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Identifying psychiatric and neurological comorbidities associated with hoarding disorder through network analysis

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Abstract

Background—The relationships between hoarding disorder (HD) and other neurological and psychiatric disorders remain largely unknown. Although psychiatric burden in those with HD is high, less is known about neurological disorders. Furthermore, which disorders are primarily associated with HD vs which can be better explained via a relationship with another disorder has not been determined. To address these questions, we examined comorbidity patterns of psychiatric and neurological disorders in a large online registry of adults using network analyses.

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Contributions

LSV: Conceptualization, Methodology, Formal Analysis, Writing -Original Draft, Writing -Review & Editing, Funding acquisition, **SN, AG, AO, HS, JZ, CA, NL, BN**: Investigation, Writing -Review & Editing, **MJG:** Data Curation, Writing -Review & Editing, **RN,MW:** Writing-Review and Editing, **RSM:** Conceptualization, Funding acquisition, Supervision, Writing -Review & Editing, Project administration **CAM:** Conceptualization, Methodology, Formal Analysis, Writing -Original Draft, Writing -Review & Editing, Funding acquisition, Supervision, Project administration

Methods—We first examined psychiatric comorbidity among 252 participants completing clinician administered psychiatric assessments. Using the Brain Health Registry (BHR) (N=15,978), we next analyzed prevalence of self-reported neurological and psychiatric disorders among participants with no/minimal hoarding, subclinical hoarding, and clinically significant hoarding and used network analyses to identify direct and indirect relationships between HD and the assessed psychiatric and neurological disorders.

Results—The most prevalent comorbidity in clinically assessed participants with HD was major depressive disorder (MDD, 62%), followed by generalized anxiety disorder (GAD, 32%). Network analyses in the BHR indicated that the strongest direct relationships with HD were attention-deficit hyperactivity disorder (ADHD), major depressive disorder (MDD), and obsessive-compulsive disorder (OCD). The relationships between HD and neurological disorders, including mild cognitive impairment, were weak or non-existent after controlling for other disorders.

Conclusions—ADHD, MDD, and OCD form a triad of psychiatric disorders directly associated with HD. Despite their high comorbidity rates, the associations among anxiety disorders and HD were weak or indirect.

Introduction

Hoarding disorder (HD), one of the obsessive-compulsive and related disorders (OCRDs) in the DSM-5 (American Psychiatric Association, 2013) is characterized by significant difficulty discarding objects due to indecision and/or distress about what to save, leading to accumulation of clutter in living and workspaces that causes impairment in daily functioning. Historically, hoarding has been considered to be a symptom of obsessive-compulsive personality disorder (OCPD), or more recently, a subtype of obsessive-compulsive disorder (OCD)(American Psychiatric Association, 2000). However, previous studies indicate that fewer than 20% of individuals who meet diagnostic criteria for HD also meet criteria for OCD (Frost et al., 2011), and that OCD symptomatology does not predict any of the core features of HD (Tolin & Villavicencio, 2011). Partly for this reason, in 2013, HD was included in the DSM-5 as a diagnosis separate from OCPD and from OCD (American Psychiatric Association, 2013).

Hoarding behaviors have long been known to occur in a variety of psychiatric and neurological diseases or disease states, including autism, eating, mood, anxiety disorders and psychotic disorders, Parkinson’s disease and dementia (Frost et al., 2011; Hwang et al., 1998; Lo Monaco et al., 2020; Novara et al., 2016; Nutley et al., 2021; Pertusa et al., 2010), and recent research has focused on the co-occurrence of HD with other psychiatric (and increasingly, non-psychiatric) disorders independent of OCD (Archer et al., 2019; Frost et al., 2011; Nordsletten, Reichenberg, et al., 2013). Because hoarding has a high psychiatric burden, determining which disorders are directly associated with hoarding vs indirectly related to hoarding due to high co-occurrence with another disorder (e.g., major depressive disorder (MDD) and generalized anxiety disorder (GAD)) is difficult. There is strong evidence that the most common psychiatric comorbidity in HD is not OCD, but rather MDD (Archer et al., 2019; Ayers & Dozier, 2015; Frost et al., 2011; Mathews, 2021). Anxiety disorders, and possibly attention deficit hyperactivity disorder (ADHD), are also highly prevalent among individuals with HD (Frost et al., 2011; Tolin & Villavicencio,

2011). Previously reported rates of MDD in populations with HD range from 26.3%−51% (Archer et al., 2019; Ayers & Dozier, 2015; Frost et al., 2011; Mathews, 2021; Nordsletten, Reichenberg, et al., 2013), rates of GAD range from 5%, to 24.4% (Archer et al., 2019; Ayers et al., 2010; Frost et al., 2011) and ADHD rates vary widely from 2.9% to 28% (Archer et al., 2019; Frost et al., 2011; Fullana et al., 2013; Mathews, 2021; Tolin & Villavicencio, 2011).

Increasing evidence suggests that rates of medical comorbidities, including neurological disorders, are also elevated among individuals with HD. For instance, HD and/or hoarding behaviors are associated with higher rates of metabolic and cardiovascular conditions, diabetes, chronic pain, head injuries, and sleep apnea (Ayers et al., 2010, 2014; Nutley et al., 2021). Less is known about neurological comorbidities, although hoarding behaviors are common in dementia (Hwang et al., 1998; Mitchell et al., 2019). For example, between 22% and 28% of patients with dementia display hoarding behavior (Hwang et al., 1998; Mitchell et al., 2019) and individuals with HD often exhibit mild cognitive impairments (Mackin et al., 2016; Mitchell et al., 2019; Pertusa et al., 2010). Similarly, approximately 12% of those with Parkinson's disease display excessive hoarding (O'Sullivan et al., 2010), while 15% with focal brain lesions have abnormal collecting behaviors (Anderson et al., 2005). 26% of participants with hoarding in the Brain Health Registry (BHR) also reported a history of traumatic brain injury (TBI) or concussions (as compared to 17.4% of those without hoarding)(Nutley et al., 2021). Unfortunately, studies examining rates and correlates of neurological comorbidities among individuals with a primary diagnosis of HD (rather than studies of hoarding behaviors in those with neurological disorders) are few, limited by small sample sizes, and tend to focus on only one or two conditions (e.g., head injuries, seizures) (Ayers et al., 2014; Nutley et al., 2021).

In the current study, we examined the prevalence of hoarding and psychiatric and neurological disorders in a large sample of adults recruited from the BHR (medical comorbidity, including TBI, in HD was examined in a previous paper (Nutley et al., 2021)). Additionally, we evaluate the relationships between these psychiatric and neurological disorders and HD. We hypothesized that, among psychiatric disorders, depression would be the most commonly comorbid condition, followed by anxiety disorders and that rates of mild cognitive impairment and dementia would be increased in HD.

Methods and Materials

The present work was approved by the Universities of Florida and California San Francisco Institutional Review Boards. Informed consent was obtained from all participants.

To better understand the psychiatric and neurological comorbidities with hoarding, we completed three analyses. First, we compared the prevalence of psychiatric disorders as diagnosed via a structured clinical interview in 135 participants with likely or definite HD and 117 participants without HD. Next, we examined prevalence of self-reported psychiatric and neurological disorders among individuals with clinically significant hoarding, subclinical hoarding and no to minimal levels of hoarding using self-reported diagnoses in a larger online sample of 15,978 Brain Health Registry participants.

Third, we used a data-driven network-based approach to identify associations between co-occurring psychiatric and neurological disorders, after accounting for the presence of all disorders, to identify independent correlates of hoarding disorder. The benefit of using a network approach is that it can identify novel relationships between diagnoses that could explain high co-occurrences between these and other disorders (Cramer et al., 2010), as well as highlighting underlying relationships between latent variables (e.g. diagnoses) and possible shared neurobiological processes within diagnoses.

Participants:

Participants in this study included 15,978 individuals who completed both the medical module and the hoarding module of the Brain Health Registry (BHR, brainhealthregistry.org) at least twice as of December 2020. The BHR is an online observational research registry that aims to study changes associated with brain aging and neurodegenerative disorders. It collects online self-reported data on medical and psychiatric history, family history, symptom-based instruments assessing quality of life, sleep quality, depression symptomatology, and hoarding symptomatology, and measures of subjective and objective neurocognitive functioning (Weiner et al., 2018). Upon registration, participants are asked to answer questions about their medical, psychiatric, and neurological histories (the medical module) and to complete symptom-based questionnaires about a variety of conditions, including hoarding (Weiner et al., 2018). The hoarding module contains questions focused on hoarding behaviors and symptoms (Hoarding Rating Scale-self report; HRS) and obsessive-compulsive related disorders. Participants are invited back every six months to provide updated information and complete any new surveys that may have been added in the interim.

Participants self-identify their ethnicity as Latino, not Latino, or prefer not to say and their race as Black/African American, Asian, White/Caucasian, Native American/Alaska Native, Pacific Islander, Other, or Prefer not to say with the ability to choose multiple races. Participants come from all 50 states, and the sample is skewed towards a White, female, and highly educated population (see (Nutley et al., 2020, 2022) and Table 2).

Measurement and definition of hoarding.

Our previous analyses of self-reported psychiatric diagnoses in the BHR indicated that self-reported HD diagnosis in the BHR is skewed towards false negatives (Sordo Vieira et al., 2022). Thus, as the primary measurement of hoarding we used the HRS total score to identify individuals with likely HD and those with subclinical hoarding symptoms, as well as those with no or minimal hoarding, based on our previous work (Nutley et al., 2020, 2021). We categorized participants as having clinically significant hoarding if their mean HRS score across two or more timepoints was ≥14 (Tolin et al., 2010), subclinical hoarding if their mean HRS was ≥10 but <14, and as no-to-minimal hoarding otherwise.

Psychiatric and neurological disorders assessed

The psychiatric disorders assessed in the BHR include lifetime history of MDD, OCD, specific/social phobias, eating disorders (ED), ADHD, GAD, post-traumatic stress disorder (PTSD), panic disorder, schizophrenia, psychosis, and bipolar disorder (BD). The question

assessing psychiatric disorders is: **"**Have you ever been diagnosed with any of the following psychiatric conditions?" and participants are given the option of endorsing current or past (we grouped current or past as a single lifetime diagnosis) for the disorders. As the BHR does not have a specific self-report question about substance use disorder diagnoses or alcohol abuse, the following question was used as a proxy: "Please indicate whether you currently have or had experienced drug abuse [alcohol abuse] in the past".

Neurological diseases are assessed by "Please indicate whether you currently have or have had any of the following conditions in the past" and include Alzheimer's disease, mild cognitive impairment (MCI), dementia, frontotemporal dementia, Lewy body disease, multiple sclerosis, epilepsy/seizures, movement disorders, Parkinson's disease, and stroke. We combined self-reported diagnoses of dementia, Lewy body disease, frontotemporal dementia, and Alzheimer's disease into a single dementia category. Based on our previous work examining the stability and reliability of diagnoses across multiple timepoints, for this analysis, diagnoses were deemed to be present if a participant had endorsed that disorder more than 50% of the time (Sordo Vieira et al., 2022).

Comparison with formal clinical assessments

252 BHR participants underwent direct clinical interview to assess for psychiatric disorders and to validate the HRS cutoffs for HD as part of a larger study on hoarding symptoms (Nutley et al., 2020). These participants were recruited as either possible controls or as possible HD based on their HRS-SR scores (see (Nutley et al., 2020) for details on study design). The interviewers used the Mini International Neuropsychiatric Interview (MINI) (Sheehan et al., 1998)), the Yale-Brown Obsessive Compulsive Scale (Y-BOCS) (Goodman et al., 1989), the Structured Interview for Hoarding Disorder (SIHD) (Nordsletten, Fernández de la Cruz, et al., 2013), the Savings Inventory-Revised (SI-R)(Frost et al., 2004), and the UCLA Hoarding Severity Scale (UHSS), (Saxena et al., 2015). Personnel trained in research assessments conducted the interviews via telephone or teleconference.

Diagnoses were made using a best-estimate consensus procedure as previously described in (Nutley et al., 2020). Briefly, a best estimator (blinded to HRS-SR scores and who did not perform the interview) reviewed all clinical interview data, and participants were assigned diagnoses as either "definite", "probable" or "not present", with probable indicating that the participant did not meet full diagnostic criteria according to the available data, but that sufficient data were available to suggest that the diagnosis was likely to be present. If any diagnosis was assigned as probable or definite, a second estimator was assigned, and the two estimators would attempt to reach consensus in the case of discrepancy. If consensus could not be achieved, a third estimator would be assigned to reach a consensus. We grouped "present" and "probable" into a single positive diagnosis. Diagnoses for which there was missing data or which a diagnosis could not be made were marked as not present; 135 participants were given a probable or definite HD diagnosis and 117 participants were found to not have HD. Demographics for these participants are presented in Table 1.

Analyses of clinically assessed subgroup

Fisher's exact tests were performed to test for differences in psychiatric conditions between HD and the control group in the clinically assessed sample. Differences between means of continuous variables for the two groups were assessed using t-tests or Kruskal-Wallis Rank Sum test. 95% confidence intervals (Clopper-Pearson) for prevalence (# of cases/size of population) of conditions were computed using the epi.conf function from epiR, stratified by HD status.

Analyses of BHR prevalence based on hoarding categorical severity

95% confidence intervals (Clopper-Pearson) for prevalence (# of cases/size of population) of conditions co-occurring with our HD group were computed using the epi.conf function from epiR, stratified by clinical, subclinical, and no-to-minimal hoarding groups. Adjusted odds ratios between the three different hoarding strata were computed by logistic regression, including neurological/psychiatric condition as the outcome variable and age at baseline, sex, race, and hoarding strata as predictor variables. For this analysis, Native American/ Alaska Native, Pacific Islander, Other, or Prefer not to say were combined into a single category due to small numbers.

Network analyses

We took a network approach where two nodes (disorders) are determined to be connected if a relationship exists between them after controlling for other disorders in the network. We used the IsingFit package (van Borkulo et al., 2015) to estimate a network based on comorbidities, which uses logistic regression with an imposed penalty on regression coefficient (here, we used gamma=0.25 as the penalty hyperparameter, and the OR-rule to account for unidirectional relationships) to obtain a sparse network together with model selection based on Extended Bayesian Information Criterion. An edge between two nodes in the network represents conditional dependence (controlling for all other disorders in the network), and an absence of an edge between two nodes corresponds to conditional independence (Hevey, 2018; van Borkulo et al., 2015). To avoid having too many nodes in the network (and thus reduce the number of edges to be estimated), we only included nodes where odds ratio and 95% confidence intervals did not overlap 1 for participants with clinical hoarding (mean HRS>=14) vs. no to minimal-hoarding groups (mean HRS<10). To build a consensus network with hoarding, psychiatric disorders, and neurological disorders, based on the original network, we kept only the nodes from each model for which there was a direct connection to hoarding. Communities in networks were found using the igraph cluster_optimal function (on the absolute value of the adjacency matrix), which calculates the optimal community structure while maximizing modularity. We used non-parametric bootstrapping with n=1,000 bootstraps using the R bootnet package to construct 95% CIs for edge weights to assess accuracy, and the edge difference test for statistical significance (Epskamp et al., 2018).

Results

Psychiatric comorbidities in a clinically assessed subsample of individuals with and without HD

In the sample of 252 clinically assessed participants, demographics were similar among those with and without HD, apart from race (Table 1). Of the 135 participants with HD, 31 participants (23%) had one comorbid psychiatric disorder, 31 participants (23%) had two comorbid psychiatric disorders, and 51 participants had three or more comorbid psychiatric disorders, with 22 (16.2%) participants having HD as their sole diagnosis. The most commonly co-occurring psychiatric disorder in the HD participants was MDD (61.5%, compared with 28.2% in the no-HD participants, followed by GAD (31.9% vs 10.3%) and panic disorder (22.2% vs 9.4%) (Figure 1). Forty-seven subjects with HD had co-occurring MDD plus an anxiety disorder (34.8%) vs 15 (12.8%) in the no-HD participants. Overall, participants with HD had much higher rates of psychiatric conditions than the non-HD participants (Table 1).

Psychiatric comorbidities and hoarding in the BHR.

We next investigated the prevalence rates of self-reported history of psychiatric disorders in the entire BHR sample (N=15,978) (Table 2). As seen in Figure 2, rates of all self-reported psychiatric diagnoses were elevated in the clinically significant hoarding group as compared to the minimal hoarding symptoms group. Rates of psychiatric comorbidities were also higher in the subclinical hoarding group compared to the minimal hoarding group. As with the clinically assessed sample, MDD and GAD were the most frequent comorbid conditions. In comparison to the subclinical hoarding group, participants with clinically significant hoarding had higher odds of self-reporting diagnoses of all psychiatric disorders other than alcohol or substance abuse, PTSD, and psychosis (which had similar rates in the hoarding and subclinical hoarding group), after adjusting for age, race, and sex (Figure 3).

Neurological comorbidities and hoarding in the BHR.

We next compared prevalence of self-reported neurological conditions among those with and without hoarding. After adjusting for age, race, and sex, participants with clinical hoarding were at significantly higher odds of self-reporting diagnoses of epilepsy, MCI, dementia, stroke, essential tremors, and movement disorders as compared with the non-hoarding group (Figure 3). In contrast to psychiatric disorders, the only significant difference in rates of neurological disorders between participants with clinically significant hoarding and those with subclinical hoarding was for movement disorder, for which the clinically significant group had significantly higher odds than the subclinical group (Figure 3). The most prevalent neurological condition in participants with clinically significant hoarding was MCI (10%, Figure 2).

Network analyses of psychiatric and neurological conditions in relation to hoarding

To determine which conditions were associated with hoarding independent of the status of other comorbidities, we took a network approach for binary data (in this case, whether a disorder/disease was self-reported as present or not present) (Epskamp et al., 2018;

van Borkulo et al., 2015; van Buitenen et al., 2020). In this network model, two nodes are disconnected if they are conditionally independent, given the state of the other nodes (Epskamp et al., 2018; van Borkulo et al., 2015). An edge between two conditions represents comorbid conditions that cannot be better explained via comorbidity with other disorders (e.g. GAD being highly comorbid with hoarding due to its high comorbidity with MDD). To examine direct relationships between hoarding and neurological and psychiatric disorders, we built a comorbidity network including self-reported diagnoses (both psychiatric and neurological) where the 95% confidence intervals for the odds ratio between clinical and no hoarding did not overlap 1, indicating an increased rate of that disorder among individuals with hoarding (Figure 3). In this network, the hoarding node is defined as HRS≥14 (clinically significant hoarding).

The optimal community detection analysis identified 4 distinct communities: Community 1 included the anxiety disorders, ADHD, OCD, depression, PTSD, eating disorders and hoarding; Community 2 included bipolar disorder, psychosis, and schizophrenia; Community 3 included alcohol and substance use; and Community 4 included neurological disorders (Figure 4).

Based on this original network, we built a secondary consensus network excluding all nodes that were not directly connected to hoarding and leaving only the nodes with a direct connection to hoarding (OCD, ADHD, MCI, bipolar disorder, depression, eating disorder, PTSD, GAD, and phobias) (Figure 5). The strongest connection with hoarding in this secondary consensus network occurred with ADHD, followed by MDD and OCD. To assess accuracy of the edges in the network, we performed bootstrapping (n=1,000) using the bootnet R package for estimation of 95% confidence intervals (Epskamp et al., 2018). Five disorders were directly associated with clinically significant hoarding after bootstrapping: OCD, ADHD, MDD, eating disorders, and social/specific phobias. Importantly, the strongest connection with clinically significant hoarding was with ADHD, and this connection was significantly stronger than all other edges with hoarding except the edge between HD and MDD, as measured by the edge difference test (Epskamp et al., 2018). MCI did not have a direct connection with HD, but rather was most strongly connected to bipolar disorder/depression, OCD, and ADHD.

Discussion

In this work we utilized a unique resource, the BHR, a longitudinal online registry focused on mental health and aging, to examine the prevalence of and associations between psychiatric and neurological disorders and hoarding. Given the high reported comorbidities for some psychiatric disorders among individuals with HD, we were interested in parsing out the primary comorbidities, that is, those with a direct link to HD, from the secondary comorbidities. These relationships can be used to guide studies investigating the neurobiological and environmental contributors to HD.

This work confirms previous findings indicating that the psychiatric burden of hoarding disorder is high (Archer et al., 2019; Ayers et al., 2014; Frost et al., 2011; Mathews, 2021). Eighty four percent of clinically assessed participants with HD had at least one

other psychiatric condition, compared to 45% of those with no HD. Similarly, 71% of BHR participants with clinically significant hoarding had at least one other psychiatric condition, compared to 58% in those with subclinical hoarding and 36% in those with no to minimal hoarding. 24% of participants in the BHR with clinically significant hoarding had at least one neurological disorder, vs 17% of those with no significant hoarding.

The most common comorbid condition in both the clinical and registry samples was MDD, followed by GAD, which is consistent with previous findings (Archer et al., 2019; Ayers & Dozier, 2015; Frost et al., 2011; Nordsletten, Reichenberg, et al., 2013). In the BHR, almost half of the participants with clinically significant hoarding self-reported having lifetime MDD, while 61.5% of the clinically assessed participants with HD met DSM-5 criteria for lifetime MDD, in line with previously reported rates (26.3%−51%) (Archer et al., 2019; Ayers & Dozier, 2015; Frost et al., 2011; Mathews, 2021; Nordsletten, Reichenberg, et al., 2013).

Despite a high rate of self-reported GAD (>30%) among the clinically significant hoarding subgroup, network analyses suggested that the relationship between GAD in HD was not direct, but was better explained through a relationship with MDD, as the edge between hoarding and GAD was weak, and bootstrapped confidence intervals overlapped zero. This was supported by the observation that in the clinically assessed cohort, the majority (72%; N=31/43) of participants with HD and GAD also had co-occurring MDD.

It is of interest that there were significant differences between the rates of MDD, eating disorders, ADHD, PTSD, bipolar disorder, phobias, and OCD between the clinically significant and subclinical hoarding subgroups, suggesting an association between worsening hoarding symptom severity and higher psychiatric burden. In contrast, observed associations between HD and self-reported neurological disorders were more subtle. While, rates of some neurological disorders were elevated in hoarding compared to the no hoarding group, the prevalence of these disorders was not different between the clinical and subclinical hoarding groups. Although this could be due to the lower prevalence of neurological disorders compared to psychiatric disorders, we find this to be unlikely. For relatively common self-reported neurological diseases in the BHR (MCI, essential tremor, and movement disorders), there were no differences between the clinical and sub-clinical populations. However, these findings might differ in clinical populations, or an even older population, due to age being a significant risk factor for dementia and MCI (“2020 Alzheimer’s Disease Facts and Figures,” 2020; Campbell et al., 2013; Jia et al., 2020). It is also possible that in those with neurological conditions, hoarding as a symptom (rather than hoarding disorder) drives the difference in rates between no significant hoarding and clinically significant hoarding.

Although ~10% of the population with clinically significant hoarding reported mild cognitive impairment, which on the surface suggests an association between MCI and hoarding, MCI itself is a very heterogenous condition. Due to the self-report nature of the data in the BHR, we cannot ascertain whether hoarding is a symptom of MCI and/or early dementia or whether subjects with hoarding disorder are at higher risk of developing MCI and dementia. The results of the network analyses suggest that neither may be the case, as

the relationship between MCI/dementia and HD was mediated through ADHD, OCD and MDD in these analyses. It is thus possible that a third explanation is a better fit for the observed data, that is, that most of the self-reporting of MCI in the BHR is indicative of subjective problems with executive functioning rather than true clinically diagnosed MCI.

While the initial network analyses yielded four communities: neurological disorders, substance use disorders, psychotic disorders and bipolar disorder, and other psychiatric disorders, with hoarding belonging to the psychiatric disorders community, as expected, and consistent with previous literature (Lee et al., 2019), the secondary network analyses suggests that HD is most strongly associated with ADHD, OCD, and MDD with the strongest relationship to ADHD. The fact that the strongest connection with hoarding was between HD and ADHD is particularly notable, considering that the BHR is largely an older population, and ADHD is likely under-diagnosed in this sample.

Although our clinical interviews did not assess for ADHD (not included in our MINI version), this link is consistent with previously reported comorbidity rates of ADHD and hoarding. Previous work suggests that the inattentive symptomatology of ADHD is predictive of the severity of clutter, difficulty discarding, and excessive acquisition in HD, whereas the associations with hyperactive/impulsive symptomatology with HD are less consistent across studies (Hartl et al., 2005; Morein-Zamir et al., 2022; Sheppard et al., 2010; Tolin & Villavicencio, 2011). A relationship with both hyperactivity and inattention with problematic hoarding has been previously reported (Hartl et al., 2005), and hyperactivity but not impulsivity is associated with clutter in ADHD (Morein-Zamir et al., 2022), where a relationship between hoarding and both inattention and hyperactivity/impulsivity was found in an independent online cohort in the same study. A relationship between hoarding and impulsivity has also been documented via neuropsychological testing (Grisham et al., 2007). Altogether, several independent studies, now including ours, establish a link between ADHD symptoms and hoarding. Thus, shared executive dysfunctions, especially problems with attention, might be important targets in the treatment of HD.

Importantly, the relationship between MCI and hoarding was weak, as revealed by confidence intervals for the MCI—HD edge overlapping 0. Mild cognitive impairment and adult ADHD are known to share many features, including subjective problems with memory and cognitive complaints (Callahan et al., 2017; Ivanchak et al., 2012). Therefore, the relationship between HD and MCI might be better explained through shared features and cognitive problems of ADHD, MDD, and OCD. Future research should explore these relationships in clinical samples.

Limitations

The self-report nature of these data places some limitations on our conclusions, and neither causality nor timing of events can be assessed using the current methods. Finally, the BHR population is a largely White, older, highly educated, and female population, with access to the internet, and thus not representative of the US population. An advantage is that it is largely based on a population who were not recruited for the purposes of studying hoarding. Although the BHR is biased in other ways (e.g. self-selection bias), it is not biased towards individuals with known HD.

Conclusions

Hoarding is highly comorbid with psychiatric conditions, and worsening hoarding symptomatology increases the odds of having a psychiatric disorder. MDD is the most highly comorbid disorder with HD or with severe hoarding symptomatology, followed by an anxiety disorder. Co-occurrence of anxiety disorders with HD appears to be mediated through comorbid MDD rather than being a primary association, which may provide hints to the underlying shared biological underpinnings of these disorders. This study also yielded a strong association between hoarding and ADHD in an older population, and suggests a phenotypic relationship between MCI, ADHD, OCD, depression, and HD.

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Declaration of interests

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Highlights:

- Hoarding disorder is most strongly associated with ADHD, MDD, and OCD
- Psychiatric burden increases with hoarding symptomatology
- Network analysis suggests anxiety relationship with hoarding might be secondary to MDD or OCD

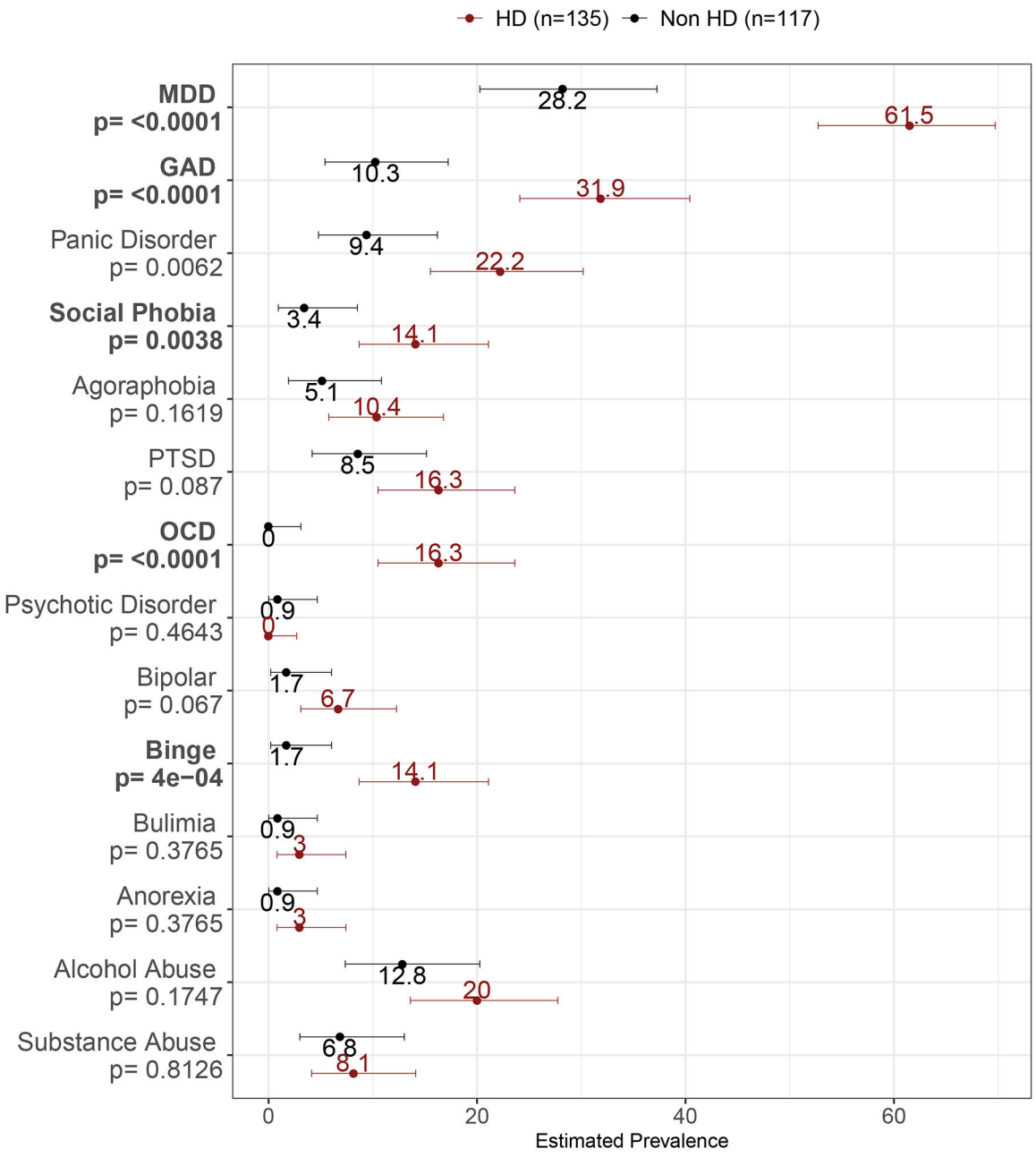

Figure 1—.

Rates (cases/total subpopulation) and 95% confidence intervals (Clopper-Pearson) of conditions in HD vs non-HD clinically assessed cohort (total N=252). p-value computed from Fisher's Exact Test. Bolded text represents p-value <0.05.

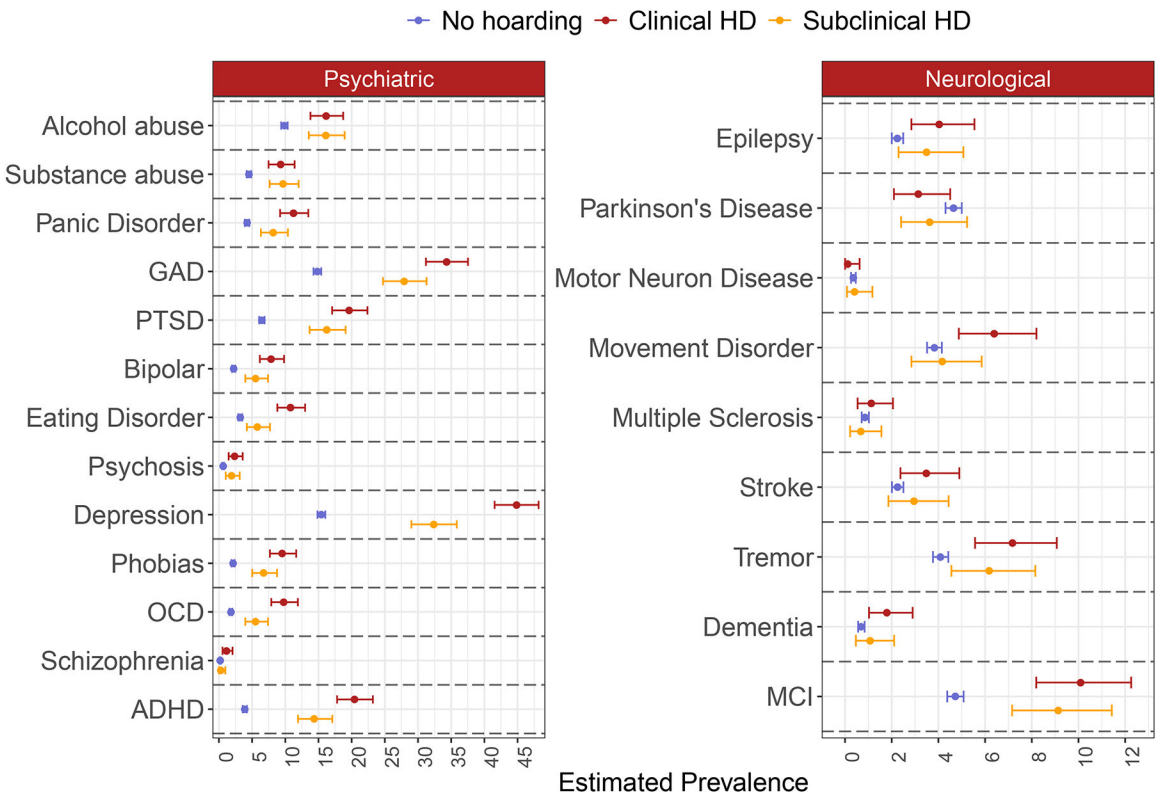

Figure 2—.

Prevalence (cases/size of population) with 95% Clopper-Pearson confidence intervals for various psychiatric and neurological diseases in the BHR sample.

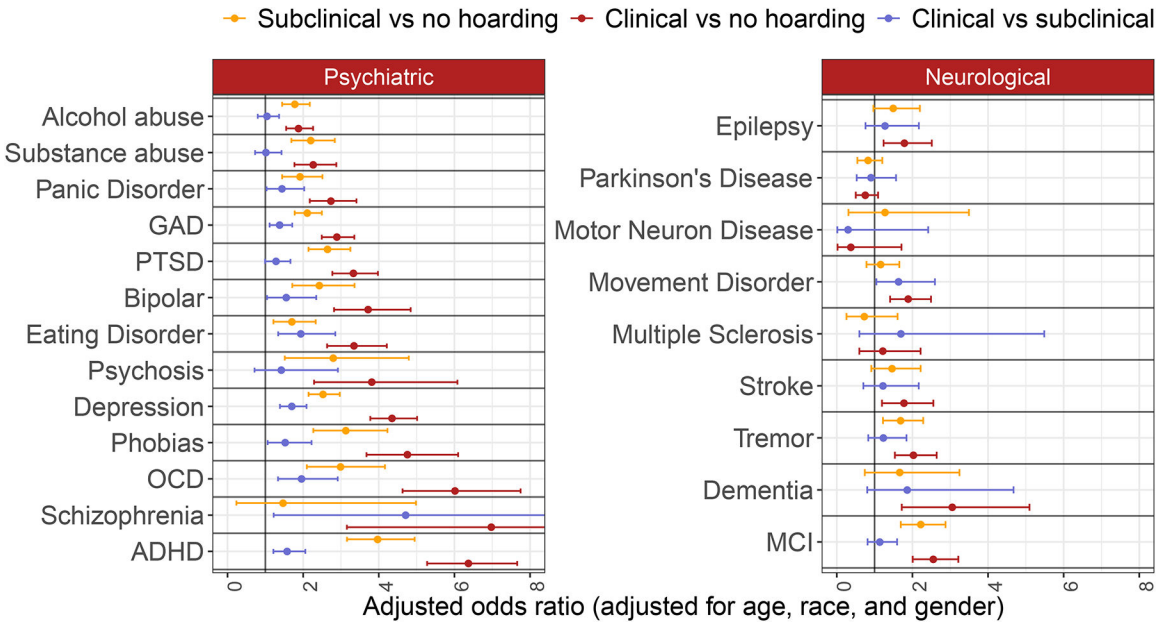

Figure 3—.

Adjusted Odds ratio for various psychiatric and neurological disorders after adjusting for age, sex, race, and hoarding strata with 95% confidence intervals in the BHR sample.

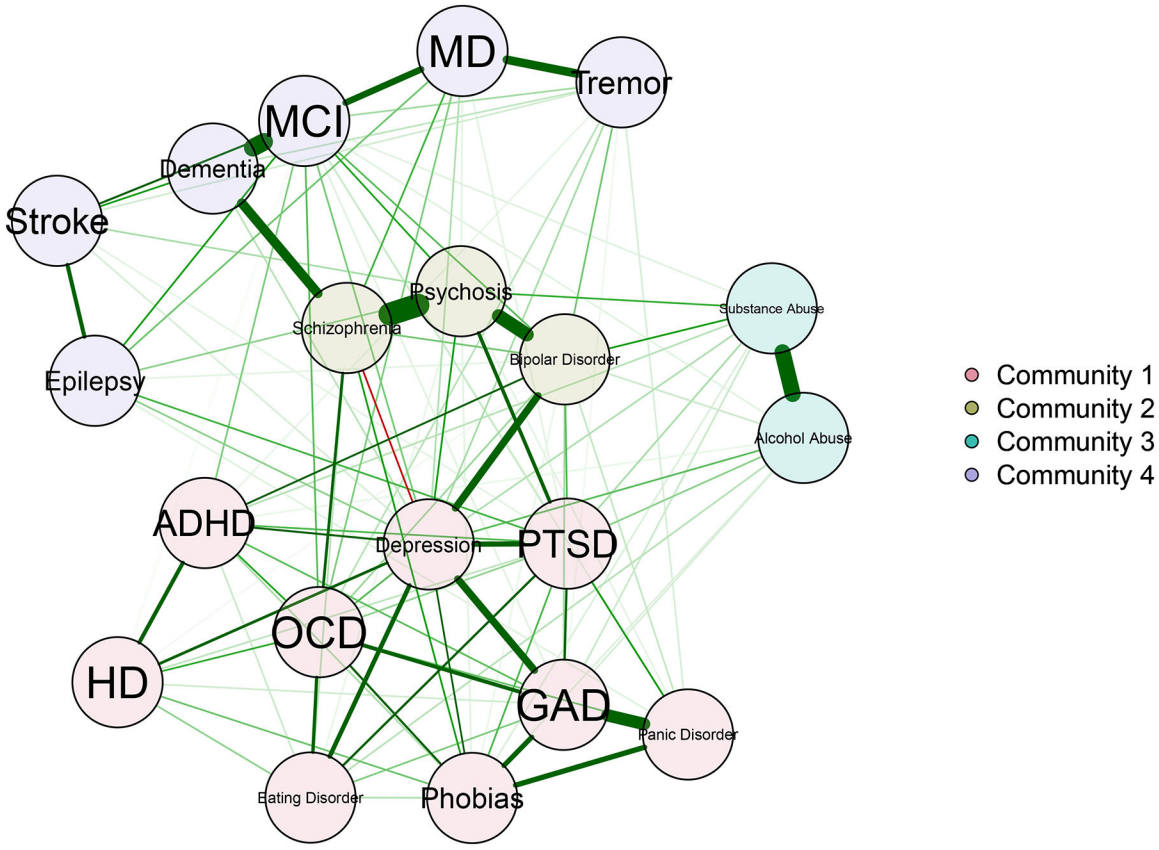

Figure 4—.

Comorbidity network based on self-reported data on the BHR using the IsingFit R package. Nodes are color coded by which community they belong to, based on optimal community detection.

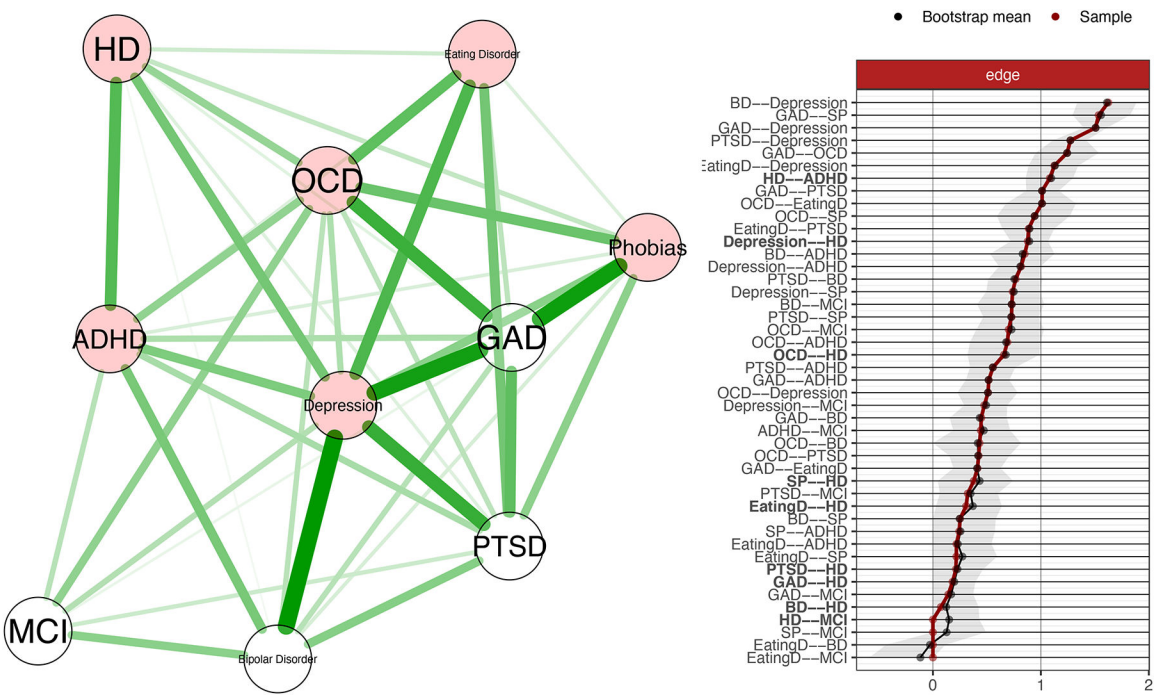

Figure 5—.

Consensus network (left) together with bootstrapped confidence intervals for edge strengths (right). Red nodes represent disorders directly associated with HD after bootstrapping.

Table 1—

Demographics of participants with and without HD in the clinically assessed subsample. Ages 90+ at baseline are encoded as 90.

	HD Status			
Characteristic	**Overall, N = 252[1]**	**Likely/definite HD, N = 135[1]**	**No HD, N = 117[1]**	**p-value[2]**
Age at baseline	61 (55, 67)	61 (55, 67)	61 (55, 67)	0.6
Gender				0.9
Female	195 (77%)	104 (77%)	91 (78%)	
Male	57 (23%)	31 (23%)	26 (22%)	
Race				0.013
Black/African American	4 (1.6%)	3 (2.2%)	1 (0.9%)	
Asian	4 (1.6%)	4 (3.0%)	0 (0%)	
White/Caucasian	237 (94%)	121 (90%)	116 (99%)	
Multiple races self-endorsed	4 (1.6%)	4 (3.0%)	0 (0%)	
Other	3 (1.2%)	3 (2.2%)	0 (0%)	
Ethnicity				0.8
Declined to state	1 (0.4%)	0 (0%)	1 (0.9%)	
Latino	3 (1.2%)	2 (1.5%)	1 (0.9%)	
Not Latino	248 (98%)	133 (99%)	115 (98%)	
Number of comorbid conditions				<0.001
0	86 (34%)	22 (16%)	64 (55%)	
1–2	102 (40%)	62 (46%)	40 (34%)	
>=3	64 (25%)	51 (38%)	13 (11%)	

[1] n (%); Median (IQR)

[2] Pearson’s Chi-squared test; Wilcoxon rank sum test; Fisher’s exact test

Table 2—

Demographics of all BHR participants included in this study. Ages 90+ at baseline are encoded as 90.

	HD Status				
Characteristic	**Overall, N = 15,978[1]**	**No hoarding, N = 14,341[1]**	**Subclinical, N = 745[1]**	**Clinically Sig., N = 892[1]**	**p-value[2]**
Age at baseline	62 (55, 68)	63 (55, 69)	60 (53, 67)	60 (54, 66)	<0.001
Gender					<0.001
Female	11,892 (74%)	10,586 (74%)	572 (77%)	734 (82%)	
Male	4,086 (26%)	3,755 (26%)	173 (23%)	158 (18%)	
Race					
Black/African American	227 (1.4%)	200 (1.4%)	12 (1.6%)	15 (1.7%)	
Asian	320 (2.0%)	273 (1.9%)	20 (2.7%)	27 (3.0%)	
White/Caucasian	14,587 (91%)	13,145 (92%)	655 (88%)	787 (88%)	
Declined To State	119 (0.7%)	103 (0.7%)	6 (0.8%)	10 (1.1%)	
Multiple races self-endorsed	404 (2.5%)	333 (2.3%)	33 (4.4%)	38 (4.3%)	
Native American/Alaska Native	29 (0.2%)	26 (0.2%)	0 (0%)	3 (0.3%)	
Not available	1 (<0.1%)	1 (<0.1%)	0 (0%)	0 (0%)	
Other	280 (1.8%)	251 (1.8%)	18 (2.4%)	11 (1.2%)	
Pacific Islander	11 (<0.1%)	9 (<0.1%)	1 (0.1%)	1 (0.1%)	
Ethnicity					0.4
Declined to state	265 (1.7%)	239 (1.7%)	12 (1.6%)	14 (1.6%)	
Latino	475 (3.0%)	415 (2.9%)	24 (3.2%)	36 (4.0%)	
Not Latino	15,238 (95%)	13,687 (95%)	709 (95%)	842 (94%)	
Number of comorbid psychiatric disorders					<0.001
0	9,811 (61%)	9,234 (64%)	313 (42%)	264 (30%)	
1–2	4,502 (28%)	3,894 (27%)	262 (35%)	346 (39%)	
>=3	1,665 (10%)	1,213 (8.5%)	170 (23%)	282 (32%)	
Number of comorbid neurological disorders					<0.001
0	13,147 (82%)	11,893 (83%)	577 (77%)	677 (76%)	
1–2	2,585 (16%)	2,253 (16%)	148 (20%)	184 (21%)	
>=3	246 (1.5%)	195 (1.4%)	20 (2.7%)	31 (3.5%)	

[1] Median (IQR); n (%)

[2] Kruskal-Wallis rank sum test; Pearson's Chi-squared test