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DOI:
[10.1002/eat.22571](https://doi.org/10.1002/eat.22571)

Document Version
Peer reviewed version

[Link to publication record in King's Research Portal](#)

Citation for published version (APA):

Kekic, M., Bartholdy, S., Cheng, J., McClelland, J. K., Boysen, E., Musiat, P., O'Daly, O., Campbell, I. C., & Schmidt, U. H. (2016). Increased temporal discounting in bulimia nervosa. *International Journal of Eating Disorders*. Advance online publication. <https://doi.org/10.1002/eat.22571>

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Manuscript word count: 1704

Abstract word count: 205

ABSTRACT

Objective: There is evidence that people with eating disorders display altered intertemporal choice behaviour (the degree of preference for immediate rewards over delayed rewards). Compared to healthy controls (HC), individuals with anorexia nervosa and binge-eating disorder show decreased and increased rates of temporal discounting (TD; the devaluation of delayed rewards), respectively. This is the first study to investigate TD in people with bulimia nervosa (BN).

Method: Thirty-nine individuals with BN (2 men) and 53 HC (9 men) completed a hypothetical monetary TD task. Over 80 binary choices, participants chose whether they would prefer to receive a smaller amount of money available immediately or a larger amount available in 3 months. Self-reported ability to delay gratification (the behavioural opposite of TD) was also measured.

Results: Individuals with BN showed greater TD (i.e., a preference for smaller-sooner rewards) and a decreased self-reported capacity to delay gratification relative to HC. Experimental groups did not differ in age, gender ratio, or BMI.

Discussion: Increased rates of TD may contribute to some of the core symptoms of BN that appear to involve making choices between immediate and delayed rewards (i.e., binge-eating and compensatory behaviours). Altered intertemporal choice behaviour could therefore be a relevant target for intervention in this patient group.

Increased temporal discounting in bulimia nervosa

The pathophysiology of bulimia nervosa (BN) is poorly understood and strong evidence to guide treatment is lacking (1). Exploration of neurocognition in BN has the potential to elucidate mechanisms underpinning associated behavioural abnormalities, and to promote the development of tailored therapeutic interventions.

Several neuropsychological difficulties have been observed in BN (2). For example, individuals with BN, as well as other eating disorders (EDs; anorexia nervosa [AN] and binge-eating disorder [BED]), have an increased preference for risky and disadvantageous choices in a context of uncertainty (3). There is also evidence that patients with EDs make maladaptive intertemporal choices. A reward arriving sooner is often more appealing than one arriving later, even when the later reward is larger. Thus, individuals discount the value of delayed outcomes – a phenomenon known as temporal discounting (TD). This tendency to devalue future rewards appears to be accentuated in BED (increased TD) (4) and diminished in AN (decreased TD) (5), which may underlie the disinhibited and restrictive eating that characterise these disorders. This study investigated whether individuals with BN display altered rates of TD and differences in the self-reported capacity to delay gratification relative to healthy controls (HC).

MATERIAL AND METHODS

Participants

Participants were men and women ≥ 18 years with BN or no current/previous diagnosis of any psychiatric disorder (HC): their data were pooled from two larger studies conducted by our group (currently in preparation for publication). Patients with BN were recruited via online advertisements on the King's College London (KCL) and Beat™ research recruitment webpages and through the South London and Maudsley NHS Foundation Trust ED Outpatient Service, while HC responded to online and poster advertisements at KCL. Group classification was established via

self-report and checked over email/telephone: DSM-V BN diagnosis was confirmed using an edited version of the Eating Disorder Diagnostic Scale (EDDS) (6), and the absence of a psychiatric disorder in HC was confirmed using the EDDS and the Structured Clinical Interview for DSM-IV Axis I Disorders Screening Module (7).

One hundred and thirty participants (BN = 55; HC = 75) completed the screening and 122 (BN = 52; HC = 70) were eligible for inclusion. Of these, 92 (BN = 39; HC = 53) completed the study and were included in the analyses.

The two larger studies were approved by the KCL Psychiatry, Nursing and Midwifery Research Ethics Subcommittee and the London City Road & Hampstead Research Ethics Committee. Participants gave informed consent prior to taking part and were compensated for their time.

Procedure

Full procedural details are provided in Appendix A. All participants attended a testing session at the Institute of Psychiatry, Psychology & Neuroscience, KCL. Study procedures undertaken prior to the TD task were comparable between the two studies: both involved providing written consent and completing several identical questionnaires, including the Depression Anxiety and Stress Scales (DASS-21) (8) and the Delaying Gratification Inventory (DGI) (9). Additionally, in both cases the TD task was done on a laptop with an experimenter present. Data were collected between May 2014 and September 2015.

Temporal discounting task

TD was assessed using a computerised hypothetical monetary choice task, modelled on an established paradigm (5). On each of 80 trials, participants had an unrestricted amount of time to indicate whether they would prefer to receive a smaller amount of money immediately (smaller-sooner reward) or a larger amount after 3 months (larger-later reward). Two types of decision

framing were employed: ‘Accelerate’ (larger-later reward remained at £100, smaller-sooner reward increased from £20 to £98 in £2 increments) and ‘Delay’ (smaller-sooner reward remained at £50, larger-later reward increased from £52 to £130 in £2 increments) (40 trials for each). The trials were pseudo-randomly interleaved, so that the two decision frames were intermixed.

TD was quantified by determining participants’ discount factor (DF) – the magnitude of reduction in the present value of a future reward – for each choice set using a two-step procedure (5) (see Appendix B). Global DF was calculated as the mean of the two DFs, and was used as the primary outcome variable in this study. The value obtained can range from 0 to 1, with smaller numbers indicating greater TD (i.e., a greater tendency to choose the smaller-sooner reward).

Delaying Gratification Inventory

Self-reported ability to delay gratification was measured with the DGI, which requires respondents to rate the extent to which they agree with 35 statements on a 5-point Likert scale. Scores are generated for five domains of delay behaviour (Food, Physical Pleasures, Social Interactions, Money, and Achievement) and a total score (Global DGI score) is calculated. This was used as the outcome variable here. Higher values indicate a greater capacity to delay gratification.

RESULTS

Statistical analyses were performed using SPSS® (tests were two-tailed, $\alpha = 0.05$). Key sample characteristics and raw intertemporal choice data are provided in Table 1. TD data were positively skewed, therefore square-root transformations were applied and transformed values were used in all subsequent analyses. Global DFs and Global DGI scores were correlated in the sample as a whole [$r = 0.33$, $p = .002$] (i.e., the higher the rate of TD, the lower the ability to delay gratification).

A one-way multivariate ANOVA showed that individuals with BN had lower Global DFs (indicating an increased rate of TD) [$F(1, 90) = 5.72$, $p = .019$] and Global DGI scores (indicating a

reduced capacity to delay gratification) [$F(1, 90) = 41.65, p < .001$] than HC. To examine whether these group differences persisted after controlling for other possible determinants, age, gender, BMI, and DASS-21 depression, anxiety, and stress scores were entered into the model as covariates. This revealed a significant effect of group on Global DF [$F(1, 84) = 5.52, p = .021$] but not Global DGI score [$F(1, 84) = 2.24, p = .138$], due to the inclusion of DASS-21 stress scores [$F(1, 84) = 5.25, p = .024$]. An exploratory mixed ANOVA revealed no significant main effect of framing (Accelerate vs. Delay) or framing x group interaction on DFs [both $p \geq .654$].

Bivariate correlations were used to explore relationships between Global DFs, Global DGI scores, clinical outcomes (DASS-21 and EDE-Q scores, illness duration, and frequency of binge-eating, vomiting, laxative use, and excessive exercise), and BMI. Pearson's r and Spearman's ρ correlation coefficients were employed. In the BN group, Global DFs were not significantly related to any clinical variables [all $p > .109$], and Global DGI scores were also not significantly correlated with any clinical variables [all $p \geq .278$] except for DASS-21 depression [$r = -0.34, p = .036$] and stress [$r = -0.39, p = .013$] scores. Neither Global DFs nor Global DGI scores were associated with BMI when the BN and HC groups were considered separately or together [all $p \geq .233$].

DISCUSSION

This is the first study to assess intertemporal choice behaviour in BN. Individuals with BN displayed steeper rates of TD (i.e., an increased preference for smaller-sooner rewards) and a reduced self-reported capacity to delay gratification compared to HC. This is consistent with observations of disadvantageous monetary decision-making in BN (3) and with TD findings in BED (4), but contrasts with the lower rates of TD reported in AN (which reflect an increased preference for larger-later rewards) (5).

Group differences in TD remained significant after controlling for variables reported to influence discounting rates (age, gender, BMI, depression, anxiety, and stress). TD did not correlate with illness duration, symptom severity, general psychopathology, or BMI among individuals with

BN, suggesting that elevated TD reflects a stable neurocognitive feature of BN; however, as our study only included acutely ill individuals, we cannot determine whether TD is a trait- or state-based marker of illness. Interestingly, a recent study reported that reduced TD in AN normalised after weight restoration (10); thus, studies should explore whether increased TD in BN persists after recovery. In contrast to TD rates, group differences in DGI scores disappeared after controlling for stress, and a decreased self-reported capacity to delay reward was associated with greater stress and depression in the BN group. Stress may therefore influence the perception of one's tendencies to delay gratification, but not the behaviour itself. We did not replicate the finding that people discount future rewards more when they are asked to delay consumption than when they are offered the chance to accelerate consumption (5, 11), which may be due to differences in the TD task administered.

A reduced capacity to delay reward may underpin some of the core symptoms of BN. For example, greater TD is proposed to reflect choice impulsivity and poor reward-related inhibitory control (12), and these neurocognitive difficulties are implicated in binge-eating and compensatory behaviours. Furthermore, binge-eating can be regarded as a manifestation of the tendency to act in pursuit of immediate pleasure-driven desires, as people with BN have heightened reward sensitivity to food cues (13) and report that binge-eating relieves negative affect (14). Altered intertemporal choice behaviour could therefore be a relevant target for intervention in this patient group.

Excessive TD is not exclusive to BN and BED: it relates to a broader set of psychiatric conditions, including addictions and schizophrenia, and to a number of behavioural maladies, such as unsafe sex and poor health practices (15). It has therefore been proposed to function as a trans-disease process, potentially underscored by a neurobiological imbalance between the 'impulsive' and 'executive' decision systems, which are embodied in parts of the limbic/paralimbic brain regions and prefrontal cortices, respectively (15). In this view, effective interventions will be those that restore regulatory balance to these competing systems (16). Indeed, we recently found that

direct manipulation of the executive system with transcranial magnetic stimulation concurrently altered TD and improved symptoms in AN (17).

This study has some limitations. Firstly, most participants were women, which may have introduced a gender bias (18); however, the male-to-female ratio did not differ between groups and a predominantly female sample reflects the higher prevalence of BN in women than in men. Secondly, we were unable to explore between-group differences in income, education, or IQ, which may influence the subjective evaluation of monetary rewards (19, 20). Finally, although the paradigm included more trials than most TD tasks, our findings are restricted to choices between immediate rewards and those delayed by three months: future studies should confirm the results using multiple time-points, permitting hyperbolic modelling of discounting.

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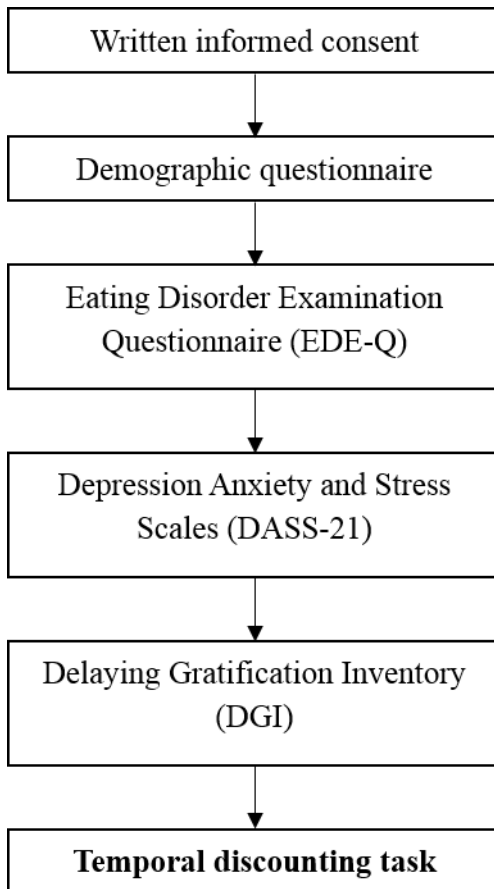
APPENDIX A

Further description of the two larger studies

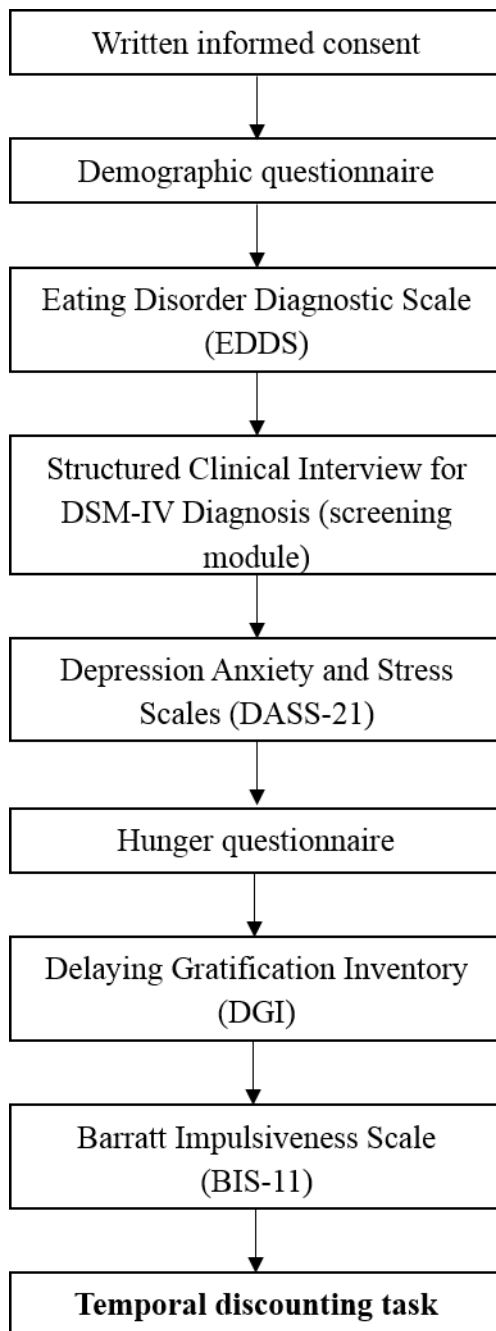
The two studies had unrelated aims: Study 1 was a crossover randomised controlled trial assessing the effects of transcranial direct current stimulation (tDCS) in bulimia nervosa, and Study 2 explored the impact of acute food restriction and distractor relevance on inhibitory control in healthy controls. Whereas these studies assessed within-subject differences in temporal discounting due to tDCS treatment and acute fasting, respectively, the present research combined their baseline temporal discounting and delaying gratification data to evaluate between-group differences in intertemporal choice behaviour.

The flow charts below show the measures completed prior to the temporal discounting task in each study. Full procedural details are available on request.

Study 1: Transcranial direct current stimulation improves symptoms, mood, and self-regulatory control in bulimia nervosa: A proof-of-principle clinical trial



Study 2: The impact of acute food restriction and distractor relevance on inhibitory control in healthy adults



APPENDIX BTwo-step procedure for quantification of discounting rate

First, the ‘indifference point’ was established. This is the amount of money that the participant judged as equivalent to the fixed reward – i.e., the value of the variable reward when the participant switched from larger-later to smaller-sooner in the Accelerate set and from smaller-sooner to larger-later in the Delay set (5). Second, a mathematical formula was fitted to the indifference point: $\delta = (x_1/x_2)^{1/(t_2-t_1)}$, where x_1 is the smaller-sooner reward, x_2 is the larger-later reward, and t_2-t_1 is the delay to reward presentation (in years), which in this case was 0.25 (5, 11). This procedure is a sensitive measure of temporal discounting that is independent of hyperbolic modelling and area under the curve analyses (5, 11).

Table 1. Sample characteristics and raw intertemporal choice data

| | HC (<i>n</i> = 53) | | BN (<i>n</i> = 39) | | <i>p</i> |
|---|---------------------|---------|---------------------|---------|---------------------|
| | M [<i>n</i>] | SD [%] | M [<i>n</i>] | SD [%] | |
| Age | 25.55 | 7.33 | 25.85 | 6.62 | .442 ^c |
| Gender | - | - | - | - | .083 ^d |
| Female | [44] | [83.02] | [37] | [94.87] | - |
| Male | [9] | [16.98] | [2] | [5.13] | - |
| BMI ^a | 21.71 | 2.17 | 21.65 | 3.20 | .420 ^c |
| DASS-21 depression | 2.68 | 2.96 | 20.62 | 10.39 | < .000 ^c |
| DASS-21 anxiety | 2.57 | 3.60 | 15.23 | 11.65 | < .000 ^c |
| DASS-21 stress | 6.64 | 5.24 | 21.97 | 10.19 | < .000 ^e |
| EDE-Q global | - | - | 4.21 | 1.06 | - |
| Illness duration (months) | - | - | 110.87 | 95.62 | - |
| Binge-eating frequency ^b | - | - | 22.23 | 31.66 | - |
| Vomiting frequency ^b | - | - | 50.87 | 169.5 | - |
| Laxative use frequency ^b | - | - | 4.69 | 17.28 | - |
| Excessive exercise frequency ^b | - | - | 7.21 | 9.99 | - |
| DF Accelerate | 0.45 | 0.35 | 0.32 | 0.34 | .046 ^c |
| DF Delay | 0.42 | 0.31 | 0.27 | 0.04 | .012 ^c |
| DF Global | 0.44 | 0.31 | 0.30 | 0.29 | .020 ^c |
| DGI global | 140.79 | 12.86 | 121.85 | 15.24 | < .000 ^e |

HC, healthy controls; BN, bulimia nervosa; DF, discount factor (from temporal discounting task); DGI, Delaying Gratification Inventory; M, mean; SD, standard deviation; BMI, body mass index.

^a weight(kg)/(height(m))²

- ^b Number of times in the previous 28 days
- ^c Mann-Whitney U test
- ^d Pearson chi-squared test
- ^e Independent samples t -test

ACKNOWLEDGEMENTS/DISCLOSURE OF CONFLICTS

Maria Kekic is supported by an Institute of Psychiatry, Psychology and Neuroscience/Medical Research Council Excellence Studentship. Savani Bartholdy is supported by a studentship awarded by the National Institute for Health Research (NIHR) Mental Health Biomedical Research Centre (BRC) at South London and Maudsley (SLaM) NHS Foundation Trust and KCL. Jessica McClelland is supported by the NIHR Mental Health BRC at SLaM NHS Foundation Trust and KCL. Owen O'Daly receives salary support from an NIHR Infrastructure grant for the Wellcome Trust/KCL Clinical Research Facility. Ulrike Schmidt and Iain Campbell receive salary support from the NIHR Mental Health BRC at SLaM NHS Foundation Trust and KCL. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.