



The profile of executive function in OCD hoarders and hoarding disorder



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ABSTRACT

Hoarding disorder is a new mental disorder in DSM-5. It is classified alongside OCD and other presumably related disorders in the Obsessive-Compulsive and Related Disorders chapter. We examined cognitive performance in two distinct groups comprising individuals with both OCD and severe hoarding, and individuals with hoarding disorder without comorbid OCD. Participants completed executive function tasks assessing inhibitory control, cognitive flexibility, spatial planning, probabilistic learning and reversal and decision making. Compared to a matched healthy control group, OCD hoarders showed significantly worse performance on measures of response inhibition, set shifting, spatial planning, probabilistic learning and reversal, with intact decision making. Despite having a strikingly different clinical presentation, individuals with only hoarding disorder did not differ significantly from OCD hoarders on any cognitive measure suggesting the two hoarding groups have a similar pattern of cognitive difficulties. Tests of cognitive flexibility were least similar across the groups, but differences were small and potentially reflected subtle variation in underlying brain pathology together with psychometric limitations. These results highlight both commonalities and potential differences between OCD and hoarding disorder, and together with other lines of evidence, support the inclusion of the new disorder within the new Obsessive-Compulsive and Related Disorders chapter in DSM-5.

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1. Introduction

The clinical presentation of obsessive-compulsive disorder (OCD) is heterogeneous with patients suffering from different, potentially non-overlapping symptoms. The disorder is characterized by obsessions, which are recurrent intrusive thoughts and/or compulsions, which are persistently recurring behaviours or mental rituals. Factor analytic studies have identified different symptom dimensions that have been associated with distinct patterns of co-morbid psychiatric conditions, treatment response,

genetic transmission and functional neural activity (Bloch et al., 2008). Thus, although performance on neuropsychological tasks often suggests worse performance in OCD cohorts compared to controls (Kuelz et al., 2004), findings are inconsistent possibly due in part to heterogeneity in symptom presentation obscuring the overall profile (Mataix-Cols et al., 2004; McKay et al., 2004). Hoarding consistently appears as a separate factor in many factor analytic studies and represents a possible source of variability in results. To date, most OCD symptom assessments have gauged hoarding symptoms at least to some degree, and historically these symptoms were conceptualized as being part of OCD (Goodman et al., 1989).

Recently, not only has OCD been reclassified in the DSM-5 (American Psychiatric Association, 2013), where it has been moved from anxiety disorders to a newly created chapter of Obsessive-Compulsive and Related Disorders (Fineberg et al., 2007; Hollander et al., 2009; Phillips et al., 2010; Stein et al., 2010), but also hoarding disorder is now considered a new disorder separate from OCD within this new category (Mataix-Cols et al., 2010;

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Pertusa et al., 2010). The diagnostic criteria for hoarding disorder include persistent difficulty discarding or parting with possessions, regardless of the value others may attribute to these possessions; the accumulation of a large number of possessions that fill up and clutter active living areas of the home or workplace to the extent that their intended use is no longer possible; the symptoms cause clinically significant distress or impairment in social, occupational, or other important areas of functioning (including maintaining a safe environment for self and others) (see also Frost and Hartl, 1996). Hoarding disorder is not diagnosed if the symptoms are better attributed to other conditions such as brain lesions, a neurodegenerative disorder, obsessions in OCD, lack of energy in major depression, or delusions in schizophrenia. Hoarding disorder is associated with high levels of serious disability and is often accompanied by reduced insight and although it typically onsets by early adulthood, if and when treatment is sought, it is usually later in life (Pertusa et al., 2010). Whilst hoarding disorder is now recognized as distinct from OCD but within the same DSM-5 chapter, there are both overlaps and differences between the two disorders in phenomenology, treatment, co-morbidity, genetic and neurobiological profiles (Saxena, 2008; Mataix-Cols et al., 2011). One important observation is prevalence rates: 18–40% of OCD patients exhibit some level of hoarding, yet the majority of individuals with hoarding difficulties do not display other OCD symptoms including obsessions or anxiety-related compulsions (Frost et al., 2000; Pertusa et al., 2008; Samuels et al., 2008).

Executive function performance in OCD patients with hoarding is of interest given the noted heterogeneity in the literature. In particular, difficulties in executive function, which are likely mediated by frontostriatal neural substrates, are believed to characterize OCD and contribute to symptom development and maintenance (Chamberlain et al., 2005). Nevertheless, neuropsychological studies often include mixed samples of patients or exclude those suffering from primary hoarding symptoms (Kuelz et al., 2004). To date, there have been only a few studies examining executive function performance in moderate to severe hoarders. Abnormalities specific to hoarding have been suggested in prefrontal areas such as the dorsal anterior cingulate and ventromedial prefrontal cortex over and above the fronto-striatal abnormalities typically found in OCD (Saxena, 2008; Mataix-Cols et al., 2011), suggesting that executive functions may be specifically informative in characterizing hoarders with and without OCD. Studies of hoarders where most or all had comorbid OCD have reported deficits in spatial memory and sustained attention (Grisham et al., 2007). Evidence regarding the Iowa Gambling Task (IGT) in OCD hoarders is mixed (Lawrence et al., 2006; Grisham et al., 2007; Blom et al., 2011), possibly because of between-study differences in hoarding severity and OCD symptom frequency. Other studies have examined individuals with hoarding symptoms, the majority of which did not meet criteria for OCD (Hartl et al., 2004; Grisham et al., 2010; Tolin et al., 2011). Difficulties were found in spatial planning, and spatial memory and organizational strategies (Grisham et al., 2010; Hartl et al., 2004). However, recent studies testing hoarders with no OCD did not find evidence for executive function difficulties, including spatial planning (Tolin et al., 2011) or on the IGT (Tolin and Villavicencio, 2011). Individuals with hoarding symptoms have also been found to have unimpaired cognitive flexibility, inhibitory control for emotional stimuli, decision-making and verbal organization strategies (Grisham et al., 2010).

Previous neuropsychological studies of executive functions in OCD patients specifically without hoarding symptoms (typically exhibiting washing and checking obsessions and compulsions) have reported worse performance in response-inhibition, cognitive flexibility, spatial working memory and spatial planning tasks

(Chamberlain et al., 2007a, 2007b), though a recent study did not find response-inhibition difficulties (Blom et al., 2011). The evidence for decision-making difficulties is inconsistent (Cavedini et al., 2002; Nielen et al., 2002; Chamberlain et al., 2007a) and organizational deficits have been implicated in memory difficulties that are sometimes observed (Savage et al., 1999). Deficits in stop-signal response-inhibition and cognitive flexibility but not decision-making have also been demonstrated in the unaffected first-degree relatives of such OCD patients, suggesting these particular cognitive functions may play a key role in identifying endophenotypes of OCD (Chamberlain et al., 2007b). In summary, there are limited data on response-inhibition as assessed by the stop-signal task in hoarding, despite its significance in OCD (Chamberlain et al., 2005; Blom et al., 2011). This task is particularly suited to examine response-inhibition as it requires suppressing already-initiated motor responses, enlisting greater inhibitory demands and less action selection than go/no-go tasks which have yielded varied results in OCD samples (Morein-Zamir et al., 2013). Likewise, as noted above, the evidence regarding cognitive flexibility and decision making is inconsistent. Such inconsistencies may have been due to differing degrees of overlap with OCD between the various hoarding samples, and the use of different tasks across studies.

Here we examined the executive function profile of OCD patients with prominent and severe hoarding symptoms, comparing them to a healthy control group. Given that hoarding is now considered a distinct disorder (Pertusa et al., 2008; Mataix-Cols et al., 2010; American Psychiatric Association, 2013), a separate group of patients meeting criteria for hoarding disorder but no comorbid OCD was also assessed. Performance measures were obtained for response inhibition, cognitive flexibility, spatial planning and decision-making, on executive functions tasks previously used to characterize cognitive deficits in non-hoarding OCD patients. Should both hoarding groups have a similar profile to non-hoarding OCD, difficulties compared to controls would be hypothesized in response-inhibition (stop-signal reaction time; SSRT), cognitive flexibility as measured by extra-dimensional (ED) shifting and spatial planning as measured by problems solved in the Tower of London (TOL), but not decision-making as measured by a gamble task. A probabilistic learning and reversal task was also employed, as evidence for deficits in OCD have been inconsistent in both behaviour and functional brain imaging (Clarke et al., 2004; Remijnse et al., 2006; Chamberlain et al., 2007a; Ersche et al., 2011). Such tasks depend on intact orbitofrontal and cingulate function (Cools et al., 2002; Fellows and Farah, 2003), which is believed to be impaired in OCD, particularly in hoarders (An et al., 2009; Mataix-Cols et al., 2011). In sum, this study investigated the cognitive profile of OCD patients with prominent hoarding symptoms and of individuals with hoarding disorder who do not have comorbid OCD. Following the main analyses, we then compared the resulting cognitive profiles of the two groups with those previously obtained in the same tasks, in a sample of non-hoarding OCD patients (Chamberlain et al., 2006, 2007a).

2. Methods

2.1. Participants

Twenty-four severe hoarders meeting DSM-IV-TR criteria for OCD and 22 individuals with severe hoarding who did not meet criteria for OCD participated in the study. Hoarders were recruited from specialist OCD and hoarding clinics and through independent charities. All were assessed by experienced clinicians (N.F., D.M. and A.P.) supplemented with the MINI (Sheehan et al., 1998) to establish diagnosis and meeting inclusion criteria. Inclusion criteria included severe hoarding as indicated by the criteria outlined by Frost and colleagues (Frost and Hartl, 1996; Steketee and Frost, 2003) and a Savings Inventory-Revised (SI-R) (Frost et al., 2004) score above 35. All hoarders confirmed that their hoarding was chronic and

did not begin later in life. All cases with hoarding met the diagnostic criteria for Hoarding Disorder (American Psychiatric Association, 2013). Exclusion criteria included no neurological disorder, psychosis, head/brain injury or excessive drug use. Individuals with co-morbid anxiety and mood disorders were not excluded provided hoarding was their main problem. Twenty-eight controls, screened for past or current psychiatric disorders, neurological conditions and psychotropic medication also participated in the study. OCD symptoms were assessed with the YBOCS (Goodman et al., 1989) and the Obsessive-Compulsive Inventory-Revised (OCI-R) (Foa et al., 2002). Montgomery-Asberg Depression Rating Scale (MADRS) (Montgomery and Asberg, 1979) and Beck Depression Inventory (BDI) (Beck et al., 1961) assessed depression, State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1983) measured anxiety, and National Adult Reading Test (Nelson, 1982) assessed verbal IQ. The study was approved by the Essex Research Ethics Committee and all participants provided written informed consent. Co-morbid depression, albeit often mild, co-occurred in thirteen OCD hoarders and seven individuals with hoarding disorder, and anxiety disorders co-occurred in four OCD hoarders (generalized anxiety disorder=3 and social phobia=1) and seven hoarding disorder cases (generalized anxiety disorder=4, social phobia=1, agoraphobia=1, panic disorder=1, and posttraumatic stress disorder=1) and anorexia nervosa in one. Four hoarding disorder cases were taking psychotropic medication, three were on selective serotonin reuptake inhibitors (SSRIs) and one on an antidepressant (agomelatine). All 13 OCD hoarders taking psychotropic medication were on SSRIs, with three also taking anti-psychotic medication, one also taking a benzodiazepine and one taking agomelatine.

2.2. Procedure

Participants completed a battery of well-validated tasks characterizing executive function, mainly from the Cambridge Neuropsychological Test Automated Battery (CANTAB) (www.camcog.com). Task order was counterbalanced across participants and within each group.

The stop-signal task (Logan and Cowan, 1984; Aron et al., 2003) measures response activation (median Go reaction time; RT) and response inhibition (SSRT). Participants respond to left and right arrows (go stimuli) with left and right key presses respectively, unless they hear a beep (stop stimulus, on a random 25% of trials) signalling to withhold the response. The delay between go and stop stimulus onsets varies using a tracking algorithm resulting in successful inhibition of responses on half the stop trials, allowing the estimation of SSRT using a race horse model (Logan and Cowan, 1984).

The Intradimensional/Extradimensional Shift (IED) Task (Owen et al., 1991) is a nine-stage visual discrimination task of rule acquisition examining set-shifting as an index of cognitive flexibility. Two multidimensional stimuli are displayed and feedback is provided so that participants learn which stimulus is correct. To pass each stage, six consecutive correct responses are required within 50 trials, otherwise, the task ends. The rule for correct responding is modified at each stage to dissociate different aspects of cognitive flexibility. The extra-dimensional shift stage examines inhibiting or shifting attention away from previously relevant stimulus dimensions. Key measures are errors made in the extra-dimensional stage (EDS) and total errors.

The TOL task (Owen et al., 1990) examines spatial planning and problem solving. In each trial participants move stacks of coloured balls in a lower arrangement to resemble an arrangement on the top half of the display. The minimum number of moves progresses from 2 to 4 per problem. The average number of moves required, the number of trials solved in the minimum possible number of moves, and the time to complete the pattern provide measures of planning ability.

The Cambridge Gamble Task (Rogers et al., 1999) is a decision-making task where participants accumulate points by gambling over different probabilities of winning. On each trial, 10 red and blue boxes are displayed, with the ratio of coloured boxes varying across trials. Participants decide on the colour they think a token is hidden behind and also decide how many points to gamble. Key measures include mean percentage of points gambled and percent of rational decisions made.

Probabilistic learning and reversal (PLR) (Swainson et al., 2000) examines acquiring and reversing a two-choice discrimination, gauging cognitive flexibility. Participants choose between two stimuli with probabilistic feedback in an 80:20 ratio. Participants complete 40 trials in two stages, with the rules reversed in the second stage. Participants are assumed to have learned the discrimination when a criterion of eight consecutive responses to the 'correct' stimulus is achieved. Key outcome measures are the number of participants passing each stage, and trials to criterion. Additionally, a maintenance score indicates greater difficulty maintaining the relevant discrimination once achieved.

2.3. Data analysis

One hoarding disorder case and four OCD hoarders did not complete all the tasks and this is reflected in the reported degrees of freedom. Prior to analysis, proportion data were arcsine transformed, count data were square-root transformed and latencies were logarithmically transformed to stabilize variance or reduce skew in the distributions (Howell, 2007). To examine performance relative to controls in each group, planned contrasts were used, though analyses of variance (ANOVA) are also reported. The χ^2 test was used to analyse the number of participants passing each stage of the PLR. Where patients were significantly worse than controls ($p < 0.05$), effect sizes were computed. Subsequently, in a secondary analysis, the two hoarding groups (with and without OCD) were compared to 20 non-hoarding OCD patients previously collected (see Chamberlain et al., 2007a for full details). As they differed significantly in age ($F(2, 63) = 14.76, p < 0.01$), analyses were performed on normalized scores, where each individual's score was normalized to the appropriate control group, both of which had a mean score of 0.

3. Results

As seen in Table 1, there were no significant group differences in age and verbal IQ. The two patient groups did not differ from the control group but differed from each other in gender distribution ($\chi^2(1) = 5.12, p < 0.05$). OCD hoarders showed the highest levels of OCD symptoms, depression as assessed by the MADRS, and trait anxiety. Hoarding disorder cases did not differ from controls on OCD severity as measured by the YBOCS, but had worse levels of depression, anxiety and self-reported OCD symptoms. Importantly, hoarding severity was comparable in the two hoarding groups.

Table 2 displays the planned contrasts for the different tasks between the two hoarding groups and controls. In the stop-signal task, both groups had slowed SSRTs compared to controls (overall ANOVA: $F(2, 70) = 3.17, p < 0.05$) with preserved go RT. Mean proportion of successful stops was approximately 0.5 for all groups indicating the tracking algorithm was successful. In the TOL, both hoarding groups had impaired performance, requiring more

Table 1
Demographic and clinical characteristics of OCD hoarders, compulsive hoarders without OCD and control participants.

Characteristic	OCD Hoarders		Compulsive Hoarders		Control Participants		F	p
	Mean	S.D.	Mean	S.D.	Mean	S.D.		
Male:female	12:12		4:18		12:16			
Age (years)	48.75	11.2	53.95	8.66	51.50	10.51	1.49	0.23
National Adult Reading Test (verbal IQ estimate)	119.13	3.71	119.60	3.63	119.32	3.28	0.11	0.90
Savings Inventory-Revised	59.13 ^a	12.32	60.34 ^a	14.14	11.54 ^b	6.98	159.28	< 0.001
Yale-Brown Obsessive Compulsive Scale	19.63 ^a	5.17	0.18 ^b	0.85	0 ^b	0	349.70	< 0.001
Montgomery-Asberg Depression Rating Scale	13.75	9.10	8.59 ^b	6.56	1 ^c	1.56	26.51	< 0.001
State-Trait Anxiety Inventory state	50.54 ^a	11.12	48.10 ^a	11.26	27.57 ^b	5.47	46.91	< 0.001
State-Trait Anxiety Inventory trait	57.13 ^a	8.86	50.67 ^b	12.53	28.11 ^c	5.07	75.38	< 0.001
BDI	15.30 ^a	10.10	12.93 ^a	9.83	2.25 ^b	2.29	19.78	< 0.001
OCI	36.42 ^a	13.50	19.27 ^b	7.77	4.61 ^c	3.69	79.64	< 0.001
OCI no H	26.58 ^a	12.71	9.91 ^b	7.29	3.21 ^c	3.20	50.84	< 0.001

Note: BDI=Beck's Depression Inventory; OCI=obsessive compulsive inventory; OCI no H=OCI without the hoarding subscale; Values with different superscripts significantly differ from each other as measured by Tukey's Honest Significant Difference.

Table 2
Neuropsychological tests results.

Task and measure	OCD Hoarders		Compulsive Hoarders		Healthy Comparison Participants		OCD Hoarders vs. Controls			Compulsive Hoarders vs. Controls			OCD Hoarders vs. Controls	Compulsive Hoarders vs. Controls	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	F	d.f.	p	F	d.f.	p	d	d	
Stop-signal task															
Stop-signal reaction time	215.10	73.76	208.72	76.69	174.07	14.06	42.06	6.29	1,50	< 0.05*	4.09	1,47	< 0.05	0.70	0.56
Median go reaction time	350.79	43.84	384.90	81.62	360.43	52.04	52.04	0.52	1,50	0.47	1.64	1,47	0.21		
Mean proportion successful stops	0.48	0.08	0.51	0.07	0.50	0.06	0.06	0.47	1,50	0.49	0.27	1,47	0.60		
Tower of London															
Mean attempts	4.57	0.76	4.33	0.50	4.06	0.45	8.53	1,46	< 0.01*	4.26	1,48	< 0.05	0.86	0.59	
Number of minimum moves	7.65	2.34	8.23	2.37	9.50	1.55	11.43	1,46	< 0.01*	5.64	1,48	< 0.05*	0.99	0.68	
Latency	8094.07	6019.80	9100.19	11011.94	6542.69	4797.50	0.47	1,46	0.18	1.74	1,48	0.19			
Intradimensional/Extradimensional Shift															
EDS errors	27.45	23.31	19.50	21.63	14.04	19.63	4.89	1,46	< 0.05	1.16	1,48	0.37	0.65	0.34	
Total errors	41.85	39.90	27.82	21.69	22.36	20.89	5.35	1,46	< 0.05*	1.00	1,48	0.49	0.68	0.42	
Probability reversal															
Stage 1															
Passing:fail (N)	20:4	18:4	27:1												
Trials to criterion	17.29	11.38	17.73	11.72	11.82	7.57	4.70	1,50	< 0.05	5.07	1,48	< 0.05	0.60	0.64	
Maintenance Score	0.04	0.06	0.02	0.06	0.02	0.04	2.08	1,45	0.16	0.16	1,43	0.69			
Stage 2															
Passing:fail (N)	19:5	15:7	27:1												
Trials to criterion	20.25	12.08	22.36	13.20	15.04	7.87	3.43	1,50	< 0.07	5.83	1,48	< 0.05*	0.52	0.69	
Maintenance Score	0.08	0.14	0.02	0.03	0.03	0.07	2.48	1,42	0.12	0.46	1,38	0.50			
Cambridge Gamble Task															
Percentage of points gambled	49.75	12.45	52.48	13.01	53.72	12.68	1.12	1,46	0.29	0.09	1,48	0.76			
Percentage of rational decisions made	0.900	0.15	0.922	0.14	0.945	0.09	0.64	1,46	0.43	0.50	1,48	0.48			

Note: χ^2 tests for probability reversal task pass/fail rates are reported in the results section. All latencies are reported in milliseconds.

* P values where < 0.05 denote comparisons surviving Bonferroni correction.

moves to complete problems and solving less problems in the minimal moves possible (ANOVAs: $F(2, 67)=4.78, p < 0.05$, and $F(2, 67)=5.27, p < 0.05$, respectively). At the same time, their latencies did not differ from controls.

In the IED task, OCD hoarders had significantly increased errors, whereas the hoarding disorder group did not differ significantly from controls (overall ANOVAs: $F(2, 67)=2.90, p=0.06$, and $F(2, 67)=2.45, p=0.09$ for total and EDS errors, respectively) (Fig. 1). In PRL, χ^2 tests on pass/fail rates indicated that in stage 1, neither OCD hoarders ($\chi^2(1)=2.55, p=0.11$) nor hoarding disorder cases ($\chi^2(1)=2.92, p=0.09$) differed significantly from controls. In stage 2, the difference between OCD hoarders and controls reaching criterion just approached significance ($\chi^2(1)=3.77, p=0.05$), and the difference between the hoarding disorder and control groups was significant ($\chi^2(1)=7.31, p < 0.01$) (see Fig. 2A). Hoarders required more trials than controls to reach criterion but did not differ in their maintenance score suggesting that once at criterion, they could maintain the correct stimulus despite misleading feedback (ANOVAs: $F(2, 71)=3.01, p=0.05$, and $F(2, 71)=2.93, p=0.06$, for trials to criterion in stages 1 and 2, respectively). To further inspect learning, per cent correct choice was computed for eight-trial blocks. Choosing the correct stimuli was similarly impaired across all blocks in both stages (i.e., there was no significant interaction between block and group, $p > 0.33$ for both) (see Fig. 2B). The two hoarding groups did not differ from controls on either measure of the Cambridge Gamble Task (see Table 3). Finally, there were no significant differences between the two hoarding groups on any performance indices.

To investigate the possible role of depression, we examined only hoarders across both hoarding groups who were non-depressed, with the stringent criteria of a MADRS score below 12 (MADRS mean was 4.8). Similar group differences were found (although SSRT now became marginally significant ($p < 0.08$)), suggesting the present findings were unlikely to result from

comorbid depressive symptoms. Additionally, no correlations between depression scores or anxiety scores and the key performance measures of stop-signal, spatial planning, set-shifting or probability reversal were significant. Hoarders who scored below the median anxiety score demonstrated significant impairments in TOL, set shifting, PRL, and marginal significance in SSRT ($p < 0.06$), replicating the results reported in Table 2. When examining only unmedicated hoarders the results remained similar (stop-signal SSRT, TOL and PRL indices remained significant). Similarly, when examining only medicated hoarders, they performed significantly worse than controls (stop-signal SSRT, TOL and ED errors remained significant, with PRL indices at marginal significance). No correlations between symptom severity and key performance measures of stop signal, probability reversal, set-shifting or spatial planning were significant in the hoarders. Covarying for gender did not change any of the results above.

Secondary ANOVAs investigating hoarders and non-hoarding OCD patients, and comparing the normalized scores, revealed no significant differences between the three patient groups ($p > 0.33$ for all comparisons). Replicating the results above, all three groups had impaired response inhibition and spatial planning with intact decision making compared to their respective controls. Cognitive flexibility as measured by EDS errors indicated a graded impairment with non-hoarding OCD patients most impaired, followed by OCD hoarders and best performance by hoarding disorder cases (normalized scores for the three groups, respectively: 0.804, 0.683, and 0.278). As in previous analyses, only the first two groups were significantly worse than controls. Reversal learning as measured by errors to criterion following a reversal showed the opposite pattern, with best performance by OCD patients, followed by OCD hoarders and worst performance by hoarding disorder cases (for the three groups, respectively: 0.500, 0.675, and 0.961). Similar results were found for pass/fail, as 90% of non-hoarding OCD

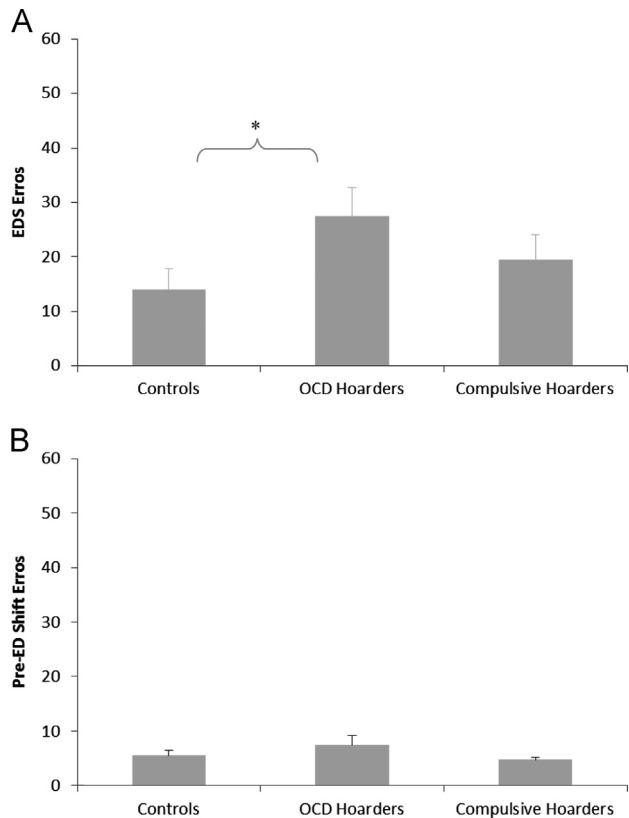


Fig. 1. Performance in OCD hoarders, compulsive hoarders without OCD and controls in the Intradimensional/Extradimensional shift task. Panel (A) shows extradimensional shift (EDS) errors. Panel (B) shows the errors before the EDS stage. Only OCD hoarders had significantly more EDS errors compared to controls and there were no differences in errors before the EDS stage.

patients passed following reversal. As in previous analyses, only the two hoarding groups were significantly worse than controls.

4. Discussion

This study investigated the profile of executive functions in two distinct groups: OCD hoarders and hoarding disorder patients without comorbid OCD. Performance in the two groups was similar overall, despite strikingly different clinical presentations (best seen in YBOCS scores). The neuropsychological evidence dovetails with the similar phenomenology of hoarding behaviours across the two groups (Pertusa et al., 2008). The hoarding groups did not differ significantly in task performance, though OCD hoarders had increased OCD symptoms, greater trait anxiety and depressive symptom severity. As hypothesized, the neurocognitive profile of the two hoarding groups is largely similar to that previously reported using the same tasks in non-hoarding OCD patients (Chamberlain et al., 2006, 2007a). Firstly, this extends the notion that response inhibition and spatial planning deficits together with intact decision making are characteristic of the obsessive-compulsive spectrum, regardless of the presence of severe hoarding. Secondly, the present findings support the notion that this neuropsychological profile is associated with the compulsive nature of OCD and hoarding rather than the time consuming obsessions and rituals reported in OCD but absent in those with hoarding disorder.

Worse performance in spatial planning using similar tasks has been previously reported in mixed groups of OCD patients (Veale et al., 1996; Purcell et al., 1998; Watkins et al., 2005) and in hoarders (Grisham et al., 2010). Similar inhibitory difficulties were

reported in non-hoarding OCD (Chamberlain et al., 2006), although a recent study failed to find SSRT difficulties in a group of non-hoarding OCD and a group of hoarders where just over half had OCD (Blom et al., 2011). Current results lend converging validity for difficulties in these two domains across both OCD hoarders and those with hoarding disorder. This suggests that these two groups, similar to other OCD patients, would have abnormalities in lateral prefrontal–striatal circuits (van den Heuvel et al., 2005; Menzies et al., 2007) in addition to the probable orbitofrontal dysfunction. Intact decision-making in the gambling task is also consistent with previous reports of non-hoarding OCD patients (Chamberlain et al., 2007a). Although cognitive theories of hoarding propose decision making difficulties (Frost and Hartl, 1996), current evidence suggests such difficulties manifest only in situations where choices are personally relevant (Wincze et al., 2007; Grisham et al., 2010; Tolin et al., 2012). Hence, as here, hoarders appear unimpaired in structured decision-making situations which do not pertain to highly personal matters.

In contrast to the evidence regarding response inhibition, spatial planning and decision making, the findings regarding cognitive flexibility were less straightforward. OCD hoarders had worse ED shifting than controls while hoarding disorder cases with no comorbid OCD were not significantly worse, their performance being intermediate between controls and OCD hoarders. Previously in this task non-hoarding OCD patients performed worse than controls (Chamberlain et al., 2007b) whilst non-OCD hoarders did not (Grisham et al., 2010; Tolin et al., 2011). It is tempting to attribute ED shifting difficulties to OCD per se. However, in light of the large inconsistencies in the OCD literature on cognitive flexibility (Kuelz et al., 2004) and given the two hoarding groups did not differ significantly, such a conclusion might be premature. To demonstrate statistically significant differences between the two hoarding groups in ED-shifting would require groups of 140 individuals each.

While ED shifting entails moving attention to a dimension thus far considered irrelevant, in reversal learning the correct response is now associated with a previously incorrect response. OCD hoarders and hoarding disorder cases performed worse than controls on the PRL, in contrast to previous findings in non-hoarding OCD patients using the same task (Chamberlain et al., 2007a). Several lines of evidence suggest hoarders may exhibit particular difficulties in reversal learning. First, brain regions subserving reversal learning, such as the ventromedial prefrontal cortex (Cools et al., 2002; Fellows and Farah, 2003) appear to be particularly implicated in severe hoarding (Mataix-Cols et al., 2011). Second, higher levels of hoarding in OCD were associated with worse IGT performance, with worse performance emerging in later blocks, consistent with the notion that hoarding patients had difficulties overcoming an initial preference to disadvantageous decks (Fellows and Farah, 2005; Lawrence et al., 2006). Worse performance in IGT could be explained by underlying reversal difficulties (Fellows and Farah, 2005). However, direct group comparisons again demonstrated graded performance with no significant differences. Thus, it is possible that weakness in cognitive flexibility in OCD and hoarders are a matter of degree (see also Tolin and Villavicencio, 2011). This weakness may also become more pronounced in older adults as it may interact with normal aging related decline (Ayers et al., 2013).

Taken together, variations in ED shifting and PRL performance putatively reflect subtle variations in underlying fronto-striatal pathology. ED shifting is likely more sensitive to lateral prefrontal functionality (Hampshire and Owen, 2006), while PRL is likely more sensitive to medial prefrontal functionality, particularly with few reversals (Fellows and Farah, 2003). This suggests that future investigations of cognitive flexibility in OCD should be particularly

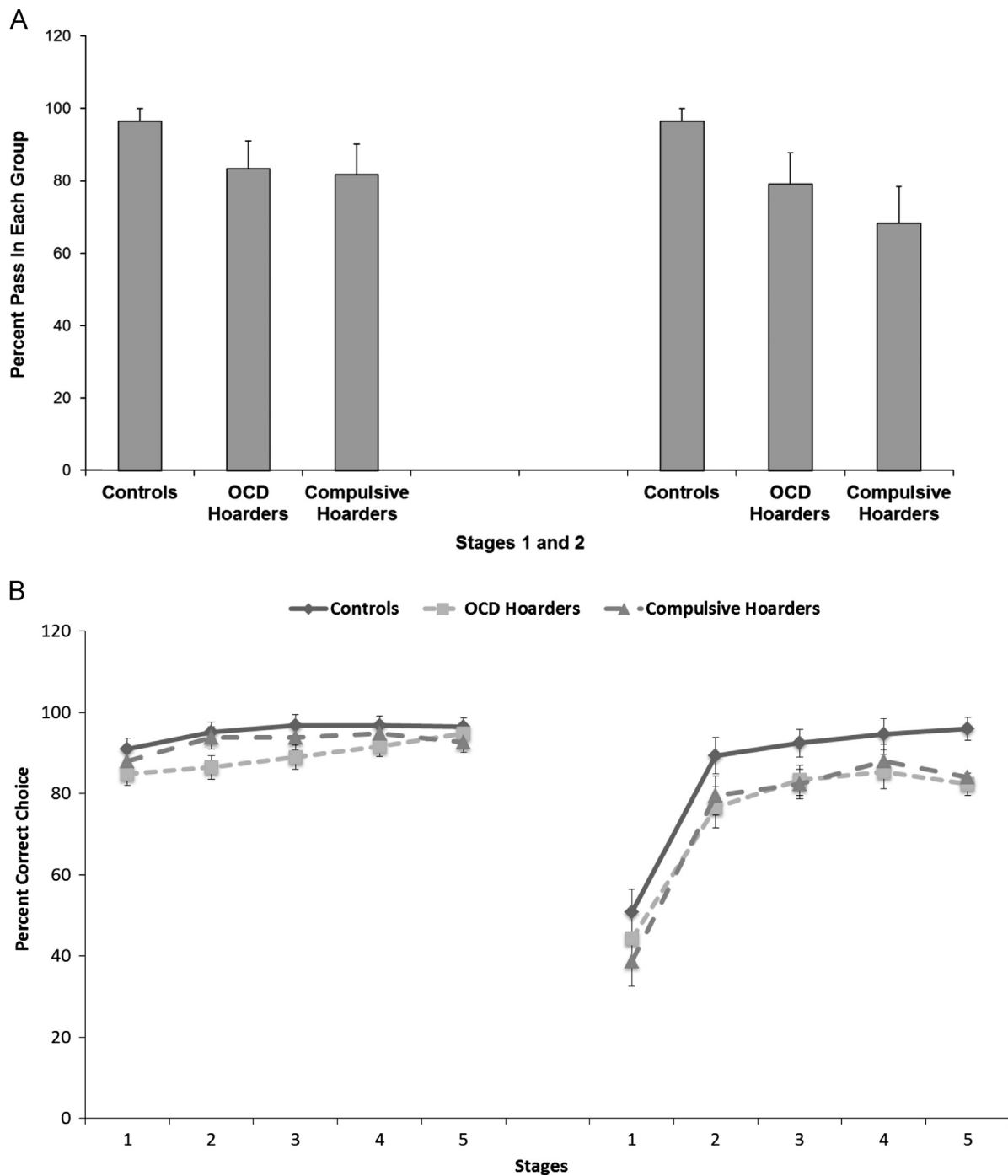


Fig. 2. Performance in OCD hoarders, compulsive hoarders without OCD and control participants in the probabilistic learning and reversal task. Panel (A) shows the per cent of participants who passed in each group. Significantly more compulsive hoarders failed in Stage 2 and marginally more OCD hoarders failed compared to controls. Panel (B) shows the per cent of the correct stimulus chosen in the two stages of the task.

careful in assessing hoarding symptoms, given a large minority of patients exhibit some degree of hoarding symptoms (Frost et al., 2000; Pertusa et al., 2008; Samuels et al., 2008).

One limitation of this study was that many of the OCD hoarders were medicated. There were too few unmedicated OCD patients to conduct analyses in this group separately, however analyses in unmedicated and medicated patients yielded a similar pattern of cognitive difficulties suggesting medication was unlikely to have a large influence on observed results. Moreover, the inhibitory and cognitive flexibility difficulties are consistent with previous studies where healthy unmedicated first-degree relatives of OCD

patients were similarly impaired (Chamberlain et al., 2007b). Additionally, SSRI manipulations do not appear to influence response-inhibition performance (Clark et al., 2005). Medication is also unlikely to underlie PRL deficits as unimpaired performance was previously found in medicated OCD patients (Chamberlain et al., 2007a; Ersche et al., 2011). We did not exclude hoarders with depression and anxiety. Importantly however, similar results were found with analyses restricted to non-depressed hoarders, or those with relatively low anxiety. Our approach enabled a pragmatic recruitment policy and resulted in depression and anxiety rates comparable to previously reported studies (Pertusa et al.,

Table 3

Summary of cognitive profile in OCD hoarders, compulsive hoarders (from the current study) and non-hoarding OCD from previous studies using the same tasks.

	OCD Hoarders (current study)	Compulsive Hoarders (current study)	Non-hoarding OCD (previous studies)
Stop-signal task	+	+	+
Tower of London	+	+	+
Cambridge Gamble Task	–	–	–
Probabilistic learning and reversal	+	+	(–)
Intradimensional/ Extradimensional Shift Task	+	(–)	+

Note. + =impaired compared to healthy controls; – =unimpaired compared to healthy controls; (–) =not significantly different from controls or other hoarding/OCD patients. Previous studies of non-hoarding OCD using identical (stop-signal task, Intradimensional/Extradimensional Shift Task Shift task, Cambridge Gamble Task and Probabilistic learning and reversal) or highly similar (Tower of London) tasks: (Chamberlain et al., 2007a, 2007b).

2008; Tolin et al., 2011). Depression and anxiety correlate with hoarding in OCD and even non-clinical samples (Coles et al., 2003; Wu and Watson, 2005). Thus, to exclude such co-morbidities in hoarders may yield a restricted and unrepresentative clinical sample. Moreover, evidence from previous studies reaffirms that neither anxiety nor depression were likely to account for the observed results (Bedard et al., 2009). For example, a stop-signal meta-analysis found no evidence for inhibitory deficits in anxiety disorders (Lipszyc and Schachar, 2010). Additionally, co-morbid depression did not influence response-inhibition impairments in OCD (Morein-Zamir et al., 2010). Studies of anxiety disorders found no deficits in cognitive flexibility and spatial planning (Purcell et al., 1998). Taken together, the evidence suggests co-morbid anxiety or depression per se unlikely to account for present findings. Future studies can benefit from inclusion of a depression and/or anxiety clinical control group (Grisham et al., 2007; Grisham et al., 2010). The present study investigated OCD hoarders and individuals with hoarding disorder and no OCD, whilst also subsequently comparing these two groups to a previously collected sample of non-hoarding OCD. Although we note that no neuropsychological study to date has contrasted all three groups *a priori*, this would be useful in future to obtain a complete understanding of the relationship between the disorders (see for example Neziroglu et al., 2012). As we used planned comparisons, we did not employ corrections for multiple comparisons. Nevertheless, as the results are consistent across both groups and converge with previous studies employing the same tasks, an inflated type I error is unlikely. Current hoarders were predominantly female and older than in previous non-hoarding OCD studies, but representative of other reports of excessive hoarders (Pertusa et al., 2008). It is presently unclear whether a gender bias exists in recruitment or referral, whereby females are more likely to seek assistance, or whether this results from underlying prevalence rates. Preliminary epidemiological evidence suggests increased hoarding in males (Samuels et al., 2008; Iervolino et al., 2009), but likely accompanied by even greater lack of insight. Hoarding often becomes problematic only later in life, and studies consistently report older samples (Pertusa et al., 2010). At the same time, hoarding begins for many in their teens but recognition of the problems lags considerably (Grisham et al., 2006). When presently asked about onset, most participants reported hoarding symptoms since childhood and early adolescence which steadily worsened, but had difficulties pinpointing a specific age retrospectively. Age of onset of hoarding symptoms may be an important determinant in distinguishing potential mechanisms contributing to hoarding behaviour (Grisham et al.,

2006). For example, considerably greater cognitive dysfunction has been reported in geriatric hoarding patients (Ayers et al., 2013). Identifying younger hoarders and hoarders who do not seek help remains a challenge for future research.

In sum, we examined executive functions in individuals with OCD and severe hoarding as well as in a clinically distinct group of individuals meeting DSM-5 criteria for hoarding disorder without comorbid OCD. Although OCD symptoms differed markedly between the two hoarding groups, their task performance did not differ, nor did their performance differ significantly in a subsidiary analysis from a previously reported group of non-hoarding OCD patients. Impairments in response-inhibition and spatial planning together with intact decision making were present in all groups, which all exhibited increased compulsivity regardless of excessive time-consuming obsessions, compulsions and hoarding. Tests of cognitive flexibility showed the least amount of convergence between the groups; however differences were small and likely reflected the psychometric limitations of the tasks together with possible variation in underlying brain pathology. Future studies in OCD would benefit from ascertaining hoarding severity rather than the mere presence of hoarding symptoms to better characterize OCD groups and the comparability of their clinical profiles across studies, particularly in tests sensitive to cognitive flexibility.

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References

- An, S.K., Mataix-Cols, D., Lawrence, N.S., Wooderson, S., Giampietro, V., Speckens, A., Brammer, M.J., Phillips, M.L., 2009. To discard or not to discard: the neural basis of hoarding symptoms in obsessive-compulsive disorder. *Molecular Psychiatry* 14, 318–331.
- Aron, A.R., Fletcher, P.C., Bullmore, E.T., Sahakian, B.J., Robbins, T.W., 2003. Stop-signal inhibition disrupted by damage to right inferior frontal gyrus in humans. *Nature Neuroscience* 6, 115–116.
- American Psychiatric Association, 2013. *Diagnostic and Statistical Manual of Mental Disorders-5*, Fifth Edition.
- Ayers, C.R., Wetherell, J.L., Schiehser, D., Almklov, E., Golshan, S., Saxena, S., 2013. Executive functioning in older adults with hoarding disorder. *International Journal of Geriatric Psychiatry*.
- Beck, A.T., Ward, C.H., Mendelson, M., Mock, J., Erbaugh, J., 1961. An inventory for measuring depression. *Archives of General Psychiatry* 4, 561–571.
- Bedard, M., Joyal, C.C., Godbout, L., Chantal, S., 2009. Executive functions and the obsessive-compulsive disorder: on the importance of subclinical symptoms and other concomitant factors. *Archives of Clinical Neuropsychology* 24, 585–598.
- Bloch, M.H., Landeros-Weisenberger, A., Rosario, M.C., Pittenger, C., Leckman, J.F., 2008. Meta-analysis of the symptom structure of obsessive-compulsive disorder. *American Journal of Psychiatry* 165, 1532–1542.
- Blom, R.M., Samuels, J.F., Grados, M.A., Chen, Y., Bienvenu, O.J., Riddle, M.A., Liang, K.Y., Brandt, J., Nestadt, G., 2011. Cognitive functioning in compulsive hoarding. *Journal of Anxiety Disorders* 25, 1139–1144.
- Cavedini, P., Riboldi, G., D'Annunzi, A., Belotti, P., Cisima, M., Bellodi, L., 2002. Decision-making heterogeneity in obsessive-compulsive disorder: ventromedial prefrontal cortex function predicts different treatment outcomes. *Neuropsychologia* 40, 205–211.
- Chamberlain, S.R., Blackwell, A.D., Fineberg, N.A., Robbins, T.W., Sahakian, B.J., 2005. The neuropsychology of obsessive compulsive disorder: the importance of failures in cognitive and behavioural inhibition as candidate endophenotypic markers. *Neuroscience and Biobehavioral Reviews* 29, 399–419.
- Chamberlain, S.R., Fineberg, N.A., Blackwell, A.D., Clark, L., Robbins, T.W., Sahakian, B.J., 2007a. A neuropsychological comparison of obsessive-compulsive disorder and trichotillomania. *Neuropsychologia* 45, 654–662.

- Chamberlain, S.R., Fineberg, N.A., Blackwell, A.D., Robbins, T.W., Sahakian, B.J., 2006. Motor inhibition and cognitive flexibility in obsessive-compulsive disorder and trichotillomania. *American Journal of Psychiatry* 163, 1282–1284.
- Chamberlain, S.R., Fineberg, N.A., Menzies, L.A., Blackwell, A.D., Bullmore, E.T., Robbins, T.W., Sahakian, B.J., 2007b. Impaired cognitive flexibility and motor inhibition in unaffected first-degree relatives of patients with obsessive-compulsive disorder. *American Journal of Psychiatry* 164, 335–338.
- Clark, L., Roiser, J.P., Cools, R., Rubinstein, D.C., Sahakian, B.J., Robbins, T.W., 2005. Stop signal response inhibition is not modulated by tryptophan depletion or the serotonin transporter polymorphism in healthy volunteers: implications for the 5-HT theory of impulsivity. *Psychopharmacology* 182, 570–578.
- Clarke, H.F., Dalley, J.W., Crofts, H.S., Robbins, T.W., Roberts, A.C., 2004. Cognitive inflexibility after prefrontal serotonin depletion. *Science* 304, 878–880.
- Coles, M.E., Frost, R.O., Heimberg, R.G., Steketee, G., 2003. Hoarding behaviors in a large college sample. *Behavioural Research and Therapy* 41, 179–194.
- Cools, R., Clark, L., Owen, A.M., Robbins, T.W., 2002. Defining the neural mechanisms of probabilistic reversal learning using event-related functional magnetic resonance imaging. *Journal of Neuroscience* 22, 4563–4567.
- Ersche, K.D., Roiser, J.P., Abbott, S., Craig, K.J., Müller, U., Suckling, J., Ooi, C., Shabbir, S.S., Clark, L., Sahakian, B.J., Fineberg, N.A., Merlo-Pich, E.V., Robbins, T.W., Bullmore, E.T., 2011. Response perseveration in stimulant dependence is associated with striatal dysfunction and can be ameliorated by a D(2/3) receptor agonist. *Biological Psychiatry* 70 (8), 754–762.
- Fellows, L.K., Farah, M.J., 2003. Ventromedial frontal cortex mediates affective shifting in humans: evidence from a reversal learning paradigm. *Brain* 126, 1830–1837.
- Fellows, L.K., Farah, M.J., 2005. Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex* 15, 58–63.
- Fineberg, N.A., Saxena, S., Zohar, J., Craig, K.J., 2007. Obsessive-compulsive disorder: boundary issues. *CNS Spectrums* 12 (359–364), 367–375.
- Foa, E.B., Huppert, J.D., Leiberg, S., Langner, R., Kichic, R., Hajcak, G., Salkovskis, P.M., 2002. The Obsessive-Compulsive Inventory: development and validation of a short version. *Psychological Assessment* 14, 485–496.
- Frost, R.O., Hartl, T.L., 1996. A cognitive-behavioral model of compulsive hoarding. *Behavioural Research and Therapy* 34, 341–350.
- Frost, R.O., Steketee, G., Grisham, J., 2004. Measurement of compulsive hoarding: saving inventory-revised. *Behavioural Research and Therapy* 42, 1163–1182.
- Frost, R.O., Steketee, G., Williams, L.F., Warren, R., 2000. Mood, personality disorder symptoms and disability in obsessive compulsive hoarders: a comparison with clinical and nonclinical controls. *Behavioural Research and Therapy* 38, 1071–1081.
- Goodman, W.K., Price, L.H., Rasmussen, S.A., Mazure, C., Fleischmann, R.L., Hill, C.L., Heninger, G.R., Charney, D.S., 1989. The Yale-Brown Obsessive Compulsive Scale. I. Development, use, and reliability. *Archives of General Psychiatry* 46, 1006–1011.
- Grisham, J.R., Brown, T.A., Savage, C.R., Steketee, G., Barlow, D.H., 2007. Neuropsychological impairment associated with compulsive hoarding. *Behavioural Research and Therapy* 45, 1471–1483.
- Grisham, J.R., Frost, R.O., Steketee, G., Kim, H.J., Hood, S., 2006. Age of onset of compulsive hoarding. *Journal of Anxiety Disorder* 20, 675–686.
- Grisham, J.R., Norberg, M.M., Williams, A.D., Certoma, S.P., Kadib, R., 2010. Categorization and cognitive deficits in compulsive hoarding. *Behavioural Research and Therapy* 48, 866–872.
- Hampshire, A., Owen, A.M., 2006. Fractionating attentional control using event-related fMRI. *Cerebral Cortex* 16, 1679–1689.
- Hartl, T.L., Frost, R.O., Allen, G.J., Deckersbach, T., Steketee, G., Duffany, S.R., Savage, C.R., 2004. Actual and perceived memory deficits in individuals with compulsive hoarding. *Depression and Anxiety* 20, 59–69.
- Hollander, E., Kim, S., Braun, A., Simeon, D., Zohar, J., 2009. Cross-cutting issues and future directions for the OCD spectrum. *Psychiatry Research* 170, 3–6.
- Howell, D.C., 2007. *Statistical Methods for Psychology*. Thomson Wadsworth, Belmont, California.
- Iervolino, A.C., Perroud, N., Fullana, M.A., Guipponi, M., Cherkas, L., Collier, D.A., Mataix-Cols, D., 2009. Prevalence and heritability of compulsive hoarding: a twin study. *American Journal of Psychiatry* 166, 1156–1161.
- Kuelz, A.K., Hohagen, F., Voderholzer, U., 2004. Neuropsychological performance in obsessive-compulsive disorder: a critical review. *Biological Psychology* 65, 185–236.
- Lawrence, N.S., Wooderson, S., Mataix-Cols, D., David, R., Speckens, A., Phillips, M.L., 2006. Decision making and set shifting impairments are associated with distinct symptom dimensions in obsessive-compulsive disorder. *Neuropsychology* 20, 409–419.
- Lipszyc, J., Schachar, R., 2010. Inhibitory control and psychopathology: a meta-analysis of studies using the stop signal task. *Journal of the International Neuropsychology Society* 16, 1064–1076.
- Logan, G.D., Cowan, W.B., 1984. On the ability to inhibit thought and action: a theory of an act of control. *Psychological Review* 91 (3), 295–327.
- Mataix-Cols, D., Frost, R.O., Pertusa, A., Clark, L.A., Saxena, S., Leckman, J.F., Stein, D.J., Matsunaga, H., Wilhelm, S., 2010. Hoarding disorder: a new diagnosis for DSM-V? *Depression and Anxiety* 27, 556–572.
- Mataix-Cols, D., Pertusa, A., Snowden, J., 2011. Neuropsychological and neural correlates of hoarding: a practice-friendly review. *Journal of Clinical Psychology* 67, 467–476.
- Mataix-Cols, D., Wooderson, S., Lawrence, N., Brammer, M.J., Speckens, A., Phillips, M.L., 2004. Distinct neural correlates of washing, checking, and hoarding symptom dimensions in obsessive-compulsive disorder. *Archives of General Psychiatry* 61, 564–576.
- McKay, D., Abramowitz, J.S., Calamari, J.E., Kyrios, M., Radomsky, A., Sookman, D., Taylor, S., Wilhelm, S., 2004. A critical evaluation of obsessive-compulsive disorder subtypes: symptoms versus mechanisms. *Clinical Psychology Review* 24, 283–313.
- Menzies, L., Achard, S., Chamberlain, S.R., Fineberg, N., Chen, C.H., del Campo, N., Sahakian, B.J., Robbins, T.W., Bullmore, E., 2007. Neurocognitive endophenotypes of obsessive-compulsive disorder. *Brain* 130, 3223–3236.
- Montgomery, S.A., Asberg, M., 1979. A new depression scale designed to be sensitive to change. *British Journal of Psychiatry* 134, 382–389.
- Morein-Zamir, S., Fineberg, N.A., Robbins, T.W., Sahakian, B.J., 2010. Inhibition of thoughts and actions in obsessive-compulsive disorder: extending the endophenotype? *Psychological Medicine* 40, 263–272.
- Morein-Zamir, S., Pappmeyer, M., Gillan, C.M., Crockett, M.J., Fineberg, N.A., Sahakian, B.J., Robbins, T.W., 2013. Punishment promotes response control deficits in obsessive-compulsive disorder: evidence from a motivational go/no-go task. *Psychological Medicine* 43, 391–400.
- Nelson, H.E., 1982. *The National Adult Reading Test Manual*. NFER-Nelson, Windsor.
- Neziroglu, F., Weissman, S., Allen, J., McKay, D., 2012. Compulsive hoarders: how do they differ from individuals with obsessive compulsive disorder? *Psychiatry Research* 200, 35–40.
- Nielen, M.M., Veltman, D.J., de Jong, R., Mulder, G., den Boer, J.A., 2002. Decision making performance in obsessive compulsive disorder. *Journal of Affective Disorders* 69, 257–260.
- Owen, A.M., Downes, J.J., Sahakian, B.J., Polkey, C.E., Robbins, T.W., 1990. Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia* 28, 1021–1034.
- Owen, A.M., Roberts, A.C., Polkey, C.E., Sahakian, B.J., Robbins, T.W., 1991. Extra-dimensional versus intra-dimensional set shifting performance following frontal lobe excisions, temporal lobe excisions or amygdalo-hippocampectomy in man. *Neuropsychologia* 29, 993–1006.
- Pertusa, A., Frost, R.O., Fullana, M.A., Samuels, J., Steketee, G., Tolin, D., Saxena, S., Leckman, J.F., Mataix-Cols, D., 2010. Refining the diagnostic boundaries of compulsive hoarding: a critical review. *Clinical Psychology Review* 30, 371–386.
- Pertusa, A., Fullana, M.A., Singh, S., Alonso, P., Menchon, J.M., Mataix-Cols, D., 2008. Compulsive hoarding: OCD symptom, distinct clinical syndrome, or both? *American Journal of Psychiatry* 165, 1289–1298.
- Phillips, K.A., Stein, D.J., Rauch, S.L., Hollander, E., Fallon, B.A., Barsky, A., Fineberg, N., Mataix-Cols, D., Ferrao, Y.A., Saxena, S., Wilhelm, S., Kelly, M.M., Clark, L.A., Pinto, A., Bienvenu, O.J., Farrow, J., Leckman, J., 2010. Should an obsessive-compulsive spectrum grouping of disorders be included in DSM-V? *Depression and Anxiety* 27, 528–555.
- Purcell, R., Maruff, P., Kyrios, M., Pantelis, C., 1998. Neuropsychological deficits in obsessive-compulsive disorder: a comparison with unipolar depression, panic disorder, and normal controls. *Archives of General Psychiatry* 55, 415–423.
- Remijnse, P.L., Nielen, M.M., van Balkom, A.J., Cath, D.C., van Oppen, P., Uylings, H.B., Veltman, D.J., 2006. Reduced orbitofrontal-striatal activity on a reversal learning task in obsessive-compulsive disorder. *Archives of General Psychiatry* 63, 1225–1236.
- Rogers, R.D., Owen, A.M., Middleton, H.C., Williams, E.J., Pickard, J.D., Sahakian, B.J., Robbins, T.W., 1999. Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. *Journal of Neuroscience* 19, 9029–9038.
- Samuels, J.F., Bienvenu, O.J., Grados, M.A., Cullen, B., Riddle, M.A., Liang, K.Y., Eaton, W.W., Nestadt, G., 2008. Prevalence and correlates of hoarding behavior in a community-based sample. *Behavioural Research and Therapy* 46, 836–844.
- Savage, C.R., Baer, L., Keuthen, N.J., Brown, H.D., Rauch, S.L., Jenike, M.A., 1999. Organizational strategies mediate nonverbal memory impairment in obsessive-compulsive disorder. *Biological Psychiatry* 45, 905–916.
- Saxena, S., 2008. Neurobiology and treatment of compulsive hoarding. *CNS Spectrums* 13, 29–36.
- Sheehan, D.V., Lecrubier, Y., Sheehan, K.H., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Baker, R., Dunbar, G.C., 1998. The Mini-International Neuropsychiatric Interview (M.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry* 59 (Suppl. 20), 22–33. (quiz 34–57).
- Spielberger, C.D., Gorsuch, R.L., Lushene, R., Vagg, P.R., Jacobs, G.A., 1983. *Manual for the State-Trait Anxiety Inventory (Form Y)*. Consulting Psychologists Press, Palo Alto, CA.
- Stein, D.J., Fineberg, N.A., Bienvenu, O.J., Denys, D., Lochner, C., Nestadt, G., Leckman, J.F., Rauch, S.L., Phillips, K.A., 2010. Should OCD be classified as an anxiety disorder in DSM-V? *Depression and Anxiety* 27, 495–506.
- Steketee, G., Frost, R., 2003. Compulsive hoarding: current status of the research. *Clinical Psychology Review* 23, 905–927.
- Swainson, R., Rogers, R.D., Sahakian, B.J., Summers, B.A., Polkey, C.E., Robbins, T.W., 2000. Probabilistic learning and reversal deficits in patients with Parkinson's disease or frontal or temporal lobe lesions: possible adverse effects of dopaminergic medication. *Neuropsychologia* 38, 596–612.
- Tolin, D.F., Stevens, M.C., Villavicencio, A.L., Norberg, M.M., Calhoun, V.D., Frost, R.O., Steketee, G., Rauch, S.L., Pearson, G.D., 2012. Neural mechanisms of decision making in hoarding disorder. *Archives of General Psychiatry* 69, 832–841.
- Tolin, D.F., Villavicencio, A., 2011. An exploration of economic reasoning in hoarding disorder patients. *Behaviour Research and Therapy* 49, 914–919.
- Tolin, D.F., Villavicencio, A., Umbach, A., Kurtz, M.M., 2011. Neuropsychological functioning in hoarding disorder. *Psychiatry Research* 189 (3), 413–418.
- van den Heuvel, O.A., Veltman, D.J., Groenewegen, H.J., Cath, D.C., van Balkom, A.J., van Harskamp, J., Barkhof, F., van Dyck, R., 2005. Frontal-striatal dysfunction

- during planning in obsessive-compulsive disorder. *Archives of General Psychiatry* 62, 301–309.
- Veale, D.M., Sahakian, B.J., Owen, A.M., Marks, I.M., 1996. Specific cognitive deficits in tests sensitive to frontal lobe dysfunction in obsessive-compulsive disorder. *Psychological Medicine* 26, 1261–1269.
- Watkins, L.H., Sahakian, B.J., Robertson, M.M., Veale, D.M., Rogers, R.D., Pickard, K.M., Aitken, M.R.F., Robbins, T.W., 2005. Executive function in Tourette's syndrome and obsessive-compulsive disorder. *Psychological Medicine* 35, 571–582.
- Wincze, J.P., Steketee, G., Frost, R.O., 2007. Categorization in compulsive hoarding. *Behavioural Research and Therapy* 45, 63–72.
- Wu, K.D., Watson, D., 2005. Hoarding and its relation to obsessive-compulsive disorder. *Behavioural Research and Therapy* 43, 897–921.