Review

Cognitive mechanisms of disgust in the development and maintenance of psychopathology: A qualitative review and synthesis

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A B S T R A C T

A growing body of research has implicated disgust in various psychopathologies, especially anxiety-related disorders. Although the observed role of disgust in many disorders is robust, the mechanisms that may explain this role are unclear. Cutting-edge research in cognitive science has the potential to elucidate such mechanisms and consequently improve our understanding of how disgust contributes to the etiology and maintenance of psychopathology. In this qualitative review, we systematically assess cognitive bias mechanisms that have been linked to disgust and its disorders. This review suggests that disgust-related biases may be observed in memory, interpretation, judgment of expectancies, and attention, as well as at implicit levels. Of these cognitive domains, the most robust bias appears to be observed at the level of attention. However, reliable moderators of attentional biases for disgust have not yet been identified, and this bias has not been systematically linked to other levels of analysis. Despite these limitations, the available research indicates that attentional avoidance rather than orienting or maintenance may be the most characteristic of disgust. Attentional avoidance of disgust may have important implications for etiological and treatment models of disorders characterized by excessive disgust reactions. The implications for advancing such models are discussed in the context of a combined cognitive bias hypothesis.

1. Introduction

Disgust is a negatively-valenced emotion that serves a disease-avoidance function (Rozin & Fallon, 1987; Tybur, Lieberman, Kurzban, & DeScioli, 2013) by motivating avoidance of stimuli that may result in physical or psychological contamination (Rozin, Haidt, & Fincher, 2009)[1]. Although the experience of disgust is normative, for some individuals this experience can interfere in everyday life. Individuals with high disgust proneness, who experience disgust more frequently and perceive disgust as more harmful, are more likely to experience anxiety-related psychopathology; this relationship is robust and remains significant even when accounting for negative affect (Olatunji, Armstrong, & Elwood, 2017). While most commonly linked to anxiety-related disorders such as spider phobia, blood-injection-injury (BII) phobia, health anxiety, and obsessive-compulsive disorder (OCD), disgust proneness has also been associated with borderline personality disorder, schizophrenia (Schienle et al., 2003), eating disorders (Davey, Buckland, Tantow, & Dallos, 1998; Troop, Treasure, & Serpell, 2002), and sexual dysfunction (Jong, Overveld, & Borg, 2013).

A disease-avoidance motivation may explain the link between disgust proneness and some disorder symptoms. For example, the excessive experience of disgust may motivate contamination fear, which underlies many cases of OCD (Moretz & McKay, 2008; Rachman, 2004). Similarly, disgust is evident in spider and other small-animal phobias, possibly because small animals such as spiders, rats, and insects can spread pathogens or are otherwise associated with contagion (Matchett & Davey, 1991; Mulkens, de Jong, & Merckelbach, 1996). Blood is also a disease vector that may explain the robust relationship between measures of BII phobia and disgust proneness (Sawchuk, Lohr, Tolin, Lee, & Kleinknecht, 2000). Disgust proneness may also be observed in health anxiety due to concerns with contracting a serious disease (Davey & Bond, 2006). Although a disease-avoidance process may explain the role of disgust in some anxiety-related disorders, disgust has been observed in other disorders that are not primarily characterized by disease-avoidance concerns (i.e., height phobia, posttraumatic stress disorder). This suggests that a disease-avoidance model may not fully account for the role of disgust in psychopathology.

Although findings from extant research implicate disgust in

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[1] Note that previous research has identified an impact of moral disgust on cognitive processes (e.g., Olatunji, Puncochar, & Cox, 2016). However, given limited research examining the role of moral disgust in the cognitive biases reviewed here, moral disgust is not given further treatment.

psychopathology, it remains largely unclear *how* disgust contributes to the development of psychopathology. In this review, we examine and evaluate evidence that biased cognitive processing may partially explain the link between disgust and the development and maintenance of psychopathology. The present review highlights the current status of research on various cognitive biases (attentional bias, memory bias, interpretation bias, and judgment or expectancy bias) in relation to disgust-relevant stimuli and trait disgust proneness. We review evidence that these biases can exist at both the explicit and implicit levels and examine the role of potential moderators of these biases. Finally, we turn toward a discussion of how knowledge of these biases can inform treatment of psychopathology and suggest future directions for research.

2. Cognitive mechanisms of disgust in psychopathology

Cognitive biases describe errors and/or variability in cognitive function that result in maladaptive behavior and/or subsequent cognition (Beck, 2008). Such biases can affect multiple cognitive processes, including memory of events, interpretations of ambiguous stimuli, judgments of likelihood of potential outcomes, and allocation of attention. These biased processes may contribute to the development of psychopathology via excessive processing of and attention to disgust-relevant information (Mathews & MacLeod, 2005; Muris & Field, 2008). For example, functional systems have evolved that allow humans to associate cues in the environment with the presence of pathogens (Tybur et al., 2013). However, some individuals develop heightened sensitivity to pathogen-related cues, which may lead to an attentional bias toward disgust-relevant information. While improved detection of disgust may help an individual avoid pathogen contamination, it may also increase the number of false alarms, leading to increased avoidance behavior. Additionally, individuals who have a biased memory for disgusting events may discount their relative infrequency and spend increased cognitive resources worrying about the possibility of contamination. Furthermore, Teachman (2006) has suggested that interpretations of disgusting stimuli as personally meaningful or threatening and beliefs about one's inability to cope with disgusting experiences are what lead to avoidance and pathological experiences of disgust, which may in turn affect the development of psychopathology. These cognitive biases as well as common paradigms used to measure them are described below.

Memory bias refers to the preferential recall of memories that are consistent with a given emotional state (Muris & Field, 2008). Experiments measuring memory bias are comprised of two stages. In the encoding stage, participants are exposed to stimuli for subsequent retrieval, such as faces, words, or scenes. In the retrieval stage, memory for these stimuli is tested, either through explicit instruction to recall the encoded material or through implicit memory tasks, such as a word stem completion test (Mitte, 2008a). Remembering more negative or threatening stimuli (i.e., threat words, angry faces, sad scenes) than other stimuli suggests a memory bias. In the context of psychopathology, memory bias typically involves selective memory for negative or threatening information (Coles & Heimberg, 2002; Gilboa-Schechtman, Erhard-Weiss, & Jeczemien, 2002; Mitte, 2008a; Watkins, Martin, & Stern, 2000). Memory bias for disgust-relevant cues may maintain psychopathology by increasing the saliency of disgust information and related experiences.

Interpretation bias refers to the tendency to generate negative interpretations of ambiguous events or stimuli (Beard, Rifkin, & Björgvinsson, 2017), and this bias is observed in many disorders (Hirsch, Meeten, Krahé, & Reeder, 2016; Mathews & MacLeod, 2005; Mathews, Richards, & Eysenck, 1989; Nunn, Mathews, & Trower, 1997). For example, an interpretation bias may manifest as catastrophic misinterpretation of bodily sensations (i.e., heart attack) in panic disorder (Richards, Austin, & Alvarenga, 2001). A common method for sampling interpretation bias involves presenting participants with an ambiguous stimulus (e.g., photo, vignette, incomplete sentence) and having participants choose an interpretation in a forced-choice format with options such as neutral, positive, and threat/negative/etc. Another commonly used method involves presenting participants with auditory recordings of homophones with neutral or threatening interpretations (e.g., die/dye) and having participants spell the word they hear. Interpretation bias may reflect increased endorsement of disgust-relevant interpretations of ambiguous stimuli or homophones. This bias may then maintain disorders via overestimation of the likelihood or consequences of contact with disgusting stimuli.

Expectancy bias is a form of biased judgment found in anxious individuals, in which the likelihood of the occurrence of a negative outcome is exaggerated (Davey, 1995; Foa, Franklin, Perry, & Herbert, 1996; MacLeod & Byrne, 1996). Indeed, negatively biased expectations of disgust-relevant outcomes (i.e., disease) may be a key component in the development of anxiety by motivating avoidance behavior (Reiss, 1991). Expectancy bias can be assessed by asking participants to rate the likelihood that a given outcome will occur after viewing a given stimulus (*a priori*), or by asking participants to report how often two types of stimuli co-occurred during the course of the experiment (*a posteriori*; Davey & Dixon, 1996). In anxious samples, two kinds of expectancy bias have been found: expecting positive outcomes to occur less frequently and expecting negative outcomes to occur more frequently (Cabeleira et al., 2014; Chan & Lovibond, 1996). Expectancy bias is sometimes referred to as covariation bias, as anxious individuals demonstrate a tendency to form illusory correlations between randomly presented stimuli (Tomarken, Mineka, & Cook, 1989).

Attentional biases refer to a variety of ways in which individuals preferentially attend to threat-related information over non-threat information. Manifestations of attentional bias include threat-distractor interference, preferential orienting toward threat, maintenance of attention on threatening stimuli, and avoidance of threat (Cisler & Koster, 2010; Mogg & Bradley, 2016). These biases can be further divided by whether they involve dysfunction in bottom-up cognitive functions (such as automatic evaluation of threat and initial orienting to threat) or top-down cognitive control (such as controlled attention, task-switching, goal-directed inhibitory control, and motivated avoidance; Mogg & Bradley, 2016). Several experimental paradigms have been developed to assess different aspects of attentional bias. Common performance-based methods for sampling threat-distractor interference include the emotional Stroop task (Williams, Mathews, & MacLeod, 1996) and emotional attentional blink task (Most, Chun, Widders, & Zald, 2005). The dot-probe task (MacLeod, Mathews, & Tata, 1986) is typically used to assess initial orienting to threat, while the emotional spatial-cueing task (Fox, Russo, Bowles, & Dutton, 2001) can provide information on orienting as well as maintained attention toward threat. The visual search task (Öhman, Flykt, & Esteves, 2001) has been used to examine orienting to threat and threat-distractor interference. Importantly, seemingly small modifications in each of these tasks, such as the length of stimuli presentation, can affect whether a task is measuring automatic, bottom-up processes or strategic, top-down processes (Mogg & Bradley, 2016).

Research using various attentional paradigms in anxious samples suggests that a vigilant-avoidant attentional pattern is commonly observed, in which anxious individuals quickly orient toward a threatening stimulus and then avoid it (Mogg & Bradley, 1998; Rinck & Becker, 2006). However, the relationship between attention and psychopathology is highly complex (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Rinck & Becker, 2006), and the pattern of attentional bias observed may vary by the nature of the disorder (i.e., Beevers, Lee, Wells, Ellis, & Telch, 2011; Chen, Ehlers, Clark, & Mansell, 2002; Mogg, Philippot, & Bradley, 2004; Olatunji, Armstrong, McHugo, & Zald, 2013). Accordingly, disgust-based disorders may be characterized by a unique pattern of attentional bias that consists of a different imbalance in bottom-up and top-down processing compared to fear-based disorders. It has also been suggested

that attentional biases may vary as a function of individual differences (Taylor, Cross, & Amir, 2016). Disgust proneness may be one individual difference that moderates patterns of attentional biases for disgust-relevant cues in the environment to influence anxiety-related symptoms.

2.1. Cognitive biases and disgust: what have we learned?

Considering research linking disgust to psychopathology (Olatunji et al., 2017; Olatunji, Cisler, McKay, & Phillips, 2010), as well as research highlighting the impact of emotion on cognitive processes (Kissler & Keil, 2008; Most et al., 2005), cognitive biases may be one set of mechanisms by which disgust contributes to psychopathology. For example, biased memory for disgust-relevant stimuli, disgusting interpretations of ambiguous stimuli, and increased expectations of aversive outcomes in the presence of disgust-relevant stimuli likely reinforce psychopathological processes such as experiential avoidance (Hayes, Wilson, Gifford, Follette, & Strosahl, 1996) and negative beliefs (Clark, 1999) by contributing to an overestimation of threat (Cisler et al., 2011). Similarly, increased vigilance for disgust-relevant information or prolonged maintenance of attention toward disgust-eliciting stimuli may also lead to failure to detect relevant non-threatening information, which may lead to less accurate estimations of the likelihood and severity of the potential threat. However, no review to date has examined biased cognitive processing of disgust-related cues or the role of disgust proneness in these cognitive biases. To critically evaluate and synthesize this literature, we conducted a systematic review of extant findings on disgust and cognitive biases in order to highlight the cognitive biases in disgust processing that are relevant to the development and maintenance of psychopathology across a broad range of paradigms and populations. Additionally, a comprehensive evaluation of this literature was employed in order to identify important future research directions.

2.2. Selection of studies for review and synthesis

A systematic literature search was conducted in PsycINFO and PubMed using the terms "memory," "interpretation," "expectancy," "attention," and "implicit" in combination with the term "disgust." Additional searches of disgust with the terms "judgment bias," "judgmental bias," and "covariation bias" were also completed, due to their close association with the term expectancy bias. The initial search yielded 1,382 articles. After duplicate records (*n* = 617) were removed, the abstracts of 765 were screened for inclusion. Abstracts that did not discuss bias or a similar cognitive process were excluded. Figure 1 shows that of these articles, 191 were read in full, and 99 were included in the final sample. Articles were selected for inclusion based on the following criteria: (1) published in English, (2) peer-reviewed, and (3) empirically tested a relationship between disgust and biases in memory, interpretation, judgments of expectancy, or attention. The findings of these studies were then reviewed with regards to the extent to which biases in domains of memory, interpretation, judgments, and attention, at both the explicit and implicit levels, are observed.

3. Disgust and memory bias

Disgust-related memory bias can take at least two forms. First, there can be increased memory for disgusting stimuli. Second, the experience of disgust can enhance subsequent memory performance. Research from cognitive science has found evidence for both effects, though the majority of findings implicate enhanced memory for disgust-related stimuli. For example, in a sample of unselected adults, recognition of disgust words is increased compared to negative and neutral words (Duesenberg et al., 2016). For individuals with contamination fear or those with high trait anxiety, disgust words are more likely than threat or neutral words to be recalled in an implicit memory task (Charash & McKay, 2009). Likewise, previous findings with unselected adults indicate increased memory for disgust faces compared to neutral and
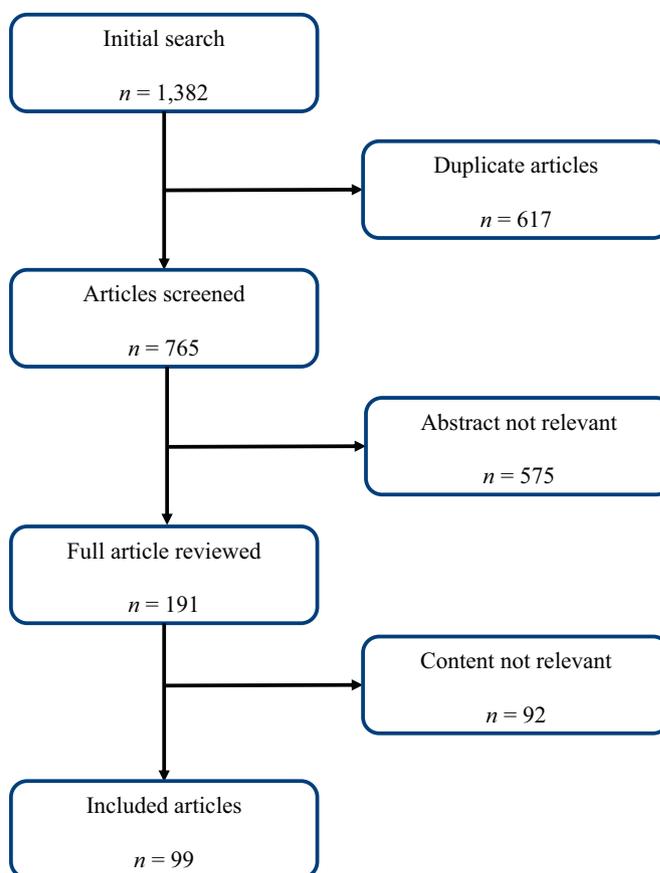

Fig. 1. Flow diagram illustrating the search process.

positive faces (Román et al., 2015) and enhanced memory for disgusting images compared to fear-inducing images (Chapman, Johannes, Poppenk, Moscovitch, & Anderson, 2013; Croucher, Calder, Ramponi, Barnard, & Murphy, 2011) and neutral images (Chapman et al., 2013). Notably, one study found that though disgusting images were most likely to be recognized by unselected adults, they also resulted in the highest rates of false alarms (Marchewka et al., 2016), suggesting a sensitivity-specificity trade-off for memory for disgust-related stimuli. Table 1 summarizes available research that has examined disgust-related memory biases. Taken together, these findings suggest a memory bias for disgust-related stimuli, such that memory for these stimuli is enhanced relative to neutral stimuli. Importantly, results showing such an effect over and above the impact of negative and threat stimuli suggest that enhanced memory for disgust-related stimuli is not simply an epiphenomenon of elevated arousal.

Individual differences in disgust may also enhance the memory bias for disgust-related stimuli. For example, research has shown that those high in contamination concerns recall more disgust words than those low in contamination concerns (Charash & McKay, 2009), and disgust proneness predicts increased disgust words recalled following disgust priming (Charash & McKay, 2002). Further, those with BII phobia, a disorder characterized by elevated levels of disgust (Page, 1994), recall more disgust words in an implicit memory task than healthy control participants (Sawchuk, Lohr, Lee, & Tolin, 1999). In contrast, another study found no differences in recognition of disgusting images between BII phobia, spider phobia, and healthy control participants (Sawchuk, Meunier, Lohr, & Westendorf, 2002). These discrepant findings suggest that features of the stimuli may moderate the extent to which biases in memory are observed. Research has also shown that recognition of images rated as disgusting is greater for higher intensity images after 6 months for unselected adults (Marchewka et al., 2016), suggesting a relationship between prospective memory and initial emotional

Table 1
Characteristics of studies assessing disgust-related memory bias.

Bias	Authors	Sample	Disgust measure	Cognitive measure
Memory bias: increased memory for disgust	Charash & McKay, 2002	Unselected adults primed with disgust ($n = 20$), fear ($n = 20$), or neutral ($n = 20$) stories	DS	Recall of disgust, fear, and neutral words used in Stroop task
	Charash & McKay, 2009	High contamination fear ($n = 20$), high trait anxiety ($n = 20$), and healthy control participants ($n = 20$)	DS	Completion of disgust, threat, and neutral stems of words used in Stroop task
	Chapman et al., 2013	Unselected adults ($N = 51$)	Self-reported disgust response to emotional images	Recall of disgust, fear, and neutral images previously displayed during a line discrimination task
	Croucher et al., 2011	Unselected adults ($N = 32$)	Self-reported disgust response to emotional images	Recognition of previously encoded disgust, fear, and positive images
	Duesenberg et al., 2016	Unselected adults ($N = 75$)	None	Recognition of previously encoded disgust, negative, positive, and neutral words
	Marchewka, Wypych, Michałowski, et al., 2016	Unselected women ($N = 18$)	None	Directed forgetting task with disgust, fear, sad, and neutral images
	Marchewka, Wypych, Moslehi, et al., 2016	Unselected adults ($N = 17$)	None	Directed forgetting task with positive, negative, and neutral images
	Román et al., 2015	Unselected adults ($N = 76$)	None	N-back task with disgust, positive, and neutral faces
	Sawchuk et al., 1999	BII participants who underwent a disgust ($n = 28$) or neutral ($n = 25$) mood induction and healthy control participants who underwent disgust ($n = 25$) or neutral ($n = 29$) mood induction	MDES	Completion of disgust, medical, negative, and neutral stems of words used in Stroop task
Memory bias: enhancement	Bomyea & Amir, 2012	Unselected adults ($N = 30$)	DS-R	Thought monitoring task following exposure to trauma-related film
	Clayton et al., 2017	Nicotine-deprived adults ($N = 50$)	3 disgust items about response to anti-tobacco advertisement	Recognition of audio clips from previously viewed anti-tobacco advertisement
	Leshner et al., 2011	Unselected adults ($N = 49$)	None	Recognition of audio clips from previously viewed anti-tobacco advertisement
	Teachman & Smith-Janik, 2009	Adults with high ($n = 158$) or low ($n = 108$) spider fear	DS	Free recall of previously displayed spider, panic, and neutral words
Memory bias: decreased memory for disgust	Gasbarri et al., 2008	Women in menstrual ($n = 14$), follicular ($n = 21$), or luteal phase ($n = 21$)	None	Delayed matching-to-sample task
	Medina et al., 2016	Unselected adults who viewed disgusting image ($n = 41$) or neutral image ($n = 40$)	None	One story from logical memory subtest of the *Wechsler Memory Scale-III*
Memory bias: no effect	Sawchuk et al., 2002	BII ($n = 37$), spider phobic ($n = 39$), and healthy control participants ($n = 40$)	None	Recognition of disgust, surgical, spider, and neutral images

Note. BII = Blood-injection-injury; DS = Disgust Scale; DS-R = Disgust Scale-Revised; MDES = Modified Differential Emotion Scale

Table 2
Characteristics of studies assessing disgust-related interpretation bias.

Bias	Authors	Sample	Disgust measure	Cognitive measure
Interpretation bias (disgust interpretation)	Charash & McKay, 2009	High contamination fear (n = 20), high trait anxiety (n = 20), and healthy control participants (n = 20)	DS; disgust interpretations	Ambiguous scenarios with disgust, threat, and neutral interpretation choices (i.e., "A powerful smell occurs to you. What is it?" Disgust interpretation = Vomit
Interpretation bias (disgust-induced negative interpretation)	Davey et al., 2006	Unselected adults who underwent a disgust (n = 25), anxiety (n = 25), happy (n = 25), or neutral (n = 25) mood induction (e.g., disgust induction = audio of disgusting noises [e.g., burping, vomiting] while reading a disgusting vignette [e.g., "You go into a public toilet and find it has not been flushed. The bowl of the toilet is full of diarrhoea."])	DPSS	Homophone spelling task (e.g., threat vs neutral, "die/dye")
	Davey et al., 2008	Unselected adults who underwent a disgust induction (n = 30) or neutral induction (n = 30) (e.g., disgust induction = audio of disgusting noises [e.g., burping, vomiting] while reading a disgusting vignette [e.g., "You go into a public toilet and find it has not been flushed. The bowl of the toilet is full of diarrhoea."])	DPSS	Self-reported anxiety to ambiguous scenario images (e.g., a person holding a snake [fear and disgust relevant], a person in an enclosed pothole [fear relevant, disgust irrelevant], a person riding a bike [fear and disgust irrelevant] following mood induction)
	Krusemark & Li, 2013	Unselected adults (N = 39)	None	Rating of distance from Greeble following viewing disgust (e.g., roaches), fear (e.g., guns), or neutral (e.g., animals) image
	Leathers-Smith & Davey, 2011	Unselected adults who underwent a disgust (n = 20), anxiety (n = 20), or neutral (n = 20) mood induction (e.g., disgust induction = audio of disgusting noises [e.g., burping, vomiting] while reading a disgusting vignette [e.g., "You are walking barefoot along the beach. You tread in a dog poo, it is warm and squishes between your toes."])	DPSS-R	Homophone spelling task (e.g., threat vs neutral, "grown/groan")
	Mayer et al., 2009	Unselected adults who underwent a disgust (n = 30), anxiety (n = 30), happy (n = 30), or neutral (n = 30) mood induction (e.g., disgust induction = audio of disgusting noises [e.g., burping, vomiting] while reading a disgusting vignette [e.g., "You go into a public toilet and find it has not been flushed. The bowl of the toilet is full of diarrhoea."])	DS	Open-ended ambiguous scenarios (e.g., threat-related scenario = "You are waiting for a good friend to come. Normally she is very punctual, but now she is already more than a quarter of an hour late. Her cell phone is switched off."; threat related interpretation = She has had an accident")
Interpretation bias (disgust interpretation)	Muris et al., 2012	Children given disgust information (n = 47; e.g., "The Cuscus eats brown grunge") or neutral information (n = 47) about a novel animal	DEC	Open-ended ambiguous scenarios (e.g., "You discover the nest of a Cuscus in the woods"
	Whitton et al., 2013	Unselected adults who participated in cognitive bias modification to train disgust (n = 30; e.g., unfinished sentence = "Squelching mud between my toes reminds me of __"; disgust solution = "St_pping in do_poo") or neutral (n = 30) interpretive biases	DPSS-R; EMG; BAT	Ratings similarity of disgust and neutral sentences to ambiguous sentences (e.g., ambiguous = "When I go to a restaurant where I can watch the chef prepare my meal, I always think the same thing."; disgust = "When I go to a restaurant where I can watch the chef prepare my meal, I always think about how dirty the chef's hands might be.")

Note. BAT = Behavioral approach task; EMG = Electromyography; DEC = Disgust Emotion Scale for Children; DS = Disgust Scale; DS-R = Disgust Scale- Revised; DPSS = Disgust Propensity and Sensitivity Scale; DPSS-R = Disgust Propensity and Sensitivity Scale-Revised

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experience. Interestingly, one study found decreased recognition of disgust faces for women in the follicular phase of the menstrual cycle (Gasbarri et al., 2008), suggesting that variation in hormone levels may attenuate the memory enhancement effect for disgust stimuli.

Though less consistent, research also suggests that elevated levels of disgust enhance memory. For example, anti-tobacco advertisements are better remembered by both unselected and nicotine-deprived adults when the message includes disgusting content (Clayton, Leshner, Tomko, Trull, & Piasecki, 2017; Leshner, Bolls, & Wise, 2011). Further, disgust propensity predicts increased memory intrusions in unselected adults after viewing a disgusting video (Bomyea & Amir, 2012). Importantly, these findings are strengthened by independence of the outcome measurement and the elicitation of disgust. Finally, one study found that exposure to a large spider increased disgust levels, and memory for spider words was increased for both individuals with and without spider fear if the spider was present during encoding (Teachman & Smith-Janik, 2009). However, the relationship between state and trait levels of disgust and memory performance was not significant when state anxiety was controlled, suggesting that more general negative affect may better account for this effect. In contrast, one study of unselected adults found decreased memory for details of a disgusting stimulus compared to a neutral stimulus (Medina, Clark, & Thorne, 2016), suggesting that the memory enhancement effect of disgust may promote more general stimulus memory that does not extend to specific elements of the stimulus. In contrast to the evidence for the specificity of enhanced memory for disgust-related stimuli, it remains unclear whether there is a unique enhancement effect of elevated disgust on memory.

The findings of multiple studies that indicate enhanced memory for disgust-related stimuli are consistent with evolutionary function of disgust in facilitating disease avoidance. That is, it is adaptive to remember disgust-related stimuli in order to avoid future contact and potential contamination (Chapman et al., 2013). Notably, this effect is facilitated by individual differences in disgust, including disgust sensitivity and contamination concerns. These relationships highlight one pathway by which an adaptive process may become maladaptive. Specifically, excessive memory for disgust-related stimuli among those high in trait disgust may contribute to the development of some disorders. However, it is important to note that currently available studies examining memory biases for disgust have largely utilized relatively short-term memory paradigms, and few studies have examined the long-term effect of disgust on memory. Furthermore, currently available studies have largely relied on static disgust stimuli (i.e., photos, words), which limits the ability to generalize these findings to real-world situations.

3.1. Disgust and interpretation bias

Available studies suggest that the experience of disgust may cause negative interpretations of ambiguous cues. For example, inducing disgust in unselected adults results in increased threat interpretations of homophones (Davey, Bickerstaffe, & MacDonald, 2006; Leathers-Smith & Davey, 2011) and more negative interpretations of ambiguous scenarios (Mayer, Muris, Busser, & Bergamin, 2009). Similarly, inducing disgust leads to increased anxiety to emotional images (Davey, MacDonald, & Brierley, 2008). Further, one recent study of unselected adults found that a disgust induction resulted in high estimation of imminence of an anthropomorphic figure, suggesting a disgust-induced overestimation of threat (Krusemark & Li, 2013). This interpretation bias is also evident in children. When given disgust-related information about a novel animal, children provide more negative interpretations of ambiguous situations with the animal than children given neutral information about the novel animal (Muris, Huijding, Mayer, & de Vries, 2012). Research also suggests that individual differences in disgust may moderate biases in interpretation. Compared to those with high trait anxiety and control participants, those with high contamination

concerns are more likely to choose a disgust-related interpretation of an ambiguous scenario. Further, disgust proneness was associated with increased disgust-related interpretations in the total sample (Charash & McKay, 2009). Interestingly, one recent study found that a cognitive bias modification paradigm that trained unselected participants to interpret ambiguous statements in a disgusting manner increased self-reported disgust propensity, negative affect, and obsessive-compulsive symptoms but did not affect subsequent interpretations of novel stimuli (Whitton, Grisham, Henry, & Palada, 2013). Disgust-related interpretation bias appears to be resistant to modification, but no study to date has employed a cognitive-bias modification paradigm to attempt to *reduce* disgust-related interpretation bias.

Table 2 summarizes available research suggesting that increased disgust, either through experimental induction or elevated disgust-related traits, leads to more negative interpretations of ambiguous stimuli. Although extant research has implicated disgust in interpretation bias, evidence for the specificity of this effect has been mixed. Importantly, some studies that have revealed a disgust-related interpretation bias did not include a negative emotion comparison group, which precludes specific inferences (Davey et al., 2008; Muris et al., 2012). One study did find some evidence for a disgust-specific interpretation bias (Charash & McKay, 2009). However, other studies indicate a similar pattern of interpretation bias for disgust and anxiety inductions (Davey et al., 2006; Leathers-Smith & Davey, 2011; Mayer et al., 2009). This suggests that while experiencing disgust results in a biased interpretation of ambiguous stimuli, this bias may not be distinct from that which is observed for other negative emotions/traits.

3.2. Disgust and expectancy bias

The literature on expectancy bias suggests that people generally have a bias to expect negative outcomes to follow exposure to disgust stimuli. A study of unselected adults found that a painful outcome (i.e., shock) was anticipated after viewing predatory animals, while disgust-related outcomes (i.e., juice that makes you vomit) were associated with viewing phobic but non-predatory animals (spider, maggot, cockroach, and slug); disgust proneness was not associated with an increased expectancy bias for disgust-related outcomes (Davey, Cavanagh, & Lamb, 2003). A similar study found that disgust sensitivity significantly predicted an expectancy bias for contracting a disease after performing an imagined disgust-relevant behavior, such as cleaning other people's hair from a drain (Mitte, 2008b). In contrast to these two studies, Thorpe and colleagues collected information regarding unselected adults' estimates of the likelihood of catching a disease and the severity of any potential illness after submerging their hands in dirt for five minutes. While estimates of the likelihood of catching a disease were not significantly related to disgust proneness or the length of time spent washing their hands after the task, individuals with higher disgust proneness expected that their potential illness would be more severe, and they spent more time washing their hands after dirt exposure (Thorpe, Barnett, Friend, & Nottingham, 2011).

In analogue samples, however, there is mixed evidence for a greater expectancy bias for disgust-related fears, such as contamination, BII, and spider fears. Table 3 summarizes the available research examining expectancy bias for disgust. Individuals with high contamination fear did not demonstrate a greater bias for disgust outcomes paired with disgust stimuli than individuals with low contamination fear, although they did show a marginally greater expectancy for disgust outcomes to follow fear stimuli (Olatunji, Lohr, Willems, & Sawchuk, 2006). Similarly, individuals with high contamination fear overestimated the contamination/fear stimulus/outcome pairing and underestimated the contamination/neutral stimulus/outcome pairing compared to individuals with low contamination fear (Connolly, Lohr, Olatunji, Hahn, & Williams, 2009). Individuals with BII phobia did not show a greater expectancy bias for disgust or harm outcomes after viewing fear-relevant stimuli compared to a control group in one study (de Jong &

Table 3
Characteristics of studies assessing disgust-related expectancy bias.

Bias	Authors	Sample	Disgust measure	Cognitive measure
Expectancy bias: *a priori*	Armstrong & Olatunji, 2017	High (n = 32) and low (n = 30) contamination-fearful adults	DS-R; Self-reported disgust response	Expectancy ratings of disgust image (US) following neutral faces (CS) after different stages of an associative learning task (habituation, acquisition, and extinction)
Expectancy bias: *a posteriori*	Connolly, Lohr, Olatunji, et al., 2009	High (n = 32) and low (n = 30) contamination-fearful adults	DS	Percentage estimates of given stimulus-outcome pairings (fear, disgust, and neutral images with fear, disgust, or neutral facial expressions)
Expectancy bias: *a priori*	Davey et al., 2003	Unselected adults (N = 91)	DS	Expectancy ratings of hypothetical pain and disgust-related outcomes for predatory, disgusting, and safe animals
Expectancy bias: *a priori* and *a posteriori*	de Jong & Peters, 2007b	High (n = 25) and low (n = 24) spider-fearful women	None	Expectancies of harm and disgust-related outcomes after viewing safe, disgusting, and harm-related animals and spiders
Expectancy bias: *a priori*	Mason & Richardson, 2010	Unselected adults assigned to extinction (n = 27) or no extinction (n = 28)	DS-R	Expectancy ratings of disgust image (US) following neutral faces (CS) during acquisition and after extinction; eye tracking during passive viewing of CS and US
Expectancy bias: *a priori* and *a posteriori*	Mayer, Muris, & Wilschut, 2011	Unselected women (N = 61)	DS	Expectancy ratings of hypothetical pain and disgust-related outcomes for images of obese bodies, slim bodies, and neutral scenes; percentage estimates of given stimulus-outcome pairings (obese bodies, slim bodies, and neutral scenes with fear, disgust, or neutral facial expressions)
	Mayer, Muris, Kramer Freher, Stout, & Polak, 2012	Unselected adolescents (N = 148)	None	Expectancy ratings of hypothetical pain, disgust, and positive outcomes after viewing words describing controlled or uncontrolled eating behavior; percentage estimates of given stimulus-outcome pairings (words describing controlled or uncontrolled eating behavior with fear, disgust, happy, or neutral facial expressions)
Expectancy bias: *a priori*	Mitte, 2008b	Unselected adults (N = 86)	DPSS-R	Rating likelihood of catching a disease after performing a hypothetical disgust-related behavior
	Olatunji et al., 2006	High (n = 30) and low (n = 30) contamination-fearful adults	DES	Expectancy ratings for hypothetical pairings of fear, disgust, and neutral images with fear, disgust, or neutral facial expressions
	Olatunji et al., 2008	High (n = 22) and low (n = 28) spider-fearful adults	None	Expectancy ratings for hypothetical pairings of spiders, disgust images, and neutral images with fear, disgust, or neutral facial expressions
	Olatunji, Etzel, & Ciesielski, 2010	Adult blood donors (N = 446)	None	Rating expected disgust during blood donation
	Sharvit, Vuilleumier, Delplanque, & Corradi-Dell'Acqua, 2015	Unselected adults (N = 18)	Self-reported disgust rating; skin conductance; HR; respiration	Subjective ratings of disgust and pain after "low," "medium," or "high" disgust or pain cue
	Thorpe et al., 2011	Unselected adults (N = 30)	DS; Self-reported disgust rating	Expectancies of likelihood of becoming ill and severity of illness after contamination BAT
	van Overveld et al., 2006	High (n = 27) and low (n = 28) spider-fearful women	None	Expectancies of hypothetical harm and disgust-related outcomes after viewing safe, disgusting, and harm-related animals and spiders
	van Overveld, de Jong, & Peters, 2010a	High (n = 30) and low (n = 30) blood-fearful individuals	DS; DPSS-R	Expectancies of hypothetical harm and disgust-related outcomes after viewing blood, fear, disgust, combined fear and disgust, and neutral images
	van Overveld, de Jong, Huijding, & Peters, 2010	High spider-fearful (n = 60) and non-fearful (n = 30) individuals	None	Expectancies of hypothetical harm and disgust-related outcomes after viewing safe, disgusting, and harm-related animals and spiders, before and after exposure treatment
Expectancy bias (*a posteriori*) for affect-congruent stimuli	Connolly, Lohr, Williams, et al., 2009	High (n = 32) and low (n = 30) BII-fearful adults	DS-R	Percentage estimates of given stimulus-outcome pairings (fear, disgust, and neutral images with fear, disgust, or neutral facial expressions)
Expectancy bias (*a priori*) for negative only	Engelhard, Leer, Lange, & Olatunji, 2014 (Study 1)	Unselected adults assigned to extinction (n = 20) or no extinction (n = 20)	None	Expectancy ratings of disgust image (US) following neutral faces (CS) during acquisition and after extinction
No expectancy bias	de Jong & Peters, 2007a	High (n = 25) and low (n = 27) BII-fearful women	DES	Expectancies of harm and disgust-related outcomes after viewing fear-irrelevant and fear-relevant (blood donation) images

Note. CS = conditioned stimulus; DES = Disgust Emotion Scale; DPSS-R = Disgust Propensity and Sensitivity Scale-Revised; DS = Disgust Scale; DS-R = Disgust Scale- Revised; HR = heart rate; US = unconditioned stimulus

Peters, 2007a), but did show a greater bias toward aversive outcomes and blood images in another study (van Overveld, de Jong, & Peters, 2010a). A third study found only a general expectancy bias for affect-congruent stimuli in high versus low BII-fearful individuals (Connolly et al., 2009). However, Olatunji, Cisler, Meunier, Connolly, and Lohr (2008) found that spider-fearful individuals demonstrated increased expectancy for pairings of spider pictures with disgust expressions compared to non-fearful individuals, and this expectancy bias was associated with behavioral avoidance. In another study, spider-fearful individuals displayed a contamination-relevant expectancy bias associated with spiders, while control participants displayed a harm-relevant expectancy bias, but these biases were not present after the image viewing was complete (de Jong & Peters, 2007b). One study found that expectancy bias toward disgust-relevant consequences was the best predictor of spider fear (van Overveld, de Jong, & Peters, 2006). Additionally, disgust-related expectancy bias was reduced among those with spider phobia following a single session of exposure treatment (van Overveld, de Jong, Huijding, & Peters, 2010). Thus, an expectancy bias for disgust outcomes and spiders appears to contribute to spider phobia, though this bias appears to be sensitive to exposure-based treatment. However, this bias is not robust in BII phobia. Individuals with contamination fear appear to have a more general expectancy bias, where more aversive (but not disgust-specific) outcomes were expected after contamination stimuli.

3.3. Implicit biases in disgust

Cognitive biases in disgust processing have also been examined at the implicit level (for a comprehensive listing, see Table 4). For example, an implicit memory bias has been demonstrated for disgust words over threat or neutral words for individuals with high contamination fear and high trait anxiety (Charash & McKay, 2009). Individuals with BII phobia remembered more implicitly-presented disgust words than healthy control participants (Sawchuk et al., 1999). Another study found an implicit attentional bias for disgust in unselected college students; using a version of the emotional Stroop task that masked stimuli after brief presentation, the authors found that individuals high in disgust proneness responded more quickly to disgust words (Charash, McKay, & Dipaolo, 2006). Disgust proneness can also be assessed at an implicit level, using either an Implicit Association Test (IAT) or Implicit Relational Assessment Procedure (IRAP). In unselected adults, implicit disgust proneness had a unique effect on automatic avoidance behavior towards a worm (Zinkernagel, Hofmann, Dislich, Gschwendner, & Schmitt, 2011) and predicted obsessional beliefs and concerns (Nicholson & Barnes-Holmes, 2012; Nicholson, McCourt, & Barnes-Holmes, 2013).

Other studies demonstrate implicit associations between disgust and broad constructs like negative personality traits (Niedenthal, 1990, Study 2) and asymmetry (Evans et al., 2012), and even self-concept in women with a history of sexual trauma (Rüsch et al., 2011). Implicit associations between sex and disgust may be specifically relevant for understanding sexual dysfunction. Women implicitly associate sex with disgust more than men (Grauvogl et al., 2015). Women also tend to implicitly associate pornography with disgust (Borg, de Jong, & Georgiadis, 2014), and women with sexual dysfunction associate sex with disgust more than healthy women (Borg, de Jong, & Schultz, 2010). For individuals with spider or snake fear, disgust is implicitly associated with their feared animal (Teachman, Gregg, & Woody, 2001). Additionally, individuals who implicitly associate disgust with personal responsibility have higher obsessive-compulsive symptoms than those who do not (Nicholson, Dempsey, & Barnes-Holmes, 2014).

Findings suggesting that implicit disgust associations can be modified are mixed. Although one study found that implicit associations between spiders and disgust were reduced over the course of exposure therapy for individuals with spider phobia (Teachman & Woody, 2003), these findings did not replicate in a second treatment study (Huijding &

de Jong, 2007). Furthermore, an implicit bias modification was unable to reduce implicit associations between disgust and contamination in contamination-fearful adults (Green & Teachman, 2013). While implicit associations between disgust and feared stimuli in those with psychopathology appear to be as strong as explicit associations, more research is needed to determine if these associations are malleable over the course of treatment.

4. Disgust and attentional bias

4.1. Interference effects: the emotional Stroop and attentional blink tasks

The first studies of attentional bias for disgust used the emotional Stroop task to examine the interference of disgust-related words (i.e., vomit, phlegm, feces) in the processing of other information (i.e., word color). In some studies, priming effects were also examined; participants were asked to read a brief story that elicited either disgust (a cockroach crawls into your mouth), fear (two intruders break into your apartment), or a neutral emotion (running errands after work) before completing the emotional Stroop task (Charash et al., 2006; Charash & McKay, 2002). Slow performance on the emotional Stroop task is hypothesized to reflect a priority for threat-relevant information in cognitive processing (an attention bias). Priming participants with threat-relevant information may also increase attentional awareness for threats. In one study, unselected participants demonstrated an attentional bias for disgust, such that the latency of response time for disgust words and fear words was significantly greater than for neutral words, regardless of what kind of story was used for priming; disgust proneness was correlated with response latency for disgust words only for those primed with a disgust story (Charash & McKay, 2002). The emotional Stroop has been used to explore attentional bias for disgust in clinical and analogue clinical samples, but an attentional bias for disgust was not found in individuals with elevated contamination fear (Charash & McKay, 2009) or BII phobia (Sawchuk et al., 1999), or using an adapted pictorial Stroop task in children with anxiety disorders (Benoit, McNally, Rapee, Gamble, & Wiseman, 2007). These findings are not surprising, given that interference effects are strongly related to individuals' present mood state (cf., Mathews & MacLeod, 2005); other measures may demonstrate a more robust effect of attentional bias for disgust on psychopathology.

The attentional blink task has also been employed to probe for disgust-related attentional biases. In the emotional attentional blink task, participants are asked to respond to a neutral target stimulus that occurs at various lags subsequent to an emotional distractor in a rapid serial visual presentation (RSVP; Most et al., 2005)[2]. The task is predicated on the attentional blink, a phenomenon by which a stimulus captures attention, and subsequent stimuli are not perceived for a limited period of time (Chun & Potter, 1995). While the attentional blink phenomenon is an interference effect, the specific time lags used in the RSVP task may help discriminate between automatic and strategic attentional processes. For example, decreased target detection when the distractor is placed earlier in the visual presentation (i.e., 200 ms) suggests an initial orienting bias, while decreased target detection when the distractor is placed later in the visual presentation (i.e., 800 ms) may reflect impaired goal-directed inhibitory control.

In one study comparing unselected adults' responses to fear and disgust faces, results indicated that the attentional blink was greater for fear faces than for disgust faces (Vermeulen, Godefroid, & Mermillod, 2009). However, these findings might not generalize to stimuli that evoke emotion without relying on facial expressions, which may be

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[2] The RSVP tasks used in disgust and other emotion research typically ask participants to identify a single neutral target after presentation of a task-irrelevant emotion word or picture distractor. The traditional RSVP task asks participants to identify two neutral targets that occur in close sequence (Chun & Potter, 1995).

Table 4
Characteristics of studies assessing disgust-related implicit biases.

Bias	Authors	Sample	Disgust measure	Cognitive measure
Amygdala activation during implicit attention to disgust	Anderson, Christoff, Panitz, de Rosa, & Gabrieli, 2003	Unselected adults (N = 12)	None	fMRI while viewing disgust, fear, and neutral faces superimposed on scene images
Implicit association between disgust and sex for women with vaginismus and dyspareunia	Borg et al., 2010	Women with vaginismus (n = 24), dyspareunia (n = 24), and healthy control women (n = 31)	Subjective disgust ratings; facial EMG	IAT
Implicit association between disgust and pornography	Borg et al., 2014	Healthy women (N = 20)	Subjective disgust ratings of pornographic stimuli	IAT
Implicit memory bias	Charash & McKay, 2009	High contamination fear (n = 20), high trait anxiety (n = 20), and healthy control participants (n = 20)	DS	Completion of disgust, threat, and neutral stems of words used in implicit Stroop task
Implicit bias: Interference effect	Charash et al., 2006	Unselected adults primed with disgust (n = 20), fear (n = 20), or neutral (n = 20) stories	DS	Implicit Stroop task with disgust, threat, and neutral words
Implicit association between disgust and asymmetry	Evans et al., 2012	Unselected adults (Study 1 N = 82; Study 2 N = 26)	None	IAT
Implicit association between sex and disgust greater for women than men	Grauvogl et al., 2015 (Study 2)	Healthy, sexually active women (n = 24) and men (n = 19)	DPSS-R; DS-R	IAT
No effect of implicit bias modification on implicit associations between disgust and contamination	Green & Teachman, 2013	High contamination fear adults (N = 81)	DS-R	IAT
No effect of treatment on implicit associations between disgust and spiders	Huijding & de Jong, 2007	Adults seeking treatment for spider phobia (n = 60) and non-phobic (n = 30) adults	AMDS	IAT
Implicitly measured disgust sensitivity predicted avoidance and washing concerns; disgust propensity predicted obsessing	Nicholson & Barnes-Holmes, 2012	Unselected adults (N = 33)	DS-R	IRAP
Implicit negative-disgust association predicted obsessional beliefs	Nicholson et al., 2013	Unselected adults (N = 44)	None	IRAP
Implicit association between responsibility and disgust predicted high OC symptoms	Nicholson et al., 2014	Unselected adults (N = 29)	DS-R	IRAP
Implicit association between disgust and negative traits	Niedenthal, 1990 (Study 2)	Unselected adults (N = 72)	None	Masked presentation of joy, disgust, or neutral faces with a cartoon
Explicit (but not implicit) spider fear associated with high disgust proneness	Ouimet, Bahl, & Radomsky, 2017	Unselected adults (N = 134)	DPSS-R	GNAT
No implicit association between fat (self) and disgust	Ritzert et al., 2016	Unselected adults (N = 75)	DPSS-R	IRAP
Women with BPD and/or PTSD implicitly associated self-concept with disgust	Rüsch et al., 2011	Women with BPD, (n = 20), PTSD (n = 20), both BPD and PTSD (n = 15), and healthy women (n = 37)	QADS	IAT
Implicit memory bias	Sawchuk et al., 1999	BI participants who underwent a disgust (n = 28) or neutral (n = 25) mood induction and healthy control participants who underwent disgust (n = 25) or neutral (n = 29) mood induction	MDES	Completion of disgust, medical, negative, and neutral stems of words used in Stroop task
Implicit extraversion positively related to cerebellar response to masked disgust faces	Suslow, Kugel, Lindner, Dannlowski, & Egloff, 2017	Healthy adults (N = 40)	None	IAT; implicitly presented emotional faces
Implicit associations between disgust and feared animal	Teachman et al., 2001	Snake-fearful (n = 30) spider-fearful (n = 37) adults	None	IAT
Implicit associations between spiders and disgust reduced over the course of exposure therapy	Teachman & Woody, 2003	Spider-phobic (n = 31) and healthy control participants (n = 30)	None	IAT
Implicit disgust proneness had a unique effect on automatic, but not strategic, avoidance behavior	Zinkernagel et al., 2011	Unselected adults (N = 75)	DS (German version)	IAT

Note. AMDS = Armfield and Mattiske (Spider) Disgust Scale; DES = Disgust Emotion Scale; DPSS-R = Disgust Propensity and Sensitivity Scale-Revised; DS = Disgust Scale; DS-R = Disgust Scale-Revised; GNAT = Go/No-go Association Task; IAT = Implicit Association Test; IRAP = Implicit Relational Assessment Procedure; MDES = Modified Differential Emotions Scale; OC = obsessive-compulsive; QADS = Questionnaire for the Assessment of Disgust Sensitivity

processed differently due to the importance of social cuing. Results from a study of unselected adults comparing fear, disgust, erotic, and neutral images found that emotional images, regardless of specific content, led to an attentional blink at 200 ms, 400 ms, and 600 ms, but enhanced target processing at a lag of 800 ms (Ciesielski, Armstrong, Zald, & Olatunji, 2010). Here, emotional images appear to have captured but not held attention for a significant period of time, and disgust was not observed to have a unique effect on attention.

Specific temporal aspects of the attentional blink may explain the difference between the processing of fear and disgust. In an RSVP task with unselected adults, task-irrelevant disgust stimuli influenced attention 240 ms after the onset of disgust stimuli, but at 120 ms after the onset of fear stimuli (Cisler, Olatunji, Lohr, & Williams, 2009). Similarly, for targets presented 200 ms after disgust, fear, or neutral images, disgust stimuli led to slower reaction times and lower accuracy than both fear and neutral images among unselected adults (van Hooff, Devue, Vieweg, & Theeuwes, 2013). Additionally, an attentional blink was found for targets presented at 100 ms after disgust stimuli, but not for fear or happiness stimuli (van Hooff, van Buuringen, El M'rabet, de Gier, & van Zalingen, 2014), suggesting a specific early effect of disgust on attention compared to other emotional stimuli. It appears that the overall attentional blink for disgust may be greater (i.e., maintained longer) than for fear, but it is unclear why differences have been found at very short (100-120 ms) intervals.

Disgust proneness may also be related to the attentional blink for disgust, but findings are inconsistent. One study found that individuals with higher disgust proneness evinced impaired detection of probes after disgust targets compared to fear targets, while individuals with lower disgust proneness did not demonstrate a similar bias for disgust stimuli (Cisler et al., 2009). However, this relationship was not found in a similar sample (van Hooff et al., 2014). One potential explanation for this difference is that the Cisler et al. sample included both male and female university students, while van Hooff and colleagues' sample was restricted to females. Indeed, there are important gender differences in the experience of disgust (Oaten, Stevenson, & Case, 2009) and frequency of attending to disgust cues (Kraines, Kelberer, & Wells, 2016). Differences in stimulus cues may also account for discrepant findings, as Cisler and colleagues used emotion-relevant words, whereas van Hooff and colleagues used emotional images. These differences may reflect an important distinction between linguistic and visual processing of disgust that may yield different attentional effects.

Studies examining the attentional blink have consistently shown that disgust information captures attention when stimuli are presented one at a time in rapid succession. However, it is important to note that a specific attentional blink for disgust has not been found in clinical populations. In a study examining veterans with PTSD, healthy veterans, and a healthy non-veteran control group, a large attentional blink for disgust images was apparent for all groups, regardless of veteran or clinical status (Olatunji et al., 2013). Additionally, individuals with GAD did not differ from healthy control participants with regard to an attentional blink for disgust (Olatunji, Ciesielski, Armstrong, Zhao, & Zald, 2011). These results are not surprising, however, as disgust has not traditionally been implicated in the development and maintenance of PTSD and GAD (but see Badour & Feldner, in press, for a recent review of the role of disgust in PTSD). Olatunji, Ciesielski, and Zald (2011) examined patients with OCD and a control group during an emotional attentional blink paradigm in which participants searched for a target embedded within a series of rapidly presented images. Critically, an erotic, fear, disgust, or neutral distracter image appeared 200 ms or 800 ms before the target. Impaired target detection was observed among OCD patients relative to control participants following only erotic distracters, but only when presented 800 ms, and not 200 ms, prior to the target. These findings indicate maintained attention toward arousing cues in OCD, but not for disgust-related stimuli specifically. Although specific interference effects of disgust stimuli have not been found in clinical or clinical analogue populations, effects may

be found in future research if the disgust stimuli are more directly relevant to the disorder of interest (i.e., images of bodies in a war zone for participants with PTSD, or images of needles for individuals with BII phobia). Larger interference effects may also be found for images of disgusting objects that more specifically signal contagion.

4.2. Biases in initial orienting

The dot-probe task has also been employed to examine attentional biases for disgust. In the task, one threat-related cue and one neutral cue appear simultaneously at different locations, and one of the cues is subsequently replaced with the target. Participants are asked to respond to the target as quickly and accurately as possible (MacLeod et al., 1986). Assessment of both orienting and maintenance bias is possible with a dot-probe task. Decreased reaction time on congruent versus incongruent trials suggests an orienting bias, while increased reaction time on incongruent versus congruent trials suggests a maintenance bias (Fox et al., 2001). One study found that unselected individuals attended more rapidly to disgusting cues than neutral cues, regardless of whether they underwent a disgust-induction procedure. In addition, individuals in the disgust-induction condition demonstrated an orienting bias for images representing cleanliness (Vogt, Lozo, Koster, & de Houwer, 2011). Similarly, unselected individuals who were asked to suppress their emotions after a disgust induction attended more rapidly to disgust images compared to neutral images, but they attended more rapidly to cleanliness images compared to disgust images (Vogt & de Houwer, 2014). These findings suggest a robust orienting bias for disgust that may then motivate a unique pattern of regulatory strategies. Versions of the dot probe task have also revealed important attentional differences for disgust and fear. For example, a discrimination task is similar to a dot-probe task in that reaction times are used as a measure of the ability of a stimulus to capture attention. In the task, an image (disgusting, fear-inducing, or neutral) is displayed with a white line positioned either below or above the image; participants press a key to indicate if the line is above or below the image. Latencies for disgusting images were found to be slower than for fear images among an unselected sample, indicating enhanced attentional capture for disgust compared to fear (Chapman et al., 2013).

Dot-probe studies have also found an orienting bias for disgust in some disorders. For example, individuals with OCD demonstrated an orienting bias for disgust-relevant words compared to individuals with high trait anxiety (Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996). Individuals with anxious attachment attended to open-mouthed disgust faces, which are associated with core disgust (Rozin, Lowery, & Ebert, 1994), but avoided close-mouthed or other emotional faces, which the authors suggest reflects social-moral disgust and social rejection (Westphal, Bonanno, & Mancini, 2014). In a treatment study, socially anxious individuals who underwent an attention modification protocol demonstrated reduced orienting bias toward disgust faces in a dot-probe task compared to individuals in a control condition, and individuals in the treatment group also had reduced anxiety in response to a social stressor (Amir, Weber, Beard, Bomyea, & Taylor, 2008). However, the use of disgust facial expressions as the threat cue likely indicates increased sensitivity to social threat rather than concerns of contagion or disease. Another study examined the effect of oxytocin, a neuromodulatory hormone hypothesized to affect social emotional processing, on a disgust orienting bias in individuals with anorexia nervosa. No initial differences in attentional bias toward disgust were found between individuals with anorexia and a healthy control group, although both groups oriented more rapidly toward disgust faces than other emotional faces. Individuals who received an intranasal dose of oxytocin had a reduced orienting bias toward disgust faces, with a larger effect found in healthy control participants than in those with anorexia (Kim, Kim, Park, Pyo, & Treasure, 2014). One interpretation of these findings is that disgust-related attentional biases may be malleable processes that can be targeted during treatment.

Although improved reaction time measures have been developed to better differentiate components of attention, many researchers have turned to eye-tracking technology as an alternative to manual reaction time measures. Eye movements are more closely linked to attention than key press behavior, which occurs downstream of intervening response selection and skeletal muscle movement (Weierich, Treat, & Hollingworth, 2008). Eye-tracking tasks measure spontaneous viewing patterns; indeed, eye movements are a direct indicator of overt attention, and eye-tracking devices are one method that enables researchers to parse the orientation and maintenance of attention, as the locations of initial fixations indicate orientation (i.e. where one looks first), while the duration of these fixations indicate the maintenance of attention (i.e. how long one looks). When spontaneous viewing favors disgust cues when other cues are available, this may be a risk factor for psychopathology, especially for individuals high in disgust proneness. Research employing eye-tracking methods has revealed an orienting bias for disgust similar to that commonly observed for fear cues. For example, three-year-old children oriented to disgust and fear images after hearing a disgust or fear vocalization, but not a sad vocalization. Additionally, children whose parents had higher disgust proneness looked longer at fear and disgust images when hearing disgust and fear sounds (Stevenson, Oaten, Case, & Repacholi, 2014). Although these results suggest an orienting bias toward threatening information in young children that is not specific to disgusting cues, parental disgust proneness does appear to be associated with that general threat bias.

Eye-tracking studies examining the orienting bias toward disgust faces in clinical and analogue samples have also revealed an orienting bias to threat that is not specific to disgust (Çek, Sánchez, & Timpano, 2016). For example, individuals with high trait anxiety were found to orient more quickly to disgust and fear faces than individuals with low trait anxiety (Holas, Krejtz, Cypryanska, & Nezlek, 2014). Individuals high in contamination fear have also been found to orient more quickly to fear faces compared to individuals low in contamination fear, but there were no differences between the groups in orienting biases for disgust faces (Armstrong, Olatunji, Sarawgi, & Simmons, 2010). However, one study using threat images rather than facial expressions found that individuals high in contamination fear oriented toward disgust-relevant images more often than individuals low in contamination fear, and this orienting bias mediated group differences in behavioral avoidance (Armstrong, Sarawgi, & Olatunji, 2012). Individuals high in contamination fear also showed a fragmented viewing style by making more but shorter fixations on disgust-relevant images compared to those low in contamination fear. This particular style may represent a vigilant-avoidant pattern of attention (Mogg & Bradley, 1998).

Examination of psychophysiological correlates may provide important insights into mechanisms associated with an attentional bias for disgust. This has often been done using electroencephalography (EEG), which records electrical activity in the brain using electrodes placed at multiple locations on the scalp. EEG has high temporal resolution and thus can monitor rapid changes in neural electrical activity, referred to as event-related potentials (ERPs). Several ERPs are considered important in the study of the early allocation of attention, including the P1, P2, N1, and N2 components, which occur between 50 and 350 ms after stimulus onset. For example, P2 amplitudes are higher in response to emotional stimuli, reflecting automatic, bottom-up attention allocation to these stimuli (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004). In two ERP studies of healthy adults, larger P2 amplitudes were found for disgusting compared to fear-inducing and neutral images (Lu et al., 2016; Xu et al., 2015), whereas both fear-inducing and disgusting stimuli produce greater N2 amplitudes than neutral stimuli (Lu et al., 2016). Another study found that P2 amplitudes were greater during disgusting image distractors than during fear-inducing and neutral image distractors, and participants responded more slowly and made more errors in a digit task when disgusting images were displayed (Carretié, Ruiz-Padial, López-Martín, & Albert, 2011). Attentional biases for disgust and fear have also been compared using ERP

under conditions of attention and inattention with unselected adults. During the superimposed face/place task, when attention was directed away from faces, fear faces produced greater P1 amplitudes than disgust faces. Additionally, when attention was directed toward faces, fear faces elicited greater N1 amplitudes than neutral faces, while the same pattern was not present for disgust (Santos, Iglesias, Olivares, & Young, 2008). The authors suggest that fear may attract automatic attention, while attention to disgust is more voluntary, as it is less relevant for avoiding danger. This suggests that fear may involve a greater reliance on bottom-up attentional processes, while disgust biases may involve more top-down cognitive control.

Early selective attention to disgust, as evidenced by ERP, has not been consistently found in anxious individuals. In a study comparing individuals with high and low trait anxiety during a visual search task, fear-inducing images produced greater P2 amplitudes than neutral images, and disgusting images elicited reduced amplitudes compared to neutral images. The same pattern was found for P1, but trait anxiety moderated this result, such that individuals with higher trait anxiety had a greater differential between the amplitudes during fear and disgust trials (Krusemark & Li, 2011). Because individuals in this study were selected based on their relative high or low trait anxiety, it is possible that this finding may be driven by a particularly large potential amplitude for fear images, rather than a diminished amplitude for disgust images. However, another study of socially anxious individuals found a significantly increased N2 amplitude in response to disgust faces compared to neutral faces, but no such effect for control participants (Judah, Grant, & Carlisle, 2016).

Another component of the ERP response is the late positive potential (LPP), which typically occurs after 300 to 400 ms from stimulus onset. The LPP is an index of motivated attention toward emotional stimuli (Olofsson, Nordin, Sequeira, & Polich, 2008). While it does not represent an orienting bias per se, it is a marker of attention that has been found in response to disgust in healthy samples as well as in individuals with psychopathology. In healthy adult women, attending to disgust faces produced a greater LPP amplitude relative to neutral faces, and no difference was found between fearful and neutral faces during this period (Santos et al., 2008). A similar larger LPP amplitude was found for healthy adults viewing disgusting and fear-inducing images compared to neutral images, with no differences between the former two (Lu et al., 2016). For both adults and children with spider phobia, fear-inducing and disgusting images produced greater LPP amplitudes than neutral images, but this response pattern did not differ from that of control participants (Leutgeb, Schäfer, Köchel, Scharmüller, & Schienle, 2010; Scharmüller, Leutgeb, Schäfer, Köchel, & Schienle, 2011). Finally, a study of healthy female children found that those administered a placebo that was said to reduce disgust symptoms reported experiencing less disgust when viewing disgusting pictures but had greater LPP amplitudes in response to both fear-inducing and disgusting pictures than those who did not receive the placebo (Übel, Leutgeb, & Schienle, 2015). This finding suggests that some cues may modulate the physiology of attention to disgust cues in meaningful ways. Overall, while some studies demonstrate a specific orienting bias toward disgust stimuli, the majority of research shows a more general initial orienting response to threat in both anxious and disgust-prone individuals.

4.3. Maintenance bias

A maintenance bias toward disgusting cues may play a role in anxiety symptoms. For instance, individuals high in social anxiety maintained their attention on disgust faces for significantly longer than those with low social anxiety (Buckner, Maner, & Schmidt, 2010). However, this result may demonstrate a more general propensity to maintain attention on negative social cues rather than disgust specifically, as the only social cues used in this study were happy and disgust faces. Another study of socially anxious participants used a dot-probe task along with a concurrent *n*-back task in order to assess attention with and

Table 5
Characteristics of studies assessing disgust-related attentional bias.

Bias	Authors	Sample	Disgust measure	Cognitive measure
Attentional bias: interference effect	Charash & McKay, 2002	Unselected adults primed with disgust (n = 20), fear (n = 20), or neutral (n = 20) stories	DS	Stroop task with disgust, threat, and neutral words
	Charash et al., 2006	Unselected adults primed with disgust (n = 20), fear (n = 20), or neutral (n = 20) stories	DS	Stroop task with disgust, threat, and neutral words
	Cisler et al., 2009	Unselected adults (N = 99)	DS	RSVP with disgust, fear, or neutral word targets
	Olatunji, Ciesielski, Armstrong, et al., 2011	GAD (n = 30) and healthy control adults (n = 30)	None	ACS; RSVP with disgusting, fear-inducing, erotic, or neutral image distractors
	Olatunji et al., 2013	Veterans with PTSD (n = 20), veterans without PTSD (n = 16), and healthy control non-veterans (n = 22)	None	RSVP with disgusting, combat-related, pleasant, or neutral image distractors
	van Hooff et al., 2013	Unselected adults (N = 30)	DS-R	RSVP with disgusting, fear-inducing, and neutral images
Attentional bias: general emotion interference effect	Ciesielski et al., 2010	Unselected adults (N = 50)	None	RSVP with disgusting, fear-inducing, erotic, or neutral image distractors
Attentional bias: no interference effect	Benoit et al., 2007	Children with an anxiety disorder (n = 52) and healthy control children (n = 46)	Self-reported disgust in response to emotional faces	Stroop task with disgust, anger, happy, and neutral faces
	Charash & McKay, 2009	High contamination fear (n = 20), high trait anxiety (n = 20), and healthy control participants (n = 20)	DS	Stroop task with disgust, social threat, and neutral words
	Sawchuk et al., 1999	BII participants who underwent a disgust (n = 28) or neutral (n = 25) mood induction and healthy control participants who underwent disgust (n = 25) or neutral (n = 29) mood induction	MDES	Stroop task with disgust, medical, negative, and neutral words
	van Hooff et al., 2014	Unselected adults (N = 46)	DS-R	RSVP with disgusting, fear-inducing, happy, and neutral images
	Vermeulen et al., 2009	Unselected adults (N = 18)	None	RSVP with disgust, fear, sad, and happy face primes before each trial
Attentional bias: orienting (not maintenance) (disgust-specific)	Armstrong et al., 2012	Adults with high (n = 19) and low contamination fear (n = 20)	DS-R; BAT	Eye tracking during free viewing of array of contamination, threat, pleasant, and neutral images
Attentional bias: orienting (disgust-specific)	Carretié et al., 2011	Unselected adults (N = 26)	Self-reported disgust response to emotional images	EEG; EOG; Digit categorization task with disgusting, fear-inducing, and neutral image distractors
	Chapman et al., 2013	Unselected adults (Study 1 N = 51; Study 2 N = 23)	Self-reported disgust response to emotional images	Line discrimination task with disgusting, fear-inducing, or neutral images
	Lu et al., 2016	Unselected adults (N = 22)	Self-reported disgust response to emotional images	EEG; EOG; Oddball task with disgusting, fear-inducing, and neutral images
	Santos et al., 2008	Unselected adults monitoring disgust/neutral faces (n = 8) or fear/neutral faces (n = 8)	None	EEG; EOG; Identification of previously seen faces (disgust, fear, or neutral) and houses
	Tata et al., 1996	Adults with contamination OCD (n = 13), high trait anxiety (n = 18), and low trait anxiety (n = 26)	None	Dot-probe task with contamination and social threat words
	Xu et al., 2015	Unselected adults (N = 18)	None	EEG; EOG; Go/no go task superimposed on disgusting, fear-inducing, and neutral images
Attentional bias: Orienting (cleanliness > disgust)	Vogt et al., 2011	Unselected adults who underwent a disgust (n = 20) or neutral mood induction (n = 19)	DS-R	Dot-probe with disgusting, clean, or neutral image cues
	Vogt & de Houwer, 2014	Unselected adults instructed to suppress (n = 19) or maintain (n = 19) disgust response following disgust induction	Self-reported disgust response to disgust induction	Dot-probe with disgusting, clean, or neutral image cues
Attentional bias: Orienting (threat)	Çek et al., 2016	Unselected adults (N = 55)	None	Eye tracking during free viewing of pairs of emotional (disgust, angry, or happy) and neutral faces
	Holas et al., 2014	Adults with high (n = 22) or low trait anxiety (n = 26)	None	Eye tracking during free viewing of pairs of emotional (disgust, fear, angry, sad, or happy) and neutral faces
Attentional bias: Orienting (threat/rejection)	Judah et al., 2016	Social anxiety disorder (n = 20) and healthy control adults (n = 22)	None	EEG; Change detection task with disgust and neutral faces

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Table 5 (*continued*)

Bias	Authors	Sample	Disgust measure	Cognitive measure
Attentional bias: Orienting (threat)	Leutgeb et al., 2010	Spider phobia adolescent females ($n = 14$) and healthy control participants ($n = 14$)	QADS; Self-reported disgust response to emotional images	EEG; EOG; Free-viewing task with disgusting, spider, fear-inducing, or neutral images
	Scharmüller et al., 2011	Spider phobia females ($n = 25$) and healthy control females ($n = 20$)	QADS; Self-reported disgust response to emotional images	EEG; EOG; Free-viewing task with disgusting, spider, fear-inducing, or neutral images
	Stevenson et al., 2014	Unselected children ($n = 20$) and adults ($n = 23$)	DS	Eye tracking during free viewing of pairs of emotional (disgusting, fear-inducing, or happy) and neutral images
	Übel et al., 2015	Disgust-prone adolescent girls ($n = 28$)	QADP-C	EEG during passive viewing of disgusting and neutral images
Attentional bias: Reduced orienting to disgust	Krusemark & Li, 2011	Unselected adults ($N = 43$)	Self-reported disgust response to emotional images	EEG; Visual search task with disgusting, fear-inducing, or neutral images displayed before each trial
Orienting bias reduced after ABM	Amir et al., 2008	High social anxiety adults who underwent attention modification program ($n = 47$) or control training ($n = 47$)	None	Dot-probe with social threat or neutral word cues
Orienting bias reduced with oxytocin	Kim et al., 2014	Anorexia nervosa ($n = 31$) and healthy control adults ($n = 33$)	None	Dot-probe with disgust, angry, happy, or neutral faces
Attentional bias: orienting to open-mouth disgust faces; avoidance of closed-mouth disgust faces	Westphal et al., 2014	Unselected adults ($N = 92$)	None	Dot-probe with disgust, angry, happy, or sad faces
Attentional bias: maintenance (not orienting) (disgust-specific)	Armstrong et al., 2010	Adults with high ($n = 23$) or low contamination fear ($n = 25$)	DS-R; BAT	Eye tracking during free viewing of pairs of emotional (disgust, fear, or happy) and neutral faces
Attentional bias: maintenance (disgust-specific)	Cisler et al., 2011	Unselected adults ($N = 108$)	DPSS-R: disgust propensity subscale; Chain of contagion task	Spatial cueing task with disgusting, fear-inducing, or neutral images
Attentional bias: aintenance (threat/rejection)	Buckner et al., 2010	Unselected adults ($N = 46$)	Self-reported disgust to emotional faces	Eye tracking during free viewing of disgust and happy faces
Attentional bias: maintenance (threat)	Cisler & Olatunji, 2010	High contamination fear ($n = 23$) and healthy control adults ($n = 28$)	Self-reported disgust to emotional images	Spatial cueing task with disgusting, fear-inducing, or neutral images
Attentional bias: avoidance (disgust-specific)	Armstrong et al., 2014	Unselected adults conditioned with disgust US ($n = 55$) or negative US ($n = 65$)	DS-R	Eye tracking during Pavlovian conditioning paradigm
	Bradley et al., 2015	Unselected adults ($N = 42$)	16 items from DS; Skin conductance	Eye tracking during free viewing of contamination, mutilation, threat, food, nude male, or nude female images paired with neutral images
	Mason & Richardson, 2010	Unselected adults ($N = 61$)	DS-R	Eye tracking during Pavlovian conditioning paradigm with disgust US
	Zimmer, Höfler, Koschutnig, & Ischebeck, 2016	Unselected adults ($N = 32$)	None	fMRI and eye tracking during a spatial cueing task with disgust and fear auditory cues
Attentional bias: avoidance (threat)	Grisham et al., 2015	High social anxiety adults ($n = 29$) and low social anxiety adults ($n = 28$)	None	Avoidance view-time task with disgust, anger, happy, and neutral faces
	Sarlo & Munafò, 2010	Snake phobia ($n = 15$) and healthy control adults ($n = 15$)	None	EEG during target detection task with disgust, angry, fear, and neutral faces
	Staugaard & Rosenberg, 2011	Social anxiety disorder ($n = 8$) and healthy control adults ($n = 34$)	None	Eye tracking during free viewing of disgust, angry, happy, sad, or neutral faces
	White et al., 2015	Adolescents with autism ($n = 15$) and healthy control adolescents ($n = 18$)	None	Eye tracking during free viewing task with disgust, fear, angry, happy, sad, and surprise faces
Attentional bias: avoidance; orienting under cognitive load (threat/rejection)	Judah et al., 2013	Social anxiety disorder ($n = 19$) and healthy control adults ($n = 22$)	None	Dot-probe task with disgust, disgust, happy, and neutral faces

Note. ABM = Attention Bias Modification; ACS = Attentional Control Scale; BAT = Behavioral approach task; DPSS-R = Disgust Propensity and Sensitivity Scale-Revised; DS = Disgust Scale; DS-R = Disgust Scale-Revised; EEG = electroencephalography; EOG = electrooculography; fMRI = Functional magnetic resonance imaging; GAD = Generalized anxiety disorder; PTSD = Posttraumatic stress disorder; QADP-C = Questionnaire for the assessment of disgust propensity in children; QADS = Questionnaire for the Assessment of Disgust Sensitivity; RSVP = Rapid serial visual presentation; US = unconditioned stimulus

without a working memory load. Socially anxious participants avoided disgust faces when sufficient cognitive resources were available, but had difficulty disengaging their attention from disgust faces during a working memory load, suggesting that they lacked the cognitive resources to shift their attention away from social threat (Judah, Grant, Lechner, & Mills, 2013).

Using a spatial cueing task, individuals high in contamination fear demonstrated maintained attention for fear and disgust stimuli compared to individuals low in contamination fear (Cisler & Olatunji, 2010). Notably, this pattern was found over viewing intervals of 100 and 500 ms but was not examined over longer intervals. A similar study extended these findings by demonstrating the role of maintained attention toward disgust in contamination fear and found that maintained attention on disgust cues predicted performance on a chain of contagion task, in that unselected participants who exhibited a maintenance bias for disgust cues rated pencils with a more distal relationship to an original contaminated pencil as more contaminated than individuals who did not demonstrate this bias (Cisler et al., 2011). Similarly, eye-tracking results demonstrated that individuals high in contamination fear maintained greater attention on both disgust and fear faces compared to individuals low in contamination fear over longer (3 s) trials (Armstrong et al., 2010). When the stimuli were disgust-relevant, general threat, pleasant, and neutral images, however, there was no difference in gaze maintenance between high and low contamination fear individuals over a 30 s interval (Armstrong et al., 2012). Evidence for the absence or presence of a maintenance bias in contamination fear seems at least partially dependent on the time course that is examined. While one study has demonstrated an association between disgust proneness and a maintenance bias for contamination stimuli at a short interval (500 ms or less; Cisler et al., 2011), longer intervals do not appear to demonstrate a consistent, specific maintenance bias toward disgust stimuli. Together, the available research suggests that maintenance of attention on disgust is driven primarily by goal-directed, strategic processes directed toward threat.

4.4. Attentional avoidance

Attentional avoidance may maintain anxiety disorders by preventing elaborative processing of disgusting stimuli, which in turn prevents reappraisal and maintains learned associations with harm/contamination. Multiple studies have examined the extent to which attentional avoidance is characteristic of disgust. For example, among unselected adults, choice viewing behavior in a selective looking paradigm was initially heightened for all affective content but was subsequently followed by significant avoidance of scenes depicting contamination or nude males (Bradley, Costa, & Lang, 2015). Other studies have found a significant relationship using eye tracking in which individuals with high disgust proneness demonstrated greater attentional avoidance of disgust stimuli (Armstrong, McClenahan, Kittle, & Olatunji, 2014; Mason & Richardson, 2010). Similar results were found in a disgust conditioning study, which demonstrated that disgust reactions were resistant to extinction as measured by attentional avoidance, and individuals with higher disgust proneness exhibited higher resistance to extinction (Mason & Richardson, 2010). These findings suggest that attentional avoidance may be a coping strategy used by disgust-prone individuals to down-regulate their experience of disgust (Armstrong et al., 2014).

Other studies have examined anxious populations and found relationships between attentional avoidance and disgust proneness. For example, socially anxious participants were found to spend less time viewing anger and disgust faces than non-socially anxious participants, potentially because anger and disgust faces are viewed as socially threatening (Grisham, King, Makkar, & Felmingham, 2015). Another eye-tracking study found that socially anxious individuals had shorter fixations on sad and disgust faces compared to non-anxious control participants, specifically avoiding the eyes (Staugaard & Rosenberg,

2011). Similarly, in a study comparing youth with and without autism spectrum disorder (ASD), both participants with and without ASD had shorter average fixation durations for disgust and anger faces than for happy faces, which was significantly correlated with fear of negative evaluation (White, Maddox, & Panneton, 2015). Finally, attentional avoidance was also found in individuals with snake phobia using an attention-shifting task of emotional and neutral faces while measuring ERP. While no behavioral differences were found on the shifting task between individuals with snake phobia and a control group, those with snake phobia had a lower P200 amplitude in response to fear and disgust faces, suggesting avoidance in the early stages of attention (Sarlo & Munafò, 2010). Table 5 summarizes available research that has examined disgust-related attentional biases. Taken together, these findings suggest that specific attentional biases for disgust-related stimuli can be found in both bottom-up processes, such as initial orienting, and top-down cognitive control processes, such as avoidance. However, the majority of research suggests that bottom-up processes are influenced by general threat detection, rather than disgust specifically. Furthermore, motivated avoidance appears to be specific to disgust stimuli among individuals high in contamination fear (i.e., Armstrong et al., 2012; Tata et al., 1996).

4.5. Attentional avoidance as a distinct disgust response?

The extant literature clearly demonstrates that disgusting stimuli, like other motivationally-relevant stimuli, have several modulatory effects on attention (e.g., Ciesielski et al., 2010). However, this qualitative review of the available literature suggests that the effects of disgusting stimuli on attention appear to most strongly emerge later in exposure, after the transition from stimulus-driven to goal-driven, strategic processing (Cisler & Koster, 2010; Mogg & Bradley, 2016). These effects lie beyond the early time window (< 1000 ms) typically probed by measures of attention (Bar-Haim et al., 2007) and thus have largely eluded research on the emotional modulation of attention. Although attentional avoidance is not unique to disgust, it tends to be more characteristic of disgust cues compared to threat cues. However, this pattern of findings may be an artifact of the observation that disgusting stimuli, such as an unflushed toilet, are intrinsically more visually aversive than stimuli representing physical harm, such as a gun.

The first study to document possible strategic attentional avoidance of disgust-relevant stimuli in disorders characterized by heightened disgust proneness used an *ad libitum* viewing task, in which participants voluntarily decided when to terminate viewing of stimuli through a key press (Tolin, Lohr, Lee, & Sawchuk, 1999). Tolin et al. (1999) found that BII-phobic participants terminated viewing of disgusting BII-relevant stimuli faster than spider-phobic participants and control participants, and spider-phobic individuals terminated viewing of spider stimuli faster than BII-phobic individuals and control participants. However, a recent study suggests visual avoidance in the context of *ad libitum* viewing may be driven by the general unpleasantness of stimuli (Kron et al., 2014). Thus, it is unclear if phobic individuals in Tolin et al.'s (1999) study were motivated to avoid viewing phobic stimuli due to disgust specifically. Improving upon this early measure of visual avoidance, more recent studies have used eye tracking to measure visual attention on a larger time scale that encompasses strategic processing (Armstrong & Olatunji, 2012). Consistent with the findings of Tolin et al. (1999), Rinck and Becker (2006) found that spider-phobic individuals, but not control participants, avoided attending to spiders within the first 3 seconds of a trial, and this pattern was maintained for the full 60 s of stimulus exposure. Likewise, Armstrong, Hemminger, and Olatunji (2013) found that injection-phobic individuals, but not control participants, avoided attending to images of injection over the course of 18 s trials. Furthermore, a meta-analysis of the eye-tracking literature found that attentional avoidance was only characteristic of specific phobias linked to disgust (Armstrong & Olatunji, 2012).

Although the eye-tracking literature on anxiety-related disorders

has not conclusively established that attentional avoidance is specifically linked to disgust, more direct evidence that attentional avoidance is specific to disgust comes from basic research on Pavlovian conditioning. Two studies to date have found that attentional avoidance is both an unconditioned and a conditioned disgust response; that is, both disgusting stimuli and neutral stimuli previously associated with disgusting stimuli elicit attentional avoidance (Armstrong et al., 2014; Mason & Richardson, 2010). Further, one of these studies included a group that underwent conditioning with a generally threatening unconditioned stimulus, which did not exhibit attentional avoidance as an unconditioned or conditioned response (Armstrong et al., 2014). This study is in line with a handful of other eye-tracking studies that have observed attentional avoidance of disgust-relevant stimuli, but not fear-relevant stimuli (Armstrong et al., 2012; Bradley et al., 2015).

4.6. A functional perspective on attentional avoidance of disgust

In their review of attentional biases for threat in anxiety disorders, Cisler and Koster (2010) suggest that attentional avoidance at later stages of processing serves the function of emotion regulation. Attending away from locations that might contain an unpleasant stimulus can mitigate the distress caused by perceiving and contemplating the stimulus. Thus, attentional avoidance provides a strategy for down-regulating disgust. Armstrong and Olatunji (2012) suggest that attentional avoidance is a mode of strategic processing reserved for low-urgency stimuli. Fear and disgust have been contrasted in terms of the appraisal of urgency (Scherer, 2001), which refers to the evaluation of how rapidly one must respond to a stimulus. Fear-eliciting stimuli, such as a stray dog baring its teeth, demand an immediate behavioral response in order to prevent harm. Accordingly, attention may be maintained upon fear-eliciting stimuli at the cost of experiencing more distress, in order to promote the goal of harm avoidance (Armstrong & Olatunji, 2012). Indeed, eye-tracking studies have found that veterans with PTSD continue monitoring threat cues, rather than avoiding them, perhaps due to the perceived urgency of trauma cues in this disorder (Armstrong, Bilsky, Zhao, & Olatunji, 2013; Armstrong & Olatunji, 2012). Disgusting stimuli, in contrast, are usually low in urgency. Disgusting stimuli present the risk of contamination, rather than imminent bodily harm (Armstrong & Olatunji, 2017; Woody & Teachman, 2000), and preventing contamination typically does not require a rapid or sophisticated response. In light of this low urgency, individuals may use strategic attention to pursue emotion regulation goals in the presence of disgusting stimuli, choosing to attend away from disgusting stimuli (and experience less displeasure) rather than monitoring the stimuli in the service of harm avoidance.

Another perspective on the link between disgust and attentional avoidance is provided by Royzman and Sabini's (2001) theory of disgust. These authors argue that disgust is not elicited by cognitive appraisals (e.g., urgency) about the state of affairs in the world and is thus not an emotion. On their account, disgust is more akin to a drive or a reflex, because it is elicited by the concrete perceptual features of a stimulus, rather than its abstract meaning. Indeed, others have noted that disgust is "peculiar" as an emotion, because it is so consistently elicited by certain sensory qualities, regardless of context (Inbar, Pizarro, Knobe, & Bloom, 2009). Setting aside debates about the status of disgust as an emotion, several theoretical accounts of disgust argue that disgusting stimuli are intrinsically unpleasant to perceive. The eyes and legs of a spider or the oozing of pus in a wound for example, may be repulsive in themselves, regardless of the potential harm they signify. In line with this thinking, Rozin, Haidt, and McCauley (2008) suggest that whereas fear protects the body, disgust protects the mind. This perspective would predict that disgusting stimuli, compared to other negatively-valenced stimuli, would most reliably elicit attentional avoidance, because these stimuli are intrinsically unpleasant to perceive and will thus be unpleasant regardless of what a stimulus signifies in a particular context.

4.7. A combined cognitive bias hypothesis for disgust

It has been proposed that biased cognitive processes influence each other in that a bias at one stage (e.g., attention) affects information processing at other stages (e.g., interpretation). This notion has been referred to as the combined cognitive bias hypothesis (Hirsch, Clark, & Mathews, 2006). Unfortunately, there has been no systematic research examining the functional relation or dependence between disgust-related cognitive biases in healthy, analogue, or clinical samples. Existing research supports the notion that biased cognitive processes associated with disgust may not be isolated mechanisms but instead influence each other (i.e., Everaert, Duyck, & Koster, 2014). Research on functional relations between attention biases at elaborative stages and memory suggests that emotional biases in attention explain congruent biases in recall and recognition (Everaert, Tierens, Uzieblo, & Koster, 2013). This research would be consistent with the hypothesis that selective orienting of attention to disgust-relevant cues may lead to an interpretation bias (harm/contamination), which in turn is associated with a congruent bias in memory. This hypothesis highlights the interplay between cognitive science mechanisms that contribute to maladaptive emotion regulation in various anxiety and related disorders. Disgust associated biases in attention, interpretation, and memory processes may result in maladaptive emotion regulation strategies (e.g., avoidance) which then maintain anxious symptoms. However, testing this hypothesis as it relates to the development of anxiety and related disorders will require assessment of disgust-mediated biases across multiple cognitive levels of analysis in future research.

4.8. Potential moderators of cognitive bias in disgust processing

Although cognitive biases in disgust processing likely influence one another to confer risk for clinical anxiety, individual differences in disgust proneness may differentially affect cognitive processing of disgust cues in the environment. Disgust proneness can be further separated into *disgust propensity*, or how frequently a person experiences disgust, and *disgust sensitivity*, or how harmful the experience of disgust is perceived to be (Olatunji, Cisler, Deacon, Connolly, & Lohr, 2007; van Overveld, de Jong, & Peters, 2010b). Of the studies reviewed, only four directly examined both disgust propensity and disgust sensitivity as moderators of the effect of cognitive bias. One found that neither disgust propensity nor disgust sensitivity moderated the effect of the interpretation bias (Leathers-Smith & Davey, 2011), while a study of interpretation bias modification found that disgust propensity, but not disgust sensitivity, moderated the efficacy of the training, although this was largely driven by changes in negative affect (Whitton et al., 2013). Mitte (2008b) found that expectancy bias was related to disgust sensitivity, but not disgust propensity. Disgust sensitivity measured at an implicit level predicted avoidance of disgusting stimuli and washing concerns, while implicit disgust propensity predicted obsessing (Nicholson & Barnes-Holmes, 2012). Delineating the roles of disgust propensity and disgust sensitivity in cognitive biases in disgust is an important next step in understanding the cognitive mechanisms underlying psychopathology.

In addition to individual differences in disgust proneness, various demographic characteristics may interact with disgust biases to explain variance in psychopathology. For example, women are consistently found to have greater disgust proneness than men (Oaten et al., 2009), which may be related to evolutionary pressures (Fessler, Eng, & Navarrete, 2005; Fleischman & Fessler, 2011). Although there is a paucity of research examining gender differences in cognitive bias for disgust, one study did find that women demonstrate a greater attentional bias toward disgust compared to men, based on analysis of viewing patterns of emotional faces (Kraines et al., 2016). However, it remains unclear if gender differences in cognitive bias for disgust account for the gender differences in some anxiety disorders. Ethnic and racial differences in cognitive biases in disgust processing may also be

relevant but they are also not well-studied. Although African-Americans consistently exhibit higher contamination fear compared to white participants (Williams, Abramowitz, & Olatunji, 2012), differences in disgust proneness are less consistent, with higher disgust proneness found in two studies (Haidt, McCauley, & Rozin, 1994; Tolin, Woods, & Abramowitz, 2006), but not in a study that specifically examined the effects of race on disgust proneness (Williams et al., 2012). Given the pattern of findings observed in gender and ethnic differences in disgust proneness, future programmatic research is clearly needed to examine if such differences also translate to biases in the cognitive processing of disgust.

4.9. Looking ahead: treatment implications of attentional bias for disgust

The effects of attentional avoidance may be functionally equivalent to the effects of behavioral avoidance. By avoiding perceptual contact with spiders, injuries, or other disorder-relevant stimuli, individuals prevent disgust responding from undergoing habituation. Although disgust appears to habituate more slowly than fear during repeated exposure (Olatunji, Wolitzky-Taylor, Willems, Lohr, & Armstrong, 2009), there is evidence that disgust responding eventually undergoes habituation. Rozin (2008), for example, found that disgust at touching a cadaver was reduced by over 50% in medical students following extensive exposure. From a cognitive perspective, attentional avoidance may preclude the possibility of reframing a disgust-eliciting stimulus as less aversive. For example, Mason and Richardson (2012) suggest that disgust may be reduced by rethinking the nature of a disgusting stimulus. Specifically, individuals may "deconstruct" a disgusting stimulus by attending to its constituent parts, thereby interrupting the holistic processing and categorization that leads to an evaluative response. Such "conceptual reorienting" (Mason & Richardson, 2012) would likely require viewing a stimulus (e.g., Gross, 1998) and thus would be undermined by attentional avoidance.

In light of the potential role of attentional avoidance in maintaining anxiety-related disorders, it may be worth considering as a treatment target. Indeed, there is evidence (Hellström, Fellenius, & Öst, 1996; Öst, Fellenius, & Sterner, 1991) that merely attending to BII-related stimuli provide clinically significant symptom reduction for individuals with BII phobia. Attention modification procedures (Beard, Sawyer, & Hofmann, 2012) that train individuals to attend *towards* disgust eliciting stimuli could be utilized to 'reverse' attention avoidance. However, such procedures appear to target early, relatively automatic attentional processes (Beard et al., 2012). One approach to targeting later, more strategic biases in selective attention would be to reward dwelling on disgusting stimuli, through a gaze-contingent operant conditioning procedure (see Price, Greven, Siegle, Koster, & de Raedt, 2016). By reversing attentional avoidance, these procedures could facilitate beneficial processes such as habituation and reappraisal.

4.10. Is disgust cognitively impenetrable?

An important issue that must be addressed by cognitive science is the extent to which disgust responding is encapsulated from corrective information. This research question has direct implications for the extent to which excessive disgust reactions can effectively be treated in various disorders. Dating back to the earliest laboratory studies of disgust (e.g., Rozin, Millman, & Nemeroff, 1986), researchers have noted the emotion's stubborn resistance to reason. For example, Rozin et al. (1986) observed that appraisals of disgust operate according to 'laws of sympathetic magic.' These include the law of contagion, which holds that a negative essence transfers from one stimulus to another through contact and cannot be reversed ('once in contact, always in contact') and the law of similarity, which holds that the essence of an object is contained in its image, such that bearing the image of a contaminant, for example, constitutes possessing some of that contaminant. Rozin and colleagues demonstrated the law of contagion by showing

that participants refused to drink their preferred juice after a sterilized cockroach was dipped in the juice. Similarly, they demonstrated the law of similarity by showing that participants refused to eat a brownie in the shape of dog poop. In both cases, corrective information was provided to ensure that participants knew there was no actual risk of contamination. However, participants were unable to use reason to overcome the laws of sympathetic magic, which Rozin and colleagues believe constitute a deeply ingrained, rudimentary form of thinking.

Taking this argument a step further, Royzman and Sabini (2001) argue that disgust is entirely impenetrable to reason. On their account, disgust is not based on cognitive appraisals (propositions about a state of affairs in the world). Instead, Royzman and Sabini (2001) argue that disgust is a reflexive response to concrete perceptual features of a stimulus. Thus, reappraising the meaning of a stimulus is futile, because disgust responding is based on concrete rather than abstract (i.e., semantic) properties of a stimulus. Royzman and Sabini's (2001) account nicely explains the law of similarity, as perceptual qualities (i.e. appearance) of a contaminating object appear sufficient to elicit disgust. However, their theory has more difficulty accounting for the law of contagion, as contaminated objects elicit disgust without possessing the perceptual qualities of an original contaminant. Royzman and Sabini (2001) address this inconsistency by arguing that contaminated stimuli activate imagery of the original contaminant, which in turn reflexively elicits disgust. A further limitation of Royzman and Sabini's (2001) theory is that disgust does appear to yield to some forms of reappraisal. For example, Feinberg, Antonenko, Willer, Horberg, and John (2014) found that using reappraisal to modify initial disgust reactions reduced disgust-based forms of prejudice. In addition, several of the classic studies of emotion regulation have used disgust-eliciting stimuli (e.g., videos depicting body envelope violation; Gross, 1998) to show that changing the meaning of a stimulus can reduce the intensity of one's emotional reaction.

5. Conclusion

Disgust has been implicated in the development of various forms of psychopathology, especially anxiety-related disorders. Cognitive science theories may have utility in clarifying the underlying mechanisms that may explain how disgust confers risk for these disorders. Our review of the literature suggests that attentional avoidance may be the most characteristic of disgust. However, this attentional avoidance feature does not appear to be fully consistent with the adaptive function of disgust. For example, monitoring disgust stimuli (i.e., not avoiding) in one's environment facilitates disease avoidance; it is adaptive to maintain attention on the sneezing waiter at a restaurant to ensure that he does not contaminate your food. Future research is needed to clarify the conditions in which visual avoidance that is motivated by the experience of disgust becomes maladaptive. Adaptive visual avoidance may function to monitor actual contagion threat, whereas maladaptive visual avoidance may function to regulate one's distress about contagion (independent of threat value). Focusing on attentional avoidance also offers avenues for developing novel treatments for disgust-based disorders. For example, attention bias modification tasks that direct attention toward disgusting stimuli may be clinically useful as adjunctive treatments alongside in vivo exposure to disgust and psychoeducation regarding the functional nature of disgust.

Although this review suggests that attentional avoidance may be uniquely associated with disgust, a combined cognitive bias hypothesis suggests that attentional biases for disgust may confer risk for various disorders by having a downstream biasing influence on interpretation, memory, and judgment. However, future research is needed to test this hypothesis and the extent to which it accounts for meaningful variance in different disorders. Importantly, a combined cognitive bias hypothesis also highlights the potential value of examining the extent to which disgust responds to a wider range of cognitive interventions. Mason and Richardson (2012) suggest that efforts to directly reframe the

evaluation of a disgusting stimulus (i.e., "that is not disgusting") are likely futile. Instead, they recommend multiple strategies for rethinking the nature of a stimulus, either through subsuming the stimulus under a different category (e.g., yogurt instead of rotten milk) or by deconstructing the stimulus into constituent elements (e.g., blood cells, platelets, and plasma instead of blood). In the event that disgust proves impenetrable to these cognitive interventions, Mason and Richardson suggest focusing on secondary disgust appraisals that include cognitions about one's disgust response (e.g., if I feel nauseated it is bad for me; van Overveld, de Jong, & Peters, 2010b). Indeed, studies of expectancy bias in disgust suggest that individuals high in disgust sensitivity appraise disgust stimuli as being more likely to cause contamination or illness compared to individuals low in disgust sensitivity (e.g., Mitte, 2008b); however, no studies have examined the effects of an expectancy bias modification procedure in highly disgust-sensitive individuals. There is some evidence that such appraisals predict unique variance in symptoms of anxiety-related disorders and may be more clinically important than the magnitude of initial disgust responding (i.e., propensity; Engelhard, Olatunji, & de Jong, 2011). Thus, targeting such appraisals appears to be an important next step in the treatment of psychopathology in which disgust is central. There have been important advances in cognitive science that have improved our understanding of the etiology and maintenance of psychopathology, and these advances may also be translated in meaningful ways to develop interventions that can more effectively treat excessive disgust reactions in various disorders.

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The authors declare no conflict of interest.

Contributors

Kelly A. Knowles conducted literature searches and provided summaries of relevant research studies on attention. Rebecca C. Cox conducted literature searches and provided summaries of relevant research studies on memory and interpretation. Thomas Armstrong conducted literature searches and provided summaries of relevant research studies on attentional avoidance and its clinical implications. Bunmi O. Olatunji designed the structure of the search design/synthesis and collectively wrote this manuscript with the coauthors. All authors contributed to and have approved the final manuscript.

Research Highlights

➢ Cognitive science may elucidate how disgust contributes to the etiology of psychopathology.
➢ Disgust-related biases can be observed in memory, interpretation, expectancies, and attention.
➢ Attentional avoidance may be the most characteristic of disgust.
➢ Attentional avoidance of disgust may have important implications for etiological and treatment models.

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