Neuropsychology

Neurocognitive Performance in Unmedicated Patients With Hoarding Disorder

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CITATION
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Objective: Hoarding disorder (HD) is an often incapacitating psychiatric illness associated with a wide range of neurocognitive abnormalities. Some prior neuropsychological studies have found executive dysfunction in HD, but no clear pattern has emerged. One potential reason for discrepant results in previous studies might be the inclusion of patients on psychotropic and other medications that can affect neurocognitive performance. Therefore, we examined neurocognitive functioning in medication-free HD patients. We also added a novel investigation of implicit learning, which has been found to be abnormal in obsessive–compulsive disorder (OCD) and related disorders. Method: Twenty-six participants meeting the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM–5; American Psychiatric Association, 2013) diagnostic criteria for HD and 23 normal controls were administered a battery of neuropsychological tests and symptom rating scales. All participants were free of psychotropic medications for at least 6 weeks prior to the study. Results: HD participants showed no significant differences from normal controls on measures of verbal memory, attention, or executive functioning, including response inhibition, planning, organization, and decision making. However, HD participants demonstrated a trend toward less implicit learning and greater use of explicit learning strategies during perceptual categorization compared to normal controls. HD participants who used an implicit strategy performed significantly worse than controls who used an implicit strategy. Hoarding symptom severity was not associated with neurocognitive performance. Conclusions: HD patients may have a tendency to use explicit rather than implicit learning strategies for perceptual categorization but perform as well as normal controls on many other neurocognitive measures. Future studies should assess unmedicated participants and examine test strategies, not just outcomes.

Keywords: neurocognitive, hoarding, compulsive, implicit, unmedicated

Hoarding is defined as the excessive acquisition of, and inability to part with, items that appear to have no value (Frost & Gross, 1993). Frost and Hartl (1996) developed the first systematic definition and diagnostic criteria for clinically significant compulsive hoarding: (a) the acquisition of and failure to discard a large number of possessions that appear to have no value, (b) living or work spaces are sufficiently cluttered so as to preclude activities for which those spaces were designed, and (c) significant distress or impairment in functioning is caused by the hoarding behavior or clutter. Hoarding and saving symptoms are part of a discrete clinical syndrome that includes the core symptoms of difficulty in discarding, urges to save, excessive acquisition, and clutter, as well as the associated features of indecisiveness (Samuels et al., 2008), perfectionism, procrastination, disorganization, and avoidance (Saxena et al., 2002).

In community-based population samples, clinically significant compulsive hoarding is common, with a population prevalence of 1.5–5.8% (Iervolino et al., 2009; Mueller, Mitchell, Crosby, Glaesmer, & de Zwaan, 2009; Nordsletten et al., 2013; Samuels et al., 2008; Timpano et al., 2011). Initial onset of compulsive hoarding symptoms is usually around 12–13 years of age (Ayers, Saxena, Golshan, & Wetherell, 2010; Frost & Gross, 1993; Grisham, Frost, Steketee, Kim, & Hood, 2006; Samuels et al., 2008; Tolin, Frost, & Steketee, 2010). The course tends to be chronic and progressive, with severe levels of hoarding starting in the mid-30s and symptoms often worsening with age (Ayers et al., 2010; Grisham et al., 2006; Tolin et al., 2010).
Hoarding disorder (HD) is now classified as a separate diagnosis in the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*; American Psychiatric Association, 2013). The diagnostic criteria for HD have been found in a clinical field trial to have excellent sensitivity, specificity, interrater reliability, and validity (Mataix-Colís et al., 2010). Several factors have influenced the *DSM–5* classification of HD, including evidence that individuals with HD have neurocognitive deficits, and that the pattern of their deficits differs from that seen in patients with obsessive–compulsive disorder (OCD; Pertusa et al., 2010). Although differences between groups have been found, a consistent pattern of neurocognitive impairment in HD has not yet emerged.

Studies that have measured attention, response inhibition, and impulsivity in HD have had discrepant findings. Grisham, Brown, Savage, Steketee, and Barlow (2007) administered Conner’s Continuous Performance Test II (CPT–II; Conners, 2000) and the visual memory span subtest from the Wechsler Memory Scale—Revised (WMS–R; Wechsler, 1987) to compulsive hoarding participants, mixed clinical (non-OCD) participants, and normal controls. Hoarding participants showed slower and more variable hit reaction time (RT), increased impulsivity, more commission errors, and poor spatial attention. In a later study, administration of the CPT–II to individuals with HD, individuals with nonhoarding OCD, and normal controls revealed no significant differences between groups on the number of commission errors made (Tolin, Villavicencio, Umbach, & Kurtz, 2011). However, a significant difference was found in hit RTs, with the HD group demonstrating poorer attentional capacity than normal controls. Grisham, Norberg, Williams, Certoma, and Kadib (2010) administered the Attentional Go/No-Go (AGN) task, the Intra–Extra Dimensional (IED) Set Shifting task, the Stockings of Cambridge task (SOC), and the Cambridge Gambling Task (CGT) to HD participants, mixed clinical (non-OCD) participants, and normal controls. Compared to mixed clinical participants and normal controls, HD participants showed deficits in planning and problem-solving ability on the SOC task. However, they did not demonstrate impairment on any tasks of response inhibition, impulsivity, cognitive flexibility, attention, or decision making or strategy learning. Morein-Zamir et al. (2014) found similar results on the IED. Although subjects with comorbid OCD and hoarding had significantly increased errors on the IED, HD and control subjects showed comparable performance.

Phenomenological models suggest that compulsive hoarding is linked to information-processing deficits in decision making, organization, and categorization (Frost & Hartl, 1996; Steketee & Frost, 2003; Wincke, Steketee, & Frost, 2007). Individuals who hoard demonstrate impairment in the ability to categorize information, manifested by their large amounts of disorganized clutter and problems finding possession when needed. Frost and Hartl (1996) hypothesized that individuals who compulsively hoard may define category boundaries too narrowly, leading to smaller category sizes and a larger number of categories. They suggested that hoarding patients see each possession as unique and complex, resulting in little perceived similarity between objects. Wincke et al. (2007) found evidence of such underinclusive categorization of personally relevant household items in people with primary compulsive hoarding. Hoarding patients created a larger number of piles, took more time, and reported more anxiety during the categorization task than nonclinical controls. Further, hoarding severity was correlated with the number of piles created. Grisham et al. (2010) found very similar deficits in hoarding participants on several sorting and categorization tasks. These findings are consistent with HD patients’ self-reports of difficulty grouping their possessions and developing efficient storage systems for them.

Varied results have been obtained on measures of executive functioning, planning, and set shifting. Morein-Zamir et al. (2014) found that on the Tower of London (ToL), subjects with comorbid OCD and hoarding and subjects with HD alone required more moves to complete problems than controls and solved fewer problems in the minimal moves possible. Several studies have found that hoarding is associated with poorer performance on the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948), a test of executive functioning that assesses set shifting, planning, and perseveration. One study found that OCD participants who reported higher levels of hoarding performed significantly worse on the test than participants who reported lower levels of hoarding (Lawrence et al., 2006). McMillan and Rees (2013) found that HD participants showed deficits in WCST performance compared to published norms. Ayers et al. (2013) found that older adults with HD made significantly more errors on the WCST than demographically matched controls. Further, elderly HD participants made significantly more nonperseverative errors and performed worse on conceptual-level responses on the WCST. Severity of hoarding was strongly correlated with poor performance on the WCST (Ayers et al., 2013). In contrast, Tolin, Meunier, Frost, and Steketee (2011) found that HD participants performed better on the WCST than participants with nonhoarding OCD, demonstrating fewer total errors.

Decision making and organizational strategies have been investigated in HD using the Iowa Gambling Task (IGT; Bechara, Damasio, Tranel, & Damasio, 1997), but results have been inconsistent. Lawrence et al. (2006) found that OCD patients who reported higher levels of hoarding symptoms displayed less effective strategies on the IGT than OCD participants without hoarding symptoms and normal controls. In contrast, Blom et al. (2011) reported that HD participants performed better than OCD participants on the IGT by learning faster and obtaining a greater overall net score. Tolin and Villavicencio (2011) found no differences among individuals with HD, individuals with nonhoarding OCD, and normal controls on the IGT, while Grisham et al. (2007) found that HD participants had a similar performance on the IGT compared to nonhoarding OCD participants.

Studies of memory in hoarding have also been inconsistent. Hartl et al. (2004) found that patients with compulsive hoarding had difficulty with visual memory compared to controls, showing lower scores in delayed recall and organizational strategy on the Rey–Osterrieth Complex Figure Test (RCFT; Osterrieth, 1944). Hoarding participants also underperformed controls on short and long delayed recall of the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987), which indicated problems in verbal memory. Another study found a significant difference between HD patients and normal controls on RCFT measures of organizational strategy but no difference between the HD and OCD groups (Tolin et al., 2011). Pinto and colleagues (2011) found a positive correlation between hoarding symptom severity scores and organizational strategy for the copy portion of the RCFT in participants with OCD. However, in contrast to the other findings, Jang et al. (2010) reported that the presence of hoarding...
symptoms in participants diagnosed with OCD was not correlated with RCFT performance.

Many explanations have been suggested for the discrepancies in neuropsychological findings in HD. One possible contribution to these discrepancies might be the neurocognitive effects of psychotropic medications taken by participants in those studies. A review of the previously published literature on neurocognitive functioning in compulsive hoarding shows that the majority of prior studies (Ayers et al., 2013; Blom et al., 2011; Kathmann, Rupertseder, Hauke, & Zaudig, 2005; Lawrence et al., 2006; Morein-Zamir et al., 2014; Pinto et al., 2011; Tolin et al., 2011; Tolin & Villavicencio, 2011) included subjects taking psychotropic and other medications. The remainder did not report whether their subjects were taking medications and did not list medications as exclusion criteria. In fact, our literature review did not reveal any neuropsychological studies of hoarding that listed psychotropic medication use as an exclusion criterion, which raises the question of whether their results may have been due to pharmacological alterations in cognitive functioning. Many psychotropic drugs act as central nervous system depressants; have anticholinergic properties that can adversely affect cognition; or have side effects that may impact cognition via dizziness, drowsiness, headache, disorientation, confusion, memory impairment, or psychomotor slowing. While the adverse effects of benzodiazepines, mood stabilizers, and antipsychotics on cognitive performance are well known (Amado-Boccara, Gouguilhs, Poirier-Litré, Galimowskis, & Loo, 1995; Dias et al., 2012; Stein & Strickland, 1998; Stewart, 2005; Wadsworth, Moss, Simpson, & Smith, 2005), even serotonin reuptake inhibitor medications and other antidepressants have been associated with impairment in attention, episodic memory, nonverbal memory, and executive function, both in healthy controls (Wadsworth et al., 2005) and in patients with mood and anxiety disorders (Tempesta et al., 2013). The SRI paroxetine was found to impair generalization of sequence learning in patients with MDD (Herzallah et al., 2013), while escitalopram has been found to reduce attentional performance in some populations of older adults with GAD (Lenze et al., 2013). Further, cognitive side effects are more prevalent when patients are treated with the higher doses of SRI medications needed for treatment of OCD (Bloch, McGuire, Landeros-Weisenberger, Leckman, & Pittenger, 2010) and related obsessive–compulsive spectrum disorders such as HD (Saxena, 2011). Therefore, we sought to eliminate the potential confounds of medication effects on neurocognitive performance by studying only HD patients who were not taking any psychotropic drugs or other medications that could affect brain function.

The present study sought to test neurocognitive function on a wide range of neuropsychological measures in an attempt to more accurately and reliably identify neurocognitive abnormalities in participants with HD. Additionally, participants were identified as having HD only after meeting appropriate diagnostic criteria and severity thresholds based on structured diagnostic assessments and standardized symptom rating measures.

We also sought to investigate implicit category learning in HD. Implicit category learning involves the ability to acquire categorization skills by trial-and-error feedback and relies on procedural-based learning processes (Ashby, Alfonso-Reese, Turken, & Waldron, 1998). In contrast, explicit category learning requires the conscious acquisition of rules that dictate category membership (e.g., a vehicle with two wheels and an engine is a motorcycle). Implicit category learning is mediated by the striatum, while explicit category learning is mediated by frontal and medial temporal structures (Ashby & Spiering, 2004; Filoteo, Maddox, Salmon, & Song, 2005; Nomura et al., 2007). No study to our knowledge has examined implicit or procedural-based learning in HD. However, previous studies have examined these processes in patients with other psychiatric disorders, such as OCD, and have shown deficits on tasks such as the serial RT test (SRT; Deckersbach et al., 2002; Goldman et al., 2008; Joel et al., 2005; Kathmann et al., 2005; Marker, Calamari, Woodard, & Riemann, 2006; Nissen & Buller, 1987). Goldman and colleagues (2008) found that OCD patients with prominent hoarding symptoms had a significantly different pattern on the SRT than other OCD patients—they showed no implicit learning at all. These findings suggest that patients with HD might have a specific deficit in implicit, procedural-based learning.

Specific hypotheses regarding deficits on particular domains were difficult to base on previous neuropsychological studies of HD, because of their disparate findings and variability in their assessment measurements. However, based on the replicated findings of poor attention, poor visual memory organizational strategy on the RCFT, and poor performance on the WCST in HD patients, as well as evidence of poor planning and problem solving on the TOL and SOC tasks in HD and a deficit in implicit learning on the SRT in OCD patients with prominent hoarding symptoms, we hypothesized that unmedicated patients with HD would show impaired performance in selected neurocognitive domains. Our primary hypotheses were that (a) individuals with HD would perform significantly worse than normal controls on tests of attention, visuospatial memory, organizational strategy, executive functioning, planning, and implicit category learning and (b) greater severity of hoarding symptoms would be significantly associated with poorer performance on neurocognitive measures.

Materials and Method

This study was approved by the University of California, San Diego, Institutional Review Board (IRB) in accordance with the Declaration of Helsinki. All participants gave informed consent to participate in the study.

Participants

Participants were recruited from the San Diego area with flyers, print, and Internet advertisements, as well as referrals from local clinicians. Two groups of participants were enrolled in the study: individuals with HD and normal controls. To be enrolled, HD participants had to meet DSM–5 diagnostic criteria for HD as their primary, most distressing, or impairing condition. All participants were first diagnosed by clinical interview and then were more formally assessed through the MINI International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). For further clarification of OCD and related OCD spectrum disorders, all participants were also administered the OCD spectrum module from a revision of the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders (4th ed.; DSM–IV; SCID–I; First, Spitzer, Gibbon, & Williams, 1996) developed by Lochner, du Toit, Van Kradenburg, and Stein, (2005). Normal controls had no current psychiatric disorders and no history of psychiatric disor-
ders. All participants were matched for age, gender, education, and race.

Patients with primary psychotic disorders, bipolar disorder, panic disorder, posttraumatic stress disorder, substance abuse or dependence, eating disorders, dementia, or mental retardation were excluded. Participants were also excluded if they had any severe medical problems, a history of head injury or neurological disorders, or if they were participating in ongoing psychotherapy. All participants were free of psychotropic medication and any other medication that could affect brain function for at least 6 weeks. All participants were native English speakers.

Procedures

Study evaluations included clinician-administered psychiatric rating scales, self-report questionnaires, and a battery of neuropsychological tests. A psychiatrist, a neuropsychologist, and/or an advanced graduate student administered all study procedures.

Symptom Rating Scales

The Saving Inventory—Revised (SI–R; Frost, Steketee, & Grisham, 2004) is a well-validated, 23-item, self-report questionnaire used to assess hoarding severity. Subscales include difficulty discarding, excessive clutter, and excessive acquisition. To be enrolled, HD participants had to score more than 40 on the SI–R (maximum score = 92). The SI–R cutoff was based on the results of prior studies that constructed receiver operating characteristic (ROC) curves to distinguish HD patients from controls and other diagnostic groups with maximal sensitivity and specificity (Frost & Hristova, 2011; Tolin et al., 2010).

The UCLA Hoarding Severity Scale (UHSS; Saxena, Brody, Maidment, & Baxter, 2007) is a 10-item, clinician-administered scale that assesses the severity of different features of compulsive hoarding syndrome, including difficulty discarding, urges to save, excessive acquisition, clutter, indecisiveness, perfectionism, slowing, procrastination, and social and occupational impairment. The UHSS is internally consistent and demonstrates convergent, discriminant, and known group validity (Saxena, Ayers, Dozier, & Maidment, 2015). In order to be enrolled, HD participants had to score more than 18 on the UHSS (maximum score = 40).

The Yale–Brown Obsessive Compulsive Scale (Y–BOCS; Goodman et al., 1989) is a 10-item, clinician-administered scale used to assess the severity of OCD symptoms. It has five rating domains for obsessions and compulsions: time spent or occupied; interference with functioning or relationships; degree of distress; resistance; and control (i.e., success in resistance).

The Hamilton Depression Rating Scale (HDRS; Hamilton, 1960) is a 15-item questionnaire used to assess the severity of depression by exploring an individual’s mood, suicidal ideation, feelings of guilt, agitation or retardation, insomnia, anxiety, weight loss, and somatic symptoms.

The Hamilton Anxiety Rating Scale (HAM–A; Hamilton, 1959) is a clinician-administered, 14-item questionnaire that measures the severity of anxiety symptoms. The scale assesses levels of mental agitation and psychological distress as well as physical complaints related to anxiety.

The Global Assessment of Functioning Scale (GAF; Endicott, Spitzer, Fleiss, & Cohen, 1976) is a numeric rating scale used to measure the overall functioning of an individual during a specified period of time. The scale assesses social, occupational, and psychological functioning and ranges from complete dysfunction to superior functioning.

The Obsessive–Compulsive Inventory—Revised (OCI–R; Foa, Kozak, Salkovskis, Coles, & Amir, 1998) is an 18-item self-report questionnaire intended to measure the severity and intensity of OCD symptoms over the previous month.

The State Trait Anxiety Inventory Form Y (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is an instrument used to measure transient state anxiety and more long-standing trait anxiety in adults. All items are rated on a 4-point scale (e.g., from almost never to almost always). Higher scores indicate greater anxiety.

Neuropsychological Battery

The North American Adult Reading Test (NAART; see Spreen & Strauss, 1991, 1998) is a modification of the National Adult Reading Test (NART) developed by Blair and Spreen (1989; see also Spreen & Strauss, 1991, 1998) for use with the North American population. Examinees are asked to read two columns of words without examiner feedback. This brief measure is used to estimate verbal intellectual (VIQ) ability and was utilized in the present study both to estimate verbal intelligence and to ensure that groups did not differ significantly in basic intellectual function. This test has proven to be a reliable and valid measure of verbal intelligence, similar in psychometric properties to the Wechsler Adult Intelligence Scale—Revised (WAIS–R) Vocabulary Test (Uttl, 2002).

The California Verbal Learning Test—Second Edition (CVLT–II; Standard and Alternate Forms; Delis, Kaplan, Kramer, & Ober, 2000) evaluates the participant’s ability to recall a list of 16 words over five trials. It includes an immediate and delayed recall as well as a recognition trial. The test can also assess the efficiency of organizational strategies that affect later learning.

The Stroop Color and Word Test (Stroop, 1935) is a measure of response inhibition and selective attention. The test taker looks at three sheets of color and word combinations, reading the words or naming the ink colors as quickly as possible within a time limit.

The Object Alternation Test (OAT; Friedman, 1990) assesses an individual’s ability to shift problem solving after examiner feedback. It also measures response inhibition and perseveration. The test resembles a shell game in which the participant has to guess under which cup a penny lies hidden over several trials, with the penny alternating position after each correct response.

The Tower of London—Drexel University (ToL3X; Calbertson & Zillmer, 1998b) requires the participant to plan ahead to determine the order of moves necessary to rearrange three colored beads from their initial positions to a new set of predetermined positions. The time it takes the participant to make the first move and the total time for completion are recorded to assess decision-making speed. The ToL3X also assesses visual working memory, attention allocation, ability to shift mental sets, and response inhibition.

The Controlled Oral Word Association Test (COWAT; Benton, Hamsher, & Sivan, 1994) is a test of verbal fluency and ability to categorize given verbal cues. The phonemic portion of the test requires the participant to generate words beginning with a partic-
ular target letter in a 1-min time frame. During the semantic fluency portion of the test, participants are asked to generate words that fit into a given category within 1 min.

The Rey–Osterreith Complex Figure Test (RCFT; Osterreith, 1944) is a measure of nonverbal memory, visuospatial construction, and organizational strategy. Participants are asked to copy a geometric figure and remember it for later recall. The organizational strategy for the RCFT is evaluated using a system developed by Savage et al. (1999). Findings suggest that this organizational approach is highly reliable (Deckersbach et al., 2000).

The Perceptual Categorization Task (PCT; Ashby & Gott, 1988) examines implicit and explicit procedural-based category learning. The PCT has been used extensively to examine implicit and explicit category learning processes in normal controls and various patient populations (Ashby et al., 1998; Filoteo, Maddox, & Davis, 2001a; Maddox & Ashby, 2004; Maddox, Filoteo, Lauritzen, Connally, & Hejl, 2005; Maddox, Glass, O’Brien, Filoteo, & Ashby, 2010). Participants in this study were asked to categorize stimuli consisting of Gabor patches into one of two categories (Category A or Category B), and immediately following their response they were provided feedback that indicated the correct answer (see Figure 1). The Gabor patches varied in orientation and spatial frequency across trials. Five blocks of 40 separate stimuli were presented to each participant. An equal number of Category A and B stimuli were presented.

An important aspect of the PCT is that computational models have been developed that can be applied to PCT data to determine the strategy being used by the participant during the task (Ashby & Maddox, 1993; Maddox & Ashby, 1993; Maddox, Ashby, & Bohil, 2003; Maddox, Ashby, Ing, & Pickering, 2004; Zeithamova & Maddox, 2006). These models enable a more detailed investigation of procedural learning. Previous studies have shown that patient groups can differ from controls in category learning, not because of impairment in learning ability, but because they adopted a different strategy than controls when learning (Ashby, 1992; Filoteo & Maddox, 1999; Filoteo, Maddox, & Davis, 2001a, 2001b; Maddox, 1999; Maddox & Ashby, 1993, 1996; Maddox, Filoteo, Delis, & Salmon, 1996; Maddox, Filoteo, & Huntington, 1998; Shohamy et al., 2004). Three classes of models were applied to the final block of data for each participant (the details of these models can be found in Maddox, 1999, and Maddox & Ashby, 1993). One class of models assumes that the participant used an implicit, procedural-based (PB) approach by performing an implicit, nonlinear (quadratic) integration of the spatial frequency and orientation of the stimuli (see Figure 2). A number of previous studies have shown that when participants learn the nonlinear quadratic rule, they are likely using implicit processes (Filoteo et al., 2001a, 2001b). The second class of models applied to the PCT data is the hypothesis testing (HT) model, which assumes that the participant used a verbalizable (explicit) rule when performing the task. A final model applied assumes that the participant responded randomly (RR). Akaike’s information criterion (AIC) was used to determine the model that provided the best account of the data.

Statistical Analyses

All data were evaluated using SPSS 17.0 (IBM, Armonk, New York). The data were first statistically screened for distributional properties, outliers, and missing values. This process did not reject any variables. Raw scores were utilized for all analyses of neurocognitive tests. Demographic data and rating scales were analyzed for both groups using one-way analysis of variance (ANOVA) and chi-square. An omnibus multivariate analysis of variance (MANOVA) was performed on neuropsychological variables across all tests except for the PCT to correct for multiple comparisons. Wilks’ lambda was set at $p < .05$ for an overall effect of group. Univariate ANOVAs were conducted only for neurocognitive variables found to have a significant effect of group in the omnibus MANOVA results.

For the PCT, accuracy from the five blocks of trials was analyzed using a 2 (group: HD vs. controls) $\times$ 5 (Blocks 1–5) mixed-design ANOVA. To determine if groups differed in their applied strategy on the PCT, we examined the number of participants in each group whose Block 5 data were best fit by the PB or the HT model using Pearson chi-square. Block 5 data were chosen for analysis because a participant’s pattern of responding is most stable at this point, and the models are more likely to reflect the actual approach a participant used (Filoteo et al., 2005).

To identify significant associations between symptom severity and cognitive deficits, partial correlations were calculated between hoarding symptom severity scores and performance on cognitive tests, controlling for anxiety (HAM–A) and depression (HDRS).

Results

Forty-nine participants met the inclusion criteria for this study. Twenty-six participants with HD (23 female, three male; age: $M = 49.85$, $SD = 10.42$ years) and 23 normal controls (19 female, four male; age: $M = 52.43$, $SD = 6.27$ years) were enrolled. Of the HD group, 19 participants were White, three were Hispanic, one was Asian American, two were mixed race, and one declined racial identification. Seventeen controls identified as White, four as

Figure 1. Gabor patch.
Hispanic, one as African American, and one as mixed race. There were some participants with HD who also met diagnostic criteria for comorbid major depressive disorder (MDD; \( N = 4 \)), attention-deficit/hyperactivity disorder (ADHD; \( N = 4 \)), generalized anxiety disorder (GAD; \( N = 3 \)), social phobia (\( N = 2 \)), dyslexia (\( N = 2 \)), panic disorder (\( N = 1 \)), and OCD (\( N = 1 \)). All normal control participants were free of any psychiatric illness. Hoarding symptom severity was in the moderate to severe range in the HD group, with a mean UHSS score of 23.65 ± 4.63 and a mean SI–R score of 67.20 ± 10.88. All symptom severity rating scales showed significant differences between the two groups (see Table 1). However, the groups did not differ significantly on any measured demographic characteristic, including age, education, gender, handedness, race, or estimated VIQ scores. Sample sizes decreased over time due to technological malfunctions, examiner medical leave, and a history of previous testing on a specific task (see Tables 1 and 2 for sample sizes).

The omnibus MANOVA of neurocognitive performance (see Table 2) revealed no significant differences between groups on measures of verbal memory, attention, or executive functioning, including response inhibition, planning, organization, and decision making. \( F(18, 24) = 1.83, p = .09 \); Wilks’ \( \lambda = .421 \), partial \( \eta^2 = .58 \). Both groups performed well within the normal range of functioning based on published norms (Spreen & Strauss, 1991, 1998).

Accuracy results for the PCT displayed a main effect for block, \( F(1, 3.39) = 8.18, p < .0001, \eta^2 = .19 \), 95% confidence intervals (CIs) \([- .06, .07], [- .07, .07], [- .13, .03], [- .13, .02] \), as both HD and control participants’ performances improved significantly across the five trials (see Table 3). However, there was no significant effect for group and no significant interaction effect of group by block. To determine if accuracy on the PCT was associated with any clinical measures, a learning slope was calculated by subtracting the first block accuracy from the final block accuracy for each participant. The learning slope was then correlated with all rating scale raw scores. No significant correlations were found.

In the HD group, six subjects’ PCT data sets were best fit by the PB model (implicit approach), 15 were best fit by the HT model (explicit approach), and one was best fit by the RR model (random responding). However, in the control group, eight subjects’ PCT data sets were best fit by the PB model, five were best fit by the HT model, and four were best fit by the RR model. These frequencies demonstrated a trend toward greater HT model use and less PB model use on the PCT by HD participants than control participants \( (\chi^2 = 5.48, N = 38, p = .065, \text{Cramer’s } V = .38) \). Though the difference between groups was not statistically significant, control participants were somewhat more likely than HD

### Table 1

<table>
<thead>
<tr>
<th>Sample Characteristics</th>
<th>Mean for HD participants; ( n = 26 )</th>
<th>Mean for normal controls; ( n = 23 )</th>
<th>( F ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>3.49 (10.42)</td>
<td>5.23 (6.27)</td>
<td>ns</td>
</tr>
<tr>
<td>Education</td>
<td>15.23 (2.03)</td>
<td>15.04 (2.16)</td>
<td>ns</td>
</tr>
<tr>
<td>NAART error score</td>
<td>19.96 (8.81); estimated VIQ = 111</td>
<td>23.13 (9.67); estimated VIQ = 108</td>
<td>ns</td>
</tr>
<tr>
<td>Gender</td>
<td>3 male, 23 female</td>
<td>4 male, 19 female</td>
<td>ns</td>
</tr>
<tr>
<td>Race</td>
<td>19 White, 3 Hispanic, 1 Asian, 2 Mixed, 1 unidentified</td>
<td>17 White, 4 Hispanic, 1 African American, 1 Mixed</td>
<td>ns</td>
</tr>
<tr>
<td>UHSS</td>
<td>23.65 (4.63)</td>
<td>13.52 (6.02)</td>
<td>444.83*</td>
</tr>
<tr>
<td>SI–R</td>
<td>67.20 (10.88); ( n = 25 )</td>
<td>6.14 (7.45); ( n = 21 )</td>
<td>473.88*</td>
</tr>
<tr>
<td>Y–BOCS</td>
<td>21.28 (4.03); ( n = 25 )</td>
<td>0 (0)</td>
<td>641.41*</td>
</tr>
<tr>
<td>OCI–R</td>
<td>18.19 (9.71); ( n = 16 )</td>
<td>1 (1.41); ( n = 17 )</td>
<td>52.19*</td>
</tr>
<tr>
<td>OCI–R nonhoarding</td>
<td>8.06 (8.82); ( n = 16 )</td>
<td>.29 (.59); ( n = 17 )</td>
<td>13.15*</td>
</tr>
<tr>
<td>HDRS</td>
<td>14.39 (9.04)</td>
<td>2.39 (2.82)</td>
<td>41.28*</td>
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<tr>
<td>HAM–A</td>
<td>10.35 (5.31)</td>
<td>2.39 (2.59)</td>
<td>39.31*</td>
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<tr>
<td>STAI–S</td>
<td>40.73 (14.04)</td>
<td>25.57 (7.54)</td>
<td>21.37*</td>
</tr>
<tr>
<td>STAI–T</td>
<td>46.23 (13.13)</td>
<td>25.52 (6.95)</td>
<td>45.82*</td>
</tr>
<tr>
<td>GAF</td>
<td>54.77 (7.38)</td>
<td>84.59 (5.50); ( n = 22 )</td>
<td>244.25*</td>
</tr>
</tbody>
</table>

*Note.* Standard deviations are in parentheses. \( ns \) = not significant. HD = hoarding disorder; \( ns \) = not significant; NAART = North American Adult Reading Test; VIQ = verbal intellectual; UHSS = UCLA Hoarding Severity Scale; SI–R = Saving Inventory—Revised; Y–BOCS = Yale–Brown Obsessive Compulsive Scale; OCI–R = Obsessive–Compulsive Inventory—Revised; HDRS = Hamilton Depression Rating Scale; HAM–A = Hamilton Anxiety Rating Scale; STAI–S = State Trait Anxiety Inventory–S; STAI–T = State–Trait Anxiety Inventory–T; GAF = Global Assessment of Functioning Scale. \( p < .001 \).
subjects to adopt an implicit approach on the PCT. For those participants whose data were best fit by a PB model (implicit approach), HD subjects performed significantly worse than controls, HD accuracy = .59, control accuracy = .77; t(12) = −2.37, p = .035, d = −1.30, 95% CI [−.35, −.02]. This did not hold true when comparing accuracy rates for participants who used the HT model—explicit approach; HD accuracy = .66, control accuracy = .66; t(18) = −.12, p = .91, d = −.063, 95% CI [−.06, .05].

To ascertain whether implicit versus explicit model usage influenced HD participants’ performance on neurocognitive measures outside of the PCT, we compared the neurocognitive test performance of HD participants who used the implicit PB model on the PCT to that of HD participants who used the explicit HT model. Results indicated that those HD subjects who used the PB model on the PCT scored significantly higher in CVLT serial clustering (M = 2.13, SD = 1.32) than those who used the explicit HT model on the PCT, M = .439, SD = .951; t(15) = 2.85, p = .012, d = 1.47, 95% CI [−.32, 2.95]. There were no other significant correlations found between model usage on the PCT and performance on any other neurocognitive measures.

### Table 2

<table>
<thead>
<tr>
<th>Neurocognitive test variables</th>
<th>Raw score mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD participants</td>
<td>Normal controls</td>
</tr>
<tr>
<td>CVLT Trials 1–5 total</td>
<td>58.09 (8.60)</td>
</tr>
<tr>
<td>CVLT Trial 1</td>
<td>7.87 (1.94)</td>
</tr>
<tr>
<td>CVLT SDFR</td>
<td>12.32 (2.80)</td>
</tr>
<tr>
<td>CVLT LDFR</td>
<td>12.91 (2.69)</td>
</tr>
<tr>
<td>Stoop total time (Stoop Color and Word Test)</td>
<td>120.09 (26.07)</td>
</tr>
<tr>
<td>ToL\textsuperscript{DX} total move</td>
<td>35.96 (18.46)</td>
</tr>
<tr>
<td>ToL\textsuperscript{DX} total correct</td>
<td>3.91 (2.04)</td>
</tr>
<tr>
<td>ToL\textsuperscript{DX} total initiation time</td>
<td>74.70 (43.23)</td>
</tr>
<tr>
<td>ToL\textsuperscript{DX} total execution time</td>
<td>253.35 (127.16)</td>
</tr>
<tr>
<td>OAT learning criteria</td>
<td>Yes (16), no (7)</td>
</tr>
<tr>
<td>OAT perseverations</td>
<td>2.43 (2.21)</td>
</tr>
<tr>
<td>FAS</td>
<td>41.91 (9.37)</td>
</tr>
<tr>
<td>Animal naming</td>
<td>21.91 (4.00)</td>
</tr>
<tr>
<td>RCFT copy</td>
<td>32.87 (3.00)</td>
</tr>
<tr>
<td>RCFT delay</td>
<td>20.33 (6.15)</td>
</tr>
<tr>
<td>RCFT organizational copy</td>
<td>4.70 (1.18)</td>
</tr>
<tr>
<td>RCFT organizational delay</td>
<td>4.48 (1.59)</td>
</tr>
</tbody>
</table>

*Note.* Standard deviations are in parentheses. HD = hoarding disorder.

Our second hypothesis, which suggested that greater hoarding severity would be correlated with worse neurocognitive performance, was largely unsupported by our results. Partial correlations indicated that hoarding severity, as measured by the SI–R, was negatively associated with semantic clustering on the CVLT–II, r(19) = −.50, p = .02. This indicates that individuals with more severe hoarding symptoms were less likely to use semantic clustering as an efficient strategy for verbal recall. However, there were no significant correlations found between UHSS scores and performance on any neurocognitive measures.

### Discussion

The present study sought to examine neurocognitive functioning in unmedicated individuals with HD compared to a group of matched healthy controls. To our knowledge, this is the first study to examine neurocognitive functioning in HD participants who were not taking any medications that affected brain function. As such, these results expand upon previous research and present a novel perspective on neuropsychological performance in individuals with HD.

Our hypothesis regarding deficient implicit, procedural-based learning in HD was partially confirmed. Participants in both groups had relatively similar overall accuracy scores on the PCT. However, for those participants whose Block 5 data were best fit by either a PB or HT model, only 29% of the participants in the HD group used an implicit approach, while 71% used an explicit approach. In contrast, 62% of the healthy controls used an implicit approach, whereas only 38% used an explicit approach. While this difference did not quite reach statistical significance (p = .06), the trend suggests that individuals with HD may have less of a propensity to learn a procedural-based task using an implicit approach, instead using explicit rules to learn perceptual category structures. It may be worthwhile to note that previous studies using
the PCT incorporated more than five blocks of 40 trials (Ashby et al., 1998; Filoteo et al., 2001a; Maddox & Ashby, 2004; Maddox et al., 2005, 2010). Our truncated version of the PCT may have compromised study findings, resulting in the lack of significant differences. Nevertheless, among participants whose data were best fit by the PB model, indicating implicit strategy use, HD participants performed significantly worse than controls. In contrast, there was no difference in performance between the two groups for those participants whose data were best fit by an HT model (indicating the use of an explicit approach). Thus, although there were no overall group differences in accuracy, modeling results suggest that HD participants have less of a tendency to use an implicit approach than controls, and even when they do use such an approach, their accuracy is worse than that of controls.

Previous studies of patients with OCD have also demonstrated abnormal implicit, procedural-based learning processes (Kathmann et al., 2005), as well as parallel implicit and explicit processing (Deckersbach et al., 2002) on the SRT test, a measure of procedural learning. Notably, Kathmann et al. (2005) found that the implicit learning deficits observed in OCD subjects were not the result of more generalized cognitive impairment such as impaired attention. Our findings suggest a similar trend toward implicit learning deficits without other executive dysfunction in patients with HD. Our findings are also in accordance with those of Goldman et al. (2008), who found that OCD patients with prominent hoarding symptoms showed no indication of any implicit learning on the SRT, and with those of Blom et al. (2011), who found disturbed implicit memory in hoarding subjects on the SRT when compared to controls.

Contrary to our primary hypothesis that the HD group would perform more poorly than healthy controls on tests of attention, executive functioning, and organizational strategy for visual recall, our two groups did not differ significantly on any neurocognitive tests that assessed attention, impulsivity, planning, organization, decision making, or memory. Both groups scored well within the normal range of functioning on all tests. However, although HD participants in the present study scored almost equivalent to healthy controls on measures of learning accuracy and verbal recall, higher levels of hoarding severity in the HD group were associated with decreased semantic clustering on the CVLT–II. Semantic clustering is an indication of efficient verbal recall strategy. This result, paired with our findings from the PCT, suggests that HD patients seem to perform roughly equally well as normal controls on neurocognitive tests but may use different strategies to do so.

In light of previous findings, the lack of significant differences in performance between HD and control groups on most neuro-psychological measures may seem surprising. However, the majority of prior studies that have addressed neurocognitive functioning in compulsive hoarding reported the inclusion of subjects who were taking prescribed psychotropic medications (Ayers et al., 2013; Blom et al., 2011; Kathmann et al., 2005; Lawrence et al., 2006; Morein-Zamir et al., 2014; Pinto et al., 2011; Tolin et al., 2011; Tolin & Villavicencio, 2011), and the remainder did not report whether subjects were taking medications or list medication use as exclusion criteria. Thus, the neurocognitive deficits in attention, memory, and executive functioning found in those studies might have been due to the effects of psychotropic medications (Amado-Boccara et al., 1995; Dias et al., 2012; Stein & Strickland, 1998; Stewart, 2005; Wadsworth et al., 2005), even those of SRI medications (Herzallah et al., 2013; Lenze et al., 2013; Tempesta et al., 2013) and other antidepressants (Wadsworth et al., 2005). Some prior studies also included subjects who had other comorbid psychiatric disorders known to cause neurocognitive dysfunction, whereas the present study excluded subjects with most of those disorders. While previous study findings may or may not have been compromised by such confounding variables, studies that exclude or control for medications that affect brain functioning may be necessary to determine valid neurocognitive performance in any population.

Though the present study has many strengths, including a medication-free experimental group, an age- and gender-matched healthy control group, the use of gold-standard neurocognitive instruments, structured psychiatric interviews, and both self-report and clinician-administered measures of hoarding symptom severity, there were also limitations. First, the small sample size for both groups limited statistical power. A larger sample may have shown significant differences in implicit versus explicit category learning on the PCT. However, our study sample size is very similar to or larger than those of other related neuropsychological studies of hoarding (Blom et al., 2011; Grisham et al., 2007; Hartl et al., 2004; McMillan & Rees, 2013; Morein-Zamir et al., 2014; Tolin et al., 2011; Wincze & Steketee, 2007). Second, the HD group in the present study was mostly composed of participants who were seeking treatment for HD. Consequently, results of this study might not be generalizable to the broader population of HD patients with variable insight and motivation for treatment. Third, our study did not include a group of HD participants taking psychoactive medication. Such an additional comparison group of medicated patients would allow for a more thorough examination of medication effects on neurocognitive performance in HD patients. Finally, some of our HD patients had comorbid disorders, including MDD, ADHD, GAD, social phobia, dysthymia, panic disorder, and OCD. It is possible that inclusion of participants with these comorbidities could have affected our results. However, given the presence of these disorders, it was surprising that more neurocognitive deficits were not found in our HD sample. The sample sizes within each comorbid disorder were not large enough to ascertain their specific effects on neurocognitive performance. Further studies assessing the impact of comorbidities on neuropsychological performance in HD subjects are warranted. Future research examining the neurocognitive performance of HD patients should focus on performance strategies and include a larger sample composed of individuals with varying levels of current treatment and comorbidities. Additionally, studies measuring neurocognitive performance before and after medication treatment would yield greater insight into medication effects on both symptoms and neurocognitive performance in HD.

References


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