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Intact capacity for implicit learning in obsessive-compulsive disorder

Assaf Soref[a,*], Nira Liberman[a], Amitai Abramovitch[b], Yael Poznanski[c], Reuven Dar[a]

[a] School of Psychological Sciences, Tel-Aviv University, Tel-Aviv, Israel
[b] Department of Psychology, Texas State University, San Marcos, TX, USA
[c] Achva Academic College, Shikmim, Israel

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ABSTRACT

Background and objectives: Individuals with OCD tend to rely on explicit processing when performing implicit learning tasks. However, it is unclear whether this tendency reflects impaired capacity for implicit processing or a preference toward explicit processing. We sought to use a psychometrically valid task to examine the hypothesis that individuals with OCD have intact capacity for implicit learning.

Methods: Twenty-four participants with OCD and 24 non-psychiatric controls completed a modified artificial grammar learning task where acquisition and retrieval of the underlying grammatical rules are considered strictly implicit. In an exploratory condition designed to examine the effect of nudging participants toward controlled processing, 12 participants in each group were told that the stimuli presented at acquisition were composed according to grammatical rules and were encouraged to identify these rules.

Results: As predicted, participants with OCD acquired and expressed knowledge of the grammatical rule, demonstrating intact capacity for implicit learning, with no differences found between the OCD and controls on the extent of implicit learning. The exploratory intentional learning instructions had no effect, as participants in this condition were unable to adhere to the instructions, supporting the robust implicit nature of the artificial grammar learning task.

Limitations: The relatively small sample size did not allow comparisons between OCD symptom subtypes.

Conclusions: Our results provide evidence for intact implicit learning in OCD, and challenge previous studies suggesting a general deficiency in implicit learning in OCD.

1. Introduction

Early conceptualizations of obsessive-compulsive disorder (OCD) (e.g., Shapiro, 1965) as well as contemporary research (Bucci et al., 2007; Soref et al., 2018) maintain that excessive reliance on controlled processing and controlled behavior plays a central role in the formation, manifestation, and maintenance of OCD. More specifically, in the past two decades, several neurocognitive and behavioral studies have suggested that the hyper-control seen in OCD may be linked to a deficit in implicit learning and/or excessive dependence on explicit learning (Goldman et al., 2008; Kathmann et al., 2005).

Implicit learning is a fundamental cognitive process of acquiring and retrieving complex regularities in an automatic, unintentional manner (Cleeremans & Jiménez, 1998; Frensch, 1998). Knowledge acquired this way is often not accessible to verbalization (Reber, 1989, 2013). For example, toddlers acquire their native language in a seemingly effortless and passive fashion, in the absence of explicit knowledge of its grammatical rules. In contrast, explicit learning is an intentional, controllable and effortful process of knowledge acquisition that often results in verbalizable knowledge (Ellis, 2009; O'Brien-Malone & Maybery, 1998).

1.1. Implicit vs. explicit learning in OCD

Studies examining implicit learning in individuals with OCD have utilized two main paradigms– the Serial Reaction Time (SRT; Nissen & Bullemer, 1987) task and probabilistic learning tasks. Overall, research findings suggest that OCD is associated with reliance on explicit processing when performing implicit learning tasks, which has been viewed as evidence of a general deficiency for implicit learning in OCD. In the following sections, we review and elaborate on these studies. Studies' sample sizes varied between 9 (Rauch et al., 1997) and 62 (Goldman et al., 2008).

* Corresponding author. School of Psychological Sciences, Tel-Aviv University, Tel-Aviv 6997801, Israel.
E-mail address: assafs@tauex.tau.ac.il (A. Soref).

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1.1.1. The Serial Reaction Time paradigm

In SRT tasks, participants view a neutral target stimulus (e.g., a white circle) that appears at one of four locations, and are required to quickly and accurately press the key that corresponds spatially to the location of the stimulus. Unbeknown to participants, the stimulus location is altered in successive trials according to a fixed underlying sequence. Learning the underlying sequence is evidenced by gradual decrease in reaction time (RT) throughout training and a significant increase in RT when the sequence is altered. Most studies using SRT have reported that OCD participants performed worse than controls (Goldman et al., 2008: $\eta 2 = 0.13$; Kathmann et al., 2005; Marker et al., 2006) or even completely failed to acquire the regularities embedded in the SRT task (Deckersbach et al., 2002). In contrast, two studies by Rauch and his colleagues reported comparable performance of OCD and non-clinical participants in the SRT task (Rauch et al., 1997, 2007). At the same time, the results of brain imaging conducted during the task in both studies suggested different brain activity patterns in the two groups. In contrast to control participants, whose brain activation pattern was typical for implicit processing, OCD participants recruited brain systems (particularly orbitofrontal and hippocampal areas) that are typically associated with explicit processing. These findings led the authors to conclude that OCD is characterized by excessive reliance on explicit/controlled processing, perhaps as a compensation for an implicit processing deficit.

1.1.2. Probabilistic learning paradigm

Joel and colleagues (2005) used the card betting task (Friedland, 1998) – a probabilistic learning task – to assess implicit learning in individuals with OCD, major depressive disorder, Parkinson's disease, and non-clinical controls. In this task, participants are asked to bet on one of four decks of cards, each containing a different proportion of red (win) and blue (lose) cards. Participants are unaware that each deck has a different probability of winning and are expected, by trial and error, to gradually shift to the deck with the highest probability of winning. Joel and colleagues (2005) found that most of the OCD sample did not acquire the task, and interpreted these findings as reflecting either a dysfunction in implicit learning in OCD or an interference in implicit learning from explicit processing, which is unhelpful for learning this task. Note, however, that the task used by these authors was not validated as an implicit/procedural learning task, and was rather developed to examine decision-making in the context of gambling. Moreover, the task involves risk taking. For risk-averse group such as people with OCD, this could elevate controlled processing, which may account for the failure to acquire the task.

The weather prediction task (WPT; Knowlton et al., 1994) is another probabilistic learning paradigm in which participants learn to predict a binary weather outcome (rain or sunshine) from four different cards. Each card or card-combination is associated with a specific probability for the outcome of rain or sunshine, which is unknown to participants. Results from studies utilizing this task with OCD participants are inconsistent. Whereas one study found poorer performances of individuals with OCD as compared to controls (Kelmendi et al., 2016: $\eta p2 = 0.04$), other studies (Exner et al., 2014: $d = 0.99$; Zetsche et al., 2015) found no between-group differences when the content of the task was neutral (predicting sunny or rainy weather), but impaired performance in OCD compared to controls when the content was related to OCD symptomology (predicting an epidemic from virus infection). More recently, a neuroimaging study utilizing the same experimental design (neutral/OCD-specific stimuli) reported a pattern of hyperactive striatal and hippocampal over-recruitment in OCD compared to controls, with no significant performance differences in either stimulus condition (Hansmeier et al., 2018). The group differences in brain activity were observed in both the neutral and the disorder-specific context, though they were particularly evident in the latter. Similar to Rauch et al. (1997), the authors interpreted the aberrant hippocampal recruitment as a compensation for a general striatal deficiency in OCD.

1.1.3. Preference for explicit learning vs. general impairment in implicit learning

Recently, Soref et al. (2018) challenged the possibility of a general deficiency in implicit learning in OCD. They suggested that the inconsistent findings reviewed above may be attributed to ambiguities inherent to the predominant experimental paradigms that were used to examine implicit learning. Specifically, the most commonly used tasks (the SRT and the weather prediction task) do not allow to conclusively distinguish between a deficient *capacity* for implicit processing and a tendency to *prefer* explicit over implicit processing. This is because these tasks allow participants to deliberately search for the underlying regularity, even if experimenters do not instruct them to do so. In fact, the weather prediction task was criticized for not being a valid operationalization of implicit learning precisely on these grounds (Kemény & Luká; Price, 2009). This criticism was based on studies that found explicit strategies, such as deliberate memorization, to be the most common among participants performing this task (for a review, see Ashby & Maddox, 2005). Moreover, individuals with OCD were found to have superior explicit knowledge of the underlying sequence in comparison to controls, suggesting that they employed explicit strategies throughout the SRT task (Goldman et al., 2008; Marker et al., 2006).

Soref et al. (2018) argued that a diminished capacity for implicit processing in OCD is improbable, because such a deficit would compromise basic behaviors such as speaking or walking. Instead, they proposed that automatic processes like those involved in implicit learning may be perceived by individuals with OCD as signaling loss of control and would therefore be associated with discomfort or anxiety. Consequently, individuals with OCD attempt to either avoid, or attempt to gain control over, automatic processing by switching into an explicit processing mode. In support of this notion, these authors demonstrated that individuals with OCD were able to acquire the SRT task under standard, implicit learning conditions. Most importantly, the performance of individuals with OCD, but not that of control participants, improved when the experimenter suggested that there was a rule that they might want to search for (Soref et al., 2018: $d = 1.28$). These findings suggest that OCD is associated with a preference for explicit-controlled processing, rather than with a general deficit in implicit learning.

The aim of the present study was to determine whether previous findings of impaired performance of OCD participants in implicit learning tasks (e.g., Goldman et al., 2008; Joel et al., 2005) reflect a true deficiency in implicit learning. Toward this aim, we used the artificial grammar learning (AGL) task (Reber, 1967), which is considered a hallmark paradigm of implicit learning (Batterink et al., 2019). The AGL task has been widely used for more than five decades to study implicit learning in clinical (e.g., Brown et al., 2010; Danion et al., 2001) and non-clinical (e.g., Tanaka et al., 2008) samples. Like the SRT and the WPT, the AGL task assesses participants' ability to acquire complex information without intending to do so, and even without being aware of the learning products (Batterink et al., 2019). However, in parallel with the methodological weaknesses found in the SRT and WPT tasks, several studies have demonstrated that under certain conditions, employment of intentional strategy can be beneficial for task performance in the AGL task, undermining its validity as an implicit learning task (for a review see Pothos, 2007). To address this problem, Poznanski and Tzelgov (2010) have developed a revised version of the AGL task, specifically designed to assess implicit learning as an automatic process. According to Bargh (1989, 1992), the one characteristic common to any automatic process is that such processes are *autonomous* – that is, the process run by itself without the need for conscious guidance or monitoring. In the modified AGL task, automaticity is demonstrated through the acquisition and retrieval of knowledge when it is not beneficial, and may be even harmful, to the task intentionally performed. By imposing specific task demands, it is possible to ascertain that the process of acquisition and retrieval of knowledge is not monitored (i.e., autonomous) and therefore is indeed implicit.

In the modified AGL task, participants are presented with a series of meaningless letter-strings written in different fonts and are asked to count how many fonts each letter-string contains. Unbeknown to participants, each letter string is composed according to a complex set of grammatical rules. As learning the underlying grammar is neither part of the task requirement nor beneficial to the task that participants intentionally perform, acquiring it is considered automatic, or strictly implicit (Perlman & Tzelgov, 2006). Similarly, in the retrieval phase, participants are presented with letter strings from three different categories: old strings from the acquisition phase; new-grammatical strings which they have not seen before; and new-nongrammatical strings (strings that were generated by switching two letters in the center of the new-grammatical strings, and therefore violate the grammatical rules). Participants are asked to perform a recognition task, in which they classify the letter strings as either old (i.e., encountered during the acquisition phase) or new (i.e., not presented during the acquisition phase). Retrieving the underlying grammar automatically is evident by the number of errors participants make when classifying new-grammatical strings as old. The retrieval phase is therefore also automatic or strictly implicit, as participants express the knowledge they have acquired in a situation in which they are not required to do so, and despite the fact that doing so impairs performance.

Based on our assumption that individuals with OCD are not generally impaired in their implicit learning ability, our main hypothesis was that OCD participants would be able to acquire the underlying grammatical rules in the AGL task and that their performance would not be inferior to that of non-psychiatric control (NPC) participants. We also added an exploratory condition in which half of the participants in each group were instructed to search for the complex rule underlying the AGL task. Because the instructions explicitly required the learning of the rule structure, we refer to this condition as the intentional learning condition. We hypothesized that the explicit learning instructions would impair the performance of all participants, because explicit/intentional learning, in comparison to implicit learning, was found to be inefficient for acquiring complex and non-salient regularities (e.g., Berry & Broadbent, 1988; Howard & Howard, 2001). Berry and Broadbent (1988) explained this detrimental effect on performance in terms of the qualitative difference between the implicit and explicit modes of learning. In the implicit learning ("unselective") mode, which is not subject to working memory limited resources, complex regularities and their contingencies are acquired concurrently, and therefore it is best suited for processing such stimuli. In contrast, the explicit ("selective") learning mode is a hypothesis-testing mode, limited by working memory capacity and executive processing resources (Kaufman et al., 2010). Consequently, it limits processing scope to only few variables (mostly salient), and only the contingencies between these identified variables are observed. Since the selective mode cannot convey the full complexity of the underlying rule structure, it is prone to false inductions and consequent impairments in performance. In light of previous studies suggesting prominence of explicit processing mode in OCD (e.g., Rauch et al., 2007; Soref et al., 2018), a secondary goal of the present study was to explore whether the extent of this impairment would be different for the OCD as compared to the NPC participants.

2. Materials and method

2.1. Participants

Demographic and clinical characteristics of the study samples are presented in Table 1.

Participants were 24 individuals with a DSM-IV diagnosis of OCD (62.5% females) and 24 non-psychiatric control (NPC) participants (62.5% females), matched for age, gender, and education. All participants were native Hebrew speakers and the study was conducted in Hebrew, using instruments that were validated and widely used in Hebrew. OCD participants were recruited through advertising in an online OCD forum, which included a brief description of the study. NPC participants were recruited via advertisements in social media as well as on the public notice boards at Tel-Aviv University. Screening and DSM-IV diagnoses were conducted using the Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). Inclusion criteria for the OCD sample were age between 18 and 60 and a primary diagnosis of OCD. Participants with a history of any neurological disorder or insult, psychotic disorder, post-traumatic stress disorder, attention deficit/-hyperactivity disorder, anorexia nervosa, bulimia nervosa, bipolar disorder, Tourette's syndrome, tic disorder, or substance abuse disorder were excluded from this study. Based on these criteria, three participants with OCD were excluded upon screening. Of the 24 OCD participants in the final sample, two also met criteria for dysthymia, six met criteria for a past major depressive episode, and eight were on a stable dose of SSRIs. All participants in the control group were free from lifetime psychiatric, neurologic, or developmental disorders. The study protocol was approved by the Tel-Aviv University Institutional Review Board.

Table 1
Demographic and clinical characteristics of the study samples.

	OCD (N = 24)		NPC (N = 24)		*t* (46)	Sig
	Mean	*SD*	*Mean*	*SD*		
Age	30.5	9.5	29.9	9.7	0.04	.97
Education (years)	13.4	1.7	13.6	2.1	0.36	.72
Age of onset	25.92	7.15				
OCI-R Total Score	32.63	10.22	9.70	7.34	8.92	<.001
OCI-R Checking	5.42	3.78	1.63	2.02	4.34	<.001
OCI-R Hoarding	5.04	3.86	2.38	2.20	2.94	.005
OCI-R Neutralizing	3.54	2.86	0.29	1.28	5.21	<.001
OCI-R Obsessing	7.96	3.03	1.88	2.33	7.80	<.001
OCI-R Ordering	5.54	3.35	2.96	2.51	3.02	.004
OCI-R Washing	5.13	3.83	0.58	1.38	5.47	<.001
Y-BOCS Total Score	20.58	7.03				
Y-BOCS Obsessions	9.75	4.09				
Y-BOCS Compulsions	10.83	3.60				
BDI-II	16.96	12.40	4.17	4.05	4.80	<.001

Note. OCI-R = Obsessive–Compulsive Inventory-Revised. Y-BOCS = Yale Brown Obsessive Compulsive Scale (Y-BOCS score represent moderate degree of severity; Storch et al., 2015). BDI = Beck Depression Inventory II. OCD = obsessive-compulsive disorder. NPC = non-psychiatric controls.

2.2. Measures

2.2.1. Implicit learning task

A modified AGL task was adopted from Poznanski and Tzelgov (2010). The stimuli consisted of five Hebrew letters, בחשוי, that were used to generate meaningless letter-strings according to a rule originally designed by Vokey and Brooks (1992); note that single letters can alter grammar in the Hebrew language). As depicted in Fig. 1, moving from left to right is possible via two alternative paths. Each transition in the path adds a letter, where letters which are placed above a repeat (↻) symbol could be either ignored (i.e., not added to the string) or added once or more. The letter-strings varied between five and nine letters in

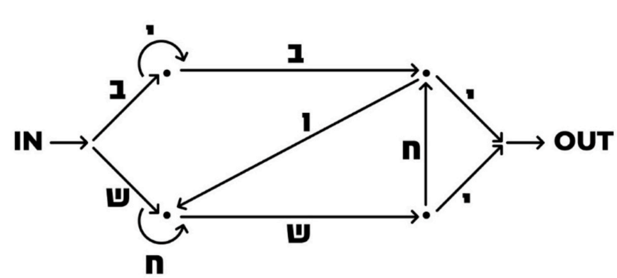

Fig. 1. The grammatical rules used to generate the letter strings in the artificial grammar learning task.

length. Twenty strings were generated for the acquisition (learning) phase and 60 strings were generated for the retrieval (test) phase.

In the acquisition phase, participants were presented with 20 letter strings composed of 1–4 different fonts. Each letter string was presented 10 times in random order. Participants were instructed to count the number of fonts contained in each string. The retrieval phase immediately followed the acquisition phase. Participants were presented with 60 strings typed in one font and consisting of three categories, 20 strings per category: old strings (the strings participants had encountered during the acquisition phase), new-grammatical strings (strings that were generated according to the grammatical rule, but participants had not encountered during the acquisition phase), and new-nongrammatical strings. The new-nongrammatical strings were generated by switching two letters in the center of the new-grammatical strings. Participants were asked to perform a recognition task, in which they had to classify letter strings as old (i.e., encountered during the acquisition phase) or new (i.e., not encountered during the acquisition phase). The experimental task was programmed using E-Prime software (Schneider et al., 2002).

2.2.2. Clinical assessment and self-report measures

Mini International Neuropsychiatric Interview, version 5.0 (MINI; Sheehan et al., 1998). The MINI is a brief semi-structured diagnostic interview for DSM-IV psychiatric disorders and is considered a valid and time-efficient alternative to the SCID (Lecrubier et al., 1997). The Hebrew version of the MINI was obtained via the publisher (Sheehan et al., 1998).

Yale-Brown Obsessive-Compulsive Scale (Y-BOCS; Goodman et al., 1989a; Goodman et al., 1989b). The Y-BOCS is a reliable and valid semi-structured clinician administered interview that was used to measure the severity of obsessions and compulsions. The Y-BOCS includes ten items rated on a 4-point scale. The total score is computed by summing the items and ranges from 0 (no symptoms) to 40 (most severe OCD). We used the Hebrew version, which was translated and back translated for previous studies conducted in Israel (e.g., Shahar et al., 2017; Shimshoni et al., 2011). Internal consistency for the Y-BOCS in the present study was good (Cronbach's alpha = .85).

Obsessive–Compulsive Inventory-Revised (OCI-R; Foa et al., 2002). The OCI-R is an 18-item self-report measure of OCD symptom severity. Responders are asked to rate their level of distress pertaining to 18 statements in the past month on a 5-point scale. The Hebrew version of the OCI-R has been approved by one of the original authors of the OCI-R (Prof. Jonathan Huppert) and has been extensively used (e.g., Kreiser et al., 2019; Reuven-Magril et al., 2008). Cronbach's alpha of the OCI-R in the present study was 0.91.

Beck Depression Inventory II (BDI-II; Beck et al., 1996). The BDI-II is a 21-item self-report scale assessing the severity of depression during the past two weeks. The BDI-II is a valid and reliable measure of depression (Arnau et al., 2001). We used the Hebrew version, which was translated and back translated for previous studies conducted in Israel (e.g., Kahn et al., 2019; Kivity & Huppert, 2018). In this study, Cronbach's alpha of the BDI-II was 0.91.

2.3. Procedure

Participants completed the experiment individually in a quiet room. Participants first signed an informed consent and completed the diagnostic interview. Those who met inclusion criteria completed the computerized learning task followed by the questionnaires. A licensed psychologist (the first author) conducted the entire experimental procedure (including the diagnostic interview and administration of the questionnaires). Prior to the computerized task stage, participants from each group were randomly allocated to one of the two experimental conditions, using the randomization command on Microsoft Excel Version 15.0. In the implicit (standard) learning condition, participants were presented with the letter strings and instructed to count the number of different fonts in each letter string (1–4) as accurately as they could and type in the answer. If they typed in the wrong number of fonts, a 50-ms tone of 400 Hz sounded. In the intentional learning condition, participants were additionally informed that the letter strings were composed according to a set of rules and were asked to search for these rules. The retrieval phase was identical for both learning conditions.

At the conclusion of the computerized task, participants from the implicit learning condition were informed that the letter strings they saw were composed according to a set of rules. We then asked these participants if they noticed the underlying rule, and whether they searched for a rule while counting fonts. We also asked participants from the intentional learning condition how compliant they were with instructions to search for the underlying rule as they were performing the task. We additionally asked participants from both conditions to report any rules they thought they had detected. Finally, participants were fully debriefed and reimbursed with the equivalent to $25 US.

2.4. Data analyses

Analyses were conducted using SPSS Version 21.0. To assess implicit acquisition and retrieval of the underlying grammar, we calculated the percentage of times each participant responded with "old" to each of the three strings types. The primary dependent measure of interest was the difference in participants' classification of new-grammatical and new-nongrammatical strings as old. From the perspective of recognition-based judgment, participants are expected to classify both string types as new, as they have never encountered them before. Mistakenly classifying new-grammatical strings as old while classifying new-nongrammatical strings as new indicates that rule-based knowledge acquired during the acquisition phase has created a sense of familiarity which mislead participants to believe they had seen these letter-strings before. We additionally used this difference between new-grammatical and new-nongrammatical strings ($M_{\text{new-grammatical}} - M_{\text{new-nongrammatical}}$) to calculate a *grammaticality index* for each participant. Higher values of this index indicate better acquisition of the underlying rule.

To examine our main hypothesis that the OCD group will demonstrate intact acquisition under the implicit learning condition, and to assess the potential adverse effect of intentional instructions, we conducted a 2 × 2 × 2 (group: OCD vs. NPC; instructions: implicit vs. intentional; string type: new-grammatical vs. new-nongrammatical) mixed model analysis of variance (ANOVA). To establish that learning has occurred within each group and learning condition, we conducted a repeated measure ANOVA on string type (new-grammatical vs. new-nongrammatical) within each of the four conditions separately (OCD implicit, OCD intentional, NPC implicit, NPC intentional). Post hoc power analysis for the results of this analytic model performed using G*Power software.

To examine whether the capacity of OCD for implicit processing is affected by OCD and depression symptoms, we computed Pearson correlations between the grammaticality index and the corresponding self-report measures. We examined the correlation of the performance with scores on the self-reported measures of depression, to ascertain that depression, which tends to co-occur with OCD (Overbeek et al., 2002) and may impair performances on implicit learning tasks (e.g., Naismith et al., 2006), cannot account for our findings. Finally, we qualitatively examined participants' verbal responses from the concluding inquiry stage.

3. Results

3.1. Artificial grammar learning (AGL) task

The percentage of instances where participants responded with "old" to each of the three strings types is presented in Fig. 2. As can be seen, grammatical strings (old and new) were identified as old more often than nongrammatical strings.

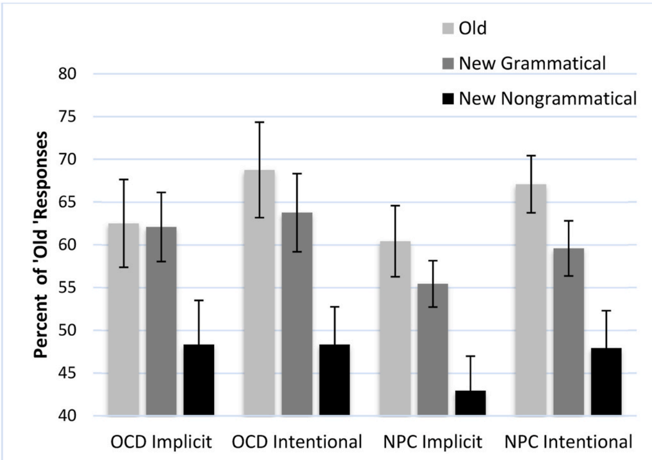

Fig. 2. *Percentage of times participants responded with "Old" for each of the three strings types. Note:* Error bars represent standard error. OCD = obsessive-compulsive disorder. NPC = non-psychiatric controls.

In accordance with our main hypothesis, a significant effect was found only for the type of test strings [F (1,44) = 46.81, $p < .001$, d = 0.94], with no significant main effect for group [F (1,44) = 0.41, p = .53, d = 0.13]. There was no effect of learning condition [F (1,44) = 0.01, p = .92, d = 0.02], or group X learning condition interaction [F (1,44) = 0.01, p = .75, d = 0.07]. Further comparison of the pair of new-grammatical vs. new-nongrammatical strings within each of the four conditions separately yielded significant learning in all four conditions (see Table 2), with all d's ranging between 0.84 and 1. Specifically, the grammatically index effect size for implicit learning ($M_{\text{new-grammatical}} - M_{\text{new-nongrammatical}}$) for the OCD group was similar to the effect size found for the NPC group (d = 0.99 and d = 1.0, respectively). Post hoc power analyses for the results of this analytic model (Table 2), given the effect sizes and sample size per condition, indicated that these results are well powered (1-β range = 0.81–0.92).

To examine a possible moderating effect of medications, we conducted two independent-samples t-tests between medicated and unmedicated OCD participants on the learning index, in both learning conditions. There were no significant differences between the medicated and unmedicated subgroups in either the implicit [t (10) = 1.54, p = .16] or the intentional [t (10) = 1.03, p = .33] learning conditions.

Pearson correlations between the grammaticality index and the OCI-R total score, the BDI-II total score, and the Y-BOCS scores within the OCD group were weak and non-significant (all r's < 0.17, p's > 0.25), suggesting that the capacity for implicit learning in OCD is not related to OCD or depression symptom severity.

3.2. Rule identification

As reported above, there was no indication that the intentional instructions manipulation affected the performance of participants from either group. To explicate this finding, we examined the responses of participants in the intentional instructions condition to an inquiry conducted following the experiment to examine whether they indeed adopted an intentional strategy to discover the underlying grammatical rule. This examination indicated that both OCD and NPC participants in the intentional instructions condition found the rule searching task too difficult to conduct concurrently with the primary task of font counting; consequently, at some early point during the experiment, they abandoned the rule searching and focused only on the main task.

A subject-by-subject examination revealed that none of the participants were able to correctly identify the grammatical rule. Consistent with previous findings (e.g., Reber, 1976), participants tended to explicitly report false rules, such as rules concerning the font regularities instead of the underlying syntax ("after a string written in one font there is a great chance that a string with three fonts will follow"), or rules concerning the regularities of string lengths ("a short string appears after a long string"). When participants were able to correctly identify parts of the underlying rules, they mainly reported on small fragments of the strings such as the letters which usually opened or ended the strings, which were not different for the grammatical and nongrammatical test strings. Two participants from the implicit learning condition (one from the OCD group and one from the control group) reported that they suspected that the strings represented some underlying rules, but they did not search for them voluntarily.

4. Discussion

The present study examined the hypothesis that OCD is associated with intact capacity for implicit learning. To address limitations of previous studies, we used the AGL task, which can unequivocally assess the capacity for implicit learning. As predicted, OCD participants implicitly acquired and expressed the deep structure of the grammatical rules. Furthermore, the extent of implicit learning achieved by the OCD group (d = 0.99) was similar to the effect found in the NPC group (d = 1.0). We also found that the performance of OCD participants was not related to OCD or depression symptom severity, which is in line with meta-analytic findings of generally small and non-significant correlations between cognitive function and OCD symptom severity (Abramovitch et al., 2019). To the best of our knowledge, the present study constitutes the most rigorous examination of this hypothesis to date, and our findings strongly suggest that OCD is not associated with a deficit in implicit learning.

Contrary to our expectations, instructions that encouraged participants to exert control over the learning process did not impair the performance of participants in either group. This may be because the task was constructed specifically to minimize the possibility that participants will monitor the secondary, rule-based dimension. Participants were required to count the number of fonts in each letter string while simultaneously attempting to uncover the underlying grammatical rules. The considerable difficulty these requirements imposed on participants is made clear by the reports of participants in the intentional instructions, who were encouraged to search for the underlying rule, that they have given up doing so early on during the procedure. Participants in this condition were in fact faced with two concurrent and considerably demanding *explicit* tasks (i.e., the main task of counting fonts, and the competitive task of rule searching), which competed over working memory and executive attention resources. As was previously demonstrated, a cognitive bottleneck occurs when concurrent tasks depend on similar mental processes, resulting in delay or impairment of one or both tasks (Dux et al., 2006; Ruthruff et al., 2001). In retrospect,

Table 2
Comparison between new-grammatical and new-nongrammatical strings in each group and instructions conditions.

Group	Learning condition	*Mean (SD)* New-Grammatical	*Mean (SD)* New-Nongrammatical	F (1, 11)	Sig.	*Cohen's d*
NPC	Implicit	55.42 (9.40)	42.92 (14.05)	12.31	.005	1.0
	Intentional	59.58 (11.17)	47.92 (15.14)	9.89	.009	.85
OCD	Implicit	62.08 (14.05)	48.33 (17.88)	10.37	.008	.99
	Intentional	63.75 (15.83)	48.33 (15.28)	14.78	.003	.84

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

the intentional instructions condition may be regarded as a secondary check for the possibility that participants would spontaneously search for the underlying grammar; our results indicate that acquisition of the underlying grammar was indeed very difficult to monitor, and hence that learning was essentially implicit.

Our findings offer a new perspective on previous reports of implicit learning deficits in OCD, where individuals with OCD demonstrated either impaired learning (Goldman et al., 2008; Kathmann et al., 2005; Marker et al., 2006), or completely failed to acquire the task (Deckersbach et al., 2002; Joel et al., 2005). These results were interpreted as evidence for a general impairment for implicit learning in OCD. Our finding of intact implicit processing in OCD undermines this conclusion, and is consistent with the alternative hypothesis offered by Soref et al. (2018); Namely, that OCD is associated with a preference for explicit processing which can interfere with otherwise preserved capacity for implicit learning. This proposition resonates with findings indicating elevated need for control in OCD (e.g., Moulding & Kyrios, 2006; Reuven-Magril et al., 2008), as well as with those associating OCD with adherence to an 'on guard' and careful strategy (e.g., Kalanthroff et al., 2014; Soref et al., 2008). It is also in line with Rauch et al.'s. (2007) suggestion that in people with OCD, brain areas associated with explicit processing interfere with functioning of brain areas associated with implicit processing. At the same time, we should note that the current investigation did not directly assess preference for explicit processing among participants with OCD.

Our study had certain limitations. First, it was conducted with a relatively small sample that did not allow us to compare OCD symptoms subtypes. Future studies can examine whether specific OCD symptoms, such as checking, may be particularly associated with a preference for explicit processing. Second, our sample was diagnosed by a single rater. Although the rater is an experienced clinical psychologist with a specific expertise with research and treatment of OCD, the screening lacked a reliability check. Finally, the AGL task which we employed assesses specific facets of implicit learning (linguistic, judgment-based). It would be important to examine whether results with tasks that tap other types of implicit learning (i.e., perceptual-motor, categorization) would corroborate our present findings.

5. Declarations of conflict of interests

None.

CRediT author statement

Assaf Soref: Conceptualization, Methodology, Software, Investigation, Formal analysis, Writing – original draft. Nira Liberman: Supervision, Conceptualization, Writing – review & editing. Amitai Abramovitch: Formal analysis, Writing – review & editing. Yael Poznanski: Methodology.Reuven Dar: Supervision, Conceptualization, Writing – review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2021.101667.

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