Cognitive Therapy and Research (2019) 43:693–704
https://doi.org/10.1007/s10608-018-09991-6

ORIGINAL ARTICLE

Does Modification of Implicit Associations Regarding Contamination Affect Approach Behavior and Attentional Bias?

Christina Dusend[1] · Laura M. S. De Putter[2] · Ernst H. W. Koster[2] · Fanny A. Dietel[1] · Ulrike Buhlmann[1]

Published online: 2 January 2019

Abstract

Individuals with contamination concerns show aberrant interpretational and attentional processes. Yet, it is unclear whether threat-related associations play a causal role in anxiety symptoms and attentional bias. The objective of our study was to investigate if training implicit associations affects stress reactivity and attention in the context of contamination concerns. In a double-blind randomized design, we used a modified Implicit Associations Task (IAT) to train associations between contamination and danger in a non-clinical sample ($N = 121$). Dependent measures were a brief-IAT to assess changes in associations, contamination-related behavior approach tasks, and a spatial cueing task to measure attentional bias. Results show that training successfully modified implicit associations. However, there were no transfer effects on approach behavior or attention. Findings suggest that the modified IAT is a useful task for training implicit associations, but that transfer to other domains (attention and behavior) is limited. Limitations and future implications are discussed.

Keywords Cognitive bias modification · Implicit associations · Attention · Contamination · Stressor task

Introduction

Cognitive models of the development and maintenance of anxiety stress the importance of aberrant information processing, and propose that among others, biased attention and interpretation processes influence each other. For instance, Ouimet et al. (2009) state in their multi-process model that threat-related associations prompt individuals to interpret stimuli as dangerous, which triggers preferential attentional processing of these stimuli. These processing biases are thought to subsequently influence behavior. Specifically, threat-related associations and attentional bias strengthen fear schemas that lead to avoidance behavior, which in turn prevents disconfirmation of threat (e.g., Beck and Clark 1997). Indeed, a rich body of empirical evidence supports the claim that individuals with obsessive–compulsive disorder (OCD) show biased information processing (for a review, see Hezel and McNally 2016). Jelinek et al. (2009) demonstrated that individuals with OCD produced more threat-related associations as compared to mentally healthy controls, suggesting that threat-related associations represent an important correlate of OCD symptomatology in general.

Recent research has further isolated the role of *specific* threat-related associations within OCD dimensions, such as contamination concerns and washing compulsions. For individuals with these symptoms, the most prominent associated dysfunctional schema is the overestimation of threat (Obsessive Compulsive Cognitions Working Group 2005; for an overview, see Taylor et al. 2010). Such dysfunctional schemas are believed to foster negative appraisals of recurring thoughts, leading to emotional distress and thereby

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10608-018-09991-6) contains supplementary material, which is available to authorized users.

✉ Ulrike Buhlmann
ulrike.buhlmann@uni-muenster.de

Christina Dusend
tina.dusend@uni-muenster.de

Laura M. S. De Putter
Laura.DePutter@UGent.be

Ernst H. W. Koster
Ernst.Koster@UGent.be

Fanny A. Dietel
dietel@uni-muenster.de

[1] Department of Clinical Psychology and Psychotherapy, Westfälische Wilhelms-Universität Münster, Fliednerstrasse 21, 48149 Münster, Germany

[2] Department of Experimental and Clinical Health Psychology, Ghent University, Ghent, Belgium

maintaining OCD symptoms (Salkovskis 1985). Further, for contamination concerns, Green and Teachman (2012) conceptualize schemas, such as overestimation of threat, as implicit associations stored in memory. To investigate overestimation of threat in an implicit way, Nicholson et al. (2014) presented the Implicit Relational Assessment Procedure (IRAP)—a measure of appraisal tendencies at the implicit level—to individuals with elevated washing concerns. As expected, high OC-washers showed a greater threat bias toward contamination-related trials than did low OC-washers. Further, contamination-bias scores predicted avoidance behavior in a subsequent contamination-specific behavioral approach task (BAT, Nicholson et al. 2014).

In addition to the IRAP, other measures have also been shown to predict overestimation of threat. Specifically, in individuals with elevated contamination fears, Green and Teachman (2013) investigated how well approach behavior could be predicted by an implicit measure of threat overestimation, namely the Brief Implicit Association Test (B-IAT), and an explicit measure of threat overestimation, namely questionnaire data. Importantly, they found that contamination-specific behavioral approach could be predicted by the implicit (but not the explicit) measures of threat overestimation (Green and Teachman 2013). These results show that, consistent with the aforementioned theoretical assumptions, threat bias correlates with contamination fears and that this bias is related to symptomatology, such as avoidance. However, their maintaining role within OCD symptoms remains unclear.

Investigating the malleability of implicit associations through cognitive bias modification (CBM) paradigms, namely, computerized trainings tailored to alter information processing, represents a potential step in elucidating this question (e.g., Green and Teachman 2012). Meta-analyses suggest that experimentally modifying pathological information processing via CBM produces medium-sized effects on cognitive patterns and small post-training effects on symptoms in anxious individuals, while far transfer measures, such as emotional reactivity in response to stressor tasks, are rarely affected (e.g., Cristea et al. 2015; Menne-Lothmann et al. 2014). Some studies, however, did find far transfer effects. Regarding the modification of implicit associations, a conditioning paradigm showed modified associations as well as reduced reactivity to a specific stressor task after training for socially anxious participants (Clerkin and Teachman 2010). Green and Teachman (2012) used the same conditioning paradigm to train positive versus neutral associations in individuals with contamination concerns: They presented contamination-related pictures that were followed by smiling faces (positive training), faces with different expressions (neutral training) or no faces (control condition). In this study, they did not find changes in implicit associations and, consequently, no group differences on approach behavior or emotional reactivity to subsequent contamination stressor tasks (Green and Teachman 2012). Since training did not alter implicit associations, the question of causal influence of threat associations on other information processing indices and contamination-specific symptomatology (e.g., attentional bias, avoidance behavior) could not be answered.

To investigate the causal role of threat biases on emotional reactivity, it is important to investigate not only bias reduction (as is often done in CBM research), but also the experimental induction of cognitive biases towards threat (see Van Bockstaele et al. 2014). As outlined above, overestimation of threat can be assessed as a feature of contamination concerns using measures of implicit associations (Green and Teachman 2013; Nicholson et al. 2014). Research shows that implicit associations can be induced using an IAT-training task (Ebert et al. 2009). In this study, the authors were able to modify participants' positive versus negative associations of chocolate and gummy bears by contingently pairing these categories with positive/negative valence. They presented words that participants had to assign to one of four categories (chocolate, gummy bears, positive, negative). Combinations of categories constantly appeared in the upper corners of the screen (e.g., chocolate/positive on the left and gummy bears/negative on the right). Thus, participants reacted to positive words the same way they reacted to chocolate. As a result, participants in the chocolate/positive (vs. gummy bears/positive) condition showed more positive implicit attitudes towards chocolate (vs. gummy bears, respectively) in a subsequent independent assessment task. However, there are no studies to date that have investigated how these altered associations causally relate to symptomatology via inducing implicit associations in contamination concerns.

Cognitive models of anxiety not only emphasize the importance of implicit and explicit information processing, but they also stress the influence of threat schemas and threat associations on attentional orienting (Beck and Clark 1997; Ouimet et al. 2009). To our knowledge, there are no studies focusing on the interplay between implicit associations and attentional bias. Research on the modification of attentional bias in participants with contamination concerns shows that a reduction of attentional bias enhances performance on subsequent concern specific stressor tasks (Najmi and Amir 2010). If implicit threat appraisals indeed determine attentional processes and subsequent avoidance behavior (cf. Beck and Clark 1997; Ouimet et al. 2009), modifying implicit threat associations should influence attentional bias as well as behavioral approach.

The aim of the current study was to modify implicit associations of the construct dimensions *contamination/cleanliness* with *dangerous/not dangerous*. We adapted an implicit association test (IAT, Greenwald et al. 1998), which strengthened the associations of these constructs with contingent feedback. We contrasted two feedback guided conditions to investigate if experimentally induced threat bias influences emotional

reactivity, approach behavior, and attentional processes. In the negative training group (NT), the associations between *contamination* and *dangerous* were strengthened. In the positive training group (PT), the associations between *contamination* and *not dangerous* were strengthened. The control group (CC) did not receive training in a specific direction. After training, we first assessed the modified associations with a brief-IAT (B-IAT, Sriram and Greenwald 2009) as a near transfer task: we measured the strength of associations based on how fast participants correctly categorized the presented words. We predicted training-congruent associations for the targeted (trained) categories for the active groups, namely stronger associations between *contamination* and *dangerous* in the NT and stronger associations between *contamination* and *not dangerous* in the PT compared to the CC. Second, we investigated the effects of training on behavioral approach and emotional reactivity using two BATs that induced contamination-specific concerns. We hypothesized that participants in the NT versus PT group would perform fewer versus more steps in the BATs and exhibit higher versus lower anxiety ratings compared to the CC. Third, we assessed if training effects transferred to attentional processes using the spatial cueing paradigm (Posner 1980) where we examined effects on early versus late attentional bias. In line with previous work, we hypothesized higher versus lower attentional bias in early and late processing stages in the NT versus PT group compared to the CC.

Methods

Participants

Participants were recruited at a state university and were submitted to an online screening questionnaire for eligibility. Exclusion criteria were current or recent (last 2 years) mental disorder, psychotherapy or intake of psychotropic drugs, current suicidal ideation, or age of < 18 years. Participants were only included if they negated all separately assessed criteria.[1] Further, psychology students were only included if they were first year students to prevent effects of salient knowledge of our experimental task or cognitive biases in OCD. The final sample consisted of $N = 121$ mentally healthy individuals (84 female).

Design

We conducted a double-blind randomized control group experiment. Experimental manipulation was the modification of implicit associations of contamination and danger, via a modified IAT training task. There were two active training groups, the negative training group (NT; $n = 40$), with paired categories of contamination/dangerous, and the positive training group (PT; $n = 40$), with paired categories of contamination/not dangerous. Both training groups received feedback on whether categorization was correct or not. The no-training control group (CC; $n = 41$) received a sham training, with changing categories and without feedback. There were three dependent measures: we assessed differences in (1) implicit associations, (2) approach behavior and emotional reactivity, and (3) attentional bias between groups. Participants and the experimenter were blind to group allocation.

Materials and Tasks

Self-report Measures

To rule out severe obsessive–compulsive symptomatology, the widely used *Obsessive–Compulsive Inventory-Revised* (OCI-R, Foa et al. 2002; German version: Gönner et al. 2007) was administered. It is a reliable 18-item self-report questionnaire using a 5-point Likert scale to assess OC symptom severity on six subscales (washing, checking, ordering, obsessing, hoarding, and neutralizing). The internal consistency in this study was $\alpha = .86$.

The *State-Trait Anxiety Inventory* for Adults (STAI Form Y: Spielberger et al. 1977) assesses state and trait components of anxiety separately with good psychometric properties. Both versions were administered consisting of 20 items rated on a 4-point Likert scale, with higher sum scores indicating higher state and trait anxiety, respectively. The trait version was administered to control for baseline group differences. The state version was conducted to examine effects of the stressor task on change in anxiety. Internal consistency in the current sample was $\alpha = .87$ (STAI-S_1), $\alpha = .94$ (STAI-S_2) and $\alpha = .92$ (STAI-T).

To control for depressive symptoms, the widely used *Beck Depression Inventory-II* (BDI-II, Beck et al. 1996; German version:; Hautzinger et al. 2006) was administered, a reliable and valid self-report questionnaire that consists of 21 items rated on a 4-point-scale with higher scores indicating more severe symptoms. Internal consistency of our sample was $\alpha = .82$.

Stimuli for Reaction Time Tasks

A set of contamination-related (CR) words was validated prior to this study (for a more detailed description, see Dusend et al. (2018). Words for the categories *cleanliness* and *not dangerous* were taken from the Berlin Affective Word List Reloaded (BAWL-R, Võ et al. 2009). Words

[1] We assessed current depressive symptoms and suicidal ideation again upon arrival prior to study conduction. Participants were excluded prior to the study when they had a sum score of more than 19 or a score of more than 1 on the item no 9 in the BDI-II ($N = 0$).

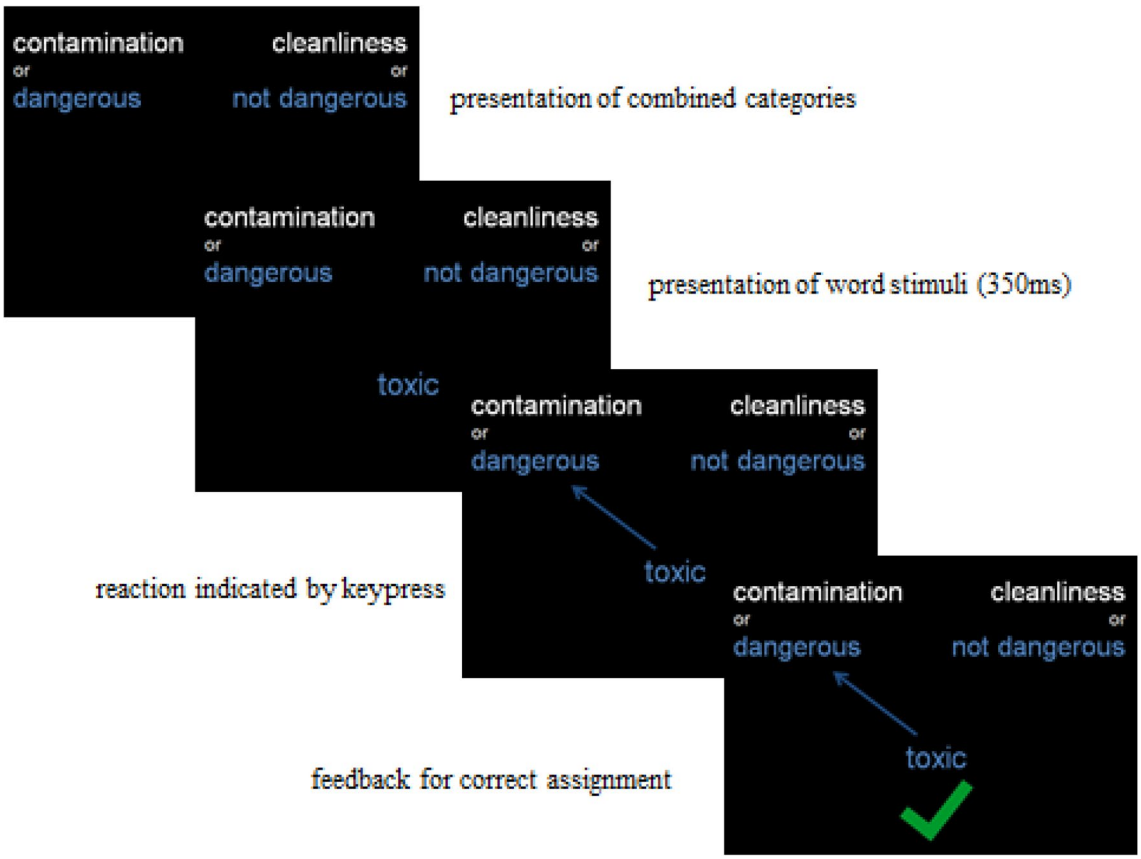

Fig. 1 Sequence of a negative training trial on the modified IAT

were matched within categories *contamination/cleanliness* and *dangerous/not dangerous* by number of syllables and letters and word frequency. Word sets are listed in the Supplementary Material.

Experimental Manipulation

To modify implicit associations, we used a modified version of the Implicit Association Test (IAT, Greenwald et al. 1998). Words were presented in the middle of the screen, and participants had to correctly assign them to their category by pressing a key on the corresponding side (see Fig. 1). We used four different sets of words that could be assigned to one of four categories: *contamination/cleanliness* and *dangerous/not dangerous*. Categories were combined and presented at the top corners of the screen during the whole experiment. Modification training was defined as per the presented combination of categories: OC-relevant pairs in the NT: *contamination/dangerous* and *cleanliness/not dangerous* (by assigning words of the category *contamination* to the same side with the same reaction key as words of the category *dangerous*, associations between these concepts are implicitly strengthened); OC incompatible pairs in the PT: *contamination/not dangerous* and *cleanliness/dangerous*, such that contrary associations were strengthened. In the CC, all pairs were alternately presented and in a balanced ratio; thus, no associations were purposefully strengthened. Feedback about correct or incorrect assignment of words was presented after each trial in the two active training groups to enhance modification effects.

Participants learned the initial assignments of words and categories in practice trials. Only two categories (e.g., *dangerous* and *not dangerous*) were presented to which all words (e.g., toxic, creative) of these categories were assigned. All participants received feedback about the correct assignment of words to categories. Incorrect responses had to be corrected. We selected only adjectives for the categories *dangerous/not dangerous* and only nouns for the categories *contamination/cleanliness* to facilitate assignment of words and make it more distinct. Adjectives were presented in blue text and nouns in white text on a black screen. Participants conducted four practice blocks with 16 trials each. One trial was defined by assigning the presented word (350 ms presentation duration) to one of the categories and receiving feedback. The training phase consisted of 256 words split into four blocks. For each block, all word stimuli were

presented twice in a randomized order. To increase chances of transfer, we doubled the number of trials used in the induction study by Ebert et al. (2009). Between blocks, categories switched sides in the active training groups or were interchanged in the control group. There was a 1 min break after the first two blocks to allow participants to rest between blocks, thus minimizing effects of fatigue on concentration.

Implicit Associations

Modification effects on implicit associations were assessed with the Brief Implicit Association Test (B-IAT; Sriram and Greenwald 2009). The short version of the IAT measures associations of *one* relevant concept (i.e., contamination *or* cleanliness) and two attribute dimensions (i.e., dangerous and not dangerous). Of interest was the change in association between *contamination/dangerous* versus *contamination/not dangerous*, as a near transfer dependent measure for the modification in the NT versus PT. We thus conducted a contamination B-IAT. This means that the category *contamination* was displayed in the top middle position of the screen throughout the task in combination with either the *dangerous* or the *not dangerous* attribute. We randomized position (top/bottom) of displayed concepts resulting in four blocks (*contamination/dangerous, contamination/not dangerous, dangerous/contamination, not dangerous/contamination*)[2] that were presented in randomized order. We presented the same words of all four categories as in the modified IAT. Words were presented at random order in the middle of the screen (32 trials per block) and participants had to indicate whether or not the presented word (e.g., "toxic") belonged to one of the two categories displayed (e.g., *contamination/dangerous*) by pressing the corresponding key (e.g., "yes"). Reaction times and error rates were assessed over 128 trials. The most reliable indicator for strength of association is the *D* Score (Greenwald et al. 2003; Nosek et al. 2014). We therefore calculated the mean difference of category pairs of interest (*contamination/dangerous* minus *contamination/not dangerous*) divided by the overall standard deviation to compare association strength of the relevant concepts. A negative *D* indicates stronger association of *contamination/dangerous* as compared to association of *contamination/not dangerous*.

Approach Behavior

To test for modification effects on anxiety and approach behavior during a contamination-specific stressor task, we used two *Behavioral Approach Tests* (BATs). BATs were conducted using (1) the toilet of the laboratory and (2) artificial animal feces (a mixture of potting soil, cocoa, curry, chocolate spread sprayed with a fragrance that smells like feces). Each BAT consisted of six steps increasing in difficulty (for the toilet-BAT, step 1: touch toilet seat with a paper towel, step 2: touch toilet seat with index finger, step 3: touch toilet seat with palm, step 4: touch inside of toilet with a paper towel, step 5: touch inside of toilet with index finger, step 6: touch inside of toilet with index finger and then rub hands and upper arms and chest; for the feces-BAT, step 1: pull plate with feces towards self, step 2: hold face over feces (ca. 5 cm away), step 3: touch feces with a paper towel, step 4: touch feces with index finger, step 5: touch feces with index finger and then rub hands, step 6: touch feces with index finger and then rub upper arms and chest). Number of conducted steps indexed approach behavior. For emotional reactivity, participants rated their anxiety, disgust and urge to wash their hands on a scale from 0 (*not at all*) to 10 (*very much*) after each conducted step of the BAT. Participants rated the credibility of the BATs on a 5-point scale (ranging from 1 *not at all* to 5 *very* credible) at the end of the experiment.

Attentional Bias

We used the *spatial cueing task* (cf. Posner 1980) adapted by Cisler and Olatunji (2010) to assess attentional bias. Two empty white placeholders were displayed left and right of a white fixation cross on a black screen. The cue, a contamination, generally threatening or neutral[3] word, was presented in one of the two boxes and the other box was left empty. Presentation durations of words were 14 ms for early or 500 ms for later processing, respectively. A discrimination probe (either "X" or "/") appeared either in the location of the word replacing it (valid trials) or in the opposite location of the empty box (invalid trials). Participants had to respond correctly to the probe by pressing the corresponding key as fast as possible. We used 160 trials (96 CR) for analyses and computation of bias scores[4]. Trials were counterbalanced by validity and presentation duration. Internal consistency for types of trials was $\alpha = .76–.87$.

As conventional mean attentional bias scores, we calculated cue validity scores (Koster et al. 2005; Mogg et al.

[2] In the following we will describe the blocks using the notation contamination/dangerous and contamination/not dangerous. This includes the blocks with reversed positions of same categories.

[3] Words of the cleanliness set were used as neutral words for the spatial cueing task. To keep consistent with other studies, we refer to them as neutral words (since they are not related to danger or specific concerns) for the spatial cueing task.

[4] The spatial cueing task contained 192 trials. Due to an error in programming, general threatening words were presented only on the left side of the screen. We did not use them for analyses to avoid bias of presentation location.

2008). First, we calculated cue validity for CR trials (subtracting average *valid* from average *invalid* CR reaction times) and cue validity for neutral trials (subtracting average *valid* from average *invalid* neutral reaction times). Second, we computed attentional bias by subtracting neutral cue validity scores from CR cue validity scores. Thus, positive scores indicate faster reactions for CR compared to neutral cues. Attentional bias scores were calculated separately for automatic (14 ms) and strategic (500 ms) processing.

We further focused on temporal dynamics of attentional bias using the methodology from Zvielli et al. (2015): we calculated trial-level bias scores (TLBS) using the difference in reaction times of adjacent trials, matching neutral trials with the most proximate CR trials and vice versa, for each duration time and each participant, separately. This generated bias scores over the time course of the experiment, accounting for the nature of attentional bias as a process expressed repeatedly over time (cf. Zvielli et al. 2015). We adapted this method to fit the spatial cueing paradigm as described by Davis et al. (2016): We computed the mean $TLBS_{towards}$ (the degree to which the attention is shifted toward the CR-stimuli), and the mean $TLBS_{away,}$ (the degree to which the attention is shifted away from the CR-stimuli). We then computed the variability in TLBS (the sum of all distances between sequential TLBS divided by the total number of TLBS), indicating the dynamic changes of the attentional bias toward or away from CR-stimuli.

Manipulation Checks

Participants filled out ratings of word stimuli on a 10-point scale (*not at all* to *extremely*) assessing contamination-relevant emotions (anxiety, disgust, shame, arousal) triggered by the words. Likewise, we assessed valence of words (*unpleasant* to *pleasant*). We also checked the readability of words presented for 14 ms with a categorization task, where the set up was the same as in the spatial cueing task. Contamination and cleanliness words were presented for 14 ms and participants had to select the correct category via keypress. Finally, participants were asked to indicate what experimental task on the IAT they had encountered (NT, PT or CC), after receiving information about experimental conditions. We conducted analyses on these measures to ensure effectiveness of the conducted experimental tasks. See Supplementary Material for more detailed information and results.

Procedure

Our institutional ethics committee approved the study. Measures, tasks and instructions for the experimenter were standardized. All computer tasks were programmed and presented with Inquisit 4 (2016) on a 21.5 inch ProLite Iiyama computer screen. Randomization to condition was also programmed, leaving participants and the experimenter blind to condition.

Participants conducted the experiment in a 90-min single session. Upon arrival, participants provided informed consent and filled out a demographic questionnaire and self-report measures (STAI-S, STAI-T, OCI-R, BDI-II). Then the experimental manipulation via the modified IAT was presented, after which participants first conducted the B-IAT, then the spatial cueing task and last the BATs. Participants were instructed through an active relaxation exercise (e.g., stretching) for a short break between reaction time tasks. Finally, participants rated their current feeling on the STAI-S again and conducted further manipulation checks (categorization task, credibility ratings of BATs, ratings of word stimuli, indication of experimental group). Afterwards, they were debriefed and received either course credit or financial compensation.

Results

Baseline Measures

Table 1 presents means and standard deviations of the demographic characteristics and baseline measures per group. Groups did not differ on gender, $\chi^2(2) = 1.65$, $p = .44$, $V = 0.08$. There were significant differences on mean years of education (cf. Table 1). Yet, there were no significant differences on educational degree between groups, $\chi^2(4) = 5.61$, $p = .23$, $V = 0.11$. Education was not considered as a relevant covariate for analyses since there is no a priori reason for influences of education on any of the variables of interest.

Modification of Implicit Associations

Data from the B-IAT were prepared for analyses according to Nosek et al. (2014). Participants with an error rate of more than 30% or a higher than 10% rate of reactions below 300 ms were excluded from analyses ($n = 1$). Further, we prepared data for analyses by winsorizing reaction times to 400 ms on the faster end and 2000 ms on the slower end. Results of the one-way ANOVA on the *D* for our focal category *contamination* showed significant group differences, $F(2,117) = 4.07$, $p = .02$, $\eta_p^2 = .05$. Follow-up independent samples *t*-tests showed a significantly lower *D* in the NT group (vs. PT group), $t(77) = 2.85$, $p < .01$, $d = 0.64$, indicating stronger negative associations in the NT group. Comparisons of the NT to the CC group, $t(78) = 0.82$, $p = .41$, $d = 0.18$, and of the CC to the PT group, $t(79) = 1.96$, $p = .053$, $d = 0.44$, were non-significant.

Table 1 Demographics and questionnaire data for each group

	Negative training ($n=40$)		No training ($n=41$)		Positive training ($n=40$)		F	p	η_p^2
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*			
Age (years)	23.18	(3.00)	23.90	(3.27)	23.25	(3.59)	0.60	.55	.01
Education (years)	16.25	(2.50)	17.17	(3.01)	15.70	(2.38)	3.20	.04	.05
OCI-R	9.16	(11.02)	7.27	(6.11)	5.55	(4.30)	2.23	.11	.04
OCI-R_wash	0.83	(1.62)	0.56	(1.00)	0.68	(1.65)	0.34	.72	.01
BDI-II	6.00	(5.38)	5.00	(4.20)	5.20	(4.46)	0.51	.60	.00
STAI-T	32.83	(7.50)	32.32	(8.74)	32.05	(9.47)	0.08	.92	.00
STAI-S1	30.45	(5.58)	31.32	(6.47)	31.50	(6.72)	0.32	.73	.00
STAI-S2	34.50	(9.53)	35.32	(9.40)	33.68	(10.14)	0.29	.75	.00

OCI-R Obsessive–Compulsive Inventory-Revised, *OCI-R_wash* subscale of the OCI-R assessing contamination concerns and washing compulsions, *BDI-II* Beck Depression Inventory-II, *STAI-T* State-Trait Anxiety Inventory Form Y Trait Version, *STAI-S1* State-Trait Anxiety Inventory Form Y State Version at pre-assessment, *STAI-S2* State-Trait Anxiety Inventory Form Y State Version at post-assessment

Behavioral Approach Task

We collapsed analyses of emotional reactivity over both BATs and calculated total mean scores of anxiety, disgust and urge to wash-ratings as well as total number of conducted steps. Correlational analyses of emotional ratings and steps between BATs lend statistical support for this reduction of data (all $r > .484$, all $p < .001$). Figure 2 gives mean scores of emotion ratings and number of steps per group.

The between-group comparison using Pillai's trace showed no significant group differences on emotional reactivity ratings, $V = 0.03$, $F(8,232) = 0.43$, $p = .90$, $\eta_p^2 = .02$, indicating similar emotion ratings and number of conducted steps on the BATs in all groups.

We assessed state anxiety ratings at the beginning of the experiment and again after the stressor task to explore valid stress induction via BATs. A 3 (group: NT vs. CC vs. PT) × 2 (time: pre-stressor vs. post-stressor) mixed ANOVA with repeated measures on the second factor showed a significant main effect of Time $F(1,118) = 28.43$, $p < .001$, $\eta_p^2 = .19$. There was an overall increase in state anxiety from pre ($M = 31.09$, $SD = 6.28$) to post ($M = 34.50$, $SD = 9.70$) assessment, suggesting the effectiveness of the BATs as a stressor task[5]. The main effect of group, $F(2,118) = 0.16$, $p = .86$, $\eta_p^2 < .01$, and the interaction effect, $F(2,118) = 0.93$, $p = .40$, $\eta_p^2 = .02$, were non-significant.

We also assessed ratings of credibility for constructed BATs. BATs were rated as quite credible (feces: $M = 3.68$, $SD = 1.01$; toilet: $M = 3.80$, $SD = 1.02$). The between group comparison using Pillai's trace showed no significant group differences on any credibility ratings, $V = 0.02$, $F(4,236) = 0.59$, $p = .67$, $\eta_p^2 = .01$.

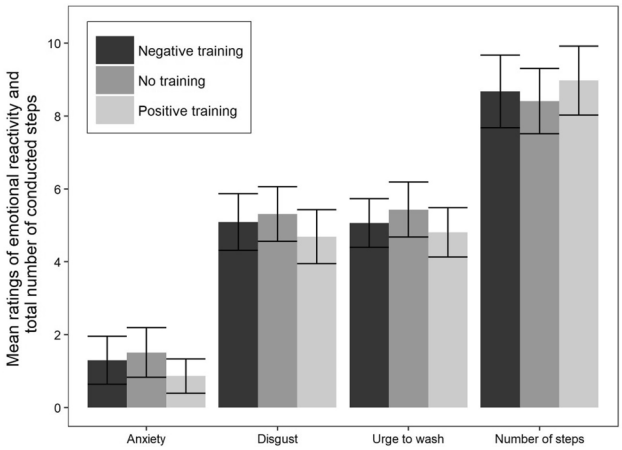

Fig. 2 Mean performance ratings on the BATs per group

Attentional Bias

Reaction time data from the spatial cueing task were prepared for analyses in line with previous research (e.g., Zvielli et al. 2014). We eliminated error trials and trials with reaction times outside of a fixed range of 200 ms and 1500 ms. We cleared the data of outliers having ±3 standard deviations of the participant's mean reaction time. This resulted in a mean number of 7.85 eliminations per participant. We thus included 95.09% of reaction time data for analyses. Table 2 provides means and standard deviations of reaction times on the spatial cueing task for group, presentation duration, validity and valence separately.

For the conventional analyses of attentional bias, one participant was excluded due to too many errors and outliers

[5] We provide further analyses in the Supplementary Material confirming our conclusion that increase in stress reactivity occurred in response to the BATs and is not related to other aspects of the experiment. Please find a time-course of adverse emotionality ratings assessed over visual analogue scales in the Supplementary Material.

Table 2 Reaction time means on the spatial cueing task

	Negative training ($n=40$)		No training ($n=40$)		Positive training ($n=40$)	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
14 ms						
Valid CR	443	(72)	441	(69)	439	(54)
Valid neutral	442	(78)	436	(65)	443	(57)
Invalid CR	418	(66)	427	(82)	422	(55)
Invalid neutral	419	(77)	420	(74)	426	(66)
500 ms						
Valid CR	496	(82)	482	(81)	493	(85)
Valid neutral	498	(98)	491	(78)	506	(94)
Invalid CR	478	(76)	475	(68)	489	(57)
Invalid neutral	478	(75)	481	(79)	490	(68)

Standard deviations are in parentheses, reaction times in milliseconds

CR contamination-related word type, *neutral* neutral word type

Table 3 Conventional mean bias scores and TLBS per presentation duration for each group

	Negative training ($n=40$)		No training ($n=40$)		Positive training ($n=39$)		*F*	*p*	η_p^2
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)			
14 ms									
Conventional AB	−1.41	(38.86)	1.48	(51.57)	−0.03	(46.70)	0.05	.95	< .01
$TLBS_{towards}$	100.13	(35.65)	101.71	(36.52)	93.99	(30.28)	0.56	.57	.01
$TLBS_{away}$	−103.09	(48.22)	−104.46	(43.50)	−98.66	(26.85)	0.22	.80	< .01
$TLBS_{variability}$	130.28	(52.12)	132.31	(47.67)	122.59	(29.81)	0.53	.59	.01
500 ms									
Conventional AB	2.33	(60.53)	2.80	(53.33)	11.27	(49.13)	0.49	.62	.01
$TLBS_{towards}$	108.21	(53.85)	110.48	(34.61)	111.56	(53.15)	0.05	.95	< .01
$TLBS_{away}$	−110.16	(42.11)	−106.89	(34.53)	−114.09	(45.87)	0.30	.74	.01
$TLBS_{variability}$	143.62	(60.02)	139.23	(40.11)	147.61	(58.85)	0.24	.79	< .01

Standard deviations are in parentheses; reaction times in milliseconds; conventional AB = mean cue validity bias score; *TLBS* trial-level bias score

(69% missing data after cleaning). An overall 3 (group: NT vs. CC vs. PT) × 2 (valence: CR vs. neutral) × 2 (validity: valid vs. invalid) × 2 (presentation duration: 14 ms vs. 500 ms) mixed ANOVA was conducted with mean reaction times. Results showed a significant main effect of validity, $F(1,117) = 24.17$, $p < .001$, $\eta_p^2 = .17$, showing faster reactions on invalid ($M = 452$, $SD = 65$) than valid trials ($M = 468$, $SD = 70$). There also was a significant main effect of presentation duration, $F(1,117) = 359.02$, $p < .001$, $\eta_p^2 = .75$, showing faster reactions for words presented for a shorter duration (14 ms; $M = 431$, $SD = 65$) than for a longer duration (500 ms; $M = 488$, $SD = 70$). The 4-way interaction effect of interest for our hypothesis testing was not significant, $F(2,117) = 0.19$, $p = .83$, $\eta_p^2 < .01$. There were no other significant main or interaction effects (all Fs < 2.48, all ps > .12).[6] Table 3 shows the test results of the ANOVAs with the mean cue validity attentional bias scores per presentation duration.

We further investigated data with the newer dynamic approach of TLBS. We excluded two participants for the analyses because of too few matches of bias pairs. We calculated mean TLBS towards and away from CR stimuli as well as TLBS variability. Table 3 gives test results of the ANOVAs. The results showed no between-group differences on TLBS, indicating the same information processing pattern

[6] We also conducted the same analyses with only both of the active training groups (NT vs. PT), since analyses of the B-IAT suggested significant differences only between those two. Results showed the same pattern, and there were no further significant results supporting hypothesis testing.

over the course of time for CR stimuli compared to neutral words across groups, irrespective of training condition.

Manipulation Check

We checked whether participants saw through the experimental manipulation. At the end of the experiment, we gave information about the three conditions and participants indicated if they thought they conducted the negativity training (selected by $n = 20$), the positivity training ($n = 15$) or no specific training ($n = 86$). A Chi square test showed no differences between groups on indication of training received, $\chi^2(4) = 4.81$, $p = .31$. Results imply that most participants thought they did not receive any specific training and that especially the participants in the active training groups were not aware of receiving certain training.

Discussion

To our knowledge, this is the first study investigating the modification of implicit associations with contamination-relevant material. The aim of our study was to extend previous research by investigating causal effects of contamination-relevant threat bias on behavioral approach, anxiety, and attentional processes as consistent with existing cognitive-behavioral theories (e.g., Ouimet et al. 2009; Salkovskis 1985). We predicted that modification of contamination-relevant associations would lead to elevated versus reduced emotional reactivity, reduced versus enhanced approach behavior in a subsequent contamination stressor task as well as elevated versus reduced attentional bias dependent on negative versus positive association training. Results showed that contamination-relevant associations can be modified using an implicit associations training task. However, in contrast to our hypotheses, no effects of contamination-relevant threat bias on emotional reactivity or attentional bias were observed.

Our study showed that implicit associations between the constructs *contamination* and *dangerous* can be strengthened as well as weakened via training with a modified IAT. The active negative training group showed stronger associations on the B-IAT on the focal categories *contamination/dangerous* compared to focal categories *contamination/not dangerous*, relative to the active positive training group. Results are in line with previous findings that state association strength can be modified using the IAT via implicit learning (Ebert et al. 2009). Further, our results show that contamination-relevant associations can be induced and trained with implicit methods; as such they extend previous research that showed OC beliefs can be modified with explicit methods, such as the ambiguous sentence paradigm (Beadel et al. 2014; Clerkin and Teachman 2011; Williams and Grisham 2013).

Importantly, differences on the B-IAT were evident between the active training groups (NT and PT) but did not reach a significant level in pairwise comparisons with the no-training control group. This might be due to a priori association of targeted categories that the negative *D* score in the CC indicates. These a priori associations show that contamination concerns are present in non-clinical populations as well (e.g., Abramowitz et al. 2014). Changing a priori associations takes longer than inducing new ones (Ebert et al. 2009). In our case, the number of training trials might be an indicator of the duration of the changing process: Assuming that there is no training in the control group, the training duration comparing one of the active groups to the CC is half as long as comparing both active training groups due to the fact that they train in opposite directions. It is possible that changes would have been better detected if the training process had been longer. Further, as mentioned by Clerkin and Teachman (2011), a 50–50 no-training control group could be inappropriate because a priori associations would be modified as well. Future research should consider these points by increasing the number of training trials and assessing bias measures at baseline. Another reason for the absence of differences could be due to our category labels. By choosing the dichotomous category labels *dangerous* and *not dangerous*, the concept of *dangerous* might have been activated for both labels (Park et al. 2001). Further experiments should thus consider a different choice of labels.

The modification of participants' implicit associations was observed on the reaction times in the B-IAT. However, in contrast to what we predicted in our second hypothesis, transfer effects of the training on behavioral approach and emotional reactivity did not occur. Groups neither differed in number of conducted steps on the contamination BATs nor in their ratings of anxiety, disgust or urge to wash hands during these tasks. While these results extend previous failures to modify implicit associations in contamination concerns (Green and Teachman 2012), they are analog to studies targeting modification of interpretation in individuals with OC concerns or compulsions: even though the training was successful via experimental assessment, transfer effects on behavior in subsequent stressor-tasks were not observed (Beadel et al. 2014; Clerkin and Teachman 2011; Williams and Grisham 2013).

Since there is growing evidence that emotional reactivity is altered when a change in bias is evident (e.g., MacLeod and Grafton 2016), our null results are somewhat unexpected. A possible explanation is the different design of the BATs we used compared to the assessments in the aforementioned studies. Clerkin and Teachman (2011) used a thought–action-fusion stressor task targeting Importance of Thought, which is not CR specific nor comparable to our BATs. Williams and Grisham (2013) used a task targeting the overestimation of threat by measuring the time

participants took to clean the keyboard they used in preparation for the next participant. This resembles a neutralizing rather than an approach behavior. Beadel et al. (2014) used an actual contamination BAT instructing participants to touch a pen taken out of the trash in several steps increasing in intensity. We constructed only contamination-specific BATs resembling the ones used by Green and Teachman (2013) and Najmi and Amir (2010), considering our contamination-specific training task.

With these differences in methods used to assess behavior, it is possible that we did not have a good fit between the sample and the BATs, whereby we investigated healthy students and not subclinical OC washers. A meta-analysis on induction procedures showed that OC symptoms are more easily elicited in (sub)clinical samples compared to healthy individuals (De Putter et al. 2017). Therefore, using a subclinical population may have made it easier to detect the transfer effects of changes in contamination-relevant associations to emotional reactivity and behavior. However, the high percentage of participants refusing to continue the BATs shows that negative affect has been evoked in our study. Interestingly, exploratory follow-up analyses on subsamples confirmed an effect of trait-anxiety scores on emotional reactivity, supporting the suggestion that a healthy sample might be too resilient (see Supplementary Material for more detailed information). There was also a methodological limitation in the BATs we used: our results on emotion ratings show that anxiety has a flooring effect. Though credibility ratings were acceptable, it seems that the BATs did not elicit sufficient variability on anxiety ratings and therefore lacked sensitivity to detect differences between groups. Exploratory follow-up analyses on sub-samples lend support that the flooring effect is especially present in participants scoring low on trait anxiety (see Supplementary Material for more detailed information). Even though we used considerably more training trials than comparable studies, it might be that the single-session training or the number of training trials was too short to evoke effects on approach behavior in a healthy sample. In accordance with recent suggestions made by Mogg and Bradley (2018), future studies should use different training procedures that are more likely to target different domains of cognitive processes and more robustly elicit far transfer.

Our third hypothesis regarding transfer of altered contamination-relevant associations to attentional bias cannot be confirmed. There were no interaction effects between reaction times and group or group differences on any reaction times or mean bias scores. Even with the more dynamic approach of TLBS (Zvielli et al. 2015), there were no differences between groups. We additionally conducted a Bayesian repeated measures ANOVA that strengthens our interpretation of findings as null results (see Supplementary Material for more detailed information). These null results are in line with previous research investigating this transfer effect in highly anxious individuals, which found no effect of an 8-session attention training on interpretation bias (Bowler et al. 2017). Accordingly, our results do not lend support for theoretical models stating this transfer (Ouimet et al. 2009), and they contradict earlier findings in socially anxious individuals (Amir et al. 2010). However, we conducted a single-session training on healthy individuals. It might be that transfer effects become evident with a higher dosage of training in a more vulnerable sample. Methodologically, we need to comment on the unexpected reversed main effect of invalidity, indicating faster responses on invalid than on valid trials across presentation duration and groups. This might be due to our 50:50 proportion of valid and invalid trials, since the validity effect correlates with the proportion of valid trials (Arjona et al. 2016). Most previous studies on attentional bias used a 2/3 valid to 1/3 invalid ratio so that the cue can become a valid predictor for the probe and captures participants' attention (Amir et al. 2003; Fox et al. 2002). We reduced the number of trials resulting in a balanced proportion in order to avoid prolonging the already long experimental task, since the cue validity effect nevertheless was evident in previous investigations using a 50:50 proportion (Arjona et al. 2016). For future studies, this proportion should be readapted in favor of valid trials. Finally, although our sample size was quite large compared to previous studies on attentional bias in contamination fear [cf. 26 per group for Najmi and Amir (2010), 23 and 28 per group with Cisler and Olatunji (2010)], our null results could be due to a problem of statistical power. Observed power for the overall interaction only was .11. Post hoc analyses on G*Power (Buchner et al. 2011) revealed that we had sufficient power to detect only large effects. Future research should use larger samples. Besides these methodological adaptations, it would be interesting to compare the IAT-modification paradigm to other procedures that have been shown effective in the field of contamination concerns, such as the modified dot-probe task (Najmi and Amir 2010) or the recently tested word–sentence association task (Conley and Wu 2018).

In sum, our study is the first to show that modification of contamination-relevant implicit associations is possible in a convenience sample. This extends previous research that failed to modify associations in individuals with contamination concerns. Our results not only lend support for the malleability of implicit associations, but they also show that such processes can be trained in a pathological direction. This is a first important step to further understand the mechanisms that cause aberrant information processing in the development of anxiety in OCD. However, while the modification of contamination-relevant associations was effective, we did not find effects on emotional reactivity or behavioral approach in the current sample. Moreover, unlike

previous research, we also did not find transfer effects from the change in contamination-relevant associations onto attentional bias. The latter null finding is not in line with information processing models that state that implicit associations influence attentional orientation and avoidance behaviors. Further research is necessary to understand the underlying processes that relate implicit associations, attention and avoidance.

Acknowledgements We thank Laura Brockhoff, Christina Martin, Ina Tuxhorn and Steffi Wenderlich for their assistance in data collection and preparation. We thank Celeste Brennecka for her valuable support with language and style.

Compliance with Ethical Standards

Conflict of Interest Christina Dusend, Laura M. S. de Putter, Ernst H. W. Koster, Fanny A. Dietel, and Ulrike Buhlmann declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Research Involving Human and Animal Participants This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

Abramowitz, J. S., Fabricant, L. E., Taylor, S., Deacon, B. J., McKay, D., & Storch, E. A. (2014). The relevance of analogue studies for understanding obsessions and compulsions. *Clinical Psychology Review, 34*(3), 206–217. https://doi.org/10.1016/j.cpr.2014.01.004.

Amir, N., Bomyea, J., & Beard, C. (2010). The effect of single-session interpretation modification on attention bias in socially anxious individuals. *Journal of Anxiety Disorders, 24*(2), 178–182. https://doi.org/10.1016/j.janxdis.2009.10.005.

Amir, N., Elias, J., Klumpp, H., & Przeworski, A. (2003). Attentional bias to threat in social phobia: Facilitated processing of threat or difficulty disengaging attention from threat? *Behaviour Research and Therapy, 41*(11), 1325–1335.

Arjona, A., Escudero, M., & Gómez, C. M. (2016). Cue validity probability influences neural processing of targets. *Biological Psychology, 119*, 171–183. https://doi.org/10.1016/j.biopsycho.2016.07.001.

Beadel, J. R., Smyth, F. L., & Teachman, B. A. (2014). Change processes during cognitive bias modification for obsessive compulsive beliefs. *Cognitive Therapy and Research, 38*(2), 103–119. https://doi.org/10.1007/s10608-013-9576-6.

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research and Therapy, 35*(1), 49–58.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *BDI-II, Beck depression inventory: Manual* (2nd edn.). San Antonio: Psychological Corp.; Harcourt Brace.

Bowler, J. O., Hoppitt, L., Illingworth, J., Dalgleish, T., Ononaiye, M., Perez-Olivas, G., & Mackintosh, B. (2017). Asymmetrical transfer effects of cognitive bias modification: Modifying attention to threat influences interpretation of emotional ambiguity, but not vice versa. *Journal of Behavior Therapy and Experimental Psychiatry, 54*, 239–246. https://doi.org/10.1016/j.jbtep.2016.08.011.

Buchner, A., Erdfelder, E., Faul, F., & Lang, A.-G. (2011). *G*Power (Version 3.1.3)*. Kiel.

Cisler, J. M., & Olatunji, B. O. (2010). Components of attentional biases in contamination fear: Evidence for difficulty in disengagement. *Behaviour Research and Therapy, 48*(1), 74–78. https://doi.org/10.1016/j.brat.2009.09.003.

Clerkin, E. M., & Teachman, B. A. (2010). Training implicit social anxiety associations: An experimental intervention. *Journal of Anxiety Disorders, 24*(3), 300–308. https://doi.org/10.1016/j.janxdis.2010.01.001.

Clerkin, E. M., & Teachman, B. A. (2011). Training interpretation biases among individuals with symptoms of obsessive compulsive disorder. *Journal of Behavior Therapy and Experimental Psychiatry, 42*(3), 337–343. https://doi.org/10.1016/j.jbtep.2011.01.003.

Conley, S. L., & Wu, K. D. (2018). Experimental modification of dysfunctional interpretations in individuals with contamination concerns. *Journal of Behavior Therapy and Experimental Psychiatry, 59*, 56–64. https://doi.org/10.1016/j.jbtep.2017.11.005.

Cristea, I. A., Mogoaşe, C., David, D., & Cuijpers, P. (2015). Practitioner review: Cognitive bias modification for mental health problems in children and adolescents: A meta-analysis. *Journal of Child Psychology and Psychiatry, 56*(7), 723–734. https://doi.org/10.1111/jcpp.12383.

Davis, M. L., Rosenfield, D., Bernstein, A., Zvielli, A., Reinecke, A., Beevers, C. G., et al. (2016). Attention bias dynamics and symptom severity during and following CBT for social anxiety disorder. *Journal of Consulting and Clinical Psychology, 84*(9), 795–802. https://doi.org/10.1037/ccp0000125.

De Putter, L. M. S., Van Yper, L., & Koster, E. H. W. (2017). Obsessions and compulsions in the lab: A meta-analysis of procedures to induce symptoms of obsessive-compulsive disorder. *Clinical Psychology Review, 52*, 137–147. https://doi.org/10.1016/j.cpr.2017.01.001.

Dusend, C., De Putter, L. M. S., Koster, E. H. W., Möllmann, A., & Buhlmann, U. (2018). Inducing attentional bias in individuals with elevated contamination concerns: Effects on information processing and approach behavior (Manuscript in preparation).

Ebert, I. D., Steffens, M. C., von Stülpnagel, R., & Jelenec, P. (2009). How to like yourself better, or chocolate less: Changing implicit attitudes with one IAT task. *Journal of Experimental Social Psychology, 45*(5), 1098–1104. https://doi.org/10.1016/j.jesp.2009.06.008.

Foa, E. B., Huppert, J. D., Leiberg, S., Langner, R., Kichic, R., Hajcak, G., & Salkovskis, P. M. (2002). The obsessive-compulsive inventory: Development and validation of a short version. *Psychological Assessment, 14*(4), 485–496. https://doi.org/10.1037/1040-3590.14.4.485.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion, 16*(3), 355–379. https://doi.org/10.1080/02699930143000527.

Gönner, S., Leonhart, R., & Ecker, W. (2007). Das Zwangsinventar OCI-R - die deutsche Version des Obsessive-Compulsive Inventory-Revised. *PPmP: Psychotherapie · Psychosomatik · Medizinische Psychologie, 57*(09/10), 395–404. https://doi.org/10.1055/s-2007-970894.

Green, J. S., & Teachman, B. A. (2012). Is "cootie" in the eye of the beholder? An experimental attempt to modify implicit associations tied to contamination fears. *Journal of Experimental Psychopathology, 3*(3), jep.026111. https://doi.org/10.5127/jep.026111.

Green, J. S., & Teachman, B. A. (2013). Predictive validity of explicit and implicit threat overestimation in contamination fear.

Journal of Obsessive-Compulsive and Related Disorders, 2(1), 1–8. https://doi.org/10.1016/j.jocrd.2012.09.002.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. (1998). Measuring individual differences in implicit cognition: The implicit association test. *Journal of Personality and Social Psychology, 74*(6), 1464–1480.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the implicit association test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology, 85*(2), 197–216.

Hautzinger, M., Keller, F., & Kühner, C. (2006). *Beck Depressionsinventar: BDI II. Revision*. Frankfurt/Main: Harcourt Test Services.

Hezel, D. M., & McNally, R. J. (2016). A theoretical review of cognitive biases and deficits in obsessive–compulsive disorder. *Biological Psychology, 121*, 221–232. https://doi.org/10.1016/j.biopsycho.2015.10.012.

Inquisit 4 [Computer Software]. (2016). Retrieved from http://www.millisecond.com/download/.

Jelinek, L., Hottenrott, B., & Moritz, S. (2009). When cancer is associated with illness but no longer with animal or zodiac sign: Investigation of biased semantic networks in obsessive-compulsive disorder (OCD). *Journal of Anxiety Disorders, 23*(8), 1031–1036. https://doi.org/10.1016/j.janxdis.2009.07.003.

Koster, E. H. W., De Raedt, R., Goeleven, E., Franck, E., & Crombez, G. (2005). Mood-congruent attentional bias in dysphoria: Maintained attention to and impaired disengagement from negative information. *Emotion, 5*(4), 446–455. https://doi.org/10.1037/1528-3542.5.4.446.

MacLeod, C., & Grafton, B. (2016). Anxiety-linked attentional bias and its modification: Illustrating the importance of distinguishing processes and procedures in experimental psychopathology research. *Behaviour Research and Therapy, 86*, 68–86. https://doi.org/10.1016/j.brat.2016.07.005.

Menne-Lothmann, C., Viechtbauer, W., Höhn, P., Kasanova, Z., Haller, S. P., Drukker, M., et al. (2014). How to boost positive interpretations? A meta-analysis of the effectiveness of cognitive bias modification for interpretation. *PLoS ONE, 9*(6), e100925. https://doi.org/10.1371/journal.pone.0100925.

Mogg, K., & Bradley, B. P. (2018). Anxiety and threat-related attention: Cognitive-motivational framework and treatment. *Trends in Cognitive Sciences, 22*(3), 225–240. https://doi.org/10.1016/j.tics.2018.01.001.

Mogg, K., Holmes, A., Garner, M., & Bradley, B. P. (2008). Effects of threat cues on attentional shifting, disengagement and response slowing in anxious individuals. *Behaviour Research and Therapy, 46*(5), 656–667. https://doi.org/10.1016/j.brat.2008.02.011.

Najmi, S., & Amir, N. (2010). The effect of attention training on a behavioral test of contamination fears in individuals with subclinical obsessive-compulsive symptoms. *Journal of Abnormal Psychology, 119*(1), 136–142. https://doi.org/10.1037/a0017549.

Nicholson, E., Dempsey, K., & Barnes-Holmes, D. (2014). The role of responsibility and threat appraisals in contamination fear and obsessive-compulsive tendencies at the implicit level. *Journal of Contextual Behavioral Science, 3*(1), 31–37. https://doi.org/10.1016/j.jcbs.2013.11.001.

Nosek, B. A., Bar-Anan, Y., Sriram, N., Axt, J., & Greenwald, A. G. (2014). Understanding and using the Brief Implicit Association Test: Recommended scoring procedures. *PLoS ONE, 9*(12), e110938. https://doi.org/10.1371/journal.pone.0110938.

Obsessive Compulsive Cognitions Working Group. (2005). Psychometric validation of the obsessive belief questionnaire and interpretation of intrusions inventory—Part 2: Factor analyses and testing of a brief version. *Behaviour Research and Therapy, 43*(11), 1527–1542. https://doi.org/10.1016/j.brat.2004.07.010.

Ouimet, A. J., Gawronski, B., & Dozois, D. J. A. (2009). Cognitive vulnerability to anxiety: A review and an integrative model. *Clinical Psychology Review, 29*(6), 459–470. https://doi.org/10.1016/j.cpr.2009.05.004.

Park, J. W., Yoon, S. O., Kim, K. H., & Wyer, R. S. (2001). Effects of priming a bipolar attribute concept on dimension versus concept-specific accessibility of semantic memory. *Journal of Personality and Social Psychology, 81*(3), 405–420.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*(1), 3–25. https://doi.org/10.1080/00335558008248231.

Salkovskis, P. M. (1985). Obsessional-compulsive problems: A cognitive-behavioural analysis. *Behaviour Research and Therapy, 23*(5), 571–583. https://doi.org/10.1016/0005-7967(85)90105-6.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1977). *State-trait anxiety inventory for adults*. Redwood City: Mindgarden Inc.

Sriram, N., & Greenwald, A. G. (2009). The brief implicit association test. *Experimental Psychology, 56*(4), 283–294. https://doi.org/10.1027/1618-3169.56.4.283.

Taylor, S., Coles, M. E., Abramowitz, J. S., Wu, K. D., Olatunji, B. O., Timpano, K. R., et al. (2010). How are dysfunctional beliefs related to obsessive-compulsive symptoms? *Journal of Cognitive Psychotherapy, 24*(3), 165–176. https://doi.org/10.1891/0889-8391.24.3.165.

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. W. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*(3), 682–721. https://doi.org/10.1037/a0034834.

Võ, M. L. H., Conrad, M., Kuchinke, L., Urton, K., Hofmann, M. J., & Jacobs, A. M. (2009). The Berlin Affective Word List Reloaded (BAWL-R). *Behavior Research Methods, 41*(2), 534–538. https://doi.org/10.3758/BRM.41.2.534.

Williams, A. D., & Grisham, J. R. (2013). Cognitive Bias Modification (CBM) of obsessive compulsive beliefs. BMC Psychiatry. https://doi.org/10.1186/1471-244X-13-256.

Zvielli, A., Bernstein, A., & Koster, E. H. W. (2014). Dynamics of attentional bias to threat in anxious adults: Bias towards and/or away? *PLoS ONE, 9*(8), e104025. https://doi.org/10.1371/journal.pone.0104025.

Zvielli, A., Bernstein, A., & Koster, E. H. W. (2015). Temporal dynamics of attentional bias. *Clinical Psychological Science, 3*(5), 772–788. https://doi.org/10.1177/2167702614551572.