Food Quality and Preference 107 (2023) 104851

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Experimental validation of the food disgust scale using olfactory stimuli

Jeanine Ammann[a,*], Aisha Egolf[b], Jeannette Nuessli Guth[b], Michael Siegrist[b]

[a] Agroscope, Research Group Economic Modelling and Policy Analysis, Ettenhausen, Switzerland
[b] ETH Zurich, Department of Health Science and Technology (D-HEST), Consumer Behaviour, Switzerland

ARTICLE INFO

Keywords:
Odour
Scale
Development
Food disgust
Olfactory stimuli
Sensory

ABSTRACT

Individual disgust reactions can be elicited through different types of sensory stimuli. Most well-known scales measuring disgust are text-based, thus more cognitive stimuli. This study aimed to validate the food disgust scale using olfactory stimuli related to food. For this, 150 participants were invited to our lab to rate different odours for the level of disgust evoked. Exploratory factor analysis (principal axis factoring) revealed two factors. The seven more disgusting items loaded on a first factor, whereas the two less disgusting items loaded on a second factor. The seven items loading on Factor 1 had acceptable reliability (Cronbach's $\alpha = 0.73$, McDonald's $\Omega = 0.72$). Further, Factor Score 1 was significantly correlated with the FDS short, a food disgust sensitivity questionnaire ($r = 0.40$, $p < .001$). We conclude that food disgust sensitivity can help predict individuals' odour perception and our data support the incremental validity of the FDS short. Our study is the first to validate the FDS short using olfactory stimuli. Finally, our study indicates that there is significant potential for the creation of a food disgust odour scale.

1. Introduction

Sufficient food intake is necessary for our survival, but at the same time, food intake poses the risk of coming into contact with pathogens. Omnivores like humans eat a variety of different foods but face the problem of recognising the edibility of foods across different food groups. It has been proposed that the emotion of disgust is a mechanism that helps people to recognise and avoid foods that are potentially harmful (Schaller & Park, 2011). If a stimulus evokes the feeling of disgust, an avoidance reaction is triggered, and this behaviour reduces the risk of coming into contact with harmful bacteria or parasites preventing infections and illness (Curtis et al., 2011; Schaller & Park, 2011). Certain odours (e.g., smell of decayed food), tastes (e.g., bitter taste as a typical taste for plant toxins), or visual cues (e.g., mould) are probably the most immediate valuable indicators of the edibility of foods, respectively the presence harmful pathogens.

There are large individual differences in how strongly a certain stimulus evokes disgust. These differences in the level of disgust experienced are called disgust sensitivity (Curtis et al., 2011; Tybur et al., 2018). The observed differences between individuals may have been caused by differences in the environment (e.g., different levels of pressure from pathogens), or by weighing trade-offs with other competing needs differently (e.g., the need to consume enough calories versus the need to avoid harmful contaminants) (Curtis et al., 2011; Tybur et al., 2018). Different scales for measuring disgust sensitivity have been developed (e.g., Haidt et al., 1994; Hartmann & Siegrist, 2018; Tybur et al., 2009). These scales measure for various domains (e.g. death, sex, moral) how much different stimuli evoke disgust. In all these scales, only a few food related items were used, despite the fact that we are confronted with food related risks on a daily basis. Due to this deficiency of food related stimuli in all existing scales, the food disgust scale (FDS) has been proposed with a purely food and eating related focus (Hartmann & Siegrist, 2018). The study by Hartmann and Siegrist (2018) among others showed that the short version of the FDS (FDS short) is substantially correlated with the Disgust Scale revised (Olatunji et al., 2007) ($r = 0.59$, $p < .001$) and with Food Neophobia (Pliner & Hobden, 1992; Siegrist et al., 2013) ($r = 0.37$, $p < .001$). The FDS short has been further validated in several studies. For instance, Hartmann and Siegrist (2018) demonstrated that individuals with high food disgust sensitivity showed lower willingness to eat insect-based foods. Experimental validation of the FDS short was also provided by another study which used three behavioural tasks and found that the amounts consumed of potentially disgusting products decreased with increasing food disgust sensitivity (Ammann et al., 2018b). Moreover, another study found that

* Corresponding author. Address: Agroscope, Research Division on Sustainability Assessment and Agricultural Management, Tänikon 1, CH-8356 Ettenhausen, Switzerland.
E-mail addresses: jeanine.ammann@alumni.ethz.ch, jeanine.ammann@agroscope.admin.ch, jeanine.ammann@agroscope.admin.ch (J. Ammann).

https://doi.org/10.1016/j.foodqual.2023.104851
Received 24 August 2022; Received in revised form 23 February 2023; Accepted 14 March 2023
Available online 20 March 2023

participants' willingness to eat chocolate decreased with increasing food disgust sensitivity when a behavioural task with chocolate presented as dog poo was conducted in a virtual reality environment, even though participants were aware of the artificiality of the virtual environment (Ammann, Hartmann, et al., 2020).

There are disgust scales that cover odour stimuli. For example, the scale by Haidt et al. (1994), in which one item "While you are walking through a tunnel under a railroad track, you smell urine" was related to odours (but not to food). Liuzza, Lindholm, et al. (2017) developed the Body Odour Disgust Scale (BODS), which has been used in a number of different studies, predicting moral judgement (Liuzza et al., 2019), confirming a source effect[1] (Stefanczyk & Oleszkiewicz, 2020) and extending the behavioural immune system framework (Zakrzewska et al., 2020). Further, they validated it against a criterion variable, namely the emotional reactivity to sweat samples (Liuzza, Olofsson, et al., 2017). The BODS is to our knowledge the only scale with a specific focus on odours, but the scale completely builds on text-based items that describe the odours. Thus, it does not use olfactory stimuli. One explanation for this lack of odour related items in general is the fact that, as pointed out in a review, individuals differ in the way they perceive odours, perception may vary over time, and individuals differ in the way they describe odours (Kaeppler & Mueller, 2013). Therefore, to measure participants' reactions to various olfactory stimuli, instead of using descriptions of these, participants need to smell and evaluate them themselves.

Little is known about how disgust sensitivity and the disgust reaction provoked by cues related to different senses are correlated. For instance, in terms of taste, disgust was found related to bitterness perception, as determined by the PROP taster status (Ammann, Hartmann, et al., 2019; Herz, 2011). For vision, a food disgust picture scale was found to be a reliable measure of disgust sensitivity, which seems to work across cultures (Ammann, Egolf, et al., 2020; Ammann et al., 2018a). For the sense of smell, previous research suggested that it is among the central components of the disgust avoidance system (Stafford et al., 2018). Still, few disgust studies worked with actual odours. One of them was conducted by Croy et al. (2014), who found a significant correlation between disgust sensitivity and unpleasantness of the odour ratings for Civette, an odour that smells like faeces. Higher disgust sensitivity was associated with more unpleasantness compared with lower disgust sensitivity. For pleasant odours like rose, vanilla or coconut, no associations with food disgust sensitivity were observed, however (Croy et al., 2014).

The aim of the present study was to validate the FDS short using olfactory stimuli. For this, we examine how text-based and odour-based measures of disgust are related. Given the substantial correlation between the FDS short and food neophobia, we further examined the correlation between food neophobia and odour related disgust.

2. Materials and methods

2.1. Participants

From June to August 2020, we invited 150 participants to take part in an experimental study in Zurich, Switzerland. Based on medium to large correlations reported between the FDS short and various disgust stimuli in previous studies (Ammann et al., 2018a, 2018b), medium effect sizes were expected. The appropriate sample size for sufficient statistical power to detect medium effect sizes was calculated with the G*Power software (version 3.1.9.4) (Faul et al., 2007)[2]. We recruited participants through online advertisements and from our panel consisting of people who previously participated in one of our studies and stated that they were willing to participate in future studies. To take part in the study, participants had to be between 18 and 75 years old and have a good command of the German language. We made it clear in the advertisement that participation in this study would require participants to smell different odours. Ninety-two participants were female (61%) and participants' age ranged from 18 to 73 years, with an average age of 33 years (SD = 14 y). Five individuals indicated that they follow a vegan diet.

2.2. Questionnaires

As a measure of food disgust sensitivity, we included the eight-item Food Disgust Scale (FDS short, Hartmann & Siegrist, 2018). The FDS short is a measure of food-specific disgust sensitivity, which relies on text-based items to evoke disgust. The scale consists of eight items that depict food-related cues that are considered potential disgust elicitors. Participants rate them on a 6-point scale from 1 (not disgusting at all) to 6 (extremely disgusting). A sample item is: "To eat brown-coloured avocado pulp". All eight items were averaged to calculate mean values ($M = 3.36$, $SD = 0.82$) and the scale's reliability was good ($\alpha = 0.70$).

Participants' tendency to avoid new and unfamiliar foods was assessed through the Food Neophobia Scale (FNS, Pliner & Hobden, 1992). On a scale from −3 (do not agree at all) to 3 (totally agree), participants indicated their level of agreement with ten items. A sample item is: "I do not trust new foods". The ten items were averaged to calculate mean values ($M = 2.48$, $SD = 0.93$) and the scale's reliability was good ($\alpha = 0.82$).

2.3. Stimuli

Odour stimuli were selected based on two criteria. First, we only included substances that can be used as food additives and pose no health risk. Second, we aimed to obtain a diverse selection of odours, covering a range of different domains (e.g., meat, fruit, body odour) and various levels of disgust, as assessed in a small pretest among members of the research group. For disgust studies, stimuli must be chosen with care to prevent possible ceiling effects. If a chosen odour elicited very strong feelings of disgust, this could result in carry-over effects, meaning that substances that participants subsequently smell would be perceived more negatively.

All stimuli used are listed in Table 1, together with a short description of the odours, and the concentration used in our study. The concentrations were chosen in accordance with the safety data sheets to make sure that there was no health risk for participants. We coded each odour with a capital letter, which we used to guide participants through the experiment.

The substances were diluted using propylene glycol to produce a total amount of 15 ml liquid, which was then filled into a small wide-neck brown glass flacon. The bottles had a total capacity of 30 ml. By filling them with 15 ml only, there was enough headspace so that odours can develop more easily and accidental spilling of the liquid was less probable.

2.4. Procedure

The time of data collection made it necessary to introduce protective measures against a possible infection with the new corona virus (SARS-CoV-2). These measures included regular hand washing with soap, treatment of all surfaces and objects before and after the experiments

[1] Source effect: Unpleasant odours emitted by an external source are perceived as more disgusting than those emitted by oneself, as described by Herz, R. (2012). *That's disgusting: Unraveling the mysteries of repulsion.* WW Norton & Company.

[2] The results indicated that a sample size of 138 can detect medium effect sizes ($\rho = 0.3$, $\alpha = 0.05$, two-tailed), statistic power = 0.95.

Table 1
Information about the odour stimuli used including sample codes, concentrations in propylene glycol used, and CAS numbers.

Chemical substance	Name (Code)	CAS number	Smell	Conc. [%]
1) Dimethyl trisulfide	Meat (O)	3658-80-8	Foul, meaty	0.10
2) O-Toluenethiol	Liver (T)	137-06-4	Meat/liver, sulfurous	0.10
3) 2-Furan-methan-ethiolformate	Egg (K)	59020-90-5	Meat/egg, sulfurous	0.10
4) Trimethylamine HCl (10% solution)	Fish (E)	593-81-7	Fish, ammoniac	0.05
5) Valeric Acid (10% solution)	Sweat (W)	109-52-4	Sweat putrid	0.07
6) Ghee flavour	Ghee (L)	none	Rancid milk	0.60
7) Salami flavour	Salami (C)	none	Salami, smoky	0.60
8) 2-Heptanone	Cheese (S)	110-3-0	Blue cheese, fruity	2.00
9) Isoamyl acetate (10% solution)	Banana (R)	123-92-2	Banana, fruity	0.07

Note. Disgust ratings were given on a scale from 0 (not disgusting at all) to 100 (extremely disgusting).

with disinfectant and strict admission of healthy individuals only. Furthermore, the experimenter exercised physical distancing when instructing participants and left the room while they completed the study.

Upon arrival in our laboratory, participants were greeted by the experimenter who introduced them to the study design. It consisted of two parts and participants were asked to sign a written consent. In a first part of the study, participants filled in a few questionnaires, including questions about demographics, the FDS short and the FNS. In the second part, participants smelled nine odour samples. The experimenter explained them in detail how to smell samples during the introduction. Participants were instructed to take the flask into their hand, open it and first smell the lid. Next, they should smell the flask and rate the odour using the questions displayed on the computer screen. For each of the nine odour samples, participants indicated how disgusting they found them on an interactive slider ranging from 0 (not disgusting at all) to 100 (extremely disgusting). After participants had smelled and rated five odours, we instructed them to take a short break and smell coffee beans. This procedure aimed to prevent olfactory fatigue. Finally, to minimise possible carry over effects, all stimuli were presented in randomised order.

We collected all data through an online survey, which we created and ran with Qualtrics XM (Provo, UT, USA). We gave participants a computer to provide their answers. Upon completion of this second part, the experimenter thanked and debriefed participants before paying them. The study took around 15 min to complete and participants received 10 Swiss Francs (approximately 10 USD) for their participation. The Ethics Committee of ETH Zurich approved the study (application EK 2020-N-13).

2.5. Data analysis

We conducted an exploratory factor analysis (principal axis factoring) and varimax rotation to identify the underlying factors for the nine odours. The main aim of the exploratory factor analysis was to reduce the items into a smaller set of factors that explain the maximum amount of variance using the smallest number of explanatory constructs (Field, 2009). We used both the scree plot and the eigenvalues larger than one criterion to identify the number of factors. Further, we used the interpretability criterion, that is, we made sure that factors were interpretable. We used the Kaiser-Meyer-Olkin measure (KMO $\geq$ 0.5) and Bartlett's test of sphericity (p <.05) to determine the adequacy of the dataset for a factor analytical procedure (Yong & Pearce, 2013). Factor scores were calculated using the Anderson-Rubin method. In addition, we investigated the relationship between the factor scores, food neophobia and food disgust sensitivity using Pearson's correlations. Data were analysed with Statistical Package for the Social Sciences (SPSS) version 26 (IBM, New York, USA) for Windows.

3. Results

We ran an exploratory factor analysis using principal axis factoring and varimax rotation on the nine odour stimuli. The overall KMO measure was 0.74 and Bartlett's test of sphericity revealed statistical significance (p <.001). Following both Kaiser's criterion and inspection of the screeplot, the analysis revealed two factors (Table 2). The first factor explained 22.2 % of variance, whereas the second factor explained 9.5 % of variance. Table 2 shows the factor loadings after rotation. The odours clustering on the same factor indicate that Factor 1 summarises the more disgusting odours, whereas Factor 2 summarises the less disgusting odours.

The cheese (S) and banana (R) odours received the lowest disgust ratings. From previous work, we know that plants pose different risks than meat (Ammann, Siegrist, et al., 2019). It is therefore not surprising that the banana odour received the lowest disgust ratings. As only two items loaded on Factor 2, subsequently resulting in a low Cronbach's α, and those items were generally rated as not disgusting, we decided to omit them from further analyses.

The remaining seven odours loaded on Factor 1 with factor loadings between 0.41 and 0.72. Next, we investigated the relationship between the Factor Score 1, food neophobia and food disgust sensitivity using Pearson's correlations (Table 3). As expected, the FDS short and FNS were also correlated (r = 0.50, p <.001). We further find that Factor Score 1 is significantly negatively correlated with age (r = -0.34, p <.001). Additionally, significant positive correlations are found for the FDS short (r = 0.40, p <.001), and significant but smaller correlation with food neophobia (r = 0.19, p <.05). Overall, these results support the validity of the FDS short.

4. Discussion

In the present study, we aimed to add experimental validation for the FDS short by using odour stimuli. Seven disgust odours loaded on a first factor, whereas the two less disgusting odours, that is, banana and cheese, loaded on a second factor. The banana smell was evaluated very

Table 2
Odours used to assess individual disgust reactions, including their factor loadings following principal axis factor analysis and varimax rotation, mean values, standard deviations, minimum and maximum values (N = 150).

Items	Factor Loading		Disgust rating		
	1	2	M (SD)	Min	Max
Meat (O)	**0.72**	−0.17	75.7 (27.2)	0	100
Liver (T)	**0.61**	0.12	74.6 (26.1)	2	100
Egg (K)	**0.57**	0.168	68.6 (29.9)	0	100
Sweat (W)	**0.45**	−0.01	56.6 (30.5)	0	100
Fish (E)	**0.45**	0.09.	64.0 (30.2)	0	100
Salami (C)	**0.45**	0.38	27.2 (27.5)	0	100
Milk (L)	**0.41**	0.18	46.3 (30.4)	0	100
Cheese (S)	0.03	**0.62**	23.6 (24.6)	0	96
Banana (R)	0.04	**0.46**	15.8 (20.7)	0	93
% of variance	22.20	9.47			
Cronbach's α	0.73	0.45			
McDonald's Ω	0.72	–			

Note. Seven items loaded on Factor 1, two items loaded on Factor 2. The percentage of variance explained and the Cronbach's α / McDonald's Ω are calculated for the items loading on the factor (printed in bold).

Table 3
Correlations for sex, age, food disgust sensitivity, food neophobia and the two factor scores (N = 150).

		1	2	3	4	5
1	Sex	1				
2	Age	−0.14	1			
3	FDS short	0.19*	-0.05	1		
4	FNS	0.05	0.09	0.50***	1	
5	Factor Score 1	0.15	-0.34***	0.40***	0.19*	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sex = 0 (male), 1 (female); FDS short = eight-item Food Disgust Scale, FNS = Food Neophobia Scale.

positively, and a ceiling effect seems plausible. Cheese is generally a very positively valued product in Switzerland, the country of chocolate and cheese. Therefore, the smell of cheese is probably more related to liking of cheese and less to disgust sensitivity. This could be different in countries in which cheese is less appreciated, however. Factor Score 1 was highly correlated with the FDS short. Noteworthy, these items relate all to foods with a high risk of contamination and sweat, which can be seen as indicator of a lack of hygiene, thus supporting the construct validity of the scale.

We found not only a significant, but also a substantial correlation between the FDS short and Factor Score 1. In other words, the FDS short predicts quite well how much disgust is evoked by various smells. This is relevant for the validity of the FDS short, because the present results suggest that the FDS short is correlated with the perception of sensory cues (odours) that are not included in the items of the FDS short. The study by Ammann et al. (2018b) included a meat, a juice, and an insect task. Correlations between the behavioural tasks and the FDS short in their study ranged from 0.26 to 0.51, which is a similar range as the correlations reported here for the different odours.

The size of the correlation between FDS short and Factor Score 1 suggest that both measure only to some extent the same construct. Higher correlations with the FDS short ($r = 0.64$) were found for the Food Disgust Picture Scale, which uses pictures to elicit disgust (FDPS; Ammann et al., 2018a). It seems that the type of disgust elicitor used impacts the resulting disgust reaction. The FDS short and FDPS have in common that they use 'visual' stimuli (text or pictures) and are therefore processed in a similar way. The FDS is text-based, thus the processing of the stimuli is based on higher cognitions such as imagination of the food and beliefs about how it would taste. In contrast, the FDPS uses directly visual perceptive disgust cues using pictures, a real exposure is missing and the disgust evaluation probably to some degree anticipated. The direct exposure to the olfactory stimuli measures disgust reaction rather on the sensory level of perception. Odours can be processed without conscious perception (Albrecht & Wiesmann, 2006), enabling them to be more automatically processed and less influenced by cognitions.

There are a few limitations of our study that need to be acknowledged. Due to the fact that our study was conducted at ETH Zurich, many students participated, resulting in a comparably young sample. In future studies, it would be of interest to test for age differences in odour perception, especially because odour perception varies over time (Kaeppler & Mueller, 2013). For instance, it would be interesting to investigate whether participants rate the odours as more pleasant or disgusting with increasing age. Additionally, conducting this study during the COVID-19 pandemic made it difficult to recruit and test a sufficiently large sample. Future studies should replicate the findings using larger sample sizes.

Our study provides first and exploratory evidence for the relationship between disgust ratings of various odours and individuals' food disgust sensitivity. Building on the results of our study, future research could aim to create an odour scale. As we only tested nine odours, future research should add to this evidence and test a wider selection of odour stimuli and also test it in other countries. We think that the FDS short and an odour scale would be to some degree complementary instruments. If we are interested in the acceptance of unprocessed insects as food (i.e., a visual stimuli), the FDS short seems to be a good instrument to predict consumers' reactions (Ammann et al., 2018b). We would expect however, that for the acceptance of algae in food, where the smell aspect may be more important compared to the visual aspect, an odour scale may have more predictive power. An interesting avenue for future research is to better understand in which situation an odour scale and in which situation the FDS short has more explanatory power.

Our results indicate that there is great potential for the development of a disgust odour scale for the assessment of disgust sensitivity. Furthermore, future research should investigate in more detail how disgust measures differ when using different sensory channels. Given that previous research reported that effects differed depending through which sensory channel a disgust stimulus was presented (Croy et al., 2013), it is of crucial importance to investigate various sensory channels to understand the underlying mechanisms and the resulting disgust reactions. As mentioned earlier, as odours can be processed without conscious perception (Albrecht & Wiesmann, 2006), the resulting disgust reaction is less influenced by cognitions as compared to the visual stimulus of text. For food, the perception and assessment of odours is especially important. It allows a second sensory evaluation after visual contact, without having to expose oneself to pathogens by means of tasting.

5. Conclusion

In this study, we provide additional experimental validation for the FDS short. Still, given that the two measures are not perfectly correlated, we conclude that depending on the sensory channel through which a disgust stimulus is presented, individuals' disgust reaction differs. This is an important finding which provides fertile ground for future research to build on.

CRediT authorship contribution statement

Jeanine Ammann: Formal analysis, Supervision, Writing – original draft. **Aisha Egolf:** Conceptualization, Supervision, Writing – review & editing. **Jeannette Nuessli Guth:** Methodology, Writing – review & editing. **Michael Siegrist:** Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

The authors thank Stephan Nelius for his support in data collection and Margret Keck for sharing her expertise in odour research. This study was financially supported by the Swiss National Science Foundation (project number 165630).

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