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Cognitive rigidity in unipolar depression and obsessive compulsive disorder: Examination of task switching, Stroop, working memory updating and post-conflict adaptation

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ABSTRACT

Obsessive compulsive disorder (OCD) and depressive rumination are both characterized by cognitive rigidity. We examined the performance of 17 patients (9 suffering from unipolar depression [UD] without OCD, and 8 suffering from OCD without UD), and 17 control participants matched on age, gender, language and education, on a battery covering the four main executive functions. Results indicated that, across both disorders, patients required more trials to adjust to single-task conditions after experiencing task switching, reflecting slow disengagement from switching mode, and showed abnormal post-conflict adaptation of processing mode following high conflict Stroop trials in comparison to controls. Rumination, which was elevated in UD and not in OCD, was associated with poor working memory updating and less task preparation. The results show that OCD and UD are associated with similar cognitive rigidity in the presently tested paradigms.

1. Introduction

Many psychological disorders are characterized, phenomenologically, by some form of cognitive rigidity. Two such disorders are obsessive compulsive disorder (OCD) and unipolar depression (UD, see also Pronin and Jacobs, 2008). In OCD, patients suffer from obsessions: recurrent, persistent and distressing intrusive thoughts, impulses, or images which are difficult to disengage from or suppress (American Psychiatric Association, 1994). In UD, patients tend to ruminate: repetitively think about the causes, consequences and symptoms of their negative affect (Nolen-Hoeksema, 1991). Understanding the nature of these two forms of rigid thinking may lead to important insights regarding these pathologies, especially given the rapidly growing body of knowledge regarding the cognitive and neurological underpinning of cognitive rigidity. The questions addressed in this study are, "What characterizes the cognitive rigidity found in these two psychopathologies?" and "Are there differences between these two disorders in terms of type or nature of cognitive rigidity?" Understanding rigidity in these two pathologies is important both theoretically and clinically. For example, if the pathologies are associated with similar rigidity, this would suggest that rigidity may be a general risk factor for these disorders. Clinically, incorporating recently developed training protocols that have been shown to improve flexibility may be indicated (e.g., Karbach and Kray, 2009).

In order to be able to address these questions, we had to use precise and rich measurements that would cover a wide variety of differential aspects of rigidity. Such an approach allowed us to address the question regarding whether the *profile* of rigidity is similar or different across indices. We also had to take into account the high co-morbidity of these two pathologies, which could potentially cause them to appear to be similar. For this reason, we excluded from the study patients exhibiting both OCD and depressive symptoms. In the next section we present the rationale for choosing our measurements, especially those based on the task switching paradigm.

The task switching paradigm (Meiran, 2010; Monsell, 2003, for reviews) is considered to be the most precise measure of cognitive rigidity to date. In this paradigm, participants are asked to rapidly switch between simple cognitive tasks, such as color judgment (e.g., green vs. red), shape judgment (e.g., circle vs. square) and size (e.g., small vs. large). This paradigm enables researchers to study the processes associated with forming and changing trains of thoughts, in this case "task sets". It provides several advantages relative to classical neuropsychological tests such as the Wisconsin Card Sorting Test (WCST, Berg, 1948), in which participants need to find a sorting rule based on correct/incorrect feedback provided by the experimenter. The most notable

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advantage of the task switching paradigm is that it taps different aspects of rigidity, including the cost of actual switching, the cost of maintaining readiness for a switch, the degree of disengagement from a previous set, the rate of disengagement and others. In contrast, the WCST provides a single measure of rigidity: the number of perseverative errors. These are the errors associated with employing the previously relevant but no longer relevant sorting rule. Additionally, like the WCST, performance in the task switching paradigm is multifactorial, but unlike the WCST, the different factors are clearly distinguishable from one another. We will give just one example: Perseverative errors may result from poor memory of the previous choices, poor memory of the sorting rule or from difficulty in processing the correct/incorrect feedback. In the task switching paradigm, however, the classification rules appear on the screen and therefore require minimal if any memory and there is no need to keep track of past choices. Thus, measurements of rigidity are not contaminated by working memory and feedback processing (e.g., Miyake et al., 2000). Another notable advantage of this paradigm is that its indices have been linked to differential neurological substrates and processes (e.g., Derrfuss et al., 2005, Dosenbach et al., 2006; Sakai, 2008, for reviews), which we discuss further in the sections below.

Only two studies have examined task switching performance in OCD. Moritz et al. (2004), who examined two widely studied task switching-related parameters (switching cost and backward inhibition), did not find any abnormality among OCD patients. *Switching cost* is believed to reflect the difficulty associated with actual switching. It is reflected in a decrement in performance (reaction time, RT, and proportion of errors, PE) in trials involving a task switch as compared to trials in which the task is repeated from the preceding trial. *Backward inhibition* reflects a hypothetical process responsible for suppressing the previously relevant task set when switching to a new task set, so that the previous task set does not interfere with performance. Gu et al. (2008), on the other hand, did find increased PE in switch trials, but not in task repetition trials, among OCD patients compared to controls. This pattern suggests that OCD is related to increased task switching cost, seen for some reason only in errors and not in RT. Only one study investigated task switching in depression. Whitmer and Banich (2007) found that depression and rumination scores correlated with both task switching cost and backward inhibition in a college sample. The results of these three studies suggest that there is a differential profile of rigidity in the two pathologies. OCD seems to be related to a relatively mild increase in switching cost while depression seems to be related to both increased switching cost and impaired task-set inhibition. Research based on classical neuropsychological tests has reached a similar conclusion, at least regarding set switching. Such research has found a relatively consistent pattern of set switching difficulties in UD (see Austin et al., 2001; Rogers et al., 2004, for review) whereas the picture regarding OCD (Chamberlain et al., 2005; Greisberg and McKay, 2003; Kuelz et al., 2004; Menzies et al., 2008; Olley et al., 2007, for review), is mixed, with some studies finding impairment and some not, suggesting that the impairment is rather mild.

We examined cognitive flexibility in these two patient groups using a task switching paradigm (described below). Because set shifting ability (measured with task switching) is considered to be an executive function, we also measured other executive functions for completeness sake. To choose these functions, we relied on Miyake et al.'s (2000) taxonomy including three fundamental executive functions: shifting, inhibition, and working memory updating. We also studied a fourth, widely mentioned executive function — conflict monitoring (e.g., Botvinick et al., 2001). Functional imaging studies have linked problems with monitoring to abnormal functioning of the anterior cingulate cortex in patients suffering from OCD and depression (e.g., Elliot, 1998; Ullsperger, 2006). Another motivation to include additional executive functions in this study was their conceptual link to rigidity. Specifically, successful monitoring is required in order to detect a need to change processing mode. Failing to adjust processing mode according to changing contextual demands would count as rigidity. Likewise, successful inhibition is required in order to suppress one's tendency to operate based on the old, no-longer-relevant mode (see especially Friedman and Miyake, 2004). Accordingly, habitual behavior in situations requiring non-habitual responses would also count as rigidity. Finally, when there is a context change and an accompanying goal change, this information needs to be updated in working memory. Failure to update working memory with the new goal would result in perseverative and rigid behavior.

To study inhibition, we employed the Stroop (1935) test in which participants are asked to name the ink color of congruent (e.g., the word RED written in red ink, and requiring "red" response) and incongruent (e.g., the word GREEN written in red ink and requiring "red" response) words. The critical index of inhibition is the Stroop effect, which is the difference in performance between congruent and incongruent trials. To study working memory *updating* we used Oberauer's (2002) paradigm (see description below). To study monitoring, we examined an index called post-conflict adaptation — also known as the Gratton effect (Gratton et al., 1992; see also Freitas et al., 2007; Kerns et al., 2004). Post-conflict adaptation refers to the sharpened focusing on task-relevant information following high conflict trials. In the case of the Stroop task, it is evidenced by a smaller Stroop effect following incongruent trials as compared to congruent trials.

1.1. Predictions

Results from prior studies, reviewed above, tentatively support the hypothesis that OCD and UD have differential rigidity profiles. Yet, to date, there is no study that has directly compared OCD and UD in task switching. Given the immense variability among task switching paradigms, any cross-study comparison is seriously limited. Moreover, previous studies have focused on only two measurements: switching cost and backward inhibition. In the present investigation we decided to broaden the exploration and include several additional parameters conceptually related to set perseveration and switching, especially to aspects that are likely to differentiate between the two pathologies. This is in accordance with the current Zeitgeist proposing that there is a differential underlying neurology, expressed as differential types of rigidity. Specifically, OCD has been linked to basal ganglia and prefrontal impairments (e.g., Kuelz et al., 2004; Menzies et al., 2008) whereas UD has been linked to cortical impairments, especially the anterior cingulate cortex and the dorso-lateral prefrontal cortex (e.g., Rogers et al., 2004). Moreover, the basal ganglia have been shown to be related to very distinct aspects of rigidity (e.g., Yehene et al., 2008). Below we explain the indices which we used in the present study and how they may be linked to UD and OCD.

When computing switching cost, the performance measure (e.g., reaction time, RT) in task switch trials is subtracted from that in task repetition trials. Note that task switch trials and task repetition trials occur in contexts in which a task switch *could* take place. Hence, in both conditions, participants need to maintain some readiness for a task switch. To assess the cost associated with maintaining readiness to switch tasks, we included a context in which task switching *could not* take place since only one task was required, "single-task". The comparison between performance in task repetition trials and single-task trials provides an index of the cost associated with maintaining readiness to switch tasks, called "mixing cost" (e.g., Braver et al., 2003; Rubin and Meiran, 2005). We also focused on the period of transition from the condition in which task switching could occur to the single-task condition, in which task switching could not occur. Specifically, we examined how RT became shorter in the course of this single-task block. Previous results by Mayr and Liebscher (2001; see also Meiran et al., 2001) indicate that aging is related to a very slow adaptation to single-task conditions following task switching. This "fadeout" effect reflects the rate of disengagement from a switching mode and, thus, indicates rigidity because it shows that the person maintains readiness for a task switch despite the change in context to one in which switching is no

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longer required. Note, however, that unlike task switching cost, which indicates rigidity on the time scale of seconds, the fadeout effect indicates rigidity over a period of dozens of seconds or even minutes. Unfortunately, the neurological underpinning of the fadeout effect has not yet been examined. The fact that it is impaired in old age, however, implicates the prefrontal cortex as a likely candidate (Meiran et al., 2001).

Since the literature consistently shows that poor preparation and the repetition of the key press make switching more difficult, we randomly varied the interval between the presentation of the task instruction (e.g., the stimulus indicating that the upcoming task is right–left) and the presentation of the task stimulus (the stimulus whose right vs. left location was to be judged) and included response repetition as a variable in the analyses.

Finally, we included (task rule) congruency as a variable in our analyses. The congruency effect, which is explained shortly, reflects the degree of disengagement from the previous set. Congruent trials are those in which the two task rules indicate the same key as the correct response. Incongruent trials are those in which the currently irrelevant task rule indicates a different key press as the correct response than does the currently relevant task rule. Importantly, the congruency effect in errors has been clearly and strongly linked to basal ganglia functioning (Yehene et al., 2008), a brain region believed to be impaired in OCD (Menzies et al., 2008) but not (or less so) in UD. Thus, we predicted that OCD, more so than UD, would be associated with increased congruency effects in PE.

Based on previous results, we predicted that OCD would *not* be associated with increased RT switching cost. Based on the phenomenology of the two pathologies, we anticipated abnormal fadeout effects, and possibly increased mixing cost, in both patient groups. Since OCD has been linked to abnormalities in the basal ganglia, we tentatively predicted an increased congruency effect in PE among OCD patients.

We did not predict any patient-related impairment on Stroop (which served as our index of inhibition), based on the mixed picture in the literature (Kuelz et al., 2004; Rogers et al. 2004). The same was true for (verbal) working memory updating. With respect to OCD, most of the studies employed spatial working memory (Purcell et al., 1998a, 1998b; van der Wee, et al., 2003), and the only study with a non-spatial task (Thibault et al., 2008) did not find behavioral differences. With respect to UD, some studies did not find impairment (e.g., Barch et al., 2003; Purcell et al., 1998b) where others did (e.g., Harvey et al., 2004; Joormann and Gotlib, 2008).

The only study focusing on behavioral indices of post-conflict adaptation in OCD was conducted by Soref et al. (2008), who found lesser post-conflict adaptation among university students with high obsessive compulsive (OC) tendencies compared with those with low OC tendencies. Regarding UD, neither Pizzagalli et al. (2006), who used the flanker task (a measure of inhibition, arguably similar to the Stroop task) with normals as a function of their depression scores, nor Holmes and Pizzagalli (2008), who used the Stroop task with patients, found significant depression-related differences. Holmes and Pizzagalli (2007) used the Simon task (another inhibition measure) and the Stroop task and studied normal participants as a function of their scores on a depression scale. They found abnormal behavioral adjustments among those scoring high in depressive symptoms, including abnormal post-conflict adaptation, but only with negative feedback and not with positive feedback. Based on this literature, we predicted abnormal post-conflict adaptation for OCD and not for UD.

2. Methods

2.1. Participants

Nine individuals with OCD, 8 individuals with UD and 17 non-clinical controls participated in the study. Participants in the two clinical groups were recruited from the depression and OCD clinics at the Beer-Sheva Mental Health Center. Control participants, matched for age, gender, native language and education, were recruited via advertisements posted at Ben-Gurion University located near the mental health center. Most of the participants had completed high school. Seven control participants did not complete high school and were therefore tested on a Hebrew Vocabulary test (Fischman, 1982) to insure their intellectual functioning was comparable to that of people who completed high school. Using the mean and standard deviation for Israeli college students (28 and 6, respectively, based on $N=98$, taken from Yehene and Meiran, 2007), the Z scores for these 7 subjects were −2.3, −1.0, −1.0, −0.7, −0.5, 0.3, 0.5 and 0.6. These Z scores indicate that the scores of six out of seven participants performed within the college-level norm (i.e., 2 S.D.s from the mean). The score of one participant fell outside the norm. However, the low score could be explained by the fact that this control participant was not a native Hebrew speaker. Descriptive statistics regarding age, gender and first language appear in Table 1.

All participants were assessed using the Mini International Neuropsychiatric Interview (MINI; Sheehan, et al., 1998), the 24-item version of the Hamilton Rating Scale for Depression (HRSD; Hamilton, 1960), the 5 reflective pondering and 5 brooding items from the Ruminative Responses Scale (RRS; Treynor et al., 2003) and the Yale–Brown Obsessive Compulsive Scale (YBOCS; Goodman et al., 1989). In the UD group, all participants met DSM-IV (American Psychiatric Association, 1994) criteria for Major Depressive Disorder. Three also met criteria for co-morbid Panic Disorder, one for co-morbid Dysthymia and one for co-morbid Social Phobia. In the OCD group, all participants met DSM-IV criteria for OCD and none met the criteria for depression. One of the OCD patients also met criteria for co-morbid Social Phobia and another OCD participant met criteria for co-morbid Tourettes. No members of the control group met criteria for any mental disorder.

The three groups were perfectly discriminable based on their scores on the symptom checklists. All members of the depressed group scored 11 or above on the HRSD, whereas members of the OCD and control groups all scored 10 or below. Likewise, all members of the OCD group scored in at least the moderately severe clinical range of the YBOCS (20 or above), whereas members of the depressed and control groups all scored zero. All of the patients in both the depressed and OCD groups were currently taking medication, primarily SSRIs, and had been for at least 3 months prior to the start of the study.

2.2. General procedure

Individuals reviewed and signed an informed consent, were then administered the MINI and symptom checklists and if they met inclusion criteria were then administered the executive functions tests in front of a laptop computer in the following order: working memory updating, Stroop, and task switching. The entire procedure was completed in 1 or 2 two-hour meetings and participants received an equivalent of $25.00 reimbursement for their time.

2.3. Executive functions tests

Stimulus size is described in visual angles.

2.3.1. Working memory updating

The stimuli included one, two or three square frames of $2^\circ \times 2^\circ$ that appeared in the center of the screen. Inside each frame appeared a digit at first ($0.7^\circ \times 0.5^\circ$), and then a calculation sign ("+" or "−", $0.5^\circ \times 0.5^\circ$). Each trial began with one, two or three blue frames containing a black digit (1–9), arranged in a row in the middle of the screen with a white background. Participants were asked to memorize these digits and press the space bar when they were ready. The numbers then disappeared and a series of steps began. In each step, an arithmetic operation was displayed inside one of the squares. The frames where chosen pseudo-randomly, with equal probability. The arithmetic operations (i.e., "−2", "+4", "−1") were also chosen pseudo-randomly, with the constraint that the operation's result was between 1 and 9. The participants were required to mentally perform the operation on the memorized digit in the square, to memorize the result, and to press the space bar in order to present the next step. Each run included 6 steps in the one- and two-frame conditions, and 9 steps in the three-frame condition. After these steps, a question mark appeared in each frame in turn, from left to right, and participants were asked to type the final result for a given frame.

Following 3 practice runs, one for each set-size, there were 5 experimental blocks ordered (in terms of frame numbers) 1–2–3–2–1. Each block included 6 runs in the

Table 1
Participants' characteristics.

	Group			
	OCD	OCD control	UD	UD control
Age (years)	27.0	26.3	44.4	44.1
Native Hebrew speakers	7 of 8	7 of 8	2 of 9	2 of 9
Gender (F,M)	1,7	1,7	7,2	7,2
Hamilton (mean, S.D., min, max)	6.0, 2.3, 3–10	2.0, 1.8, 0–4	20.6, 6.5, 11–33	2.6, 2.4, 0–6
YBOCS (mean, S.D., min, max)	24.2, 3.2, 20–28	0.0	0.0	0.0

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single-frame condition, 3 runs in the two-frame condition, and 4 runs in the three-frame condition. In order to minimize frustration due to poor performance, the experimenter terminated a block after 3 successive unsuccessful runs.

2.3.2. Stroop (inhibition)

The stimuli were the Hebrew words (0.7°×2.5°) for red, blue, yellow and green colored in red, blue, yellow or green (16 stimuli, 4 congruent). The experiment began with a warm-up block of 8 trials, followed by 4 blocks of 32 trials. Each trial began with a fixation point ("+") that appeared for 500 ms, followed by the colored word stimuli that appeared until a vocal response was indicated. After the response, a 900 ms black screen appeared.

2.3.3. Task switching

The procedure and stimuli were similar to those used by Meiran et al. (2001, Experiment 1). The task involved switching between two spatial location tasks: Vertical (V, up vs. down) and Horizontal (H, right vs. left), in which the location of a target within a 2×2 grid (3.4°, width×2.9°, height) was determined (see Fig. 1). The target was a white rectangle (0.3°, width×0.5°, height). The arrowheads (0.3°×0.5°) were positioned 0.7° from the end of the grid.

The experiment began with a warm-up block of 10 trials of one task (horizontal or vertical), followed by a 40-trial block of this task. Then, a warm-up block of 10 trials of the other task was administered, followed by a 40-trial block of the other task. The order of the tasks in the single-task condition was counterbalanced between the participants. After the single-task blocks, a warm-up block of 20 mixed-task trials appeared, followed by 8 mixed-tasks blocks of 40 trials each. Finally, 2 single-task blocks of 40 trials were administered. The order of the tasks was the opposite of their order at the beginning of the experiment.

Each trial consisted of an empty grid presented during the response-cue interval (1500 ms). It was followed by the presentation of the instructional cue during the preparation interval, with a randomly varying length (100 or 1000 ms). Finally, the target stimulus was presented along with the task cue until the response was given. A 400 Hz tone was presented for 1000 ms after an error was conducted. Half of the participants used the (upper-left) U Key to indicate UP and LEFT (depending on which task was required), and the (lower-left) V Key to indicate DOWN and LEFT. The other half of the participants used the (upper-left) "T" (for UP and LEFT) and the (lower-right) "N" key (for DOWN and RIGHT), instead. The response keys were also counterbalanced between the participants.

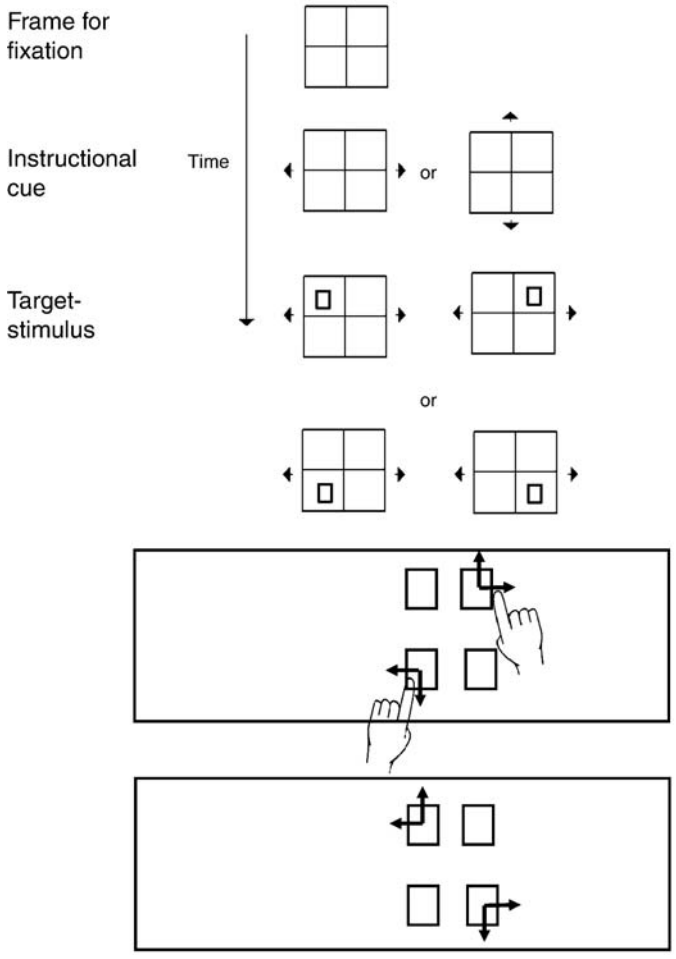

Fig. 1. Schematic description of the task switching paradigm.

3. Results

3.1. Analytic design

The between-subjects variables were Patient vs. Control and Control + Patient Type (UD and their controls vs. OCD and their controls). In this design, there are two patient groups and two control groups so that each patient group is compared with a different control group matched on age, gender and education. The design permits examining both overall difference between patients and controls and differences between OCD vs. their control compared to UD vs. their control. Difference between patients and controls would be indexed by the main effect of Patient vs. Control (see Table 2). Note that despite the age differences between the groups, the main effect of Patient vs. Control is not confounded with age because each patient group has an age-matched control group. The differences between OCD and UD are indexed by the 2-way interaction between Patient vs. Control and Control + Patient Type. This interaction reflects whether one patient group has a larger difference relative to its control group as compared with the other patient group. In this analysis we do not interpret any effects of Control + Patient Type (OCD patients and their controls vs. UD patients and their controls) because of age confound. In the following analyses we first analyzed group effects on Rumination and then analyzed performance on executive function paradigms, with Rumination as an additional (continuous) independent variable. Thus, influences of Rumination and Group on performance are each controlled for the influence of the other.

3.2. Rumination

All the effects were significant including Control + Patient Type, $F(1, 30) = 4.23$, $P<0.05$, $\hat{\eta}_p = 0.12$, Patient vs. Control, $F(1,30) = 20.69$, $P<0.0001$, $\hat{\eta}_p = 0.41$, and the interaction, $F(1,30) = 7.41$, $P<0.05$, $\eta_p^2 = 0.20$. These results reflect the fact that the depression group had significantly higher rumination scores ($M = 31.3$, S.D. = 10.8) than all the remaining groups ($M = 18.9, 12.4, 14.3$, S.D. = 9.9, 2.5, 2.8 for OCD, depression controls and OCD controls, respectively), which did not differ significantly from one another.

In none of the following analyses was there a significant interaction involving both Control + Patient Type and Patient vs. Control. These non-findings indicate that, within the limits of the current study which are discussed below, the deficiencies in executive functions were similar among UD and OCD.

3.3. Task switching

Before the analyses we excluded trials following an error and replaced RTs>5000 ms with missing values. To further maximize the statistical power (Ratcliff, 1993), we computed the harmonic mean RT for each condition. These conditions were formed by the factorial combination of Transition (switch, repeat single-task), Preparation Time (operationalized as the duration of the presentation of the task instruction before the target appeared, 100 vs. 1000 ms), Congruency (congruent vs. incongruent), and Response Repetition (repeated, changed). For brevity's sake, we do not report the various repeated-

Table 2
Illustration of variables analyzed.

	Patient type	
	UD and their controls	OCD and their controls
Patients	OCD patients	UD patients
Controls	OCD controls	UD controls

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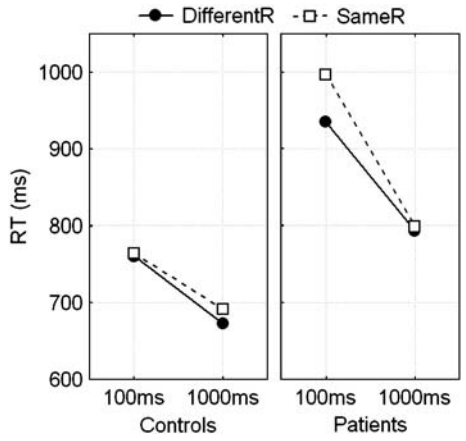

Fig. 2. Mean task switching RT as a function of group, preparation time, and response repetition. R = response.

measures effects that were not qualified by Patient vs. Control, by the interaction between the two group variables or by Rumination. We also do not report effects that are qualified by higher order interactions.

There was a significant triple interaction between Response Repetition, Preparation, and Patient vs. Control, $F(1,29)=5.17$, $\eta_p^2=0.15$ (Fig. 2). Slowing following response repetition was (almost significantly) more pronounced among patients than among controls when there was little time to prepare, $F(1, 19)=4.05$, $P=0.053$, but not when preparation time was long, $F<1$. A closer examination of the results (see Fig. 3) reveals the usual pattern of results for the controls, whereby response repetition resulted in response slowing in switch trials ($P<0.05$), in facilitation in task repetition trials ($P<0.05$), and in no effect in single-task conditions. As is typically observed (e.g., Yehene and Meiran, 2007), this trend was found only for short preparation interval. In contrast, the patients showed response repetition slowing in all the Transition conditions, including task repetition ($P<0.05$), which is abnormal.

There was also a significant interaction between Rumination, Preparation and Switch, $F(2,58)=3.69$, $P<0.05$, $\eta_p^2=0.11$. The interaction was examined by computing the partial correlations between the respective preparation effects and Rumination, after controlling for the grouping variables, −0.32, $P=0.08$, and −0.36, $P<0.05$, for the preparation-related reduction in mixing cost and switching cost, respectively. This finding indicates that rumination results in lesser preparation towards a new task. There was also a significant interaction between Preparation, Transition, and Patients vs. Controls, $F(2, 58)=3.64$, $P<0.05$, $\eta_p^2=0.11$ (Fig. 4). This interaction reflects the larger

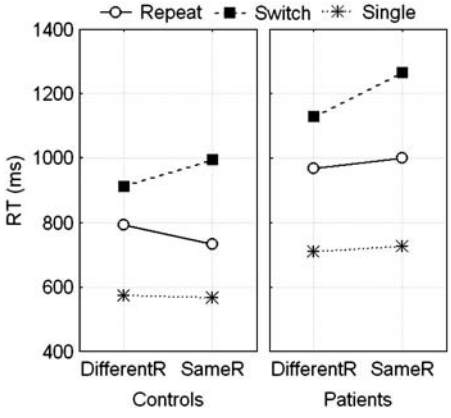

Fig. 3. Task switching — short preparation results: Mean RT according to group, transition, and response repetition. R = response. Transition was not involved in the significant interaction, but is included in the figure in order to highlight the causes for the significant interaction presented in Fig. 2.

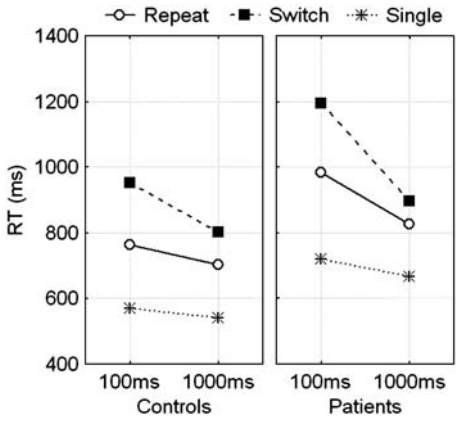

Fig. 4. Mean task switching RT according to Patient vs. Control, transition and preparation.

reduction in both switching cost and mixing cost due to preparation found among the patients as compared to their controls. We found that the preparation effect on mixing cost was significantly larger for patients than for controls, $F(1, 29)=4.33$, $P<0.05$, but that the patient vs. control difference in the preparation on switching cost fell short of significance, $F=2.45$, $P=0.13$. There were no significant effects in error whatsoever.

3.4. Fadeout effects

To analyze fadeout effects, we divided the 40 trials of the first single-task block which followed task switching into groups of 10 trials (Trials 1–10, 11–20, 21–30, and 31–40) and computed mean RT for each of these Miniblocks. The fadeout results of one OCD-control were lost due to equipment failure. We ran an ANOVA according to Miniblock (4), Control + Patient Type and Patient vs. Control. The interaction between Miniblock and Patient vs. Control was significant, $F(3, 84)=3.33$, $P<0.05$, $\eta_p^2=0.11$ (Fig. 5). We then examined the linear trend in the simple effect of Miniblock separately for patients, $F(1, 28)=15.55$, $P<0.0005$, where it was significant, and for controls, $F<0.3$, where it was not. There were barely any errors committed (0.6% in the third Miniblock).

3.5. Stroop (inhibition)

The only (relevant) significant effect was a 3-way interaction between Patient–Control, Congruency and Previous Trial Congruency, $F(1,29)=6.77$, $P<0.05$, $\eta_p^2=0.19$ (Fig. 6). Whereas the patients showed a significantly *reversed* post-conflict adaptation (smaller congruency effect following congruent trials), $F(1,29)=4.63$ and 6.59 for UD and OCD respectively, their controls did not show any post-conflict adaptation. A similar ANOVA on PE did not reveal any significant effect whatsoever. There were no between-group differences in the Stroop effect.[1]

3.6. Working memory updating

The score on this task was the proportion of sequences which were correctly performed. One depressed patient and one OCD patient found the working memory updating task so difficult that they could not perform it at all. We stopped the testing with an additional depressed

[1] We examined the patient–control differences in the post-conflict adaptation within OCD and UD, separately. We did so for each transition type. None of the comparisons were significant. We also ran analyses in which we examined how transition type modulated post-conflict adaptation (whether the effect is modulated by switch/repeat or by repeat/single-task). Again, none of these contrasts were significant.

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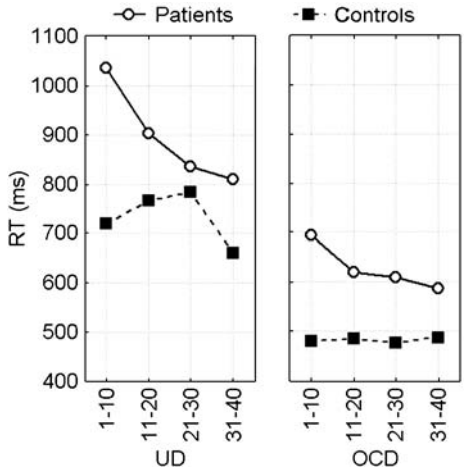

Fig. 5. Mean task switching RT according to Patient vs. Control and sequential Miniblock within the first single-task block following task switching.

patient when reaching the three object phase because the patient exhibited great difficulty. Their missing results were replaced with the lowest scores in their groups. The ANOVA included Rumination, the two grouping variables, and Number of Objects as independent variables. There was a significant interaction between Number of Objects and Rumination, $F(2, 58)=3.58$, $P<0.05$, $\eta_p^2=0.11$. This interaction is explained by the fact that there was also a negative correlation between Rumination and WM performance which increased with the number of objects, −0.12 (ns), −0.31 (ns), and −0.44 ($P<0.05$). Thus, more rumination was associated with poorer working memory updating.

4. Discussion

In the present study we tried to determine if OCD and UD are characterized by differential or similar profiles of rigidity. In order to address this question, we employed the task switching paradigm which yields a profile of rigidity indices linked to differential cognitive and neurological processes. We also incorporated other measures of executive functioning and compared the two pathologies while excluding patients exhibiting co-morbidity. We found that patients were different from their controls but that the patient groups did not differ from one another. Specifically, the fact that none of the interactions involving both Control + Patient Type and Patients vs. Control were significant suggests that the two disorders are

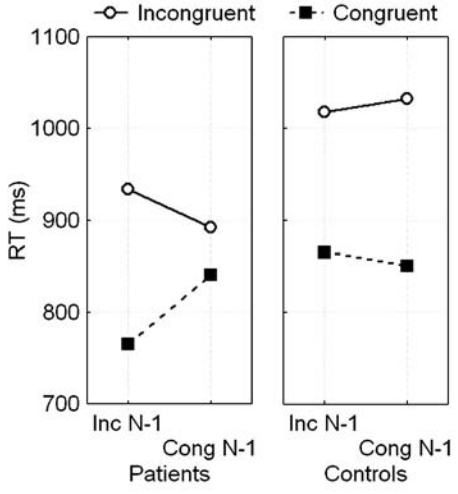

Fig. 6. Mean Stroop RT as a function of Patient vs. Control, congruency and the congruency in trial $n-1$. Inc = incongruent, Cong = congruent, $N-1$ = Trial $n-1$.

characterized by a similar profile of cognitive inflexibility, at least based on the presently examined paradigms. First, we found evidence that both groups of patients had difficulty disengaging from switching mode. More specifically, both patient groups took longer than control participants to adjust to single-task conditions following task switching (i.e., increased fadeout effect). Conceptually, this effect reflects the fact that the patients maintained readiness for task switching (i.e., "a switching mode"), even when told that switching would no longer take place. The fact that, among patients, switching cost was normal but fadeout was slow suggests that while patients were able to (more or less) successfully adopt or engage in a switching mode, they were less able to disengage from or inhibit a previous mode when it became irrelevant. Note that the rigidity reflected in fadeout effects refers to mental sets which typically persist over the course of at least dozens of seconds or minutes.

Interestingly, the UD patients showed impaired fadeout even after statistically controlling for rumination, suggesting that it was other aspects of their depression, not their ruminative symptoms per se, that were associated with an inability to disengage from a cognitive set. Apparently, inflexibility refers to a rather wide range of somewhat independent abilities. This is underscored by prior research showing that even equivalent measures of switching cost taken from paradigms involving different task content correlate only moderately (Yehene and Meiran, 2007). Therefore, rumination and fadeout may represent different aspects of inflexibility. There is already evidence that supports this conjecture as reflected by a process by age dissociation. Specifically, fadeout increases in old age (Mayr and Liebscher, 2001; Meiran et al., 2001) whereas rumination appears to be relatively stable from adolescence through old age (Garnefski and Kraaj, 2006). Additionally, there are some indications that UD and rumination may involve different brain regions. Putnam and McSweeney (2008) gathered electrophysiological measures in resting state, focusing primarily on Alpha oscillations. They found that UD patients, but not controls, exhibited Alpha hemispheric asymmetry with lower Alpha power (interpreted as increased activity) recorded over the right prefrontal cortex. Rumination recorded in the week following the electrophysiological recording was predicted by bilateral increase in Alpha power indicating less prefrontal activity in both hemispheres. Finally, there is evidence that inflexible negative cognitive styles, such as the tendency to ruminate, personalize and blame oneself, exist independent of depression. Research shows that previously depressed, at-risk individuals maintain such cognitive sets, even during periods when they are not depressed (Ingram et al., 2007; Joiner, 2001).

Second, we found that the adverse effect of response (key press) repetition was more pronounced for patients than for their controls, when little opportunity was given for preparation. Interestingly, this slowing effect was greater for both UD and OCD patients than for non-clinical controls and was found even in task repetition trials, a condition in which non-clinical samples show facilitation, not slowing. These results can be explained by Druey and Hübner's (2008) inhibitory account. According to these authors, participants inhibit responses after having executed them in order to prevent their erroneous re-execution. Perhaps this heightened effort in the task switching conditions made it more difficult to disengage from switching mode afterwards (the slow "fadeout" effect). Yet, even if this account was correct, it implies that response inhibition, as reflected in the response repetition effect, is quite different from the kind of inhibition reflected in the Stroop effect.

Third, we showed that UD and OCD patients both suffered from abnormal post-conflict adaptations effects in the Stroop task. These results may reflect abnormality in the anterior cingulate cortex associated with these psychopathologies (e.g., Elliot, 1998; Ullsperger, 2006), a brain region believed to subserve performance monitoring (Botvinick et al., 2001). This may contribute to rigid behavior due to an inability to monitor (notice) one's own rigidity. Beyond the association between UD and OCD and cognitive rigidity, our results also revealed the insidious effects of rumination on cognitive functioning. More

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specifically, we found that rumination — above and beyond depression and across patient and control groups — was associated with impaired task preparation. In other words, greater rumination was associated with lesser ability to translate advance task information into performance. This was evident by the fact that those who were ruminative were less able to reduce switching and mixing cost by utilizing preparation.

Our non-finding regarding switching cost replicates previous results on OCD (Gu et al., 2008; Moritz et al., 2004). Whitmer and Banich (2007), who studied a college sample, also found that depression scores did not predict switching cost when rumination scores were entered into the model (as in our analyses).

Fourth, across all four groups, high Rumination scores were correlated with poorer working memory updating. It is difficult to tell which is the cause and which is the effect here. On one hand, being preoccupied with ruminative thoughts may make one less alert and less able to update working memory. On the other hand, poorer working memory updating may be the cause of rumination. Namely, it is likely that working memory updating is needed to index the fact that sufficient information has been gathered regarding faults and that it is time to stop pondering. Watkins and Brown (2002) found that induced rumination resulted in stereotyped random number generation and to poor inhibition (Philippot and Brutoux, 2008), two findings which tentatively support the former interpretation. As noted above, in the present study rumination was associated with a relatively poor ability to prepare towards a task switch. Interestingly, some theories suggest that the preparation towards a task switch involves updating task goals (Altmann and Gray, 2008; Meiran et al., 2008) or task rules in working memory (e.g., Mayr and Kliegl, 2000, 2003). Thus, it is interesting to speculate that rumination impairs working memory updating, which eventually results in lesser ability to prepare towards a task switch. The reason for that could be that rumination occupies working memory resources, leaving less available resources for the task at hand.

Fifth, there were no patient effects in the congruency effect, which reflects the degree of disengagement from a previous set. This finding is interesting, partly because other conditions that are known to impact executive functioning, such as attention deficit disorder (Cepeda et al., 2000) and old age (Meiran et al., 2001), are associated with an increased congruency effect. Additionally, the congruency effect in PE serves as a clear marker of basal ganglia impairment (Meiran et al., 2004; Yehene, et al., 2008). Thus, our null result suggests that basal ganglia pathology may not be implicated in the task switching performance of OCD and UD patients. Our results also allow us to rule out general motivation to execute the task as a reason for the impairments because the patients made better use of the preparation interval than the controls.

There are some notable clinical implications stemming from the present results. First, the fact that both pathologies are associated with a similar rigidity profile suggests that rigidity may be a common risk factor and perhaps even a common etiological factor. In order to examine this intriguing possibility, it would be interesting to examine if improving flexibility is associated with improvement in UD and OCD symptomatology. Some recent reports suggest that executive functioning can be trained despite their very high heritability (Friedman et al., 2008). For example, Diamond et al. (2007) showed that preschool programs which foster self control improve performance on executive functions tests. Bialystok (2007) review a series of studies showing that bilinguals, who arguably need to constantly exercise self control to suppress their dominant language, show better performance on tests of executive functions and show better resilience against detrimental aging effects including dementia. Moreover, there is indirect evidence that teaching individuals how to become more flexible in their thinking, or at least avoid rigid, habitual, negative cognitive sets, may help protect them from developing disorders such as depression. Over the past decade, a number of cognitive behavioral programs which specifically focus on promoting more flexible, accurate thinking have been developed and tested (Horowitz et al., 2007; Gillham et al., 2008). Findings suggest that these prevention models are, in some cases, more effective than control conditions in preventing depression up to two years later, and that this effect is mediated by cognitive, explanatory styles (Gillham et al., 1995; Seligman et al., 2007).

Confidence in our findings, especially those related to the common features of UD and OCD, is bolstered by the high internal validity of the study design. More specifically, we went to great efforts (i.e., differential diagnosis, symptom checklists, etc.) to insure that depressed patients did not also suffer from OCD symptoms and vice versa. This is important due to the high rates of co-morbidity between these two disorders, though this led to a decrease in the number of available subjects. The resulting small sample size was, in fact, a function of placing a premium on internal vs. external validity. This decision was deliberate and, in our opinion, reflects the developmental stage of research in this area. Nevertheless, such a small sample implies that our results, especially the null results, should be interpreted very cautiously. Moreover, all the patients were medicated when we examined them. Although they were clearly symptomatic when tested, we cannot completely rule out the possibility that some of the findings reflect the side effects of the medication. This is especially true for the findings which were common to both patient groups because almost all of the patients were treated with SSRIs. Finally, although we examined four executive functions, each such function was instantiated by only one test, and we cannot be completely sure if the findings reflect the test characteristics rather than the relevant executive function (e.g., Yehene and Meiran, 2007).

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