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Explicit instructions facilitate performance of OCD participants but impair performance of non-OCD participants on a serial reaction time task

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ABSTRACT

Previous studies have shown that individuals diagnosed with OCD tend to rely on explicit processing while performing implicit learning tasks. We sought to investigate whether individuals with OCD are capable of implicit learning, but would demonstrate improved performance when explicit processing strategies are enhanced. Twenty-four participants with OCD and 24 non-psychiatric control (NPC) participants performed an implicit learning task in which they responded to a single target stimulus that successively appears at one of four locations according to an underlying sequence. We manipulated the learning strategy by informing half of the participants that the target stimulus location was determined by an underlying sequence, which they should identify (intentional learning). The other half of the participants was not informed of the existence of the underlying sequence, and was expected to learn the sequence implicitly (standard learning). We predicted that OCD participants will exhibit inferior performance compared to NPC participants in the standard learning condition, and that intentional learning instructions would impair the performance of NPC participants, but enhance the performance of OCD participants. The results supported these predictions and suggest that individuals with OCD prefer controlled to automatic processing. We discuss the implications of this conclusion to our understanding of OCD.

1. Introduction

Obsessive-compulsive disorder (OCD) is characterized by prominent cognitive symptoms, including obsessions, doubt, distrust of memory and perception, mental checking and reconstruction, and difficulty in decision making (Nestadt et al., 2016; Radomsky & Alcolado, 2010; Samuels et al., 2017; van den Hout & Kindt, 2003). Ample research and subsequent theoretical models have focused on understanding obsessive-compulsive (OC) phenomena in terms of information processing impairment (Muller & Roberts, 2005; Purcell, Maruff, Kyrios, & Pantelis, 1998; Radomsky & Alcolado, 2011). This research includes a growing body of evidence suggesting that understanding the interplay between explicit and implicit learning in OCD may be of particular relevance.

Implicit learning is characterized by non-intentional acquisition of knowledge (Frensch, 1998), and is typically employed when acquiring complex or non-salient regularities such as language (Berry & Broadbent, 1987, 1988; Reber, 1976; Reber, Kassin, Lewis, & Cantor, 1980). Knowledge resulting from implicit learning is difficult to express verbally (Dienes & Berry, 1997; Reber & Lewis, 1977), and instead manifests itself as a feeling-of-knowing (Reber, 1997; Spehn & Reder, 2000) or intuition (Lieberman, 2000; McCrea, 2010; Reber, 1989). For example, participants in a standard implicit learning task have an evocative feeling of what is the right action or solution (Dulany, 1991, 1996), but nevertheless often fail to verbalize or recognize the underlying regularity of the task in post experiment questioning (Frensch & Rünger, 2003).

In contrast to implicit learning, explicit learning is characterized by intentional acquisition of information (Frensch & Rünger, 2003; Dienes & Perner, 2002). It typically results in verbalizable, symbolic knowledge (Sun, Slusarz, & Terry, 2005; O'Brien-Malone & Maybery, 1998). This type of learning is considered most suitable for discovering simple and salient regularities (Berry & Broadbent, 1988). The dissociation between implicit and explicit learning is particularly evident when individuals who would naturally learn implicitly (such as in the artificial grammar learning task; see Reber, 1989) are instructed to search for the underlying rule structure and as a result employ explicit strategies. In such situations, if the underlying pattern is complex or non-salient, attempts at explicit learning often impede learning compared to a situation in which no explicit strategies are encouraged (Berry &

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Broadbent, 1987, 1988; Reber, 1976, 1989).

Several studies have shown that individuals with OCD perform poorly on tasks that require implicit learning (Deckersbach et al., 2002; Marker, Calamari, Woodard, & Riemann, 2006) or entirely fail to learn such tasks (Joel et al., 2005). Early brain imaging studies substantiated these findings by examining the brain activation patters in individuals with OCD when performing a Serial Reaction Time (SRT) task (Nissen & Bullemer, 1987). Performance in this task is typically correlated with activation in striatal brain regions that are associated with implicit learning (Rauch et al., 1997). However, OCD participants showed increased activity in orbitofrontal and hippocampal brain areas that are typically involved in explicit learning. These findings led Rauch et al. (1997) to conclude that the striatal system, which normally subserves implicit learning, is dysfunctional in OCD, and that recruitment of the orbitofrontal and hippocampal systems may compensate for this dysfunction in implicit processing.

Deficient performance in implicit learning is consistent with the clinical features of OCD. The phenomenology of OCD suggests that these individuals operate in a highly focused, intentional and tense mode. They tend to continuously monitor their own actions and thoughts (Purdon & Clark, 2002; Ursu, Stenger, Shear, Jones, & Carter, 2003) and their behavior is marked by deliberateness and conscious efforts (Liberman & Dar, 2009; Wahl, Salkovskis, & Cotter, 2008). This mode of operation is accompanied by a prominent impoverishment in the feeling of knowing, which is reflected in questioning and doubting perceptions, thoughts and motives (Dar, Rish, Hermesh, Taub, & Fux, 2000; O'Connor, Aardema, & Pélissier, 2005; Rapoport, 1989; Reed, 1985; van den Hout et al., 2009). Deficiency in implicit learning may therefore represent a specific aspect of a more general mode of operating and information processing in OCD.

But what is the nature of the deficiency in implicit learning in OCD? In a study that replicated and extended the earlier study by Rauch et al. (1997) mentioned above, Rauch et al. (2007) obtained fMRI scans of participants with OCD and matched controls while performing the SRT task. Consistent with their previous findings, Rauch and colleagues found comparable learning between groups but greater recruitment of brain areas associated with explicit learning in OCD compared to a non-psychiatric control sample. However, in contrast to the previous study (Rauch et al., 1997), OCD participants showed intact activation of the striatal brain areas associated with implicit learning. Rauch et al. (2007) argued that the normal striatal activation in the OCD group challenges the notion of striatal dysfunction in OCD, and instead points to the primary role that aberrant hippocampal activity plays in OCD. Moreover, although across different studies participants with OCD performed the SRT task more poorly than non- psychiatric controls (Goldman et al., 2008; Kathmann, Rupertseder, Hauke, & Zaudig, 2005; Marker et al., 2006), they nevertheless performed the task reasonably well, at levels that were was much above chance. Furthermore, in another implicit task, the Pursuit Rotor, participants with OCD demonstrated better implicit learning during the early (but not later) trial blocks of the task, as compared to non-clinical controls (Roth, Baribeau, Milovan, O'Connor, & Todorov, 2004).

Interpreting the results of previous SRT studies is complicated, however, due to a particular methodological weakness. In the SRT task, participants are required to press as rapidly and accurately as possible keys that spatially correspond to the location of a single target stimulus that successively appears at one of four locations. Unknown to participants, the stimulus location is altered according to an underlying fixed sequence. Learning the underlying sequence is evidenced by the gradual decrease in reaction times (RTs) throughout training, and more critically, by the significant increase in RTs once the sequence is altered (Schwarb & Schumacher, 2012; for a more detailed description of the task see the Methods section). The SRT task is considered to be a measure of implicit learning because participants acquire the underlying sequence even though they are not instructed to identify it. However, not instructing participants to search for the underlying sequence does not prevent them from adopting an explicit strategy if they decide to do so. Hence, performance on this task confounds intentional and non-intentional processes.[1] Specifically, in the studies described above, participants with OCD may have explicitly searched for an underlying rule more than did participants in the control condition. If this was the case, it is possible that those participants performed the task well, whereas among participants that relied primarily on implicit strategies, OCD was associated with poorer performance.

In order to reduce the probability that participants would intentionally search for regularities, Destrebecqz and Cleeremans (2001) introduced a modified version of the SRT task in which the target stimulus is removed as soon as a key is pressed and the next stimulus appears immediately (i.e., no-Response-Stimuli-Interval; no-RSI). The no-RSI version of the SRT is believed to minimize opportunity for conscious monitoring and control, so that the knowledge acquired while performing the task remains predominantly implicit (Destrebecqz & Cleeremans, 2001, 2003; Destrebecqz et al., 2005). These authors rationalized that under the no-RSI, participants do not have sufficient time to consciously anticipate the next target location, whereas longer RSI's enable the development of such conscious anticipation and control over the expression of the acquired sequence knowledge. In the same vein, Cleeremans and Jiménez (2002) argued that no-RSI may reduce representation quality of acquired implicit knowledge, and therefore make it harder to become available to consciousness and control. For the present study we used this modified version of the SRT task, and in order to facilitate interpretation of task performance we introduced a direct manipulation of participants' strategy.

Specifically, this study tested the hypothesis that individuals with OCD would be capable of implicit learning, but would perform better in explicit rather than implicit mode. Participants with OCD and matched non-psychiatric control participants performed the no-response stimuli interval version of the SRT task. Half of the participants in each group received explicit instructions to search for the rule, whereas the other half performed the task with standard instructions. We hypothesized an interaction between group and instructions, so that in the standard instructions condition OCD participants will show inferior performance compared to the control group of participants. Since people with OCD were found in previous research to rely less than controls on implicit learning and more on explicit learning in the SRT task, we hypothesized that intentional learning instructions will impair the performance of control participants, but will enhance the performance of OCD participants.

2. Material and method

2.1. Participants

Participants were 24 individuals with a DSM-IV diagnosis of OCD and 24 non-psychiatric control (NPC) participants who were matched for age, gender, and education to the OCD sample. Participants in the OCD group responded to advertisements in a large online OCD forum, which included a brief description of the study. Participants' ages ranged from 19 to 44 years, and no age difference was found between the OCD ($M = 29.3$, $SD = 6.9$) and NPC ($M = 27.6$, $SD = 5.3$) groups [$t(46) = 0.96$, $p = 0.34$]. Both samples included similar proportions of women (54.1%), so that no difference was found between samples on

[1] A similar problem in distinguishing between intentional and non-intentional processing has been raised with respect to the Weather Prediction Task (WPT; Knowlton, Squire, & Gluck, 1994), a task evaluating implicit learning in OCD (i.e., Exner, Zetsche, Lincoln, & Rief, 2014; Kelmendi et al., 2016; Zetsche, Rief, Westermann, & Exner, 2015). In some studies using the WPT, poorer acquisition of the task by individuals with OCD was reported (e.g., Kelmendi et al., 2016). However, the use of the WPT as a valid measure of implicit learning has been criticized (see Newell, Lagnado, & Shanks, 2007; Poldrack & Foerde, 2008), and in fact is currently associated with intentional-explicit strategies (Ashby and Maddox, 2005; Price, 2009).

gender proportions [$\chi^2(1) = 0.33, p = 0.56$). In addition, no difference was found in years of education between the OCD ($M = 13.8$, $SD = 1.8$) and the NPC ($M = 13.7$, $SD = 2.0$) groups [$t(46) = 0.07$, $p = 0.94$].

Participants from both groups were screened for diagnostic status and comorbid conditions using *the Mini International Neuropsychiatric Interview* semi-structured diagnostic interview (Sheehan et al., 1998). OCD participants were excluded if they met criteria for lifetime psychotic episodes or features, post-traumatic stress disorder, substance abuse disorder, anorexia nervosa, bulimia nervosa, or bipolar disorder. Based on these criteria, seven participants with OCD were excluded upon screening. Of the 24 participants with OCD that were included in the final sample, three also met criteria for dysthymia, and two met criteria for a past major depressive episode. Fifteen of the OCD participants were receiving treatment with serotonin reuptake inhibitors (eight within the standard instructions condition, and seven within the intentional instructions condition).

The study protocol was approved by Institutional Review Board at the School of Psychological Sciences at Tel-Aviv University in accordance with the declaration of Helsinki.

2.2. Measures

2.2.1. Implicit learning task

Participants performed a modified serial reaction time task (Destrebecqz & Cleeremans, 2001), in which they were required to press keys spatially corresponding to the location of a single neutral target stimulus (a white circle) that appeared at one of four locations according to an underlying deterministic sequence. Participants were presented with one of the following two 12-elements second-order conditional sequences (SOCs; Reed & Johnson, 1994), which were equated with respect to location frequency: 342312143241 (SOC1) or 341243142132 (SOC2).

The experiment was composed of 15 blocks with each block comprising 96 trials (8 presentations of the 12-elemnts sequence), for a total of 1440 trials. On each trial, participants responded to the location of the target as quickly as possible by pressing the corresponding key. Keys *V, B, N,* and *M* corresponded to Locations 1–4, respectively. Participants were required to respond to Locations 1 and 2 with the middle and index fingers, respectively, of their left hand and to Locations 3 and 4 with the index and middle fingers, respectively, of their right hand. Participants were told to respond to the target as fast and as accurately as possible. Half of the participants in each instruction and group condition were trained on SOC1 during the first 12 blocks and during Blocks 14 and 15, and on SOC2 during Block 13. This design was reversed for the other half of the participants. Increased RTs during Block 13, in which the sequence changes, reflect the knowledge participants acquired during training over Blocks 1–12.

In order to reduce the probability that participants would intentionally search for regularities when not instructed to do so (i.e., in the no instructions condition), we used a modified version of the SRT task (Destrebecqz & Cleeremans, 2001) in which the target stimulus is removed as soon as a key is pressed, and the next stimulus appears immediately, (i.e., no-Response-Stimuli-Interval; no-RSI). Previous studies demonstrated that the no-RSI manipulation minimized the probability to exert conscious monitoring and control, so that the knowledge acquired while performing the task remains predominantly implicit. (Destrebecqz & Cleeremans, 2001, 2003; Destrebecqz et al., 2005).

2.2.2. Clinical assessment and self-report measures

Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). Primary and co-morbid diagnoses were assessed in individual clinical interviews with the MINI. The MINI is a short semi-structured diagnostic interview for DSM-IV and ICD-10 psychiatric disorders considered to be a valid and time-efficient alternative to the SCID-P and CIDI (Sheehan et al., 1997; Lecrubier et al., 1997).

Yale-Brown Obsessive Compulsive Scale (Y-BOCS), (Goodman, Price, Rasmussen, Mazure, Fleischmann et al., 1989; Goodman, Price, Rasmussen, Mazure, Delgado et al., 1989) is a reliable and valid semi-structured clinician administered interview that is frequently used to measure the severity of obsessions and compulsions. The Y-BOCS comprises ten items rated on a 4-point scale. Five items are summed to derive the obsessions score and five to derive the compulsions score. In addition, a total score is computed, ranging from 0 (no symptoms) to 40 (most severe OCD).

Obsessive–Compulsive Inventory-Revised (OCI-R; Foa et al., 2002). This inventory includes 18 items representing characteristic symptoms of OCD. Responders are asked to rate the extent to which each symptom was distressing or bothersome to them in the past month on a 5-point scale. Previous studies found very good internal consistency (Cronbach's $\alpha = 0.88$; Hajcak, Huppert, Simons, & Foa, 2004). Similarly, in the present study the OCI-R demonstrated very good internal consistency ($\alpha = 0.91$).

2.3. Procedure

The experiment was administered individually in a quiet room, where participants signed an informed consent and completed the diagnostic interview. Participants who met inclusion criteria continued to perform the computerized learning task and subsequently complete the questionnaires. Half of each group of participants was randomly allocated to one of the two instructions conditions. In the intentional instructions condition participants were told that the target stimulus location was determined by an underlying sequence, and were instructed to try to find out what the sequence was. In the control, standard instructions condition participants were not informed of the existence of the underlying sequence. The computerized task followed, after which participants were fully debriefed and reimbursed with the equivalent to $25 US.

2.4. Data analyses

We used an alpha level of 0.05 for all statistical tests. In order to generate learning curves, the median RT was calculated out of the correct responses for each block separately, for each participant.

The primary dependent measure of interest in our study was the extent of learning. As in previous studies with the SRT (e.g., Stefaniak, Willems, Adam, & Meulemans, 2008) we calculated a learning index as RT on the transfer block (block 13) minus RT on the block that preceded it (block 12), that is, $RT_{Block13} - RT_{Block12}$. To the extent that participants had learned the sequence during training over Blocks 1–12, their RT was expected to increase from Block 12 (the last block with the old sequence) to Block 13 (the first block with the new sequence). Larger values of this index mean a stronger interruption in performance as a result of violations of expectancies, and indicate better learning of the underlying sequence.

3. Results

The clinical characteristics of both groups are presented in Table 1.

3.1. Sequence learning

No significant difference was found on overall accuracy rate between the control ($M = 97.74\%$, $SD = 1.97$), and OCD ($M = 98.13\%$, $SD = 1.80$) groups ($F(1,40) = 0.47$, $p = 0.50$).

For each participant, the median RT was calculated out of the correct responses for each block separately. Fig. 1 presents it by block, for each experimental group. We conducted a 2 (group: OCD vs. control) X 2 (instructions: standard vs. intentional) X 2 (sequence 1 vs. sequence 2) X 15 (Blocks 1–15) mixed model analysis of variance (ANOVA), with blocks (15 levels) as a within-subjects variable. Because there was no

Table 1
Clinical characteristics by group.

	OCD (N = 24)		NPC (N = 24)		F (1, 46)	Sig
	Mean	*SD*	*Mean*	*SD*		
Age of onset	23.58	6.27				
OCI-R	30.67	9.22	9.46	6.66	83.45	< 0.001
Y-BOCS Total Score	19.92	6.19				
Y-BOCS Obsessions	10.13	2.98				
Y-BOCS Compulsions	9.79	4.18				

OCI-R = Obsessive–Compulsive Inventory-Revised. Y-BOCS = Yale Brown Obsessive Compulsive Scale (Y-BOCS score represent moderate degree of severity). OCD = obsessive-compulsive disorder. NPC = non-psychiatric controls.

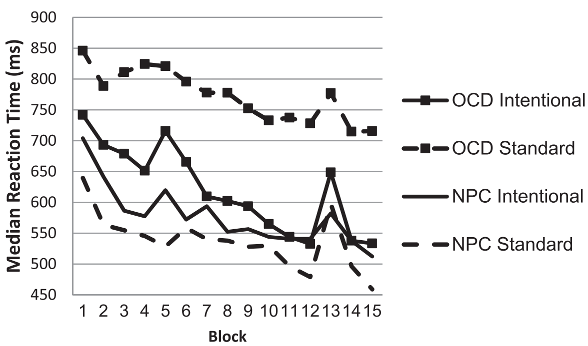

Fig. 1. Mean of the median RTs of correct responses for each block, by group and type of instructions. *Note:* OCD = obsessive-compulsive disorder. NPC = non-psychiatric controls.

significant effect for sequence, $F(1, 40) = 2.04$, $p = 0.16$, and no significant interactions involving sequence [group X sequence: $F(1, 40) = 0.41$, $p = .53$; instructions X sequence: $F(1, 40) = 0.06$, $p = 0.81$; group X instructions X sequence: $F(1, 40) = 2.38$, $p = 0.13$], we excluded the sequence variable from further analysis. Significant main effects emerged for blocks, $F(14, 616) = 20.68$, $p < 0.001$, partial $\eta^2 = 0.31$, and group, $F(1,44) = 6.99$, $p = 0.011$, Cohen's $d = 0.78$. The difference between groups reflects an overall slower RTs in the OCD group ($M = 697.14$, $SD = 37.39$) than in the control group ($M = 557.25$, $SD = 37.39$). There was no effect for instructions, $F(1,44) = 1.12$, $p = 0.30$, and no interaction between group and instructions, $F(1,44) = 3.33$, $p = 0.07$. Comparison of the two groups within each instructions condition revealed that the OCD group RT's were significantly slower than the control group in the standard instructions condition, $F(1,22) = 7.11$, $p = 0.014$, $d = 1.14$, but not in the intentional instructions condition, $F(1,22) = 0.57$, $p = 0.46$.

To establish that learning has occurred within each group and instructions condition, we conducted univariate analyses of variance (ANOVA) on the learning index, in each of the four conditions separately. These analyses yielded significant learning in all four conditions (see Table 2).

In order to examine the hypothesis that OCD participants will show inferior performance compared to the control group under the standard instructions condition, and better performance under the intentional

Table 2
Means and Standard deviations of learning index in each group and instructions conditions.

Group	Instructions	N	*Mean*	*SD*	*F* (1,22)	Sig.	*Cohen's d*
NPC	Standard	12	118.29	55.11	55.28	< 0.001	0.81
	Intentional	12	41.29	41.47	11.90	0.005	0.29
OCD	Standard	12	49.13	61.92	7.55	0.019	0.20
	Intentional	12	114.21	75.67	27.33	< 0.001	0.92

Note: OCD = obsessive-compulsive disorder. NPC = non-psychiatric controls.

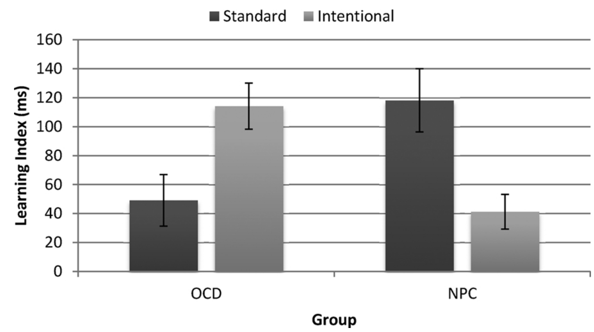

Fig. 2. Learning index by group and type of instructions (vertical bars denote standard error of the mean). *Note:* OCD = obsessive-compulsive disorder. NPC = non-psychiatric controls.

instructions condition, we conducted a 2 (group: OCD vs. control) X 2 (instructions: standard vs. intentional) ANOVA on the learning index. As predicted, a significant Group X Instructions interaction was found, $F(1,44) = 16.92$, $p < 0.001$, $d = 1.28$, indicating that NPC participants learned better with standard instructions than with intentional learning instructions, ($F(1,22) = 14.95$, $p = 0.001$), $d = 1.58$, whereas participants with OCD learned better with intentional instructions than with standard instructions, ($F(1,22) = 5.32$, $p = 0.031$), $d = 0.94$, (See Fig. 2). No main effect was found for group, $F(1,44) = 0.012$, $p = 0.91$, or instructions, $F(1,44) = 0.12$, $p = 0.73$. To examine a possible moderating effect of medications on the learning index within the OCD group, an independent-samples *t*-test was conducted in both instructions conditions. The results of this analysis yielded no significance differences between medicated and unmedicated subgroups in the standard instructions condition [$t(10) = 0.04$, $p = 0.971$], and in the intentional learning condition [$t(10) = 0.31$, $p = 0.765$].

4. Discussion

The present study examined the hypothesis that individuals with OCD would be capable of implicit learning, but would perform better in explicit rather than in implicit mode. OCD and control participants were administered a modified SRT task, in which participants responded to a single target stimulus that appears successively at one of four locations according to an underlying predetermined sequence. Participants in both groups performed the task with either standard instructions, or with instructions to search for the underlying sequence. In accordance with our hypothesis, individuals with OCD were able to learn the task under the standard learning condition, but their performance was enhanced when explicit processing was encouraged. In contrast, NPC participants exhibited better learning under the standard learning condition than with instructions that encouraged intentional searching for the underlying rule.

The version of the SRT task we administered, in which no time interval is introduced between a response and the next sequence (no-RSI), is believed to minimize spontaneous recruitment of explicit strategies. Under these conditions (with the standard instructions), the performance of OCD participants was inferior to that of the NPC participants. We interpret this finding as suggesting that OCD participants were not comfortable in a condition that lends itself to implicit learning. This interpretation is also consistent with the particularly slow response time of the OCD participants in the standard instructions condition. This pattern was reversed when participants were told about the underlying rule and encouraged to use explicit learning strategies. These instructions seem to have successfully overridden the default mode of implicit learning in this task. Indeed, previous studies showed that although no-RSI inhibits spontaneously developing explicit knowledge concerning the underlying sequence (Destrebecqz and Cleeremans, 2001), explicit sequence learning is still possible in this condition (e.g., Miyawaki, 2006; Norman, Price, & Duff, 2006; Wilkinson & Shanks, 2004). Our results suggest that facilitating explicit learning in this task had a beneficial effect for the OCD participants but a detrimental one for the non-psychiatric participants. As discussed in more detail below, we propose that for OCD participants, but not for the control participants, the intentional mode of learning, which involved explicit search for the underlying rule of the presented sequence, was consistent with their preferred mode of processing.

Our findings replicate and extend previous findings suggesting dominance of explicit processing over implicit processing in OCD (Deckersbach et al., 2002; Goldman et al., 2008; Kathmann et al., 2005; Marker et al., 2006; Rauch et al., 1997). Previous findings, however, were interpreted as evidence for an impaired capacity for implicit learning in OCD. Our results suggest that individuals with OCD were able to acquire the task under the standard instructions, but did so less efficiently. It is important to note that although in previous studies performance of individuals with OCD was inferior to that of NPC participants, they were nevertheless able to acquire the implicit learning tasks. In fact, a complete failure to learn the underlying properties of the complex stimuli in an implicit learning task by individuals with OCD was reported in only one study (Joel et al., 2005), which involved risk taking in a card betting game.[2]

In our view, severely diminished capacity for implicit processing in OCD is improbable, because such an impairment would compromise even the most basic and automatic aspects of performance, such as bicycle riding and language acquisition, which are intact in people with OCD. We suggest that the impaired performance of OCD in previous studies reflects a strategic choice, or a preference, rather than a general impairment in implicit processing. This view is in line with studies that found elevated need for control in individuals with OCD (Moulding & Kyrios, 2006; Purdon & Clark, 2002; Reuven-Magril, Dar, & Liberman, 2008; Wells, 1997). We propose that automatic processes such as those involved in implicit learning may be perceived by individuals with OCD as a potential loss of control and would therefore be associated with discomfort or anxiety. As a result, individuals with OCD would attempt to either avoid or attempt to gain control over automatic processing, by slowing down or by switching into an explicit processing mode. Furthermore, we propose that preference for explicit or controlled processing could be triggered not only in disorder-relevant contexts, but also in neutral situations, if OC individuals experience them as involving loss of control (Soref, Dar, Argov, & Meiran, 2008). This hypothesis is in line with the characterization of people with OCD as attempting to "monitor closely and take control over processes that would otherwise operate in automatic and well-practiced ways" (Salkovskis, 1998, p. 40). Furthermore, this conceptualization is in line with findings from imaging and neurocognitive studies suggesting that individuals with OCD may recruit explicit executive systems to engage in tasks that would normally be "processed implicitly, and without conscious awareness" (Saxena and Rauch, 2000, p. 573), and that this preference for explicit processing may interfere with tasks that require implicit processing for success (Deckersbach et al., 2002). Our hypothesis is also in line with findings associating OCD with intolerance of ambiguity (Calleo, Hart, Björgvinsson, & Stanle, 2010; Tolin, Worhunsky, & Maltby, 2006), as implicit learning is by definition more ambiguous than explicit learning and results in knowledge that is vaguer and less verbalizable.

Our findings may appear to contrast with previous findings that while participants with OCD exhibit poorer learning in SRT task, they had equal or superior explicit knowledge of the underlying sequence in a post-training test as compared to control participants (Goldman et al., 2008; Kathmann et al., 2005; Marker et al., 2006). The authors interpreted these results as suggesting that OCD is associated with greater reliance on explicit learning strategies, which are less efficient in the standard SRT task. In fact, the results of these studies resemble the results we have obtained in the standard instructions condition, in which participants were not informed of the existence of the underlying regularity. This condition, we propose, is an ambiguous, doubt-promoting context for participants with OCD. As such, it may challenge these participants' need for control (e.g., Moulding & Kyrios, 2006; Reuven-Magril et al., 2008) and lead to attempts to regain control by reducing response speed while increasing explicit processing (i.e., reducing reliance on implicit processing). In contrast to this standard instructions condition, our instructions to intentionally search for the underlying sequence created a non-ambiguous context, which reassures participants that a rule exists and can be followed. This context, we suggest, encourages participants to engage in explicit learning strategy, which is both effective under these conditions and in harmony with the OCD participants' need for control.

The finding that intentional instructions impaired performance of the NPC group may appear inconsistent with some previous studies that examined the effect of intentional instructions in the SRT task. In these studies, performance of non-psychiatric participants was either unaffected (e.g., Miyawaki, Sato, Yasuda, Kumano, & Kuboki, 2005; Rauch et al., 1995), or even enhanced (e.g., Curran & Keele, 1993) by explicit instructions to search for the rule. These studies, however, differ from ours in the length of the repeated sequence, the difficulty of the sequence structure, the number of learning blocks and the RSIs they employed, which typically ranged between 200 ms and 500 ms. Recently, Rünger (2012) conducted the only comparison to date between intentional and standard/incidental learning instructions on the SRT task using the same sequence structure used in the present study. In that study, all participants learned the underlying sequence, but enhanced performance was found in the intentional condition (compared to the standard condition) and in the 500-ms RSI (compared to the no-RSI). Rünger (2012), however, did not use alternate-sequence transfer block (block 13 in our study) to assess learning, but rather assessed only improvement over training in the form of gradual RT reduction. This gradual improvement may not reflect learning per se, but rather mere visuomotor association between the position of the visual cue and the required corresponding response, and may be more susceptible to contaminating influences of fatigue and motivation (Robertson, 2007). Thus, the results of the current study are the first to demonstrate impaired learning due to intentional (as opposed to implicit) learning in non-psychiatric individuals.

Considered jointly with previous findings, our findings suggest that people with OCD are less willing to operate under the implicit mode, and tend to counter their reluctance to rely on implicit processing with controlled processing. The hypothesized preference for controlled over automatic processing may account for important phenomenological and epistemological aspects of OCD. Provided that many behaviors contain of a mix between automatic and controlled processing, reduction in the component of the automatic processing may impair the evocative feeling of knowing, which is considered to be the output of automatic processing (Reber, 1997; Spehn & Reder, 2000). This may result in deficient sense of task completion and further exertion of control in order to regain certainty, which in turn result in additional reduction in confidence (Dar et al., 2000).

Our findings also suggest that the reluctance to operate in an implicit-automatic mode is not domain-specific (e.g., within domains that involve specific fear or responsibility), but may be a more generalized tendency of individuals with OC. In the spirit of Abramovitch, Dar, Hermesh, and Schweiger's (2012) suggestion that OCD is associated with fear of impulsivity, we suggest that 'fear of automaticity' might be an important characteristic of OCD.

Our results appear to contradict the recent conceptualization of OCD in terms of a deficit in deliberate goal-directed behavior (e.g., Gillan et al., 2011; Gillan et al., 2014; Gillan & Robbins, 2014; Gillan, Kosinski, Whelan, Phelps, & Daw, 2016). According to this approach, a

[2] For a risk averse group such as OCD, betting on cards could elevate controlled processing which, in that specific task, impairs rather than facilitate performance. As noted by Joel et al. (2005), the use of an explicit strategy in this task could account for their results.

deficit in goal-directed action control in OCD results in over-dominance of habitual control, resulting in a strong tendency to rapidly form and rely on habitual automatic behavior. This conceptualization appears inconsistent with the behavioral pattern of OCD participants in the SRT task in the current and previous studies (Goldman et al., 2008; Marker et al., 2006). In all these studies there was no evidence for uncontrolled executions of learned responses, but rather slower and probably excessively governed one (see also Soref et al., 2008, in which similar slowness was observed with the flanker task). The inconsistency in results between studies that employed the SRT task and the 'habit-driven' behavior studies could be due to the difference in tasks. In studies on habit-driven behavior, learning was based on simple stimulus-response association, whereas the SRT task involves incremental and more complex learning. In our view, the SRT task is closer in terms of ecological validity to habits in everyday life, including typical compulsive routines such as hand washing or sequential checking routines. Therefore, implicit learning and S-R habit learning may reflect different learning mechanisms or different levels of processing. Possibly, dominance of a habitual system may characterize more primary processing and thus contribute to one's experience of a low sense of control and motivate a compensatory exertion of control over these behaviors.

Our results may have important implication for understanding psychopathological mechanisms in OCD and for informing treatment. We can speculate that taking control over processes that are typically automatic may incur costs. For example, studies by Lazarov, Liberman, Hermesh, and Dar (2014) suggest that people with OCD have reduced access to their internal states, which may be related to excessive monitoring and checking (Liberman, & Dar, 2009; Shapira, Gundar-Goshen, Liberman, & Dar, 2013). Abramovitch et al. (2012) have suggested that excessive attempts to control behavior in OCD may result in a paradoxical loss of control and behavior which resembles impulsivity. These insights can be integrated into the psychoeducational component of CBT for OCD, which can also clarify that automaticity does not entail the loss of control; in fact, it is most often indicative of skill and mastery (Logan, 1982; Long, 1976; Rabbitt, P. M. A., 1978; Rabbitt, P., 1978). Therapy for OCD can help clients to re-trust their routine behaviors by challenging basic assumptions, such as "I must be in control in order to function well and avoid making mistakes." In the same vein, interventions derived from Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, & Wilson, 1999), which are based on the premise that "control is the problem, not the solution", may be helpful additions to CBT for the disorder.

Finally, we should note several limitations of our findings. We did not assessed participants' reliance on implicit or explicit processing, but instead chose to impose task demands designed to minimize or maximize reliance on explicit processing during learning. It would be important to replicate our findings with a methodology that allows a clearer determination of the degree to which participants rely on implicit or explicit processing. Furthermore, due to difficulty in recruiting a large number of clinical participants, the current study was conducted with a relatively small sample. Beyond limiting the generalizability of our findings, the small sample size did not allow us to develop insights concerning possible differences between OCD subtypes. In the same vein, adding another clinical group (e.g., of participants with other anxiety disorders; see Lazarov et al., 2014) in future studies would allow determining whether our findings are specific to OCD, as we hypothesize, or may be attributable to related conditions such as depression or anxiety.

Conflicts of interest

None.

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