

Review of the gastric physiology of disgust: proto-nausea as an under-explored facet of the gut-brain axis

Sameer N. B. Alladin ¹, Ruth Judson ¹, Poppy Whittaker ¹, Angela S. Attwood, PhD ¹, Edwin S. Dalmaijer, DPhil ¹

Affiliations

1. School of Psychological Science, University of Bristol, United Kingdom

Contact Details

Sameer N.B. Alladin, School of Psychological Science, University of Bristol, 12A Priory Road, Bristol, BS8 1TU, United Kingdom. sa13889@bristol.ac.uk

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Conflicts of Interest

The author declares that they have no competing interests (financial or other) that could have influenced or appeared to influence the work reported here.

Abstract

Humans feel visceral disgust when faced with potential contaminants like bodily effluvia. The emotion serves to reject potentially contaminated food, and is paired with proto-nausea: alterations in gastric rhythm in response to disgust. Here, we offer a narrative synthesis of the existing literature on the effects of disgust on the stomach as measured through electrogastrography, a non-invasive technique that measures stomach activity with electrodes placed on the abdominal skin surface. After identifying and assessing 376 studies for eligibility and inclusion based on the PRISMA process, here we review a final sample of only 9 papers that measured or manipulated gastric state to assess stomach responses to unpleasant and disgusting stimuli. Reviewed findings illustrate that changes in gastric rhythm are associated with negatively valenced emotions, and most reliably with visceral disgust elicitors. This rhymes with recent evidence for a causal role of gastric state in reductions of visceral disgust avoidance. Because limitations in the reviewed body of work come from the low number of studies and relatively small sample sizes, we strongly encourage studies of proto-nausea in designs with higher statistical power, ideally paired with experimental manipulations of gastric state.

Keywords

Disgust; electrogastrography; gastric rhythm; gut-brain axis; emotion

Introduction

Disgust is recognised as one of the basic emotions that exist across cultures (Ekman & Friesen, 1971). At its core, disgust exists as a protective mechanism against the ingestion of potential toxins and contaminants (Angyal, 1941; Darwin, 1872), and is thus primarily inspired by bodily effluvia. In addition, disgust is thought to extend to a variety of additional illness-associated stimuli, including ectoparasites (Kupfer & Fessler, 2018), body envelope violations (Haidt et al., 1994), sexual emissions (De Jong et al., 2010; Freud, 1955/1905), and animals (Olatunji et al., 2008). Taxonomies of these separate stimuli and functions have been published elsewhere (Rozin & Fallon, 1987; Tybur et al., 2013). Here, we instead focus on *visceral disgust*, also known as *core disgust*, which we argue is a close collaboration between brain and body to avoid potential contaminants.

Even early conceptualisations of disgust are strikingly visceral, with Darwin (1872) emphasising the primacy of taste in the experience of disgust. He saw disgust as “a sensation rather more distinct in its nature, and refer[ring] to something revolting primarily in relation to the sense of taste, as actually perceived or vividly imagined” (Darwin, 1872), and went on to indicate that disgust may also be brought on secondarily by “anything which causes a similar feeling, through the sense of smell, touch, and even of eyesight” (Darwin, 1872). Particularly relevant is Darwin’s observation of disgusting stimuli eliciting a specific oral physiological response: contracted nostrils to restrict airflow and the activation of particular facial muscles that facilitate “[letting] an offensive morsel drop out”. One of the earliest modern accounts of disgust echoes this oral physiological focus, describing the emotion as “a specific reaction towards the waste products of the human and animal body” aimed at avoiding their ingestion (Angyal, 1941).

The above casts disgust as a response to physical stimuli, while extensions into other domains (e.g. moral disgust) reflect “disgust” as a metaphor (Danovitch & Bloom, 2009), lexical fallacy (Armstrong et al., 2021; Fiske, 2020), or mixture of emotions (Van der Eijk & Columbus, 2023). This echoes the Oral Origins hypothesis, which states that disgust evolved as a mechanism to orally reject substances that can cause harm and disease (Angyal, 1941; Rozin & Fallon, 1987). While others have since pointed out disgust is also evoked by non-oral disease vectors (Curtis et al., 2004) and emerges later in life than one might expect for evolutionary beneficial behaviour (Rottman, 2014; Stevenson et al., 2010) (although see Dalmaijer & Armstrong, 2020), popular theoretical frameworks cast disease avoidance as disgust’s original purpose with higher-order disgust developing as later extensions that co-opted some of the existing functions (Rozin & Fallon, 1987; Tybur et al., 2013). With this review, we do not intend to solve the debate on disgust’s evolutionary origins and structure, but merely to explore the evidence for the orogastric nature of visceral disgust.

Facial responses to disgust

As Rozin and Fallon (1987) point out, the facial expression associated with disgust mostly features those parts involved in food consumption. That is, the contraction of the nostrils serves to restrict offensive odours, and the gaping of the mouth allows for contents to dribble out (Ekman & Friesen,

1971; Izard, 1971; Rozin et al., 1994). Several studies have indeed found involvement of the mouth in response to disgusting stimuli (De Jong et al., 2011; Olatunji et al., 2008; Shenhav & Mendes, 2014; Van Overveld et al., 2009), specifically finding that the levator labii (muscle involved in elevating the upper lip) and the corrugator (involved in frowning) show increased activation in response to (core) disgust elicitors. The salivary glands are also part of the facial disgust response, with increased digastricus activity (muscle involved in saliva production) and saliva production (De Jong et al., 2011; Van Overveld et al., 2009).

Research on facial expressions of emotion is notoriously difficult, and the basic emotions of anger, disgust, fear, happiness, sadness, and surprise (Ekman & Friesen, 1971) are not as reliable or specific as initially thought (Feldman Barrett et al., 2019). Despite this, it is compelling that disgust-related activity of facial muscles is parsimonious with the oral origins hypothesis.

Proto-nausea: an alteration of typical gastric rhythms

One of the most characteristic manifestations of a disgust response is that of nausea, indicating the involvement of not only the oral, but also the gastrointestinal system (Rozin & Fallon, 1987). Nausea is an uncomfortable symptom, typically in the stomach, that serves to prevent further ingestion of toxins (Stern et al., 2011). In most cases, it is correlated with alterations in gastric rhythm (Babic & Browning, 2014). While nausea is neither necessary nor sufficient for an emotional experience to be labelled as “disgust” (Ekman & Friesen, 1971), it does often accompany particularly strong experiences of the emotion. In addition, episodes of disgust can produce what we describe as “*proto-nausea*”: a measurable alteration of gastric state/rhythm without necessarily consciously experiencing feelings of nausea (we review evidence for this claim later in this paper).

Proto-nausea can be measured using electrogastrography (EGG), a technique that measures the electric potential over the stomach to identify a characteristic rhythm of around 3 cycles per minute (cpm), or 0.05 Hz. EGG is non-invasive, and uses cutaneous electrodes placed on the abdominal skin over the stomach to record myoelectrical activity produced by interstitial cells of Cajal in the pacemaker region of the stomach (Koch & Stern, 2003). Typical alterations in this stomach rhythm are in amplitude, as an attenuation of the signal magnitude at 3 cpm; or in frequency, as a shift of signal magnitude towards lower (1-2.5 cpm, bradygastria) or higher frequencies (3.7-10 cpm, tachygastria). Specific studies are reviewed below. (For an EGG tutorial paper, see Yin & Chen, 2013)

Proto-nausea can also be experimentally manipulated using pharmacological interventions. For example, when paired with an incentivised exposure procedure (Dalmaijer et al., 2021), the anti-emetic drug domperidone reduces disgust avoidance behaviour in humans, but does not alter self-reported disgust (Nord et al., 2021).

Literature review of gastric responses to emotion

Here we summarise and review work published on disgust that uses electrogastrography. We used the search phrase “(TI=(disgust*) OR TI=(unpleasant)) AND (ALL=(electrogastrograph*) OR ALL=(core) OR ALL=(gastric) OR ALL=(orogastric) OR ALL=(visceral) OR ALL=(myoelectric*))” on 16 November 2022 to identify 345 relevant papers included in Web of Science.

Additional studies were identified from Google Scholar using the combined keywords “disgust, stomach, gastric, electrogastrograph”, references within articles, and through Google Scholar alerts for the terms “disgust” and “electrogastrography” (to capture studies published after our main search). This generated a further 32 articles.

Duplicates were removed, and records were screened by reviewing their abstracts. Remaining records were then selected or excluded by reading the full-text articles. This led to a final count of five studies that focussed on the use of electrogastrography in emotion research, three studies that focussed on electrogastrography and disgust, and one study that experimentally manipulated gastric state. Details are shown in the PRISMA diagram in Figure 1.

Given the heterogeneity of study designs and outcome measures, as well as the relatively limited number of studies focused on the gastric nature of disgust, a narrative synthesis was pursued rather than a meta-analysis. This allows for linking together several studies, identify points of convergence, and suggest future directions (Baumeister & Leary, 1997). We first summarise research that investigates gut involvement (particularly as measured with electrogastrography) in emotional processes in general, before summarising research that focuses on disgust in particular.

Where possible, effect sizes have been calculated and included as part of section summaries. However, we advise caution when interpreting these, because the relatively small sample size in the reviewed studies would not have permitted detection of smaller effects.

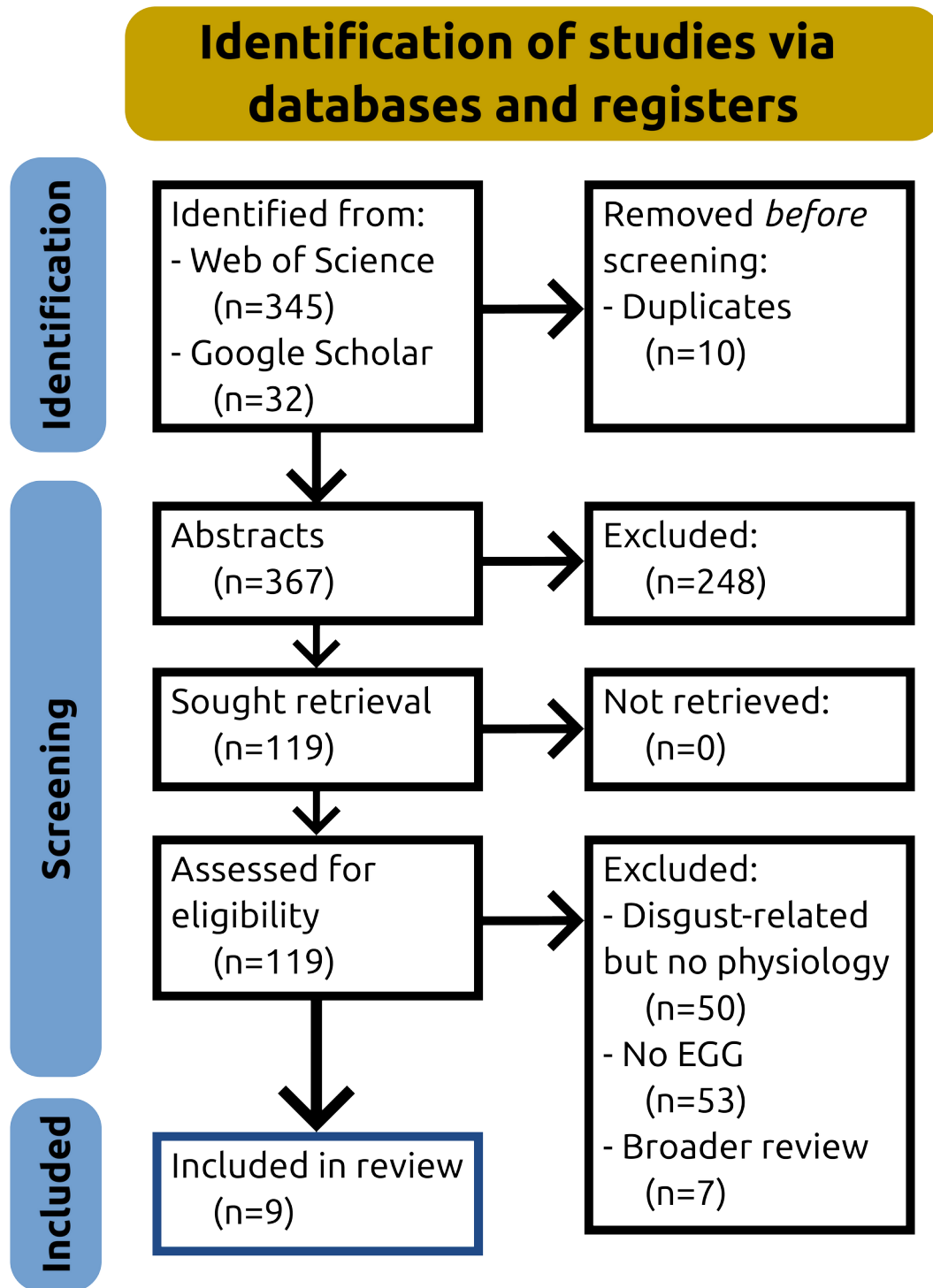


Figure 1. PRISMA flow diagram (Page et al., 2021) for the identification and inclusion of studies in this review.

Gastric activity and emotion

Baldaro and colleagues (2001) were the first to explore the effect of highly aversive dynamic visual stimuli on respiratory and electrogastric activity. They used two electrodes, one placed between the umbilicus and xiphoid process, and the other placed in the upper left quadrant. Using a sample of 40 female psychology students, they showed a surgery video and neutral video after 10 minutes of baseline recording. Despite self-report ratings indicating that the surgery video was significantly more unpleasant and more arousing than the neutral film, there was no effect on normogastric activity.

Zhou and colleagues (2004) explored the effect of viewing pleasant and unpleasant photographs on electrogastric activity. Their setup involved two electrodes, one placed to the left of the midline and the reference placed right of the midline. They divided 32 undergraduate students into two equal groups to view photographs from the International Affective Picture System (IAPS) that were rated as being highly pleasant and calming, or as highly unpleasant and exciting. They found that unpleasant photographs reduced normogastric amplitude, while pleasant photographs had no effect. The reduction in normogastric activity compared to baseline for unpleasant stimuli was inconsistent with that of Baldaro et al. (2001).

Vianna and Tranel (2006) explored the effect of emotionally salient videos on gastric myoelectrical activity in a sample of 16 participants. Their setup comprised two Ag-AgCl electrodes, placed above the umbilicus and below the lower left rib. Their manipulation involved the use of ten standardised videos that were deemed to elicit discrete emotions of happiness, disgust, fear, and sadness, as well as a neutral video. They found evidence for gastric changes in response to emotional stimuli compared to neutral stimuli. Particularly, there was an increase in peak amplitude of the normogastric signal for happy emotions, but a decrease in activity for negatively valenced stimuli. There was also a strong positive correlation between maximum amplitude and subjective rating of arousal level, indicating a meaningful relation between body processes and phenomenological experience of that emotion.

Vianna and colleagues (2009), rather than looking at the effects of viewing images or a video, employed an emotional imagery task. They explored the relations between arousal, valence, and vividness and maximum spectral electrogastric values. Consistent with Vianna and Tranel (2006), there was a strong positive correlation between spectral values and subjective arousal ratings ($r = 0.83$, $p < .01$). They also found a strong negative relation between maximum spectral values and vividness ($r = -0.75$, $p = .04$), and no significant relation between vividness and arousal. To explain the latter finding, they suggest that vivid recall involves relying more on neural structures than on feelings within the body, thus producing lower amplitude signalling in the gastrointestinal tract. On the other hand, less vivid recall may involve a greater reliance on body signals as neural systems are not as heavily involved.

More recently, Valentina and colleagues (2018) conducted a study involving 22 healthy participants viewing 21 videos of positive, negative, and neutral valences while electrogastric activity was recorded with a 6-channel setup. They found evidence for both positive and negative stimuli decreasing normogastric peak power compared to neutral stimuli, but no differences between positive and negative stimuli. Additionally, by comparing subjective emotional intensity (by grouping responses into low and high intensity), they found that low intensity stimuli had a higher

normogastric peak power than high intensity stimuli. For the former finding (valence), they suggested that normogastric power may be modulated by the central nervous system inhibiting enteric nervous system activity, potentially associated with the fight-or-flight response.

In sum, while it appears that the electrogastragram is responsive to emotion, results are mixed. Gastric signal was reported to increase (Vianna & Tranel, 2006), remain unchanged (Zhou et al., 2004), or decrease (Valentina et al., 2018) in response to positively valenced stimuli. More consistently reported was a general decrease in normogastric peak power for unpleasant emotional stimuli (Valentina et al., 2018; Vianna et al., 2009; Vianna & Tranel, 2006; Zhou et al., 2004). From the available statistical data provided in Zhou et al. (2004) and Vianna and Tranel (2006), these effects appear to be large ($d = 0.78$ in Zhou et al., 2004., $\eta^2 = 0.27$ in Vianna & Tranel, 2006).

Gastric activity and visceral disgust

Stern and colleagues (2001) explored the effect of unappetizing (disgusting) food on gastric activity. This study involved 38 healthy participants, and an electrogastrography setup that involved an electrode placed above the umbilicus, another placed diagonally upwards from this, and a reference placed to the right of the umbilicus. Participants were divided into two groups, one given appetising and the other unappetising foods. Participants in the unappetising condition rated their food as significantly more unpleasant, disgusting, and less appetising compared to those in the appetising condition. Crucially, those in the unappetising group had a decrease in normogastric (3 cpm) power.

Meissner and colleagues (2011) investigated gastric responses to disgusting pictures, and between gastric activity and disgust sensitivity and intensity. In a sample of 31 healthy participants, they administered 60 IAPS stimuli (30 highly disgusting and 30 with neutral content). Disgusting stimuli were further subdivided into highly arousing and moderately arousing. (It should be noted that the moderately arousing stimuli consisted of a mix of core and body envelope violations, while the highly arousing stimuli consisted of mostly body envelope violations.) Meissner et al. used a two-electrode setup, with both being placed on the skin above the abdomen. They observed no significant differences between the three categories for percentage of bradygastria, normogastria, and tachygastria. However, they did find that bradygastric activity predicted disgust ratings for highly arousing pictures, and predicted disgust sensitivity for moderately arousing pictures. This finding is noteworthy because gastric dysrhythmias are particularly associated with nausea and vomiting (Xing, 2006).

Shenhav & Mendes (2014) explored the effect of various videos on gastric reactivity (among other measures). Eighty participants were shown videos that displayed visceral/core disgust elicitors (pus, faeces, and vomit), gore disgust (injuries), and neutral stimuli (e.g. scenes of animals in nature). Core and gore stimuli were chosen to avoid contamination across domains – that is, core disgust stimuli did not include bodily harm, and gore stimuli did not include bodily effluvia. Electrodes were placed similar to Stern et al. (2001), with the ground placed below the right rib. Participants rated core disgust and painful injury stimuli as more negative than control stimuli, with further analyses indicating that core disgust stimuli were rated as more disgusting than gore stimuli. Normogastric amplitude was significantly reduced in participants in the core disgust condition compared to other conditions. There was no difference between electrogastric response to gore

disgust and neutral stimuli, suggesting that visceral stimuli had a unique effect on the stomach. Finally, there was a moderate negative correlation between subjective ratings of disgust and normogastric reactivity for visceral disgust stimuli ($r = -.47$, $p = .036$); with higher disgust ratings being associated with more strongly reduced normogastric activity.

In sum, there is evidence for an effect of visceral disgust on gastric activity, particularly in reduced normogastric amplitude. This appears to be a medium to large effect, with Cohen's d ranging from 0.59 (Shenhav & Mendes, 2014, disgusting vs. painful stimuli) to 0.769 (Stern et al., 2001, disgusting vs. non-disgusting food). These findings offer support for the idea that visceral disgust is an orogastric phenomenon in the truest sense, as both oral and gastric organs are involved.

Are gastric responses unique to disgust?

The reviewed studies present a varied picture on the effect of emotional stimuli on gastric rhythm. Amplitude in the normogastric range was reported to increase (Vianna & Tranel, 2006), decrease (Valentina et al., 2018), or be unaffected (Zhou et al., 2004) by positively valenced stimuli; whereas non-disgust negatively valenced stimuli generally produced decreases (Valentina et al., 2018; Vianna & Tranel, 2006; Zhou et al., 2004), but not always (Baldaro et al., 2001). For gore-related disgust, findings are inconsistent too, with some finding a decrease in normogastric EGG amplitude (Zhou et al., 2004) where others did not (Baldaro et al., 2001; Shenhav & Mendes, 2014). More consistently reported are reductions of normogastric amplitude and/or bradygastria in response to visceral disgust elicitors (Meissner et al., 2011; Shenhav & Mendes, 2014; Stern et al., 2001).

Where previous studies found that gastric activity was *associated* with disgust sensitivity, Nord and colleagues (2021) suggest that this relationship could be *causal* by pharmacologically manipulating gastric rhythms to reduce disgust avoidance. They conducted a pre-registered, randomised, double-blind, placebo-controlled, cross-over study of domperidone in 25 healthy participants. Domperidone is a peripheral dopamine antagonist that is commonly used as an anti-emetic drug to normalise gastric rhythm, but barely passes the blood-brain barrier (and indeed had no measurable central effects in a control experiment). Using an established eye-tracking paradigm that incentivised participants to directly look at disgusting stimuli (Dalmaijer et al., 2021), Nord and colleagues found a significant reduction in oculomotor disgust avoidance to bodily effluvia while participants were on domperidone. This strengthens the view that the experience of disgust may be especially tied to gut activity.

Somewhat less clear results have been reported for ginger supplements, which are a weak anti-emetic (Ernst & Pittler, 2000) that have been successfully used to treat pregnancy-related nausea (Thomson et al., 2014; Viljoen et al., 2014), but fail to work as adjuvant in chemotherapy (Crichton et al., 2019). In a between-subjects design, self-reported disgust when viewing images with pathogen-disgust content did not decrease when participants had ingested ginger compared to a sugar-based placebo (Tracy et al., 2019). (While originally reported as “marginally significant”, results were not statistically significant: $F(1,240)=3.47$, $p=0.064$.) Despite there not being an interaction effect of stimulus severity and condition, $F(1,240)=2.41$, $p=0.122$, post-hoc tests were conducted. These showed no effect of ginger on self-reported disgust for highly disgusting stimuli, $t(240)=1.04$, $p=0.299$, and a statistically significant effect on moderately disgusting stimuli

$t(240)=2.03$, $p=0.043$. (Note that while 11 tests within this family were reported, no corrections for multiple comparisons were performed.) No effects were found of ginger on other self-reported emotions. While not immediately compelling, these results are promising and deserve replication with a more powerful design in a larger sample.

In sum, visceral disgust seems to be the most reliably associated with gastric function, but changes in the electrogastrogram are not uniquely associated with disgust. Behavioural experiments suggest that visceral disgust avoidance does not habituate and is not altered by incentivised exposure, which is unique to disgust compared to other unpleasant stimuli (Armstrong et al., 2022; Dalmaijer et al., 2021). Crucially, when the stomach is pharmacologically normalised, self-reported disgust (Nord et al., 2021; Tracy et al., 2019) and disgust avoidance (Nord et al., 2021) are not immediately reduced, but disgust avoidance *does* reduce after incentivised exposure (Nord et al., 2021). This suggests that input from the stomach is used to determine behaviour specifically in the context of disgust, perhaps by using gastric activity as a gauge of how potentially harmful a disgusting stimulus is. We speculate that brain-driven changes in the stomach might not be unique to disgust, but that stomach-driven changes in behaviour are.

Conclusion

We reviewed the limited but promising literature on emotion and stomach rhythms as measured with electrogastrography, and described the concept of proto-nausea: changes in gastric rhythm in response to experiencing disgust. The reviewed findings illustrate that changes in gastric rhythm are associated with negatively valenced emotions, and most reliably with visceral disgust elicitors. Furthermore, there is causal evidence that changes in gastric state reduce visceral disgust avoidance. Limitations in the reviewed body of work come from the low number of studies, the relatively small number of participants in each, and a tendency towards between-subjects comparisons (which offer low statistical power compared to within-subjects designs). We see promising future avenues for the incorporation of electrogastrography in visceral disgust research, particularly in designs with higher statistical power, and those that combine physiological recordings and causal manipulations of gastric state (e.g. with domperidone or ginger). Ultimately, despite seeming a bit silly due to all the poo, disgust is an excellent model system for studying interoception and embodied emotions.

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