

Accepted for publication in 'Journal of Obsessive-Compulsive and Related Disorders'

Note: This is an uncorrected version of an author's manuscript accepted for publication.

Copyediting, typesetting, and review of the resulting proofs will be undertaken on this manuscript before final publication. During production and pre-press, errors may be discovered that could affect the content. The final publication is available at Elsevier via

<https://doi.org/10.1016/j.jocrd.2017.09.003>

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Do obsessive-compulsive symptoms and contamination-related stimuli affect inhibition
capacity?

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Abstract

The current study set out to investigate trait versus state views regarding inhibitory deficits in participants scoring high and low on contamination fear. Furthermore, it was investigated whether inhibitory deficits are specific for contamination-related stimuli. Participants were selected on high ($n = 40$) vs. low ($n = 44$) contamination fear and subsequently randomly assigned to receive either a neutral induction or an obsessive-compulsive (OCD) symptom induction. Participants performed a stop-signal task including contamination-specific, general negative, and neutral pictures before and after the induction. In contrast to state views, no change in inhibitory performance after the OCD symptom induction and no differential effect of contamination-related picture valence was found. Moreover, in contrast to the trait view, baseline inhibition capacity did not predict an increase in symptoms after an OCD symptom induction. Finally, contrary to expectations, participants high in contamination fear showed better inhibition than low contamination fear controls. Therefore, the results of the current study are inconclusive regarding the state-trait debate, but are clearly in contrast with the idea of trait inhibitory deficits in contamination fear.

Key words: obsessive-compulsive disorder, OCD, inhibition, contamination fear, stop-signal task

1. Introduction

Obsessive-compulsive disorder (OCD) is a persistent and highly invalidating psychiatric disorder characterized by intrusive thoughts and/or compulsions (American Psychiatric Association, 2013). It is a common psychiatric disorder, with a lifetime prevalence of 2-3.5% and is characterized by high levels of individual suffering and substantial economic and societal costs (Angst et al., 2004; Ruscio, Stein, Chiu, & Kessler, 2010). Despite the availability of many efficacious psychological and pharmacological treatments for OCD, many patients suffer from symptoms even after undergoing treatment (Fisher & Wells, 2005). In order to improve treatment, a better understanding of OCD is required.

There is a wealth of research on the etiological and maintaining factors of this disorder. Abnormal functioning of the frontostriatal circuits in OCD has been established as the main neural model for OCD (Saxena & Rauch, 2000). These neural circuits underlie executive functioning (Pauls, Abramovitch, Rauch, & Geller, 2014). Therefore, much of the research on the mechanisms of OCD has focused on the relation between executive functioning and OCD (for meta-analyses see Abramovitch, Abramowitz, & Mittelman, 2013; Shin, Lee, Kim, & Kwon, 2014; Snyder, Kaiser, Warren, & Heller, 2014). Given the repetitive nature of obsessions and compulsions, response inhibition is of specific interest in OCD (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005). Response inhibition refers to the ability to inhibit a prepotent motor response (Logan, 1994).

There are distinct views on the nature of these deficits. Chamberlain et al. (2005) suggested response inhibition to be an *endophenotype* of OCD, which thus would be related to elevated genetic risk for developing OCD. This implies that a deficit in inhibition is largely state *independent* (Gottesman & Gould, 2003). Thus, factors such as the valence of stimuli and current OCD symptoms should not affect inhibition capacity. Studies that support the endophenotype (trait) view show underperformance in inhibition both in OCD patients and

their healthy relatives (Menzies et al., 2007), similar underperformance in OCD patients in remission, and similar underperformance in OCD patients pre- compared to post-treatment (Bannon, Gonsalvez, Croft, & Boyce, 2006). Moreover, several studies have shown that good inhibitory control can protect from negative effects of repeated checking (Linkovski, Kalanthroff, Henik, & Anholt, 2013) and priming response inhibition affects behavioral responses to uncertainty, which is an important aspect in OCD (Kalanthroff, Linkovski, Henik, Wheaton, & Anholt, 2017). In contrast, Abramovitch and Cooperman (2015) argue that the current empirical evidence challenges this assumption. For instance, although some studies do not find differences in neuropsychological performance after treatment, other research has shown improvement in neuropsychological performance following successful treatment (e.g., Andrés et al., 2008; Kuelz et al., 2006; Voderholzer et al., 2013). Moreover, some studies find an association between neuropsychological functioning and OCD symptom severity (e.g., Abramovitch, Dar, Schweiger, & Hermesh, 2011; Trivedi et al., 2008), although these results are mixed (see Kuelz, Hohagen, & Voderholzer, 2004). However, the lack of a clear association between neuropsychological functioning and OCD severity could be due to methodological shortcomings (Abramovitch & Cooperman, 2015).

As an alternative to the endophenotype (trait) view, Abramovitch, Dar, Hermesh, and Schweiger (2012) introduced the executive overload model of OCD. In this state model, the overflow of symptoms in OCD, which is associated with hyperactivity of the frontostriatal system, is caused by continuous attempts of OCD patients to control automatic processes. This subsequently leads to an overload on the executive system that causes neuropsychological impairments. The manifestations of these cognitive impairments can subsequently activate “fear of impulsivity” or the feeling that one is not in control. In order to compensate, patients exert increased control over automatic processes, which results in a vicious cycle. This state model implies that an OCD symptom induction in the lab could

overload the executive system, which should subsequently lead to an underperformance in inhibition tasks.

To date, few studies took such context dependent effects of current OCD symptoms and valence-specific stimuli into account. Some research that has taken into account the valence-specificity of stimuli has found that disorder-relevant stimuli influence inhibition capacity (Harkin & Kessler, 2012; Linkovski, Kalanthroff, Henik, & Anholt, 2016). Moreover, Kalanthroff, Aslan, and Dar (2017) showed that inducing mental contamination through threatened morality negatively impacted response inhibition capacity if the effects of the induction were not nullified by washing hands. Currently most research that examines the nature of inhibitory impairments has been of correlational nature. Therefore it is not possible to establish the direction of the influence of inhibition on OCD (Abramovitch & Cooperman, 2015).

The current study tested the differential hypotheses of trait versus state models of inhibitory control in OCD in the context of contamination fear. We focused on the contamination subtype of OCD, as contamination fear is relatively easy to induce in the laboratory (Rachman, 2004). Contamination fear is one of the most common subtypes of OCD (Ball, Baer, & Otto, 1996) and consists of fears of being contaminated or spreading contamination (Markarian et al., 2010). In order to test the effect of a contamination fear induction on inhibition, we chose to select participants scoring high on contamination fear (HCF) and participants scoring low on contamination fear (LCF). Abramowitz et al. (2014) showed that OCD symptoms are dimensional rather than categorical in frequency and severity and that similar causal and maintenance factors occur in clinical and nonclinical samples. Since response inhibition has been suggested as an endophenotype of OCD (Chamberlain et al., 2005), we would expect to observe decreased inhibition capacity in participants scoring high in contamination fear. We investigated whether a deficit in inhibition would be specific

for a symptomatic state by assessing inhibition before and after an OCD symptom induction. According to the trait view this manipulation should have little effect on inhibitory control whereas state-related views predict changes in line with state manipulations. One of the methods that is used to elicit contamination fear symptoms in the lab is mental contamination (De Putter, Van Yper, & Koster, 2017). Mental contamination consists of a sense of internal dirtiness and is often characterized by a moral element (Rachman, 2004). Mental contamination is often evoked by the non-consensual kiss paradigm, in which participants imagine that someone tries to kiss them without their consent (e.g., Elliott & Radomsky, 2012). Furthermore, we examined whether a deficit in inhibition is specific for contamination-related stimuli. This was investigated by using negative, contamination-related, and neutral pictures in the Stop-Signal Task (SST). Finally, if inhibition capacity is indeed an endophenotype, we expected that baseline capacity to inhibit contamination-related stimuli would predict the magnitude of the increase of symptoms after an OCD symptom induction.

2. Methods

2.1. Participants

According to an a priori power analysis based on a medium effect size ($f = 0.25$), with $\alpha = 0.05$ and a power of 0.9, we needed a minimum of 64 participants in total. In total 91 healthy females ranging in age from 17 to 34 years ($M = 19.29$, $SD = 2.07$) participated. Undergraduate students of Ghent University interested in participating in experiments could subscribe to the website <http://www.screeningpsychologie.be/>, where they filled out the contamination subscale of the Padua Inventory revised online (PI-R; Van Oppen, Hoekstra, & Emmelkamp, 1995). Participants were invited to the laboratory when they scored 2 or lower for the LCF group and 13 or higher for the HCF group. Thirteen is the average score of an OCD patient on the PI-R washing subscale and thus is a representative score for an analogue

sample (Van Oppen et al., 1995). Furthermore, this is in line with the cut-off for HCF used in previous research (e.g., Deacon & Maack, 2008). Since symptoms can fluctuate over time and we were interested in those participants that had stable OCD symptoms, these criteria were checked again with the PI-R washing subscale at the beginning of the experiment as the pre-selection could have taken place two months before the actual experiment. Whenever the score of a participant in the HFC group was lower than 9 (mean plus 1SD of the score in a healthy control population) the participant was excluded. Similarly, participants of the LCF group were excluded if they scored higher than 4 (the mean for the PI-washing subscale for the healthy control population; Van Oppen et al., 1995). This resulted in 44 participants in the LCF group and 40 participants in the HCF fear group. The study was approved by the ethical committee at Ghent University. Informed consent was obtained from all individual participants included in the study. Participants were either paid 20 euro or received course credit for their contribution.

2.2. Measures

2.2.1. Impulsiveness–Venturesomeness–Empathy questionnaire (I₇). Since impulsivity can have an effect on inhibition, group differences in impulsivity were checked with the Impulsiveness subscale of the I₇ (Eysenck, Pearson, Easting, & Allsopp, 1985; Lijffijt, Caci, & Kenemans, 2005). The impulsiveness subscale of the I₇ consists of 19 dichotomous (yes/no) items.

2.2.2. Mood and Anxiety Symptoms Questionnaire (MASQ-D30). Since depression levels can have an effect on cognitive functioning (McDermott & Ebmeier, 2009), the anhedonic depression scale of the short adaptation of the MASQ (Wardenaar et al., 2010; Watson, Clark, et al., 1995; Watson, Weber, et al., 1995) was used to check for group

differences in levels of depression. The anhedonic depression scale of the MASQ-D30 consists of 10 items on a scale rated from 1 (not at all) to 5 (very much).

2.2.3. Padua Inventory-revised (PI-R). The PI-R (Van Oppen et al., 1995) was used in order to assess OCD symptoms. The PI-R consists of five subscales: impulses, washing, checking, rumination and precision. The 41 items are rated on a scale from 0 (never/not at all) to 4 (very often).

2.2.4. Mental Contamination Report (MCR). The MCR as designed by Radomsky, Elliott, Rachman, Fairbrother, and Newth (2008) was administered after the induction as a manipulation check of the OCD symptom induction (see supplementary material.). This version is a modification of the mental contamination report as used by previous studies (Fairbrother, Newth, & Rachman, 2005; Herba & Rachman, 2007). It consists of 21 items assessing internal negative emotions (i.e., how participants feel about themselves), external negative emotions (i.e., how participants feel about themselves and/or the man in the scenario), feelings of dirtiness, urge to wash, ease to imagine the scenario, desirability of the kiss, the man's morality before and after the kiss, and whether participants experienced a previous non-consensual sexual encounter (such as an unwanted kiss). All ratings use a scale from 0 (not at all) to 100 (completely).

2.2.5. Visual Analogue Scales (VAS). As another manipulation check seven VAS were adopted from the Profile of Mood States (McNair, Lorr, & Dropplemann, 1992) in line with Rossi and Pourtois (2012). Positive mood was estimated using the mean of the scales "energetic", "satisfied", and "happy". Negative mood was estimated using the mean of the scales "angry", "tense", "depressed", and "disgusted", a scale added because of the relevance of disgust for contamination OCD (Broderick, Grisham, & Weidemann, 2013).

2.2.6. Dimensional Obsessive-Compulsive Scale (DOCS). Three items of the contamination subscale of the DOCS (Abramowitz et al., 2010) were adapted in order to

measure momentary symptoms after the induction. The adapted questions were: “How much time have you spent during the experiment on thinking about contamination?”, “How much time have you spent during the experiment on washing or cleaning behaviors because of contamination?”, and “How difficult was it for you during the experiment to disregard thoughts about contamination and refrain from behaviors such as washing, showering, cleaning and other decontamination routines when you tried to do so?”. These items were rated on a scale from 0 (none at all/not at all difficult) to 4 (most of the time/extremely difficult).

2.2.7. Hand washing. As a manipulation check of the induction we included washing behavior as an analogue of compulsive behavior for the contamination subtype of OCD. We asked all participants at the end of the experiment to wash their hands using a hand sanitizer pump. The time spent on washing hands was measured with a stopwatch in seconds.

2.3. Materials

2.3.1. Stop-Signal Task (SST). In order to assess inhibition capacity in the context of contamination-related stimuli, the adapted SST (Logan, 1994) of Verbruggen and De Houwer (2007) was used. This task ran using Presentation® software (version 17.2, Neurobehavioral Systems). In this task participants were presented with a fixation cross for 500ms (70 x 100 pixels) followed by a picture for 500ms (384 x 288 pixels) and subsequently the target (“#” or “@”, 100 x 100 pixels). Participants were instructed to respond as quickly as possible to the target with key “D” to “#” and key “K” to “@” on an AZERTY keyboard. This mapping rule was reversed for half of the participants. A response was required within 1250ms. The intertrial interval was set at 1500ms. A clearly audible stop-signal (75ms) was presented on 30% of the trials through headphones. In this case participants were required to inhibit their response. The stop-signal delay (SSD) was initially set at 250ms and continuously adjusted

using a separate staircase tracking procedure (Levitt, 1971) to attain a probability of stopping of 50%. More specifically, whenever participants successfully inhibited their response, the SSD was increased by 25ms and whenever participants responded after a stop-signal, the SSD was decreased with 25ms. Note that the longer the SSD, the more difficult it is to inhibit a response.

The task started with a practice phase of 30 trials in which participants received immediate feedback on their performance. The experimental phase consisted of eight blocks of 60 trials in which participants received feedback on their performance on the end of every block (accuracy, mean reaction time, and mean probability of stopping).

For this study the pictures were neutral, negative or contamination-related. We presented 160 trials per picture type and 48 stop trials per picture type. Every picture was presented four times during the SST. In total 40 neutral (e.g., a leaf) and 40 negative (e.g., a gun) pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997). The 40 contamination-related pictures (e.g., a dirty toilet) were selected from the IAPS, the Maudsley Obsessive-Compulsive Stimuli Set (Mataix-Cols, Lawrence, Wooderson, Speckens, & Phillips, 2009), the picture set of Morein-Zamir et al. (2013) and publically available online sources. In order to match negative and contamination-related pictures on arousal, these pictures were rated by an independent sample ($n = 28$) on arousal, and how much fear and disgust the pictures elicited on a Likert scale ranging from 1 (none) to 9 (very much). Furthermore, they rated the valence of the pictures on a Likert scale ranging from 1 (negative) to 9 (positive)¹.

¹ M arousal OCD pictures = 4.17, SD arousal OCD pictures = 0.94, M arousal negative pictures = 4.90, SD arousal negative pictures = 0.73; M fear OCD pictures = 2.56, SD fear OCD pictures = 0.91, M fear negative pictures = 4.29, SD fear negative pictures = 1.38; M disgust OCD pictures = 4.51, SD disgust OCD pictures = 1.44, M disgust negative pictures = 3.01, SD disgust negative pictures = 1.06; M valence OCD pictures = 3.63, SD valence OCD pictures = 0.60, M valence negative pictures = 3.01, SD valence negative pictures = 0.63

The Stop-Signal Reaction Times (SSRTs) were estimated using the integration method². The integration method assumes that the point at which the stop process finishes is equal to the n^{th} reaction time of the distribution of the trials in which there was no stop-signal. The n^{th} reaction time is equal to the point in the distribution at which the integral equals the probability of responding after a stop-signal. The SSRT can then be calculated by subtracting the SSD from the finishing time (Verbruggen, Chambers, & Logan, 2013). In this study the split-half reliability of the SST was satisfactory (first SST $r_{sb} = .85$; second SST $r_{sb} = .91$).

2.3.2. OCD symptom induction. A modified version of the Non-Consensual Kiss (NCK) task of Elliott and Radomsky (2012) was used for an OCD symptom induction. This induction was selected since a meta-analysis on induction procedures of OCD symptoms (De Putter et al., 2017) revealed that mental contamination, and specifically the NCK task, was one of the strongest inductions that also elicited symptoms in healthy participants. The audio script of the NCK task was the same as the script of the non-consensual physically dirty condition of Elliott and Radomsky (2012). In this induction participants listen to a scenario that describes a party and at the end of the party they are kissed non-consensual by a physically dirty man. The audio script for the neutral induction was based on the consensual physically clean condition of Elliott and Radomsky (2012). In order to make the script more neutral, the consensual kiss on the mouth was substituted with a kiss on the cheek as a means of saying goodbye, which is a common informal way of saying goodbye in Belgium. The audio recordings were administered through headphones and participants were instructed to imagine being the woman described in the scenario and that the events were happening at that moment in time.

2.3.3. Reminder Induction. During the second SST there was a short break between every two blocks (three breaks in total) in which participants rated their current disgust level,

² For every participant the assumption of the horse race model was examined by checking if the signal respond RT was faster than the no-signal RT. Sensitivity analyses showed that all results were still robust if participants violating this assumption were excluded.

right before and after being asked to focus on the scenario again on the moment they received a kiss. This was done in order to ensure that the induction would remain active throughout the second SST.

2.4. Procedure

See Figure 1 for an overview of the procedure. After reading and signing the informed consent, participants filled out the I_7 , MASQ, and PI-R. Subsequently participants performed the first SST. After the SST participants filled out the VAS scales. Subsequently, subclinical and healthy participants were randomly allocated to either the neutral mood induction or the OCD symptom induction. Following the induction participants filled out the VAS scales again, the MCR, and the DOCS. Afterwards, participants performed the second SST, during which they were reminded of the induction every two blocks and rated their disgust levels. Finally, participants were asked to wash their hands using hand sanitizer and the time they spent on washing their hands was recorded in seconds using a stopwatch. At the end of the study the participants were fully debriefed.

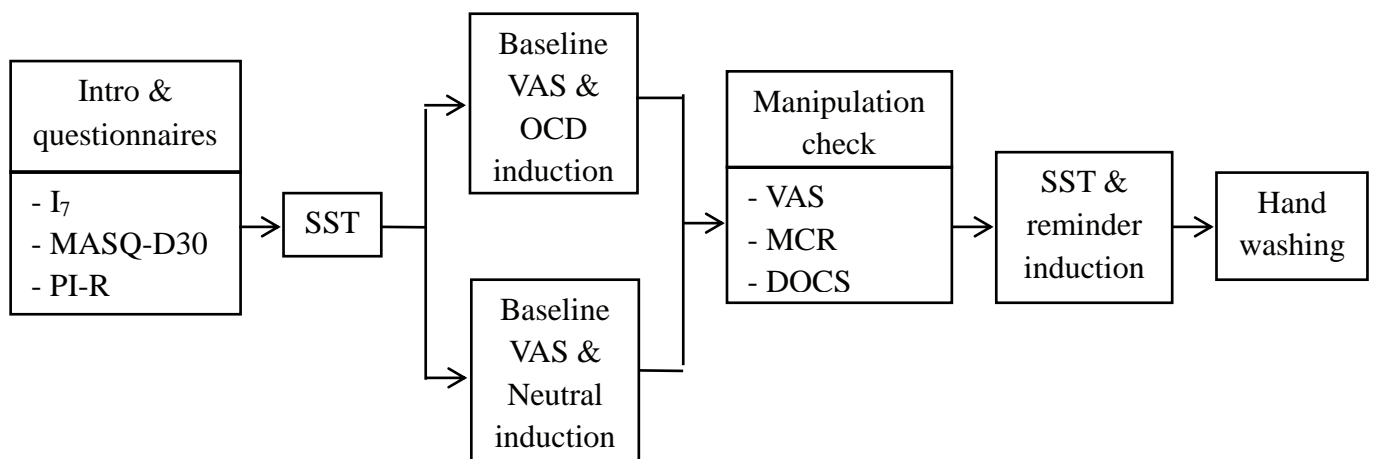


Figure 1. Overview of the procedure. I_7 = Impulsiveness–Venturesomeness–Empathy questionnaire, MASQ-D30 = Mood and Anxiety Symptoms Questionnaire, PI-R = Padua

Inventory Revised, SST = Stop-Signal Task, VAS = Visual Analogue Scale, MCR = Mental Contamination Report, DOCS = Dimensional Obsessive Compulsive Scale.

2.5. Statistical Analysis

Statistics were performed using SPSS (version 20; IBM Corp, 2011) and a significance level of 0.05 was used. Effect sizes are reported in the form of partial eta-squared (η_p^2). For outlier analysis, since the integration method already excludes outlier reaction times by selecting a specific point within the distribution of the reaction times, we only checked whether any participants had consistent scores higher than 3 standard deviations from the other participants. This resulted in the exclusion of one participant from the HCF group.

Differences between groups or inductions in age, impulsiveness, MASQ depression, ease to imagine the induction scenario, PI total scores, scores on the washing subscale of the PI, baseline positive and negative mood were analyzed using separate one way ANOVA's. Potential differences between groups or inductions in experienced previous non-consensual sexual encounters were analyzed using Fisher's exact test, since a difference in the experience of a previous non-consensual sexual encounter could influence the effectiveness of the induction.

As the effectiveness of the induction was crucial to our design, we investigated this with multiple measures such as the MCR, VAS negative and positive mood, DOCS, and time spent on washing hands. For the MCR, in line with Elliott and Radomsky (2012), we performed separate ANOVA's on perceived kiss desirability and the difference score of pre- and post-physical dirtiness of the man as dependent variables and group and induction as independent variables. A multivariate ANOVA was conducted in order to assess the effects of the induction on feelings of mental contamination (i.e., feelings of dirtiness, urges to wash, internal negative emotions, and external negative emotions) as the dependent variables and

group and induction as the independent variables. Furthermore, in order to assess the effect of the manipulation on positive and negative mood separate mixed ANOVA's with Time (pre- and post-induction) as a within-subject factor and group and inductions as between-subject factors was performed. Moreover, in order to assess the effect of the manipulation on the DOCS an ANOVA was performed on the DOCS scores with group and induction as the independent variables. Finally, in order to assess the effect of the manipulation on hand washing, as an analogue for compulsive behavior, an ANOVA was performed on the time spent on hand washing with group and induction as the independent variables.

The effectiveness of the reminder of the induction during the SST was assessed with a mixed ANOVA on the disgust VAS scales administered before and after the reminder with Time (pre-post induction) and Reminder (3 reminders in total) as within-subject factors and group and induction as between-subject factors. Results for the manipulation checks are presented in the supplementary material. In short, the induction procedure was found to be successful on all but one measure.

In order to investigate the hypothesis that contamination-related pictures and current OCD symptoms would have an effect on inhibition a mixed ANOVA was performed on the SSRTs with Time (pre- and post-induction) and Valence (negative, neutral, contamination-related) as within-subject factors and group and induction as between-subject factors.

Finally, in order to test whether baseline SSRTs would be able to predict an increase in symptoms after the induction separate linear regressions were performed per OCD symptoms measure after the induction (i.e., feelings of dirtiness, urge to wash, hand washing, internal negative emotions, external negative emotions, DOCS, VAS negative, and VAS positive) with baseline SSRT for contamination-related, negative and neutral pictures as independent variables. For the analysis of VAS positive and VAS negative we corrected for baseline VAS positive and negative scores. As we only expected an increase in symptoms after the OCD

induction, we excluded participants that had received the neutral mood induction ($n = 40$) from these analyses.

3. Results

3.1. Sample Characteristics

See Table 1 for the means and standard deviations of the sample characteristics. Age, impulsiveness, MASQ depression, baseline positive mood, and ease to imagine the scenario were not significantly different between groups (HCF or LCF), inductions (OCD induction or neutral induction) or Group x Induction (all F 's(1,79) < 3.47, all p 's > .05). Moreover, in this sample 31% experienced a previous non-consensual sexual encounter (such as an unwanted kiss), but this did not differ per group ($\chi^2(1) = .01, p = .92$), or induction ($\chi^2(1) = .06, p = .80$). Importantly, in line with the pre-selection, there was a significant difference between groups for PI-R washing ($F(1,79) = 327.72, p < .001, \eta_p^2 = .81$) and the PI total score ($F(1,79) = 117.44, p < .001, \eta_p^2 = .60$). Furthermore, there was a significant difference between groups for baseline negative mood ($F(1,79) = 9.12, p = .003, \eta_p^2 = .10$), which was to be expected comparing subclinical to healthy participants.

Table 1.

Means and standard deviations on demographic and baseline ratings for each condition

	HCF/OCD		HCF/neutral		LCF/OCD		LCF/neutral	
	induction (<i>n</i> =		induction (<i>n</i> =		induction (<i>n</i> =		induction (<i>n</i> =	
	20)		19)		23)		21)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Age	19.15 ^a	2.06	18.63 ^a	1.38	19.22 ^a	2.75	19.00 ^a	1.90
Impulsiveness	6.50 ^a	3.98	3.79 ^a	2.55	7.22 ^a	4.91	6.29 ^a	5.52
MASQ	27.70 ^a	6.38	30.42 ^a	9.00	26.78 ^a	8.71	25.90 ^a	8.29
depression								
Baseline	42.62 ^a	21.46	34.77 ^a	21.20	46.26 ^a	14.36	42.21 ^a	16.47
positive mood								
Baseline	27.73^a	15.17	28.71^a	19.08	16.77^b	10.36	20.99^b	10.75
negative mood								
Ease to	64.00 ^a	21.75	73.60 ^a	10.10	70.41 ^a	20.76	71.19 ^a	13.44
imagine the								
scenario								
PI-R washing	16.90^a	5.90	18.95^a	6.60	0.74^b	1.14	0.48^b	0.93
subscale								
PI-R total	66.80^a	21.38	66.00^a	19.49	30.35^b	13.13	22.62^b	11.87

Note. HCF = high contamination fear group, LCF = low contamination fear group, MASQ = Mood and Anxiety Symptom Questionnaire, PI-R = Padua Inventory-revised. For each row, variables that are significantly different from each other ($p < .05$) share a different subscript and are presented in bold.

3.2. Effects of Contamination-Related Pictures and Current OCD Symptoms on

Inhibition

In order to reduce the positive skew of the SSRT distribution over participants the SSRT were transformed using a square root transformation. The mixed ANOVA on the transformed SSRT with Time (pre- and post-induction) and Valence (negative, neutral, and contamination-related) as within-subject factors and group and induction as between-subject factors revealed a significant main effect of Valence ($F(2,78) = 4.69, p = .01, \eta_p^2 = .11$). Follow-up paired t -tests showed that there was no significant difference between contamination-related and negative pictures ($t(82) = 1.15, p = .25$) or contamination-related and neutral pictures ($t(82) = 1.60, p = .11$), but there was a significant difference between negative and neutral pictures ($t(82) = 2.95, p = .004$, Cohen's $d = 0.21$). Participants were faster after negative pictures ($M = 208\text{ms}, SD = 39\text{ms}$) than after neutral pictures ($M = 217\text{ms}, SD = 46\text{ms}$). However, it is important to note that the effect size is small. Moreover, there was a significant main effect of Time ($F(1,79) = 4.62, p = .03, \eta_p^2 = .06$) in which participants were faster in the second SST ($M = 208\text{ms}, SD = 39\text{ms}$) than the first ($M = 216\text{ms}, SD = 46\text{ms}$). Furthermore, there was a significant main effect of Group ($F(1,79) = 4.60, p = .04, \eta_p^2 = .06$) in which participants in the HCF group were faster ($M = 204\text{ms}, SD = 38\text{ms}$) than participants in the LCF group ($M = 220\text{ms}, SD = 38\text{ms}$). There was also a main effect of induction ($F(1,79) = 5.32, p = .02, \eta_p^2 = .06$) in which participants receiving the OCD symptom induction were faster ($M = 203\text{ms}, SD = 32\text{ms}$) than participants in the neutral induction ($M = 222\text{ms}, SD = 43\text{ms}$). As this effect did not interact with Time, this indicates a coincidental preexisting difference in SSRTs between inductions. The other predicted interaction effects were also not significant (F 's $< 1.84, p$'s $> .16$). Based on the current data,

there was no effect of an OCD symptom induction on SSRTs and contamination-related picture valence did not affect the HCF group and LCF group differently³.

3.3. Predicting Symptoms based on Baseline Inhibition Capacity

The linear regressions did not reveal any significant effects (all p 's > .11). Baseline SSRTs after any type of picture were not able to predict the increase in symptoms after the OCD symptom induction.

4. Discussion

This study set out to test differential hypotheses of trait versus state models of inhibitory control in OCD by investigating a sample of undergraduates scoring high and low on contamination fear. Moreover, we investigated whether underperformance in inhibitory control would be specific for contamination-related stimuli. State-related views such as the executive overload model of OCD (Abramovitch et al., 2012) predict changes in inhibition capacity after state manipulations of OCD symptoms, whereas the endophenotype (trait) view predicts little effect of such a manipulation. Moreover, as inhibition capacity would be a marker for vulnerability to develop OCD, the endophenotype view implies that baseline capacity to inhibit contamination-related stimuli would predict the magnitude of elevated symptoms after an OCD symptom induction. Surprisingly, the current results failed to support either a trait or a state view on inhibitory deficits in contamination fear given the absence of baseline contamination-related inhibitory deficits as well as the absence of state influences on such deficits. We discuss these findings in more detail below.

³ After exclusion of participants who experienced a non-consensual sexual encounter (such as a kiss) there was no longer a significant main effect of induction (i.e., coincidental preexisting difference in SSRTs between inductions) or valence (i.e., faster SSRT after negative than neutral pictures). Given the small effect size, this is likely due to loss of power. The other results remained unchanged.

First of all, the manipulation checks (see supplementary material) showed that for most outcome measures the induction proved successful in inducing OCD symptoms. The induction successfully elicited feelings of mental contamination and a change in general positive and negative mood. However, there was no generalization of the induction effect to time spent on washing hands as an analogue of compulsive behavior or to an adapted version of the DOCS in order to measure current OCD symptoms. This suggests that although the induction was potent enough to induce feelings of mental contamination, which is strongly related to the contamination fear subtype of OCD (Rachman, 2004), it did not generalize to intrusive thoughts (as measured with the DOCS) or behavior. However, it should be noted that the adapted DOCS used in this study enquired after symptoms experienced during the experiment in general. In hindsight, this manner of enquiry may have been too broad. Indeed, a recent study using the same OCD symptom induction in which the adapted DOCS specifically enquired after symptoms experienced during induction found that participants receiving an OCD symptom induction reported more intrusive thoughts compared to participants receiving a neutral mood induction (De Putter & Koster, 2017). Moreover, the manipulation check of the reminder of the induction during the second inhibition task showed that reminder of the induction was successful in maintaining the effects of the induction. These findings are crucial as they imply that, according to the state view, one could expect interference effects of the induction during the second inhibition task.

According to the executive overload model (Abramovitch et al., 2012) we had expected a change in inhibitory functioning after the OCD symptom induction (as had been shown by Kalanthroff et al. 2017) and a differential effect of contamination-related, negative and neutral picture valence. Yet, results showed that the induction had no effect on subsequent performance on inhibition and there was no effect of contamination-related picture valence. Here, although the effect size was small, in contrast to Verbruggen and De Houwer

(2007), participants displayed faster SSRTs following negative pictures compared to neutral pictures. Moreover, this effect disappeared when participants that experienced a non-consensual encounter were excluded. Given the already small effect size, this is likely due to a loss of power. However, future research is warranted on valence-specific differences in inhibitory functioning in participants that did and did not experience a previous non-consensual sexual encounter. According to the endophenotype view, we had expected differences between the subclinical HCF and control LCF group at baseline, no change in inhibitory functioning after an OCD symptom induction, and the ability of baseline inhibition to predict an increase in symptoms after an OCD symptom induction. Although there was indeed no change in inhibitory functioning after the induction, baseline performance on inhibition was not a significant predictor of an increase in symptoms after the OCD symptom induction. Moreover, the significant difference between the HCF and the LCF group was in the opposite direction than predicted by the endophenotype view. The HCF group actually performed better on inhibition than the LCF group. The endophenotype (trait) view regards underperformance in inhibition as a sign of increased genetic risk for developing OCD (Chamberlain et al., 2005). Therefore this finding is in contrast with the endophenotype view and meta-analyses showing a deficit in inhibition in OCD (e.g., Abramovitch et al., 2013; Snyder et al., 2014). However, this finding could be due to the choice of the subtype of OCD. Indeed, a meta-analysis on differences in neuropsychological performance between subtypes showed that the contamination subtype generally outperforms the checking subtype with especially large effect sizes for response inhibition (Leopold & Backenstrass, 2015). Current evidence of differential performance in response inhibition according to subtype stems from studies using Stroop and go/no go tasks. The current study suggests that this effect may generalize to the SST in subclinical participants of the contamination subtype and that they may even outperform comparison participants low on contamination fear. Importantly,

although this effect was characterized by a medium effect size, the significant difference between groups should be interpreted with caution as the p -value (i.e., $p = .04$) only just fell below the threshold of significance. In conclusion, the current results are in contrast with the trait endophenotype view, but do not provide support for the state view either.

There are several limitations to the current study. Most importantly, this study used a female subclinical contamination fear population instead of a clinical OCD population, which may limit the generalizability of these findings. Yet, the utility of analogue samples in research on OCD has already been shown by Gibbs (1996) and Abramowitz et al. (2014). Moreover, as inhibition was suggested as an endophenotype of OCD, we had expected decreased inhibition in women scoring high on contamination fear. However, there might be protective factors at play preventing these participants to progress to a clinical level. For instance, intact inhibition capacity could be one of these protecting factors. Second, it is possible that the contamination-related pictures presented during the SST could also have served as an induction of state OCD symptoms. However, in that event we would have expected a strong effect of contamination-related picture valence, which we did not observe. Third, although the choice of the OCD symptom induction was based on its effectiveness in evoking OCD symptoms (De Putter et al., 2017), the inhibition task was independent of the nature of the induction. If the induction would have been relevant for the inhibition task, as is the case in real life for OCD patients, the results might have been different. Similarly, Linkovski et al. (2016) found that repeated checking only affected inhibition for previously checked stimuli. Relatedly, the contamination-related pictures used in the SSTs were selected based on their relevance for the contamination subtype in general. However, even within subtypes, OCD is characterized by substantial heterogeneity in what triggers their symptoms (Rufer, Grothausen, Maß, Peter, & Hand, 2005). Future research investigating the state-trait debate with an OCD symptom induction and disorder-relevant stimuli should therefore

include idiosyncratic material and an induction that is more relevant for the subsequent information processing task. Moreover, although the SST is a suitable measure for response inhibition, Abramovitch and Cooperman (2015) argue that different measures of response inhibition can lead to different results as the SST mainly assess action cancellation and involves a relatively high inhibitory load. Therefore, the results may not generalize to other measures of inhibition. It is worth noting though that problems with response inhibition in OCD are most often found with the SST (Abramovitch & Cooperman, 2015). Finally, in the current study we did not screen for clinical DSM disorders or neurological disorders and thus we were unable to check for these effects.

Limitations notwithstanding, this study was one of the first studies investigating the differential hypotheses of the state-trait debate and taking valence-specificity into account with an experimental design. In conclusion, in an analogue sample we failed to find support for the endophenotype as well as the executive overload model. Interestingly, the group difference between HCF and LCF was in the opposite direction than predicted by the endophenotype (trait) view. Based on the current data, no evidence was found for state models such as the executive overload model (Abramovitch et al., 2012) as we did not find any difference in performance on inhibition after an OCD symptom induction or according to preceding contamination-related picture valence. Therefore, the results of this study are in contrast with the idea of stable or state inhibitory deficits in contamination fear in an analogue sample.

Role of Funding Sources

Funding for this study was provided by a Grant of the Special Research Fund (BOF) of Ghent University (B/13811/01). BOF had no role in the study design, collection, analysis

or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Contributors

Laura M. S. de Putter, Gideon E. Anholt and Ernst H. W. Koster designed the study. Sofie Cromheeke programmed the adapted Stop Signal Task according to Verbruggen and De Houwer (2007). Laura M. S. de Putter collected the data and conducted the statistical analysis. Laura M. S. de Putter wrote the first draft of the manuscript and all authors contributed to and have approved the final manuscript.

Conflict of Interest

All authors declare that they have no conflict of interest.

Acknowledgments

The authors would like to thank Corinna M. Elliott and Adam S. Radomsky for kindly sharing the audio scripts for the NCK task and Luna Vermeulen and Lotte Van Yper for their assistance in data collection.

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Supplementary Material

Manipulation Checks

In order to check whether the manipulation was successful we analyzed scores from the MCR, VAS negative and positive mood, DOCS, and hand washing as shown in Tables S1a and S1b. As expected, the MCR revealed significant differences between inductions: participants in the OCD induction reported more mental contamination, a larger difference between pre- and post-physical dirtiness of the man and less kiss desirability than participants in the neutral induction. Moreover, the VAS for positive and negative mood showed significant interaction effects between Time x Induction. Follow-up independent samples *t*-tests revealed that there was no difference between inductions before the induction (negative mood: $t(81) = 0.87$, $p = .39$; positive mood: $t(81) = 1.46$, $p = .15$), while there was a significant difference between the inductions after the induction (negative mood: $t(81) = 5.02$, $p < .001$, Cohen's $d = 1.10$; positive mood: $t(81) = 3.33$, $p = .001$, Cohen's $d = 0.73$). As expected, after the induction participants in the OCD induction reported more negative mood and less positive mood than participants in the neutral induction. Furthermore, contrary to our predictions, there were no significant effects of induction on the DOCS or time spent on hand washing at the end of the experiment. To conclude, participants reported more mental contamination and a change in their mood after the OCD symptom induction, while participants did not differ from participants in the neutral induction on the DOCS or their time spent on washing their hands.

Moreover, these analyses showed some interesting group effects. Participants in the HCF group reported higher scores on the DOCS, more negative mood, less positive mood, and more feelings of mental contamination than participants in the LCF group. Finally, there was a small significant interaction effect between Group x Induction for time spent on washing hands. Follow-up independent *t*-tests revealed that this interaction effect is due to the

lack of a difference between inductions in the HCF group ($t(37) = 0.83, p = .41$), whereas the inductions differed significantly in the LCF group ($t(42) = 2.22, p = .03$, Cohen's $d = 0.67$). In the LCF group participants that received the OCD induction spent more time washing their hands than participants that received the neutral induction.

Table S1a.

Results manipulation check

Variables	Main effect of Induction				Main effect of Group				Induction x Group interaction			
	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2
<i>Mental Contamination Report</i>												
Perceived kiss desirability ^a	22.82	1, 79	< .001	.22	0.80	1, 79	.374	.01	0.17	1, 79	.680	< .01
Difference pre- and post-physical dirtiness of the man ^a	44.81	1, 79	< .001	.36	0.71	1, 79	.403	.01	0.54	1, 79	.467	.01
Feelings of Mental Contamination ^b	26.42	4, 76	< .001	.58	5.70	4, 76	< .001	.23	1.39	4, 76	.245	.07
<i>VAS</i>												
Negative Mood ^c	7.99	1, 79	.006	.09	10.65	1, 79	.002	.12	0.21	1, 79	.645	< .01
Positive Mood ^c	1.29	1, 79	.259	.02	4.32	1, 79	.041	.05	0.47	1, 79	.494	< .01
<i>Other measures</i>												
DOCS ^a	1.74	1, 79	.191	.02	24.71	1, 79	< .001	.24	1.44	1, 79	.234	.02
Time hand washing ^a	0.38	1, 79	.539	< .01	2.73	1, 79	.103	.03	4.00	1, 79	.049	.05

Note: DOCS = Dimensional Obsessive-Compulsive Scale. ^a Represents results of 2 (Induction) x 2 (Group) ANOVA's; ^b Represents results of a 2 (Induction) x 2

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(Group) MANOVA with feelings of dirtiness, urges to wash, internal negative emotions, and external negative emotions as dependent variables representing feelings of mental contamination; ^c Represents results of 2 (Induction) x 2 (Group) x 2 (Time) Mixed ANOVA's.

Table S1b.

Results manipulation check continued

Variables	Main effect Time				Time x Induction interaction				Time x Group interaction				Time x Induction x Group interaction			
	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2
VAS																
Negative Mood ^c	0.04	1, 79	.837	< .01	47.10	1, 79	< .001	.37	0.13	1, 79	.720	< .01	0.02	1, 79	.899	< .01
Positive Mood ^c	0.18	1, 79	.672	< .01	43.99	1, 79	< .001	.36	2.75	1, 79	.101	.03	0.26	1, 79	.613	< .01

Note: ^c Represents results of 2 (Induction) x 2 (Group) x 2 (Time) Mixed ANOVA's.

Manipulation Check Reminder Induction

In order to assess the effect of the reminder of the induction during the second SST, a mixed ANOVA was performed on the disgust VAS scales administered before and after the reminder with Time (pre-post reminder induction) and Reminder (3 reminders in total) as within-subject factors and group and induction as between-subject factors. This revealed a significant Reminder x Time interaction effect ($F(2,78) = 6.63, p = .003, \eta_p^2 = .14$) and a significant Time x Induction interaction effect ($F(1,79) = 47.56, p < .001, \eta_p^2 = .38$). Follow-up paired samples *t*-tests comparing reminder at the different time points for the increase pre-post induction, showed that the Reminder x Time interaction effect was due to a significant difference in the increase in disgust between the first reminder and the second reminder ($t(82) = 3.38, p = .001, \text{Cohen's } d = 0.18$), between the first reminder and the third reminder ($t(82) = 3.12, p = .002, \text{Cohen's } d = 0.20$), but not between the second and third reminder ($t(82) = 0.45, p = .65$). The difference between pre- and post-scores was larger after the first reminder ($M_{\text{diff}} = 17.42, SD_{\text{diff}} = 27.17$) than after the second ($M_{\text{diff}} = 12.64, SD_{\text{diff}} = 24.33$) and third reminder ($M_{\text{diff}} = 12.06, SD_{\text{diff}} = 24.59$), indicating a habituation of the reminder of the induction. Furthermore, follow-up independent samples *t*-test showed that the Time x Induction effect was due to the absence of a difference between inductions before the reminder ($t(81) = 1.19, p = .24$), while the difference between inductions was significant after the reminder ($t(81) = 4.52, p < .001, \text{Cohen's } d = 0.99$). After the reminder participants in the OCD symptom induction reported more disgust ($M = 49.83, SD = 25.76$) than participants in the neutral induction ($M = 26.08, SD = 21.73$), indicating that the reminder of the induction was successful.