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Don't look now! Oculomotor avoidance as a conditioned disgust response

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Abstract

Pavlovian conditioning paradigms have revealed fear learning tendencies that may be implicated in the etiology and maintenance of anxiety disorders. Given the prominence of disgust in certain anxiety disorders, it may be fruitful to study disgust learning in addition to fear learning. The present study utilized eye tracking to examine the effects of disgust conditioning on attentional bias, a phenomenon that characterizes anxiety disorders. Participants completed either a disgust condition, in which a face (conditioned stimulus; CS+) was paired with videos of individuals vomiting (unconditioned stimulus; US), or a negative condition, in which a face was paired with videos of individuals being harmed in motor vehicle accidents. Eye movements were used to measure attentional biases related to the USs and the CSs. In line with prior research, attentional avoidance was observed for the disgust CS+. However, this effect did not reach significance until *after* extinction and was linked to self-reported disgust post-acquisition, yet decoupled from self-reported disgust post-extinction. Attentional avoidance of the CS+ was not found in the negative condition, and post-extinction differences in attentional bias for the CS+ between conditions were found to be mediated by differences in attentional bias for the US, as only the disgust US elicited attentional avoidance. Also, individual differences in disgust sensitivity were found to be associated with attentional avoidance of the disgust US, and this effect was mediated by self-reported disgust in response to the US. Further, disgust sensitivity was associated with attentional avoidance of the disgust CS+, and this effect was mediated by attentional avoidance of the disgust US. These findings provide new insight into a complex pattern of relations between disgust, evaluative learning, and attention that may have implications for the etiology and maintenance of certain anxiety disorders.

Keywords

disgust; eye movements; attention; conditioning

Pavlovian fear conditioning is regarded as one of the most successful paradigms in translational research on anxiety disorders (Beckers, Krypotosa, Boddezb, Effting, & Kindta, 2013). This classic procedure involves repeated pairing of an inherently aversive stimulus (unconditioned stimulus; US), such as an electrodermal shock, with a neutral stimulus (conditioned stimulus; CS). According to contemporary accounts (Bouton, 2007), an association forms between the US and the CS that allows the CS alone to activate the

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mental representation of the US, and thereby elicit an aversive response. The aversive response elicited by the CS (conditioned response; CR) often consists of an unpleasant anticipatory state related to the expectation of the US, as well as an evaluative response to the CS itself, caused by the apparent transfer of affective properties from the US to the CS (“affective” or “evaluative” learning; Hermans, Crombez, Vansteenwegen, Baeyens, & Eelen, 2002). Individuals with anxiety disorders have been found to exhibit a variety of fear learning abnormalities, including increased acquisition and impaired extinction of CRs (see Lissek et al., 2005), overgeneralization of CRs (Lissek et al., 2010), and failure to inhibit CRs to safety cues (Lissek et al., 2009).

While conditioning research on anxiety disorders has focused mainly on fear-eliciting USs (e.g., CO₂-enriched air, Forsyth & Eifert, 1998; a loud scream, Indovina, Robbins, Núñez-Elizalde, Dunn, & Bishop, 2011), it may be fruitful to examine learning related to disgust-eliciting USs, as well. Disgust is a basic emotion that motivates avoidance of contact with pathogen sources such as rotting food, bodily fluids, and rodents, and thus may have evolved to prevent disease transmission (Matchett & Davey, 1991; Oaten, Stevenson, & Case, 2009). There is mounting evidence suggesting that disgust plays a role in the etiology and maintenance of certain anxiety disorders (Olatunji, Cisler, McKay, & Phillips, 2010). For example, how easily and how intensely one experiences disgust, an individual difference known as *disgust sensitivity* (Haidt, McCauley, & Rozin, 1994), has been found to predict symptoms of obsessive-compulsive disorder (OCD), blood-injection-injury (BII) phobia, spider phobia, and post-traumatic stress disorder (PTSD), even when controlling for negative affect (Olatunji et al., 2010). Disgust sensitivity may confer risk for certain anxiety disorders by enhancing the acquisition and retention of disgust responses to stimuli associated with these disorders. Although few studies have examined Pavlovian learning of disgust, disgust sensitivity has been found to be associated with greater acquisition of self-report disgust CRs (Olatunji, Lohr, Smits, Sawchuk, & Patten, 2009), and individuals high in BII fear have been found to acquire more disgust, but not fear, to the CS+ in a study using BII stimuli as USs (Olatunji et al., 2009).

In order to fully understand the role of disgust learning in anxiety disorders, it is important to delineate the proximal mechanisms through which disgust may contribute to dysfunction. Recent findings suggest that attentional biases are a potential disease mechanism in anxiety disorders, as inducing attentional biases that characterize anxiety disorders appears to increase anxious reactivity in healthy individuals (MacLeod, Rutherford, Campbell, Ebsworthy & Holker, 2002), and ‘reversing’ attentional biases in individuals with anxiety disorders has been found to provide lasting symptom relief (Schmidt, Richey, Buckner, & Timpano, 2009) and improve behavioral functioning (Najmi & Amir, 2010). Several Pavlovian fear conditioning studies (Kelly & Forsyth, 2009; Lee, Lim, Lee, Kim, & Choi, 2009; Pischek-Simpson, Boschek, Neumann, & Waters, 2009; Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006) have documented an attentional bias for the CS+ that accompanies acquisition of other CRs (e.g., increased skin conductance; Pischek-Simpson et al., 2009), suggesting that an attentional bias is one mechanism through which aversive learning could contribute to anxiety disorders.

Whereas fear conditioning has been found to lead to an attentional bias towards the CS+, disgust conditioning may be associated with an attentional bias away from the CS+, as the UR to disgust-evoking stimuli may involve visual avoidance (Armstrong, Sarawgi, & Olatunji, 2012; Tolin, Lohr, Lee, & Sawchuk, 1999), due to the offensive sensory properties of disgust-evoking stimuli (Royzman & Sabini, 2001). Indeed, 'attentional avoidance' of threat appears to be most prominent in specific phobias, such as BII phobia (Mogg, Bradley, Miles, & Dixon, 2004) and spider phobia (Rinck & Becker, 2006), which may be due to the disgusting quality of stimuli in these disorders (Armstrong & Olatunji, 2012). Attentional avoidance is believed to play a functional role similar to behavioral avoidance, in that it prevents extinction and reappraisal, thereby maintaining harm associations (Cisler & Koster, 2010; Mogg, Mathews, & Weinman, 1987).

In the first study to investigate the effects of Pavlovian disgust conditioning on attentional bias, Mason and Richardson (2010) found that disgust images elicited attentional avoidance, and that a facial stimulus came to elicit attentional avoidance after being paired with disgust images, as revealed by eye tracking. Interestingly, attentional avoidance of the CS+ was not affected by an extinction procedure, consistent with past research suggesting that disgust associations can be resistant to extinction (Olatunji, Forsyth, & Cherian, 2007). Mason and Richardson also found that disgust sensitivity was associated with the retention of attentional avoidance of the CS+ after extinction, but not with the initial acquisition of attentional avoidance of the CS+. However, it is not clear if these findings are specific to disgust learning. Attentional avoidance may be related to more general attributes of aversive learning, and thus may be observed for CSs associated with any unpleasant stimulus.

To determine if attentional avoidance is specific to disgust learning, the present study contrasted the effects of disgust learning on attention with the effects of more general aversive learning, by including a condition with a US that evoked negative emotion more broadly. Prior research along these lines has assessed attention with a very small number of trials, constraining the reliability of the attentional biases that may be observed.

Accordingly, the present study assessed CS-related attentional bias over a larger number of trials, at three time points (post-habituation, post-acquisition, post-extinction). It was predicted that attentional avoidance of the US and the CS+ would only characterize disgust learning. Second, mediational analysis was utilized to provide further insight into the relations between attentional bias, disgust learning, and disgust sensitivity. It was predicted that disgust sensitivity would lead to increased attentional avoidance of the disgust US through its effect on the amount of disgust experienced in response to this stimulus. Further, it was predicted that disgust sensitivity would lead to increased attentional avoidance of the disgust CS+ through its effect on attentional avoidance of the disgust US.

Methods

Participants

One-hundred and twenty participants at a southern university participated in the experiment in exchange for course credit. Participants completed either a condition with a disgust-specific US ($n = 55$; 76.9% female; age $M = 19.36$, $SD = 1.28$) or a condition with a generally negative US ($n = 65$; 76.4% female; age $M = 19.49$, $SD = 1.11$).

Measures

The *Disgust Scale—Revised* (DS-R; Haidt et al., 1994; Modified by Olatunji et al., 2007) is a 25-item questionnaire assessing sensitivity to a range of disgust elicitors, including core (e.g., rotting food), animal-reminder (e.g., mutilation), and contamination-based (e.g., contact with germs) disgust domains. The DS-R had good internal consistency ($\alpha = .89$) in the present study.

Materials and Apparatus

The videos used as USs were selected from publically available online sources. Four videos of individuals vomiting were used as disgust USs; four videos of individuals being harmed in sudden motor vehicle accidents were used as generally negative USs, and four videos of different streams and rivers were used as control video stimuli. Videos were in color, did not contain audio, and were re-sized to subtend a visual angle of $14.62^\circ \times 11.71^\circ$. Two male faces and two female faces were selected from the NimStim Face Stimulus Set (Tottenham et al., 2009). One male-female pair was used for the CS+ (paired with US) and CS− (paired with control videos), with gender-CS pairing counterbalanced (Lee et al., 2009). The other male-female pair was not presented during phases of the conditioning task, but was instead included as “filler” (e.g., Kellough, Beevers, Ellis, & Wells, 2008) in the assessment of attentional biases, in order to delay habituation to the CSs. Face stimuli were converted to greyscale, matched for luminance and contrast, and resized to subtend a visual angle of $5.71^\circ \times 7.14^\circ$. Stimuli were presented using E-Prime version 2.0 software on a 17-in. widescreen monitor (1280×1024 resolution, 60 Hz). Eye movements were recorded with the iView X RED-III system from SensoMotoric Instruments (SMI), a video-based eye tracker with a dark pupil tracking method. This system has a sampling rate of 60 Hz, and a spatial resolution of $.5^\circ$ – 1° . Participants’ heads were stabilized with a chinrest at a viewing distance of 60.5 cm.

Procedure

Participants provided informed consent to a protocol approved by the Institutional Review Board, and then completed the measures as well as a basic demographic survey. Participants then completed the following tasks on the computer:

Conditioning procedure

Habituation: This stage consisted of 4 non-reinforced presentations (15 s) of each CS in random order. Participants were instructed to look directly at the CS. CSs were preceded by a fixation cross (1.5 s) and followed by an inter-trial interval (ITI; blank screen) that varied randomly between 12 s and 18 s. The CSs were centered in the lower third of the screen.

Acquisition: During this stage, the CSs were presented for 20 s in the lower third of the screen. After 5 s of presentation, a video began playing in the center of the screen for the remaining 15 s of the CS presentation. Participants were instructed to look directly at the CS until the video began, and then to watch the video. CSs were preceded by a fixation cross (1.5 s) and followed by an ITI that varied randomly between 12 s and 18 s. The CS+ cued the US video; the CS− cued the control video. There were two blocks of trials, each

consisting of 4 presentations of CS+ trials, and 4 presentations of CS– trials, presented in a random order. Eye movements were recorded during acquisition trials to assess gaze tendencies in response to the US.

Reacquisition: The acquisition procedure was repeated, but with only one block (4 trials of the CS+ and 4 trials of the CS–) in order to reactivate the associations prior to extinction (Kelly et al., 2007). Eye movements were again recorded.

Extinction: The acquisition procedure was repeated without US presentation (8 trials of CS+ and 8 trials of CS–).

Self-report CR assessment—Participants rated how disgusted and how afraid the CS's made them feel using the unidimensional version of the Empirical Valence Scale (EVS; Lishner, Cooter, & Zald, 2008). This visual analog scale has verbal descriptors placed at empirically determined locations—not at all (0), barely (7), slightly (12), mildly (24), moderately (38), strongly (70), extremely (85), and most imaginable (100)—and is designed to reduce floor effects for subtle responses (such as those expected for the CSs) and to limit ceiling effects for intense responses (such as those expected for the USs). Ratings can be made at any point along the scale using a mouse cursor. CS ratings were collected after habituation, midway through and after acquisition, and after extinction. In addition, participants completed the same ratings procedure for the US videos once they completed the conditioning procedure. Ratings were collected after a 5 s sample of each video.

Eye movement CR assessment—After the habituation, conditioning, and extinction stages of the conditioning procedure, an eye tracking procedure was conducted to assess attention allocation to the CSs. The CS+ and CS– were presented side by side, for 3 s, with centers separated by 10° of visual angle. Participants were told to view the faces as they please, and were asked to respond to a central fixation point (X or O) that preceded the CSs by clicking or not clicking the mouse, in order to obscure the nature of the task (e.g., Armstrong et al., 2010). The fixation point was presented for 700 ms or until participants responded. Following the CSs, the ITI consisted of a blank screen for 1.5 s, 2 s, or 2.5 s, varied randomly. The task consisted of 16 trials of the CS+ and CS–, as well as 16 “filler” trials of the male and female face not presented during conditioning phases. Location (right or left) was balanced for both face pairs.

Eye movement data reduction

Eye movement events (saccades, fixations, blinks) were defined using BeGaze 2.0 software from SMI, and a fixation was classified as 100 ms or more in which gaze was stable within 1.5° of visual angle. For acquisition and reacquisition phases, the rectangle containing the US video was the area of interest (AOI). Total fixation duration (dwell time), averaged across trials, was computed for the US video and the control video for each participant. These values were used in Analysis of Variance (ANOVA). For correlational and mediational analyses, dwell time on the control video was subtracted from dwell time on the US video, in order to control for individual differences in fixation time on the videos that were unrelated to stimulus content (e.g., differences related to quality of eye tracking

signal). Thus, negative values reflect visual avoidance of the US video relative to the control video. This variable was initially computed for the first half of acquisition (prior to midpoint CS ratings), for the second half of acquisition, and for reacquisition. These three indices had excellent internal consistency ($\alpha = .92$) and were combined to create a composite variable that would be more reliable, stable, and resistant to error (Campbell & Fiske, 1959). For the eye movement CR assessment, the rectangles containing the CSs were the area of interest (AOI). We computed the average dwell time on the CS+ and the CS– for each assessment (i.e., after habituation, after acquisition, and after extinction). These values were used in ANOVAs. For correlational and mediational analyses, dwell time on the CS– was subtracted from dwell time on the CS+, in order to control for individual differences in fixation time overall. Thus, negative values on the resulting variable reflected attentional avoidance of the CS+ relative to the CS–.¹

Data analytic plan

For US validation, A 2 (condition: disgust, negative) X 2 (video: US, control) X 2 (emotion: disgust, fear) mixed-effects ANOVA was conducted on self-reported emotion to the videos, and a 2 (condition: disgust, negative) X 2 (video: US, control) mixed-effects ANOVA was conducted on fixation duration on the videos. In line with other Pavlovian conditioning studies (e.g., Kelly & Forsyth, 2007; Lissek et al., 2008; Mason & Richardson, 2010), CR analyses were conducted separately for each stage of the conditioning procedure (habituation, acquisition, extinction). For the self-reported emotion CR, a 2 (condition: disgust, negative) X 2 (CS: CS+, CS–) X 2 (emotion: fear, disgust) mixed-effects ANOVA was conducted. Self-report data from the midpoint and end of acquisition were collapsed together for all analyses. Analyzing only the endpoint acquisition ratings yielded the same pattern of results. For the eye movement CR, a 2 (condition: disgust, negative) X 2 (CS: CS+, CS–) mixed-effects ANOVA was conducted. In addition, planned interaction contrasts were used to explore differences in CR discrimination between phases of the conditioning procedure (Kelly & Forsyth, 2007). Lastly, for correlational and mediational analyses, variables reflecting discriminant responding to the CSs (CS+ – CS–) and the USs (US – control) were used (e.g., Indovina et al., 2011; Lissek et al., 2008; Mason & Richardson, 2010). Mediation was tested using Preacher and Hayes's (2008) boot-strapping procedure, which does not impose distributional assumptions often violated in smaller samples.

Results

Group characteristics

Participants in the disgust and negative condition did not significantly differ in gender, $\chi^2(1, N = 110) = .005$; age, $t(118) = .59$; or disgust sensitivity, $t(118) = -1.15$, all $ps > .05$.

¹Orienting bias was also examined by considering the proportion of initial fixations captured by each CS. This variable may be more relevant to fear conditioning, as it shows convergent validity with reaction time variables (Armstrong & Olatunji, 2012) used in studies of fear conditioning (Pishek-Simpson et al., 2009). No effects were found on this variable in either condition.

US validation

Self-report UR assessment—There was a significant main effect of video, $F(1, 118) = 338.45, p < .001$, such that regardless of condition, the US elicited more negative emotion than the control video, as intended. The main effect of condition was not significant, $F(1, 118) = .45, p > .05$, nor was the condition by video interaction, $F(1, 118) = .23, p > .05$. Thus, the conditions did not differ in terms of the overall negative emotion elicited by the US videos. Importantly, the predicted condition by video by emotion interaction was significant, $F(1, 118) = 272.84, p < .001$, indicating that the conditions differed in terms of the specific negative emotions elicited by the US videos. To interpret this effect, the video by emotion type interaction was examined in each condition separately. For the disgust condition, significant main effects of video, $F(1, 54) = 217.08, p < .001$, and emotion, $F(1, 54) = 219.66, p < .001$, were qualified by a significant video by emotion interaction, $F(1, 54) = 261.97, p < .001$, indicating that while the disgust videos elicited more fear and disgust than the neutral videos, disgust was the predominant negative emotional reaction to the disgust videos compared to the neutral videos. Likewise, for the negative condition, there were significant main effects of video, $F(1, 64) = 145.36, p < .001$, and emotion, $F(1, 64) = 13.03, p < .001$, qualified by a significant video by emotion interaction, $F(1, 64) = 24.65, p < .001$, indicating that while the negative videos elicited more fear and disgust than the neutral videos, fear was the predominant emotional response to the negative videos compared to the neutral videos. Table 1 provides *Ms* and *SDs* for US ratings, and Figure 1 depicts these ratings.

Eye movement UR assessment—Significant main effects of condition, $F(1, 118) = 30.56, p < .001$, and video, $F(1, 118) = 33.39, p < .001$ were qualified by a condition by video interaction, $F(1, 118) = 32.45, p < .001$. To interpret this interaction, planned contrasts were conducted in each condition comparing fixation duration on the US video versus the control video. In the disgust condition, the US was viewed less ($M = 7.24$ s, $SD = 4.27$) than the control video ($M = 9.53$ s, $SD = 2.47$), $t(54) = -6.44, p < .001$, whereas in the negative condition, viewing times for the US ($M = 11.16$ s, $SD = 2.79$) and control video ($M = 11.18$ s, $SD = 2.00$) did not differ, $t(54) = -.08, p > .05$. Thus, the disgust US was uniquely characterized by a UR of attentional avoidance.

Habituation

Self-report CR assessment—The main effect of CS, the condition by CS interaction, and the condition by CS by emotion interaction were all non-significant, $F_s(1, 118) < 1, p_s > .05$. Thus, there were no differences in emotional responding to the CSs prior to acquisition in either group. Table 2 provides *Ms* and *SD* for all CS ratings, and Figure 2 depicts these ratings.

Eye movement CR assessment—The main effect of CS and the condition by CS interaction were both non-significant, $F_s(1, 118) < 1, p_s > .05$, as there were no differences in attentional responses to the CSs prior to acquisition in either the disgust condition (CS+: $M = 1038$ ms, $SD = 180$, CS–: $M = 1036$ ms, $SD = 201$, $t(54) = .05, p > .05$) or the negative condition (CS+: $M = 1026$ ms, $SD = 199$, CS–: $M = 1042$ ms, $SD = 211$, $t(64) = -.37, p > .05$).

Acquisition

Self-report CR assessment—There was a significant main effect of CS, $F(1, 118) = 45.67, p < .001$, reflecting acquisition of negative emotion to the CS+ vs. CS– in both conditions. The condition by CS interaction was not significant, $F(1, 118) = .11, p > .05$, indicating that the overall negative emotion acquired in both conditions was similar. However, a significant condition by CS by emotion interaction revealed that the conditions differed in terms of the specific negative emotional responses that were acquired, $F(1, 118) = 13.14, p < .001$. To interpret this interaction, the main effect of CS and the CS by emotion interaction term were examined in both conditions separately. The main effect of CS was significant in both conditions, $ps < .001$. In the disgust condition, the CS by emotion interaction was significant, $F(1, 54) = 18.77, p < .001$, such that more disgust than fear was acquired for the CS+ relative to the CS–. However, in the negative condition, this interaction was not significant, $F(1, 64) = .22, p > .05$, such that similar levels of disgust and fear were acquired for the CS+ relative to the CS–.

Eye movement CR assessment—The main effect of CS and the condition by CS interaction were not significant, $F_s(1, 118) < 1, ps > .05$, as dwell time on the CSs did not significantly differ after acquisition in the disgust condition (CS+: $M = 986$ ms, $SD = 233$; CS–: $M = 1020$ ms, $SD = 244, t(54) = -.63, p > .05$) or in the negative condition (CS+: $M = 988$ ms, $SD = 245$; CS–: $M = 987$ ms, $SD = 262, t(64) = .02, p > .05$).

Extinction

Self-report CR assessment—There was a main effect of CS, $F(1, 118) = 18.60, p < .001$, indicating that discriminant negative emotional responding to the CS+ persisted after extinction. The main effect of CS was not qualified by a condition by CS interaction, $F(1, 118) = .47, p > .05$, such that overall residual negative emotion to the CS+ versus CS– did not differ between conditions. However, a significant condition by CS by emotion interaction, $F(1, 118) = 4.47, p < .04$ indicated that the conditions differed in terms of the specific negative emotion to the CS+ remaining after extinction. To interpret this interaction, the main effect of CS and the CS by emotion interaction term were examined in both conditions separately. The main effect of CS was significant in both conditions, $ps < .001$. In the disgust condition, the CS by emotion interaction was significant, $F(1, 54) = 4.65, p < .04$, such that more disgust than fear remained for the CS+ relative to the CS–. However, in the negative condition, this interaction was not significant, $F(1, 64) = .67, p > .05$, such that similar levels of disgust and fear remained for the CS+ relative to the CS–.

This pattern of findings, which was highly consistent with the pattern of findings at acquisition, indicated that complete extinction was not achieved in either condition. To determine if partial extinction was achieved, an exploratory analysis was conducted to test if self-reported negative emotion to the CS+ declined between acquisition and extinction. Conditioning phase was added to the ANOVA model, and limited to the levels of acquisition and extinction. The analysis revealed a CS by phase interaction, $F(1, 118) = 7.33, p < .01$, suggesting that negative emotion to the CS+ did decline as a function of extinction in both conditions. This interaction was not qualified by any further interactions ($ps > .05$), indicating that extinction effects did not differ as a function of condition, emotion rating, or

their interaction. To determine if negative emotion in response to the CS+ vs. CS– after extinction was greater than baseline levels, a similar analysis was conducted comparing habituation and extinction. Again, there was a significant CS by phase interaction, $F(1, 118) = 15.85, p < .001$, confirming that residual negative emotion was greater than baseline levels. The CS by phase interaction was not qualified by further interactions ($ps > .05$).

Eye movement CR assessment—A significant main effect of CS, $F(1, 118) = 16.40, p < .001$, was qualified by a condition by CS interaction, $F(1, 118) = 4.76, p < .04$. To interpret this interaction, paired samples t -tests were conducted in each condition. In the disgust condition, individuals viewed the CS+ less compared to the CS– (CS+: $M = 877$ ms, $SD = 211$; CS–: $M = 1097$ ms, $SD = 261, t(54) = -4.06, p < .001$). In the negative condition, viewings times did not differ between CSs, (CS+: $M = 976$ ms, $SD = 225$; CS–: $M = 1042$ ms, $SD = 223, t(64) = -1.43, p > .05$). An exploratory analysis compared dwell time on the CSs between habituation and extinction, in order to control for any baseline differences in dwell time on the faces. There was a CS by phase interaction, $F(1, 118) = 11.37, p = .001$, which was further qualified by a condition by CS by phase interaction, $F(1, 118) = 4.55, p < .05$. In order to interpret this interaction, we examined the CS by phase interaction within each condition. In the disgust condition, the CS by phase interaction was significant, $F(1, 54) = 13.43, p = .001$, whereas in the negative condition, the CS by phase interaction was not significant, $F(1, 64) = .87, p > .05$. Thus, an attentional bias away from the CS+ after extinction only differed from baseline attentional bias in the disgust condition. Figure 3 depicts changes in attentional bias across phases in the both conditions.

Do differential attentional biases for disgust and negative USs account for differential attentional biases for disgust and negative CSs?

A mediational model was tested in which differences in attentional CRs between conditions were a function of differences in attentional URs between conditions, consistent with theoretical accounts of associative learning and Pavlovian conditioning (e.g., Mackintosh, 1983). The indirect path from condition (disgust vs. negative) to attentional avoidance of the CS+ through attentional avoidance of the US was significant ($p < .05$) as indicated by the 95% confidence intervals not containing 0 (lower limit = -206.92 , upper limit = -19.34 ; $B = -103.073, SE = 47.53$). Thus, mediation was demonstrated (Figure 4). Whereas this analysis required the full sample, the remaining analyses focus on participants in the disgust condition.

What are the relations between disgust sensitivity, disgust URs, and disgust CRs?

Disgust sensitivity and URs—Disgust sensitivity was strongly correlated with disgust responding to the US video ($r = .59, p < .001$) and dwell time on the US video ($r = -.47, p < .001$), such that individuals who were more disgust sensitive reported being more disgusted by the vomit videos and viewed them less. Also, disgust responding to the US video was strongly correlated with dwell time on the US video ($r = -.57, p < .001$), such that individuals who reported more disgust in response to the videos viewed them less. A mediational analysis was conducted to test the hypothesis that disgust sensitivity increased the experience of disgust in response to the vomit videos, which in turn increased the use of visual avoidance to downregulate disgust. The indirect path from disgust sensitivity to visual

avoidance through self-reported disgust was significant ($p < .01$) as indicated by the 99% confidence intervals not containing 0 (lower limit = -131.01 , upper limit = -20.18 ; $B = -61.93$, $SE = 20.04$). Thus, mediation was demonstrated (Figure 5).

Disgust sensitivity, URs and CRs—Disgust sensitivity was not correlated with discriminant self-reported disgust in response to the CSs after acquisition or after extinction ($r_s < .20$, $p_s > .05$) in the disgust condition. However, disgust sensitivity was correlated with discriminant dwell time on the CSs after extinction ($r = -.28$, $p < .05$), such that individuals with higher disgust sensitivity avoided looking at the CS+ relative to the CS− in the disgust condition. Interestingly, discriminant dwell time on the CSs after extinction was associated with discriminant disgust in response to the CSs after acquisition ($r = -.29$, $p = .03$), but not after extinction ($r = -.15$, $p > .05$), such that attentional avoidance of the CS+ post-extinction was linked to the amount of disgust initially acquired, but not to the amount of disgust remaining after extinction (on self-report measures). In addition, discriminant dwell time on the CSs after extinction was associated with dwell time on the disgust US, such that a tendency to avoid looking at the vomit videos predicted a tendency to avoid looking at the CS+ after extinction.

Does attentional avoidance of the disgust US mediate the relationship between disgust sensitivity and attentional avoidance of the disgust CS?—A mediational analysis was conducted to test the hypothesis that disgust sensitivity confers a tendency to avoid looking at unconditioned disgust stimuli, which in turn leads to increased visual avoidance of conditioned disgust stimuli post-extinction. The indirect path was significant ($p < .05$) as indicated by the 95% confidence intervals not containing 0 (lower limit = -8.22 , upper limit = $-.04$; $B = -3.26$, $SE = 2.07$). Thus, mediation was demonstrated (Figure 6).

Discussion

The present study is the first, to our knowledge, to contrast the effects of disgust learning and more general aversive learning on attention using comparable USs. Individuals in the disgust condition showed robust attentional avoidance of the CS+ relative to the CS−, a pattern not observed in the negative condition. However, this effect did not reach significance immediately after acquisition, and instead became pronounced following subsequent reacquisition and extinction. Although this pattern of results was unexpected, attentional avoidance of the disgust CS+ post-extinction nonetheless appeared to be a *learned* bias that resulted from the pairing of the CS+ with the US during acquisition and reacquisition. Importantly, attentional avoidance of the CS+ post-extinction was significantly greater than baseline levels (i.e., post-habituating), was correlated with the initial acquisition of self-reported disgust to the CS+, and was correlated with disgust URs (both self-reported disgust and attentional avoidance). Further, two mediational models, one contrasting the disgust and negative conditions, and one focusing within the disgust condition, both suggested that attentional avoidance of the disgust CS+ was a function of attentional avoidance of the disgust US, providing additional evidence that attentional bias post-extinction was related to a transfer of affective properties from the disgust US to the CS+.

Attentional avoidance of the disgust CS+ observed in the present study was correlated with the initial acquisition of self-reported disgust, yet emerged later in the conditioning procedure. Robust attentional avoidance of the CS+ may have developed after extinction, rather than after acquisition, because this more distal CR relies on greater consolidation of the disgust memory. Increased consolidation may have been achieved through the additional reinforced trials in the reacquisition phase, or by the passage of time between acquisition and extinction. This pattern of dissociation between self-reported disgust ratings and attentional avoidance may suggest that these CRs reflect distinct underlying learning processes. Disgust ratings closely tracked the contingency between the CS+ and the disgust US, increasing at acquisition and attenuating at extinction. This may suggest that disgust ratings reflect expectancy learning, as self-reported fear ratings of the CS+ in fear conditioning studies have been found to mostly track this type of learning (e.g., Hermans et al., 2002). In contrast, attentional avoidance may reflect evaluative or affective learning, the process by which the affective properties of the US “transfer” to the CS. Evaluative learning has been found to be less sensitive to extinction compared to expectancy learning (e.g., Olatunji et al., 2007), which may explain why attentional avoidance of the CS+ post-extinction was decoupled from self-reported disgust post-extinction, yet was linked to self-reported disgust post-acquisition. In addition, evaluative learning is often observed on *implicit* measures that are outside of a participant’s awareness or control (e.g., affective priming, Hermans et al., 2002; startle blink potentiation, Sevenster, Beckers, & Kind, 2012). Eye tracking may be conceptualized as an implicit measure that is sensitive to evaluative learning because the effect of the CS–US association on eye movements occurs without the participant’s awareness or effort (De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009).

The present findings may have important implications for understanding the association between disgust sensitivity and symptoms of certain anxiety disorders (Olatunji et al., 2010), as multiple points of evidence suggest that disgust sensitivity increases attentional avoidance, which is a potential mechanism in the etiology or maintenance of anxiety (Cisler & Koster, 2010). First, disgust sensitivity was found to increase attentional avoidance of disgust USs. This effect was mediated by self-reported disgust elicited by the USs, which suggests that attentional avoidance is a coping strategy used to down-regulate the experience of disgust in individuals who are highly sensitive to this emotion. Second, by increasing attentional avoidance of disgust USs, disgust sensitivity was found to indirectly increase attentional avoidance of disgust CSs after extinction. These effects may have clinical significance, because attentional avoidance appears to deprive anxious individuals of beneficial exposure to disorder-related USs and CSs. For example, in the case of BII phobia, a disorder involving elevated disgust sensitivity as well as enhanced disgust conditioning (Olatunji et al., 2009), merely viewing images (Öst, Fellenius, & Sterner, 1991) or videos (Hellström, Fellenius, & Öst, 1996) related to BII threat has been found to provide considerable symptom relief in up to 50% of patients (Öst et al., 1991). Specifically, visual exposure to USs (e.g., venipuncture in BII phobia) may cause habituation of URs and subsequent US re-evaluation (i.e., reappraisal as less threatening). In addition, visual exposure to CSs (e.g., syringe in BII phobia) may promote extinction of CRs. Indeed, training attention away from threat signals has been found to impair extinction, compared to training attention towards threat signals (Van Bockstaele, Verschuere, De Houwer &

Crombez, 2010). In light of this evidence, attentional avoidance is one potential mechanism through which disgust sensitivity and related disgust learning tendencies could contribute to anxiety disorders.

The present findings also suggest that attentional avoidance may be relatively specific to disgust learning, as generally negative learning did not lead to attentional avoidance of the CS+ after acquisition or extinction. Mediation analyses revealed that differential attentional bias acquisition between conditions was a function of the differential effect of the USs on attention, as disgusting stimuli appear to have a unique ability to repel attention. Disgusting content may motivate attentional avoidance more than other negative content because it is intrinsically unpleasant to perceive (Armstrong & Olatunji, 2012). Indeed, Royzman and Sabini (2001) argue that compared to other negative emotions, disgust is more easily elicited by a stimulus's concrete sensory and perceptual qualities. Interestingly, disgust has also been contrasted with other negative emotions in terms of its cognitive impenetrability. For example, Rozin and Nemeroff (1990) showed that individuals could not overcome an aversion to eating chocolate fudge shaped to look like dog poop, or an aversion to drinking water into which a sterilized cockroach was dipped, despite knowing that their disgust responses were irrational. The insensitivity to extinction found to characterize attentional avoidance of disgust CS+s (Mason & Richardson, 2010) may be conceptualized as a form of cognitive impenetrability; once acquired, attentional avoidance may be encapsulated from higher cognitive processes, such that it is unaffected by knowledge that the CS no longer predicts the US (Barrett & Kurzban, 2006). In addition, disgust may be resistant to extinction because disgust USs are highly salient in episodic memory (Chapman, Johannes, Poppenk, Moscovitch, & Anderson, in press), which may allow the disgust US to resist inhibition from the extinction memory when activated by the CS+ post-extinction.

The attentional bias *away* from disgust CS+s observed in the present study contrasts with the bias that has been observed for fear CS+s. The handful of studies examining attentional bias for fear CSs (Kelly & Forsyth, 2009; Lee et al., 2009; Pischek-Simpson et al., 2009; Van Damme et al., 2006) suggests that fear learning is related to increased rather than decreased attention to the CS+, and that this bias may track expectancy learning rather than evaluative learning. For example, Kelly and Forsyth (2009), employing a video-based conditioning procedure, found that attentional bias for the fear CS+ was highly sensitive to an extinction procedure, as did Van Damme et al. (2006) in a more classical fear conditioning procedure that utilized electrocutaneous shocks as the US. One possibility is that hypervigilance in anxiety disorders is driven by threat signaling related to expectancy learning, whereas subsequent attentional avoidance is driven by intrinsic aversiveness related to evaluative learning. Accordingly, the hypervigilant-avoidant pattern of attention to threat observed in some anxiety disorders, particularly specific phobias, may reflect a combination of fear and disgust learning (Armstrong & Olatunji, 2012).

Although these findings provide new insight into a complex pattern of relations between disgust, evaluative learning, and attention that may inform etiological models of some anxiety disorders, the findings should be interpreted with several limitations in mind. First, the failure to observe attentional avoidance of the disgust CS+ immediately after acquisition limits the conclusions that can be made regarding extinction, because it is unclear if the bias

developed in time to be effected by the extinction trials. However, the present findings are consistent with prior research showing that attentional avoidance acquired through disgust conditioning is insensitive to extinction (Mason & Richardson, 2010). In addition, the present study did not collect US expectancy ratings or measure skin conductance responses (SCR) to the CSs. These measures of expectancy learning (Sevenster et al., 2010) could have helped parse expectancy and evaluative learning, and would have allowed more thorough comparison with aversive learning examined in other paradigms (e.g., Hermans et al., 2002). Also, the effects of conditioning on self-reported emotion, although statistically significant, were quite modest. This may be due to the use of brief video clips as USs, as viewing unpleasant videos is less intense than receiving a shock (Hermans et al., 2002) or a hearing a 103 dB scream (Indovina et al., 2011). Lastly, the negative US may not have been ideally matched to the disgust US, because it did not strongly elicit a specific negative emotion; instead, it moderately elicited a blend of negative emotions (fear and disgust). If the negative US had been more specific to fear, it would have allowed stronger conclusions about the specificity of the findings in relation to other basic emotions. Future research that reconciles some of these limitations and employs a longitudinal approach would allow more inferences to be made regarding how disgust learning confers risk for the development of certain anxiety disorders through its effects on attention.

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Figure 1.

Self-reported emotion in response to the unconditioned stimuli (i.e., videos). US = unconditioned stimulus; Error bars represent *SE*.

Figure 2.

Self-reported emotion in response to the conditioned stimuli (i.e., faces). CS+ = face paired with unconditioned stimulus video; CS- = face paired with control video; HAB = post-habituation; ACQ = post-acquisition, EXT = post-extinction. Error bars represent *SE*.

Figure 3.

Fixation duration on the conditioned stimuli. CS+ = face paired with unconditioned stimulus video; CS- = face paired with control video; HAB = post-habituation; ACQ = post-acquisition, EXT = post-extinction. Error bars represent *SE*.

Figure 4.

Mediation model of the relations between condition, fixation duration on the US, and fixation duration on the CS+ in the full sample. Fixation duration on the CS+ is relative to the CS-, fixation duration on the US is relative to the control video, and t -values are for path coefficients. US = unconditioned stimulus; CS = conditioned stimulus (faces); CS+ = face paired with unconditioned stimulus video; CS- = face paired with control video; * = $p < .05$; ** $p < .01$; *** $p < .001$.

Figure 5.

Mediation model of the relations between disgust sensitivity, self-reported disgust in response to the US, and fixation duration on the US in the disgust condition. Fixation duration on the US is relative to the control video, disgust in response to the US is relative to the control video, and t -values are for path coefficients. US = unconditioned stimulus; CS = conditioned stimulus (faces); CS+ = face paired with unconditioned stimulus video; CS- = face paired with control video; ** $p < .01$; *** $p < .001$.

Figure 6.

Mediation model of the relations between disgust sensitivity, fixation duration on the US, and fixation duration on the CS+ in the disgust condition. Fixation duration on the CS+ is relative to the CS-, fixation duration on the US is relative to the control video, and t -values are for path coefficients. US = unconditioned stimulus; CS = conditioned stimulus (faces); CS+ = face paired with unconditioned stimulus video; CS- = face paired with control video; $^{\dagger} = p = .07$; $^{*} = p < .05$; $^{***} = p < .001$.

Table 1Means (*SDs*) for self-reported emotional responses to the US

Rating	Video	Condition	
		Disgust	Negative
Disgust	US	60.91 (26.50)	30.47 (24.04)
	Control	2.74 (5.55)	2.82 (5.32)
Fear	US	12.65 (14.88)	39.73 (23.97)
	Control	1.47 (3.89)	1.58 (3.30)

Note. US = unconditioned stimulus.

Table 2Means (*SDs*) for self-reported emotional responses to the CSs

Disgust condition				
Rating	CS	Phase of conditioning		
		Habituation	Acquisition	Extinction
Disgust	CS+	11.89 (13.33)	23.01 (23.04)	13.09 (17.73)
	CS–	10.33 (12.68)	7.78 (9.15)	5.95 (12.29)
Fear	CS+	15.82 (15.90)	15.62 (15.99)	9.6 (12.80)
	CS–	19.13 (18.22)	9.93 (11.69)	7.4 (10.09)
Negative condition				
Rating	CS	Phase of conditioning		
		Habituation	Acquisition	Extinction
Disgust	CS+	8.49 (11.87)	15.75 (15.09)	13.48 (18.06)
	CS–	8.89 (12.63)	6.70 (10.09)	7.95 (14.62)
Fear	CS+	14.05 (15.27)	18.53 (15.37)	13.14 (15.77)
	CS–	16.03 (17.75)	8.61 (13.02)	5.80 (12.80)

Note. CS = conditioned stimulus (face); CS+ = face paired with unconditioned stimulus video; CS– = face paired with control video.