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A model-based analysis of decision making under risk in obsessive-compulsive and hoarding disorders

Gabriel J. Aranovich, M.D. [a, *], Daniel R. Cavagnaro, Ph.D. [b], Mark A. Pitt, Ph.D. [c], Jay I. Myung, Ph.D. [c], Carol A. Mathews, M.D. [d]

[a] Department of Neurology, University of California, San Francisco, United States
[b] Information Systems and Decision Sciences, California State University, Fullerton, United States
[c] Department of Psychology, The Ohio State University, United States
[d] Department of Psychiatry, University of Florida, United States

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ABSTRACT

Attitudes towards risk are highly consequential in clinical disorders thought to be prone to "risky behavior", such as substance dependence, as well as those commonly associated with excessive risk aversion, such as obsessive-compulsive disorder (OCD) and hoarding disorder (HD). Moreover, it has recently been suggested that attitudes towards risk may serve as a behavioral biomarker for OCD. We investigated the risk preferences of participants with OCD and HD using a novel adaptive task and a quantitative model from behavioral economics that decomposes risk preferences into outcome sensitivity and probability sensitivity. Contrary to expectation, compared to healthy controls, participants with OCD and HD exhibited less outcome sensitivity, implying less risk aversion in the standard economic framework. In addition, risk attitudes were strongly correlated with depression, hoarding, and compulsion scores, while compulsion (hoarding) scores were associated with more (less) "rational" risk preferences. These results demonstrate how fundamental attitudes towards risk relate to specific psychopathology and thereby contribute to our understanding of the cognitive manifestations of mental disorders. In addition, our findings indicate that the conclusion made in recent work that decision making under risk is unaltered in OCD is premature.

1. Introduction

It is commonly believed that so-called "risky behavior" is over-represented in mental disorders. Examining attitudes towards risk may be particularly fruitful in disorders hypothesized to be characterized by impulsivity, such as substance use disorders (SUD), as well as in those commonly regarded as excessively risk averse, such as obsessive-compulsive disorder (OCD) and hoarding disorder (HD). Current models of OCD and HD assert that both disorders involve impaired decision making (Cavedini et al., 2002; Grisham et al., 2010; Tolin and Villavicencio, 2011; Woody et al., 2014), and it has been suggested that abnormal attitudes towards uncertainty play a fundamental role in both (Admon et al., 2012; Grisham et al., 2010; Starcke et al., 2010; Zhang et al., 2015). In particular, the most prominent models of OCD and HD implicate excessive risk aversion and intolerance of uncertainty (Pushkarskaya et al., 2015).

The first studies to examine risk preferences in OCD and HD primarily utilized the Iowa Gambling Task (IGT) (Bechara et al., 1994). Studies based on the IGT have yielded mixed results. Lawrence et al. (2006) found evidence of a "link between hoarding and [increased] risky behavior on the IGT," while the OCD group did not differ from controls. In contrast, neither Grisham et al. (2007), nor Tolin and Villavicencio (2011) found that hoarding participants differed from controls on the IGT (Grisham et al., 2007; Tolin and Villavicencio, 2011). A large study by Mackin and colleagues found no differences between HD, OCD, or age matched controls on the IGT (Mackin et al., 2015). The IGT was designed as a measure of impatience and probabilistic learning, and its suitability as an assessment of risk preferences has been questioned in recent years (Buelow and Suhr, 2009; Pushkarskaya et al., 2015). Sohn et al. (2014) utilized the Balloon Analogue Risk Task (BART) and found lower levels of risk taking in OCD relative to HC. Several recent studies have utilized tasks more appropriate for the quantification

* Corresponding author. 912 Cole Street #368, San Francisco, CA 94117, USA.
E-mail address: garanovich@gmail.com (G.J. Aranovich).

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of risk preferences and have found evidence that subjects with OCD differ from HC in decision making under *ambiguity* (decisions between uncertain outcomes with uncertain probabilities), exhibiting greater ambiguity aversion, but do not differ from HC in decision making under *risk* (outcome probabilities are known) (Pushkarskaya et al., 2015; Starcke et al., 2010; Zhang et al., 2015).

Perhaps one reason that previous work has been inconclusive is that decision making under risk is a complex process involving multiple distinct subprocesses (Sokol-Hessner et al., 2015; Tversky and Fox, 1995). The fact that individuals frequently purchase both disaster insurance and lottery tickets indicates that people are not defined by a single risk preference. Significant controversy exists with regard to whether individual risk preferences are domain-specific (e.g., risky choices about stock investments versus alcohol consumption) (Weber et al., 2002; Weber and Johnson, 2009), or stable and domain-general (Einav et al., 2012; Pushkarskaya et al., 2015). Economic analyses have tended to find greater evidence for domain-general risk preferences (Einav et al., 2012), while studies from the psychology literature have been more likely to find that risk preferences are largely domain-specific (Weber et al., 2002; Weber and Johnson, 2009).

In the current study, we take advantage of tools from behavioral economics and recent advances in machine learning that permit a quantitative, dimensional analysis of decision making under risk that extends beyond the group-level summary measures of traditional decision making experiments. Tools from economics may prove especially useful in the characterization of alternative phenotypes, or endophenotypes, of mental disorders because they target specific cognitive processes thought to be impaired (Bickel et al., 2007; Hartley and Phelps, 2012; Sharp et al., 2012). Given the potential of such behavioral endophenotypes for refining the nosology of mental disorders (Insel et al., 2010), it is not surprising that tools from behavioral economics have been gaining popularity in the study of mental illness (Bickel et al., 2011; Hartley and Phelps, 2012; Sharp et al., 2012).

In economics, risk aversion is defined as "a preference for a sure outcome [e.g., $5 guaranteed] over a prospect with equal or greater expected value [e.g., 25% chance of receiving $20 dollars]" (Tversky and Fox, 1995). An individual's preferences over outcomes are summarized with a utility function; linear utility functions imply risk-neutrality, concave utility functions imply risk aversion, and convex functions imply risk seeking. Tversky and Kahneman demonstrated that participants tend not to have a single characteristic risk attitude (i.e., pure risk aversion vs. pure risk-seeking); the most common pattern involves overweighting of small probabilities along with underweighting of high probabilities (Kahneman and Tversky, 1979). This pattern is consistent with the popularity of both lottery tickets (small probability of large reward) and disaster insurance (small probability of large loss), and can account for well-known behavioral findings such as the certainty effect (the overweighting of outcomes that are certain relative to those that are highly probable) (Kahneman and Tversky, 1979).

To account for these complexities, Tversky and Kahneman introduced the "probability weighting function" (PWF), which transforms objective probabilities into subjective probability *weights* (Kahneman and Tversky, 1979). The PWF is a central component of Cumulative Prospect Theory (CPT) (Tversky and Kahneman, 1992), the most popular and empirically successful theory of decision making under risk in behavioral economics. As shown in Fig. 2, the case in which subjective probability weights equal objective probabilities corresponds to a linear PWF, which is classically accepted as the standard of rational choice in economics (Tversky and Wakker, 1995). Empirical findings are better accounted for by *nonlinear* PWFs (Camerer and Ho, 1994; Gonzalez and Wu, 1999).

The CPT model affords a more nuanced description of risk preferences than the standard economic framework. In place of a single measure of risk seeking or aversion, risk preferences are decomposed into "outcome sensitivity" and "probability sensitivity." The curvature of the value function (the CPT analogue of the classical utility function) captures outcome sensitivity, while the PWF captures probability sensitivity (Glöckner and Pachur, 2012). Generally, a concave value function (i.e., diminishing sensitivity to larger outcomes) is associated with risk aversion.[1] For that reason, we hypothesized that the clinical populations would exhibit greater concavity of the value function than healthy controls, on average.

2. Methods and materials

2.1. Participants

Individuals ≥18 years of age with OCD (n = 29, 17 female; mean age = 35, SD = 13), HD but not OCD (n = 29, 19 female; mean age = 58, SD = 11), and healthy controls (HC; n = 28, 14 women; mean age = 46, SD = 16) participated. The participants were part of a larger study that included a comprehensive clinical assessment, neuropsychological battery, and electrophysiology (EEG) measurements. Psychosis, dementia, intellectual disability, history of head trauma with loss of consciousness, active substance abuse, current use of antipsychotic medications, or any medical conditions known or suspected to affect cognitive function were exclusionary criteria. The majority of participants in the OCD and HD groups suffered from a comorbid depressive disorder (Major Depressive Disorder (MDD), Dysthymic Disorder) and/or an anxiety disorder (Generalized Anxiety Disorder (GAD), panic disorder, specific phobia, social phobia). Participants in these groups were excluded if they met criteria for any other active DSM-IV-TR Axis I disorders in the past year. Diagnosis of OCD, as well as absence of exclusionary psychiatric disorders, was confirmed using the Structured Clinical Interview for DSM-IV (SCID) (First et al., 2002). Subjects with OCD were excluded if they endorsed significant hoarding symptoms. HD diagnosis was determined according to DSM-V criteria (APA, 2013). HC participants were excluded if they met criteria for active DSM-IV-TR Axis I diagnoses within the past year. Sample size target of 30 per group was selected on the basis of previous findings of similar studies in the literature (Grisham et al., 2010; Sokol-Hessner et al., 2009). Participants were recruited from mental health clinics, media advertisements, and the Mental Health Association of San Francisco. Written informed consent was obtained from all participants under protocols approved by the Institutional Review Board of the University of California, San Francisco.

2.2. Clinical measures

For the parent study, participants received extensive clinical assessments. We focused on the results of a relevant subset of these measures: the Saving Inventory, Revised (SI-R) (Frost et al., 2004), the UCLA Hoarding Symptom Scale (UHSS) (Saxena et al., 2007), the Yale Brown Obsessive Compulsive Scale (YBOCS) (Goodman et al., 1989), the Beck Depression Inventory (BDI) (Beck et al., 1961), and the Beck Anxiety Inventory (BAI; Beck et al., 1988).

[1] Technically, due to the influence of the PWF, a concave value function would not be sufficient to guarantee overall "risk aversion" (Schmidt and Zank, 2008). Following previous authors (Neilson and Stowe, 2002), we will attribute risk aversion, neutrality, or seeking to the value function, rather than to the individual participant or group.