *emmeans* package (Lenth, 2019) was used to retrieve

pairwise comparisons, which employed Tukey method for p value adjustments.

Results

General evaluative conditioning effects

There was a main effect of US pairings (CS +, CS-, CS-None) on food evaluations, $F(2, 90.3) = 5.02, p = .008$. Orthogonal contrasts indicated that foods were evaluated more negatively when paired with negative stimuli ($M_{CS+} = 4.22, SE_{CS+} = .12$) compared to those paired with neutral stimuli and those that were unpaired ($M_{CS-} = 4.34, SE_{CS-} = .11, M_{CS-None} = 4.29, SE_{CS-None} = .11$), $p = .01$. These results correspond with a general evaluative conditioning effect.

Differences in the effect of US based on US emotion content

The US effect (i.e., US pairing) described above was not moderated by negative emotion content (i.e., whether the negative US was pathogen relevant), $F(2, 676) = 0.28, p = .76$. Food type (i.e., meat versus plant) did not further moderate this effect, $F(2, 7594) = 0.60, p = .55$, and food form (i.e., raw versus cooked) did not further moderate the aforementioned effect, $F(2, 7594) = 1.44, p = 0.24$ (see Figure 4.1).

In sum, results from Study 1 indicated that foods paired with negative stimuli were evaluated more negatively than those paired with neutral stimuli. However, this effect did not vary across negative emotion content – that is, foods previously paired with pathogen-relevant negative images were rated similarly to those paired with pathogen-irrelevant negative images. Further, pathogen-relevant conditioning was not different for meats compared to plants. Study 1 contained a notable limitation though: the pathogen-irrelevant negative stimuli (e.g., physical assault with a gun or a knife, or a group of individuals about to be prosecuted by hanging) may have elicited disgust due to their

moral content. In fact, some of the participants reported being disgusted by these pictures. Study 2 addressed this limitation by changing the USs and assessing individual valence and emotion ratings for the USs.

Study 2

Method

Participants

The targeted sample size was 480 with $N = 120$ per between-subjects condition. Upon anticipating an exclusion of 8% based on diet and sex, and an 8% based on failure to pass attention checks, 560 participants were aimed for enrollment. Participants were again recruited through MTurk ($N = 563$) for a compensation of \$2.00. All participants indicated being either male or female, therefore there was no exclusion based on sex. After excluding vegetarians and pescatarians ($N = 50$), participants who failed either of the attention check questions on a pass or fail basis ($N = 15$) and participants that did not meet the English comprehension criteria by two raters ($N = 20$), the final sample consisted of 495 participants (223 female, $M_{\text{age}} = 37.60$, $SD_{\text{age}} = 11.06$).

Conditioned stimuli

The CSs were the same as Study 1.

Unconditioned stimuli

The pathogen-irrelevant USs were different than those from Study 1. A separate Mturk sample rated 70 positive and negative images (some of which were pathogen-relevant and others were pathogen-irrelevant) on both valence and disgust on 7-point Likert scales. Pathogen-irrelevant images depicted misery, sadness, or grief (e.g., funeral images, crying individuals).

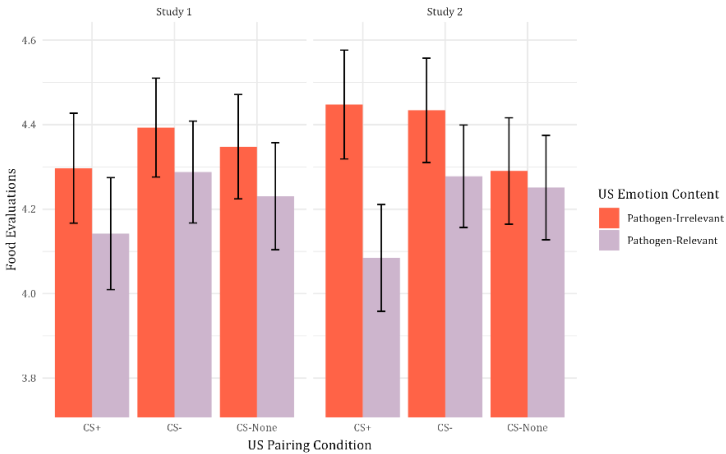


Figure 4.1. Mean values of food evaluations for each US Pairing condition (CS+, CS-, and CS-None) under each negative emotion content coming from Studies 1 and 2. Error bars represent standard error retrieved from model summaries. In both studies general evaluative conditioning effects were present in both Study 1, $F(2, 90.3) = 5.01, p < .01$, and Study 2, $F(2, 90) = 3.72, p = .028$. This effect was moderated by negative emotion content in Study 2, $F(2, 857) = 8.19, p < .001$, but not in Study 1, $F(2, 676) = 0.28, p = .76$.

We selected pathogen-irrelevant negative images that were rated similarly on valence to the pathogen-relevant images ($M_s = 2.00$ and 1.92 respectively) but lower on disgust ($M_s = 1.73$ and 5.62 , respectively). We replaced two of the pathogen-relevant USs with images that were rated higher on disgust. Neutral USs were the same as those used in Study 1.

Individual valence and emotion ratings

As in Study 1, participants began with the first attention check question and continued with the conditioning procedure. Participants described their impressions of the negative USs in an

open-ended question after conditioning. We used responses to identify careless participants, computer bots, and respondents with poor English ability. Participants then rated the valence of each US (1 = Extremely negative, 7 = Extremely positive). Afterwards, participants saw all negative images on a page and rated how strongly they felt several emotions (anger, disgust, fear, sadness, happiness) as they went through these negative images (1 = Not strong at all, 7 = Extremely strong). See Supplementary Materials for individual valence and emotion ratings. Finally, participants answered the same attention check question as the one in Study 1, and completed three demographics questions (dietary preferences, sex, and age). They were then debriefed.

Results

General evaluative conditioning effects

As in Study 1, there was a main effect of US pairing (CS+, CS-, CS-None) on food evaluations, $F(2, 90) = 3.72, p = .028$. Although the direction of the means suggested an evaluative conditioning effect similar to that found in Study 1 ($M_{CS+} = 4.27, SE_{CS+} = .12, M_{CS-None} = 4.27, SE_{CS-None} = .11, M_{CS-} = 4.36, SE_{CS-} = .11$), orthogonal contrasts did not detect a difference in evaluations between negatively-paired stimuli and neutrally-paired and unpaired stimuli, $p = .18$.

Differences in the effect of US based on US Emotion Content

Unlike in Study 1, the US pairing effect was moderated by negative emotion content (pathogen-relevant vs. pathogen-irrelevant), $F(2, 857) = 8.19, p < .001$. Foods paired with pathogen-relevant negative USs ($M_{CS+} = 4.08, SE_{CS+} = .13$) were evaluated more negatively than foods paired with pathogen-irrelevant negative USs ($M_{CS+} = 4.45, SE_{CS+} = .13$), $p = .011$. This effect is consistent with the prepared learning account.

Differences in the effect of US Emotion Content across meat versus non-meat food CSs

Negative emotion content of the US had a main effect on food evaluations. Participants who saw pathogen-relevant USs at any time evaluated foods more negatively ($M = 4.20$, $SE = .12$) than participants who saw pathogen-irrelevant USs at any time ($M = 4.39$, $SE = .12$), $F(1, 442) = 3.96$, $p = .047$ (see Figure 4.1). This effect means that pathogen-relevant emotion content influenced evaluations more than pathogen-irrelevant emotion content and this effect extended beyond specific US pairings.

This difference was further moderated by food type, $F(1, 365) = 5.27$, $p = .022$. Participants who saw pathogen-relevant US at any time evaluated meats less positively than participants who saw pathogen-irrelevant negative USs at any time (M 's = 4.36, 4.71, SE s = .17), $p = .021$, whereas no difference was present for plants (M s = 4.05, 4.07 and SE 's = 0.16, 0.17 respectively), $p = .997$. However, consistent with Study 1, we did not detect a three-way interaction between food type (meat vs. plant), US pairing (CS+, CS-, CS-None), and negative emotion content (pathogen-relevant vs. pathogen-irrelevant), $F(2, 7308) = 2.03$, $p = 0.13$. Hence, although participants who saw pathogen-relevant USs at any time evaluated meats more negatively than participants who saw pathogen-irrelevant USs, this effect did not differ across foods that were paired with pathogen-relevant USs and those that were unpaired.

There was also no four-way interaction with US pairing, food type, food form, and negative emotion content, $F(2, 7308) = 0.15$, $p = .86$. Hence no differential effect of US was observed for meats and plants in either raw or cooked forms.

In sum, the two-way interaction between US pairing and negative emotion content suggested that pathogen-relevant USs reduced food evaluations more than pathogen-irrelevant USs. Further, participants who saw pathogen-relevant negative

stimuli during the conditioning phase evaluated meats (irrespective of whether they had been paired with a US) more negatively than participants who saw pathogen-irrelevant negative stimuli. However, this effect did not interact with US pairing (CS+, CS-, CS-None) – that is, effects of the USs were not specific to the images they were paired with, but rather generalized to all images participants rated, whether seen in the conditioning phase or not.

Both Study 1 and Study 2 used online data collection. Although this approach allows for a large number of participants, it limits control over participants behavior (and, hence, attention). Additionally, the presentation format did not standardize pairing times or inter-trial intervals. Further, in Studies 1 and 2, to encourage participants to attend to the images, we also included a top-down task during the conditioning task (i.e., asking participants to rate the pairings in terms of color and content similarity). Contingency awareness is an important boundary condition for EC effects (see, Hofmann et al., 2010), and using top-down tasks might lead to ineffective EC procedures (e.g., Dedonder et al., 2010).

In Studies 3 and 4, neutral USs were replaced with positive ones. Presentation time and inter-trial intervals were standardized, and participants only passively viewed images. Participants also went through two conditioning procedures – once each with the two different emotion contents – approximately one week apart, to allow for further within-participant comparisons. Finally, given results of Study 2 and previous research on meat and pathogens (e.g., Çınar et al., 2021; Tybur et al., 2016), only meats were used as a food CS, and abstract geometric shapes were used as a CS that might be less affected by pathogen-relevant conditioning.

Study 3

Method

Participants and exclusion

We aimed to collect data from 160 participants and we pre-registered to stop collecting data when we reached the target. We initially collected data from 166 participants. All participants indicated being either male or female, therefore there was no exclusion based on sex. After excluding one person indicating being a vegetarian or vegan, and one participant whose demographics data was not available, the final sample consisted of 164 participants (125 female, $M_{\text{age}} = 20.44$, $SD_{\text{age}} = 2.23$). All participants were compensated with either course credits or €15 (or half the amounts if they showed up for only one session). Due to technical errors (e.g., file overwritten or wrong condition entered), data from nine sessions were excluded. None of the participants reported knowing Chinese – a fact relevant for an implicit measure used in the study (see below). Further, following recommendations from Payne and Lundberg (2014), one session from each of four participants was excluded due to participants responding with the same key throughout an assessment of implicit attitudes.

Design

The study followed a 2 (CS-type, between: geometric shape vs. meat) \times 2 (negative emotion content, within: pathogen-relevant vs. pathogen-irrelevant) \times 3 (US pairing, within: CS₊pos vs. CS₊neg vs. CS-None) design.

Conditioning

Participants went through an evaluative conditioning procedure with sequential pairing via OpenSesame (Mathôt et al., 2012). Following Gawronski, Gast, & De Houwer (2015), a fixation point appeared for 250 ms, followed by a CS for 1000 ms. The CS was

then immediately replaced by the US image for 1000 ms. The inter-trial interval was 1500 ms. Participants saw each of 4 CSs paired with all the 12 negative USs and 4 CSs with all the 12 positive USs. The order for the CS-US pairings was random.

Conditioned stimuli. Participants assigned to the meat condition saw raw meats in one session and cooked meats in the other session, whereas participants in the geometric shape condition saw one set of geometric shapes in one session and another set in the other session. Each image pool was composed of 12 images. The geometric shapes were created in Microsoft Paint. Each shape was white on a black background. Images of cooked and raw meats were as described in Study 1. In each session, 4 of the CSs were rated prior to conditioning, and the remaining 8 images were used in the conditioning procedure. Participants saw a random set of CSs with the USs.

Unconditioned stimuli. Twelve pathogen-relevant negative, 12 pathogen-irrelevant negative, and 24 positive images (divided into two pools of 12 images) were used. USs were rated by a separate MTurk sample for valence and disgust. The image ratings were based on the pilot data described in Study 2. Pathogen-irrelevant negative images and pathogen-relevant negative images were similar on valence ratings ($M_{\text{rel}} = 2.08$, $M_{\text{irrel}} = 2.12$). Pathogen-irrelevant images were rated low on disgust ($M = 1.74$), and pathogen-relevant images were rated high on disgust ($M = 5.34$). Positive images were rated low on disgust ($M_{\text{pool1}} = 1.11$, $M_{\text{pool2}} = 1.10$) and positively on valence ($M_{\text{pool1}} = 6.13$, $M_{\text{pool2}} = 6.12$).

Affect Misattribution Procedure

To assess implicit evaluations of the CSs, participants went through an Affect Misattribution Procedure (AMP; Payne et al.,

2005) via OpenSesame (Mathôt et al., 2012). In AMP, a positive or a negative prime precede Chinese character and then a masking stimulus appears. Participants are asked to solely rate whether Chinese characters are pleasant or unpleasant during the masking stimulus. The valence of the prime stimulus putatively crosses over to the Chinese characters, resulting in pleasantness (or unpleasantness) responses in the direction of the prime valence. In the current chapter, participants saw the CS_{+pos} and CS_{+neg} images as primes for 75 ms. After 75 ms, the prime disappeared, and there was no image for 125 ms. Then, the target Chinese character appeared for 100 ms followed by a masking stimulus for 5000 ms. If the participant did not press any buttons, the program automatically skipped to the next trial. In each trial, a new Chinese character was presented and the order of presentations of each trial was random. Participants were told to press “E” if the Chinese character was less visually pleasing than average, and “I” if it was more visually pleasing than average. Participants saw “Unpleasant” and “Pleasant” anchors on the top of the page corresponding to the order of the keys they needed to press. There were 144 trials in total (48 for CS-None, 48 for CS_{+pos} and 48 for CS_{+neg} primes).

Procedure

Participants came to the lab twice, approximately one week apart. After providing informed consent, they were escorted to a cubicle and were asked to rest their chins on a chin rest installed 70 centimeters away from the computer screen. Participants began by rating four randomly selected CSs on the item “How much do you like this image?” (1 = Strongly dislike, 7 = Strongly like). Ratings of the 4 images were later used for the “CS-None” comparisons. Participants were told that these ratings were done to familiarize them with the procedures.

Participants then moved on to the conditioning phase. After conditioning, participants completed implicit and explicit measures. The order of these measures was counterbalanced. For the explicit self-report measure, participants rated the 4 CS_{+pos} and 4 CS_{+neg} images on “How much do you like this image?” (1 = Strongly dislike, 7 = Strongly like). The order of the images was random. For the implicit measure, participants completed ratings throughout the Affect Misattribution Procedure on a binary dependent variable (unpleasant versus pleasant). At the end of each session, participants saw the 12 CSs (4 CS_{+pos}, 4 CS_{+neg}, 4 No-CS) and reported whether these pictures were paired with a positive or a negative image or if they were not paired with anything before.

Participants then called the research assistant. In Session 1, the research assistant opened a Qualtrics survey that included demographic questions, some of which were used to exclude participants who spoke Chinese or do not eat meat. In both Session 1 and Session 2, participants reported their hunger (1 = Not hungry at all, 7 = Extremely hungry) and the last time they have eaten (e.g., less than an hour ago, one hour ago, two hours ago, three hours ago..., ten hours ago, more than ten hours ago). The survey also included measures for another study (for details see, the project page on OSF). At the end of Session 2, participants were fully debriefed and compensated for their participation.

Analytic approach for explicit evaluations

A linear mixed-model analysis was conducted on CS evaluations (See Supplementary Materials for the model). Our main hypothesis concerned the interaction between US pairing (CS_{+neg} versus CS_{+pos} versus CS-none), negative emotion content (pathogen-relevant vs. pathogen irrelevant), and CS-type (meat vs. shape). We tested fixed effects of the negative emotion content (pathogen relevant vs. pathogen irrelevant negative), CS-type

(meat vs. shape), and US pairings. We also examined two-way interactions between participant sex and CS-type, negative emotion content and CS-type, US pairing and CS-type, US pairing and negative emotion content, and a three-way interaction between CS-type, US pairing, and negative emotion content. We controlled for participant sex and modelled participants and stimuli as random intercepts. We modelled random slopes for US pairing and CS-type within stimuli and negative emotion content and US pairing within participant. We additionally included session number into the model as a fixed factor.

Analytic approach for implicit ratings

Affect Misattribution Procedure data were analyzed with linear mixed models following Wolsiefer, Westfall, and Judd (2017). See Supplementary Materials for the model. As our study contained results from each participant across 2 sessions, and because participants might become familiarized with the procedure, we controlled for session number. Random slopes were modeled for pairing within Chinese characters and within participant and random intercepts were modelled for stimuli (see Supplementary Materials for the model).

Results

Explicit ratings

General evaluative conditioning effects. CS evaluations varied as a function of US pairings (CS_{neg}, CS_{pos}, CS-None), $F(2, 66) = 50.89, p < .001$. Images paired with negative stimuli ($M = 3.57, SE = .11$) were evaluated more negatively than images paired with positive stimuli ($M = 4.53, SE = .10$), $p < .001$, and unpaired images ($M = 4.29, SE = .10$), $p < .001$. Images paired with positive stimuli were evaluated more positively than unpaired images, $p = .002$.

Differences in the effect of US based on negative emotion content. Participants who saw pathogen-irrelevant negative USs at any point evaluated CSs more positively than participants who saw pathogen-relevant negative USs at any point, $F(1, 156) = 8.92, p = .003$ ($M = 4.20, SE = .09, M = 4.07, SE = .09$ respectively). Further, negative emotion content (pathogen-relevant vs. pathogen-irrelevant) interacted with US pairing (i.e., CS+_{neg}, CS+_{pos}, CS-None), $F(2, 3135) = 3.81, p = .022$. Stimuli paired with pathogen-relevant negative images were liked less than stimuli paired with pathogen-irrelevant negative stimuli (M s = 3.44, and 3.71 respectively, SE s = .11), $p = .004$.

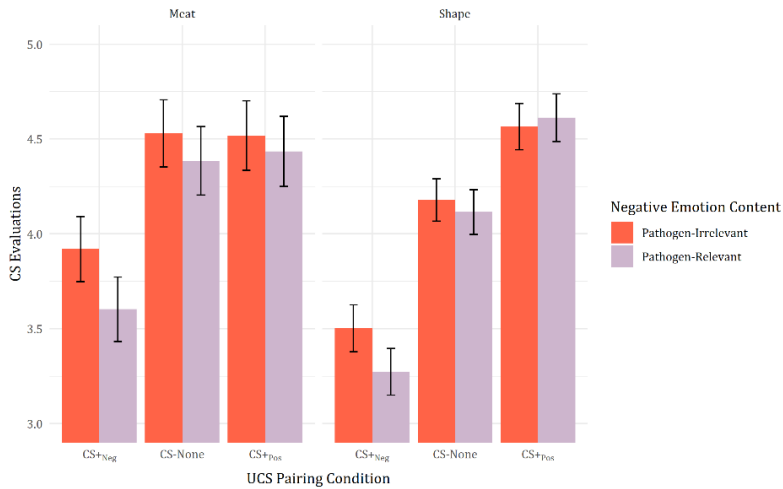


Figure 4.2. Study 3 explicit CS evaluations of meats and shapes for each US Pairing condition (CS+_{neg}, CS+_{pos}, CS-_{none}) under each negative emotion content. Error bars represent standard error from model summaries. General conditioning effects were present $F(2, 66) = 50.89, p < .001$ and negative emotion content interacted with US pairings $F(2, 3135) = 3.81, p = .022$.

However, as in Studies 1 and 2, there was no three-way interaction between US pairings, CS-types (i.e., meats vs. shapes), and negative emotion content, $F(2, 3135) = 0.06, p = .99$ (see Figure 4.2). Hence, while evaluative conditioning was stronger with pathogen-relevant USs than with pathogen-irrelevant USs, this difference did not vary across CS-type.

Implicit evaluations

General evaluative conditioning. US pairing (CS_{+neg}, CS_{+pos}, CS-None) had a main effect on stimuli evaluations, $\chi^2(2, N = 163) = 47.13, p < .001$. Chinese characters were rated more negatively when they preceded by negative primes (i.e., CSs paired with negative USs) compared to those that followed positive primes (i.e., CSs paired with positive USs) ($OR = 0.59, p < .0001$) and neutral primes (i.e., CS-None or unpaired stimuli) ($OR = 0.69, p < .0001$). Chinese characters that appeared after positive primes (CSs previously paired with positive USs) were rated more positively than those that appeared after unpaired stimuli ($OR = 1.17, p = .001$).

Differences in the effect of US based on Emotion Content. Negative emotion content had a main effect on stimulus evaluations, $\chi^2(1, N = 163) = 9.93, p = .002$. Participants in the pathogen-irrelevant negative US condition were more likely to evaluate Chinese characters positively compared to participants in the pathogen-relevant negative US condition, $OR = 1.07, p = .002$. However, the effect of US pairing on implicit evaluations differed neither as a function of the negative emotion content ($p = .43$), nor as a function of negative emotion content and CS-type ($p = .99$). Therefore, the effect of US pairings on evaluations did not differ as a function of negative emotion content across meats and abstract shapes at an implicit level.

In sum, results from Study 3 showed an effect of US pairings on both explicit and implicit evaluations of the stimuli in the predicted direction –stimuli paired with negative images were rated more negatively than stimuli paired with positive images and unpaired stimuli, and stimuli paired with positive images were rated more positively than unpaired stimuli. Negative emotion content had a main effect on both explicit and implicit evaluations, such that pathogen-relevant negative stimuli decreased liking of CSs more than pathogen-irrelevant negative stimuli – that is, participants who saw pathogen-relevant USs later rated CSs more negatively regardless of whether those CSs had earlier been paired with the US. Negative emotion content interacted with US pairings in explicit evaluations (i.e., stimuli paired with pathogen-relevant negative content were rated more negatively than stimuli paired with pathogen-irrelevant negative content), but not for implicit evaluations. Lastly, the effect of US pairing on explicit and implicit evaluations was not moderated by CS type and negative emotion content. Study 4 aimed to replicate these effects using a different pairing method (i.e., simultaneous pairings instead of sequential pairings).

Study 4

Method

Participants and exclusion

We aimed to collect data from 160 participants. Due to the anticipated drop-outs, we pre-registered as we would stop collecting data when we reached 160 participants completing both sessions. All participants were compensated for either course credits or €15 (or half the amounts if they showed up for only one session). Individuals who participated Study 3 were not allowed to enroll in this study. Of 182 participants, 161 completed both sessions. Seven individuals indicating being neither male

nor female, knowing Chinese, and/or being vegan or vegetarian were excluded from the analysis, leaving 175 participants in the sample (144 female, $M_{\text{age}} = 20.77$, $SD_{\text{age}} = 2.64$). One session of two participants were removed due to a technical error by the experimenter. Following the recommendations from Payne and Lundberg (2014), one session was dropped from each of three participants given that those participants responded with the same key throughout the implicit attitudes assessment.

Procedure

Study 4 procedures were identical to those used in Study 3, except that simultaneous pairings were used instead of sequential pairings. Here, a fixation point appeared for 250 ms, followed by a CS, which appeared at the same time as the US. Together, the images appeared on the screen for 1000 ms. The intertrial interval was 1500 ms (following Study 1 of Gawronski et al., 2015). The CSs and USs were presented next to each other, with CSs appearing on the right half of the time.

Results

Explicit ratings

General evaluative conditioning effects. Evaluations of conditioned stimuli varied as a function of US pairings, $F(2, 76) = 45.42$, $p < .001$. Images paired with negative stimuli (i.e., CS+_{neg}; $M = 3.65$, $SE = .11$) were evaluated more negatively than those paired with positive images (i.e., CS+_{pos}; $M = 4.38$, $SE = .11$) and images that were previously not paired (i.e., CS-None; $M = 4.32$, $SE = .11$), p 's $< .001$. Evaluations did not differ across non-paired (CS-None) and positively paired images (CS+_{pos}), $p = .67$.

Differences in the effect of US based on emotion content. Participants who saw pathogen-relevant USs at any time evaluated CSs more negatively ($M = 4.05$, $SE = .10$) than

participants who saw pathogen-irrelevant USs at any time ($M = 4.19$, $SE = .10$), $p = .002$, $F(1, 161) = 9.03$, $p = .003$. However, the emotion content of negative USs did not interact with US pairing conditions, $F(2, 3155) = 0.65$, $p = .52$ – that is, we did not detect a difference in the effect of negative US content across images that had and had not been paired with the negative US. Nor did negative emotion content interact with pairing condition and CS-type, $F(2,3155) = 0.87$, $p = .42$ (see Figure 4.3). Therefore, as in Studies 1-3, we did not detect differential US effects as a function of CS-type and negative emotion content.

Implicit evaluations

General evaluative conditioning effects. Implicit evaluations of conditioned stimuli varied as a function of US pairings (CS_{+neg}, CS_{+pos}, CS-None), $\chi^2(2, N = 173) = 38.94$, $p < .001$. Chinese characters were evaluated more negatively when they appeared after CSs paired with negative USs, compared to Chinese characters that appeared after CSs paired with positive USs ($OR = 0.69$, $p < .0001$), and compared to Chinese characters that preceded by CSs that were not paired with any US (OR , $p = .0002$). Chinese characters were evaluated more positively when they appeared after CSs paired with positive US, compared to CSs that were not conditioned ($OR = 1.19$, $p = .0001$).

Differences in the US pairing effect for meat versus non-food CSs. The effect of US pairing (CS_{+neg}, CS_{+pos}, CS-none) on implicit evaluations was moderated by CS-type (meat versus shape), $\chi^2(2, N = 173) = 10.10$, $p = .006$. Participants in the meat condition rated Chinese characters more negatively when the Chinese character preceded by meat CSs paired with negative USs compared to Chinese characters that preceded by meat CSs paired with positive US ($OR = 0.57$ $p < .0001$) and compared to meat CSs that were not paired with any US ($OR = 0.78$, $p = .002$).

Chinese characters were rated more positively when they preceded by meat CSs paired with positive USs compared to Chinese characters that preceded by meat CSs that were not paired with any US ($OR = 1.37, p < .0001$). Chinese characters that followed shapes were rated similarly in each three US pairing groups, $ps > .05$. The effect of pairing on implicit evaluations neither varied as a function of negative emotion content (pathogen-relevant negative vs. pathogen-irrelevant negative), nor as a function of negative emotion content and CS-type together, $ps > .05$. Therefore, as in Study 3, the effect of US pairings on stimuli liking did not differ as a function of emotion content across meat and abstract shape CSs at an implicit level.

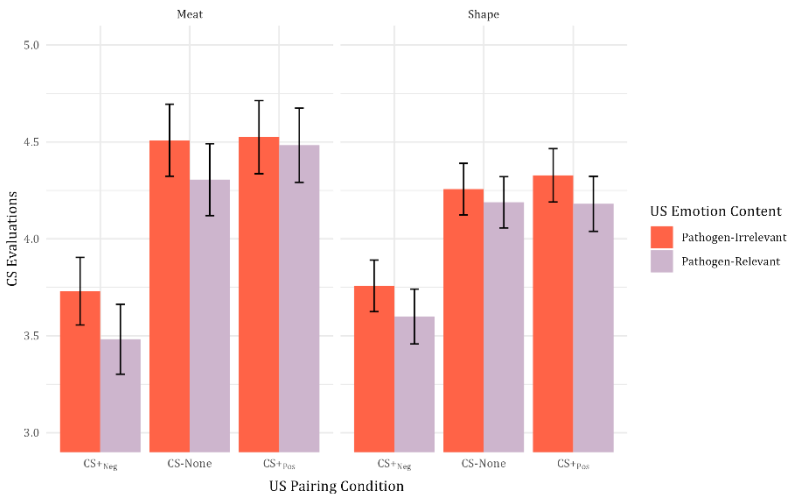


Figure 4.3. Study 4 explicit CS evaluations of meats and shapes for each US Pairing condition (CS+neg, CS+pos, CS-None) under each negative emotion content. Error bars represent standard error from model summaries. General conditioning effects were present, $F(2, 76) = 45.42, p < .001$, but negative emotion content did not interact with US pairings, $F(2, 3155) = 0.65, p = .52$.

In sum, results from Study 4 were similar to those from Study 3, though more discrepancies were observed between implicit and explicit evaluations. US pairings had an effect on both explicit and implicit evaluations of the CS. Even though negatively paired stimuli were rated more negatively than positive or unpaired stimuli in both explicit and implicit ratings, post-hoc pairwise comparisons showed no difference between positively paired stimuli and unpaired stimuli in explicit evaluations. Emotion content had a main effect only on explicit evaluations of the CS. Finally, US pairing condition was moderated by CS-type only in implicit evaluations, with post-hoc pairwise comparisons showing predicted direction of the effects for meats but not for shapes. However, this effect was not distinguishable across pathogen-relevant and pathogen-irrelevant negative USs.

Mega-analyses

At the suggestion of reviewers, and given some inconsistencies across studies, we pooled all data. All observations were assigned one of four US pairings (non-pathogen negative, pathogen-negative, positive, neutral/no-stimulus) and one of three CS types (meat, plant, shape). The linear mixed model included random intercepts for CS, participant, and study number, fixed effects for US pairing, CS types, participant sex, and the interaction between US pairing and CS-type, and the interaction between CS-type and participant sex. Random slopes were modelled for CS-type within CS, and US pairing within participant.

Results revealed a main effect of US pairing, $F(3, 1300) = 83.96$, $p < .001$. CSs paired with negative USs ($M_s = 3.97, 3.80$ and $SE_s = 0.11$ and 0.11 for pathogen-irrelevant and pathogen-relevant negative USs respectively) were rated as more negative than those paired with neutral (or no) USs ($M = 4.20$, $SE = .11$)

and those paired with positive USs ($M = 4.32, SE = 0.11$), all $ps < 0.0001$. Further, CSs paired with positive USs were rated as more positive compared to CSs paired with neutral (or no) USs, $p = .0001$. Contrasts showed a difference between ratings of CSs paired with pathogen-relevant USs ($M = 3.80, SE = 0.11$) and those paired with pathogen-irrelevant negative USs ($M = 3.97, SE = 0.11$), $p < 0.001$. There was no main effect of CS type (meat versus plant versus shape), $F(2, 76.3) = 3.03, p = .053$. However, there was an interaction between CS-type and US-pairing, $F(6, 3201) = 18.36, p < .001$. Our main hypothesis concerns the contrasts between pathogen-relevant and pathogen-irrelevant negative USs and a stronger effect for meats than other food or non-food items. The mega analyses revealed a difference between meats paired with pathogen-relevant negative USs ($M = 4.05, SE = 0.16$) and pathogen-irrelevant negative USs ($M = 4.30, SE = 0.16$), $p < .0001$. The difference between CSs paired with pathogen-relevant versus pathogen-irrelevant negative USs was larger for meats than for plants ($p = .03$), but it was not different for meats versus shapes ($p = 0.46$).

Analyses also revealed an interaction between participant sex and CS-type, $F(2, 2414) = 227.82, p < .001$. Men rated meats more favorably than women ($M = 4.60$ and $4.00, SE = 0.16$, and 0.16 respectively, $p < .001$) and women rated plants more favorably than men ($M = 4.01$ and $3.69, SE = 0.16$ and 0.16 respectively, $p < 0.001$). While men rated meats more favorably than plants, $p < 0.001$, women rated both similarly, $p = 1.00$. Men and women rated shapes similar to meats and plants, all $ps > .05$.

Overall, the mega-analyses point towards an evaluative conditioning effect, and a differential conditioning effect for foods (and, specifically, meats) paired with pathogen-relevant stimuli versus pathogen-irrelevant stimuli.

General Discussion

Findings across four studies were generally consistent with the evaluative conditioning literature; evaluations of CSs were influenced by the valence of USs that they were previously paired with. However, results did not reveal differences in this effect across types of CSs and types of negative USs (i.e., pathogen-relevant versus pathogen-irrelevant). Foods paired with pathogen-relevant negative USs were evaluated more negatively than foods paired with pathogen-irrelevant negative USs in Study 2 but not in Study 1. In Studies 3 and 4, foods paired with pathogen-relevant negative USs were not evaluated more negatively than abstract shapes paired with pathogen-relevant negative USs. These results were consistent across explicit and implicit procedures (Studies 3 and 4). A mega-analysis across studies was consistent with the general evaluative conditioning findings from individual studies, and it pointed towards differential conditioning effects for meats specifically. In the following section, we discuss the implications of these findings for prepared learning and broader evaluative conditioning.

Theoretical Implications

Implications for prepared learning

Prepared learning refers to learning mechanisms that are specialized to more easily form associations that produced survival benefits in ancestral conditions (Seligman, 1971). For example, rhesus monkeys that observe models expressing fear in response to objects that resemble threats (e.g., snakes) subsequently express fear toward those same objects. This effect is muted relative to when models express fear in response to objects that do not pose a direct threat (e.g., flowers) (Cook & Mineka, 1989). This selective association happens even if the object merely resembles a threat (e.g., a toy snake). Similarly, human children learn and retain information regarding

dangerous animals more easily than information regarding other characteristics (e.g., dietary behavior) (Barrett & Broesch, 2012).

Existing work testing for prepared learning has mostly focused on fear-relevant physical dangers. We should also expect a rich prepared learning psychology built around pathogenic threats. And, indeed, some evidence appears consistent with prepared learning specialized for avoiding pathogens. Foods are good candidates for transportation of pathogens to one's body via the mouth and hence learning nausea as an indicator of pathogen presence in the body is relatively easy for omnivores (Garcia & Koelling, 1966; Arwas et al., 1989; Nesse et al., 1980, Boudreaux, 1995). Based on these findings, we hypothesized that evaluative conditioning would show similar domain specificity, with the content of negatively-valenced USs leading to a stronger conditioning effect for some CSs than for others. Specifically, we hypothesized that USs with pathogen-relevant negative content would condition evaluations of foods stronger than USs with pathogen-irrelevant negative content. Our findings from the pre-registered individual studies did not show a specialization in learning food-pathogen associations as compared to pathogen-irrelevant negative associations or as compared to non-food CSs. However, a mega-analysis using data from all studies indicated a stronger effect of pathogen-relevant conditioning than pathogen-irrelevant conditioning for meats. This difference between pathogen-relevant and pathogen-irrelevant USs was stronger than that for plants, though not for abstract shapes.

Previously, stronger disgust learning was reported for meats as compared to plants in a similar evaluative conditioning procedure (Tybur et al., 2016). Those studies are different from the current ones in multiple ways. Here we used linear mixed models, taking stimulus effects into consideration, making our current analysis more conservative. Not modelling for stimulus effects (i.e., averaging effects across all stimuli), as done in

previous studies (e.g., Tybur et al., 2016) can inflate Type I error rates (Judd et al., 2012; Wolsiefer et al., 2017). On the other hand, the stimulus-sampling approach applied here for the CS stimuli can increase Type II error depending on the stimulus sample size and the variability of the effect across stimuli (Matuschek et al., 2017). Further, the three- and four-way interactions that were modelled for each study might have been underpowered, and null results from individual studies might reflect Type II errors. Nevertheless, combining the data across four studies using the mega-analysis approach revealed results similar to those reported by Tybur et al. (2016). There was one key difference, though – the relative effect of pathogen-relevant conditioning was not stronger for meats than it was for non-foods (abstract shapes). Hence, results could also be interpreted as suggesting that pathogen-relevant conditioning is especially ineffective for plants rather than especially effective for meats.

Implications for evaluative conditioning

In line with hundreds of existing studies, we found a main effect of US valence on evaluations of conditioned stimuli (meats and plants in Studies 1 and 2, meats and shapes in Studies 3 and 4). In the decade when psychological science has been facing criticisms regarding replicability, reproducibility, and publication biases in meta-analysis (Ferguson & Brannick, 2012; Open Science Collaboration, 2015), the current chapter reveals robust evaluative conditioning using multiple methods (sequential and simultaneous pairing) in both online and lab settings with pre-registered hypotheses, methods, and stopping rules.

Contact contamination and obsessive-compulsive disorder

Existing work suggests that rats avoid flavored water consumed after feeling radiation-induced nausea (Garcia & Koelling, 1966). Similarly, results from Studies 2-4 suggested that participants

who viewed pathogen-relevant negative USs evaluated food and non-foods more negatively independent of the US pairings. These results might indicate that the intertrial interval was not enough to prevent the negative valence of the pathogen cues to cross-over to unpaired CSs. Such a possibility is in line with research showing a generalization in disgust conditioning using a Pavlovian conditioning paradigm with various US modalities (sound; Olatunji & Tomarken, 2023; video clips; Berg et al., 2021). Such generalizations might have emerged especially because CSs not paired with pathogen-relevant negative USs were similar to those that were paired with pathogen-relevant negative USs. These results may also correspond with the law of contagion which posits that contact with an item results in a transfer of the characteristics of that item and leads to a change of value of the contacted item (Rozin et al., 1989). For example, a study conducted on American and Hindu-Indian children revealed that a juice that came in contact with a cockroach, even if it was told to be decontaminated through boiling, is rejected (Hejmadi et al., 2004). In parallel to the law of contagion, the close proximity of pathogen-relevant US with the CSs might have resulted in an overall reduction in the value of target CSs and a physical contact might not be necessary for the contact contamination to happen, similar to the rats avoiding flavored water feeling nauseated after a period of time passed in between the two occasions.

An overgeneralization specific to pathogen-relevant stimuli might indicate the adaptive value of more strongly learning contact (-or proximity) related contamination which can in turn explain psychopathology in contamination-related obsessive-compulsive disorder (OCD). In fact, contamination-related OCD patients seem vulnerable to thoughts of contamination via being in contact with a source of contaminant or in contact with an object that has previously been in contact

with a contamination source as compared to non-OCD anxious and non-OCD non-anxious participants (Tolin et al., 2004).

Limitations and future directions

Findings suggest that evaluative conditioning via pathogen-relevant negative stimuli is more resistant to extinction than conditioning via other stimuli (Engelhard et al., 2014; Olatunji et al., 2007). The current studies did not measure extinction and, hence, cannot rule out the possibility that the acquired association between pathogen-relevant stimuli and food related stimuli is more resistant to extinction than associations with non-food stimuli (or if pathogen-relevant stimuli associations with food is more resistant to extinction than pathogen-irrelevant stimuli associations with food stimuli). Future studies can further test this effect by collecting participants' responses at prolonged time points during the post-acquisition phase.

It is also possible that procedures used here might underestimate ecologically valid effects of pathogen-relevant conditioning, which should more often result from more visceral disgust and/or nausea (e.g., Garcia & Koelling, 1966; Rozin, 1986). Relatedly, gustatory rather than visual cues might lead to stronger conditioning effects. Prior research shows that memory is not consolidated in evaluative conditioning processes that include smell-auditory pairings while smell-taste pairings (a modality pair that might better simulate real-life experience of eating) succeed in showing prepared learning effects (Ruszpel & Gast, 2020). Future work could use motion sickness (e.g., Arwas et al., 1989) to trigger nausea and test hypotheses similar to those tested here.

The current work provides some evidence for pathogen-relevant prepared learning, but that evidence was inconsistent across individual studies. Future work can aim to gather further evidence for or against this phenomenon, both using methods

employed here and using other paradigms and measures (e.g., of extinction). Such endeavors can improve our understanding of how and why people learn to prefer or detest specific foods.

Chapter 5

How does social information affect food perceptions?

Disjunctions across meats versus plants and novel versus familiar foods

Abstract

Choosing what to eat is a complex decision-making process due to the risks involved with different foods. Acquiring social information about others' experiences with foods might help individuals make informed decisions and avoid food-borne pathogens. In two studies (N's = 215, 212), we presented participants third-party individuals' experiences with different types of food (either familiar or unfamiliar, and either meat or plant-based). Participants were then shown these foods and asked to answer two questions: 1) whether these foods had positive or negative outcomes, and 2) their expected enjoyment of consuming these foods. Based on the existence of riskier outcomes and culturally diverse taboos aimed at mitigating these food-related risks, we hypothesized that individuals would have better recall for negative (versus positive) outcomes, for unfamiliar (versus familiar) foods, and for meats (versus plants). Using signal detection theory, we also tested for biases in associating negative outcomes with unfamiliar (versus familiar) foods, and meats (versus plants). Preliminary analyses contradict some of our main predictions, as participants were more accurate in recalling positive (versus negative) outcomes, as well as recalling outcomes for familiar foods more accurately than unfamiliar foods. Signal detection analyses indicated a bias in associating unfamiliar foods with negative outcomes. Additionally, participants expected to enjoy the foods associated with negative outcomes less than those associated with positive outcomes. These initial findings provide valuable insights into specific biases and accuracies related to food-related information.

Keywords: learning, bias, recall, disgust, food

Social learning occurs by observing and interacting with others, or the products and/or outcomes of others' actions (Laland & Hoppitt, 2013). Not all information acquired socially is retained the same, though; several biases lead to information with specific content being transmitted or retained better (for reviews, see Laland & Hoppitt, 2013, pg. 196; Henrich et al., 2015; Henrich & McElreath, 2003). The tendency to transmit and retain emotionally arousing content is one such bias. For example, one study found that the emotion disgust was involved in 25% of a random sample of urban legends (Heath et al., 2001). Further, participants were more willing to transfer stories as the degree of disgust content in the stories also increased (Heath et al., 2001). In addition to disgust, willingness to pass along stories also increased for higher levels of happiness, interest, and surprise (Peters et al., 2009). In a similar vein, students at a hospital morgue were more willing to share the emotional experience with others as the degree of their emotional reaction increased and the emotional reaction of the observer also affected the transmission of the story across second-degree and third-degree social links (Harber & Cohen, 2005). Similar biases have been observed outside of Western populations. In one study, both Shuar and American children received information about 16 unfamiliar animals that differed in the danger they posed (dangerous or not) and in their diet (plant-based or animal based) (Barrett & Broesch, 2012). Both groups of children were better at remembering the danger information of the animals as compared to their names and diets. Similar phenomena have been observed in older children in Fiji (Broesch et al., 2014).

These biases have putatively been shaped by selection pressures imposed by predators, cheaters, and dangerous conspecifics (Haselton et al., 2015). In the context of an adaptive problem, such as detecting whether a snake is present, individuals can either commit a false positive (wrongly detecting

a tree branch as a snake) or a false negative (not detecting a snake). According to error management theory, individuals are more likely to err on the false positive side, as committing a false negative under this circumstance would lead to a greater cost (being bit by the snake) in comparison to the cost of wrongly categorizing a branch (Haselton et al., 2009).

Retention of information about foods

Pathogens (and the infectious diseases they cause) have constituted one of the most important selection pressures over human evolution (Fumagalli & Sironi, 2014; Novembre & Han, 2012). While pathogens can be transmitted through multiple pathways (e.g., airborne, or physical contact with an infected individual), they are often acquired via food, which can be directly or indirectly contaminated (Newell et al., 2010; Tack et al., 2019; Nerin et al., 2016; Larkin, 1981). As microbes are very small, they may not be detected unless the food has obvious signs of decay such as mold or foul odor. Indirect cues, such as others' positive or negative experiences, provide a way to learn about food risks (Wertz & Moya, 2019).

Omnivores, who eat foods from both animal and plant origin, face greater risks in food selection due to the wide array of foods they consume (Rozin, 1976). Food neophobia (i.e., wariness towards novel foods) reduces the risks of ingesting harmful foods, such as those containing toxins or pathogens (Pliner & Salvy, 2006). Unfamiliar foods have greater risks than familiar foods, as the outcomes are less certain than those following from the consumption of familiar foods. Due to the difference in the risks across familiar and unfamiliar foods, categorizing unfamiliar foods as dangerous or associating them with negative outcomes might reduce the chances of consuming a food that causes harm. If such a bias exists, then individuals should be more likely to associate novel foods with negative

outcomes regardless of socially transmitted information about another person's experience with that food.

Foodborne illnesses from foods of animal origin likely pose a greater threat to humans than do illnesses of plant origin (Fessler & Navarrete, 2003). However, plants also pose toxin risks, and some toxic plants are easily confused with edible ones (Negroni et al., 2019). There are multiple ways for which such risks are neutralized, including food preparation techniques (Billing & Sherman, 1998), taboos (Fessler & Navarrete 2003), individual learning (i.e., by experience; Rozin, 1986) and social learning (Wertz & Wynn, 2014b). Given that both meats and plants pose consumption risks, it is also possible that others' negative outcomes with a food are remembered better or worse for either food type. Some evidence points towards asymmetrical biases in addressing risks from these food groups, erring on the side of caution for meats relative to plants (e.g., Fessler & Navarrete 2003, Billing & Sherman, 1998, Rozin, 1986). In parallel, individuals might categorize unfamiliar meats as causing more negative outcomes than unfamiliar plants regardless of the outcome information due to the asymmetric risks that meats (versus plants) pose to humans. Familiar meats and plants should not elicit as much of an asymmetric bias simply because of familiarity and experience with the foods.

The present study

The purpose of the current research is to test whether social learning related content biases occur in detecting food risks. In two studies, we tested to see if negative experiences with foods are recalled better than positive experiences with foods. In both studies, participants saw familiar and unfamiliar meats and plants paired with images of individuals who had consumed the food and information about those individuals' positive or negative experiences with the food. Participants later saw the

foods and recalled if the consumer's experience was positive or negative. We also asked whether the food was eaten by a man or a woman to assess another aspect of memory unrelated to the type of food. In parallel to its effect on memory, others' experiences with foods might also affect willingness to eat those foods. We expected participants to expect more enjoyment in eating foods shown with positive experiences and less enjoyment in eating foods shown with negative experiences.

We initially pre-registered the following predictions for each of two studies:

- 1) Food-relevant outcome information will be recalled more accurately than other available information (i.e., the gender of the individual describing their food experience).
- 2) Negative (versus positive) outcomes will be recalled more accurately.
- 3) Differences in recall accuracy will vary across familiar and unfamiliar foods. For positive outcomes, we do not expect to see a difference in memory retention for familiar and unfamiliar foods.
- 4) There might be better recall accuracy for unfamiliar (versus familiar) meats.
- 5) There might be better recall accuracy for meats (versus plants).

We further used signal detection theory to distinguish biases (e.g., categorizing experiences as negative or positive *irrespective of the given information*) from accuracy. In other words, we tested whether individuals are biased to remember unfamiliar (versus familiar) foods more with negative experiences; meats (versus plants) more with negative experiences; and if this association would most be seen for unfamiliar meats (i.e., interaction of familiarity and food category). Using signal detection theory, we differentiated pre-

existing biases from accuracies (i.e., forming better associations). This approach was pre-registered only in Study 2.

Study 1

Method

Design

The study followed a 2 (within: meat versus plant) × 2 (within: familiar versus unfamiliar) × 2 (within: positive versus negative outcome) design for the recall outcomes and 2 (within: meat versus plant) × 2 (within: familiar versus unfamiliar) × 3 (within: positive versus neutral versus negative outcome) design for the expected enjoyment ratings. Foods and outcome descriptions were treated as random factors.

Participants

We aimed to collect data from 190 participants on Prolific based on 95% power to detect an effect size of .07 for outcome and food type interaction and 0.07 for food familiarity and outcome interaction. The power analysis was conducted using superpower (Lakens & Caldwell, 2021)⁶. Considering the possibility of excluding participants based on the attention check questions, we collected data from 221 participants in total. After excluding participants⁷ based on attention check (N = 6), we used the data from 215 participants for data analysis (109 male, 105 female, 1

⁶ (https://shiny.ieis.tue.nl/anova_power). More information on power analysis calculation be found as part of the supplementary documents in the OSF repository of this project.

⁷ The pre-registered exclusion criteria included participants who 1) indicate being younger than 18; 2) fail in either of the two attention checks, and 3) do not eat meat will be excluded. For the exclusion based on diet, we prescreened participants for the diet on Prolific and additionally asked whether or not participants followed a vegetarian/vegan diet as part of the survey. One of the attention checks asked the participants to write the word 'broccoli' to a text box Considering individuals who might misspell the word, words resembling "broccoli" was not flagged for exclusion.

non-binary; $M_{\text{age}} = 31.64$, $SD_{\text{age}} = 12.37$). Participants received £1.25.

Materials and stimuli

Faces. Face stimuli consisted of 16 images of White individuals with a neutral expression (8 male, 8 female) retrieved from Chicago Face Database (Ma et al., 2015).

Foods. Food stimuli consisted of 48 images (24 meats, 24 plants). Half of the meats and half of the plants were generally familiar in the U.S., and half were generally unfamiliar. The images were retrieved from the novel food stimuli set used in earlier research (Çınar et al., 2021; Perone et al., 2021). All images were cropped or selected to minimize any other components that might be present in a plate such as garnish.

Outcome scenarios. Scenarios were generated by the research team and had an outcome that was either positive (e.g., This food was absolutely yummy; This food tasted great, and I later learned that it's pretty nutritious) or negative (e.g., A few hours after eating this food, I had horrible diarrhea that lasted for days; Right after eating this food, I felt nauseous and ended up vomiting several times).

Procedure

After providing consent, participants answered a multiple-choice attention check question. Participants were informed that they would see 16 individuals along with brief descriptions of food outcomes. Participants then saw 16 random combinations of faces, foods, and scenarios. Each participant saw the 16 faces with four familiar meats, four unfamiliar meats, four familiar plants, and four unfamiliar plants. Within each of these four food categories, participants saw two items with positive outcomes

and two items with negative outcomes. Next, participants rated the 16 food images that they had seen and an additional two images that they had not previously seen per food category (hence a total of 24 foods) on “*Imagine eating this food. How much would you enjoy eating it?*” on a 7-point Likert scale (1 = Not at all, 7 = Extremely). These extra food items formed a comparison condition for the ratings. After rating these foods, participants went through a surprise memory task. They saw the 16 foods that were earlier paired with outcome information and answered two questions; 1) did a woman or a man eat this food?; 2) did the person who ate this food have a positive or negative experience with the food? Participants then completed the pathogen disgust subscale of the Three Domain Disgust Scale (Tybur et al., 2009)⁸ and reported their age, sex, and whether they eat meat. At the end of the survey participants answered another attention check question (Please write the word “broccoli” into the text box below).

Results

Accuracy

Binomial outcome variables for the two memory questions were computed on accuracy based on participant’s correct versus incorrect answers on the two memory questions (i.e., outcome of the experience and target’s gender). Food category (meat versus plant), food novelty (familiar versus unfamiliar), and outcome (negative versus positive) as well as the 3-way interaction between novelty, experience, and food category, and the 2-way interactions between experience and food type, and experience and novelty were regressed using a linear mixed model.

⁸ Disgust sensitivity is measured for exploratory analyses as a moderator variable.

In the model, food items, scenario outcomes, face stimuli, and participants were added as random intercepts⁹.

Target outcome accuracy. The model's total explanatory power was $R^2 = 0.05$, indicating that fixed effects accounted for 5% of the variance in outcome recall accuracy. Outcomes were more likely to be recalled accurately when foods were familiar ($p = .83$) than unfamiliar ($p = .79$), $\beta = 0.67$, 95% *CI* [0.27, 1.06], $p < .001$. Outcomes were also more likely to be recalled accurately when the outcome was positive ($p = .84$) than negative ($p = .78$), $\beta = 1.04$, 95% *CI* [0.66, 1.43], $p < .001$. There was also an interaction between food novelty and food type ($\beta = -0.74$, 95%, *CI* [-1.28, -0.19], $p = 0.008$). Outcomes for familiar meats were recalled as well as outcomes for unfamiliar ones ($p = .47$), whereas outcomes for familiar plants were recalled better than outcomes for unfamiliar ones, $p = .001$. Finally, there was an interaction between food novelty and outcome, ($\beta = -1.57$, 95% *CI* [-2.07, -1.07], $p < .001$. Unfamiliar food outcomes were recalled better when negative, $p = .03$, whereas familiar food outcomes were recalled better when positive, $p < .001$.

Target gender accuracy. The model's total explanatory power was less than that concerning food outcome recall, $R^2 = 0.01$ (see Table 5.1; Supplementary materials).

Signal detection analysis

After following our pre-registered analysis plan, we decided to also use signal detection to distinguish between biases and accuracies in recall. Doing so involves reparametrizing hit rates

⁹ Though face stimuli and outcome scenarios were not pre-registered as random intercepts, for the study's design, we later decided to include them into our model considering some scenarios and faces might be more memorable than others.

and false alarm rates within participants to obtain measures of accuracy discriminating between positive and negative outcomes corrected for biases in responding, which are apportioned to a separate parameter. Accordingly, we reparametrized dichotomized outcomes corresponding to hit rates and false alarms into measures of sensitivity (d') and bias (c) following standard formulas assuming normally distributed signal and noise distributions (MacMillan and Creelman, 2005).

Table 5.1 Summary of findings from Study 1 on recall accuracies for the two models; outcome accuracies (Left) and target gender accuracies (Right)

Predictors	Outcome Accuracy			Target Gender Accuracy		
	Odds	CI	<i>p</i>	Odds	CI	<i>p</i>
Familiarity (Fam)	1.94	1.31 - 2.88	0.001	0.96	0.68 - 1.37	0.822
Outcome (OutC)	2.84	1.93 - 4.17	<0.001	1.45	1.01 - 2.08	0.045
Food Type (FoodT)	1.14	0.79 - 1.66	0.483	1.17	0.81 - 1.68	0.403
Fam × OutC	0.21	0.13 - 0.34	<0.001	0.94	0.56 - 1.55	0.798
Fam × FoodT	0.48	0.28 - 0.83	0.008	0.61	0.37 - 0.99	0.047
OutC × FoodT	0.83	0.50 - 1.40	0.488	0.66	0.39 - 1.09	0.103
Fam × OutC × FoodT	1.97	0.99 - 3.95	0.055	1.58	0.79 - 3.19	0.198

Table 5.2. Summary of findings from Study 1 on expected enjoyment ratings of foods.

Predictors	SS	NumDF	DenDF	<i>F</i> value	<i>p</i>
Familiarity (Fam)	433.942	1	47.903	186.936	<0.001
Outcome (OutC)	187.621	2	4902.409	40.412	<0.001
Food Type (FoodT)	25.306	1	47.903	10.901	0.002
Fam × OutC	2.645	2	4902.375	0.57	0.566
Fam × FoodT	53.989	1	47.903	23.258	<0.001
OutC × FoodT	5.454	2	4902.402	1.175	0.309
Fam × OutC × FoodT	9.578	2	4902.38	2.063	0.127

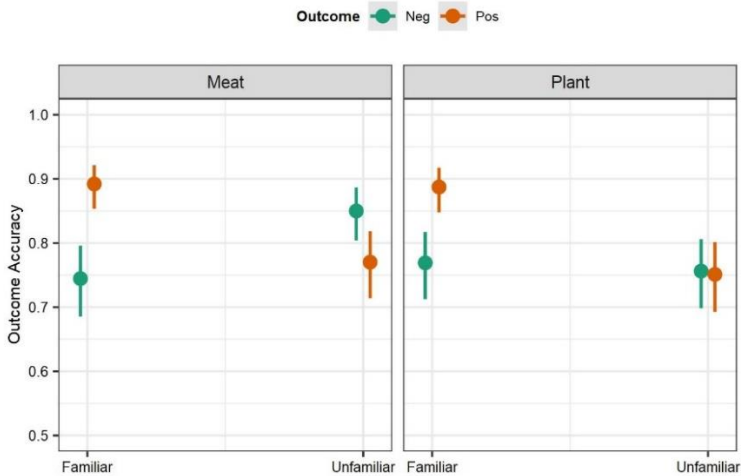


Figure 5.1. Figure shows the estimated marginal means on the probability of outcome accuracies as retrieved from sjPlot package’s plot_model function (Lüdtke, 2023). Meat (left) and plant (right) outcomes are on separate facets. Each facet distinguishes familiar (left) and unfamiliar (right) food types and negative (dark grey) and positive (light grey) outcomes.

Specifically, we tested whether individuals categorize unfamiliar foods as having produced negative outcomes more so than they categorize familiar foods as having negative outcomes, and whether individuals categorize meats as having produced negative outcomes more so than plants as having produced negative outcomes. Positive values of MacMillan and Creelman’s c indicate a bias to remember outcomes of ingesting the food as “negative”. A RMANOVA found a main effect of familiarity, $F(1, 214) = 27.378, p < .001, \eta_p^2 = .113$, but not of food type, $F(1, 214) = .571, p = .45$.

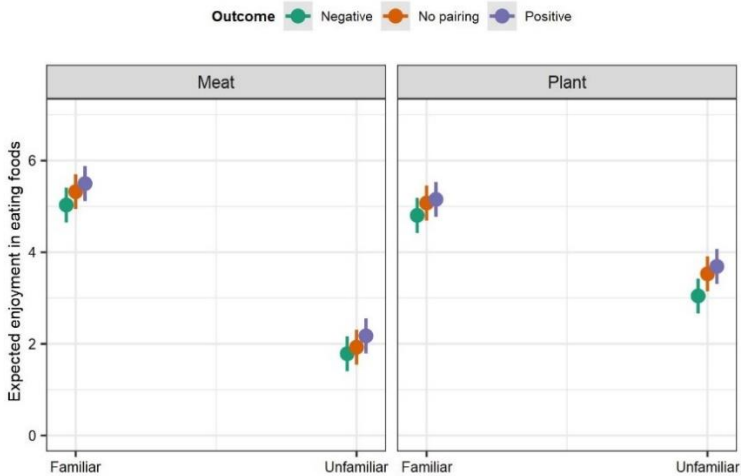


Figure 5.2. Figure shows the estimated marginal means on the expected enjoyment ratings of participants in Study 1. The graph is retrieved from sjPlot package’s plot_model function (Lüdtke, 2023). Meat (left) and plant (right) are on separate facets. Each facet distinguishes familiar (left) and unfamiliar (right) food types with the corresponding outcomes; negative (green), positive (purple) and no outcome (orange).

There was no interaction between food type and familiarity, $F(1, 214) = 3.307, p = .07$. Participants did not differ in their biases to remember (neither familiar nor unfamiliar foods) with either of the food types with a negative outcome. There was only a higher bias to remember the unfamiliar food as being associated with a negative outcome, Cohen’s d ’s = 1.05 and 1.07 for meats and plants, respectively.



Figure 5.3. Bias towards remembering negative outcomes per food category and familiarity of the food (Left); and bias towards remembering women as the consumer of the food (Right)

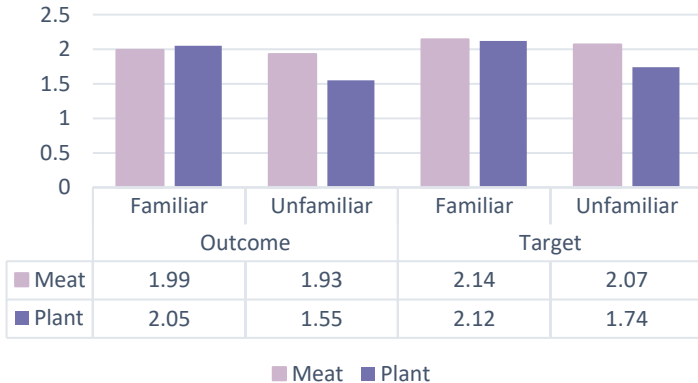


Figure 5.4. Participants' sensitivity in detecting signal (negative outcome for outcome category and the gender women for the category) from noise with a higher value indicating being better at recognizing the signal.

Expected enjoyment of foods

We regressed anticipated enjoyment on food category (meat versus plant), food novelty (familiar versus unfamiliar), and outcome content (negative versus positive versus none). We also entered the 3-way interaction between food novelty, outcome content, and food category, as well as 2-way interactions between outcome content and food type, and outcome content and food novelty. In the model, food items, and participants were added as random intercepts, but outcome scenarios and faces were not as the extra food items in the study did not have any paired scenarios or faces.

Food novelty, $F(1, 48) = 186.94, p < .001$, outcome content, $F(2, 4902) = 40.41, p < .001$ and food type, $F(1, 48) = 10.90, p = .002$, had main effects on expected enjoyment eating the food products. The effect of outcome content showed that foods paired with negative content were anticipated as less enjoyable ($M = 3.67, SE = .10$) than foods that were not previously shown to participants ($M = 3.96, SE = .10$) and foods that were paired with positive content ($M = 4.13, SE = .10$). The effect of novelty on anticipated enjoyment was moderated by food type, $F(1, 48) = 47.90, p < .001$. Expected enjoyment did not differ across familiar meats ($M = 5.28, SE = .19$) and familiar plants ($M = 5.01, SE = .19$), $p = .28$, while participants expected less enjoyment from eating unfamiliar meats ($M = 1.96, SE = .19$) than the unfamiliar plants ($M = 3.42, SE = .19$), $p < .001$. Contrary to our hypotheses, food type and novelty did not moderate the effect of outcome information, $ps > .05$ (see Table 5.2).

Discussion

In Study 1, we tested whether experiences with foods are remembered better when a social informant's experience is negative (versus positive), when the food is unfamiliar (versus familiar), and when the food is a meat (versus plant). We

expected negative experiences to be remembered better for unfamiliar (versus familiar) foods and expected a similar recall for familiar and unfamiliar foods that resulted in a positive experience. Further we expected this effect to be stronger for meats than plants. Contrary to our hypotheses, results indicated that people were more likely to remember the outcomes accurately if the foods were familiar and if the outcomes were positive rather than negative. While the accuracy of recalling outcomes for familiar meats was like that of unfamiliar meats, the accuracy of recalling outcomes for familiar plants was better than that of unfamiliar plants. For unfamiliar food outcomes, negative outcomes were better remembered, whereas for familiar foods positive outcomes were better remembered. Signal detection analyses pointed towards a bias to remember unfamiliar foods as negative, but this bias did not differ for meats and plants. Our results further showed that outcome information influences outcome accuracy more than gender accuracy.

Lastly, we conducted a test to examine the potential influence of manipulating food outcomes on individuals' anticipated pleasure when consuming the foods associated with positive or negative outcomes. We also compared these ratings with foods that were not presented to the participants, ensuring a neutral outcome. Results indicated that participant expected the least enjoyment for foods that resulted in a negative outcome for the target (versus neutral and positive) while highest enjoyment ratings were given for foods that the target had a positive experience with (versus neutral and positive).

As results portrayed a different picture than our expectations, and we changed our analytic approach after our pre-registration (i.e., using signal detection theory), we decided to do a follow-up study. For Study 2, we pre-registered the same hypotheses. Because Study 1 did not have many items and trials per food type-outcome categories, we modified the design to

include more observations for more stable estimates per participant in Study 2 by doubling the number of trials - instead of 16, participants saw 32 trials with food-person-outcome pairings. We also used a delay of 3 seconds in between the trials before the participants could go to the next page to make sure that they spent enough time to read the outcomes. Finally, instead of a binary outcome variable for the memory check, we used a 6-point Likert scale that reflected recall confidence. Therefore, the questions “was this person’s experience with this food positive or negative?” and “did a woman or a man eat this food?” had the following answer options: definitely negative, probably negative, maybe negative, maybe positive, probably positive, definitely positive; definitely a man, probably a man, maybe a man, maybe a woman, probably a woman, definitely a woman respectively. These were transformed into binary variables for the main analysis but provided room for exploration of degree of confidence as well.

Study 2

Method

Participants

We aimed to collect data from 150 participants from Prolific based on 99% power to detect the main effects of food category, food novelty, and outcome observed in Study 1 (η_p^2 s .15, .81 and .20 respectively). The power to detect outcome interactions remain low based on the power analysis using effect sizes from Study 1 (11-17%). The power analysis¹⁰ was conducted using superpower (Lakens & Caldwell, 2021¹¹). Considering the possibility of excluding participants based on our pre-registered exclusion

¹⁰ More information on power analysis calculation be found as part of the supplementary documents in the OSF repository of this project.

¹¹ https://shiny.ieis.tue.nl/anova_power

criteria, we enrolled 221 participants in total. Exclusion of participants who failed the attention check questions ($N=2$) and indicated being vegan, vegetarian, or pescetarian ($N=6$) yielded a sample size of 212 (106 female, $M_{\text{age}} = 39.77$, $SD_{\text{age}} = 13.48$). The study was expected to take 20 minutes and, based on the recommended compensation rate on Prolific (£8.25/hour), participants received £2.75.

Exclusion criteria

We excluded any participants with a d' more than 2.5 standard deviations below the mean. This exclusion criteria were used for food outcome memory.

Results

Accuracy

Binary outcome variables for the two memory questions were computed on accuracy based on participant's correct versus incorrect answers on the two memory questions (i.e., outcome of the experience and target's gender). Food category (meat versus plant), food novelty (familiar versus unfamiliar), and outcome (negative versus positive) as well as the 3-way interaction between novelty, experience, and food category, and the 2-way interactions between experience and food type, and experience and novelty were regressed into a linear mixed model. In the model, food items, scenario outcomes, face stimuli, and participants were added as random intercepts¹².

Target outcome accuracy. The model's total explanatory power was $R^2 = 0.05$, meaning the fixed effects

¹² Though face stimuli and outcome scenarios were not pre-registered as random intercepts, for the study's design, we later decided to include them into our model considering some scenarios and faces might be more memorable than others.

accounted for five percent of variance in outcome accuracy. Consistent with Study 1, results indicated a main effect of food novelty, ($\beta = 0.88$, 95% *CI* [0.56, 1.19], $p < .001$) and outcome ($\beta = 0.85$, 95% *CI* [0.59, 1.12]) and interactions between food novelty and outcome ($\beta = -2.10$, 95% *CI* [-2.42, -1.77], $p < .001$), and food novelty and food type ($\beta = -0.90$, 95% *CI* [-1.34, -0.47], $p < .001$). Outcomes were more likely to be recalled accurately when foods were familiar ($p = .78$) than unfamiliar ($p = .72$), and when the outcome was positive ($p = .75$) than negative ($p = .74$). Contrasts with Bonferroni corrections indicated that pairings with familiar (versus unfamiliar) plants resulted in better accuracy, $p < .001$, while pairings with familiar (versus unfamiliar) meats did not affect accuracies, $p = .20$. For both negative and positive outcome pairings, accuracies were better for familiar (versus unfamiliar) foods p 's $< .001$. We also detected a three-way interaction between outcome type, familiarity, and food type, $\beta = 1.19$, 95% *CI* [0.74, 1.65], $p < .001$. Negative pairings of unfamiliar meats resulted in better accuracies compared to negative pairings of familiar meats ($\beta = 0.88$), and negative pairings of unfamiliar plants ($\beta = 0.78$) resulted in better accuracies, p 's $< .001$. Within positive pairings, familiar meats (versus unfamiliar meats) ($\beta = 1.22$), familiar meats (versus unfamiliar plants) ($\beta = 0.88$), familiar plants (versus unfamiliar meats) ($\beta = 1.27$) and familiar plants (versus unfamiliar plants) ($\beta = 0.93$) had better accuracies.



Figure 5.5. Figure shows the estimated marginal means on the probability of outcome accuracies as retrieved from sjPlot package’s plot_model function (Lüdtke, 2023). Meat (left) and plant (right) outcomes are on separate facets. Each facet distinguishes familiar (left) and unfamiliar (right) food types and negative (dark grey) and positive (light grey) outcomes.

Table 5.3. Summary of findings from Study 2 on recall accuracies for the two models; outcome accuracies (Left) and target gender accuracies (Right)

Predictors	Outcome accuracy			Target gender accuracy		
	Odds	CI	p	Odds	CI	p
(Intercept)	2.19	1.72 - 2.78	<0.001	2.82	2.24 - 3.53	<0.001
Familiarity (Fam)	2.40	1.76 - 3.28	<0.001	0.84	0.63 - 1.12	0.241
Outcome (OutC)	2.34	1.80 - 3.05	<0.001	1.15	0.92 - 1.44	0.224
Food Type (FoodT)	1.13	0.84 - 1.52	0.423	1.16	0.87 - 1.56	0.319
Fam × OutC	0.12	0.09 - 0.17	<0.001	1.39	1.02 - 1.91	0.04
Fam × FoodT	0.40	0.26 - 0.62	<0.001	0.79	0.53 - 1.20	0.269
OutC × FoodT	0.93	0.67 - 1.30	0.668	0.97	0.71 - 1.34	0.869
Fam × FoodT × OutC	3.30	2.09 - 5.21	<0.001	0.65	0.42 - 1.01	0.057

Target gender accuracy. The model’s total explanatory power was $R^2 = 0.01$. (see Table 5.3; Supplementary materials)

Signal detection analyses

Positive values of MacMillan and Creelman’s c indicate a bias to remember outcomes of ingesting the food as “negative” A RMANOVA found strong main effect on both familiarity— $F(1, 212) = 90.26, p < .001, \eta_p^2 = 0.299$ and food type — $F(1, 212) = 13.65, p < .001, \eta_p^2 = 0.06$ —and these were qualified by an interaction— $F(1, 212) = 22.24, p < .001, \eta_p^2 = 0.095$ —and so we assessed simple effects of meat vs. plant within levels of familiarity. For familiar foods, a paired sample t-test showed no significant difference ($t < 1$), but for unfamiliar foods, there was a higher bias to remember meat as being associated with a negative outcome, $t(212) = 5.22, p < .001$, Cohen’s $d = 0.36$. Consistent with this, the highest false alarm (FA) rate to recall positive outcomes negative was seen for unfamiliar meat (FA = 40.8%).

Table 5.4 Summary of findings from Study 1 on expected enjoyment ratings of foods.

Predictors	SS	NumDF	DenDF	F value	p
Familiarity	522.9	1	48.32	257.38	0.000
Outcome content (OutC)	120.69	2	8263.39	29.7	0.000
Food Type	46.13	1	48.32	22.71	0.000
Fam × OutC	0.75	2	8263.4	0.18	0.83
Fam × FoodT	56.81	1	48.32	27.96	0.000
OutC × FoodT	4.63	2	8263.4	1.14	0.32
Fam × OutC × FoodT	6.17	2	8263.4	1.52	0.22

Expected enjoyment in eating foods

Food novelty ($F(1,48) = 257.38, p < .001$), outcome content ($F(2,8263) = 29.70, p < .001$), and food type, ($F(1, 48) = 22.71, p < .001$), had main effects on expected enjoyment in eating the food products. The effect of outcome content showed that pairings with negative content ($M = 3.81, SE = .09$) resulted in less enjoyment expectations in eating paired foods as compared to foods that were not previously shown to participants ($M = 3.94, SE = .09$), and foods that were paired with positive content ($M = 4.08, SE = .09$) (all mean differences were significant, p 's $< .001$). We also observed a two-way interaction between food type (meat versus plant) and familiarity, ($F(1, 48) = 27.96, p < .001$). Expected enjoyment did not vary across familiar meats ($M = 5.27, SE = .17$) and familiar plants ($M = 5.18, SE = .17$), $p = .71$, but expected enjoyment was much lower for unfamiliar meats ($M = 1.86, SE = .17$) than unfamiliar plants ($M = 3.47, SE = .17$), $p < .001$. Positive versus negative outcome did not moderate this interaction (or any other effects in the model), $ps > .05$ (see Table 5.4).

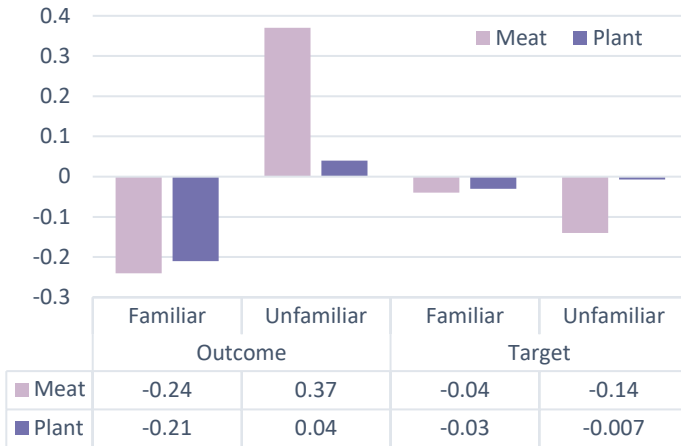


Figure 5.6. Bias towards remembering negative outcomes per food category and familiarity of the food (Left); and bias towards remembering women as the consumer of the food (Right)

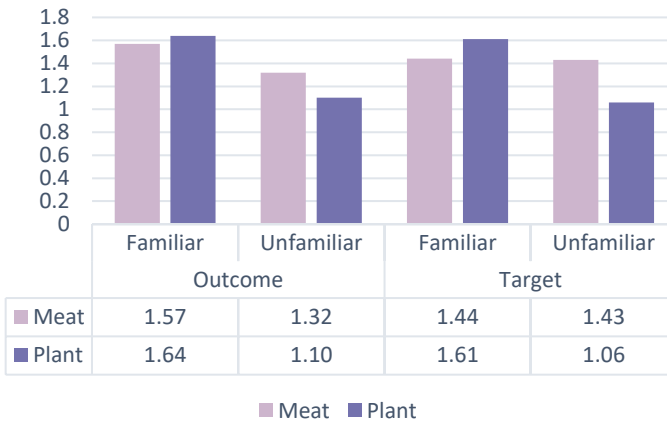


Figure 5.7. Participants' sensitivity in detecting signal (negative outcome for outcome category and the gender women for the target category) from noise with a higher value indicating being better at recognizing the signal.



Figure 5.8. Figure shows the estimated marginal means on the expected ratings of participants in Study 2. The graph is retrieved from sjPlot package's `plot_model` function (Lüdtke, 2023). Meat (left) and plant (right) are on separate facets. Each facet distinguishes familiar (left) and unfamiliar (right) food types with the corresponding outcomes; negative (green), positive (purple) and no outcome (orange).

General discussion

The current study investigated recall accuracies of social information regarding third parties' positive and negative experiences of foods. These foods differed in terms of familiarity and food type (i.e., meats versus plants). We tested accuracies based on recall of the outcome and the consumer's gender. Additionally, we tested participants' expected enjoyment of these foods. Our data further enabled us to use signal detection theory to check for any bias to remember specific types of foods as being paired with negative outcomes. Based on the riskier outcomes

and culturally diverse taboos that aim to tackle these foods risks (Fessler & Navarrete, 2003), we expected individuals to be more sensitive to the information on meats and specifically unfamiliar (versus familiar) meats. We also expected individuals to be more biased in remembering unfamiliar (versus familiar) foods with negative experiences; meats (versus plants) with negative experiences; and we expected this bias to be directed at especially unfamiliar meats.

Contrary to expectations, findings indicated better outcome recall for positive (versus negative) outcomes, and for familiar (versus unfamiliar) foods. Two-way interactions indicated that, when outcomes were negative, outcomes for unfamiliar foods (versus familiar) were better, and when outcomes were positive, outcomes for familiar foods were better. Further signal detection analyses suggested that these differences in accuracies were driven by biases to remember others' experiences with negative foods as negative and others' experiences with familiar foods as positive. This finding is consistent with the idea that human cognition uses cues to detect possible food dangers and that an overall wariness towards unfamiliar foods (versus familiar), i.e., food neophobia, could drive the effect that unfamiliar food with negative outcomes is recalled better. This cognition does not seem to generalize to all foods but specifically to unfamiliar ones. Some mental associations might be more accessible based on individual references (e.g., a food that is recently consumed, or is preferred by the individual). In such cases, experiences might be reinforced by the positive outcomes of the third-party target and remembered better once confirmed. Here, we could speculate this to be an outcome of the self-reference effect on memory (i.e., better recall when information is related to one's own self) (see, Klein, 2012). However, the current design does not enable us to investigate the mnemonic properties in relation to the self.

In addition to the converging findings on outcome accuracies across the two studies, Study 2 also pointed towards a three-way interaction between food type, food novelty, and outcome content. Within negative outcomes, the effect of unfamiliarity was stronger for meats. The effect we see here, i.e., superior accuracies for unfamiliar meats, could be an indication of adaptive memory. For example, research indicates that objects that are touched by sick individuals as compared to healthy individuals (in other words, objects that might be contaminated by others) are remembered better (Fernandes et al., 2017). This research further showed that the mnemonic advantage over contaminated objects disappears under conditions that do not improve fitness (e.g., being informed that the cues representing contamination are not valid). In the case of familiar versus unfamiliar foods, unfamiliar foods are especially important in the context of fitness as these foods are riskier and therefore more threatening to one's health than familiar foods (e.g., foods already consumed within one's culture or by oneself could be deemed safe). While this rationale would be expected to result in a mnemonic advantage of all unfamiliar foods, the effect was especially strong for unfamiliar meats (versus plants). This shows the possibility of a different information processing for plant risks and meat risks. While the negative outcomes could be attributed to contamination (e.g., sickness) this information was not explicit. Future studies could test if different learning mechanisms/processes occur under the explicit information about illnesses (hence a cue to contamination that should induce disease avoidance) versus other food-originated harms, such as choking. Given the differences between meat neophobia and plant neophobia among the Western population (Çınar, 2021), it might be worth expanding the understanding of food harms to distinguish toxin avoidance, allergen avoidance, and disease

avoidance when it comes to the psychology of food selection and food avoidance.

In both studies, results indicated that participants expected less enjoyment of eating foods when the third-party target had a negative experience (as compared to positive experiences) with the food earlier. Further, enjoyment expectations for foods that were not shown in the study before were higher than negatively paired foods and less than positively paired foods. These results indicate that our manipulation worked in both studies. They bear similarity to evaluative conditioning effects, which refer to the phenomenon in which a positively or negatively valenced stimuli's valence transfers to a paired stimulus (Hofmann et al., 2010).

Limitations and future directions

We did not ask participants their liking or their allergies in foods that they saw. We used a large stimulus set and although it did not include all foods, we expect to average out any specific associations the participants might have with each food, in addition to controlling for variance at the participant and stimuli level using multi-level modeling. This approach does not let us answer whether individuals are also biased based on a specialized diet that they follow for longer periods of time. For example, shellfish allergies or nut allergies can result in anaphylaxis if ingested by allergic individuals (Sicherer & Sampson, 2010). Hence, these individuals should be especially sensitive in detecting specific food dangers accurately.

Previously consolidated information on threat cues in food might especially be relevant in hunter gatherer societies. Future studies could further test if existing taboos within a culture make individuals in that culture more sensitive in detecting biases specific to the foods locally categorized as taboos. Additionally, having a vegan or vegetarian diet could result in

more bias in remembering animal products with negative outcomes since these are already intentionally avoided as a food category and having a sensitivity to cues that signal potential threats from animal products might help consolidating this food choice. However, as avoiding animal products already come with a set of rules and the specific food category is already excluded from the decision-making processes in vegan and vegetarian diets, having such diets might have implications in the other direction than those who might be avoiding certain food categories due to health concerns.

The background features a light orange gradient with several large, irregular, darker orange shapes that resemble organic or abstract forms. These shapes are scattered across the page, with one large one in the top left, another in the middle right, and two more in the bottom left and bottom right.

Chapter 6

General Discussion

The desire to eat has been described as the most important drive among animals (Rozin, 2020). Our food decisions would be easy if they were driven only by the goal to achieve satiation in an environment with abundant foods of equal nutritional value. In reality, there are multiple factors to take into account when choosing foods. Is this food healthy? Is it suitable for my body? Will it taste good? Is this thing that I put in my mouth to chew even food? Asking such questions about the food's properties or their effect on our body might just scratch the surface of understanding why we choose to eat certain foods.

Like other selection pressures (e.g., predators, exploitative in-group members, aggressive out-group members), food risks (e.g., food-borne illnesses) have shaped the evolution of several adaptations for avoiding risky food decisions. Food candidates can carry allergen, toxin, and pathogen risks that have adverse effects on the human body such as food anaphylaxis (Wang & Sampson, 2007), poisoning due to secondary (toxic) metabolites (e.g., tropane alkaloids; Adamse et al., 2014) and foodborne illnesses (e.g., salmonella; Barrow et al., 2012). Accordingly, individuals handle information on foods and manage food risks through multiple learning processes ranging from trial and error to mere exposure to observing social actors surrounding them. The current dissertation investigated whether this information is handled differently based on what the food product is and where it comes from.

Foods of animal origin, especially meats, carry more risks as compared to foods of plant origin (Fessler & Navarette, 2003). Humans are especially vulnerable to the risks posed by meats due to a number of characteristics that differ for plants vs. meats, including; 1) plant defenses (toxins, thorns) can be detected via categorization of plants and through observing visual cues (Fallon & Rozin, 1983; Tybur et al., 2016; Wertz & Wynn, 2014a); 2) pathogen growth in meats is quicker than it is for

plants and not all pathogens can be detected via discoloration or smell (Billing & Sherman, 1998; Bryan, 1988; Sherman & Hash, 2001; Sockett, 1995; Sperber, 2009); 3) biochemical similarity between humans and animal carcasses turn the human body into an optimal place for infection if pathogens are consumed through meats (Fessler & Navarrete, 2003).

Across four empirical chapters, we investigated food preferences pertaining to meats and plants by focusing on individual differences (**Chapter 2**), genetics (**Chapter 3**), individual or associative learning (**Chapter 4**), and social learning (**Chapter 5**). In addition to investigating differential learning effects towards meats and plants, the construct of food neophobia (wariness towards unfamiliar foods – or willingness to eat unfamiliar foods) was investigated across all chapters, by either measuring meat and plant neophobia (**Chapters 2, 3**) or making a distinction between familiar and unfamiliar foods in the learning processes (**Chapters 4, 5**). First, food neophobia was investigated to better understand how individuals vary in their approaches towards novel food products of animal and plant origin (**Chapter 2**). Second, meat and plant preferences were investigated using methods from behavior genetics, which enabled estimates of variance accounted for by genes, environmental factors shared between twins, and environmental factors not shared by twins (**Chapter 3**). Notably, in this chapter investigating the overlap in childhood and adult consumption/preferences, we also examined what portion of recalled food consumption in childhood is carried onto adulthood. Thirdly, we employed an evaluative conditioning procedure to test whether meat and plant learning is similarly impacted by pathogen-relevant and pathogen-irrelevant (negative) visual stimuli (**Chapter 4**). In the final empirical chapter, we took a social learning approach to see which information on food consumption (e.g., having a bad experience such as vomiting or

having a good experience such as enjoying the texture of a food) is retained better, and we assessed memory retention after exposing participants to social targets with various food-specific positive and negative experiences (**Chapter 5**). Using a signal detection paradigm, we also assessed biased recalls of food-relevant information.

The main findings from the four chapters are summarized below. After summarizing our key findings, we discuss their implications for theory (e.g., information processing theories of pathogen avoidance; theories of sex differences in meat preferences) as well as practice (e.g., introducing meat alternatives and understanding pathologies of eating behavior).

Summary of main findings

In **Chapter 2**, we developed a picture-based instrument to separately measure meat neophobia and plant neophobia. The reasoning behind this decision was that existing food neophobia scales do not distinguish between food categories. In two online and two lab studies (N 's = 210, 306, 160, 161), we repeatedly found that people are less willing to try novel meats than novel plants. A few important differences stood out between meat and plant neophobia. First, sex differences indicated that women report greater meat neophobia than men, while no sex differences emerged for plant neophobia. Second, out of multiple individual difference variables, meat neophobia (but not plant neophobia) had a negative relationship with masculinity, meat-eating frequency, and plant-eating frequency, and a positive directional relationship with animal empathy. Plant neophobia, on the other hand, had a negative directional relationship with animal empathy and plant-eating frequency. Despite both plant and meat neophobia correlating with pathogen disgust sensitivity, meat neophobia was more strongly related to pathogen avoidance motives. Third, when predicting the real-life

behavior of eating a novel food product (snack bar based on insect flour), meat neophobia emerged as a unique predictor. Overall, measuring food neophobia for different food categories highlighted multiple differences in approaching novel foods that might have otherwise flown beneath the radar in food research.

Chapter 3 employed a survey of identical (monozygotic) and fraternal (dizygotic) twins ($N = 9,319$). Participants reported meat and plant preferences by means of 1) recalling childhood meat and plant consumption; 2) rating current meat and plant preferences; 3) rating meat and plant neophobia; 4) abstaining from meat (that is by reporting whether or not they were vegans or vegetarians). Participants' recall for meat and plant consumption related to their current meat and plant consumptions respectively. However, twin modelling indicated that the current meat or plant consumptions did not originate from their early exposures. Sex differences were observed in the genetic underpinnings of childhood meat consumption ($h^2_{\text{men}} = .31$, $h^2_{\text{women}} = .11$) and current meat preferences ($h^2_{\text{men}} = .26$, $h^2_{\text{women}} = .51$ respectively). The twin data also suggested that different genes were responsible for meat preferences in men and women. Even though the sample size did not enable to test for sex differences in vegetarianism/veganism, abstention from meat was found to be 76% heritable.

In **Chapter 4**, food images were shown next to emotion-laden (negative and positive or neutral) images. We used an evaluative conditioning procedure in two online and two lab studies (N 's = 515, 495, 164, 175) to see whether food-negative image pairs affected participants' willingness to eat foods more when the negative image consisted of pathogen cues (e.g., a person vomiting) as opposed to those that did not feature any pathogen cues (e.g., a person attacking with a knife). The data were in line with what is expected from the evaluative conditioning procedure; foods paired with negative (vs. positive)

images resulted in a lower (vs. higher) preference compared to foods paired with neutral images or unpaired foods. In parallel to the pre-registered hypotheses, negative images with and without pathogen cues had a different effect in reducing meat (versus plant) preferences. However, the evaluations were similar in food versus non-food contrasts. The evaluative conditioning effect was similar for familiar and unfamiliar food. Therefore, while we see the presence of evaluative conditioning effects, results had limited support for specialized (implicit or explicit) learning related to food and pathogen cue associations.

Chapter 5 investigated how food learning is impacted by the experiences of social targets. In two online studies (N 's = 216, 212), participants read about individuals' positive and negative experiences with various meat and plant products that were familiar and unfamiliar. We tested how different experiences from social targets affect participants' expected enjoyment in eating these foods as well as their recall accuracies and response biases. We expected individuals to have better accuracies and more bias in matching foods to negative (versus positive) outcome accuracies, and especially for foods that were unfamiliar (versus familiar) and meats (versus plants). On average, participants had better outcome recall for positive (versus negative) outcomes, and for familiar (versus unfamiliar) foods. In Study 1, results indicated a bias to remember unfamiliar foods with negative outcomes. In Study 2, results further indicated this bias to be especially high for unfamiliar meats. In both studies participants anticipated lower enjoyment in eating food when the social target had a negative experience with the food as opposed to positive experiences.

Theoretical Implications

Across four empirical chapters, we showed how food preferences is shaped by factors such as food novelty and the animal versus

plant origin of food and by individual factors such as sex, genes, and disgust sensitivity. The theoretical implications section specifically focuses on how our findings add to the literature by 1) demonstrating that food novelty might serve as an input into the information processing mechanisms in food-related decision-making, 2) providing an in-depth overview on sex differences in meat and plant preferences.

Information processing mechanisms

As proposed by Tybur & Lieberman (2016), information-processing mechanisms underlying decisions to engage in contact with or avoid potentially pathogenic objects should weigh and incorporate many different factors (e.g., pathogen estimation, nutritional state, kinship; see, Figure 6.1). In other words, contact risk with a potentially pathogen carrying object (such as food) is either taken or avoided based on the expected contact value, which is calculated by indices of pathogens (i.e., pathogen cues as perceived by odor or visual cues), nutritional state, and kinship.

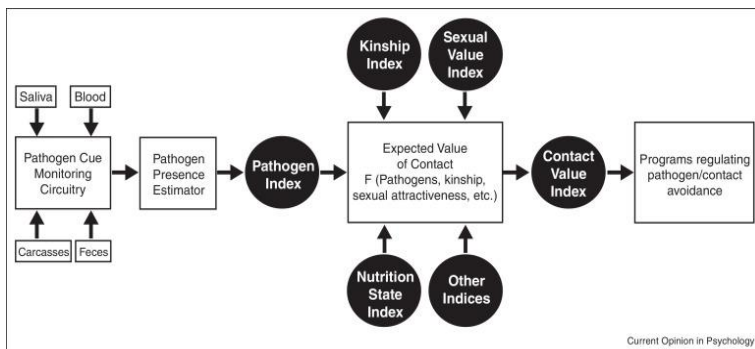


Figure 6.1. The information processing model illustrating the indices that might result in pathogen avoidance behaviors, by Tybur & Lieberman (2016), p.8, 2352-250 /© 2015 Elsevier

The posited pathogen index and nutrition state index are especially relevant for making food decisions by informing the expected value of contact with foods. The pathogen index is putatively based on cues that might indicate the presence of pathogens (e.g., mold on the food, smell of rot), and the nutrition state index is based on the nutritional state of the individual (e.g., satiated, or hungry). According to this model, these indices might differently influence the expected value of contact with food. For example, under circumstances of food abundance in which a person is satiated, a pathogen cue (e.g., mold) might result in the experience of disgust leading to the decision to avoid the food and guide an individual to throw the moldy food into the garbage. However, the expected value of contact could arguably be higher if the decision is taken during a time of food scarcity when the nutrition index receives pressing internal cues to hunger. Therefore, one might end up eating the food despite the mold that signifies pathogens on it. Another perspective suggests that bodily resistance to pathogens might be lower under food scarcity as the nutrients necessary to provide energy to the body to fight off pathogens might be lacking, and therefore individuals might be especially sensitive to avoiding pathogen cues under food scarcity (Perone et al., 2021).

Applying the model and the example described above, we can ask if novelty of foods acts as a cue that is monitored for pathogen presence in a food item. Food risks might be especially prominent when the food is unfamiliar as neither the benefit nor the possible adverse effects are known prior to trying a portion of food. In order to rule out the risks, animals prefer to handle unfamiliar foods differently from their familiar counterparts. For example, rhesus monkeys sniff novel food items more often than the feed that they are used to eating (Johnson, 2000). Sensory characteristics (e.g., appearance, smell, texture, taste) are important in eating decisions, but what if access to these kinds of

information is limited? Further, to understand taste and texture, sampling the food would be a necessity – which means that the person would take a step in risking their health with food that might potentially have pathogens, toxins, or allergens. Under these circumstances, could unfamiliarity be used as a cue that motivates food avoidance?

Meats, as compared to plants, cause more food-related problems including – but not limited to – food-borne illnesses. For example, data on food-borne illness outbreaks in the US suggests that outbreaks were more commonly attributed to meats between the years 1990 and 2003 ($n_{\text{beef}} = 438$, $n_{\text{pork}} = 170$, $n_{\text{poultry}} = 476$) than plants ($n_{\text{fruits}} = 93$, $n_{\text{vegetables}} = 205$, $n_{\text{produce_dishes}} = 256$) (Dewaal et al., 2006) as well as between the years 2009–2018 ($n_{\text{land_animals}} = 787$, $n_{\text{plants}} = 452$) (White et al., 2022). In line with this, the visual attributes present in our studies (e.g., organ meats versus greens; **Chapters 2, 4, 5**) could be an input to the pathogen-avoidance mechanism and result in a greater preference for novel plants than for novel meats. We also showed (**Chapter 2**) that pathogen disgust sensitivity more strongly relates to meat neophobia. In other words, individuals who are more sensitive to pathogen cues show a stronger avoidance motivation for unfamiliar meats. We speculate that cues from meats are not only processed differently from plants but also feed into the pathogen processing mechanism differently. These results indicate the possibility that visual cues present in novel meats trigger an implicit motivation to avoid pathogens. Further, in **Chapter 4**, we found partial support for a prepared learning effect, such that pairing meats and plants with pathogen cues influenced liking meats and plants differently. Therefore, pathogen processing mechanism could work differently for meats and plants, and this is observed in learning to associate visual pathogen cues with meats and plants. It is worth mentioning that **Chapter 4** did not measure extinction and hence cannot rule out

the possibility that the learned associations for pathogen-meat pairings linger longer than pathogen-plant associations.

The next step in research would be to breakdown which aspects of novel meats are of importance when processing information. For example, willingness to eat a novel meat might further depend on the meat's nutritional value (e.g., meats varying in fat value), time of preparation (e.g., how long ago was the meat prepared), or different preparation techniques (e.g., boiling, smoking) and contexts (e.g., who prepares it, where it is prepared). In our statistical analyses across chapters, we treated all food items as random factors, and therefore controlled for any variance that might arise based on the images. However, systematically looking at different visual components or information and what they might imply regarding the food's nutritional value and pathogen presence might reveal how much weight is given to different properties of novel meats and provide insights on the pathogen avoidance mechanism pertaining to dietary behavior.

In the current dissertation, internal cues that affect food intake (e.g., hunger) were not investigated. However, recent research shows that compared to participants who recently had lunch, participants who fast for 15 hours are more willing to try novel foods (Perone et al., 2021). This increase in willingness to eat novel foods does not differ for meats and plants though. Perone and colleagues (2021) show that despite the differential preferences for novel meats and plants, the nutritional index might have similar weights in determining the expected value of contact in a novel food product, regardless of the food's type. Of course, more extreme situations (e.g., starvation), might yield different outcomes.

Sex differences in meat and plant choice

Food choice differs per sex. Men prefer and consume meat more than women while women prefer and consume plants more than men (e.g., Rosenfeld & Tomiyama, 2021; Ocean et al., 2019). Our findings from **Chapter 3** align with this robust finding. Men had a greater preference for meats and recalled eating more meat during their childhood as compared to women. Further, there were considerably more female vegetarians than male vegetarians in Finland. In **Chapter 4**, women reported liking meats less than plants. Both **Chapter 2** and **Chapter 3** further showed that this effect extends to novel meats, with men showing greater anticipation in enjoying novel meats than women. To further investigate this phenomenon, **Chapter 3** investigated sex differences and similarities in meat and plant choice using methodologies from the field of behavioral genetics. Results suggested that the genes accounting for meat preferences might be different for men and women while this might not be the case for meat neophobia. Therefore, despite women and men's different novel meat preferences, this difference cannot be explained by different genes – contrary to familiar meat preferences.

Practical implications

There are two major practical implications of these four empirical chapters when it comes to (1) introducing meat alternatives in near future (**Chapters 2, 3, 5**) and (2) understanding food relevant pathologies within the clinical field of psychology (**Chapters 2, 4**).

Introducing meat alternatives

“Overall, all food decisions are embedded within personal time and historical time” (Sobal & Bisogni 2009).

In the 21st century, greenhouse emissions have reached to a critical level, and scientific and technological advances are focusing on ways to cut down the emission levels. Additionally, food decisions that we are currently facing are inherently determined by the climate crisis of our era. Reducing meat intake is one of the leading ways to reduce carbon footprint; there are also new food technologies and meat alternatives to replace commonly consumed livestock, reduce and reuse water waste, and optimize harvest yields (e.g., lab grown meat, genetically modified foods, consumption of filtered wastewater, insects or yeast by-products) (Bonny et al., 2015; Jiang et al., 2020; Verni et al., 2019; Tortajada, 2020). These alternatives are not commonly endorsed by a significant part of the world population and the willingness to use such products heavily depends on disgust and disgust-relevant concepts (e.g., anticipated disgust; Wester et al., 2016, pathogen disgust sensitivity; Royzman et al., 2017, disgust beliefs; Ruby & Rozin, 2019).

Changing eating patterns, especially by introducing novel foods and novel ingredients, does not happen on a whim. In the case of changing from livestock to lab-grown meats or to insects, there are several psychological barriers to consumption. **Chapter 2** shows that novelty of the food and disgust sensitivity may induce avoidance. Here, both meat and plant neophobia was correlated with levels of disgust sensitivity, hence implying that introducing novel food products might especially be challenging for individuals high in disgust sensitivity. Further, in the same chapter, willingness to consume insects was predicted by how wary individuals were towards novel meats. This pattern might be extended towards lab-grown meats, which are produced using

stem cells of animals and produce fewer greenhouse emissions than the actual livestock.

Reducing perceptions of novelty might help us reach the ultimate goal of reducing the consumption of livestock via increasing consumption of meat alternatives. However, our findings suggest that reaching this goal might not be so straightforward. In **Chapter 5**, participants were more likely to remember the novel meats resulting in a negative food experience as compared to plants or familiar meats and plants. Yet, evaluative conditioning seems to increase liking of unfamiliar and familiar foods similarly. Therefore, continuous advertisements along with positive stimuli could help in both familiarizing with – and increasing overall liking towards – a novel meat. However, any negative news or social media content communicating another individual’s negative experiences of these novel products might make these foods especially unattractive. In addition to these insights, **Chapter 3** also informs of the consumption patterns that are carried to adulthood. Specifically, both men’s and women’s meat preferences in adulthood correlate with consumption of the same foods in childhood (r 's = .29, .32). Therefore, introducing lab-grown meats or insect-based foods in childhood might lead to the consumption of meat alternatives in the long term. In conclusion, using multiple methods is advisable and even then, the transition from traditional meats to alternative meat products may not happen in an instance.

Understanding food-relevant pathologies

Recently, disgust-relevant learning mechanisms and biases are attracting more research in clinical psychology (Knowles et al., 2019). Disgust is argued to play a role in multiple psychopathologies including sexual disorders (Pawłowska et al., 2020), obsessive-compulsive disorders (Novara et al., 2021),

post-traumatic stress disorder (PTSD; Jones et al., 2020), and eating disorders (Anderson et al., 2021). The combined results from the current dissertation inform on aspects of disgust learning specific to pathogen cues and foods. Such understanding of the mechanisms of various psychopathologies can be utilized in treatments.

Eating disorders and disgust

The Diagnostic and Statistical Manual of Mental Disorders (5th ed., DSM-V; American Psychiatric Association, 2013) includes different types of eating disorders including (but not limited to) anorexia nervosa, bulimia nervosa, and avoidant/restrictive food intake disorder (ARFID). Early food experiences emerge as an important factor in food pathologies. In anorexia nervosa, an eating disorder characterized by restrictive eating in addition to cognitive distortions in self-perception, patients report fearing not only losing control or gaining weight but also experiencing disgust and appearing ‘disgusting’ (Cardi et al., 2019; American Psychiatric Association, 2013).

Therapies target pathological food associations to facilitate “unlearning” associations. Accordingly, anorexia nervosa patients benefit from exposure therapy using foods (Cardi et al., 2019). The positive outcomes from ‘unlearning’ the learned behavior in exposure therapies indicate that the root of developing eating disorders might indeed lie in abnormal patterns of learning associations. Such associations with disgust also seem to generalize toward one’s body perceptions and affect one’s body-image concepts. For example, patients with anorexia nervosa describe touching their bodies as “feeling disgusting” (Espeset et al., 2012). Even though some papers conceptualize self-disgust as a factor that needs to be addressed in therapies as well (Glashouwer & de Jong, 2021), it is not clear if the description of disgust felt towards one’s body is the same emotion

felt towards food experiences in patients with anorexia nervosa. Across our empirical chapters, we addressed disgust as an emotion that is induced in response to pathogen cues as a means to avoid the source of pathogens. Individuals with anorexia nervosa might be describing their thoughts and feelings as ‘disgust’ even though they are not experiencing revulsion but experience some form of negative affect accompanied by a sense of uneasiness and discomfort due to distorted thought patterns. However, it could also be the case that disgust-food associations are learned and reinforced to the extent that disgust is generalized and experienced under circumstances that are no longer functional. One way to test this prediction would be to investigate for differential responses given towards disgust-evoking stimuli and stimuli that supposedly evokes disgust (e.g., own image, other bodies varying in weight, and other objects relevant to the pathologies such as various food products). In addition to self-reports, physiological measures (facial electromyography and heart rate response) can be utilized for an in-depth inspection of how and if the emotion disgust is experienced.

ARFID and food aversions

Among other eating disorders, ARFID is a recent addition to DSM-V, characterized by avoiding or restricting foods to the extent that the disorder results in nutritional deficiency, dependency on nutritional supplements, or inability to meet daily tasks due to unmet energy necessities (Zimmerman & Fisher, 2017). Further, ARFID is distinguished from anorexia and bulimia nervosa such that, in ARFID cognitive distortions leading to pathological perceptions of body image do not exist (Zimmerman & Fisher, 2017). ARFID diagnosis applies to individuals who show a severe form of selective or picky eating (Zimmerman & Fisher, 2017; Zickgraf et al., 2016). The etiology of ARFID distinguishes

different reasons underlying the development of ARFID; lack of eating, avoiding due to sensory properties of foods, and avoiding foods to limit food-related negative consequences (American Psychiatric Association, 2013). I will be referring to these as ARFID subtypes below (though note that this is not an official sub-division of the diagnosis).

The current dissertation provides insights into ARFID's food aversion subtype, that is, individuals diagnosed with ARFID are eating only a select few foods and avoiding other options to limit the experience of aversive consequences such as vomiting or illnesses (Norris et al., 2018; Kennedy et al., 2022; Burton Murray et al., 2021). The function of food neophobia appears to overlap with ARFID in the sense that individuals with ARFID and individuals high on food neophobia might both be avoiding unfamiliar food options to reduce aversive outcomes such as gastrointestinal issues. Accordingly, individuals diagnosed with ARFID report more food neophobia than non-ARFID counterparts (Nicholas et al., 2021; Zickgraf et al., 2016), and cognitive behavioral therapy addressing ARFID in children and adolescents reduces food neophobia across 20-30 sessions (Thomas et al., 2021).

It is possible that individuals with ARFID, as compared to individuals with typical eating patterns, process pathogen information differently. For example, the present environmental cues on foods might more readily result in avoidance of the food due to higher disgust sensitivity. Relatedly, recent studies suggest disgust as a mediator between anxiety and ARFID (Harris et al., 2019). Having an oversensitive pathogen-processing mechanism might result in such pathologies, as disgust is an emotion that proves to result in learning associations that are more difficult to 'unlearn' (Olatunji et al., 2007). To understand if disgust associations are indeed stickier for patients diagnosed with ARFID, future studies could conduct disgust conditioning studies

and compare the number of trials necessary for extinction in participants diagnosed (versus not diagnosed) with ARFID.

ARFID and food neophobia

Since ARFID is a new classification under DSM-V, more research is needed to establish how novel and familiar foods are processed and how disgust sensitivity influences the food choices of individuals diagnosed with ARFID. The multidimensional approach to food neophobia, as exemplified in **Chapter 2**, could shed more light on cognition differences in ARFID. For example, as ARFID shows an extreme selection in food, novel foods in different categories might show less differentiation as compared to individuals without pathologies related to eating. Another possibility is that ARFID with different classifications (e.g., lack of eating type or avoiding due to sensory properties type) show differences in their approaches to different types of novel foods. As disgust sensitivity more strongly relates to meat neophobia than plant neophobia (**Chapter 2**), ARFID's subclassified category on food aversions (as compared to the *lack of eating* and *sensory property* subclassifications) might show less willingness in eating unfamiliar meats. If the willingness to eat novel meats and novel plants differs per classification categories of ARFID (lack of eating, sensory properties, food aversion), then our instrument might be useful as an alternative classification method. Further, if such differences in meat/plant neophobia are found within ARFID sub-types, then interventions targeting diversifying food pallets might consider systematically starting with familiarizing foods that individuals diagnosed with a given ARFID diagnosis are more willing to eat.

ARFID and differences in disgust learning

Applying an evaluative conditioning experiment, similar to that of **Chapter 4**, might inform on the mechanisms underlying food aversion learning in ARFID. In **Chapter 4** we did not collect any information on eating disorder symptomologies. However, several studies using disgust conditioning procedures show that populations with various mental disorders show superior learning in disgust associations (Pawłowska et al., 2020; Novara et al., 2021). Collecting further data from individuals diagnosed with ARFID could further inform our understanding of food-relevant information processing with and without pathogen cues. For example, would sub-classifications of ARFID show a differential learning? Is “sticky” disgust learning (i.e., associations with disgust-evoking stimuli being more difficult to diminish; Olatunji et al., 2007) even stickier for individuals diagnosed with ARFID, and is the extent of aversive learning different for ARFID-food aversion subtypes?

Limitations and future research directions

Along with rich insights on the underlying psychological and genetic determinants of meat and plant preferences and learning processes for avoiding novel and familiar meat and plant products, this dissertation also comes with some limitations. One limitation present across the empirical chapters entails the limited variety of food categories that have been studied. Specifically, all studies in this dissertation focused on understanding meat and plant choice. Using meats and plants in all studies limits the generalizability of the results to other food categories such as dairy or fish. Both dairy products and fish pose food risks that overlap meat and plant risks. For example, fish can accumulate toxins from toxic algae (Whittle & Gallagher, 2000), and milk products may contain salmonella, especially before the milk is processed (Marth, 1969; Napoleoni et al., 2021).

Some dairy products are commonly consumed despite visual signs of mold such as the well-known mold-ripened cheese roquefort, camembert, and gorgonzola, or lesser-known local cheese varieties such as mold-ripened (küflü) Tulum cheese from Turkey which show high rates of pathogen presence at hazardous levels (Hayaloglu & Kirbag, 2007). The underlying reason why such products are consumed or considered delicacies - especially when they contain clear visual pathogen signs - requires further research along with hedonic reversals in food, that is developing a liking towards foods that would otherwise result in aversion (Rozin et al., 2013). Such reversals are often seen for bitter (e.g., coffee) and spicy (e.g., jalapenos) foods that despite being aversive are commonly consumed possibly through learning (e.g., continuous sampling and cultural learning) (Rozin et al., 1982; Cines & Rozin, 1982).

A second limitation of the current dissertation is that the studies mostly utilized visual cues (i.e., images) as part of the self-report questions measuring individuals' willingness to eat novel foods while actual eating behavior was not measured (except for **Chapter 2**). However, other sensory cues such as taste, texture, and odor are as important as the visual aspects of food when individuals determine novel food decisions (Farrow & Coulthard, 2018). Future studies could test whether presenting other cues (e.g., smell) result in similar self-reported neophobia levels for meats and plants when it is measured upon presentation of visual cues.

Further, self-reports of willingness to eat a food or an expected enjoyment eating a food product (e.g., **Chapters 2, 5**) imperfectly relate to behavior. One of the biases that jeopardize the validity of measures include social desirability bias which indicates individuals' tendencies to respond in a desirable manner (van de Mortel, 2008). If men feel pressured to convey masculinity and women feel pressured to convey femininity

through their eating behavior (where traditional masculinity would correlate with meat eating and femininity with plant eating respectively; Rozin et al., 2012; De Backer et al., 2020), then it is possible that individuals would report more willingness to eat an item from the food category aligned with the social expectations that they feel.

Further, intention-behavior gap, a concept in behavior change that indicates an imperfect overlap of one's intention and one's observed behavior (e.g., Sheeran & Webb, 2016), could also apply to the studies in this dissertation. Even though individuals might report willingness in trying foods, when presented with the same food, this willingness or intention, might not translate into actual eating behavior. Therefore, one should be careful to derive conclusions based on the response scales in food preference studies. Terminologies on liking, preferences, willingness to eat, and consumption might not be interchangeable, though some studies show that food preferences predict food consumption (Drewnowski et al., 1999). Still, how much food liking or preferences overlap with dietary intake needs further testing for when and how food preferences translate into actual eating behavior and how much of this relationship can be observed for novel foods and food technologies.

Conclusion

The current dissertation informs on the underlying psychological influences of food learning processes and brings social, emotional, and genetic roots to the conversation. Our empirical work demonstrates that the pathogen avoidance mechanisms are relevant to food choice. Further, distinguishing food neophobia toward different food categories brings a new perspective to food neophobia research. For example, we showed that women's neophobia toward meats is greater than men's, but the sexes have similar neophobia levels toward plants. While a distinction

between animal-origin and other types of foods has been of discussion in earlier food neophobia research, ours is the first to showcase how individual difference variables relate similarly or differently toward meat and plant neophobia. We further showed that this difference is not explained by differences in heritability or by means of different genes. Finally, exposure to negative visual or social information affects attitudes towards foods. In addition to a specialized learning for pathogen-specific (versus other-negative) information, data suggests the possibility that individuals might hold more bias towards remember negative outcomes especially with unfamiliar (versus familiar) foods. We hope this work inspires future research in understanding food preferences and could shed some light on the etiology of eating disorders, as well as provide insights to trigger behavior change towards a sustainable future.

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Supplementary Materials

Chapter 2: The multidimensional nature of food neophobia***Model information***

For each variable of interest, the following model was used:

```
model <- lmer(scoreNeo ~ sex + foodtype*varInterest + (1 | Study) +
(1 | ID), data = data + REML = TRUE)
```

For hunger, the following model was used:

```
model.hunger <- lmer(scoreNeo ~ sex+ Hunger*foodtype + (1
| Study)+ (1 | Session) + (1 | ID), data = hunger_data, + REML =
TRUE)
```

Relationship between animal empathy and meat / plant eating frequency

Animal empathy correlations with frequency eating

	Meat	Plant
Study 2	0.09	0.09
Study 3	-0.16	-0.01
Study 4	-0.01	-0.01

Note. Partial correlations controlling for participant sex

Factor analyses

Additional information over meat and plant neophobia

Secondary loadings in both factors varied from .12 to -.17. The scree plots in Study 2 and both sessions in Study 3 and 4 also suggested the presence of two factors. The two highest eigenvalues were 12.12 and 3.75 in Study 2. Plants and meats loaded on separate factors, with all items loading between .52 to .90, and cross-loadings ranged from .14 to -.17. In Study 3, the two highest eigenvalues for Session 1 was 8.95 and 3.95. Meats and plants formed two separate factors with primary loadings varying from .49 to .84 and secondary loadings varying from .22 to .13. Session 2 values were nearly identical to the values from Session 1. Meat and plant neophobia scores in Session 1 were almost identical with Session 2, r 's = 0.94 and 0.86 respectively. In Study 4, the two highest eigenvalues for Session 1 was 7.86 and 4.08. Meats and plants formed two separate factors with primary loadings varying from .49 to .79 and secondary loadings varying from .12 to .23.

Unfamiliar and familiar food

Participants in Study 4 rated liking for both familiar and unfamiliar food products (i.e., meat and plant neophobia items). Factor analyses suggested 3 factors. Using oblimin rotation, we extracted 3 factors. Highest three eigenvalues were 9.25, 5.40, and 2.58. Novel meats and novel plants most strongly loaded on two separate factors. Familiar meats formed a third factor while familiar plants did not strongly load on a single factor.

Below are the loadings.

Foods	MR1	MR2	MR3
zucchini	0.19	-0.48	0.25
tomato		-0.23	0.15
banana		-0.16	0.14
carrot	0.17	-0.26	
spinach	0.25	-0.41	0.28
apple	0.3	-0.15	0.21
chicken	-0.21	0.12	0.42
steak		0.1	0.6
hamburger			0.59
ham	-0.2		0.56
turkey	-0.1		0.55
sausages	-0.16		0.64
m1	0.8		
m2	0.82		
m3	0.52	0.2	
m4	0.83		0.14
m5	0.56	0.14	-0.18
m6	0.61	0.14	
m7	0.72	0.11	
m8	0.72	-0.13	
m9	0.77		-0.12
m10	0.61	0.19	0.1
m11	0.83		
m12	0.77		
p1		0.81	
p2	-0.15	0.77	
p3	-0.24	0.51	
p4		0.75	-0.14
p5	-0.19	0.56	-0.18
p6	0.16	0.76	
p7		0.65	
p8	0.15	0.5	
p9	-0.15	0.63	
p10		0.44	-0.18
p11	0.13	0.71	
p12		0.82	

Chapter 4: Four studies yield limited evidence for prepared (disgust) learning via evaluative conditioning

Table 1. Mean and SD values for individual valence and emotion ratings

Pathogen-Relevant US							
	<i>Anger</i>	<i>Disgust</i>	<i>Fear</i>	<i>Sadness</i>	<i>Happiness</i>	<i>Negative Valence</i>	<i>Neutral Valence</i>
Mean	2.39	6.25	2.7	2.93	1.22	1.55	4.83
SD	1.94	1.2	1.98	2.04	0.86	0.57	0.76
Pathogen-Irrelevant US							
	<i>Anger</i>	<i>Disgust</i>	<i>Fear</i>	<i>Sadness</i>	<i>Happiness</i>	<i>Negative Valence</i>	<i>Neutral Valence</i>
Mean	2.01	1.84	2.44	5.21	1.28	1.68	4.55
SD	1.58	1.46	1.8	1.83	0.91	0.85	0.63

Syntax used for the linear mixed model analysis in Studies 1 and 2

Emotion: Negative emotion content (pathogen-relevant vs. pathogen-irrelevant)

Food: Food type (meat vs. plant)

Pairing: US pairing (CS+, CS-, CS-none)

Raw: Food form (raw vs. cooked)

```
model.s1 <- lmer(DV ~ sex * Food +
  Emotion * Food * Pairing * Raw + (1 | participant) + (1 | stimuli) +
  (Pairing + Emotion + sex | stimuli) + (Food + Raw + Pairing | participant),
  data = data.f.s1, REML = FALSE)
```

Syntax used for the linear mixed model analysis in Studies 3 and 4

Emotion: Negative emotion content (pathogen-relevant vs. pathogen-irrelevant)

Pairing: US pairing (CS_{neg}, CS_{pos}, CS-None)

CScategory: CS stimulus (shape vs. meat)

Explicit ratings

```
model.explicit<-lmer(DV~ session_number + sex*CScategory +  
  Emotion*CScategory*Pairing +  
  (Pairing+CScategory | stimuli) + (Emotion+Pairing  
|participant) + (1|participant) + (1|stimuli),  
  REML=FALSE, data=explicit)
```

Implicit ratings

```
model.implicit <- glmer(DV ~ session_number + sex* CScategory +  
Pairing * Emotion * CScategory + (Pairing | participant) + (Pairing  
|AMP image) + (1|image_name), data=implicit.data,  
family=binomial(logit))
```

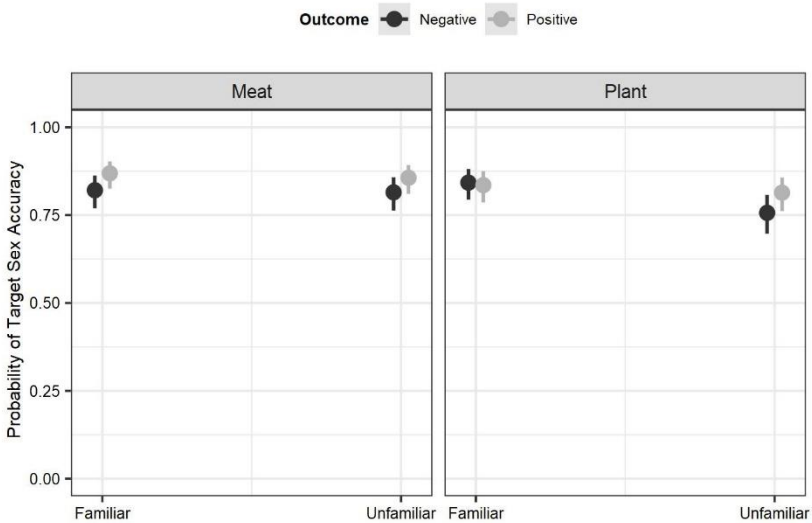
Chapter 5: How does social information affect food perceptions? Disjunctions across meats versus plants and novel versus familiar foods

Generated outcome scenarios as used in Study 2

<i>Positive</i>	<i>Negative</i>
This food looked great, and it tasted even better.	I was sick in bed all day after eating this food.
I liked this food so much that I ordered a second portion.	This food gave me a bad stomachache.
This food was absolutely yummy!	This food made me super nauseous.
This food was so good that I recommended it to all my friends.	This food was gross, and it gave me a rash.
The food was delicious!	This food gave me horrible diarrhea.
This food smelled great!	This food's smell turned my stomach.
This food tasted great, and I later learned that it's pretty nutritious.	This food had a terrible texture and it made me sick.
I felt much healthier after eating this food!	This food made me so sick that I didn't eat again for a day.
This was really tasty.	This food made me gag.
This was such an appetizing food.	This tasted like vomit.
This food gave me a full day worth of energy.	This was one of the grossest things I've ever put in my mouth.
This food had a pleasant texture.	This food made me sick.
I truly enjoyed this food.	Blech! This was so gross!
Every bite of this food was heavenly.	This food gave me stomach cramps.
This food smells wonderful.	This was disgusting.
I liked this food.	This smelled like sewage!

Target gender accuracy**Study 1**

Outcome content had a main effect on participants' accuracies in remembering target gender, $\beta = 0.37$, 95% CI [7.67e-03, 0.73], $p = 0.045$). Further, there was an interaction effect of food novelty and food type on accuracies ($\beta = -0.50$, 95% CI [-1.00, -5.95e-03], $p = 0.047$). Contrasts indicated that target gender was better recalled for positive outcome pairings. Further, target gender was better recalled with familiar plant pairings as compared to unfamiliar plant pairings, $p = .008$. No such effect was there for meat pairings, $p = 0.59$.



Study 2

Results indicated an interaction effect of food novelty with outcome content on accuracies, ($\beta = 0.33$, 95% *CI* [0.02, 0.65], $p = 0.040$). Contrasts indicated better accuracy for unfamiliar foods paired with negative content, and familiar foods with positive content, p 's < .001.



We vary in what we choose to eat and what we choose not to eat. The current dissertation sheds light on the psychological factors that underlie food learning and discusses social, emotional, and genetic foundations of food preferences. In four empirical chapters, I apply concepts and methods from the literatures on (specialized) learning and learning strategies (e.g., social information, previous food experiences, associative learning) on meat and plant preferences. Our empirical research illustrates the relevance of disease avoidance systems to food selection as well as new insights in the ways the unfamiliarity of a food interacts with decision-making or learning processes. **Chapter 2**, which examines food neophobia (wariness towards unfamiliar foods), gives a fresh perspective by differentiating food neophobia toward various meats and plants. In four studies (N 's = 210, 306, 160, and 161), I demonstrate that both sexes have comparable levels of food neophobia toward plants, but women compared to men have higher levels of food neophobia against meats. Our study is the first to reveal how individual difference characteristics interact similarly or differently toward meat and plant neophobia, even though a differentiation between foods of animal origin and other types has been discussed in past food neophobia research. **Chapter 3**, which examines genetic and environmental foundations of meat and plant preferences, demonstrates that within-population preferences for meats and plants are heritable, but only somewhat result from common environmental factors. Data from 9319 Finnish twins and siblings of twins resulted in heritability factors for childhood meat consumption ($h^2_{\text{men}} = .31$, $h^2_{\text{women}} = .11$), current meat preferences

($h^2_{\text{men}} = .26$, $h^2_{\text{women}} = .51$), childhood plant consumption ($h^2_{\text{men}} = .41$, $h^2_{\text{women}} = .17$), current plant preferences ($h^2_{\text{men}} = .45$, $h^2_{\text{women}} = .53$), meat neophobia ($h^2_{\text{men}} = .48$, $h^2_{\text{women}} = .55$) and plant neophobia ($h^2_{\text{men}} = .56$, $h^2_{\text{women}} = .54$). Genes underpinning childhood meat consumption and current meat preferences (but not childhood plant consumption and current plant preferences) vary between the sexes. Contrary to overall meat preferences, results indicate no sex-specific differences in the heritability of meat neophobia (or plant neophobia). In four studies (N 's = 515, 495, 164, 175), **Chapter 4**, which examines specialized learning, tests if there is a specialized mechanism that enhances learning foods with pathogen specific images as compared to other negative images. Focusing both at explicit attitudes and implicit attitudes towards food and non-food items, this chapter shows a pattern consistent with evaluative conditioning effects, such that negative images result in less liking to the images they are shown with. While the individual results from the studies do not support a fully specialized mechanism that affects attitudes towards foods (and especially meats) more strongly, a mega-analysis indicated towards a specialized learning mechanism for meats. **Chapter 5**, which examines social learning, manipulates food experiences from social counterparts in two studies (N 's = 215, 212), and tests if positive and negative consequences are recalled differently for meats and plants as well as for familiar and unfamiliar foods. Using signal detection theory, I also examine potential biases in linking negative consequences to unfamiliar as opposed to familiar foods, and to meats as opposed to plants. Contrary to expectations, participants demonstrate better accuracy in

remembering positive outcomes compared to negative ones. Moreover, familiar foods are recalled better than unfamiliar ones. Signal detection analyses point to a tendency to associate unfamiliar foods with negative consequences. Furthermore, participants anticipate enjoying foods linked to negative outcomes less than those connected to positive outcomes. In **Chapter 6**, I discuss these findings in relation to their theoretical implications in disgust and food research, as well as their practical implications in introducing meat alternatives for a sustainable future and suggest clinical strategies informed by our research, emphasizing their potential in addressing eating disorders, with a specific focus on Avoidant/Restrictive Food Intake Disorder (ARFID).

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Curriculum Vitae

Çağla Çınar graduated from Psychology with a minor in Communication and Design from Bilkent University in Ankara, Turkey. She then moved to the Netherlands and continued her studies at Vrije Universiteit Amsterdam. She received the VUFP Academic Excellence Scholarship and completed her Research Master's degree in Social Psychology (cum laude) before pursuing her PhD at the same university. In 2021, she started teaching at University of Amsterdam and is part of the Developmental Psychology group. Outside of her academic pursuits, ceramics provide a means for her artistic expression.

Publications

- Çınar, Ç.**, Perone, P., Tybur, J.M. (in press). Four studies yield limited evidence for prepared (disgust) learning via evaluative conditioning, *Appetite*
- Karinen, A.K., **Çınar, Ç.**, Tybur, J.M., De Vries, R.E. (2023). "Who likes the grotesque? Mapping individual differences in liking of grotesque artworks", *Psychology of Aesthetics, Creativity, and the Arts*, Advance online publication.
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