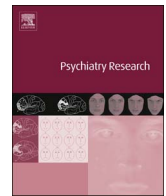


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Value-based decision making under uncertainty in hoarding and obsessive-compulsive disorders

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A B S T R A C T

Difficulties in decision making are a core impairment in a range of disease states. For instance, both obsessive-compulsive disorder (OCD) and hoarding disorder (HD) are associated with indecisiveness, inefficient planning, and enhanced uncertainty intolerance, even in contexts unrelated to their core symptomology. We examined decision-making patterns in 19 individuals with OCD, 19 individuals with HD, 19 individuals with comorbid OCD and HD, and 57 individuals from the general population, using a well-validated choice task grounded in behavioral economic theory. Our results suggest that difficulties in decision making in individuals with OCD (with or without comorbid HD) are linked to reduced fidelity of value-based decision making (i.e. increase in inconsistent choices). In contrast, we find that performance of individuals with HD on our laboratory task is largely intact. Overall, these results support our hypothesis that decision-making impairments in OCD and HD, which can appear quite similar clinically, have importantly different underpinnings. Systematic investigation of different aspects of decision making, under varying conditions, may shed new light on commonalities between and distinctions among clinical syndromes.

1. Introduction

Individuals with obsessive compulsive disorder (OCD) and hoarding disorder (HD) often report difficulties with decision making, such as indecisiveness, pathological doubt, increased deliberation times, and general avoidance of decisions (Frost and Shows, 1993; Hunink et al., 2014). OCD and HD together impact over 5% of the population, causing great suffering and substantial economic burden (Koran et al., 1996; Tolin et al., 2008; Timpano et al., 2011; Pittenger, 2017). Those with primary hoarding symptoms were formerly diagnosed with OCD. However, recently, primary hoarding symptoms have led to development of HD as a distinct clinical diagnosis (Black and Grant, 2014). Pathological indecisiveness, doubt, and intolerance of uncertainty are often prominent sources of disability in individuals with OCD or HD (Reed, 1985, 1985; Rasmussen and Eisen, 1992; Tolin et al., 2003; Taillefer et al., 2016). We employ the Risk & Ambiguity task (Levy et al., 2010), a behavioral task grounded in economic theory, to investigate value-based decision making under uncertainty in individuals

with OCD and HD. Specifically, we examine whether the clinically similar abnormalities in decision making seen in OCD and HD relate to similar or to distinct basic sub-processes of decision formation (Rangel et al., 2008).

Converging empirical evidence suggest differences in decision formation during value-based decision making and perceptual decision making (Summerfield and Tsetsos, 2012; Polanía et al., 2014; Dutilh and Rieskamp, 2016). Perceptual decision making entails accumulation of sensory information towards a categorical choice between alternatives (e.g., a melon is bigger than an apple). In studies employing a range of behavioral paradigms, those with OCD tend to act more cautiously during perceptual decision making than healthy individuals (Beads Task: Fear and Healy, 1997; Pélissier and O'Connor, 2002, Random Dot Motion task: Banca et al., 2015; but also note negative results by Jacobsen et al. (2012) and Chamberlain et al. (2007)). In contrast, value-based decisions depend on subjective goals (e.g., I like melons more than apples) and are assumed to follow several simple and intuitive rules (Rangel et al., 2008). Decision-makers aim to maximize

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Table 1
Demographics.

		Matched groups			Pooled controls, N = 57
		OCD	OCD/HD	HD	
AGE	Patients, N = 19	33.3 ± 2.6	40.6 ± 3.0	51.3 ± 1.9	37.2 ± 2.0
	Controls, N = 19	29.1 ± 1.9	35.3 ± 3.4	47.4 ± 3.7	
	p-value	0.2	0.25	0.35	
Male	Patients, N = 19	0.37 ± 0.1	0.47 ± 0.1	0.32 ± 0.1	0.40 ± 0.1
	Controls, N = 19	0.37 ± 0.1	0.58 ± 0.1	0.37 ± 0.1	
	p-value	0.5	0.53	0.74	
IQ	Patients, N = 19	102.4 ± 3.2	114.9 ± 2.4	111.2 ± 3.7	111.8 ± 1.6
	Controls, N = 19	107.4 ± 2.3	110.9 ± 3.4	112.3 ± 3.2	
	p-value	0.13	0.17	0.83	
Income	Patients, N = 19	3.8 ± 0.5	3.0 ± 0.5	3.2 ± 0.5	4.3 ± 0.3
	Controls, N = 19	4.6 ± 0.6	4.2 ± 0.6	4.0 ± 0.5	
	p-value	0.27	0.12	0.22	
Education	Patients, N = 19	4.2 ± 0.3	4.3 ± 0.2	5.0 ± 0.2	4.9 ± 0.1
	Controls, N = 19	4.8 ± 0.2	4.8 ± 0.2	5.0 ± 0.2	
	p-value	0.12	0.12	0.86	

Note: Significance of the between-group difference, p-value, for Age, IQ, Income and Education is based on the one-way ANOVA; significance of the between -group difference, p-value, for Male is based on the Pearson's chi-squared test (χ^2). Age is significantly different across patients groups; $F(2,54) = 12.59, p < 0.001$. Income is assessed on a 10 point scale (SM S.1.), where "3" = \$25,000–34,999; "4" = \$35,000–49,999, and "5" = \$50,000–74,999. Education is assessed on a 5-point scale (SM S.1) with "4" = College Graduate, and "5" = Advanced graduate or professional degree.

some subjective measure of expected value across available options, choose one option over another if clearly more valuable, and be largely consistent choices unless the available alternatives are close in subjective value (Neumann and Morgenstern, 1944). Studies of value-based making have also employed a variety of behavioral tasks, but have produced less consistent results. For instance, using the Iowa Gambling task (Bechara et al., 1994), some studies found that individuals with OCD perform worse than controls (Da Rocha et al., 2011; Zhang et al., 2015) while others studies found no between-group differences (Nielen et al., 2002; Lawrence et al., 2006). On the Cambridge Gambling Task (Manes et al., 2002), Dittrich and Johansen (2013) found that individuals with OCD are less likely to choose an objectively more valuable option and take longer to decide, but Chamberlain et al. (2007) found no between-group differences. On the Game of Dice task, some studies (Brand et al., 2002; Admon et al., 2012) found that individuals with OCD are more risk averse than healthy individuals, while others (Zhang et al., 2015) found no difference. These inconsistent findings may be attributed to OCD group size and composition, effects of medication, or lack of control for effects of anxiety, depression, and other comorbidities (Kuelz et al., 2004).

In light of largely conflicting evidence, the replication studies that carefully control for potential confounds are critically important. Note, however, that the Cambridge Gambling Task, the Game of Dice task, and the Iowa Gambling task all provide feedback and thus allow participants to learn. Thus, it is not clear whether impaired performance on these tasks should be attributed to value-based choice, feedback evaluation, strategy update, or ability to learn about the decision context. This limits the construct validity of these tasks (Buelow and Suhr, 2009). To characterize abnormal decision-making performance in clinical populations, it is vital to use tasks that avoid such confounds (as in Pushkarskaya et al., 2015, Sip et al., 2016, Aranovich et al., 2017).

In our recent work (Pushkarskaya et al., 2015), we employed the Risk and Ambiguity Task (Levy et al., 2010) to investigate value-based decision making in OCD. We found that individuals with OCD were more likely to make "noisy", inconsistent choices than participants from the general population, suggesting impairments in basic value-based computations in OCD. Our study found no group differences in how they valued uncertain options whose outcome probabilities were known (risk) but that those with OCD were more likely than controls to avoid uncertain options whose outcome probabilities were imprecisely specified (ambiguity), perhaps reflecting the intolerance of uncertainty commonly reported in OCD.

The aim of the present study was to replicate and extend these previous findings (Pushkarskaya et al., 2015) in a larger sample of unmedicated individuals with OCD, HD, and comorbid OCD and HD ($n = 19$ in each clinical group), compared with 57 individuals from the general population. Given similarities in clinically observed difficulties in decision making in OCD and HD, we expected to find impaired basic value-based computations and higher levels of uncertainty avoidance in HD. Our alternative hypothesis was that OCD and HD are associated with distinct impairments in basic sub-processes of value-based decision formation, despite similarities in clinically observed difficulties in decision making.

2. Methods

2.1. Participants

All procedures were approved by the Yale University Human Investigation Committee and the Hartford Hospital Institutional Review Board. All participants provided written informed consent, completed a demographic questionnaire (Supplementary materials S.1), and were assessed using the Kaufman Brief Intelligence Test (Kaufman, 1979).

Fifty-seven patients, unmedicated for at least 8 weeks, were recruited through the Yale OCD Research Clinic and the Anxiety Disorders Center at the Institute of Living, Hartford Hospital. Nineteen patients had OCD but not HD symptoms, 19 had HD but not OCD, and 19 had both OCD and HD. Of these, 10 individuals with OCD and 10 individuals with comorbid OCD and HD participated in our prior study (Pushkarskaya et al., 2015). Diagnoses were established by doctoral-level clinicians and confirmed using the Structural Clinical Interview for DSM-IV Disorders (SCID-IV; First et al., 2012) or a structured diagnostic interview for DSM-5 anxiety, mood, and obsessive-compulsive and related disorders (DIAMOND; Tolin et al., 2016).

The three clinical groups did not differ significantly in terms of gender, IQ, income, or education (Table 1). However, they differed significantly on age ($p < 0.001$), with the HD group significantly older than the OCD group.

Severity of OCD was assessed by clinicians using the Yale-Brown Obsessive-Compulsive Scale (Goodman et al., 1989a, Goodman et al., 1989b). Assessment included a question about the degree of indecisiveness, from 0 = "None" to 4 = "Extreme". Severity of hoarding symptoms was assessed using the Saving Inventory – Revised (SI-R; Frost et al., 2004). Since patients were recruited over 3 years at two

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