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Delay Discounting as a Transdiagnostic Process in Psychiatric Disorders
A Meta-analysis

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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.

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Supplemental content

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Examination of underlying neurocognitive processes that transcend multiple diagnostic categories is a longstanding priority in psychiatry. Consistent with this focus is the Research Domain Criteria (RDoC) framework from the US National Institute of Mental Health,[1,2] 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.[3] 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.[4,5]

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).[6,7] Furthermore, Levin et al[8] 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[6] and Lempert et al[3] 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.[9-12] In addition, Bickel et al[6] and Lempert et al[3] also summarized evidence of steep delay discounting in several other psychiatric disorders, including schizophrenia,[13,14] bipolar disorder,[13,15] major depressive disorder,[16,17] and borderline personality disorder.[18,19] In contrast, disorders such as anorexia nervosa[20,21] and obsessive-compulsive personality disorder[22] 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[3]). 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 studies have reported statistically significant differences between individuals with psychiatric disorders and healthy controls, a notable number of studies have not found these differences,[23-26] 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.

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.

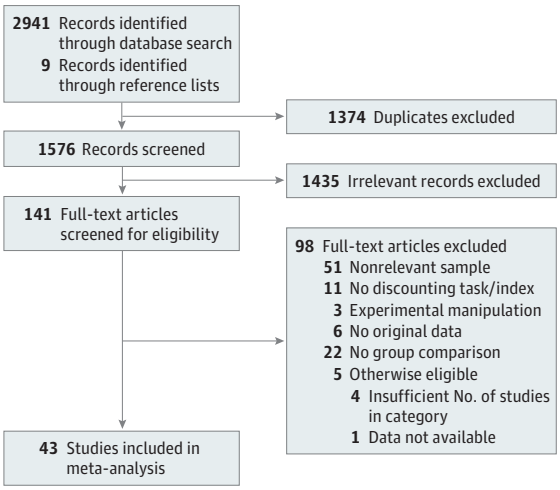
Meaning Evidence from this study suggests that delay discounting decision-making is a robust transdiagnostic process across a range of psychiatric disorders and may be a viable target for treatment interventions.

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.[9,11,12] 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*][27,28]) 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[21,22,29]) 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[30,31] 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.[32] 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[13-26,29,33-60] are presented in **Table 1**; a list of excluded full-text articles and reasons for exclusion is provided in eTable 4 in the Supplement. 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[15] specified whether participants were in a manic or depressive state at testing, 1 study on binge-eating disorder[33] included controls who were overweight or obese, and Wierenga et al[34] 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,[61] with 1 study using an experiential discounting task.[15] 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.[62] 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^2 statistic captures the proportion of variation within study effect sizes explained by heterogeneity. The tau (τ) reflects the SD of the mean effect. Borenstein et al[62] emphasized that Q is less reliable with small sample sizes, whereas I^2 and τ 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.[63] 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
Major Depressive Disorder					
Brown et al,[39] 2018	MDD (32); HC (61)	*DSM-IV*	DDT	$10	*k*
Cáceda et al,[17] 2014	MDD (20); HC (20)	*DSM-IV*	MCQ	$55 (mean)	*k*
Dombrovski et al,[40] 2011	MDD (42); HC (31)	*DSM-IV*	MCQ	$55 (mean)	*k*
Engelmann et al,[38] 2013	MDD (11); HC (15)	*DSM-IV*	DDT	$10 000	β
Imhoff et al,[16] 2014	MDD (20); HC (20)	BDI	DDQ	$10	AUC
Pulcu et al,[41] 2014	MDD (24); HC (29)	*DSM-IV*	MCQ	$75-$85	*k*
Weidberg et al,[23] 2015	MDD (30); HC (65)	BDI	DDT	€1000	*k*
Schizophrenia					
Ahn et al,[13] 2011	SZ/SZA (21); HC (30)	*DSM-IV*	DDT	$800	*k*
Avsar et al,[36] 2013	SZ/SZA (14); HC (14)	*DSM-IV*	DDT	$28-86	*k*
Brown et al,[39] 2018	SZ/SZA (31); HC (61)	*DSM-IV*	DDT	$10	*k*
Heerey et al,[14] 2007	SZ/SZA (42); HC (29)	*DSM-IV*	MCQ	$55 (mean)	*k*
Heerey et al,[37] 2011	SZ (37); HC (24)	*DSM-IV*	DDT	$75-$85	*k*
Horan et al,[42] 2017	SZ (131); HC (70)	*DSM-IV*	DDT	$1000	AUC
MacKillop and Tidey,[43] 2011	SZ/SZA (23); HC (24)	*DSM-IV*	MCQ	$25-$85	*k*
Wang et al,[44] 2018	SZ (25); HC (30)	*DSM-IV*	DDT	$45	ICR
Wing et al,[24] 2012	SZ/SZA (34); HC (37)	*DSM-IV*	MCQ	$55 (mean)	*k*
Yu et al,[45] 2017	SZ/SZA (47); HC (42)	*DSM-IV*	DDT	$25-$35	*k*
Borderline Personality Disorder					
Barker et al,[18] 2015	BPD (19); HC (21)	*DSM-IV*	DDT	£100	*k*
Berenson et al,[46] 2016	BPD (35); HC (45)	*DSM-IV*	DDT	$55 (mean)	*k*
Coffey et al,[47] 2011	BPD (19); HC (28)	*DSM-IV*	DDT	$1000	*k*
Dougherty et al,[48] 1999	BPD (13); HC (17)	*DSM-III*	DDT	$.15	ICR
Krause-Utz et al,[49] 2016	BPD (25); HC (24)	*DSM-IV*	DDT	€100	*k*
Lawrence et al,[19] 2010	BPD (30); HC (28)	*DSM-IV*	DDT	$1000	*k*
Maraz et al,[25] 2016	BPD (36); HC (111)	*ICD-10*	DDT	50 000 HUF	*k*
Bipolar Disorder					
Ahn et al,[13] 2011	BP (22); HC (30); manic-depressive state not specified	*DSM-IV*	DDT	$800	*k*
Brown et al,[39] 2018	BP (16); HC (61); manic-depressive state not specified	*DSM-IV*	DDT	$10	*k*
Strakowski et al,[15] 2010	BP (108); HC (48); acute manic/mixed-episode state	*DSM-IV*	eDDT	$.15	ICR
Urošević et al,[50] 2016	BP (32); HC (32); manic-depressive state not specified	*DSM-IV*	DDT	$10	AUC
Obsessive-Compulsive Disorder					
Norman et al,[51] 2017	OCD (20); HC (20)	*ICD-10*	DDT	£100	*k*
Pinto et al,[22] 2014	OCD (25); HC (25)	*DSM-IV*	DDT	$80-$100	AUC
Sohn et al,[35] 2014	OCD (80); HC (76)	*DSM-IV*	DDT	$100	*k*

(continued)

Table 1. Characteristics of Included Studies (continued)

Source	Groups (No. of Participants)	Diagnostic Tool	DD Measure	Delayed Amount	DD Index
Steinglass et al,[52] 2017	OCD (50); HC (75)	*DSM-IV*	DDT	$47-$78	*k*
Bulimia Nervosa					
Bartholdy et al,[53] 2017	BN (27); HC (28); all female	*DSM-5*	DDT	£100	AUC
Kekic et al,[29] 2016	BN (39); HC (53)	*DSM-5*	DDT	£100-£130	DF
Neveu et al,[54] 2014	BN (18); HC (18); all female	*DSM-IV*	DDT	€10	*k*
Binge-Eating Disorder					
Bartholdy et al,[53] 2017	BED (11); HC (28); all female	*DSM-5*	DDT	£100	AUC
Davis et al,[55] 2010	BED (65); HC (71)	*DSM-IV*	DDT	$100	IDP
Manasse et al,[33] 2015	BED (31); obese/overweight controls (43); all female	EDE	DDT	$1000	AUC
Manwaring et al,[56] 2011	BED (27); HC (30); all female	*DSM-IV*	DDT	$100	AUC
Mole et al,[57] 2015	BED (30); HC (30)	*DSM-IV*	MCQ	$55 (mean)	*k*
Steward et al,[58] 2017	BED (24); HC (80); all female	*DSM-IV*	MCQ	$55 (mean)	*k*
Yan et al,[59] 2018	BE (85); HC (928)	BES	DDT	¥10 000	*k*
Anorexia Nervosa					
Bartholdy et al,[53] 2017	AN (28); HC (28); all female	*DSM-5*	DDT	£100	AUC
Decker et al,[20] 2015	AN (54); HC (39)	*DSM-5*	DDT	$5-$40	*k*
King et al,[60] 2016	AN (31); HC (31); all female	*DSM-IV*	DDT	€30	*k*
Neveu et al,[54] 2014	AN-R (16); HC (18); all female	*DSM-IV*	DDT	€10	*k*
Ritschel et al,[26] 2015	AN (34); HC (53); all female	*DSM-IV*	DDT	€20-€789	*k*
Steinglass et al,[21] 2012	AN (36); HC (28)	*DSM-IV*	DDT	$80-100	DF
Steinglass et al,[52] 2017	AN (27); HC (75)	*DSM-IV*	DDT	$47-$78	*k*
Steward et al,[58] 2017	AN-R (37); HC (80); all female	*DSM-IV*	MCQ	$55 (mean)	*k*
Wierenga et al,[34] 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[64] and the 1-tailed Egger test.[65] Owing to low statistical power for the funnel plot indices with small sample sizes,[66] 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.[67] 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 nervosa, 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 *g* Effect Size	*P* Value	95% CI	OSR	Cochran Q Test of Homogeneity	Cochran Q Test *P* Value	I^2 Statistic	SD of Aggregate Effect Size, τ
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^2, 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^2 and τ 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[35] 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[23] (OSR Hedges g = 0.45; P < .001) and schizophrenia[36] (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 = 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 (≥$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

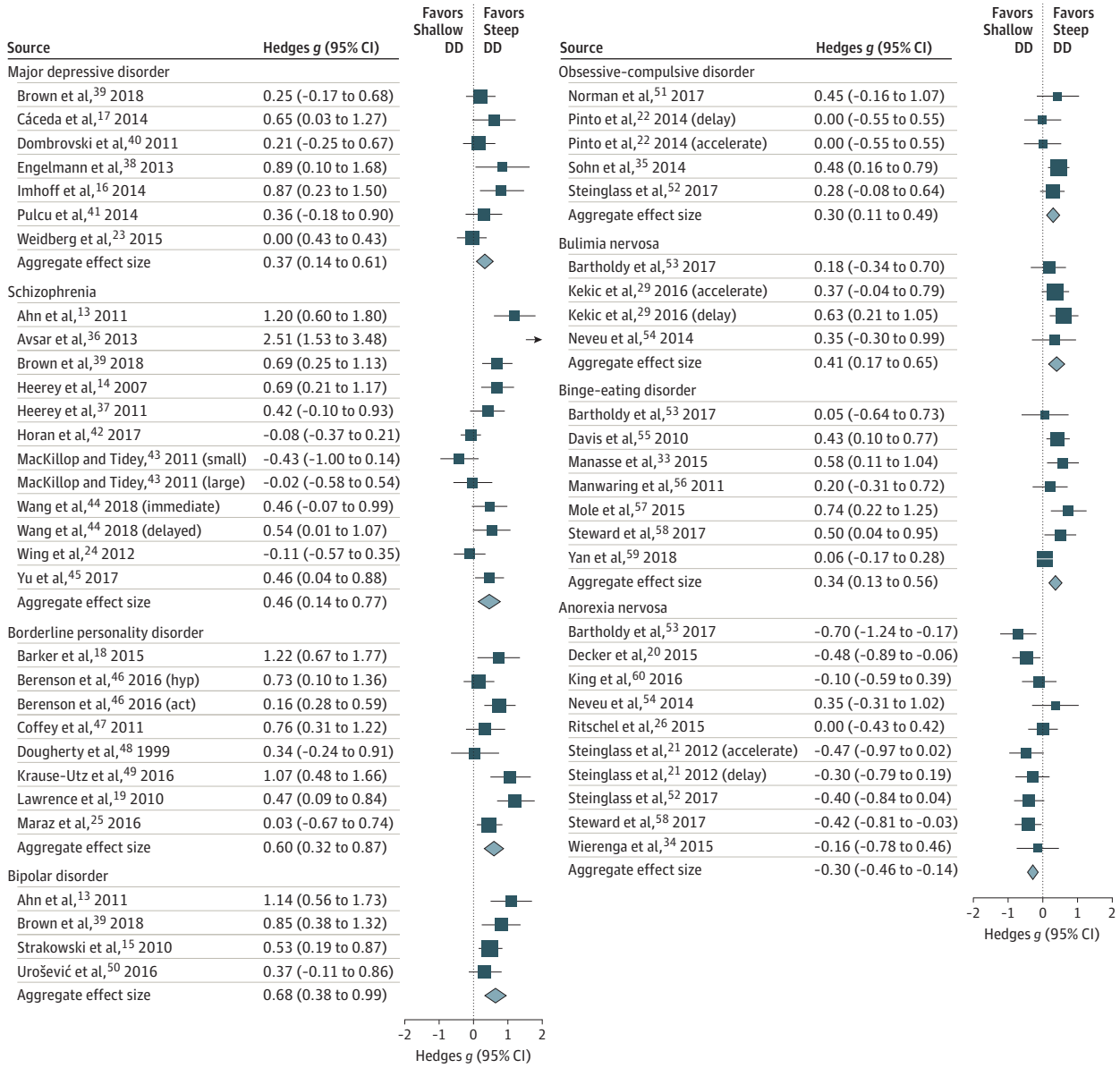
Publication bias indices are reported in **Table 3**. Two disorder categories (schizophrenia and anorexia nervosa) had more than the recommended minimum of 10 studies for the Begg-Mazumdar test or Egger test. The Egger intercept was statistically significant for schizophrenia. Major depressive disorder 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 Kendal 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.[66]

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.[3] 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[9]). 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[12]). 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 dysfunction in competing neurobehavioral decision systems[68,69] 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.[70-76] 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 τ	*P* Value	Egger Intercept	SE	*P* Value	Trim and Fill	Imputed Hedges *g*
Major depressive disorder	0.71	.02[a]	4.93	0.96	.002[a]	2	0.26
Schizophrenia	0.24	.27	4.97	2.02	.02[a]	0	NA
Borderline personality disorder	0.00	>.99[a]	1.21	2.87	.34[a]	0	NA
Bipolar disorder	0.33	.497[a]	3.55	3.22	.19[a]	1	0.58
Obsessive-compulsive disorder	−0.33	.46[a]	−1.98	1.54	.14[a]	0	NA
Bulimia nervosa	0.00	>.99[a]	−2.04	2.43	.25[a]	0	NA
Binge-eating disorder	0.14	.65[a]	1.98	1.26	.09[a]	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.

[a] 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,[77] whereas reduced self-control in bulimia nervosa and binge-eating disorder is partially associated with disruption in the similar frontal circuits.[77,78]

Other psychological mechanisms may explain the observed results. First, future-oriented cognitive processes, such as episodic future thinking,[79] 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.[37,80-83] 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,[84-87] 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.[88] 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.[89] Although numerous psychiatric disorders are characterized by heightened intolerance of uncertainty,[88,90,91] 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,[92] and discounting is associated with specific symptoms of schizophrenia (eg, apathy[93]). 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.[31,94] Future research should also investigate whether discounting rates can be normalized via treatment interventions.[95] Various interventions such as episodic future thinking training have been shown to reduce impulsive discounting in individuals with addictive disorders.[85,86] 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,[38,96] 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[97,98]) 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.

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