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Cognitive Control and Context Maintenance in Individuals with Obsessive-Compulsive Disorder (OCD)

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ABSTRACT

Cognitive Control and Context Maintenance in Individuals
with Obsessive-Compulsive Disorder (OCD)

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Context maintenance, an aspect of cognitive control, is the internal representation and utilization of task-relevant information that helps achieve task goals. Alterations in context maintenance may be responsible for the cognitive difficulties seen in people with obsessive-compulsive disorder (OCD). We used two tasks designed to measure context maintenance: a) the cued-Stroop, a single-trial version of Golden's Stroop test that varies the cue for each trial (color-naming or word-reading), and b) the AX-CPT task, a continuous performance task that has participants respond to an "A" only when followed by an "X," with all other non-target trials labeled as AY, BX, and BY (and "Y" and "B" representing all non-X and non-A letters, respectively). Participants included 31 people with OCD and 30 psychiatrically-healthy controls that completed a neuropsychological test battery, self-report questionnaires measuring mood and symptom severity, and the computerized cued-Stroop and AX-CPT tasks. There was a 1s or 5s delay between the cue and probe for both tasks so as to vary the duration of context maintenance. We conducted a 2 (Group) x 2 (Delay) x 3 (Trial Type) repeated measures ANOVA for the cued-Stroop and a 2 (Group) x 2 (Delay) x 4 (Trial Type) repeated measures ANOVA for the AX-CPT. Dependent measures included median reaction times (RT) and mean error rates (ER). Both groups showed a congruency effect for the cued-Stroop, with slower RTs and greater ERs for the incongruent trials than the neutral and congruent trials, as well as lower ERs for BY trials compared to BX and AY trials of the AX-CPT task. There were no significant differences in RTs or ERs between groups for delay or condition for the cued-Stroop (ps > .45) or for the AX-CPT (ps > .07). The present study shows that people with OCD did not show deficits in context maintenance in two separate tasks. Limitations include low power, higher functioning participants with OCD, and the presence of comorbid depression and anxiety in some participants with OCD.

Keywords: obsessive-compulsive disorder, cognitive control, context maintenance

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Cognitive Control and Context Maintenance in Individuals with Obsessive-Compulsive Disorder (OCD)

Obsessive-compulsive disorder (OCD) is a debilitating psychiatric disorder that affects approximately 2.3% of the population over a lifetime (Ruscio, Stein, Chiu, & Kessler, 2010). The obsessive component of OCD consists of recurrent and persistent thoughts, urges, or images that are difficult to ignore or suppress, while the compulsive component consists of repetitive behaviors or mental acts that are performed in order to reduce the anxiety or distress associated with the obsessions (American Psychiatric Association [APA], 2013). OCD is also characterized by a broad range of often co-occurring functional impairments including sleep disturbance, decreased occupational and academic performance, reduced quality of life, and increased healthcare utilization (see Markarian et al., 2010, for review). The direct and indirect costs, as well as lost productivity, in those seeking treatment for OCD are estimated at $9,540.96 per person over a 9-week period (Diefenbach & Tolin, 2013). Given the prevalence, level of impairment, and expense associated with OCD, a comprehensive understanding of OCD-related dysfunction could enhance the welfare of many by improving functional outcomes through more specific and effective treatments.

OCD has been referred to as a disorder of cognition due to its association with intrusive thoughts and dysfunctional beliefs (Rachman, 1997, 2002; Salkovskis, 1985). In cognitive models of OCD, the onset and maintenance of OCD is associated with dysfunctional beliefs, which can include inflated responsibility, overestimation of threat, the need to control thoughts, perfectionism, and intolerance of uncertainty, among others (Obsessive Compulsive Cognitions Working Group [OCCWG], 1997; Rachman, 1997); however, there are several inconsistencies with the cognitive model of OCD (Cougle & Lee, 2014). For instance, intrusive thoughts may

be perceived as distressing to nonclinical populations as well, the content of the intrusive thoughts may lead to the distress rather than the catastrophic interpretations of them, and the level of dysfunctional beliefs experienced by those with OCD is similar to those with other anxiety disorders, indicating a lack of specificity (Cougle & Lee, 2014). These criticisms have led others to investigate alternative cognitive theories.

Some of these alternative theories focus on the importance of metacognition in the etiology and maintenance of OCD (Fisher, 2009; Wells, 1997). Metacognition refers to awareness or regulation of one's own cognitive processes (Flavell, 1979), and is often described as "thinking about thinking." The metacognitive theory of OCD states that metacognitive beliefs such as thought-event fusion (believing that having the intrusive thought can cause, or will cause, the event to happen), thought-action fusion (believing that having the intrusive thought can force the person to perform the unwanted action), and thought-object fusion (believing that negative thoughts or feelings can be transferred to objects or people) are activated after an intrusive thought enters the mind (Fisher, 2009). These beliefs can then trigger the negative appraisal of the intrusive thought followed by worry and compulsions as coping mechanisms (Fisher, 2009). Fisher explains that the metacognitive theory of OCD symptoms extends the ideas of Rachman's (1997, 2002) and Salkovskis' (1985) cognitive theory by emphasizing the importance of the processes and knowledge underlying the negative appraisal (i.e., how the appraisal arises), rather than the specific content of the appraisal.

There is mounting evidence that problematic metacognition plays a role in the etiology and maintenance of OCD (Fisher, 2009). For example, specific aspects of metacognition, such as "Negative Beliefs About Thoughts," "Themes of Superstition, Punishment, and Responsibility," and "Cognitive Self-Consciousness," positively correlate with OCD symptoms,

mediate the association between OCD symptoms and anxiety, and differentiate between those experiencing symptoms of OCD and those experiencing other anxiety disorders (Cartwright-Hatton & Wells, 1997; Irak & Tosun, 2008; Janeck, Calamari, Riemann, & Heffelfinger, 2003). Additionally, investigations into the role of metamemory, specifically, show that confidence in memory, decision-making, and attention as well as high standards of one's cognitive performance (e.g., "I must perform tasks perfectly") may account for OCD symptoms such as harmful thoughts and impulses, contamination fears, grooming compulsions, and especially checking compulsions (Nedeljkovic & Kyrios, 2007).

From a neural perspective, the frontal lobe is implicated in a variety of cognitive functions and may be responsible, in part, for the occurrence of dysfunctional thoughts and metacognitive disturbance in people with OCD. The specific cognitive functions associated with frontal lobe activity include attention, decision-making, executive function, judgment, language, prospective memory, and planning, as well as mood and personality (Absher & Cummings, 1995). Compared to healthy controls, people with OCD often show abnormal activity in various brain regions, including their frontal lobe (Melloni et al., 2012). For example, when performing specific cognitive tasks designed to test frontal lobe functions, such as the Tower of London planning task, a reversal learning task, and a Go/No-Go task, people with OCD, relative to controls, tend to have excessive activity in the orbito-frontal cortex (OFC) and anterior cingulate cortex (ACC) and decreased activity in the dorsolateral prefrontal cortex (dlPFC), which are implicated in inhibition and evaluation of performance as well as executive planning (Maltby, Tolin, Worhunsky, O'Keefe, & Kiehl, 2005; Melloni et al., 2012; Ursu & Carter, 2009; van den Heuvel et al., 2005). Ursu and Carter (2009) found that the level of increased activity in the OFC while responding to high-conflict trials in a cognitive task correlated with the self-reported

severity of anxiety symptoms in those experiencing symptoms of OCD and suggest that the hyperactivity in the OFC may be responsible for the excessive anticipation of aversive events in those with OCD.

Moreover, many studies have tested how activity in the OFC, ACC, and dlPFC differ between those with OCD and healthy controls while at rest. These resting-state studies suggest that those with OCD have increased resting activity in the OFC and ACC compared to controls (Alptekin et al., 2001; Baxter et al., 1988; Niu et al., 2017; Swedo et al., 1989). Niu and colleagues (2017) also found decreased activity in the thalamus in those with OCD compared to controls, and suggest that the thalamic activity is associated with inefficient management of incoming and outgoing information. The potential mismanagement of thalamic inputs and outputs may then result in hyperactivity in the OFC and ACC, which they believe could be involved in the pathological intrusive thoughts and anxiety of OCD, respectively (Niu et al., 2017). In a review of both neuroimaging and neuropsychological data of people with OCD, Melloni and colleagues (2012) posit that the constellation of excessive activity in the OFC, ACC, and basal ganglia, and reduced activity in the dlPFC and parietal cortex may also be responsible for many of the deficits seen in the executive/frontal lobe functioning of those experiencing OCD.

Neuropsychological functioning is also altered in individuals with OCD compared to psychiatrically-healthy individuals. In a large meta-analysis, Abramovitch and Cooperman (2015) report consistent findings of decreased performance on tasks involving planning, processing speed, higher load trials of verbal and visuo-spatial working memory, and non-verbal memory in those diagnosed with OCD compared to healthy controls. However, Abramovitch and Cooperman (2015) also note that performance on tasks involving set shifting (the ability to

transfer attention to task-relevant stimuli and ignore task-irrelevant stimuli according to the task's changing rules and demands) is comparable to healthy controls and that alterations in some cognitive abilities often thought to be deficient in those with OCD, including response inhibition, verbal and figural fluency, and visuospatial abilities, are still up for debate.

Despite the mixed results across neuropsychological domains, studies of the difficulties in executive functioning in people with OCD are consistent (Abramovitch, Abramowitz, & Mittelman, 2013; Snyder, Kaiser, Warren, & Heller, 2015). Generally, there are significant small-to-medium effect size differences between those diagnosed with OCD and healthy controls on many aspects of executive functioning including shifting, inhibition, updating, and planning that are not due to generalized slowing or co-occurring depression, and that seem to go above and beyond deficits seen in anxiety disorders such as generalized anxiety disorder (Airaksinen, Larsson, & Forsell, 2005; Snyder et al., 2015). Additionally, some studies suggest that people with OCD struggle specifically with decision-making, making worse decisions and taking longer to do so than healthy controls (Dittrich & Johansen, 2013; Dittrich, Johansen, Landrø, & Fineberg, 2011), which further implicates difficulties in their executive control and overall cognitive functioning.

Executive functioning difficulties often seen in those diagnosed with OCD may represent the specific behavioral manifestations of impaired cognitive control. Cognitive control is the ability to utilize thoughts and behaviors in order to effectively achieve goals (Miller & Cohen, 2001). Cognitive control theory suggests that cognitive control is a generally automatic process that is comprised of two main component processes: an evaluative component and a regulative component (Botvinick, Braver, Barch, Carter, & Cohen, 2001). The evaluative component is responsible for monitoring the demands of a task and an individual's performance and then

signaling when an adjustment is necessary. The regulative component is responsible for implementing these adjustments. The regulative component also maintains an internal representation of the task requirements, helps to process information associated with the task's goals, and helps to suppress information that is not relevant (van Veen & Carter, 2006).

A more recent theoretical model of cognitive control, the Dual Mechanism Framework, divides cognitive control into two separate, but parallel, components: proactive control, which is similar to the regulative component, and reactive control, which is similar to the evaluative component (Braver, 2012). A key difference between the two cognitive control theories is that Braver's Dual Mechanism Framework suggests that reactive control not only signals for the adjustment as the evaluative component does, but it also implements the correction as the regulative component does. Both models suggest that the component responsible for maintenance of task- and goal-relevant information is more of a long-term mechanism with a top-down bias implemented by sustained lateral prefrontal cortex activity (Braver, 2012; Kerns et al., 2004). The main theories of cognitive control also are similar in that the component responsible for detecting errors is a short-term mechanism with a bottom-up bias that likely originates in the ACC (Braver, 2012; Kerns et al., 2004; MacDonald, Cohen, Stenger, & Carter, 2000). However, Braver's (2012) model adds that error detection and implementation require both transient activation of the lateral prefrontal cortex for compensation and adjustment following the error in addition to other brain regions. Both models also posit that the two components (i.e., regulative and evaluative; proactive and reactive) operate independently but interact substantially (Gonthier, Braver, & Bugg, 2016; MacDonald et al., 2000).

People with OCD often exhibit specific difficulties in both regulative and evaluative components of cognitive control compared to healthy individuals. For example, individuals with

OCD tend to have overactive performance monitoring, an element of evaluative control that includes the detection and signaling of conflict or errors in performance (Nawani et al., 2018; Riesel, Klawohn, Kathmann, Endrass, 2017). Indeed, in their review, Abramovitch and Cooperman (2015) noted that most studies show that people with OCD do not commit more errors than healthy controls, which may be due to their increased vigilance to tasks and heightened performance monitoring; however, people with OCD tend to exhibit slower reaction times on a Go/No-Go task and congruent trials of the Stroop task compared to healthy controls (Abramovitch & Cooperman, 2015). People with OCD also exhibit some difficulties with regulative control (Kalanthroff, Anholt, & Henik, 2014). Since regulative control involves the maintenance of goal-relevant information, it is possible that the deficits seen in executive functioning in those with OCD as opposed to controls (Abramovitch & Cooperman, 2015; Snyder et al., 2015) could be due to poorer regulative control. Specifically, problems with ignoring task-irrelevant information could account for the decreased executive control, such as the slower reaction times in making decisions and poorer performance on set shifting and planning tasks (Dittrich & Johansen, 2013; Dittrich et al., 2011; Snyder et al., 2015).

A specific aspect of regulative control where individuals with OCD may show difficulty is context maintenance, or the internal representation and utilization of task-relevant information to successfully accomplish the task goals (Braver, Barch, & Cohen, 1999). For example, if after playing a game of pick-up soccer, the players decide to switch up the teams, you must update and maintain the context of who your new teammates are in order to achieve the goal of scoring and winning the game. Poor context maintenance may lead you to pass the ball to a player on the opposite team that was previously on your original team. Research has shown that individuals with higher working memory capacity perform better on tasks requiring context

maintenance, suggesting that working memory is a prerequisite for context maintenance (Redick, 2014; Redick & Engle, 2011). Regarding working memory capacity, individuals with OCD show slightly worse working memory capacity than health controls, but this is only a small effect (Abramovitch et al., 2013). For example, on a specific task of working memory, the Digit Span subtest of the Wechsler Adult Intelligence Scale (WAIS), a meta-analysis showed no significant differences in performance between those with OCD and healthy controls (Shin, Lee, Kim, & Kwon, 2014). However, it seems that the effect size differences exist more so when the tasks are more complex and of higher load, such as the verbal N-Back task (Abramovitch & Cooperman, 2015; Kashyap, Kumar, Kandavel, & Reddy, 2013).

Cognitive Control Tasks

Interference tasks such as the Stroop test (Stroop, 1935) have often been utilized to investigate automatic processes associated with cognitive control and, in some specific studies, context maintenance (Scarpina & Tagini, 2017). A revised version of the Stroop test, the single-trial cued-Stroop task, developed by Cohen, Barch, Carter, and Servan-Schreiber (1999), specifically tests context maintenance by presenting only one Stroop trial at a time and providing a task instruction cue (color-naming or word-reading) that the participant must keep in mind for each trial. This adaptation requires participants to continually update their representation of context with each trial, whereas the traditional Stroop task persistently reinforces the appropriate context by presenting trials of the same context in blocks. In the cued-Stroop task, each trial begins with an instructional cue that informs the participants to which aspect of the stimulus they should pay attention (i.e., “color” or “word”). Following a 1s or 5s delay (the delay manipulation is also important as it provides differences in the amount of time context maintenance is implemented), a congruent, incongruent, or neutral Stroop stimulus is presented.

Congruent stimuli present the word printed in its own color (e.g., the word GREEN printed in green), whereas incongruent stimuli present the word printed in a color other than its own (e.g., the word GREEN printed in red), and neutral stimuli do not contain a task-irrelevant dimension (e.g., XXXX printed in color for the color-naming task and the word GREEN printed in white for the word-naming task). By cueing the relevant aspect of the stimulus before the presentation of the stimulus and manipulating the time between the instruction cue and the Stroop stimulus, underlying context maintenance processes can be dissociated from processes underlying conflict detection and resolution.

The single-trial cued Stroop task has been used in several studies to assess context maintenance in clinical samples. For example, Seignourel and colleagues (2005) used the single-trial cued-Stroop to study context maintenance deficits in individuals with moderate-to-severe traumatic brain injury (TBI). Cognitive control theory would suggest that those with impaired context maintenance, compared to controls, would have worse performance on items that demand the participant to override a pre-potent response (e.g., naming the color) than those that do not (e.g., reading the word). Indeed, results showed that moderate-to-severe TBI patients had greater error rates on trials that necessitated overcoming the pre-potent response, but only when they had to maintain task instructions for a longer versus shorter period of time. The difference in performance based on the timing of the instruction cue suggests that those with context maintenance difficulties are more likely to make mistakes when the context must be maintained for longer rather than shorter periods of time (i.e., there may be degradation of the context representation over time; Msetfi, Murphy, Kornbrot, & Simpson, 2009; Seignourel et al., 2005). The use of the cued-Stroop task also allowed the authors to conclude that differences in performance between those with TBI and healthy controls were not due to generalized slowing

or deficits in inhibition of pre-potent responses. Seignourel and colleagues (2005) also found that deficits in context maintenance are associated with the severity of symptoms in TBI, suggesting that the wide-ranging difficulties experienced by those suffering from pathology may be related to poorer performance on cognitive tasks of context maintenance.

The cued-Stroop was also utilized in a similar study of cognitive control in people with schizophrenia (Cohen et al., 1999). As expected, those diagnosed with schizophrenia had a greater increase in errors for color-naming trials in the incongruent condition compared to both healthy- and psychiatric-control participants. However, participants with schizophrenia did not differ in error rates between the long and short delay, as was hypothesized. Cohen and colleagues (1999) also found that compared to both control groups, people with schizophrenia had longer reaction times on incongruent than congruent trials, but only for color-naming trials. Lastly, they showed that cognitive performance negatively correlated with disorganization symptoms, again indicating that performance on cognitive tasks of context maintenance may be related to symptomology.

Another task designed to test context maintenance processes is the AX version of a continuous performance task (AX-CPT), developed by Cohen and colleagues (Cohen et al., 1999; Servan-Schreiber, Cohen & Steingard, 1996). In the AX-CPT task, participants are asked to indicate when they see an "X" with a button press, but only when the "X" is preceded by an "A," requiring inhibition of all other responses, such as an "X" that is not preceded by an "A" or a non-"X" letter that was preceded by an "A." The target trials (AX) occur 70% of the time, with the other three trials types (referred to as AY, BX, and BY trials, where "B" represents any cue letter that is not an "A," and "Y" represents any probe letter that is not an "X") each occurring 10% of the time. Incorrect responses on BX trials are referred to as context-failure errors since

participants did not successfully update their context before the "X" probe displayed (i.e., there was no "A" presented, so they should not have pressed the button). Thus, those that incorrectly respond to BX trials are thought to have poorer context maintenance since they did not use the preceding "B" cue, or context, to override the tendency to respond when the X probe is presented. Incorrect responses on AY trials are referred to as context-induced errors since participants acted on an expectancy bias, due to the probability that an "X" will follow an "A" 70% of the time. People that incorrectly respond to AY trials are thought to have better context maintenance because they are using the preceding "A" cue, or context, to prepare a response that is then harder to terminate when the "Y" probe is presented than if no response had been prepared. Lastly, BY trials act as a control trial since no target cues are involved.

Similar to the cued-Stroop, the AX-CPT task has not been used to test the role of context maintenance in people with OCD. The AX-CPT task was originally used to study context processing in people with schizophrenia (Servan-Schreiber et al., 1996), but now is used in a variety of populations, including attention-deficit/hyperactivity disorder (ADHD), bipolar disorder, borderline personality disorder, bilingual individuals, and people who have experienced a traumatic brain injury (Brambilla et al., 2007; Larson, Perlstein, Demery, & Stigge-Kaufman, 2006; Morales, Gómez-Ariza, & Bajo, 2013; van Dijk et al., 2014). Results from studies of the AX-CPT consistently show that individuals with psychiatric or neurologic disorders, such as those with ADHD and traumatic brain injury, often exhibit deficits in context maintenance. Specifically, compared to controls, they show greater error rates on AX and BX trials but not AY trials. This is consistent with the results expected in people with impaired context maintenance since incorrect responses on AX trials indicate that the participant did not process the "A" before

being presented with the "X" and incorrect responses on BX trials represent context-failure errors, while incorrect responses on AY trials represent context-*induced* errors.

Having a better understanding of the possible impairments in context maintenance in people with OCD may help with the conceptualization and treatment of OCD. Reduced context maintenance may manifest itself as difficulties completing tasks requiring working memory, changing demands, or performance monitoring, likely resulting in academic and occupational struggles in addition to day-to-day activities. One study showed that when compared to individuals with low-trait anxiety and psychiatrically-healthy controls, people with high-trait anxiety had slower reaction times on the incongruent and congruent trials of the cued-Stroop task when the trials were preceded by negative valence stimuli but not neutral valence stimuli (Kalanthroff, Henik, Derakshan, & Usher, 2016). The results suggest that when exposed to negative emotional distractors, individuals with high-trait anxiety are unable to adequately adjust regulative control (i.e., context maintenance abilities) to overcome the effects of the task-irrelevant stimuli. Kalanthroff and colleagues (2016) also posit that this deficiency may result in poor daily functioning and therefore poorer quality of life. These findings may be extended to individuals with OCD who often experience intrusive thoughts, which could affect their ability to engage regulative control, and therefore impair their context maintenance.

Since problems with context maintenance may be associated with impairment in academic and occupational settings, as well as day-to-day living and quality of life, it is important to identify the presence and magnitude of context maintenance difficulties in individuals with OCD. As such, the present study aims to test potential differences in context maintenance between individuals diagnosed with OCD and psychiatrically-healthy control participants through the use of the cued-Stroop and the AX-CPT tasks. The use of two separate

tasks both measuring context maintenance processes is a strength of the study as we seek a convergence of information between multiple measurements of context maintenance. Since neuropsychological studies comparing those with OCD and healthy controls indicate that it is not likely people diagnosed with OCD will commit more errors than controls (Abramovitch & Cooperman, 2015), our hypotheses are focused on differences in context maintenance as measured by reaction times rather than error rates. That said, due to the reported difficulties with working memory, executive functioning, and regulative and evaluative components of cognitive control in people with OCD, we hypothesize that, compared to controls, people with OCD will exhibit behaviors, such as slower reaction times, that indicate poorer context maintenance abilities.

Specifically, we hypothesize that individuals with OCD will have longer reaction times than healthy comparison participants on incongruent trials of the cued-Stroop task at the long delay versus short delay, but only for the color naming condition. The long delay condition is when demands on inhibition (i.e., of the pre-potent response of reading the word) and context maintenance are at their highest and, thus, the most likely condition for context maintenance difficulties to manifest. Additionally, for the AX-CPT task, we expect that those with OCD will have longer reaction times than controls on AY and BX trials at the short delay, since AY trials require inhibition of a response and BX trials measure context failure. At the long delay, we hypothesize that participants with OCD will have increased reaction times compared to controls on AX and BX trials, since we expect context maintenance to degrade with time, thus increasing the probability they will respond when they see an "X." However, at the long delay we also expect reaction times on AY trials to hold constant or decrease for subjects with OCD, but not controls, as degradation of context maintenance would reduce the expectancy bias created by the

"A" cue. We hypothesize that there will be no difference in reaction times on BY trials between those with OCD and healthy controls at both the short and long delays as context maintenance is not required for a successful response.

Method

All study data, a codebook, and analysis output can be found on the Open Science Framework (OSF) at https://osf.io/v8rcp/.

Participants

Participants were recruited from university and community mental health counseling centers as well as fliers posted on campus and in the local community. All participants provided written informed consent as established by the Brigham Young University Institutional Review Board and received financial compensation or course credit for participation. All participants with OCD met DSM-IV diagnostic criteria for OCD confirmed by administration of the anxiety disorders module of the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I; First & Gibbon, 2004) by a licensed psychologist or by a trained graduate-student rater under the supervision of a licensed clinical psychologist. Exclusion criteria for participants with OCD included any medication changes within the last 2 months, reported alcohol or substance abuse within the past year, current antiepileptic medication use, neurological disorders (e.g., seizure disorder, stroke), and/or uncorrected visual impairment. Exclusion criteria for healthy control participants were the same as those for participants with OCD, with the additional exclusion of current psychoactive medication use.

Initial enrollment consisted of 34 participants diagnosed with OCD and 30 age-, education-, and sex-matched neurologically healthy, right-handed controls, ranging in age from 18 to 55. The final overall sample included 31 individuals with OCD (15 female) and 30 healthy

controls (15 female) because, prior to data analysis so their effect on the final data are unknown, three participants with OCD were excluded due to a diagnosis of epilepsy or not meeting OCD criteria. The Stroop task included 31 individuals with OCD (15 female) and 29 healthy controls (15 female) because one control participant was colorblind and, thus, not included. The AX-CPT task included 29 individuals with OCD (13 female) and 26 (13 female) healthy controls because two participants with OCD had an error rate greater than 50%, while four healthy control participants had an error rate greater than 50% or missing data.

For comorbid diagnoses, five participants with OCD endorsed a learning disability or attention-deficit/hyperactivity disorder, seven participants with OCD endorsed a depressive and/or anxiety disorder, one participant with OCD endorsed an eating disorder, and one control was diagnosed with depression six years prior to completing the present study (none of these participants were excluded from the study). Demographic summary information for all included study participants is presented in Table 1, with no significant differences between OCD and control groups in regard to years of age, $F(59) = .05$ $p = .85$, years of education $F(59) = 1.17$, $p = .64$, or male/female ratio, χ^2 (1) = .02, $p = .90$.

Table 1
Demographic Data for Healthy Control Participants and Participants with OCD

Characteristic	Controls (n = 30)	OCD (n = 31)	Range	t(df)	Cohen's d
Age in years (*SD*)	25.5 (8.1)	25.9 (8.5)	18 – 55	-0.19(59)	0.05
Sex					
Male	15	16			
Female	15	15			
Male:Female Ratio	1:1	1.07:1			
Education in years (*SD*)	15.2 (1.5)	15.0 (1.8)	12 – 19	0.48(59)	0.12
Handedness					
Left	0	3			
Right	30	27			
Ambidextrous	0	1			
Ethnicity					
Caucasian	28	30			
Hispanic	2	1			

Procedure

Each participant completed two separate 90-minute testing sessions on separate days approximately one week apart. During one session, participants completed the SCID-I structured interview for diagnosis, self-report questionnaires, and neuropsychological tests. During the other session, participants completed two computerized tasks, the cued-Stroop task and the AX-CPT, the order of which was counterbalanced across participants. Details of the measures and computerized tasks are provided below.

Cued-Stroop Task

Participants completed a modified, single-trial cued version of the Stroop test (see Figure 1; MacDonald & Carter, 2002; Perlstein, Larson, Dotson, & Kelly, 2006; Stroop, 1935). In this task, participants were presented with one of four words (RED, GREEN, BLUE, XXXX) appearing in either red, green, blue, or white in 32-point uppercase Arial font on a black background using E-Prime 2.0 Professional software (Psychology Software Tools, 2002). At the beginning of each trial, participants were provided with an instructional cue (i.e., "color" or "word") on the computer screen for 750ms followed by a fixation cross for either 1s or 5s. The color-word stimulus then appeared for 1.5s followed by another fixation cross lasting 1s, which served as the inter-trial interval (ITI). Participants were required to respond within 2500ms of stimulus presentation or else the trial was considered an omission error.

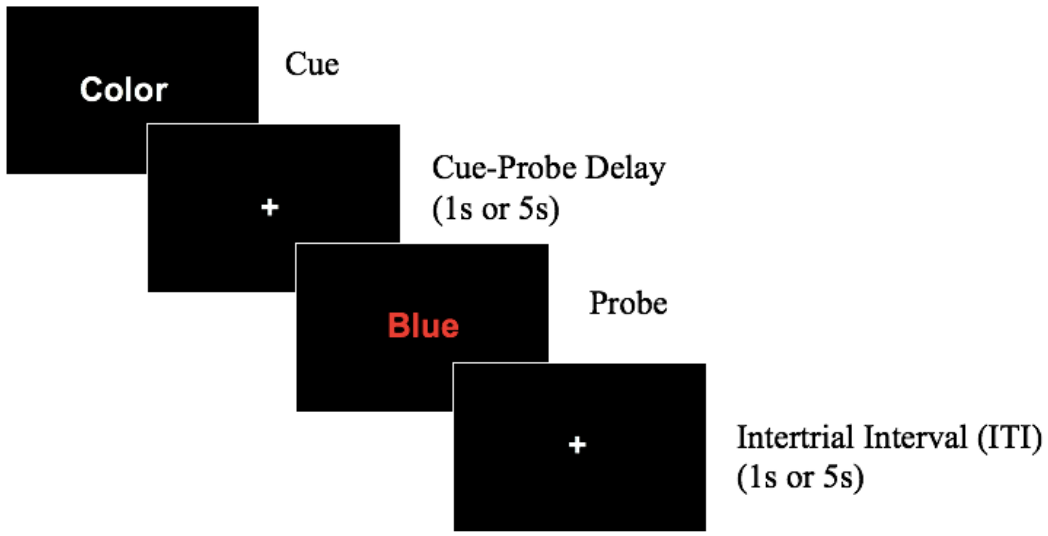

Figure 1. A visual representation of the cued-Stroop task displaying the cue, cue-probe delay, a probe, and the intertrial interval of an incongruent, color-naming trial.

Trials were administered in six blocks of 70 trials, with a participant-determined brief break between blocks that was terminated by button press. Of the 420 trials, 25% were congruent, 50% were incongruent, and 25% were neutral, with all trials pseudorandomly ordered so that each of the seven trial types (i.e., color- vs. word-naming; 1s vs. 5s cue-probe delay; congruent vs. incongruent vs. neutral) occurred 10 times in each block. Congruent stimuli were comprised of color-words presented in the same color font (e.g., the word RED shown in red font); incongruent stimuli were comprised of color-words presented in a different color font (e.g., the word RED shown in green font); and neutral stimuli consisted of four colored Xs (for color-naming trials only) or color-words presented in white (for word-reading trials only). Before beginning the task, participants were instructed to respond as quickly and accurately as possible. Responses were recorded via a button press to one of three color-coded response keys using the index, middle, and ring fingers of their right hand.

Prior to beginning the task, all participants completed a 100-item color-to-key mapping practice block using only the XXXX stimuli presented in the three different colors to ensure

accurate responding, where they were required to achieve at least 80% accuracy. Following the color-key acquisition, participants completed a 50-item cued-Stroop practice task to ensure adequate understanding. Accuracy of at least 70% was required on the practice task; the task was repeated until 70% accuracy was obtained.

AX-CPT

Participants also completed a computerized version of the AX-CPT task (see Figure 2; Cohen et al., 1999; Larson et al., 2006; Servan-Schreiber et al., 1996). For the AX-CPT task, sequences of letters were presented one-at-a-time on a computer screen for 300 ms in white, 18-point uppercase bold Courier New font on a black background using E-prime 2.0 Professional software (Psychology Software Tools, 2002). Participants had a 1500ms response window for each trial or else it was considered an error of omission. Before beginning the task, participants were instructed to respond as quickly and accurately as possible. Participants were also instructed to respond with a button press by their dominant hand index finger for target trials and by their middle finger for non-target trials. Target trials occurred 70% of the time and were defined as the sequence in which the letter "A" preceded the letter "X". Non-target trials (any trial that was not an "AX" trial) occurred the remaining 30% of the time. Specifically, "BX" trials were invalid cues (non-As) followed by the target (X); "AY" trials were valid cues (As) followed by non-target probes; and "BY" trials were invalid cues followed by non-target probes. All letters of the alphabet had equal probability of presentation for "B" and "Y" trials, with the exception of the letters K and Y which were not included at all due to their similar appearance to the letter X.

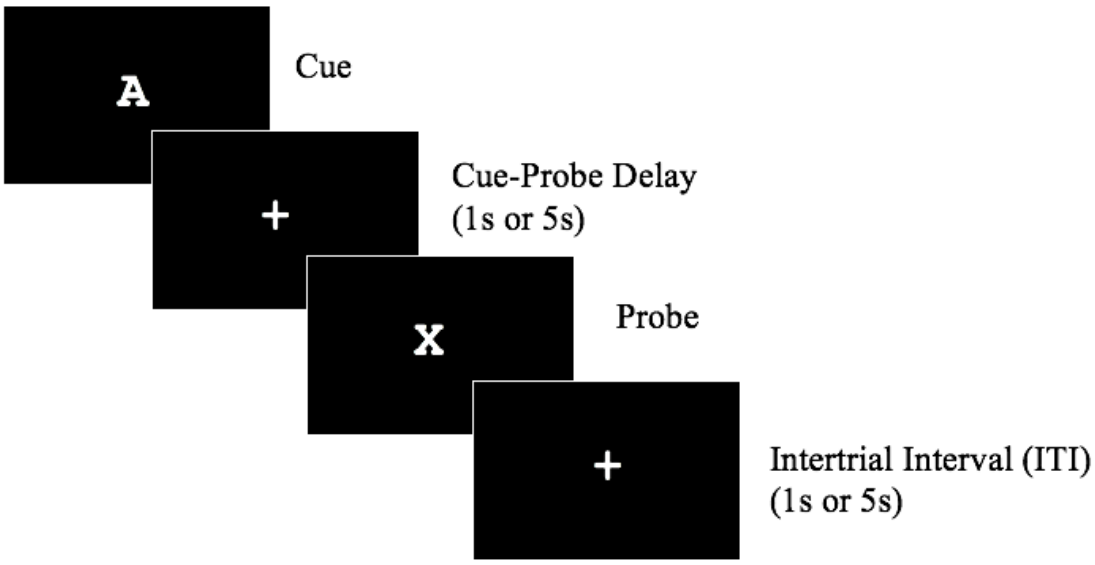

Figure 2. A visual representation of the AX-CPT task displaying an example cue, cue-probe delay, probe, and intertrial interval for an AX trial.

Trials were presented in six blocks of 50 trials for a total of 300 trials, with the inter-trial interval systematically varied by short- and long-delay blocks. In short delay blocks, there was a 1s delay between cue and probe and 5s between the probe and next cue (ITI). In long delay blocks, there was a 5s delay between cue and probes and 1s between the probe and next cue. This delay-ITI constellation allows for identical duration of trial blocks and controls for factors that might affect performance, such as task pace, response frequency, or total time on task. Trial type and delay were varied pseudorandomly over trials, with the constraints that 50% of the trials occur at each delay over the course of the entire task. Prior to beginning the task, participants completed a 12-trial practice task while being observed by a research assistant to ensure adequate understanding. If participants missed approximately 50% of the trials during the practice administration, the practice was repeated until understanding was evident.

Structured Interviews and Self-Report Measures

All participants completed measures that included the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I) anxiety disorders module, the Mental Health Screening

Form-III (MHSF-III), the Penn State Worry Questionnaire (PSWQ), the Interpersonal Reactivity Index (IRI), and the Obsessive-Compulsive Inventory – Revised (OCI-R). We administered only the anxiety disorders module of the SCID-I due to our primary interest in determining the presence of OCD and related disorders. We administered the MHSF-III in order to quickly assess for other comorbid disorders. Given the high rates of comorbid depression and anxiety associated with OCD, participants also completed the Beck Depression Inventory-2nd edition (BDI-II) and State-Trait Anxiety Inventory (STAI). Only individuals diagnosed with OCD completed the Yale-Brown Obsessive Compulsive Scale (Y-BOCS). All structured interviews, including the SCID-I, MHSF-III, and Y-BOCS, were administered by a trained clinical psychology PhD student under the direction and supervision of a licensed clinical psychologist. Descriptions of each of these measures/interviews are provided below. These measures were administered to characterize the sample of participants; however, only some aspects of the measures were analyzed and reported in order to prevent inflation of Type I error.

Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I). The SCID-I is a commonly used, semi-structured interview for diagnosis of DSM-IV disorders in research. Interviewers ask structured questions designed to elicit information about specific diagnostic criteria. Test-retest reliability ranges from .35 to 1.0 depending on the diagnostic criteria being examined and diagnostic validity of the SCID-I is better than a standard clinical interview for the diagnosis of OCD (see Grabill et al., 2008).

Mental Health Screening Form (MHSF-III). Participants were screened for major psychiatric disorders using the MHSF-III (Carroll & McGinley, 2001). The MHSF-III provides excellent inter-rater reliability (> .95), good internal consistency (Cronbach's $\alpha > .83$), and good construct validity (87% rate of agreement between independently assigned mental health

diagnoses and endorsed items on the MHSF-III; (Carroll & McGinley, 2001).

Yale-Brown Obsessive Compulsive Scale (Y-BOCS). The Y-BOCS is a clinician-administered rating scale of OCD symptom severity. First, the clinician goes through a symptom checklist with the patient, followed by ratings of OCD symptom severity on a 5-point Likert scale ranging from 0 to 4. The Y-BOCS is considered the "gold standard" for assessing OCD symptom severity and has good inter-rater and test-retest reliabilities (*r*'s > .80). Internal consistency ranges from alpha levels of .69 to .91 (see Grabill et al., 2008).

Obsessive-Compulsive Inventory – Revised (OCI-R). The OCI-R is an 18-item scale where obsessive-compulsive symptoms are rated by the participant on a five-point Likert scale from 0 (not at all distressing) to 4 (extremely distressing). The OCI-R has good internal consistency (α between .82 and .90). Two-week test-retest reliability ranged from .74 to .91 (Foa et al., 2002).

Beck Depression Inventory – 2nd edition (BDI-II). The BDI-II is a 21-item self-report instrument assessing the presence and severity of depression symptoms over the preceding two weeks (Beck, Steer, & Brown, 1996). Its internal consistency ranges from .91 to .93, its one-week test-retest reliability is .93 (Beck et al., 1996).

Interpersonal Reactivity Index (IRI). The IRI is a 28-item self-report measure that assesses four domains of empathy. There are seven items that assess each of the four domains or subscales: Perspective Taking (PT), Fantasy (FS), Empathic Concern (EC), and Personal Distress (PD). The IRI shows acceptable internal consistency for each of the subscales (>.70), with test-retest correlations after more than two-months, being between .61 and .81 for each of the subscales (Davis, 1983).

The State-Trait Anxiety Inventory (STAI). The STAI is a 40-item self-report measure of anxiety symptoms that was developed to measure a patient's anxiety in their everyday life, as well as anxiety at the time of the evaluation. There is a large literature demonstrating the reliability and validity of this measure. Test-retest correlations range from .73 to .86 and internal consistency coefficients from .89 to .92; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).

Neuropsychological Measures

All participants also completed a brief neuropsychological test battery that included the North American Adult Reading Test (NAART), the Digit Span forward and backward subtests from the Wechsler Adult Intelligence Test–Third Edition (WAIS-III), the Golden version of the Color Stroop task, Trail Making Test Parts A and B, the Controlled Oral Word Association Test (COWAT) and Category Fluency tests (Animals), the Rey-Auditory Verbal Learning Test (Rey-AVLT) and the Wechsler Memory Scale-Revised (WMS-R) Logical Memory I and II subtests. Order of neuropsychological task presentation was counterbalanced across participants, with the exception of the AVLT list that was presented first to allow adequate time for the long-recall delay. WMS-R stories were administered following completion of the AVLT delay. A brief description of each of the measures used is provided below.

North American Adult Reading Test (NAART). The NAART is a word-list pronunciation task designed to provide an estimate of intellectual ability. Participants read a series of obscure and complex words that require word-knowledge to correctly pronounce. Internal consistency estimates are above .90, with test-retest reliability also above .90 (see Spreen & Strauss, 1998; Blair & Spreen, 1989).

Digit Span forward and backward. In the digit span forward test of the WAIS-III, increasingly longer strings of numbers are recalled (1-9 letters). In the backward version,

participants repeat the numbers in reverse order. Span length is defined as the numbers of digits recalled correctly before two strings of the same length were failed. Reliability estimates of the Digit Span range from 0.84 to 0.93 (Wechsler, 1997).

Golden's Stroop Task. The three-card version of Golden's Stroop task (1978) was used. Participants were presented with cards of words, color-words, and colored Xs and instructed to read as may items as possible within a 45-second time period. Test-retest reliabilities are between .73 and .86 and Raw Interference score reliabilities fall in the .70 range (Golden & Freshwater, 2002).

Trail Making Test Parts A and B. Trail Making Test Parts A and B are well-documented measures of visual scanning, processing speed, and task switching (Lezak, 1995; Reitan, 1958). The Trail Making Test consists of two parts. In Part A, participants connect consecutively numbered circles, while in Part B participants connect consecutively numbered and lettered circles that alternate between the two sequences. Psychometric studies indicate reliability coefficients above .80 (Spreen & Strauss, 1991).

Controlled Oral Word Association Test (COWAT) and Category Fluency (Animals). In the COWAT, participants are asked to produce as many words as possible that begin with three different letters (F, A, and S) in one minute each (phonemic fluency). Participants are instructed to avoid using proper names and words that are only changed based on different suffixes (e.g., eat, eating). One study reports test-retest reliability as high as .82 (Harrison, Buxton, Husain, & Wise, 2000). Similarly, for semantic or category fluency participants are asked to name as many animals as possible in a one-minute time period, with test-retest reliability around .68 (Harrison et al., 2000). These tasks measure phonemic and semantic verbal fluency (Benton & Hamsher, 1976).

Rey-Auditory Verbal Learning Test (AVLT). The AVLT is a measure of auditory list-learning memory that consists of two 15-item word lists (Rey, 1964**)**. Five initial learning trials are presented, with a total learning score calculated by adding trials 1 through 5. After a 30-minute delay, long-delay free recall and a forced choice recognition trial are administered. The AVLT has modest test-retest reliability at one year (up to .70) and correlates significantly with other measures of learning (> .50; see Lezak, Howieson, Bigler, & Tranel, 2012).

WMS-R Logical Memory I and II. Logical memory is a test of contextual auditory memory that consists of two stories, each containing 25 items of information. For Logical Memory I participants are asked to immediately recall the passages after each reading to assess verbal memory, while Logical Memory II asks for a recall of the passages approximately 30-minutes later. Reliability estimates are .74 for Logical Memory I and .75 for Logical Memory II (Wechsler, 1987).

Data Analysis

All demographic information and neuropsychological test result data were analyzed using independent-samples (between OCD and control groups) *t*-tests with Cohen's *d* presented as an estimate of effect size. An arcsine transformation was applied to error rates to satisfy the normality assumption for subsequent analyses (Neter, Wasserman, & Kutner, 1990) and only median reaction times of correct responses were used to reduce the effects of outliers common in RT data (Ratcliff, 1993). If Levene's test for equality of variances (Levene, 1960) indicated variance inequalities between groups, an adjusted *p*-value accounting for the inequality was reported.

Data from the computerized tasks were analyzed using repeated measures analyses of variance (ANOVAs) and subsequent planned contrasts. For all ANOVAs, corrected *p*-values

using the Huynh-Feldt epsilon adjustment were reported when there were more than two levels of a within-subjects factor to correct for possible sphericity violations (Huynh & Feldt, 1976); effect sizes were reported using partial η^2 (η_p^2). For the cued-Stroop task, we conducted a 2 (Group) x 2 (Delay) x 3 (Condition) repeated measures ANOVA. We used planned between-subject *t*-test comparisons to (a) verify the Stroop effect and (b) determine the RT interference score (Perlstein et al., 2006; Seignourel et al., 2006). For the first goal, we conducted independent-samples *t*-test of both RTs and error rates in the incongruent and neutral conditions for each group. For the second goal, we computed the RT interference score separately for each delay by subtracting performance in the neutral condition from performance in the incongruent condition and conducted group analyses of this interference score and of error rates in the incongruent condition. Sensitivity analysis indicates that, given the aforementioned analyses and number of participants, with $\alpha = .05$, power = .80, and a correlation between measures of .50, the present study was powered to detect a medium Cohen's *f* effect size of $f = 0.29$, $\eta_p^2 = .08$.

For the AX-CPT task, a 2 (Group) x 2 (Delay) x 4 (Condition) repeated measures ANOVA was conducted, with error rates (misses and false alarms), signal detection indices (*d'* and *d'* context), and RTs serving as dependent variables. A modified version of *d'* was calculated using only AX hits and BX false alarms and is referred to as "*d'* context." This measure of signal detection provides a more specific index of sensitivity to context than traditional computation of *d'* by indicating the participant's ability to distinguish between target and non-target trials based on the cue (Cohen et al., 1999; Servan-Schreiber et al., 1996). Sensitivity analysis conducted using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) with $\alpha = .05$, power = .80, and a correlation between measures of .50 indicated that, given

these statistical analyses and number of participants, the study had sufficient power to detect a medium Cohen's *f* effect size of $f = 0.27$, $\eta_p^2 = .07$.

Results

Self-Report Questionnaires and Neuropsychological Functioning

Results from measures of emotional functioning, OCD symptomology, and neuropsychological functioning are presented in Table 2. Participants with OCD, compared to healthy controls, scored significantly higher on the BDI-II, $t = -8.19$, $p < .001$, STAI State, $t = -5.82$, $p < .001$, STAI Trait, $t = -10.35$, $p < .001$, and OCI-R, $t = -8.08$, $p < .001$. Scores on the Y-BOCS (*Mdn* = 18, *M* = 18.13, *SD* = 6.37, range = 5-29) indicate that severity of OCD symptoms for participants with OCD ranged from subclinical to severe, with the average and median scores in the moderate range. Although one participant with OCD scored in the subclinical range on the Y-BOCS, he still met criteria for OCD per the SCID-I[1]. Participants with OCD and healthy controls showed no statistically significant differences in performance on the measures of neuropsychological functioning.

[1] Re-running all major analyses excluding this participant did not change the significance of the results presented.

Table 2
Self-Report Questionnaires and Neuropsychological Functioning Data for Controls and Participants with OCD

Characteristic	Controls Mean(*SD*) (*n* = 30)	OCD Mean(*SD*) (*n* = 31)	*t*	*p*	Cohen's *d*
BDI-II	3.73(4.17)	21.13(11.04)	-8.19(38.65)	<.001	2.09
STAI State	29.57(6.55)	43.16(11.18)	-5.82(48.70)	<.001	1.49
STAI Trait	31.67(5.40)	54.77(11.16)	-10.35(43.65)	<.001	2.63
OCI-R Total	8.43(6.49)	28.13(11.87)	-8.08(46.78)	<.001	2.05
YBOCS Total		18.13(6.37)			
AVLT Total Recall	57.00(8.40)	55.52(7.19)	0.74	.46	0.19
AVLT Short Delay Recall	12.03(2.63)	11.65(2.85)	0.55	.58	0.11
AVLT Long Delay Recall	11.93(2.82)	11.52(2.95)	0.56	.58	0.14
Digit Span Total	20.23(3.52)	19.61(3.44)	0.70	.49	0.17
Digit Span Forward	11.60(1.99)	11.32(1.85)	0.56	.58	0.15
Digit Span Backward	8.63(2.27)	8.29(2.33)	0.58	.56	0.13
Verbal Fluency					
Letter Total	43.80(8.76)	44.52(11.09)	-0.28	.78	0.07
Category Total	22.80(6.48)	24.00(5.15)	-0.80	.43	0.21
Trails A in seconds	18.37(5.96)	20.92(7.47)	-1.47	.15	0.37
Trails B in seconds	45.80(14.38)	52.70(36.33)	-0.97	.34	0.25
NAART Errors[a]	22.03(5.76)	21.32(6.27)	0.46	.65	0.12
FSIQ Estimate	110.61(4.49)	111.17(4.89)	-0.46	.65	0.13
VIQ Estimate	109.09(5.13)	109.72(5.58)	-0.46	.65	0.11
Card Stroop					
Color-Word Total[b]	55.03(9.71)	50.73(9.37)	1.73(57)	.09	.45
Word Total[c]	112.83(12.33)	114.14(12.97)	-0.39(55)	.70	.10
Color Total[c]	84.03(11.03)	80.50(11.12)	1.20(55)	.23	.32
Logical Memory I and II Total[d]	60.37(13.09)	58.87 (13.73)	0.43(58)	.67	0.11

Notes. BDI-II = Beck Depression Inventory, 2nd edition; STAI = State-Trait Anxiety Inventory; OCI-R = Obsessive Compulsive Inventory – Revised; AVLT = Auditory Verbal Learning Test; NAART = North American Adult Reading Test; FSIQ Estimate = Full Scale IQ estimate based on number of NAART errors; VIQ Estimate = Verbal IQ estimate based on number of NAART errors
[a]Raw scores. [b]One participant with OCD's card Stroop Color-Word Total was not recorded. [c]Three participants with OCD's card Stroop Word Totals and Color totals were not recorded. [d]One participant with OCD was not given Logical Memory II.

Cued-Stroop

Verification of Stroop RT interference. For the color-naming condition, healthy control participants showed robust differences in RTs between the incongruent and neutral conditions at both the short delay, $t(28) = 10.72$, $p < .001$, and long delay $t(28) = 10.31$, $p < .001$, with longer RTs in the incongruent condition than the neutral condition. Participants with OCD showed

similar results for both the short delay $t(30) = 9.85$, $p < .001$, and the long delay $t(30) = 10.10$, $p < .001$. Healthy controls, $t(28) = -1.68$, $p = .10$, and participants with OCD, $t(30) = -1.80$, $p = .08$ did not show an effect of delay on the extent of interference.

RT. A summary of RTs by group, congruency, and delay can be seen in Table 3. Examination of RTs showed no difference between controls and participants with OCD on trial type, $F(1.73,100.33) = .09$, $p = .89$, $\eta_p^2 = .002$, delay, $F(1,58) = .56$, $p = .46$, $\eta_p^2 = .01$, or interaction of trial type and delay $F(1.93,111.88) = .79$, $p = .45$, $\eta_p^2 = .01$.

Table 3
Mean reaction times (ms) and error rates (%) for controls and participants with OCD on the color-naming and word-reading condition of the cued-Stroop task

	Color naming task		Word reading task	
	Controls (n = 29)	OCD (n = 31)	Controls (n = 29)	OCD (n = 31)
RT (ms)				
Short delay				
Congruent	691.8(164.7)	671.5(140.4)	738.7(167.0)	703.1(179.8)
Neutral	684.5(150.0)	683.1(143.1)	753.5(196.4)	710.7(198.0)
Incongruent	941.4(247.8)	921.4(192.6)	879.9(217.1)	852.9(228.2)
Long delay				
Congruent	796.8(222.0)	756.9(167.8)	843.0(232.9)	798.3(201.5)
Neutral	788.5(217.6)	749.6(202.8)	796.0(204.4)	777.5(208.4)
Incongruent	1029.6(277.9)	1010.2(250.8)	991.8(267.3)	959.4(248.4)
Error rates (%)				
Short delay				
Congruent	2.29(3.04)	5.41(9.44)	1.15(3.00)	2.88(5.58)
Neutral	4.20(3.68)	6.42(6.64)	3.30(3.92)	4.60(7.88)
Incongruent	12.8(8.84)	17.3(14.8)	8.21(8.42)	11.9(13.2)
Long delay				
Congruent	2.81(4.94)	4.46(6.22)	2.85(4.74)	2.64(5.64)
Neutral	4.60(4.78)	6.35(7.96)	5.03(8.37)	5.54(8.40)
Incongruent	13.6(12.4)	17.5(12.8)	12.1(11.9)	13.2(12.5)

Error rates. A summary of error rates by group, congruency, and delay can be seen in Table 3. Examination of error rates showed no difference between controls and participants with

OCD on trial type, $F(1.37,79.40) = .70$, $p = .65$, $\eta_p^2 = .01$, delay, $F(1,58) = .68$, $p = .41$, $\eta_p^2 = .01$, or interaction of trial type and delay $F(2,116) = .12$, $p = .88$, $\eta_p^2 = .002$.

In summary, both participants with OCD and healthy controls showed robust RT interference for the cued-Stroop task, with longer RTs in the incongruent condition compared to the neutral condition, and the two groups did not differ in the extent of interference. There were no differences in either RT or error rates on trial type, delay, or interaction of trial type and delay between healthy controls and participants with OCD.

AX-CPT

***d'* and *d'* context.** For *d'*, controls and participants with OCD did not differ significantly, $t(53) = 0.25$, $p = .81$. Similarly, for *d'* context, controls and participants with OCD did not differ significantly, $t(53) = -0.36$, $p = .72$. For *d'* context at the short delay, healthy controls and participants with OCD did not differ significantly, $t(53) = -.16$, $p = .87$. For *d'* context at the long delay, healthy controls and participants with OCD did not differ significantly, $t(53) = -.01$, $p = .99$.

Table 4
d' and d' context for the AX-CPT task

Measure	Controls	OCD	*t* df = 52	*p*
d'	3.23(0.88)	3.16(0.91)	0.26	.79
d' context	3.06(1.01)	3.17(0.91)	-0.41	.69
d' context, short delay	3.16(0.74)	3.20(0.89)	-0.20	.98
d' context, long delay	2.70(1.21)	2.71(1.05)	-0.03	.84

RT. A summary of RTs by group, trial type, and delay can be seen in Table 5. Examination of RTs showed no difference between controls and participants with OCD on trial type, $F(1.93,98.28) = 1.10$, $p = .33$, $\eta_p^2 = .02$, delay, $F(1,51) = 3.04$ $p = .09$, $\eta_p^2 = .06$, or interaction of trial type and delay, $F(1.70,86.55) = 2.39$, $p = .11$, $\eta_p^2 = .05$.

Error rates. Compared to BY trials, participants had significantly more errors on BX trials, $t(54) = -5.42$, $p < .001$, and AY trials, $t(54) = -2.21$, $p = .03$, but not AX trials, $t(54) = 0.01$, $p = .99$. Additionally, compared to AX trials, participants made significantly more errors on AY trials $t(54) = -.06$, $p = .001$, but not BX trials, $t(54) = -.05$, $p = .09$. A summary of error rates by group, trial type, and delay can be seen in Table 5. Examination of error rates showed no difference between controls and participants with OCD on trial type, $F(1.54,81.42) = .3.03$, $p = .07$, $\eta_p^2 = .05$, delay, $F(1,53) = .05$, $p = .83$, $\eta_p^2 = .001$), or interaction of trial type and delay, $F(1.92,101.79) = .53$, $p = .46$, $\eta_p^2 = .01$).

Table 5
Means (and Standard Errors) for AX-CPT Task Performance, as a Function of Delay

Measure	Controls	OCD
	Reaction Time (ms)	
	Short Delay	
AX	349.4(94.8)	350.1(120.0)
AY	534.0(122.1)	489.4(133.6)
BX	423.1(179.8)	366.5(244.1)
BY	366.5(123.1)	330.6(131.8)
d' context	3.16(0.74)	3.20(0.89)
	Long Delay	
AX	387.7(84.6)	389.5(117.9)
AY	580.0(140.2)	538.4(121.6)
BX	394.4(115.7)	421.3(188.6)
BY	404.3(124.6)	377.7(133.9)
d' context	2.70(1.21)	2.71(1.05)
	Error Rate (%)	
	Short Delay	
AX	2.77(2.84)	3.74(3.85)
AY	7.02(11.2)	12.4(17.1)
BX	14.4(31.7)	5.10(8.47)
BY	10.1(31.6)	2.54(5.19)
	Long Delay	
AX	8.12(11.1)	11.7(16.2)
AY	14.7(11.7)	17.9(18.2)
BX	20.4(41.6)	10.7(16.2)
BY	9.85(27.8)	5.75(14.2)

Discussion

The goal of the current study was to test for potential differences in context maintenance between participants with OCD and psychiatrically-healthy control participants through the use of the cued-Stroop and AX-CPT tasks. People diagnosed with OCD often show altered neural activity in areas such as the OFC, ACC, dlPFC, and thalamus (Melloni et al., 2012; Rachman, 1997, 2002; Salkovskis, 1985) and have difficulty with certain cognitive tasks, including planning, shifting, and inhibition (Abramovitch & Cooperman, 2015). This altered neural activity and poorer performance on cognitive tasks may reflect impaired cognitive control, and more specifically, context maintenance (Braver et al., 1999). Determining whether people with OCD show problems with context maintenance could help us understand why people with OCD show difficulty with cognition, how context maintenance contributes to their functional impairment, and how we may better curate treatments for OCD.

Although it is well documented that people with OCD often have difficulty on measures of neuropsychological and executive functioning (Abramovitch & Cooperman, 2015; Snyder et al., 2015), our sample did not differ significantly on any of these cognitive measures. Specifically, the two groups performed similarly on tests of working memory, switching, and inhibition. The absence of differences on these measures of cognitive function eases interpretation of results by eliminating the possibility that potential differences in performance on the cued-Stroop and AX-CPT are due to generalized deficits in cognitive functioning; however, it may also indicate that our sample is higher functioning than the general population with OCD.

We hypothesized that people with OCD compared to healthy controls would show impaired context maintenance on both tasks by taking longer to respond on trials that maximize

the demand for context maintenance. Specifically, for the cued-Stroop task, we predicted that participants with OCD will have greater RTs on incongruent trials at the long delay for color-naming trials than healthy controls. For the AX-CPT task, we predicted that participants with OCD will have greater RTs on AY and BX trials at the short delay, greater RTs on AX and BX trials at the long delay, and similar or shorter RTs for AY trials at the long delay compared to healthy controls.

Analyses of RT interference on the cued-Stroop task indicates that participants showed the expected pattern of performance, with longer RTs and greater error rates on incongruent vs. neutral and congruent trials at both delays. However, participants with OCD did not differ from healthy controls in either RTs or error rates on the cued-Stroop for trial type, delay, or the interaction of trial type by delay. Additionally, for the AX-CPT, participants had significantly fewer errors on BY trials than BX and AY trials, but not AX trials, which may be due to good attention during the task and lower error rates on AX trials rather than higher error rates on BY trials. However, participants with OCD did not differ from healthy controls in either RTs or error rates for trial type, delay, or the interaction of trial type by delay. The results potentially suggest that the sample does not have difficulty with context maintenance.

Since our sample of people with OCD do not show decreased performance on tasks measuring context maintenance, this implies that context maintenance is not primarily responsible for possible difficulties in neuropsychological performance (although there were no difficulties in neuropsychological performance in the current sample), and specifically executive functioning. Additionally, findings suggest that context maintenance would not be a likely target in the treatment of OCD.

Originally, research suggested that a deficit in context maintenance was a specific marker of schizophrenia, as healthy controls and participants with depression did not show the same pattern of performance on the cued-Stroop and AX-CPT (Cohen et al., 1999). Since then, studies have shown that there are indeed differences in a variety of populations compared to healthy controls, with worse performance in people with ADHD (N = 78), borderline personality disorder (N = 78), bipolar disorder (N = 41), and traumatic brain injury (N = 70) and improved performance in people that are bilingual (N = 44; Brambilla et al., 2007; Larson et al., 2006; Morales et al., 2013; Servan-Schreiber et al., 1996; van Dijk et al., 2014). However, null findings have been published for people with autism and depression, suggesting that there are still some psychiatric groups that do not seem to be affected by problems with context maintenance (Cohen et al., 1999; Hogeveen, Krug, Elliott, Carter, & Solomon, 2018). Despite the findings of poorer context maintenance in these populations, results are based largely on single studies and often have some results that are contradictory to hypotheses based on cognitive control and context maintenance theory.

Studies show that people with OCD tend to have overactive performance monitoring (Abramovitch & Cooperman, 2015; Nawani et al., 2018; Reisel et al, 2017). Because of this heightened performance monitoring, participants with OCD rarely show significant differences in error rates on tests of neuropsychological measures when compared to healthy controls. The similar error rates in the aforementioned studies are consistent with our results both on neuropsychological measures as well as the cued-Stroop and AX-CPT tasks. The overactive performance monitoring seen in those with OCD may have been responsible for the null results in our study by allowing participants to overcome any potential deficits in context maintenance.

Another recent study investigating cognitive inflexibility in OCD found that adolescents with OCD may be better than controls at reusing previously abandoned task rules when appropriate (Wolff, Giller, Buse, Roessner, & Beste, 2018). Many cognitive tests measure the ability of people to process and utilize new task rules, from tests measuring set shifting to subtests that vary rules with each new condition, but do not report on how people do with repeating task rules. Thus, in a task such as the cued-Stroop and the AX-CPT where the cue is ever-changing but ultimately repeating (i.e., indicate the word or the color; an "A" or a non-"A" cue), it may be that people with OCD are more likely to perform similarly to healthy controls, rather than exhibiting the problems in context maintenance that were expected.

A recent study revealed that engagement in cognitive control on the AX-CPT task activates the anterior insula and ventrolateral prefrontal cortex (vlPFC; Ryman et al., 2019). Many studies of neural activity in OCD do not implicate the vlPFC but rather the dlPFC both at rest and during cognitive tasks (Maltby et al., 2005; Melloni et al., 2012; van den Heuvel et al., 2005). It may be that since cognitive control seems to require activity from the vlPFC, those with OCD may not show problems in cognitive control and context maintenance.

Despite the absence of between-group differences in context maintenance that was contrary to our hypotheses, the current study has many strengths and puts forth more information on cognition in OCD. As noted above, context maintenance has been tested in many psychiatric populations including people with attention-deficit/hyperactivity disorder, borderline personality disorder, depression, schizophrenia, and traumatic brain injury, but has not been tested in people with anxiety or OCD (Larson et al., 2006; Msetfi et al., 2009; Servan-Schreiber et al., 1996; van Dijk et al., 2014). Our sample of participants with OCD also, on average, had moderate severity of OCD (M = 18.13; Mdn = 18), providing a better picture of potential deficits in context

maintenance than would a sample with only mild or only severe OCD. Additionally, the present study used two separate tasks to detect problems with context maintenance, both of which showed no differences between participants with OCD and healthy controls.

However, this study is not without its limitations. Although the two groups performed similarly on measures of neuropsychological functioning, the participants with OCD had significantly higher scores on the BDI-II, STAI State, and STAI Trait measures, indicating that the OCD group had higher levels of depression and anxiety than the healthy controls. Despite the significantly higher scores on depression and anxiety measures, some studies show that people with depression tend to perform similarly to controls on cognitive control tasks (Cohen et al., 1999; Holmes et al., 2005) and anxiety symptomatology did not correlate with AX-CPT measures in a study of participants with TBI (Larson et al., 2006). Furthermore, our sample showed moderate levels of OCD symptom severity, but is considered overall to be a high functioning group since most participants were undergraduate students at a private university. Additionally, our sample was predominantly Caucasian, emerging adults, limiting the generalization to other age and ethnic groups. Lastly, sensitivity analyses indicate that the present study would have required a moderate effect size in order to detect between-group differences, leading to an increased probability of Type II error. Upon further investigation, given the effect sizes produced during this study, it would have required a sample size of 482 for the cued-Stroop and 74 for the AX-CPT to detect difficulties in context maintenance, showing that any differences may not be clinically meaningful.

Future studies may want to investigate whether difficulties with context maintenance exist in people with severe OCD and a larger sample size to decrease the probability of Type II error. It may also be worth investigating the specific clinical correlates of context maintenance

in addition to performance on tasks measuring context maintenance. Additionally, further investigation into whether the presence of context maintenance difficulties exist in other related populations, such as generalized anxiety disorder and posttraumatic stress disorder, may be beneficial.

In summary, the present study aimed to determine whether people with OCD exhibited problems with context maintenance through the use of two tasks designed to measure context maintenance, the cued-Stroop and the AX-CPT. Results indicate that the current sample of people with OCD did not perform differently than healthy controls on either task, even on trials that maximize the demand for context maintenance. Thus, the results of our study potentially indicate that people with OCD are not impaired in context maintenance, although further research across a range of OCD severity is necessary.

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