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Perseveration causes automatization of checking behavior in obsessive-compulsive disorder

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ABSTRACT

Repeated checking leads to reductions in meta-memory (i.e., memory confidence, vividness and detail), and automatization of checking behavior (Dek, van den Hout, Giele, & Engelhard, 2014, 2015). Dek et al. (2014) suggested that this is caused by increased familiarity with the checked stimuli. They predicted that defamiliarization of checking by modifying the perceptual characteristics of stimuli would cause de-automatization and attenuate the negative meta-memory effects of re-checking. However, their results were inconclusive. The present study investigated whether repeated checking leads to automatization of checking behavior, and if defamiliarization indeed leads to de-automatization and attenuation of meta-memory effects in patients with OCD and healthy controls. Participants performed a checking task, in which they activated, deactivated and checked threat-irrelevant stimuli. During a pre- and post-test checking trial, check duration was recorded and a reaction time task was simultaneously administered as dual-task to assess automatization. After the pre- and post-test checking trial, meta-memory was rated. Results showed that relevant checking led to automatization of checking behavior on the RT measure, and negative meta-memory effects for patients and controls. Defamiliarization led to de-automatization measured with the RT task, but did not attenuate the negative meta-memory effects of repeated checking. Clinical implications are discussed.

1. Introduction

Most patients with obsessive-compulsive disorder (OCD) perform perseverative behavior like checking, washing, or counting. Eighty percent of patients engage in checking, making it the most prevalent type of compulsive behavior (Ruscio, Stein, Chiu, & Kessler, 2010). Patients with OCD tend to distrust their memory for earlier checks (Rachman, 2002; Reed, 1985), and are less confident about their memory than healthy controls (Hermans, Martens, De Cort, Pieters, & Eelen, 2003; MacDonald, Antony, MacLeod, & Richter, 1997). There is no robust evidence that patients with OCD have a general memory deficit. Some studies did find general memory dysfunction (e.g., Joel et al. 2005; Kathmann, Rupertseder, Hauke, & Zaudig, 2005; Savage et al. 2000), but others did not (e.g., Jelinek, Moritz, Heeren, & Naber, 2006; Moritz, Kloss, von Eckstaedt, & Jelinek, 2009; Radomsky & Rachman, 1999). Although checking seems to be a coping strategy to reduce uncertainty, many studies have demonstrated that *repeated* checking is, paradoxically, counterproductive.

van den Hout and Kindt (2003a, 2003b, 2004) were the first to experimentally demonstrate the ironic effects of perseveration. They asked participants to perform checks in a computer task. Participants had to activate, deactivate, and check gas rings by turning knobs on a virtual gas stove. At a pre- and post-test, memory accuracy was assessed, and participants rated their memory confidence, vividness, and detail. Between the pre- and post-test, half of the participants performed 20 checks on the same stimuli used in the pre- and post-test ('relevant checking'), whereas the other half performed checks on different stimuli ('irrelevant checking'). Results showed that repeated relevant checking did not affect memory accuracy, but reduced memory confidence, vividness, and detail. These results have been replicated using a real-life kitchen instead of a computer task (Radomsky, Gilchrist, & Dussault, 2006), with threat-irrelevant stimuli (Dek, van den

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Hout, Engelhard, & Giele, 2010), and with mental instead of physical checking (Radomsky & Alcolado, 2010). The negative effects of repeated checking appear relatively fast: after 2-5 checks (Coles, Radomsky, & Horng, 2006). Furthermore, the effects of repeated checking are not bound to cognitions about the present: repeated checking induces uncertainty about the ability to discriminate between future threat and safety (Giele, van den Hout, Engelhard, Dek, Damstra, et al., 2015). Compared to healthy controls, patients with OCD show similar reductions on the meta-memory ratings after repeated checking (Radomsky, Dugas, Alcolado, & Lavoie, 2014), even though they have lower confidence in memory overall (Boschen & Vuksanovic, 2007).

van den Hout and Kindt (2003a) proposed that repeated checking increases familiarity with the checked stimuli. Familiarity leads to inhibition of processing of perceptual elements of checked stimuli, and prioritizes their semantic aspects (Johnston & Hawley, 1994; Roediger, 1990). It decreases vividness and detail of recollections, which undermines confidence in memory (van den Hout & Kindt, 2003a). This switch from perceptual to conceptual processing could be the underlying mechanism of the paradoxical perseveration phenomenon. Extrapolating from this work, Dek et al. (2014) proposed that the paradoxical effects of perseveration might be the result of automatization of the checking procedure.

Dek et al. (2014) suggested that practice (i.e., the repetitive act of checking), as well as increased familiarity with the stimuli and the act of checking itself, lead to automatization of checking behavior. To investigate automatization, they focused on efficiency, which is a feature of automaticity that pertains to the extent of demands on attentional resources (Bargh, 1994). Because efficiency can be studied with dual task paradigms (McNally, 1995; Teachman, Joormann, Steinman, & Gotlib, 2012), Dek and colleagues modified the checking task into a dual task by combining it with a secondary reaction time (RT) task in the pre-test and post-test. That is, while participants completed a checking trial in the pre-test and post-test, they also completed the RT task by responding as quickly as possible to tones. Automatization was operationalized as more efficient (faster) performance of the checking procedure and on the RT task at the post-test. Indeed, compared to irrelevant checking, repeated relevant checking led to automatization of the checking procedure (check durations at the post-test were shorter). Because the pre-to-post-test reductions in RT on the secondary task did not differ between the conditions, replication was required in order to make definite inferences about automatization of checking behavior. Subsequently, Dek, van den Hout, Giele, and Engelhard (2015) conducted two replication experiments, and found that relevant checking, compared to irrelevant checking, reduced check duration and RTs which indicates automatization of checking behavior. In sum, repeated checking leads to automatization in non-clinical samples.

Dek et al. (2014) also tested if *de*familiarization leads to *de*-automatization of the checking procedure. Stimulus familiarization is reached by prolonged contact with that specific stimulus. In contrast, defamiliarization is achieved by modifying perceptual characteristics of the stimulus. De-automatization was operationalized as less efficient (slower) performance on the checking task and the RT task at the post-test, compared to the relevant checking condition. Dek et al. (2014) also predicted that defamiliarization (by modifying the background color of the stimuli at the post-test) would reduce the negative effects of repeated checking on meta-memory. This was not found, and the authors suggested that the modification procedure may have been too weak. In a similar experiment, Boschen, Wilson, and Farrell (2011) changed the perceptual characteristics of the stimuli themselves every five checks. They found that repeated checking of perceptually altered stimuli attenuates the negative effects of repeated checking on memory confidence, vividness, and detail. In a recent study, Dek et al. (2015) altered the color of the stimuli and knobs instead of the background color (‘moderate defamiliarization’), and increased the amount of color alterations of the stimuli (‘strong defamiliarization’). They demonstrated that moderate defamiliarization resulted in partial de-automatization: defamiliarization reduced efficiency on the secondary RT task, but not check durations. However, it also did not attenuate meta-memory ratings. An unexpected finding was that strong defamiliarization did not lead to de-automatization, but did reduce the drops in memory confidence and vividness after repeated checking. In sum, results on the effects of defamiliarization on de-automatization and attenuation of the meta-memory effects of re-checking are inconclusive.

Patients with OCD typically have a tendency to exert control over their daily-life automatic routines. They “attempt to monitor closely and take control over processes that would otherwise operate in automatic and well-practiced ways” (Salkovskis, 1998, p. 40). Therefore, automatization on the checking/RT task may develop differently (more slowly) for OCD patients than for healthy controls. An experimental study that used a flanker task demonstrated that individuals scoring high on obsessive compulsive symptoms are more reluctant to shift from focused to parallel processing strategies (Soref, Dar, Argov, & Meiran, 2008).

The first objective of this study was to replicate the paradoxical perseveration phenomenon in a sample of patients with OCD. The second objective was to investigate whether checking behavior automates more slowly in patients with OCD than in healthy controls. We hypothesized that (1) repeated relevant checking leads to reductions in memory confidence, vividness, and detail in patients with OCD and healthy controls, and that (2) compared to healthy controls, the degree of automatization after repeated relevant checking is smaller for patients (reflected by less steep reductions in check duration and RTs from pre-test to post-test). The third objective was to explore the effects of defamiliarization in patients with OCD compared to healthy controls. Because we had no strong predictions about this effect, we explored whether (3) patients with OCD differ from healthy controls in the way that defamiliarization leads to de-automatization (reflected by different reductions in check duration and RT), and (4) OCD patients differ from non-clinical controls in their meta-memory ratings after defamiliarization. Research on the effects of perseverative behavior is extensive. However, few studies have focused on the origin of these effects. This research could provide more insight about the way repeated checking affects memory confidence and whether automatization is an underlying mechanism in a clinical sample, which would have implications for treatment.

2. Method

2.1. Participants

Patients with OCD were recruited from the Altrecht Academic Anxiety center (AAA; ambulant care) and the Vincent van Gogh Center for Anxiety and Obsessive-Compulsive Disorders (VVGi-CAD; inpatient care). We included patients who had a DSM-IV diagnosis of OCD using the Dutch version of the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I: First, Spitzer, Gibbon, & Williams, 1996; van Groenestijn, Akkerhuis, Kupka, Schneider, & Nolen, 1999). The SCID-I was administered by the first author or a psychologist under her supervision. We excluded patients if they used benzodiazepines on a regular basis, were addicted to alcohol and/or drugs, suffered from symptoms from the psychotic spectrum, were insufficiently proficient in the Dutch language, or suffered from color blindness. For the healthy controls the same exclusion criteria applied, including a diagnosis of OCD or any other current psychiatric disorder. We recruited healthy controls through advertisements, and matched them to the OCD patients based on age, gender and education level. We used a three point scale to determine a participant's highest educational level: 1) primary education, low/level vocational training, or intermediate general vocational training; 2) intermediate professional vocational training, or college-bound high school; 3) college, or university. This research was approved by the Medical Research Ethics Committee (METC) of the University Medical Center Utrecht (UMCU). Participants gave written informed consent prior to their participation.

Prior to the analyses, we removed three participants from the OCD group from the dataset because they were in partial or full remission ($n = 2$), or did not follow task instructions ($n = 1$). We removed one participant from the healthy control group because of a current dysthymic disorder. The final sample consisted of 48 patients with OCD as a primary diagnosis ($M = 33.8$ years, $SD = 10.2$; 30 females, 18 males), and 48 matched healthy controls ($M = 32.4$ years, $SD = 13.1$; 30 females, 18 males) who received a small financial reimbursement for their participation.

2.2. Procedure, materials and design

We tested participants in a quiet and dimly lit room at either the university, the center where they received treatment, or their home. They sat at a table in front of a portable computer, a mouse, and a response box. First, they filled out four symptom questionnaires on paper (see Clinical assessments). Then they performed the checking/RT task combination on the computer, during which they completed two more questionnaires on paper (see Metamemory assessment). The computer task took approximately 20 min.

2.3. Computer task, part I: checking task

Six threat irrelevant stimuli (six large circles with a star in it or six small grey circles), and six corresponding turning knobs were presented on a dark grey background on a computer screen (cf. Dek et al., 2015; see Fig. 1). The six large circles + stars and six corresponding turning knobs had a color combination consisting of: green circles + red stars and grey knobs, or: black circles + white stars and blue knobs, respectively.

The checking task started with a training phase, in which participants practiced with activating and deactivating the stimuli by turning the corresponding knobs using the computer mouse (half of the participants practiced with the green circles + red stars and grey turning knobs, half practiced with the black circles + white stars and blue turning knobs, and all participants practiced with the small grey circles). In this training phase, participants received false feedback about their performance, in order to keep them alert. An instruction on the computer screen said that they had not turned off all stimuli correctly. Next, the pre-test was administered, in which a schematic diagram was presented that corresponded with the six circles. Three out of six circles were marked, and participants were instructed to activate, deactivate, and check these three circles. Check duration of this trial (i.e., activating, deactivating and checking for accurate deactivation) was recorded by the computer. Then participants filled out a metamemory questionnaire about their last check. After this pre-test, another 15 checking trials of random selections of three marked circles followed. Finally, the post-test was unexpectedly administered, which consisted of one last checking trial and the metamemory questionnaire.

Participants were randomly assigned to one of three conditions. All conditions presented the large circles + stars at the pre- and post-test (see Fig. 1). In the *relevant checking without defamiliarization condition (R-)*, the stimuli shown during the 15 checking trials were identical to the pre- and post-test. In the *irrelevant checking condition (IR)*, different stimuli were used in between the pre- and post-test (i.e., the large circles + stars at the pre- and post-test, but small grey circles during the 15 checking trials). In the *relevant checking with defamiliarization condition (R+)*, the stimuli presented during the 15 checking trials were identical to the pre- and post-test, but at the post-test the color of the stimuli was changed (from green circles + red stars and grey knobs to black circles + white stars and blue knobs, or vice versa; the administration of the two different color combinations was counterbalanced across participants).

2.4. Computer task, part II: Rapid Interval Repetition (RIR) task

We used the RIR task (Vandierendonck, Voogt, & Goten, 1998) as a secondary RT task (cf. Dek et al., 2014, 2015) before the checking task (RIR training phase, RIR Only baseline measure), and during the checking task (RIR pre-test, RIR post-test). In the RIR task, beeps were presented at a pitch of 250 Hz, for a maximum duration of 200 ms, with random intervals (range: 2.5–5 s).

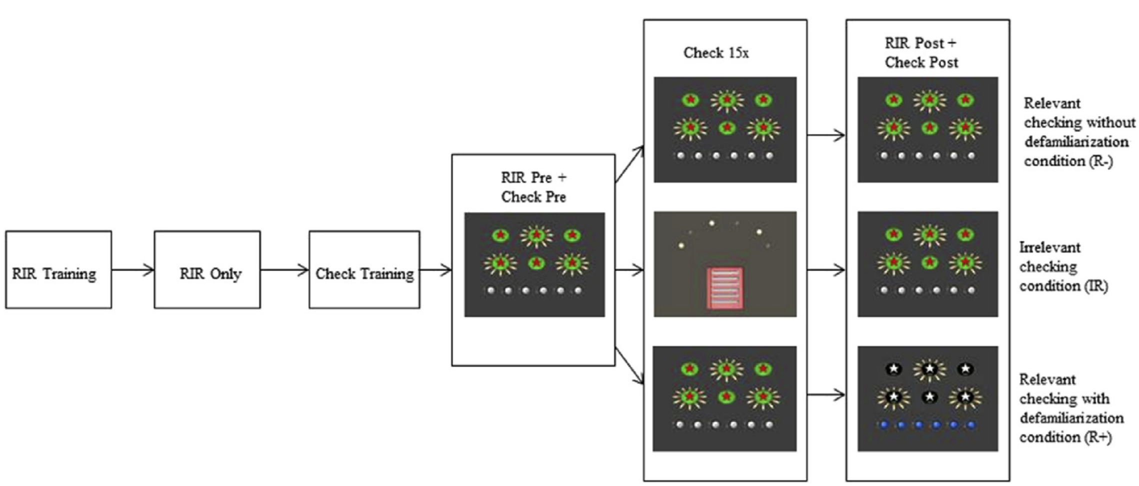

Fig. 1. Schematic overview of task administration over time for the different phases of the Rapid Interval Repetition (RIR) task and the checking task (cf. Dek et al., 2015).

Participants were instructed to respond as fast and accurately as possible to a beep by pressing a knob on the response box with the index finger of their non-dominant hand. After the training phase (20 s), the RIR Only baseline measure (60 s) followed. During the instruction of the pre-test of the checking task, participants were instructed to keep their finger on the response knob during the entire experiment, because the beeps might re-appear any moment. However, the beeps only re-appeared as part of the RIR Pre-test and RIR Post-test during the simultaneous administration of the RT task to the pre- and post-test of the checking task (see Fig. 1).

2.5. Measures

2.5.1. Clinical assessments

The self-rated version of the Yale-Brown Obsessive-Compulsive Scale (Y-BOCS: Goodman et al., 1989), and the Obsessive-Compulsive Inventory-Revised (OCI-R: Foa et al., 2002) were used to assess obsessive-compulsive symptoms and severity. For the Y-BOCS, the internal consistency in the present sample was good for both the clinical ($\alpha = .82$) and control ($\alpha = .86$) groups. Internal consistency of the OCI-R was also good (clinical: $\alpha = .83$; control group ($\alpha = .74$). The Beck Anxiety Inventory (BAI: Beck & Steer, 1990) and Beck Depression Inventory-II (BDI-II: Beck, Steer, & Brown, 1996) were used to measure symptom severity of anxiety and depressive symptoms. In the present study, the BAI showed excellent internal consistency in both the clinical and control groups (both αs = .96). Internal consistency of the BDI was excellent for the clinical group ($\alpha = .92$), and very good for the control group ($\alpha = .87$).

2.6. Meta-memory assessment

Memory accuracy at the pre-test and post-test was measured by asking participants to indicate which three out of six circles they had to check during the last checking trial on a schematic representation of the six circles.

Memory confidence was measured by asking participants to rate how confident they were that their answer on the accuracy question was correct on a 100 mm Visual Analogue Scale (VAS), which ran from '0 = absolutely not confident' to '100 = absolutely confident'.

Vividness and *detail* of the last check were rated on two separate VASs (0 = not vivid, 100 = extremely vivid; 0 = not detailed, 100 = extremely detailed).

2.7. Data preparation

2.7.1. RIR task

For each participant, mean reaction times (RTs) were calculated for each of the three phases of the RT task (RIR Only, RIR Pre and RIR Post). The first RT on RIR Pre and RIR Post were removed from the mean calculation, because at these moments the beeps came relatively unexpected. Reaction times faster than 100 ms were excluded. Extreme RTs (>M + 3SD) were calculated for each RIR phase and each condition separately and were removed from the data. After outlier removal, new mean RTs were calculated for each RIR phase and condition.

2.8. Statistical analyses

Extreme outliers were removed from the analyses (this is mentioned when applicable). Although we noticed violation of the assumption of homogeneity of variances, and the assumption of homogeneity of intercorrelations, we did not apply statistical corrections because analysis of variance is reasonably robust against violation of these assumptions when group sizes are equal, which was the case.

Pearson correlations between the memory ratings at the pre-test (memory confidence and vividness, $r = .64$; memory confidence and detail, $r = .55$; vividness and detail, $r = .83$, all $ps < .001$) suggested appropriateness of MANOVA. A mixed factorial MANOVA with Time (pre-test, post-test) as within group variable, and Condition (R-, IR, R+) and Group (OCD, controls) as between group variables, was conducted to examine the effects of repeated checking on memory confidence, vividness and detail. Univariate analyses and simple main effects analyses were performed where appropriate. Hypotheses were tested using planned comparisons ($\alpha = .05$), that examined whether differences in dependent variable ratings between R-vs. IR, R-vs. R+, and R+ vs. IR were significant. Because check duration at the pre-test and RIR Pre did not significantly correlate ($r = -.06$, $p = .56$), two separate mixed factorial ANOVAs examined the effect of repeated checking on check duration and RT.

3. Results

3.1. Descriptive statistics of clinical characteristics

Patients with OCD scored significantly higher on all clinical measures, see Table 1. Because the healthy controls were matched on age, gender and education level to the OCD patients, the groups did not differ on these parameters. Within the group of OCD patients, the three conditions were similar regarding age, $F(2,45) = 1.3$, $p < .05$, and gender, χ^2 (2, $N = 48$) = 1.0, $p > .05$. Although participants were randomly assigned to one of the three conditions, the level of education was significantly lower in the R+ condition than in the R- or IR condition, χ^2 (4, $N = 48$) = 11.4, $p < .05$. Within the matched controls, conditions were similar regarding age, $F(2,45) < 1$, $p > .05$, gender, χ^2 (2, $N = 48$) = 0, $p = 1$, and level of education, χ^2 (4, $N = 48$) = 0.4, $p > .05$.

3.2. Memory accuracy

Fig. 2-A suggests differences in the effects of repeated checking on memory accuracy between groups. However, results of the 2 (Time: pre-test, post-test) x 3 (Condition: R-, IR, R+) x 2 (Group: OCD, controls) mixed factorial ANOVA showed no significant main effects or interaction effects, all $Fs < 1.07$, all $ps > .35$, all η_p^2s $< .02$.

3.3. Memory confidence, vividness and detail

Fig. 2-B suggests that, compared to irrelevant checking (IR), the effect of repeated relevant checking (R-) on memory confidence was larger for patients compared to controls, but Fig. 2-C and -D suggest only minor differences in the effects of perseverative checking on vividness and detail. However, the mixed factorial MANOVA with memory confidence, vividness and detail as dependent variables indicated a non-significant

Table 1
Descriptive statistics of the clinical characteristics per group.

	OCD		Non-clinical		
	M	*SD*	*M*	*SD*	*F* (*p*)
Y-BOCS	21.21	6.17	1.94	3.09	374.23 (<.001)
OCI-R	25.75	11.98	5.83	4.60	115.57 (<.001)
BAI	32.08	16.24	15.27	10.93	35.41 (<.001)
BDI-II	22.65	12.17	5.63	5.73	76.91(<.001)

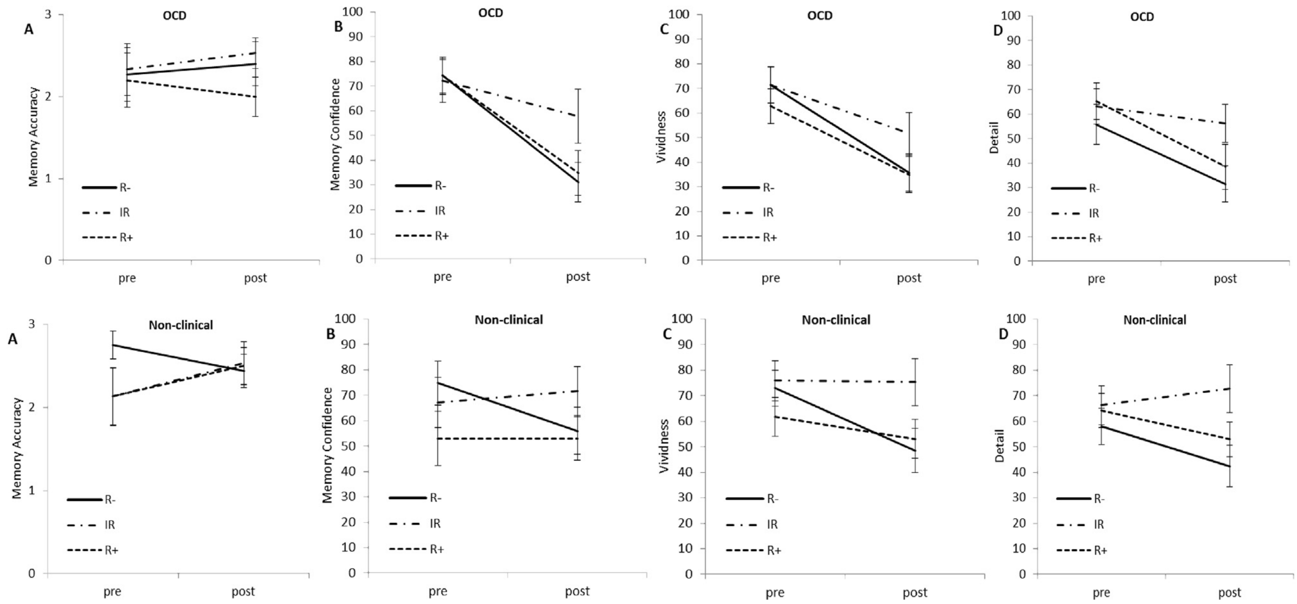

Fig. 2. Mean ratings for patients with obsessive-compulsive disorder (OCD) and non-clinical controls before and after repeated checking for (A) memory accuracy, (B) memory confidence, (C) vividness, and (D) detail, for the relevant checking without defamiliarization condition (R-), the irrelevant checking condition (IR), and the relevant checking with defamiliarization condition (R+).

Time × Condition × Group interaction, $F(6,170) <1$, $p = .82$, $\eta_p^2 = .02$, suggesting no differences between groups in the effect of repeated checking on memory confidence, vividness and detail. The RM MANOVA did show the predicted Time × Condition interaction, $F(6,170) = 2.2$, $p < .05$, $\eta_p^2 = .07$. To further investigate the effects of re-checking on memory confidence, vividness, and detail, three univariate RM ANOVAs were performed in which the three-way interaction was removed from the analyses.

To test the effects of repeated checking on *memory confidence*, a 2 (Time: pre-test, post-test) x 3 (Condition: R−, IR, R+) x 2 (Group: OCD, controls) mixed ANOVA was conducted. Results indicated a main effect of Time, $F(1,88) = 20.48$, $p < .001$, $\eta_p^2 = .19$, which was qualified by a significant Time × Condition interaction, $F(2,88) = 3.41$, $p < .05$, $\eta_p^2 = .07$. Memory confidence declined after repeated relevant checking without defamiliarization (R-), $F(1,88) = 19.4$, $p < .001$, $\eta_p^2 = .18$, and after relevant checking with defamiliarization (R+), $F(1,88) = 7.79$, $p < .01$, $\eta_p^2 = .08$, but not after irrelevant checking (IR), $F(1,88) <1$, $p = .50$. Furthermore, the decline in memory confidence was significantly larger for R-than for IR, $t(59) = 2.57$, $p < .05$, $d = .66$, but the reductions for R+ and R−, $t(60) = 1.01$, $p = .32$, and R+ and IR, $t(59) = 1.38$, $p = .17$, did not differ. The significant Time × Group interaction, $F(1,88) = 11.37$, $p < .01$, $\eta_p^2 = .11$, indicated that patients with OCD showed an overall pre-to-post-test reduction in memory confidence compared to controls. Patients did not differ from non-clinical controls in memory confidence scores at pre-test, $M_{diff} = 8.59$, $p = .24$, but OCD patients reported less confidence in memory at post-test compared to healthy controls, $M_{diff} = 18.97$, $p < .05$.

Fig. 2-C suggests a similar pattern for the effects of repeated checking on *vividness*. The 2 × 3 × 2 ANOVA indicated a significant main effect of Time, $F(1,88) = 33.17$, $p < .001$, $\eta_p^2 = .27$, but the main effects for Condition, $F(2,88) = 2.98$, $p = .06$, $\eta_p^2 = .06$, and Group, $F(1,88) = 3.43$, $p = .07$, $\eta_p^2 = .04$, did not reach significance. The Time × Condition interaction showed a trend, $F(2,88) = 2.9$, $p = .06$, $\eta_p^2 = .06$, whereas the Time × Group interaction was significant, $F(1,88) = 6.0$, $p < .05$, $\eta_p^2 = .06$. Both groups showed overall reductions in vividness ratings from pre-to-post-test, but the decline was larger for OCD patients. There was no difference in vividness ratings at pre-test, $M_{diff} = 1.58$, $p = .79$, but patients with OCD showed lower vividness scores at post-test compared to controls, $M_{diff} = 18.2$, $p < .01$.

Results from the 2 × 3 × 2 mixed ANOVA with *detail* as dependent variable showed significant main effects of Time, $F(1,88) = 13.99$, $p < .001$, $\eta_p^2 = .14$, and Condition, $F(2,88) = 3.87$, $p < .05$, $\eta_p^2 = .08$, which were qualified by the Time × Condition interaction, $F(2,88) = 3.36$, $p < .05$, $\eta_p^2 = .07$. The reductions in detail after repeated checking were significant for relevant checking without defamiliarization (R-), $F(1,88) = 11.05$, $p < .01$, $\eta_p^2 = .11$, and relevant checking with defamiliarization (R+), $F(1,88) = 9.97$, $p < .01$, $\eta_p^2 = .10$, but not for irrelevant checking (IR), $F(1,88) <1$, $p = .97$. The decline in detail was significantly larger for R-than for IR, $t(59) = 2.2$, $p < .05$, $d = .57$, and for R+ compared to IR, $t(59) = 2.4$, $p < .05$, $d = .62$., but did not differ between R- and R+, $t(60) = .11$, $p = .91$. The Time × Group interaction was not significant, $F(1,88) = 3.21$, $p = .08$, $\eta_p^2 = .04$.

In sum, compared to irrelevant checking, repeated relevant checking reduced memory confidence, vividness, and detail, without affecting memory accuracy. There was no difference between OCD patients and healthy controls in meta-memory ratings at the pre-test, but at the post-test, patients gave lower ratings overall for their confidence in memory and vividness. Our first hypothesis (patients with OCD and healthy controls show reductions in memory confidence, vividness, and detail after repeated relevant checking without memory accuracy being affected) was supported: Patients with OCD did not differ from healthy controls in the effect of perseverative checking on meta-memory. Our fourth hypothesis (OCD patients differ from non-clinical controls in their meta-memory ratings after defamiliarization) was not confirmed: in both groups, defamiliarization did not reduce drops in memory confidence, vividness and detail.

3.4. Check duration

Check duration data from one participant (OCD group) was not logged and therefore this subject was excluded from these analyses. Two participants (1 OCD, 1 control group) were extreme outliers on

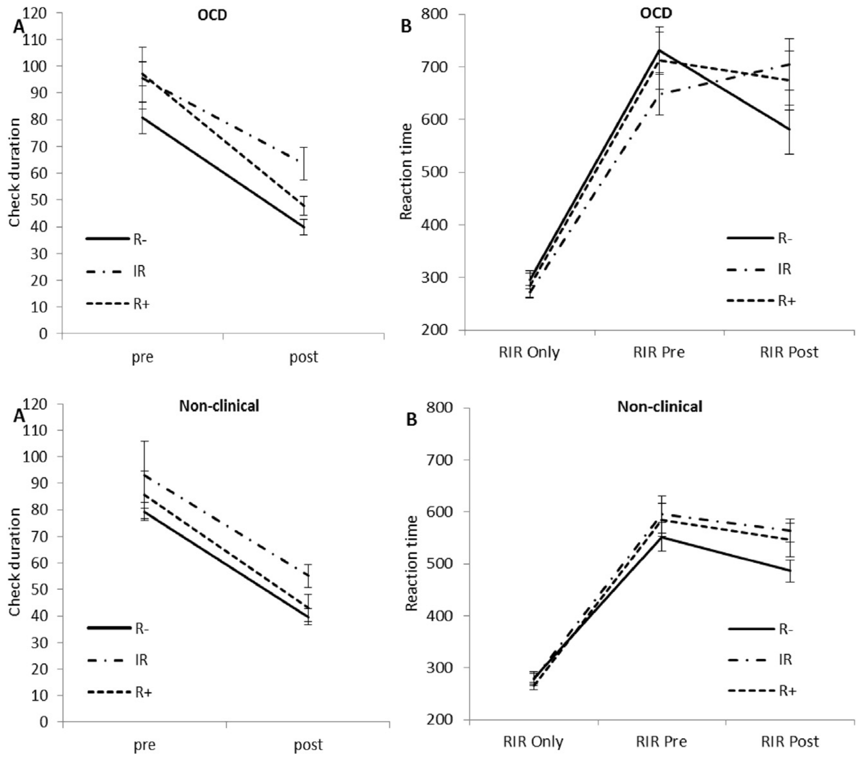

Fig. 3. (A) Mean check duration (s) before and after repeated checking, and (B) mean reaction times (ms) on the Rapid Interval Repetition task (RIR) for patients with obsessive-compulsive disorder (OCD) and non-clinical controls, for the relevant checking without defamiliarization condition (R−), the irrelevant checking condition (IR), and the relevant checking with defamiliarization condition (R+).

the check duration pre-test, and were excluded from the analysis.[1] Fig. 3-A shows check duration at the pre- and post-test for both groups. The 2 (Time) x 3 (Condition) x 2 (Group) ANOVA indicated a significant main effect of Time, $F(1,87) = 190.72$, $p < .001$, $\eta_p^2 = .69$, and a main effect of Condition, $F(2,87) = 4.22$, $p < .05$, $\eta_p^2 = .09$. There was an overall pre-to-post-test reduction of the duration of checking procedures. Check durations were shorter for relevant checking without defamiliarization (R-) compared to irrelevant checking (IR), $M_{diff} = 16.97$, $p < .05$, but there was no significant difference between relevant checking with and without defamiliarization (R+ versus R-), $M_{diff} = 8.73$, $p = .42$, or R+ and IR, $M_{diff} = 8.25$, $p = .47$. No effects involving Group emerged, suggesting that check duration developed similarly across the groups. There were no significant interaction effects.

In sum, although the relevant checking (R−) condition had shorter check durations overall, there were no differences in check duration reductions as a result of repeated checking for the relevant checking, compared to irrelevant checking. Patients were as fast as non-clinical controls in performing the checking procedures. Our second hypothesis (compared to healthy controls, the degree of automatization after repeated relevant checking is smaller for OCD patients) was not confirmed with the check duration data. Defamiliarization did not lead to longer check durations at the post-test. Our third hypothesis (OCD patients differ from healthy controls in the way defamiliarization leads to de-automatization) was not confirmed with the check duration data: there was no difference in the effect of defamiliarization on check duration in OCD patients compared to healthy controls.

3.5. Reaction times: Rapid Interval Repetition (RIR) task

Six participants (five patients with OCD, one healthy control) did not have RTs on all three RIR phases, and were excluded from the analyses. Fig. 3-B shows RTs on the different phases of the RIR task for OCD patients and healthy controls. The 3 (Time: RIR Only, RIR pre-test, RIR post-test) x 3 (Condition: IR, R-, R+) x 2 (Group: OCD, Controls) ANOVA indicated significant main effects of Time, $F(2,83) = 361.22$, $p < .001$, $\eta_p^2 = .90$, and Group, $F(1,84) = 14.46$, $p < .001$, $\eta_p^2 = .15$, which were qualified by a Time × Group interaction, $F(2,83) = 9.67$, $p < .001$, $\eta_p^2 = .19$, and a Time × Condition interaction, $F(4,168) = 4.11$, $p < .01$, $\eta_p^2 = .09$. The Condition × Group interaction, $F(2,84) < 1$, $p = .784$, and Time × Condition × Group interaction, $F(4,168) = 1.69$, $p = .154$, $\eta_p^2 = .04$, were not significant, indicating that there was no difference between OCD patients and healthy controls regarding the effect of repeated checking on RT.

Simple main effects analyses on the Time × Group interaction revealed that both groups were equally fast on RIR only, $M_{diff} = 10$, $F(1,84) < 1$, $p = .41$, but OCD patients were slower overall compared to healthy controls on RIR pre-test, $M_{diff} = 119$, $F(1,84) = 13.70$, $p < .001$, $\eta_p^2 = .14$, and RIR post-test, $M_{diff} = 121$, $F(1,84) = 14.24$, $p < .001$, $\eta_p^2 = .15$. Simple main effects analyses on the Time × Condition interaction revealed no difference in RTs between conditions on the RIR Only and RIR pre-test, all Fs < 1. On the RIR post-test, relevant checking without defamiliarization (R-) was faster than irrelevant checking (IR), $F(2,84) = 3.49$, $p < .05$, $\eta_p^2 = .08$, $M_{diff} = .101$, $p = .013$, and tended to be faster than relevant checking with defamiliarization (R+), $M_{diff} = .076$, $p = .057$, but IR and R+ did

[1] Inspection of the data of these two outliers did not provide a plausible explanation for their extreme scores. Results from the 2 × 3 × 2 ANOVA on the check duration data with these two outliers included indicated a main effect of Time, $F(1,89) = 120.51$, $p < .001$, $\eta_p^2 = .58$, while the main effect of Condition was not significant, $F(2,89) = 1.86$, $p = .16$, $\eta_p^2 = .04$. There were no significant interaction effects.

not differ in RT, $M_{diff} = .025$, $p = .526$. Furthermore, the RIR Only to RIR Pre increases were significant for all conditions (all M_{diff}s > 346, all Fs (2,83) > 101, all ps < .001, all η_p^2s > .71). The RIR Pre to RIR Post decrease was significant for R-, $M_{diff} = 108$, $p < .001$, but there were no significant reductions for IR, $M_{diff} = 14$, $p = .56$, and R+, $M_{diff} = 39$, $p = .09$. The RIR Pre to RIR Post reduction in RT for R- differed significantly from IR, $t(57) = 3.29$, $p < .01$, $d = .70$, and from R+, $t(58) = 2.11$, $p < .05$, $d = .54$, but there was no significant difference in RT reductions between R+ and IR, $t(59) < 1.54$, $p = .13$.

In sum, compared to irrelevant checking, performance on the RT task was faster for repeated relevant checking. Compared to controls, patients were approximately 100 ms slower in responding to the tones while simultaneously performing checks. However, when they only had to respond to the tones, patients were equally fast as non-clinical controls. Our second hypothesis (compared to healthy controls, the degree of automatization after repeated relevant checking is smaller for patients) was rejected with the RT data: patients with OCD showed similar pre-to-post-test reductions in RT. Relevant checking with defamiliarization did lead to smaller pre-to-post-test reductions in RT compared to relevant checking without defamiliarization. However, our third hypothesis (OCD patients differ from healthy controls in the way defamiliarization leads to de-automatization) was rejected with the RT data: there was no difference in the effect of defamiliarization on RTs between OCD patients and healthy controls.

4. Discussion

The current study investigated automatization of perseverative checking behavior in a clinical sample. First, we aimed to replicate the paradoxical perseveration phenomenon in a sample of patients with OCD. Second, we studied whether, as a result of repeated checking, checking procedures automate in a different way in patients with OCD compared to healthy controls. Third, we investigated whether defamiliarization after repeated checking has different effects on de-automatization and attenuation of the negative meta-memory effects of re-checking in OCD patients compared to non-clinical controls.

The results showed that, compared to irrelevant checking, repeated relevant checking leads to reductions in meta-memory ratings in both patients and controls, while memory accuracy remains unaffected, thereby replicating earlier studies (Boschen & Vuksanovic, 2007; Coles et al., 2006; Dek et al., 2010; van den Hout & Kindt, 2003a, 2003b, 2004; Radomsky et al., 2006). Although the reduction in memory confidence after relevant checking seemed to be larger for patients compared to controls, the effect of repeated checking on memory confidence, vividness and detail did not differ between OCD patients and controls, which replicates earlier studies (Boschen & Vuksanovic, 2007; Radomsky et al., 2014). In contrast to the study by Boschen and Vuksanovic (2007), we did not find lower meta-memory ratings overall for patients. Although patients in all conditions rated their memory confidence and vividness significantly lower at the post-test, their pre-test ratings did not differ from controls. Furthermore, even though OCD has been associated with working memory impairments (e.g., Abramovitch, Abramowitz, & Mittelman, 2013) and general memory deficits (e.g., Joel et al. 2005), the present study contradicts this and in line with earlier findings indicates that OCD patients do not show impaired memory accuracy on a checking task (Boschen & Vuksanovic, 2007; Radomsky et al., 2014). Our data do not support the notion that lower initial memory confidence in patients with OCD induces re-checking, but their lower overall memory confidence and vividness ratings after checking may strengthen their motive to continue persevering.

In contrast to our expectations, results showed that irrespective of condition, repeated checking leads to shorter check durations at the post-test, and patients did not differ from controls in their automatization pattern. Data on the RT task indicated that repeated relevant checking led to significant pre-to-post-test reductions in RT, whereas irrelevant checking did not (cf. Dek et al., 2015). In sum, repeated relevant checking led to automatization of checking behavior, but the specificity of this effect was only evident on the dual RT task, and OCD patients did not differ from non-clinical controls in the automatization pattern.

The check duration data indicated that there seems to have been a general automatization effect of checking: irrespective of condition, participants became faster in checking. The resemblance of requested motoric behaviors in the relevant and irrelevant condition (that is, moving the computer mouse) might have been too strong to detect differences on this particular outcome measure. Future research may address this issue by creating conditions that demand different motoric executions.

Although the automatization pattern on the RT task did not differ between patients and controls, OCD patients were on average 100 ms slower in responding to the tones while simultaneously performing the checking procedures. One might suggest that this can be explained by the presence of depressive symptoms. OCD has high comorbidity rates with depression (Overbeek, Schruers, Vermetten, & Griez, 2002), and our patient sample indeed scored significantly higher on the depressive symptom inventory. However, this seems implausible, because mean RTs on the RIR Only baseline measure were not slower for OCD patients, and OCD patients did not have longer check durations in general. A more likely explanation of the slower RTs for OCD patients on the RIR pre- and post-test seems to be that the checking/RT dual task places higher demands on executive functioning (e.g., visuospatial working memory, general motor speed, and divided attention). Three recent meta-analyses showed that OCD is associated with broad impairments in cognitive functioning (i.e., verbal fluency, processing speed, attention, and executive function: inhibition, shifting, verbal and visuospatial working memory, and planning), although the magnitude of the effects is generally moderate (Abramovitch et al., 2013; Shin, Lee, Kim, & Kwon, 2014; Snyder, Kaiser, Warren, & Heller, 2014). We did not find evidence for general slower motor or processing speed in OCD patients. However, in case of the more complex, dual task phases in which participants had to allocate their attentional resources among two competing tasks (i.e., checking during RIR Pre and RIR Post) patients were significantly slower compared to healthy controls. This seems to indicate impaired ability to divide attention, a domain which is associated with impairments in OCD (Abramovitch et al., 2013).

Although the execution of checking behavior remained fast, defamiliarization induced less efficient (slower) performance on the RT task, which indicates de-automatization. Defamiliarization did not attenuate the negative effects of repeated checking on memory confidence, vividness and detail. Furthermore, patients and controls did not differ in the effect of defamiliarization on the dependent variables. An explanation for the finding that defamiliarization did not increase meta-memory ratings, despite causing de-automatization, might be that modification of the stimuli caused a degree of distortion that actually reduced participants' confidence in their *performance in general*, and as a consequence *also* resulted in lower meta-memory ratings. However, the most plausible explanation for our results and the discrepancy with the study by Boschen et al. (2011), who did find attenuating effects of perceptual modification on meta-memory, seems to be a different operationalization of defamiliarization. We altered the stimuli and turning knobs into one dissimilar color, whereas Boschen et al. (2011) used multiple dissimilar colors to induce defamiliarization. Although our 'moderate' defamiliarization procedure did lead to partial de-automatization (cf. Experiment I by Dek et al., 2015), the perceptual modification might not have been distinct enough to attenuate the detrimental meta-memory effects of re-checking.

Dek et al. (2015) demonstrated that 'strong defamiliarization' does attenuate the negative meta-memory effects of repeated checking. Therefore, an interesting direction for future research would be to administer the checking/RT task with a 'strong defamiliarization' procedure to a clinical sample.

Some potential limitations merit discussion. First, we included a heterogeneous OCD sample, instead of only OC checkers. However, the paradoxical perseveration phenomenon appears to be a general phenomenon, because perseveration studies in other cognitive domains demonstrate the same counterproductive effects as repeated checking: perseverative washing leads to uncertainty about contamination (Deacon & Maack, 2008), staring at an object induces uncertainty about perception (van den Hout, Engelhard, de Boer, du Bois, & Dek, 2008; van den Hout et al., 2009), and sentence repetition induces uncertainty about the meaning of the sentence (Giele, van den Hout, Engelhard, & Dek, 2014). Therefore, we specifically aimed at investigating the perseverative checking phenomenon in a heterogeneous OCD sample.

Second, we used threat-irrelevant stimuli, whereas real-life checking in OCD patients usually occurs in the presence of elevated anxiety. Although our main objective was to investigate potential general efficiency differences in perseverative behavior in OCD, results on automatization might have been different and the effects of perseveration in OCD patients might have been even stronger with the use of OCD-relevant stimuli. The existing literature suggests that real-life checking in patients with OCD usually occurs in the presence of elevated anxiety and responsibility. For instance, several studies have demonstrated that perceived responsibility is directly related to perseverative behavior in patients with OCD (e.g., Arntz, Voncken, & Goosen, 2007). Although a study in compulsive checkers demonstrated similar meta-memory ratings compared to healthy controls with the use of OCD-relevant (i.e., stove, sink) stimuli (Radomsky et al., 2014), another study demonstrated that, compared to healthy controls, reductions in memory confidence were larger under conditions of high perceived responsibility for patients with OCD (Boschen & Vuksanovic, 2007). Furthermore, a recent review on automatic processing in psychological disorders demonstrated elevated automatic processing of threat-relevant information in OCD (Teachman et al., 2012). Efficiency on the checking/RT dual task may well be affected by automatic processing of the emotional (anxiety inducing) information that is inherent to threat-relevant stimuli. Thus, with OCD-relevant stimuli, participants may experience inflated responsibility, which may induce feelings of uncertainty from the beginning of the experiment onwards. This in turn, might induce the need to exert control, potentially leading to a different automatization pattern. Investigating automatization in perseverative behavior with (idiosyncratic) OCD-relevant stimuli in a clinical sample would therefore be a valuable direction for future research. This study confirms the counterproductive effects of perseveration in a clinical sample. It also adds to understanding the mechanism underlying this phenomenon: perseveration leads to automatization of checking behavior. These findings provide a theoretical and empirical rationale for response prevention in Exposure and Response Prevention (ERP) therapy, the treatment of choice for OCD. Helping patients to understand why their perseverative behavior is counterproductive may add to their motivation to refrain from ritualizing (Dek et al., 2014). The checking/RT task might be used to illustrate the paradoxical perseveration phenomenon to patients during psycho-educational training about OCD. Radomsky (2014) addressed the beneficial value of incorporating experimental designs as a treatment method into behavioral experiments. Although defamiliarization was initially used as a measure to test the automatization hypothesis, there may be clinical implications of defamiliarization. Although 'moderate' defamiliarization did not reduce drops in meta-memory in the current study, it did induce de-automatization and earlier studies demonstrated attenuating effects of 'strong' perceptual modification (Boschen et al., 2011; Dek et al., 2015). When these effects are replicated in a clinical sample, defamiliarization can be incorporated into behavioral experiments (e.g., by putting colorful stickers on door locks, water taps, et cetera; as suggested in Dek et al., 2015) as a short-term demonstration of the positive effects on meta-memory, and serve as an additional motivator to refrain from ritualizing.

Conflict of interest

None.

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