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A computerized neuropsychological evaluation of cognitive functions in a subclinical obsessive-compulsive sample

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ABSTRACT

Background and objectives: Ample research in obsessive-compulsive disorder (OCD) reveals a moderate degree of underperformance on various neuropsychological tasks. Less is known about neuropsychological function in subclinical obsessive-compulsive (OC) samples. Most analogue OCD studies did not use a comprehensive neuropsychological battery and none utilized a fully computerized battery. To fill this gap in the literature, the present study aimed at assessing cognitive functions in a subclinical OC sample using a validated computerized neuropsychological battery.

Methods: Initially, a sample of 165 students completed the Obsessive-Compulsive Inventory-Revised (OCI-R). Using a psychometrically valid methodology, a high OC (HOC, n = 29) and low OC (LOC, n = 29) groups were selected based on scores in the upper and lower quartiles on the OCI-R. The two groups completed the NeuroTrax computerized neuropsychological battery and clinical questionnaires.

Results: Although the HOC group underperformed on most outcome measures, controlling for state-anxiety and depression symptoms, no significant differences were found on major domains (i.e., memory, attention, executive functions, processing speed, visuospatial functions, verbal functions, and motor skills), and subdomains. Normalized scores, produced using population norms, indicated that both groups performed within the normative range.

Limitations: Not all neuropsychological subdomains were assessed.

Conclusions: Results are consistent with the general picture in analogue OC samples, and may be more reliable than paper-pencil testing, given that a full computerized neuropsychological battery minimizes examiner-examinee interactions, and increases timing accuracy. In sum, analogue OC samples, characterized by equivalent symptom severity but high functioning compared to OCD samples, do not present with cognitive deficits.

1. Introduction

Obsessive-compulsive disorder (OCD) is a disabling condition with a worldwide estimated prevalence rate of 2.5% (Ruscio, Stein, Chiu, & Kessler, 2010). OCD is characterized by persistent intrusive thoughts, images, or urges (obsessions) that cause marked anxiety and distress. Individuals diagnosed with OCD engage in repetitive and ritualized behaviors or mental acts (compulsions) in order to alleviate or avoid the distress and anxiety associated with obsessions (American Psychiatric Association, 2013). A large body of neuropsychological literature documents deficient performance on neuropsychological tests in OCD samples across multiple domains, particularly executive functions, nonverbal memory, and information processing speed (Abramovitch et al., 2015a; Shin, Lee, Kim, & Kwon, 2014; Snyder, Kaiser, Warren, & Heller, 2015). However, said samples display largely-intact performance on verbal functions and verbal memory (Abramovitch, Shaham, Levin, Bar-Hen, & Schweiger, 2015b). Overall, results from neuropsychological studies in OCD are grossly inconsistent and effect sizes are, on average, moderate (Abramovitch et al., 2015a; Shin et al., 2014).

Less is known about the association between obsessive-compulsive (OC) symptoms and neuropsychological test performance in the general population (Abramovitch et al., 2015b). Intrusive obsessive thoughts are common symptoms in the general population (Clark & Rhyno, 2005; Rachman & de Silva, 1978), and the continuum approach to these symptoms is supported by research indicating that what distinguishes OCD from the general population in terms of obsessive intrusive thoughts is the "… *degree rather than kind*" (Clark & Rhyno, 2005, p. 13). In fact, OC symptoms may be better conceptualized as dimensional (Apter et al., 1996), as opposed to categorical and the use of analogue sample research is of meaningful contribution to the understanding of

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OCD (for review see Abramowitz et al., 2014). This methodology (also referred to as subclinical samples research) is commonly employed in psychopathological and neuropsychological studies into OC phenomena, in which (usually) two groups with high OC symptoms (HOC) and low OC symptoms (LOC) are compared on tasks and questionnaires.

Relative to neuropsychological studies in clinical OCD samples, there are far fewer neuropsychological investigations in analogue samples. In addition, this literature is more inconsistent than the OCD literature in terms of neuropsychological test performance. Across analogue OCD studies, deficient task performance is found only in some cases and especially in executive function, while no deficits have been found in verbal memory, non-verbal memory, and attention.

1.1. Executive function

Research into executive function yield inconsistent findings in subclinical OC samples. Deficient performance among HOC samples has been found on set-shifting tasks, such as the Trail Making Test part B (TMT-B), the Wisconsin Card Sorting Test (WCST) and the Object Alteration Test (OAT; Goodwin & Sher, 1992; Kim, Jang, & Kim, 2009; Spitznagel & Suhr, 2002; Zohar, LaBuda, & Moschel-Ravid, 1995). In contrast, others reported no differences between HOC and LOC on the TMT-B and WCST (Mataix-Cols et al., 1999b). As with OCD samples, planning was found to be deficient in subclinical OC samples, as measured by the Tower of Hanoi test (Mataix-Cols, 2003; Mataix-Cols et al., 1999b). However, in contrast to extensive reports of deficient performance in OCD samples, largely intact-performance was found in subclinical OC samples in response inhibition/interference control tasks as measured by the Stroop test (Hajcak and Simons, 2002; Mataix-Cols et al., 1999b). One study found a significant difference between HOC and LOC samples in response-inhibition using a Go/No-Go task in, albeit both groups performed in the normative range when compared to population norms (Abramovitch et al., 2015b).

Verbal and design fluency have been associated with small effect sizes in OCD (Abramovitch, Abramowitz, & Mittelman, 2013; Shin et al., 2014), and an inconsistency in terms of group difference (Abramovitch and Cooperman, 2015). In terms of group differences, no difference was reported in analogue OC samples on verbal fluency as measured by the Controlled Oral Word Association Test (COWAT; Kim et al., 2009; Mataix-Cols, Barrios, Sanchez-Turet, Vallejo, & Junque, 1999a; Mataix-Cols et al., 1999b). In contrast, one study reported underperformance on figural fluency in an HOC sample as measured by the Design Fluency Test (DFT), but only in the free condition, implying difficulty in organizing unstructured material (Mataix-Cols et al., 1999a). In terms of effect sizes, subclinical OC samples usually exhibit a small effect sizes, exemplifying minor underperformance on executive function tasks.

1.2. Memory

Verbal memory and non-verbal memory have been found to be intact in subclinical OC individuals across studies with small effect sizes found on average (Kim et al., 2009; Mataix-Cols, 2003; Mataix-Cols et al., 1999b). Specifically, no significant differences were reported between HOC and LOC participants on verbal memory as the Rey Auditory Verbal Learning Test (RAVLT) and the California Verbal Learning Test (CVLT; Kim et al., 2009; Mataix-Cols, 2003; Mataix-Cols et al., 1999b). In direct contrast to robust findings pointing to impaired performance in OCD samples, one study found intact non-verbal memory in an HOC sample as measured by the Rey-Osterrieth Complex Figure Test (ROCF; Kim et al., 2009). Interestingly, deficient performance on memory tasks has been reported in studies that focused specifically on subclinical compulsive checkers (Cuttler & Graf, 2007; Rubenstein, Peynircioglu, Chambless, & Pigott, 1993; Sher, Frost, & Otto, 1983).

1.3. Attention

Similar to findings in OCD samples, simple selective attention appears to be intact in HOC individuals (d2 task; Kim et al., 2009). One study examined fluctuation in sustained attention and reported that HOC had a significantly larger reaction time standard deviation on a Go/No-Go task compared to a LOC sample. However, both samples performed in the normative range (Abramovitch et al., 2015b). Sustained attention was also found to be intact in subclinical OC samples when measured by omission errors on a Go/No-Go test (Abramovitch et al., 2015b) and when assessed using a Continuous Performance Test (CPT; Mataix-Cols et al., 1997). Similar to other cognitive domains, attention has been generally associated with small effect sizes in subclinical OC samples.

1.4. Methodological issues in neuropsychological studies in analogue OC samples

Most neuropsychological analogue OC studies administered limited selected tests and only two studies utilized a comprehensive neuropsychological battery as means of exploring a hypothetical neuropsychological profile of subclinical OC individuals. Mataix-Cols et al. (1999b) tested several aspects of executive functions such as set shifting, planning, response inhibition, verbal fluency, and as verbal memory. The results showed no significant differences between the HOC and LOC samples on any neuropsychological measure, except for the TOH – a task assessing planning – in which HOC exhibited deficient task performance. In the second comprehensive neuropsychological study, Kim et al. (2009) investigated aspects of executive function (i.e., set shifting and verbal fluency), verbal memory, non-verbal memory, and selective attention in a subclinical OC sample. The HOC group exhibited underperformance on the WCST and the TMT, but the TMT comparison was found non-significant after controlling for depression and anxiety. No significant differences were found on all the other neuropsychological outcome measures. Notably, the Kim et al. study (2009) utilized a highly unusual cut-off point differentiating HOC and LOC, namely, the top and bottom 3% on an OC symptom scale. This unusual methodology may be less representative of the continuum of OC symptoms in the general population and more akin to a comparison between OCD and non-clinical controls.

Although the majority of comparisons conducted between HOC and LOC samples yielded no significant differences, this small body of neuropsychological literature is highly inconsistent; as is the case in neuropsychological research in OCD. Such inconsistency could be, in part, associated with a substantial variability between studies in tasks used to assess the same cognitive domain (Abramovitch & Cooperman, 2015). In addition, different measures of OC symptoms, and operational definitions for differentiating between high and low OC samples may contribute to this inconsistent picture (Abramowitz et al., 2014). Another factor that may have an effect on these results is the difference in administration methods, namely, computerized versus traditional pencil-paper administration of neuropsychological tests. For example, one study that utilized a computerized version of the WCST reported a significant difference between HOC and LOC samples, whereas a similar study administrating the card version of the WCST did not find such a difference (Goodwin & Sher, 1992; Mataix-Cols et al., 1999b). Indeed, it has been previously suggested that this difference may, in part, account for this inconsistency associated with neuropsychological testing in the context of OC phenomena, namely, examiner-examinee interaction. Traditional paper and pencil neuropsychological testing involves frequent examiner-examinee interactions. In the context of OC phenomena these interactions include frequent reassurance-seeking communications which are a prominent feature of OC symptomatology (Salkovskis, 1999). These interactions are intended to decrease anxiety and distress which, in turn, may impact test performance in an unpredictable fashion and contribute to the inconsistent findings (Abramovitch, Dar,

Schweiger, & Hermesh, 2011; Perna et al., 2016). Thus, utilization of a computerized battery which minimizes examiner-examinee interactions, may be less susceptible to this problem. Moreover, a full computerized battery improves accuracy of timed responses, and may reduce fatigue, given the relatively short administration time.

Another factor that may affect the inconsistency found in analogue OCD neuropsychological studies is the impact of depressive and anxiety symptom severity on test performance. Depressive severity was found to explain some of the variance associated with deficient neuropsychological performance in OCD samples (Basso, Bornstein, Carona, & Morton, 2001; Moritz, Kloss, Jahn, Schick, & Hand, 2003) albeit it was not found to be a significant moderator in terms of severity or comorbidity in meta-analyses (Abramovitch et al., 2013; Shin et al., 2014). Some OCD studies also suggest that state anxiety affects performance in OCD (Abramovitch, Dar, Hermesh, & Schweiger, 2012; Moritz, Hauschildt, Saathoff, & Jelinek, 2017). Our review of the literature indicated that many analogue OCD studies either did not assess depressive and anxiety severity (e.g., Cuttler & Graf, 2007), or did not control for it (e.g., Spitznagel & Suhr, 2002). Only a minority of studies used these variables as covariates (e.g., Kim et al., 2009).

In sum, there is a need for more studies utilizing broader neuropsychological batteries in analogue OCD samples and, more so, that the assessment be computerized. In order to fill this gap in the literature, the aim of the present study was to assess neuropsychological functions in HOC versus LOC samples, utilizing a validated comprehensive computerized neuropsychological battery (NeuroTrax; Neurotrax, 2003). In light of previous research, we hypothesized that the HOC group will exhibit underperformance compared to a LOC group, particularly in executive functions. However, we hypothesize that the HOC performance may be considered in the normative range when assessed in comparison to test norms.

2. Methods

2.1. Participants

Fifty-eight college students were recruited from a pool of 165 students based on their scores on the Obsessive-Compulsive Inventory–Revised (OCI-R; Foa et al., 2002). In line with previous subclinical OCD studies (Najmi, Hindash, & Amir, 2010; Purdon & Clark, 1994) out of the total sample of 165, participants who scored in the top and bottom percentage quartiles formed the High OC group (HOC, $n = 29$, OCI-R total score ≥ 31) and Low OC group (LOC, $n = 29$, OCI-R score ≤ 13), respectively. These scores are typically seen in clinical OCD samples and non-psychiatric controls (see Table 1; e.g., Abramovitch et al., 2012, 2015b; Menzies et al., 2007). Inclusion criteria for the present study were: age between 18 and 65, no color blindness, and intact or corrected vision. The primary exclusion criteria included past neurological disorder (e.g., traumatic brain injury, epilepsy). In addition, participants were asked to refrain from using stimulant medication, benzodiazepines and drinking more than 2 alcoholic drinks 24 h prior to the testing session. Three participants from the HOC group self-reported that they were diagnosed in the past with ADHD, anorexia nervosa, and OCD with comorbid eating disorder. These participants reported receiving medications: the participant with ADHD reported using Ritalin (but not at time of testing), and the two other participants reported using selective serotonin reuptake inhibitors (SSRIs). Two participants in the LOC group reported being diagnosed with bipolar disorder and an undisclosed anxiety disorder. Both participants reported taking SSRIs. After receiving a comprehensive description of the study, the participants signed a written informed consent form. The students received course credit for their participation in the study. The study was approved by the [masked for review] Academic Center Institutional Review Board.

2.2. Measures

2.2.1. Clinical measures

The OCI-R (Foa et al., 2002) is a self-report questionnaire that measures the distress that accompanies obsessive-compulsive (OC) symptoms and is frequently used as a measure of severity of OC symptoms. This scale includes 18 items and participants are requested to rate the degree to which they have been bothered by these symptoms over the past month on a Likert –like scale. Each item is score range from 0 (not at all) to 4 (extremely bothered). The OCI-R demonstrated very good psychometric properties in both clinical (Foa et al., 2002) and non-clinical populations (Hajcak, Huppert, Simons, & Foa, 2004), and had excellent internal consistency in the present study (Cronbach's $\alpha = 0.91$, and 0.95 for the first and second administrations respectively). We used the *Beck Depression Inventory-II* (BDI-II; Beck, Steer, & Brown, 1996) to assess the level of depressive symptoms. The *State-Trait Anxiety Inventory* (STAI; Marteau & Bekker, 1992; Spielberger, Gorsuch, & Lushene, 1970) was used to assess trait anxiety and state anxiety.

2.2.2. Neuropsychological measures

The NeuroTrax Computerized Neuropsychological Battery is a computerized neuropsychological battery assessing a wide range of cognitive domains (i.e., memory, executive function, attention, information processing speed, visuospatial perception, verbal function and motor skills). The battery is a reliable and valid measurement and has been used previously in a wide variety of studies (e.g., Abramovitch et al., 2012, 2015b; Herman et al., 2015; Mamikonyan, Xie, Melvin, & Weintraub, 2015). The cognitive scores are normalized for age and education level ($M = 100$, $SD = 15$). The battery includes the following subtests:

Expanded Go/No-Go test- Participants are instructed to click the mouse button when any colored square is presented (Go stimuli), except for the red squares (No-Go stimulus). The squares are presented at variable delays. Different test blocks include blocks with increased “No-

Table 1
Demographic and clinical characteristics of the HOC and LOC groups.

Variable	HOC ($n = 29$)			LOC ($n = 29$)			F (1, 56)	P-value
	Mean	*SD*	Range	Mean	*SD*	Range		
Demographics								
Age (years)	23.45	2.47	19–32	23.41	1.92	20–28	0.00	0.95
Education (years)	12.41	0.73	12–15	12.38	0.49	12–13	0.04	0.83
Clinical								
OCI-R	35.17	8.88	18–58	9.55	6.17	1–35	162.74	< 0.001
BDI-II	12.38	7.62	2–37	4.31	4.53	0–17	24.04	< 0.001
STAI- State	13.34	4.15	6–22	11.03	3.94	6–20	4.72	0.03
STAI- Trait	45.59	10.41	28–64	29.97	9.07	20–64	37.13	< 0.001

HOC, high obsessive-compulsive symptom group; LOC, low obsessive-compulsive symptom group; OCI-R, obsessive-compulsive inventory-revised; BDI-II, Beck depression inventory-II; STAI- State- Trait, state-trait anxiety inventory; Years of education were counted as 12 years for complete high school education, and an additional year for every year of higher education.

Go" stimulus proportion, shorter intervals between stimuli, and distracting shapes. This task measures response speed, sustained attention, and response inhibition.

Verbal memory test- Ten pairs of words are presented. In the recognition trial, the participant is required to choose which word (out of four choices) matches the previously presented word. There are four sets of recognition tests in the "Immediate Recognition" set. Additionally, delayed recognition set after approximately 10 min is administered.

Problem solving task- In the problem solving task, which is similar to common Matrix tests, an incomplete array, with three geometric forms is presented and the participant is instructed to choose which of the six alternative forms, would best fit as the fourth form.

Stroop interference- The Stroop test comprises three phases. In these phases, one word and two squares in different colors are presented. In the first phase, participants are required to click the colored square that matched letters' font color. In the second phase, participants are instructed to choose the square that matches the word's meaning (e.g., red). In the third phase, participants are requested to choose the square with the color that matches the word's font color while ignoring the word's meaning (e.g. the font of the word 'BLUE' is green). This test measures interference control.

Non-verbal memory test- Eight geometric forms are presented and the participants are required to remember the orientation of each form. In the recognition test, the participants are instructed to choose the picture that presents the form's orientation that matches that one that was previously presented, out of four different options. In the "Immediate Recognition" set, there are four repetitions. After approximately 10 min of delay, an additional recognition test is administered.

Finger tapping test- Participants are instructed to click the left mouse button as fast as they can for 12 s. This action is repeated twice and measures motor skills.

Catch game- In the catch game, participants are instructed to "catch" a white object with a green paddle while it falls from the top of the screen. The left and right mouse keys control the paddle. The participant is required to "catch" the white object before it reaches the bottom edge of the screen. This task measures planning and motor skills and a central outcome measure is the mean number of steps in excess used to "catch" the white object.

Staged information processing speed- In this test, there are three levels of information processing load: Single digits, two digit (e.g., 8-5), and three-digit arithmetic problems (e.g., 1 + 6-2). For each level, the digits are presented at three fixed rates that increase as test continues. If the result is 4 or less, the participant is required to press the left mouse button. For results that greater than 4, the participant require pressing the right mouse bottom. This task measures information processing speed.

Verbal function- The verbal function test includes two phases. In the first phase, pictures of less or more familiar objects are presented. Participants are required to choose the word that rhymes with the object in the picture out of four possible words. In the second phase, participants are required to identify the name of the object out of a list of four words.

Visuospatial processing- A red pillar is presented in different locations in a 3D scene. The participant is required to decide which of four alternative views of the scene matches the vantage view of the red pillar. This task assesses visuospatial function.

2.3. Procedure

In the first phase of the study, students responded to the study invitation posted on the college research participant pool platform. One hundred and sixty five participants responded to this invitation by following a link to an online OCI-R questionnaire. Based on their scores, participants were divided into two groups (HOC, LOC) and were invited to the second phase of the study for which they were told that they had been randomly selected. Fifty eight students participated in the second phase (HOC $n = 29$, LOC, $n = 29$). Prior to the testing session, participants were informed that they should not take stimulants or benzodiazepines or drink more than two alcoholic drinks 24 h prior to the testing session. Participants signed an informed consent form and completed a demographic questionnaire and were then individually tested in the same laboratory room, on the same computer using a 21.5 inches computer monitor. Subsequent to completing the NeuroTrax battery participants then completed BDI-II, STAI and OCI-R questionnaires. Completion of the neuropsychological battery took 45 min on average, and the entire session ranged between 60 and 90 min.

2.4. Data analysis

Data analysis was conducted using IBM SPSS version 20 (SPSS, 2011). Continuous clinical and demographic variables were analyzed using analysis of variance (ANOVA), and binary variables were analyzed using Pearson's χ^2 tests, with Fisher's Exact Test correction. Major neuropsychological domain comparisons were analyzed using multivariate analysis of covariance (MANCOVA) with BDI-II and STAI-State as covariates. Notably, we did not control for trait anxiety because trait anxiety is strongly correlated with depressive severity (in the present study Pearson's $r = 0.80$, $p < .0001$) for which we controlled across analyses. Furthermore, trait anxiety has been found to have negligible impact on cognitive functions in both clinical (Smitherman, Huerkamp, Miller, Houle, & O'Jile, 2007) and non-clinical (Waldstein, Ryan, Jennings, Muldoon, & Manuck, 1997) samples. Neuropsychological outcome measures included in each major domain (subdomain analyses) were analyzed using MANCOVAs. Toallow interpretation of participasnts' performance level compared to the population, we analyzed scaled scores produced by the NeuroTrax battery using its normative database. These scores were normalized on a scale similar to the Wechsler intelligences scales (i.e., $M = 100$, $SD = 15$). In order to control for familywise inflation of Type I error we employed the Bonferroni method for multiplicity corrections (Bland & Altman, 1995). For the seven major domain analyses (i.e., memory, executive function, attention, information processing speed, visuospatial functions, verbal function, and motor skills) the significance threshold (p-value) was set at (0.05/7) 0.0071. For each domain subtest (see Table 3) significance threshold was calculated by dividing 0.05 by the number outcome measures in each domain subtest group. This yielded the following p-value significance thresholds: Memory, 0.0125; executive function, 0.0167; attention, 0.01; information processing speed 0.0125; visuospatial, 0.05; verbal function, 0.05, and motor skills 0.0167.

3. Results

3.1. Demographic characteristics and clinical measures

The HOC and LOC groups included mostly females (HOC females = 96.6%, LOC females = 93.1%) and did not differ on gender proportions [$\chi^2(1) = 0.352$, $p = .553$]. Similarly, the groups did not differ significantly on age and education (Table 1). No difference was found on handedness between the HOC (percent lefties = 3.4%, $n = 1$) and the LOC (10.3%, $n = 3$) groups [$\chi^2(1) = 1.074$, $p = .611$]. With regards to clinical measures, the HOC group scored significantly higher than the LOC group on the OCI-R [$F(1,56) = 162.73$, $p < .001$], BDI-II [$F(1,56) = 24.04$, $p < .001$] and the STAI state [$F(1,56) = 4.72$, $p = .34$] and STAI trait [$F(1,56) = 37.13$, $p < .001$] scores (see Table 1). Therefore, in order to control for factors that may potentially impact neuropsychological test performance, BDI-II and STAI-state were controlled for in all subsequent analyses.

3.2. Neuropsychological major domains

Group differences on the seven neuropsychological domains (i.e.,

Table 2
Comparisons between the HOC and LOC groups on major neuropsychological domains.

	HOC (n = 29)		LOC (n = 29)		F (1, 54)	P-value	Cohen's d[a]
	Mean	SD	Mean	SD			
Memory	94.68	11.75	99.75	9.04	3.95	0.05	0.48
Executive Function	101.47	8.52	102.39	9.17	0.03	0.87	0.10
Attention	99.48	7.83	100.02	9.15	0.31	0.58	0.06
Information Processing Speed	96.53	9.51	94.45	14.42	1.71	0.20	−0.17
Visuospatial	98.03	12.51	95.06	18.49	0.74	0.39	−0.19
Verbal Function	90.37	23.10	96.78	20.37	1.58	0.21	0.30
Motor Skills	104.94	8.96	104.49	6.82	0.60	0.44	−0.06

Domain index scores are normalized on a Wechsler IQ scale (Mean = 100, SD = 15). HOC, high obsessive-compulsive symptom group; LOC, low obsessive-compulsive symptom group.
[a] Positive effect sizes indicate higher scores in the LOC group, and negative effect size indicate higher scores in the HOC group.

memory, executive function, attention, information processing speed, visuospatial, verbal function, and motor skills) were entered to the MANCOVA model, controlling for state anxiety and depressive severity. No significant overall effect was found between the groups [Wilks' Lambda = 0.803, $F(7, 48) = 1.683$, $p = .136$]. Similarly, no significant difference was found on the composite neuropsychological performance index score between the HOC ($M = 97.92$, $SD = 6.81$), and the LOC ($M = 99.00$, $SD = 7.64$) groups [$F(1, 54) = 0.016$, $p = .900$]. As presented in Table 2, No significant differences were found for all major domains (p's range 0.052–0.869), and effect sizes for major domains were all small in magnitude (d range 0.06–0.30), except for the memory domain effect size which was of small-medium magnitude ($d = 0.48$). For graphic representation of the neuropsychological profiles of the HOC and LOC groups, see Fig. 1.

3.3. Neuropsychological domain subtests

As presented in Table 3, in order to assess individual outcome measures pertaining to specific subdomains, we performed 5 MANCOVA analyses i.e., (memory, executive function, attention, information processing speed, and motor functions). The visuospatial and verbal function domains included only a single outcome measure that were analyzed in the previous section. No significant differences were found across all individual outcome measures between the groups (p's range 0.11–0.94, see Table 3) and all effect sizes were small (Cohen's d range 0.00–0.41). Two additional subtest analyses included total commission errors and total omission errors from the Go/No-Go test. No significant difference was found on the total number of commission errors between the HOC ($M = 92.90$, $SD = 19.26$), and the LOC ($M = 98.62$, $SD = 13.47$) groups [$F(1,54) = 1.470$, $p = .231$]. Similarly, no significant difference was found on the total number of

Table 3
Neuropsychological domain subtests.

	HOC (n = 29)		LOC (n = 29)		F (1, 54)	P-value	Cohen's d[a]
	Mean	SD	Mean	SD			
Memory							
Verbal memory: total accuracy	91.99	18.31	99.19	17.03	1.22	0.27	0.41
Delayed verbal memory: Accuracy	98.35	13.54	101.51	14.39	1.15	0.29	0.23
Non- verbal memory: total accuracy	94.27	15.45	100.00	12.25	2.61	0.11	0.41
Delayed non- verbal memory: Accuracy	96.48	16.65	98.31	15.12	0.59	0.44	0.12
Executive Function							
Expanded Go/No-Go: Composite Score	100.77	11.70	101.34	15.11	0.24	0.62	0.04
Stroop: Composite score, 3	100.21	18.56	99.61	17.99	0.03	0.85	−0.03
Catch Game: Total score	103.46	15.30	106.23	10.17	0.01	0.94	0.21
Attention							
Expanded Go/No-Go: RT	104.39	9.40	103.09	10.72	0.97	0.32	−0.13
Expanded Go/No-Go: RT SD	101.71	8.50	102.81	10.40	0.07	0.80	0.12
Stroop RT, level 2	101.92	14.98	101.74	18.85	0.28	0.60	−0.01
Staged Info RT 1.2	97.71	18.73	96.72	17.22	0.59	0.45	−0.06
Staged Info Accuracy 2.3	91.72	15.83	95.78	14.30	0.54	0.46	0.27
Information Processing Speed							
Staged info composite score 1.1	98.25	14.44	98.19	19.03	0.54	0.46	0.00
Staged info composite score 1.3	100.07	15.17	98.37	11.47	0.50	0.48	−0.13
Staged info composite score 2.1	92.88	11.22	90.00	18.50	0.77	0.38	−0.19
Staged info composite score 2.2	97.06	12.42	94.89	17.59	2.09	0.15	−0.14
Visuospatial							
Visuospatial: Accuracy	98.03	12.51	95.06	18.49	0.74	0.39	−0.19
Verbal Function							
Verbal Function: Rhyming, Accuracy	90.37	23.10	96.78	20.37	1.58	0.21	0.29
Motor Skills							
Finger Tapping: Inter- Tap Interval	101.96	15.06	98.63	11.59	1.12	0.29	−0.25
Finger Tapping: Inter- Tap Interval SD	105.00	11.43	107.12	11.37	0.10	0.75	0.19
Catch Game: Time to first move	107.88	12.46	107.71	10.00	0.47	0.49	−0.02

Domain index scores are normalized on a Wechsler IQ scale (Mean = 100, SD = 15). HOC, high obsessive-compulsive symptom group; LOC, low obsessive-compulsive symptom group. RT = Response Time. Stroop level 2 = choice reaction time, selecting color named by a word in white letter-color. Staged info. 1.1 = staged information processing task low load low speed, 1.2 = low load medium speed, 2.1 = medium load low speed, 2.2 = medium load medium speed.
[a] Positive effect sizes indicate higher scores in the LOC group, and negative effect size indicate higher scores in the HOC group.

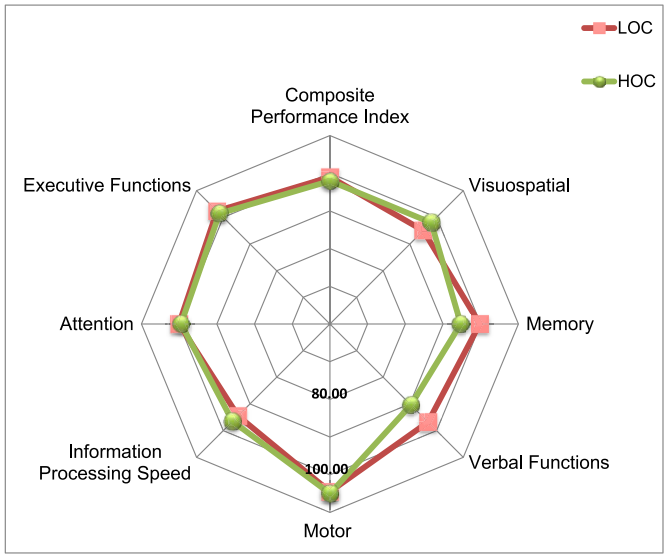

Fig. 1. Neuropsychological performance across cognitive domains. A comparative graphic illustration of the seven Neurotrax neuropsychological battery domain index scaled scores (equivalent to the Wechsler IQ scale with $M = 100$, $SD = 15$), and the Composite Performance neuropsychological index scaled score, between the HOC, and LOC samples.

omission errors between the HOC ($M = 93.80$, $SD = 19.41$), and the LOC ($M = 96.27$, $SD = 13.54$) groups [$F(1,54) = 0.638$, $p = .428$].

3.4. Self-reported diagnosis and medication status

Across the entire sample, 5 individuals reported a lifetime diagnosis by a licensed mental health professional (3 HOC participants, and 2 LOC participants), all of which reported taking SSRI medications (apart from the participant with ADHD which was free from stimulant medication at the time of testing). In order to examine the impact of self-reported diagnostic status and medication status, we compared medicated/diagnosed versus un-medicated participants on major neuropsychological domain scores. No significant differences were found across all 7 scores (p's range 0.09–0.97). However, given the small sample of medicated participants, we repeated all group comparative analyses while excluding the five participants. Only one significant difference emerged on visuospatial functions [$F(1,48) = 4.342$, $p = .043$]. However, these analyses did not survive multiplicity correction for which the significant threshold was set on 0.0071. No other significant differences were detected (p's range 0.054–0.81).

4. Discussion

To our knowledge, this is the first study to utilize a comprehensive computerized neuropsychological battery to assess cognitive functions in a subclinical OC sample. In accordance with our hypotheses, controlling for severity of depression symptoms and state anxiety, the HOC groups performed lower than controls, particularly on memory tasks, but not to a significant level. In addition, both groups' performance on all outcome measures were in the normative range, when compared to test norms. Negligible effect sizes were found for the major domains of attention, motor skills and executive functioning; and, small effect sizes for verbal function, processing speed, and visuospatial functions. Notably the HOC group scored better on the latter two domains. Although all the above-mentioned differences were not significant, the largest effect size indicating underperformance in the HOC group (medium magnitude) was found in the memory domain.

Our results are similar to previous studies in analogue OC samples that did not find significant differences in verbal memory (Kim et al., 2009; Mataix-Cols, 2003; Mataix-Cols et al., 1999b), non-verbal memory (Kim et al., 2009), executive function (Abramovitch et al., 2015b; Hajcak & Simons, 2002; Mataix-Cols et al., 1999b), and attention (Abramovitch et al., 2015b; Kim et al., 2009; Mataix-Cols et al., 1997). Although, a minority of studies found differences in some executive functions (Goodwin & Sher, 1992; Kim et al., 2009; Mataix-Cols, 2003; Mataix-Cols et al., 1999b; Spitznagel & Suhr, 2002). Nevertheless, similar to the results of this study, this body of literature is characterized by small effect sizes.

Notably, most investigations on cognitive functions in analogue OC samples did not control for depression severity and state anxiety. Out of the studies that did employ such control, some studies noted that controlling for these factors resulted in lack of a significant difference on neuropsychological tasks (Goodwin & Sher, 1992; Kim et al., 2009; Mataix-Cols et al., 1999a), but other studies employing such control reported no moderating effects on their results (Abramovitch et al., 2015b; Mataix-Cols, 2003; Mataix-Cols et al., 1997, 1999b). Thus, the roles of depressive severity and state anxiety are unclear in the context of cognitive function in subclinical OC, samples, albeit meta analytic investigations found that these variables do not have a significant mediating effect on cognitive functions in OCD samples (Abramovitch et al., 2013; Shin et al., 2014).

Overall, our findings of largely negligible to small effect sizes, indicate that no deficits on any cognitive function are associated with OC phenomena in this student population. Meta-analyses of neuropsychological function in OCD demonstrate small to moderate effect sizes across multiple domains (Abramovitch et al., 2013; Shin et al., 2014; Snyder et al., 2015). In addition, it has been argued that these effect sizes may not be indicative of any clinically-relevant impairments or deficits (Abramovitch et al., 2013; Moritz et al., 2017). Although our HOC sample had OC severity scores that are equivalent with ones commonly found in OCD samples, our sample was comprised of high functioning participants (students), which may explain the lower effect sizes. In addition, one study that selected the high OC group, according to the three top percentile scores on an OC severity scale, found only differences in two outcome measures out of six. One of the two outcome measures was not found significant after controlling for depression and anxiety (Kim et al., 2009). Finally, we believe that our use of a computerized battery enabled more precise measurements of cognitive performance in terms of both more accurate time assessment and lack of interference that may stem from examiner and examinee interactions (Abramovitch et al., 2011; Perna et al., 2016).

The largest effect size was found in the memory domain which is in accordance with OCD studies where non-verbal memory is found to have moderate to large effect size and is commonly the domain with the largest effect across studies (Abramovitch et al., 2013; Shin et al., 2014). This finding may be important given that nearly every study that ever assessed non-verbal memory in OCD utilized the Rey Complex Figure Test. However, while this domain was found to have the largest effect size in our study, performance of both groups was found to be in the normative range when compared to the population norms. In the context of memory functions, a surprising finding in the present study was an equivalent effect size for verbal memory, a domain which is considered largely intact in OCD (Abramovitch et al., 2015b), and non-verbal memory. As is the case in most computerized memory tests, the verbal and non-verbal memory tests on the Neurotrax battery are largely recognition based. These tasks ask participants to identify one symbol or word (that was presented in the coding phase) out of a group of six items. It is plausible that the well-documented deficient confidence in memory in OCD (Göz, Karahan, & Tekcan, 2016; Hermans et al., 2008) that often underlies underperformance on memory tests, may underlie the fact that the largest effect sizes were found for memory. Notably, the vast majority of verbal memory tests employed in OCD samples utilized an auditory verbal memory tests (e.g., CVLT; Abramovitch et al., 2015b) where trials 1–7 are commonly reported and included in meta-analyses, and less so the recognition trial. However, there is lack of research regarding a differential effect in OCD, between

word list retrieval and recognition, in the context of deficient confidence in memory.

The present study has several strengths. Primarily, the fact that this is only the third analogue OC neuropsychological study that administrated a comprehensive neuropsychological battery, and the first to administer a computerized battery to an analogue OC sample. The computerized battery may be advantageous because it prevents potential interferences which may be caused by the examiner-examinee interaction in paper and pencil neuropsychological tasks. However, this study is not without limitations. The majority of participants were females, which may potentially limit the generalizability of the results. Although, one study found that gender was not a major distinguishing factor in the neuropsychological functioning in individuals with OCD (Mataix-Cols et al., 2006). We did not conduct a formal psychiatric screening in the present study. Thus, it is possible that some of the participants had a diagnosis of OCD or another disorder. However, the present study did include self-reported psychiatric diagnoses. In addition, any conclusion drawn from our findings may not be considered specific to obsessive-compulsive phenomena or OCD given the lack of a secondary clinical or subclinical control group. Another limitation of the present study is the small sample sizes. Although our sample sizes are similar or larger compared to the majority of neuropsychological investigations in analogue OC samples, small sample sizes may theoretically hinder the detection of true differences. However, effect size calculations in the present study, as well as the differences on standardized scaled scores, point to negligible to small performance differences that cannot be considered to be of clinical significance. Furthermore, small effect sizes have been found rather consistently across most analogue OC studies of cognitive function, which further solidify the conclusions drawn from our results. Finally, although that this was a comprehensive neuropsychological battery, we did not cover all the main neuropsychological domains such as verbal fluency and working memory, domains which are surprisingly under-researched and ought to receive research attention in analogue OC samples. However, previous studies did not document deficient performance on verbal fluency tasks in analogue OC samples (Kim et al., 2009; Mataix-Cols et al., 1999a,b).

5. Conclusion

We found no significant differences between high and low OC with small effect sizes. In addition, cognitive functioning on all domains was found to be in the normative range. This study adds to the recent literature in OCD, suggesting that neuropsychological performance associates with small to moderate effect size, and with recent claims that this may not translate to significant impairments (Abramovitch et al., 2015a; Ahmari, Eich, Cebenoyan, Smith, & Blair Simpson, 2014; Moritz, Hottenrott, Jelinek, Brooks, & Scheurich, 2012).

Although some studies report symptom severity in subclinical OC samples to be equivalent to that of OCD samples, we still found smaller effect sizes compared to clinical OCD samples. One possible explanation is that the level of functioning itself affects the presence and the severity of the symptoms. Further studies should investigate this hypothesis regarding the different findings between analogue samples and clinical samples, and in particular the association between cognitive functions and general daily functioning.

Declaration of interest

The authors declare no conflict of interest.

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