When Evolution Works Against the Future: Disgust's Contributions to the Acceptance of New Food Technologies

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New food technologies have a high potential to transform the current resource-consuming food system to a more efficient and sustainable one, but public acceptance of new food technologies is rather low. Such an avoidance might be maintained by a deeply preserved risk avoidance system called disgust. In an online survey, participants ($N = 313$) received information about a variety of new food technology applications (i.e., genetically modified meat/fish, edible nanotechnology coating film, nanotechnology food box, artificial meat/milk, and a synthetic food additive). Every new food technology application was rated according to the respondent's willingness to eat (WTE) it (i.e., acceptance), risk, benefit, and disgust perceptions. Furthermore, food disgust sensitivity was measured using the Food Disgust Scale. Overall, the WTE both gene-technology applications and meat coated with an edible nanotechnology film were low and disgust responses toward all three applications were high. In full mediation models, food disgust sensitivity predicted the disgust response toward each new food technology application, which in turn influenced WTE them. Effects of disgust responses on the WTE a synthetic food additive were highest for and lowest for the edible nanotechnology coating film compared to the other technologies. Results indicate that direct disgust responses influence acceptance and risk and benefit perceptions of new food technologies. Beyond the discussion of this study, implications for future research and strategies to increase acceptance of new food technologies are discussed.

KEY WORDS: Acceptance; benefit perception; disgust; new food technologies; risk perception

1. INTRODUCTION

1.1. Importance of New Technologies

The global human population continues to grow, and to supply its increasing food demand while environmental resources are limited, new food technologies and new food sources are required. Especially, the consumption of animal-based food products demands excessive environmental resources (González, Frostell, & Carlsson-Kanyama, 2011; Walker, Rhubart-Berg, McKenzie, Kelling, & Lawrence, 2007). Furthermore, animal-based food consumption is quite high in developed countries (Bruinsma, 2003), which is associated with an increased occurrence of certain types of chronic diseases (Walker et al., 2007). Thus, it is crucial to change traditional food production to a more efficient and sustainable system. New food technologies provide diverse opportunities for that purpose. By using gene technology, for example, the nutrient quality of meat can be improved or animals can be engineered to be more resistant to diseases (Lievens, Petrillo, Querci, & Patak, 2015). Other technologies, for example, nanotechnology, have advantages such as prolonging food shelf life, which could reduce

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food waste and thus conserve resources (Chaudhry et al., 2008). A high potential to reduce greenhouse gas emissions and conserve land, water, and energy use can be accomplished by substituting animal proteins through more environmental-friendly alternatives like artificial meat (Tuomisto & de Mattos, 2011) or milk (Gahzoul, 2014). In light of recent studies showing an association between disgust and the acceptance of new food technologies like gene technology (Clifford & Wendell, 2016; Prokop, Ozel, Usak, & Senay, 2013; Scott, Inbar, & Rozin, 2016) and artificial meat (Siegrist, Sütterlin, & Hartmann, 2018; Verbeke et al., 2015), this study aimed to understand how disgust impacts public acceptance and risk and benefit perceptions of various new food technologies.

1.2. Acceptance of New Food Technologies

Despite the enormous potential of new food technologies, public acceptance tends to be low (Gaskell et al., 2000; Rollin, Kennedy, & Wills, 2011; Siegrist, Cousin, Kastenholz, & Wiek, 2007). The major reasons for this reluctance seem to be the risk and benefit perceptions of new technology (Alhakami & Slovic, 1994; Bearth, Cousin, & Siegrist, 2014; Gupta, Fischer, & Frewer, 2012; Siegrist, 2008; Siegrist et al., 2007). New food technologies, such as gene technology (Finucane & Holup, 2005; Slovic, 1987; Sparks & Shepherd, 1994) or nanotechnology (Kuzman & VerHage, 2006; Stampfli, Siegrist, & Kastenholz, 2010), pose an unknown (vs. known) risk as they are relatively new sciences (Finucane & Holup, 2005). Thus, the consequences for human health and the environment are still difficult for scientists to accurately estimate. On the consumer side, the perceived risk of new food technologies is seemingly shaped by factors related to unknown risks (e.g., uncontrollability, unfamiliarity, observability) and to dread (e.g., certain to be fatal, high risk for future generations, involuntary) (Slovic, 1987). Further investigations revealed that a rather large proportion of people are apparently not well informed about various new technologies (Bearth et al., 2014; Bearth, Cousin, & Siegrist, 2016; Eurobarometer, 2001; Gaskell et al., 2000). Nevertheless, providing risk and benefit information to increase acceptance is rather difficult and, in some cases, even counterproductive (Kahan, Braman, Slovic, Gastil, & Cohen, 2009; Scholderer & Fewer, 2003; Siegrist et al., 2018). It seems people cannot accurately evaluate information regarding the risks and benefits of new technologies (Finucane, Alhakami, Slovic, & Johnson, 2000; Schütz & Wiedemann, 2008).

In complex situations with insufficient knowledge, people often rely on simple cues to make decisions about risks and benefits (Siegrist & Cvetkovich, 2000). An increasing number of studies found that feelings associated with a new food technology impacted risk and benefit perceptions (Connor & Siegrist, 2010; Finucane et al., 2000; Siegrist et al., 2007; Siegrist, Hartmann, & Sütterlin, 2016; Siegrist, Stampfli, Kastenholz, & Keller, 2008) as well as acceptance of new food technologies (Scott et al., 2016; Siegrist & Sütterlin, 2016; Siegrist et al., 2007, 2016, 2018). This kind of decision making was described by Finucane and colleagues under the term "affect heuristic" (Finucane et al., 2000; Slovic, Finucane, Peters, & MacGregor, 2002, 2004), which postulates that the affect associated with an object impacts perceptions and evaluations of that object. Using one's feelings (affect or emotions) as a source of information for making judgments (Schwarz, 2012) is largely based on the rapid, associative, automatic *experiential system* of thinking rather than on the slow, logical, rational *analytical system* (Epstein, 1991, 1995; Slovic et al., 2002, 2004). This was empirically supported by studies showing that people seem to rely especially on their feelings if they do not know much about a topic (Ottati & Isbell, 1996; Sedikides, 1995; Sokolowska & Sleboda, 2015). Knowledge is related to the analytical system. However, affect is a quite broad concept that refers to the valence (positive/ negative) and arousal (high/low) elicited by an object of judgment. Although an evaluation of an object by affect can be positive or negative, emotions convey additional information about a specific appraisal pattern (Clore & Huntsinger, 2007; Clore & Ortony, 2008; Lerner, Gonzalez, Small, & Fischhoff, 2003; Lerner & Keltner, 2000; Schwarz, 2012) and have more emotion-specific target influences (Clore & Huntsinger, 2007; Lerner & Keltner, 2000; Lerner et al., 2003; Schnall, Haidt, Clore, & Jordan, 2008; Schwarz, 2012). One emotion that recently attracted attention when examining attitudes toward new food technologies is disgust (Clifford & Wendell, 2016; Kahan & Hilgard, 2016; Prokop et al., 2013; Scott et al., 2016; Siegrist et al., 2018). Disgust is inseparable from affect as it is also associated with negative valence and arousal (Gerber et al., 2008; Haberkamp, Glombiewski, Schmidt, & Barke, 2017). However, disgust fulfills quite specific functions that are discussed in the next section.

1.3. Acceptance and Disgust

Disgust functions to protect an organism against the ingestion of potentially harmful agents (Curtis & Biran, 2001; Rozin & Fallon, 1987). In particular, it is assumed that disgust prevents an organism from coming in contact with hard-to-detect parasites and is therefore sensitive to cues that indicate a risk for pathogenic contamination (Curtis, de Barra, & Aunger, 2011). In our ancestral past, every unknown food source entailed the risk of eating harmful substances (Clifford & Wendell, 2016; Nesse, 2005; Prokop et al., 2013; Scheibehenne et al., 2014). Given the burden of low food availability, our ancestors were pressed to find new food sources and eat anything available. However, since new food sources entailed the risk of eating contaminated foods, there was a tradeoff between food intake and eating contaminated, and especially, new foods. A system that restrained eating risky foods was advantageous and disgust was the most likely motivator for avoidance (Al-Shawaf, Lewis, Alley, & Buss, 2015; Curtis, Aunger, & Rabie, 2004; Curtis & Biran, 2001; Haidt, McCauley, & Rozin, 1994).

To date, little is known about the impact of disgust on acceptance of new food technologies. The available evidence supports a negative association between disgust and the acceptance of gene technology (Prokop et al., 2013; Scott et al., 2016) and artificial meat (Siegrist et al., 2018). These associations were observed for state disgust (Scott et al., 2016; Siegrist et al., 2018; Verbeke et al., 2015) as well as trait disgust (Prokop et al., 2013; Scott et al., 2016). Hence, people with higher direct disgust responses (state) toward a new food technology (Scott et al., 2016; Siegrist et al., 2018) as well as people who are generally more disgust sensitive (trait) seem be more opposed to new food technology (e.g., gene technology) (Prokop et al., 2013; Scott et al., 2016). Moreover, new food technologies are often perceived as unnatural (Siegrist & Sütterlin, 2017; Siegrist et al., 2016, 2018), which was recently shown to be associated with disgust responses toward (Siegrist et al., 2018; Verbeke et al., 2015) and rejection of new technologies (Siegrist et al., 2018; Tenbult, de Vries, Dreezens, & Martijn, 2005). Unnaturalness also appears to relate to contamination (Rozin, 2005b; Scott, Inbar, Wirz, Bossard, & Rozin, 2018) as unnatural substances seemingly have contagious properties (Rozin, 2005a, 2006). For example, in a study by Rozin (2005a), tiny amounts of an unnatu-

ral substance added to a food reduced participants' perceived naturalness of the food substantially. Furthermore, Jaeger et al. (2018) observed that people rate pictures of apples with internal browning as less natural (and more disgusting and more rotten) than apples with no such signs of decay (i.e., potential contamination). Noteworthy, unnatural foods rather act as a contaminant themselves instead of transmitting an infection (Scott et al., 2018). However, what is not yet clear is the impact of disgust on other new food technologies (next to genetically modified [GM] foods, or artificial meat), which also compromise disgust-related aspects (e.g., unfamiliarity, unnaturalness) such as nanotechnology, artificial milk, and synthetic food additives; and whether these effects vary for different new food technologies. Thus, the aim of the first study was to compare the impact of disgust on the acceptance of a broader range of new food technologies.

The impact of disgust on new technologies was further investigated and discussed in the area of moral psychology (Blancke, Van Breusegem, De Jaeger, Braeckman, & Van Montagu, 2015; Gray & Schein, 2016; Inbar, Scott, & Rozin, 2016; Scott et al., 2016). The causes for moral opposition to new food technologies (i.e., gene technology) have encouraged a debate within the scientific community (Gray & Schein, 2016; Inbar et al., 2016; Scott et al., 2016). Much of that debate revolves around the causal relationships between disgust, risk, and (moral) opposition to new food technologies (Gray & Schein, 2016; Inbar et al., 2016; Scott et al., 2016). Scott et al. (2016) found that disgust is the main factor for (moral) oppositions to gene technology and concluded that (moral) opponents are insensitive to risks. In contrast, Gray and Schein (2016) argue that a link between disgust and (moral) judgments is fully mediated through perceived risk. Moreover, Gray and Schein claim that making a moral judgment would not be possible or make sense without considering the risks or harms.

Indeed, it seems reasonable that the risk posed by a new food technology is a crucial factor for its acceptance. Nevertheless, we suggest that people are unlikely to consciously make risk (and benefit) analyses to decide if they accept a certain technology. We rather assume that such a risk assessment is done more or less unconsciously through working mechanisms such as the disgust system. The disgust system is sensitive to various sources of information (e.g., local infection risk, experiences with sickness, one's current physiological state, exposure history

of disgust elicitors, general environmental infection risk) that must be absorbed and integrated to adaptively shape a person's risk avoidance behaviors (Curtis et al., 2011). Such risk analysis by the disgust system is likely done on the rapid, automatic system of thinking and the experience of disgust will motivate an organism to avoid a risky behavior or object. Nevertheless, it might be that people's experience of disgust is used as a source of information to guide their risk and benefit perceptions of new food technologies, which we also wanted to test in this study.

In sum, we suggest that evaluations of acceptance as well as risk and benefit perceptions regarding a new technology are influenced by experienced disgust in which the disgust system assesses a potential danger rather unconsciously prior to the evaluation. Therefore, we were also interested in examining the effects of state and trait disgust on acceptance as well as risk and benefit perceptions of a technology.

1.4. Study Aim

This study aimed to examine how the disgust system impacts evaluation of new food technologies. Considering the literature, we suggest that state disgust evoked by a new food technology not only influences overall judgment for acceptance measured by willingness to eat (WTE) or willingness to drink (WTD), but also risk and even benefit perceptions. Additionally, we hypothesized that trait food disgust sensitivity—the individual difference in experiencing disgust toward food-related disgust elicitors—is a determining factor for a state disgust response toward a specific new food technology application. In contrast to previous research (Prokop et al., 2013; Scott et al., 2016; Siegrist et al., 2018; Verbeke et al., 2015), we examined these associations for a broad range of new food technologies, including gene technology, nanotechnology, artificial meat, artificial milk, and a synthetic food additive. Furthermore, to date, only few studies have examined the effect of disgust toward a food technology on risk perception (e.g., Kahan & Hilgard, 2016; Scott et al., 2016) and to the best of our knowledge, no one has studied its effects on benefit perceptions of food technologies.

Our hypothesized model (depicted in Fig. 1) is applied to each examined new food technology (gene technology, nanotechnology, and synthetic food additive) and new food sources (artificial meat and milk). In particular, we hypothesized that food disgust sensitivity increases the disgust response, which decreases the acceptance (measured by WTE/WTD)
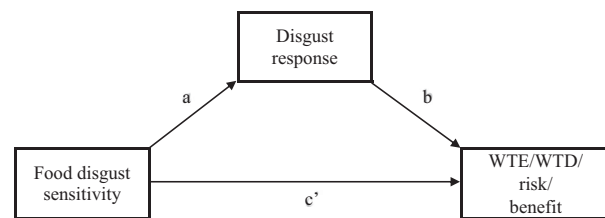

Fig. 1. Proposed model explaining willingness to eat (WTE) /willingness to drink (WTD), risk and benefit perceptions of new food technologies by food disgust sensitivity, and state disgust response. A full mediation over disgust response was expected while controlling for the direct effect (c') of food disgust sensitivity on WTE/WTD and risk and benefit perceptions.

and benefit perception but increases risk perception. For all models, we expected that the disgust response would fully mediate an association between trait disgust and WTE/WTD, risk, and benefit.

2. METHODS

2.1. Participants

An online survey was completed by 330 people from the German-speaking part of Switzerland. Participants were recruited from a commercial provider of sampling services (Respondi AG). Quota sampling was used for the gender and age variables. Participants whose total survey duration time was less than half of the median (as it was recommended by the commercial provider) were excluded ($N = 17$). The final sample consisted of $N = 313$ participants with a mean age of 45 years ($SD = 14$ years) and with 50.8% ($N = 159$) being female. The educational levels were 4.8% ($N = 15$) low (primary and secondary school), 46.3% ($N = 145$) middle (vocational middle or higher vocational school), and 47.9% ($N = 150$) high (higher secondary school, college, or university). A small proportion of 1.0% ($N = 3$) indicated they had none of the mentioned education levels.

2.2. Questionnaire/Measures

Since several technologies included meat, fish, or milk products, we wanted to rule out any confounding effects of general disgust responses to these. Thus, participants were asked how disgusting they perceived meat, fish, and milk to be before the food technology descriptions were rated. Response ratings were given on a sliding scale ranging from 0 (not disgusting at all) to 100 (extremely disgusting).

Food disgust sensitivity was measured by the short version of the Food Disgust Scale (FDS) (Hartmann & Siegrist, 2018), which consists of eight items from eight food disgust domains: animal flesh, hygiene, human contamination, mold, decaying fruits, decaying vegetables, fish, and living contaminants. In the FDS, people rate how disgusting they perceive different situations with foods (e.g., "To eat with dirty silverware in a restaurant" or "To eat hard cheese from which mold was cut off") on a six-point scale ranging from 1 (not disgusting at all) to 6 (extremely disgusting). Average scores were calculated across all items ($M = 3.58$, $SD = 0.97$, Cronbach's $\alpha = 0.78$). The scale seems to be a reliable and valid measurement tool to predict various eating and food behaviors (Ammann, Hartmann, & Siegrist, 2018b; Egolf, Siegrist, & Hartmann, 2018).

The survey included different product descriptions regarding GM meat, GM fish, edible nanotechnology coating films, nanotechnology food boxes, artificial meat, artificial milk, and a synthetic food additive (citric acid) for beverages. For every technology, the functions and purposes were explained. For the nanotechnology applications, participants received additional general information[1] because, apparently, they do not have much knowledge, such as the meaning of nano (Cobb & Macoubrie, 2004; Eurobarometer, 2001). Thus, for nanotechnology applications, we also mentioned that experts are not sure about possible risks for human health and environment, similar to other studies (Gaskell et al., 2010; Siegrist et al., 2007). The detailed descriptions of the different food technologies and new food sources can be found in Table I.

Participants rated each technology application according to acceptance, perceived risk and benefit, and disgust. Food acceptance was assessed by asking participants whether they were willing to eat a given product using a sliding scale ranging from 0 (certainly not) to 100 (absolutely). Because the products related to nanotechnology were food packaging applications and not the food itself, we changed the phrasing for "willingness to eat" to "willingness to eat meat that is coated with such a nanotechnology film" and "willingness to eat food that was stored in

such a nanotechnology food box." With respect to artificial milk and the citric acid in beverages (synthetic food additive), we asked people about their WTD.

Participants had to indicate how risky (e.g., "How risky do you perceive GM fish?") or beneficial (e.g., "How beneficial do you perceive GM fish?") they perceived each product and whether they perceived the product as disgusting ("Do you perceive GM fish as disgusting?"). The end points of the sliding scale for risk and benefit were labeled with 0 (not risky/beneficial at all) to 100 (very risky/beneficial) and for disgust with 0 (not disgusting at all) to 100 (extremely disgusting).[2]

2.3. Statistical Analysis

By repeated measurement analysis of variance, we examined whether the disgust response, risk perception, benefit perception, and WTE/WTD were different for the separate food technologies. Mediation models were used to test the suggested associations according to the model depicted in Fig. 1. Separate mediation models were tested for each food technology application regarding WTE/WTD and risk and benefit perceptions. All mediation analyses were done by using the PROCESS macro (Hayes, 2013) in IBM SPSS statistics software package, version 23 (SPSS Inc., Chicago, IL, USA). To rule out an association between disgust responses to new technologies and WTE/WTD that are not due to disgust toward meat, fish, or milk in general, partial correlation analyses were used. Thus, correlations between disgust responses and WTE GM meat, edible nanotechnology coating film, and artificial meat were controlled for general disgust toward meat. The correlation between disgust response and WTE GM fish was controlled for general disgust toward fish. Finally, the correlation between disgust response and WTD artificial milk was controlled for general disgust toward milk.

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[1]General nanotechnology information: "Nanotechnology is a general term for a broad range of technologies that are based on particles and structure of sizes smaller than 100 nanometers. One nanometer is one part in a million."

[2]The complete questionnaire also included other scales to assess people's food technology neophobia, preferences for naturalness, and two questions regarding moral judgments related to GM food and artificial meat. These variables are not relevant for the research reported here and are therefore omitted. All participants filled in the same questionnaire. Sample size was determined for correlational analysis with a power of 0.90, a small to medium effect size of 0.20, and an α error of 0.01 (Cohen, 1988). For data exclusion criteria, see Section 2.1.

Table I. Information Regarding New Food Technology Applications Provided to Participants

New Food Technology Application	Description
GM meat (pork)	Gene technology offers the possibility to produce pork meat that contains healthy omega-3 fatty acids. To do so, a gene that enables production of omega-3 fatty acids is transferred from a roundworm into the pig genome, and thereby, the pig can produce omega-3 fatty acids rather than just unhealthy omega-6 fatty acids.
GM fish	Fish can be genetically modified to increase their resistance against diseases by inserting a human lactoferrin gene. Lactoferrin is an enzyme with antiviral and antimicrobial properties.
Edible nanotechnology coating film	By using nanotechnology, edible coatings for food can be produced that have a thickness of just 5 nm and are not visually detectible. These thin edible films can be used to package, for example, meat, to prevent moisture loss, and thus prolong shelf life. Negative impacts of nanoparticles on health and the environment are still not well understood.
Nanotechnology food box[a]	In nanotechnology food packaging, food boxes with small nanoparticles were developed. Small silver particles in plastic boxes prevent bacterial growth. The main advantage is longer product shelf life. Next to its benefits, this nanotechnology also poses some dangers. Experts are uncertain about whether the silver particles might migrate from the packaging material into the food. Negative impacts on health and the environment are still not well understood.
Artificial meat[b]	Red meat such as beef can be produced through tissue cultivation. To do so, a few cells are obtained from the muscle tissue of cows. These cells are artificially grown and develop into muscle cells. This production method is more environmentally friendly and associated with less animal suffering compared to conventional meat production. The taste of meat produced by tissue cultivation is comparable to conventionally produced meat.
Artificial milk	Basically, milk consists of water, several milk proteins, and fats. To make artificial milk, the DNA sequences of the different milk proteins are constructed and inserted into yeast. The yeast then produces milk proteins. By adding water and aromatic fatty acids, the artificial milk is finished. The artificial milk tastes similar to cow's milk and results in less CO_2 emissions than the traditional milk production. The artificial milk can also be produced lactose-free.
Synthetically produced food additive (citric acid)	Beverages (e.g., lemonades) often include synthetically produced citric acid (E330) as a preservative. The citric acid is produced by specific mold cultures (*Aspergillus niger*).

[a]Description adapted from Siegrist et al. (2007).
[b]Description adapted from Siegrist et al. (2018).
GM, genetically modified.

3. RESULTS

3.1. Effects of Technology on Disgust Response, WTE/WTD, Risk, and Benefit

Mean values and standard deviations of the disgust response, risk, benefit, and WTE/WTD are depicted in Table II. Repeated measurement analysis of variance with Huynh-Feldt correction yielded a significant effect of technology on the disgust response, $F(5.36, 1,671.65) = 50.71$, $p < 0.001$. Subsequent *post hoc* tests with Bonferroni correction revealed that GM applications and the edible nanotechnology coating film were perceived as most disgusting. Analysis of variance revealed a significant effect for risk, $F(4.88, 1,523.85) = 70.80$, $p < 0.001$, with subsequent *post hoc* tests indicating that GM applications and the edible nanotechnology coating film were perceived as riskier than all the other food products. Benefit perceptions were also significantly different for the food technologies, $F(5.12,$ $1,596.52) = 22.51$, $p < 0.001$. *Post hoc* tests showed that artificial meat and milk, the nanotechnology food box, and the synthetic food additive were perceived as the most beneficial. Finally, analysis of variance regarding WTE/WTD was significant, $F(4.93, 1,538.46) = 67.14$, $p < 0.001$. Subsequent *post hoc* tests indicated that people were more willing to drink the synthetic food additive in beverages than any other food technology application.

3.2. Mediation Models

As can be seen in Table III, the mediation effect of the disgust response for the relationship between food disgust sensitivity and the WTE/WTD was significant for all tested food technologies. None of the 95% bias-corrected bootstrap confidence intervals (based on 10,000 bootstrap samples) for the indirect effects included 0, which indicates that the indirect effects from food disgust sensitivity to WTE/WTD

Table II. Mean and Standard Deviation for Disgust Response, Risk Perception, Benefit Perception, and Willingness to Eat (WTE) or Willingness to Drink (WTD) of Different New Food Technologies

	GM Meat M (SD)	GM Fish M (SD)	Nano. Film M (SD)	Nano. Box M (SD)	Art. Meat M (SD)	Art. Milk M (SD)	Syn. Food Additive M (SD)
Disgust response	64.82[a] (30.75)	65.97[a] (29.93)	65.59[a] (30.38)	53.39[b] (29.37)	57.65[b] (31.69)	54.35[b] (31.15)	42.49[c] (29.72)
Risk perception	73.37[a] (25.03)	74.86[a] (23.70)	73.91[a] (25.62)	65.04[b] (26.81)	63.73[b] (27.02)	59.95[b] (27.46)	49.34[c] (27.54)
Benefit perception	26.59[b] (27.07)	26.66[b] (27.15)	27.20[b] (28.40)	39.80[a] (30.19)	37.74[a] (31.91)	34.93[a] (30.42)	36.96[a] (27.67)
WTE/WTD	27.16[c,d,e] (29.17)	24.93[d,e] (27.62)	23.23[e] (26.51)	37.36[b] (30.65)	32.94[b,c] (31.69)	30.95[b,c,d] (30.74)	51.80[a] (31.09)

Note. $N = 313$. For each response, the sliding scale ranged from 0 to 100. Higher values mean higher disgust responses, risk and benefit perceptions, and WTE/WTD. Different superscript letters indicate significant differences at the level of $p \leq 0.001$ between cells for each column. GM, genetically modified; nano. film, edible nanotechnology coating film; nano. box, nanotechnology food box; art., artificial; syn., synthetic.

Table III. Nonstandardized Mediation Coefficients Predicting Willingness to Eat (WTE) or Willingness to Drink (WTD) of Different New Food Technology Applications by the Food Disgust Scale (FDS) and the Disgust Response Toward Each Application

	FDS → Disgust Response B_a	SE	Disgust Response → WTE/WTD B_b	SE	Direct Effect: FDS → WTE/WTD $B_{c'}$	SE	Indirect Effect: FDS → Disgust Response → WTE/WTD $B_a \times B_b$	SE	95% CI	Disgust Response R^2	WTE[a]/ WTD[a] R^2
GM meat	**8.60**[*]	1.73	**−0.59**[*]	0.04	−0.76	1.38	**−5.07**	1.25	(−7.60–−2.67)	0.07	0.39
GM fish	**8.53**[*]	1.68	**−0.60**[*]	0.04	0.34	1.28	**−5.13**	1.21	(−7.55–−2.78)	0.08	0.42
Nano. film	**6.64**[*]	1.74	**−0.42**[*]	0.05	0.68	1.40	**−2.76**	0.90	(−4.69–−1.17)	0.04	0.22
Nano. box	**6.89**[*]	1.67	**−0.71**[*]	0.04	−0.22	1.35	**−4.87**	1.33	(−7.53–−2.31)	0.05	0.46
Art. meat	**10.91**[*]	1.75	**−0.63**[*]	0.05	0.83	1.54	**−6.91**	1.28	(−9.53–−4.48)	0.11	0.39
Art. milk	**7.94**[*]	1.77	**−0.56**[*]	0.05	2.58	1.55	**−4.45**	1.10	(−6.65–−2.31)	0.06	0.31
Syn. food additive	**5.83**[*]	1.71	**−0.75**[*]	0.04	−0.65	1.28	**−4.39**	1.34	(−7.06–−1.82)	0.04	0.52

Note: $N = 313$. Bold indicates significance. Results based on 10,000 bias-corrected bootstrap samples. Nonstandardized coefficients can be interpreted in a similar way as regression coefficients.
[*]$p < 0.001$.
[a]Explained variance by effect B_b and $B_{c'}$.
CI, confidence interval; GM, genetically modified; nano. film, edible nanotechnology coating film; nano. box, nanotechnology food box; art., artificial; syn., synthetic.

were significant. In contrast, none of the direct effects were significant. Therefore, the results indicate that food disgust sensitivity influences the disgust response that subsequently influences the WTE/WTD a food produced across various food technologies. The directions of the effects indicate that the higher the food disgust sensitivity, the stronger the disgust response to a new food technology application and consequently the lower the WTE/WTD.

Table IV depicts the results of the mediation analysis to predict risk perception. As can be seen, all coefficients of food disgust sensitivity predict-

ing the disgust response as well as all coefficients of the disgust response predicting risk perception were significant and in the expected direction. All 95% bias-corrected bootstrap confidence intervals (based on 10,000 bootstrap samples) of the indirect effects were significant. None of the direct effects from food disgust sensitivity to risk perception were significant. The results indicate that people with higher food disgust sensitivity showed higher disgust responses to a new food technology application, which in turn predicted higher risk perception.

Table IV. Nonstandardized Mediation Coefficients Predicting Risk Perception of Different New Food Technology Applications by the Food Disgust Scale (FDS) and the Disgust Response Toward Each Application

	FDS → Disgust Response		Disgust Response → Risk		Direct Effect: FDS → Risk		Indirect Effect: FDS → Disgust Response → Risk			Disgust Response	Risk[a]
	B_a	SE	B_b	SE	$B_{c'}$	SE	$B_a \times B_b$	SE	95% CI	R^2	R^2
GM meat	**8.60***	1.73	**0.49***	0.04	−2.06	1.23	**4.23**	1.01	(2.30–6.31)	0.07	0.35
GM fish	**8.53***	1.68	**0.52***	0.04	−2.45	1.12	**4.41**	1.01	(2.48–6.39)	0.08	0.40
Nano. film	**6.64***	1.74	**0.40***	0.04	−2.79	1.37	**2.62**	0.79	(1.15–4.26)	0.04	0.21
Nano. box	**6.89***	1.67	**0.63***	0.04	−3.60	1.20	**4.31**	1.12	(2.09–6.52)	0.05	0.45
Art. meat	**10.91***	1.75	**0.44***	0.04	2.43	1.40	**4.85**	0.95	(3.09–6.80)	0.11	0.31
Art. milk	**7.94***	1.77	**0.53***	0.04	−1.65	1.34	**4.22**	1.00	(2.28–6.21)	0.06	0.35
Syn. food additive	**5.83***	1.71	**0.58***	0.04	0.38	1.28	**3.39**	1.06	(1.35–5.48)	0.04	0.40

Note: $N = 313$. Bold indicates significance. Results based on 10,000 bias-corrected bootstrap samples. Nonstandardized coefficients can be interpreted in a similar way as regression coefficients.
*$p < 0.001$.
[a]Explained variance by effect B_b and $B_{c'}$.
CI, confidence interval; GM, genetically modified; nano. film, edible nanotechnology coating film; nano. box, nanotechnology food box; art., artificial; syn., synthetic.

Table V. Nonstandardized Mediation Coefficients Predicting Benefit Perception of Different New Food Technology Applications by the Food Disgust Scale (FDS) and the Disgust Response Toward Each Application

	FDS → Disgust Response		Disgust Response → Benefit		Direct Effect: FDS → Benefit		Indirect Effect: FDS → Disgust Response → Benefit			Disgust Response	Benefit[a]
	B_a	SE	B_b	SE	$B_{c'}$	SE	$B_a \times B_b$	SE	95% CI	R^2	R^2
GM meat	**8.60***	1.73	**−0.48***	0.04	0.35	1.39	**−4.12**	1.04	(−6.24–−2.14)	0.07	0.29
GM fish	**8.53***	1.68	**−0.59***	0.04	3.27	1.29	**−4.99**	1.20	(−7.41–−2.67)	0.08	0.39
Nano. film	**6.64***	1.74	**−0.41***	0.05	2.56	1.54	**−2.75**	0.86	(−4.56–−1.20)	0.04	0.19
Nano. box	**6.89***	1.67	**−0.65***	0.05	0.71	1.41	**−4.50**	1.25	(−7.03–−2.09)	0.05	0.40
Art. meat	**10.91***	1.75	**−0.57***	0.05	5.04	1.68	**−6.17**	1.15	(−8.49–−3.96)	0.11	0.28
Art. milk	**7.94***	1.77	**−0.54***	0.05	5.10	1.56	**−4.26**	1.02	(−6.33–−2.33)	0.06	0.28
Syn. food additive	**5.83***	1.71	**−0.40***	0.05	1.65	1.50	**−2.31**	0.78	(−3.93–−0.91)	0.04	0.18

Note: $N = 313$. Bold indicates significance. Results based on 10,000 bias-corrected bootstrap samples. Nonstandardized coefficients can be interpreted in a similar way as regression coefficients.
*$p < 0.001$.
[a]Explained variance by effect B_b and $B_{c'}$.
CI, confidence interval; GM, genetically modified; nano. film, edible nanotechnology coating film; nano. box, nanotechnology food box; art., artificial; syn., synthetic.

Mediation models regarding benefit perception yielded similar results (Table V). All coefficients of food disgust sensitivity predicting disgust responses and all coefficients of the disgust response predicting benefit as well as all indirect effects were significant. None of the direct effects were significant. Thus, people who responded with more disgust to a new food technology rated the benefits for a certain food technology application lower than people who responded with less disgust.

3.3. Control Variables

Control analyses (correlations and partial correlations) to rule out confounding effects of general disgust toward meat, fish, and milk were all significant at the level of $p < 0.001$. The effect sizes of the correlation and partial correlation (controlled for meat disgust) between the disgust response toward GM meat and the WTE GM meat were both high ($r = -0.63$ and $r_{partial} = -0.62$). Similar results were

observed for WTE meat coated with the edible nanotechnology film ($r = -0.47$ and $r_{\text{partial}} = -0.46$) and WTE artificial meat ($r = -0.63$ and $r_{\text{partial}} = -0.62$). After controlling for fish disgust between the disgust response toward GM fish and the WTE GM fish, the partial coefficient remained similarly high as did the correlation coefficient ($r = -0.65$ $r_{\text{partial}} = -0.64$). Correlation and partial correlation coefficients (controlled for milk disgust) of the disgust response and WTD artificial milk were high as well ($r = -0.55$ and $r_{\text{partial}} = -0.55$).

4. DISCUSSION

New food technologies have high potentials to improve food quality and/or reduce food waste, but the acceptance in the general population seems to be rather low (Gaskell et al., 2000; Rollin et al., 2011; Siegrist et al., 2007). Recent research indicates that lack of acceptance is caused by disgust evoked by some new food technologies such as gene technology (Scott et al., 2016) and artificial meat (Siegrist et al., 2018; Verbeke et al., 2015). However, there is a research gap concerning the role of trait and state disgust in acceptance as well as risk and benefit perceptions of other new food technologies (nanotechnology, artificial milk, and synthetic food additives). Thus, there was need to compare a wider range of new technologies to provide recommendations for their scope of application and to discuss strategies to increase acceptance.

4.1. Acceptance of Various Food Technologies

In general, people accepted (measured by WTE/WTD) the synthetic food additive the most. GM meat, GM fish, and the edible nanotechnology coating film were accepted the least, which fits with previous reports about low acceptance of these technologies (Gaskell et al., 2000; Rollin et al., 2011; Siegrist et al., 2007). The nanotechnology food box and artificial meat and milk were accepted in between. It must be noted that WTE artificial meat (and milk) was rather low, which is in line with previous observations (Siegrist & Sütterlin, 2017; Siegrist et al., 2018; Wilks & Phillips, 2017). Nevertheless, a review by Bryant and Barnett (2018) indicates that the level of acceptance of artificial meat seems to vary according to how acceptance is assessed and what kind of descriptions are provided.

Benefit perceptions of the different technologies showed a relatively similar pattern to WTE/WTD. Risk perceptions showed a reverse pattern to acceptance and benefit perception with the highest risk perceptions of GM meat, GM fish, and edible nanotechnology coating film; the lowest risk perceptions were observed for the synthetic food additive. Taken together, ratings of WTE/WTD, risk (reversed) and benefit perceptions, as well as disgust responses were quite similar for the different food technologies except for the synthetic food additive. WTE/WTD was highest for the synthetic food additive, even though benefit rating was not so high but neither was the risk rating. The synthetic food additive differs from the other food technologies in that it was the only food technology the Swiss population has been and is exposed to. The experience with this food technology might have been the reason for the quite distinct perceptions of risk and benefit, WTD, and for the low disgust response compared to the other food technologies.

4.2. Mediation Effect of Disgust Response Among Technologies

With regard to our predicted model, the data revealed that people with higher food disgust sensitivity responded with stronger disgust to each new food technology. The stronger people responded with disgust, the less willing they were to eat or drink a food produced by each technology. The fact that the relationship between food disgust sensitivity and acceptance of a food technology was mediated by the disgust response supports our assumption that a food technology can evoke disgust. The results are comparable to previous findings concerning a direct effect of a disgust response on the acceptance of new food technologies (Scott et al., 2016; Siegrist et al., 2018).

Interestingly, the disgust response was the strongest predictor for the WTD the synthetic food additive in beverages among all new food technologies, even though the mean disgust response for the synthetic food additive was the lowest among all tested food technologies. Thus, we found a rather strong effect of state disgust for the acceptance of a well-known food technology, which seemingly does not elicit strong disgust in the majority of participants. In other words, even if a food technology does not evoke disgust among most consumers, disgust can still be a reason for rejection of that food technology among a consumer subgroup.

Our data further revealed that the effect of the disgust response on WTE meat coated in an edible nanotechnology film was somewhat smaller compared to the other food technologies. The description of the other food technologies may have included additional or more obvious contamination-related disgust cues than unfamiliarity and unnaturalness (Siegrist & Sütterlin, 2017; Siegrist et al., 2016, 2018; Verbeke et al., 2015), which might have evoked a stronger disgust-related food rejection than the description of the edible nanotechnology coating film. For example, the description of GM foods may have provoked an association with contamination because it was mentioned that a gene is transferred from one organism to another organism (Scott et al., 2018). Furthermore, we used gene transfer examples between quite distant species, which was shown to be seen as less acceptable than a gene transfer between organisms of the same species (Lusk & Rozan, 2006). Scott et al. (2018) argue that such distant effects can be due to the fact that people treat DNA from a source organism as also transferring properties of the entire organisms. Thus, as the distance between a source organism and a target organism increases, the more contaminating the gene transfer is perceived according to the authors. Another contamination fear in gene technology may arise out of the thought that a gene inserted in an animal (or plant) produces something foreign that likely spreads through the organisms' tissues, which would then be eaten. Consequently, gene technology might have various disgust-eliciting properties that can lead to rejection.

In case of the artificial meat, it seems reasonable that the intensive processing by humans was an additional disgust elicitor. This food technology requires the most intense human intervention in the production process among the investigated food technologies. Results of a study by Rozin (2005a) indicate that the processing of food is a more important factor for people's perceptions of naturalness than the change in food ingredients. In other words, the more transformations (i.e., processing) an original food has undergone, the stronger the reduction of its acceptability (Rozin, 2006) and perceived naturalness (Rozin, 2005a, 2006). However, it is imaginable that intense human processing raises the fear of human contamination in artificial meat, and thus human contamination disgust. Interestingly, the highest effect of food disgust sensitivity on the disgust response was observed for artificial meat. The short version of the FDS (Hartmann & Siegrist, 2018) used in this study also measures human contamination disgust but only

with one item. By using the subscales of the FDS (e.g., human contamination, animal flesh, or hygiene) in future research, it might be possible to identify which aspects of artificial meat are prominently disgusting. Similarly, disgust-evoking aspects of artificial milk should be examined to determine if there are other potentially disgusting properties than the usage of gene technology.

As mentioned earlier, the strongest effect of disgust among all tested food technologies was observed for the synthetic food additive. It seems reasonable that mentioning mold cultures in the production process elicited a disgust-related food rejection as mold was repeatedly shown to be a disgust elicitor (Ammann, Hartmann, & Siegrist, 2018a; Haberkamp et al., 2017; Hartmann & Siegrist, 2018; Tybur, Lieberman, & Griskevicius, 2009). Finally, the description regarding the other nanotechnology application (nanotechnology food box) included the information that nanoparticles from the box might migrate into the food. Thus, a potential contamination was explicitly mentioned. Taken together, the outlined results indicate that there might be some disgust cues that signal a potential contamination, provoking a disgust reaction and likely leading to the rejection of a new food technology more so than other cues (e.g., unfamiliarity of unnaturalness).

4.3. Mediation Effects of Disgust Response on Acceptance and Risk and Benefit Perceptions Within a Technology

In contrast to numerous previous studies that examined a model with risk and benefit perceptions as the causal factors influencing acceptance of new technologies (Alhakami & Slovic, 1994; Gupta et al., 2012), we suggest a model in which people's emotional response associated with a new technology impacts acceptance and risk and benefit perceptions of a technology similarly. Our assumption is based on the idea that people probably lack the knowledge or cognitive resources to conduct a risk and benefit analysis (Finucane et al., 2000) on which acceptance of a technology is based. Regarding new food technologies, we further suggest that state disgust plays an important role in acceptance, risk, and benefits.

In line with our assumption, the present data revealed that the predictive potential of the disgust responses on WTE/WTD and risk and benefit perceptions was comparable within a new food technology. Ongly for the synthetic food additive, slightly different effects of the disgust response on

risk, benefit, and WTE/WTD were observed. The effect of the disgust response on acceptance in terms of WTE/WTD was somewhat stronger than on risk and benefit perceptions of the synthetic food additive. As indicated before, people have been exposed to and are used to (synthetic) food additives in foods and drinks for many years (Bearth et al., 2014, 2016; Shim et al., 2011). This kind of experience may have been responsible for the attenuated effect of the disgust response on risk and benefit perceptions. However, since the function of disgust seems to lie in the behavioral avoidance of potential harmful agents (Al-Shawaf & Lewis, 2013; Darwin, 1872; Rozin & Fallon, 1987), it comes to no surprise that the impact of disgust response remains strong with regard to WTE.

4.4. Implications

Even though it was shown that providing information about a new food technology can be counterproductive (Scholderer & Fewer, 2003; Siegrist et al., 2018), evidence exists indicating that it is important to whom the information is addressed (e.g., people with different worldviews) (Kahan et al., 2009) and how the information is labeled and described (Bryant & Barnett, 2018; Siegrist et al., 2018). Siegrist et al. (2018) examined WTE artificial meat by using technical versus nontechnical phrasing for its descriptions and found that acceptance can be increased by providing a nontechnical description. The authors suggested that if descriptions and information highlight similarities with conventional meat, perceived unnaturalness and disgust likely decreases and consumers are more willing to eat it. Considering the results of this study, scientists talking to the public about new food technologies should avoid information about a food technology that includes disgust elicitors (e.g., citric acid produced by mold cultures).

However, it might not be possible or ethical for governmental interventions to omit such information because it might be an essential part of information they are obligated to provide to consumers (e.g., risks of migrating nanoparticles) or it may even be part of the food technology's definition (e.g., gene technology). Another approach to increase acceptance might be based on the fact that people seemingly can get used to disgust elicitors through repeated exposure (Rozin, 2008). Thus, repeated exposure might be a strategy to lower the disgust response toward a new food technology (Rozin, Haidt, & McCauley, 2000). Artificial meat, for example, could be introduced to people in cooking shows or at

the food events that are currently rapidly increasing in various countries (Hall & Sharples, 2008; Payne, 2002). Because what people consider disgusting is influenced by social norms and culture (Curtis & Biran, 2001; Rozin & Fallon, 1987), it might be possible to increase acceptance by increasing visibility of such new technologies.

The data of this study showed that the highest average disgust response occurred toward gene technology applications and edible nanotechnology coating film, and the disgust response was a strong predictor for its acceptance. Considering these findings and the preceding discussion, we suggest that promotion of artificial meat and milk and investment in intervention to increase their acceptance might be most fruitful. The strong disgust response in the majority of participants and the rather strong negative effect of disgust response on acceptance of nanotechnology indicated that using nanotechnology to reduce food waste will be difficult at the consumer level. Thus, using nanotechnology to prolong food shelf life, for example, will probably not be accepted by consumers. Given that a recently published study found a positive association between food disgust sensitivity and food waste frequency (Egolf, Siegrist, & Hartmann, 2018), the present finding is disappointing.

Summing up, new food technologies likely inherent common cues indicating a potential danger of eating a contaminated food (e.g., novelty or unnaturalness), but also technology-specific cues might be perceived as a potential contamination (e.g., a foreign gene inserted in another organism like in gene technology). Interventions to increase acceptance in consumers should avoid mentioning disgust-eliciting aspects (i.e., cues) of a new food technology as much as possible.

4.5. Limitations

As mentioned before, it is likely that the elicited disgust responses were largely due to the description of the food technology applications. The descriptions of GM foods, which included a gene transfer from one organism into another, likely activated associations with contamination and thus elicited disgust. If we had asked people solely if they would eat GM meat containing healthy fatty acids, for example, disgust responses might have been weaker. In this case, other sources of information like trust in regulators (Bearth et al., 2014; Siegrist et al., 2007) are probably important to cope with the lack of knowledge (Siegrist & Cvetkovich, 2000;

Siegrist, Gutscher, & Earle, 2006). However, disgust is a quite strong emotion with powerful affective and behavioral responses aimed to prevent contact with an offensive object (Curtis, 2011). Thus, if a person is disgusted by food produced by a new food technology, he/she most likely will reject it no matter how much trust he/she has in regulators or scientists.

Another limitation of this study is that we only examined the contributions of food disgust sensitivity on the disgust responses. Future research might test additional factors like perceived naturalness or moral concerns and how these may interact with disgust responses. An interesting topic might also be how people's knowledge and information provision affects disgust responses or affects the influence of disgust on acceptance and risk and benefit perceptions. It seems rather unlikely that the disgust response is influenced by information provision, but its impacts on WTE/WTD and risk and benefit perceptions may be differently affected.

It must also be noted at this point that as disgust is rather inseparable from affect (i.e., the experiences of disgust automatically influences the experienced affect), directly comparing the affect heuristic and the disgust heuristic seems not possible. However, the observed association between people's food disgust sensitivity and their disgust response indicates that experienced disgust plays a role in the evaluations of acceptances, risk, and benefit of new food technologies.

Another limitation of this study might be that people's risk and benefit perceptions were assessed quite unspecifically. We assume that people rely on their feelings to a similar degree when judging more specific risks (e.g., health or environmental risks) because they probably lack the knowledge and/or cognitive resources to analytically assess most kinds of risks (or benefits). Nevertheless, it would be interesting to test this assumption in future research.

5. CONCLUSION

In summary, for each food technology, the disgust response fully mediated the effect between food disgust sensitivity and WTE/WTD, which was also observed for risk and benefit perceptions regarding each food technology application. Thus, people with higher levels of food disgust sensitivity responded with stronger disgust toward each food technology, and the higher the disgust response, the less a technology was accepted and perceived as beneficial. Results indicate that people with high dis-

gust sensitivity in the food domain have higher risk perception related to and are more concerned about new food technologies and food production practices when compared to people who are less food-disgust sensitive. Overall, the present results indicate that people likely rely on their experienced disgust as a source of information to evaluate acceptance (i.e., WTE/WTD) as well as risk and benefit perceptions of various new food technologies.

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