



An investigation of delay and probability discounting in hoarding disorder

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ABSTRACT

Behavioral impulsivity may be a mechanism of hoarding disorder (HD). A commonly used and well-validated measure of impulsivity is the delay and probability discounting task, which consists of making decisions about receiving monetary rewards after varying delay intervals and delivery probabilities. We compared delay and probability discounting and self-reported behavioral impulsivity in 81 patients with a primary diagnosis of HD and 45 nonclinical controls. HD participants completed the impulsivity measures before and after 16 weekly sessions of cognitive-behavioral therapy (CBT), whereas control group participants completed the measures before and after a 16-week waiting period. Despite the fact that self-reported impulsivity was greater in the HD group than the control group, delay and probability discounting did not differ between groups. Additionally, while self-reported behavioral impulsivity improved over the course of CBT in HD participants, delay and probability discounting did not change during treatment. Furthermore, higher delay discounting scores (i.e., greater preference for immediate rewards, indicating greater impulsivity) were associated with *lower* hoarding symptom severity. The findings suggest that self-reported impulsivity, but not objective performance on a behavioral impulsivity task, may be impaired in HD, and are discussed in terms of cognitive and affective factors in decision-making.

1. An investigation of delay and probability discounting in hoarding disorder

Hoarding disorder (HD) is a debilitating disorder that is characterized by difficulty discarding possessions, resulting in severe clutter in the home (American Psychiatric Association, 2013). Patients with HD usually engage in excessive acquiring (R. O. Frost, Rosenfield, Steketee and Tolin, 2013), although this symptom is not required for the HD diagnosis. HD is a relatively common condition that affects approximately 4% of the population (Samuels et al., 2008) and is associated with significant functional impairment (Saxena et al., 2011), poor quality of life (Ong et al., 2015), and significant economic and social burden (Tolin et al., 2008). The efficacy of cognitive-behavioral treatments for HD is significant but modest, with a meta-analysis showing low rates of clinically significant change following treatment (Tolin et al., 2015). In order to improve the efficacy of existing treatments for HD, it will be important to better understand the underlying mechanisms of HD that should be targeted in treatment.

One potential mechanism underlying excessive acquiring and difficulty discarding behavior in HD may be behavioral impulsivity. Impulsivity is a complex and multidimensional construct, comprised of

cognitive/executive functioning (e.g., working memory, attention), affective (e.g., negative affect, emotional intensity), and behavioral (e.g., engaging in goal-directed actions) factors (for a review, see Bari and Robbins, 2013). Behavioral impulsivity refers to a predisposition toward unplanned reactions to external or internal stimuli, without concern for the potentially negative implications of these reactions to others or oneself (Moeller et al., 2001). Various impulse control disorders, particularly compulsive buying, are highly comorbid with HD (R. O. Frost, Steketee and Tolin, 2011), suggesting that there may be a common underlying mechanism across these disorders. Among student volunteers with hoarding symptoms, self-reported cognitive and behavioral impulsivity have shown positive associations with excessive acquiring behaviors (Timpano et al., 2013). Patients with HD report greater self-reported behavioral impulsivity than healthy controls without psychiatric disorders (Tolin et al., 2018c) and patients with anxiety and depressive disorders (Grisham et al., 2007). However, recent work by Pinto et al. (2014) found that patients with obsessive-compulsive personality disorder (OCPD), a personality disorder that overlaps with the symptoms of HD, demonstrated greater capacity to delay monetary reward (i.e., less impulsivity) as compared to patients with OCD and healthy control subjects. More research is needed to

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clarify the potential role of impulsivity in HD.

It should be noted that much of the prior research on impulsivity in HD has relied on self-report measures, which are subject to the influence of social desirability and other response biases. Of the research that has examined impulsivity using behavioral tasks, most studies have used the Continuous Performance Task (CPT) or the Go/No-Go task, though results are mixed. While Grisham et al. (2010) found that patients with HD evidenced more errors of commission on the CPT than did non-clinical control participants, suggesting potential deficits in behavioral impulsivity, Tolin et al. (2011) failed to find differences between HD, OCD, and HC participants on CPT commission errors. On the Go/No-Go task, Tolin et al. (2014) failed to find group differences between HD and HC participants. These null group differences were replicated by Hough et al. (2016), who only found group differences on the Go/No-Go task between HD and OCD patients, but not between HD and HC participants.

Behavioral impulsivity may also be experimentally quantified using Delay and Probability Discounting laboratory tasks, which assess a trait-like tendency towards impulsive choice, or the inability to defer gratification in order to obtain a larger and/or more certain reward. Delay discounting (DD) refers to a decline in subjective value of a reward as a result of having to wait for the reward, while probability discounting (PD) is the decline in subjective value of a reward as the probability of receiving the reward decreases (for a review, see Bari and Robbins, 2013). There are demonstrable differences between DD and PD in the circumstances that lead to devaluation, but both involve cognitive processes that represent an estimation of value. DD and PD may also share similar neural mechanisms that have been implicated in valuation (e.g., striatal regions), planning and executive function (e.g., prefrontal cortex), and emotional processing (e.g., amygdala; R. Frost and McNaughton, 2017). Although both can be informative paradigms, DD has been more often examined in the context of externalizing psychopathology. An excessive rate of DD (i.e., a strong preference for immediate payoffs) has been linked to several disorders, such as attention-deficit/hyperactivity disorder (ADHD; Barkley et al., 2001), substance use disorders (de Wit, 2009; Reynolds et al., 2004), borderline personality disorder (Barker et al., 2015), and compulsive buying (Nicolai and Moshagen, 2017). Based on these findings, research into DD and PD among individuals with HD is warranted.

DD and PD can be measured using a straightforward, well-validated computerized Delay Discounting/Probability Discounting Questionnaire (DDQ/PDQ). Participants are presented with a series of choices between different amounts of money available after varying delay intervals (e.g., \$5 now, or \$10 25 days from now), and delivery probabilities (e.g., \$5 dollars for sure, or \$10 with a 50% chance). Both DD and PD produce theorized “indifference points,” or the point at which two reinforcers have equivalent effectiveness in their reinforcement (Reynolds et al., 2003). Using a hyperbolic function, it is possible to calculate k values, which reflect the steepness of such a discount curve. Larger k values indicate greater delay and probability discounting, respectively, and prior research supports that these indices are representative of greater impulsivity and risk aversion traits (Evenden, 1999; Richards et al., 1999).

The present study examined impulsive choice using the DDQ/PDQ task and self-reported behavioral impulsivity in a large sample of HD patients and healthy controls (HCs) without psychiatric disorders. Our working premise was that if experimentally-measured impulsive choice is a feature of HD, it should be found at higher levels in HD relative to HCs, relate to self-reported HD severity, and possibly be amenable to successful HD treatment. Because our study was part of a larger clinical trial investigating the neural mechanisms of cognitive-behavioral therapy (CBT) response in HD, we also were able to assess whether impulsivity changed over the course of CBT. Consistent with our premise, we hypothesized that we would replicate prior findings of elevated self-reported impulsivity in HD but also find greater DD and PD behaviorally-measured impulsive choice relative to HCs. We further

hypothesized that the impulsivity measures would predict HD severity, even when controlling for general negative affect (depression and anxiety symptoms). Finally, we predicted that impulsivity would improve over the course of CBT, as evidenced by lower self-reported impulsivity and lower DD and PD k and h indices following 16 weekly sessions of CBT.

2. Method

2.1. Participants

Participants were 81 treatment-seeking patients with a primary diagnosis of HD of at least moderate severity (“HD group”). They completed an intake assessment as part of a larger waitlist-controlled trial of group CBT for HD that involved functional magnetic resonance imaging (fMRI; results of the trial and the fMRI component will be reported in separate papers). Patients on psychiatric medications had to be on a stable dose for at least eight weeks and maintain the same dose for the duration of the study. Only antidepressants, stimulants, and benzodiazepines were permitted; stimulants and benzodiazepines were prohibited on the day of testing. Exclusion criteria for the HD group were current suicidality, psychosis, bipolar disorder, substance use disorder, any severe psychiatric problem requiring a higher level of care, and prior CBT for HD.

An additional 45 age- and sex-matched healthy control participants (“HC group”) completed the same assessment. Participants in the HC group could not have any current or past psychiatric disorder. Exclusion criteria for both groups were lack of English fluency; cognitive dysfunction that could interfere with the capacity to understand study procedures and/or provide informed consent; and history of anoxic or traumatic brain injury with loss of consciousness for more than five minutes. See Table 1 for the demographic characteristics of the sample.

2.2. Measures

2.2.1. Clinician-administered interviews

Participants’ diagnoses were assessed using the *Diagnostic Interview for Anxiety, Mood, and Obsessive-Compulsive and Related Neuropsychiatric Disorders* (DIAMOND; Tolin et al., 2018a), a structured diagnostic interview based on the DSM-5 that has demonstrated good reliability and validity estimates for anxiety, obsessive-compulsive, and depressive disorders, including HD (Tolin et al., 2018a). To verify whether HD was of at least moderate severity, interviewers also completed a modified version of the *Clinical Global Impression* (CGI) scale (Guy, 1976), the CGI-HD (Tolin et al., 2018b). The CGI-HD is a single-item rating that reflects overall HD symptom severity across six dimensions, including clutter, difficulty discarding, acquiring, health or safety hazard, functional impairment, and distress. A recent psychometric study using the

Table 1
Demographic characteristics of the sample.

Variable	Full, N = 126		HD, n = 81		HC, n = 45		Comparison t or χ^2 (p)
	n	%	n	%	n	%	
Age, M (SD)	53.72	8.65	53.99	9.39	53.24	7.21	0.46 (.646)
Female sex	102	81.0	68	84.0	34	75.6	1.32 (.250)
Race							9.80 (.020)
White	109	86.5	74	91.4	35	77.8	
Black	12	9.5	3	3.7	9	20.0	
Asian	3	2.4	2	2.5	1	2.2	
Other	2	1.6	2	2.5	0	0.0	
Ethnicity							1.48 (.223)
Hispanic/ Latino	7	5.6	3	3.7	4	8.9	
Not	119	94.4	78	96.3	41	91.1	

Note. HD = Hoarding disorder group. HC = Healthy control group.

same sample of HD and HC participants showed good inter-rater and test-retest reliability for the CGI-HD (Tolin et al., 2018b). Interviewers were psychology postdoctoral fellows under supervision or licensed psychologists who received extensive training in administration of the DIAMOND and CGI-HD.

2.2.2. Behavioral task

To examine impulsive choice, we used the DDQ/PDQ, a computerized questionnaire that measures the decline in subjective value of specific rewards as a result of varying delays and probabilities. Participants answer a series of 100 questions about their preferences in receiving rewards (e.g., “Would you prefer \$10 in 30 days or \$2 now?” and, “Would you prefer \$5 for sure or \$10 with a 25% chance?”). The DDQ/PDQ task utilizes an adjusting amount procedure to derive an indifference point at which the delayed and immediate options (delay discounting) or probabilistic and certain options (probability discounting) are of equivalent subjective value. These indifference points are plotted to form two separate discount functions derived through curve-fitting analyses, and produce a hyperbolic delay-discounting function parameter k . Larger k values indicate greater delay and probability discounting, respectively. Latency in responding to each item was also recorded in the current study (in milliseconds).

2.2.3. Self-report measures

To assess self-reported self-control and impulsivity, we administered the *Brief Self-Control Scale* (BSCS; Tangney et al., 2004), which is a 13-item measure rated on a 5-point scale (1 = *Not at all like me* and 5 = *Very much like me*). Items assess perceived capability of restraint (e.g., “I am good at resisting temptation”), goal-directed behaviors (e.g., “I am able to work effectively toward long-term goals”), and impulsivity (e.g., “I do certain things that are bad for me, if they are fun”). While the original authors used only a total score, Maloney et al. (2012) later published a 2-factor solution for the BSCS comprised of impulsivity and restraint subscales. Higher scores indicate greater perceived self-control. The BSCS total score and subscales showed adequate internal consistency in this sample (total, $\alpha = 0.88$; impulsivity, $\alpha = 0.79$; restraint, $\alpha = 0.72$).

Self-reported HD severity was assessed with the *Saving Inventory-Revised* (SI-R; R. O. Frost, Steketee and Grisham, 2004), which contains three subscales (acquiring, difficulty discarding, and clutter). Items are rated on a 5-point scale (0 = *None* and 4 = *Almost all/complete*) with higher scores indicating greater hoarding severity. The SI-R demonstrated excellent internal consistency in this sample ($\alpha = 0.98$).

General negative affect was assessed using the *Depression Anxiety Stress Scales* (DASS; Lovibond and Lovibond, 1995), a 42-item measure that assesses depression, anxiety, and general stress symptoms in the past week. Items are rated on a 4-point scale (0 = *Did not apply to me at all* and 3 = *Applied to me very much, or most of the time*) to indicate the frequency of each symptom. We used only the depression and anxiety subscales in the current study, and they showed adequate internal consistency (depression, $\alpha = 0.90$, anxiety, $\alpha = 0.81$).

2.3. Procedure

This investigation was carried out in accordance with the latest version of the Declaration of Helsinki. All study procedures took place at a specialty hospital-based outpatient program for hoarding disorder and were approved by the hospital's Institutional Review Board. To assess cognitive impairment that could interfere with the capacity to understand study procedures and/or provide informed consent, all participants completed the Orientation-Memory-Concentration Test (OMC; Katzman et al., 1983) and the Shipley Institute of Living Scale (Shipley; Zachary, 1986) prior to providing informed consent; only those who scored 8 or below on the OMC (normal or minimal impairment) and 80 (low average) or above on the Shipley were included in the study. After the screening measures, participants read through and

signed the consent form. They then completed an intake interview. If eligible for the study, HD group participants returned to the clinic for a second assessment day, which included the DDQ, PDQ, and self-report measures. They were then randomized to condition. If randomized to the waitlist group, they completed the same assessment measures 16 weeks later but did not receive any treatment during the waiting period. After the waiting period, waitlist group patients received treatment and completed the assessment measures again at post-treatment (16 weeks later). If randomized to the immediate condition, patients started treatment right away and completed the assessment again at post-treatment. Treatment consisted of 16 weekly sessions of CBT conducted in a group format; treatment procedures included psychoeducation about HD, decision-making and problem-solving skills, emotion regulation skills (e.g., distress tolerance), cognitive restructuring of maladaptive hoarding-related beliefs, motivational enhancement, and relapse prevention (Tolin et al., 2017). HC group participants completed the assessment again 16 weeks later but did not receive any treatment.

2.4. Statistical analyses

To assess normality, we first examined skewness and kurtosis values. DDQ and PDQ k values were non-normal (i.e., skewness > 3 and kurtosis > 10 ; Kline, 2009), so a log-transformation was applied to these values prior to conducting mean comparisons. Because the log of 0 is undefined and we had many 0 k values, first we scaled the k values by 1 prior to computing log transformations. All other measures had acceptable skew and kurtosis values, so no transformations were applied to these data.

Using independent samples t tests and Cohen's d effect sizes, we compared the HD and HC groups on the variables of interest. Because these analyses showed no significant group differences in DDQ/PDQ k values, we ran a series of follow-up analyses on the DDQ data to ensure that the k values were calculated accurately and showed reliability within a given time point and across time. First, to examine response consistency within the baseline time point, we calculated Pearson correlations between pairs of DDQ indifference points and latency values (i.e., items 1 and 11, 2 and 12, etc.). Second, to examine response consistency across time, we calculated Pearson correlations between pairs of DDQ indifference points and latencies at baseline and week 16 (i.e., item 1 at baseline correlated with item 1 at week 16). These analyses included the HC group and patients in the HD group that were randomized to the waitlist condition, meaning they did not receive treatment between time points. Third, with the same sample of HC participants and HD patients in the waitlist condition, we compared groups on the individual DDQ indifference points and response latencies across time using 2 (group, HC vs. HD) \times 2 (time, baseline vs. week 16) mixed analyses of variance (ANOVAs). To examine the convergent validity of the DDQ/PDQ task with related measures, we conducted Pearson correlations between baseline DDQ/PDQ k values and scores on the BSCS.

To investigate changes in self-control and impulsivity over the course of treatment, we compared the immediate and waitlist conditions on DDQ, PDQ, and BSCS values using 2 (condition) \times 2 (time, pre-treatment/pre-waitlist or post-treatment/post-waitlist) ANOVAs. We then collapsed all patients into one group and compared pre- and post-treatment DDQ, PDQ, and BSCS values using repeated-measures ANOVAs.

Using Pearson correlations, we examined the associations between the impulsivity measures and HD severity (SI-R total and subscale scores). To investigate the predictive utility of DDQ, PDQ, and BSCS on HD symptom severity, we conducted a series of hierarchical multiple regressions predicting SI-R scores while controlling for general negative affect (DASS depression and anxiety). Due to strong intercorrelations between BSCS total and subscale scores (all $r_s \geq 0.74$), indicating multicollinearity, we included only the BSCS total score in the

Table 2
Group differences on outcome measures.

Measure	HD group		HC group		Comparison		
	M (SD)	Range	HC, M (SD)	Range	t (df)	p	d
BSCS Total	38.54 (9.00)	19–62	53.16 (5.80)	38–62	–11.02 (120.68)	< .001	–1.93
BSCS Impulsivity	16.05 (3.97)	7–24	22.47 (2.63)	14–25	–10.82 (119.61)	< .001	–1.91
BSCS Restraint	9.27 (3.16)	4–18	13.89 (2.52)	9–20	8.41 (124)	< .001	–1.62
Delay Discounting	0.03 (0.06)	0–0.37	0.05 (0.13)	0–0.63	–1.38 (58.49)	.172	–0.24
Probability Discounting	7.27 (18.39)	0.14–125.44	7.73 (20.84)	0.04–125.44	–0.43 (124)	.665	–0.08

Note. Raw mean k values for delay and probability discounting are displayed. Log-transformed mean k values were used for mean comparisons and effect sizes due to non-normality of the original values.

regression models.

3. Results

3.1. Mean comparisons

HD patients and HCs did not differ in DDQ or PDQ k values (see Table 2). However, the HD group had significantly lower BSCS total and subscale scores with large effect sizes, indicating impaired self-reported impulsivity among HD patients. Groups did not significantly differ on DDQ or PDQ latency values (all t s \leq 1.94, all p s $>$.05).

3.2. Delay discounting reliability analyses

Pearson correlations between pairs of DDQ indifference points and latencies at baseline were positively correlated (all r s \geq 0.51, all p s $<$.001), indicating that participants responded reliably across pairs of related items within the baseline time point.

Pearson correlations between pairs of DDQ indifference points at baseline and week 16 were mostly correlated (all r s \geq 0.32, all p s $<$.01), with the exception of items 1 ($r = 0.17$, $p = .151$), 2 ($r = 0.20$, $p = .093$), and 11 ($r = 0.07$, $p = .554$). All pairs of reaction times at baseline and week 16 were also correlated (all r s \geq 0.31, all p s $<$.01), as were the log-transformed k values ($r = 0.53$, $p = .001$). These results suggest that DDQ responding was consistent across time.

For the individual DDQ indifference points, there were main effects of group (HDs greater than HCs) for items 4, 5, and 15 (all F s \geq 4.21, all p s $<$.05), and a main effect of time for item 12, $F(1, 72) = 5.37$, $p = .023$. There were no interaction effects. For the response latencies, there were effects of time on all items with the exception of item 2 (all F s \geq 4.76, all p s $<$.05), and one group \times time interaction on item 1, $F(1, 72) = 7.55$, $p = .008$. There were no main effects of group and no other interactions. Taken together, these results indicate that HD patients in the waitlist group and HCs responded similarly to the DDQ task across time.

DDQ and PDQ k values were not correlated with BSCS total or subscale scores (all r s \leq .16, all p s $>$.05), suggesting that the DDQ/PDQ task may have poor convergent validity with related impulsivity measures.

3.3. Treatment effects

When comparing the immediate and waitlist conditions on DDQ log-transformed k values, results failed to show significant main or interaction effects (all F s \leq 3.74, all p s $>$.05), indicating no change in DDQ across time or between conditions. Similarly, results failed to show main effects or interactions for PDQ log-transformed k values (all F s \leq 0.43, all p s $>$.05), BSCS total scores (all F s \leq 3.38, all p s $>$.05), BSCS impulsivity (all F s \leq 3.17, all p s $>$.05), or BSCS restraint (all F s \leq 1.60, all p s $>$.05). See Table 3 for descriptive statistics at pre- and post-treatment/waitlist.

When collapsing patients into one group, we found no change from

pre- to post-treatment in DDQ, $F(1, 62) = 2.15$, $p = .148$, $\eta^2 p = .03$ or PDQ, $F(1, 62) = 0.07$, $p = .795$, $\eta^2 p = .00$ log transformed k values. BSCS total scores significantly increased from pre- to post-treatment, $F(2, 70) = 3.46$, $p = .037$, $\eta^2 p = .09$, but BSCS impulsivity and restraint scores did not change (both F s \leq 2.95, both p s $<$.05). See Table 3 for descriptive statistics at pre- and post-treatment.

Although we will be reporting treatment results in a separate paper as indicated above, for the purposes of this paper we verified that SI-R scores significantly improved over the course of treatment (Cohen's d values for pre- and post-treatment comparisons ranged from 1.11 to 1.25, depending on the SI-R score). Change in BSCS scores (difference scores, calculated as pre – post) was negatively correlated with change in SI-R scores (difference scores, calculated as pre – post; r s ranged from –0.49 to –0.67, all p s $<$.01), indicating that greater improvement in self-control corresponded to greater reduction in HD severity.

3.4. Associations with hoarding symptoms

Correlations between SI-R scores, BSCS scores, and DD and PD log transformed k values are presented in Table 4. BSCS scores were negatively correlated with the SI-R total and subscale scores, indicating that lower self-control was associated with greater HD severity. DDQ and PDQ were not significantly correlated with HD severity, other than a small negative correlation between DDQ and the SI-R saving subscale.

As can be seen in Table 5, the BSCS was a significant negative predictor of all SI-R scores, indicating that lower self-control was associated with greater hoarding severity even after controlling for depression and anxiety. By contrast, PDQ failed to predict HD severity across SI-R subscales. DDQ k values were significant negative predictors of clutter and saving, indicating that greater preference for immediate rewards was associated with lower clutter and saving severity.

4. Discussion

The purpose of this study was to compare self-reported and behavioral impulsivity in patients with HD and control participants without psychiatric disorders. We also aimed to assess the association between impulsivity and HD symptom severity and the degree to which impulsivity may change over the course of HD treatment. Consistent with our hypotheses and prior research (Grisham et al., 2007; Timpano et al., 2013; Tolin et al., 2018c), hoarding patients endorsed greater self-reported behavioral impulsivity on the BSCS than did healthy control participants. Furthermore, self-reported impulsivity predicted the severity of hoarding symptoms even after controlling for general negative affect. These results support the notion that impulsivity may be a mechanism of hoarding symptomatology. Encouragingly, self-reported impulsivity improved over the course of CBT, suggesting that behavioral impulsivity can be treated with existing interventions. Nevertheless, delay and probability discounting as measured by the computerized DDQ/PDQ task did not differ between HD patients and HC participants. The groups also did not differ on reaction time during the DDQ/PDQ task. Greater preference for immediate rewards (i.e., larger k

Table 3
Means and standard deviations across assessment points.

Variable	Immediate Group				Waitlist Group				Full Sample			
	Pre, <i>M (SD)</i>	Range	Post, <i>M (SD)</i>	Range	Pre, <i>M (SD)</i>	Range	Post, <i>M (SD)</i>	Range	Pre, <i>M (SD)</i>	Range	Post, <i>M (SD)</i>	Range
DDQ	0.03 (0.07)	0–0.31	0.04 (0.11)	0–0.50	0.01 (0.03)	0–0.10	0.04 (0.14)	0–0.63	0.02 (0.06)	0–0.31	0.04 (0.12)	0–0.63
PDQ	1.30 (0.94)	0.14–4.33	1.32 (0.87)	0.19–4.31	1.31 (0.80)	0.31–3.41	1.22 (0.77)	0.34–2.80	1.30 (0.88)	0.14–4.33	1.27 (0.82)	0.19–4.31
BSCS Total	39.05 (9.55)	22–62	41.72 (9.65)	21–65	37.95 (8.41)	20–61	38.37 (8.75)	27–61	38.74 (9.15)	20–62	41.72 (9.65)	21–65
BSCS-I	16.19 (4.14)	7–24	17.69 (3.98)	9–25	15.89 (3.82)	5–24	15.83 (4.01)	11–24	16.05 (3.99)	5–24	17.69 (3.98)	9–25
BSCS-R	9.37 (3.27)	4–18	10.03 (3.54)	4–20	9.16 (3.07)	4–20	9.20 (3.77)	5–20	9.34 (3.49)	4–20	10.03 (3.54)	4–20

Note. For the immediate group, *n* = 43 at pre-treatment and *n* = 36 at post-treatment. For the waitlist group, *n* = 36 at pre-treatment and *n* = 29 at post-treatment. DDQ = Delay Discounting Questionnaire log-transformed *k* value. PDQ = Probability Discounting Questionnaire log-transformed *k* value. BSCS = Brief Self-Control Scale. BSCS-I = Brief Self-Control Scale-Impulsivity subscale. BSCS-R = Brief Self-Control Scale-Restraint subscale.

Table 4
Correlations between self-control, delay and probability discounting, and hoarding severity.

Measure	SI-R Total	SI-R Clutter	SI-R Saving	SI-R Acquiring
BSCS Total	−0.68***	−0.65***	−0.64***	−0.63***
BSCS Impulsivity	−0.67***	−0.64***	−0.65***	−0.63***
BSCS Restraint	−0.62***	−0.60***	−0.58***	−0.58***
Delay Discounting	−0.15	−0.16	−0.18*	−0.08
Probability Discounting	−0.00	0.02	−0.01	−0.03

Note. SI-R = Saving Inventory – Revised. Log-transformed mean *k* values were used for correlation analyses due to non-normality of the original values. **p* < .05. ****p* < .001.

Table 5
Hierarchical Multiple Regression Analyses Predicting Hoarding Severity from Self-Control and Delay and Probability Discounting, Controlling for General Negative Affect.

	<i>B</i>	<i>SE B</i>	β	ΔR^2
Model 1 (Predicting SI-R Total)				
Step 1:				0.31
Depression	1.82***	0.43	0.53	
Anxiety	0.15	0.57	0.03	
Step 2:				0.20
Self-Control	−1.45***	0.22	−0.57	
Delay Discounting	−45.47	23.91	−0.13	
Probability Discounting	2.90	1.97	0.11	
Model 2 (Predicting SI-R Clutter)				
Step 1:				0.30
Depression	0.86***	0.20	0.55	
Anxiety	−0.01	0.26	−0.01	
Step 2:				0.18
Self-Control	−0.62***	0.10	−0.54	
Delay Discounting	−23.58*	11.09	−0.15	
Probability Discounting	1.60	0.91	0.13	
Model 3 (Predicting SI-R Saving)				
Step 1:				0.28
Depression	0.53***	0.14	0.49	
Anxiety	0.07	0.19	0.05	
Step 2:				0.19
Self-Control	−0.44***	0.07	−0.55	
Delay Discounting	−17.70*	7.87	−0.16	
Probability Discounting	0.98	0.65	0.11	
Model 3 (Predicting SI-R Acquiring)				
Step 1:				0.26
Depression	0.44**	0.13	0.45	
Anxiety	0.10	0.17	0.08	
Step 2:				0.17
Self-Control	−0.40***	0.07	−0.54	
Delay Discounting	−4.18	7.38	−0.04	
Probability Discounting	0.32	0.61	0.04	

Note. SI-R = Saving Inventory-Revised. Log-transformed mean *k* values were used due to non-normality of the original values. **p* < .05. ***p* < .01. ****p* < .001.

values) on the DDQ/PDQ task was associated with lower self-reported HD severity. These results are contrary to our predictions and previous research that has found significant differences in impulsive responding between hoarding patients and healthy controls (Tolin et al., 2018c) and patients with other mental health diagnoses (Grisham et al., 2007). However, Pinto et al. (2014) reported that patients with OCPD demonstrated greater capacity to delay monetary rewards than OCD patients and HCs, suggesting that HD-related syndromes may be characterized by lower impulsivity.

Given these contradictory findings, we conducted additional follow-up analyses to ensure that the DDQ task was reliable and valid in our sample. The results of these analyses supported the reliability of the task, indicating that the null effects could not be attributed to the measurement approach. Furthermore, there were generally no differences between the HD and HC groups on specific DDQ items or reaction times, indicating that the null effects were also not attributable to poor or invalid task performance in the HD group. On the other hand, DDQ/PDQ *k* values were not correlated with BSCS scores, indicating that the DDQ/PDQ task may have poor convergent validity with other impulsivity measures.

Taken together, the findings of the present study suggest that self-reported behavioral impulsivity, but not objective behavioral performance on an impulsivity-related task, may be impaired in hoarding patients. There are a number of potential explanations for these results. First, impulsivity is a multidimensional construct that can be operationalized and assessed in many ways (Bari and Robbins, 2013; Fineberg et al., 2010; Hamilton et al., 2015; Khadka et al., 2017). As such, it is possible that HD patients are perceiving impulsivity difficulties as assessed by self-report measures that tap a facet of impulsivity that is distinct from those assessed by behavioral DD and PD tasks. This may also explain why the DDQ/PDQ *k* values were not correlated with self-reported impulsivity, as others have reported (e.g., Crean et al., 2000). Second, it could be that treatment-seeking HD patients may over-report or overemphasize their difficulties on self-report measures, leading to discrepancies between scores on self-report and behavioral measures of impulsivity. Third, these findings may highlight the complexity of decision-making in different types of psychopathology. Decision-making is comprised of both cognitive (e.g., attention, working memory) and affective (e.g., emotional arousal, valuation) elements. Prior research suggests that patients with HD have both cognitive/executive function (Grisham et al., 2007; Tolin et al., 2011; Woody, Kellman-McFarlane and Welsted, 2014) and affective/valuation (e.g., Lawrence et al., 2006; Tolin et al., 2012) difficulties, both at baseline and during decision-making about possessions. However, the HD patients did not show devaluation tendencies in the context of the DDQ/PDQ task in the present study. When considered in light of prior HD research using different tasks (e.g., making decisions about possessions vs. control items in Tolin et al., 2012) where abnormal valuation is implicated, this suggests that any HD valuation deficit that leads to impulsive decisions is likely not a generalized phenomenon. Put plainly, it is clear that patients with HD have difficulty refraining from

acquiring objects which they perceive to be of practical or sentimental value, but they may not have difficulty with valuation on hypothetical reward-based tasks like the DDQ and PDQ. Perhaps it is the personalization of the context that matters most to this HD symptomatology. It is also possible that because the DDQ/PDQ tasks primarily assess acquiring-related behaviors (i.e., imagining acquiring monetary rewards), and not discarding-related behaviors, this could result in null effects when comparing HD patients and HCs on these tasks. As noted previously, difficulty discarding is the hallmark behavioral feature of HD, whereas compulsive acquiring is not required for the HD diagnosis. Future replication and extension of this work should seek to confirm that DD and PD are not impaired in HD patients. If future tests of DD across different tasks and computational models continue to find no impairments among HD patients, we will feel increasingly confident that these forms of discounting are not an HD-specific feature. If so, future therapeutic development or refinement efforts might not benefit from addressing discounting as a focus of HD treatment.

In terms of study limitations, it is possible that the analytic approach for the DDQ/PDQ task impacted our findings. We used a hyperbolic discounting model, which computes the indifference points as the amount of the reward divided by the delay to receive the reward. Although the hyperbolic model is widely used and accounts for significant variability in DD data across various species and reward types (for a review, see Odum, 2011), other models such as the Bayesian selection algorithm approach (Franck et al., 2015) have recently been proposed. Once these newer models are fully validated, they might prove more sensitive to the underlying impulsive choice trait. In addition, the longest delay we used on the DDQ task was 365 days (item 5), which did show group effects (HD indifference points > HCs). We cannot rule out the possibility that delay discounting effects in hoarding patients might be seen only at longer time intervals than we used in the present study. This is an empirical question that would be interesting to further explore in future research. We did not explicitly assess compulsive buying disorder or other impulse control disorders, so it is possible that some patients with HD also met criteria for these disorders. The presence of impulse control disorders is likely to affect performance on the DDQ/PDQ tasks, particularly in terms of increasing k values (i.e., greater impulsivity). Similarly, we did not assess symptoms of OCPD, including the tendency to be perfectionistic and cognitively inflexible. OCPD and perfectionism more generally may also affect performance on the delay and probability discounting tasks, as patients with these comorbidities may have difficulties “shifting sets” to comprehend and apply the changing delay intervals and delivery probabilities when responding to the task questions. We required that all patients be stable on psychiatric medications for at least eight weeks; however, this duration may not have been sufficient to establish medication stability. Finally, as is the case in all laboratory-based research, it is unclear whether the DDQ/PDQ task is representative of actual decision-making behavior in participants’ natural environments. Because the DDQ/PDQ task presents hypothetical scenarios, and not monetary rewards, it is possible that responses on the task are different from actual decisions when participants are faced with the prospect of real financial compensation. It would be interesting to examine whether the DD task correlates with actual acquiring, discarding, and monetary decisions among hoarding patients, although this seems unlikely given our findings.

To conclude, the results of the present study indicate that while hoarding patients may *perceive* that they have impulsivity difficulties, more objective measures of impulsive choice do not show impulsivity impairments in these patients. To build on this work, future studies should examine other facets of behavioral impulsivity beyond delay and probability discounting to determine whether other impulsivity difficulties may be present in HD patients. This may provide novel targets for intervention that may improve the efficacy of existing treatments.

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Declarations of interest

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Contributors

All authors contributed to the preparation of this manuscript. Authors Levy, Katz, and Das wrote sections of the manuscript, whereas authors Stevens and Tolin reviewed the drafts and provided feedback and edits. All authors have approved the final article.

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