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Brief communication

A bitter taste in the mouth: The role of 6-n-propylthiouracil taster status and sex in food disgust sensitivity

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ABSTRACT

We investigated the relationship between perceived bitterness, food disgust sensitivity, and sex. Participants completed the 8-item Food Disgust Scale and a 6-n-propylthiouracil (PROP) taster test and were categorised as PROP non-tasters, medium-tasters, or supertasters. An analysis of variance of between-subject factors sex and PROP taster status was conducted with disgust sensitivity as the dependent variable. We found a significant interaction of sex and PROP taster status on disgust sensitivity and an association between disgust sensitivity and PROP taster status in males but not in females. Our study provided new evidence on sex differences in food disgust and PROP taste sensitivity.

1. Introduction

Disgust and distaste share the same facial expression and both can follow a bad taste in the mouth [1]. However, disgust is more than the rejection of an unpleasant taste. It is an adaptive, protective mechanism aiming to prevent pathogenic infection [2]. Although disgust has a protective function, at the same time, it can restrict our diet by narrowing our food choices [3].

Food disgust sensitivity, that is, an individual’s likelihood of reacting with disgust to certain food-specific cues [4], has been related to eating behaviour and preferences for particular foods. For instance, Egolf and colleagues [3] reported that food disgust sensitivity was positively associated with picky eating and negatively associated with seeking variety in foods. Together with physiological and environmental factors, individual and social learning shape and refine an individual’s set of disgust elicitors [1,5].

Another important factor in food acceptance and rejection is the perception of taste [1]. While humans are born with an innate preference for sweet tastes, bitter tastes are innately recognised as aversive [6]. Many secondary metabolites produced by plants have a bitter taste, which can act as an indicator of their toxicity, thereby protecting plants against consumption by herbivores [6]. In humans, there is evidence for a relationship between bitter taste perception, emotions, and behaviour. For instance, oral exposure to bitter compounds was found to enhance participants’ self-reported negative emotions [7], and links have been observed between sensitivity to bitter tastes and increased negative emotional responses [8] as well as general emotional approach-avoidance behaviour [9].

The substance 6-n-propylthiouracil (PROP) tastes bitter to some people but is tasteless to others. An individual’s PROP taster status is physiologically determined. In the existing body of literature, there is some disagreement concerning sex differences in PROP taster status. Some studies have reported that females are more sensitive to PROP [10], while others did not find this effect [11]. Several studies have shown that PROP sensitivity, as a measure of taste responsiveness, is linked to food acceptance, eating behavior, food preferences, and even personality characteristics [12]. The proposed connection between PROP sensitivity and food acceptance raises the question of whether there might also be a connection to food disgust sensitivity. Given that disgust is, a food rejection mechanism, a relationship between disgust and bitter taste sensitivity could be expected.

Preliminary work by Herz [13] focused on the relationship between different types of disgust and bitter taste responsiveness. Scales measuring overall disgust sensitivity; pathogen, sexual, and moral disgust; and disgust propensity and sensitivity, have been completed by participants alongside PROP taste sensitivity tests. Results revealed that overall disgust, pathogen disgust, sexual disgust, and disgust propensity were positively associated with PROP taster status. Consequently, super-tasters were more responsive to disgust cues related to diseases, body products, and sexuality, than medium or non-tasters. Even though sex influences disgust sensitivity, and it is assumed to influence PROP taster status, the study by Herz [13] did not test for sex differences. This
makes it difficult to draw conclusions regarding potential sex effects. Thus, the extent of sex differences in the relationship between PROP taster status and disgust sensitivity remained an interesting question which we examined in the present research.

In the present study, we investigated whether food disgust sensitivity was connected to chemosensory responsiveness, that is, whether food disgust sensitive individuals showed higher taste responsiveness and were able to perceive lower concentrations of an aversive bitter taste. Specifically, we examined whether food disgust sensitive participants were more sensitive to the bitter taste of PROP. We hypothesised that the intensity of perceived bitterness would be positively associated with food disgust sensitivity. Given the sex differences in disgust sensitivity, we aimed to clarify whether and how bitter taste sensitivity and food disgust sensitivity were related in males and females.

2. Method

2.1. Participants

A total of 120 healthy non-smokers participated in this study. We recruited participants through leaflets, personal recruitment, online advertisements, and from our group's experimental panel, which consists of people who have participated in one of the group's previous studies and agreed to be contacted for future studies. The exclusion criteria mentioned in the adverts included smokers, pregnancy, food studies and agreed to be contacted for future studies. The exclusion criteria consists of people who have participated in one of the group's previous advertisements, and from our group's experimental panel, which considered them to be. However, none of the FDS items are related to bitterness, and only 2.1. Participants

2.2. Taste stimuli

Our taste stimuli were solutions of sodium chloride (NaCl, table salt, 99.5% purity, obtained from a local store and PROP (CAS 51-52-5, Sigma-Aldrich). We dissolved PROP and NaCl in tap water and stirred it on a hotplate under mild heat (45°C). We stored solutions in the refrigerator and brought them to room temperature before tasting to control for temperature influences on taste perception. We kept all samples in the refrigerator for no longer than seven days.

2.3. Questionnaires

To assess participants' food disgust sensitivity, we used the 8-item FDS short [4]. The FDS short is a text-based measure of food-specific disgust sensitivity. Sample items included the following: to eat with dirty silverware in a restaurant and to eat apple slices that turned brown when exposed to air. Participants rated these items on a scale from 1 (not disgusting at all) to 6 (extremely disgusting). The mean food disgust sensitivity of this sample (M = 3.12, SD = 0.80) was comparable to the values obtained in other studies [3].

2.4. Procedure

We tested one participant at a time. Upon arrival in our laboratory, participants were introduced to the experimenter. Then, participants read a brief description of the present study and signed a written consent form before tasting the products. The experimenter informed participants that they would taste different products and answer a few questionnaires and that they were free to opt out of the study at any time without having to give a reason. The tasting experiment consisted of two parts. In the first part, we asked participants to rate two different food products. In the second part, we asked participants to complete a one-solution PROP taster test [following [14]]. For this, we asked participants to taste a 0.1 M NaCl solution and a 0.32 mM PROP solution and to rate the taste intensity on the Labelled Magnitude Scale [LMS, [15]] with a total length ranging from 0 to 100. We instructed participants to rinse their mouth with water after each product. We abstained from randomising the order of the PROP taster test based on data from Tepper and colleagues [14], which showed that the order in which salty and bitter solutions were presented did not influence participants' assessment of them. The instructions as well as the scale as used in this study can be found in Appendix A.

2.5. Data analysis

We correlated participants' score on the food disgust measure (FDS short) with PROP taster status (supertasters, medium-tasters, non-tasters) and computed a two-way analysis of variance with between-subjects factors sex (females and males) and PROP taster status (non-tasters, medium-tasters, and supertasters). The dependent variable was food disgust sensitivity. All data were analysed with SPSS Statistics software package (IBM) version 25.

3. Results

3.1. Sex differences in PROP taster status and food disgust sensitivity

We used cut-off values from previous studies to group participants into non-taster, medium-taster, or supertaster [14,16,17]. Individuals who gave PROP intensity ratings of ≤17 (moderate) were classified as non-tasters, those who gave PROP intensity ratings of ≥53 (very strong) were classified as supertasters, and participants who provided ratings that fell in between these two groups were classified as medium-tasters (Appendix B contains more information about the sample distribution). With these criteria, our sample was grouped into 47 non-tasters (24 female, 23 male), 35 medium-tasters (14 female, 21 male), and 37 supertasters (23 female, 14 male). Participants' ratings of the sodium chloride (NaCl) solution were only used to classify the PROP taster status of participants who gave borderline ratings of PROP [14]. No participants were reclassified using this procedure. There was no statistically significant difference between the proportions of PROP tasters in the male and female groups, χ²(2) = 3.54, p = .18.

Females (M = 3.33, SD = 0.69) had higher FDS short scores than males (M = 2.90, SD = 0.85). The difference in food disgust sensitivity between the sexes was statistically significant, t(117) = 3.04, p < .01.

3.2. Associations between food disgust sensitivity, PROP taster status, and sex

To investigate the association between food disgust, PROP taster

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1 One reviewer asked whether food disgust sensitivity and distaste are similar concepts. The FDS is based on various descriptions of food-related situations, which participants must evaluate in regard to how disgusting they perceive them to be. However, none of the FDS items are related to bitterness, and only one item of the FDS short is related to vegetables. The focus of this vegetable item is the food's appearance, which shows signs of spoilage. Therefore, the FDS vegetable item does not measure distaste.

2 We aimed to make the product taste disgusting by adding to it two concentrations of a bitter compound (orange juice) or flavour (chocolate yoghurt). The results of these product tastings will not be published and will not be discussed further, because the results were inconclusive, indicating that our manipulation was unsuccessful.
status, and sex, we conducted a two-way analysis of variance with participants’ scores on the FDS short as the dependent variable and sex (female, male) and PROP taster status (supertaster, medium-taster, or non-taster) as independent variables. The main effect for PROP taster status on participants’ food disgust sensitivity was not statistically significant, $F(2, 113) = 2.72, p = .07, \eta^2_p = .05$. However, the main effect for sex on food disgust sensitivity, $F(1, 113) = 7.70, p < .01, \eta^2_p = .06$, was significant. Similarly, the interaction effect of sex and PROP taster status on food disgust sensitivity reached statistical significance, $F(2, 113) = 3.70, p < .05, \eta^2_p = .06$.

To follow up the observed interaction effect, we performed an analysis of simple main effects for food disgust sensitivity with Bonferroni adjustment. For females, we did not find a statistically significant difference in mean food disgust sensitivity between PROP taster groups ($F(2, 113) = 0.68, p = .51, \eta^2_p = .01$). However, there was a statistically significant difference in mean food disgust sensitivity between males classified as non-tasters, medium-tasters, or supertasters, ($F(2, 113) = 4.88, p < .01, \eta^2_p = .08$). Furthermore, as shown in Fig. 1, there was a statistically significant difference in mean food disgust sensitivity between males and females in the non-taster ($F(1, 113) = 7.38, p < .01, \eta^2_p = .06$) and medium-taster groups ($F(1, 113) = 8.22, p < .01, \eta^2_p = .07$), but not in the supertaster group ($F(1, 113) = 0.40, p = .53, \eta^2_p < .01$).

4. Discussion

Given that one of the main functions of disgust is to protect the self by encouraging the refusal of potentially dangerous food items [2,4], we hypothesised that bitter taste sensitivity (operationalised, in this study, as the taste of PROP) would be related to participants’ food disgust sensitivity. Our findings provided partial support for this hypothesis, as we found a positive association between food disgust sensitivity and PROP taster status for males but not for females. More importantly, we found a significant interaction effect of PROP taster status and sex on food disgust sensitivity. With this, our study is, to the best of our knowledge, the first to shed light on the interplay between food disgust sensitivity, PROP taster status, and sex.

Our findings, based on a sex-balanced sample and a food-specific measure of disgust, replicated some of the findings reported by Herz [13], though we used a different measure of disgust. We replicated the positive association between disgust sensitivity and PROP taster status for food disgust sensitivity. Furthermore, we found that this relationship existed for males but not for females. In light of known sex differences in both disgust and PROP taster status, this is an interesting point that was not studied by Herz [13]. Our study has extended the available evidence in two ways. First, we have used a new measure of disgust, and second, we have unveiled an interaction effect of sex and PROP taster status on food disgust sensitivity.

We hypothesise that different adaptive mechanisms are responsible for the observed interaction effect of sex and PROP taster status on disgust sensitivity. The absence of a significant association between food disgust sensitivity and PROP taster status in females might originate from a single mechanism that aims to maximise safety in food choice by maintaining a high level of disgust sensitivity independent of PROP taste sensitivity. In males, our results showed that high food disgust sensitivity appeared with high bitter taste responsiveness (PROP taste sensitivity) and low food disgust sensitivity appeared with non-taster status. In a resource-rich environment, the cost of being disgust and bitter sensitive, and thus, probably also more conservative in food choice, is low, as this environment provides plenty of food sources from which to choose. In resource-poor environments, however, high disgust and bitter taste sensitivity might be disadvantageous, as this combination further narrows available food choices. Therefore, we argue that depending on the environment, either one or the other combination of food disgust sensitivity, PROP taste sensitivity, and dietary selectivity in males could have been more successful.

Our interpretations of the data and the effects we observed in our study are rather novel and should be underpinned by additional evidence from further studies. The current body of literature provides initial support for our interpretation, suggesting that there are, among others, two important factors that influence disgust sensitivity, namely the environment and sex. In regard to the environment, Tybur [18] argued that between-culture variability in disgust might, to some extent, reflect adaptive responses to ecologically-specific conditions, and Rozin [1] explained that most within-culture variance in food preference is environmental. In his disgust model, Kelly [5] identified three subsystems: the acquisition subsystem, the execution subsystem, and downstream effects. The acquisition system enables an individual to acquire, through individual or social learning, disgust elicitors that are not innately present. The environment is an important route for the acquisition of these disgust elicitors, independent of whether learning is social or individual. In a dangerous food environment, the rate at which individuals are exposed to dangerous foods is higher, which, in turn, can promote learning and increase food disgust sensitivity. This is also in line with the idea that disgust evolved in response to environmental threats [2].

The second major factor that influences an individuals’ food disgust sensitivity is sex. Females are reportedly more food disgust sensitive than males [3,4]. In general, heightened disgust sensitivity among females can be partly explained by their higher vulnerability to sexually transmitted diseases, such as human immunodeficiency virus, chlamydia, and human papilloma virus [19]. Furthermore, females can pass diseases on to their offspring not only during childbirth and nursing but also when taking care of them [20]. It has also been reasoned that parental investment is higher for females, who should, therefore, be more sensitive to disease cues in order to protect their offspring [2,19]. Finally, the fact that females go through periods of heightened vulnerability to disease during their menstrual cycle and during pregnancy is yet another factor that suggests the functional properties of higher disgust sensitivity in females [20].
5. Conclusion

In the present study, we demonstrated that food disgust sensitivity was positively associated with an oral sensation of bitterness in response to PROP in males but not in females. We found a significant interaction effect between sex and PROP taster status on participants' food disgust sensitivity. Regarding food disgust sensitivity, females in the PROP non-taster group did not differ from females in the PROP supertaster group. For males, however, food disgust sensitivity in the PROP supertaster group was significantly higher compared to the non-taster group. Our findings have added to existing evidence on the link between food disgust sensitivity and chemosensory responsiveness, that is, individuals' perception of bitterness. We have provided new evidence on sex differences regarding food disgust sensitivity and PROP taste sensitivity.

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Appendix A

Fig. A1. The Labelled Magnitude Scale (LMS) used in the present study, adapted from Green and colleagues [15].
Fig. B1. Classification of subjects according to the one-solution PROP test; values are means (± 95% confidence interval), and the cut-off criteria for PROP taster group classification were: non-tasters ≤ 17, medium-tasters > 17 and < 53, and supertasters ≥ 53.

References