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Probing Implicit Learning in Obsessive-Compulsive Disorder: Moderating Role of Medication on the Weather Prediction Task

Benjamin Kelmendi, MD^{a,e}, Thomas Adams Jr, Ph.D.^{a,e,*}, Ewgeni Jakubovski, MS^b, Keith A. Hawkins, Psy.D.^a, Vladimir Coric, MD^{a,1}, and Christopher Pittenger, MD, Ph.D.^{a,b,c,d}

^aDepartment of Psychiatry, Neuroscience Program Yale University

^bChild Study Center, Neuroscience Program Yale University

^cDepartment of Psychology, Neuroscience Program Yale University

^dInterdepartmental Neuroscience Program Yale University

^eNational Center for Post-Traumatic Stress Disorder VA Connecticut Healthcare System

Abstract

Deficits in implicit learning, a process by which knowledge is acquired accretively through practice independent of conscious awareness, have been implicated in Obsessive-Compulsive Disorder (OCD). The weather-prediction task (WPT) was used to assess implicit learning in 26 unmedicated patients with OCD and 23 healthy controls. An additional analysis compared these two groups with 25 medicated patients with OCD. In the comparison of unmedicated patients with healthy controls there was a subtle but statistically significant group-by-block interaction. Patients with OCD showed slower improvement in performance during the middle phase of learning. In a three-group comparison, there was no main effect of group; in post-hoc tests, medicated patients with OCD differed from unmedicated patients and were not different from healthy controls. Unmedicated patients with OCD have a subtle deficit in implicit learning in the WPT. This may be mitigated by pharmacotherapy, although prospective studies would be required to confirm this conclusion.

Keywords

obsessive-compulsive disorder; implicit learning; weather prediction task; pharmacotherapy

Introduction

Obsessive-compulsive disorder (OCD) is characterized by recurrent, intrusive thoughts (obsessions) and repetitive behaviors (compulsions) that result in significant distress and/or

*Correspondence: Thomas Adams, Ph.D. 34 Park Street, W312, New Haven, CT, 203-974-7696. thomas.adamsjr@yale.edu.

¹Current address: 234 Church Street, Suite 301, New Haven, CT 06510

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functional impairment. OCD affects approximately one person in 40 worldwide (Ruscio, 2010). Neuropsychological and neuroimaging studies have implicated dysfunction of fronto-striatal circuitry in its pathophysiology, noting hyperactivity of orbitofrontal cortex (OFC) and striatum (right caudate) at baseline and during symptom provocation tasks (Menzi, 2008). Frontostriatal circuitry is implicated in probabilistic classification learning (Knowlton, 1996; Squire, 1996). Studies have suggested that patients with OCD have general difficulties in learning probabilistic association between cues and outcome (Deckersbach, 2002; Kathmann, 2005; Marker, 2006; Goldman, 2008).

Probabilistic classification learning describes a family of implicit learning tasks in which participants learn arbitrary associations between cues and a predicted outcome (Shohamy, 2008), knowledge is acquired accretively over multiple repetitions, independent of conscious awareness. Associations are stochastic: rather than directly predicting the outcome, a cue or constellation of cues determines a probability of a given outcome. This makes the associations difficult to learn by an explicit strategy; even an optimal rule-based explicit strategy will not produce the correct result on every trial, due to the stochastic nature of the outcome. In contrast, explicit learning – the conscious acquisition and retrieval of knowledge – is associated with activity in the hippocampus and parahippocampal cortex and the dorsolateral prefrontal cortex (Squire, 2002).

The Weather Prediction Task (WPT) was developed as a probabilistic classification task to probe abnormalities in implicit learning (Knowlton, 1996; Knowlton, 1994; Marsh, 2004). On this task, participants learn to categorize a set of visually presented cues that are probabilistically related to one of two outcomes by receiving feedback on the accuracy of their response. Patients with Parkinson's or Huntington's disease, both of which affect integrity of the basal ganglia, show deficits in the WPT (Knowlton, 1996; Knowlton & Squire, 1996). A more subtle deficit in the WPT has been shown in patients with Tourette syndrome (Keri, 2002; Marsh, 2004). In contrast, amnesic patients with hippocampal damage (Knowlton, 1994) or Alzheimer's disease (Eldridge, 2002) show normal learning in the WPT, despite explicit memory impairments. For this reason, the WPT has been used extensively to examine the neurocircuitry to support implicit learning (Price, 2009).

Functional neuroimaging data support dependence of the WPT on intact striatal function (Wilkinson, 2007; Wilkinson, 2009). The striatum (right caudate) is activated during WPT task completion, as are cortical areas that project to it (Aron, 2006; Poldrack, 1999; Seger, 2005). Patients with Parkinson's disease, who show impaired implicit learning, show a corresponding decrease in learning-related activation of the striatum (Moody, 2004). Interestingly, they show enhanced activation of the medial temporal lobe, suggesting that when the implicit learning system is compromised they attempt to compensate by engaging the explicit learning system (Moody, 2004). Although the WPT is commonly considered a measure of implicit learning, recent neuropsychological evidence suggests that participants can use explicit strategies to improve performance (Ashby, 2005; Price, 2009; Shohamy, 2008).

Studies of implicit learning in OCD have produced mixed results. Several studies have shown a modest deficit in putative implicit learning tasks, including a serial reaction time

task (SRT), (Deckersbach, 2002; Goldman, 2008; Kathmann, 2005; Marker, 2006) an implicit card betting task (Joel, 2005), and an implicit learning component in the Tower of Hanoi task (Cavedini, 2001). However, other studies employing implicit learning tasks, including the WPT (Exner, 2014) and pursuit rotor task (Roth, 2004), have shown no deficit. In the SRT, patients with OCD showed activation of the medial temporal lobe, while healthy controls showed activation of the inferior striatum (Rauch & Rosen, 1997; Rauch, 2007). This finding has been interpreted as suggesting that patients with OCD, much like Parkinson's patients, compensate by engaging the explicit learning system (Joel, 2005). Consistent with this interpretation, patients with OCD exhibit a deficit in the SRT when required to perform a concurrent explicit task (Deckersbach, 2002).

Inconsistent results in studies of implicit learning in OCD may be partly due to the heterogeneity of the studied populations, including comorbidity and the inclusion of medicated patients. Pharmacotherapy with SRIs reduces symptomatology in a majority of patients with OCD (Jenike, 2004; Soomro, 2008) and reverses hyperactivity in the striatum and interconnected frontal cortical areas (Atmaca, 2013; Saxena, 2000). Whether or not SRI pharmacotherapy in OCD mitigates deficits in implicit learning remains an important unresolved question.

We tested implicit learning in OCD using WPT. We expected patients with OCD to show a general deficit in implicit learning relative to healthy controls. We further expected that the performance of the medicated patients on WPT to differ from unmedicated and healthy controls.

Methods

Participants

All participants were recruited using advertisements and provided written informed consent. The study was approved by the Yale University Institutional Review Board. Participants consisted of 26 unmedicated patients with OCD, 25 SRI-medicated patients with OCD, and 23 healthy controls; groups were matched for age and gender (see Table 1). Of the 51 patients with OCD, 22 also met the criteria for major depressive disorder (MDD); 10 of these were medicated. All 25 patients with OCD in the medicated group were on a stable dose (> 8 weeks) of an SRI. In addition, one patient was treated with riluzole, one with duloxetine, and two with PRN alprazolam. Diagnoses were established by a doctoral-level clinician and confirmed using the Structured Clinical Interview (SCID) for DSM-IV (First, 1996). Patients were free of comorbid substance abuse or dependence, current Tourette syndrome, psychotic disorders, and neurological disease or major head trauma.

Materials

Severity of symptoms was assessed using the Yale-Brown Obsessive-Compulsive Scale (Y-BOCS) (Goodman, 1989) and the 25-item Hamilton Depression Scale (HAM-D) (Hamilton, 1960).

The WPT is an implicit learning task that requires participants to predict which of two possible outcomes will occur on each trial, based on a set of visual cues. Participants were

told that their job was to decide whether a given set of cues predicted rain or sunshine. They were told that the relationship between cues and outcomes was complex, and that they would initially be guessing but would gradually become better at deciding which cues predicted rain or sunshine.

The full experiment consisted of 100 trials. Each trial consisted of stimulus presentation, decision, and feedback. Stimuli consisted of 1–3 cards displaying four geometric shapes, for a total of 14 possible card combinations. The relationship between the presented cards and the ‘correct’ decision was probabilistic rather than deterministic (see Table 2). Each individual card was associated with the outcomes according to a fixed probability; the probability associated with each collection of cards (Table 2) was calculated from the probabilities associated with the component cards (Table 3). Due to the probabilistic nature of the task, the ‘true’ outcome on each trial, on the basis of which feedback was given, did not always correspond to the outcome most likely to be associated with the presented stimuli. For analyses, a correct response was defined as one that corresponded to the outcome most likely to be associated with the presented cues. Mean accuracy, determined as the proportion of correct responses, was computed for blocks of 10 trials.

Analytic Strategy

Data were analyzed by using mixed factor ANOVAs with blocks of 10 trials as the within-subjects factor and group as the between-subjects factor. We first compared unmedicated patients with healthy controls, to test our primary hypothesis; we then included medicated patients in a three-group mixed factor ANOVA to examine the effect of medication. An alpha level of .05 was used for all statistical tests; p values of greater than 0.05 but less than 0.10 are reported as trends. All analyses were performed using the Statistical Package for the Social Sciences (SPSS, Version 22.0).

Results

Participants

Clinical characteristics of all three groups of participants are presented in Table 1. Both medicated and unmedicated patients with OCD had Y-BOCS scores in the severe range; Y-BOCS scores were marginally higher for unmedicated patients ($p = .07$). Medicated and unmedicated patients with OCD reported similar levels of depression ($p = .64$). There was no difference in Y-BOCS scores between patients with MDD compared to patients without MDD ($p = .47$).

WPT performance in unmedicated patients with OCD

We first compared unmedicated patients with OCD to healthy controls, to test the hypothesis that implicit learning is impaired in OCD (Figure 1). In this two-group analysis, Mauchly’s test of sphericity was significant [$\chi^2(44) = 65.86, p = .02$]; Huynh-Feldt correction was used to correct for violation of sphericity. There was a significant main effect of block [$F(8.7, 409) = 10.63, p < 0.01, \eta^2 = .19$] but not of group [$F(1, 47) = 1.08, p = .30, \eta^2 = .02$]. There was a significant group-by-block interaction [$F(8.7, 409) = 2.00, p = .04, \eta^2 = .04$], indicating that improvement in classification accuracy across the 10 blocks varied between

the two groups. Polynomial contrasts of the group-by-block interaction revealed that the quadratic function was the only significant curve, [$F(1, 47) = 8.16, p < .01, \eta^2 = .15$]; the cubic function was marginally significant [$F(1, 47) = 3.57, p = .07, \eta^2 = .07$]. This matches qualitative differences in group performance across blocks (Figure 1): WPT performance worsened and then improved in middle training blocks in both groups, but unmedicated patients with OCD worsened more, and improvement was delayed relative to healthy controls.

Effect of medication

We next performed a mixed ANOVA including the medicated patients with OCD (Figure 1), to test the hypothesis that WPT performance is affected by pharmacotherapy. In this three-group analysis, Mauchly's test of sphericity was not significant [$\chi^2(44) = 51.33, p = .21$]. Classification accuracy improved over the course of the task [main effect of block: $F(9, 639) = 16.43, p < .001, \eta^2 = .19$]. There was not a significant main effect of group [$F(2, 71) = 0.55, p = .58, \eta^2 = .02$]. There was a trend-level group-by-block interaction [$F(18, 639) = 1.49, p = .09, \eta^2 = .04$]. Examination of polynomial contrasts of the group-by-block interaction again revealed that the quadratic function was the only significant curve [$F(2, 71) = 4.06, p = 0.02; \eta^2 = 0.10$], suggesting that differences between groups changes nonlinearly across blocks.

Secondary mixed ANOVAs were carried out to compare medicated patients with OCD to the other two groups. The main effect of block was significant for both analyses (all p s $< .01$); the main effect of group was significant for neither ($p > .4$). There was a trend-level group-by-block interaction when comparing medicated and unmedicated patients with OCD [$F(9, 441) = 1.72, p = .08, \eta^2 = .03$], but no such interaction when comparing healthy controls and medicated patients with OCD [$F(9, 414) = .76, p = .66, \eta^2 = .02$].

Qualitative differences in performance trajectory

To characterize the difference in WPT performance across time, 3×1 ANOVAs were carried out for each block to compare classification accuracy between the three groups. There was a significant effect of group on block seven [$F(2, 71) = 4.78, p = .01$, uncorrected]. T-tests revealed that unmedicated patients with OCD were significantly less accurate than healthy controls [$t(47) = 3.14$, uncorrected $p < .01$] and medicated patients with OCD [$t(47) = 2.20$, uncorrected $p = .03$] on block seven.

Post-hoc analyses, and the significance of the quadratic curve in group-by-block interactions, suggest that the between-group difference derives from divergence of unmedicated patients with OCD from the other two groups in the middle part of training. Qualitative examination of the performance trajectories supports this (Figure 1). Unmedicated patients improved from chance similarly to healthy controls in early blocks, but their trajectory was largely flat through the middle of the experiment (blocks 5–8), before catching up with other groups on block 9. Performance of all groups fell on block 10. This may be due to anticipation of the end of the experiment, as the participants knew that there would be 100 trials. Regardless, performance on block 10 did not differ significantly between the three groups.

Discussion

We set out to investigate the hypothesis that unmedicated patients with OCD exhibit worse performance in implicit learning relative to healthy controls. We included medicated patients as a third comparison group to investigate whether medication might mitigate the predicted deficit. We used the WPT, a well-characterized implicit learning task (Knowlton, 1996). There were no significant between group differences in overall performance. However, change in performance over time (blocks) was significantly different for unmedicated patients with OCD compared to healthy controls. There was also a marginally significant difference in performance over time between medicated and unmedicated patients with OCD. Unmedicated patients' performance plateaued during the middle portion of the task, suggesting that accretive learning stalled.

Because of the replicated finding that striatal activity is abnormal in patients with OCD, a number of studies have probed implicit learning in patients with OCD. Two predictions are possible. First, hypermetabolism in the striatum might indicate that this circuitry is potentiated and thus that implicit learning that depends on it might be enhanced. Alternatively, hypermetabolism might indicate that the circuitry is operating inefficiently in an inflexible regime, leading to a deficit in implicit learning tasks. Early studies were contradictory, with some finding a deficit in implicit learning tasks and others not (Rauch & Rosen, 1997; Rauch, 2007). Rauch & Rosen et al (1997) put forward a possible solution of these contradictions. They found that, while patients with OCD and healthy controls performed similarly on the SRT, SRT performance activated different brain regions: healthy controls showed activation in the striatum, while patients with OCD showed enhanced activity in medial temporal lobe structures typically observed with explicit learning tasks (Rauch & Rosen, 1997). Although a follow-up study (Rauch, 2007) did not replicate the finding of deficient striatal activation, it did replicate increased activity in the medial temporal lobe. This was interpreted to suggest that patients with OCD have deficits in implicit learning, but they are often able to compensate for this deficit by recruiting the medial temporal lobe to achieve adequate performance. Consistent with this interpretation, patients have been reported to develop greater explicit understanding of the embedded patterns in the SRT (Goldman, 2008; Marker, 2006). When the SRT task is complicated by simultaneously performing an explicit learning task – holding an arbitrary sequence of letters in mind – a deficit in implicit learning is revealed (Deckersbach, 2002). This is presumably because the demands of the explicit learning task impair the ability of medial temporal lobe-dependent strategies to compensate for a deficit in implicit learning in OCD patients. Joel et al (2005) used a similar strategy to reveal subtle deficits in implicit learning in OCD, by placing implicit and explicit strategies into competition with one another.

The WPT has been argued to be less susceptible to compensation using explicit strategies. Patients with Parkinson's disease show a clear performance deficit in implicit learning (Knowlton, 1996) but also show shifts in brain activation from the striatum to the medial temporal lobe (Moody, 2004), similar to that seen when patients with OCD attempt the SRT task (Rouch, 1997, 2007). This suggests that patients are attempting compensation with explicit learning strategies, but that this compensation is inadequate. Employing explicit learning strategies affects implicit learning in the WPT in some cases (Gluck, 2002; Meeter,

2008; Price, 2009), but explicit strategies may not come into play until later in WPT (many studies use 160–200 trials rather than the 100 used here). Regardless, an analysis of trial-by-trial performance based on such strategy-shifting does not outperform an analysis more geared to capturing the implicit learning (Meeter, 2008).

A recent study by Exner et al (2014) examined implicit learning in OCD using the WPT and found that patients with OCD performed as well as healthy controls. A deficit was revealed when the task was made more salient to patients' symptoms by making the prediction about the onset of an epidemic rather than the more neutral prediction of weather. This suggests that a deficit in implicit learning may depend on the engagement of patients' symptoms. A similar effect has been reported when the details of an implicit learning task are engineered to evoke symptoms in other populations (Thomas, 2008). If the emergence of a deficit in implicit learning in patients with OCD depends on symptom activation during testing, it may be highly dependent on details of task administration or environment. It is noteworthy that our participants were more severely symptomatic than those described by Exner et al (2014). It may be that symptoms were correspondingly more engaged during the ostensibly neutral WPT in the current study, despite the absence of specific task details designed to invoke OCD symptomatology.

We found a difference in learning trajectory between unmedicated patients with OCD and healthy controls; medicated patients, on the other hand, did not significantly differ from healthy controls, and indeed separate from the unmedicated group, at trend level (Figure 1). This is somewhat at odds with previous reports that SRI pharmacotherapy does not affect neuropsychological functioning in OCD (Mataix-Cols, 2002) and that symptom improvement (after CBT) does not ameliorate deficits in the SRT (Kathmann, 2005). It is possible that SRI pharmacotherapy mitigates implicit learning deficit(s); it is notable that SRI treatments can help corticostriatal activity return to more normal levels in patients with OCD (Benkelfat, 1990; Baxter, 1992). However, the cross-sectional design of our study means that other explanations for the effect cannot be ruled out. Unmedicated patients were marginally more symptomatic than medicated patients (Table 1); it may be that this difference in severity was sufficient to unmask an implicit learning deficit. The inclusion of both medicated and unmedicated patients may have masked a deficit in WPT performance in previous studies (Exner, 2014).

The deficit in implicit learning seen in OCD in the WPT here and in the SRT (Deckersbach, 2002) and similar tasks (Joel, 2005) contrasts with a developing literature on other habit-like tasks. As noted above, abnormalities in the corticostriatal circuitry could lead to either a deficit in or an enhancement of implicit learning processes. It has been proposed that symptoms in OCD may represent a pathological over-reliance on habit-like processes (Graybiel, 2000). Roth et al (2004) reported that individuals with OCD perform better than healthy controls in the pursuit rotor task, a measure of implicit learning – although another study using the same task found no effect of diagnosis (Martin, 1993). More recently, Gillan et al (2011, 2014) have described a bias towards habit-like learning in patients with OCD in several variants of an instrumental learning task. This has been interpreted as reflecting a weakness in explicit learning, for which habit-driven processes must compensate.

The present study had several limitations. Our sample size was not large enough to differentiate learning performance across OCD subtypes. Different dimensions of OCD symptomatology appear to be associated with abnormalities in distinct components of frontostriatal circuitry and may represent an important source of variance in the behavioral performance of individuals with OCD (Mataix-Cols, 2004). We investigated implicit learning without a concurrent explicit learning load. Results may have been different if explicit learning had been simultaneously engaged by a parallel task (Deckersbach, 2002). We used a single test of implicit learning, so interpretations of our findings are constrained by the aforementioned limitations with the WPT. Whether or not deficits in implicit learning resolve in parallel with symptom improvement in OCD under standard treatment regimens remains largely an unresolved question, requiring a longitudinal design. Future studies should include more participants and should examine implicit learning using a range of measures, both at their untreated baseline and over the course of treatment.

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Highlights

- The Weather Prediction Task (WPT) is a putative measure of implicit learning.
- Patients with OCD and healthy controls completed the WPT.
- Unmedicated patient with OCD showed subtle deficits in WPT performance.
- Performance deficits were not evident for medicated patients with OCD.
- Use of explicit learning strategies may mask deficits in implicit learning in OCD.

Figure 1.

Classification accuracy for unmedicated ($n = 26$) and medicated ($n = 25$) OCD patients, and healthy controls ($n = 23$) across 10 blocks of the Weather Prediction Task (WPT). Average mean accuracy in blocks of 10 trials are shown, with 95% confidence intervals.

Table 1

Demographic and clinical characteristics of participants

VARIABLE	HEALTHY CONTROLS (<i>M, SD</i>)	MEDICATED OCD (<i>M, SD</i>)	UNMEDICATED OCD (<i>M, SD</i>)	TEST STATISTIC
<i>N</i>	23	25	26	
AGE	31.6 (12.16)	37 (12.91)	32.85 (13.48)	$F = 1.17$
GENDER (M/F)	12/11	11/14	14/12	$\chi^2 = 0.56$
Y-BOCS		26.44 (5.24)	28.84 (3.68)	$F = 3.51^{\dagger}$
HAM-D		23.46 (10.41)	24.90 (9.61)	$F = .22$

Note. All p -values > .10. Y-BOCS = Yale-Brown Obsessive Compulsive Scale; HAM-D = Hamilton Depression Scale. Y-BOCS and HAM-D test statistics for comparisons between medicated and unmedicated OCD patients. All tests were non-significant at the $p < .05$ level.

† denotes trend-level significance ($p < .10$). YBOCS data were missing from one unmedicated OCD patient, HAM-D data were missing from 6 unmedicated and 3 medicated OCD patients.

Table 2

Probability structure of the Weather Prediction Task

Cards						
Cue Pattern	1	2	3	4	p (pattern)	p (outcome)
1	0	0	0	1	0.14	0.14
2	0	0	1	0	0.08	0.38
3	0	0	1	1	0.09	0.11
6	0	1	1	0	0.06	0.5
7	0	1	1	1	0.04	0.25
8	1	0	0	0	0.14	0.88
9	1	0	0	1	0.06	0.5
10	1	0	1	0	0.06	0.83
11	1	0	1	1	0.03	0.33
12	1	1	0	0	0.09	0.89
13	1	1	0	1	0.03	0.67
14	1	1	1	0	0.04	0.75

Table 3

Card-outcome probability, across all compound cues.

	p (outcome)	p (outcome)
	Sunshine	Rain
Card 4	0.76	0.24
Card 3	0.58	0.43
Card 2	0.43	0.58
Card 1	0.24	0.76