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A Neurocognitive Comparison of Pediatric Obsessive-Compulsive Disorder and Trichotillomania (Hair Pulling Disorder)

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Abstract

Obsessive-compulsive disorder (OCD) and trichotillomania (hair pulling disorder, HPD) are both considered obsessive-compulsive and related disorders due to some indications of shared etiological and phenomenological characteristics. However, a lack of direct comparisons between these disorders, especially in pediatric samples, limits our understanding of divergent versus convergent characteristics. This study compared neurocognitive functioning between children diagnosed with OCD and HPD. In total, 21 children diagnosed with HPD, 40 diagnosed with OCD, and 29 healthy controls (HCs), along with their parents, completed self−/parent-report measures and a neurocognitive assessment battery, which included tasks of inhibitory control, sustained attention, planning, working memory, visual memory, and cognitive flexibility. A series of analyses of variance (or covariance) indicated significant differences between groups on tasks examining planning and sustained attention. Specifically, children in both the OCD and HPD groups outperformed HCs on a task of planning. Further, children with OCD underperformed as compared to both the HPD and HC groups on a task of sustained attention. No between group differences were found with respect to tasks of reversal learning, working memory, spatial working memory, visual memory, or inhibitory control. The implications these findings may have for future, transdiagnostic work, as well as limitations and future directions are discussed.

Keywords Children · Obsessive-compulsive disorder · Trichotillomania · Neurocognitive functioning

The current version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) created a new category of Obsessive-Compulsive and Related Disorders (OCRDs) that includes obsessive-compulsive disorder (OCD), excoriation

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disorder, and trichotillomania (hair pulling disorder; HPD; American Psychiatric Association [APA] 2013) among others. Most researchers appear to agree that OCRDs fall along a continuum of impulsivity and compulsivity, with particular disorders varying in degrees of each (Adams 2012; Fineberg et al. 2010; Hollander et al. 2016). However, others have questioned this category, arguing for a fine-grained review of processes underlying symptoms (Abramowitz and Jacoby 2015). As such, research seeking to better delineate the shared and unique pathophysiology within the OCRDs may inform future transdiagnostic research and targets for intervention. The primary aim of the current study was to begin to address a gap in the literature - neurocognitive similarities and differences between pediatric OCD and HPD.

Despite some shared characteristics including estimated prevalence rates from 1 to 3% and a late childhood age of onset, pediatric HPD and OCD are separated by distinct symptomology (Abramowitz and Jacoby 2015; APA 2013; Tanidir et al. 2015). Pediatric HPD is characterized by repeatedly pulling out one's hair, resulting in hair loss (APA 2013). Two styles of hair pulling, focused and automatic, have been examined and found to frequently coexist (Flessner et al. 2007; Flessner et al. 2016). Focused pulling occurs intentionally and may serve to decrease anxiety or provide gratification. In contrast, automatic pulling occurs out of one's awareness so that a person may not realize he/she is pulling until after the behavior has occurred. Pediatric OCD is characterized by intrusive thoughts (obsessions) and compensatory ritualistic behaviors (compulsions) that cause high levels of distress and impairment in daily functioning (APA 2013; Tanidir et al. 2015). In addition, the function of OCD and HPD symptoms differ. While fear-provoking obsessions commonly serve as a trigger for compulsions, pulling in HPD is often triggered by other emotions (e.g., boredom). Further, the pleasurable experience that can result from pulling in HPD is nonexistent in OCD (Abramowitz and Jacoby 2015). The divergence in clinical symptomatology and function is suggestive of distinct characteristics that may underlie differences in neurocognitive functioning. However, direct comparisons of neurocognitive performance in OCD and HPD, both in pediatric and adult samples, are scarce in the literature. Within adult samples, previous literature has indicated that there may be deficiencies in motor inhibition in both patients diagnosed with OCD and HPD, suggesting at least a partial explanation for the repetitive behaviors seen in both disorders (Chamberlain et al. 2006).

An extensive body of research has examined the neural correlates of OCD and HPD. While the associated neurobiological structures vary, research has supported the involvement of the orbitofrontal cortex and the anterior cingulate cortex in both disorders (ACC; Chamberlain et al. 2010; Graybiel and Rauch 2000; Roos et al. 2015). As such, youths with OCD have shown differences in ACC volume and density compared to HCs (Maia et al. 2008). Given previous evidence for an association between ACC volume, emotion regulation, and performance on attentional tasks, it follows that volumetric discrepancies in this area may be related to several of the well documented characteristics of OCD (i.e., deficits in self-regulation and attentional control; Maia et al. 2008; Posner et al. 2007). Similarly, in adults with HPD, studies have indicated differences in brain regions including the frontal lobe (Chamberlain et al. 2008) and the ACC (Chamberlain et al. 2010). It is possible that abnormalities in the above-mentioned areas could predict lowered performance on tasks including cognitive flexibility, planning, inhibitory control, and working memory, together often falling under the broader term of executive functioning (EF; Funahashi and Andreau 2013; Morton 2010).

The vast majority of what is understood in relation to the neurocognitive correlates of HPD is derived from adult samples. One meta-analytic review examined the neurocognitive features of adult HPD. Across studies, sample sizes of the HPD group ranged from 11 to 111 ($M = 27.56$, $SD = 24.39$). Results indicated normative performance on tasks of visual and verbal abilities, attention, planning, problem solving, and decision making (Slikboer et al. 2017). In areas including working memory, set shifting, divided attention, inhibitory control, spatial memory, and processing speed, single studies found significant differences between groups while others were unable to replicate findings, illustrating the need for additional research in this area (Slikboer et al. 2017). To our knowledge, only two studies have examined neurocognitive functioning in pediatric HPD. Together, these studies demonstrated impairments in planning and reversal learning, comparably stronger performance in relation to inhibitory control, and no differences with respect to cognitive flexibility and working memory among patients with HPD as compared to HCs (Flessner et al. 2016). Additional research is necessary in order to develop a better understanding of the neural and developmental correlates of pediatric HPD.

Evidence for neurocognitive deficiencies related to pediatric OCD have been similarly inconsistent. Recently, Abramovitch et al. (2015) conducted a meta-analysis examining effect sizes across 11 studies comparing neurocognitive functioning in pediatric OCD and HCs (Abramovitch et al. 2015). Results indicated that children with OCD underperformed controls in most domains including planning, inhibitory control, cognitive flexibility, memory, processing speed, visuospatial abilities, and working memory; however, across studies, these effects were small in magnitude and none were statistically significant (Abramovitch et al. 2015). In a more recent study, Geller et al. (2017) found that children with OCD underperformed HCs on tasks where speed was a factor, (i.e., tests of processing speed, timed tasks of motor ability, etc.) but failed to demonstrate any differences when speed was not a factor. This implies that slower processing speed may be

implicated in OCD and underlie other neurocognitive deficiencies (Geller et al. 2017). Additionally, a study comparing EF in children with OCD, children with generalized anxiety disorder, and HCs found that children with OCD had difficulties on tasks of planning. Specifically, these children demonstrated impaired planning efficiency compared to other groups (Kim et al. 2019).

In the two studies comparing neurocognitive factors associated with OCD and HPD in adults, specific differences were observed. In one case, results indicated no significant differences in performance between participants with OCD, HPD, and HCs on tasks of visuospatial abilities, memory, and organization. However, significant differences did emerge on a task requiring response flexibility (Bohne et al. 2005). Specifically, participants with HPD underperformed those with OCD. In contrast, on a task requiring learning from feedback (i.e., reversal learning), participants with OCD underperformed those with HPD. A more recent study, utilizing an automated cognitive test battery, found that both participants with OCD and HPD underperformed HCs on tasks of spatial working memory; however, only participants with OCD showed deficits on tasks of strategy, attentional flexibility, planning, and visual pattern recognition memory (Chamberlain et al. 2007). Analogous research in pediatric populations of patients with OCD or HPD is, to date, nonexistent (See Table 1 for a review of relevant prior literature).

Based on previous neurocognitive comparisons, it appears that patients with OCD and HPD demonstrate both similarities (i.e., spatial working memory) and differences (i.e., strategy, attentional flexibility, planning, visual pattern recognition, reversal learning, and cognitive flexibility) with respect to neurocognitive profiles. However, these results are tentative due to the limited breadth of literature in pediatric populations. The current study begins to address an important gap in the literature by comparing neurocognitive functioning in HCs, children with OCD, and children with HPD. Based upon prior (albeit limited) research comparing patients with OCD to those with HPD, it was hypothesized that groups would differ in their reaction times on a task of inhibitory control, with the HC group having the shortest reaction time, followed by OCD, and finally HPD (Brennan et al. 2016; Flessner et al. 2016). Groups were also hypothesized to differ in performance on tasks of cognitive flexibility and planning, with the OCD group showing the lowest success rate (Bohne et al. 2005; Chamberlain et al. 2007). On a task of working memory and spatial working memory, it was hypothesized that both OCD and HPD groups would underperform HCs (Chamberlain et al. 2007). Finally, on a task of sustained attention, it was hypothesized that there would be no group differences (Chamberlain et al. 2007). Given indications of common comorbidities (e.g., depression, anxiety, ADHD) and the use of psychotropic medications within this population, these variables were theorized to differ between groups, and potentially impact outcomes (Kempton et al. 1999; Peris et al. 2017; Walther et al. 2014). As such, psychotropic medication use, along with anxiety, depressive, and inattentive symptoms were considered as covariates in the current study's hypotheses.

Method

Participants

Participants were recruited at two sites located within Northeastern Ohio (Site 1) and Rhode Island (Site 2) via newspaper advertisements, fliers, letters to pediatricians, and/or clinical referrals as part of a larger study examining risk factors for the development of pediatric anxiety and related problems. For the purposes of the larger study, recruited participants included those with concerns about anxiety symptoms, other related concerns (e.g., OCD, HPD), or healthy controls. Prior to enrolling participants, both sites obtained Institutional Review Board approval. For the purposes of the current study, participants were included in all subsequent analyses and included in the HC group if the child (1) was between 7 and 17 years of age, (2) did not meet diagnostic criteria for any psychiatric condition, (3) reported English as their primary language, and (4) completed all study measures described below. Participants were included in all subsequent analyses and included in symptoms groups if the child met criteria 1, 3, and 4 above, and met DSM-5 diagnostic criteria for HPD or OCD (but not both). Additionally, participants were excluded from analyses if they a) were previously diagnosed with a developmental disorder or b) met criteria for major depressive disorder. For these analyses, a total of 21 children met DSM-5 criteria for a diagnosis of HPD, 40 met criteria for OCD, and 29 met criteria for HC, as assessed via clinical diagnostic interview. Due to Site 2's focus as an outpatient clinic with an emphasis on the evidence-based assessment and treatment of pediatric OCD, neither HCs nor children with a diagnosis of HPD were recruited at this site. Demographic, as well as phenomenological characteristics for the combined and site-specific samples are presented in Table 2. No statistically significant differences were found, by site, with respect to demographic characteristics. Differences with respect to phenomenological characteristics are denoted in Table 2 as well as below (see *Data Analytic Plan*).

A subset of the analyses presented in this study have been reported elsewhere. Specifically, a portion of participants included in the HPD and HC groups have been included in two previous studies examining inhibitory control and EF (Brennan et al. 2016; Flessner et al. 2016). Similarly, a portion of participants included in the OCD group have also been previously reported in a study which compared the cognitive

Table 1 Summary of relevant neurocognitive findings

Authors	Sample	Domains	Results
Slikboer et al. 2017	Adult HPD	Processing speed, attention, memory, verbal ability, visual ability, EF, motor functions, and somatosensory function	• Mixed evidence for deficits in processing speed, memory, divided attention, set shifting, cognitive inhibition, and suppression of automatic motor reactions.
Flessner et al. 2016	Pediatric HPD	Cognitive flexibility/reversal learning, planning/organization, and working memory	• Deficits on measures of reversal learning and planning/organization.
Abramovitch et al. 2015	Pediatric OCD	Planning, response inhibition/interference control, set shifting/cognitive flexibility, verbal memory, nonverbal memory, processing speed, working memory, visuospatial functions, and attention	• No statistically significant deficits.
Geller et al. 2017	Adult OCD & HPD	Processing speed, visuospatial abilities, working memory, non-verbal working memory, and EF	• Deficits among participants with OCD in processing speed, working memory, visuospatial abilities.
Bohne et al. 2005	Adult OCD & HPD	Visuospatial abilities, memory, and EF	• Deficits in OCD on planning and learning from feedback. • Deficits in HPD on response flexibility.
Kim et al. 2019	Pediatric OCD & GAD	Working memory, planning ability/efficiency, cognitive flexibility, and visuospatial memory	• Deficits in planning abilities.
Chamberlain et al. 2007	Adult OCD & HPD	Affective processing, decision making, impulsivity, learning, memory, and EF	• Deficits in both OCD and HPD on spatial working memory tasks. • Additional deficits in OCD on planning, visual pattern recognition memory, and affective Go Nogo tasks.

performance of children with OCD and children with GAD (Kim et al. 2019). Despite these previous studies, a neurocognitive comparison of OCD and HPD has yet to be conducted.

Measures

Structured Interview for DSM Diagnoses. Participants completed either the Kiddie-Schedule for Affective Disorders and Schizophrenia – Present and Lifetime Version (K-SADS-PL; Ambrosini 2000) or the Anxiety Disorders Interview Schedule for DSM-IV: Child Version (ADIS-C; Silverman and Albano 1996). Previous research has indicated that the ADIS-C demonstrates excellent test-retest reliability while the K-SADS-PL demonstrates good to excellent test-retest reliability. Additionally, both interviews yield comparable diagnostic information (Ambrosini 2000; Kaufman et al. 1997; Merlo et al. 2005; Silverman and Nelles 1988; Silverman et al. 2001; Wood et al. 2002).

Trichotillomania Diagnostic Interview (TDI; Rothbaum and Ninan 1994). The TDI is a semi-structured diagnostic interview designed to assess HPD symptoms in both youths and adults (Diefenbach et al. 2005). As neither the K-SADS-PL or ADIS-C contain HPD modules, the TDI was used for purposes of ascertaining a diagnosis of HPD. At the time this study began, DSM-5 diagnostic criteria had not yet taken effect; however, all participants included in the present study would have met both DSM-IV-TR and DSM-5 criteria for HPD. To meet criteria for a diagnosis of HPD, participants were required to respond affirmatively to items from the TDI aligned with DSM diagnostic criteria for HPD.

Children's Yale-Brown Obsessive-Compulsive Scale (CY-BOCS; Goodman et al. 1991). The child version of the Yale-Brown Obsessive-Compulsive Scale is a structured interview used to assess obsessive-compulsive symptoms and severity in children and adolescents. The CY-BOCS has demonstrated good internal consistency ($\alpha = 0.90$) and test-retest reliability (Storch et al. 2004). As such, the CY-BOCS was used to complement the K-SADS-PL/ADIS-C with regard to ascertaining OCD diagnostic status (i.e., duration of time spent engaging in obsessions/compulsions, impairment/distress).

Child Behavior Check List (CBCL; Achenbach 1991). The 112-item CBCL assesses a diverse array of emotional and behavioral problems in youths based upon parent-report. The CBCL has been shown to distinguish between community and clinical samples (Achenbach 1991; Achenbach and Edelbrock 1983; Jensen et al. 1996; Nakamura et al. 2009). Prior studies have also supported the use of the CBCL and its subscales as a diagnostic screener (Rishel et al. 2005). For the present study, the anxious/depressed, inattention, and depressed/withdrawn subscale scores were utilized as dimensional measures of anxiety, ADHD (i.e., inattention, impulsivity, combined), and depressive symptoms, respectively. This approach has been recommended by other researchers as an appropriate use of the CBCL subscales (Lampert et al. 2004).

Table 2 Demographic and clinical information

Variables	HCs		HPD		OCD	
	M	SD	M	SD	M	SD
Child Age	12.39	0.504	11.25	0.376	11.75	0.566
Child Anxiety[a,b]	53.83	7.34	61.81	8.44	60.93	12.78
Child Depression	53.66	5.46	57.00	6.77	51.99	11.98
Child Inattention[b,c]	51.86	3.16	65.67	13.35	48.49	13.61
CYBOCS Total[a,c]	0.522	1.12	3.88	6.37	20.25	7.97
CYBOCS Obsessions[a,c]	0.174	0.576	1.94	3.00	11.08	7.10
CYBOCS Compulsions[a,b,c]	0.3913	0.988	2.59	4.29	11.15	2.24
	%	N	%	N	%	N
Males	58.6%	17	33.3%	7	55.0%	22
Race/Ethnicity*						
Caucasian	93.1%	27	95.2%	20	40.0%	16
African American	6.9%	2	0.0%	0	2.5%	1
Hispanic/Latino	6.9%	2	19.0%	4	2.5%	1
Multi-racial	0.0%	0	0.0%	0	0.0%	0
Family Income*						
Under $10,000/year	0.0%	0	0.0%	0	2.5%	1
$10,000–$20,000/year	3.4%	1	0.0%	0	0.0%	0
$20,001–$30,000/year	6.9%	2	4.8%	1	10.0%	4
$30,001–$40,000/year	10.3%	3	0.0%	0	5.0%	2
$40,001–$50,000/year	10.3%	3	0.0%	0	2.5%	1
$50,001–$60,000/year	10.3%	3	14.3%	3	7.5%	3
Over $60,000/year	55.2%	16	76.2%	16	55.0%	22
Comorbidities						
Depressive Disorder NOS	0.0%	0	0.0%	0	7.5%	3
Panic Disorder	0.0%	0	0.0%	0	2.5%	1
PTSD	0.0%	0	4.8%	1	2.5%	1
Separation	0.0%	0	0.0%	0	7.5%	3
Phobia	0.0%	0	14%	3	7.5%	3
Social Phobia	0.0%	0	0.0%	0	15%	6
Enuresis	0.0%	0	0.0%	0	2.5%	1
Overanxious Disorder	0.0%	0	0.0%	0	2.5%	1
CD	0.0%	0	4.8%	1	0.0%	0
GAD	0.0%	0	28.6%	6	20%	8
ADHD	0.0%	0	38%	8	10%	4
ODD	0.0%	0	14%	3	2.5%	1
TS	0.0%	0	0.0%	0	12.5%	5
Chronic Tic Disorder	0.0%	0	4.8%	1	2.5%	1
Other	0.0%	0	14%	3	0.0%	0
Psychotropic*[a,b]	0.0%	0	38.1%	8	32.5%	13
Stimulant*[a]	0.0%	0	14%	3	30%	12
SSRI*[b]	0.0%	0	24%	5	7.5%	3
Site						
1: Northeast Ohio[a,c]	100%	29	100%	21	42.5%	17
2: Rhode Island[a,c]	0%	0	0%	0	57.5%	23

NOS Not otherwise specified, *PTSD* Posttraumatic Stress Disorder, *CD* Conduct Disorder, *GAD* Generalized Anxiety Disorder, *ADHD* Attention-Deficit/Hyperactivity Disorder, *ODD* Oppositional Defiant Disorder, *TS* Tourette's Syndrome, *SSRI* Selective Serotonin Reuptake Inhibitor

*Parent-report measure. Missing data is a result of participants choosing not to complete specific questions

[a] statistically significant difference between HC and OCD; [b] statistically significant difference between HC and HPD; [c] statistically significant difference between OCD and HPD

Cambridge Neurocognitive Test Automated Battery (CANTAB; Cambridge Cognition 2018).

The CANTAB is a touch screen computerized assessment battery examining cognitive functioning. The current study used six tasks from the battery. The CANTAB's executive functioning and processing speed subtests have shown a modest association with traditional neuropsychological subtests (Luciana 2003; Smith et al. 2013). Additionally, previous literature has demonstrated the CANTAB's ability to differentiate between clinical populations (De Luca et al. 2003; Rhodes et al. 2011; Robbins et al. 1994). Tests were administered in identical order and at an identical timepoint in the study protocol across both sites.

Pattern Recognition Memory (PRM) The PRM task measures visual pattern memory and takes approximately four minutes to administer. In the PRM task, participants are shown a series of consecutive patterns. Subsequently, participants are shown

two patterns, one new and one they have seen before. Participants are instructed to select the pattern they have seen before. The test is then repeated. Data is collected on response time and number of correct responses.

Stop Signal Task (SST) The Stop Signal Task is a computerized test of motor inhibition and takes 20 min to administer (Lawrence et al. 1998). Participants are instructed to push the button on the right side of a push pad when the arrow points to the right and the left button when the arrow points to the left. They are told to stop pressing either button when they hear a tone. Data is collected on stop signal response time, number of correct directional pushes, and number of successful stops.

Intradimensional/Extradimensional Task (IED) The IED is a computerized analogue of the Wisconsin Card Sorting test and is a task of cognitive flexibility and reversal learning which takes 7 min to administer. The participant is presented with two images and is instructed to choose one. Feedback is given as to whether the response was correct or incorrect, based on an unknown rule. Upon adequate understanding of the rule, the computer changes the rule. At block 6, the intradimensional set shift occurs. At block 7, intradimensional reversal learning occurs. At block 8, the participant is presented with novel shapes and lines; however, the rule is now dependent upon the line dimension rather than the shape dimension. At block 9, extradimensional reversal learning occurs. The primary outcomes of interest for the IED are total (adjusted) errors in Blocks 6 and 8 (cognitive flexibility/set shifting; Flessner et al. 2015) and Blocks 2, 5, 7 and 9 (reversal learning; Kim et al. 2019).

Stockings of Cambridge Task (SOC) The SOC is a computerized test of planning and takes 10 min to administer. Participants are instructed to move balls at the top of the screen to copy the pattern at the bottom of the screen. This task is followed by a motor control sequence in which the participant copies the movements of the computer by moving the balls in the order shown. Both tasks are repeated. Data is collected on the number of moves in each trial, initial response time, and subsequent response time.

Rapid Visual Information Processing (RVP) The RVP test is a measure of sustained attention and takes 6 min to administer. Participants are shown a series of numbers, one after another and are told to push a button when they see the target sequence (1,2,3). Data is collected on response time, false responses, and sensitivity to the target.

Spatial Span (SSP) The SSP is a computerized test of working memory and takes 5 min to administer. Participants are shown a screen filled with several white boxes. The participant is instructed to select boxes in the order they change color. Data is collected on response time, number of attempts, the longest sequence remembered, and number of errors.

Procedures

Institutional Review Boards at Kent State University and Brown University approved all procedures. Potential participants contacted a research assistant at either site and were provided with an overview of the methods, procedures, and aims of the current study. A brief phone screen was conducted to determine eligibility. Potentially eligible children and a parent/legal guardian completed measures mailed in advance to their homes including a demographic questionnaire (i.e., child age, medical history, psychological history, current medications, etc.) and several self- and parent-report measures. Upon arriving for their scheduled assessment, parents provided written informed consent and children provided verbal assent. Research staff, trained in the proper administration of the semi-structured and structured interviews by the second (site 1) and last (site 2) authors, administered these interviews jointly to the parent and child. Finally, all eligible children completed the CANTAB neurocognitive test battery including (in order of presentation) the PRM, SST, IED, SOC, RVP, and SSP. All testing with the child (diagnostic interviews and neurocognitive tasks) was completed within one session which did not exceed 3 h.

Data Analytic Plan, Preliminary Analyses, and Power Analysis Assumptions of analysis of variance (i.e., equal sample sizes, normality, homogeneity of variance) were examined and, in most cases, violated in regard to homogeneity of variance (i.e., within group variability in scores across groups differ). As such, raw scores were used for all analyses with appropriate corrections (i.e., Welch's test for violations in regard to homogeneity of variance) made as necessary. Selection of potential covariates were employed using a two-stage process. First, control variables were considered based upon an integration of prior literature with data collected as part of the present study and included child age, symptoms of anxiety, depression, and inattention (as assessed via the CBCL), and current psychotropic medication use. Second, preliminary analyses were conducted, and variables were selected as a covariate if they achieved a pre-determined level of statistical significance (i.e., $p \leq 0.01$) in relation to the particular outcome measure of interest. As such, only a subset of subsequent analyses utilized covariates and are identified as such when appropriate in the text as well as in Table 3.

Due to the multisite nature of this study, preliminary analyses were also conducted in relation to important variables that may differentiate the two study sites as well as in relation to the covariates mentioned above. Results of these analyses

revealed no site differences in relation to child age, family income, child anxiety, or current use of psychotropic medication; however, differences were noted in relation to symptoms of depression ($t = 3.095$, $p = 0.004$, Cohen's $d = 0.82$) and inattention ($t = 6.727$, $p < .001$, Cohen's $d = 1.63$) such that those youths enrolled at Site 1 demonstrated greater depressive ($M = 55.7$, $SD = 7.4$) and inattentive ($M = 58.0$, $SD = 10.7$) symptoms than those enrolled at Site 2 ($M = 47.7$, $SD = 11.7$; $M = 40.6$, $SD = 10.6$, respectively). It is possible that these differences may be attributed to differing recruitment patterns between sites. Additionally, in preliminary analyses comparing variables in relation to group membership, significant differences were noted in regard to the use of psychotropic medication ($\chi^2(2) = 13.26$, $p = 0.001$), symptoms of anxiety ($F = 5.09$, $p = 0.008$, $\eta^2 = 0.10$), and symptom of inattention ($F = 16.47$, $p < .001$, $\eta^2 = 0.27$) such that those in the HPD group demonstrated significantly higher inattentive ($M = 65.67$, $SD = 13.35$) symptoms than those in the OCD ($M = 48.49$, $SD = 13.61$) or HC group ($M = 51.86$, $SD = 3.16$). Participants in the HC group also demonstrated significantly lower anxiety ($M = 53.83$, $SD = 7.34$) symptoms than those in either the OCD group ($M = 60.93$, $SD = 12.78$) or the HPD group ($M = 61.81$, $SD = 8.44$). Finally, in regard to use of psychotropic medication, those in the HC group were significantly less likely to be taking medication than those in either disorder group. Due to these differences, the above-mentioned variables were considered as covariates. Next, based upon the criterion described above for selecting covariates, in only three instances (i.e., RVP, SST, IED) were inattentive (SST, RVP), depressive (SST, RVP), or anxiety symptoms (IED) determined to be appropriate covariates. Because only youth with OCD were recruited at Site 2, however, conducting a factorial ANCOVA was deemed inappropriate and therefore, caution was taken in interpreting results germane to these particular sets of analyses.

Power analyses were conducted based upon prior research examining neurocognitive functioning among adults with OCD compared to those with HPD. A review of these findings revealed effect sizes ranging from 0.48 to 1.05, with an average effect size of 0.74 (Bohne et al. 2005; Chamberlain et al. 2007). Consequently, a sample size of 21 is necessary to detect a significant effect, if present. Thus, the sample size utilized for purposes of this study ($N = 90$) is sufficient to examine our primary aim.

Results

Table 3 displays the results from a series of ANOVAs and ANCOVAs, when applicable, examining differences in neurocognitive functioning between youths in OCD, HPD, and HC groups. Results from these analyses revealed no statistically significant differences between groups with respect to cognitive flexibility, reversal learning, spatial working memory, working memory, or inhibitory control. However, results did reveal statistically significant differences between groups with respect to several planning and sustained attention tasks.

With regard to performance on the SOC task, a measure of planning, results revealed significant differences with respect to Mean Initial Think Time 2 Moves, $\eta_p^2 = 0.071$ and Mean Subsequent Think Time 3 Moves, $\eta_p^2 = 0.07$. A trend towards statistical significance was also noted with respect to Mean Initial Think Time 5 Moves, $\eta_p^2 = .08$. Post hoc analyses revealed that both the HPD ($p = 0.02$, Cohen's $d = 0.55$) and OCD ($p = 0.04$, Cohen's $d = 0.41$) groups demonstrated significantly faster think times than the HC group with respect to Mean Initial Think Time 2 Moves but demonstrated no statistically significant differences from one another. Further, post hoc analyses revealed that those in the OCD group ($p = 0.03$, Cohen's $d = 0.62$) demonstrated significantly quicker latency with respect to Mean Subsequent Think Time 3 moves as compared to HCs. No significant differences were found between those in the HPD group and either the OCD or HC groups, though a trend in the latter instance was notable.

Finally, after controlling for attentional problems and depressive symptoms, an ANCOVA revealed significant between groups differences with respect to sustained attention (i.e., RVP'A performance; $\eta_p^2 = 0.31$). Post hoc analyses revealed those in the OCD group to perform worse on this task than those in the HC ($p \leq 0.001$, Cohen's $d = 1.53$) and HPD groups ($p = 0.03$, Cohen's $d = 0.87$), demonstrating a lack of sensitivity to the target. Performance by those in the HPD group did not differ from those in the control group, though a trend towards statistical significance was noted.

Discussion

The present study sought to address a substantial gap in the current literature through a neurocognitive comparison of pediatric OCD and HPD. To our knowledge, this is the first study of its kind within a pediatric population. In contrast with our hypotheses, several domains indicated no notable differences between groups (i.e., cognitive flexibility, reversal learning, inhibitory control, working memory, spatial working memory), while significant differences were demonstrated in relation to planning. In line with our hypotheses, significant differences were also found on a task of attention. Previously, researchers have suggested that the current conceptualization of OCD and HPD as falling on spectrum from compulsivity to impulsivity may overlook important distinguishing factors in processes underlying the disorders. Results from the current study suggest an overall similar neurocognitive profile among children with these disorders, apart from significant differences noted in relation to planning

Table 3 Mean scores on neurocognitive tasks across groups

CANTAB Task	Control	HPD	OCD	*df*	*F*	*p*
Intradimensional/Extradimensional Set Shift (IDED)						
Adjusted Cognitive Flexibility Errors[1]	0.83 (0.60)	0.85 (0.58)	1.08 (0.70)	2	1.55	0.219
Adjusted Reversal Learning Errors[2]	0.415 (0.04)	0.451 (0.05)	0.384 (0.03)	2	0.972	0.382
Spatial Span						
Span Length[3]	5.86 (1.89)	5.24 (2.07)	5.45 (2.01)	2	0.255	0.775
Total Errors[1]	45.96 (126.9)	40.74 (90.72)	55.81 (115.4)	2	0.136	0.964
Stockings of Cambridge (SOC)						
Mean Initial Think Time 2 Moves[3]	2518 ms(2885 ms)[a]	1340 ms (838 ms)[a]	1563 ms (1645 ms)[a]	2	3.27	0.043
Mean Initial Think Time 3 Moves[1]	3298 ms (2206 ms)	3463 ms (2113 ms)	3309 ms (2581 ms)	2	0.036	0.964
Mean Initial Think Time 4 Moves[1]	4416 ms (3075 ms)	3656 ms(3455 ms)	3912 ms (3058 ms)	2	0.390	0.678
Mean Initial Think Time 5 Moves[1]	6606 ms (6607 ms)	3274 ms(2763 ms)	3870 ms (3935 ms)	2	2.94	0.062
Mean Subsequent Think Time 2 Moves[1]	49.28 ms(124.8 ms)	265.6 ms(529.8 ms)	135.4 ms(370.8 ms)	2	2.41	0.103
Mean Subsequent Think Time 3 Moves[1]	262.9 ms(601.4 ms)[a,T]	922.8 ms (1280 ms)[T]	993.3 ms (1553 ms)[a]	2	5.21	0.009
Mean Subsequent Think Time 4 Moves[1]	1132 ms (1141 ms)	1196 ms (1099 ms)	1255 ms (1374 ms)	2	0.083	0.921
Mean Subsequent Think Time 5 Moves[3]	734.5 ms(725.5 ms)	861.9 ms (1477 ms)	635.7 ms(1136 ms)	2	0.331	0.719
Rapid Visual Processing (RVP)						
RVP'A[4]	0.98 (0.02)[a]	0.95 (0.07)[b]	0.88 (0.09)[a,b]	2	4.34	0.016
Probability of a hit[1]	0.91 (0.19)	1.3 (1.1)	2.3 (9.1)	2	0.495	0.611
Probability of a false alarm[1]	0.04 (0.18)	0.09 (0.25)	0.13 (0.29)	2	1.26	0.293
Pattern Recognition Memory (PRM)						
Percent Correct[1]	92.1 (7.2)	89.9 (9.9)	90.9 (8.6)	2	0.420	0.658
Mean Correct Latency[3]	2134 ms (564.2 ms)	2316 ms (625.7 ms)	2184 ms (426.8 ms)	2	0.122	0.885
Stop Signal Task (SST)						
Median Correct Reaction Time on Go Trials[1]	457.4 ms (240.5 ms)	477.4 ms(201.2 ms)	421.9 ms (185.0 ms)	2	0.551	0.579
Proportion of Successful Stops[1]	11.30 (40.4)	22.2 (68.7)	25.5 (69.9)	2	0.460	0.633
Directional Errors[1]	16.4 (45.1)	24.8 (66.5)	29.1 (64.7)	2	0.388	0.680
Reaction Time[3,4]	208.9 ms (87.0 ms)	217.3 ms (61.4 ms)	208.1 ms (82.9 ms)	2	0.099	0.906

[a] statistically significant difference between groups; [b] statistically significant difference between groups [T] trend towards statistical significance between groups; [1] no covariates; [2] controlling for child anxiety symptoms; [3] controlling for child age; [4] controlling for child inattention and depressive symptoms

and attention. While other underlying processes may differ between the disorders, general neurocognitive similarities suggest parallel underlying functioning in this domain. Collectively, findings from the current study hold several implications for understanding the overlapping and unique etiology of pediatric OCD and HPD.

Children in the OCD group performed significantly worse on a task of sustained attention compared to children in the HPD and HC groups. Though previous research is mixed, current findings are somewhat consistent with research demonstrating other attention-related difficulties amongst children and adults with OCD (e.g., poor attention flexibility, selective attention bias; Abramovitch et al. 2013; Chamberlain et al. 2007) and may support broader attentional issues within this disorder. Specifically, though OCD is characterized by an increased focus on obsessions, this focus may be at the expense of the ability to provide attention to non-symptom related stimuli (e.g., neutral stimuli presented in the RVP task), resulting in observed attentional issues. Notably, such conjecture is in line with interventions such as attention bias modification, which has been used to alleviate attention biases in pediatric anxiety and has also been preliminarily investigated in OCD child samples (Bechor et al. 2014; Chamberlain et al. 2007, Chang et al. 2018; Riemann et al. 2013). Given current and previous findings in relation to attentional problems in OCD, future intervention adaptation may also consider targeting broader attentional issues - though this may be of limited utility within the context of HPD. For example, within a therapeutic context, in addition to targeting threat bias, increased therapist consideration of how attention problems may distract children from therapeutic activities such as exposure and use of skill building activities to increase attention flexibility may be of benefit. It is important to note, however, that contradictory research exists assessing sustained attention specifically in pediatric OCD – as well as within adult OCD (Abramovitch et al. 2013; Milliery et al. 2000; Shin et al.

2008). As part of replication and extension of this research, it will be important to further investigate potential reasons for the above-mentioned mixed findings. For example, differences in assessment methodology (i.e., paper and pencil versus automated batteries), overall severity of obsessions (i.e., attention difficulties in adults is perhaps related to obsession severity rather than overall OCD presence; Lee et al. 2009), and age of disorder onset (i.e., worse neurocognitive difficulties in late onset compared to early onset OCD; Brennan and Flessner 2015) may potentially explain these findings and warrant further testing. With relation to HPD, findings herein are consistent with previous research within adult populations indicating no attentional difficulties and may suggest an important difference in the pathophysiology between pediatric HPD and OCD. Specifically, inattention may be a distinguishing etiological or phenomenological marker for OCD as opposed to HPD and may suggest differences in underlying pathways between the disorders. Again however, given little previous research comparing these two disorders further replication is needed.

Results of the present study also indicated that children in the OCD and HPD groups demonstrated faster initial think times and slower subsequent think times on several planning problems compared to HCs; however, these groups did not demonstrate differences in overall planning task success. Findings indicate that children in disorder groups spent less time planning their responses prior to the task and took longer to plan subsequent moves after beginning the task. This suggests similar planning abilities between OCD and HPD, such that children with these disorders undertake different processes or strategies (compared to HCs) to reach conclusions in problem solving tasks. This may support some research suggesting slower processing speed in children with OCD and HPD (Flessner et al. 2016; Geller et al. 2017; Irak and Flament 2007). It is worth considering whether these differential processes prove impairing on tasks of higher difficulty. Though overall task success was unaffected in the current study, slower processing speed, or other maladaptive processes/strategies undertaken by children with OCD and HPD, may contribute to impaired performance on increasingly demanding tasks. Thus, additional research may wish to compare child performance on timed versus untimed tasks of EF as well as include tasks of varying demand and specific tasks of processing speed for further analysis. Furthermore, given mixed and scant findings within the literature, future research may also wish to assess other potential conditions that may help explain mixed findings in the literature (e.g., comparing assessment methods, age of onset, particular symptoms). For example – though not exclusive to planning – some prior research suggests that heterogeneity within HPD may contribute to difficulties specifying neurocognitive impairment, in that children with different styles of pulling (i.e., automatic versus focused) may exhibit different patterns of neurocognitive performance. Specifically, Flessner et al. (2016) found that automatic pulling and was negatively correlated with performance on a task of working memory. In this vein, future research assessing neurocognitive comparisons between pediatric HPD and OCD may wish to recruit larger sample sizes and further deconstruct the symptoms assessed to determine the impact of symptom variability on performance (e.g., assessing differences between automatic versus focused pulling as well as variable OCD-related symptom profiles).

Lastly, results indicated no significant group differences with respect to cognitive flexibility, reversal learning, working memory, or inhibition. With relation to cognitive flexibility and working memory, such findings are consistent with previous pediatric HPD research suggesting normative functioning in these areas (Flessner et al. 2016). In contrast, findings with respect to inhibitory control are inconsistent with both prior OCD and HPD research (Chamberlain et al. 2007; Penades et al. 2007; Woolley et al. 2008). Given the theoretical conceptualization of HPD and OCD and the large body of literature indicating inhibitory difficulties amongst adults with these disorders, this current finding is perhaps most perplexing. It is possible that inhibitory deficits are uncharacteristic of children with OCD or HPD and may instead be a marker exclusive to adults. For example, children with OCD or HPD may initially demonstrate normative levels of inhibitory control compared to their peers (e.g., all children demonstrating lower levels of inhibition), however as the child and/or disorder matures, deficits may become more apparent (e.g., healthy children achieve improvements in inhibitory control as they mature, while those with OCD and HPD maintain lower levels). Such conjecture is in line with current hypotheses proposing differences in maturational trajectory of the prefrontal cortex in children with OCD (Evans et al. 2004; Marsh et al. 2009); however, additional longitudinal research is needed to confirm or refute these hypotheses in children with HPD. Alternatively, it is again possible that some of the conditions previously discussed may contribute to these contradictory findings (e.g., influence of disorder heterogeneity on neurocognitive performance, differences in assessment methodology). For instance, recent research by Berlin and Lee suggests that SST impairment may only be associated with compulsion severity, rather than broad OCD symptoms, highlighting the importance of disorder heterogeneity in neurocognitive performance (Berlin and Lee 2018). Furthermore, within the same study, it is noted that comparisons of mean/median SSRT performance may not sufficiently identify task components deficient in OCD. Rather, burgeoning research suggests that future studies may wish to also include error-monitoring indices of SST performance (ERM; computed reaction times indicating slowed down performance after successful inhibition [i.e., excessive error monitoring]). It is hypothesized that this excessive monitoring may be an inhibitory deficit characteristic of OCD not captured in

the traditional SST performance outcomes, and thus warrants further investigation. Given the small number of studies to examine these comparisons (i.e., OCD versus HPD versus HCs) in detail, additional research is necessary to further explore these and other hypotheses.

Though findings of this study raise several points of conjecture, limitations must also be considered. First, though this study used a well validated automated battery of neurocognitive functioning, assessment of neural correlates was not included (e.g., functional brain imaging). Conjunct use of these measures may further clarify research findings and provide a more comprehensive picture of pediatric OCD and HPD functioning. It is possible that youth with each disorder engage different neural processes to arrive at the same behavioral endpoint on neurocognitive tasks. Such a finding has been demonstrated in Tourette's Syndrome (TS). Those with TS show equal behavioral performance on tasks of motor inhibition and cognitive control as typically developing children but hyper-engage prefrontal cortical areas to do so (Marsh et al. 2006; Raz et al. 2009). Thus, it is possible that findings of normative behavioral performance in OCD and HPD obscure neural dysfunction that may become evident with fMRI measurement or at the behavioral level only with more demanding or complex neurocognitive tasks. Second, the current sample was fairly homogeneous with relation to ethnicity and socioeconomic status. Future research should recruit more heterogeneous samples to increase generalizability of findings. Relatedly, increased sample size and diagnostic distribution between sites may also provide a useful context to further assess impact of disorder heterogeneity on neurocognitive performance and allow for the use of additional analyses. Additionally, the current study did not assess differences in overall functioning and impairment between OCD and HPD participants. As noted previously, research in adult OCD samples hypothesizes that some neurocognitive deficits may be more indicative of higher levels of disorder severity rather than mere OCD presence. Thus, it is possible that levels of functioning (e.g., poorer functioning in the OCD group compared to the HPD group or vice versa) may contribute to differences in neurocognitive performance demonstrated between groups as well as lack of differences noted between disordered groups and HCs. Future research should consider utilizing measurements of functioning as well as exploring effects of age, length of illness, and comorbidities (e.g., global assessment of functioning [GAF] scores, use of therapy) to investigate such hypotheses.

In summation, results herein suggest both similarities and differences in the neurocognitive functioning of pediatric OCD and HPD. Though performance in specific domains largely demonstrate contradictory findings compared to previous research, proposed hypotheses highlight several potential implications for exploration (e.g., potential benefit of an attention focus in pediatric OCD intervention, impact of disorder heterogeneity on performance, role of processing speed in OCD and HPD). Continued investigation addressing this conjecture may help further clarify understanding of these disorders.

Compliance with ethical standards

Conflict of Interest All other authors have no potential conflicts of interest to report.

Ethical Approval This was obtained from the ethics committee of Kent State University and Brown University. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed Consent This was obtained from all parents and informed assent was obtained from all children included in the study. One author (D. Dickstein) receives current grant support from NIMH and has received prior grant support from NARSAD.

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