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Effective behavioural strategies for reducing disgust in contamination-related OCD: A review

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HIGHLIGHTS

- Disgust is a central emotion in C-OCD.
- Disgust is acquired through evaluative conditioning (EC).
- Exposure (C-OCD treatment of choice) is based on Pavlovian conditioning.
- Counterconditioning or US revaluation may prove more effective reducing disgust than exposure.

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ABSTRACT

Disgust is an understudied but important emotion in various psychological disorders. Over the last decade, increasing evidence suggests that disgust is also present in various subtypes of obsessive–compulsive disorder (OCD), especially in contamination-related OCD (C-OCD). The treatment of choice for C-OCD is exposure with response prevention, originally designed to reduce fear-associated emotions thought to be acquired through Pavlovian conditioning (PC). However, disgust has been proposed to be acquired through evaluative conditioning (EC) and according to the referential model of this form of learning, there are functional differences between PC and EC that need to be considered in the treatment of disgust-related responses. Alternative strategies suggested by EC-based models include counterconditioning (contingent presentation of the CS with a US of opposite valence) and US revaluation (contingent presentation of the US with US of opposite valence). Drawing on the referential model, this paper reviews evidence for the effectiveness of each strategy to identify the most theoretically sound and empirically valid intervention to reduce disgust in C-OCD.

Contents

1. Disgust . . . 0
   1.1. Disgust sensitivity and disgust propensity . . . 0
2. Search strategy for the review . . . 0
3. Disgust in C-OCD . . . 0
   3.1. Self-report measures . . . 0
   3.2. Cognitive and behavioural measures . . . 0
   3.3. Neurofunctional measures . . . 0
4. Acquisition and maintenance of disgust reactions . . . 0
   4.1. Evaluative conditioning . . . 0
      4.1.1. CS–US relations in evaluative conditioning . . . 0
      4.1.2. Comparing evaluative conditioning and Pavlovian conditioning . . . 0
5. Modifying EC learning . . . 0
   5.1. Exposure . . . 0
   5.2. Mechanisms underlying ineffectiveness of exposure in disgust . . . 0

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5.3. Counterconditioning . . . 0
5.4. US revaluation . . . 0
6. Discussion . . . 0
6.1. Integration of previous research . . . 0
7. Conclusion . . . 0
Appendix A. List of relevant studies included in the review from search of "OCD AND Disgust". . . . 0
Appendix B. List of relevant studies included in the review from search of "Disgust AND (Condition* OR Treat*)". . . . 0
References . . . 0

Obsessive–compulsive disorder (OCD), is a debilitating disorder that affects between 2% and 3% of the population, often leading to high levels of social and occupational impairment (Slade, Johnston, Browne, Andrews, & Whiteford, 2009) and physical health complications (Drummond et al., 2012). Behavioural treatments for OCD have been repeatedly demonstrated to be effective (Rosa-Alcázar, Sánchez-Meca, Gómez-Conesa, & Marín=Martínez, 2008), even in the most severe and refractory cases (Boschen & Drummond, 2012; Boschen, Drummond, & Pillay, 2008; Farrell et al., 2013). Despite this success, increasing research interest (Boschen, 2008), and applications of technological advances to the treatment of OCD (Lind, Boschen, & Morrissey, 2013), there are many for whom treatment is ineffective (Fisher & Wells, 2005), and predictors of treatment response have been difficult to identify (Boschen, Drummond, Pillay, & Morton, 2010; Boschen & Farrell, 2011). Together, this suggests an ongoing need for further research to identify methods which may improve the effectiveness of treatments for OCD.

The most common obsessions in OCD relate to fear of contamination (Summerfeldt, Antony, Downie, Richter, & Swinson, 1997). According to Rachman's (2004) model, obsessive thoughts of contamination in OCD elicit irrational fear that leads to compulsive neutralizing behaviours and excessive avoidance of the potentially contaminated substances. As such, contamination-related OCD (C-OCD) has previously been conceptualised as a disorder of anxiety. Fear has been found to be acquired through Pavlovian conditioning (PC) and therefore the current treatment of choice (exposure with response prevention, ERP) draws upon this theoretical framework. However, more recent research suggests that some anxiety disorders previously conceptualised within fear-based models, might also incorporate other emotions (Mason & Richardson, 2010). Since individuals with C-OCD often report obsessional thoughts of dirt and contamination, it is plausible to suggest that disgust may be another emotion implicated in the genesis and maintenance of this disorder.

Current exposure-based treatments may effectively reduce fear in anxiety disorders and OCD, but their ability to reduce disgust to the same extent remains unclear. Failure to effectively reduce disgust responses in C-OCD treatment may be problematic, leading to avoidance of contaminated stimuli. This means that whether or not disgust is the most important emotion in C-OCD, disgust associated avoidance may contribute to the maintenance of C-OCD symptomatology. Moreover, understanding and addressing disgust in treatment may be useful in improving treatment of C-OCD, particularly considering that 50% of patients do not respond, drop out, or refuse interventions (Foa et al., 2005) and up to 75% of patients show residual symptoms after treatment completion (Fisher & Wells, 2005).

This paper reviews evidence for the role of disgust in C-OCD. It examines how disgust is acquired and also how it can be extinguished through the learning process of evaluative conditioning (EC; Schienle, Stark, & Vaitl, 2001; Woody & Teachman, 2000). The evidence examining the effectiveness of the current treatment of choice, based on the Pavlovian model is also examined. Drawing upon the referential model, which suggests different learning processes in EC and PC based interventions, this review identifies potential effective behavioural strategies for reducing disgust in C-OCD.

1. Disgust

Before reviewing the role of disgust in C-OCD, it is important to evaluate the basic function and structure of disgust itself. Disgust has been recognised as one of the basic emotions since Darwin (1872). Rozin and Fallon (1987) suggested that, like other basic emotions, disgust has distinctive characteristics, including a unique facial expression (levator labii activation), action (distancing of the self from an offensive object), physiological manifestations (nausea), and a subjective feeling state (revulsion). From an evolutionary perspective, disgust has evolved to protect an organism from contamination with potentially threatening toxins and infections (Oaten, Stevenson, & Case, 2009). Contemporary interpretations conceptualise disgust as a basic response to a wide range of stimuli that may signal uncleanliness, contamination, and the potential for disease (Rozin, Haidt, & McCauley, 2000).

1.1. Disgust sensitivity and disgust propensity

Disgust is a multifactorial construct consisting of disgust propensity and disgust sensitivity. Disgust propensity (DP) is the ease with which a person becomes disgusted, while Disgust sensitivity (DS) refers to the degree of negativity associated with the elicitation and experience of disgust, or in other words, the emotional vulnerability that reflects how concerned an individual is by being disgusted (Goetz, Lee, Cougle, & Turkel, 2013). Disgust sensitivity itself is a multifactorial construct that comprises three dimensions: Core Disgust, Contamination-Based Disgust, and Animal Reminder Disgust (Olatunji et al., 2007). Core disgust is linked with the evaluation of objects as possible sources of contamination (e.g., rotting foods or waste products; Rozin et al., 2000). Unlike core disgust, contamination disgust is thought to involve a perceived risk of contamination from other people, rather than other objects (Olatunji, Haidt, McKay, & Bieke, 2008). Animal reminder disgust involves a repugnance of objects and acts that remind humans of our animal origins and of our mortality (e.g., mutilation or injury). Patients with OCD washing compulsions tend to score significantly higher on core disgust and contamination-based disgust, but not on animal reminder disgust, implying that the former two are more specific to C-OCD (Olatunji, Sawchuk, de Jong, & Lohr, 2007).

In earlier studies, it has been suggested that increased DS may play a specific role in C-OCD. Elevated DS has been observed to be greater in OCD patients with contamination fears than in other subtypes of OCD (Woody & Tolin, 2002). Other researchers have also suggested that DS predicts C-OCD symptoms (Cisler, Reardon, Williams, & Lohr, 2007; David et al., 2009; Rozin, Taylor, Ross, Bennett, & Hejmadi, 2005; Tolin, Woods, & Abramowitz, 2006). Further, DS fully mediates the association between DP and C-OCD symptoms (Olatunji et al., 2010). As a result, a number of studies investigating disgust, have assessed DS only and do not included measures of DP in their assessment (e.g., Cisler et al., 2007; Rozin et al., 2005).

More recent research, however, suggests that DP might also be associated with C-OCD symptomatology. Disgust propensity was found to be uniquely associated with OCD when compared with generalised anxiety disorder, indicating that DP may be more specific to OCD than general anxiety (Olatunji, Tart, Ciesielski, McGrath, & Smits, 2011;

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Olatunji et al., 2010). Further, DS is associated with a general inability to regulate emotions (Olatunji, Wolitzky-Taylor, Willems, Lohr, & Armstrong, 2009). The differential nature of DP and DS was recently investigated by Goetz et al. (2013) using self-reported and behavioural measures across two studies. Disgust propensity was associated with avoidant actions while DS did not predict behavioural approach task outcomes beyond DP. Further, increased DS was correlated with heightened anxiety sensitivity that is present across the anxiety disorders, suggesting DS might be more general across anxiety disorders and less specific to C-OCD than previously thought.

Goetz et al. (2013) suggested that these findings have important clinical implications as it may be useful to refine treatment for individuals who are more prone to DP than DS, or vice versa, given that the constructs exhibit more unique rather than shared variance (Fergus & Valentiner, 2009). Consequently, Goetz and colleagues suggested that behavioural interventions that lead to extinction, such as exposure, could be employed with individuals scoring high in DP to reduce their heightened reaction to disgust-related stimuli. On the other hand, cognitive strategies focused more on reducing negative emotions, such as disgust or anxiety, could be more effective for those high on DS. Hence, both DS and DP seem to be important in C-OCD and research should ensure measures of disgust propensity and sensitivity are used when assessing this construct.

2. Search strategy for the review

This paper presents a review of OCD and disgust in articles identified from the Medline and Scopus databases, based on searches conducted in April 2015. The search involved peer-reviewed journal articles published in English. Abstracts of all the articles returned by the search were examined and those identified as suitable were reviewed in full. All articles on the topic published since 1997 were examined. Initially, to identify importance of disgust in C-OCD, the search terms included "OCD AND Disgust". Inclusion criteria were that the study must report on the role of disgust in adult OCD symptomatology through either self-report data, cognitive and behavioural measures, or psychophysiological recordings. Studies using children were excluded. The search resulted in 110 articles, out of which 41 directly investigated the role of disgust in C-OCD (see Fig. 1, Appendix A).

Next, to identify effective behavioural strategies in reducing disgust, search terms were "Disgust AND (Condition* OR Treat*)". The reference lists of these articles were also examined in order to identify additional studies that did not emerge in the initial database search. Included were studies that attempted to reduce disgust responses using either exposure, counterconditioning, or US revaluation. Twelve relevant articles were identified out of 57, two of which were duplicates from the previous search. Due to the limited number of studies investigating counterconditioning and US revaluation, four additional studies that investigated other evaluatively conditioned responses were also included in this review, resulting in a total of 16 studies investigating exposure ($n = 9$), counterconditioning ($n = 2$) exposure and counterconditioning ($n = 3$), and US Revaluation ($n = 2$, Fig. 1, Appendix B). Six of these studies were treatment outcome studies and ten used experimental designs.

3. Disgust in C-OCD

3.1. Self-report measures

Disgust reactions in C-OCD are commonly assessed using self-report questionnaires, with results providing support for the unique, independent contribution of disgust to C-OCD. When demographic factors such as age and gender, and associated psychopathology such as anxiety and depression symptoms, are controlled, self-reported disgust makes a unique contribution to severity of self-reported OCD symptoms in individuals with and without clinical OCD (Mancini, Gragnani, & D'Olimpio, 2001; Olatunji, Sawchuk, Lohr, & de Jong, 2004; Rozin et al., 2005; Woody & Tolin, 2002), C-OCD behaviours that showed the strongest relationship with disgust are associated primarily with washing and checking subtypes of OCD (Olatunji, Williams, et al., 2007; Olatunji et al., 2004). Some evidence also indicates that religious obsessions are predictive of DS towards sex and death specifically, after controlling

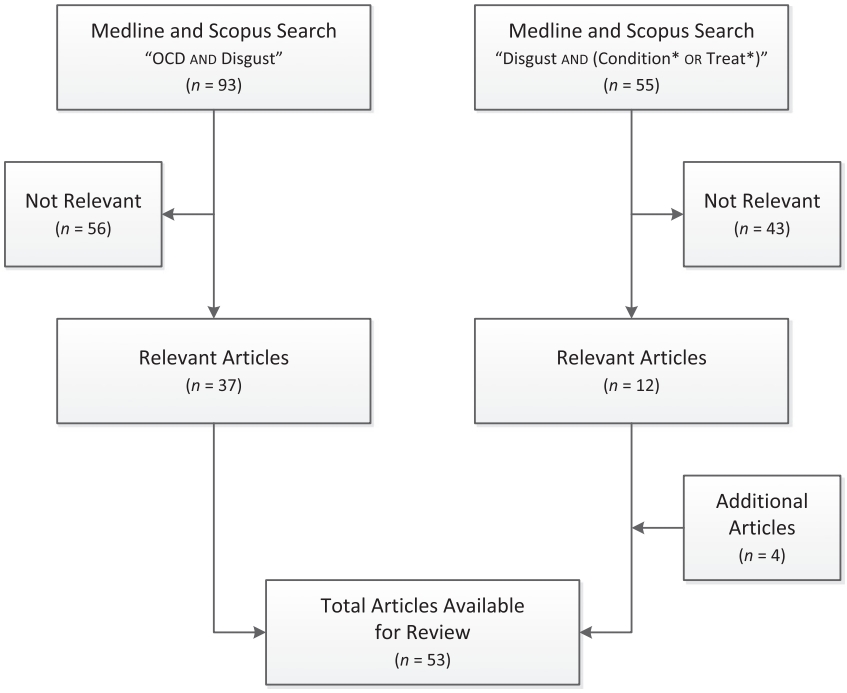

Fig. 1. Flow of studies for inclusion in the review.

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for general fearfulness and cleanliness fears (Olatunji, Tolin, Huppert, & Lohr, 2005). Even in studies where DS is associated with non-contamination OCD symptoms such as ordering and checking, the strongest association is with contamination-related symptoms (Tolin et al., 2006).

3.2. Cognitive and behavioural measures

Behavioural approach or avoidance tasks are typically used to investigate the role of disgust in OCD at a behavioural level. Researchers that employ this approach consistently report that elevated disgust towards a stimulus is associated with greater avoidance and less approach towards the stimulus. Consistent conclusions have been drawn using student samples (Adams & Lohr, 2012; Goetz et al., 2013), an OCD analogue sample (Deacon & Olatunji, 2007), as well as a clinical sample of C-OCD patients (Olatunji, Lohr, Sawchuk, & Tolin, 2007).

A number of cognitive processes have been associated with disgust and OCD tendencies (Cisler, Brady, Olatunji, & Lohr, 2010; Whitton, Henry, & Grisham, 2014). The association between disgust, OCD, and rigid moral reasoning was supported by Whitton et al. (2014) in OCD patients. Poor attentional shifting in students (Adams & Lohr, 2012) and problems with perspective taking in OCD outpatients (Kang, Namkoong, Yoo, Jhung, & Kim, 2012) have also been found to be associated with disgust and OCD symptoms.

The tendencies to overestimate the probability and severity of harm have been highlighted as contributing cognitive distortions in other forms of OCD such as compulsive checking (Rachman, 2002). In contamination fears, this tendency to overestimate contamination threat may interact with an individual's disgust propensity to exacerbate the experience of disgust. Although only examined in a non-clinical sample, this synergistic interaction between disgust propensity and contamination-based cognitive errors may also serve as a contributor to elevated disgust in C-OCD (Cisler et al., 2010)

The subjective experience of disgust has been associated with reasoning errors in individuals with heightened contamination fears. Rather than experiencing disgust in reaction to a contaminant, these individuals may be more prone to inferring contamination on the basis of the subjective experience of disgust. This specific form of the cognitive distortion of emotional reasoning has been termed disgust-based reasoning, and involves the individual erroneously perceiving contamination on the basis of their disgust reaction (Verwoerd, de Jong, Wessel, & van Hout, 2013). For individuals high on contamination fears, this erroneous reasoning may occur even in situations with low levels of objective threat, potentially acting to perpetuate C-OCD symptoms through confirmation of existing perceptions about contamination threat in the environment.

Another disgust-related cognitive error that may play an important role in the maintenance of disgust responses in OCD is "sympathetic magic", an irrational understanding of how contagion is transmitted (Tolin & Meunier, 2007). Sympathetic magic operates through the "law of contagion" (i.e., once in contact, always in contact) and the "law of similarity" (i.e., an object is contaminated due to its similarity to another previously contaminated object). Individuals with C-OCD perceive a longer chain of contamination compared to anxious and non-anxious controls, perceiving contamination in objects that have not come into contact with an originally contaminated stimulus. This chain of contamination has been reported to extend even up to objects that are 12 steps removed from the original contaminant (Tolin, Worhunsky, & Maltby, 2004). As such, the law of contagion reflects a belief that contagion is approaching, spreading, or escalating, and is characteristic of C-OCD patients. The second component of sympathetic magic, the law of similarity, has also been demonstrated using non-contaminated objects that are visually similar to disgust-eliciting stimuli (e.g., fudge that was shaped like dog faeces, a cup holding water labelled as saliva; Rozin, Millman, & Nemeroff, 1986; Tsao & McKay, 2004).

Overall, a number of cognitive distortions have been identified to potentially influence the persistent feelings of disgust in C-OCD, including rigid moral reasoning, obsessive beliefs, and disgust-based reasoning. C-OCD patients may also generalise disgust-related feelings to other objects through sympathetic magic. Together or separately, these factors may contribute to the role and persistence of disgust reactions in C-OCD.

3.3. Neurofunctional measures

Neurobiological studies also support the role of disgust in OCD. Noradrenaline levels increase during exposure to disgust-related stimuli in individuals with OCD, but not in non-clinical individuals (Fluitman, Denys, Heijnen, & Westenberg, 2010). White matter abnormalities and water diffusivity have also been observed in brain regions associated with disgust in individuals with OCD, but not in healthy individuals (Nakamae et al., 2008).

Neuroimaging studies suggest that certain brain regions associated with disgust, specifically the insula, may be more easily activated in OCD patients than in controls. This conclusion has been supported in studies using functional magnetic resonance imaging (fMRI; Phillips et al., 2000) and positron emission topography (PET; Stein, Arya, Pietrini, Rapport, & Swedo, 2006). Research also indicates that brain regions linked to OCD and particularly C-OCD are associated with disgust rather than fear. Disgusting visual images activate insula regions related to the experience of disgust in C-OCD patients, rather than fear-related centres such as the amygdala (Davis, 1992; Phillips et al., 2000). In compulsive washers, visual stimuli associated with contaminants and washing (e.g., basins, cigarette ash, dirty plates) also activate these regions associated with disgust. These cleaning-related stimuli do not activate disgust centres to the same extent in compulsive checkers, or individuals without OCD, suggesting a specific neurological contribution to disgust in contamination-based OCD (Phillips et al., 2000). These findings suggest that neurological circuits involved in disgust processing may play role in the pathophysiology of OCD.

4. Acquisition and maintenance of disgust reactions

With the increasing recognition that disgust is an important emotion in C-OCD, treatment may be improved through a comprehensive theory-based understanding of the processes underlying the acquisition and maintenance of disgust. Although some previously mentioned cognitive distortions may be responsible for maintenance of the abnormal disgust reactions seen in OCD, this does not fully explain the process by which disgust reactions are acquired. As previously mentioned, the evolutionary perspective proposes that disgust evolved as a disease-avoidance mechanism (Oaten et al., 2009). However, other authors have questioned whether spiders, slugs or other commonly disgust-associated creatures are carriers of disease (McNally, 2002). This is true for rats but whether it is true for other animals is unclear. Further, the avoidance in C-OCD is not restricted to contaminants directly associated with dirt, germs and diseases but can be associated with virtually any object including sticky substances or even soaps. This has led some researchers to suggest that "disease avoidance may be nothing more than a post hoc rationalization of an otherwise mysterious aversion" (McNally, 2002, p. 562). Moreover, testing evolutionary theory in a prospective experimental fashion is difficult.

4.1. Evaluative conditioning

A behavioural model has been proposed that suggests that disgust reactions may be attained and preserved through the process of evaluative conditioning (EC; Schienle et al., 2001; Woody & Teachman, 2000). Evaluative conditioning refers to a change in the valence of a stimulus (conditioned stimulus or CS) resulting from a previous pairing of the stimulus with another stimulus, the unconditioned stimulus (US, e.g., de Houwer, 2007; Gast, Gawronski, & De Houwer, 2012;

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Levey & Martin, 1975). Therefore EC can explain acquired disgust responses to any stimulus, including those without evolutionary value in disease avoidance. Moreover, it is also important to note that EC and evolutionary perspective are not necessarily incompatible; that is EC of disgust can have an adaptive function for an organism and some stimuli might more readily acquire disgust reactions than others.

An EC-acquired model of disgust was first proposed by Schienle et al. (2001). In their study, the authors demonstrated that through the contingent presentation of a neutral picture (CS) and a disgusting picture (US), the neutral picture was subsequently able to elicit a disgust-based reaction. The robustness of the findings was supported in studies using self-evaluative and electrodermal recordings (Olatunji, Forsyth, & Cherian, 2007); psychophysiological assessment of facial muscles and heart rate (i.e., facial electromyogram and electrocardiogram respectively; Schienle et al., 2001), and other objective measures such as an affective priming task (Mason & Richardson, 2010). Moreover, findings have been supported in studies using student samples (Mason & Richardson, 2010; Olatunji, Forsyth, & Cherian, 2007), a blood-injury-injection (BII) phobic analogue sample (Olatunji, Lohr, Smits, Sawchuk, & Patten, 2009), clinical samples of BII phobics (Schienle, Schafer, Walter, Stark, & Vaitl, 2005), and spider phobics (Olatunji, 2006).

4.1.1. CS–US relations in evaluative conditioning

de Houwer (2007) proposed that EC is best defined as an effect, as different kinds of CS–US relations produce evaluative conditioning. Through understanding of these relations, more theoretically sound strategies can be established regarding how these relations could be modified to reduce EC-acquired disgust responses. de Houwer (2011), in his comprehensive review on EC, suggested that relations between a CS and a US can be implemented concretely or abstractly. While relations implemented abstractly refer to the relational properties between stimuli and possible changes in those properties, concrete relations can be informative about the type, context or the way the relation is communicated. De Houwer further proposed that taking into consideration both abstract and concrete relations may reveal aspects of EC that will impact on the behaviour as well as the circumstances in which this occurs.

4.1.1.1. Concrete relations. Concrete relations refer to the implementation of the relation between the CS and US. Hofman et al.'s (2010) meta-analysis evaluated 214 studies, which investigated evaluative conditioning phenomena in order to identify a number of concrete relations between a CS and a US that can potentially exert a moderating effect on EC. These include organisms under investigation, stimulus properties, CS–US assignment, and the contextual features of the relation. Firstly, in respect to the organism under investigation, EC effects appear to be comparable in clinical and non-clinical samples. With respect to stimulus properties, early studies have found significant EC effects using visual CSs, such as pictures (e.g., Levey & Martin, 1975). Comparing other stimulus types, EC effects seem to be the least effective with sensical verbal CSs (i.e., meaningful verbal information) and haptic CSs (i.e., relating to sense of touch). However, studies involving electrocutaneous stimulation, which may also be more intensive, seem to be more effective than other modalities. Further, in relation to the modality as a function of the stimulus presented, the magnitude of the EC effect does not seem to differ when the presentation is unimodal (e.g. picture–picture) or cross-modal (e.g., picture–smell). When considering CS–US assignment, while EC effects are stronger if USs are assigned individually to participants based on their pre-test scores, CS assignment at a group level does not reliably change EC effects as long as the CS is evaluatively neutral. Further to the stimulus assignment, a priori match of CS and US (i.e. on perceptual similarity) does not influence EC effects and it does not appear to matter whether the CS was always presented with the same US or various USs of the same valence during acquisition (Hoffman et al., 2010).

In addition to organism and stimulus properties, Hofman et al. (2010) also considered contextual features of the relation, including CS–US contingency awareness, the explicitness of the learning context, and instructions to evaluate US spontaneously versus intuitively. The CS–US awareness refers to the extent to which EC occurs only when the participant is aware of the CS–US contingencies. The effectiveness of EC for participants aware of the CS–US contingency is approximately three times higher than for participants unaware of this contingency. Despite this, EC is still seen in the absence of contingency awareness, suggesting that while CS–US awareness is an important moderator of evaluative learning, it is not a necessary condition to observe EC effects. Further, explicit learning of the relations shows greater EC effects than when participants are not instructed to learn about the CS–US relation, although only at a descriptive level as these differences are not statistically significant. Finally, in regard to spontaneity, EC effects are significantly reduced when participants are urged to evaluate the CS in a spontaneous manner as opposed to instructed evaluations.

Overall, when concrete relations are considered, visual and electrocutaneous stimulation seems to be the most effective in producing EC effects. Moreover, explicit and instructed learning is also more effective in showing EC effects. Finally, effects are stronger when the participants are aware of the contingency between the CS and the US.

4.1.1.2. Abstract relations. Abstract aspects encompass the statistical properties of the relation between the stimuli that are paired (e.g., the co-occurrence, redundancy and the degree of statistical contingency; de Houwer, 2011). Co-occurrence refers to the extent to which an increased number of CS–US pairings makes the effects stronger. The strongest EC acquisition effects have been observed when the CS and US were paired 10 times, with further pairings have little additional effect (Baeyens, Eelen, van den Bergh, & Crombez, 1992). Research also suggests that EC can occur when the CS and US have never co-occurred together (Hammerl & Grabitz, 1996). This conditioning happens indirectly through the co-occurrence of each variable with a third stimulus, a phenomenon described as sensory pre-conditioning (Walther, 2002). Sensory pre-conditioning may be particularly relevant to C-OCD because it closely resembles the previously described cognitive distortion of sympathetic magic. Through this distortion, individuals tend to misclassify the number of objects as contaminated; however this effect does not seem to be due to the process of generalisation (Walther, 2002). It is possible that C-OCD patients may be more susceptible to the effects of sensory pre-conditioning because of their tendency to engage in the cognitive distortion of sympathetic magic. Moreover, once disgust responses spread to other objects, they may be more difficult to modify. Therefore, sympathetic magic might be an important mediator of disgust acquisition and extinction in C-OCD symptomatology.

Another abstract CS–US relational property is "redundancy" or the extent to which the CS–US relation overlaps with other CS–US relations (de Houwer, 2011). Accordingly, if CS_A always co-occurs with CS_B, and CS_B co-occurs with the US, the relation between CS_A and the US is redundant. Lipp, Neumann, and Mason (2001) observed a larger change in liking of the CS_A when the CS_A–US relation was redundant than when the CS_A–US relation was not redundant.

EC does not seem to be affected by the statistical contingency or the predictability of the US (de Houwer, 2011). This was shown in studies that examined conditioning with a pair of pictures (Baeyens, Hermans, & Eelen, 1993; Kattner, 2014) and flavours (Baeyens, Crombez, de Houwer, & Eelen, 1996). Overall, EC effects can be influenced to some degree by the CS–US co-occurrence or the relational redundancy but the predictability of the US does not seem to have impact on EC learning. This finding is especially important because it suggests that exposure, which attempts to change US predictability, may be less effective in modifying EC based learning of disgust.

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4.1.2. Comparing evaluative conditioning and Pavlovian conditioning

The current psychological treatment of choice for C-OCD is exposure (with ritual prevention), focusing on fear as a central emotion in treatment. Myers and Davis (2007) asserted in their review that fear is acquired through PC during which a neutral stimulus (the to-be CS; e.g., a tone) is paired with an aversive US (e.g., an electric shock). After a number of pairings, presentation of the CS alone comes to elicit a learned or conditioned fear response (CR, e.g., increased skin conductance, salivation etc.). In this sense, the CS becomes a predictor for the US. Exposure-based treatment attempts to reduce the fear response by repeated sole presentation of the CS without the US, so the CS no longer predicts the US and the CS-related fear responses can be reduced.

The finding that predictability of the US does not affect EC learning is therefore important, as it differs from Pavlovian conditioning, in which the US predictability clearly affects the learning process (de Houwer, 2011). Some controversy has existed around whether EC and PC represent two different forms of learning (Davey, 1994). By conceptualising EC as an effect that can be influenced a number of different CS–US relations, rather than viewing it as a fixed procedure (de Houwer, 2007), it has been proposed that EC could be viewed as a subtype of PC (de Houwer, 2011). Like all other PC effects, EC effects concern changes in the response to a stimulus that result from pairing this stimulus with another stimulus. What is unique to EC effects is that it emphasises the changes in valence rather than changes in other responses (e.g., skin conductance, salivation, de Houwer, 2007) and while certain stimuli may lead to contingent behavioural responses, this relationship is fully mediated by a change in appraisals (Schienle et al., 2001).

4.1.2.1. The referential model. The referential model (Baeyens & De Houwer, 1995; Baeyens et al., 1992) helps to explain the differences between EC and PC that are relevant to the understanding of disgust responses. It postulates that although EC and PC effects depend on a single learning mechanism, they operate through two different learning rules. PC can be described in terms of expectancy learning, in which the CS serves as a reliable predictor of the US. In contrast, EC can be described in terms of referential learning, in which the CS serves as a reference to the US, but without resulting in anticipation of the US. Consequently, expectancy learning depends on a statistical contingency between the CS and the US, and learning will occur to the extent that the organism is able to predict the US occurrence (Rescorla & Wagner, 1972). In contrast, EC depends on a referential-learning process, in which CS and US co-occurrences strengthen the CS–US association. EC effects supposedly occur because presentations of the CS activate the associated representation of the US (i.e., its valence) without generating an expectancy of the US to actually occur. Hence, EC is based on (automatic) association–formation processes which depend on contiguity, but not on statistical contingency.

5. Modifying EC learning

According to the referential model, unpaired CS and US presentations, as used in exposure-based interventions of C-OCD, should not have a major effect on the EC-acquired disgust learning. However, the referential model also indicates that procedures that utilise contiguity in the association formation should. Based on this rationale, de Houwer (2011) proposed two behavioural strategies that could effectively modify EC based learning: counterconditioning and US revaluation. The following section will briefly examine functional processes underlying exposure, counterconditioning and US revaluation and it will review evidence examining the effectiveness of each strategy in reducing disgust-related emotional reactions.

5.1. Exposure

Exposure is explicitly based on the extinction process that underlies PC-based learning (Mineka, 1985). During exposure, a CS is repeatedly presented alone without the US, which results in the change of behaviour associated with US expectancy as the CS no longer predicts the US (Myers & Davis, 2007, see Fig. 2). Because EC learning is relational and requires contingent presentation between two stimuli, it is not surprising that the CS alone presentations, utilised in exposure, often do not diminish evaluatively conditioned responses (Baeyens, Crombez, van den Bergh, & Eelen, 1988). This evidence comes from treatment outcome studies as well as studies which directly tested the underlying mechanism of acquisition and extinction of disgust in exposure.

Empirical investigation has supported the idea that disgust is more resilient than fear responses to exposure, when assessed in OCD analogue samples. Repeated exposure to a threat-relevant stimulus (e.g., a dirty bed-pan) has been shown to reduce subject fear ratings, but not ratings of subjective disgust in students high on contamination fears (Olatunji, Wolitzky-Taylor, Willems, Lohr, & Armstrong, 2009). In cases where exposure results in fear and disgust reductions, disgust responses may be more likely to return, suggesting that the changes occurring in extinction are more ephemeral for disgust responses (Rachman, Shafran, Radomsky, & Zysk, 2011). This resilience of disgust responses may be most pronounced in individuals with C-OCD. Previous research has demonstrated that habituation to disgust stimuli may occur more slowly in individuals with C-OCD than those with other OCD subtypes, suggesting that extinction-resistant disgust responses may contribute to the maintenance of the condition, and may serve to reduce the effectiveness of exposure-based treatments (McKay, 2006).

5.2. Mechanisms underlying ineffectiveness of exposure in disgust

Although the studies described above investigated the effects of exposure in reducing disgust, they have not tested the mechanisms

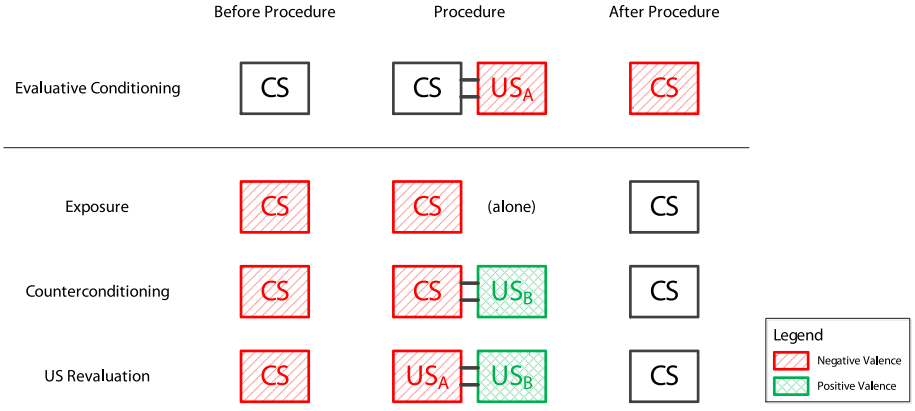

Fig. 2. Procedures for evaluative conditioning, exposure, counterconditioning, and US revaluation.

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underlying this effect. Some researchers (e.g. McKay, 2006) have postulated that the resistant nature of disgust to exposure reflects the procedural differences between EC and PC (as described by the referential model) but such differences were not directly tested in their study designs. The following section describes studies which directly examined the underlying mechanism of acquisition and subsequent extinction processes in disgust-related reactions.

Studies examining the mechanism of disgust extinction have traditionally paired a neutral stimulus with a disgusting US over 6 to 12 trials (CS+ condition), while at the same time two other neutral stimuli have been also paired (CS− condition) using the same number of pairings. After disgust is acquired through EC, as indicated by higher disgust ratings to the CS+ than CS−, effects of exposure have been then tested through repeated CS alone presentations over 8 to 10 trials. Empirical evidence suggested that through the contingent presentation of subjectively neutral pictures (CS) with disgusting pictures (US), the neutral stimuli will acquire the ability to evoke disgust responses. Exposure, although effective in reducing fear-based responses, has been found less effective in reducing disgust, as indicated by self-reported measures, behavioural observations, electrodermal responses, a visual-avoidance task and an affective priming task (Engelhard, Leer, Lange, & Olatuji, 2014; Mason & Richardson, 2010; Olatunji, Forsyth, et al., 2007). When investigating changes in expectancy and evaluative learning prior and after exposure, research has demonstrated that exposure is effective in reducing expectancy learning, while evaluative ratings remain unchanged (Engelhard et al., 2014; Olatunji, Forsyth, & Cherian, 2007). Even when expectancy and evaluative ratings are assessed randomly during the exposure trials, rather than as a pre- and post-assessment, the results show changes in US expectancy only, while evaluative ratings remain unchanged (Mason & Richardson, 2010). These findings are consistent with the referential model, in which expectancy learning can be effectively reduced by sole repeated presentation of the CS (i.e., exposure), while changes in EC-based learning require contingent CS–US presentation and are, therefore, unaffected by exposure.

Other aspects of EC-based learning are consistent with aspects of the presentation of individuals with clinical C-OCD, and may also serve to explain the reduced effectiveness of exposure interventions in this group. Individuals high on DS report stronger EC effects and seem to have responses which are more resistant to exposure (McKay, 2006). Individuals with C-OCD tend to score higher on DS (Woody & Tolin, 2002) and therefore, it is possible that in this particular population, reducing disgust-based emotional responses using traditional exposure procedures may be especially difficult. Previous research has also found a small evaluative shift in controlled non-paired stimuli in addition to paired stimuli, suggesting that paired CSs can potentially contagiously transfer valence to unpaired ones (Olatunji, Lohr, Jasper, Sawchuck, & Patten, 2009). This resembles the law of contagion phenomenon previously described, which is highly characteristic of individuals with C-OCD, and may further inhibit exposure effects in this particular population.

Research in which exposure has been effective in reducing disgust may suggest that there are differences in subtypes of disgust responses to different stimuli. Where disgust is related to mutilation or injury as in blood, injury, and injection phobia, limited research has suggested that this may respond to exposure (Olatunji, Lohr, Jasper, Sawchuck, & Patten, 2009). This contrasts with previous research in which contamination-based disgust has been assessed (Mason & Richardson, 2010; Olatunji, Forsyth, & Cherian, 2007). More research is required to examine whether this differential responding of subtypes of disgust is observed consistently.

Failure to find exposure effects on evaluatively acquired disgust may be an artefact of pen and pencil assessment taken before and after conditioning, as the passage of time between extinction and test may be sufficient to constitute a context change analogous to the one responsible for the return of extinguished conditioned responses, i.e., the renewal phenomenon (Lipp, Oughton, & LeLievre, 2003). When evaluative ratings of a CS are conducted on each extinction trial (rather than only before and after the extinction procedure), this has shown extinction of affective valence similar to that seen in traditional PC research. This research also indicates that exposure effects in reducing disgust-based reactions may be highly sensitive to the process of renewal, and that even slight changes in the environment immediately after the intervention can result in the return of the disgust levels reported prior to the intervention. In clinical terms, this means that even if exposure is effective in reducing disgust, return of disgust may occur after the treatment. This is consistent with inhibitory learning models of extinction that have been successfully applied to fear/anxiety responses (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). In this model, extinction procedures result in the acquisition of a new association between the CS and the *absence* of the US (i.e., CS–noUS). This suggests that renewal of the conditioned response may be observed when the context is different from that used in the extinction procedure (Boschen, Neumann, & Waters, 2009; Neumann, Boschen, & Waters, 2008). In relation to disgust these effects are, however, underexplored in the current literature.

Overall, many studies have found exposure to be ineffective, or less effective, in reducing disgust-related reactions, especially in individuals high on DS. Moreover, if the effects are observed, disgust reduces at a slower rate and the effects are not sustained in the long term. This may lead to a continuous avoidance of the stimulus that may potentially lead to relapse. Further, return of disgust through renewal, reinstatement, reacquisition or absence of future exposure to disgust related stimuli is also possible and currently unexplored. The higher levels of DS in C-OCD individuals and the cognitive distortion of sympathetic magic (law of contagion and law of similarity) may further interfere with successful habituation of disgust-related emotional responses in this population. The ineffectiveness of exposure in reducing disgust has been observed in studies using students, analogue samples, as well as clinical samples of spider and BII phobics, but studies directly investigating the EC mechanism in C-OCD have not been conducted despite the importance of disgust-related emotions in this psychopathology. Finally, these findings seem to be in line with the referential model, in which contingent presentation of the two stimuli has been proposed to be necessary in modifying EC learning but the CS only presentation utilised in exposure should not have any effect of EC-based learning. Indeed, a number of studies have supported the referential model as exposure changed expectancy learning but not evaluative responses associated with disgust-related stimuli.

While the referential model explains why exposure is not entirely effective in reducing EC acquired disgust, it also helps to indicate which interventions may be more effective. As the model suggests, the contingent presentation of the CS or US with a new stimulus of opposite valence may help to create a new reference towards the CS and may be therefore be effective in modifying EC-based learning. This is the concept underlying counterconditioning and US revaluation (Hofman et al., 2010). Although these strategies have been proposed as possibly effective in reducing disgust, the research investigating their effects is limited, as outlined below.

5.3. Counterconditioning

In counterconditioning the CS is repeatedly paired with a US of the opposite valence from the original US (see Fig. 2). Counterconditioning is not only effective but may also have additional benefits over exposure in reducing disgust and other evaluatively conditioned responses, such as likes and dislikes or food preferences. These results have been observed in studies using self-report measures, affective priming tasks and behavioural tasks (Engelhard et al., 2014; Kerkhoff, Vansteenwegen, Baeyens, & Hermans, 2011).

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However, research also indicates that counterconditioning needs to use a sufficiently intense pleasant US for it to be effective. For example pairing disgusting images with small money rewards has been unsuccessful in changing disgust as indexed by self-reported, behavioural, and neuroimaging assessment (Scweckendiek et al., 2013). When an intense pleasant US is used, researchers have found that counterconditioning is more effective than exposure in reducing disgust-related emotions (Engelhard et al., 2014). Interestingly, counterconditioning reduces not only evaluative ratings of disgust but also US expectancy ratings, suggesting that this intervention may be effective in reducing fear as well as disgust. These results are not surprising because the necessary conditions for modification of predictive as well as expectancy learning are satisfied with counterconditioning. Firstly, reference learning is changed through contingent presentation of the CS and pleasant US, and this same pairing also changes the predictability of the disgusting US, since the CS no longer follows the disgusting US. Nonetheless, counterconditioning and exposure have not yet been directly compared in a single sample, as two different samples were used (Engelhard et al., 2014). Further, only negative valence was used as the indicator of evaluative learning, limiting the ability to draw disgust-specific conclusions.

Research has also investigated whether adding counterconditioning to traditional exposure therapy improves treatment efficacy in a spider phobic sample (de Jong, Vorage, & van den Hout, 2000). Three main findings were observed: First, both interventions were effective in reducing avoidance behaviour and self-reported fear of spiders. Second, the disgusting properties of spiders were attenuated and the disgust-related evaluative responses to spiders shifted in a positive direction equally across both conditions. Finally, both treatments were equally effective immediately after the treatment and in a one-year follow-up. Therefore the authors concluded that counterconditioning as well as exposure are equally effective in reducing disgust related emotional responses in a clinical context. Nonetheless, it is important to note that de Jong et al. (2000) used Öst and Sterner's (1987) single session exposure method. This type of exposure does not exclusively utilise exposure processes, and also includes a number of other strategies such as psychoeducation, modelling examples, encouragement and corrective information provided by the therapist. Such strategies may indirectly serve as a US revaluation strategy, rationalizing feared responses to the negative stimuli, which may have consequently lead to revaluation of that stimulus (e.g., a disgusting spider could be revaluated in the carnivorous group of animal species that prevent insect overpopulation). This notion was first proposed by Merckelbach, de Jong, Arntz, and Schouten (1993), who have also found Öst's exposure effective in the treatment of spider phobics high on DS. Consequently, if some aspects of Öst's exposure may have served as US revaluation strategies that help to attenuate disgust responses in de Jong et al.'s (2000) and Merckelbach et al.'s (1993) studies, then it is important to distinguish whether it was the effect associated with exposure or US revaluation that reduced disgust.

5.4. US revaluation

US revaluation occurs when the valence of the original US is changed via pairing this US with information or stimuli of the opposite valence (see Fig. 2). The revaluation of the US can lead to changes in response to the CS with which the US was originally paired. Future research is needed to investigate whether disgust related emotions can be modified using US revaluation and how this strategy compares to other interventions, such as exposure and counterconditioning. To date, no studies have compared exposure with US revaluation. Although the proposition that US revaluation can be effective in reducing disgust has not been directly tested, the effectiveness of this strategy could also be suggested through studies investigating its effects on other EC-acquired responses. For example, US revaluation has been found to be effective in changing individual's likes and dislikes or attitudes towards human faces (Baeyens et al., 1992; Walther, Gawronski, Blank, & Langer, 2009). This has been supported using self-report measures but also using the more objective affective priming task. Research also indicates that, although attitudes can be significantly changed in both directions, this effect seem to be stronger in changing positive attitudes to negative (Walther et al., 2009). On the other hand, when artificial fruit flavours have been used as CSs and a soap-like aftertaste as USs, US revaluation effects were not observed (Baeyens, Vanhouche, Crombez, & Eelen, 1998). This indicates that the specific nature of the US used in US revaluation matters, as the pictures of faces might produce more pronounced elaborative encoding than simple gustatory stimuli.

Research also indicates that US revaluation effects are not dependent on explicit memory for the revaluation information, with the US revaluation effects being even stronger at one week follow-up (Walther et al., 2009). The latter may be attributable to the "sleeper effect" in which attitude change is inversely proportional to memory for its source (Pratkanis, Greenwald, Leippe, & Baumgardner, 1988). Previous research has also randomised CS–US pairings to ensure that the learning of the responses is not due to a similarity effect, but instead the change of valence assigned to the CS during the post-acquisition (Walther et al., 2009, Study 3). Positive correlations between CS–US ratings suggested that evaluative changes in the CS are based on associative links between CS and US, rather than intrinsic changes in the valence of the CS itself. Overall, the findings provided compelling evidence for US revaluation as a potentially effective strategy in changing evaluatively acquired responses. Although no studies to date have attempted to reduce disgust-related emotional responses through US revaluation, the results from the above mentioned studies suggest that like other evaluatively acquired learning, disgust conditioned responses may be effectively reduced using this strategy.

6. Discussion

6.1. Integration of previous research

Exposure is the frontline treatment for OCD, including C-OCD. The intervention is based on a model which has been successfully applied to extinction of fear responses (i.e., Pavlovian conditioning) where the predictability of the negative outcome is reduced through the contingent presentation of the feared object (CS) without the negative outcome (US). Through this review it has been shown that disgust also plays an important, even central, role in C-OCD. Schienle et al. (2001) and Woody and Teachman (2000) proposed a model in which disgust is acquired through evaluative conditioning, where the reference between CS and US is learned, rather than the expectancy of the US occurrence. Hence, the question remains whether fear-based exposure that changes the predictability of a US can also change the learned reference towards a US (i.e., whether exposure can be successful in reducing disgust as well as fear). Through this review it was found that exposure is not always effective in reducing disgust. Where exposure does work, the effects are temporary, and disgust habituates more slowly and to a lesser extent than fear.

According to the referential model (Baeyens et al., 1992), different relations affect expectancy learning associated with fear, compared to evaluative learning associated with disgust. While in expectancy learning, repeated sole presentation of the CS reduces predictability of the US, it does not change the evaluatively-learned reference towards the US, which can only be changed through contingent presentation of the two stimuli that can create a new reference towards the CS. In other words, repeated sole presentation of the disgust related object will reduce individual's expectancy that this object will be followed by something disgusting, but will not

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modify reference towards that object as being disgusting. Counterconditioning, in which CS is paired with positively charged US, or US-revaluation, in which a US is paired with another US of the opposite valence, are theoretically sound and potentially effective strategies in reducing disgust-based reactions, including in clinical conditions such as C-OCD. These strategies can modify the originally learned reference towards the disgusting object. The current review supports their potential effectiveness in treating OCD, while being cautious of the limited number of the studies investigating these strategies. Based on the integration of different theories and empirical evidence, the current review has a number of suggestions that can advance the current research to effectively reduce disgust in C-OCD.

While the current psychological treatment of choice for C-OCD is exposure, it is not entirely effective in reducing disgust in C-OCD. Previous research has proposed several methods to maximize the effects of exposure based on the inhibitory learning model (Craske et al., 2014). This review suggested that exposure that maximally violates expectancies regarding the frequency or intensity of aversive outcomes, attempts to extinguish multiple CSs first, occasionally reinforces learning during extinction, eliminates safety behaviours, includes retrieval cues, varies the context of extinction and promotes the reconsolidation of the memory of the adverse event could have potentially more effective and longer lasting effects on extinction of fear (Craske et al., 2014). It remains to be seen, however, whether similar mechanisms will enhance extinction of evaluatively acquired disgust responses. For example, current research investigating exposure effects on reducing disgust has used mostly six to eight trials of US exposure. It is possible that using more trials over a longer period of time in exposure may reduce disgust at a comparable level as other strategies such as counterconditioning. Nevertheless, even if this is the case, identifying interventions that reduce disgust at a faster rate may reduce costs and drop-out rates associated with lengthy and expensive treatments.

Based on the referential model, counterconditioning and US revaluation are alternative theoretically sound strategies for reducing disgust in C-OCD. Despite this clear theoretical rationale, only three studies to date have investigated the effects of counterconditioning on disgust-based emotions and US revaluation has not yet been investigated in relation to disgust. However, the results from the available studies suggest that these alternative interventions might be effective and that counterconditioning might be more effective than exposure. However, to evaluate this hypothesis, future research needs to control for the limitations found in previous studies and compare interventions across one sample, using disgust-specific ratings measured at comparable intervals.

To maximize the effect of counterconditioning, the stimulus used during the intervention needs to be intensive enough in terms of its valence. Further, past research has suggested that US revaluation through visual stimuli might be more effective than with gustatory stimuli. This finding is consistent with the referential model which suggests that EC effects are stronger in visual sensory modalities than any other modalities. However, it has been also proposed that electrocutaneous stimulation induces even stronger EC effects than visual stimuli (de Houwer, 2011). Thus if pairing a neutral stimulus with tactile electrocutaneous stimulation (rather than with the visual stimulus) produces stronger effects in changing positive evaluative ratings to negative ones, future research should also explore whether other methods of modifying arousal (e.g., relaxation strategies) would be also able to elicit stronger evaluative shift in a positive direction.

A significant problem in exposure-based treatments for anxiety disorders is the high rate of relapse after successful treatment (Boschen et al., 2009; Neumann et al., 2008). This return of fear has been proposed to occur due to the persistence of the original conditioned response, which survives extinction. According to current models of inhibitory learning (e.g., Bouton, 2002; Craske et al., 2014), PC-based exposure treatments lead to the creation of a new association of the CS with safety, rather than the removal of the existing association. It is unclear whether evaluatively conditioned associations also retain this original association after procedures such as counterconditioning and US revaluation. If these traces persist, this would suggest that procedures such as counterconditioning and US revaluation may be vulnerable to the same effects as fear extinction. Alternatively, if such procedures lead to removal of the original association, then this would suggest that relapse may be less likely following EC-based treatments. To our knowledge this has not been tested.

Investigation of EC-based interventions in C-OCD is essential as no previous research has assessed whether disgust-related reactions can be attenuated via either counterconditioning or US revaluation in this clinical population. This is especially important as C-OCD patients may be more sensitive to disgust acquisition than a healthy population (McKay, 2006). Further, if individuals with C-OCD are more sensitive to EC-acquired disgust, future research should explore the mechanism that underlies this effect. Evaluative conditioning can be affected by number of CS–US relations. One is the effect of sensory pre-conditioning, in which the learning between the CS and US can occur indirectly through the third variable. This means that a learned disgust reaction may easily spread to other objects. C-OCD patients score high on the cognitive distortion of sympathetic magic in which they erroneously believe that contamination spreads to other objects based on their similarity or brief encounter with an originally contaminated object. It is therefore possible that individuals with C-OCD may be more prone to disgust acquisition and the effects of sensory preconditioning through the effect of this particular cognitive distortion, making it more difficult to attenuate disgust reactions in C-OCD symptomatology. Therefore, the mediating role of sympathetic magic between C-OCD symptomatology and EC effects may also be considered in order to design effective intervention that could attenuate disgust-based reactions in this population.

Similarly, increased DS has been associated with more resistance to exposure (McKay, 2006). As C-OCD symptomatology has been already found to be associated with increased DS levels (Woody & Tolin, 2002), it remains to be seen whether DS influences evaluative learning in this particular population. To evaluate this assumption, future research could also compare the moderating effect of DS and sympathetic magic with other cognitive distortions commonly identified with C-OCD. A number of other cognitive factors including rigid moral reasoning, obsessive beliefs, and disgust-based reasoning may also play a role in acquisition and maintenance of OCD symptomatology and need to be further investigated.

7. Conclusion

This review investigated effective interventions in treating disgust-related emotional responses in C-OCD. This was done by examining the role of disgust in C-OCD, and describing a theory of the underlying processes of its acquisition and extinction in clinical and non-clinical population. It is suggested that current exposure treatment for C-OCD is not always effective in reducing disgust. In line with the referential model, counterconditioning and US revaluation are proposed alternative interventions, utilising necessary conditions for change in EC acquired disgust. Although the research investigating their effectiveness is in its infancy, preliminary findings suggest that these strategies may be more effective in reducing disgust than exposure based interventions, which are currently used in the treatment of disgust-related emotions in C-OCD. Further research is required to examine the underlying mechanisms of these strategies and to apply them in clinical populations to develop novel treatment approaches.

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Appendix A. List of relevant studies included in the review from search of "OCD AND Disgust".

Study	Evidence type	Assessment	Participants	Findings
Melli et al. (2014)	Self-report	VOCI, DPQ, DOCS, BAI, BDI-II	$N = 63$ C-OCD	Significant correlations between DP, mental contamination and C-OCD, controlling for anxiety and depression
Broderick et al. (2013)	Self-report, physiological	PI-WSUR, Emotion Reaction Ratings to Pictorial Stimuli, Heart Rate	$N = 54$ non-clinical (high and low on C-OCD)	High OCD-greater levels of self-reported disgust and heart rate deceleration in addition to fear.
Armstrong et al. (2014)	Cognitive	Lexical Decision Task, PI, Mood Scale, Audiovisual Mood Induction	$N = 83$ students	Contamination sensitivity predicted increased disgust and arousal to the negative mood induction. Contamination sensitivity was also a better predictor of reaction times to disgust and fear words than happy words.
Olatunji et al. (2011)	Self-report	OCI-R, DES, DPSS-R, BDI, BAI, PSWQ	$N = 153$ OCD	Disgust and negative affect latent factors independently related to OCD symptoms. When modelled simultaneously only disgust remained significantly associated with OCD.
Olatunji et al. (2010)	Self-report	DPSS-R, PI, PANAS, BDI-II, OCI-R	Study 1: $N = 417$ students, Study 2: $N = 101$ students, Study 3: $N = 46$ OCD	General disgust related to contamination fear. Both DS and DP independently predicted contamination fear (Study 1). Higher contamination fear associated with less reduction in contamination fear over 6 weeks (Study 2). DP associated with concurrent levels of excessive washing in OCD (Study 3).
David et al. (2009)	Self-report	OCI-R, DPSS-R, ASI-3, PANAS	Study 1: $N = 270$ students, Study 2: $N = 300$ students	Significant association between DS and OCD symptoms. Specific association found between DS and C-OCD.
Tolin et al. (2006)	Self-report	DSc, OCI-R, ZSRS, CES-D	$N = 1005$ students	DS associated with OCD (washing, ordering, checking). Clearest relationship between washing OCD and DS.
Olatunji, Williams, et al. (2007)	Self-report	DSc, DES, OCI-R, DS-R, PI, VOCI, STAI, SCID	Study 1: $N = 655$ students, Study 2: $N = 993$ students, Study 3: $N = 215$ students, Study 4: $N = 56$ OCD	Women scored higher than men. Only core and contamination disgust predicted OCD, with C-OCD patients reporting the highest scores.
Cisler et al. (2007)	Self-report	DSc, VOCI, ASI	Study 1: $N = 1377$ students, Study 2: $N = 98$ students	Anxiety sensitivity and DS independently predict contamination fear.
Olatunji (2010)	Self-report	PI, DPSS-R, PANAS, BDI-II	$N = 177$ students	Change in DS over 12 weeks uniquely predicted change in C-OCD symptoms.
Olatunji, Williams, Lohr, and Sawchuk (2005)	Self-report	DSc, PI, VOCI, ASI, STAI	$N = 259$ students	Females reported higher levels of contamination fear and DS than males. DS independently predicted contamination fears
Olatunji, Tolin, et al. (2005)	Self-report	PIOS, FSS, PI, DSc	$N = 100$ students	Relations found among fearfulness, DS and religious obsessions. Religious obsessions predicted by relational and contamination fears, and DS towards sex and death.
Olatunji, Sawchuk, et al. (2005)	Self-report	DSc, PI, VOCI, STAI, ASI	$N = 259$ students	DS independently predicted contamination fears. Females report higher levels of contamination fear and DS than males.
Mancini et al. (2001)	Self-report	STAI, BDI, PI-R, DSc	$N = 278$ non-clinical	Significant positive relationship between disgust and OCD symptoms, with washing and checking symptoms being the best predictors
Woody and Tolin (2002)	Self-report	SCID-I, Y-BOCS, DSc	$n = 56$ OCD, $n = 12$ generalized social phobia, $n = 14$ non-anxious	OCD (C-OCD subtype) reported greatest DS.
Deacon and Olatunji (2007)	Self-report, behavioural	PI, DSc, BAI, BDI, CCS, BAT	$N = 56$ students (high and low on C-OCD)	DS associated with avoidance on BAT. Association between contamination cognitions and BAT fully mediated by DS.
Olatunji, Lohr, Sawchuk, and Tolin (2007)	Self-report, behavioural	Disgust eliciting video, BAT, BTRS, VOCI, DSc, PANAS	$N = 60$ students (high and low on C-OCD)	High C-OCD group reported stronger DS, was more disgusted when watching disgusting video and demonstrated less approach on BAT. DS mediated avoidance on BAT.
Adams and Lohr (2012)	Cognitive, behavioural	ACS-R, BAT	$N = 33$ students	Poor attentional shifting ability and greater subjective disgust related to less approach to disgust stimuli. Disgust fully mediated attentional shifting and avoidance
Nicholson and Barnes-Holmes (2012)	Cognitive, behavioural	IRAP, BAT, DS-R, OCI-R, DASS	$N = 33$ students	DS predicted BAT avoidance, washing compulsions. DP predicted self-reported OC tendencies. Both individually predicted obsessing.
Whitton et al. (2014)	Cognitive	ADIS, DPSS-R, DS-R, OCI-R, NART, Moral Dilemmas Task	$n = 23$ OCD, $n = 21$ anxiety disorder, $n = 24$ non-clinical	High DS in OCD group was associated with increased rigid moral reasoning, while anxious group showed decreased moral reasoning.
Verwoerd et al. (2013)	Cognitive	Online Rating Task of disgust-based reasoning scenarios, PI	$N = 164$ students (high and low on C-OCD)	High C-OCD associated with disgust-based reasoning (inferred risk of becoming ill on the basis of experienced disgust) even in low-threat scenarios
Olatunji et al. (2004)	Cognitive	DSc, DES, PI	$N = 323$ students (high and low on C-OCD)	High C-OCD scored significantly higher than the low C-OCD on all disgust domains
Tolin et al. (2004)	Cognitive	Y-BOCS, SCID, BDI, LOC, Contamination Ratings, Pencil Contamination Task	$n = 12$ OCD, $n = 16$ non-anxious controls, $n = 13$ anxious	Sympathetic magic mediated the relationship between diagnostic group and the chain of contagion
Olatunji and Armstrong (2009)	Cognitive	Disgust inducing vignettes Public Restroom Distress Task, PI, DPSS-R, STAI, Mood Scale	$N = 83$ non-clinical (high and low on C-OCD)	High C-OCD showed more distress during restroom exposure. This relationship was mediated by disgust and task difficulty, as differences between groups were seen in low not high potential contagion stimuli.
Cisler et al. (2010)	Cognitive	DPSS-R, PI, PANAS, OBQ-44	Study 1: $N = 252$ non-clinical, Study 2: $N = 308$ non-clinical	OCD beliefs, particularly overestimations of threat, interact with DP to potentiate contamination fear.
Kang et al. (2012)	Facial recognition	Interpersonal Reactivity Index, Facial emotion perception task, SCID, TAS-20, Y-BOCS,	$n = 107$ OCD, $n = 130$ non-clinical	OCD impaired emotional awareness such as lower perspective taking and fantasy seeking had a perception bias towards disgust in response to ambiguous facial expressions

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Appendix A *(continued)*

Study	Evidence type	Assessment	Participants	Findings
Rector, Daros, Bradbury, and Richter (2012)	Facial recognition	Pictures of Facial Affect, SCID	$n = 20$ OCD, $n = 15$ panic disorder with agoraphobia, $n = 15$ social phobia	OCD patients only showed significant disgust recognition impairment. CBT normalized this deficit.
Jhung et al. (2010)	Facial recognition	Computerized Emotion Perception Task, Y-BOCS, SCID, MADRS	$n = 41$ OCD, $n = 37$ normal controls	OCD patients, particularly C-OCD subtype, more likely to perceive disgust in ambiguous facial expressions
Concoran, Woody, and Tolin (2008)	Facial recognition	ADIS-IV, SCID, Y-BOCS, BDI, DSc, Facial Expression Task	$n = 40$ OCD, $n = 36$ panic disorder, $n = 36$ non-clinical	OCD patients impaired in ability to recognise disgust expressions, with deficits related to OCD symptom severity and general functioning
Rozin et al. (2005)	Self-report, facial recognition	Emotion Recognition Test, OCI, DSc	$N = 166$ students	Correlation between OCD and DS but no association between OCD and disgust-related facial recognition deficit.
Parker, McNally, Nakayama, and Wilhelm (2004)	Facial recognition	Facial Expression of Emotion Task	$N = 15$ OCD	Failed to support disgust recognition deficits in OCD.
Fluitman et al. (2010)	Neurobiological	Disgust provocation paradigm, SCID, Y-BOCS	$n = 10$ OCD, $n = 10$ non-clinical	Noradrenalin levels increased during exposure to disgust related objects in OCD but not in healthy participants
Nakamae et al. (2008)	Neurofunctional	Diffusion Tensor Imaging	$n = 15$ OCD, $n = 15$ healthy participants	White matter abnormalities and water diffusivity in disgust-associated brain regions in OCD but not controls
Lawrence et al. (2007)	Neurofunctional	fMRI, Y-BOCS, OCI-R, BDI, DSc	$n = 17$ C-OCD, $n = 19$ non-clinical	C-OCD (especially in females) showed greater activation in the left ventrolateral prefrontal cortex, but reduced activation in the thalamus, to facial expressions of disgust but not fear
Stein et al. (2006)	Neurofunctional	PET, Disgust Inducing and Resting Task	$n = 11$ OCD, $n = 14$ non-clinical	Greater regional cerebral blood flow in the left insula across both tasks in OCD participants.
Shapira et al. (2003)	Neurofunctional	fMRI	$n = 8$ C-OCD, $n = 8$ non-clinical	Compare to healthy individuals, OCD participants had greater activation in right insula during disgust inducing stimulation.
Phillips et al. (2000)	Neurofunctional	fMRI	$n = 7$ C-OCD, $n = 7$ checking OCD, $n = 14$ non-clinical	For all subjects disgusting pictures activated visual regions implicated in perception of aversive stimuli and the insula. Only in C-OCD were similar regions activated by washer relevant pictures. In checkers these pictures activated frontostriatal regions. Non-clinicals were more similar to checkers.

Note. ACS-R = Attentional Control Scale—Revised, ADIS-IV = Anxiety Disorder Interview Schedule for DSM-IV, ASI = Anxiety Sensitivity Index, BAI = Beck Anxiety Inventory, BAT = Behavioural Approach Test, BDI = Beck Depression Inventory, BDI-II = Beck Depression Inventory II, BTRS = Behavioural Task Rating Scale, CAPS = Clinician Administered PTSD Scale, CCS = Contamination Cognitions Scale, CES-D = Center for Epidemiological Studies Depression Scale, CGI = Clinical Global Impression Scale, C-OCD = Contamination Obsessive–Compulsive Disorder, DES = Disgust Emotion Scale, DOCS = Dimensional Obsessive Compulsive Scale, DPQ = Disgust Propensity Questionnaire, DP = Disgust Propensity, DPSS-R = Disgust Propensity and Sensitivity Scale—Revised, DSc = Disgust Scale, DS = Disgust Sensitivity, DS-R = Disgust Scale—Revised, fMRI = Functional Magnetic Resonance Imaging, FSS = Fear Survey Schedule, IRAP = Implicit Relational Assessment Procedure, LOC = Looming of Contamination Scale, MADRS = Montgomery–Asberg Depression Rating Scale, MINI = Mini International Neuropsychiatric Interview, NART = National Adult Reading Test, OBQ-44 = Obsessive Beliefs Questionnaire-44, OCD = Obsessive–Compulsive Disorder, OCI = Obsessive–Compulsive Inventory, OCI-R = Obsessive–Compulsive Inventory—Revised, PANAS = Positive and Negative Affect Scales, PET = Positron Emission Tomography, PI = Padua Inventory, PIOS = Penn Inventory of Scrupulosity, PI-WSUR = Padua Inventory–Washington State University Revision, SCID = Structured Clinical Interview for DSM-IV, SCL-90R = Symptom Checklist 90—Revised, STAI = State-Trait Anxiety Inventory, TAS-20 = Toronto Alexithymia Scale, TMT-B = Trail Making Test B, VOCI = Vancouver Obsessional Compulsive Inventory, Y-BOCS = Yale-Brown Obsessive–Compulsive Scale, ZSRS = Zung Self-Rated Anxiety Scale.

Appendix B. List of relevant studies included in the review from search of "Disgust AND (Condition* OR Treat*)".

Study	Sample	Design	Measures	Intervention	Effectiveness in reducing emotions	Limitations
Olatunji, Wolitzky-Taylor, Willems, Lohr, and Armstrong (2009)	$N = 20$ C-OCD analogue	Treatment	Self-reported Behavioural	Exp	Disgust-ineffective Fear-effective	Small sample size Analogue sample Self-delivered exposure
Rachman et al. (2011)	$N = 80$ students	Treatment	Self-reports Behavioural	Exp	Disgust-effective	C-OCD patients reduced more slowly and to a lesser degree
McKay (2006)	$n = 10$ OCD, $n = 9$ C-OCD	Treatment	Self-reported	Exp	Disgust: C-OCD patients habituate more slowly & to a lesser degree	Use of self-reports only Other OCD subtypes may be associated with different disgust elicitors
Olatunji et al. (2011)	$n = 30$ OCD, $n = 30$ GAD, $n = 30$ non-clinical	Treatment	Self-reported	Exp	Disgust-effective	Results representative for general OCD not C-OCD Self-reports only
Olatunji, Cisler, and Tolin (2007), Olatunji, Forsyth, and Cherian (2007), Olatunji, Lohr, Sawchuk, and Tolin (2007), Olatunji, Williams, et al. (2007)	$N = 30$ students	Experimental	Electrodermal	Exp	Disgust-ineffective Fear-effective	Body mutilations pictures used as US
Mason and Richardson (2010)	$N = 61$ students	Experimental	Visual avoidance task	Exp	Disgust-ineffective Fear-effective	Specificity of effects in relation to disgust versus other emotions is unclear

(continued on next page)

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Appendix B *(continued)*

Study	Sample	Design	Measures	Intervention	Effectiveness in reducing emotions	Limitations
Olatunji, Lohr, Jasper, Sawchuck, and Patten (2009)	$n = 40$ BII analogue and $n = 40$ students	Experimental	Self-reported	Exp	Disgust-effective Fear-effective	Long-term effects not assessed
Lipp et al. (2003)	$N = 34$ students	Experimental	Self-reported Electrodermal	Exp	Disgust-effective	Quick renewal with exposure possible suggests effects are not long-term
Kerkhoff et al. (2011)	$N = 63$ students	Experimental	Self-reported Affective priming	CC, Exp	Food preferences--counterconditioning effective only.	Study assessed other evaluatively acquired responses and not disgust directly
Scweckendiek et al. (2013)	$N = 28$ non-clinical	Experimental	Neurofunctional recording (fMRI)	CC	Disgust-ineffective	Disgusting properties of US were not intensive enough
Engelhard et al. (2014)	Students Study 1 $N = 40$, Study 2 $N = 50$	Experimental	Self-reported Affective priming Behavioural	CC, Exp	Counterconditioning reduced fear and disgust, exposure reduced fear	Compared across two samples Lack of disgust specific ratings Only self-reports of fear
de Jong et al. (2000)	$N = 34$ spider phobia	Treatment	Behavioural Self-reports	Exp, Exp + CC	Both effective equally for reducing fear and disgust	The type of the exposure used included aspects that may have served as US revaluation
Merckelbach et al. (1993)	$n = 46$ spider phobic, $n = 28$ non-clinical	Treatment	Self-reported Behavioural	Exp	Disgust-effective Fear-effective	The type of the exposure used included aspects that may have served as US revaluation
Baeyens et al. (1992)	$N = 32$ students	Experimental	Self-reported Electrodermal	CC	Effective in changing attitudes	Disgust not assessed
Baeyens et al. (1998)	Students Study 1 $N = 38$, Study 2 $N = 48$	Experimental	Self-reported	USR	Effective in changing food preferences	Disgust not assessed CS–US pairings not randomised Potential memory bias
Walther et al. (2009)	Students Study 1 $N = 45$, Study 2 $N = 33$, Study 3 $N = 96$	Experimental	Self-reported Affective priming	USR	Effective in changing attitudes	Disgust not assessed

Note. BII = Blood Injury Injection Phobia, CC = Counterconditioning, C-OCD = Contamination OCD, Exp = Exposure, OCD = Obsessive–Compulsive Disorder, USR = US Revaluation.

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