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I've Seen Enough! Prolonged and Repeated Exposure to Disgusting Stimuli Increases Oculomotor Avoidance

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Abstract

Disgust motivates avoidance of stimuli associated with pathogens. Although disgust primarily inhibits oral and epidermal contact, it may also inhibit perceptual contact, particularly given the outsize role of sensory qualities in eliciting disgust. To examine perceptual avoidance of disgust, we presented images of bodily products or spoiled food paired with neutral images for 12-s trials and recorded eye movements (Experiment 1; *N*= 127). We found that overall, these disgusting images were not visually avoided compared to neutral images. However, viewing of disgusting images decreased with prolonged (within-trial) and repeated (between-trial) exposure, and these trends were predicted by self-reported disgust to the images. In Experiment 2 (*N* = 84), we replicated Experiment 1 with a novel set of disgusting images, as well as other unpleasant image categories (suicide, threat) and pleasant images. We found that disgusting stimuli were viewed less than the other unpleasant image categories, and we again found that viewing of disgusting images decreased with prolonged and repeated exposure. Further, we replicated the finding that disgust ratings predicted decreasing viewing of disgusting images, but only for prolonged exposure (within-trial). Unexpectedly, we found that disgust ratings predicted a similar pattern of decreasing viewing for the suicide and threat images as well. These findings suggest that disgust inhibits perceptual contact, but in competition with motivational processes that steer attention towards pathogen threats. We discuss the implications for measuring disgust with eye tracking.

Keywords: disgust, eye tracking, attention, measurement, curiosity

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> Disgust is a sensation rather more distinct in its nature and refers to something revolting, primarily in relation to the sense of taste, as actually perceived or vividly imagined; and secondarily to anything which causes a similar feeling, through the sense of smell, touch, and even of *eyesight* [emphasis added]. (Darwin, 1872/2005, p. 253)

Disgust is a basic emotion that motivates avoidance of "revolting" stimuli, including spoiled food, bodily products, gore, and debased individuals (Angyl,1941; Rozin & Fallon, 1987; Goffman, 1963). Although human cultures repurpose disgust to various ends (e.g., norm enforcement; Rozin, Haidt, & McCauley, 2008), this "rejection response" likely evolved under selective pressure from pathogens. Indeed, nearly all disgust elicitors have some association with illness or disease (Davey, 2011; Oaten, Stevenson, & Case, 2009; Tybur, Lieberman, Kurzban, & DeScioli, 2013), and the extent of disgust elicited by these stimuli depends on how much they have contacted or entered the body (Tybur et al., 2013). Initially, disgust targets oral contact, as children learn which objects and substances can render food inedible and should not be placed in the mouth (Rozin & Fallon, 1987). Several theorists consider the resulting "oral inhibition" (Royzman, Cusimano, & Leeman, 2017) to be the core of disgust. As children grow older, disgust expands beyond its oral core to target additional forms of physical contact, including interpersonal contact (Oaten et al., 2009; Rozin & Fallon, 1987).

In addition to targeting physical contact, disgust may also motivate avoidance of mental contact (Rozin et al., 2008). In contrast to other unpleasant emotions, disgust seems to target the concrete, sensory properties of stimuli rather than their abstract meaning (Royzman & Sabini, 2001), rendering these stimuli unpleasant to merely perceive or imagine. As Inbar, Pizarro, Knobe, and Bloom (2009) note, disgust is peculiar because "it is readily elicited by a simple smell, sound, sight, or even word" (p. 435). Indeed, an object can elicit disgust by merely appearing like something disgusting, even when one knows the appearance is false. As Rozin, Millman, and Nemeroff (1986) famously demonstrated, participants reject brownies shaped like dog feces despite being aware of the illusion. The appearance of feces and other disgusting objects may be inherently revolting, capable of eliciting rejection and avoidance in itself, without higher cognition (Royzman & Sabini, 2001). Interestingly, the facial expression of disgust may actually function to reduce sensory exposure to offensive stimuli, as it reduces field-of-view and nasal inspiratory capacity, whereas the facial expression of fear has the opposite effect (Susskind et al., 2008). From an evolutionary perspective, aversion to the mere perception of disgusting stimuli, regardless of context, might further promote behavioral avoidance and thereby prevent contagion. Also, this low threshold for disgust responding could reflect the relative costs of false positives versus false negatives in pathogen detection (the "smoke detector principle"; Nesse, 2005; Schaller & Park, 2011).

In line with the hypothesis that disgust promotes the avoidance of perceptual as well as physical contact, a handful of studies have documented reduced viewing of disgusting stimuli ("oculomotor avoidance"; Armstrong, McClenahan, Kittle, & Olatunji, 2014; Bradley, Costa, & Lang, 2015; Mason & Richardson, 2010). In addition, evidence from both event-related potentials (Zimmer, Keppel, Poglitsch, & Ischebeck, 2015) and functional magnetic resonance imaging (Zimmer, Höfler, Koschutnig, & Ischebeck, 2016) suggests that a disgusting sound elicits a shift in spatial attention away from its location. Finally, specific phobias (snake or spider: Rinck & Becker, 2006; Hamm, Cuthbert, Globisch, & Vaitl, 1997; blood-injection-injury phobia: Armstrong, Hemminger, & Olatunji, 2013), linked to elevated disgust responding (Olatunji, Armstrong, & Elwood, 2017), are characterized by avoidance of viewing phobic stimuli. Individuals with these phobias may avoid viewing spiders or injections because they find them inherently revolting to perceive (Armstrong & Olatunji, 2012).

Perceptually avoiding pathogen threats, however, could potentially undermine the goal of physically avoiding them. Indeed, threatening stimuli (and motivationally-relevant stimuli more generally) have been shown to capture and hold attention across a wide variety of attentional paradigms (see Yiend, 2009). Given their threat value and motivational relevance, disgusting stimuli may be perceptually approached rather than avoided: attentional mechanisms may prioritize the processing of disgusting stimuli so that they can be rapidly detected and avoided. In line with this hypothesis, a number of studies have observed increased attention to disgusting stimuli (Charash & Mckay, 2002; Ciesielski, Armstrong, Zald, & Olatunji, 2010; Cisler, Olatunji, Lohr, & Williams, 2009), and some studies have actually found greater attention to disgusting stimuli than to fear-eliciting stimuli (Carretié, Ruiz-Padial, López-Martín, & Albert, 2011; van Hooff, Devue, Vieweg, & Theeuwes, 2013).

Although these findings of an attentional bias toward disgusting stimuli would seem to contradict findings of a bias away from disgusting stimuli, the direction of the bias may depend on the stage of processing. Attentional biases *toward* threatening or other motivationally-relevant stimuli tend to be observed at earlier, more automatic stages of processing (e.g., Mulckhuyse & Dalmaijer, 2016). For example, attentional capture by emotional stimuli in the rapid serial visual presentation task (RSVP) peaks in the first few hundred milliseconds and ends by 800 ms (Ciesielski et al., 2010). Similarly, the modified dot probe and emotional spatial cueing tasks commonly used in research on attentional bias for threat tend to probe attention within 500 ms of exposure and very rarely later than 1000 ms (Bar Haim et al., 2007; Carretié, 2014), because attentional capture peaks within this early window. Likewise, in eye tracking studies, increased overt attention to emotional compared to neutral images may be most robust in the initial orienting of gaze, reflected in dwell time in the first 500 ms of exposure (Calvo & Lang, 2004). Although attentional bias away from threat has been documented with much less frequency, it tends to be observed *after* an attentional bias towards threat (Armstrong et al., 2013; Rinck & Becker, 2006) and is thought to involve top-down, strategic processing (see Cisler & Koster, 2010).

Of the handful of studies documenting perceptual avoidance of disgusting stimuli, only one has carefully probed its time course. Bradley and colleagues (2015) examined eye movements in response to different categories of emotional images (erotic nudes, food, violence, mutilation, contamination) paired with neutral images. The images of contamination included feces and vomit, prototypical disgust stimuli. Over 3 s exposures, they found that all emotional contents captured attention compared to neutral images in the first 1 s of processing. Beginning around 1.5 s into exposure, this effect declined, particularly for less arousing emotional images. From 2 s to 3 s (the final second of exposure), only the most arousing images (desired nudes) were viewed more than neutral images, violence and mutilation were viewed similarly to neutral images, and critically, contamination and undesired nudes were viewed less than neutral images. Thus, the disgusting contamination images captured gaze early in exposure, at a more automatic stage of processing, and then repelled gaze later in exposure, at a more controlled stage of processing. Undesired nudes, which may be conceptualized as sexual disgust stimuli (see Tybur et al., 2013), had a similar effect. These findings suggest that an adaptive mechanism for detecting and evaluating motivationally-relevant stimuli may cause individuals to initially attend to disgusting stimuli. However, once the stimuli are adequately appraised, individuals avoid further perceptual contact with disgusting stimuli, presumably due to their uniquely aversive nature.

Although Bradley and colleagues (2015) findings shed important light on the time course of visual processing of disgusting stimuli, they only address one dimension of exposure: prolonged exposure within a trial. Perceptual avoidance may also increase with repeated exposure between trials, as disgusting stimuli become less novel and more expected with repeated viewing. Indeed, a recent study observed that over the course of 6 s trials, participants dwelled longer on disgusting images (feces and an infected wound) compared to neutral images on the first few trials, and then gradually came to avoid viewing the disgusting images with additional exposures (Armstrong, Engel, Press, Sonstroem, & Reed, 2019). This counterintuitive finding of sustained dwell on revolting images suggests that disgusting stimuli may elicit a fleeting interest (Turner & Silvia, 2006) or "morbid curiosity" (Oosterwijk, 2017) that gives way to revulsion as their novelty wears off. Alternatively, novel disgusting stimuli may capture gaze due to a broader tendency to explore motivationally-relevant stimuli before choosing to approach or avoid them (Kron et al., 2014). Several studies of ad libitum viewing, in which participants terminate exposure to an image with a key press, have found that participants view both pleasant and unpleasant images longer than neutral images, and some of these studies suggest that viewing time is determined by arousal rather than valence (e.g., Bradley et al., 1991; Lang, Greenwald, Bradley, & Hamm, 1993; Vrana, Spence, & Lang, 1988). However, Kron and colleagues (2014) demonstrated that this tendency to dwell longer on *both* pleasant and unpleasant images is limited to the first exposure. In six experiments, Kron and colleagues

(2014) found that on a second exposure to images, participants viewed pleasant images longer than unpleasant images, and valence ratings of images reliably predicted viewing time, even after controlling for complexity.[1] As Kron and colleagues (2014) note, a similar behavioral tendency can be seen in rodents, as they initially explore aversive situations and only avoid them after repeated exposure.

In addition to understanding how oculomotor avoidance relates to exposure, it is important to clarify how oculomotor avoidance relates to disgust relative to other unpleasant emotional states. Although there is evidence that oculomotor avoidance is specific to disgust-related content (Armstrong et al., 2014; Bradley et al., 2015), attentional avoidance of aversive stimuli has been observed in other contexts (e.g., blood-injection-injury phobia; Mogg, Bradley, Miles, & Dixon, 2004) in which it is less clear if disgust, fear, or a broader dimension of affect such as negative valence or arousal is driving the avoidance. For example, Mogg and colleagues (2004) suggest that in specific phobias, attentional avoidance of threat may reflect efforts to downregulate negative emotion in general (e.g., fear and anxiety), or alternatively, may reflect search for escape routes driven by fear responding. If oculomotor avoidance is indeed driven by disgust, it should be associated with self-reported disgust in response to the stimulus. Further, oculomotor avoidance should be more strongly related to disgust responses than fear, and should not be accounted for by more general response properties such as negative valence or arousal. A link between oculomotor avoidance and self-reported disgust to stimuli has been previously observed (Armstrong et al., 2014; see Bradley et al., 2015 for mixed results), but without efforts to control for negative affect more broadly. Clarifying the specificity of the relation between

1 Suri, Sheppes, and Gross (2012) found that both valence and arousal predicted picture viewing when participants chose which image to view (rather than how long to view an image).

oculomotor avoidance and disgust would shed light on the nature of oculomotor avoidance and would also clarify the utility of oculomotor avoidance as behavioral measure of disgust.

The present study sought to test the hypothesis that disgust prevents perceptual contact with revolting stimuli. We predicted that disgusting stimuli would elicit oculomotor avoidance, and that oculomotor avoidance would increase with exposure within and between trials, as competing motivational processes that steer attention towards disgusting stimuli weaken. We also predicted that greater self-reported disgust would be associated with greater oculomotor avoidance, and that oculomotor avoidance would not be accounted for by other forms of affective responding. To test these hypotheses, we repeatedly presented pairs of disgusting and neutral images while recording eye movements. Images were presented for 12 s exposures, longer than in prior studies (Bradley et al., 2015; Mason & Richardson, 2010) to provide ample time for avoidance to emerge. Finally, we included images of spoiled food, as prior eye tracking studies of disgust have focused almost exclusively on bodily products, raising questions about the generalizability of oculomotor avoidance of disgust.

Experiment 1

Methods

Participants

Adults (aged 18 to 50; $N = 134$) were recruited from an undergraduate psychology subject pool and community advertisements, and provided informed consent to a protocol approved by the Meharry Medical College Institutional Review Board. After excluding participants with unusable eye tracking data, the final sample size was 127 (age: $M = 23.06$ years, SD = 8.32; gender identity: 72.4% female, 25.2% male, 2.4% other identity; racial/ethnic identity: 78.7% White, 17.3% Black, 2.4% Latino/a, 0.8% Asian, and 0.8% other identity). We planned for a final sample of 120, anticipating a loss of roughly 10% of participants due to eye tracking difficulty. Data and materials are available on the Open Science Framework (OSF) at https://osf.io/mgje2/.

Measures

The Empirical Valence Scale (EVS; Lishner, Cooter, & Zald, 2008) is a labeled magnitude scale designed for rating subjective experiences. In contrast to the equidistant verbal labels of visual analogue or Likert-like scales, the verbal labels on the EVS are spaced according to prior research assessing how participants rate the verbal labels themselves on a 0-100 scale. Participants only rated the disgusting images. They rated how disgusted and how afraid the images made them feel using the unipolar version of the EVS scale. The unipolar version of the scale contains the following labels and corresponding values: not at all (0), barely (7), slightly (12), mildly (24), moderately (38), strongly (70), extremely (85), and most imaginable (100). Participants rated how pleasant or unpleasant (valence) and how aroused or unaroused (arousal) the images made them feel on the bipolar version of the scale, which contains the label "neutral" in the center and the same labels as the unipolar scale in each direction to the two poles. Labels are placed on a line (without the corresponding numeric values). Ratings are made by clicking anywhere on the line with a mouse.

Materials and Apparatus

Ten neutral images were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Five images of bodily products (mucous on tissue, 1123; blood in sink, 1130; diarrhea in toilet, 1131; feces in toilet, 1135; mucous in tissue, 1138) and 5 images of spoiled food (moldy cheese dip, 1007; rotten apple, 1019; rotten peach, 1022; moldy hot dog, 1026; moldy tin of food, 1038) were selected from the Disgust-Related-Images database

(DIRTI; Haberkamp, Glombiewski, Schmidt, & Barke, 2017). Images were scaled to 400 x 300 pixels and presented in color against a black background on a screen set to 1280 x 1024 resolution using OpenSesame software (Mathôt, Schreij, & Theeuwes, 2012). The experiment was run on a Dell PC with a 22” monitor and a 50 cm viewing distance. Eye movements were recorded using an Eye Tribe eye tracker (60 Hz; Copenhagen, Denmark) controlled by the PyGaze toolbox (Dalmaijer, Mathôt, & Van der Stigchel, 2014). Although the Eye Tribe is intended for a range of consumer applications, it has been rigorously tested in comparison to research-grade eye trackers, and it has been shown to be comparable in performance for measuring fixation time (Dalmaijer, 2014; Ooms, Dupont, Lapon & Popelka, 2015).

Procedure

Participants were seated at a computer with a head-stabilizing chin rest, and completed the DS-R and other measures[2], followed by the free viewing task, followed by stimulus ratings. For the free viewing task, participants were instructed to keep their eyes on the screen and look wherever they please. To conceal the nature of the study, they were told the eye tracker was a pupillometer and that the study investigated effects of pictures on pupil size. The eye tracker was calibrated using a 9-point procedure at the beginning of the task. The images were presented for 12 s and preceded by a fixation cross (1.5 s) and followed by an inter-trial interval (ITI; 3 s). There were 40 trials presented in two blocks of 20 trials. Disgusting images were randomly paired with different neutral images separately for each block. Within each block, each

2 We also included measures of disgust/contamination sensitivity, which are not reported here for the sake of brevity, but are included in the dataset shared on the OSF. In Experiment 1, disgust sensitivity as measured by the 25-item Disgust Scale – Revised (Olatunji et al., 2007) was associated with disgust ratings and with decreasing viewing of disgusting images within trial, but not between trials. In Experiment 2, due to time constraints, we used the 7-item Pathogen Disgust subscale of the Three Domains of Disgust scale (Tybur et al., 2009); however, the scale had inadequate internal consistency in our sample and was not correlated with self-reported disgust to disgusting images or viewing time on disgusting images.

disgusting image was presented twice, once on the left side and once on the right side, both times paired with the same neutral image. Trial order was randomized, with the constraint that no image pairs were presented twice in a row. Following the free viewing task, participants rated each of the disgusting images in terms how disgusted, afraid, pleasant-unpleasant, and aroused-unaroused it made them feel.

Eye Movement Data

Using MATLAB 2016a (Mathworks, 2016), each sample of eye movement data was coded in terms of whether or not it targeted an image, which type of image it targeted, how many times the image had been presented (1-4; number of exposure), and which trial epoch it occurred within (1-12; epochs of 1 s). Samples were filtered by these characteristics to create the dwell time variables. Consistent with Armstrong et al. (2019), trials in which the images were fixated for less than 50% of the 12-s trials were excluded (6.65% of trials), and participants with more than 50% excluded trials were removed (n = 7). All dwell time totals were divided by the number of included trials for the relevant analysis. To simplify analyses and data visualization, and to make the data more readily interpretable, we examined dwell time on disgust as a proportion of the total time spent viewing either image (disgusting or neutral) in a given time period (epoch or trial).

Analysis Plan

We used paired sample t-tests to compare the disgusting images in terms of overall dwell time and ratings. We examined the effect of the disgusting images on gaze as a function of both prolonged exposure (within-trial) and repeated exposure (between-trial) for both types of images (bodily products, rotten food). The dependent variable in these analyses was the proportion of dwell time on the disgusting images. Multilevel models were specified using hierarchical linear models (HLM v.6; Raudenbush et al., 2004) consisting of a within-person (i.e., level 1) submodel describing how each individual's dwell time on disgusting images changed across 12 epochs (i.e., 0-1s, 1-2s, 2-3s, 3-4s, 4-5s, 5-6s, 6-7s, 7-8s, 9-10s, 10-11s, 11-12s) and across 4 presentations of the images; a between-person (i.e., level 2) submodel described how these changes varied across individuals (Bryk & Raudenbush, 1992; Singer & Willett, 2003). Subjective ratings of disgusting images on the EVS (i.e., disgusted, afraid, aroused, pleasant) were included in the level 2 submodel as moderators of changes in dwell time across epochs and presentations. The HLM model assessing gaze for bodily products across epochs was as follows:

Level 1:

$$\textit{Dwell time proportion (bodily products)} = \beta_0 + \beta_1 (\textit{epoch}) + R$$

Level 2:

$$\beta_0 = \gamma_{00} + \gamma_{01} (\textit{Disgust}) + \gamma_{02} (\textit{Afraid}) + \gamma_{03} (\textit{Aroused}) + \gamma_{04} (\textit{Pleasant}) + U_0$$

$$\beta_1 = \gamma_{10} + \gamma_{11} (\textit{Disgust}) + \gamma_{12} (\textit{Afraid}) + \gamma_{13} (\textit{Aroused}) + \gamma_{14} (\textit{Pleasant})$$

In this model, γ_{00} represents the mean dwell time on bodily products in the first epoch and γ_{10} represents the linear change of dwell time on bodily products across the 12 epochs. Moderators of within-person changes in dwell time across epochs are reflected in the following parameters: disgust ratings (γ_{11}), fear ratings (γ_{12}), arousal ratings (γ_{13}), and pleasant/unpleasant ratings (γ_{14}). The HLM model assessing gaze for spoiled food across epochs was identical but included corresponding ratings for those images. HLM models assessing gaze across presentations were identical except the parameter γ_{10} represented linear change of dwell time across the four presentations. The multilevel modeling approach used maximum likelihood estimation to account for missing data.

To compare slopes of viewing between image types, we used the approach suggested by Clogg, Petkova, and Haritou (1995) for comparing regression coefficients between models (see also Paternoster et al. 1998). The following equation is used to compute a Z statistic for testing the difference between two standardized coefficients:

$$Z = (\beta_1 - \beta_2) / \sqrt{(SE_1^2 + SE_2^2)}$$

We used Holm-Bonferroni tests to correct for multiple comparisons of regression coefficients.

Results

Image Ratings

The bodily product images were rated as more disgusting than the spoiled food images, $t(126) = 7.58$, $p < .001$, 95% CI [8.93, 15.20], $d_z = .67$). On average, the bodily product images were rated between “moderately” and “strongly” disgusting, whereas the spoiled food images were rated “moderately” disgusting. The bodily product images were also rated as more fear-eliciting, $t(126) = 5.02$, $p < .001$, 95% CIs [3.45, 7.95], $d_z = .45$, unpleasant, $t(126) = -4.92$, $p < .001$, 95% CIs [-14.51, -6.18], $d_z = -.44$, and arousing, $t(126) = 5.24$, $p < .001$, 95% CIs [5.68, 12.59], $d_z = .47$, compared to the spoiled food images (see Table 1 for *M*s and *SD*s). Also, while both disgusting image types were rated as “slightly” to “mildly” fear-eliciting, they each elicited more disgust than fear to a large degree (bodily products: $t(126) = 18.99$, $p < .001$, 95% CI [27.47, 33.87], $d_z = 1.68$; spoiled food $t(126) = 16.35$, $p < .001$, 95% CI [21.34, 27.22], $d_z = 1.45$).

Overall Dwell Time on Image Types

The bodily product images were viewed less than the spoiled food images, $t(126) = 7.04$, $p < .001$, 95% CI [.04, .07], $d_z = .62$. One-sample *t*-tests against the value of .5 (even viewing) revealed that overall, the bodily product images were not viewed more or less than the neutral images, *M* = .50, *SD* = .18, *t*(126) = .22, *p* = .820, 95% CI [-.04, .03], d_z = .02, and the food images were viewed more than the neutral images, *M* = .55, *SD* = .17 *t*(126) = 3.54, *p* < .001, 95% CI [.02, .08], d_z = .31.

Effects of Prolonged Exposure on Dwell Time and Moderation by Individual Differences in Disgust Ratings

Disgusting stimuli initially captured attention, as evident in greater dwell time during the first epoch on bodily products (*b* = 0.599, *SE* = .014, *p* < .001) and on spoiled food (*b* = 0.619, *SE* = .015, *p* < .001) compared to neutral images. Across epochs, perceptual avoidance of disgusting stimuli was evident in significant decreases in dwell time on bodily products (*b* = -0.018, *SE* = .002, *p* < .001) and spoiled food (*b* = -0.012, *SE* = .002, *p* < .001) compared to neutral images. Decreases in dwell were sharper for bodily product compared to spoiled food images, *Z* = 2.12, *p* = .034. Figure 1 depicts dwell time on the disgusting images as a function of both prolonged and repeated exposure. Table 2 contains Ms and SDs for effects of prolonged exposure on dwell time.

Disgust ratings were significantly associated with changes in dwell time on bodily products across epochs (*b* = -0.004, *SE* = .001, *p* = .001). Simple slope analyses revealed that dwell time on bodily products decreased more rapidly for individuals with higher (+1 SD) disgust ratings (*b* = -0.022, *SE* = .001, *p* < .001) compared to those with lower (-1 SD) disgust ratings (*b* = -0.014, *SE* = .001, *p* < .001). Changes in dwell time on bodily products were not significantly associated with fear, arousal, or pleasant ratings (*p*'s > .07).

Disgust ratings were also significantly associated with changes in dwell time on spoiled food across epochs (*b* = -0.004, *SE* = .001, *p* < .001). Simple slope analyses revealed that dwell time on spoiled food decreased more rapidly for individuals with higher (+1 SD) disgust ratings

(b = -0.034, SE = .006, p < .001) compared to those with lower (-1 SD) disgust ratings (b = -0.008, SE = .001, p < .001). Changes in dwell time on spoiled food were not significantly associated with fear, arousal, or pleasant ratings (p's > .30).

Effects of Repeated Exposure on Dwell Time and Moderation by Individual Differences in Disgust Ratings

Disgusting stimuli held attention on the first trial, as evident in greater dwell time during the first presentation on bodily products (b = 0.535, SE = .015, p < .001) and on spoiled food (b = 0.579, SE = .015, p < .001) compared to neutral images. Across presentations, perceptual avoidance of disgusting stimuli was evident in significant decreases in dwell time on bodily products (b = -0.028, SE = .004, p < .001) and spoiled food (b = -0.017, SE = .004, p < .001) compared to accompanying neutral images. Decreases in dwell did not significantly differ between bodily products and spoiled food, Z = .52, p = .604. Table 3 contains Ms and SDs for effects of repeated exposure on dwell time.

Disgust ratings were significantly associated with changes in dwell time on bodily products across presentations (b = -0.015, SE = .006, p = .024). Simple slope analyses revealed that dwell time on bodily products decreased significantly for individuals with higher (+1 SD) disgust ratings (b = -0.042, SE = .008, p < .001) but did not change over presentations for those with lower (-1 SD) disgust ratings (b = -0.013, SE = .008, p = .091). Changes in dwell time on bodily products were not significantly associated with fear, arousal, or pleasant ratings (p's > . 10).

Disgust ratings were also significantly associated with changes in dwell time on spoiled food across presentations (b = -0.017, SE = .005, p = .020). Simple slope analyses revealed that dwell time on spoiled food decreased significantly for individuals with higher (+1 SD) disgust ratings (b = -0.034, SE = .006, p < .001) but did not change over presentations for those with lower (-1 SD) disgust ratings (b = -0.0003, SE = .006, p = .962). Changes in dwell time on spoiled food were not significantly associated with fear, arousal, or pleasant ratings (p's > .40).

Discussion

The results of Experiment 1 shed new light on the oculomotor effects of disgusting stimuli. To our surprise, disgusting images were not viewed less *overall* compared to neutral images, in contrast to prior studies (Armstrong et al, 2014; Mason & Richardson, 2010). Indeed, the less-disgusting rotten food images were viewed more overall than neutral images. This discrepancy may be due to stimulus selection. Prior studies observing oculomotor avoidance of disgusting images have employed images of feces and vomit. In the present study, the bodily products images included feces, but also mucous and blood, which may be perceived as somewhat less polluting.

However, there was still evidence that participants attempted to limit visual contact with disgusting stimuli. Within trials, participants viewed the disgusting images increasingly less across the 12-s exposures. Consistent with Bradley et al. (2015), the disgusting images captured attention in the initial 0-2 s of the trial, which likely reflects automatic prioritization of motivationally-relevant stimuli ("motivated attention"; Bradley et al., 2001; Nummenmaa, Hyönä, & Calvo, 2006). However, participants steadily reduced their visual contact with the disgusting images over the remainder of the trial. Decreased viewing could be attributed to factors other than disgust. It may simply reflect the decay of motivated attention, rather than an active process of avoiding the disgusting image. Also, it could reflect some form of inhibition of return, as there appears to be a mechanism that inhibits attention to salient items after they have been attended; otherwise, the salient features of the item would continue to grab attention, even after all necessary information has been gleaned from the item (Posner & Cohen, 1984). However, those who rated the images as more disgusting reduced their visual contact faster after initial capture, suggesting that decreasing viewing was driven in part by disgust. Similarly, viewing decreased faster for the more disgusting bodily products images compared to the less disgusting rotten food images. However, it is possible that other differences between these stimulus categories, besides disgustingness, explained this pattern (e.g., food may still attract attention as an appetitive stimulus, even when compromised by disgusting mold).

A similar dynamic could be seen between trials, as well. There was a substantial decline in overall viewing of a disgusting image from the first to second exposure. This reduction was maintained, but did not substantially increase, on subsequent exposures. These findings are in line with Kron and colleagues (2014) experiments showing that ad libitum viewing of unpleasant images declines after the images have been viewed once. The present findings suggest that most of this effect may occur on the initial exposure, as the stimulus transitions from being novel to familiar. In line with the effects of within-trial exposure, the effect of between trial exposure was also contingent upon disgust ratings, with greater declines across exposures in participants who reported more disgust to the images. However, the more disgusting bodily products images were not avoided at a greater rate across trials compared to the less disgusting rotten food images, in contrast to the pattern observed for within trial exposure.

In summary, disgusting images capture attention when they first appear and hold attention when they are novel. This tendency, which we attribute to the general motivational relevance of disgusting stimuli, competes with the tendency to avoid perceptual contact with disgusting images, which we attribute specifically to the disgusting properties of the image. Experiment 1 provides some evidence for this specificity, as only disgust ratings uniquely predicted decreasing viewing of disgusting images. However, it is possible that any unpleasant image would be perceptually avoided with increasing exposure. It is also possible that avoidance of unpleasant images is predicted by whichever affective response is most salient to the participant. Thus, while disgust ratings uniquely predict oculomotor avoidance of disgusting stimuli, other affective responses may uniquely predict oculomotor avoidance of other unpleasant stimuli.

Experiment 2

Experiment 2 sought to replicate key findings from Experiment 1 and to test the hypothesis that oculomotor avoidance is specific to disgusting stimuli. To address the discrepancy between the findings of Experiment 1 and other studies observing more robust oculomotor avoidance of disgust (Armstrong et al., 2014; Mason and Richardson, 2010), we selected a different set of bodily product images for our disgust stimuli consisting exclusively of feces and vomit, in line with prior studies. For additional unpleasant contents, we included threatening images (attacking dogs; Armstrong et al., 2013) and suicide images. We also included pleasant images (happy people). To provide a more comprehensive assessment of affective responding to the images, we added the discrete emotion rating of "sadness."

We predicted that all of the emotional images would initially capture gaze relative to the neutral image. We predicted that gaze would subsequently decline within-trial for unpleasant images, as the motivated attention effect decayed. We predicted that gaze would decline the fastest for disgusting images, resulting in avoidance relative to the neutral images. In contrast, we predicted that declines in gaze would not lead to avoidance relative to the neutral image for the other unpleasant images. We also predicted that gaze would not decline for the pleasant images, consistent with prior studies (e.g., Kellough et al., 2008). Further, we predicted that we would replicate the finding from Experiment 1 that only disgust ratings would uniquely predict decreasing viewing of the disgusting image within and between trials. Finally, we conducted exploratory analyses of the effects of affective responding on viewing of the other image categories.

Participants

Participants (*N* = 92) were recruited from an undergraduate psychology subject and provided informed consent to a protocol approved by the Queens University Institutional Review Board. After excluding participants with over 50% missing eye tracking data (*N* = 8), the final sample size was 84 (age: *M* =19.71 years, *SD* = 2.06; gender identity: 83.3% female, 14.3% male, 1.2% nonbinary; racial/ethnic identity: 46.4% White, 36.9% Asian, 6% Indigenous, 4.8% Latino/a, 3.6% Black, and 1.2% Middle Eastern or North African). One participant did not complete the image ratings following the eye tracking task. This data was collected as part of a larger ongoing study of suicide risk. We ended data collection for this experiment at the present sample size because we had reached a natural stopping point (end of semester), and our sample size exceeded the sample size (*N* = 39) of a prior eye tracking study showing that similar disgusting images are avoided relative to other unpleasant image categories (Bradley et al., 2015).

Measures, Materials and Apparatus

We used the same EVS scales from Experiment 1 to collect self-report ratings of affective responding to the images. However, we added a unipolar rating of sadness. For the disgusting images, rather than using bodily product images from the DIRTI set, we used images of feces and vomit from the IAPS and publicly available online resources. For the threatening images, we used images of attacking dogs from the IAPS and publicly available online resources. These images were previously used in Armstrong et al. (2013) and were shown to elicit mostly fear, rather than disgust, on discrete emotion ratings. For the suicide images, we selected images from the Self-Directed Violence Picture System (SDVPS; Nazem, Forster, & Brenner, 2017) that did not include body envelope violations (i.e., gore), to minimize disgust responding. For the pleasant images, we selected images of social pleasure (groups of happy people) from the IAPS. For the neutral images, we selected 20 images of household objects from the IAPS. Images were sized to 400 x 300 pixels and displayed on a Dell 24" monitor at a viewing distance of 60 cm with the screen set to a resolution of 1280 x 1024 by OpenSesame to keep the stimuli within a trackable range. A Gazepoint HD3 eye tracker (150 hz) was controlled by PyGaze within OpenSesame. Similar to the Eye Tribe, the Gazepoint is an affordable eye tracker intended for a broad range of applications and has been shown to be sufficiently accurate and precise for dwell time research (Funke et al., 2016). Data were reduced using a custom script written in Python 3 (Dalmaijer, 2017) using the same approach described in Experiment 1. Overall dwell time and image ratings were analyzed using repeated-measures analysis of variance and post hoc tests with Holm-Bonferroni correction for multiplicity using jamovi software (version 1.2; 2020).

Procedure

The procedure was modeled on Experiment 1. There were again five images in each category, which were each presented four times, twice on the left and twice on the right. There were 80 trials total, 20 per category. The trials were presented in two blocks of 40. In each block, the emotional images were randomly assigned neutral pairs at the beginning. Also, in contrast to Experiment 1, we ensured that all images were presented once before one was repeated. Finally, we shortened the ITI from 3 s to 1.5 to reduce overall task length. The eye tracker was calibrated

(9-point procedure) at the beginning of the session and after the first block. Image ratings were collected after the viewing task.

Analysis Plan

The analytic strategy in Experiment 2 was similar to the one used in Experiment 1. Multilevel models were used to examine how each individual's dwell time on images changed across 12 epochs and across 4 presentations of the images, and how these changes varied across individuals. HLM models were run separately for image types (i.e., disgust, suicide, threat, pleasant) across time (epoch, presentation), and subjective ratings (i.e., disgust, afraid, aroused, pleasant, sad) were included in the level 2 submodel as moderators of changes in dwell time. The HLM model assessing gaze for disgusting images across epochs was as follows:

Level 1:

$$\textit{Dwell time proportion (disgusting images)} = \beta_0 + \beta_1\,(\textit{epoch}) + R$$

Level 2:

$$\beta_0 = \gamma_{00} + \gamma_{01}\,(\textit{Disgust}) + \gamma_{02}\,(\textit{Afraid}) + \gamma_{03}\,(\textit{Aroused}) + \gamma_{04}\,(\textit{Pleasant}) + \gamma_{05}\,(\textit{Sad}) + U_0$$

$$\beta_1 = \gamma_{10} + \gamma_{11}\,(\textit{Disgust}) + \gamma_{12}\,(\textit{Afraid}) + \gamma_{13}\,(\textit{Aroused}) + \gamma_{14}\,(\textit{Pleasant}) + \gamma_{15}\,(\textit{Sad})$$

In this model, γ_{00} represents the mean dwell time on disgusting images in the first epoch and γ_{10} represents the linear change of dwell time on disgusting images across the 12 epochs. Moderators of within-person changes in dwell time across epochs are reflected in the following parameters: disgust ratings (γ_{11}), fear ratings (γ_{12}), arousal ratings (γ_{13}), pleasant/unpleasant ratings (γ_{14}), and sad ratings (γ_{15}). The HLM models assessing gaze for other image types (i.e., suicide, threat, pleasant) across epochs were identical but included corresponding ratings for those images. HLM models assessing gaze across presentations were identical except the parameter γ_{10} represented linear change of dwell time across the four presentations.

Results

Image Ratings

Discrete emotion

We conducted a 2 (image type: disgust, suicide, threat) by 3 (rating: disgusted, afraid, sad) repeated-measures ANOVA with Greenhouse-Geisser correction for non-sphericity. We did not include pleasant images in these analyses because all of the discrete emotions rated were unpleasant. The main effects of type, F (1.88,154.27) = 73.53, $p < .001$, $\eta p^2 = .47$, and rating, F (1.99,162.85) = 24.30, $p < .001$, $\eta p^2 = .23$, and the type by rating interaction, F (2.99, 244.97) = 267.42, $p < .001$, $\eta p^2 = .77$, were all significant. We explored this interaction further by examining the image type main effect for each rating. The images significantly differed for each rating: disgust: F (1.75, 143.82) = 365.62, $p < .001$, $\eta p^2 = .82$; afraid: F (1.99, 163.51) = 38.58, $p < .001$, $\eta p^2 = .32$; sad: F (1.72, 141.30) = 150.06, $p < .001$, $\eta p^2 = .65$. Post hoc tests with Holm-Bonferroni correction for multiple comparisons revealed that disgusting images elicited more disgust compared to suicide [t(164) = 21.18, $p < .001$] or threat images [t(164) = 25.25, $p <$ .001], and suicide images elicited more disgust than threat images [t(164) = 3.96, $p < .001$]. Suicide images elicited more fear than threatening [t(164) = 521, $p < .001$] and disgusting images [t(164) = 8.73, $p < .001$], and threatening images elicited more fear than disgusting images [t(164) = 3.52, $p < .001$]. Finally, suicide images elicited more sadness compared to disgusting [t(164) = 15.45, $p < .001$] or threatening images [t(164) = 14.50, $p < .001$], whereas disgusting and threatening images did not differ [t(164) = 0.95, $p = .341$].

Affective dimensions

We conducted a 4 (image type: disgust, suicide, threat, pleasant) by 2 (rating: valence, arousal) repeated-measures ANOVA with Greenhouse-Geisser correction for non-sphericity. The main effects of type, F (2.08,170.35) = 72.28, $p < .001$, $\eta p^2 = .47$, and rating, F (1,82) = 89.06, $p < .001$, $\eta p^2 = .52$, and the type by rating interaction, F (1.90, 155.90) = 158.62, $p < .001$, $\eta p^2 = .66$, were all significant. We explored this interaction further by examining the image type main effect for each rating. The images significantly differed for both valence, F (2.16, 177.10) = 229.34, $p < .001$, $\eta p^2 = .74$, and arousal, F (1.77, 145.49) = 22.49, $p < .001$, $\eta p^2 = .22$. Post hoc tests with Holm-Bonferroni correction for multiple comparisons were then conducted. Pleasant images, unsurprisingly, were rated as more pleasant than disgust [t(246) = 24.42, $p < .001$], suicide [t(246) = 20.50, $p < .001$], and threat images [t(246) = 15.38, $p < .001$]. Disgust images were rated as more unpleasant than suicide [t(246) = 3.92, $p < .001$] or threat images [t(246) = 9.04, $p < .001$], and suicide images were rated as more unpleasant than threat images [t(246) = 5.12, $p < .001$]. Disgust, suicide, and threat images did not differ in terms of arousal [ts(246) < 1.96, ps > .154. However, the pleasant images were rated as less arousing than disgust [t(246) = 6.69, $p < .001$], suicide [t(246) = 7.40, $p < .001$], and threat images [t(246) = 5.44, $p < .001$]. Table 1 contains *M*s and *SD*s for image ratings.

Overall Dwell Time on Image Types

We conducted a repeated-measures ANOVA with Greenhouse-Geisser correction for non-sphericity on dwell time with the factor image type (disgust, suicide, threat, pleasant). There was a significant main effect of image type, F (2.50, 207.23) = 49.77, $p < .001$, $\eta p^2 = .38$. Post hoc tests with Holm-Bonferroni correction for multiple comparisons revealed that disgusting images were viewed less than suicide [t(249) = 7.37, $p < .001$], threat [t(249) = 9.72, $p < .001$], and pleasant images [t(249) = 11.26, $p < .001$]. Suicide images were viewed less than threat [t(246) = 2.35, $p = .039$] and pleasant images [t(246) = 3.89, $p < .001$]. Viewing of threat and pleasant images was not significantly different [t(246) = 1.54, $p = .125$]. To gauge overall approach or avoidance relative to the neutral images, we compared the proportion of dwell time on the emotional images compared to the accompanying neutral images, using one-sample t-tests against the value of .5, which represents even viewing. Overall, disgust images were avoided, *M* = .41, *SD* = .19, $t(83) = 4.16$, $p < .001$, $d_z = .45$, whereas the other emotional images were approached, relative to the accompanying neutral image [suicide: *M* = .56, *SD* = .17, $t(83) = 3.05$, $p < .001$, $d_z = .33$; threat: *M* = .60, *SD* = .14, $t(83) = 6.53$, $p < .001$, $d_z = .71$; pleasant: *M* = .63, *SD* = .10, $t(83) = 11.74$, $p < .001$, $d_z = 1.28$.

Effects of Prolonged Exposure on Dwell Time and Moderation by Individual Differences in Affect Ratings

Across epochs, there were significant decreases in dwell time on disgusting images (*b* = -0.021, *SE* = .001, $p < .001$), suicide images (*b* = -0.011, *SE* = .001, $p < .001$), and threat images (*b* = -0.009, *SE* = .001, $p < .001$) compared to neutral images; no significant changes in dwell time were observed for pleasant images (*b* = -0.002, *SE* = .001, $p = .082$) compared to neutral images. Decreases in dwell on disgusting images were sharper than decreases for suicide, Z = 7.07, p < .001 and threat images, Z = 8.49, p < .001, and distinct from the relatively steady viewing of pleasant images, Z = 13.44, p < .001. Decreases in dwell on suicide and threat images, Z = 1.41, p = .157, were not significantly different, but decreases in dwell on both suicide, Z = 6.36, p < .001, and threat images, Z = 4.95, p < .001, were distinct from the relatively steady viewing of pleasant images (all comparisons Holm-Bonferroni corrected). Figure 2 depicts dwell time on the emotional images as a function of both prolonged and repeated exposure. Table 2 contains Ms and SDs for effects of prolonged exposure on dwell time.

Disgust images

Disgust ratings were significantly associated with changes in dwell time on disgusting images (b = -0.007, SE = .002, $p < .001$). Simple slope analyses revealed that dwell time on disgusting images decreased more rapidly for individuals with higher (+1 SD) disgust ratings (b = -0.028, SE = .002, $p < .001$) compared to those with lower (-1 SD) disgust ratings (b = -0.014, SE = .002, $p < .001$). A similar interaction pattern for fear ratings of disgusting images was observed (b = -0.004, SE = .002, p = .033), indicating more rapid decreases in dwell time for individuals with higher compared to lower fear ratings. A contrasting interaction pattern for sadness ratings of disgusting images was observed (b = 0.004, SE = .002, p = .031), indicating slower decreases in dwell time for individuals with higher compared to lower sadness ratings. Changes in dwell time on disgusting images were not significantly associated with valence or arousal ratings (p's > .10).

Suicide images

Disgust ratings were significantly associated with changes in dwell time on suicide images (b = -0.003, SE = .001, p = .015), indicating more rapid decreases in dwell time for individuals reporting higher compared to lower disgust ratings. Sad ratings were significantly associated with changes in dwell time for suicide images (b = 0.005, SE = .002, p = .005) in a pattern similar to that observed for disgusting images, with slower decreases in dwell time for individuals with higher compared to lower sadness ratings. Valence ratings were also significantly associated with changes in dwell time for suicide images (b = 0.003, SE = .001, p = .009), such that more rapid decreases in dwell time were observed for individuals who rated images as more unpleasant. Changes in dwell time on suicide images were not significantly associated with fear or arousal ratings (p's > .10).

Threat images

Disgust ratings were significantly associated with changes in dwell time on threat images (b = -0.006, SE = .002, p = .004) in a similar manner to that observed for disgust and suicide images, with more rapid decreases in dwell time associated with higher disgust ratings. Sad ratings were significantly associated with changes in dwell time for threat images (b = 0.006, SE = .001, p < .001) in a pattern similar to that observed for disgusting and suicide images, with slower decreases in dwell time for individuals with higher compared to lower sadness ratings. Changes in dwell time on threat images were not significantly associated with fear, arousal, or pleasant ratings (p's > .20).

Pleasant images

Arousal (b = 0.003, SE = .001, p = .015) and valence (b = 0.005, SE = .001, p < .001) ratings were both significantly associated with changes in dwell time on pleasant images. Dwell time decreased significantly for individuals with lower (-1 SD) arousal ratings (b = -0.005, SE = . 001, p < .001) but did not change significantly for individuals with higher (+1 SD) arousal ratings (b = 0.001, SE = .001, p = .710). dwell time on pleasant images decreased for individuals with lower (-1 SD) pleasantness ratings (b = -0.007, SE = .001, p < .001) but increased for individuals with higher (+1 SD) pleasantness ratings (b = 0.003, SE = .001, p = .044). Changes in dwell time on pleasant images were not significantly associated with disgust, fear, or sadness ratings (p's > .20).

Effects of Repeated Exposure on Dwell Time and Moderation by Individual Differences in Affect Ratings

Across repeated presentations, perceptual avoidance of stimuli was evident in significant decreases in dwell time on disgusting images (b = -0.026, SE = .007, p < .001) and suicide images (b = -0.020, SE = .006, p = .001) compared to neutral images. In contrast, increases in dwell time on pleasant images were observed across presentations (*b* = 0.013, *SE* = .006, *p* = .036) compared to neutral images. No significant changes in dwell time were observed for threat images (*b* = -0.006, *SE* = .006, *p* = .317) compared to neutral images. Change in dwell on the disgust images did not significantly differ from change in dwell on the suicide images, *Z* = .65, *p* = .515, or threat images, *Z* = 2.20, *p* = .030, but change in dwell for the disgust images, *Z* = 4.23, *p* < .001, and suicide images, *Z* = 3.89, *p* < .001, were significantly different compared to change in dwell on the pleasant images. Change in dwell for suicide versus threat images, *Z* = 1.65, *p* = .099, and for threat versus pleasant images, *Z* = 2.24, *p* = .025, did not significantly differ (all comparisons Holm-Bonferroni corrected). Table 3 contains Ms and SDs for effects of repeated exposure on dwell time.

Disgust images

Fear ratings were significantly associated with changes in dwell time on disgust images across presentations (*b* = 0.022, *SE* = .011, *p* = .047), indicating slower decreases in dwell time for individuals reporting higher compared to lower fear ratings. Arousal ratings were also significantly associated with changes in dwell time on disgust images across presentations (*b* = -0.020, *SE* = .007, *p* = .007), indicating significant decreases in dwell time for individuals reporting higher arousal but no significant changes in dwell time for individuals reporting lower arousal. Changes in dwell time on disgust images were not significantly associated with disgust, valence, or sadness ratings (*p*’s > .10).

Suicide, threat, and pleasant images

Subject ratings did not significantly moderate changes in dwell time on suicide (*p*’s > .05), threat (*p*’s > .20), or pleasant (*p*’s > .07) images.

Discussion

In Experiment 2, we found that highly disgusting images of feces and vomit elicit oculomotor avoidance, both in terms of decreasing viewing within and across trials, and in terms of overall viewing. The disgusting images were viewed less compared to other unpleasant image types, and only the disgusting images were viewed less compared to the accompanying neutral image. The other unpleasant image categories were viewed more than the accompanying neutral image overall, and they did not appear to elicit consistent avoidance relative to the neutral image at any point during exposure. Experiment 2 also replicated the finding from Experiment 1 that self-reported disgust elicited by disgusting images predicts decreasing viewing of these images within trials when covarying for valence and fear. The more disgust a participant reported to these images, the more they reduced perceptual contact with the image with prolonged exposure. A similar pattern was observed for fear ratings of disgusting images, but to a lesser degree, a finding not observed in Experiment 1. In contrast to Experiment 1, self-reported disgust did not predict decreasing viewing of disgusting images with repeated exposure. Instead, fear ratings predicted weaker declines in viewing disgusting images across repeated exposures, and arousal ratings predicted stronger declines across repeated exposures. Interestingly, self-reported disgust predicted within-trial declines in viewing not just disgusting images, but also suicide and threat images. In contrast, self-reported sadness had an opposite effect compared to disgust for each of the three unpleasant image categories, as it was associated with weaker declines in viewing across the 12-s exposures.

General Discussion

In this study, we tested the theory that disgusting stimuli are inherently unpleasant to perceive. Specifically, we tested the prediction that disgusting stimuli would repel gaze, which may constitute a severe test (Popper, 1963), given that visual contact is less intimate than other forms of sensory contact (e.g., touch or smell). Our findings suggest that disgusting stimuli indeed repel gaze, but with important caveats. First, disgusting stimuli also possess properties that attract gaze. As motivationally-relevant stimuli, they are initially prioritized, resulting in a tendency to view them *more* than accompanying neutral stimuli early in exposure. This phenomenon has been referred to as “motivated attention” or “natural selective attention” (e.g., Bradley et al., 2015). Individuals are motivated to avoid physical contact with disgusting stimuli, due to their association with harmful pathogens (Tybur et al., 2013). However, avoiding physical contact with disgusting stimuli requires identifying and appraising these stimuli, which in turn requires visual contact. In both experiments, we noted a strong tendency in the first 0-2 s to visually approach disgusting images, consistent with Bradley et al. (2015). However, once this relatively automatic tendency subsided and strategic control of gaze emerged, viewing of disgusting images steadily declined. Further, such declines were sharper for disgust compared to other unpleasant contents and predicted by self-reported disgust to the disgusting images, even when covarying for negative affect. This link between self-reported disgust to a stimulus and decreasing viewing replicated in a second sample and generalized across categories of disgusting stimuli. In light of the robust link between decreasing viewing and self-reported disgust, we interpret this viewing dynamic as an effort to avoid perceptual contact with a stimulus that is inherently unpleasant to view due to its disgust properties, yet immediately salient due to its motivational relevance.

Surprisingly, the link between self-reported disgust and decreasing viewing was observed for suicide and threat images, as well. Although we intended for these categories to elicit minimal disgust, the suicide images were rated on average as mildly disgusting and the threat images were rated as slightly disgusting (and both ratings had substantial variance). Suicide images may have elicited disgust because dead bodies are disgusting (death was found to be a distinct domain of disgust elicitors in the original disgust scale; Rozin, Haidt, & McCauley, 2008) or because injuries to the body can constitute a form of body envelope violation (e.g., disfigurement), even without open wounds (Rozin et al., 2008). The threat images may have elicited disgust because the menacing dogs were perceived as dirty (violent dogs may be associated with low socioeconomic status or junk yards) or perhaps because the images tended to focus on the dogs open mouths and often depicted slobber.

We also found that across unpleasant image categories, sadness ratings were associated with *weaker* declines in viewing. This finding was unexpected; however, it is consistent with research linking depression (a disorder of excessive sadness; Horowitz & Wakefield, 2008) to a ruminative processing style (e.g., Kaiser et al., 2018). Depressed individuals have been found to show increased elaborative processing of dysphoric content as revealed by increased dwell time (Kellough et al., 2008; see Armstrong & Olatunji, 2012). State sadness may be associated with a similar bias to “visually ruminate” on the source of affect. Indeed, there is a broad literature linking rumination and sadness, often in non-clinical samples (Kirkegaard & Thomsen, 2006). In addition, sadness ratings of unpleasant images with humans or animals may reflect empathic concern, which could lead to greater engagement with these stimuli.

Not only were disgusting stimuli viewed less with prolonged exposure (within a trial), they were also viewed less with repeated exposure (between trials). In Experiment 1, decreasing viewing across exposures was associated with self-reported disgust. However, in the second study, this tendency to view disgusting stimuli less with repeated exposure was not linked to self-reported disgust. Instead, it was associated with arousal, such that more arousal predicted sharper declines, and it was associated with fear, such that more fear predicted weaker declines. Also, decreases in viewing disgust across exposures were not greater than decreases for other unpleasant image types. Thus, we are reluctant to draw conclusions regarding the affective determinants of decreased viewing with repeated exposure.

However, our findings may still shed light on the effects of repeated exposure on viewing behavior. Consistent with Kron and colleagues (2014) category-based analysis, we found that viewing moderately pleasant images (happy people) increased with exposure; viewing moderately to highly unpleasant images (disgust, suicide) decreased with exposure; and viewing mildly unpleasant images (threat) did not decrease with exposure. These findings are consistent with Kron and colleague's (2014) conclusion that the "hedonic principle" is suspended on initial viewing due to the primacy of gathering information from motivationally relevant stimuli. On subsequent viewing, when the hedonic principle holds, the largest increases or decreases are seen for the stimuli that are most pleasant or unpleasant, respectively. A complementary explanation is that on the first encounter with disgust and suicide images, participants are inspired to view these images out of a fleeting curiosity (Oosterwijk, 2017) or interest (Turner & Silvia, 2006) that is satisfied once their novelty wears off (Armstrong et al., 2019). Indeed, curiosity may also bear on viewing dynamics within trials. We attribute increased viewing of unpleasant images in the first few seconds of the trial to "motivated attention" in the service of rapid behavioral responding. However, declines in viewing unpleasant images often stretched out over several seconds, suggesting that increased viewing early in the trial may also be related to a voluntary effort to retrieve information. Perhaps as more information is gathered within the trial, the disgust response increases, and the need for information wanes, causing a transition to avoidance. In future research, we plan to include measures of self-reported state curiosity and trait morbid curiosity (Scrivner, 2020) to determine how epistemic goals are related to the viewing patterns for unpleasant images observed in the present study.

Although the present study found evidence that disgusting stimuli repel gaze, it is still unclear to what extent disgust stimuli are unique in their capacity to repel gaze. Kron and colleagues (2014), for example, found substantial evidence that valence predicts decreased viewing, such that a disgusting stimulus might be avoided because it is unpleasant, rather than disgusting, per se. Although disgusting images were viewed less than other unpleasant images (suicide, threat) in Experiment 2, they were also rated as more unpleasant than other unpleasant images, leaving open the possibility that they were viewed less due to the higher-order factor of valence.

Although we consider this an important limitation to be addressed in future research, there are few details that mitigate this concern. First, disgust ratings, rather than valence ratings, were the strongest predictor of decreasing viewing of disgusting images (as well as suicide and threat images). Second, there appeared to be more oculomotor avoidance of the bodily product images in Experiment 1 compared to the suicide images in Experiment 2, even though the suicide images in Experiment 2 were rated as more unpleasant than the bodily product images in Experiment 1. Third, Kron and colleagues focused on higher-order dimensions of affect, rather than discrete emotion labels; it is possible that disgust ratings would have been a stronger predictor of shorter viewing times in their studies, compared to the higher-order dimension of valence. Indeed, the unpleasant images that were viewed least on second exposure in Kron and colleagues (2014) category-based analysis were mutilation images, which have been found to elicit disgust more than other negative emotions (e.g., fear; Connolly et al., 2008). Finally, the greater unpleasantness of disgusting stimuli relative to suicide and threat stimuli may reflect the very fact that disgusting images are inherently unpleasant to perceive. Indeed, other studies have had difficulty matching the valence of disgust and fear stimuli (pictures: Perone, Becker, & Tybur, 2019; videos: Armstrong et al., 2014). Some have argued that disgust (and its concomitant unpleasantness) may be easier to elicit in the laboratory compared to other negative emotions, because disgust requires only the perception of a stimulus, whereas fear, sadness, or anger require additional situational appraisals that are difficult to elicit in a contrived setting (Royzman & Sabini, 2001; Russell & Giner-Sorolla, 2011).

In addition to theoretical implications, our study may have important measurement implications. One difficulty in measuring disgust is that people use the term to express a range of disapproval that outstrips its scientific meaning (Nabi, 2002; Royzman et al., 2017). Although one solution is to assess the construct using more technical, precise terms (Fiske, 2019), it would be useful to have a language-independent measure, both to validate self-report and to address the limits of introspection. Researchers have measured disgust through its facial expression, by recording levator labii activity; however, this measure does not consistently track self-reported disgust (Vartanian et al., 2008) and may have low reliability (Hess et al., 2017). Our findings suggest that oculomotor avoidance may provide a promising measure of disgust, particularly for research examining individual differences in disgust responding to visual stimuli. Further, we show that oculomotor avoidance and other patterns of emotional modulation can be reliably measured with affordable eye trackers. These consumer-oriented instruments are not only affordable, but also user-friendly, and could radically democratize the field of eye tracking. In summary, our study provides new evidence for the old theory that disgusting stimuli are inherently offensive to the senses (Darwin, 1872/2005), and in doing so, suggests a novel means for measuring disgust.

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Table 1. Image ratings M*s (*SD*s)*

Experiment 1			*Experiment 2*			
Rating	Image Category		Image Category			
	Bodily Products	Spoiled Food	Disgust	Suicide	Threat	Pleasant
Disgust	50.00 (22.40)	37.91 (21.53)	72.75 (21.48)	24.59 (23.02)	15.58 (17.80)	4.62 (6.56)
Fear	19.33 (22.07)	13.63 (17.68)	19.62 (23.63)	41.47 (26.71)	28.43 (21.95)	4.32 (7.88)
Sadness	—	—	14.92 (19.26)	54.88 (28.22)	17.39 (20.83)	9.66 (10.66)
Valence	-30.97 (27.22)	-20.62 (20.93)	-58.12 (29.89)	-42.54 (33.27)	-22.15 (23.47)	39.05 (23.68)
Arousal	8.47 (33.18)	-.67 (26.57)	16.13 (38.79)	18.99 (37.02)	11.16 (27.04)	-10.63 (28.60)

Note: Disgust, fear, and sadness ratings completed on unipolar scale from 0–100; valence and arousal ratings completed on bipolar scale from -100–100.

Table 2. Proportion of dwell time M*s (*SD*s) on image types as a function of within trial exposure*

	Epoch											
Image	0-1s	1-2s	2-3s	3-4s	4-5s	5-6s	6-7s	7-8s	8-9s	9-10s	10-11s	11-12s
Experiment 1												
Bodily products	.63 (.12)	.62 (.20)	.57 (.19)	.52 (.20)	.49 (.20)	.48 (.21)	.46 (.22)	.44 (.21)	.45 (.21)	.45 (.22)	.44 (.23)	.42 (.23)
Spoiled food	.65 (.12)	.62 (.17)	.60 (.18)	.57 (.19)	.56 (.19)	.54 (.20)	.52 (.20)	.53 (.21)	.52 (.22)	.53 (.22)	.51 (.22)	.52 (.22)
Experiment 2												
Disgust	.69 (.13)	.50 (.22)	.46 (.23)	.43 (.20)	.39 (.19)	.37 (.20)	.37 (.21)	.37 (.23)	.36 (.23)	.36 (.25)	.35 (.24)	.35 (.23)
Suicide	.69 (.11)	.62 (.18)	.58 (0.2)	.55 (.19)	.55 (.19)	.54 (.19)	.53 (.21)	.52 (.21)	.54 (.21)	.53 (.21)	.53 (.22)	.52 (.22)
Threat	.70 (.12)	.63 (.16)	.63 (.15)	.60 (.16)	.59 (.17)	.60 (.18)	.59 (.19)	.59 (.18)	.58 (.19)	.58 (.19)	.57 (.19)	.57 (.19)
Pleasant	.68 (.09)	.61 (.12)	.63 (.13)	.65 (.14)	.63 (.14)	.62 (.15)	.64 (.15)	.63 (.15)	.62 (.15)	.63 (.15)	.63 (.16)	.64 (.15)

Table 2. Proportion of dwell time M*s (*SD*s) on image types as a function of between trial exposure*

	Presentation Number			
Image	1	2	3	4
Experiment 1				
Bodily products	.55 (.16)	.49 (.21)	.47 (.22)	.46 (.23)
Spoiled food	.59 (.15)	.55 (.19)	.55 (.21)	.53 (.22)
Experiment 2				
Disgust	.48 (.19)	.41 (.23)	.41 (.23)	.40 (.24)
Suicide	.59 (.14)	.57 (.21)	.54 (.21)	.53 (.24)
Threat	.61 (.14)	.60 (.18)	.59 (.20)	.60 (.18)
Pleasant	.60 (.11)	.63 (.16)	.63 (.15)	.65 (.18)

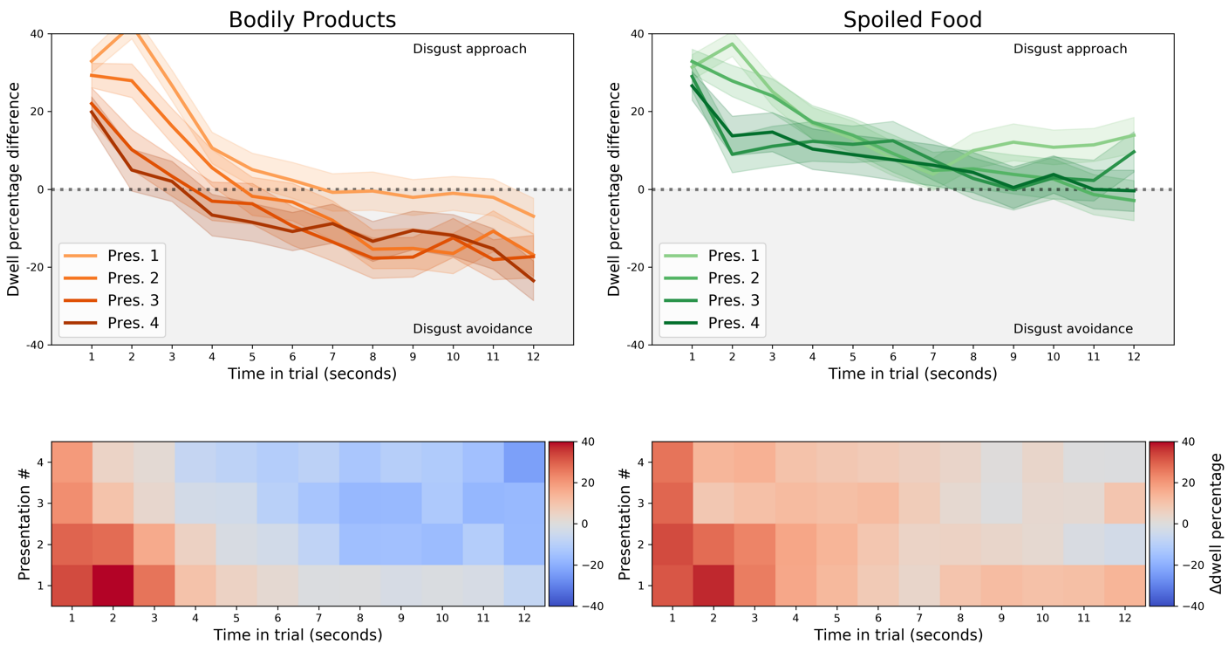

Figure 1. Dwell time on the two types of disgusting images in Experiment 1 as a function of prolonged (within-trial) and repeated (between-trial) exposure. Shading around lines indicates the within-subjects standard error of the mean.

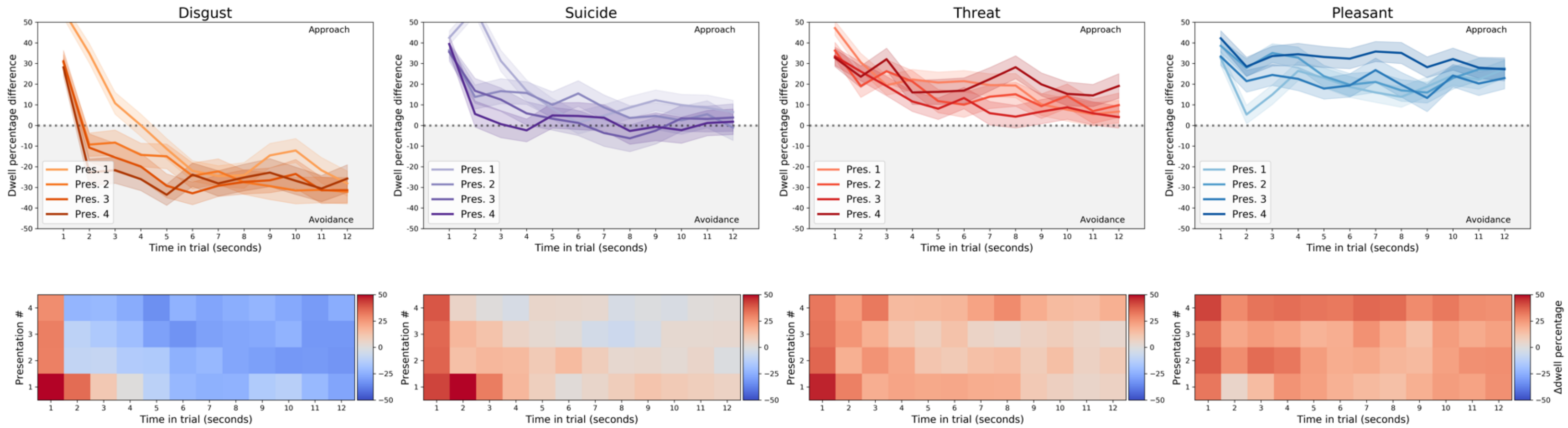

Figure 2. Dwell time on the four emotional image types in Experiment 2 as a function of prolonged (within-trial) and repeated (between-trial) exposure. Shading around lines indicates the within-subjects standard error of the mean.