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Disgust Propensity and the Bitter Aftertaste Response

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Abstract

Introduction A high level of disgust propensity (the general tendency to respond with the emotion of disgust to any given situation) is associated with an increased sensitivity to bitter taste. The present study examined the relationship between disgust propensity and the sensitivity to bitter aftertaste.

Methods A total of 200 women rinsed their mouth with concentrated wormwood tea (*Artemisia absinthium*). The resulting aftertaste was evaluated (intensity of bitterness and disgust) every 15 s for 10 min. A multiple linear regression analysis was calculated to capture the association between aftertaste ratings and affective variables (e.g., disgust propensity, depression symptoms).

Results Higher disgust propensity was associated with higher initial disgust ratings and faster reduction of disgust over time. Higher depression scores were associated with a slower disgust reduction.

Conclusion We demonstrated that affective variables predict the temporal course of the wormwood aftertaste response. Having a higher disgust propensity was associated with a shortened disgust recovery.

Implications A shortened disgust recovery may be adaptive because it enables faster processing of new disgust stimuli.

Keywords Bitter · Aftertaste · Disgust propensity · Depression symptoms

Introduction

The control of ingestive behavior is one of the main functions of the human gustatory (and olfactory) system (Stevenson, 2010). According to approaches from evolutionary biology, it is critical for survival to correctly identify food suitable for eating and reject harmful food. Food rejection is connected to the distaste response (Rozin et al. 2009). Distaste is a primitive rejection impulse triggered by unpleasant-tasting substances, many of which are toxic. Food toxicity is often indexed by a bitter taste. Many poisonous plant compounds taste bitter. Moreover, the decomposition of meat by bacteria and fungi is associated with a bitter taste (Reed and Knaapila 2010). However, not all bitter-tasting compounds are dangerous but nonetheless can be perceived at low concentrations (Glendinning 1994). Thus, the ability to sense bitterness may serve other purposes in addition to poison detection.

Interestingly, humans show great variability in bitter taste sensitivity. Some individuals are extremely sensitive to the taste of bitter substances, while others perceive little or no bitter taste. For one of the most studied bitter-tasting chemicals, 6-n-propylthiouracil (PROP), it has been shown that about 25% of the population is extremely sensitive to the taste of this chemical ("supertasters"), while others cannot taste it ("non-tasters"; approximately 25–30%) or report moderate taste intensity (40–50%; Bartoshuk et al. 1994).

PROP sensitivity is associated with several biological variables, such as sex and age (for reviews see Tepper et al. 2017; Sollai et al. 2017). For example, age is negatively correlated with the bitterness perceived (e.g., adults typically perceive lower bitter intensity than children), and women rate PROP bitterness higher than men.

Additionally, relationships between PROP sensitivity and various personality variables (e.g., punishment sensitivity, psychopathy, disgust propensity) have been analyzed (e.g., De Toffoli et al. 2019; Mahmut & Banzer 2020). Disgust propensity is the general tendency of a person to experience disgust across different situations (Schienle et al. 2002). For example, Herz (2011) demonstrated that PROP supertasters obtained higher scores on several disgust questionnaires measuring different components of disgust (e.g., pathogen, sexual) than

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PROP non-tasters. In a study by Herbert et al. (2014), PROP tasters reported more intense disgust feelings toward body products (e.g., excrements) than non-tasters. Similar associations have been found for other bitter compounds. Schienle and Schlintl (2019) showed that a high sensitivity to quinine hydrochloride was correlated with high scores on a questionnaire for the assessment of disgust propensity. Thus, there is convergent evidence for a connection between the ability to perceive bitterness and the personality trait disgust propensity.

Additionally, the disgust response to bitter taste is associated with the personality trait disgust sensitivity. Individuals with high disgust sensitivity show the general tendency to experience their disgust symptoms (e.g., nausea) as extremely aversive and uncontrollable (Schienle et al. 2010). In a study by Schienle et al. (2015), women with high disgust sensitivity reported to experience more intense disgust when tasting different bitter herbs (e.g., dandelion, wormwood) compared with women with low disgust sensitivity.

Some bitter compounds not only induce a bitter taste and disgust while they are in the mouth but also after they have been swallowed or spat out. This bitter aftertaste response can last for a few seconds or even several minutes (e.g., Schwab et al. 2017). In general, aftertaste is defined as the taste intensity of a gustatory stimulus that is perceived after this stimulus has been removed from the mouth (Neely and Borg 1999). The neurobiological mechanisms of aftertaste signal transduction from the taste receptors in the mouth to the brain have not been elucidated completely. Aftertaste results from a combination of both receptor-dependent and receptor-independent processes (Peri et al. 2000; Naim et al. 2002). Bitter tastants can permeate into taste cells, where they accumulate. This may explain, at least in part, the slow taste onset and lingering aftertaste (Peri et al. 2000). Aftertaste perception involves similar brain regions as taste perception. For example, James et al. (2009) observed prolonged activation in the insula (the gustatory cortex) during the sensation of bitter aftertaste induced by aspartame (a non-sugar sweetener).

The present experiment focused on the bitter aftertaste response to study the regulatory capacities of the disgust system. The participants received highly concentrated wormwood tea, which tasted extremely bitter. After removal of the tea from the mouth, the intensity of bitterness and the intensity of disgust were assessed every 15 s for 10 min. We investigated if the temporal aftertaste profile would be associated with the personality traits disgust propensity and disgust sensitivity.

Method

Sample

A total of 200 women with a mean age of 23.3 years (SD = 7.41; range: 17–74 years) participated in the study. The majority (81%) had a high school diploma. At the time of testing, none of the women was pregnant or reported mental or somatic disorders. All participants provided written informed consent. The sample was restricted to females because of gender differences in both disgust propensity and bitter sensitivity (Schienle et al. 2002). All relevant guidelines and regulations for research with human participants were followed, including the Declaration of Helsinki for medical research involving human subjects. The study was approved by the ethics committee of the university.

Test Stimulus

The participants rinsed their mouth with 20-ml concentrated wormwood tea that was made with one teaspoon of dried herbal powder (*Artemisia absinthium*; one package purchased from a local pharmacy) per 300 ml of water. The main bitter constituent of wormwood is absinthin. The tea steeped for exactly 7 min and then cooled down to room temperature. The preparation of the tea was based on previous investigations (Schwab et al. 2017; Schienle et al. 2017) that had shown that a prolonged aftertaste response of at least 10 min can be elicited using this concentration.

Procedure

The experiment was conducted in a group setting (40 participants per group). The tea was brewed for each group testing. The participants were asked to keep the fluid in the mouth for 30 s. Then it was spat out. The aftertaste was evaluated via a smartphone app every 15 s for 10 min. The participants rated the bitterness intensity and disgust intensity on 9-point Likert scales (1 = very low; 9 = very high). The data were collected via a website through python flask and SQL. To ensure that the participants could not see each other's answers, they were at a sufficient distance from each other. Two hours before the testing, the participants were asked not to eat or drink (except for water). One person was excluded from the sample because no bitter taste was perceived.

Questionnaires

The participants completed the Questionnaire for the Assessment of Disgust Propensity (QADP; Schienle et al. 2002). The QADP describes 37 situations (e.g., "someone with bad breath speaks to you"), which have to be judged on 5-point Likert scales (0 = not disgusting; 4 = very disgusting). An average total score is computed (range: 0–4) with higher values indicating greater disgust propensity. The QADP had a Cronbach's alpha of .90 in the present sample.

Furthermore, the participants completed the Scale for the Assessment of Disgust Sensitivity (SADS, Schienle et al. 2010). The SADS assesses the tendency of a person to

appraise disgust feelings as very aversive and uncontrollable. The scale has seven items (e.g., "Feeling disgusted makes me nervous") that are answered on 5-point scales (1 = never to 5 = always; $\alpha = .88$). An average total score was computed (range: 1–5) with higher values indicating greater disgust sensitivity.

Symptoms of depression were assessed with the Depression scale of the Brief Symptom Inventory (BSI-18; German version by Spitzer et al. 2011). The BSI-18 is a self-report instrument designed to measure psychological problems and their intensity. The subscale Depression ($\alpha = .80$) has six items (e.g., "How much have you been suffering from sadness during the last seven days?") which are answered on 5-point Likert scales ranging from 0 (not at all) to 4 (very strong). A sum score is computed (range: 0–24) with higher values indicating more intense depression symptoms.

Statistical Analyses

The duration of the total experiment (600 s) was divided into four time intervals (0–150 s, 151–300 s, 301–450 s, 451–600 s) and the median for each affective variable was computed (QADP_disgust propensity: median = 2.23; SADS_disgust sensitivity: median = 1.43; BSI_depression: median = 2.00). Then, analyses of variance (ANOVAs) were performed to test the effects of time (intervals 1–4) and group (high vs. low questionnaire scores as determined via median split) on the intensity ratings for the aftertaste (bitterness, disgust).

Additionally, we calculated difference scores for both bitterness intensity and disgust intensity (interval 1 minus interval 4) which served as the criteria in two multiple linear regression analyses (forced entry: all independent variables were entered into the regression equation at the same time). This was done to capture the association between disgust/bitterness reduction (criteria) and disgust propensity, disgust sensitivity, depression, and age (predictors). The models were assessed for multicollinearity (tolerance: age: .97; QADP_disgust propensity: .88; SADS_disgust sensitivity: .91; BSI_depression: .91) and residual distribution (Cook's distance max score = .07, Durbin Watson = 2.08). The analyses were conducted with SPSS version 26 (IBM Corp., 2019).

Results

Questionnaire Scores The questionnaire scores for the two median split groups are displayed in Table 1. Compared with the average scores (QADP, SADS) reported in the questionnaire manuals, the scores of the high vs. low groups were significantly above or below this average value ($p < .01$). The t scores for the BSI-depression groups were 49 (low group) and 66 (high group).

Analyses of Variance

Disgust Propensity For the disgust ratings and the bitterness ratings, the effects of group and time as well as the interaction group × time were statistically significant (see Table 2). The post hoc t tests showed that participants with high disgust propensity gave higher disgust/bitter ratings compared with low scorers during interval 1 to interval 3, while during interval 4, the groups did not differ anymore (Table 3; Fig. 1).

Disgust Sensitivity For the disgust ratings and the bitter ratings, the effects of group and time as well as the interaction group × time were statistically significant (see Table 3). The post hoc t tests showed that participants with high disgust sensitivity gave higher disgust/bitter ratings compared with low scorers during interval 1 and interval 2, while during intervals 3 and 4, the groups did not differ anymore.

Depression The main effect of Time for the disgust/bitterness ratings was statistically significant (the other effects were not significant; Table 3). The ratings decreased over time.

Multiple Linear Regression Analyses For the criterion "disgust reduction" (mean disgust ratings; interval 1 minus 4), a significant regression equation was found ($F(4, 187) = 5.75$; $p < .001$; $R^2 = .11$). Disgust propensity and disgust sensitivity were positive predictors of disgust reduction, whereas depression was a negative predictor (see Table 4).

For the criterion "bitterness reduction" (intensity ratings; interval 1 minus 4), no significant regression equation was found ($F(4, 187) = 1.93$; $p = .11$; $R^2 = .04$). However, disgust propensity ($\beta = .15$, $p = .05$) showed a positive association,

Table 1 Questionnaire scores of the median split groups

Questionnaire scores	Group_high *M* (*SD*); *n*	Group_low *M* (*SD*); *n*	*t* (*p*)
Disgust propensity (QADP)	2.68 (0.36); 99	1.77 (0.36); 97	− 17.79 (< .001)
Disgust sensitivity (SADS)	2.20 (0.63); 99	1.12 (0.15); 100	− 16.67 (< .001)
Depression symptoms (BSI)	6.05 (3.65); 99	0.73 (0.82); 99	− 14.17 (< .001)

QADP Questionnaire for the Assessment of Disgust Propensity, *SADS* Scale for the Assessment of Disgust Sensitivity, *BSI* Brief Symptom Inventory

Table 2 Ratings of the median split groups across the four time intervals

		Group	Disgust intensity		Bitterness intensity	
			M (SD)	*t (p)*	*M (SD)*	*t (p)*
Interval 1	Median split QADP_disgust proneness	High	6.02 (2.25)	− 3.77 (< .001)	6.33 (1.81)	− 2.73 (.007)
		Low	4.85 (2.27)		5.62 (1.75)	
Interval 2		High	4.20 (2.62)	− 3.29 (.001)	4.03 (2.14)	− 2.31 (.022)
		Low	3.07 (2.18)		3.37 (1.79)	
Interval 3		High	2.91 (2.25)	− 2.18 (.031)	2.77 (1.84)	− 2.09 (.038)
		Low	2.28 (1.76)		2.27 (1.42)	
Interval 4		High	1.91 (1.48)	0.02 (.982)	1.80 (1.16)	− 0.20 (.843)
		Low	1.91 (1.71)		1.77 (1.21)	
Interval 1	Median split SADS_disgust sensitivity	High	5.98 (2.17)	− 3.44 (.001)	6.24 (1.72)	− 2.09 (.038)
		Low	4.86 (2.40)		5.70 (1.87)	
Interval 2		High	4.10 (2.37)	− 2.72 (.007)	3.99 (1.94)	− 2.19 (.030)
		Low	3.16 (2.48)		3.38 (1.98)	
Interval 3		High	2.81 (2.08)	− 1.61 (.108)	2.66 (1.63)	− 1.24 (.216)
		Low	2.35 (1.94)		2.37 (1.66)	
Interval 4		High	1.86 (1.73)	− 0.58 (.565)	1.85 (1.07)	− 0.80 (.426)
		Low	1.99 (1.50)		1.71 (1.27)	
Interval 1	Median split BSI_depression	High	5.37 (2.37)	0.21 (.834)	5.90 (1.79)	0.43 (.668)
		Low	5.44 (2.33)		6.02 (1.88)	
Interval 2		High	3.73 (2.54)	− 0.57 (.567)	3.66 (2.02)	0.19 (.846)
		Low	3.52 (2.40)		3.71 (1.98)	
Interval 3		High	2.74 (2.24)	− 1.10 (.273)	2.54 (1.80)	− 0.30 (.767)
		Low	2.42 (1.78)		2.47 (1.49)	
Interval 4		High	2.12 (1.81)	− 1.87 (.064)	1.71 (0.96)	− 0.35 (.399)
		Low	1.69 (1.30)		1.85 (1.36)	

QADP Questionnaire for the Assessment of Disgust Propensity, *SADS* Scale for the Assessment of Disgust Sensitivity, *BSI* Brief Symptom Inventory; time intervals 0–150 s, 151–300 s, 301–450 s, and 451–600 s

and depression showed a negative association ($\beta = -.13$, $p = .09$) with the bitterness reduction. Age and disgust sensitivity were not relevant ($p > .32$).

The computed Pearson correlations between the questionnaire scores were as follows: disgust propensity – depression: $r = .21$ ($p = .003$), disgust propensity – disgust sensitivity: $r = .22$ ($p = .002$), disgust sensitivity – depression: $r = .21$ ($p < .003$). The disgust ratings were significantly correlated with the bitterness ratings for the aftertaste ($r = .83$; $p < .001$).

Discussion

In this study, we examined the temporal course of the wormwood aftertaste response. The reduction of bitterness intensity and disgust intensity was recorded every 15 s for 10 min.

The reduction of disgust was associated with reported disgust propensity (DP), disgust sensitivity (DS), and symptoms of depression (D). Additionally, at the beginning of the experiment, the participants with high DP/DS rated the aftertaste as more disgusting and bitter than the participants with low questionnaire scores. Thus, we were able to replicate previous findings on the relationship between DP/DS and bitter sensitivity (Herz 2011; Herbert et al. 2014; Schienle and Schlintl 2019; Schienle et al. 2015).

The new finding of the present study showed that trait disgust was associated with the temporal dynamics of the disgust-aftertaste response. Individuals with high DP/DS showed a faster decline in their disgust response. They returned faster to baseline. At the end of the experiment, both groups high and low in DP rated the wormwood aftertaste as only slightly disgusting and did not differ anymore in their evaluation. Thus, high DP was characterized by a greater initial magnitude of the disgust response and a faster disgust recovery. Both components can be considered indicators of the excitability and regulatory capacities of the disgust system.

The basic emotion disgust has been described as the core mechanism of the behavioral immune system (Schaller and Duncan 2007). Disgust motivates individuals to avoid, reject, and/or remove pathogens. Some researchers (e.g., Rozin et al. 2009) have argued that the most primitive or basic form of disgust ("core disgust") is built upon the distaste response, which is part of a preadapted bitter (toxin) avoidance system

Table 3 Results of the analyses of variance

	F	*df*	*p*	*part.η²*
Disgust ratings				
Disgust propensity				
Main effect group	8.3	1.0, 186.0	.005	.04
Main effect interval	250.0	2.1, 386.1	.001	.57
Group × interval	8.1	2.1, 386.1	< .001	.04
Disgust sensitivity				
Main effect group	8.3	1.0,190.0	.004	.04
Main effect interval	251.3	2.1392.1	< .001	.57
Group × interval	6.9	2.1392.1	.001	.04
Depression				
Main effect group	1.1	1.0,189.0	.30	.01
Main effect interval	244.7	2.0,382.7	< .001	.56
Group × interval	.9	2.0, 382.7	.40	.01
Bitterness ratings				
Disgust propensity				
Main effect group	5.2	1.0,186.0	.02	.03
Main effect interval	548.6	2.2401.4	< .001	.75
Group × interval	3.6	2.2401.4	.03	.02
Disgust sensitivity				
Main effect group	5.3	1.0,190.0	.02	.03
Main effect interval	559.4	2.2411.1	< .001	.75
Group × interval	5.3	2.2411.1	.04	.02
Depression				
Main effect group	0.7	1.0,189.0	.79	< .001
Main effect interval	544.9	2.1405.4	< .001	.74
Group × interval	0.3	2.1405.4	.76	.002

Table 4 Results of the regression analysis

	B	*SE B*	95% CI for *B*	*β*	*p*
Constant	.84	1.05	[− 1.23; 2.90]		
BSI depression	− .09	.04	[− .188; 0.00]	− .14	.05
QADP	1.08	.32	[0.44; 1.71]	.25	.001
SADS	.59	.26	[0.09; 1.09]	.17	.02
Age	− .02	.03	[− .07; 0.04]	− .04	.56

BSI Brief Symptom Inventory, *QADP* Questionnaire for the Assessment of Disgust Propensity, *SADS* Scale for the Assessment of Disgust Sensitivity, *B B* values, *SE B* standard error of *B*, *95% CI for B* 95% confidence interval for *B*, *β* beta values, *p p* values

(Curtis et al. 2011). Disgust signals that the likelihood of contagion is high, and motivates adaptive behavior. For example, oral rejection is initiated (gape spitting, vomiting) to free the body from these health-threatening substances.

Finally, we identified depression symptoms as a negative predictor of disgust reduction for the bitter aftertaste. It has been proposed that taste sensitivity to bitter compounds represents a genetic marker for increased vulnerability to depression (e.g., Thomas et al. 2014). The findings are however heterogeneous. Thomas et al. (2014) observed lowered bitter sensitivity in anhedonia. Schienle and Schlintl (2019) identified trait depression as a negative predictor of bitter sensitivity (quinine) in children but not in adults. Similar, in a study by Arrondo et al. (2015), adult patients with a diagnosis of major depression and healthy controls did not differ in their quinine sensitivity. In line with these findings, in the present investigation, individuals who reported a higher degree of depression symptoms did not rate the aftertaste as more bitter or disgusting. However, the disgust decline was slowed down. Delayed emotional recovery (i.e., long-lasting emotions after the termination of an emotionally evocative stimulus) has been described as a marker of different mental disorders

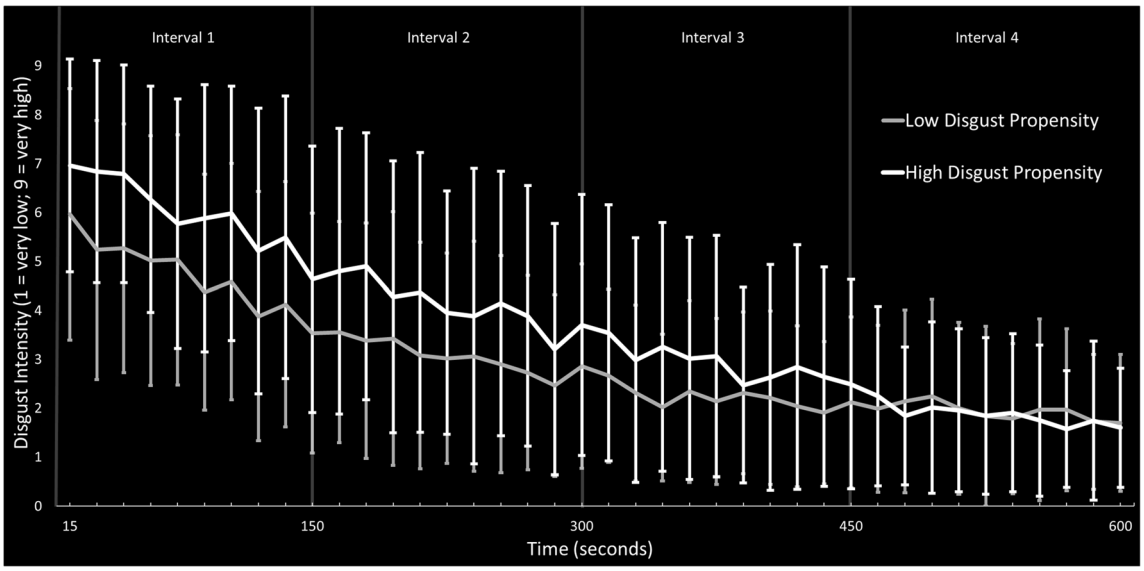

Fig. 1 Time course of the disgust response for participants with high vs. low disgust propensity. Groups created via median split based on the average scores obtained in the Questionnaire for the Assessment of Disgust Propensity (QADP)

(e.g., borderline personality disorder, social anxiety disorder) (Fitzpatrick and Kuo 2015). Somewhat similar, Gold and Zakowski (2004) observed slower emotional and physiological recovery in participants with high vs. low scores on the Beck Depression Inventory. The authors investigated catecholamine responses and mood changes during and after a social stress test.

In conclusion, to the best of our knowledge, this is the first study to examine the temporal course of the wormwood aftertaste response. We were able to demonstrate that trait disgust and low mood were associated with the temporal dynamics of the disgust-aftertaste response.

The present study is limited by a solely female sample and the investigation of only one specific bitter compound. Previous research indicated that some bitterants linger longer than others (e.g., Green and Hayes 2004). Future studies now need to replicate the present findings and need to broaden the research scope. For example, the next step would be to investigate the relationship between the bitter aftertaste response and food preferences/choices, and how disgust propensity impacts these measures. Furthermore, a clinical study should be conducted with patients diagnosed with depression.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval The study protocol was approved by the ethics committee of the University. All procedures were in accordance with the 1964 Helsinki Declaration and its later amendments.

Informed Consent All participants provided written informed consent before data collection.

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