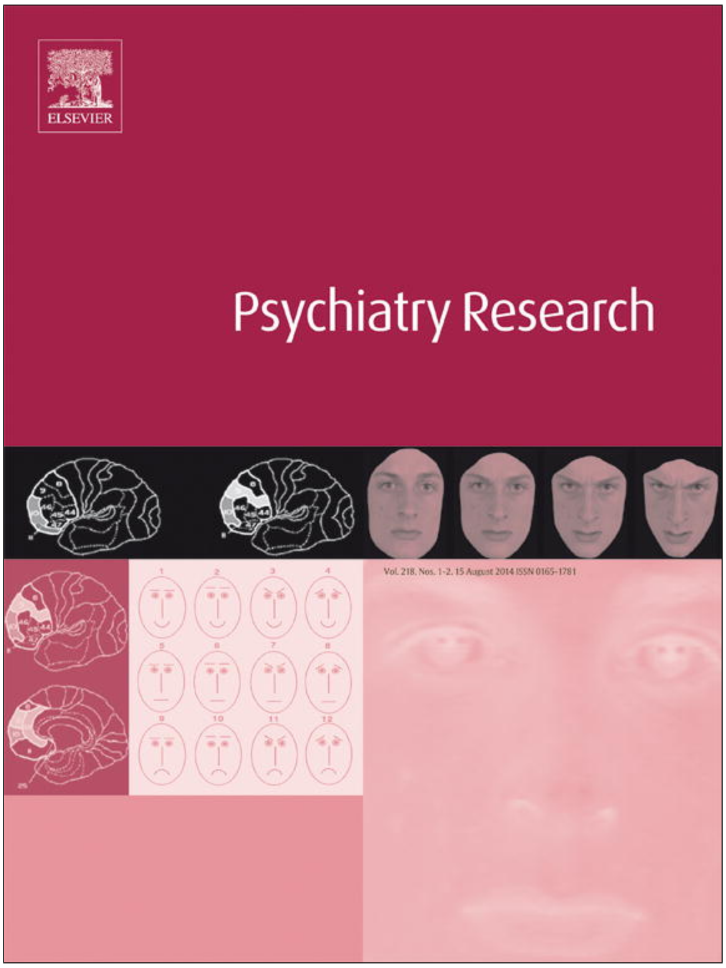
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Obsessed not to forget: Lack of retrieval-induced suppression effect in obsessive-compulsive disorder

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ABSTRACT

The aim of the present study was to investigate the role of executive functions in resolving memory interference in a clinical sample of patients with obsessive-compulsive disorder (OCD). Retrieval of memories has been shown to involve some form of executive act that diminishes the accessibility of rival memory traces, leading to retrieval-induced forgetting (RIF). These executive control processes might suppress unwanted thoughts and irrelevant memories during competitive retrieval. We assessed RIF with the retrieval practice paradigm among 25 OCD patients and 25 healthy controls matched for age and education. Retrieval of target memories led to enhancement of target memory recall in both groups, but suppression of related memories (RIF) occurred only among controls. Our results suggest that suppression of irrelevant, interfering memories during competitive recall is impaired in OCD.

1. Introduction

Obsessive-compulsive disorder (OCD) is a highly debilitating neuropsychiatric condition characterized by intrusive unwanted thoughts and/or repetitive, compulsive behavior or mental rituals (American Psychiatric Association, 2000).

The cognitive profile of the disorder is marked by the deficit of executive functions (Olley et al., 2007; Rao et al., 2008; Cavedini et al., 2010). However, some studies of OCD patients have found intact performance on traditional executive neuropsychological tasks (for reviews see Greisberg and McKay, 2003; Kuelz et al., 2004; Chamberlain et al., 2005; Abramovitch et al., 2013).

According to Chamberlain et al. (2005) failures of cognitive and behavioral inhibition could also explain many of the relevant clinical symptoms as well as executive deficits observed on tasks requiring inhibition of prepotent responses, set-shifting, and inadequate strategy use in memory tasks. Lesion and functional neuroimaging studies (e.g., De Bruin et al., 1983; Bokura et al., 2001; Chudasama and Robbins, 2003; Aron et al., 2004) suggest that abnormalities in the lateral orbitofrontal loop might lead to inhibitory dysfunctions. In OCD there is evidence for the hyperactivity of the lateral orbitofrontal (lOFC) and the dorsal anterior cingulate cortex (dACC) and the hypoactivity of the medial orbitofrontal cortex (mOFC) (for a review see Milad and Rauch, 2012).

Behavioral experiments have provided only partial support for cognitive inhibitory deficits in OCD. Some studies found impaired performance on Stroop (Martinot et al., 1990), GoNogo (Bannon et al., 2002; Penades et al., 2007), Antisaccade (Tien et al., 1992) and negative priming tasks (Enright and Beech, 1993a, 1993b; Enright et al., 1995). Also, OCD patients manifested poorer performance on memory tasks that require updating of the executive system, such as the Letter Memory Task (e.g., Morris and Jones, 1990), the n-back Task (e.g., Kashyap et al., 2013; Nakao et al., 2009; Van der Wee et al., 2003), and prospective memory tasks (Racsmány et al., 2011; Harris et al., 2010). However, many studies failed to detect such impairments on executive tasks (e.g., Aronowitz et al., 1994; Maruff et al., 1999; Bannon et al., 2002; Aycicegi et al., 2003; Spengler et al., 2006; Moritz et al., 2010).

Importantly, another controversial body of literature assessing verbal, visual, and spatial memory in OCD (for reviews see Kuelz et al., 2004; Abramovitch et al., 2013) could be explained by a less effective organizational strategy use and impaired executive functioning (Christensen et al., 1992; Savage et al., 2000; Deckersbach et al., 2005).

Executive functions are crucial in everyday memory. Importantly, their role is not restricted to organizing during encoding,

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planning retrieval, and monitoring memory output, but also in adaptive forgetting (Baddeley, 1996; Anderson, 2003; Dobbins et al., 2002). Indeed, the act of retrieval itself has been shown to cause forgetting of material related to the retrieved memory (Anderson et al., 1994; Anderson, 2003). This research line has shown that when one tries to retrieve a memory that is associated to a given cue, other memories associated to the same cue will become less accessible for later recall (Anderson et al., 1994; Camp et al., 2007; Racsmány et al., 2010).

This phenomenon has been widely studied with the *retrieval practice paradigm* (Anderson et al., 1994). In this paradigm participants study a list of category-exemplar pairs (e.g., vegetables – carrot, vegetables – tomato, sports – cycling, etc.), then practice retrieval of half of the exemplars from half of the categories (e.g., vegetables – ca___?). After a short delay, all exemplars from all categories are tested by a cued recall test. Typically, this final test shows that exemplars (e.g., tomato) associated to practiced exemplars (e.g., carrot) are less accessible than exemplars unrelated to any practiced exemplar (e.g., cycling). This effect has been termed retrieval-induced forgetting (RIF) and was replicated with a wide range of materials and research designs (Anderson and Bell, 2001; Levy and Anderson, 2002; Anderson, 2003; Bajo et al., 2006; Levy et al., 2007; Anderson and Levy, 2011; Storm, 2011).

Several mechanisms have been proposed to explain RIF. These include retrieval inhibition (Anderson et al., 1994), inhibitory executive control (Anderson, 2003), episodic inhibition (Racsmány and Conway, 2006), and, based on the Search of Associative Memory (SAM) theory (Raaijmakers and Shiffrin, 1981), noninhibitory interference processes (e.g., Raaijmakers and Jakab, 2012). Although these explanations contradict each other as to the involvement of inhibitory and/or executive control processes, neuroimaging studies of RIF clearly indicate that competitive retrieval activates cognitive control related areas in the human brain (Kuhl et al., 2007, 2007; Johansson et al., 2007; Kuhl et al., 2008; Wimber et al., 2009). These results show that when one tries to retrieve a target memory associated to a given cue, interference from other competing memories related to the same cue has to be resolved. According to these studies, interference resolution during memory retrieval involves prefrontal areas, as well as the anterior cingulate gyrus.

Problems in interference resolution through cognitive control (e.g., inhibition of intruding memories) have been suggested to be at the core of several psychiatric syndromes (Chamberlain et al., 2005). Therefore, RIF has been a popular tool to assess cognitive control in memory retrieval in schizophrenia (Racsmány et al., 2008) depression (Groome and Sterkaj, 2010), posttraumatic stress disorder (PTSD) (Amir et al., 2009), and OCD (Jelinek et al., 2012).

Jelinek et al. (2012) found intact RIF for neutral words and a tendency for reduced RIF for personally salient OCD relevant words in patients compared to healthy controls. They concluded that OCD is not characterized by a general inhibitory deficit, and that the reduced RIF for OCD-relevant memories is most likely due to cognitive biases. However, at the final test in their experiment, Jelinek et al. (2012) used a category cued recall where participants were given a category (e.g., vegetables) and were instructed to recall all words they had learnt together with that category in the experiment. When using this type of test, the observed RIF can be explained by response competition or output interference at test; practiced items come to mind first, and this blocks access to non-practiced memories (Anderson, 2003). Inhibition is unnecessary for the emergence of RIF in such a procedure, and non-inhibitory models (e.g., Raaijmakers and Shiffrin, 1981; Anderson, 1983) can account for a significant RIF. To eliminate the contribution of output interference to RIF, the final test should use category plus word stem cues which are specific to one given word in the experiment. Such a test could establish whether lower accessibility of a memory is due to interference resolution during an earlier retrieval act (Anderson, 2003). Therefore, in the current study we used this type of final test procedure.

In the clinical studies of RIF reviewed by the authors (Moulin et al., 2002; Nestor et al., 2005; Racsmány et al., 2008; Groome and Sterkaj, 2010; Storm and White, 2010) the final test was a category cued free recall task. As discussed above, in the RIF effects found in such studies output interference and inhibitory mechanisms are confounded. It follows that when output interference is ruled out from mechanisms producing the RIF effect, the effect itself becomes smaller, and less detectable (for a similar argument see Storm, 2011). Therefore, in our study, we focused on differences in recall latencies as a measure of RIF to ensure that any effect that decreases accessibility of memories due to competitive retrieval would be detected. Our choice for measuring RTs was motivated by earlier studies which suggested that RTs may be indeed sensitive to the effect of interference (Anderson, 2003; Keresztes and Racsmány, 2013) and may be more direct measures of the effect of interference resolution (Veling and van Knippenberg, 2004) than retrieval failure per se. Indeed, RTs proved to be a sensitive measure of the magnitude of RIF, even in cases when recall accuracy did not reveal any forgetting effect (Veling and van Knippenberg, 2004; Racsmány and Conway, 2006; Verde and Perfect, 2011).

Our goal was to investigate the role of executive functions in competitive retrieval in OCD. According to the executive deficit hypothesis both adaptive forgetting induced by retrieval (RIF) and suppression of unwanted thoughts are driven by similar executive processes (Levy and Anderson, 2008). In line with this hypothesis, Aslan and Bäuml (2010) found that the RIF effect was modulated by working memory capacity among healthy adults. Therefore we also assessed working memory using an *n*-back task which requires continuous updating of working memory contents. Apart from variables that are known to influence memory, such as symptom severity, depression, we also controlled for stress that has also been suggested to eliminate the RIF effect (Koessler et al., 2009). We hypothesized that OCD patients manifest reduced RIF compared to the matched healthy controls due to impaired executive functions that are supposed to resolve interference during competitive retrieval.

2. Methods

2.1. Participants

Twenty five patients diagnosed with OCD who satisfied the diagnostic criteria in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (American Psychiatric Association, 2000) were examined at the Nyírő Gyula Hospital, Psychiatry II, Budapest, Hungary. A psychiatrist confirmed the diagnosis following the Structural Clinical Interview for DSM-IV Axis I Disorders (SCID-I) (First et al., 1997). The severity of OCD symptoms was assessed using the Yale Brown Obsessive-Compulsive Scale (Y-BOCS) (W.K. Goodman et al., 1989; W.L. Goodman et al., 1989). Severity of depression of the clinical sample was assessed using the Hamilton Rating Scale for Depression (HAM-D, 21-item) (Hamilton, 1960; Warren, 1994). Anxiety was assessed by the Spielberger State and Trait Anxiety Inventory (STAI). We used the State subscale of the STAI to estimate the stress induced by the experiment (Spielberger et al., 1970; Sipos, 1978; Spielberger, 1983). (See Table 1 for a summary of these assessments.)

We excluded participants who met the criteria for severe depression (Hamilton score $>$ 24). Fourteen participants in our OCD sample were mildly depressed (Hamilton score between 7 and 17). We also excluded participants who met criteria for any other comorbid psychiatric diagnosis (Axis I or Axis II) and who had a lifetime history of drug or alcohol dependence or neurological disorder. Regarding medication, two patients had not been medicated for at least three months, eleven were taking selective serotonin reuptake inhibitors (seven paroxetin, two citalopram, one fevarin, and one stimuloton), ten were taking double action noradrenaline and serotonin agents (seven clomipramine and three venlafaxine) and two patients were taking serotonin reuptake inhibitors combined with double action noradrenaline and serotonin agents (paroxetin and clomipramin).

Table 1
Sample demographics and basic assessment results.

Characteristics	OCD (n=25) Mean	S.D.	Healthy control (n=25) Mean	S.D.	Independent t-test t	p
Age (years)	36.4	10.2	36.24	9.69	−0.05	ns
Education (years)	13.36	2.99	14.28	2.76	1.12	ns
Sex (M/F)	17/8		19/6			
DSF	6.04	0.93	6.16	1.31	0.37	ns
2-back hit %	84.36	18.04	93.92	10.71	2.27	<0.05
2-back correct rejection %	95.04	5.66	97.48	2.78	1.93	ns
3-back hit %	72.68	22.98	85.84	17.64	2.27	<0.05
3-back correct rejection %	93.32	5.12	95.88	2.69	2.2	<0.05
STAI-T	55.8	11.57	37.2	4.94	−7.38	<0.001
STAI-S	45.91	10.99	36.28	7.43	−3.57	<0.01
Y-BOCS total	26.6	7.3				
Y-BOCS ORS	13.04	3.65				
Y-BOCS CRS	13.64	4.80				
HAM-D	9.48	4.98				

Note. OCD, obsessive-compulsive disorder; M, male; F, female; DSF, Digit Span Forward; STAI-T, Spielberger Trait Anxiety Score; STAI-S, Spielberger State Anxiety Score; Y-BOCS Total, Yale Brown Obsessive Compulsive Scale Total score, Y-BOCS ORS, Yale Brown Obsessive Compulsive Scale, Obsessions-Severity Score; Y-BOCS CRS, Yale Brown Obsessive Compulsive Scale, Compulsions Severity Score; HAM-D, Hamilton Depressive Rating Scale; and ns, not significant.

Both concerning medication and symptoms, the OCD group was heterogeneous, and due to the sample size, no subgroup data could be analyzed.

The study was approved by the hospital's ethical review board. Patients received a detailed description and explanation of the study before they decided to sign the informed consent forms. All patients were assured that participation in the study would not interfere with their clinical treatment. The healthy control group (n=25) was matched in age and education (see Table 1).

2.2. Experimental design and materials

2.2.1. The retrieval practice paradigm

2.2.1.1. Design and material. We used 60 category-word pairs, six words belonging to each of ten categories. To induce the competitive retrieval supposed to be necessary to produce RIF, and to avoid moderation of the RIF effect (see Anderson, 2003), we followed strict selection criteria described in detail in Keresztes and Racsmány (2013). Briefly, we used neutral words of moderate frequency, based on the Frequency Dictionary of the Hungarian Webcorpus (Halácsy et al., 2004; Kornai et al., 2006). We used categories that were not associated to each other (either semantically or phonetically), and category members that were not associated to another member of another category. (see for the list of words used.)

Twelve category-word pairs (belonging to two categories) were used as fillers. The other 48 category-word pairs were assigned to one of the four item types. This was done in a fully randomized manner for each experimental session. First, each category was randomly assigned to be practiced or unpracticed (baseline) categories, so that half of the categories were selected for both category type. Words within each category were randomly assigned into two groups. Half of the words (Rp+) in each practiced category was to be practiced during the practice phase, the other half (Rp−) was not. For unpracticed (baseline) categories, half of the words (Nrp+) were assigned to be baseline items for Rp+ words, the other half (Nrp−) were assigned to be baseline items for Rp− words. We used Presentation 14.5 to randomly assign items to conditions, for presentation of stimuli and data recording. All participants performed the experiment on an IBM T40p ThinkPad.

2.2.1.2. Procedure. In the study phase, all 60 words were presented to participants together with their category label, at a rate of 5000 ms with a 500 ms intertrial interval, in the center of the computer screen, with the category label on the left and the category member on the right. Participants were instructed to memorize the words with the help of the category label. Presentation of the pairs was pseudo-randomized with the constraint that two words belonging to the same category could not appear consecutively. The study phase started and ended with two filler items to avoid primacy and recency effects.

The practice phase consisted of three blocks, each containing 18 practice trials. Each block consisted of 12 trials with Rp+ items and six trials with fillers. The first and the last two items in each series were filler items. The order of the rest of the items was pseudo-randomized with the constraint that two consecutive trials never involved members of the same category. In each trial, the category label of the target word plus a two-letter stem cue for the target word appeared in the middle of the screen. Participants were instructed to say aloud the corresponding target. They had 6000 ms in the first block and 4000 ms in the second and third block to answer. Answers were recorded with a voice-key, and the correctness of the answers was manually checked by the experimenter after each session. In each trial, trigger onset time of the voice key was considered the response reaction time.

The three practice blocks followed each other in a repeated spaced retrieval schedule in order to increase the effect of practice (see Karpicke and Bauernschmidt, 2011). We introduced three, and six minutes of delay filled with simple arithmetic (adding or subtracting three-digit numbers randomly generated by the experimental software), before the second, and third practice block and a 5 min delay before the final test, respectively.

During the final test phase we used category plus word stem cues. This way, we ensured that each cue corresponded to only one test item in the experimental set. To further control for the effect of output interference, we tested Rp− items before testing Rp+ items. This procedure ensured that accessibility of Rp− items was not influenced by response competition arising during the final test (i.e., that a practiced word accessed during the test phase blocks access to a related memory that is tested after this practiced word). The final test phase consisted of two blocks. Rp− items and their controls (Nrp− items) were tested in the first block, followed by Rp+ items and their controls (Nrp+ items) in the second block (Camp et al., 2007). The order of items within blocks was randomized. Testing Rp− items first was necessary to avoid output interference created by Rp+ retrieval during test. Without such output control, output interference cannot be ruled out as an alternative explanation for any RIF effect observed. Controlling for output order of Rp− and Rp+ items necessitated the use of two baselines (Nrp− and Nrp+). This was necessary because recall of items tested at the end of a test session is usually lower than recall of items tested at the beginning of the session. This might then lead to a masking of the RIF effect because of a low overall baseline (see Anderson, 2003). Both blocks started and ended with two filler items. Filler items were necessary during the test phase to ensure consistency between experimental phases, and served as warm up trials. Trials in the test phase were the same as in the first retrieval practice block except that the category-plus-word-stem cue contained only a first-letter stem of the category member.

2.2.2. Assessment of short term and working memory

2.2.2.1. Digit span forward (DSF). We used the Hungarian version of the DSF task (Racsmány et al., 2005) as a measure of verbal short-term memory. In this task, a series of digits are presented orally by the examiner at a rate of one digit per second. The digits are to be repeated by the participant in the same order. Each trial consisted of four series of equal length (three digits in the first trial), and was considered successful if the participant reproduced at least two series correctly. In this case, the examiner advanced to the next trial which included series that were one digit longer. Digit span was determined by the length of the series in the last trial where the participant could recall at least two series correctly (see Table 1).

2.2.2.2. n-Back task. We designed visual 2-back and 3-back tasks with digits to measure the updating function of working memory. Each task consisted of five blocks of 30 trials. The first block served as practice in both the 2-back and the 3-back task. In these practice blocks participants were given feedback about correct hits, false alarms and misses. After each block, participants had a short self-paced break. In each trial, lasting 2000 ms, a digit, randomly sampled from one to nine, appeared in the center of the screen for 700 ms, followed by a blank screen for 1300 ms. Participants had to press the space bar on the keyboard if the digit on the screen was identical to the digit seen two (in the 2-back task), or three (in the 3-back task) trials before (see Table 1).

2.3. Statistical analysis

Statistical analyses were performed using mixed analysis of variance (ANOVAs), one-tailed t-tests and bivariate correlation (Pearson correlation coefficient). Partial Eta squared was used as a measure of the effect size for ANOVA and Cohen's d for the t-test analyses (Cohen, 1988; Field, 2005).

3. Results

3.1. Psychiatric assessment

Statistics and p values for the differences between scores of OCD patients and controls on the psychiatric scales are shown in Table 1. Patients were at the lower end of the mild depression range as revealed by the HAM-D. Their level of both trait and state anxiety was higher than that of controls, as indexed by the STAI-T and STAI-S respectively.

3.2. Short term and working memory

We performed independent *t*-tests to compare OCD patients' and controls' performance on the digit-span task, and hit and correct rejection rates in the 2-back and 3-back tasks. Statistics and corresponding *p* values are shown in Table 1. In brief, although short term memory span was almost identical in the two groups, working memory performance of OCD patients was lower than that of controls, as qualified by both hit rates and correct rejection rates.

3.3. Performance during retrieval practice

Recall performance during practice cycles can be seen in Fig. 1. To analyze memory improvement during retrieval practice, we conducted a mixed design ANOVA on recall RTs and recall percentages, with practice cycles (1–3) as a repeated measures factor, and group (OCD vs. Control) as a between-subject variable.

As can be seen in Fig. 1, there was a significant decrease in Recall RTs from cycle 1 through cycle 3, $F(2,90)=57.56$, $p<0.0001$, $\eta^2_{partial}=0.64$, indicating that participants' recall performance improved during retrieval practice, although participants' recall accuracy (77%,76%,78% and 77%, 80%, 79% from cycle 1 to cycle 3 in the OCD and the control group respectively) did not improve from cycle 1 through cycle 3, $F(2,94)=0.69$, $p=0.51$, $\eta^2_{partial}=0.01$. These main effects were not qualified by either a main effect of group ($F(1,45)=0.12$, $p=0.73$, $\eta^2_{partial}=0.00$, for recall RTs and $F(1,47)=0.11$, $p=0.74$, $\eta^2_{partial}=0.00$, for recall accuracy) or a group × practice cycle interaction ($F(2,90)=0.34$, $p=0.71$, $\eta^2_{partial}=0.01$, for recall RTs and $F(2,94)=1.12$, $p=0.33$, $\eta^2_{partial}=0.02$, for recall accuracy). In sum, memory improved in both groups during practice cycles, and this improvement was similar among participants with OCD and among controls.

3.4. The effect of retrieval practice on final test performance

Recall performance during the final test can be seen in Fig. 2. In order to see the differential effect of retrieval practice on recall of different item types, we conducted a mixed design ANOVA on recall RTs and recall accuracies (see Table 2) with item type (Rp+, Rp−, Nrp+, Nrp−) as a repeated measures variable, and group (OCD vs. controls) as a between subject variable. Item type had a significant main effect both on recall RTs, $F(3,126)=12.77$, $p<0.001$, $\eta^2_{partial}=0.23$, and recall accuracy, $F(3,144)=57.68$, $p<0.001$, $\eta^2_{partial}=0.55$. Item type did not interact significantly with group, neither for recall RTs, $F(3,126)=1.44$, $p=0.24$, $\eta^2_{partial}=0.03$, nor for recall accuracy, $F(3,144)=0.52$, $p=0.67$, $\eta^2_{partial}=0.01$.

Importantly, the healthy control group recalled more Nrp− items than Nrp+ $t(24)=2.02$, $p=0.027$, $d=0.82$. This was not surprising given that Nrp− items were tested first, and Nrp+ items second, i.e., we observed the effect of output interference (see Anderson, 2003). However this effect was absent among OCD patients, which might indicate that patients were not sensitive to output interference.

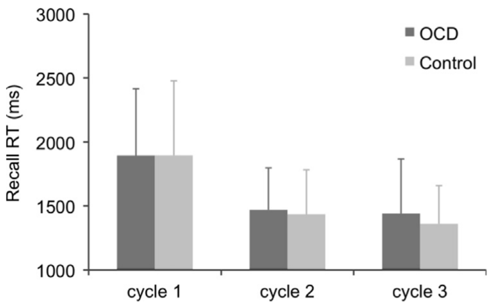

Fig. 1. Average recall reaction times in the three consecutive cycles of retrieval practice in the two groups. *Note.* Error bars represent standard deviations.

3.4.1. Practice effect

Fig. 2 (left panel) shows the positive effect of retrieval practice, the practice effect (Rp+ minus Nrp+) for recall RTs in the two groups separately. To detect a practice effect, we performed one sided paired-samples *t*-tests for the OCD and the control group separately, contrasting Rp+ recall with Nrp+ recall. Retrieval practice enhanced later recall of practiced memories based on recall RTs, ($t(23)=3.75$, $p<0.001$, $d=1.56$, for controls, and $t(19)=3.84$, $p<0.001$, $d=1.76$ for the OCD group) as well as recall accuracy ($t(24)=6.73$, $p<0.001$, $d=2.75$ among controls, and $t(24)=8.66$, $p<0.001$, $d=3.54$ among participants with OCD). In brief, practicing retrieval enhanced recall enhanced later memory for practiced items among both the OCD patients and controls.

3.4.2. Retrieval-induced forgetting

Fig. 2 (right panel) shows the negative effect of retrieval practice, the RIF effect (Nrp− minus Rp− recall) for recall RTs in the two groups separately. To detect a RIF effect, we performed paired-samples *t*-tests (one-sided) for the OCD and the control group separately, contrasting Rp− recall with Nrp− recall. Recall RTs revealed a significant RIF among controls, $t(24)=2.12$, $p=0.022$, $d=0.87$, but not among OCD patients, $t(19)=0.33$, $p=0.75$, $d=0.15$. The same pattern emerged from recall accuracy data, with no RIF observed among OCD patients, $t(24)=1.02$, $p=0.16$, $d=0.42$, but a tendency for a RIF effect among controls, $t(24)=1.67$, $p=0.053$, $d=0.68$. In brief, repeated retrieval of

Table 2
Recall accuracies for the four item types in the two groups.

	Rp+	Nrp+	Rp−	Nrp−
OCD	0.70 (0.17)	0.38 (0.19)	0.39 (0.17)	0.41 (0.15)
Control	0.64 (0.20)	0.36 (0.16)	0.37 (0.17)	0.43 (0.18)

Note. Values show mean recall percentages (with standard deviations in brackets) during the final test for practiced items (Rp+), their baselines (Nrp+), and items related to practiced items (Rp−) and their baselines (Nrp−).

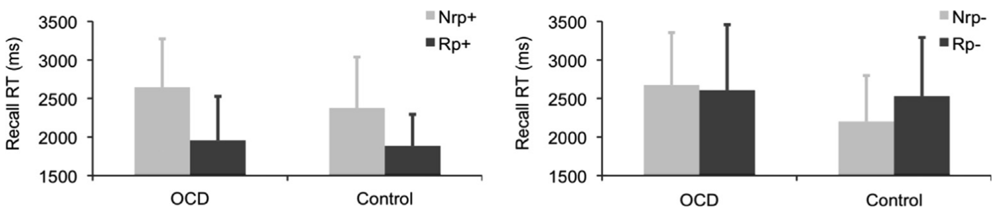

Fig. 2. Average recall reaction times on the final test in the two groups. *Note.* Final recall RTs of practiced items (Rp+), their baselines (Nrp+) (left panel), and items related to practiced items (Rp−) and their baselines (Nrp−) (right panel). The practice effect is evident in both groups (Rp+ items being recalled faster than Nrp+ items). Retrieval induced suppression is evident in the control group (Rp− recall is slower than Nrp− recall), but is absent in the OCD group. Error bars represent standard deviations.

memories caused suppression of related memories in the control group, but not among participants with OCD.

3.5. *Potential factors modifying retrieval-induced forgetting*

In the analyses below we calculated the Pearson correlation coefficients between the RIF score (calculated as the differences between Rp− recall RT and Nrp− recall RT), and potential factors related to RIF.

3.5.1. *Working memory*

Working memory did not correlate with RIF in our study: neither hit rates nor correct rejection rates in either the two-back or the three-back condition correlated with the RIF effect. This was true when correlations were calculated for the whole sample (all p's > 0.16, *ns*), as well as when the same correlations were calculated for the two groups separately (all p's > 0.29, *ns* for controls and all p's > 0.46, *ns* for participants with OCD, respectively).

3.5.2. *Anxiety*

Retrieval-induced forgetting did not correlate significantly with either the state (STAI-S) or the trait (STAI-T) measures of anxiety, $r=0.05$, $p=0.77$, and $r=0.23$, $p=0.13$, respectively. This pattern was the same when we analyzed the OCD group and the control group separately (respective statistics were: $r=0.33$, $p=0.88$; $r=-0.08$, $p=0.71$, for controls, and $r=-0.16$, $p=0.52$; $r=0.15$, $p=0.54$, for participants with OCD). In brief, the RIF effect was not correlated with anxiety.

3.5.3. *Symptom severity*

As measured by Y-BOCS total scores, symptom severity did not correlate significantly with RIF, $r=-0.19$, $p=0.38$. Also, there was no significant correlation between RIF, and either the obsessive subscale ($r=-0.21$, $p=0.33$), or the compulsive subscale of the Y-BOCS ($r=-0.12$, $p=0.55$).

4. Discussion

In this study, we aimed at assessing the ability to resolve interference during competitive retrieval in a sample of OCD patients, where the core cognitive dysfunction is characterized by executive deficits.

Our results demonstrate that retrieving memories does not induce forgetting of related memories among participants with OCD. Lack of forgetting in OCD occurred in spite of the fact that overall memory and the mnemonic effect of practicing memories was almost identical to that among healthy controls. Importantly, learning curves during the retrieval practice phase were similar in the two groups. The lack of RIF among OCD patients therefore is not related to overall recall performance, rather, we suggest that it is related to differences in resolving interference during competitive retrieval. In brief, despite similar recall performance in the two groups, recall of memories was not accompanied by adaptive suppression of related memories among OCD patients.

In line with previous work (Veling and van Knippenberg, 2004; Racsmány and Conway, 2006; Verde and Perfect, 2011) recall RTs proved to be more sensitive in detecting a RIF effect than simple recall accuracies. Among controls, we found a large and significant RIF effect (Cohen's $d=0.87$) as indexed by the RT data, and a medium size RIF effect (Cohen's $d=0.68$) that was present only at a trend level, when the measure of the effect was recall accuracy. In the OCD sample, according to the same measures, we found no effect for the RT data (Cohen's $d=0.15$) and a small and non significant effect for recall accuracy (Cohen's $d=0.42$).

Earlier, it was suggested by Koessler et al. (2009) that induced stress eliminates RIF among healthy participants by temporarily suspending the inhibitory mechanisms involved. Importantly, we found that both state and trait levels of anxiety were higher among patients than among controls, however these scores did not show any relationship with the amount of RIF. We have to mention that our study assessed stress induced by our experiment indirectly by the subjective evaluation of state anxiety (STAI-S), which could have caused the different results of our study and that of Koessler et al. (2009). In comparison with controls, updating of working memory was impaired among OCD patients, however contrary to the findings of Aslan and Bäuml (2010), WM performance did not correlate with RIF. We have to note that WM in our study was assessed by a different task (*n*-back) than the complex WM-task used by Aslan and Bäuml (2010). Although the *n*-back task and complex WM tasks have been generally thought to measure similar processes of WM, a recent meta-analysis by Redick and Lindsey (2013) implies that they are actually weakly correlated. Another difference between our study and the Aslan and Bäuml study was that our task produced much less variance, and their sample was four times as large as ours, while the effect detected in their study was weak. The correlation analyses showed no linear relationship between the RIF effect and stress, WM capacity, and symptom severity.

Our main findings are in contrast with the results of Jelinek et al. (2012) who found comparable RIF effects among OCD patients and healthy controls. However, in that study, Jelinek and colleagues also found a "tentative evidence for a weakened RIF effect for subjectively salient OCD-relevant material" (Jelinek et al., 2012, pp. 81). One potential confounding factor in their study could be the use of category cued free recall at final test. Such a test fails to control for output interference, whereby accessing memories that had been practiced during the practice phase blocks access to other related memories. In this case, the RIF effect would not be due to the effect of suppression but rather to some output interference process (Anderson, 2003). Here we showed that when item specific cues were used at the final test, retrieval practice did not impair the accessibility of related memories, i.e. no RIF was found.

From previous studies we know that OCD patients manifest problems in the use of organizational strategies during encoding of episodic memories (e.g., Savage et al., 1996; Deckersbach et al., 2005; Muller and Roberts, 2005) and in situations that involve executive functions (see; Kuelz et al., 2004; Abramovitch et al., 2013). These difficulties are particularly pronounced in tasks that are generally thought to tap inhibitory processes, such as the Stroop task (e.g., Martinot et al., 1990), the Go/NoGo task (Bannon et al., 2002; Penades et al., 2007; Watkins et al., 2005), and the antisaccade task (Maruff et al., 1999; Spengler et al., 2006; Tien et al., 1992). A strong hypothesis of Chamberlain et al. (2005) is that deficits of inhibition mechanisms are responsible for the main symptoms and neuropsychological profiles in OCD. In addition to inhibitory mechanisms, deficits in monitoring information also seem to be essential aspects of the cognitive profile of OCD, as suggested by results that indicate an overmonitoring in prospective memory tasks (Racsmány et al., 2011). Both of these processes are thought to be involved in conflict detection and conflict resolution arising during retrieval of competing memory representations (Anderson, 2003; Kuhl et al., 2007; Wimber et al., 2009; Hellerstedt and Johansson, 2013).

For instance, in an fMRI study, Kuhl et al. (2007) found evidence that repeated retrieval of target memories reduced the activity in a control network involving the ACC and dorso and ventrolateral PFC, structures important in detecting and resolving interference (Barch et al., 2000; Botvinick et al., 2004; Carter and Van Veen, 2007). The magnitude of reduction of PFC activity across repeated retrieval attempts of a target memory was associated with increased forgetting of interfering non-target memories at a final test, i.e., increased RIF. Accordingly, another fMRI study demonstrated that when memory competition is successfully resolved, the activity of the left medial and left lateral PFC, as well as activity in the left ACC is reduced (Wimber et al., 2009). Authors of both of the above studies suggest that the frontal structures are important not just in target memory selection but also in inhibition of related memories.

The ACC is of special interest in the context of interpreting our results. This area has been shown to be hyperactive in OCD compared to activity in controls, in tasks requiring cognitive conflict resolution and error detection (Bush et al., 2002; Van Veen and Carter, 2002; Fitzgerald et al., 2005; Maltby et al., 2005; Page et al., 2009; for a detailed review of brain areas affected in OCD see Milad and Rauch, 2012). Milad and Rauch (2012) suggested that the hyperactivity of the dorsal ACC might contribute to the persistence of error signals, producing the obsessive thoughts in OCD.

Given its role in conflict detection, one speculative interpretation of our results would be that the RIF effect is absent in OCD patients due to inappropriate conflict resolution processes during retrieval of competing memories driven by the constant hyperactivity of ACC and prefrontal structures. However, as no neuroimaging was involved in our study, the specific background mechanisms leading to the absence of RIF in OCD need to be addressed by novel experimental and neuroimaging studies.

Our study had a couple of limitations that have to be taken into account when interpreting the results. First, the material used in our study was not selected to be OCD relevant. Although our study was designed to address control processes in memory with emotionally neutral material, an earlier study by Jelinek et al. (2012) found tentative evidence that the use of personally salient material can modify the RIF effect. Second, the majority of the patients was under medication during the study and we included in the sample patients with mild depression. We think that studies with medication-naive patients are critical to obtain a better understanding of the relationship between clinical symptoms and cognitive deficits (e.g., Krishna et al., 2011). Third, a lot of different processes could be involved in the wide range of inhibitory tasks used in studies of inhibition, and cognitive inhibition itself has been defined in many different ways (for a review see Gorfein and MacLeod, 2007). Therefore, our conclusions may have benefited from additional results on another task measuring inhibition.

To conclude, it seems that in OCD interfering memories are not suppressed. Based on the inhibition deficit account of Chamberlain et al. (2005), one interpretation of our data is that the lack of the suppression effect is due to the inefficient suppression of irrelevant, interfering memories during competitive retrieval. However, it is also possible that the suppression effect is not produced by competitive retrieval in OCD because participants with OCD are not sensitive to interference as much as healthy participants. Further experiments are needed to clarify the role of conflict detection processes in the deficit of selective memory suppression in OCD.

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Appendix A

See Table A1.

Table A1
English translation of the categories and target words used in the experiment (The original experimental material was Hungarian).

Category cue	Target member	Category cue	Target member
Material	Silk	Bird	Vulture
Material	Marble	Bird	Seagull
Material	Ceramics	Bird	Parrot
Material	Linen	Bird	Owl
Material	Concrete	Bird	Raven
Material	Silver	Bird	Sparrow
Transport	Trolley-bus	Clothes	Pullover
Transport	Truck	Clothes	Stockings
Transport	Airplane	Clothes	Socks
Transport	Helicopter	Clothes	Tyre
Transport	Train	Clothes	Hat
Transport	Metro	Clothes	Boot
Job	Soldier	Sports	Wrestling
Job	Interpret	Sports	Fencing
Job	Model	Sports	Kayaking
Job	Waiter	Sports	Tennis
Job	Policeman	Sports	Volleyball
Job	Driver	Sports	Riding
Fruit	Cranberry	Tools[a]	Pike[a]
Fruit	Ananas	Tools[a]	Saw[a]
Fruit	Strawberry	Tools[a]	Hammer[a]
Fruit	Prune	Tools[a]	Rake[a]
Fruit	Banana	Tools[a]	Shredder[a]
Fruit	Melon	Tools[a]	Welder[a]
Instrument	Saxophone	People[a]	Mexican[a]
Instrument	Clarinet	People[a]	Norvegian[a]
Instrument	Harp	People[a]	Turkish[a]
Instrument	Trumpet	People[a]	Brazilian[a]
Instrument	Viola	People[a]	Afgan[a]
Instrument	Organ	People[a]	Ukrainian[a]

[a] Indicates filler categories and filler items.

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