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Pavlovian disgust conditioning as a model for contamination-based OCD: Evidence from an analogue study

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A B S T R A C T

Pavlovian fear conditioning provides a model for anxiety-related disorders, including obsessive-compulsive disorder (OCD). However, disgust is the predominant emotional response to contamination, which is a common theme in OCD. The present study sought to identify disgust conditioning abnormalities that may underlie excessive contamination concerns relevant to OCD. Individuals high and low in contamination concern (HCC, $n = 32$; LCC, $n = 30$) completed an associative learning task in which one neutral face (conditioned stimulus; CS+) was followed by a disgusting image (unconditioned stimulus; US) and another neutral face (CS−) was unreinforced. Following this acquisition procedure, there was an extinction procedure in which both CSs were presented unreinforced. The groups did not show significant differences in discriminant responding to the CSs following acquisition. However, following extinction, the HCC group reported less reduction in their expectancy of the US following the CS+, and also reported greater disgust to the CS+, compared to the LCC group. Increased disgust to the CS+ following both acquisition and extinction was correlated with increased symptoms of contamination-based OCD and increased disgust sensitivity. Additionally, disgust sensitivity mediated group differences in disgust responding to the CS+ at acquisition and extinction. Also, failure to adjust US expectancy in response to extinction partially mediated group differences in disgust to the CS+ following extinction. Together, these findings suggest that excessive contamination concerns observed in OCD may be related to difficulty inhibiting acquired disgust, possibly due to elevated disgust sensitivity that characterizes the disorder.

Obsessive-compulsive disorder (OCD) is a psychiatric condition that affects 1–2% of the population and is characterized by intrusive, unwanted thoughts (obsessions) that motivate rigid, ritualistic behaviors (compulsions) (American Psychiatry Association [APA], 2013). Concern with contamination (i.e., the tendency to think about and notice the possible spread of germs) is a common obsession in OCD and underlies the washing and sanitizing compulsions that typify the disorder (Ruscio, Stein, Chiu, & Kessler, 2010). OCD has a chronic course and is considered one of the ten most disabling condition by the World Health Organization (Markarian et al., 2010). Although exposure and response prevention is effective in treating OCD, many do not respond to the treatment or remain symptomatic despite improvements, indicating a need for additional insight into the etiology and maintenance of OCD (McKay et al., 2015).

Until the recent creation of the OCD-spectrum (APA, 2013), OCD was categorized as an anxiety disorder. Inline with other anxiety-related disorders, OCD has been conceptualized in terms of Pavlovian fear conditioning (e.g., Milad et al., 2013). Fear conditioning involves the acquisition of anxiety and other preparatory defensive responses to stimuli that signal the threat of immediate bodily harm (Bouton, 2007; Woody & Teachman, 2000). Although Pavlovian conditioning involves directly experiencing stimuli in temporal contiguity, contemporary learning theories of anxiety include additional fear learning pathways, such as vicarious learning (e.g., seeing that a stimulus predicts harm for another person) or verbal transmission (e.g., being told that a stimulus predicts harm; Mineka & Zinbarg, 2006). Anxiety-related disorders appear to be characterized by several fear learning abnormalities, including exaggerated acquisition, impaired extinction, and overgeneralization of conditioned fear responding (Mineka & Zinbarg,

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2006).

Although there is a large body of research on Pavlovian fear conditioning in anxiety-related disorder (Duits et al., 2015), only a handful of these studies have examined OCD. One study found that subclinical OCD was characterized by increased acquisition of eye blink conditioning (Tracy, Ghose, Stecher, McFall, & Steinmetz, 1999); however, subsequent studies failed to observe increased or overgeneralized acquisition of fear conditioning, as revealed by skin conductance, in subclinical (Kaczkurkin & Lissek, 2013) as well as clinical OCD (Milad et al., 2013). Milad and colleagues (2013) observed increased skin conductance during extinction training in patients with OCD compared to controls; however, this pattern was unexpectedly found for both danger and safety signals, and OCD symptoms were unexpectedly correlated with increased extinction, making these findings difficult to interpret (Milad et al., 2013). Finally, a study by Nanbu and colleagues (2010) found no difference between patients with OCD and controls in the acquisition or extinction of conditioned fear, as revealed by skin conductance; however, this study did find impaired suppression of the P50 auditory evoked potential during fear extinction, but not acquisition, in the OCD group compared to the control group. In summary, OCD does not appear to be characterized by a consistent fear learning abnormality revealed by skin conductance, an indicator of autonomic arousal that is one of the most common measures of conditioned fear responding (Duits et al., 2015).

These preliminary findings could indicate that fear conditioning offers limited insight into OCD. However, associative learning processes delineated in conditioning models may still be relevant to the etiology and maintenance of OCD. As Mason and Richardson (2010) have suggested, learning theories of OCD may need to look beyond the emotion of fear. Fear and disgust are both basic emotions that organize responding to threat of bodily harm; however, fear targets urgent threats (e.g., being chased by a stray dog, falling off of a ladder) that are threatening because they *damage* the body (Woody & Teachman, 2000).[1] In contrast, disgust targets less urgent threats (e.g., spoiled food, bodily secretions, taboo behaviors) that are threatening because they *defile* the body (Woody & Teachman, 2000), usually because they are associated with pathogens (Tybur, Lieberman, Kurzban, & DeScioli, 2013).

Disgust and contamination are distinct yet inseparable constructs. Disgust is the emotional response to stimuli that have the capacity to defile, stimuli that are considered offensive, polluting, or debasing (Woody & Teachman, 2000). Contamination is the cognitive appraisal that the defiling essence of one stimulus has transferred to another stimulus through contact (Rozin, Millman, & Nermeroff, 1986). Accordingly, disgust is the emotional response to contamination. This intimate relationship between disgust and contamination implies that disgust, rather than fear, may be the primary dysregulated emotion in contamination-based OCD, and indeed, patients with contamination concerns tend to describe symptom-provoking stimuli as “disgusting” rather than “frightening” (Sieg & Scholz, 2001; Tolin, Worhunsky, & Maltby, 2004). In addition, how easily and intensely one experiences disgust, a trait known as disgust sensitivity (Olatunji et al., 2007), has been found to uniquely predict symptom severity in contamination-based OCD, and appears to have a stronger relation to symptoms of contamination-based OCD than state or trait anxiety (e.g., Mancini, Gragnani, & D'Olimpio, 2001).

Disgust, as a human emotion, has only recently been studied in a conditioning framework (e.g., Mason & Richardson, 2010; Armstrong, McLenehan, Kittle & Olatunji, 2014; Olatunji, Forsyth, & Cherian, 2007). However, there is a wealth of conditioning research on *distaste*, the food-rejection reflex that is considered to be a precursor to disgust (Rozin & Fallon, 1987). Research on the associative learning of distaste (i.e., taste aversion learning; e.g., Garcia, Kimeldorf, & Koelling, 1955) has identified qualitative differences from other forms of Pavlovian conditioning, most notably, what has been referred to as a “hedonic shift” (Garcia, Hankins, & Rusiniak, 1974) in the CS. This phenomenon, also referred to as evaluative conditioning (De Houwer, Thomas, & Baeyens, 2001), involves the apparent transfer of negative valence from the unconditioned stimulus (US) to the conditioned stimulus (CS), such that the CS develops an aversive quality independent of its relation to the US. As a result, taste aversion learning is resistant to extinction, as unreinforced presentations of the CS undermine its status as a signal for the US, but do not modify its intrinsic valence (Bouton, 2007).

Although only a handful of studies have examined disgust conditioning in humans, they have consistently found that conditioned disgust responses are resistant to extinction, inline with conditioned taste aversions and other conditioned evaluative responses (Armstrong et al., 2014; Borg, Bosman, Engelhard, Olatunji, & de Jong, 2016; Bosman, Borg, & de Jong, 2016; Engelhard, Leer, Lange, & Olatunji, 2014; Mason & Richardson, 2010; Olatunji et al., 2007). Disgust learning may be highly relevant to contamination-based OCD, because the process of contamination appears to involve disgust learning. Specifically, contamination involves the acquisition of disgust responding to a novel stimulus after learning that it was associated with an offensive stimulus (Rachman, 2004). Further, the disgust learning that underlies contamination may partially explain why contaminated objects seem to inherit the offensive, disgust-eliciting properties of the original contaminant, rather than merely serving as a signal for the original contaminant (Rozin et al., 1986). As Rozin and colleagues (1986) demonstrated in their classic study, perceptions of contamination are remarkably difficult to reverse and are unaffected by re-evaluating the original contaminant (Rozin et al., 1986). Accordingly, the exaggerated perceptions of contamination in many patients with OCD may be rooted in aberrant disgust learning.

Although no studies have examined disgust conditioning in individuals with OCD or with elevated contamination concerns, a number of studies have observed links between disgust conditioning and disgust sensitivity, a trait that encompasses how easily and intensely one experiences disgust (Olatunji et al., 2007). Disgust sensitivity has been found to predict levels of conditioned disgust responding following acquisition (Mason & Richardson, 2010; Olatunji, Tomarken & Puncochar, 2013) and extinction (Armstrong et al., 2014; Mason & Richardson, 2010) of Pavlovian disgust conditioning in unselected samples. Disgust sensitivity is elevated in individuals with OCD and may serve as a risk factor for the disorder (Olatunji, Cisler, McKay, & Phillips, 2010). However, researchers have had difficulty specifying the precise mechanisms by which disgust sensitivity confers risk for the contamination variant of OCD. One possibility is that elevated disgust sensitivity in OCD leads to aberrant disgust learning, which in turn leads to increased perceptions of contamination.

The goal of the present study was to identify possible abnormalities in disgust conditioning that may underlie excessive contamination concerns characteristic of OCD. We tested two hypotheses regarding aberrant disgust learning related to excessive contamination concern. One hypothesis is that excessive contamination concern is characterized by facilitated acquisition of conditioned disgust responding, which could lead to more frequent perceptions of contamination, as more stimuli acquire disgust beyond a threshold that motivates contamination concerns. A

[1] Anxiety involves the same types of threat, but with less certainty or immediacy (Barlow, 1991).

second hypothesis is that excessive contamination concern is characterized by impaired extinction of conditioned disgust responding, which could lead to more enduring perceptions of contamination due to the persistence of disgust responding. It is important to note that these hypotheses are not mutually exclusive. We also tested the hypothesis, suggested by extant research, that aberrant disgust learning that may characterize excessive contamination concern is rooted in elevated levels of disgust sensitivity. Finally, we assessed trait anxiety in order to demonstrate the specificity of relations between disgust sensitivity and disgust learning. Although trait anxiety is elevated in OCD (Armstrong, Zald, & Olatunji, 2011), we predicted that there would be no relations between trait anxiety and disgust learning.

1. Methods

1.1. Participants

Three large undergraduate classes ($n = 331$) at Vanderbilt University were screened using the Padua Inventory – Contamination Obsessions and Washing Compulsions Subscale (PI–COWC; Burns, Keortge, Formea, & Sternberger, 1996), in order to identify students high and low in contamination concerns. In line with past studies (e.g., Deacon & Maack, 2008; Deacon & Olatunji, 2007; Olatunji, Lohr, Sawchuk, & Tolin, 2007), we based our group selection on the PI-COWC means of the OCD patient group (13.87) and control group (6.54) in Burns et al. (1996). Individuals with PI-COWC scores above 13 (n = 62; 18.73% of screening sample) were identified as eligible for the high contamination concern (HCC) group, and individuals with scores under 7 (n = 155; 46.82% of screening sample) were identified as eligible for the low contamination concern (LCC) group. We then recruited eligible students in waves, beginning with the most extreme scores in both groups in order to maximize the distinction between groups.[2] Our recruitment target was $n = 30$ in each group, as this sample size provides 80% power to detect group differences of in the medium to large effect size range and was feasible given the timeline of the study. Our final sample size was $n = 32$ in the HCC group and $n = 30$ in the LCC group.

There is compelling evidence that studies of analogue OCD samples are relevant to understanding OCD in clinical populations (see Abramowitz et al., 2014; for a review). For example, Burns, Formea, Keortge, and Sternberger (1995) found that non treatment-seeking individuals who scored highly on self-report measures of OC symptoms often met diagnostic criteria for OCD, evidenced stability of symptoms over time, and exhibited similar associated symptom features as patients diagnosed with OCD.

1.2. Measures

The Disgust Scale—Revised (DS-R; Olatunji et al., 2007) is a 25-item questionnaire assessing sensitivity to a range of disgust elicitors, including core (e.g., "You are about to drink a glass of milk when you smell that it is spoiled"), animal-reminder (e.g., "You see a man with his intestines exposed after an accident"), and contamination disgust ("You take a sip of soda, and then realize that you drank from the glass that an acquaintance of yours had been drinking from"). The resulting total score reflects one's general proneness to disgust (i.e., trait disgust). Half of the items are statements describing one's disgust response to various stimuli, with responses ranging from 0 = "Strongly disagree" to 4 = "Strongly agree"; the other half of items ask participants to rate different disgusting scenarios, with responses ranging from 0 = "Not disgusting at all" to 4 = ""Extremely disgusting." The DS-R had excellent internal consistency ($\alpha = 0.90$) in the present sample, and has been shown to have adequate split-half reliability (Olatunji et al., 2007) and convergent validity with other measures of individual differences in disgust (van Overveld, de Jong, Peters, & Schouten, 2011).

The Obsessive Compulsive Inventory – Revised (OCI-R; Foa et al., 2002). The OCI-R is an 18-item questionnaire of OCD symptoms experienced in the past month. Items gauge how much OCD symptoms have caused distress, and responses range from 0 = "Not at all" to 4 = "Extremely." The OCI-R has six dimensional subscales. Although we administered the full scale, our analyses focused on the 3-item Washing subscale, which addresses contamination concerns (e.g., "I find it difficult to touch an object when I know it has been touched by strangers or certain people"). The Washing subscale of the OCI-R had adequate internal consistency ($\alpha = 0.80$) in the present sample, and has been shown to have excellent test-retest reliability and convergent validity with other measures of contamination-based OCD (Foa et al., 2002).

The PI-COWC (Burns et al., 1996) is a 10-item measure of contamination concerns (e.g., "I wash my hands more often and longer than necessary"). Items probe how much OCD symptoms have created disturbance in one's life. Responses range from 0 = "Not at all" to 4 = "Very much." The PI had excellent internal consistency ($\alpha = 0.96$) in the present sample, and has been shown to have good test-retest reliability and to exhibit discriminant validity from other subscales of the PI and from measures of worry (Burns et al., 1996), and convergent validity with other measures of contamination concerns (Sawchuk, Lohr, Tolin, Lee, & Kleinknecht, 2000).

The State Trait Anxiety Inventory–Trait Version, Form Y (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is a 20-item scale that measures the enduring or chronic experience of anxiety (e.g., "I feel nervous and restless"). In contrast to the state version of the measure, items probe how much one *generally* experiences a symptom of anxiety, and responses range from 1 = "Not at all" to 4 = "Very much so." Trait anxiety was assessed in order to demonstrate the specificity of effects of disgust sensitivity on disgust conditioning. The STAI-T had good internal consistency in the present study ($\alpha = 0.81$), and the STAI-T has been shown to have good test-retest reliability and to have good convergent and discriminant validity with other measures of trait and state anxiety, respectively (Spielberger et al., 1983).

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 rated their state disgust response to the CSs and USs, as well as their expectancy of the US during the CS, 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). These labels are placed on a line (without the corresponding numeric values). Ratings are made by clicking anywhere on the line with a mouse.

1.3. Materials and apparatus

The CSs consisted of two neutral male faces from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt, & Öhman, 1998).

[2] Due to the large number of students eligible for the LCC group, this recruitment procedure resulted in an LCC group with PI-COWC scores of less than 6, as we met our target for this group prior to contacting 14 individuals with scores of 6 on the PI-COWC.

The CS+ and CS− were discriminated by the actor expressing the face. CS assignment was counterbalanced between participants, such that for half of participants, face #1 was the CS+ and face #2 was the CS−, and for the other half, vice versa. The USs consisted of 8 different disgusting images depicting feces (3), vomit (3), and rotting food (2) that were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and online public sources. The same 8 USs were used for each participant. We employed multiple USs to prevent habituation. Stimuli were presented on a 17" widescreen monitor (1280 × 1024 resolution; 60 Hz) using E-prime 2.0 software.

1.4. Procedure

Participants provided informed consent to a protocol approved by the Vanderbilt University Institutional Review Board, and then completed the measures as well as a basic demographic survey (age, gender, ethnicity/race). Participants then completed the associative learning task, consisting of the following stages: *Habituation.* Participants viewed 8 unreinforced presentations (6 s) of each CS. CSs were preceded by a fixation cross (1.5 s) and followed by an inter-trial interval (ITI) that varied randomly between 12 s and 18 s. The CSs appeared in the center of the screen. *Acquisition.* During this stage, the CSs were presented for 6 s in the center of the screen. Immediately after CS+ offset, the US was presented for 3 s. After CS- offset, the trial proceeded to the ITI. CSs were preceded by a fixation cross (1.5 s) and followed by an ITI, varied randomly between 12 s and 18 s. There were 8 presentations of CS+ trials, and 8 presentations of CS− trials, presented in pseudorandom order. *Extinction.* The acquisition procedure was repeated, but without US presentation. At the end of each stage, participants used the modified EVS to retrospectively rate how disgusted the CSs made them feel and how much they expected the US to follow the CS. After the associative learning task, participants rated how disgusted the USs made them feel. For all ratings, the stimuli and scale were presented simultaneously until a rating was entered.

1.5. Data analytic plan

In line with other Pavlovian conditioning studies (e.g., Kelly & Forsyth, 2007; Lissek et al., 2008; Mason & Richardson, 2010), analyses were conducted separately for each stage of the procedure (habituation, acquisition, extinction), and each stage was considered a separate family of analyses, such that no attempt was made to correct for multiple comparisons across stages. For both US expectancy and disgust ratings, 2 (CS: CS+, CS−) X 2 (group: HCC, LCC) mixed-effects ANOVAs were conducted. Although we examined all terms, the CS by group interaction term at acquisition and extinction was most relevant to our hypotheses, as this interaction term would reveal group differences in discriminant responding to the CSs at these respective stages. Significant CS by group interactions were followed up with independent samples *t*-tests comparing the groups in terms of their ratings of the CS+ and the CS− separately. We predicted that the HCC group would be distinguished by increased US expectancy and disgust in response to the CS+, not the CS−. To gain additional insight into disgust extinction learning, we conducted exploratory interaction contrasts that examined changes in US expectancy and disgust to the CSs between the acquisition and extinction stages (Kelly & Forsyth, 2007). For these analyses, we added the within-subjects factor of Stage (acquisition, extinction) to the ANOVA model that included the factors of CS and Group. The stage by CS interaction was examined to determine if there was a decrease in discriminant US expectancy or disgust responding due to the extinction procedure. This interaction was probed further by contrasting responding to the CS+ and CS− between acquisition and extinction, using paired samples t-tests. The stage by CS by group interaction was also examined to determine if effects of the extinction procedure on discriminant responding differed between groups. This interaction was probed further by conducting independent samples t-test comparing the groups on change scores in which responding at extinction was subtracted from responding at acquisition for each CS. Mediation was tested using Hayes's (2013) PROCESS bootstrapping procedure, which does not impose distributional assumptions for the indirect effect that are often violated in smaller samples.

2. Results

2.1. Group characteristics

As revealed in Table 1, the HCC and LCC groups were adequately matched in terms of demographic variables. There were not significant differences between groups in terms of age, gender, or ethnicity. As intended, the HCC group had significantly higher levels of OCD-related washing symptoms ($p < 0.001$), disgust sensitivity ($p < 0.001$), and trait anxiety compared to the LCC group ($p = 0.020$). The HCC group also rated the US stimuli[3] as more disgusting compared to the LCC group ($p = 0.007$) when rating the US after the association learning task.

2.2. Habituation

US expectancy ratings. The main effect of CS, $F(1, 60) = 2.57$, $p = 0.114$, $\eta^2_p = 0.04$, the main effect of group, $F\ (1, 60) = 0.72$, $p = 0.401$, $\eta^2_p = 0.01$, and the CS X group interaction, $F\ (1, 60) = 0.09$, $p = 0.766$, $\eta^2_p = 0.001$, were all non-significant. Thus, prior to acquisition, the CSs did not significantly differ in terms of their ability to elicit anticipation of the US, nor did the groups significantly differ in terms of their anticipation of the US. Table 2 provides *M*s and *SD*s for all CS ratings, and Fig. 1 depicts these ratings.

Disgust ratings. The main effect of CS, $F\ (1, 60) = 2.97$, $p = 0.090$, $\eta^2_p = 0.05$, the main effect of group, $F\ (1, 60) = 2.24$, $p = 0.140$, $\eta^2_p = 0.04$, and the CS X group interaction, $F\ (1, 60) = 2.60$, $p = 0.112$, $\eta^2_p = 0.04$, were all non-significant. Thus, prior to acquisition, the CSs did not significantly differ in terms of their ability to elicit disgust, nor did the groups significantly differ in terms of disgust elicited by the CSs.[4]

2.3. Acquisition

US expectancy ratings. The main effect of CS was significant, $F\ (1, 60) = 566.37$, $p < 0.001$, $\eta^2_p = 0.90$. As hypothesized, participants anticipated the US more during the CS+ compared to the CS−, indicating that participants learned the CS−US contingency during the acquisition procedure. The main effect of group, $F\ (1, 60) = 0.01$,

[3] The US stimuli were rated as moderately disgusting by the full sample (M = 51.01, SD = 24.86; 50 = "Moderately").

[4] Although there was no CS by group interaction, a post hoc test suggested by a reviewer revealed that within the HCC group, there was greater disgust to the CS+ compared to the CS− after habituation, $t\ (31) = 2.14$, $p = 0.041$, 95% CI [0.37, 15.51], $d = 0.38$. To ensure that this unexpected discriminant responding prior to acquisition in the HCC group was not determining the outcome of analyses at later time points, we repeated the ANOVA analyses involving disgust ratings after acquisition and extinction with discriminant disgust responding (disgust to CS− subtracted from disgust to CS+) after habituation as a covariate in the model, using analysis of covariance (ANCOVA). Including this covariate did not change the outcome of the *F*-test for any term in these analyses.

Table 1
Group characteristics.

	HCC (n = 32)	LCC (n = 30)	95% CI	Test Statistic
Age	20.16 (1.27)	20.40 (0.97)	[-0.82, 0.33]	t (60) = -0.84, p = 0.402, d = 0.22
Gender				$\chi^2 = 0.008$, p = 0.931
%Female	66.7	65.6		
Ethnicity				$\chi^2 = 6.15$, p = 0.191
% White	53.1	76.7		
% Black	25.0	10.0		
% Hispanic	3.1	3.3		
% Asian	9.4	10.0		
% Other	9.4	0		
Measures				
PI-COWC	20.41 (4.89)	2.93 (1.33)	[15.63, 19.32]	t (60) = 18.92, p < 0.001, d = 4.89
DS-R	56.88 (16.93)	41.27 (15.67)	[7.31, 23.91]	t (60) = 3.76, p < 0.001, d = 0.97
OCI-R Wash	4.53 (2.96)	0.57 (0.63)	[2.86, 5.07]	t (60) = 7.18, p < 0.001, d = 1.85
STAI-T	53.46 (8.04)	48.23 (9.00)	[0.48, 9.50]	t (60) = 2.39, p = 0.020, d = 0.62
US disgust rating	59.17 (25.12)	42.31 (21.76)	[4.89, 28.84]	t (60) = 2.82, p = 0.008, d = 0.73

Note: HCC = high contamination concern; LCC = low contamination concern; CI = confidence interval for mean difference; PI = Padua Inventory, Contamination Obsession Washing Compulsion subscale; DS-R = Disgust Scale—Revised; OCI-R Wash = Obsessive-Compulsive Inventory—Revised, Washing subscale; STAI-T = Spielberger State Trait Anxiety Inventory—Trait Form Y; US = unconditioned stimulus; *p < 0.05, **p < 0.01, ***p < 0.001.

Table 2
Means (*SDs*) for self-reported responses to the CSs on 100-point scale.

HCC group				
Rating	CS	Stage		
		Habituation	Acquisition	Extinction
Disgust	CS+	20.62 (24.42)	45.38 (30.06)	34.34 (32.33)
	CS-	12.69 (16.50)	9.22 (12.70)	4.16 (5.93)
US expectancy	CS+	37.88 (26.44)	81.44 (19.90)	51.84 (33.90)
	CS-	32.72 (18.74)	7.37 (15.53)	3.97 (6.53)
LCC group				
Rating	CS	Stage		
		Habituation	Acquisition	Extinction
Disgust	CS+	10.93 (14.88)	31.80 (24.97)	15.93 (15.34)
	CS-	10.67 (13.89)	4.53 (6.22)	4.20 (9.68)
US expectancy	CS+	32.80 (23.77)	85.50 (24.49)	37.77 (29.66)
	CS-	29.27 (20.27)	2.83 (5.81)	1.60 (4.45)

Note. HCC = high contamination concern; LCC = low contamination concern; CS = conditioned stimulus (face); CS+ = face followed by unconditioned stimulus; CS- = face not followed by unconditioned stimulus.

p = 0.939, η^2_p = 0.00, and the CS by group interaction, F (1, 60) = 1.71, p = 0.196, η^2_p = 0.03, were both non-significant. Thus, the groups did not significantly differ in terms of their overall or differential anticipation of the US following the acquisition stage.

Disgust ratings. The main effect of CS was significant, F (1, 60) = 72.30, p < 0.001, η^2_p = 0.55. As hypothesized, participants reported more disgust in response to the CS+ compared to the CS-. There was also a significant main effect of group, F (1, 60) = 5.87, p = 0.018, η^2_p = 0.09, but these main effects were not qualified by a significant CS by group interaction, F (1, 60) = 1.42, p = 0.238, η^2_p = 0.02. Thus, the HCC group reported experiencing more disgust to the CSs in general following the acquisition stage.

2.4. Extinction

US expectancy ratings. The main effect of CS was significant, F (1, 60) = 106.21, p < 0.001, η^2_p = 0.64, indicating that participants continued to anticipate the US more during the CS+ compared to the CS− following the extinction stage. There was also a significant main effect of group, F (1, 60) = 4.04, p = 0.049, η^2_p = 0.06, which was not qualified by a significant CS by group interaction, F (1, 60) = 2.06, p = 0.156, η^2_p = 0.03. Thus, compared to the LCC group, the HCC group reported greater anticipation of the US during CS presentation, regardless of which CS. In our exploratory analysis that included Stage (acquisition, extinction) in the ANOVA model, there was a CS by stage interaction, F (1, 60) = 83.89, p < 0.001, η^2_p = 0.58. Paired samples t-tests revealed that US anticipation during the CS+ significantly decreased from post-acquisition to post-extinction, t (60) = 9.52, p < 0.001, 95% CI [30.31, 46.43], d = 1.39, whereas US anticipation during the CS- did not significantly change, t (60) = 1.76, p = 0.084, 95% CI [-0.33, 5.04], d = 0.25. Thus, partial extinction of US anticipation during the CS+ was achieved. The CS by stage interaction was further qualified by a CS by stage by group interaction, F (1, 60) = 6.56, p = 0.013, η^2_p = 0.10. To clarify this interaction, the groups were compared in terms of changes in US expectancy from acquisition to extinction for each CS. The HCC group reported a smaller decrease in US expectancy for the CS+ from post-acquisition to post-extinction, M = 29.59, SD = 27.45, compared to the LCC group, M = 47.73, SD = 33.74, t (60) = −2.33, p = 0.023, 95% CI [-33.72, −2.56], d = 0.60. An analogous effect was not observed for the CS−, HCC: M = 3.41, SD = 14.14, LCC: M = 1.23, SD = 4.30, t (60) = 0.81, p = 0.423, 95% CI [-3.21, 7.56], d = 0.21 Thus, the HCC group exhibited reduced extinction of US expectancy for the CS+, specifically.

Disgust ratings. The main effect of CS was significant, F (1, 60) = 39.67, p < 0.001, η^2_p = 0.40. Participants reported experiencing more disgust in response to the CS+ compared to the CS- following the extinction stage. There was also a significant main effect of group, F (1, 60) = 6.98, p = 0.011, η^2_p = 0.10, and these main effects were qualified by a significant CS by group interaction, F (1, 60) = 7.69, p = 0.007, η^2_p = 0.11. Independent samples t-tests revealed that compared to the LCC group, the HCC group reported more disgust in response to the CS+, t (60) = 2.83, 95% CI [5.41, 31.41], p = 0.006, d = 0.73 but not the CS-, t (60) = −0.02, p = 0.983, 95% CI [-4.09, 4.04], d = 0.005. In our exploratory analysis that included Stage (acquisition, extinction) in the ANOVA model, there was a CS by stage interaction, F (1, 60) = 14.54, p < 0.001, η^2_p = 0.20. Paired samples t-tests revealed that disgust in response to the CS+ significantly decreased from post-acquisition to post-extinction, t (60) = 5.16, p < 0.001, 95% CI [8.19, 18.56], d = 0.48,

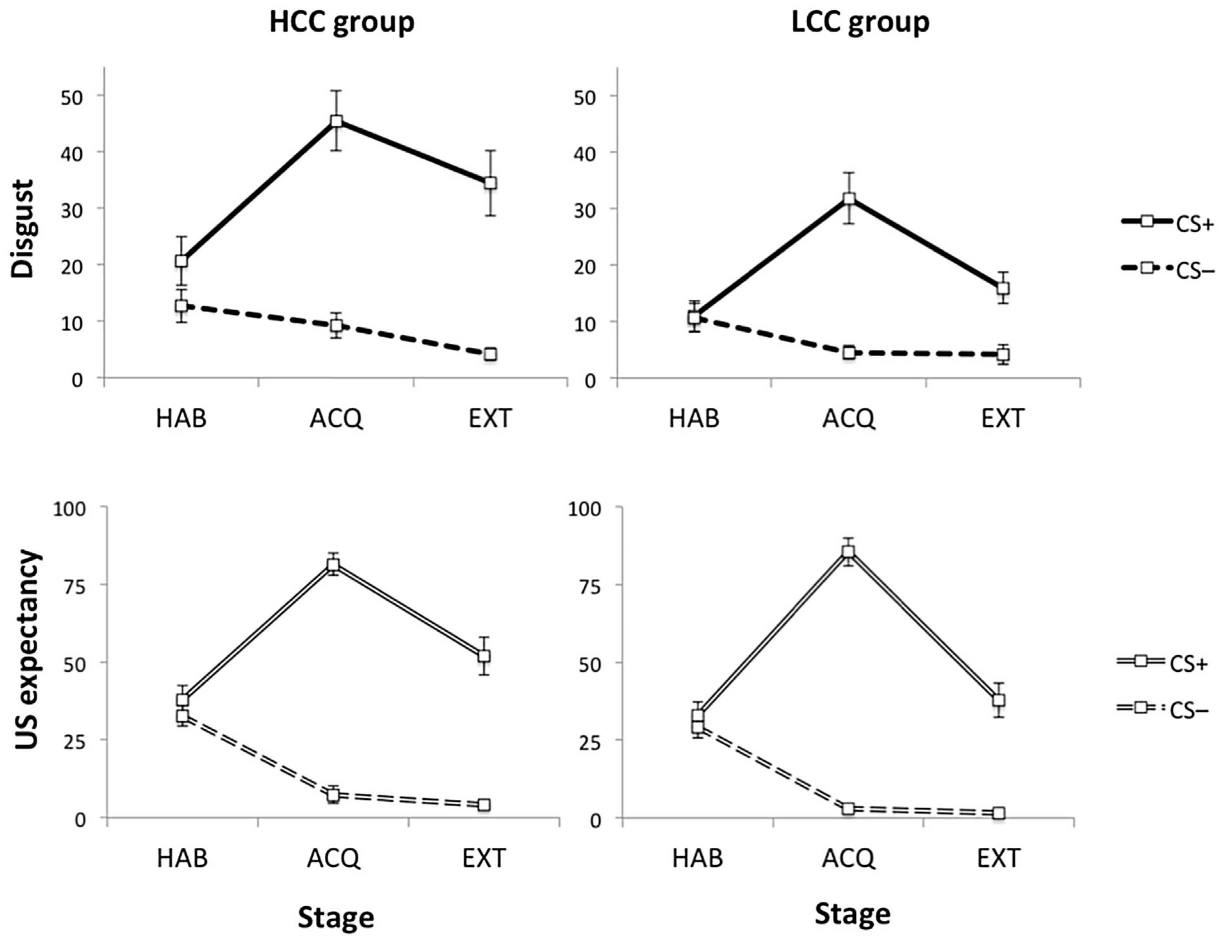

Fig. 1. Self-report responses to the CSs. HCC = high contamination concern; LCC = low contamination concern; CS = conditioned stimulus (face); CS+ = face followed by unconditioned stimulus; CS− = face not followed by unconditioned stimulus; US = unconditioned stimulus; HAB = habituation; ACQ = acquisition; EXT = extinction. Error bars represent *SE*.

whereas disgust in response to the CS− did not significantly change, $t\,(60) = 1.95$, $p = 0.056$, 95% CI [-0.08, 5.63], $d = 0.30$. Thus, partial extinction of disgust to the CS+ occurred. The CS by stage interaction was not qualified by a significant CS by stage by group interaction, $F\,(1, 60) = 2.88$, $p = 0.095$, $\eta^2_p = 0.05$.

2.5. Relations between conditioned disgust responding, symptom measures, and unconditioned disgust responding

Table 3 reports exploratory bivariate correlations between symptom measures and conditioned and unconditioned disgust responding for the full sample (uncorrected for multiple correlations). These correlations should be interpreted with caution, because the extreme groups recruitment on contamination concerns could lead to inflated correlations with indexes of contamination concerns. Of most relevance, disgust sensitivity and indicators of contamination concern (OCI-R, PI-COWC), but not trait anxiety (STAI-T), showed significant correlations with self-reported disgust to the CS+ at both acquisition and extinction, such that elevated disgust sensitivity and contamination concerns were associated with increased conditioned responding on these indexes. Disgust sensitivity and indicators of contamination concerns were not correlated with self-reported disgust to the CS− at either acquisition or extinction. Also, disgust sensitivity and indicators of contamination concern were not significantly correlated with US expectancy for the CS+ or CS− at acquisition or extinction. In terms of relations between unconditioned and conditioned responding, disgust in response to the US was strongly correlated with disgust in response to the CS+ at both acquisition and extinction, such that greater unconditioned responding predicted greater conditioned responding on these indexes. Disgust in response to the US showed a weaker yet significant correlation with disgust in response to the CS− at acquisition (but not at extinction) and with US expectancy at extinction (but not at acquisition). In both cases, increased unconditioned responding predicted increases in conditioned responding.

2.6. Does disgust sensitivity mediate group differences in conditioned disgust responding?

Given prior findings that individual differences in disgust sensitivity predict facets of conditioned disgust responding (Armstrong et al., 2014; Mason & Richardson, 2010; Olatunji et al., 2013), we tested the possibility that group differences in conditioned disgust responding were mediated by disgust sensitivity. Because our hypotheses regarded conditioned responding to the CS+ and not the CS−, we focused on responding to the CS+ and did not repeat the analyses for the CS−. Also, we included conditioning outcomes on which group differences were not observed, because significant mediation can be observed in the absence of a significant total effect (Hayes, 2013). Results of these mediational analyses are presented in Table 4. Despite the HCC group exhibiting slightly

Table 3
Bivariate correlations between measures.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. DS-R	1	0.57***	0.51***	0.41**	0.12	0.16	0.59**	0.14	0.24	0.17	0.57***	-0.01	0.80***	0.44***
2. OCI-R W		1	0.78***	0.26*	-0.02	-0.05	0.43***	-0.01	0.17	0.00	0.52***	-0.10	0.44***	0.68***
3. PI-COWC			1	0.32*	-0.12	0.07	0.29*	0.20	0.17	0.15	0.38**	-0.03	0.37**	0.93***
4. STAI-T				1	-0.34**	0.24	0.02	0.13	-0.05	0.19	0.05	-0.02	0.30*	0.30*
5. ACQ CS+ $_{exp}$					1	-0.09	0.29*	-0.21	0.36**	-0.20	0.22	-0.12	0.19	-0.09
6. ACQ CS− $_{exp}$						1	0.00	0.11	-0.04	0.47***	0.05	0.17	0.03	0.19
7. ACQ CS+ $_{disg}$							1	0.07	0.27*	-0.06	0.73***	0.05	0.66***	0.24
8. ACQ CS− $_{disg}$								1	-0.09	0.42**	0.02	0.26*	0.28*	0.23
9. EXT CS+ $_{exp}$									1	0.05	0.47***	0.03	0.26*	0.22
10. EXT CS− $_{exp}$										1	0.04	0.25*	0.05	0.09
11. EXT CS+ $_{disg}$											1	0.07	0.56***	0.34**
12. EXT CS− $_{disg}$												1	0.12	0.00
13. US $_{disg}$													1	0.34**
14. Group														1

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; DS-R = Disgust Scale – Revised; OCI-R = Obsessive Compulsive Inventory – Revised, Washing subscale; PI-COWC = Padua Inventory, Contamination Obsessions and Washing Compulsions subscale; STAI-T = The State Trait Anxiety Inventory–Trait Version, Form Y; ACQ = acquisition; EXT = extinction; US = unconditioned stimulus; CS+ = face paired with unconditioned stimulus; CS− = face not paired with unconditioned stimulus; disg = disgust rating; exp = US expectancy rating; Group is coded such that positive correlations reflect higher scores in the HCC versus the LCC group.

Table 4
Disgust sensitivity as a mediator of group differences in conditioned disgust responding.

Response to CS+		Path a (X to M)	Path b (M to Y)	Path c' (X to Y)	Indirect effect	R^2_{med}
Acquisition						
CS+ US expectancy	B (*SE*)	15.61 (4.15) ***	0.25 (0.17)	−7.94 (6.23)	3.88* (2.22)	-0.02
	95% CI	[7.31, 23.91]	[-0.10, 0.60]	[-20.40, 4.52]	[0.53, 9.50]	
CS+ Disgust	B (*SE*)	15.61 (4.15) ***	0.94 (0.18) ***	−1.04 (6.59)	14.61** (4.27)	0.06
	95% CI	[7.31, 23.91]	[0.57, 1.30]	[-14.21, 12.14]	[7.39, 24.38]	
Extinction						
CS+ US expectancy	B (*SE*)	15.61 (4.15) ***	0.31 (0.25)	9.15 (8.89)	4.92 (4.50)	0.03
	95% CI	[7.31, 23.91]	[-0.18, 0.81]	[-8.64, 26.95]	[-2.38, 15.68]	
CS+ Disgust	B (*SE*)	15.61 (4.15) ***	0.79 (0.18) ***	6.16 (6.30)	12.25 (3.96) **	0.11
	95% CI	[7.31, 23.91]	[0.43, 1.14]	[-6.45, 18.77]	[5.64, 21.32]	

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; CI = confidence interval for coefficient; Path a = effect of group (HCC, LCC) on disgust sensitivity; Path b = effect of disgust sensitivity on response to CS+; Path c' represents direct effect of group on response to CS+ controlling for indirect effect through disgust sensitivity; R^2_{med} = effect size for indirect effect (negative sign indicates possible suppression effect).

less US expectancy to the CS+ following acquisition, there was a significant ($p < 0.05$) indirect effect of group on US expectancy to the CS+ following acquisition; however, R^2_{med} was negative, indicating that the significant indirect effect likely reflects suppression rather than mediation (de Heus, 2012). Following extinction, this same indirect effect was not significant ($p > 0.10$). Despite there not being a significant difference between the HCC group and LCC group in disgust ratings to the CS+ following acquisition, there was a significant ($p < 0.01$) effect of group on disgust to the CS+ through disgust sensitivity following acquisition, and this indirect effect was also significant following extinction ($p < 0.01$).[5] In summary, the HCC groups elevated disgust in response to the CS+, relative to the LCC group, was mediated by the HCC groups elevated disgust sensitivity, relative to the LCC group, following both acquisition and extinction. Robust evidence of analogous findings involving US expectancy were not found.

2.7. Do group differences in the effect of extinction on US expectancy account for differences in the persistence of disgust responding?

A mediational model was tested in which group differences in disgust in response to the CS+ at extinction were accounted for by group differences in the effect of extinction on US expectancy for the CS+ (changes in US expectancy during the CS+ from acquisition to extinction). There was a significant effect of group on changes in US expectancy for the CS+ from acquisition to extinction, B = −18.14, SE = 7.79, p = 0.023, 95% CI [-33.72, −2.56]. There was a non-significant effect of changes in US expectancy for the CS+ from acquisition to extinction on disgust to the CS+ following extinction, B = -0.20, SE = 0.11, p = 0.062, 95% CI [-0.41, 0.01]. The indirect path from group (HCC vs. LCC) to conditioned disgust responding at extinction through change in US expectancy was significant ($p < 0.05$) as indicated by the 95% confidence intervals not containing zero, B = 3.64, SE = 2.52, 95% CI [0.26, 10.77], R^2_{med} = 0.05; however, the direct path from group to conditioned disgust responding at extinction remained significant when accounting for this indirect path (B = 14.77, SE = 6.64, p = 0.030, 95% CI [1.48, 28.06]) Thus, partial mediation was demonstrated, as group differences in disgust responding to the CS+ following extinction were explained in part, but not fully, by group differences in the change in US expectancy during the CS+ due to extinction.

3. Discussion

To our knowledge, the present study is the first to explore disgust learning abnormalities in the context of excessive contamination concern that often characterizes OCD. The HCC group, which exhibited symptoms and traits consistent with individuals with OCD, showed comparable acquisition of conditioned

[5] Both of these indirect effects remained significant ($p < 0.05$) when trait anxiety, as measured by the STAI-T, was included in the mediational model as a covariate.

disgust responding to the LCC group. The groups then began to show pronounced differences in conditioned disgust responding following the extinction procedure, although these effects differed somewhat between US expectancy and self-reported disgust. Compared to the LCC group, the HCC group did not show greater US expectancy for the CS+ versus the CS− after extinction. However, the HCC group's US expectancy during the CS+ was resistant to extinction compared to the LCC group. Specifically, the HCC group showed a smaller reduction in US expectancy to the CS+ from acquisition to extinction. Although this same pattern was not observed for self-reported disgust ratings, the HCC group did report greater levels of self-reported disgust to the CS+ following extinction compared to the LCC group. Further, disgust sensitivity was strongly correlated with self-reported disgust to the CS+ at acquisition and extinction, and group differences in self-reported disgust to the CS+ at acquisition and extinction were mediated by disgust sensitivity. These findings are consistent with prior research in unselected samples (Armstrong et al., 2014; Mason & Richardson, 2010) finding that disgust sensitivity predicts conditioned disgust responding during acquisition (Mason & Richardson, 2010; Olatunji et al., 2013) and extinction (Armstrong et al., 2014; Mason & Richardson, 2010). Finally, greater disgust to the CS+ in the HCC group relative to the LCC group following extinction was partially accounted for by the HCC group's failure, relative to the LCC group, to decrease their US expectancy for the CS+ in response to the extinction procedure.

In summary, the HCC group was distinguished from the LCC group by both cognitive and affective processes related to extinction. In terms of cognitive processes, the HCC group's representation of the contingency between the CS+ and the US, revealed by US expectancy ratings, was less impacted by extinction. Although there is a paucity of research on this aspect of disgust learning, a recent study found that fear extinction learning impairments revealed by self-reported US expectancy predicted the development of PTSD in soldiers deploying to Afghanistan (Lommen, Engelhard, Sijbrandij, van den Hout, & Hermans, 2013). In terms of affective processes, the HCC group reported a greater disgust response to the CS+ at extinction. There was some evidence that these cognitive and affective processes were related, as group differences in disgust to the CS+ at extinction were partially accounted for by the HCC group's failure to modify their representation of the CS-US contingency during extinction. This link between the appraisal of CS-US contingency and conditioned responding is consistent with propositional models of association learning, which emphasize the role of cognitions regarding the CS-US contingency in determining conditioned responding (Mitchell, De Houwer, & Lovibond, 2009). However, group differences in disgust to the CS+ following extinction remained after accounting for the HCC group's failure to modify their representation of the CS-US contingency. This finding may suggest that persistent disgust responding to the CS+ in the HCC group was partially related to an affective learning process independent from anticipatory learning (Sevenster, Beckers, & Kind, 2012), consistent with the prevailing view that evaluative conditioning features prominently in disgust learning (Olatunji et al., 2007).

The impairments in disgust extinction learning observed in the HCC group could provide insight into the etiology and maintenance of contamination-based OCD. Many of the symptoms of contamination-based OCD may be conceptualized as a failure to "unlearn" disgust responding acquired through associative learning. For example, the common symptom of excessive hand washing may reflect difficulty attenuating a disgust response to one's hands after touching a perceived contaminant, or attenuating the expectation that one will still find contaminants if they closely examine their hands. Interestingly, the present study did not find any difference between the HCC and LCC groups in terms of the initial acquisition of conditioned disgust responding. This finding may reflect the fact that concerns about hygiene and the spread of contamination are normative (Rozin & Fallon, 1987). For example, most individuals would feel disgusted by their hands and would expect to find germs on them after touching a contaminating stimulus (e.g., feces). Indeed, one of the core evolutionary functions of disgust is to prevent contact with pathogens that are largely invisible and can only be avoided by monitoring associations with known contaminants (Oaten, Stevenson, & Case, 2009; Tybur et al., 2013). Accordingly, the pathology of contamination-based OCD may be rooted less in facility acquiring conditioned disgust responding, and more in difficulty inhibiting conditioned disgust responding (through extinction and other forms of corrective learning).

The lack of pronounced group differences in the acquisition of disgust is consistent with several fear conditioning studies that have failed to observe greater acquisition of fear in individuals with anxiety-related disorders compared to controls (see Lissek, Pine, & Grillon, 2006). Lissek et al. (2006) argue that the acquisition of conditioned fear responding represents adaptive functioning, and thus should be observed in non-anxious as well as anxious individuals. In relation to OCD, a similar "strong situation" results from the unambiguous perception of contamination from a stimulus that evokes the adaptive disgust response among patients and healthy controls alike. Lissek et al. (2006) suggest using weaker conditioning procedures, such as partial reinforcement, in order to reveal learning abnormalities related to pathological anxiety. Accordingly, it may be possible to observe increased acquisition of conditioned disgust responding in HCC individuals under more ambiguous conditions. Indeed, Tolin et al. (2004) found that patients with OCD were distinguished from healthy controls and patients with other anxiety-related disorders by their tendency to perceive contagion persisting under increasingly ambiguous contact between multiple objects, leading to a longer "chain of contagion." This finding may suggest that higher-order disgust conditioning procedures could reveal abnormalities in the acquisition of disgust that are relevant to OCD. However, it should be noted that the HCC group did show a non-significant increase in disgust in response to the CS+ at acquisition, and disgust in response to the CS+ at acquisition was related to indicators of contamination concerns. Thus, acquisition of disgust under unambiguous circumstances may still be a source of impairment in contamination-based OCD.

The present study also sheds light on the possible role of disgust sensitivity in contamination-based OCD. Numerous studies have observed that individual differences in disgust sensitivity predict symptoms of contamination-based OCD; however, a specific mechanism explaining the role of disgust sensitivity in contamination-based OCD has been elusive (Olatunji et al., 2010). Although longitudinal research would be required to make strong inferences regarding the causal effects of disgust sensitivity, the present study suggests that disgust sensitivity could contribute to contamination-based OCD by causing individuals to require stronger, longer lasting conditioned disgust responses (Mason & Richardson, 2010). In addition to causing behavioral avoidance, stronger, more persistent conditioned disgust could contribute to safety behaviors, such as washing or cleaning behaviors often observed in OCD. Elevated disgust sensitivity could also interfere with treatment by causing disgust responses to be less amenable to extinction learning in the context of exposure therapy.

The present study may also have implications for the treatment of contamination-based OCD. The finding that HCC individuals are characterized by impaired extinction learning raises the possibility that contamination-based OCD, and potentially other disgust-relevant disorders, require augmented exposure therapy that addresses extinction learning deficits. Several methods for augmenting extinction learning during exposure therapy have been proposed (see Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014), all of which aim to enhance expectations that the US will not follow the CS (i.e., inhibitory learning; Craske et al., 2014). These procedures could remedy the HCC group's failure to modify expectations of the US following the CS+ in the present study. However, procedures designed to enhance inhibitory learning may be less effective in targeting the HCC group's persistent self-reported conditioned disgust to the CS, which was partially independent of their observed inhibitory learning deficit. Given that persistent self-reported disgust may be rooted in evaluative learning, it may respond better to procedures that target the affective value acquired by the CS, rather than its perceived ability to predict the US. Indeed, a recent study suggest that counter-conditioning procedures, which pair the disgust CS+ with a positive US, may be particularly effective at attenuating conditioned disgust responding (Engelhard et al., 2014).

Although the present findings provide novel insights into the role of disgust in contamination-based OCD, they should be interpreted with several limitations in mind. First, the present study utilized an analogue sample rather than a patient sample that met full criteria for contamination-based OCD. Although there is compelling evidence that research on subclinical contamination concern generalizes to clinical samples (Burns et al., 1996), these findings would be strengthened by replication in a community sample of patients. In addition, these findings would be enhanced by replication with additional objective measures of conditioned disgust responding, such as facial electromyography (Borg et al., 2016) or fMRI (Klucken et al., 2012) indices of disgust. In addition to adding an objective measure, the self-report assessment of conditioned disgust responding and US expectancy could be assessed trial-by-trial, within acquisition and extinction, to provide more insight into the time course of theses processes and perhaps a more accurate measure than retrospective reporting at the end of these procedures (Boddez et al., 2013). Also, it would be useful to employ an extinction recall test at a later time point (e.g., one day later; Milad et al., 2009), as individuals high and low in contamination concerns may also be distinguished by the extent to which they retain disgust extinction learning. Another concern regards the potency of the images used as the disgusting USs. Although the full sample rated the stimuli as moderately disgusting, more potent US stimuli would be expected to yield more robust conditioned responding (Bouton, 2007), which could in turn reveal effects that the present study was unable to detect. Finally, although the groups did not differ significantly in terms of participants' race/ethnicity, they were not optimally matched on this demographic variable; thus, replication with groups truly matched on race/ethnicity would rule out this potential confound. Future research along these lines would help clarify the nature of disgust learning abnormalities in contamination-based OCD.

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