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Focus Article

Does an unconditioned stimulus memory devaluation procedure decrease disgust memories and conditioned disgust? Results of two laboratory studies

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ABSTRACT

Research has demonstrated that disgust can be installed through classical conditioning by pairing neutral conditioned stimuli (CSs) with disgusting unconditioned stimuli (USs). Disgust has been argued to play an important role in maintaining fear-related disorders. This maintaining role may be explained by conditioned disgust being less sensitive to extinction (i.e., experiencing the CS in the absence of the US). Promising alternatives to extinction training are procedures that focus on the devaluation of US memory representations. In the current study, we investigated whether such devaluation procedures can be successful to counter conditioned disgust. We conducted two laboratory studies ($N = 120$ and $N = 51$) in which disgust was conditioned using audio-visual USs. Memory representations of the USs were devalued by having participants recall these USs while they performed a taxing eye-movement task or executed one of several control tasks. The results showed successful conditioned disgust acquisition. However, no strong evidence was obtained that an US memory devaluation procedure modulates disgust memory and diminishes conditioned disgust as indicated by subjective, behavioral, or psychophysiological measures. We discuss the relevance of our results for methodological improvements regarding US memory devaluation procedures and disgust conditioning.

1. Introduction

Disgust is a core human emotion characterized by feelings of revulsion and the tendency to move away from the evoking stimulus (Rozin, Haidt, & McCauley, 2000). Its evolutionary function is thought to be prevention and reduction of contact with disease-eliciting pathogens (Oaten, Stevenson, & Case, 2009). Disgust is often prominently featured in psychopathological conditions, such as phobias, obsessive-compulsive disorder, and Post-Traumatic Stress Disorder (PTSD) (Cisler, Olatunji, & Lohr, 2009; Engelhard, Olatunji, & de Jong, 2011; Olatunji, Cisler, Deacon, Connolly, & Lohr, 2007). As such, it is an important emotion to consider in therapeutic interventions.

Disgust is often elicited by specific cues (e.g., blood, feces, certain insects, spoiled foods; Oaten et al., 2009), but can become conditioned to initially neutral stimuli through the use of classical conditioning procedures (Borg, Bosman, Engelhard, Olatunji, & de Jong, 2016; Engelhard, Leer, Lange, & Olatunji, 2014; Olatunji, Forsyth, & Cherian, 2007; Schienle, Stark, & Vaitl, 2001). This suggests that, feelings of disgust related to an aversive experience or unconditioned stimulus (US; e.g., sexual assault), may transfer to stimuli and situations (i.e., conditioned stimuli; CSs) that did not initially evoke feelings of disgust (e.g., being in the workspace). Such learned disgust to seemingly neutral and common objects may be particularly disruptive for daily life.

Laboratory studies indicate that conditioned disgust is resistant to extinction (Bosman, Borg, & de Jong, 2016; Engelhard et al., 2014; Mason & Richardson, 2010; Olatunji, Forsyth et al., 2007). Likewise, conditioned disgust has been found to persist after therapeutic interventions that make use of the mechanism of extinction, such as cognitive-behavior therapy (CBT) (Olatunji, Wolitzky-Taylor, Willems, Lohr, & Armstrong, 2009; Smits, Telch, & Randall, 2002). These results indicate that treating feelings of disgust using CBT may be particularly challenging. Besides persistent disgust being problematic in itself, it also

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produces specific interoceptive states (e.g., nausea) which can facilitate state-dependent return of fear (Viar-Paxton & Olatunji, 2012), and can contribute to persistent avoidance responses, which could further interfere with the success of extinction procedures (Lovibond, Mitchell, Minard, Brady, & Menzies, 2009). Hence, developing successful procedures to counter (conditioned) disgust is an important step to enhance treatment effects of anxiety and disgust related disorders.

An alternative approach to reducing conditioned responses besides extinction procedures is *US devaluation*. According to modern learning theories, classical conditioning consists of both the development of expectancies regarding the probability of encountering the US in the presence of the CS, and of forming memory representations about the US (Davey, 1992; Field, 2006; Hofmann, 2008; Rescorla, 1988). In line with these theories, several studies have demonstrated that devaluation of the US representations also result in a reduction of conditioned fear responses (Hosoba, Iwanaga, & Seiwa, 2001; Leer, Engelhard, Altink, & van den Hout, 2013).

One method that appears to be successful in devaluating the US representation is to have individuals recall the US memory while simultaneously executing a working memory task, such as executing horizontal eye-movements. This recollection of memories while simultaneously performing a dual-task reduces the emotionality and vividness of these memories (Engelhard, van Uijen, & van den Hout, 2010; Leer, Engelhard, & van den Hout, 2014; van den Hout et al., 2011). A likely explanation for this effect is that the working memory taxation leaves insufficient working memory resources available for the memory reconsolidation (van den Hout & Engelhard, 2012) or leading to a reappraisal of the memory (Gunter & Bodner, 2008), thereby weakening the US representation. Previous studies have indicated that dual-task interventions reduce conditioned fear responses (Leer, Engelhard, Altink et al., 2013; Leer, Engelhard, Dibbets, & van den Hout, 2013; though see Landkroon, Mertens, & Engelhard, 2020). Likewise, in clinical practice, US memory devaluation interventions such as eye-movement desensitization and reprocessing (EMDR) reduce post-traumatic stress symptoms (Cuijpers, van Veen, Sijbrandij, Yoder, & Cristea, 2020).

So far, studies have only tested US memory devaluation procedures for conditioned fear responses, but not for conditioned disgust responses. Given the clinical potential of identifying successful ways to counter conditioned disgust, we conducted two laboratory experiments in which we investigated whether US memory devaluation using an eye-movement intervention is effective to reduce conditioned disgust.

2. Experiment 1

2.1. Participants

One hundred and twenty-three students from Utrecht University were recruited to participate in this study. Participants were screened and excluded if they reported emetophobia, no (corrected to) normal vision, prior participation in similar studies, or mental and physical health issues. The data of three participants were excluded because of not following the instructions (two participants) or due to dietary reasons (one participant). Participants were randomly assigned to one of the following conditions: eye-movements, recall only, or filler only. The no-intervention condition was later added as an additional control condition (see Section 2.3.4.4). Table 1 presents an overview of the participants characteristics across conditions. This study was approved by the ethical board of the Faculty of Social Sciences of Utrecht University (FETC15-074).

2.2. Material

2.2.1. Stimuli

The stimuli used in this experiment were two color photos of toasts with two different spreads (curry spread and celery spread). Food stimuli were chosen as CSs because these stimuli are relevant for disgust reactions (Borg et al., 2016; Bosman et al., 2016). As an unconditioned stimulus (US), three 4-s film fragments of a woman who makes herself vomit were used. The US was paired with one of the CSs (counterbalanced over participants); while the other CS was paired with neutral film clips (fragments of a weather report).

2.2.2. Questionnaires

Included questionnaires were the Disgust Propensity and Sensitivity Scale Revised (DPSS-R) (Olatunji, Cisler et al., 2007), the Vancouver Obsessive Compulsive Inventory-Contamination Fear Subscale (VOCI) (Thordarson et al., 2004), the State-Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and a hunger scale designed for the current research. The hunger scale consists of four questions about the time since participants last ate, the time until their next meal, and their current appetite (i.e., "How hungry are you at this moment?" and "How much of your favorite food could you currently eat?"; each rated on a 10-point Likert scale). However, this scale had low internal consistency (Cronbach's $\alpha = .33$) and an unexpected 2-factor structure in an exploratory factor analysis. Therefore, we only focus on the first question of this questionnaire in the current study (i.e., time since last meal).

2.2.3. Subjective ratings

Fear, disgust, and attractiveness for each CS was rated on a visual analog scale (VAS) ranging from 0 (*not at all fearful/disgusting/attractive*) to 100 (*very fearful/disgusting/attractive*). US expectancy was assessed with a 200-point VAS, with the following anchors in this order: 100 (*vomiting woman*), 0 (*neither*), and -100 (*weather report*).

The unpleasantness and disgust of each film clip were assessed with two VASs that ranged from 0 (*not at all unpleasant/disgusting*) to 100 (*very unpleasant/disgusting*). The emotionality, vividness, detail and

Table 1
Demographic information of the participants in each of the conditions of the experiment in Means (SD).

	Eye-movements N = 30	Recall only N = 30	Filler task N = 31	Control N = 29	Difference
Age (in years)	22.87 (4.31)	22.63 (3.53)	22.45 (3.00)	21.41 (2.57)	$F(3, 116) = 1.03$
Sex distribution	8 males/22 females	8 males/22 females	9 males/22 females	10 males/19 females	$X^2(3) < 1$
STAI-T	37.90 (8.90)	39.57 (9.86)	38.74 (10.86)	38.41 (11.91)	$F < 1$
STAI-S	35.52 (9.14)	34.87 (7.85)	35.43 (7.05)	33.31 (9.66)	$F < 1$
DPSS-R	39.47 (8.57)	40.40 (4.07)	38.96 (5.19)	37.28 (7.36)	$F(3, 113) = 1.17$
VOCI	6.07 (5.98)	4.38 (4.96)	3.65 (2.56)	4.93 (4.52)	$F(3, 115) = 1.46$
Time since last meal (in minutes)	105.60 (73.43)	139.50 (171.54)	109.65 (142.43)	167.21 (214.75)	$F < 1$

retrieval difficulty of US memories were assessed with four VASs ranging from 0 (*not at all unpleasant/vivid/detailed/difficult*) to 100 (*very unpleasant/vivid/detailed/difficult*).

2.3. Procedure

2.3.1. Start up

Participants were asked not to consume any food two hours before the experiment. Upon arrival at the lab, participants read the information brochure, which explicitly mentioned that disgusting film clips would be shown, and signed the informed consent form. Then, they completed open-ended introductory questions, including their background knowledge of EMDR, cognitive-behavior therapy, and exposure therapy. Participants who reported knowledge of EMDR therapy, were excluded from participation. This was done to minimize demand bias and familiarity with the intervention.

After providing informed consent and screening, participants completed demographic questions, the DPSS-R, the VOCI, the custom hunger scale, and the STAI. Next, the two food stimuli were shown to the participants – each food item presented on a separate plate and each covered by a transparent plastic cap – and participants were informed that during the experiment they would see pictures of those food items. Participants were then seated in front of the computer screen with the screen height being adjusted. Then the conditioning paradigm followed, which was largely based on earlier research (Borg et al., 2016; Bosman et al., 2016). All phases of the experiment followed one another immediately, except for the final test phase, which was conducted 24 h later.

2.3.2. Habituation phase

Participants were instructed, both verbally and on-screen, that they would see pictures of two stimuli. It was stressed that they had to pay attention to what is presented on screen. Then, they put on the headphones. During the habituation phase, each CS was presented twice in a counterbalanced order for six seconds without any reinforcement. At the end of the habituation phase, participants completed the fear, disgust, and attractiveness ratings using paper-and-pencil.

2.3.3. Acquisition phase

Verbal and on-screen instructions informed participants that they would again see the two CSs, with one of the CSs being followed by a film fragment of a disgusting film, and the other CS being followed by a neutral US. It was noted that each film consisted of the three different film-fragments. It was stressed that participants should look at the screen the whole time and that their task was to learn to predict after which picture the disgusting film followed. These instructions were included to facilitate conditioning (see Mertens, Boddez, Sevenster, Engelhard, & De Houwer, 2018). The acquisition phase consisted of 15 reinforced trials per CS (presented for six seconds). At the end of this phase, participants completed the fear, disgust, attractiveness, US expectancy, and film ratings.

2.3.4. Intervention

Participants underwent one of the following interventions: Eye-movement, recall only, filler task, or no intervention. Participants in all groups were asked first to bring to mind the three film-fragments of the disgusting film, and combine them so that they constituted a single film. Then, they were instructed to keep their eyes open and bring the disgusting film in mind, with as much detail as possible. Next, the experimenter waited for 10 s and asked participants to rate US memory. The intervention that followed for each group differed from then onwards (see below).

2.3.4.1. Dual-task intervention (eye-movements; EM). In the EM condition, participants were informed that they had to recall the memory for four times, with breaks of 10 s in-between (Leer, Engelhard, Altink et al., 2013). During memory recall, participants had to look at the screen and focus on a dot that was moving horizontally. Each memory retrieval block lasted 24 s, during which a dot moved at a speed of 1.2 Hz (1.2 left-right-left movements over the screen per second; van Veen, Wijngaards-de Meij, Littel, Engelhard, & van den Hout, 2015).

2.3.4.2. Recall only (RO). The RO condition was identical to the EM condition, except that participants were asked to remember the film while looking at the black screen.

2.3.4.3. Filler task. Participants in this group were not asked to recall the memory and completed an extended version of the filler task described in Leer and Engelhard (2015). The task consisted of 20 trials. Each trial started with a 2 s fixation cross, followed by a picture of a guitar for 6 s, and an inter-trial interval of 10 s. Ten different guitars were presented and participants had to select whether they had seen each picture for the first (by pressing "1") or second (by pressing "2") time.

2.3.4.4. No intervention. A 'no intervention' control condition was added to the experiment as a fourth condition after the data for the other conditions had already been collected. In this control condition, participants waited for the same duration as the EM intervention without executing any task. The difference with the recall only condition was that participants were not asked to recall the memory (as this could potentially lead to US memory habituation; see van Veen, van Schie, van de Schoot, van den Hout, & Engelhard, 2020).

Following the intervention, participants were again asked to bring to mind the three film-fragments of the disgust film as if it was a single film. Identical to the baseline measurement, they had to keep the film in mind for 10 s and then rated the US memory.

2.3.5. Test phase

Next, participants were asked to put on the headphones again. They were informed, both verbally and on-screen, that they would see each CS again, and that there would be a chance that they would see a disgusting film after the picture that was earlier followed by a disgusting film-fragment. In actuality, all CS presentations were unreinforced. After seeing the CSs, participants filled in the same VASs as in the acquisition phase.

2.3.6. Behavior approach task (BAT) and 24 h delayed test

Participants were seated again in front of the actual food items. They were informed that during the next phase, they would have to first evaluate the items, and then possibly eat them. Then, they were asked to choose which item they wanted to start with. After making a choice, the food item was placed in front of them. Participants then rated the item in terms of tastiness and willingness to eat (0 = *not tasteful at all/sure not*; 100 = *absolutely tasteful/sure yes*). The same procedure was followed for the second item.

The following day, participants were invited back to the lab. Participants first completed the hunger scale. Then, they completed the same test phase as on day 1. Finally, participants completed the same BAT procedure as on day 1, but this time received the option to eat the food items. Table 2 provides a schematic overview of the procedure of Experiment 1.

2.3.7. Data preprocessing and analysis

Statistical analyses were conducted both with frequentist and Bayesian ANOVAs (using JASP 0.12.2.0). For the Bayesian analyses we followed the same strategy as in previous studies from our lab (e.g., Krypotos, Mertens, Leer, & Engelhard, 2020; Krypotos & Engelhard, 2018). Bayesian analyses were included to quantify the evidence in favor of the null or the alternative hypothesis. Bayes factors larger than 3

Table 2
Schematic overview of the procedure of Experiment 1.

Day 1						Day 2
Habituation	Acquisition	Memory ratings	Intervention	Memory ratings	Test-1	Test-2
CS+ (2) CS- (2)	CS+/USdisgust (15) CS-/USneutral (15)	Rate memory USdisgust	Group 1: Recall + EM Group 2: Recall only Group 3: Filler task Group 4: No intervention	Rate memory USdisgust	CS+ (1) CS- (1)	CS+ (1) CS- (1)

Note. EM = Eye movements.

or larger than 10 are considered to be moderate and strong evidence, respectively, for either null (BF_{01}), compared to the alternative, or the alternative, compared to the null, hypothesis (BF_{10}). For the frequentist analyses an alpha level of .05 was applied.

2.3.7.1. US memory scores. Emotionality and vividness VAS scores of the US memory were subjected to two repeated measures ANOVA's with time (pre-intervention, post-intervention) as a within-subjects factor and condition (EM, recall only, filler task and control) as a between-subjects factor.

2.3.7.2. CS ratings. CS disgust, fear, attractiveness, and US expectancy rating were subjected to separate repeated measures ANOVAs with phase (habituation versus acquisition, acquisition versus test, or test versus follow-up) and CS (CS+, CS-) as within-subjects factors and condition (EM, recall only, filler task and control) as a between-subjects factor.

2.3.7.3. BAT. Tastiness of the CSs and willingness to eat were analyzed with two repeated measures ANOVAs with time (day 1, day 2) and CS (CS+, CS-) as within-subjects factors and condition (EM, recall only, filler task and control) as a between-subjects factor. Finally, we analyzed whether there was a difference between the groups with regard to whether participants took a bite from the CS + and CS- using Pearson's Chi-Squared test.

2.4. Results

2.4.1. US memory ratings

2.4.1.1. Emotionality. Analyses of the US memory emotionality VASs revealed a significant main effect of time, $F(1, 116) = 6.68$, $p = .011$, $\eta^2_p = .05$, $BF_{10} = 2.01$, and a significant interaction effect between time and condition, $F(3, 116) = 7.47$, $p < .001$, $\eta^2_p = .16$, $BF_{10} = 189.70$. The main effect of condition was not significant, $F(3, 116) = 2.11$, $p = .103$, $\eta^2_p = .05$, $BF_{10} = 0.90$. The interaction between time and condition was due to an increase in US memory emotionality ratings in the recall only condition, $t(29) = 2.56$, $p = .016$, $BF_{10} = 3.07$, while in all other conditions there was a decrease of US memory emotionality ratings (EM: $t(29) = -3.31$, $p = .002$, $BF_{10} = 14.93$; Filler: $t(30) = -2.32$, $p = .027$, $BF_{10} = 1.93$; No intervention: $t(28) = -2.53$, $p = .017$, $BF_{10} = 2.85$; see Table 3).

Table 3
Mean (SD) US memory emotionality and vividness ratings before and after the US devaluation intervention in Experiment 1.

	Emotionality ratings		Vividness ratings	
	Pre-rating	Post-rating	Pre-rating	Post-rating
EM	59.33 (23.36)	49.50 (27.73)	75.03 (15.70)	61.57 (24.27)
RO	60.93 (21.12)	68.47 (16.97)	72.97 (16.53)	70.07 (16.99)
Filler	53.35 (27.79)	45.77 (25.34)	73.26 (21.37)	60.00 (23.62)
No intervention	57.86 (27.24)	53.07 (29.86)	75.45 (17.12)	63.00 (17.91)

Note: EM = eye-movements; RO = recall only.

2.4.1.2. Vividness. Analyses of the US memory vividness VASs revealed a significant main effect of time, $F(1, 116) = 29.88$, $p < .001$, $\eta^2_p = .21$, $BF_{10} = 42{,}544.51$, but no main effect of condition, $F < 1$, $BF_{10} = 0.09$, and no interaction effect between time and condition, $F(3, 116) = 1.76$, $p = .159$, $\eta^2_p = .04$, $BF_{10} = 0.34$. The main effect of time was due to a decrease of US memory vividness in all conditions (see Table 3).

2.4.2. CS ratings

For reasons of parsimony, we only report CS disgust ratings in the main text. Results for CS fear and attractiveness ratings, and US expectancy rating are in the Supplementary Materials. In brief, these ratings showed successful conditioning, but no effect of US devaluation.

2.4.2.1. Disgust ratings

2.4.2.1.1. Habituation versus acquisition phase. The analysis of the disgust ratings from the habituation and acquisition phases revealed significant main effects of phase, $F(1, 116) = 83.62$, $p < .001$, $\eta^2_p = .42$, $BF_{10} = 4.814e+17$, and CS, $F(1, 116) = 33.88$, $p < .001$, $\eta^2_p = .23$, $BF_{10} = 1.828e+6$, and a significant interaction effect between phase and CS, $F(1, 116) = 27.82$, $p < .001$, $\eta^2_p = .19$, $BF_{10} = 649.93$. These results indicate that our procedure was successful to induce subjective conditioned disgust as evidenced by the increase of CS + disgust ratings from the habituation to the acquisition phase (see Fig. 1). Importantly, the three-way interaction between phase, CS and condition was not significant, $F(3, 116) = 1.41$, $p = .244$, $\eta^2_p = .04$, $BF_{10} = 0.13$, suggesting that disgust conditioning was comparable in the different conditions of the experiment. None of the other main or interaction effects were significant, F-values < 1.2, $BFs_{10} < 0.10$.

2.4.2.1.2. Acquisition versus test phase. The analysis of the disgust ratings from the acquisition and test phase revealed a significant main effect of CS, $F(1, 116) = 54.49$, $p < .001$, $\eta^2_p = .32$, $BF_{10} = 6.063e+16$, and a significant three-way interaction between phase, CS and condition, $F(3, 116) = 3.81$, $p = .012$, $\eta^2_p = .09$, $BF_{10} = 0.35$. The other main and interactions effects were not significant, F-values < 1.1, $BFs_{10} < 0.18$. Follow-up tests revealed that the three-way interactions was due to a non-significant trend for a reduction of disgust ratings for the CS + in the EM condition, $t(29) = -1.88$, $p = .070$, dz = 0.27, $BF_{10} = 0.92$, whereas in the other conditions there was a non-significant *increase* in disgust ratings to the CS+ (RO: $t(29) = 1.07$, $p = .293$, dz = -0.20, $BF_{10} = 0.33$; Filler: $t(30) = 1.38$, $p = .177$, dz = -0.14, $BF_{10} = 0.45$; No intervention: $t(28) = 1.93$, $p = .063$, dz = -0.20, $BF_{10} = 1.01$; see Fig. 1).

2.4.2.1.3. Test phase versus day 2 follow-up. The analysis of the disgust ratings from the test and follow-up phase only revealed a main effect of CS, $F(1, 116) = 62.47$, $p < .001$, $\eta^2_p = .35$, $BF_{10} = 3.731e+16$. This main effect of CS indicated that, both at test and at the second day follow-up, the effect of disgust conditioning was maintained (see Fig. 1). None of the other main or interaction effects were significant, F-values < 2.9, p-values $> .08$, η^2_p's $< .06$, $BFs_{10} < 1.46$.

2.4.3. BAT

2.4.3.1. Rated tastiness. Analyses of participants' rated tastiness of the

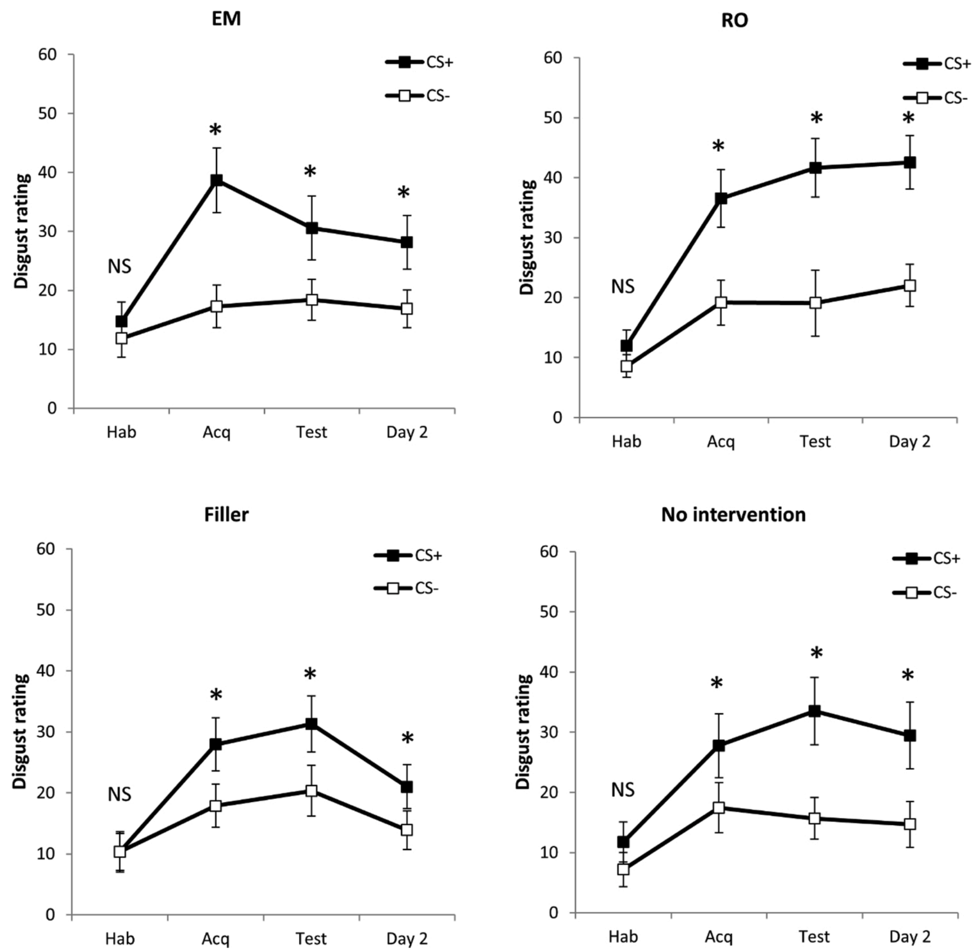

Fig. 1. CS disgust ratings for the different phases and the different conditions in Experiment 1. Error bars reflect standard errors of mean. Notes: EM = Eye-Movement; RO = Recall Only; * indicates that CS+ > CS- with $p < .05$; NS indicates no significant difference between CS+ and CS-.

CSs revealed only a main effect of CS, $F(1, 115) = 38.62$, $p < .001$, $\eta^2_p = .25$, $BF_{10} = 4.131e+12$. This main effect of CS was due to higher tastiness ratings for the CS- than for the CS+ (see Fig. 2). The other main and interaction effects were not significant, F-values < 1.4, $BFs_{10} < 0.30$.

2.4.3.2. Rated willingness to eat. The analysis of participants' rated willingness to eat the CS revealed significant main effects of CS, $F(1, 115) = 40.90$, $p < .001$, $\eta^2_p = .26$, $BF_{10} = 2.391e+11$, and of group, $F(3, 115) = 3.07$, $p = .031$, $\eta^2_p = .07$, $BF_{10} = 2.08$. The main effect of CS was due to higher reported willingness to eat for the CS- than for the CS + . The main effect of group was due to lower general rated willingness to eat in the RO group (see Fig. 2). The other main and interaction effects were not significant, F-values < 1.6, $BFs_{10} < 0.42$.

2.4.3.3. Actual bite. The analyses of whether participants took a bite from the toasts representing the CS + and CS- revealed that there was no difference between the groups for CS+, $\chi^2(3) = 2.25$, $p = .523$, $BF_{10} = 0.05$, or CS-, $\chi^2(3) = 2.55$, $p = .466$, $BF_{10} = 0.05$ (see Table 4). Furthermore, there was no difference between the proportion of participants that took a bite from the CS + and the proportion of participants that took a bite from the CS-, McNemar's exact test $\chi^2 = 0.82$, $p = .549$.

2.5. Discussion

The results showed successful acquisition of conditioned disgust as indicated by the disgust ratings and by participants' rated willingness to eat and tastiness ratings in the BAT. These results correspond with studies demonstrating successful conditioning of disgust (Borg et al., 2016; Engelhard et al., 2014; Olatunji, Cisler et al., 2007). Our results also showed a non-significant trend that US devaluation reduced conditioned disgust, as evidenced by a trend for a *decrease* of disgust ratings in the test phase for the EM condition, whereas a non-significant increase was observed in the other conditions.

However, Bayesian analyses indicated no strong evidence for reduced conditioned disgust after US devaluation. In addition, the reduction of conditioned (disgust) responses was not observed for any of the other self-report or behavioral measures. This result indicates that our US devaluation had no or only a limited effect on subjective evaluations, and did not generalize to behavioral measures of disgust. An additional limitation of this study was that the experimenter was not blind to the no intervention condition, because this condition was added after the completion of the other conditions.

3. Experiment 2

In order to further investigate whether US memory devaluation can reduce conditioned disgust we conducted a second experiment using a within-subject procedure in which two CSs were conditioned with two different disgusting audio-visual USs. One of these two USs was devalued using the eye-movement intervention. No intervention was carried out for the other USs. We reasoned that this procedure would provide a more adequate control for non-specific effects of the intervention. Furthermore, the within-subjects design provides a more powerful design for the statistical test, while requiring less participants (Brysbaert, 2019). Finally, we included psychophysiological measures of fear

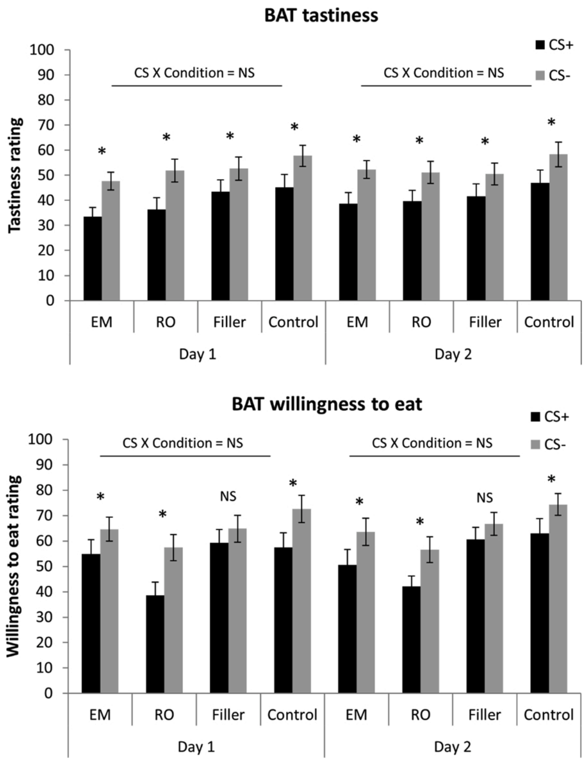

Fig. 2. Results of the rated tastiness and willingness to eat for the two CSs in the Behavioral Approach Task in Experiment 1. Error bars reflect standard error. Notes: * indicates that ratings for CS + were significantly ($p < .05$) different from CS-; NS indicates no significant differences.

Table 4
Percentages of participants that took a bite from the toasts representing the CS + and CS- in the Behavioral Approach Task across the different US devaluation conditions.

	Bite CS+		Bite CS-	
	Yes	No	Yes	No
EM	66.7 %	33.3 %	73.3 %	26.7 %
RO	63.3 %	36.7 %	73.3 %	26.7 %
Filler	74.2 %	25.8 %	64.5 %	35.5 %
No intervention	79.3 %	20.7 %	82.8 %	17.2 %

and disgust in this study to investigate whether the effect of US devaluation can be obtained using these measures.

3.1. Participants

Fifty-seven students from Utrecht University were recruited for this experiment. Six of these participants were excluded from the final analyses because they failed the contingency test. The final sample consisted of 21 males and 30 females with a mean age of 21.64 (SD = 2.28).

3.2. Material

3.2.1. Stimuli

As in Experiment 1, CSs were pictures of toasts covered with three different types of hummus (sundried tomato, natural and pesto) on a white plate. These three CSs were paired with three different movie clips (not counterbalanced[1]). Two movie clips were the same as in Experiment 1 (i.e., woman vomiting and weather report). Furthermore, an additional scene from the movie "Trainspotting" was selected as a third US. In this scene, a young man has diarrhea and reaches with his hand into the toilet. This scene was selected because it depicts, like vomiting, a relevant symptom for a disease-avoidance model of disgust (i.e., avoiding sickness symptoms such as diarrhea; Oaten et al., 2009).

3.2.2. Psychophysiology

3.2.2.1. Electromyography (EMG). Muscle activity of the corrugator supercilii was collected using two AgCl electrodes filled with Signa electrode gel. EMG electrodes were attached above the eyebrow on the side of the non-dominant hand. Two baseline electrodes were attached just below the hairline. Activity of the corrugator muscle was chosen as a measure of disgust because it is sensitive to disgust conditioning (Borg et al., 2016).

3.2.2.2. Skin conductance responses. Skin conductance responses were collected at the middle phalanges of the middle and index finger of the non-dominant hand using Biosemi GSR electrodes and Signa electrode gel. Though skin conductance is not a physiological response specifically related to disgust, we decided to include this measure because it is a commonly used measure within conditioning procedures.

3.3. Procedure

3.3.1. Habituation phase

Following electrode attachment for the psychophysiological measures, participants were instructed to read the instructions carefully. The instructions informed them that they would see different images on the screen and that they should pay close attention to these images. Furthermore, they were told that they had to indicate how disgusting they found the food in these images by moving the computer mouse over a scale presented below the images. After these instructions, participants saw two presentations of each CS. The CSs were presented on the screen for eight seconds, during which participants could indicate their disgust ratings. The inter-trial interval varied between 12, 14, and 16 s and CS presentations were preceded by a fixation cross for two second.

3.3.2. Acquisition phase

Following the habituation phase, participants were told that they would see the images again. Furthermore, they were told that these images would always be followed by specific film clips: the white toasts would always be followed by film clips of a vomiting woman, the red-brown toast would always be followed by film clips of a man in a toilet and the green toast would always be followed by film clips of a weatherman. These instructions were given to facilitate conditioning (Mertens et al., 2018). Following these instructions, participants went through a conditioning phase in which each CS was presented eight times. Each CS was paired with fragments of a specific film clip in accordance to the instructions. Inter-trial interval, fixation cross duration and trial order organization was identical to the habituation phase.

3.3.3. Contingency test

After the acquisition phase, participants were asked about their knowledge of the contingencies of the previous phase. For each of the

[1] In order to ensure successful conditioning, we decided not to counterbalance the CSs in Experiment 2. That is, we wanted to foster the relatedness between the CSs and USs by having a degree of overlap in the colors present in the CSs and USs (i.e., green toast and weather report, white toast and white vomit, red-brown toast and diarrhea).

CSs, participants were asked to indicate with which film clip this CS had co-occurred. This was included as research from the fear conditioning literature indicates that contingency awareness facilitates conditioning (Lovibond & Shanks, 2002; Mertens & Engelhard, 2020).

3.3.4. Eye-movement intervention

The dual-task intervention was exactly the same as in Experiment 1 (i.e., making horizontal eye-movement), except that the intervention consisted of six blocks of 24 s instead of four. The memory of one of the USs was recalled during this intervention, whereas the memory of the other US was not recalled (counterbalanced over participants).

3.3.5. Test phase

After the intervention, participants were told that they would see the images again and that these might be followed by the film clips again. The trial procedure of the test phase was identical to that of the habituation phase (i.e., no film clips were presented).

3.3.6. Data preprocessing and analysis

3.3.6.1. Data exclusion. Data of six participants were excluded because they did not pass the test regarding the contingencies in the acquisition phase (Mertens & Engelhard, 2020). Furthermore, psychophysiological data of another five participants were lost due to an experimenter error.

3.3.6.2. Psychophysiology preprocessing

3.3.6.2.1. Corrugator activity. Corrugator EMG activity was first filtered (20−500 Hz) and rectified using BrainVizion analyzer. Thereafter, mean EMG activity (in μV) was measured during CS presentation (0−8 s) and during US presentation (0−4 s) corrected for the baseline activity 100 ms preceding CS onset (Borg et al., 2016).

3.3.6.2.2. Skin conductance responses. SCRs were calculated by subtracting the mean value of a baseline period (2 s before CS onset) from the highest interval 1–8 seconds post CS onset (and 1–4 seconds post US onset for SCRs for the US) (Pineles, Orr, & Orr, 2009). Thereafter, skin conductance values were range corrected using the largest response for each participant and square root transformed to normalize the data. A minimum response criterium was set at 0.02 μS.

3.3.6.3. Data analyses

3.3.6.3.1. US memory ratings. US memory emotionality and vividness ratings were analyzed with two repeated measures ANOVAs with intervention (EM, control) and time (pre and post intervention) as within-subject factors.

3.3.6.3.2. Conditioned responses (disgust ratings, corrugator EMG, SCRs). Conditioned responses in the habituation and acquisition phase were analyzed with repeated measure ANOVAs with CS (CS + EM, CS + control, CS-) and trial (habituation: 1–2; acquisition: 1–8) as within-subject factors. Finally, the effect of the US memory devaluation procedure on conditioned responses was investigated by comparing responses on the last trial of the acquisition phases with reactions on the first trial of the test phase (factor time) for the different CSs (CS + EM, CS + control, CS-; factor CS) in a repeated measures ANOVA.

3.4. Results

3.4.1. US memory ratings

3.4.1.1. Emotionality. Analyses of the US memory emotionality ratings did not produce any significant effects *F*-values < 3.04, $BFs_{10} < 1.10$, and the interaction between intervention and time showed a non-significant trend, $F(1, 50) = 3.15$, $p = .082$, $\eta^2_p = .06$, $BF_{10} = 0.65$. Because of our a priori hypotheses, this interaction was followed-up with *t*-tests. These indicated that there was a significant reduction of the US emotionality ratings from pre to post-test for the US that was devalued, $t(50) = -2.07$, $p = .044$, $BF_{10} = 1.08$, but not for the control US, $t(50) = 0.47$, $p = .640$, $BF_{10} = 0.17$ (see Table 5).

3.4.1.2. Vividness. Analysis of the US memory vividness ratings revealed a significant main effect of time, $F(1, 50) = 21.54$, $p < .001$, $\eta^2_p = .30$, $BF_{10} = 82346.26$, and intervention, $F(1, 50) = 6.84$, $p = .012$, $\eta^2_p = .12$, $BF_{10} = 1.81$. The interaction between time and intervention was not significant, $F < 1$, $BF_{10} = 0.23$. The main effect of time was due to a decrease of US memory vividness from pre to post-test for both USs and the main effect of intervention was due to higher US memory vividness ratings for the control US than for the devalued US (see Table 5).

3.4.2. Conditioned disgust ratings

3.4.2.1. Acquisition phase. The analyses of the disgust ratings in the acquisition phase revealed a significant main effect of trial, $F(2.35, 117.69) = 16.67$, $p < .001$, $\eta^2_p = .25$, $BF_{10} = 1.605e+16$, but not for CS, $F(1.62, 81.03) = 2.58$, $p = .093$, $\eta^2_p = .05$, $BF_{10} = 1.23$. Most importantly, the interaction effect between CS and trial was significant, $F(4.87, 243.57) = 5.58$, $p < .001$, $\eta^2_p = .10$, $BF_{10} = 4406.53$. This interaction demonstrates that our conditioning procedure was successful to install higher disgust ratings for the CS + s compared to the CS- at the end of the acquisition phase (see Fig. 3).

3.4.2.2. Pre and post memory devaluation. Analyses of the disgust ratings pre and post the EM intervention only revealed a main effect of CS, $F(1.70, 84.87) = 5.23$, $p = .010$, $\eta^2_p = .10$, $BF_{10} = 820.36$, but no main effect of trial, $F < 1$, $BF_{10} = 0.13$ or an interaction between CS and trial, $F(1.77, 88.63) = 1.25$, $p = .289$, $\eta^2_p = .02$, $BF_{10} = 0.08$. This result indicates that our manipulation was ineffective to reduce conditioned disgust ratings (see Fig. 3).

3.4.3. Electromyography

Due to the lack of clear conditioned disgust acquisition on this measure, we report the results of this measure in the Supplementary Materials only.

3.4.4. Skin conductance responses

3.4.4.1. Acquisition phase. The analyses of the SCRs during the acquisition phase also only revealed a significant main effect of trial, $F(4.65, 204.52) = 8.78$, $p < .001$, $\eta^2_p = .17$, $BF_{10} = 3.415e+8$, but no main effect of CS, and no interaction effect between CS and trial, *F*-values < 1, $BFs_{10} < 0.03$. The main effect of trial was due to higher SCRs on the first trial of the acquisition phase compared to the later trials of the acquisition phase.

3.4.4.2. Pre and post memory devaluation. The analyses of the SCRs pre and post the EM intervention revealed significant main effects of CS, $F(2, 86) = 3.59$, $p = .032$, $\eta^2_p = .08$, $BF_{10} = 1.19$, and of time, $F(1, 43) = 20.40$, $p < .001$, $\eta^2_p = .32$, $BF_{10} = 570.16$, but no interaction effect between CS and time, $F(2, 86) = 1.53$, $p = .223$, $\eta^2_p = .03$, $BF_{10} = 0.29$. The main effect of time was due to a sharp increase in SCRs from the end of the acquisition phase to the first trial of the test phase (see Fig. 4). The

Table 5
Mean (SD) US memory emotionality and vividness ratings before and after the US devaluation intervention in Experiment 2.

	Emotionality ratings		Vividness ratings	
	Pre-rating	Post-rating	Pre-rating	Post-rating
EM condition	57.20 (27.53)	51.00 (27.38)	75.38 (18.26)	65.08 (21.97)
Control condition	58.20 (29.46)	59.86 (28.12)	78.68 (17.74)	70.12 (23.40)

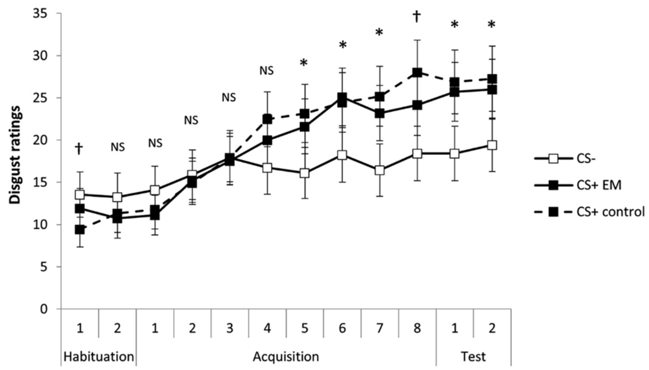

Fig. 3. Disgust ratings for the different CSs throughout the habituation, acquisition and test phase of Experiment 2. Error bars reflect standard error. Notes: * indicates that mean disgust ratings for CS + EM and CS + control were significantly ($p < .05$) different from CS-; NS indicates no significant differences; † indicates that CS+ control and CS- were significantly different, whereas the other contrasts were not.

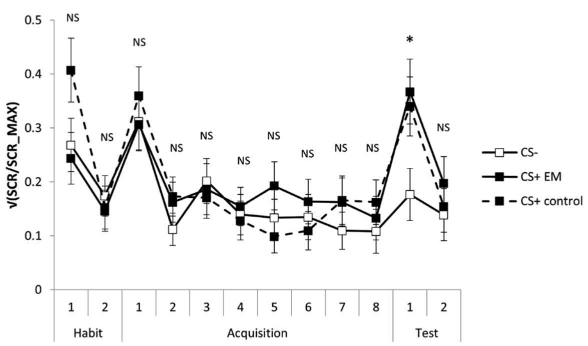

Fig. 4. Range corrected and square root transformed SCRs (measured in μS) for the different CSs throughout the habituation, acquisition and test phase of Experiment 2. Error bars reflect standard error. Notes: * indicates that SCRs for CS + EM and CS + control were significantly (p < .05) different from CS-; NS indicates no significant differences.

main effect of CS was due to stronger SCRs towards the CS + EM, $F(1, 43) = 5.33$, $p = .026$, $\eta^2_p = .11$, $BF_{10} = 2.84$, and the CS + control, $F(1, 43) = 7.93$, $p = .007$, $\eta^2_p = .16$, $BF_{10} = 3.56$, than to the CS- (see Fig. 4). CS + EM and CS + control did not differ significantly from each other, $F < 1$, $BF_{10} = 0.16$. The CS main effect likely reflects successful conditioning of SCRs, probably because participants were informed prior to the test phase that the CSs might again be followed by the USs (for similar findings in the context of conditioned fear, see: Duits et al., 2017; Mertens & De Houwer, 2016).

3.5. Discussion

The results of our second study again illustrate successful conditioning of disgust reactions as evidenced by the disgust ratings and, more tentatively, by the SCRs. However, we did not obtain evidence for disgust conditioning for corrugator EMG activity.

With regard to our main hypothesis, we did not find any evidence for effects of US memory devaluation on conditioned responses, despite trend-level evidence that our memory devaluation procedure was successful. This could indicate that conditioned disgust is not sensitive enough to devaluation of the US memory representation, or that our US memory devaluation procedure was insufficiently effective.

4. General discussion

We investigated whether a US memory devaluation procedure can reduce conditioned disgust reactions. In two experiments we found clear evidence for the acquisition of conditioned disgust, replicating previous findings (Borg et al., 2016; Bosman et al., 2016; Mason & Richardson, 2010; Olatunji, Forsyth et al., 2007). However, with regard to our main hypothesis, the results of both experiments provided no compelling evidence that US memory devaluation modulates disgust memory and reduces conditioned disgust. Particularly, even though a trend in the expected direction for disgust ratings was found in Experiment 1, this result was not confirmed in Experiment 2. Furthermore, for neither behavioral (i.e., BAT) or psychophysiological (i.e., EMG and SCR) measures of disgust could the effect of US memory devaluation be observed.

There are several possible explanations for the failure to observe clear effects of the US memory devaluation intervention on conditioned disgust responses. First, it may simply be ineffective to modulate disgust memory. In both studies, dual-task intervention effects on emotionality and vividness were on a trend-level with inconclusive Bayesian evidence. This contrasts with prior studies that found that this intervention typically reduces vividness and unpleasantness ratings of negative autobiographical memories (meta-analyses: Houben, Otgaar, Roelofs, Merckelbach, & Muris, 2020; Mertens, Lund, & Engelhard, 2020). However, these studies did not specifically address disgust memory. Leer, Engelhard, Altink et al. (2013) found that this intervention reduced negative valence ratings of disgust memory, but they did not collect disgust ratings. In the current research, the lack of intervention effects was partly due to similar decreases in ratings in control conditions, perhaps due to decay for memory of a film clip that is not personally relevant. Moreover, disgust is more refractory than fear (e.g., Olatunji et al., 2009; Bosman et al., 2016), so perhaps the interventions were also too brief (Experiment 1: 4 × 24 s; Experiment 2: 6 × 24 s) to strongly affect the unique interoceptive consequences of disgust (i.e., nausea). Perhaps a prolonged intervention (van Veen et al., 2020) would be more effective. Second, perhaps US devaluation interventions are not successful to reduce conditioned disgust responses. Earlier research found that they reduce conditioned fear (Leer, Engelhard, Altink et al., 2013; Leer, Engelhard, Dibbets et al., 2013). However, these effects have so far only been observed for subjective fear measures, and not for behavioral or psychophysiological measures (Landkroon et al., 2020). As such, it is possible that the effects of US devaluation procedures are mostly limited to self-report measures (such as the disgust ratings in Experiment 1).

With regard to clinical implications, our results do not support the use of memory devaluation techniques within clinical settings to reduce conditioned disgust. This mirrors recent findings from laboratory research regarding the limited use of US memory devaluation techniques for conditioned fear (Kunze, Arntz, & Kindt, 2019). Yet, prior research has demonstrated that disgust plays an important role in the development and maintenance of PTSD, particularly when sexual violence is the index trauma, and clinical trials have demonstrated that EMDR for PTSD is effective (Cuijpers et al., 2020). One explanation for the discrepancies between findings from laboratory and clinical studies is that the former have typically only focused on the dual-tasking component of EMDR and not on the full protocol (e.g., targeting negative cognitions and installing positive cognitions; Shapiro & Forrest, 2016). This suggests that more work needs to be done to calibrate laboratory models of such interventions (which are essential for basic research) and clinical protocols (which are patient-tailored) with one another to allow further investigation into the working mechanisms of such interventions. For example, apart from US-devaluation, cognitive reappraisal may also explain the efficacy of EMDR (Engelhard, McNally, & van Schie, 2019).

Some strengths and limitations of this work can be noted. One strength is the multi-modal assessment of conditioned fear by using subjective ratings, behavioral tasks, and psychophysiological responses. This ensures that our conclusions are not limited to a particular outcome measure, but encompass different emotional response systems (Lang, 1968). Another strength is that we observed successful conditioning for the different measures, thereby replicating earlier research and confirming the validity of the measurements. Limitations include the relatively limited ecological validity of the used CSs (pictures of toasts with different spreads) and USs (movie clips of a women vomiting and diarrhea). This differs from more personally relevant real-life experiences (e.g., experiencing workspace harassment), which may elicit much stronger disgust reactions. Another limitation is the short duration of the dual-task intervention. As mentioned earlier, future studies may want to focus on more prolonged and more powerful US memory devaluation interventions. Finally, a limitation may be that the acquisition and intervention phases were on the same day. This means that the intervention occurred during the memory consolidation process, while in clinical practice, EMDR is thought to disrupt memory *reconsolidation* (e.g., van den Hout & Engelhard, 2012).

In conclusion, in two laboratory studies, we found evidence for the acquisition of disgust through conditioning procedures. However, a dual-task intervention aimed at devaluating US memory representations was unsuccessful at reducing disgust memory and subjective, behavioral, or psychophysiological disgust responses. Further research is needed to understand whether and how US devaluation techniques can be made more effective to modulate personally relevant disgust memory.

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Declarations of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.janxdis.2021.102447.

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