

# Delay Discounting as a Transdiagnostic Process in Psychiatric Disorders

## A Meta-analysis

Michael Amlung, PhD; Emma Marsden, BA; Katherine Holshausen, PhD; Vanessa Morris, BA; Herry Patel, BSc; Lana Vedelago, BA; Katherine R. Naish, PhD; Derek D. Reed, PhD; Randi E. McCabe, PhD

 [Supplemental content](#)

**IMPORTANCE** Delay discounting is a behavioral economic index of impulsive preferences for smaller-immediate or larger-delayed rewards that is argued to be a transdiagnostic process across health conditions. Studies suggest some psychiatric disorders are associated with differences in discounting compared with controls, but null findings have also been reported.

**OBJECTIVE** To conduct a meta-analysis of the published literature on delay discounting in people with psychiatric disorders.

**DATA SOURCES** PubMed, MEDLINE, PsycInfo, Embase, and Web of Science databases were searched through December 10, 2018. The psychiatric keywords used were based on *DSM-IV* or *DSM-5* diagnostic categories. Collected data were analyzed from December 10, 2018, through June 1, 2019.

**STUDY SELECTION** Following a preregistered Preferred Reporting Items for Systematic Reviews and Meta-Analysis ([PRISMA](#)) protocol, 2 independent raters reviewed titles, abstracts, and full-text articles. English-language articles comparing monetary delay discounting between participants with psychiatric disorders and controls were included.

**DATA EXTRACTION AND SYNTHESIS** Hedges *g* effect sizes were computed and random-effects models were used for all analyses. Heterogeneity statistics, one-study-removed analyses, and publication bias indices were also examined.

**MAIN OUTCOMES AND MEASURES** Categorical comparisons of delay discounting between a psychiatric group and a control group.

**RESULTS** The sample included 57 effect sizes from 43 studies across 8 diagnostic categories. Significantly steeper discounting for individuals with a psychiatric disorder compared with controls was observed for major depressive disorder (Hedges  $g = 0.37$ ;  $P = .002$ ;  $k = 7$ ), schizophrenia (Hedges  $g = 0.46$ ;  $P = .004$ ;  $k = 12$ ), borderline personality disorder (Hedges  $g = 0.60$ ;  $P < .001$ ;  $k = 8$ ), bipolar disorder (Hedges  $g = 0.68$ ;  $P < .001$ ;  $k = 4$ ), bulimia nervosa (Hedges  $g = 0.41$ ;  $P = .001$ ;  $k = 4$ ), and binge-eating disorder (Hedges  $g = 0.34$ ;  $P = .001$ ;  $k = 7$ ). In contrast, anorexia nervosa exhibited statistically significantly shallower discounting (Hedges  $g = -0.30$ ;  $P < .001$ ;  $k = 10$ ). Modest evidence of publication bias was indicated by a statistically significant Egger test for schizophrenia and at the aggregate level across studies.

**CONCLUSIONS AND RELEVANCE** Results of this study appear to provide empirical support for delay discounting as a transdiagnostic process across most of the psychiatric disorders examined; the literature search also revealed limited studies in some disorders, notably posttraumatic stress disorder, which is a priority area for research.

**Author Affiliations:** Peter Boris Centre for Addictions Research, St Joseph's Healthcare Hamilton, McMaster University, Hamilton, Ontario, Canada (Amlung, Marsden, Holshausen, Morris, Patel, Vedelago, Naish, McCabe); Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, Ontario, Canada (Amlung, Holshausen, McCabe); Department of Applied Behavioral Science, University of Kansas, Lawrence, Kansas (Reed); Cofrin Logan Center for Addiction Research and Treatment, University of Kansas, Lawrence, Kansas (Reed).

**Corresponding Author:** Michael Amlung, PhD, Department of Psychiatry and Behavioural Neurosciences, McMaster University, 100 W 5th St, Hamilton, ON L8N 3K7, Canada ([amlungm@mcmaster.ca](mailto:amlungm@mcmaster.ca)).

*JAMA Psychiatry*. 2019;76(11):1176-1186. doi:[10.1001/jamapsychiatry.2019.2102](https://doi.org/10.1001/jamapsychiatry.2019.2102)  
Published online August 28, 2019.

Examination of underlying neurocognitive processes that transcend multiple diagnostic categories is a long-standing priority in psychiatry. Consistent with this focus is the Research Domain Criteria (RDoC) framework from the US National Institute of Mental Health,<sup>1,2</sup> which seeks to characterize the fundamental domains of cognitive, perceptual, and social processing with the aim of identifying novel targets for the treatment of mental health disorders. Within the RDoC framework, the behavioral economic index of delay discounting, which captures the extent to which rewards lose value over a temporal delay, has emerged as a promising paradigm.<sup>3</sup> Delay discounting is commonly assessed through intertemporal choice tasks involving choices between immediate and delayed rewards (eg, money) to estimate a person's discounting rate ( $k$ ) or other quantitative indices (eg, area under the curve, impulsive choice ratio). Steeper delay discounting and, subsequently, smaller area under the discounting curve is frequently interpreted as reflecting an impulsive preference for immediate rewards over delayed gratification.<sup>4,5</sup>

A growing body of research has solidified the relevance of delay discounting in the context of psychiatric disorders. This relevance has led to the proposal that excessive discounting of delayed rewards is a transdiagnostic process (ie, a behavior exhibited across multiple disorders that may provide novel insights into the common underlying features of those disorders).<sup>6,7</sup> Furthermore, Levin et al<sup>8</sup> proposed that investigating delay discounting across disorders may help inform transdiagnostic treatments by identifying target behavioral processes and providing markers of change in existing treatments.

Previous narrative reviews by Bickel et al<sup>6</sup> and Lempert et al<sup>3</sup> have summarized evidence of steep discounting associated with numerous health conditions, with addictive disorders, attention-deficit/hyperactivity disorder (ADHD), and obesity being among the most extensively studied domains to date. Several meta-analyses have reported consistent evidence of impulsive discounting associated with each of these disorders.<sup>9-12</sup> In addition, Bickel et al<sup>6</sup> and Lempert et al<sup>3</sup> also summarized evidence of steep delay discounting in several other psychiatric disorders, including schizophrenia,<sup>13,14</sup> bipolar disorder,<sup>13,15</sup> major depressive disorder,<sup>16,17</sup> and borderline personality disorder.<sup>18,19</sup> In contrast, disorders such as anorexia nervosa<sup>20,21</sup> and obsessive-compulsive personality disorder<sup>22</sup> are associated with shallower discounting compared with healthy controls. Therefore, the existing literature suggests that delay discounting lies on a continuum (Figure 2 in Lempert et al<sup>3</sup>). Indexing the location of different disorders along this continuum may elucidate the degree to which delay discounting should be considered as a viable and necessary treatment target in the pursuit of ameliorating transdiagnostic symptoms.

Narrative reviews are valuable for summarizing findings and stimulating new research on the role of delay discounting in the broad field of psychiatry, but to our knowledge, a quantitative synthesis of the research on psychiatric disorders (apart from addictive disorders and ADHD) has yet to be published. A quantitative meta-analysis is necessary for several reasons. First, although a preponderance of individual

## Key Points

**Question** Is delay discounting a transdiagnostic process in psychiatric disorders?

**Findings** In this meta-analysis of 57 effect sizes from 43 studies across 8 diagnostic categories, robust differences in delay discounting were observed between people with psychiatric disorders and controls. Most individuals with disorders (including depression, bipolar disorder, schizophrenia, borderline personality disorder, bulimia nervosa, and binge-eating disorder) exhibited steeper discounting compared with controls, whereas those with anorexia nervosa exhibited shallower discounting compared with controls.

**Meaning** Evidence from this study suggests that delay discounting decision-making is a robust transdiagnostic process across a range of psychiatric disorders and may be a viable target for treatment interventions.

studies have reported statistically significant differences between individuals with psychiatric disorders and healthy controls, a notable number of studies have not found these differences,<sup>23-26</sup> suggesting a need to clarify the nature and relative weight of the collective evidence to date. Second, a meta-analytic approach involves a systematic literature search that may identify additional studies or disorder categories otherwise excluded from narrative reviews. Third, a meta-analysis provides important quantitative data, including estimates of aggregate effect sizes across studies, indices of between-study heterogeneity, and evaluation of publication bias.

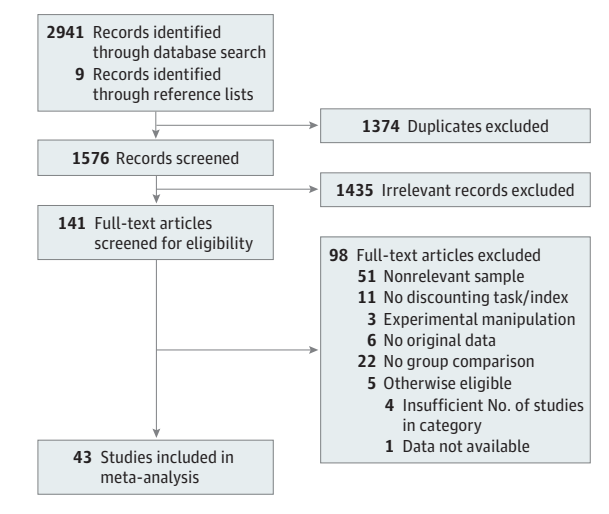
The goal of the current study was to conduct a meta-analysis of studies comparing delay discounting between individuals with psychiatric disorders and nonclinical comparison groups. Based on the hypothesis that delay discounting is a transdiagnostic process, we hypothesized the existence of robust differences across studies between individuals with psychiatric disorders and healthy controls.

## Methods

### Search Strategy

The meta-analysis protocol was preregistered on PROSPERO (The International Prospective Register of Systematic Reviews) (CRD42018105385). Candidate studies were identified through searches of PubMed, MEDLINE, PsycInfo, Embase, and Web of Science through December 10, 2018. Discounting keywords were combined using Boolean logic with psychiatric keywords based on *DSM-IV* and *DSM-5* diagnostic categories (the complete list of search terms is presented in eTable 1 in the Supplement, and a licensed clinical psychologist [R.E.M.] reviewed the psychiatric keyword list). Addiction or ADHD-associated keywords were not included to avoid redundancy with published meta-analyses.<sup>9,11,12</sup> Keywords associated with other neurodevelopmental disorders (eg, autism spectrum disorders) were excluded. In addition, the reference lists of recent reviews were manually searched for additional studies.

Figure 1. Diagram of Study Selection and Inclusion



### Inclusion Criteria and Study Selection

For inclusion, studies had to meet the following criteria: (1) published in a peer-reviewed journal, (2) available in the English language, (3) involved human participants, (4) included a monetary delay discounting measure, (5) performed a categorical comparison between individuals with a psychiatric diagnosis based on a validated diagnostic instrument (eg, SCID [Structured Clinical Interview for *DSM*]<sup>27,28</sup>) and controls, and (6) assessed monetary delay discounting under neutral conditions (eg, no experimental stress or affect manipulations). Studies with multiple discounting assessments (eg, accelerated vs delayed versions<sup>21,22,29</sup>) were included as these were not considered to be manipulations designed to alter mood or emotional state; however, these studies were collapsed into a single effect size in a follow-up analysis. Although a limited number of studies have assessed nonmonetary commodities (eg, food, effort), we focused on money as the most commonly and consistently assessed reward. Studies focused on comorbid substance use disorders and psychiatric disorders<sup>30,31</sup> were not included because disentangling the associations between substance use disorder and psychiatric illness was not possible. A minimum of 4 effect sizes was required for a diagnostic category to be included in the meta-analysis.

Study selection was completed in Covidence (Veritas Health Innovation Inc). The selection procedure is depicted in Figure 1 and followed Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) standards.<sup>32</sup> Two of us (M.A. and E.M.) independently screened titles and abstracts for clearly eligible or ineligible studies. Studies with conflicting ratings were discussed, and a consensus decision was reached between M.A. and E.M., with additional clarification from R.M. as needed. The same process was repeated for full-text articles.

### Sample Characteristics

Characteristics of the included studies<sup>13-26,29,33-60</sup> are presented in Table 1; a list of excluded full-text articles and reasons for exclusion is provided in eTable 4 in the Supple-

ment. Disorder categories reflected the primary diagnosis for the clinical group; inclusion or exclusion of other comorbidities varied across studies but was not considered in the present analyses. Notable details of the participant characteristics were that only 1 study on bipolar disorder<sup>15</sup> specified whether participants were in a manic or depressive state at testing, 1 study on binge-eating disorder<sup>33</sup> included controls who were overweight or obese, and Wierenga et al<sup>34</sup> included individuals with remitted anorexia nervosa. Although studies that explicitly focused on concurrent addictive and psychiatric disorders were excluded, a number of studies did include participants with varying levels of substance use. However, levels of substance use were not consistently reported or controlled for across studies, so we were unable to examine this factor in the present analyses. Readers are encouraged to consult the original articles for information on psychiatric comorbidities and substance use.

Studies also varied in the methods used to measure and quantify delay discounting (Table 1). Although all studies examined money, the reward magnitudes varied from small (ie, \$0.15 to approximately \$30) to large (ie, \$500-\$1000). Most studies used either a delay discounting task (ie, adjusting amount or delay) or the monetary choice questionnaire,<sup>61</sup> with 1 study using an experiential discounting task.<sup>15</sup> Hyperbolic discounting rate and area under the curve were the most common indices of discounting, with impulsive choice ratio and other indices also used.

### Meta-analytic Approach

Comprehensive Meta-Analysis, version 3.0 (Biostat), was used for all analyses. The primary effect size was Hedges *g*, which is ideal when aggregating studies with small sample sizes owing to the statistic's correction for small study bias.<sup>62</sup> Two of us (M.A. and E.M.) independently extracted and checked quantitative values (raw data values are provided in eTable 2 in the Supplement). When the required data were not reported in the published article, we contacted the corresponding authors (9 authors provided data, and data remained unavailable for 1 study). Effect sizes from studies using area under the curve or indifference points were reversed prior to analysis.

Separate meta-analyses were conducted for each diagnosis category using a random-effects model. Several indices of effect size heterogeneity were calculated. Cochran *Q* test reflects the sum of squared differences between individual weighted study effects and the overall mean. *I*<sup>2</sup> statistic captures the proportion of variation within study effect sizes explained by heterogeneity. The tau ( $\tau$ ) reflects the SD of the mean effect. Borenstein et al<sup>62</sup> emphasized that *Q* is less reliable with small sample sizes, whereas *I*<sup>2</sup> and  $\tau$  are not affected by sample size; thus, all 3 statistics were reported to be comprehensive. A one-study removed (OSR) analysis quantified the association of individual studies with the aggregate results.<sup>63</sup> Furthermore, to evaluate the overrepresentation by studies adding multiple effect sizes, we repeated the primary analysis after consolidation into a single effect size per study.

Publication bias was evaluated using multiple indices, including examination of the funnel plots using the 2-tailed

Table 1. Characteristics of Included Studies

Source	Groups (No. of Participants)	Diagnostic Tool	DD Measure	Delayed Amount	DD Index
<b>Major Depressive Disorder</b>					
Brown et al, <sup>39</sup> 2018	MDD (32); HC (61)	DSM-IV	DDT	\$10	<i>k</i>
Cáceda et al, <sup>17</sup> 2014	MDD (20); HC (20)	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Dombrowski et al, <sup>40</sup> 2011	MDD (42); HC (31)	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Engelmann et al, <sup>38</sup> 2013	MDD (11); HC (15)	DSM-IV	DDT	\$10 000	$\beta$
Imhoff et al, <sup>16</sup> 2014	MDD (20); HC (20)	BDI	DDQ	\$10	AUC
Pulcu et al, <sup>41</sup> 2014	MDD (24); HC (29)	DSM-IV	MCQ	\$75-\$85	<i>k</i>
Weidberg et al, <sup>23</sup> 2015	MDD (30); HC (65)	BDI	DDT	€1000	<i>k</i>
<b>Schizophrenia</b>					
Ahn et al, <sup>13</sup> 2011	SZ/SZA (21); HC (30)	DSM-IV	DDT	\$800	<i>k</i>
Avsar et al, <sup>36</sup> 2013	SZ/SZA (14); HC (14)	DSM-IV	DDT	\$28-86	<i>k</i>
Brown et al, <sup>39</sup> 2018	SZ/SZA (31); HC (61)	DSM-IV	DDT	\$10	<i>k</i>
Heerey et al, <sup>14</sup> 2007	SZ/SZA (42); HC (29)	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Heerey et al, <sup>37</sup> 2011	SZ (37); HC (24)	DSM-IV	DDT	\$75-\$85	<i>k</i>
Horan et al, <sup>42</sup> 2017	SZ (131); HC (70)	DSM-IV	DDT	\$1000	AUC
MacKillop and Tidey, <sup>43</sup> 2011	SZ/SZA (23); HC (24)	DSM-IV	MCQ	\$25-\$85	<i>k</i>
Wang et al, <sup>44</sup> 2018	SZ (25); HC (30)	DSM-IV	DDT	\$45	ICR
Wing et al, <sup>24</sup> 2012	SZ/SZA (34); HC (37)	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Yu et al, <sup>45</sup> 2017	SZ/SZA (47); HC (42)	DSM-IV	DDT	\$25-\$35	<i>k</i>
<b>Borderline Personality Disorder</b>					
Barker et al, <sup>18</sup> 2015	BPD (19); HC (21)	DSM-IV	DDT	£100	<i>k</i>
Berenson et al, <sup>46</sup> 2016	BPD (35); HC (45)	DSM-IV	DDT	\$55 (mean)	<i>k</i>
Coffey et al, <sup>47</sup> 2011	BPD (19); HC (28)	DSM-IV	DDT	\$1000	<i>k</i>
Dougherty et al, <sup>48</sup> 1999	BPD (13); HC (17)	DSM-III	DDT	\$.15	ICR
Krause-Utz et al, <sup>49</sup> 2016	BPD (25); HC (24)	DSM-IV	DDT	€100	<i>k</i>
Lawrence et al, <sup>19</sup> 2010	BPD (30); HC (28)	DSM-IV	DDT	\$1000	<i>k</i>
Maraz et al, <sup>25</sup> 2016	BPD (36); HC (111)	ICD-10	DDT	50 000 HUF	<i>k</i>
<b>Bipolar Disorder</b>					
Ahn et al, <sup>13</sup> 2011	BP (22); HC (30); manic-depressive state not specified	DSM-IV	DDT	\$800	<i>k</i>
Brown et al, <sup>39</sup> 2018	BP (16); HC (61); manic-depressive state not specified	DSM-IV	DDT	\$10	<i>k</i>
Strakowski et al, <sup>15</sup> 2010	BP (108); HC (48); acute manic/mixed-episode state	DSM-IV	eDDT	\$.15	ICR
Urošević et al, <sup>50</sup> 2016	BP (32); HC (32); manic-depressive state not specified	DSM-IV	DDT	\$10	AUC
<b>Obsessive-Compulsive Disorder</b>					
Norman et al, <sup>51</sup> 2017	OCD (20); HC (20)	ICD-10	DDT	£100	<i>k</i>
Pinto et al, <sup>22</sup> 2014	OCD (25); HC (25)	DSM-IV	DDT	\$80-\$100	AUC
Sohn et al, <sup>35</sup> 2014	OCD (80); HC (76)	DSM-IV	DDT	\$100	<i>k</i>

(continued)

Table 1. Characteristics of Included Studies (continued)

Source	Groups (No. of Participants)	Diagnostic Tool	DD Measure	Delayed Amount	DD Index
Steinglass et al, <sup>52</sup> 2017	OCD (50); HC (75)	DSM-IV	DDT	\$47-\$78	<i>k</i>
<b>Bulimia Nervosa</b>					
Bartholdy et al, <sup>53</sup> 2017	BN (27); HC (28); all female	DSM-5	DDT	£100	AUC
Kekic et al, <sup>29</sup> 2016	BN (39); HC (53)	DSM-5	DDT	£100-£130	DF
Neveu et al, <sup>54</sup> 2014	BN (18); HC (18); all female	DSM-IV	DDT	€10	<i>k</i>
<b>Binge-Eating Disorder</b>					
Bartholdy et al, <sup>53</sup> 2017	BED (11); HC (28); all female	DSM-5	DDT	£100	AUC
Davis et al, <sup>55</sup> 2010	BED (65); HC (71)	DSM-IV	DDT	\$100	IDP
Manasse et al, <sup>33</sup> 2015	BED (31); obese/overweight controls (43); all female	EDE	DDT	\$1000	AUC
Manwaring et al, <sup>56</sup> 2011	BED (27); HC (30); all female	DSM-IV	DDT	\$100	AUC
Mole et al, <sup>57</sup> 2015	BED (30); HC (30)	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Steward et al, <sup>58</sup> 2017	BED (24); HC (80); all female	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Yan et al, <sup>59</sup> 2018	BE (85); HC (928)	BES	DDT	¥10 000	<i>k</i>
<b>Anorexia Nervosa</b>					
Bartholdy et al, <sup>53</sup> 2017	AN (28); HC (28); all female	DSM-5	DDT	£100	AUC
Decker et al, <sup>20</sup> 2015	AN (54); HC (39)	DSM-5	DDT	\$5-\$40	<i>k</i>
King et al, <sup>60</sup> 2016	AN (31); HC (31); all female	DSM-IV	DDT	€30	<i>k</i>
Neveu et al, <sup>54</sup> 2014	AN-R (16); HC (18); all female	DSM-IV	DDT	€10	<i>k</i>
Ritschel et al, <sup>26</sup> 2015	AN (34); HC (53); all female	DSM-IV	DDT	€20-€789	<i>k</i>
Steinglass et al, <sup>21</sup> 2012	AN (36); HC (28)	DSM-IV	DDT	\$80-100	DF
Steinglass et al, <sup>52</sup> 2017	AN (27); HC (75)	DSM-IV	DDT	\$47-\$78	<i>k</i>
Steward et al, <sup>58</sup> 2017	AN-R (37); HC (80); all female	DSM-IV	MCQ	\$55 (mean)	<i>k</i>
Wierenga et al, <sup>34</sup> 2015	Remitted AN (23); HC (17)	DSM-IV	DDT	\$47-\$78	ICR

Abbreviations: AN, anorexia; AN-R, anorexia-restrictive subtype; AUC, area under the curve; BDI, Beck Depression Inventory; BED, binge-eating disorder; BES, Binge Eating Scale; BN, bulimia nervosa; BP, bipolar disorder; BPD, borderline personality disorder; DD, delay discounting; DDT, delay discounting task; DF, discount factor; eDDT, experiential-type delay discounting task; EDE, Eating Disorder Examination; HC, healthy controls; ICR, impulsive choice ratio; IDP, indifference point; *k*, hyperbolic discounting rate; MCQ, monetary choice task; MDD, major depressive disorder; OCD, obsessive-compulsive disorder; SZ, schizophrenia; SZA, schizoaffective disorder; €, Euro; HUF, Hungarian Forint; ¥, Japanese yen; £, UK pound; \$, US dollar.

Begg-Mazumdar test<sup>64</sup> and the 1-tailed Egger test.<sup>65</sup> Owing to low statistical power for the funnel plot indices with small sample sizes,<sup>66</sup> statistical significance of the funnel plot indices was considered only in categories with 10 or more effect sizes. Adjusted estimates of effect size were also generated according to imputed unpublished studies using the Duval and Tweedie trim-and-fill approach.<sup>67</sup> A 2-tailed significance value of  $P < .05$  was used for all aggregate tests.

## Results

The results of the meta-analyses by disorder category are presented in Table 2, and forest plots by category are provided in Figure 2. Complete statistical results for individual studies are provided in eTable 3 in the Supplement. A total of 43 studies met the inclusion criteria, yielding 57 effect sizes. Eight disorder categories had sufficient effect sizes (ie,  $k \geq 4$ ) to be included (Table 2). All disorder categories, except anorexia ner-

vosa, exhibited statistically significantly steeper (more impulsive) delay discounting compared with controls: major depressive disorder (Hedges  $g = 0.37$ ;  $P = .002$ ;  $k = 7$ ), schizophrenia (Hedges  $g = 0.46$ ;  $P = .004$ ;  $k = 12$ ), borderline personality disorder (Hedges  $g = 0.60$ ;  $P < .001$ ;  $k = 8$ ), bipolar disorder (Hedges  $g = 0.68$ ;  $P < .001$ ;  $k = 4$ ), bulimia nervosa (Hedges  $g = 0.41$ ;  $P = .001$ ;  $k = 4$ ), binge-eating disorder (Hedges  $g = 0.34$ ;  $P = .001$ ;  $k = 7$ ), and obsessive-compulsive disorder (Hedges  $g = 0.30$ ;  $P = .002$ ;  $k = 5$ ). Studies of anorexia nervosa revealed the opposite pattern, with the clinical group exhibiting shallower (less impulsive) discounting compared with controls (Hedges  $g = -0.30$ ;  $P < .001$ ;  $k = 10$ ). The largest aggregate effect sizes were observed for bipolar disorder and borderline personality disorder, with each of these reflecting medium-sized effects based on conventional interpretation. Small to medium effect sizes (Hedges  $g = 0.30$ - $0.46$ ) were observed for the other categories.

Statistically significant evidence of heterogeneity based on the Cochran Q statistic was found for 3 of the disorder catego-

Table 2. Meta-analytic Results by Disorder Category

Disorder	No. of Effect Sizes	Total No. of Unique Individuals	Hedges <i>g</i> Effect Size	<i>P</i> Value	95% CI	OSR	Cochran Q Test of Homogeneity	Cochran Q Test <i>P</i> Value	<i>I</i> <sup>2</sup> Statistic	SD of Aggregate Effect Size, $\tau$
Major depressive disorder	7	420	0.37	.002	0.14 to 0.61	0.29 to 0.44	8.31	.22	27.82	0.17
Schizophrenia	12	766	0.46	.004	0.14 to 0.77	0.34 to 0.53	52.97	<.001	79.23	0.48
Borderline personality disorder	8	451	0.60	<.001	0.32 to 0.87	0.51 to 0.67	15.74	.028	55.53	0.29
Bipolar disorder	4	349	0.68	<.001	0.37 to 0.98	0.55 to 0.78	4.91	.18	38.853	0.20
Obsessive-compulsive disorder	5	371	0.30	.002	0.11 to 0.49	0.20 to 0.34	3.77	.44	0.00	0.00
Bulimia nervosa	4	183	0.41	.001	0.17 to 0.65	0.31 to 0.47	1.85	.60	0.00	0.00
Binge-eating disorder	7	1483	0.34	.001	0.13 to 0.56	0.29 to 0.45	10.63	.10	43.53	0.18
Anorexia nervosa	10	655	-0.30	<.001	-0.46 to -0.14	-0.27 to -0.35	10.31	.33	12.73	0.09

Abbreviations: *I*<sup>2</sup>, proportion of variability from heterogeneity; OSR, one-study removed, or range of effect sizes obtained from OSR jackknife analysis.

ries (major depressive disorder, schizophrenia, and borderline personality disorder). However, the *I*<sup>2</sup> and  $\tau$  statistics suggested that heterogeneity was also present for bipolar disorder and binge-eating disorder. A nonsignificant Cochran Q may result from low power from the small number of studies in these disorder categories.

The OSR analysis showed that the results for all disorder categories except obsessive-compulsive disorder were generally stable (eTable 3 in the Supplement). For obsessive-compulsive disorder, omitting the study by Sohn et al<sup>35</sup> resulted in a nonsignificant aggregate effect size (Hedges *g* = 0.20; *P* = .11). Although the remaining OSR analyses yielded statistically significant aggregate effect sizes, a small number of studies with larger effect sizes tended to have a disproportionate association with the aggregate effect sizes for major depressive disorder<sup>23</sup> (OSR Hedges *g* = 0.45; *P* < .001) and schizophrenia<sup>36</sup> (OSR Hedges *g* = 0.34; *P* = .01).

For the 5 disorder categories that included multiple effect sizes from individual studies, we recalculated the aggregate effect sizes after consolidating to a single effect size per study. This recalculation yielded generally similar estimates of aggregate effect size for schizophrenia (Hedges *g* = 0.52), borderline personality disorder (Hedges *g* = 0.64), obsessive-compulsive disorder (Hedges *g* = 0.30), anorexia nervosa (Hedges *g* = -0.30), and bulimia nervosa (Hedges *g* = 0.42).

An exploratory analysis examined the association between reward magnitude and the effect sizes obtained, irrespective of diagnosis. Magnitudes were coded into 3 categories: small (<\$100; *k* = 33), medium (\$100-\$499; *k* = 14) or large ( $\geq$ \$500; *k* = 10). Modest differences in effect sizes were observed for small (Hedges *g* = 0.41; 95% CI, 0.29-0.52; *P* < .001), medium (Hedges *g* = 0.38; 95% CI, 0.23-0.53; *P* < .001), and large (Hedges *g* = 0.53; 95% CI, 0.21-0.85; *P* = .001) rewards, but the test of heterogeneity was nonsignificant (Cochran *Q* = 0.71; *P* = .70).

### Publication Bias

Publication bias indices are reported in Table 3. Two disorder categories (schizophrenia and anorexia nervosa) had more than

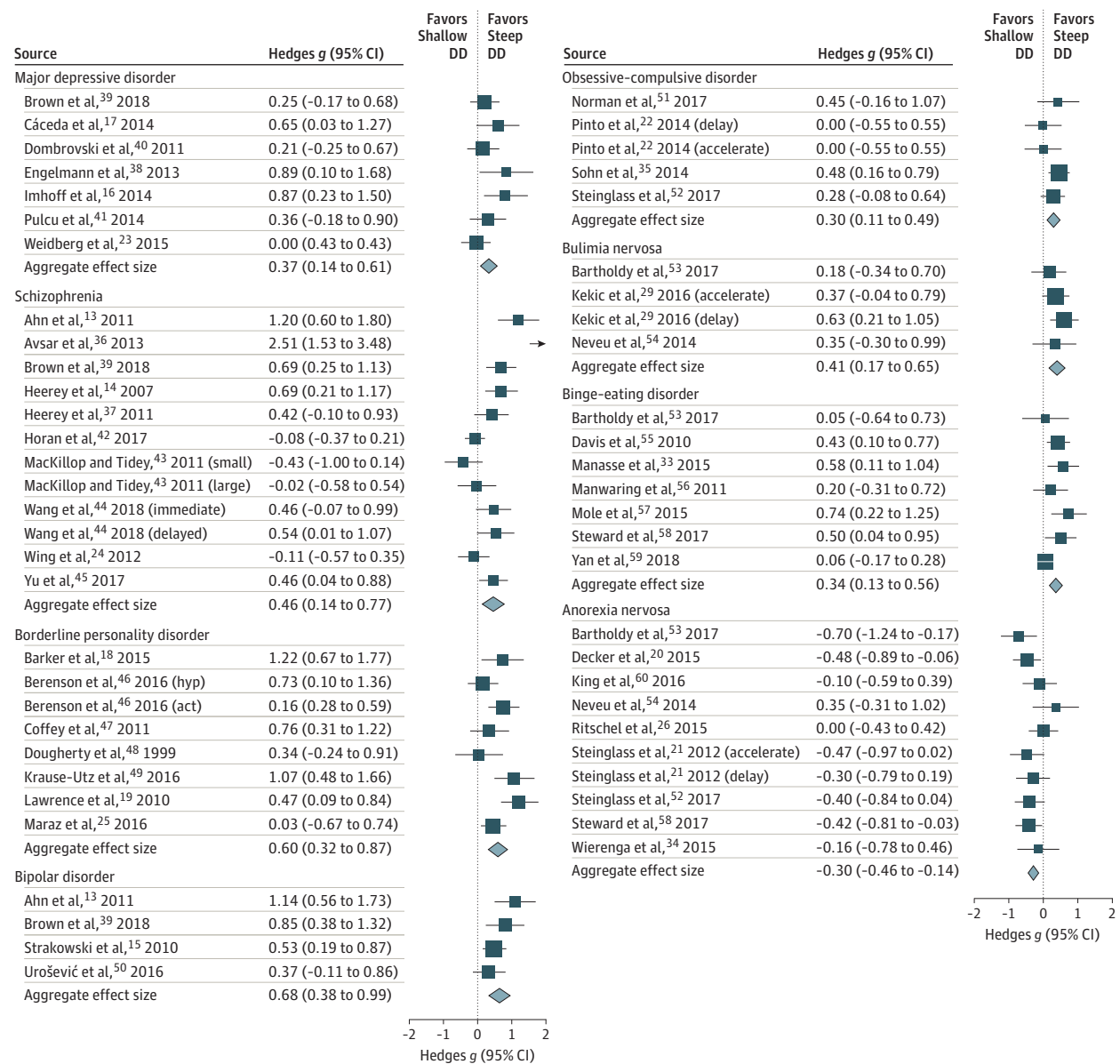
the recommended minimum of 10 studies for the Begg-Mazumdar test or Egger test. The Egger intercept was statistically significant for schizophrenia. Major depressive disorder and bipolar disorder were determined to have missing effect sizes, using the trim-and-fill method (see Table 3 for imputed effect sizes). To explore publication bias more broadly, we aggregated the 57 effect sizes into a single analysis. The Kendall tau was nonsignificant (*P* = .24), but the Egger test intercept was significant (Egger intercept = 2.2; *P* = .001). The trim-and-fill method indicated no missing studies. In sum, minimal to modest evidence for publication bias was found, but these indices should be considered with caution given the relatively small number of studies for most disorder categories.<sup>66</sup>

## Discussion

This meta-analysis evaluated the evidence supporting delay discounting as a transdiagnostic process in psychiatric disorders. Consistent with our hypotheses, statistically significant aggregate effect sizes were observed for all disorder categories included in the meta-analysis, although OSR sensitivity analyses indicated that the aggregate effect size was not reliable for obsessive-compulsive disorder. Although the relatively small number of studies in many of the disorder categories precluded thorough consideration of publication bias, the tests examined suggested modest evidence of small study bias.

The primary findings are consistent with the view that delay discounting exists on a continuum.<sup>3</sup> Most of the disorder categories examined were characterized by steep discounting in those who had the disorder compared with controls, whereas individuals with anorexia nervosa exhibited the opposite pattern. Taken together, the results support the transdiagnostic nature of delay discounting, although the overall magnitude of differences is not uniform across psychiatric disorders. Bipolar disorder and borderline personality disorder had the largest effect sizes, with differences between groups being in the medium magnitude range. The effect sizes for these disorders are comparable to the effect sizes reported in addic-

Figure 2. Forest Plots of Primary Meta-analytic Results by Disorder Category



Act indicates actual rewards; DD, delay discounting; and Hyp, hypothetical rewards. Square data points reflect effect size (Hedges g) for each study, with whiskers reflecting 95% CIs. Diamonds reflect aggregate effect sizes (Hedges g) for each category, with width of diamond indicating 95% CI.

tion studies ( $d = 0.67$  in MacKillop et al<sup>9</sup>). The other disorder categories had somewhat smaller effect sizes that were generally comparable to that for ADHD in meta-analytic findings ( $d = 0.43$  in Jackson and MacKillop<sup>12</sup>). From the standpoint of the RDoC framework, these findings appear to highlight the need to continue looking into different ways to classify presenting difficulties using a continuum rather than general categories based on DSM diagnoses.

These results raise intriguing questions about the shared underlying mechanisms that might explain the consistent association among disorder categories. One neurocognitive mechanism that is commonly discussed in the context of addiction is impaired self-control, which is associated with dys-

function in competing neurobehavioral decision systems<sup>68,69</sup>. The competing neurobehavioral decision systems model posits that delay discounting may be associated with 2 competing neural systems: a frontal cortical system that exerts executive control and a limbic-subcortical system that drives immediate reward seeking. According to this model, addiction is characterized by excessive activation of the limbic circuit and dysfunction in the frontal circuit. Disruption in these neural systems has theoretical relevance to many of the other psychiatric disorders we examined.<sup>70-76</sup> For example, the various eating disorder diagnoses illustrate both ends of the competing neurobehavioral decision systems balance. Excessive self-control over food intake in anorexia has been associated

Table 3. Publication Bias Indices by Disorder Category

Disorder	Kendall $\tau$	P Value	Egger Intercept	SE	P Value	Trim and Fill	Imputed Hedges $g$
Major depressive disorder	0.71	.02 <sup>a</sup>	4.93	0.96	.002 <sup>a</sup>	2	0.26
Schizophrenia	0.24	.27	4.97	2.02	.02 <sup>a</sup>	0	NA
Borderline personality disorder	0.00	>.99 <sup>a</sup>	1.21	2.87	.34 <sup>a</sup>	0	NA
Bipolar disorder	0.33	.497 <sup>a</sup>	3.55	3.22	.19 <sup>a</sup>	1	0.58
Obsessive-compulsive disorder	-0.33	.46 <sup>a</sup>	-1.98	1.54	.14 <sup>a</sup>	0	NA
Bulimia nervosa	0.00	>.99 <sup>a</sup>	-2.04	2.43	.25 <sup>a</sup>	0	NA
Binge-eating disorder	0.14	.65 <sup>a</sup>	1.98	1.26	.09 <sup>a</sup>	0	NA
Anorexia nervosa	-0.22	.42	2.64	2.15	.13	0	NA
Aggregate, All studies	0.11	.22	2.22	0.69	.001	0	NA

Abbreviation: NA, not applicable.

<sup>a</sup> Caution is warranted when interpreting *P* values for categories comprising fewer than 10 studies because of low statistical power.

with exaggerated activity in dorsal cognitive circuits,<sup>77</sup> whereas reduced self-control in bulimia nervosa and binge-eating disorder is partially associated with disruption in the similar frontal circuits.<sup>77,78</sup>

Other psychological mechanisms may explain the observed results. First, future-oriented cognitive processes, such as episodic future thinking,<sup>79</sup> are important for prospectively considering larger delayed rewards in the context of delay discounting. Numerous psychiatric disorders are characterized by deficits in episodic future thinking, including major depressive disorder, bipolar disorder, schizophrenia, borderline personality disorder, eating disorders, and addictive disorders.<sup>37,80-83</sup> Moreover, shifting a person's focus toward the future through experimental episodic future thinking training has been shown to decrease impulsive delay discounting in healthy samples or individuals with addiction,<sup>84-87</sup> but this shift had not been examined in the other psychiatric disorders included in this study. A second psychological mechanism relates to intolerance of uncertainty, or the tendency to react negatively to uncertain situations.<sup>88</sup> Because delayed rewards may be interpreted as uncertain, increased preferences for immediate rewards on discounting tasks could also be explained by heightened intolerance of uncertainty. Consistent with this hypothesis, a positive correlation between steeper discounting and higher scores on an intolerance-of-uncertainty scale was found in a study of healthy participants.<sup>89</sup> Although numerous psychiatric disorders are characterized by heightened intolerance of uncertainty,<sup>88,90,91</sup> we are not aware of any studies in psychiatric samples that have examined the intersection between this construct and discounting.

Further clarifying the clinical significance of differences in delay discounting appears to be a priority for psychiatric research. In particular, examining whether delay discounting is associated with specific symptoms or symptom clusters may provide greater clinical precision. The studies included in this meta-analysis focused on broad diagnostic categories and not specific subtypes or symptoms within disorders. This focus is an important consideration given that a limited number of previous studies have reported symptom-level associations. For example, the presence of

anhedonia (a symptom of major depressive disorder) is associated with decreased discounting,<sup>92</sup> and discounting is associated with specific symptoms of schizophrenia (eg, apathy<sup>93</sup>). Unfortunately, insufficient research is currently available on symptom-level associations to permit meta-analyses.

Another priority is determining whether discounting prospectively estimates treatment outcomes, in which the motivation and willingness to take active steps toward therapeutic goals may be more challenging for individuals who struggle to reliably weigh the advantages of short-term against long-term rewards. This research would dovetail with previous studies on discounting and substance use treatment outcomes.<sup>31,94</sup> Future research should also investigate whether discounting rates can be normalized via treatment interventions.<sup>95</sup> Various interventions such as episodic future thinking training have been shown to reduce impulsive discounting in individuals with addictive disorders.<sup>85,86</sup> Most of these techniques have focused on reducing discounting, which makes them less applicable to disorders with shallow discounting such as anorexia nervosa. How discounting rates can be modified in both directions is an especially novel area of research.

### Limitations

This study has a number of limitations. First, despite its comprehensive literature search strategy, the study identified a relatively small number of studies for some disorder categories. This small number may reduce confidence in the accuracy of the aggregate effect sizes observed and constrained power for heterogeneity and publication bias tests. Also notable was the insufficient number of articles on several key disorders, including posttraumatic stress disorder, generalized anxiety disorder, and other personality disorders. Although a few studies examined delay discounting in the context of trauma or posttraumatic stress disorder,<sup>38,96</sup> the study designs and samples varied considerably. Characterizing delay discounting in posttraumatic stress disorder seems to be a priority.

Second, studies used a range of criteria and scales to establish clinical diagnoses, which may have exaggerated



heterogeneity between studies. Third, although we excluded studies that explicitly examined comorbid substance use and psychiatric disorders, a few of the remaining studies included participants who endorsed use of alcohol or tobacco, whereas others did not report substance use data. Reporting of this information was highly inconsistent across articles; therefore, we were unable to identify the extent to which concurrent substance use may have been a factor in the effect sizes obtained. Fourth, this analysis focused exclusively on monetary discounting. Effect sizes were still in the small-to-medium range for the eating disorder categories despite the use of monetary rewards, but it is possible that other commodities (eg, food rewards or effort discounting<sup>97,98</sup>) may be more sensitive in specific disorders.

## Conclusions

To our knowledge, this meta-analysis is the first quantitative synthesis of delay discounting findings in psychiatric disorders, except ADHD and addictive disorders. This meta-analysis provides relatively strong evidence that delay discounting is a transdiagnostic process in psychiatric disorders. The findings suggest that discounting is not universally increased in all psychiatric disorders but is more appropriately conceptualized as falling on a continuum. Together, the findings generally support the inclusion of delay discounting in the RDoC framework and suggest that discounting is a robust marker of psychiatric illness that may have clinical utility as a target for novel interventions.

### ARTICLE INFORMATION

**Accepted for Publication:** June 11, 2019.

**Published Online:** August 28, 2019.  
doi:10.1001/jamapsychiatry.2019.2102

**Author Contributions:** Dr Amlung had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: *Amlung, Marsden, Reed.*  
Acquisition, analysis, or interpretation of data: *All authors.*

Drafting of the manuscript: *Amlung, Marsden, Holshausen, McCabe.*

Critical revision of the manuscript for important intellectual content: *Amlung, Morris, Patel, Vedelago, Naish, Reed, McCabe.*

Statistical analysis: *Amlung, Vedelago.*

Administrative, technical, or material support: *Amlung, Marsden, Morris, Patel, Naish, Reed, McCabe.*

Supervision: *Amlung.*

**Conflict of Interest Disclosures:** None reported.

**Funding/Support:** Dr Amlung was financially supported, in part, by the Peter Boris Centre for Addictions Research at McMaster University, St Joseph's Healthcare Hamilton.

**Role of the Funder/Sponsor:** The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

**Acknowledgment:** The authors recognize and acknowledge that this work was conducted on the traditional territories of the Mississauga and Haudenosaunee nations, and within the lands protected by the "Dish With One Spoon" wampum agreement.

### REFERENCES

- Insel T, Cuthbert B, Garvey M, et al. Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. *Am J Psychiatry*. 2010;167(7):748-751. doi:10.1176/appi.ajp.2010.09091379
- Cuthbert BN, Insel TR. Toward the future of psychiatric diagnosis: the seven pillars of RDoC. *BMC Med*. 2013;11:126. doi:10.1186/1741-7015-11-126
- Lempert KM, Steinglass JE, Pinto A, Kable JW, Simpson HB. Can delay discounting deliver on the

promise of RDoC? *Psychol Med*. 2019;49(2):190-199. doi:10.1017/S0033291718001770

4. de Wit H. Impulsivity as a determinant and consequence of drug use: a review of underlying processes. *Addict Biol*. 2009;14(1):22-31. doi:10.1111/j.1369-1600.2008.00129.x

5. Madden GJ, Bickel WK. *Impulsivity: The Behavioral and Neurological Science of Discounting*. Washington, DC: American Psychological Association;2009.

6. Bickel WK, Jarmolowicz DP, Mueller ET, Koffarnus MN, Gatchalian KM. Excessive discounting of delayed reinforcers as a trans-disease process contributing to addiction and other disease-related vulnerabilities: emerging evidence. *Pharmacol Ther*. 2012;134(3):287-297. doi:10.1016/j.pharmthera.2012.02.004

7. Bickel WK, Mueller ET. Toward the study of trans-disease processes: a novel approach with special reference to the study of co-morbidity. *J Dual Diagn*. 2009;5(2):131-138. doi:10.1080/15504260902869147

8. Levin ME, Haeger J, Ong CW, Twohig MP. An examination of the transdiagnostic role of delay discounting in psychological inflexibility and mental health problems. *Psychol Rec*. 2018;68(2):201-210. doi:10.1007/s40732-018-0281-4

9. MacKillop J, Amlung MT, Few LR, Ray LA, Sweet LH, Munafò MR. Delayed reward discounting and addictive behavior: a meta-analysis. *Psychopharmacology (Berl)*. 2011;216(3):305-321. doi:10.1007/s00213-011-2229-0

10. Amlung M, Petker T, Jackson J, Balodis I, MacKillop J. Steep discounting of delayed monetary and food rewards in obesity: a meta-analysis. *Psychol Med*. 2016;46(11):2423-2434. doi:10.1017/S0033291716000866

11. Amlung M, Vedelago L, Acker J, Balodis I, MacKillop J. Steep delay discounting and addictive behavior: a meta-analysis of continuous associations. *Addiction*. 2017;112(1):51-62. doi:10.1111/add.13535

12. Jackson JN, MacKillop J. Attention-deficit/hyperactivity disorder and monetary delay discounting: a meta-analysis of case-control studies. *Biol Psychiatry Cogn Neurosci Neuroimaging*. 2016;1(4):316-325. doi:10.1016/j.bpsc.2016.01.007

13. Ahn W-Y, Rass O, Fridberg DJ, et al. Temporal discounting of rewards in patients with bipolar

disorder and schizophrenia. *J Abnorm Psychol*. 2011;120(4):911-921. doi:10.1037/a0023333

14. Heerey EA, Robinson BM, McMahon RP, Gold JM. Delay discounting in schizophrenia. *Cogn Neuropsychiatry*. 2007;12(3):213-221. doi:10.1080/13546800601005900

15. Strakowski SM, Fleck DE, DelBello MP, et al. Impulsivity across the course of bipolar disorder. *Bipolar Disord*. 2010;12(3):285-297. doi:10.1111/j.1399-5618.2010.00806.x

16. Imhoff S, Harris M, Weiser J, Reynolds B. Delay discounting by depressed and non-depressed adolescent smokers and non-smokers. *Drug Alcohol Depend*. 2014;135(1):152-155. doi:10.1016/j.drugalcdep.2013.11.014

17. Cáceda R, Durand D, Cortes E, et al. Impulsive choice and psychological pain in acutely suicidal depressed patients. *Psychosom Med*. 2014;76(6):445-451. doi:10.1097/PSY.000000000000075

18. Barker V, Romaniuk L, Cardinal RN, Pope M, Nicol K, Hall J. Impulsivity in borderline personality disorder. *Psychol Med*. 2015;45(9):1955-1964. doi:10.1017/S0033291714003079

19. Lawrence KA, Allen JS, Chanen AM. Impulsivity in borderline personality disorder: reward-based decision-making and its relationship to emotional distress. *J Pers Disord*. 2010;24(6):786-799. doi:10.1521/pedi.2010.24.6.785

20. Decker JH, Figner B, Steinglass JE. On weight and waiting: delay discounting in anorexia nervosa pretreatment and posttreatment. *Biol Psychiatry*. 2015;78(9):606-614. doi:10.1016/j.biopsych.2014.12.016

21. Steinglass JE, Figner B, Berkowitz S, Simpson HB, Weber EU, Walsh BT. Increased capacity to delay reward in anorexia nervosa. *J Int Neuropsychol Soc*. 2012;18(4):773-780. doi:10.1017/S1355617712000446

22. Pinto A, Steinglass JE, Greene AL, Weber EU, Simpson HB. Capacity to delay reward differentiates obsessive-compulsive disorder and obsessive-compulsive personality disorder. *Biol Psychiatry*. 2014;75(8):653-659. doi:10.1016/j.biopsych.2013.09.007

23. Weidberg S, García-Rodríguez O, Yoon JH, Secades-Villa R. Interaction of depressive symptoms and smoking abstinence on delay discounting rates. *Psychol Addict Behav*. 2015;29(4):1041-1047. doi:10.1037/adb0000073

24. Wing VC, Moss TG, Rabin RA, George TP. Effects of cigarette smoking status on delay discounting in schizophrenia and healthy controls. *Addict Behav*. 2012;37(1):67-72. doi:10.1016/j.addbeh.2011.08.012
25. Maraz A, Andó B, Rigó P, et al. The two-faceted nature of impulsivity in patients with borderline personality disorder and substance use disorder. *Drug Alcohol Depend*. 2016;163:48-54. doi:10.1016/j.drugalcdep.2016.03.015
26. Ritschel F, King JA, Geisler D, et al. Temporal delay discounting in acutely ill and weight-recovered patients with anorexia nervosa. *Psychol Med*. 2015;45(6):1229-1239. doi:10.1017/S0033291714002311
27. American Psychiatric Association. *Structured Clinical Interview for DSM-5: Research Version*. Washington, DC: American Psychiatric Association Publishing; 2015.
28. First MB, Gibbon M. *User's Guide for the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I, Version 2.0)*. New York, NY: New York State Psychiatric Institute, Biometrics Research Department; 1995.
29. Kekic M, Bartholdy S, Cheng J, et al. Increased temporal discounting in bulimia nervosa. *Int J Eat Disord*. 2016;49(12):1077-1081. doi:10.1002/eat.22571
30. Moody L, Franck C, Bickel WK. Comorbid depression, antisocial personality, and substance dependence: relationship with delay discounting. *Drug Alcohol Depend*. 2016;160:190-196. doi:10.1016/j.drugalcdep.2016.01.009
31. Yoon JH, Higgins ST, Heil SH, Sugarbaker RJ, Thomas CS, Badger GJ. Delay discounting predicts postpartum relapse to cigarette smoking among pregnant women. *Exp Clin Psychopharmacol*. 2007;15(2):176-186. doi:10.1037/1064-1297.15.2.186
32. Stewart LA, Clarke M, Rovers M, et al; PRISMA-IPD Development Group. Preferred Reporting Items for Systematic Review and Meta-Analyses of individual participant data: the PRISMA-IPD statement. *JAMA*. 2015;313(16):1657-1665. doi:10.1001/jama.2015.3656
33. Manasse SM, Forman EM, Ruocco AC, Butryn ML, Juarascio AS, Fitzpatrick KK. Do executive functioning deficits underpin binge eating disorder? A comparison of overweight women with and without binge eating pathology. *Int J Eat Disord*. 2015;48(6):677-683. doi:10.1002/eat.22383
34. Wierenga CE, Bischoff-Grethe A, Melrose AJ, et al. Hunger does not motivate reward in women remitted from anorexia nervosa. *Biol Psychiatry*. 2015;77(7):642-652. doi:10.1016/j.biopsych.2014.09.024
35. Sohn SY, Kang JI, Namkoong K, Kim SJ. Multidimensional measures of impulsivity in obsessive-compulsive disorder: cannot wait and stop. *PLoS One*. 2014;9(11):e111739. doi:10.1371/journal.pone.0111739
36. Avsar KB, Weller RE, Cox JE, Reid MA, White DM, Lahti AC. An fMRI investigation of delay discounting in patients with schizophrenia. *Brain Behav*. 2013;3(4):384-401. doi:10.1002/brb3.135
37. Heerey EA, Matveeva TM, Gold JM. Imagining the future: degraded representations of future rewards and events in schizophrenia. *J Abnorm Psychol*. 2011;120(2):483-489. doi:10.1037/a0021810
38. Engelmann JB, Maciuba B, Vaughan C, Paulus MP, Dunlop BW. Posttraumatic stress disorder increases sensitivity to long term losses among patients with major depressive disorder. *PLoS One*. 2013;8(10):e78292. doi:10.1371/journal.pone.0078292
39. Brown HE, Hart KL, Snapper LA, Roffman JL, Perlis RH. Impairment in delay discounting in schizophrenia and schizoaffective disorder but not primary mood disorders. *NPJ Schizophr*. 2018;4(1):9. doi:10.1038/s41537-018-0050-z
40. Dombrovski AY, Szanto K, Siegle GJ, et al. Lethal forethought: delayed reward discounting differentiates high- and low-lethality suicide attempts in old age. *Biol Psychiatry*. 2011;70(2):138-144. doi:10.1016/j.biopsych.2010.12.025
41. Pulcu E, Trotter PD, Thomas EJ, et al. Temporal discounting in major depressive disorder. *Psychol Med*. 2014;44(9):1825-1834. doi:10.1017/S0033291713002584
42. Horan WP, Johnson MW, Green MF. Altered experiential, but not hypothetical, delay discounting in schizophrenia. *J Abnorm Psychol*. 2017;126(3):301-311. doi:10.1037/abn0000249
43. MacKillop J, Tidey JW. Cigarette demand and delayed reward discounting in nicotine-dependent individuals with schizophrenia and controls: an initial study. *Psychopharmacology (Berl)*. 2011;216(1):91-99. doi:10.1007/s00213-011-2185-8
44. Wang L, Jin S, He K, et al. Increased delayed reward during intertemporal decision-making in schizophrenic patients and their unaffected siblings. *Psychiatry Res*. 2018;262(262):246-253. doi:10.1016/j.psychres.2017.12.040
45. Yu LQ, Lee S, Katchmar N, Satterthwaite TD, Kable JW, Wolf DH. Steeper discounting of delayed rewards in schizophrenia but not first-degree relatives. *Psychiatry Res*. 2017;252(252):303-309. doi:10.1016/j.psychres.2017.02.062
46. Berenson KR, Gregory WE, Glaser E, et al. Impulsivity, rejection sensitivity, and reactions to stressors in borderline personality disorder. *Cognit Ther Res*. 2016;40(4):510-521. doi:10.1007/s10608-015-9752-y
47. Coffey SF, Schumacher JA, Baschnagel JS, Hawk LW, Holloman G. Impulsivity and risk-taking in borderline personality disorder with and without substance use disorders. *Personal Disord*. 2011;2(2):128-141. doi:10.1037/a0020574
48. Dougherty DM, Bjork JM, Huckabee HCG, Moeller FG, Swann AC. Laboratory measures of aggression and impulsivity in women with borderline personality disorder. *Psychiatry Res*. 1999;85(3):315-326. doi:10.1016/S0165-1781(99)00011-6
49. Krause-Utz A, Cackowski S, Daffner S, et al. Delay discounting and response disinhibition under acute experimental stress in women with borderline personality disorder and adult attention deficit hyperactivity disorder. *Psychol Med*. 2016;46(15):3137-3149. doi:10.1017/S0033291716001677
50. Urošević S, Youngstrom EA, Collins P, Jensen JB, Luciana M. Associations of age with reward delay discounting and response inhibition in adolescents with bipolar disorders. *J Affect Disord*. 2016;190:649-656. doi:10.1016/j.jad.2015.11.005
51. Norman LJ, Carlisi CO, Christakou A, et al. Neural dysfunction during temporal discounting in paediatric attention-deficit/hyperactivity disorder and obsessive-compulsive disorder. *Psychiatry Res Neuroimaging*. 2017;269(September):97-105. doi:10.1016/j.pscychresns.2017.09.008
52. Steinglass JE, Lempert KM, Choo T-H, et al. Temporal discounting across three psychiatric disorders: anorexia nervosa, obsessive compulsive disorder, and social anxiety disorder. *Depress Anxiety*. 2017;34(5):463-470. doi:10.1002/da.22586
53. Bartholdy S, Rennalls S, Danby H, et al. Temporal discounting and the tendency to delay gratification across the eating disorder spectrum. *Eur Eat Disord Rev*. 2017;25(5):344-350. doi:10.1002/erv.2513
54. Neveu R, Neveu D, Barsumian F, et al. Improved planning abilities in binge eating. *PLoS One*. 2014;9(8):e105657. doi:10.1371/journal.pone.0105657
55. Davis C, Patte K, Curtis C, Reid C. Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. *Appetite*. 2010;54(1):208-213. doi:10.1016/j.appet.2009.11.002
56. Manwaring JL, Green L, Myerson J, Strube MJ, Wilfley DE. Discounting of various types of rewards by women with and without binge eating disorder: evidence for general rather than specific differences. *Psychol Rec*. 2011;61(4):561-582. doi:10.1007/BF03395777
57. Mole TB, Irvine MA, Worbe Y, et al. Impulsivity in disorders of food and drug misuse. *Psychol Med*. 2015;45(4):771-782. doi:10.1017/S0033291714001834
58. Steward T, Mestre-Bach G, Vintró-Alcaraz C, et al. Delay discounting of reward and impulsivity in eating disorders: from anorexia nervosa to binge eating disorder. *Eur Eat Disord Rev*. 2017;25(6):601-606. doi:10.1002/erv.2543
59. Yan W-S, Zhang RR, Lan Y, Li Z-M, Li Y-H. Questionnaire-based maladaptive decision-coping patterns involved in binge eating among 1013 college students. *Front Psychol*. 2018;9:609. doi:10.3389/fpsyg.2018.00609
60. King JA, Geisler D, Bernardoni F, et al. Altered neural efficiency of decision making during temporal reward discounting in anorexia nervosa. *J Am Acad Child Adolesc Psychiatry*. 2016;55(11):972-979. doi:10.1016/j.jaac.2016.08.005
61. Kirby KN, Maraković NN. Delay-discounting probabilistic rewards: rates decrease as amounts increase. *Psychon Bull Rev*. 1996;3(1):100-104. doi:10.3758/BF03210748
62. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. *Introduction to Meta-Analysis*. West Sussex, UK: John Wiley & Sons, Ltd; 2009. doi:10.1002/9780470743386
63. Tukey JW. Bias and confidence in not quite large samples. *Ann Math Stat*. 1958;29:614. doi:10.1214/aoms/1177706647
64. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. *Biometrics*. 1994;50(4):1088-1101. doi:10.2307/2533446
65. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. 1997;315(7109):629-634. doi:10.1136/bmj.315.7109.629
66. Sterne JAC, Sutton AJ, Ioannidis JPA, et al. Recommendations for examining and interpreting

- funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ*. 2011;343:d4002. doi:10.1136/bmj.d4002
67. Duval S, Tweedie R. Trim and fill: a simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*. 2000;56(2):455-463. doi:10.1111/j.0006-341X.2000.00455.x
68. Bickel WK, Yi R. Temporal discounting as a measure of executive function: insights from the competing neuro-behavioral decision system hypothesis of addiction. *Adv Health Econ Health Serv Res*. 2008;20:289-309. doi:10.1016/S0731-2199(08)20012-9
69. Bickel WK, Miller ML, Yi R, Kowal BP, Lindquist DM, Pitcock JA. Behavioral and neuroeconomics of drug addiction: competing neural systems and temporal discounting processes. *Drug Alcohol Depend*. 2007;90(Suppl 1)(suppl 1):S85-S91. doi:10.1016/j.drugalcdep.2006.09.016
70. Anticevic A, Hu S, Zhang S, et al. Global resting-state functional magnetic resonance imaging analysis identifies frontal cortex, striatal, and cerebellar dysconnectivity in obsessive-compulsive disorder. *Biol Psychiatry*. 2014;75(8):595-605. doi:10.1016/j.biopsych.2013.10.021
71. Shin NY, Lee TY, Kim E, Kwon JS. Cognitive functioning in obsessive-compulsive disorder: a meta-analysis. *Psychol Med*. 2014;44(6):1121-1130. doi:10.1017/S0033291713001803
72. Mak ADP, Lam LCW. Neurocognitive profiles of people with borderline personality disorder. *Curr Opin Psychiatry*. 2013;26(1):90-96. doi:10.1097/YCO.0b013e32835b57a9
73. Sebastian A, Jung P, Krause-Utz A, Lieb K, Schmahl C, Tüscher O. Frontal dysfunctions of impulse control - a systematic review in borderline personality disorder and attention-deficit/hyperactivity disorder. *Front Hum Neurosci*. 2014;8:698. doi:10.3389/fnhum.2014.00698
74. Chen C-H, Suckling J, Lennox BR, Ooi C, Bullmore ET. A quantitative meta-analysis of fMRI studies in bipolar disorder. *Bipolar Disord*. 2011;13(1):1-15. doi:10.1111/j.1399-5618.2011.00893.x
75. Lorenzetti V, Allen NB, Fornito A, Yücel M. Structural brain abnormalities in major depressive disorder: a selective review of recent MRI studies. *J Affect Disord*. 2009;117(1-2):1-17. doi:10.1016/j.jad.2008.11.021
76. Ellison-Wright I, Bullmore E. Anatomy of bipolar disorder and schizophrenia: a meta-analysis. *Schizophr Res*. 2010;117(1):1-12. doi:10.1016/j.schres.2009.12.022
77. Kaye WH, Wagner A, Fudge JL, Paulus M. Neurocircuitry of eating disorders. *Curr Top Behav Neurosci*. 2011;6:37-57. doi:10.1007/7854\_2010\_85
78. Friederich H-C, Wu M, Simon JJ, Herzog W. Neurocircuit function in eating disorders. *Int J Eat Disord*. 2013;46(5):425-432. doi:10.1002/eat.22099
79. Schacter DL, Addis DR, Buckner RL. Episodic simulation of future events: concepts, data, and applications. *Ann N Y Acad Sci*. 2008;1124:39-60. doi:10.1196/annals.1440.001
80. Hallford DJ, Austin DW, Takano K, Raes F. Psychopathology and episodic future thinking: a systematic review and meta-analysis of specificity and episodic detail. *Behav Res Ther*. 2018;102:42-51. doi:10.1016/j.brat.2018.01.003
81. D'Argembeau A, Raffard S, Van der Linden M. Remembering the past and imagining the future in schizophrenia. *J Abnorm Psychol*. 2008;117(1):247-251. doi:10.1037/0021-843X.117.1.247
82. Petry NM, Bickel WK, Arnett M. Shortened time horizons and insensitivity to future consequences in heroin addicts. *Addiction*. 1998;93(5):729-738. doi:10.1046/j.1360-0443.1998.9357298.x
83. Rasmussen AS, Jørgensen CR, O'Connor M, et al. The structure of past and future events in borderline personality disorder, eating disorder, and obsessive-compulsive disorder. *Psychol Conscious Theory*. 2017;4(2):190-210. doi:10.1037/cns0000109
84. Peters J, Büchel C. Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal-mediocaudate interactions. *Neuron*. 2010;66(1):138-148. doi:10.1016/j.neuron.2010.03.026
85. Snider SE, LaConte SM, Bickel WK. Episodic future thinking: expansion of the temporal window in individuals with alcohol dependence. *Alcohol Clin Exp Res*. 2016;40(7):1558-1566. doi:10.1111/acer.13112
86. Stein JS, Wilson AG, Koffarnus MN, Daniel TO, Epstein LH, Bickel WK. Unstuck in time: episodic future thinking reduces delay discounting and cigarette smoking. *Psychopharmacology (Berl)*. 2016;233(21-22):3771-3778. doi:10.1007/s00213-016-4410-y
87. Daniel TO, Stanton CM, Epstein LH. The future is now: reducing impulsivity and energy intake using episodic future thinking. *Psychol Sci*. 2013;24(11):2339-2342. doi:10.1177/0956797613488780
88. Einstein DA. Extension of the transdiagnostic model to focus on intolerance of uncertainty: a review of the literature and implications for treatment. *Clin Psychol (New York)*. 2014;21(3):280-300. doi:10.1111/cpsp.12077
89. Luhmann CC, Ishida K, Hajcak G. Intolerance of uncertainty and decisions about delayed, probabilistic rewards. *Behav Ther*. 2011;42(3):378-386. doi:10.1016/j.beth.2010.09.002
90. Brown M, Robinson L, Campione GC, Wuensch K, Hildebrandt T, Micali N. Intolerance of uncertainty in eating disorders: a systematic review and meta-analysis. *Eur Eat Disord Rev*. 2017;25(5):329-343. doi:10.1002/erv.2523
91. Tolin DF, Abramowitz JS, Brigidi BD, Foa EB. Intolerance of uncertainty in obsessive-compulsive disorder. *J Anxiety Disord*. 2003;17(2):233-242. doi:10.1016/S0887-6185(02)00182-2
92. Lempert KM, Pizzagalli DA. Delay discounting and future-directed thinking in anhedonic individuals. *J Behav Ther Exp Psychiatry*. 2010;41(3):258-264. doi:10.1016/j.jbtep.2010.02.003
93. Hartmann MN, Hager OM, Reimann AV, et al. Apathy but not diminished expression in schizophrenia is associated with discounting of monetary rewards by physical effort. *Schizophr Bull*. 2015;41(2):503-512. doi:10.1093/schbul/sbu102
94. Sheffer C, Mackillop J, McGeary J, et al. Delay discounting, locus of control, and cognitive impulsiveness independently predict tobacco dependence treatment outcomes in a highly dependent, lower socioeconomic group of smokers. *Am J Addict*. 2012;21(3):221-232. doi:10.1111/j.1521-0391.2012.00224.x
95. Koffarnus MN, Jarmolowicz DP, Mueller ET, Bickel WK. Changing delay discounting in the light of the competing neurobehavioral decision systems theory: a review. *J Exp Anal Behav*. 2013;99(1):32-57. doi:10.1002/jeab.2
96. Li J-Z, Li S, Liu H. How has the Wenchuan earthquake influenced people's intertemporal choices?. *J Appl Soc Psychol*. 2011;41(11):2739-2752. doi:10.1111/j.1559-1816.2011.00847.x
97. Docx L, de la Asuncion J, Sabbe B, et al. Effort discounting and its association with negative symptoms in schizophrenia. *Cogn Neuropsychiatry*. 2015;20(2):172-185. doi:10.1080/13546805.2014.993463
98. Robertson SH, Rasmussen EB. Comparison of potentially real versus hypothetical food outcomes in delay and probability discounting tasks. *Behav Processes*. 2018;149:8-15. doi:10.1016/j.beproc.2018.01.014