ABSTRACT

Title of Dissertation:	PERCEPTUAL DECISION MAKING IN OBSESSIVE-COMPULSIVE DISORDER: STATE AND TRAIT SYMPTOM EFFECTS AND THE ROLE OF WORKING MEMORY
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Computational models of decision making have identified a relationship between obsessive-compulsive symptomatology and impairments in perceptual evidence accumulation. Past studies have suggested that these impairments in perceptual processing give rise to clusters of OCD symptoms (for example, not effectively "perceiving" that a door is locked or that one's hands are clean gives rise to compulsive checking or washing). That interpretation has implications for our understanding of the disorder and warrants further testing; one way to investigate that is to determine whether such impairments correlate better with state-level symptoms (i.e., obsessions and compulsions during task performance) or trait-level symptoms (i.e., in general/past week). Using hierarchical drift-diffusion modeling, the current study examines this question in consideration of the alternate possibility that these decision impairments are simply a reflection of off-task processing of active obsessions and compulsions. We also examine whether working memory may mitigate such impairments, in light of prior studies that have associated larger working memory spans with better suppression of distractors and with faster perceptual evidence accumulation.

161 adults completed the random dot-motion task, OSPAN working memory task, and OCD symptom questionnaires online. Participants who reported greater obsessive-compulsive symptoms demonstrated slower evidence accumulation ("drift rate") in the dot-motion task. These drift rate reductions were better explained by state-level symptom severity than trait-level severity. Working memory span showed a significant negative interaction with state-level symptom score on drift rate, however only for the easiest trials.

While the current study does not negate a role of perceptual evidence accumulation deficits in the pathogenesis of OCD, these findings support the possibility that such deficits may also be brought about by active symptoms during task execution. We discuss using impairments in drift rate to approximate attentional bias for off-task symptoms, as this provides a novel computational framework in closer alignment with existing clinical models of OCD.

PERCEPTUAL DECISION IMPAIRMENTS IN OBSESSIVE-COMPULSIVE DISORDER: STATE AND TRAIT SYMPTOM EFFECTS AND THE ROLE OF WORKING MEMORY

by

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Manuscript: Main text

Introduction

Obsessive-Compulsive Disorder (OCD) is characterized by the presence of perseverative, unwanted, and intrusive thoughts (obsessions) which can trigger excessive urges to perform certain overt actions and covert mental rituals (compulsions). When compared to people with anxiety or unipolar mood disorders, individuals with obsessive-compulsive disorder are less likely to be married, more likely to be unemployed, and more likely to report diminished social and occupational functioning (Abramowitz, Taylor, & McKay, 2009; Torres et al., 2006; Veale & Roberts, 2014). The substantial impact OCD has on functioning can be seen in studies showcasing an array of cognitive and behavioral abnormalities in these patients, including impairments in decision making (Foa et al., 2003; Pushkarskaya et al., 2015; Reed, 1976; Sachdev & Malhi, 2005).

The ability to make effective and timely decisions is a cornerstone of healthy human functioning. Computational modeling has formalized and quantified the intuitive idea that decision making involves accumulating evidence for and against options under consideration until a function of this evidence reaches a threshold (Bogacz, Brown, Moehlis, Holmes, & Cohen, 2006; Smith & Ratcliff, 2004; Townsend & Ashby, 1983). A particularly popular exemplar of this model class is the drift-diffusion model (DDM), which applies to decisions with two possible outcomes (Ratcliff, 1978; Ratcliff & McKoon, 2008). Each choice in the DDM is modeled as a directed random walk towards an upper or lower decision boundary, which represents the accumulation of noisy evidence in favor of one versus the other option. When the accumulated evidence reaches one of these boundaries, the decision is made and the respective response initiated. Several parameters describe this process, including: *decision threshold*, which represents the distance between the two decision boundaries; *drift rate*, which represents the rate of evidence accumulation towards either decision boundary; and *non-decision time*, which represents time spent on decision-independent processing.

Using DDM and a well-established perceptual decision task, recent studies have documented slower rates of evidence accumulation (slower drift rates) in OCD patients and individuals reporting higher trait levels of obsessive-compulsive symptoms (Banca et al., 2015; Erhan et al., 2017; Hauser, Allen, Rees, & Dolan, 2017; Marton et al., 2019). Relationships between clinical symptoms and latent parameters of computational models such as this are an important area of study within the field of computational psychiatry. A central premise of this broader work, which includes the specific case of perceptual deficits in OCD, is that information processing differences captured in lab-based studies carry causal explanatory power for disease states and symptoms. For example, in the setup explaining how OCD-related perceptual decision making deficits might be interpreted, Banca et al. (2015) state: "In the repetitive act of washing or checking, the available sensory-perceptual evidence appears insufficient to commit to a solid decision: patients appear unable to decide whether their hands are sufficiently clean or the door is properly locked" (Banca et al., 2015). An equally plausible, yet often overlooked, possibility is that causality flows in the opposite direction, and active symptoms give rise to information processing differences measured in lab-based settings. The slower drift rates exhibited by OCD subjects may simply result from attentional resources being spontaneously tied up by off-task processing, including covert obsessions and compulsions (Clayton, Richards, & Edwards, 1999; Muller & Roberts, 2005).

Caution is especially warranted if information processing differences correlate with state rather than (or in addition to) trait symptom measures. Here we investigate whether a state-based measure of obsessions and compulsions can better explain the reductions in drift rate during perceptual decision making previously reported. Although we cannot and will not make causal claims, we argue that the presence of state effects raises questions about the interpretation of previous results, and it will be necessary to develop experimental paradigms that can causally manipulate obsessions and compulsions in a controlled setting in order to resolve them. Conclusively resolving these questions has obvious important implications for treatment development. If perceptual impairments really drive obsessions and compulsions, then treatment can be directed at rescuing those impairments. On the other hand, if perceptual impairments are a byproduct of selective attention for active symptoms, such interventions will be ineffective and treatment needs to focus instead on these upstream factors. We raise these issues in the context of perceptual decision making in OCD, but we believe similar caution is also warranted in other domains within the purview of computational psychiatry, especially if reported computational differences represent deficits rather than enhancements in performance.

If attentional bottlenecks can result from off-task obsessions and compulsions, the extent to which this occurs may be reflected in working memory. Research suggests that a larger working memory span indicates better resistance to attentional disruption by off-task activity (Chun, Golomb, & Turk-Browne, 2011; Zanto & Gazzaley, 2009), or simply more limited-capacity attentional resources available in the first place (Conway & Engle, 1996). Either way, individuals with larger working memory spans appear better able to suppress irrelevant intrusive thoughts (Brewin & Smart, 2005; Geraerts, Merckelbach, Jelicic, & Habets, 2007), and demonstrate faster evidence accumulation (higher drift rate) during perceptual decision making (Ester, Ho, Brown, & Serences, 2014). Thus, the second aim of our work is to test whether state-based information processing differences interact with individual working memory span. There are a number of different ways to measure working memory span, including one based on the same perceptual decision task, as used by Ester et al. (2014) (Ester et al., 2014). However, working memory measures of perceptual or visuospatial information could be difficult to interpret because it would leave unclear whether a relationship between it and perceptual decision making performance was simply due to a shared perceptual ability indexed by both tasks. In order to ask this question rigorously, we used the OSPAN (Turner & Engle, 1989), a working memory measure largely unrelated to perceptual performance (Trick, Mutreja, & Hunt, 2011). The OSPAN task is widely used to assess verbal working memory: it involves reading simple math problems followed by words and then verbally recalling the words later on. Thus, any relationship between it and perceptual decision making would most likely be driven by more general aspects of working memory, rather than perceptual ability. An additional consideration in opting for a verbal working memory measure is the inherently verbal nature of most obsessions and many compulsions (American Psychiatric Association, 2013; Collaton & Purdon, 2015).

Methods and Materials

Participants

Data were collected online using Amazon's Mechanical Turk (MTurk). MTurk has been shown to produce behavioral data largely comparable to that of more conventional lab-based experiments, with the advantage of obtaining more diverse samples than otherwise typical (Buhrmester, Kwang, & Gosling, 2016). Eligible participants were at least 18 years of age and in the USA (i.e., US billing address with US credit card, debit card, or bank account) with a prior task approval rating of at least 95%. Upon study completion, participants were paid $5 in addition to a bonus based on overall accuracy in each task (max bonus = $1.00; M=$0.76, SD=0.19). Participant identities were unknown to the researchers; all participants provided electronic informed consent in accordance with procedures approved by the University of Maryland, College Park Institutional Review Board for Human Subjects Research.

Quality Control

Several a priori exclusion criteria were applied to ensure data quality, in line with standard practices and suggestions for studies using MTurk (Crump, McDonnell, & Gureckis, 2013; Gillan, Kosinski, Whelan, Phelps, & Daw, 2016). Prior to enrollment, potential participants first completed a training phase that consisted of written instructions followed by a brief practice round for each task. They were then required to correctly answer three comprehension questions pertaining to basic task rules in order to participate in the main experiment.

The training phase and associated comprehension questions were always administered first, followed by two tasks—a perceptual decision-making task (random-dot motion task; RDMT) and a working memory task (operation span; OSPAN)—presented in randomized order, and finally several self-report questionnaires. Of those questionnaires, the state measure of obsessive-compulsive symptoms (Y-BOCS-SR—State; see Questionnaires below) was always presented first, right after both tasks were completed. The order of the remaining questionnaires was randomized.

The following exclusions were sequentially applied based on task performance and engagement. *Operation Span Exclusion Criteria*: In line with recommendations in the OSPAN literature (Conway et al., 2005), participants were excluded if their accuracy on the processing component (i.e., mathematics problems) was below 85% (n=42), or if their accuracy on the recall component was below 10% (i.e., less than 7 out of 75 items) (n=2). To reduce instances of cheating (e.g., writing down target items to assist later recall), a 12-item catch trial was presented at the end of the task; participants who scored a 12 out of 12 were also excluded from further analyses (n=43). *Questionnaires Exclusion Criterion*: In an effort to identify participants who did not fully read questions prior to selecting their responses, we included two catch items (one in the Y-BOCS-SR—State, and one in the Padua Inventory): e.g., "Upon seeing this question, please select 'Very much' for your answer." Participants who answered either catch item incorrectly were excluded (n=26).

In total, 115 out of 276 (42%) subjects who submitted data were excluded from the study. Among the included participant data, RDMT trials with implausibly fast (<250ms) or unusually slow (>15 sec) reaction times were discarded.

Random Dot Motion Task

In each trial of the random-dot motion task (RDMT), participants were shown a dynamic kinematogram of 30 small white dots on a black background that repositioned at a new location on each computer frame. The kinematogram presented in a circular aperture (diameter of 350 pixels) centered in the middle of the screen, and each dot moved at a fixed speed of 10 pixels per frame. Trials consisted of varying levels of motion coherence either leftward or rightward – the larger the level of motion coherence, the greater the proportion of dots moving unambiguously in one direction. Participants were asked to report the primary direction of motion by pressing a key on the keyboard ("Q" for left; "P" for right). Each trial stimulus displayed until a keyboard response was given, with no time limit for responses (ITI = 500ms). Coherence levels were set to 7.5% ("High uncertainty"), 20% ("Medium uncertainty"), and 45% ("Low uncertainty"), and presented in random order across trials. Participants completed three blocks of 120 trials each.

Operation-SPAN Working Memory Task

Participants completed a computerized version of the OSPAN task (Turner & Engle, 1989; Unsworth, Heitz, Schrock, & Engle, 2005). Within each trial, participants were shown a series of alternating simple math problems and single letters, wherein a single math problem followed by a single letter is referred to as an equation-letter pair. Answers were supplied for the math problems (e.g., 2x9 – 9 = 9) and participants were asked to verify the correctness of the equation by pressing "Q" for false or "P" for true, within a time limit (20 secs). Equations were compiled randomly according to the standard OSPAN format, with equal correct and incorrect answers. Each letter was presented for 800ms in the center of the screen, and was randomly drawn without replacement from a pool of 12 non-vowel letters for each trial. Trials ranged in length from 3 to 7 successively presented equation-letter pairs. At the end of each trial, participants were prompted to recall the letters in correct order by typing each letter into a blank row from top to bottom. Three trials of each length (3-7) were presented, for a total of 15 trials. A catch trial consisting of 12 equation-letter pairs was always presented last, for exclusion purposes only. Individual working memory span scores were calculated using the partial-credit unit scoring method (for description and reasoning, see Conway et al., 2005).

Questionnaires

Consistent with prior work (Hauser et al., 2017), we used the Padua Inventory-Washington State University Revision (PI-WSUR) (Burns, Keortge, Formea, & Sternberger, 1996) to assess trait-level OCD-specific symptoms. The PI-WSUR consists of 39-items comprising five symptom-type subscales: contamination obsessions and washing compulsions, dressing/grooming compulsions, checking compulsions, obsessional thoughts of harm to self/others, and obsessional impulses to harm self/others. A recent meta-analysis confirmed good mean test-retest reliability (total score = .767, subscales = .540 - .790) and excellent mean internal consistency (total score = .929, subscales = .792 - .900) (Rubio-Aparicio et al., 2018). For studies of individual differences (i.e., not relying on diagnostic status alone), the Padua Inventory is the more commonly used measure when investigating perceptual decision impairments in this disorder (Erhan & Balcı, 2017; Hauser et al., 2017). However, the format of this measure does not lend itself well for an assessment of state-level symptoms—the two biggest challenges being that it was not originally designed to consider the impact of symptoms over any specific time frame, and that it is content-specific for different obsessions and compulsions.

Another popular measure of obsessive-compulsive symptoms is the Yale-Brown Obsessive Compulsive Scale—Self-Report (Y-BOCS-SR) (Baer, Brown-Beasley, Sorce, & Henriques, 1993), which contains a 10-item measure designed to assess the severity and impact of obsessions and compulsions without being biased for the types of content that may be present. The Y-BOCS-SR comprises subscales for obsession severity and compulsion severity. It consists of five rating dimensions for both obsessions and compulsions: time spent/occupied, interference with functioning, degree of distress, resistance, and control (i.e., success in resistance). Studies of the Y-BOCS-SR with general population samples have shown excellent test-retest reliability (total = .88, obsessions subscale = .87, compulsions subscale = .82) and internal consistency (total = .89, obsessions subscale = .85, compulsions subscale = .84) (Steketee, Frost, & Bogart, 1996), and that the total score reliably correlates with the clinician-administered original version (Federici et al., 2010; Goodman, 1989). The standard Y-BOCS-SR assesses symptoms within the past week, and thus also functions as a trait-level measure. For the current study, we modified this measure to assess the severity and impact of obsessions and compulsions that the participant experienced during the RDMT and OSPAN only. Changes to accomplish this from the standard version were minimal: we replaced wording in the prompts for each question to indicate the participant consider their symptoms specifically "during the dots and math/letters tasks" (whereas, in the standard version this is specified as "in the past week"). This modified version, which we refer to as the “Y-BOCS-SR—State” can thus provide a measure of the state effects of obsessions and compulsions that influenced performance during the experiment.

Drift-Diffusion Modeling

The drift-diffusion model (DDM) is a well-validated, widely used mathematical model that explains decision dynamics during two-alternative forced choice paradigms (Ratcliff & McKoon, 2008). Broadly, DDM describes the accuracy and reaction time of decisions using a basic mechanism of evidence accumulation with a drift-diffusion process (Figure 1). In this model, an individual will continuously extract sensory evidence from the presented stimulus (i.e., drift) which is disturbed by noise (i.e., diffusion). This noisy evidence is accumulated over time, thereby pushing a decision variable towards one or another decision boundary. Once enough evidence has been sampled to push the decision variable across a boundary, a decision is made and the respective response initiated.

In the current study, we employed hierarchical Bayesian parameter estimation of the drift-diffusion model to fit decisions in the RDMT. Simultaneously accounting for accuracy and respective reaction time distributions across conditions, hierarchical DDM estimates the posterior probability density of the model parameters using Markov chain Monte Carlo (MCMC) methods, fitting group data while also accounting for individual differences (Wiecki, Sofer, & Frank, 2013). All models were specified with the following free parameters: *drift rate* (i.e., speed of the evidence accumulation process towards either boundary or the quality of the accumulated evidence), *decision threshold* (i.e., the distance between the two boundaries, or amount of accumulated evidence necessary to make a decision), and *non-decision time* (i.e., time spent on decision-independent processing, such as initial perceptual encoding and motor execution). DDM also allows for a prepotent bias of the drift process starting point relative to the two decision boundaries. All models assumed an unbiased starting point, given that left/right responses in the RDMT were counterbalanced. Drift rate and decision threshold were allowed to vary by trial uncertainty level (i.e., dot-motion coherence). Free parameters had broad, unbiased priors. See the Supplement for model details.

For all models, four independent Markov chains were run for 1,000 iterations, with the first 200 samples discarded as burn-in. Convergence was assessed with visual inspection of the Markov chains and by computing the R-hat Gelman-Rubin statistic where successful convergence is indicated by values <1.1 (Brooks & Gelman, 1998). All models reported in this study showed good convergence with R-hat values <1.06.

Statistical Analysis

Dependent samples Welch's t-tests were used to compare the accuracy and reaction times of different trial uncertainty levels in the RDMT. Hierarchical drift-diffusion models were implemented with Stan, using the RStan package in R (R Core Team, 2019; Stan Development Team, 2018). Effect sizes were reported as the posterior median value and median 95% credible interval (CI) of the standardized beta coefficients in our models, and assessed using Bayesian hypothesis testing, whereby an effect is considered "significant" when the median 95% CI does not include 0.

Results

Sample Characteristics

The study sample comprised 161 adult participants with ages ranging from 19 to 71 years. Table 1 lists the sample's demographics and characteristics (OSPAN and questionnaire scores).

Basic Behavioral Results

Basic behavioral data from the RDMT are presented in Figure 2, which demonstrates how the level of uncertainty (coherence) in the dot motion stimulus affects difficulty. Uncertainty levels were as follows: "High" (7.5% coherence), "Medium" (20% coherence), and "Low" (45% coherence). Consistent with expectation, higher uncertainty trials in the RDMT were both less accurate (High – Med: $t = -23$, $p = 1.6\times10^{-52}$; Med – Low: $t = -8.9$, $p = 1\times10^{-15}$) and slower (High – Med: $t = 13.9$, $p = 2.1\times10^{-29}$; Med – Low: $t = 13.7$, $p = 9.4\times10^{-29}$).

There were no significant correlations of OSPAN scores with any of the self-report symptoms measures. The Y-BOCS-SR and Y-BOCS-SR—State had a significant correlation of 0.561 ($p < 0.001$). Correlations among OSPAN scores and all questionnaires in the current study are reported in Supplemental Table 1.

Hierarchical Drift-Diffusion Modeling

Results revealed a consistent main effect of stimulus uncertainty for both drift rate and decision threshold across all models: the lower the uncertainty (greater dot motion cohesion) during a trial, the faster the drift rate and smaller the decision threshold. For example, Table 2 lists this result from our first model (Model 1, described below). The posterior median estimates and 95% CIs for all regressors across all models are shown in Supplemental Table S2.

Our first model (Model 1) focused specifically on the relationship with PI-WSUR score, which has been used in prior studies to characterize OCD-related differences in perceptual decision making (Erhan & Balcı, 2017; Hauser et al., 2017). Consistent with those studies, Model 1 demonstrated a significant negative relationship between PI-WSUR score and drift rate for easier trials (i.e. Low and Medium, but not High, uncertainty level), with greater negative effect at Low than Medium uncertainty (Low: β = -0.18 [-0.26, -0.10]; Med: β = -0.08 [-0.16, -0.004]; High: β = -0.03 [-0.11, 0.05]; Difference of Low – Med: β = -0.09 [-0.12, -0.07]; Difference of Med – High: β = -0.06 [-0.08, -0.04]). There were no significant effects of PI-WSUR on decision threshold.

To test whether the standard trait-based Y-BOCS-SR ("YBOCS") similarly captured performance differences, our second model (Model 2) specifically focused on it. Results were similar to Model 1: a significant negative impact of YBOCS score on drift rate in Low uncertainty trials, more so than Medium uncertainty trials (Low: β = -0.21 [-0.29, -0.13]; Med: β = -0.10 [-0.18, -0.01]; High: β = -0.04 [-0.11, 0.05]; Difference of Low – Med: β = -0.11 [-0.14, -0.09]; Difference of Med – High: β = -0.06 [-0.08, -0.04]).

We next tested whether a state-based measure of obsessions and compulsions, the Y-BOCS-SR—State ("YBOCS-State"), better explained these differences than the PI-WSUR and the standard YBOCS. This model (Model 3) included all three scores as regressors. YBOCS-State was negatively correlated with drift rate in both the Low and Medium uncertainty conditions (Low: β = -0.28 [-0.38, -0.19]; Med: β = -0.17 [-0.26, -0.07]; High: β = 0.01 [-0.09, 0.10]; Difference of Low – Med: β = -0.11 [-0.14, -0.08];

Difference of Med – High: β = -0.17 [-0.20, -0.15]). PI-WSUR scores demonstrated a barely significant negative effect on drift rate in Low uncertainty trials only (β = -0.10 [-0.18, -0.003]), while the standard YBOCS no longer related to drift rate at any uncertainty level. Notably, the YBOCS-State effect on drift rate was significantly stronger than that of the PI-WSUR ("Padua") at both Low and Medium uncertainty (Difference of YBOCS-State – Padua for Low: β = -0.18 [-0.32, -0.05], Med: β = -0.13 [-0.27, -0.008], High: β = 0.009 [-0.13, 0.13]). This YBOCS-State effect was also significantly stronger than that of the standard YBOCS at both Low and Medium uncertainty (Difference of YBOCS-State – YBOCS for Low: β = -0.27 [-0.44, -0.10], Med: β = -0.18 [-0.35, -0.02], High: β = 0.04 [-0.13, 0.20]). These findings demonstrate that a state-based measure of obsessions and compulsions can explain drift rate impairments in perceptual decision making better than trait-based measures, consistent with our hypothesis.

To test the role of working memory in this context, our fourth model (Model 4) extended Model 3 to also include working memory span scores from the OSPAN task. Drift rate results were comparable to Model 3 for the PI-WSUR, standard YBOCS, and YBOCS-State. In contrast to the prior models, Model 4 demonstrated a small, significant effect of YBOCS-State on decision threshold for High uncertainty trials, although the effect at Low and Medium uncertainty remained non-significant (Low: β = -0.01 [-0.12, 0.10]; Med: β = -0.04 [-0.15, 0.06]; High: β = -0.12 [-0.23, -0.01]; Difference of Low – Med: β = 0.03 [0.01, 0.05]; Difference of Med – High: β = 0.07 [0.05, 0.09]). Model 4 further revealed that OSPAN score had no significant effect on drift rate or decision threshold at any of the stimulus difficulty levels.

To test the hypothesis that a larger working memory span may protect against the detrimental effect of state-based obsessions/compulsions during the RDMT, our fifth model (Model 5) included the interaction between OSPAN working memory score and YBOCS-State. There was a significant negative interaction effect for Low uncertainty trials, but not Medium or High uncertainty (Low: β = -0.18 [-0.29, -0.05]; Med: β = -0.10 [-0.21, 0.02]; High: β = -0.02 [-0.13, 0.10]; Difference of Low – Med: β = -0.07 [-0.11, -0.04]; Difference of Med – High: β = -0.09 [-0.12, -0.06]), indicating that a larger working memory span exacerbated the negative relationship of YBOCS-State score and drift rate, contrary to expectation. Other effects were similar to Model 4. Figure 3 shows posterior median 95% CI estimates for the main condition-level effects, and the effects of subject-level scores on drift rate, in Model 5.

Discussion

In a large general population sample, we examined the relative contributions of state-level obsessions and compulsions, trait-level OCD symptoms, and the interplay of verbal working memory span with state-level symptoms, to perceptual decision making processes. Our results demonstrate a consistent feature of slower drift rate in individuals with higher obsessive-compulsive symptom scores, particularly under lower uncertainty.

Drift rate is a measure of the speed of evidence accumulation over time, and represents the quality or precision of stimulus evidence entering the decision process (Ratcliff & McKoon, 2008). In a simple model including only the PI-WSUR, we found that higher scores on this measure related to slower drift rate on low and medium uncertainty trials. This finding is consistent with a majority of prior studies in both OCD patients and the general population (Banca et al., 2015; Erhan et al., 2017; Hauser et al., 2017; Marton et al., 2019), but not all studies (Erhan & Balcı, 2017). We then replicated this phenomenon using the Y-BOCS-SR, which is another popular trait measure of OCD symptom severity, thereby demonstrating that these deficits are not sensitive to a particular trait-based measure. The enhanced effect of low objective uncertainty contexts on evidence accumulation deficits in OCD is a consistent story (Banca et al., 2015), and aligns with studies demonstrating a similar pattern of impairment for subjective certainty in OCD; for example, Stern and colleagues (2013) found that patients provided greater ratings of subjective uncertainty for low but not higher uncertainty evidence during a probabilistic reasoning task (Stern et al., 2013).

Prior studies of evidence accumulation in OCD have tended to utilize just one single trait measure of symptomatology, fueling speculations that such bottom-up information processing differences causally contribute to psychiatric traits (Banca et al., 2015; Hauser et al., 2017; Marton et al., 2019). However, previous work has not tested whether state-based measures better capture these differences; any effects captured by state-based measures should cast doubt on the prior proposed direction of causality. Our models revealed that reductions in drift rate were in fact better explained by state-based symptoms, as indexed by our modified Y-BOCS-SR—State measure. This result lends credence to the alternate possibility that such deficits in perceptual evidence accumulation in OCD may be brought about by active symptoms of this disorder—for example, because of off-task attentional processing of acute intrusive thoughts and compulsions. Other studies have also called for consideration of this directional effect, whereby OCD symptoms experienced during testing were related to performance deficits on various neurocognitive tasks (Moritz, Hottenrott, Jelinek, Brooks, & Scheurich, 2012).

While our findings do not negate the role of such information processing deficits in the formation and maintenance of OCD symptoms, they call for consideration of the opposite directional relationship. In such a case, interventions that are aimed at rescuing perceptual impairments in order to reduce OCD symptom severity may not be effective. Rather, treatments that home in on upstream factors—such as cognitive appraisal style and attention bias—in order to reduce active symptom severity may perhaps be shown to thus rescue perceptual impairments.

Our findings on the role of working memory span (WM) are less clear. We found no direct relationship between working memory span and drift rate, and the interaction between working memory and Y-BOCS-SR—State was significant only for the low uncertainty condition, but in the direction opposite to what we predicted. The OSPAN was chosen in lieu of a visuospatial or perceptual-based working memory task in order to minimize potential confounds. In addition, for many patients, obsessions and compulsions include a verbal component (American Psychiatric Association, 2013; Collaton & Purdon, 2015). Thus, if state-based obsessions and compulsions reduce performance by competing with task demands in working memory, such effects should be detectable using a verbal-based measure like the OSPAN. Our results, however, counter this hypothesis and warrant further research; in particular, there is the possibility that the interaction effect we found is a Type 1 error, while another possibility is a missing variable, such as attentional bias, to clarify the relationship between WM and evidence accumulation. An alternative interpretation in support of these findings is the argument that a higher WM actually enables greater engagement with off-task thoughts, especially for lower demanding tasks (Levinson, Smallwood, & Davidson, 2012).

Studies investigating the neural correlates of evidence accumulation in perceptual decision making have suggested that, after initial processing by sensory areas, stimulus information is integrated or accumulated in parietal and frontal regions before subsequent transmission to the effector areas for response production (Heekeren, Marrett, & Ungerleider, 2008). Neurophysiological studies in monkeys have identified patterns of neuronal firing that appear consistent with stimulus evidence accumulation in the superior colliculus (Horwitz & Newsome, 2001; Ratcliff, Cherian, & Segraves, 2003; Ratcliff, Hasegawa, Hasegawa, Smith, & Segraves, 2007), frontal eye field (J. Y. Cohen, Heitz, Woodman, & Schall, 2009; Ding & Gold, 2011; B. A. Purcell et al., 2010), caudate (Ding & Gold, 2010), lateral intraparietal area (Churchland et al., 2011; Churchland, Kiani, & Shadlen, 2008; Gold & Shadlen, 2007; M. N. Shadlen & Newsome, 1996;

Michael N. Shadlen & Newsome, 2001), and dorsolateral prefrontal cortex (Kim & Shadlen, 1999). In humans, neuroimaging studies have found a similar involvement of these various regions in evidence accumulation, including dorsolateral prefrontal and parietal areas (de Lange, Jensen, & Dehaene, 2010; Heekeren, Marrett, Ruff, Bandettini, & Ungerleider, 2006; Heekeren et al., 2008; Liu & Pleskac, 2011; Mulder, van Maanen, & Forstmann, 2014; Ploran et al., 2007; Shine et al., 2016). Notably, multiple lines of research have identified anomalies in dorsolateral fronto-parietal networks of attention and working memory in OCD (Arnsten & Rubia, 2012; Menzies et al., 2008; Nakao, Okada, & Kanba, 2014; Saxena & Rauch, 2000; Whiteside, Port, & Abramowitz, 2004). Several studies have even reported altered activation of these regions and networks (e.g., DLPFC, OFC, ACC, caudate) in response to acute obsessive-compulsive symptom provocation (Nakao et al., 2014)—demonstrating a physiological overlap whereby acutely experienced OCD symptoms may relate to abnormal evidence accumulation in the brain.

The negative effects of active obsessive-compulsive symptoms on perceptual evidence accumulation may occur through attentional dysfunction. Clinically, this argument should come as no surprise, as it is consistent with well-established cognitive-behavioral and neuropsychological theories of attentional bias in psychiatric disorders (Merckelbach, 1995; Tallis, 1997). In particular, Wells' metacognitive model has long posited a cognitive-attentional syndrome in disorders such as anxiety, depression, and OCD (Adrian Wells, 1997; Adrian Wells, 2009), highlighting maladaptive attentive-regulatory strategies towards negative or unwanted thoughts. Attention training techniques using bias modification (ABM)—typically with a dot probe task—have been shown to effectively manipulate anxiety and depression symptoms in both general and clinical samples (Beevers, Clasen, Enock, & Schnyer, 2015; Hakamata et al., 2010; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Yang, Ding, Dai, Peng, & Zhang, 2015); reduce contamination bias or contamination fears in individuals with OCD symptoms (Najmi & Amir, 2010; Rouel & Smith, 2018); and improve reward-based decision making in individuals with self-reported depression (Cooper et al., 2013). In addition, attentional priority has been shown to impact evidence accumulation during perceptual decision making in non-clinical samples (Denison, Adler, Carrasco, & Ma, 2018; Macdonald, Mathan, & Yeung, 2011; Tavares, Perona, & Rangel, 2017). Recent work establishing impaired drift rates in Parkinson's patients with visual hallucinations has suggested using computational modeling of drift rate as a means to better specify attentional dysfunction (O'Callaghan et al., 2017). An important next step for this line of work would therefore be to test whether trial-based attention training (for example, with a dot-probe like task) could recover drift rate deficits in individuals prone to such impairments, such as those reporting high levels of acute OCD symptoms. Evidence accumulation improvements in OCD patients have been demonstrated using incentive manipulation for speed over accuracy with trial-based monetary reward (Banca et al., 2015). While this shows that impairments can be rescued through behavioral intervention, it is more likely that mechanisms of attentional dysfunction, rather than motivational deficits, are driving these effects in OCD according to clinical models of the disorder.

OCD is heterogeneous in symptomatology and has high comorbidity rates with other psychiatric diagnoses, such as depression and anxiety. Other studies have documented drift rate differences in patients with MDD (Lawlor et al., 2019) and with trait-based anxiety (Raymond, Steele, & Seriès, 2017). Notably, prior work in a general population sample demonstrated a significant relationship between drift rate deficits and trait-based OCD symptoms even after controlling for both depression and anxiety symptoms (Hauser et al., 2017). The current study only assessed symptomatology for OCD. Future studies may benefit by further stratification—for example, either according to more traditional measures of clinical diagnostic co-morbidities or by parsing out dimensional psychiatric symptom factors (Gillan et al., 2016)—to determine the interplay of various state and trait effects on information processing impairments.

We used a similar approach to several of the prior studies of evidence accumulation and obsessive-compulsive symptoms by investigating this effect in a general population sample, instead of clinically-diagnosed patients (Erhan & Balcı, 2017; Hauser et al., 2017; Marton et al., 2019). Our findings of impaired drift rates relative to obsessive-compulsive symptoms are convergent not only with those prior general population studies but also prior studies of patients with OCD (Banca et al., 2015; Erhan et al., 2017; Marton et al., 2019); this speaks to a conceptualization of obsessive-compulsive symptoms as on a spectrum and suggests that perceptual drift rate impairments generalize to said spectrum beyond the frank categorical entity of clinical disorder. However, given this is the first study to consider the impact of state symptoms on evidence accumulation, future studies of patients with OCD are needed to ascertain whether similar state-based processes are impaired in participants with clinically diagnosed symptoms.

It's worth noting that our observed scores distributions for both the PI-WSUR and the Y-BOCS-SR are consistent with previous work in lab-based settings. For example, the developers of the PI-WSUR, Burns and colleagues, reported total scores for both normative and OCD patient samples (normative: M=22, SD=16; patients: M=55, SD=17) (Burns et al., 1996). As expected, we observed comparable total scores (M=23, SD=24) to that of their normative sample. As for the Y-BOCS-SR, our observed total scores (M = 7, SD = 6) are comparable to those reported by Steketee and colleagues for a non-clinical sample (M = 8, SD = 6) (Steketee et al., 1996).

In conclusion, our results suggest a novel possible interpretation for impaired evidence accumulation in OCD that is more in line with existing clinical models, and invite the possibility of recovering such impairments with techniques to reduce the impact of acutely experienced symptoms, such as attention training. Alterations of perceptual evidence accumulation in the RDMT, as captured by drift-diffusion modeling, can therefore provide a valuable marker in future explanatory and therapeutic studies of obsessive-compulsive symptoms.

Manuscript: Tables

Table 1. Demographics and Characteristics of the Sample

	Total	**Min–Max**
Age, Years	39 ± 12	19–71
Sex		
Female	79 (49)	-
Male	82 (51)	-
OSPAN	0.88	0.29–1
PI-WSUR		
Total	23 ± 24	0–135
Checking	8 ± 8	0–34
Contamination	9 ± 9	0–38
Grooming	2 ± 3	0–12
Obsessional Impulses	2 ± 5	0–32
Obsessional Thoughts	3 ± 5	0–24
Y-BOCS-SR		
Total	7 ± 6	0–29
Obsessions	4 ± 4	0–14
Compulsions	3 ± 3	0–15
Y-BOCS-SR—State		
Total	4 ± 5	0–29
Obsessions	2 ± 3	0–15
Compulsions	2 ± 3	0–16

Values are mean ± SD or *n* (%).

OSPAN, partial unit score for letter recall in the Operation Span task; PI-WSUR, Padua Inventory-Washington State University Revision; Y-BOCS-SR, Yale-Brown Obsessive Compulsive Scale—Self Report standard version; Y-BOCS-SR—State, Yale-Brown Obsessive Compulsive Scale—Self Report modified to assess state-level symptoms experienced during completion of experimental tasks.

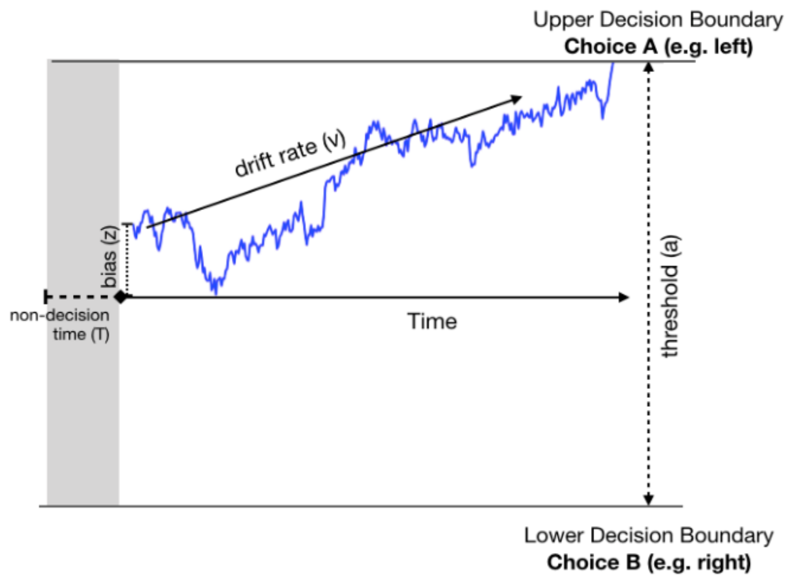
Table 2. Posterior Median 95% CI for Main Effects of Uncertainty (Model 1)

	Median	Lower	Upper
Drift rate			
Stimulus uncertainty level			
Low	1.60	1.52	1.68
Medium	1.10	1.03	1.18
High	0.36	0.29	0.44
Difference between levels			
Low – Medium	0.50	0.47	0.52
Medium – High	0.74	0.72	0.76
Decision threshold			
Stimulus uncertainty level			
Low	1.92	1.82	2.00
Medium	2.15	2.06	2.23
High	2.46	2.36	2.54
Difference between levels			
Low – Medium	-0.23	-0.25	-0.21
Medium – High	-0.30	-0.32	-0.28

Notes. The median 95% CI is represented as the range between the numbers in the "Lower" and "Upper" columns. Effects are considered significant when the median 95% CI does not include 0. As such, all of the effects and contrasts listed in Table 2, above, are significant.

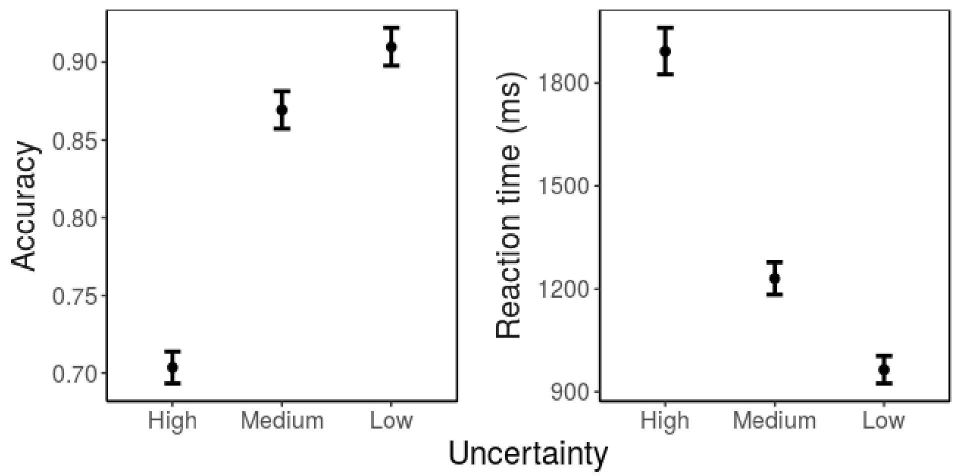
Manuscript: Figures

Figure 1. Example of a DDM Decision Process



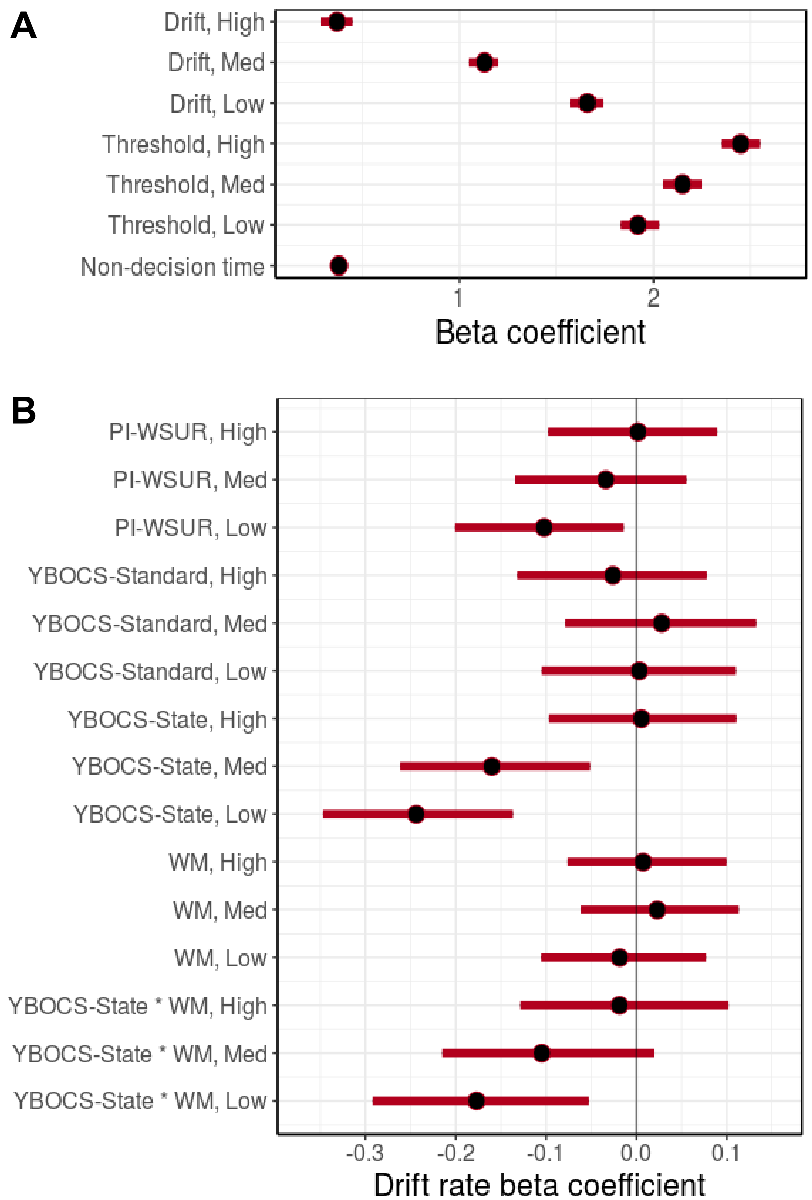
A decision variable (blue) tracks accumulated noisy evidence over time, here directed towards the decision boundary for Choice A. Parameters include: drift rate (i.e., rate of evidence accumulation), decision threshold (i.e., distance between decision boundaries), bias (i.e., initial bias for one decision over another), and non-decision time (e.g., initial perceptual encoding, motor execution).

Figure 2. Difficulty in the RDMT is Modulated by Uncertainty Level of the Motion Stimulus.



Uncertainty level represents motion stimulus coherence (Low, 45% coherence; Medium, 20% coherence; High, 7.5% coherence). Medium uncertainty trials were more accurate than high uncertainty trials (t(200)=23, p=1.6e-52), and low uncertainty trials were more accurate than medium uncertainty trials (t(200)=8.9, p=1e-15). Similarly, medium uncertainty trials had shorter reaction times than high uncertainty trials (t(200)=-13.9, p=2.1e-29), and low uncertainty trials had shorter reaction times than medium uncertainty trials (t(200)=-13.7, p=9.4e-29).

Figure 3. Posterior Median and 95% CI for Model 5 Beta Coefficients.



"Low" = low uncertainty trials at 45% dot motion coherence; "Med" = medium uncertainty trials at 20% coherence; "High" = high uncertainty trials at 7.5% coherence. The median estimate for each regression coefficient's posterior distribution is represented by a black dot, and 95% CI is represented by a red line. An effect is considered significant if the 95% CI excludes 0. (**A**) Effects of trial uncertainty level on drift rate ("Drift") and decision threshold ("Threshold"), and the subject-level mean for Non-decision time. (**B**) Effects of subject-level scores on drift rate. Consistent with the other models, scores on the Y-BOCS-SR—State ("YBOCS-State") significantly reduced drift rate at Low and Medium uncertainty trials. In this model, PI-WSUR scores had reduced effect on drift rate, such that Medium uncertainty was no longer significant and Low uncertainty only slightly significant. The interaction of YBOCS-State and OSPAN working memory score ("WM") was negative on drift rate only for Low uncertainty.

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Supplemental Table 1. Correlations of WM and Questionnaire scores

	OSPAN	PI-WSUR	YBOCS	YBOCS-State
OSPAN	1	0.052	0.016	0.157
PI-WSUR	0.052	1	0.491*	0.364*
Y-BOCS-SR	0.016	0.491*	1	0.561*
Y-BOCS-SR—State	0.157	0.364*	0.561*	1

Notes. * = $p < .001$ (fdr-corrected).

OSPAN = partial unit score for letter recall in the Operation Span task; PI-WSUR = Padua Inventory-Washington State University Revision; YBOCS = Yale-Brown Obsessive Compulsive Scale—Self Report standard version; YBOCS-State = Yale-Brown Obsessive Compulsive Scale—Self Report modified to assess state-level symptoms experienced during completion of experimental tasks.

Supplemental Table 2. Posterior Median and 95% CI for Each Model

	Model 1			Model 2			Model 3			Model 4			Model 5		
	Median	Lower	Upper	Median	Lower	Upper	Median	Lower	Upper	Median	Lower	Upper	Median	Lower	Upper
Drift rate															
Subject-level, SD	0.51	0.45	0.57	0.50	0.45	0.56	0.50	0.45	0.56	0.50	0.45	0.56	0.50	0.50	0.57
Condition-level main															
Low	1.60	1.52	1.68	1.59	1.51	1.67	1.62	1.54	1.70	1.63	1.55	1.71	1.66	1.57	1.74
Med	1.10	1.03	1.18	1.10	1.02	1.18	1.10	1.03	1.18	1.11	1.04	1.20	1.13	1.05	1.20
High	0.36	0.29	0.44	0.36	0.28	0.44	0.36	0.29	0.44	0.37	0.30	0.46	0.37	0.29	0.45
PI-WSUR															
Low	-0.18	-0.26	-0.10	—	—	—	-0.10	-0.18	0.00	-0.11	-0.19	-0.01	-0.10	-0.20	-0.01
Med	-0.08	-0.16	-0.004	—	—	—	-0.03	-0.11	0.06	-0.04	-0.13	0.05	-0.03	-0.13	0.06
High	-0.03	-0.11	0.05	—	—	—	0.001	-0.08	0.09	-0.01	-0.10	0.09	0.00	-0.10	0.09
YBOCS-Standard															
Low	—	—	—	-0.21	-0.29	-0.13	-0.01	-0.11	0.10	0.01	-0.09	0.12	0.003	-0.10	0.11
Med	—	—	—	-0.10	-0.18	-0.01	0.01	-0.09	0.12	0.03	-0.06	0.14	0.03	-0.08	0.13
High	—	—	—	-0.04	-0.11	0.05	-0.03	-0.13	0.07	-0.01	-0.11	0.09	-0.03	-0.13	0.08
YBOCS-State															
Low	—	—	—	—	—	—	-0.28	-0.38	-0.19	-0.30	-0.41	-0.20	-0.24	-0.35	-0.14
Med	—	—	—	—	—	—	-0.17	-0.26	-0.07	-0.19	-0.30	-0.09	-0.16	-0.26	-0.05
High	—	—	—	—	—	—	0.01	-0.09	0.10	-0.005	-0.12	0.09	0.01	-0.10	0.11
WM															
Low	—	—	—	—	—	—	—	—	—	0.04	-0.05	0.12	-0.02	-0.11	0.08
Med	—	—	—	—	—	—	—	—	—	0.05	-0.03	0.14	0.02	-0.06	0.11
High	—	—	—	—	—	—	—	—	—	0.01	-0.07	0.09	0.01	-0.08	0.10
*YBOCS-State * WM*															
Low	—	—	—	—	—	—	—	—	—	—	—	—	-0.18	-0.29	-0.05
Med	—	—	—	—	—	—	—	—	—	—	—	—	-0.10	-0.21	0.02
High	—	—	—	—	—	—	—	—	—	—	—	—	-0.02	-0.13	0.10
Decision threshold															
Subject-level, SD	0.57	0.51	0.64	0.57	0.51	0.63	0.57	0.51	0.64	0.57	0.51	0.64	0.57	0.51	0.64
Condition-level main															
Low	1.92	1.82	2.00	1.92	1.82	2.00	1.91	1.82	2.02	1.92	1.83	2.01	1.92	1.83	2.03
Med	2.15	2.06	2.23	2.15	2.05	2.23	2.14	2.05	2.24	2.14	2.06	2.24	2.15	2.05	2.25
High	2.46	2.36	2.54	2.45	2.35	2.53	2.44	2.35	2.54	2.45	2.36	2.54	2.45	2.35	2.55
PI-WSUR															
Low	0.05	-0.04	0.12	—	—	—	0.07	-0.02	0.18	0.08	-0.03	0.18	0.07	-0.03	0.17
Med	0.03	-0.06	0.11	—	—	—	0.05	-0.04	0.16	0.06	-0.05	0.16	0.05	-0.05	0.15
High	0.04	-0.05	0.12	—	—	—	0.07	-0.02	0.18	0.09	-0.02	0.18	0.07	-0.03	0.18
YBOCS-Standard															
Low	—	—	—	-0.03	-0.12	0.06	-0.05	-0.16	0.06	-0.05	-0.17	0.08	-0.06	-0.17	0.06
Med	—	—	—	-0.01	-0.11	0.07	-0.01	-0.12	0.10	-0.01	-0.13	0.11	-0.02	-0.13	0.10
High	—	—	—	-0.02	-0.11	0.07	0.01	-0.10	0.12	0.01	-0.11	0.13	0.01	-0.11	0.12
YBOCS-State															
Low	—	—	—	—	—	—	-0.01	-0.12	0.10	-0.01	-0.12	0.10	-0.01	-0.12	0.10
Med	—	—	—	—	—	—	-0.04	-0.15	0.07	-0.04	-0.15	0.06	-0.05	-0.16	0.06
High	—	—	—	—	—	—	-0.11	-0.22	0.00	-0.12	-0.23	-0.01	-0.12	-0.23	-0.01
WM															
Low	—	—	—	—	—	—	—	—	—	0.02	-0.07	0.11	0.02	-0.08	0.12
Med	—	—	—	—	—	—	—	—	—	0.04	-0.05	0.13	0.05	-0.05	0.14
High	—	—	—	—	—	—	—	—	—	0.06	-0.04	0.15	0.06	-0.04	0.16
*YBOCS-State * WM*															
Low	—	—	—	—	—	—	—	—	—	—	—	—	0.01	-0.12	0.13
Med	—	—	—	—	—	—	—	—	—	—	—	—	0.02	-0.10	0.15
High	—	—	—	—	—	—	—	—	—	—	—	—	0.02	-0.11	0.14
Non-decision time															
Subject-level, mean	0.38	0.36	0.40	0.38	0.36	0.40	0.38	0.36	0.40	0.38	0.36	0.40	0.38	0.36	0.40
Subject-level, SD	0.13	0.12	0.15	0.13	0.12	0.15	0.13	0.12	0.15	0.13	0.12	0.15	0.13	0.12	0.15

Here, the posterior median 95% credible interval (CI) is represented as the range between the numbers in the “Lower” and “Upper” columns. Effects are considered significant when the median 95% CI does not include 0.

Methods and Materials - Details

Stimuli and Apparatus

Task stimuli were generated using plugins from jsPsych (https://www.jspsych.org), which is a JavaScript library for designing and running behavioral experiments in web browsers online. The random-dot motion task used in the current study was modified from publicly available code online for a Random Dot Kinematogram (RDK) using the jsPsych-RDK plugin (https://github.com/vrsivananda/RDK).

To interact with the MTurk service (e.g., post our study, recruit and pay participants), we utilized the psiTurk toolbox (https://psiturk.org), which is an open platform resource for interfacing with MTurk in the context of behavioral data collection.

Drift-Diffusion Models

Reaction time data were fit with the Wiener-diffusion model in RStan, according to the following basic structure in Equation 1:

```
y ~ wiener(alpha, tau, beta, delta)
```

where `y` is the reaction time (in seconds), `alpha` is decision threshold, `tau` is non-decision time, `beta` is starting point bias, and `delta` is drift rate.

For all models, we set correct responses at the upper boundary and incorrect responses at the lower boundary. Drift rate towards a correct decision is represented as a positive value for `delta`, while drift rate towards an incorrect decision is represented as a negative value for `delta`. Because the default in Stan is to return the first passage time of the accumulation process over the upper boundary only, to fit parameters for incorrect responses we simply replaced "`delta`" with "`-delta`" in the above equation.

In specifying each model according to Equation 1, the `alpha` (decision threshold) and `delta` (drift rate) values were estimated by regression formulas comprising: a subject level parameter, a mean group condition-level parameter, and group condition-level beta coefficients for each of the respective questionnaire scores and interactions of interest. For example, the regression equations for `alpha` and `delta` in Model 1 were as follows:

```
alpha = subject_alpha[s] + condition_alpha[c] + alpha_beta[c]*score[s]

delta = subject_delta[s] + condition_delta[c] + delta_beta[c]*score[s]
```

where `[s]` is the subject-level, `[c]` is the stimulus coherence condition-level (low, medium, or high uncertainty), and `score` is the z-scored total on the PI-WSUR questionnaire.

Model 2 followed the same specifications as above, except `score` was the z-scored total on the standard Y-BOCS-SR questionnaire. Model 3 specified three condition-level beta coefficients: one for PI-WSUR score, one for the standard YBOCS score, and one for the Y-BOCS-SR—State questionnaire score. Model 4 included a fourth condition-level beta coefficient for OSPAN working memory score. Model 5 then included a final condition-level beta coefficient for the interaction term of YBOCS-State score * OSPAN working memory score.

On the subject-level parameters for decision threshold (`subject_alpha`) and drift rate (`subject_delta`), we set hierarchical prior distributions of ~normal(0, σ), in which σ had a prior of ~normal(0, 20). On the condition-level parameter for decision threshold (`condition_alpha`), we set an unbiased prior of ~normal(1, 20). On the condition-level parameter for drift rate (`condition_delta`), we set an unbiased prior of ~normal(0, 20). All condition-level beta coefficients for decision threshold and drift rate had unbiased priors of ~normal(0, 20).

As for non-decision time, this parameter was allowed to vary by subject only (entered into Equation 1 as "`tau[s]`," where `[s]` is the subject-level). We set an unbiased hierarchical prior distribution of ~normal(μ, σ) on `tau` , in which μ had a prior of ~normal(0.5, 5) and σ had a prior of ~normal(0, 5).

Finally, given that left/right responses in the RDMT were balanced, the parameter for starting point bias (`beta`) was fixed to 0.5 for all models, representing no starting bias in either direction.

Appendices

Introduction – Expanded

Obsessive-Compulsive Disorder (OCD) typically follows a chronic course and can cause significant distress in sufferers, which in many cases is highly disabling (Abramowitz et al., 2009; Torres et al., 2006; Veale & Roberts, 2014). Within the past two decades there has been considerable growth in interest into the underpinnings of the disorder, and psychological research in this area now spans various domains. Ongoing research in the fields of neuropsychology and computational psychiatry has found that individuals with obsessive-compulsive symptoms demonstrate deficits in various executive functions, including decision making (Foa et al., 2003; Reed, 1976; Sachdev & Malhi, 2005). In particular, computational models of two-alternative decision making have identified impairments in latent decision processes, suggesting that individuals with OCD symptoms are slower to accumulate stimulus evidence and may be more cautious to make decisions, even during the simplest of perceptual tasks (Banca et al., 2015; Erhan & Balcı, 2017; Erhan et al., 2017; Hauser et al., 2017; Marton et al., 2019). To date, these studies have focused exclusively on diagnostic status or trait-level symptoms of the disorder, fueling an interpretation that such information processing differences carry causal explanatory power for the disease state and symptoms of OCD (Banca et al., 2015; Tallis, 1997). This view sits somewhat at odds with prevailing cognitive-behavioral models of OCD, which suggest a causal role of maladaptive beliefs about cognitions (i.e., metacognitive beliefs) that promote overly attentive thought engagement (Adrian Wells, 2009; Adrian Wells & Matthews, 1994)—a process which may then compete with and impair other cognitive functions that rely on attentional resources.

Despite the theoretical and clinical implications that such directional hypotheses hold for our understanding of OCD, there is a surprising paucity of decision-making studies encompassing both views. The current study begins to address this by examining these decision making impairments in the context of both state- and trait-level OCD symptoms, thought focused attention, and working memory—a neuropsychological process sensitive to attentional control. Although we cannot and will not make causal claims, we argue that the presence of state-level symptom effects on decision impairments raises concerns about the directional interpretation of previous results, and it will be necessary to develop experimental paradigms that can causally manipulate obsessions and compulsions in a controlled setting in order to resolve them. Ultimately clarifying the directionality of these processes in OCD is critical, and may give insight into more optimal interventions.

Decision-making Impairments and OCD

The ability to make effective and timely decisions is a cornerstone of healthy human functioning, and is a process well captured by the mathematical approach of sequential sampling models (SSM) (Bogacz et al., 2006; Smith & Ratcliff, 2004; Townsend & Ashby, 1983). These computational models suggest that decision making involves the accumulating of evidence for and against options under consideration until some function of this evidence reaches an internal criterion, or threshold, to elicit a specific response. SSMs are used to model both rapid (Stanford, Shankar, Massoglia, Costello, & Salinas, 2010) and slow decisions (Gold & Shadlen, 2007), and have a long tradition in research on perceptual decision making (Heekeren et al., 2008; Ratcliff & Rouder, 1998; Vickers, 1970). A particularly popular and well-validated exemplar from this model class is the drift-diffusion model (DDM) (Ratcliff, 1978; Ratcliff & McKoon, 2008), which serves to describe such latent decision processes in two-alternative forced choice paradigms.

Broadly, DDM describes the accuracy and reaction time of decisions using the basic mechanism of evidence accumulation with a drift-diffusion process, as represented in Figure 1. In this model, the underlying assumption is that an individual will continuously extract evidence from the presented stimulus (i.e., drift) which is disturbed by noise (i.e., diffusion). This noisy evidence is accumulated over time, thereby pushing a decision variable towards one or another decision boundary. Once enough evidence has been sampled to push the decision variable across one of the boundaries, a decision is made. There are several parameters to describe this process, including: *boundary separation*, which represents the distance between the two decision boundaries (also referred to in this study as "decision threshold"); *drift rate*, which represents the rate of accumulated evidence towards either decision boundary; *bias*, which represents an initial starting bias closer to one or the other decision boundary; and *non-decision time*, which represents time spent on decision-independent processing.

Several recent studies have utilized DDM to investigate perceptual decision processes in OCD. Using a well-validated perceptual decision making task—the random-dot motion task (RDMT)—Banca and colleagues (2015) found that patients with OCD had slower drift rates towards the decision boundary, reflecting a poorer quality of evidence entering the decision process, and that this deficit was particularly apparent in trials with low uncertainty (Banca et al., 2015). The authors also found that patients required more perceptual stimulus evidence during high uncertainty trials, as indexed by longer response times and higher decision boundaries. In a non-clinical sample, Erhan and Banci (2017) found that higher OCD symptom scores significantly predicted higher decision boundaries in the RDMT (Erhan & Balcı, 2017), which they interpret as greater cautiousness in making decisions; these same authors also found slower drift rates in a subsequent study of pediatric OCD patients (Erhan et al., 2017). Hauser et al. (2017) also demonstrated that individuals with higher OCD symptom scores had slower perceptual evidence accumulation (slower drift rates) than low-symptomatic participants, and that this was accompanied by a reduced ability to accurately judge their performance on the task (Hauser et al., 2017). Finally, Marton et al. (2019) replicated the drift rate finding from Banca and colleagues (2015)—that OCD patients exhibit reduced drift rates at low uncertainty in the RDMT; they also found a relationship between reduced drift rate and trait-level doubt using a novel questionnaire in non-patient participants (Marton et al., 2019). In short, four out of five studies using the RDMT found reductions in drift rate as a function of obsessive-compulsive symptomatology, especially in lower uncertainty contexts, and two out of five studies found increases in decision threshold. Notably, each of these studies were conducted with relatively small samples (~40-70 participants); thus, it is important to confirm and clarify these findings in a larger replication effort. Even so, they each provide evidence for impaired decision-formation processes in OCD and appear broadly consistent with the literature establishing executive dysfunction in patients.

The relationship between clinical symptoms and latent parameters of computational models is an important area of study within the field of computational psychiatry. A common premise in this work, which includes the specific examples illustrated above, is that information processing differences captured in lab-based studies carry causal explanatory power for disease states and symptoms. For example, in the setup explaining how lab-based perceptual decision making deficits might be interpreted, Banca et al. (2015) states: “In the repetitive act of washing or checking, the available sensory-perceptual evidence appears insufficient to commit to a solid decision: patients appear unable to decide whether their hands are sufficiently clean or the door is properly locked” (Banca et al., 2015). An equally plausible possibility, which although obvious is often overlooked, is that causality flows in the opposite direction, and active symptoms give rise to information processing differences measured in lab-based settings. Caution is especially warranted if such differences correlate with state rather than (or in addition to) trait symptom measures. In that case, evidence accumulation, measured in terms of drift rate, may be disrupted by active obsessions and mental compulsions, rather than acting as a catalyst for them. Previously reported deficits in integrating perceptual evidence may simply be a result of attentional resources being tied up by off-task processing, including covert obsessions and compulsions (e.g., silent counting, prayers, affirmations).

Clinical Models

An excessive awareness of and attention to thought experiences (i.e., “cognitive self-consciousness”) has been previously identified as a key feature of OCD by clinical models of the disorder. The most widely held cognitive-behavioral model, the metacognitive model, argues that it is dysfunctional metacognitions—negative appraisals and beliefs about certain cognitive processes as well as maladaptive attentive strategies—which are the most important factors contributing to obsessive-compulsive symptoms (Adrian Wells, 1997; Adrian Wells, 2000; Adrian Wells & Matthews, 1994). In this context, metacognition[1] refers to the psychological structures, knowledge, events, and processes that are involved in the control, modification, and interpretation of thoughts (Adrian Wells & Cartwright-Hatton, 2004). This metacognitive model of OCD, also known as the Self-Regulatory Executive Function (S-REF) model (Adrian Wells & Matthews, 1994), proposes that intrusive thoughts become obsessions when they are subject to maladaptive metacognitive beliefs about the meaning and dangerous consequences of having specific thoughts. In this model, two broad domains of belief are emphasized: (1) beliefs about the importance/meaning and power of thoughts, and (2) beliefs about the need to control thoughts and/or perform rituals. Within the first domain, a range of different themes have been identified, including: "thought-event fusion," which refers to the belief that thoughts can directly cause unwanted events to occur in the world or signal that situations must exist; "thought-action fusion," which refers to the belief that thoughts can directly cause unwanted behaviors; and "thought-object fusion," which refers to the belief that thoughts can contaminate or fuse with objects.

There is compelling evidence in the literature linking measures of those beliefs (type and strength) to the severity of obsessive-compulsive symptoms (Barahmand, Tavakolian, & Alaei, 2014; Hermans, Martens, De Cort, Pieters, & Eelen, 2003; Irak & Tosun, 2008; Myers & Wells, 2005). According to Wells (1996), such appraisals of the meaning and significance of intrusive thoughts are likely to maintain activation of lower level representations of the intrusions, making them more likely to occur again (Adrian

[1] It is worth noting that there are many lab-based studies which measure an individual's metacognitive ability (i.e., "metacognitive efficiency") as the relationship between their objective performance on a task and their perception of performance. This measure of metacognitive efficiency fits within the broader definition supplied above, as it pertains to the interpretation of task performance, which can be subject to a variety of cognitive biases and dysfunctional beliefs. Moreover, individuals with OCD have been shown to display differences in this formal measure of metacognitive efficiency (Hauser et al., 2017).

Wells & Matthews, 1996). Attempts to suppress or control unwanted thoughts activates a hypervigilant monitoring plan that actively searches for instances of the intrusion, further increasing the likelihood that unwanted thoughts will be activated. Several studies have shown that increased attentional priority for negative thoughts can exacerbate intrusions (McNally & Ricciardi, 1996; Salkovskis & Campbell, 1994; Tolin, Abramowitz, Przeworski, & Foa, 2002; Trinder & Salkovskis, 1994; Wegner, Schneider, Carter, & White, 1987). Wells (2000) referred to this overall process as the Cognitive Attention Syndrome (CAS), highlighting the critical role of attention towards unwanted intrusions in OCD (Adrian Wells, 2000).

The Meta-Cognitions Questionnaire (MCQ) (Cartwright-Hatton & Wells, 1997) was developed to assess metacognitive beliefs in relation to psychiatric symptomatology and findings with this measure also suggest that thought-focused attention plays an important role for OCD. The scale assesses five metacognitive factors: positive beliefs about worry, beliefs about uncontrollability and danger of thoughts, cognitive confidence, beliefs about the need to control thoughts, and cognitive self-consciousness. Several of these factors assessed with the MCQ have been found to be positively associated with OCD symptoms (Cartwright-Hatton & Wells, 1997; Hermans et al., 2003; Janeck, Calamari, Riemann, & Heffelfinger, 2003; Adrian Wells & Papageorgiou, 1998). In particular, and consistent with the S-REF model, Cartwright-Hatton and Wells (1997) found that both OCD and General Anxiety Disorder (GAD) patients were significantly different from a control group (consisting of patients with other non-anxiety emotional disorders and healthy individuals) on two subscales of the MCQ, namely the uncontrollability and danger of thoughts, and the need to control thoughts (Cartwright-

Hatton & Wells, 1997). They also found that cognitive self-consciousness (CSC; an excessive awareness of and attention to thought experiences) was the only subscale which successfully differentiated OCD from individuals with GAD. Those findings have since been replicated (Goldman et al., 2008; Janeck et al., 2003), and have been shown to hold up in both mixed patient-nonpatient samples (Marker, Calamari, Woodard, & Riemann, 2006), as well as in a full non-patient sample (R. J. Cohen & Calamari, 2004). For example, Cohen and Calamari (2004) found that CSC predicted OCD symptoms even when controlling for other metacognitive factors and trait anxiety (R. J. Cohen & Calamari, 2004). These studies provide evidence that an excessive attention towards one's thought experiences may be a key feature in OCD (Irak & Tosun, 2008). A heightened—and thus selective—attention for any off-task obsessions and compulsions may thus exacerbate deficits of perceptual evidence accumulation during decision-making, particularly when such symptoms are acute, though no prior studies have examined this.

Working Memory Span

If attentional bottlenecks can result from off-task obsessions and compulsions in OCD, the extent to which this occurs may be reflected in working memory. Researchers have long argued for a role of attention in working memory maintenance (Chun et al., 2011), emphasizing that in situations where attention is withdrawn or "off task" – for example, due to intrusive thoughts – object representations collapse into disintegrated features in working memory (Eysenck, 1992; Rensink, 2000; Wheeler & Treisman, 2002; Zokaei, Heider, & Husain, 2014). Thus, a larger working memory span may indicate that the individual is better able to control and prioritize attentional resources during task execution, effectively ignoring off-task distractors (e.g., obsessions and compulsions) (Zanto & Gazzaley, 2009). Alternatively, individuals with a larger span may simply have more limited-capacity attentional resources available in the first place, thus rendering off-task distractors less impactful and easier to "ignore" (Conway & Engle, 1996). Either way, prior studies have established a link between working memory span and the ability to intentionally suppress or ignore unwanted intrusive thoughts, such that individuals who are better able to ignore intrusive thoughts also demonstrate larger working memory spans (Brewin & Smart, 2005; Geraerts et al., 2007).

Neuropsychological research has found that OCD patients demonstrate impaired executive functions, a group of critical cognitive abilities that control and coordinate lower-level processes to guide behavior toward a goal or decision (Banich, 2009), including working memory. For example, a 2014 meta-analysis by Snyder et al. found broad deficits across various executive functioning tasks—including measures of response inhibition (e.g., Color-word Stroop), planning (e.g., Tower of London/Hanoi), shifting (e.g., Wisconsin Card Sorting), updating (e.g., n-Back), verbal working memory (e.g., Digit Span), visuospatial working memory (e.g., Block Span), and verbal fluency (e.g., Semantic/Phonemic listing)—with effect sizes (Cohen's d) of 0.15 – 0.35 for verbal working memory, and 0.3 – 0.6 for visuospatial working memory (Snyder, Kaiser, Warren, & Heller, 2014).

These neuropsychological deficits in OCD include issues with attentional control. A 2013 meta-analysis of 115 studies comparing adult OCD patients to healthy controls revealed significant medium mean effect sizes for impairments on sustained attention tasks, in addition to the other executive functions (i.e., response inhibition, planning, shifting, working memory) (Abramovitch, Abramowitz, & Mittelman, 2013). Notably, a relationship between dysregulated attention and working memory deficits has been established in the broader context of anxious distress, and this may apply to OCD as well (Muller & Roberts, 2005). Eysenck (1992) first suggested that working memory can be consumed in task irrelevant processing at the expense of task-relevant operations due to increased levels of anxiety (Eysenck, 1992). In the context of OCD, performance deficits associated with the disorder may be caused by the cognitive interference of intrusive (task-irrelevant) information, such as obsessions and mental compulsions. Consistent with this view, Purcell et al. (1998) and others have surmised that patients with OCD are particularly challenged by working memory tasks for which they are required to rely on internal representations to guide ongoing behaviors, as these may be disrupted by the attentional processing of salient irrelevant information, such as personally disturbing thoughts (Muller & Roberts, 2005; R. Purcell, Maruff, Kyrios, & Pantelis, 1998).

The relationship of off-task attention for active symptoms and working memory span may partially explain evidence accumulation impairments (lower drift rates) in OCD during perceptual decision making. A larger working memory span may indicate that an individual is better able to ignore irrelevant, off-task intrusive thoughts (Brewin & Smart, 2005; Geraerts et al., 2007), thus reducing the attentional interference of obsessions and compulsions that would otherwise slow down their drift rates. Prior non-clinical studies have shown that a faster perceptual evidence accumulation process is indeed dependent on attentional priority during task completion (Denison et al., 2018; Macdonald et al., 2011; Tavares et al., 2017), and, importantly, correlates with larger working memory span (Ester et al., 2014).

Neurobiology of Evidence Accumulation and OCD

Physiologically, the process of evidence accumulation appears to involve brain regions in which abnormalities have been implicated in OCD. Studies investigating the neural correlates of evidence accumulation in perceptual decision making have suggested that, after initial processing by sensory areas, stimulus information is integrated or accumulated in parietal and frontal regions before subsequent transmission to the effector areas for response production (Heekeren et al., 2008). Neurophysiological studies in monkeys have identified patterns of neuronal firing that appear consistent with stimulus evidence accumulation in the superior colliculus (Horwitz & Newsome, 2001; Ratcliff et al., 2003; Ratcliff et al., 2007), frontal eye field (J. Y. Cohen et al., 2009; Ding & Gold, 2011; B. A. Purcell et al., 2010), caudate (Ding & Gold, 2010), lateral intraparietal area (Churchland et al., 2011; Churchland et al., 2008; Gold & Shadlen, 2007; M. N. Shadlen & Newsome, 1996; Michael N. Shadlen & Newsome, 2001), and dorsolateral prefrontal cortex (Kim & Shadlen, 1999). In humans, neuroimaging studies have found a similar involvement of these various regions in evidence accumulation, including dorsolateral prefrontal and parietal areas (de Lange et al., 2010; Heekeren et al., 2006; Heekeren et al., 2008; Liu & Pleskac, 2011; Mulder et al., 2014; Ploran et al., 2007; Shine et al., 2016). Notably, neurobiological studies of obsessive-compulsive disorder implicate dysfunction in several of those same regions, especially the prefrontal cortex – which is also associated with voluntary attentional control and working memory (D'Esposito & Postle, 2015; Lara & Wallis, 2015; Stuss & Knight, 2002). In particular, multiple lines of research have suggested anomalies in orbitofrontal-striatal inhibitory control pathways, as well as deficits in dorsolateral fronto-parietal systems of attention and working memory

(Arnsten & Rubia, 2012; Menzies et al., 2008; Nakao et al., 2014; Saxena & Rauch, 2000; Whiteside et al., 2004). Several studies have reported altered activation of these frontal and subcortical regions (e.g., OFC, DLPFC, ACC, caudate) during OCD symptom provocation, many of which were later rescued after successful treatment with medication or behavioral therapy (Nakao et al., 2014). Abnormal activity in those regions has also been linked to cognitive task performance deficits in individuals with OCD, namely: inhibitory control (e.g., cortico-striatal network, fronto-parietal network, anterior cingulate region); cognitive flexibility (e.g., cortico-striatal network, extended temporal, parietal, and occipital regions); and working memory (e.g., cortico-striatal network, fronto-parietal network, dorsal anterior cingulate region) (Gonçalves et al., 2016).

Similar neurological abnormalities have also been found using EEG—for example, Wong et al (2015) measured resting EEG alpha oscillations in frontal and parietal regions of non-clinical participants who scored high and low on the Padua-R, a measure of OCD-related behaviors (Wong et al., 2015). They found that participants who scored high on the Padua-R exhibited decreased overall alpha in frontal regions relative to individuals who scored low on the measure, which they interpret as a possible marker for impaired cognitive control. Drake et al. (1996) reported reduced modal and maximal EEG alpha frequency in frontal regions of OCD patients compared to controls, but no differences in temporal or occipital areas (Drake, Pakalnis, & Newell, 1996). Such functional brain abnormalities are generally consistent with other cases also known for slower drift rates as well as dysregulated attention and executive deficits, such as Attention Deficit Hyperactivity Disorder (Durston, van Belle, & de Zeeuw, 2011; Metin et al., 2013; Shue & Douglas, 1992).

The Current Study

While there is strong evidence suggesting a relationship of working memory, attention to acute OCD symptoms, and perceptual evidence accumulation during decision making, there has been surprisingly little research to date directly examining the interplay of these processes. To address those gaps in the literature, the overarching purpose of the current study is to clarify and expand our understanding of perceptual decision making in OCD by utilizing hierarchical drift-diffusion modeling in a large sample of U.S. adults.

In contrast to prevailing clinical models of the disorder, in which attention to active intrusions plays a critical role, prior studies only examined the role of diagnostic status or trait-level symptoms in perceptual decision making (Banca et al., 2015; Erhan & Balcı, 2017; Erhan et al., 2017; Hauser et al., 2017; Marton et al., 2019). The current study seeks to investigate the extent to which active, state-level symptoms of OCD play a role in perceptual decision-making processes, and whether impairments in those processes are better captured by state- or trait-level symptom measures.

Further, given that larger working memory spans are associated with better attentional control (Zanto & Gazzaley, 2009) and faster evidence accumulation (Ester et al., 2014), we examine whether working memory span interacts with state-level information processing differences.

Finally, clinical models have identified a heightened thought-focused attention (i.e., cognitive self-consciousness) in OCD, above and beyond that of other mood and anxiety disorders (Cartwright-Hatton & Wells, 1997). Our final, exploratory goal was to examine whether cognitive self-consciousness contributes to perceptual decision impairments, and whether it interacts with state-level symptoms to exacerbate those impairments.

Taken together, such information may bridge the gap between computational decision-making frameworks and prevailing clinical models of the disorder, and may help to ultimately improve intervention strategies.

Aims and Hypotheses

For this dissertation study, the detailed aims and hypotheses were as follows:

Aim 1: To verify a relationship between trait-level obsessive-compulsive symptom severity (indexed by total score in the Padua-WSUR measure) and impaired latent decision processes (indexed by drift rate and decision threshold parameters in drift-diffusion models of RDMT performance) in a large adult sample. In particular, we sought to replicate and clarify the findings of smaller-scale lab-based studies which have previously suggested these effects.

Hypothesis 1: Four out of five lab-based studies using the RDMT (Banca et al., 2015; Erhan et al., 2017; Hauser et al., 2017; Marton et al., 2019) have suggested that individuals who self-report high levels of obsessive-compulsive symptoms accumulate evidence more slowly (i.e., have lower drift rate), while two out of five studies (Banca et al., 2015; Erhan & Balcı, 2017) found that such individuals are more cautious to make decisions (i.e., have a higher decision threshold). We expected to find slower drift rates as a function of greater symptom severity; we were less certain of finding larger decision thresholds. We also expected drift rate effects to be more pronounced at higher coherence (lower uncertainty) levels in our task, and for any decision threshold effects to be more pronounced at lower coherence (higher uncertainty) levels, consistent with findings by Banca et al. (2015) and Marton et al. (2019).

Aim 2: To examine whether the relationship between obsessive-compulsive symptom severity and evidence accumulation (drift rate) is better captured by state-level or trait-level measures.

Hypothesis 2: The cognitive attention syndrome (Adrian Wells, 2000; Adrian Wells & Matthews, 1996) posits that an excessive attentional priority is given to intrusive thoughts, urges, and images in OCD. Our state-level version of the Y-BOCS-SR ("Y-BOCS-SR—State") assessed the impact of obsessions and compulsions experienced specifically during task completion, and thus may indicate the extent to which active OCD symptoms competed with task execution for cognitive resources, such as attention. Recent research demonstrates that real-time attentional priority plays a sizeable role in the evidence accumulation process within the DDM framework, such that a lowered attention toward the task stimulus results in a slower drift rate (Tavares et al., 2017). Thus, we predicted a significant negative effect of state-level score on drift rate in the RDMT, and that state-level scores would better explain drift rate impairments than trait-level scores.

Aim 3: To determine (a) the impact of verbal working memory span (indexed by Operation Span task performance) on latent decision processes in the RDMT, and (b) the interaction of WM and state-level symptoms as they pertain to drift rate.

Hypothesis 3a: Prior research has demonstrated a positive correlation between visuospatial working memory span and drift rate, but not decision threshold, in the RDMT (Ester et al., 2014). Using the Operation Span task (OSPAN), an earlier study found a positive relationship between verbal working memory span and drift rates in choice reaction tasks (Schmiedek, Oberauer, Wilhelm, Süß, & Wittmann, 2007). Thus, we expected to find a positive effect of OSPAN working memory span on drift rate in the RDMT. This would support the idea that evidence accumulation and working memory may involve similar cognitive resources, such as attentional control (Ester et al., 2014).

Hypothesis 3b: An "off-task" resource allocation towards intrusive thoughts (i.e., active, state-level symptoms) may partially explain impaired evidence accumulation in OCD, and it has been demonstrated that a larger OSPAN working memory span occurs in individuals who are better at suppressing intrusive thoughts (Brewin & Smart, 2005; Geraerts et al., 2007). Accordingly, we predicted a positive interaction effect of working memory span and state-level symptoms on drift rate; specifically, we expected that a larger working memory span would serve to reduce the negative effect of state-level symptoms on drift rate.

Exploratory Aim 4: Examine the relationship between cognitive self-consciousness (indexed by the self-report CSC-E measure) and latent decision processes in the RDMT.

Exploratory Hypothesis 4: The tendency to focus attention on thought experiences (cognitive self-consciousness) is specifically elevated for individuals with OCD, even when compared to other mood and anxiety disorders (Cartwright-Hatton & Wells, 1997; R. J. Cohen & Calamari, 2004). In line with literature suggesting an impact of attentional priority on evidence accumulation (Tavares et al., 2017), we surmised that individuals with greater cognitive self-consciousness would demonstrate reduced drift rates in the RDMT. We also suspected a significant interaction whereby a greater cognitive self-consciousness score would exacerbate the negative impact of active, state-level symptoms on drift rate.

Role of Cognitive Self-Consciousness (Exploratory Aim 4)

Clinical models and neuropsychological studies posit dysfunctional attention in psychopathology (Fergus, Bardeen, & Orcutt, 2012; Adrian Wells & Matthews, 1994). Previous work has shown that OCD is characterized by cognitive self-consciousness (CSC)— an excessive awareness of and attention to thought experiences (Cartwright-Hatton & Wells, 1997; R. J. Cohen & Calamari, 2004; Goldman et al., 2008; Janeck et al., 2003; Marker et al., 2006). Given prior research demonstrating the importance of attention in perceptual decisions (Denison et al., 2018; Macdonald et al., 2011; Tavares et al., 2017), CSC may interact with state-based symptoms to further influence information processing differences. For the current dissertation study, we conducted an exploratory analysis of whether this is the case, using the Cognitive Self Consciousness Scale – Expanded (CSC-E) (Janeck et al., 2003).

The Cognitive Self Consciousness Scale-Expanded (CSC-E) (Janeck et al., 2003) measures the excessive focusing of attention on one's thoughts (e.g., "I monitor my thoughts"; "I notice my thoughts even when I am busy with another activity"). This measure comprises the original 7-item CSC subscale of the Meta-Cognitions Questionnaire (Cartwright-Hatton & Wells, 1997), as well as an additional 7 items adapted by Janeck et al. (2003) from the Pain Vigilance and Awareness Questionnaire (PVAQ) (Roelofs, Peters, McCracken, & Vlaeyen, 2003). The CSC-E has shown good internal consistency across studies (Janeck et al., 2003; Prouvost, Calamari, & Woodard, 2016).

Results

Participant scores on the CSC-E ranged from 14 to 56, with a mean of 38 (SD=10). Scores on the CSC-E demonstrated the following (fdr-corrected) correlations: OSPAN, r=0.175, p=0.067; PI-WSUR, r=0.379, p=4.22e-06; Y-BOCS-SR, r=0.454, p=1.12e-08; Y-BOCS-SR—State, r=0.205; p=0.028.

To explore the role of cognitive self-consciousness in perceptual decision making, we assessed the effect of CSC-E score in Model 6. CSC-E was negatively correlated with drift rate only at Low uncertainty (Low: β = -0.12 [-0.21, -0.03]; Med: β = -0.04 [-0.13, 0.04]; High: β = 0.03 [-0.06, 0.12]; Difference of Low – Med: β = -0.08 [-0.11, -0.04]; Difference of Med − High: β = -0.07 [-0.10, -0.05]). In this model, PI-WSUR score no longer related to drift rate at any of the uncertainty levels (Low: β = -0.09 [-0.18, 0.01]; Med: β = -0.03 [-0.12, 0.07]; High: β = -0.01 [-0.10, 0.09]). Drift rate and decision threshold results were comparable to Model 5 for all other regressors, and the threshold effect of CSC-E was non-significant at all levels of uncertainty.

Given the negative relationship between CSC-E and drift rate at Low uncertainty, we ran an additional exploratory analysis to test the interaction of CSC-E with YBOCS-State scores (Model 7). Compared to prior models, the negative drift rate effect of YBOCS-State was even more pronounced at both Low and Medium uncertainty (Low: β = -0.33 [-0.44, -0.22]; Med: β = -0.22 [-0.33, -0.12]; High: β = -0.03 [-0.13, 0.07]; Difference of Low – Med: β = -0.11 [-0.15, -0.07]; Difference of Med – High: β = -0.19 [-0.22, -0.16]). In Model 7, CSC-E score no longer related to drift rate at Low uncertainty (β = -0.06 [-0.16, 0.04]). The interaction of CSC-E and YBOCS-State scores demonstrated a significant positive effect on drift rate in both Low and Medium uncertainty trials (Low: β = 0.19 [0.08, 0.29]; Med: β = 0.14 [0.03, 0.25]; High: β = 0.07 [-0.03, 0.17]; Difference of Low – Med: β = 0.05 [0.004, 0.09]; Difference of Med – High: β = 0.07 [0.04, 0.11]).

Posterior median estimates and the 95% CI for all regressors in Models 6 and 7 are shown in Appendix Table 1.

Discussion

The results of Model 6 and Model 7 reveal an inconsistent pattern for the effect of CSC-E score on evidence accumulation in perceptual decision making. On its own, heightened cognitive self-consciousness in OCD may not reliably inform drift rate impairments associated with the disorder. Rather, CSC may play a role via its interaction with acutely experienced obsessions and compulsions; Model 7 suggests this interaction effect actually serves to improve drift rate. This result is contradictory to our expectation, as we had prior suspected that a greater tendency for thought-focused attention (i.e., greater CSC-E score) would further exacerbate the negative impact of acute state-level obsessions and compulsions on evidence accumulation. Given that this is the first study to investigate the role of cognitive self-consciousness in perceptual decision-making, we are cautious to offer an interpretation of these unexpected results. The strength of this interaction effect at both Low and Medium uncertainty, however, warrants consideration and further research.

Appendix Table 1. Posterior Median and 95% CI for Models 6 and 7

	Model 6			Model 7		
	Median	Lower	Upper	Median	Lower	Upper
Drift rate						
Subject-level, SD	0.50	0.45	0.57	0.50	0.45	0.56
Condition-level, main						
Low	1.66	1.58	1.74	1.63	1.55	1.72
Med	1.12	1.05	1.20	1.11	1.02	1.19
High	0.37	0.30	0.45	0.36	0.28	0.45
PI-WSUR						
Low	-0.09	-0.18	0.01	-0.09	-0.19	-0.004
Med	-0.03	-0.12	0.07	-0.04	-0.14	0.05
High	-0.01	-0.10	0.09	-0.02	-0.12	0.07
YBOCS-Standard						
Low	0.06	-0.06	0.17	0.05	-0.07	0.16
Med	0.05	-0.06	0.17	0.05	-0.07	0.16
High	-0.03	-0.14	0.08	-0.03	-0.15	0.08
YBOCS-State						
Low	-0.27	-0.37	-0.16	-0.33	-0.44	-0.22
Med	-0.17	-0.28	-0.07	-0.22	-0.33	-0.12
High	0.003	-0.10	0.11	-0.03	-0.13	0.07
WM						
Low	0.003	-0.09	0.10	-0.01	-0.10	0.08
Med	0.03	-0.07	0.12	0.03	-0.06	0.11
High	0.001	-0.09	0.10	0.01	-0.08	0.09
*YBOCS-State * WM*						
Low	-0.15	-0.27	-0.03	-0.19	-0.31	-0.07
Med	-0.09	-0.21	0.02	-0.12	-0.24	0.002
High	-0.01	-0.13	0.10	-0.03	-0.14	0.10
CSC-E						
Low	-0.12	-0.21	-0.03	-0.06	-0.16	0.04
Med	-0.04	-0.13	0.04	0.000	-0.09	0.10
High	0.03	-0.06	0.12	0.04	-0.05	0.14
*YBOCS-State * CSC-E*						
Low	—	—	—	0.19	0.08	0.29
Med	—	—	—	0.14	0.03	0.25
High	—	—	—	0.07	-0.03	0.17
Decision threshold						
Subject-level, SD	0.57	0.51	0.64	0.57	0.51	0.65
Condition-level, main						
Low	1.92	1.83	2.01	1.92	1.82	2.01
Med	2.14	2.05	2.23	2.14	2.04	2.23
High	2.44	2.36	2.54	2.44	2.34	2.53
PI-WSUR						
Low	0.06	-0.05	0.16	0.07	-0.03	0.18
Med	0.05	-0.07	0.15	0.06	-0.05	0.17
High	0.08	-0.03	0.18	0.09	-0.02	0.20
YBOCS-Standard						
Low	-0.06	-0.19	0.07	-0.07	-0.20	0.07
Med	-0.01	-0.14	0.11	-0.02	-0.15	0.12
High	0.03	-0.10	0.15	0.03	-0.11	0.16
YBOCS-State						
Low	-0.01	-0.11	0.10	0.00	-0.13	0.12
Med	-0.05	-0.16	0.06	-0.05	-0.18	0.07
High	-0.12	-0.23	-0.02	-0.14	-0.27	-0.02
WM						
Low	0.02	-0.09	0.11	0.01	-0.10	0.11
Med	0.04	-0.06	0.13	0.04	-0.07	0.14
High	0.07	-0.03	0.16	0.06	-0.04	0.17
*YBOCS-State * WM*						
Low	0.01	-0.12	0.13	0.02	-0.12	0.16
Med	0.02	-0.11	0.14	0.03	-0.11	0.16
High	0.01	-0.12	0.13	0.00	-0.13	0.15
CSC-E						
Low	0.02	-0.09	0.13	0.02	-0.09	0.13
Med	-0.01	-0.10	0.11	0.002	-0.11	0.12
High	-0.05	-0.14	0.07	-0.03	-0.14	0.08
*YBOCS-State * CSC-E*						
Low	—	—	—	-0.02	-0.14	0.11
Med	—	—	—	0.001	-0.12	0.13
High	—	—	—	0.03	-0.09	0.16
Non-decision time						
Subject-level, mean	0.38	0.36	0.40	0.38	0.36	0.40
Subject-level, SD	0.13	0.12	0.15	0.13	0.12	0.15

The posterior median 95% credible interval (CI) is represented as the range between the numbers in the "Lower" and "Upper" columns. Effects are considered significant when the median 95% CI does not include 0.

Questionnaires

Demographics		
Instructions: Please fill out this form in its entirety by selecting the appropriate response. This information will be used *for research purposes only and all data will be kept strictly confidential*. Your answers will not impact your bonus or ability to participate.		
1	Age	_____
2	Sex	Male Female Prefer not to answer
3	Ethnicity	Hispanic or Latino Not Hispanic or Latino
4	Race (select all that apply)	American Indian or Alaska Native Black or African American Asian Native Hawaiian or Other Pacific Islander White Other
5	What is the highest educational degree you have completed?	Some high school, no degree High school degree or equivalent Associate's degree Some college, no Bachelor's degree Bachelor's degree or equivalent Master's degree or equivalent Doctoral degree or equivalent Other
6	Have you ever been diagnosed with any of the following conditions? (select all that apply)	Alzheimer's or Dementia Epilepsy Sleep disorder (e.g., Insomnia, Sleep apnea) Stroke Traumatic Brain Injury Parkinson's Memory disorder (e.g., Aphasia, Amnesia) None of the above
7	Are you currently diagnosed with or being treated for any of the following psychological or psychiatric conditions? (select all that apply)	Anxiety Disorder Attention Deficit Hyperactivity Disorder Bipolar Disorder Eating Disorder (e.g., Anorexia, Bulemia) Learning Disorder (e.g., Dyslexia, Reading/Writing, Math) Major Depressive Disorder Obsessive-Compulsive Disorder Post-Traumatic Stress Disorder Psychotic Disorder (e.g., Schizophrenia) Substance Use Disorder None of the above

8	Are you currently taking medication for a psychological or psychiatric condition? (select all that apply)	Stimulant ADHD medication [e.g., Ritalin (methylphenadate), Adderall (amphetamine)] Non-stimulant ADHD medication [e.g, Strattera (atomoxetine)] Antidepressant medication [e.g., Prozac (fluoxetine), Zoloft (sertraline), Wellbutrin (bupropion)] Anti-anxiety medication [e.g., Xanax (alprazolam), Valinum (diazepam), Ativan (lorazepam)] Antipsychotic medication [e.g., Risperdal (risperdone), Clozaril (chlozapine)] Mood stabilizing medication [e.g., Depakote (valproic acid), Lithobid (lithium carbonate) None of the above / Not applicable

Yale-Brown Obsessive Compulsive Scale-Self Report—State *

Before answering any questions, please read the following carefully:

Recent research has shown that intrusions (i.e., obsessions) and rituals (i.e., compulsions) occur quite commonly among normal people.

While completing the questionnaire below, please keep in mind the following definitions of intrusions/obsessions and compulsions/rituals.

INTRUSIONS/OBSESSIONS are unwelcomed and distressing ideas, thoughts, or impulses that repeatedly enter your mind. They may seem to occur against your will. In some cases, they may be repugnant to you, you may recognize them as senseless, and/or they may not always fit your personality.

Examples of intrusions can include:

- Concerns of being contaminated by germs/dirt or contaminating others
- Thoughts about losing control and harming yourself or others
- Thoughts or images that are sexually explicit or violent
- Concerns about forgetting to have done something important or not having things you might need
- Concerns about something not being "right" enough
- Repetitive worrisome thoughts about an unwanted event occurring to yourself or others
- A repeated phrase or word that may seem random or is usually out of context

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RITUALS/COMPULSIONS are behaviors or mental acts that you feel driven to perform although you may recognize them as senseless or excessive. Usually, rituals are performed in response to intrusions, according to certain rules, or in a stereotyped fashion. At times, you may try to resist doing them but this may prove difficult. You may experience discomfort that does not diminish until the ritual is completed.

Examples of compulsions can include:

- Having to do things in a certain order or number of times for them to feel right
- Performing certain prayers in response to a thought/image
- Repeated cleaning or hand-washing
- Arranging and rearranging items in set order
- Repeating certain phrases/mantras
- Repeatedly checking doors, appliances, water faucets, and locks
- Repeatedly asking others for reassurance
- Counting or repeating certain numbers in your head
- Repeated mental checking (e.g., reviewing a past experience in your mind to make sure it feels “right,” was done properly, and/or that everything is okay)

Given the above definitions, please read carefully each item on the checklist below and provide the answer that closest resembles your experience **specifically while you were doing the Dots and Math/Letters tasks**.

1	DURING THE DOTS AND MATH/LETTERS TASKS: How much of your time was occupied by *intrusions/obsessions* and how frequently did these thoughts occur? 0 = None 1 = Less than 10% of the time, or occasional intrusions 2 = 10 – 30% of the time, or frequent intrusions 3 = 30 - 80% of the time, or very frequent intrusions 4 = More than 80% of the time, or near-constant intrusions
2	DURING THE DOTS AND MATH/LETTERS TASKS: How much did your intrusive thoughts interfere with your performance in the task? 0 = No interference whatsoever 1 = Mild, slight interference but my overall performance wasn't impaired 2 = Moderate, definitive interference but it was manageable 3 = Severe interference that impaired my performance 4 = Extreme and incapacitating
3	DURING THE DOTS AND MATH/LETTERS TASKS: How much distress did your intrusive thoughts cause you? 0 = None 1 = Mild, infrequent, and not too disturbing distress 2 = Moderate, frequent, and disturbing distress, but still manageable 3 = Severe, very frequent, and very disturbing distress 4 = Extreme, near constant, and disabling distress
4	DURING THE DOTS AND MATH/LETTERS TASKS: How much of an effort did you make to resist the intrusive thoughts, and how often did you try to disregard or turn your attention away from these thoughts as they entered your mind? 0 = I made an effort to always resist (or the intrusions were so minimal that there was no need to actively resist them) 1 = I tried to resist most of the time (e.g., more than half the time) 2 = I made some effort to resist 3 = I allowed all intrusive thoughts to fill my mind without attempting to control them, but I did so with some reluctance 4 = I completely and willingly engaged with all intrusions
5	DURING THE DOTS AND MATH/LETTERS TASKS: How much control did you have over your intrusive thoughts? How successful were you in stopping or diverting your intrusions (e.g., could you dismiss the thoughts?) 0 = I had complete control 1 = Much control; usually I could stop or divert intrusions 2 = Moderate control; sometimes I could stop or divert intrusions with some effort 3 = Little control; I was rarely successful in stopping intrusions and could only divert attention with great difficulty 4 = No control; I was rarely able to even momentarily ignore the intrusions

6	DURING THE DOTS AND MATH/LETTERS TASKS: How much time did you spend performing *compulsions/rituals*, and how frequently did you perform them? 0 = None 1 = Less than 10% of the time, or occasional performance 2 = 10 – 30% of the time, or frequent performance 3 = 30 - 80% of the time, or very frequent performance 4 = More than 80% of the time, or near-constant performance
7	DURING THE DOTS AND MATH/LETTERS TASKS: How much did your compulsions interfere with your performance in the task? 0 = No interference whatsoever 1 = Mild, slight interference but my overall performance wasn't impaired 2 = Moderate, definitive interference but it was manageable 3 = Severe interference that impaired my performance 4 = Extreme and incapacitating
8	DURING THE DOTS AND MATH/LETTERS TASKS: How uncomfortable would you have become if prevented from performing your compulsions/rituals? 0 = Not at all uncomfortable 1 = Only slightly uncomfortable if my compulsions/rituals were prevented 2 = Discomfort would mount but remain manageable 3 = Prominent and very disturbing increase in discomfort if my compulsions/rituals were interrupted 4 = Extreme, incapacitating discomfort from any intervention
9	DURING THE DOTS AND MATH/LETTERS TASKS: How much of an effort did you make to resist any compulsions/rituals? 0 = I made an effort to always resist (or the compulsions/rituals were so minimal that there was no need to actively resist them) 1 = I tried to resist most of the time (e.g., more than half the time) 2 = I made some effort to resist (e.g., less than half the time) 3 = I allowed all compulsions/rituals without attempting to control them, but I did so with some reluctance 4 = I completely and willingly engaged in all compulsions/rituals
10	DURING THE DOTS AND MATH/LETTERS TASKS: How strong was the drive to perform the compulsions, as in, how much control did you have over them? 0 = I had complete control 1 = Much control; usually I could stop or divert compulsions 2 = Moderate control; sometimes I could stop or divert compulsions but it was difficult 3 = Little control; I could only delay the compulsions and eventually it had to be carried out to completion 4 = No control; I was rarely able to even momentarily suppress the compulsions

Yale-Brown Obsessive Compulsive Scale-Self Report **

Now, please answer the same set of questions with regards to any intrusions and compulsions that you may have experienced on average **OVER THE PAST WEEK**.

Recent research has shown that intrusions (i.e., obsessions) and rituals (i.e., compulsions) occur quite commonly among normal people.

While completing the questionnaire below, please keep in mind the following definitions of intrusions/obsessions and compulsions/rituals.

INTRUSIONS/OBSESSIONS are unwelcomed and distressing ideas, thoughts, or impulses that repeatedly enter your mind. They may seem to occur against your will. In some cases, they may be repugnant to you, you may recognize them as senseless, and/or they may not always fit your personality.

Examples of intrusions can include:

- Concerns of being contaminated by germs/dirt or contaminating others
- Thoughts about losing control and harming yourself or others
- Thoughts or images that are sexually explicit or violent
- Concerns about forgetting to have done something important or not having things you might need
- Concerns about something not being "right" enough
- Repetitive worrisome thoughts about an unwanted event occurring to yourself or others
- A repeated phrase or word that may seem random or is usually out of context

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RITUALS/COMPULSIONS are behaviors or mental acts that you feel driven to perform although you may recognize them as senseless or excessive. Usually, rituals are performed in response to intrusions, according to certain rules, or in a stereotyped fashion. At times, you may try to resist doing them but this may prove difficult. You may experience discomfort that does not diminish until the ritual is completed.

Examples of compulsions can include:

- Having to do things in a certain order or number of times for them to feel right
- Performing certain prayers in response to a thought/image
- Repeated cleaning or hand-washing
- Arranging and rearranging items in set order
- Repeating certain phrases/mantras
- Repeatedly checking doors, appliances, water faucets, and locks
- Repeatedly asking others for reassurance
- Counting or repeating certain numbers in your head
- Repeated mental checking (e.g., reviewing a past experience in your mind to make sure it feels “right,” was done properly, and/or that everything is okay)

Given the above definitions, please read carefully each item on the checklist below and provide the answer that closest resembles your experience **specifically in the past week**.

1	IN THE PAST WEEK: How much of your time was occupied by *intrusions/obsessions* and how frequently did these thoughts occur? 0 = None 1 = Less than 10% of the time, or occasional intrusions 2 = 10 – 30% of the time, or frequent intrusions 3 = 30 - 80% of the time, or very frequent intrusions 4 = More than 80% of the time, or near-constant intrusions
2	IN THE PAST WEEK: How much did your intrusive thoughts interfere with your work, school, social, or other important functioning? 0 = No interference whatsoever 1 = Mild, slight interference but my overall performance wasn't impaired 2 = Moderate, definitive interference but it was manageable 3 = Severe interference that impaired my performance 4 = Extreme and incapacitating
3	IN THE PAST WEEK: How much distress did your intrusive thoughts cause you? 0 = None 1 = Mild, infrequent, and not too disturbing distress 2 = Moderate, frequent, and disturbing distress, but still manageable 3 = Severe, very frequent, and very disturbing distress 4 = Extreme, near constant, and disabling distress
4	IN THE PAST WEEK: How much of an effort did you make to resist the intrusive thoughts, and how often did you try to disregard or turn your attention away from these thoughts as they entered your mind? 0 = I made an effort to always resist (or the intrusions were so minimal that there was no need to actively resist them) 1 = I tried to resist most of the time (e.g., more than half the time) 2 = I made some effort to resist 3 = I allowed all intrusive thoughts to fill my mind without attempting to control them, but I did so with some reluctance 4 = I completely and willingly engaged with all intrusions
5	IN THE PAST WEEK: How much control did you have over your intrusive thoughts? How successful were you in stopping or diverting your intrusions (e.g., could you dismiss the thoughts?) 0 = I had complete control 1 = Much control; usually I could stop or divert intrusions 2 = Moderate control; sometimes I could stop or divert intrusions with some effort 3 = Little control; I was rarely successful in stopping intrusions and could only divert attention with great difficulty 4 = No control; I was rarely able to even momentarily ignore the intrusions

6	IN THE PAST WEEK: How much time did you spend performing *compulsions/rituals*, and how frequently did you perform them? 0 = None 1 = Less than 10% of the time, or occasional performance 2 = 10 – 30% of the time, or frequent performance 3 = 30 - 80% of the time, or very frequent performance 4 = More than 80% of the time, or near-constant performance
7	IN THE PAST WEEK: How much did your compulsions interfere with your work, school, social, or other important functioning? 0 = No interference whatsoever 1 = Mild, slight interference but my overall performance wasn't impaired 2 = Moderate, definitive interference but it was manageable 3 = Severe interference that impaired my performance 4 = Extreme and incapacitating
8	IN THE PAST WEEK: How uncomfortable would you have become if prevented from performing your compulsions/rituals? 0 = Not at all uncomfortable 1 = Only slightly uncomfortable if my compulsions/rituals were prevented 2 = Discomfort would mount but remain manageable 3 = Prominent and very disturbing increase in discomfort if my compulsions/rituals were interrupted 4 = Extreme, incapacitating discomfort from any intervention
9	IN THE PAST WEEK: How much of an effort did you make to resist any compulsions/rituals? 0 = I made an effort to always resist (or the compulsions/rituals were so minimal that there was no need to actively resist them) 1 = I tried to resist most of the time (e.g., more than half the time) 2 = I made some effort to resist (e.g., less than half the time) 3 = I allowed all compulsions/rituals without attempting to control them, but I did so with some reluctance 4 = I completely and willingly engaged in all compulsions/rituals
10	IN THE PAST WEEK: How strong was the drive to perform the compulsions, as in, how much control did you have over them? 0 = I had complete control 1 = Much control; usually I could stop or divert compulsions 2 = Moderate control; sometimes I could stop or divert compulsions but it was difficult 3 = Little control; I could only delay the compulsions and eventually it had to be carried out to completion 4 = No control; I was rarely able to even momentarily suppress the compulsions

Y-BOCS-SR—State and *Y-BOCS-SR* total severity scores are calculated by summing the value of all items (no reverse scoring). Subscales are calculated by summing the value of the items below:

1. Obsessions subscale
   Items: 1, 2, 3, 4, 5
2. Compulsions subscale
   Items: 6, 7, 8, 9, 10

* This *Y-BOCS-SR—State* measure was modified to alter the original version's wording to ask specifically about the obsessions and compulsions experienced *during task performance* in this experiment. Changes included: adding a time specifier preceding each question to remind the participant that we were asking about symptoms experienced "during the dots and math/letters tasks" only. In this case, participants were already familiarized to refer to the RDMT as the "Dots Task" and to the OSPAN as the "Math/Letters Task." We also changed the answer options for items 1 and 6 of this scale to represent time in terms of a percentage of the total probed duration (the original version presents options in terms of number of hours in an 8 hour day span). Finally, we added the specifier of "intrusions" as an interchangeable term for obsessions, and the specifier of "rituals" as an interchangeable term for compulsions; given that our participants completed the experiment online, remotely, and from diverse backgrounds, this was done to help them more easily conceptualize symptoms clinically known as "obsessions" and "compulsions"

** This *Y-BOCS-SR* measure was slightly altered from the original version's wording to maintain consistency with the *Y-BOCS-SR—State*. In particular, a time specifier was added to precede each question to remind the participant that we were asking about symptoms experienced "during the past week" (which is the time frame of the original version). We also kept the change to the answer options for items 1 and 6, which represented time in terms of a percentage instead of number of hours, as well as the use of "intrusions" and "rituals" to help explains "obsessions" and "compulsions," respectively.

Padua Inventory – Washington State University Revision

The following statements refer to thoughts and behaviors which may occur to everyone in everyday life. For each statement, choose the reply which best seems to fit you about the degree of disturbance which such thoughts or behaviors may create.

The rating scale is as follows:

0 Not at all
1 A little
2 Quite a lot
3 A lot
4 Very much

1	I feel my hands are dirty when I touch money.	0	1	2	3	4
2	I think even slight contact with bodily secretions (perspiration, saliva urine, etc.) may contaminate my clothes or somehow harm me.	0	1	2	3	4
3	I find it difficult to touch an object when I know it has been touched by strangers or by certain people.	0	1	2	3	4
4	I find it difficult to touch garbage or dirty things.	0	1	2	3	4
5	I avoid using public toilets because I am afraid of disease and contamination.	0	1	2	3	4
6	I avoid using public telephones because I am afraid of contagion and disease.	0	1	2	3	4
7	I wash my hands more often and longer than necessary.	0	1	2	3	4
8	I sometimes have to wash or clean myself simply because I think I may be dirty or “contaminated”.	0	1	2	3	4
9	If I touch something I think is “contaminated”, I immediately have to wash or clean myself.	0	1	2	3	4
10	If an animal touches me, I feel dirty and immediately have to wash myself or change my clothing.	0	1	2	3	4
11	I feel obliged to follow a particular order in dressing, undressing, and washing myself.	0	1	2	3	4
12	Before going to sleep, I have to do certain things in a certain order.	0	1	2	3	4

13	Before going to bed, I have to hang up or fold my clothes in a special way.	0	1	2	3	4
14	I have to do things several times before I think they are properly done.	0	1	2	3	4
15	I tend to keep on checking things more often than necessary.	0	1	2	3	4
16	I check and recheck gas and water taps and light switches after turning them off.	0	1	2	3	4
17	I return home to check doors, windows, drawers, etc., to make sure they are properly shut.	0	1	2	3	4
18	I keep on checking forms, documents, checks, etc., in detail to make sure I have filled them in correctly.	0	1	2	3	4
19	I keep on going back to see that matches, cigarettes, etc, are properly extinguished.	0	1	2	3	4
20	When I handle money, I count and recount it several times.	0	1	2	3	4
21	I check letters carefully many times before posting them.	0	1	2	3	4
22	Sometimes I am not sure I have done things which in fact I knew I have done.	0	1	2	3	4
23	When I read, I have the impression I have missed something important and must go back and reread the passage at least two or three times.	0	1	2	3	4
24	I imagine catastrophic consequences as a result of absent-mindedness or minor errors which I make.	0	1	2	3	4
25	I think or worry at length about having hurt someone without knowing it.	0	1	2	3	4
26	When I hear about a disaster, I think it is somehow my fault.	0	1	2	3	4
27	I sometimes worry at length for no reason that I have hurt myself or have some disease.	0	1	2	3	4
28	I get upset and worried at the sight of knives, daggers, and other pointed objects.	0	1	2	3	4

29	When I hear about a suicide or a crime, I am upset for a long time and find it difficult to stop thinking about it.	0	1	2	3	4
30	I invent useless worries about germs and disease.	0	1	2	3	4
31	When I look down from a bridge or a very high window, I feel an impulse to throw myself into space.	0	1	2	3	4
32	When I see a train approaching, I sometimes think I could throw myself under its wheels.	0	1	2	3	4
33	At certain moments, I am tempted to tear off my clothes in public.	0	1	2	3	4
34	While driving, I sometimes feel an impulse to drive the car into someone or something.	0	1	2	3	4
35	Seeing weapons excites me and makes me think violent thoughts.	0	1	2	3	4
36	I sometimes feel the need to break or damage things for no reason.	0	1	2	3	4
37	I sometimes have an impulse to steal other people's belongings, even if they are of no use to me.	0	1	2	3	4
38	I am sometimes almost irresistibly tempted to steal something from the supermarket.	0	1	2	3	4
39	I sometimes have an impulse to hurt defenseless children or animals.	0	1	2	3	4

Padua-WSUR total score is obtained by summing all of the items (no reverse scoring). Subscale scores are obtained by summing the following items:

1. Contamination obsessions and washing compulsions subscale
   Items: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
2. Dressing/grooming compulsions subscale
   Items: 11, 12, 13
3. Checking compulsions subscale:
   Items: 14, 15, 16, 17, 18, 19, 20, 21, 22, 23
4. Obsessional thoughts of harm to self/others subscale
   Items: 24, 25, 26, 27, 28, 29, 30
5. Obsessional impulses to harm self/others subscale
   Items: 31, 32, 33, 34, 35, 36, 37, 38, 39

Cognitive Self-Consciousness - Expanded

This questionnaire is concerned with beliefs people have about their thinking. Listed below are a number of beliefs that people have expressed. Please read each item and indicate how much you generally agree with it by circling the appropriate number. Please respond to all of the items, there are no right or wrong answers.

The rating scale is as follows:

1 Do not agree
2 Agree slightly
3 Agree moderately
4 Agree very much

1	I think a lot about my thoughts.	1	2	3	4
2	I am aware of the way my mind works when I am thinking through a problem.	1	2	3	4
3	I monitor my thoughts.	1	2	3	4
4	I rarely question my thoughts.	1	2	3	4
5	I am constantly aware of my thinking.	1	2	3	4
6	I pay close attention to the way my mind works.	1	2	3	4
7	I constantly examine my thoughts.	1	2	3	4
8	I am very sensitive to the way my mind works.	1	2	3	4
9	I focus on my thoughts.	1	2	3	4
10	I notice my thoughts even if I am busy with another activity.	1	2	3	4
11	I find it easy to ignore my thoughts.	1	2	3	4
12	I seem to be more conscious of thinking than others.	1	2	3	4
13	I become preoccupied with my thoughts.	1	2	3	4
14	I do not dwell on my thoughts	1	2	3	4

CSC-E total score is obtained by summing all of the items (reverse scored items = 4, 11, 14).

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