University of Southampton

Faculty of Environmental and Life Sciences

School of Psychology

Executive Function, Mood State and Impulsive Spending in Bipolar Disorder: An Empirical Study, Systematic Review and Meta-Analysis

by

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Abstract

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The roles of executive function and mood state in bipolar disorder are investigated in this thesis, with exploration of their relationship with impulsive spending. The first chapter includes a systematic literature review and meta-analysis examining whether set-shifting ability varies according to mood state in bipolar disorder. Twenty studies contributed to the review, with data from 16 used in the meta-analysis. The evidence suggested a difference in set-shifting ability according to mood state, with poorer set-shifting in affective states compared to euthymia. The second chapter details an empirical study, with a longitudinal design, investigating the relationship between executive functioning and impulsive spending behaviours in a bipolar disorder population. One hundred and nineteen participants took part in the study at baseline, and 82 completed follow-up measures four weeks later. Methods of statistical analysis, including hierarchical regression, were used to investigate whether scores on computerised performance-based measures of executive function were predictive of compulsive buying, gambling or level of debt. Main findings suggested specific measures of planning and inhibition predicted compulsive buying behaviours.

The findings of both chapters have implications for future research and intervention. Recommendations are made for standardised approaches to mood state definitions and measurement of set-shifting. Further research regarding the role of executive function in expressed behaviours during mood states is needed, in addition to determining the efficacy of incorporating tailored cognitive rehabilitation in intervention. Methods of screening for vulnerability to impulsive spending, with a view to implement preventative measures, require further investigation.

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Research Thesis: Declaration of Authorship

Print name: Hannah Coman

Title of thesis: Executive Function, Mood State and Impulsive Spending in Bipolar Disorder: An Empirical Study, Systematic Review and Meta-Analysis

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

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Chapter 1 Systematic Literature Review and Meta-Analysis

Title: Does Performance on Set-Shifting Tasks Vary Depending on Mood State in Bipolar Disorder? A Systematic Literature Review and Meta-Analysis

Journal Specifications: This chapter has been prepared for submission to The Journal of Affective Disorders, which specifies a word limit of 8000 for review articles (excluding abstract, tables and references) and allows up to 10 tables. See Appendix B for full journal specifications.

Word Count: 7,235

Abstract

Background: Previous reviews have investigated executive function impairment in bipolar disorder (BD), which has been related to poor functional outcomes. Comparisons to healthy controls are common, with minimal research comparing executive function between mood states. Set-shifting has received little focus, with research often investigating working memory or inhibition. The present systematic review aimed to establish whether set-shifting abilities differ by BD mood state.

Methods: A systematic search of four databases produced 1486 titles. Studies using standardised cognitive measures of set-shifting in at least two mood states of BD were included for narrative synthesis and meta-analysis.

Results: Twenty studies met inclusion criteria, with 16 contributing to the meta-analysis. Two key measures of set-shifting were compared: the Wisconsin Card Sorting Task (WCST) and Trail Making Test Part B (TMT-B). Performance was poorer for depressed groups than euthymic, with significant effect sizes for TMT-B and two measures of the WCST. Weaker performance on one measure of the WCST was found for (hypo)manic groups compared to euthymic groups.

Limitations: With few studies, heterogeneity and publication bias analyses were unreliable. Missing data increased the possibility of bias. Magnitude of mood symptoms varied between studies. The WCST produced many variables, limiting comparability.

Conclusion: Weaker set-shifting ability in affective states of BD compared to euthymia was evidenced. There are implications for tailored cognitive rehabilitation, alongside a need for further research using within-subjects, longitudinal designs. Standardised definitions of mood states and use of the WCST are recommended.

Keywords: Bipolar disorder, set-shifting, executive function, mood state

1.1 Introduction

Bipolar disorder (BD) is a mental illness categorised into subtypes of BD I and BD II, with estimated prevalence in UK adults of 1% and 0.4% respectively (National Institute for Health and Care Excellence [NICE], 2014). BD is characterised by debilitating mood states of depression, (hypo)mania or mixed states, that occur in episodes and can significantly impair daily function; BD I is associated with mania, but may or may not include depressive episodes, whereas BD II consists of episodes of depression and hypomania (a milder form of mania) (American Psychiatric Association [APA], 2013). Periods of relative stability between mood states is referred to as euthymia (Fava & Bech, 2015).

Cognitive dysfunction in BD has been widely researched, with many studies including a cognitive assessment with comparison to healthy controls. The findings overwhelmingly conclude that participants with BD perform more poorly than healthy controls. The evidence drawn together in different literature reviews and meta-analyses commonly concludes deficits in multiple cognitive domains, including attention, processing speed, verbal learning, verbal recall, episodic memory, and, the widely focused on domain of executive function (Robinson et al., 2006; Stefanopoulou et al., 2009; Torres et al., 2007).

Executive function is not a unitary concept, and can be considered an umbrella term for functions linked to the pre-frontal cortex, including three primary functions: working memory, set-shifting and inhibition (Miyake & Friedman, 2012; Miyake et al., 2000). It has received particular attention due to the known difficulties in controlling and regulating behaviour that go hand-in-hand with BD (Dickinson et al., 2017). Reported risky behaviours often engaged with during episodes of (hypo)mania include alcohol and drug use, dangerous driving, endangering sexual activities and impulsive spending (Fletcher et al., 2013), with spending money recklessly and loss of social inhibitions listed in ICD-10 criteria for mania in BD (World Health Organization [WHO], 2019).

Recent research is of the consensus that deficits remain in remitted patients, with evidence of poorer executive function, verbal memory, psychomotor speed and sustained attention in euthymic groups when compared to healthy controls (Latalova et al., 2011; Szmulewicz et al., 2015; Torres et al., 2007). Cognitive performance is influenced by different confounding variables, such as age of onset, clinical features including presence or absence of psychosis, number of episodes, length of time since diagnosis, number of hospitalisations, familial risk factors, education and medication (Cardoso et al., 2015; Latalova et al., 2011; Mann-Wrobel et al., 2011; Peters et al., 2014; Robinson & Ferrier, 2006), with no strong evidence

of difference between BD I and II (Dickinson et al., 2017; Tsitsipa & Fountoulakis, 2015). Furthermore, psychiatric and medical comorbidities with BD are common, and have also been associated with deficits in cognitive function, in particular, executive function (Peters et al., 2014). In a meta-analysis focusing on first-episode of BD, where number of episodes and duration of illness were therefore not confounds, widespread deficits in executive function (including cognitive flexibility and working memory), verbal learning and verbal memory were found (Lee et al., 2014).

Systematic reviews and meta-analyses regarding general executive functioning in BD have been examined (Dickinson et al., 2017) and more specific attention has been given to the domain of working memory (Soraggi-Frez et al., 2017) and inhibition (Newman & Meyer, 2014). However, [*]set-shifting, (or cognitive flexibility), the third primary domain of executive function as defined by (Miyake et al., 2000), has been little studied.

Set-shifting can be defined as switching from one mental set to another as an adaptive response to a changing environment (Cochereau et al., 2021). Task impurity creates a particular challenge when measuring aspects of executive function (Diamond, 2013) and therefore consideration to task selection is important. Cochereau et al. (2021) report tests commonly considered the most suitable to measure set-shifting are The Trail Making Test Part B (Reitan, 1955), The Wisconsin Card Sorting Test (WCST) (Grant & Berg, 1948) and the Intra-Extra Dimensional (IED) Set Shift Test as part of the Cambridge Neuropsychological Test Automated Battery (CANTAB) (Cambridge Cognition, 2019). Deficits in set-shifting, displayed as cognitive inflexibility and perseveration, may be related to behaviours that are particularly associated with affective states. For example, set-shifting is implicated in rumination (Yang et al., 2017), engagement of risky activities (Linke et al., 2013) and in highly ambitious, reward-focused and goal-driven behaviour (Johnson et al., 2015). Previous reviews of cognition in BD have included set-shifting within comparisons to healthy controls, and have reported deficits ranging from small to large effect sizes (Dickinson et al., 2017; Lee et al., 2014; Mann-Wrobel et al., 2011). In reviews with specific interest in mood state, first-episode mania was associated with deficits in cognitive flexibility (Daglas et al., 2015). Kurtz and Gerraty (2009) made comparisons between euthymic vs. depressed states and manic states, also comparing each to healthy controls. For set-shifting in particular, manic groups were reported to have a greater deficit than euthymic groups, whilst depressed groups showed similarity to euthymic groups.

[*] 'Cognitive flexibility' is often used interchangeably with 'set-shifting,'; this review uses both terms in line with individual authors' usage.

The overall consensus from studies to date is of neuropsychological impairment during euthymia, with evidence of exacerbation in some areas of deficit during different mood states. However, comparisons between mood states within the same study are less common, resulting in poor understanding of the interaction of cognition with mood states. As executive function has been linked to functional outcome (Cotrena, Branco, Shansis, & Fonseca, 2016; Drakopoulos et al., 2020; O'Donnell et al., 2017; Tabarés-Seisdedos et al., 2008; Wingo et al., 2009), it is important to characterise impairments to appropriately target intervention. To the best of the author's knowledge, no review has specifically examined comparisons between mood states within BD, rather than comparisons with healthy controls, to gain an understanding of the nature of mood state dependent deficits. The present review aims to address this and answer the research question of whether set-shifting performance differs according to mood state in BD.

1.2 Method

1.2.1 Search strategy and study design

A systematic search was conducted on the electronic databases CINAHL, Medline, PsycINFO and Web of Science in December 2023. Search terms, with Boolean operators were used in each of the databases as follows: In title OR abstract "bipolar", AND in all text "Set-shift*" OR "set shift*" OR "Set-switch*" OR "set switch*" OR "cognitive flexibility" OR "task switch" OR "task-switch" OR "executive *function*" OR "mental flexibility" AND in all text "euthym*" OR "*mani*" OR "mood state" OR "mood" OR "depress*". For databases that did not permit left-hand truncation, "executive function*" OR "executive dysfunction*" were substituted, along with "mani*" or "hypomani*". The search was not restricted by date.

1.2.2 *Data collection and analysis*

1.2.2.1 Selection process

Studies using any quantitative design, with original or secondary data collection were included with the following criteria: 1) Published in English; 2) Reporting data from adults aged 18 years or over with a diagnosis of BD in any mood state or euthymia; 3) Reported outcomes from quantitative data obtained from widely accepted 'set-shifting' tasks as previously defined (Cochereau et al., 2021), or modified versions of these tests; these tasks are considered 'set-shifting' as defined by the author of this review, regardless of the definition of individual study authors; 4) Data compared between different mood states, i.e. euthymic, depressed or (hypo)manic and 5) A standardised measure of current 'mood' designed to measure either or

any combination of depression, (hypo)mania or euthymia, was administered as part of the study. Studies were excluded if: 1) They were not available in English; 2) A non-human sample was used; 3) Participants were under the age of 18 years or the age-group was restricted to an older-age sample (because of cognitive changes that occur with age and the increased possibility of influences to cognition secondary to BD); 4) Participants were experiencing psychosis and 5) Participants were recruited specifically due to physical or mental health comorbidities or neurodiversity. Intervention or longitudinal studies were included if measures had been collected at baseline, prior to the effects of any intervention. To be included in meta-analysis, means and standard deviations resulting from set-shifting tasks, alongside sample size, in at least two different mood states must have been either provided in the paper or via author request.

1.2.2.2 Data collection process

The protocol was registered with PROSPERO (registration number: CRD42023489551) and PRISMA reporting guidelines for systematic reviews and meta-analyses were followed. Produced titles were initially exported to Endnote 21 (The Endnote Team, 2013), where the software removed duplicates. Articles were subsequently exported to Rayyan software (Ouzzani et al., 2016), where further duplicates were identified and manually deleted prior to screening. Titles and abstracts were screened independently by researcher HC and were retained or excluded according to the described criteria. HC obtained papers for retained reports, which were read in full, resulting in further exclusions. Inter-rater reliability was ensured with 20% of titles and abstracts screened by a collaborator to the research team, with 98% agreement between the two raters, and 20% of articles included in full-paper screening were also examined by the second rater, with 100% agreement. Disagreements were resolved via discussion with the wider research team.

1.2.2.3 Data extraction and items

Extracted data was stored in Microsoft Excel and included: 1) Study details: researcher names, year published, country, study design; 2) Participant details: first language, age, sex, recruited from, exclusion criteria, sample sizes; 3) Clinical variables: confirmed diagnosis and method, bipolar type; 4) Mood state details: examined mood states, definition, standardised measures used and scores); 5) Set-shifting measures used and 6) Results of statistical analysis: means, standard deviations of set-shifting measures, *p* values where published and effect sizes (extracted where published and calculated otherwise).

1.2.3 Quality Assessment

The 'Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies' (National Heart, Lung and Blood Institute, 2019) assessed 14 items to guide classification of quality. For the present study, a score of < 50% on applicable items was used to indicate a rating of 'poor,' ≥ 50% and < 75% to indicate a rating of 'fair,' and ≥ 75% to indicate 'good.'

1.2.4 Data synthesis and statistical methods

Descriptive outcome data for all measures of set-shifting tasks were taken for each group (according to mood state) within studies, i.e. standard deviations, means and sample sizes. Findings from set-shifting tasks were compared between mood states ((hypo)manic vs. depressed, euthymic vs. (hypo)manic and euthymic vs. depressed), using narrative synthesis. Only $k = 3$ examined 'mixed states' and therefore comparisons were not made with this grouping. Set-shifting task variables were considered individually due to the impurity of executive function tasks, rather than combining results.

A meta-analysis was conducted including all studies with appropriate data ($k = 16$), with individual set-shifting variables included, where data was available for at least $k = 3$, using the software Comprehensive Meta-Analysis (CMA, version 4) (Borenstein et al., 2022). The meta-analyses used random effects models to allow for differences in effect between studies. The CMA software calculates values for *d* (the effect size of the difference between means), *z* (a significance test for the effect size), *Q*, (which tests for heterogeneity), I^2 (a measure of variability in effect estimates that is likely to be due to heterogeneity between studies, rather than chance), Tau (standard deviation of true effect sizes) and Tau-squared (variance of true effects). Egger's test for publication bias was also computed.

1.3 Results

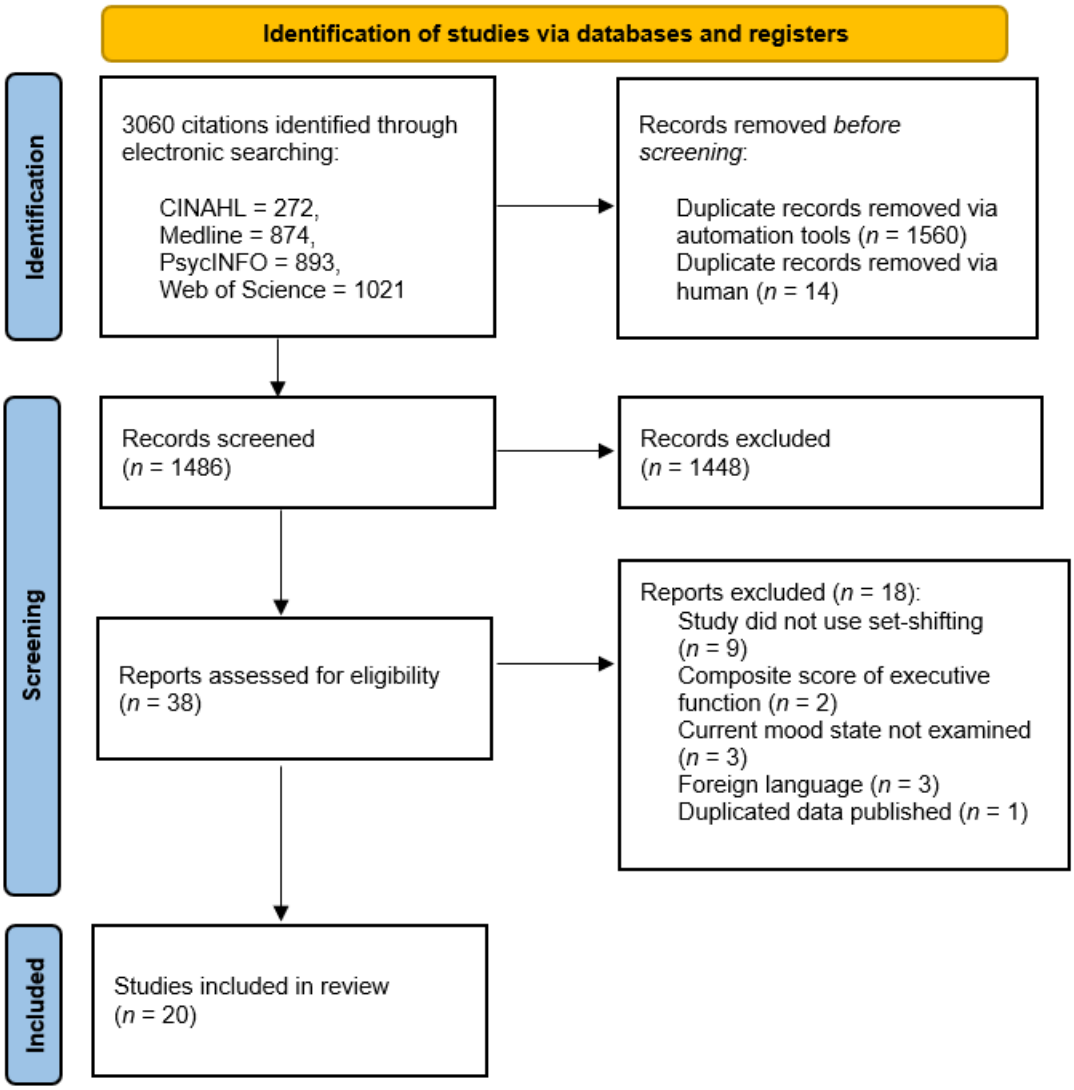
1.3.1 Search results

Twenty papers were included in the systematic review. This process is displayed in **Figure 1.** Due to the specific type of outcome measures examined, several studies ($k = 9$) could not be excluded without full paper screening, as abstracts described use of 'measures of cognitive or executive function' without sufficient detail to determine whether set-shifting tasks were used (Bernabei et al., 2020; Dixon et al., 2004; Doruk et al., 2014; Maalouf et al., 2010; Montel et al., 2014; Nishimura et al., 2015; Sagar et al., 2018; Soczynska, 2018; van der Werf-Eldering et al., 2010). Easter et al. (2022) and Langenecker et al. (2010), were excluded due to

incorporation of set-shifting into composite executive function scores. Wang et al. (2023) and Aminoff et al. (2012) were excluded as mood state referred to first-episode and not to current presentation and Xu et al. (2014) studied temperament rather than mood state. Papers by Benabarre (2003), Ioannidi et al. (2015) and Sisrová et al. (2018) were published in a language other than English. A paper by Luo et al. (2020) was excluded as it duplicated data used from their research team's previous paper, which is included in this review (Lin et al., 2019).

Figure 1

PRISMA flow diagram of the paper identification process



1.3.2 Study characteristics

Studies included in the current review were published between 2004 and 2022, from a diverse range of countries: Germany (*k* = 3), Spain (*k* = 2), Romania (*k* = 1), Poland (*k* = 1), United

States of America (*k* = 2), Brazil (*k* = 5), Republic of Korea (*k* = 2), China (*k* =2), Taiwan (*k* = 1), and Australia (*k* = 1). Four studies compared (hypo)manic and depressed mood states only, five studies compared depressed and euthymic mood states only, two studies compared (hypo)manic and euthymic mood states only and nine studies compared all three mood states (euthymic, (hypo)manic and depressed). Many of these studies made other comparisons, e.g. to healthy controls or to a major depression group, but due to the focus of this review, these comparisons are not described.

There were similarities between exclusion criteria, with exclusion of comorbidities of neurological conditions (85%), previous head injury or history of brain damage (65%) and current or previous substance abuse (85%). There was also considerable variation in exclusion criteria, with only half excluding comorbidities of physical health conditions and 40% setting criteria concerning learning disability. Other studies considered other factors which might interfere with cognitive testing, excluding on the basis of sensory impairment (Oliveira et al., 2011), severe mania or depression (Lin et al., 2019; Switalska, 2016) or educational level (Camelo et al., 2019). Medication use of participants varied across studies; 80% stated that participants were taking medication, whereas three studies reported participants were medication-free (David et al., 2014; Soeiro-de-Souza et al., 2011; Soeiro-de-Souza et al., 2012) and Fleck et al., (2012) excluded participants who had taken benzodiazepines in the past 24 hours. Malhi et al. (2004) specified no neuroleptics or antidepressants for two weeks prior to the study and medication use was not reported in the remaining study (Huang et al., 2020).

1.3.3 Participant characteristics

The majority of participants, regardless of mood state, were female (58%). Mean age was 37.3 years old. Recruitment was consistently from medical settings (hospitals or medical centres), with *k* = 7 specifying inpatient participants (**Table 1**). All studies included use of clinical interview to confirm diagnosis, with the exception of one, which did not provide this detail. The variation in studies recruiting participants with BD I or II is unknown; half (*k* = 10) reported on this distinction, of which *k* = 6 reported BD I only and none reported BD II only.

Table 1

Participant characteristics

Study author (year)	Recruitment method	Diagnosis confirmed (tool), when	*n* (Bipolar Type)	Bipolar mood states (*n*)	Gender (% female)	Age *M* (*SD*)
Gruber et al. (2007)	Inpatients	Yes (SCID for DSM-IV), in study	39 (BDI), 69 (BDII)	Manic (16) Depressed (84)	Manic: 76% Depressed: 41%	Manic: 41.9 (13.6), Depressed 46.9 (9.0)
Martinez-Aran et al. (2004)	Barcelona Bipolar Disorders Program	Yes (clinical state determined by psychiatrist using DSM-IV), prior to study	NR	Manic/Hypomanic (34) Depressed (30) Euthymic (44)	Manic/Hypomanic: 50%, Depressed: 50%, Euthymic: 59%	Manic/Hypomanic: 42.4 (11.9), Depressed: 43.4 (10.7), Euthymic 39.6 (9.5)
Fleck et al. (2008)	Secondary data Manic: Inpatients Euthymic: Outpatients	Yes (SCID for DSM-IV), prior to study (secondary data)	NR	Manic First Episode (21) Manic Multiple Episodes (23) Euthymic (25)	Manic first episode: 48% Manic multiple episodes: 53% Euthymic: 56%	Manic first episode: 25.7 (9.2) Manic multiple episodes: 28.2 (8.6) Euthymic: 30.0 (7.2)
Oliveira et al. (2011)	Hospital Care Program for Bipolar Disorder	Yes (DSM IV-TR), NR	81 (BDI)	Depressed (44) Euthymic (37)	Depressed: 86% Euthymic: 60%	Depressed: 43.8 (9.9) Euthymic: 42.0 (12.0)
Henry et al. (2013)	Inpatient and outpatient psychiatric clinics	Yes (SCID DSM-IV), NR	NR	Manic/Hypomanic (13/4) Current Depressive episode/Depressed (9/5) Euthymic (23)	Manic/Hypomanic: 24% Depressed: 57% Euthymic: 65%	Manic/Hypomanic: 33.8 (11.4) Depressed: 34.4 (8.7) Euthymic: 39.2 (8.7)

Study author (year)	Recruitment method	Diagnosis confirmed (tool), when	*n* (Bipolar Type)	Bipolar mood states (*n*)	Gender (% female)	Age *M* (*SD*)
Świtalska (2016)	NR (study setting: Central Clinical Hospital in Lodz, Poland)	Yes (DSM-IV criteria), in study	NR	Manic/Hypomanic (30) Depressed (30)	Manic/Hypomanic: 60% Depressed: 60%	Manic/Hypomanic: 48.1 (11.5) Depressed: 45.6 (12.6)
Camelo et al. (2019)	Outpatients from psychiatry clinic	Yes (SCID DSM-5 criteria, in study	NR	Manic (11) Depressed (20) Euthymic (34)	Manic: 55% Depressed: 85% Euthymic: 71%	Manic: 46.5 (11.5) Depressed: 45.1 (12.1) Euthymic: 44.5 (9.6)
Kang et al. (2022)	Outpatients from psychiatry clinic	Yes (SCID-I, DSM-IV), in study	NR	Depressed (30) Euthymic (46)	Depressed: 77% Euthymic: 59%	Depressed: 32.3 (9.98) Euthymic: 36.4 (11.09)
Wolf et al. (2010)	Hospital psychiatric department	NR	33 (BDI)	Manic (10) Depressed (12) Euthymic (11)	Manic: 80% Depressed: 58% Euthymic: 64%	Manic: 45.4 (13.53) Depressed: 47.8 (12.67) Euthymic: 49.7 (16.62)
Soeiro-de-Souza et al. (2011)	Clinical trial	Yes (SCID-I/P for DSM-IV-TR), in study	67 (BDI)	Manic (20) Mixed (21) Depressed (26)	Manic: 20% Depressed: 50% Mixed: 24%	Depressed: 26.5 (5.17) Manic: 28.9 (5.13) Mixed: 28.7 (5.00)
David (2014)	Clinical trial	Yes (SCID for DSM-IV TR), in study	110 (BDI)	Manic (41) Depressed (31) Euthymic (38)	Manic: 78% Depressed: 58% Euthymic: 66%	Manic: 29.3 (5.3) Depressed: 26.9 (5.2) Euthymic: 32.9 (10.9)

Study author (year)	Recruitment method	Diagnosis confirmed (tool), when	*n* (Bipolar Type)	Bipolar mood states (*n*)	Gender (% female)	Age *M* (*SD*)
Ha et al. (2014)	Hospital clinic	Yes (SCID-I (for DSM-IV, Korean version), in study	NR	Depressed (15) Euthymic (17)	Depressed: 67% Euthymic: 59%	Depressed: 39.2 (10.5) Euthymic: 31.6 (13.0)
Păunescu & Micluţia (2015)	Depressed: Inpatients Euthymic: Outpatients	Yes (DMS-IV-TR and ICD-10 criteria), in study	NR	Depressed (63) Euthymic (63)	71%	48.9 (12.04)
Volkert et al. (2016)	Inpatients	Yes, (DSM-IV criteria), NR	Depressed: 20 (BDI), 15 (BDII) (Hypo)manic: 15 (BDI), 5 (BDII)	Manic [Hypo]: 15 [5] Depressed (35) Euthymic: (29)	Depressed: 48% Manic: 70%	Depressed: 37.1 (11.7) Manic: 43.9 (9.7)
Lai et al. (2018)	Hospital Psychiatric Department	Yes, (SCID for DSM-IV), in study	NR	Depressed (30) Euthymic (22)	Depressed: 47% Euthymic: 55%	Depressed: 23.9 (6.95) Euthymic: 26.8 (8.86)
Lin et al. (2019)	Inpatients	Yes, (SCID-CV for DSM-IV), in study	NR	Manic/Hypomanic (48) Depressed (42) Euthymic (50)	Manic: 38% Depressed: 57% Euthymic: 48%	Manic: 34.1 (9.36) Depressed: 34.9 (8.16) Euthymic: 34.5 (9.85)
Mora et al. (2019)	Euthymic: Outpatient Manic: Inpatient	Yes (SCID for DSM-IV-TR), in study	Euthymic: 34 (BDI), 18 (BDII) Manic: 31 (BDI), 1 (BDII)	Manic (32) Euthymic (52)	Euthymic: 50% Manic: 44%	Euthymic: 47.5 (11.9) Manic: 41.3 (12.9)

Study author (year)	Recruitment method	Diagnosis confirmed (tool), when	*n* (Bipolar Type)	Bipolar mood states (*n*)	Gender (% female)	Age *M* (*SD*)
Huang et al. (2020)	Outpatient or Inpatient settings	Yes, (SADS-L, Chinese version), in study	56 (BDI), 397 (BDII)	Manic/Hypomanic (134) Mixed (149) Depressed (56) Euthymic (113)	Euthymic: 57% Depressed: 57% Manic/Hypomanic: 52% Mixed: 62%	Euthymic: 34.8 (12.81) Depressed: 35.8 (13.26) Manic/Hypomanic: 36.0 (14.15) Mixed: 35.9 (12.86)
Malhi et al. (2007)	Hospital psychiatric department	Yes, (SCID-P for DSM-IV), in study	41 (BDI)	Hypomanic (12) Depressed (14) Euthymic (15)	Overall: 68%	Overall: 38.6 (11.0)
Soeiro-de-Souza et al. (2012)	Clinical trial	Yes, (SCID-I/P for DSM-IV TR), in study	72 (BDI)	Manic (22) Mixed (21) Depressed (29)	Overall: 69%	Overall: 28.2 (5.4)

Note: NR = Not Reported, BDI = Bipolar Disorder Type I, BDII = Bipolar Disorder Type II, SCID for DSM-IV = Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, SCID-I = SCID for the assessment of Axis I disorders, SCID-P = SCID for the assessment of psychiatric populations, CV = Clinical Version, TR = Text Revision, SADS-L: Modified Schedule of Affective Disorder and Schizophrenia-Life Time (Endicott & Spitzer, 1978).

1.3.4 Study quality

Table 2 displays the results of quality assessment for included studies. A second rater assessed 10% of the studies with 100% agreement. Studies were cross-sectional (80%, including one retrospective cross-sectional study using secondary data) or cohort (20%) and most received ratings of 'fair' (85%), with 10% rated as 'good' and 5% as 'poor'. The vast majority of studies (*k* = 18) satisfactorily defined their research question or objective. However, only *k* = 4 met the quality assessment's criteria when defining the study population. Studies often described participants in detail, but details on the data collection time period was commonly missing, and details regarding the study setting were also lacking.

Due to the nature of recruitment, it was not possible to determine number of eligible participants. Only *k* = 2 did not use similar populations for all participants; one recruited from two different time periods and one from different hospital settings. Cross-sectional and cohort studies are commonly exploratory and may not report justifications for sample size; however, it

was found that *k* = 15 considered power, or the impact of their sample sizes. Cross-sectional studies measure independent and dependent variables within the same timeframe and therefore could not score on Item 7. Independent variables (commonly mood state) were recorded prior to the outcome in nearly all studies (*k* = 19), with details not reported in *k* = 1. All studies quantified the exposure (mood symptoms) using validated scales.

Table 2

Quality assessment for included studies

Study author (Year)	Study Design	1. Research Question and Objective	2. Study pop. defined	3. Participation rate ≥50%	4. Population similar - recruit., inclusion, exclusion	5. Sample size justified, power, variance, effect	6. IV measured prior to outcome	7. Sufficient timeframe IV/DV association	8. Different levels of IV examined	9. IVs clearly defined	10. IV assessed more than once over time	11. DVs clearly defined	12. Assessor blinded	13. Loss to follow up ≤20%	14. Confounding variables accounted for	Quality rating
Gruber et al. (2007)	Cohort	Y	N	CD	Y	Y	Y	Y	Y	Y	Y	Y	NR	N	N	Fair (64%)
Martinez-Aran et al. (2004)	C-S	Y	N	CD	Y	N	Y	N	Y	Y	N/A	Y	Y	N/A	Y	Fair (67%)
Fleck et al. (2008)	Retro. C-S	Y	N	CD	Y	Y	Y	N	Y	N	N/A	Y	NR	N/A	Y	Fair (58%)
Oliveira et al. (2011)	C-S	Y	N	CD	Y	N	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (58%)
Henry et al. (2013)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)
Świtalska (2016)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	N	Fair (58%)
Camelo et al. (2019)	C-S	N	Y	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)

Study author (Year)	Study Design	1. Research Question and Objective	2. Study pop. defined	3. Participation rate ≥50%	4. Population similar - recruit., inclusion, exclusion	5. Sample size justified, power, variance, effect	6. IV measured prior to outcome	7. Sufficient timeframe IV/DV association	8. Different levels of IV examined	9. IVs clearly defined	10. IV assessed more than once over time	11. DVs clearly defined	12. Assessor blinded	13. Loss to follow up ≤20%	14. Confounding variables accounted for	Quality rating
Kang et al. (2022)	C-S	Y	Y	CD	Y	N	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)
Wolf et al. (2010)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)
Soeiro-de-Souza et al. (2011)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)
David (2014)	C-S	Y	N	CD	Y	Y	NR	N	Y	NR	N/A	Y	NR	N/A	NR	Poor (42%)
Ha et al. (2014)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)
Păunescu & Micluţia (2015)	Cohort	N	N	CD	Y	N	Y	Y	Y	Y	Y	Y	NR	Y	N	Fair (57%)
Volkert et al. (2016)	Cohort	Y	N	CD	Y	Y	Y	Y	Y	Y	Y	Y	NR	N	Y	Good (83%)
Lai et al. (2018)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	N	Fair (58%)

Study author (Year)	Study Design	1. Research Question and Objective	2. Study pop. defined	3. Participation rate ≥50%	4. Population similar - recruit., inclusion, exclusion	5. Sample size justified, power, variance, effect	6. IV measured prior to outcome	7. Sufficient timeframe IV/DV association	8. Different levels of IV examined	9. IVs clearly defined	10. IV assessed more than once over time	11. DVs clearly defined	12. Assessor blinded	13. Loss to follow up ≤20%	14. Confounding variables accounted for	Quality rating
Lin et al. (2019)	C-S	Y	Y	CD	Y	N	Y	N	Y	Y	N/A	Y	Y	N/A	Y	Good (75%)
Mora et al. (2019)	C-S	Y	Y	CD	N	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)
Huang et al. (2020)	C-S	Y	N	CD	N	Y	Y	N	Y	Y	N/A	Y	NR	N/A	N	Fair (50%)
Malhi et al. (2007)	Cohort	Y	N	CD	Y	Y	Y	Y	Y	Y	Y	Y	NR	N	Y	Fair (71%)
Soeiro-de-Souza et al. (2012)	C-S	Y	N	CD	Y	Y	Y	N	Y	Y	N/A	Y	NR	N/A	Y	Fair (67%)

Note: For full version of the questions asked in this tool, see Appendix A.

Abbreviations: C-S = Cross-Sectional, Y = Yes, N = No, CD = Cannot Determine, N/A = Not Applicable, NR = Not Recorded.

1.3.5 Measurement of mood state

Mood state definitions, tool used, mean mood scores and standard deviations can be seen in **Table 3**. There was general consistency in use of validated tools measuring mood state. For depression symptoms, the Hamilton Depression Rating Scale (Hamilton, 1960) was used by 85% of the studies (*k* = 11: 17-item version, *k* = 1: 18-item version, *k* = 1: 21-item version, *k* = 1: 24-item version and *k* = 2: version not reported). The remaining 15% of studies reported using the Montgomery-Asberg Depression Rating Scale (MADRS) (Montgomery & Asberg, 1979). Two studies used the Beck Depressive Inventory (BDI) in addition (Beck et al., 1961). Manic symptoms were measured using the Young Mania Rating Scale (YMRS) (Young et al., 1978) in 100% of studies. Gruber et al. (2007) used the Self-Report Manic Inventory (SRMI) (Shugar et al., 1992) in addition to the YMRS. Some studies did not report using mood measures to assist in grouping participants and used clinical interview alone (*k* = 3), and others used interview in addition to measures (*k* = 3).

There was considerable variation in definitions of mood states, with different cut-offs on mood measurement tools used. This is highlighted by the variation in mean mood scores. For (hypo)manic groups, YMRS mean mania scores ranged from 11.6 – 25.7 (Volkert et al., 2016; Henry et al., 2013) and HAMD-17 mean depression scores ranged from 2.9 – 16.0 (Lin et al., 2019; Fleck et al., 2008). For depressed groups, YMRS mean mania scores ranged from 1.0 – 9.6 (Lai et al., 2018; Soeiro-de-Souza et al., 2011) and HAMD-17 mean depression scores ranged from 6.7 – 23.7 (Henry et al., 2013; Lin et al., 2019). Finally, for euthymic groups, YMRS mean mania scores ranged from 0.6 – 6.8 (Lai et al., 2018; Huang et al., 2022) and HAMD-17 mean depression scores ranged from 2.4 – 6.9 (Camelo et al., 2019; Mora et al., 2019; Wolf et al., 2010).

Table 3

Mood state definitions, tool used, mean scores and standard deviations

Study author (Year)	Study design	(Hypo) manic symptoms tool	Depressed symptoms tool	(Hypo) manic definition	Depressed definition	Euthymic definition	(Hypo) manic group mean manic symptoms (SD)	Depressed group mean manic symptoms (SD)	Euthymic group mean manic symptoms (SD)	(Hypo)manic group mean depressed symptoms (SD)	Depressed group mean depressed symptoms (SD)	Euthymic group mean depressed symptoms (SD)
Gruber et al. (2007)	Cohort	*T1: 1.* SRMI	*T1: 1.* BDI	SCID DSM IV	SCID DSM IV	N/A	*T1: 1.* 18.0 (9.8)	*T1: 1.* 5.8 (8.8)	N/A	*T1: 1.* 8.9 (7.3)	*T1: 1.* 23.5 (10.8)	N/A
		T1: 2. YMRS	*T1: 2.* HAMD-17				*T1: 2.* 23.3 (6.7)	*T1: 2.* 2.7 (3.7)		*T1: 2.* 7.5 (5.9)	*T1: 2.* 18.7 (6.7)	
		T2: 1. SRMI	*T2: 1.* BDI				*T2: 1.* 6.6 (6.1)	*T2: 1.* 2.6 (3.1)		*T2: 1.* 6.7 (3.9)	*T1: 1.* 7.3 (6.6)	
		T2: 2. YMRS	*T2: 2.* HAMD-17				*T2: 2.* 3.3 (3.9)	T2: 2. 1.5 (2.0)		*T2: 2.* 4.4 (4.5)	*T2: 2* 3.5 (3.3)	
Martinez-Aran et al. (2004)	Cross-sectional	YMRS (Spanish)	HAMD-17	YMRS>11 +DMS-IV	HAMD>16 +DSM IV	HAMD<9, YMRS<7 +DSM-IV	18.7 (5.4)	1.3 (1.5)	1.4 (1.8)	4.9 (3.5)	19.7 (3.2)	3.6 (2.6)

Study author (Year)	Study design	(Hypo) manic symptoms tool	Depressed symptoms tool	(Hypo) manic definition	Depressed definition	Euthymic definition	(Hypo) manic group mean manic symptoms (SD)	Depressed group mean manic symptoms (SD)	Euthymic group mean manic symptoms (SD)	(Hypo)manic group mean depressed symptoms (SD)	Depressed group mean depressed symptoms (SD)	Euthymic group mean depressed symptoms (SD)
Henry et al. (2013)	Cross-sectional	YMRS	HAMD-17	YMRS>19 +SCID DSM IV	HAMD>12 +SCID DSM IV	HAMD<12 YMRS<12 +SCID DSM IV	25.7 (8.7)	6.7 (4.1)	5.8 (4.0)	9.9 (5.2)	20.1 (6.2)	5.8 (4.0)
Świtalska (2016)	Cross-sectional	YMRS (Polish)	HAMD-18	YMRS>10	HAMD>10	N/A	19.4 (8.7)	NR	N/A	NR	20.4 (8.1)	N/A
Camelo et al. (2019)	Cross-sectional	YMRS	HAMD-17	DSM-V	DSM-V	DSM-V	20.3 (10.3)	4.3 (3.6)	1.3 (2.6)	4.3 (2.8)	15.0 (5.8)	2.4 (2.3)
Wolf et al. (2010	Cross-sectional	YMRS	HAMD-17	YMRS>11	HAMD>14	HAMD<15 YMRS<12 + 4 weeks euthymic	18.5 (4.9)	4.0 (3.7)	4.7 (2.6)	5.2 (2.6)	20.6 (2.8)	6.9 (4.3)
Soeiro-de-Souza et al. (2011)	Cross-sectional	YMRS	MADRS	YMRS>11 MADRS<18	MADRS>17 YMRS<12	N/A	18.0 (6.7)	9.6 (6.3)	N/A	10.5 (8.2)	24.3 (7.2)	N/A

Study author (Year)	Study design	(Hypo) manic symptoms tool	Depressed symptoms tool	(Hypo) manic definition	Depressed definition	Euthymic definition	(Hypo) manic group mean manic symptoms (SD)	Depressed group mean manic symptoms (SD)	Euthymic group mean manic symptoms (SD)	(Hypo)manic group mean depressed symptoms (SD)	Depressed group mean depressed symptoms (SD)	Euthymic group mean depressed symptoms (SD)
David (2014)	Cross-sectional	YMRS	HAMD-21	SCID DSM-IV	SCID DSM-IV	SCID DSM-IV	NR	NR	NR	NR	NR	NR
Volkert et al. (2016)	Cohort	YMRS	*1*. BDI	DSM-IV	DSM-IV	MADRS<12 BDI-II<15 YMRS<5 +Clinical interviews +3 months	11.6 (2.7)	2.5 (1.5)	1.4 (2.6)	*1*. 5.6 (4.8)	*1*. 22.4 (10.1)	*1*. 6.2 (3.7)
			2. MADRS							*2*. 7.6 (4.8)	*2*. 24.3 (5.8)	*2*. 4.2 (2.7)
Lin et al. (2019)	Cross-sectional	YMRS	HAMD-17	YMRS>11	HAMD>16	HAMD<9, YMRS<7	25.3 (11.4)	1.4 (1.1)	2.6 (2.1)	2.94 (2.36)	23.7 (5.1)	3.1 (2.8)
Huang et al. (2020)	Cross-sectional	YMRS	HAMD	Not defined	Not defined	HAMD<13. YMRS<11	14.4 (1.6)	8.0 (2.0)	6.4 (2.5)	11.1 (2.5)	18.5 (2.2)	6.0 (3.0)

Study author (Year)	Study design	(Hypo) manic symptoms tool	Depressed symptoms tool	(Hypo) manic definition	Depressed definition	Euthymic definition	(Hypo) manic group mean manic symptoms (SD)	Depressed group mean manic symptoms (SD)	Euthymic group mean manic symptoms (SD)	(Hypo)manic group mean depressed symptoms (SD)	Depressed group mean depressed symptoms (SD)	Euthymic group mean depressed symptoms (SD)
Malhi et al. (2007)	Cohort	YMRS	*1*. BDI	YMRS>10	HAMD>16	HAMD<10, YMRS<10 + remission ≥ one month	20.7 (3.5)	NT	NT	*1*. 8.2 (4.9)	*1*. 27.3 (15.0)	*1*. 8.2 (5.8)
			2. HAMD-17							*2*. 5.5 (2.9)	*2*. 23.1 (4.3)	*2*. 3.5 (2.3)
			3. MADRS							*3*. 4.3 (2.5)	*3*. 28.3 (4.8)	*3*. 4.3 (2.4)
Soeiro-de-Souza et al. (2012)	Cross-sectional	YMRS	MADRS	Clinical interview	Clinical interview	N/A	*Mdn* = 20.0 (8.3)	*Mdn* = 7.0 (6.0)	N/A	*Mdn* = 11.5 (7.0)	*Mdn* = 24.0 (7.0)	N/A
Oliveira et al. (2011)	Cross-sectional	YMRS	HAMD-17	N/A	HAMD>9 YMRS<12	HAMD<10 YMRS<12	N/A	6.0 (4.8)	1.2 (1.9)	N/A	15.6 (6.0)	3.3 (2.5)

Study author (Year)	Study design	(Hypo) manic symptoms tool	Depressed symptoms tool	(Hypo) manic definition	Depressed definition	Euthymic definition	(Hypo) manic group mean manic symptoms (SD)	Depressed group mean manic symptoms (SD)	Euthymic group mean manic symptoms (SD)	(Hypo)manic group mean depressed symptoms (SD)	Depressed group mean depressed symptoms (SD)	Euthymic group mean depressed symptoms (SD)
Ha et al. (2014)	Cross-sectional	YMRS	HAMD-17	N/A	HAMD>9 YMRS<10	HAMD<10, YMRS<10 + euthymic 8 weeks preceding study	N/A	3.6 (3.2	2.7 (2.3)	N/A	15.1 (4.5)	4.7 (2.8)
Păunescu & Micluţia (2015)	Cohort	YMRS	HAMD-17	N/A	HAMD>8	HAMD<7, YMRS<7 +6 months no affective symptoms	N/A	NR	1.94 (1.5)	N/A	21.2 (4.3)	4.5 (2.0)
Kang et al. (2022)	Cross-sectional	YMRS	HAMD-17	N/A	HAMD>7 +DSM IV	HAMD<8, YMRS<7	N/A	1.1 (NR)	1.3 (NR)	N/A	12.3	3.4
Lai et al. (2018)	Cross-sectional	YMRS	HAMD-24	N/A	HAMD>21, YMRS<7	HAMD<8, YMRS<8	N/A	1.0 (1.3)	0.6 (1.3)	N/A	26.8 (5.0)	2.6 (1.8)

Study author (Year)	Study design	(Hypo) manic symptoms tool	Depressed symptoms tool	(Hypo) manic definition	Depressed definition	Euthymic definition	(Hypo) manic group mean manic symptoms (SD)	Depressed group mean manic symptoms (SD)	Euthymic group mean manic symptoms (SD)	(Hypo)manic group mean depressed symptoms (SD)	Depressed group mean depressed symptoms (SD)	Euthymic group mean depressed symptoms (SD)
Fleck et al. (2008)	Retrospective Cross-sectional	YMRS	HAMD-17	NR	N/A	SCID DSM-IV (full remission)	*1st episode:* 21.7 (11.8) *Multiple:* 24.1 (9.3)	N/A	3.0 (3.2)	*1st Episode:* 16.0 (5.7) *Multiple:* 14.3 (8.1)	N/A	3.1 (3.0)
Mora et al. (2019)	Cross-sectional	YMRS	HAMD-17	YMRS>13	N/A	HAMD<8, YMRS<6 +for 3 months preceding study	31.3 (5.9)	N/A	1.4 (1.7)	8.3 (3.7)	N/A	2.4 (2.3)

Note: T = Time, NR = Not Reported, N/A = Not Applicable, HAMD = Hamilton Depression Rating Scale, BDI = Beck Depression Inventory, MADRS = Montgomery-Asberg Depression Rating Scale, YMRS = Young Mania Rating Scale, SRMI = Self-Report Manic Inventory, SCID = Structured Clinical Interview for Diagnostic Criteria, DSM = Diagnostic and Statistical Manual

1.3.6 Set-shifting

Set-shifting was measured by three different cognitive tests, including modified versions. Each test produced different numbers of variables. The Wisconsin Card Sorting Task (Grant & Berg, 1948) was used by *k* = 16 (including computerised versions and the Modified Card Sorting Task [MCST] (Nelson, 1976)) and produced 12 different variables across the studies. The Trail Making Test Part B (Reitan, 1955) was used by *k* = 11 and produced four different variables across studies. The Test Battery of Attentional Performance (TAP) Set-Shifting (Computerised) (Zimmermann & Fimm, 2002) was used by *k* = 1, with one variable measured. **Table 4** displays the reported means, standard deviations, statistical significance, effect sizes and direction for all studies included in this review, grouped by mood states examined.

1.3.7 (Hypo)manic vs. depressed groups

1.3.7.1 Wisconsin Card Sorting Task (WCST)/Modified Card Sorting Task (MCST)

1.3.7.1.1 Total errors

Only one out of the five studies measuring total errors on the WCST/MCST found a difference in scores that reached statistical significance ($p < .05$) (Soeiro-de-Souza et al., 2011), with more errors made by the (hypo)manic group with a medium-large effect size. Of the other four studies (David et al., 2014; Gruber et al., 2007; Henry et al., 2013; Huang et al., 2020), the effect sizes ranged from very small to medium, two in the direction of more errors made by (hypo)manic groups and one in the opposite direction. Magnitude and direction of effect was not reported by David et al. (2014).

1.3.7.1.2 Total correct

One study only measured this variable (Huang et al., 2020); the result did not reach statistical significance, with a very small effect size. The mean number of correct responses was slightly higher in the (hypo)manic group than in the depressed group.

1.3.7.1.3 Perseverative errors

Ten studies measured this variable. Three of these studies (David et al., 2014; Soeiro-de-Souza et al., 2011; Soeiro-de-Souza et al., 2012) found significant differences between groups for the number of perseverative errors on the WCST, with all reporting more perseverative errors made by the (hypo)manic groups. A medium effect size was reported by Soeiro-de-Souza et al. (2011). Data for effect size calculation was not provided by the other two studies. In six of the remaining

seven studies, the (hypo)manic groups made more errors than the depressed groups, with effect sizes ranging from very small to large. The opposite direction of effect was found in Gruber et al. (2007) with a small effect size.

1.3.7.1.4 Non-perseverative errors

None of the three studies measuring this variable reached statistical significance when comparing group scores. One reported a small effect size, with better performance from the depressed group, and the other two did not provide further data.

1.3.7.1.5 Perseverative responses

Three studies reported this variable; two studies (Soeiro-de-Souza et al., 2011; Soeiro-de-Souza et al., 2012) found significant differences between groups, with more perseveration made by the (hypo)manic groups with a medium-large effect size. The third study did not report a significant result, with no further data provided.

1.3.7.1.6 Categories completed

This variable was measured by four studies, with no significant differences between groups reported. Three of the studies reported the depression groups to complete more categories than the (hypo)manic groups, with effect sizes ranging from small to medium. The fourth study (Malhi et al., 2007) did not report size or direction of effect.

1.3.7.1.7 Categories corrected

Three studies reported this variable; with no statistical significance between groups found, although Soeiro-de-Souza et al., (2011) reported a medium effect size, with better performance from the depressed group. The other two studies did not provide further data.

1.3.7.1.8 Conceptual level responses

None of the four studies which reported on this variable found statistically significant difference between groups. Two of the studies reported medium-large or large effect sizes however, with better performance by the depressed groups in both. The other two studies did not provide group data.

1.3.7.1.9 Trials to complete 1st category

None of the three studies reporting data for this variable found statistical significance between groups. One study did not provide further information (Malhi et al., 2007), and the other two were opposed in findings; Switalska (2016) reported better performance from the depression

group with a small effect size and Huang et al. (2020) reported a very small effect size with marginally better performance from the (hypo)manic group.

1.3.7.1.10 Failure to maintain set

Four studies measured failure to maintain set (Malhi et al., 2007; Soeiro-de-Souza et al., 2011; Soeiro-de-Souza et al., 2012; David, 2014) none reported significant difference between (hypo)manic and depressed groups. Three studies did not provide further information, and one (Soeiro-de-Souza et al., 2011) reported a small effect size with better performance from the (hypo)manic group.

1.3.7.2 Trail Making Test Part B (TMT-B)

1.3.7.2.1 Completion time

Five studies measured completion time on TMT-B. No studies reported statistical significance for the difference between (hypo)manic and depressed groups. Effect size was small or very small for the three studies that provided data for this calculation (Martinez-Aran et al., 2004; Świtalska, 2016; Lin et al., 2019), and there was no trend for direction. Camelo et al. (2019) produced a different variable for TMT-B, which controlled for participants' scores on Part A of Trail Making (a test of attention and motor speed). The difference between groups was not reported as significant, with a small effect size and a smaller mean time (better performance) for the depressed group.

1.3.7.3 Summary of (hypo)manic vs. depressed groups

Overall, significant differences were found between (hypo)manic and depressed groups in six out of 40 comparisons of WCST/MCST variables, all of which reported poorer performance in (hypo)manic groups, with more errors made and more perseveration. None of the five comparisons made for TMT-B variables were significant.

1.3.8 Euthymic vs. depressed groups

1.3.8.1 Wisconsin Card Sorting Task (WCST)/Modified Card Sorting Task (MCST)

1.3.8.1.1 Total errors

Six of the 14 studies comparing euthymic and depressed groups measured the total number of errors on the WCST or MCST. None reported a significant difference between groups. There was a trend for better performance in the euthymic group, reported by three studies, one with a large effect size (Paunescu & Miclutia, 2015) and the other three with small/small-medium effect

sizes (Huang et al., 2020; Lai et al., 2018; Oliveira et al., 2011). Further detail was not reported by one of the studies (David et al., 2014) and no effect was found in Henry et al. (2013).

1.3.8.1.2 Total correct

Three studies measured this variable, with no statistically significant results reported. Two studies reported small or small-medium effect sizes with better performance by the euthymic group (Huang et al., 2020; Oliveira et al., 2011) and the other reported the opposite direction of effect, which was small (Paunescu & Miclutia, 2015).

1.3.8.1.3 Perseverative errors

Ten studies measured the number of perseverative errors made on the WCST/MCST. Only Huang et al. (2020) reported statistical significance, with a better performance from the euthymic group and a small-medium effect size. Paunescu and Miclutia (2015) reported a large effect size in the same direction, but did not report whether results were statistically significant. Of the other eight studies, there was a trend for better performance from the euthymic group, with four of the studies reporting this direction with effect sizes ranging from small to medium. Two studies reported medium or medium-large effect in the opposite direction and one study did not provide this data.

1.3.8.1.4 Non-perseverative errors

Only two studies measured this variable when comparing these groups (David et al., 2014; Lai et al., 2018) and neither reported statistical significance.

1.3.8.1.5 Perseverative responses

Two studies measured perseverative responses, neither reporting statistical significance between groups (David et al., 2014; Oliveira et al., 2011).

1.3.8.1.6 Categories completed

Six studies measured this variable and none reported statistically significant group differences. There was a trend for better performance by the euthymic group, with this direction of effect in four of the studies. One of these reported a large effect size but did not report whether this reached statistical significance (Paunescu & Miclutia, 2015). The others reported small or small-medium effect, with no further data given by Malhi et al. (2007).

1.3.8.1.7 Categories corrected

This variable was measured by one study only when comparing euthymic and depressed groups (David et al., 2014); difference in scores did not reach statistical significance and no further data was provided.

1.3.8.1.8 Conceptual level responses

None of the three studies measuring this variable reported statistical significance; two studies reported a small effect size with better performance from the euthymic group (Oliveira et al., 2011; Paunescu & Miclutia, 2015) and no further data was provided by David et al., (2014).

1.3.8.1.9 Trials to complete 1st category

Four studies measured this variable, with no statistically significant results. There was a trend for better performance by euthymic participants, with effect sizes ranging from small to medium-large, reported in three of the studies (Ha et al., 2014; Huang et al., 2020; Oliveira et al., 2011). No further data was provided by Malhi et al. (2007).

1.3.8.1.10 Failure to maintain set

Three studies reported failure to maintain set, none of which reported statistically significant group differences. Two studies (David et al., 2014; Malhi et al., 2007) did not provide further data. The third (Oliveira et al., 2011) showed only a small effect size, with slightly poorer performance by the euthymic group.

1.3.8.2 Trail Making Test Part B (TMT-B)

1.3.8.2.1 Completion time

Eight studies measured data from TMT-B. Kang et al. (2022) reported difference between euthymic and depressed groups that was significant (p = .07, d = 1.07), with better performance from the euthymic group. This study converted raw scores into z scores, which differed from the other studies in this review. There was a trend for better performance by the euthymic groups in the other studies; five reported this direction of effect with small effect sizes (Ha et al., 2014; Lai et al., 2018; Lin et al., 2019; Martínez-Arán et al., 2004; Păunescu & Micluţia, 2015). One study did not provide this information (Malhi et al., 2007). Camelo et al. (2019)'s variable accounting for TMT-A performance (as previously described) showed no difference between the euthymic and depressed groups (h = 0).

1.3.8.3 Summary of euthymic vs. depressed groups

Few comparisons between euthymic and depressed groups reached statistical significance where this information was provided. Only two comparisons out of 54 reported statistically significant differences, where depressed groups were more perseverative in errors on the WCST and were slower on TMT-B.

1.3.9 Euthymic vs. (hypo)manic groups

1.3.9.1 Wisconsin Card Sorting Task (WCST)/Modified Card Sorting Task (MCST)

1.3.9.1.1 Total errors

Three studies reported this variable. One of these (Huang et al., 2020) reported statistical significance between groups, with better performance from the euthymic group, $p < .05$, $d = 0.33$.

1.3.9.1.2 Total correct

Only one study reported on this variable and did not report a statistically significant difference, with a small effect size (Huang et al., 2020).

1.3.9.1.3 Perseverative errors

Seven studies reported on the number of perseverative errors when comparing euthymic and (hypo)manic groups. Three studies reported significant differences between groups (David et al., 2014; Huang et al., 2020; Mora et al., 2019), with better performance from the euthymic groups in two of these studies, but better performance from the (hypo)manic group in one. From the remaining four studies, there was no trend for better performance from either group.

1.3.9.1.4 Non-perseverative errors and perseverative responses

These variables were measured by two studies each, neither reporting statistical significance between groups for either variable.

1.3.9.1.5 Categories completed

Three studies reported this variable; Mora et al. (2019) reported statistical significance with better performance from the euthymic group ($p < .05$, $d = 0.67$). The other two did not report significance.

1.3.9.1.6 Categories corrected and conceptual level responses

Only one study measured these variables (David et al., 2014) and did not report statistical significance between groups for either.

1.3.9.1.7 Trials to complete 1st category

Two studies reported data from this variable (Malhi et al., 2007; Huang et al., 2020), neither reporting statistical significance between groups.

1.3.9.1.8 Failure to maintain set

Three studies reported failure to maintain set (Malhi et al., 2007; Fleck et al., 2008; David, 2014) with no statistical significance between groups. Two studies did not provide further information, so it is not possible to comment on a trend for direction of effect.

1.3.9.2 Trail Making Test Part B (TMT-B)

1.3.9.2.1 Completion time

Four studies reported on TMT-B when comparing euthymic and (hypo)manic groups (Malhi et al., 2007; Mora et al. 2019; Lin et al., 2019; Camelo et al., 2019). None of these reported statistical significance. There was a trend for better performance from the euthymic group; this was reported in three of the four studies with effect size ranging from very small to medium, with the fourth study not providing this information.

1.3.9.3 Summary of euthymic vs. (hypo)manic groups

Four out of 26 total comparisons between these groups were reported as statistically significant overall, generally with better performance from euthymic groups than (hypo)manic groups; higher rates of perseveration and fewer completed categories were reported in (hypo)manic groups.

Table 4

Set-shifting results study by study, grouped by mood state comparisons

(Hypo)manic vs. depressed groups									
Study author (Year)	**Study design**	**(Hypo)manic group *n***	**Depressed group *n***	**Set-shifting variables**	**(Hypo)manic group set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes (hypo)manic vs. depressed**	***p value***	**Effect size classification, group comparison**
Gruber et al. (2007)	Cohort	Time 1: 16	Time 1: 84		Time 1,	Time 1,	Time 1,	NR	Time 1,
		Time 2: 10	Time 2: 60		[a]Time 2	[a]Time 2	[a]Time 2		[a]Time 2
				MCSTc: Total Errors	17.8 (11.9),	17.3 (9.4),	*g* = 0.047		Small, D>Ma,
					[a]19.0 (8.1)	[a]10.8 (7.1)	[a]*g* = 1.05		[a]Large, D>Ma
				MCSTc: Perseverative Errors	5.2 (4.9),	5.9 (4.5),	*g* = -0.15		Small, Ma>D
					6.2 (3.6)	2.1 (2.5)	*g* = 1.32		Large, D>Ma
Martinez-Aran et al. (2004)	Cross-sectional	34	30	WCST: Categories completed	4.3 (2.0)	4.6 (1.7)	*d* = 0.162	NR	Small, D>Ma
				WCST: Perseverative Errors	19.8 (14.6)	18.9 (10.4)	*d* = 0.071		Very small, D>Ma
				TMT-B: Completion Time	131.9 (109.7)	151.2 (113.9)	*d* = 0.173		Small, Ma>D
Henry et al. (2013)	Cross-sectional	17	14	WCST: Total errors	T=37.9 (12.4)	T=43.1 (10.5)	*d* = 0.45	>.05	Medium, D>Ma
				WCST: Perseverative errors	T=36.5 (12.7)	T=45.2 (10.4)	*d* = 0.75	>.05	Large, D>Ma
				WCST: Categories completed	2.2 (1.7)	2.9 (1.6)	*d* = 0.42	>.05	Small-medium, D>Ma

(Hypo)manic vs. depressed groups									
Study author (Year)	**Study design**	**(Hypo)manic group *n***	**Depressed group *n***	**Set-shifting variables**	**(Hypo)manic group set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes (hypo)manic vs. depressed**	***p value***	**Effect size classification, group comparison**
Świtalska (2016)	Cross-sectional	30	30	WCST: Perseverative errors	24.4 (17.5)	14.0 (11.9)	*d* = -0.70	>.05	Medium-large, D>Ma
				WCST: Categories completed	3.5 (2.4)	4.7 (2.1)	*d* = 0.53	>.05	Medium, D>Ma
				WCST: Conceptual level achieved	50.0 (23.1)	64.6 (11.8)	*d* = 0.80	>.05	Large, D>Ma
				WCST: Trials to complete 1st category	31.7 (23.4)	24.5 (20.1)	*d* = 0.33	>.05	Small, D>Ma
				TMT-B: Completion time	137.7 (93.9)	152.1 (122.8)	*d* = 0.13	>.05	Very small, Ma>D
Camelo et al. (2019)	Cross-sectional	30	30	TMT-B Completion time - TMT-A Completion time/TMT-A Completion Time	1.5 (1.1)	1.3 (1.0)	*h* = 0.193	NR	Small, D>Ma
Wolf et al. (2010)	Cross-sectional	10	12	MCSTc: Perseverative errors	5.56 (4.45)	4.36 (6.86)	*d* = 0.21	>.05	Small, D>Ma

(Hypo)manic vs. depressed groups									
Study author (Year)	**Study design**	**(Hypo)manic group *n***	**Depressed group *n***	**Set-shifting variables**	**(Hypo)manic group set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes (hypo)manic vs. depressed**	***p value***	**Effect size classification, group comparison**
Soeiro-de-Souza et al. (2011)	Cross-sectional	20	26	WCST: Conceptual Level Responses	42.74 (11.54)	49.27 (6.57)	*d* = 0.7	>.05	Medium-large, D>Ma
				WCST: Perseverative Responses	13.58 (12.27)	6.85 (3.67)	*d* = 0.74,	<.05*	Medium-large, D>Ma
				WCST: Failure to Maintain Set	0.37 (0.59)	0.58 (0.98)	*d* = 0.26	>.05	Small, Ma>D
				WCST: Corrected Categories	2.89 (1.59)	3.65 (1.19)	*d* = 0.54	>.05	Medium, D>Ma
				WCST: Total Errors	21.26 (11.54)	14.15 (6.44)	*d* = 0.76	<.05*	Medium-large, D>Ma
				WCST: Perseverative Errors	11.32 (9.45)	5.92 (3.39)	*d* = 0.61	<.05*	Medium, D>Ma
				WCST: Non-Perseverative Errors	9.95 (8.59)	8.15 (5.74)	*d* = 0.25	>.05	Small, D>Ma

(Hypo)manic vs. depressed groups									
Study author (Year)	**Study design**	**(Hypo)manic group *n***	**Depressed group *n***	**Set-shifting variables**	**(Hypo)manic group set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes (hypo)manic vs. depressed**	***p value***	**Effect size classification, group comparison**
David (2014)	Cross-sectional	41	31	WCST: Conceptual level responses	NR	NR	NR	>.05	
				WCST: Perseverative Responses				>.05	
				WCST: Failure to maintain set				>.05	
				WCST: Corrected categories				>.05	
				WCST: Total Errors				>.05	
				WCST: Non-perseverative Errors				>.05	
				WCST: Perseverative Errors				<.05*	D>Ma
Volkert et al. (2016)	Cohort	20	35	TAPc: Errors	4.8 (7.6)	3.1 (5.1)	*d* = 0.26	>.05	Small, D>Ma
Lin et al. (2019)	Cross-sectional	48	42	TMT-B: Completion time	176.86 (84.09)	150.43 (74.31)	*d* = 0.33	>.05	Small, D>Ma

(Hypo)manic vs. depressed groups									
Study author (Year)	**Study design**	**(Hypo)manic group *n***	**Depressed group *n***	**Set-shifting variables**	**(Hypo)manic group set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes (hypo)manic vs. depressed**	***p value***	**Effect size classification, group comparison**
Huang et al. (2020)	Cross-sectional	134	56	WCST: Total correct	89.04 (18.58)	87.05 (20.69)	*d* = 0.10	>.05	Very small, Ma>D
				WCST: Total errors	38.77 (18.43)	39.48 (18.96)	*d* = 0.04	>.05	Very small, Ma>D
				WCST: Perseverative Errors	23.55 (17.24)	22.38 (12.99)	*d* = 0.08	>.05	Very small, D>Ma
				WCST: Completed Categories	5.96 (2.68)	5.36 (3.18)	*d* = 0.20	>.05	Small, Ma>D
				WCST: Trials to Complete 1st Category	17.70 (14.18)	18.55 (15.12)	*d* = 0.06	>.05	Very small, Ma>D
Malhi et al. (2007)	Cohort	12	14	WCSTc: Categories completed	NR	NR	NR	>.05	NR
				WCSTc: Trials to complete first category				>.05	
				WCSTc: Failure to maintain set				>.05	
				WCSTc: Perseverative Errors				>.05	
				TMT-B: Completion time				>.05	

(Hypo)manic vs. depressed groups									
Study author (Year)	**Study design**	**(Hypo)manic group *n***	**Depressed group *n***	**Set-shifting variables**	**(Hypo)manic group set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes (hypo)manic vs. depressed**	***p value***	**Effect size classification, group comparison**
Soeiro-de-Souza et al. (2012)	Cross-sectional	22	29	WCST: Conceptual level responses:				>.05	
				WCST: Perseverative responses				.02*	D>Ma
				WCST: Failure to maintain set				>.05	
				WCST: Corrected categories Errors				>.05	
				WCST: Non-perseverative errors				>.05	
				WCST: Perseverative Errors				.01*	D>Ma
				TMT-B: Completion time				>.05	

Euthymic vs. (hypo)manic groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**(Hypo)manic group *n***	**Set-shifting variables**	**Euthymic Set-shifting mean scores (SD)**	**(Hypo)manic group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. (hypo)manic**	***P value***	**Effect size classification, group comparison**
Fleck et al. (2008)	Retrospective Cross-sectional	25	First episode: 21,			First Episode,	First Episode,	NR	First Episode,
			Multiple episodes: 23			Multiple Episodes:	Multiple Episodes:		Multiple Episodes:
				WCST: Perseverative Errors (%)	13.8 (9.8)	19.2 (12.2),	*d* = 0.48		Medium E>M,
						21.7 (12.7)	*d* = 0.65		Medium E>M
				WCST: Perseverative Responses (n)	17.7 (17.5)	28.3 (22.6),	*d* = 0.52		Medium E>M,
						29.7 (22.2)	*d* = 0.57		Medium E>M
				WCST: Non-perseverative errors (n)	13.8 (14.3)	19.5 (13.8),	*d* = 0.40		Small/medium, E>M
						22.1 (12.7)	*d* = 0.60		Medium, E>M
				WCST: Unique errors (n)	2.8 (9.6)	4.9 (8.6),	*d* = 0.22		Small, E>M
						5.4 (7.0)	*d* = 0.31		Small, E>M
				WCST: Failure to maintain set (n)	1.0 (1.2)	0.5 (1.0),	*d* = 0.43		Small/Medium, M>E
						0.8 (1.0)	*d* = 0.19		Small, M>E

Euthymic vs. (hypo)manic groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**(Hypo)manic group *n***	**Set-shifting variables**	**Euthymic Set-shifting mean scores (SD)**	**(Hypo)manic group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. (hypo)manic**	***P value***	**Effect size classification, group comparison**
Henry et al. (2013)	Cross-sectional	23	17	WCST: Total errors	T=43.1 (12.8)	T=37.9 (12.4)	*d* = 0.41	>.05	Small-medium, E>M
				WCST: Perseverative errors	T=40.5 (9.3)	T=36.5 (12.7)	*d* = 0.36	>.05	Small, E>M
				WCST: Categories completed	3.0 (1.6)	2.2 (1.7)	*d* = 0.49	>.05	Medium, E>M
Camelo et al. (2019)	Cross-sectional	34	11	TMT-B Completion time - TMT-A Completion time/TMT-A Completion Time	1.3 (0.9)	1.5 (1.1)	*h* = 0.21	>.05	Small, E>Ma
Wolf et al. (2010)	Cross-sectional	11	10	MCSTc: Perseverative errors	12.73 (15.58)	5.56 (4.45)	*d* = 0.63	>.05	Medium, Ma>E
Volkert et al. (2016)	Cohort	29	20	TAPc: Errors	2.4 (2.6)	4.8 (7.6)	*d* = 0.42	>.05	Medium E>Ma
Lin et al. (2019)	Cross-sectional	50	48	TMT-B: Completion time	131.10 (65.90)	176.86 (84.09)	*d* = 0.61	>.05	Medium, E>Ma
Mora et al. (2019)	Cross-sectional	52	32	WCST: Categories completed	3.13 (2)	1.94 (1.5)	*d* = 0.67	<.05*	Medium, E>Ma
				WCST: Perseverative errors	16.81 (12.7)	10.87 (6.5)	*d* = 0.59	<.05*	Medium, Ma>E
				TMT-B: Completion time	117 (72.2)	117.9 (64.3)	*d* = 0.013	>.05	Very small, E>Ma

					Euthymic vs. (hypo)manic groups				
Study author (Year)	**Study design**	**Euthymic group *n***	**(Hypo)manic group *n***	**Set-shifting variables**	**Euthymic Set-shifting mean scores (SD)**	**(Hypo)manic group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. (hypo)manic**	***P value***	**Effect size classification, group comparison**
Huang et al. (2020)	Cross-sectional	113	134	WCST: Total correct	94.68 (17.46)	89.04 (18.58)	*d* = 0.31	>.05	Small, E>Ma
				WCST: Total errors	32.95 (16.72)	38.77 (18.43)	*d* = 0.33	<.05*	Small, E>Ma
				WCST: Perseverative Errors	17.54 (11.83)	23.55 (17.24)	*d* = 0.41	<.005	Small-medium, E>Ma
				WCST: Completed Categories	6.81 (2.83)	5.96 (2.68)	*d* = 0.31	<.05	Small, E>Ma
				WCST: Trials to Complete 1st Category	17.53 (15.38)	17.70 (14.18)	*d* = 0.011	>.05	Very small, E>Ma
Malhi et al. (2007)	Cohort	15	12	WCSTc: Categories completed	NR	NR		>.05	
				WCSTc: Trials to complete first category				>.05	
				WCSTc: Failure to maintain set				>.05	
				WCSTc: Perseverative Errors				>.05	
				TMT-B: Time taken to complete				>.05	

Euthymic vs. (hypo)manic groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**(Hypo)manic group *n***	**Set-shifting variables**	**Euthymic Set-shifting mean scores (SD)**	**(Hypo)manic group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. (hypo)manic**	***P value***	**Effect size classification, group comparison**
David (2014)	Cross-sectional	38	41	WCST: Conceptual level responses	NR	NR	NR	>.05	
				WCST: Perseverative Responses				>.05	
				WCST: Failure to maintain set				>.05	
				WCST: Corrected categories				>.05	
				WCST: Total Errors				>.05	
				WCST: Non-perseverative Errors				>.05	
				WCST: Perseverative Errors				>.05*	E>Ma

Euthymic vs. depressed groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**Depressed group *n***	**Set-shifting variables**	**Euthymic set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. depressed**	***P value***	**Effect size classification, group comparison**
Martinez-Aran et al. (2004)	Cross-sectional	44	30	WCST: Categories completed	4.8 (1.7)	4.6 (1.7)	*d* = 0.118	NR	Small, E>D
				WCST: Perseverative Errors	16.7 (14.6)	18.9 (10.4)	*d* = 0.174		Small, E>D
				TMT-B: Completion Time	109.6 (64.9)	151.2 (113.9)	*d* = 0.448		Medium, E>D
Oliveira et al. (2011)	Cross-sectional	37	44	WCST: No. of tests administered	118.7 (19.0)	121.6 (15.1)	*d* = 0.17	>.05	Small, E>D
				WCST: Total Correct	61.6 (15.6)	58.5 (18.0)	*d* = 0.19	>.05	Small, E>D
				WCST: Total Errors	57.0 (27.0)	63.1 (25.4)	*d* = 0.23	>.05	Small, E>D
				WCST: Perseverative Responses	43.0 (28.8)	52.8 (36.9)	*d* = 0.30	>.05	Small, E>D
				WCST: Perseverative Errors	35.5 (21.4)	42.3 (26.9)	*d* = 0.28	>.05	Small, E>D
				WCST: Conceptual Level Response	47.7 (21.6)	40.9 (24.6)	*d* = 0.29	>.05	Small, E>D
				WCST: Categories Completed	3.1 (2.0)	2.7 (2.2)	*d* = 0.16	>.05	Small, E>D
				WCST: Trials to Complete 1st category	33.7 (38.2)	48.7 (49.7)	*d* = 0.34	>.05	Small, E>D
				WCST: Failure to Maintain Set	1.2 (1.6)	0.8 (1.0)	*d* = 0.26	>.05	Small, D>E

Euthymic vs. depressed groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**Depressed group *n***	**Set-shifting variables**	**Euthymic set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. depressed**	***P value***	**Effect size classification, group comparison**
Henry et al. (2013)	Cross-sectional	23	14	WCST: Total errors	T=43.1 (12.8)	T=43.1 (10.5)	*d* = 0	>.05	No effect, E=D
				WCST: Perseverative errors	T=40.5 (9.3)	T=45.2 (10.4)	*d* = 0.48	>.05	Medium, D>E
				WCST: Categories completed	3.0 (1.6)	2.9 (1.6)	*d* = 0.063	>.05	Very small, E>D
Camelo et al. (2019)	Cross-sectional	34	20	TMT-B Completion time - TMT-A Completion time/TMT-A Completion Time	1.3 (0.9)	1.3 (1.0)	*h* = 0	NR	E=D
Kang et al. (2022)	Cross-sectional	46	30	[b]TMT-B (Korean letters)	*z* = -1.27 (1.36)	*z* = 0.04 (1.07)	*d* = 1.07	.07	Large, E>D
Wolf et al. (2010)	Cross-sectional	11	12	MCSTc: Perseverative errors	12.73 (15.58)	4.36 (6.86)	*d* = 0.70	>.05	Medium-large, D>E
Ha et al. (2014)	Cross-sectional	17	15	WCST: Categories achieved	5.5 (1.3)	4.7 (2.1)	*d* = 0.46	>.05	Medium, E>D
				WCST: Trials to complete first category	19.7 (22.2)	44.5 (42.0)	*d* = 0.74	>.05	Medium-large, E>D
				WCST: Perseverative errors	9.9 (8.9)	17.7 (14.8)	*d* = 0.64	>.05	Medium, E>D
				TMT-B: Completion time	79.7 (67.1)	95.1 (54.9)	*d* = 0.27	>.05	Small, E>D

Euthymic vs. depressed groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**Depressed group *n***	**Set-shifting variables**	**Euthymic set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. depressed**	***P value***	**Effect size classification, group comparison**
Păunescu & Micluţia (2015)	Cohort	63	63	WCST: Total correct	73.75 (8.69)	75.33 (8.91)	*d* = -0.18	NR	Small, D>E
				WCST: Total errors	22.11 (12.99)	37.62 (16.84)	*d* = 1.03		Large, E>D
				WCST: Perseverative errors	11.40 (7.93)	20.57 (13.10)	*d* = -1.16		Large, E>D
				WCST: Conceptual levels	66.62 (6.02)	65.41 (6.71)	*d* = 0.19		Small, E>D
				WCST: Categories completed	5.90 (0.30)	5.40 (0.81)	*d* = 0.82		Large, E>D
				TMT-B: Completion time	105.48 (45.93)	115.02 (53.64)	*d* = -0.19		Small, E>D
Volkert et al. (2016)	Cohort	29	35	TAPc: Errors	2.4 (2.6)	3.1 (5.1)	*d* = 0.17	>.05	Small, E>D
Lai et al. (2018)	Cross-sectional	22	30	WCST: Categories completed	4.68 (1.73)	4.97 (1.45)	*d* = 0.18	>.05	Small, D>E
				WCST: Total Errors	13.14 (10.04)	11.43 (7.37)	*d* = 0.19	>.05	Small, D>E
				WCST: Perseverative Errors	8.32 (8.60)	6.77 (5.61)	*d* = 0.21	>.05	Small, D>E
				WCST: Non-perseverative Errors	4.77 (2.36)	3.97 (1.61)	*d* = 0.40	>.05	Small-medium, D>E
				TMT-B: Completion Time	54.57 (17.93)	59.95 (25.00)	*d* = 0.25	>.05	Small, E>D
				TMT-B: Errors	0.18 (0.66)	0.53 (0.86)	*d* = 0.46	>.05	Medium, E>D
				TMT-B: Uptake	1.36 (1.59)	0.97 (1.37)	*d* = 0.26	>.05	Small, NR

Euthymic vs. depressed groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**Depressed group *n***	**Set-shifting variables**	**Euthymic set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. depressed**	***P value***	**Effect size classification, group comparison**
Huang et al. (2020)	Cross-sectional	113	56	WCST: Total correct	94.68 (17.46)	87.05 (20.69)	*d* = 0.4	>.05	Small-medium, E>D
				WCST: Total errors	32.95 (16.72)	39.48 (18.96)	*d* = 0.37	>.05	Small-medium, E>D
				WCST: Perseverative Errors	17.54 (11.83)	22.38 (12.99)	*d* = 0.39	<.05*	Small-medium, E>D
				WCST: Completed Categories	6.81 (2.83)	5.36 (3.18)	*d* = 0.31	<.05*	Small, E>D
				WCST: Trials to Complete 1st Category	17.53 (15.38)	18.55 (15.12)	*d* = 0.07	>.05	Very small, E>D
Lin et al. (2019)	Cross-sectional	50	42	TMT-B: Completion time	131.10 (65.90)	150.43 (74.31)	*d* = 0.28	> .05	Small, E>D
Malhi et al. (2007)	Cohort	15	14	WCSTc: Categories completed	NR	NR	NR	>.05	
				WCSTc: Trials to complete first category				>.05	
				WCSTc: Failure to maintain set				>.05	
				WCSTc: Perseverative Errors				>.05	
				TMT-B: Completion time				>.05	

Euthymic vs. depressed groups									
Study author (Year)	**Study design**	**Euthymic group *n***	**Depressed group *n***	**Set-shifting variables**	**Euthymic set-shifting mean scores (SD)**	**Depressed group set-shifting mean scores (SD)**	**Effect sizes euthymic vs. depressed**	***P value***	**Effect size classification, group comparison**
David (2014)	Cross-sectional	38	31	WCST: Conceptual level responses	NR	NR	NR	>.05	
				WCST: Perseverative Responses				>.05	
				WCST: Failure to maintain set				>.05	
				WCST: Corrected categories				>.05	
				WCST: Total Errors				>.05	
				WCST: Non-perseverative Errors				>.05	
				WCST: Perseverative Errors				>05	

Note: a>b indicates better performance by a. Ma = (Hypo)Manic, D = Depressed, E = Euthymic, MCSTc = Computerised Modified Card Sorting Test, WCST/c = Wisconsin Card Sorting Test/computerised, TMT-B = Trail Making Test Part B, TMT-A = Trail Making Test Part A, TAPc = Computerised Test Battery of Attentional Performance. [a] Gruber et al. (2007) Time 2: Participants were followed up when symptoms had remitted and groups did not meet definitions of (hypo)manic or depressed at Time 2. [b] Kang et al. (2022) Completion time was recalculated compensating for age, and then was converted to a z score.

1.3.10 Meta-analysis results

Sixteen studies were included in the meta-analysis. Variables included were those most commonly used, to provide sufficient data (WCST/MCST: 'Categories completed,' 'Perseverative errors,' 'Total errors'; TMT-B: 'Completion time'). The number of studies contributing to analyses varies. Eleven analyses were undertaken (**Table 5**).

Heterogeneity analysis and consideration of publication bias (via Egger's test) are included in the analysis. As there were fewer than 10 comparisons made per group, it must be borne in mind that heterogeneity analysis may be unreliable (Ioannidis, 2008). Egger's test must also be interpreted with caution, as $k \geq 10$ is recommended to ensure sufficient power (Ioannidis & Trikalinos, 2007).

1.3.10.1 (Hypo)manic vs. depressed

Data from eight studies were included in analysis of (hypo)manic vs. depressed groups (Gruber et al., 2007; Henry et al., 2014; Huang et al., 2020; Lin et al., 2019; Martínez-Arán et al., 2004; Soeiro-de-Souza et al., 2011; Świtalska, 2016; Wolf et al., 2010). Random effects analysis revealed non-significant effect sizes for all variables analysed for these groups. There was significant heterogeneity between the studies for all analysed variables of the WCST, with a high percentage of variance attributed to true heterogeneity (62%). There was no significant heterogeneity between studies when comparing the TMT-B completion time. There was no evidence of publication bias from Egger's test, with non-significant *p* values for all variables examined (**Table 5**).

Data from Malhi et al. (2007), David et al. (2014) and Soeiro-de-Souza et al. (2012) could not be included as it was not published and could not be obtained from the authors. Data from Camelo et al. (2019) could not be included; the TMT-B variable accounted for completion time at TMT-A and therefore was incomparable.

1.3.10.2 Euthymic vs. depressed

Comparisons of variables between euthymic and depressed groups were sourced from nine studies (Ha et al., 2014; Henry et al., 2013; Huang et al., 2020; Lai et al., 2018; Lin et al., 2019; Martínez-Arán et al., 2004; Oliveira et al., 2011; Paunescu & Miclutia, 2015; Wolf et al., 2010). Significant differences were found between scores on WCST Completed Categories (**Figure 2**), WCST Perseverative Errors (**Figure 3**) and TMT-B Completion Time (**Figure 4**) for euthymic and depressed groups, with poorer performance from depressed groups. However, there was significant heterogeneity between studies for WCST Completed Categories and WCST Perseverative Errors. There was no significant heterogeneity for TMT-B Completion Time. There was no evidence of publication bias for WCST Completed Categories or TMT-B Completion time. Egger's test was significant for WCST Perseverative Errors (**Table 5**), raising the concern of publication bias within the studies measuring this variable. On examination of factors within the quality assessment (**Table 2**), there is no evidence of undue bias within these studies.

Data from Kang et al. (2022) was incomparable due to standardization and therefore was not included within the meta-analysis.

1.3.10.3 Euthymic vs. (hypo)manic

Comparisons of WCST and TMT-B variables between euthymic and (hypo)manic groups were drawn from seven studies (Fleck et al., 2008; Henry et al., 2013; Huang et al., 2020; Lin et al., 2019; Martínez-Arán et al., 2004; Mora et al., 2019; Wolf et al., 2010). Results from the random effects analysis showed a significant effect size between group scores for WCST Completed Categories (**Figure 5**) with a better performance (more completed categories) for the euthymic group. There was no evidence of heterogeneity for this variable. For the other variables, there

was significant heterogeneity between studies for WCST Perseverative errors. There was no evidence of publication bias for any of the three variables examined for these groups (**Table 5**).

Table 5

Results of meta-analysis: Weighted mean effect sizes, heterogeneity and publication bias

Set-shifting measure	Studies	Participants		Effect size				Heterogeneity				Egger's test	
	Number	Group 1 (*n*)	Group 2 (*n*)	*d*	95% C.I.	*z*	*p* (*z*)	[a]*Q*$^{(df)}$	*p* (*Q*)	I^2	T^2 (*d* units)	[c]*t* $^{(df)}$	*p* (*t*) (one-tailed)
(Hypo)manic (group 1) vs. depressed (group 2)													
WCST: Completed Categories	4	215	130	-0.02	-0.04, 0.38	-0.08	.94	8.00$^{(3)}$	.05*	62%	0.10	0.33$^{(2)}$	.39
WCST: Perseverative Errors	7	261	252	0.15	-0.18, 0.48	0.90	.37	15.99$^{(6)}$	.01*	62%	0.12	0.02$^{(5)}$	.49
WCST: Total Errors	4	187	180	0.09	-0.33, 0.51	0.43	.67	7.91$^{(3)}$	.048*	62%	0.33	0.28$^{(2)}$	.40
TMT-B: Completion Time	3	112	110	0.04	-0.30, 0.38	0.23	.82	3.22$^{(2)}$	.20	38%	0.03	5.69$^{(1)}$	.055

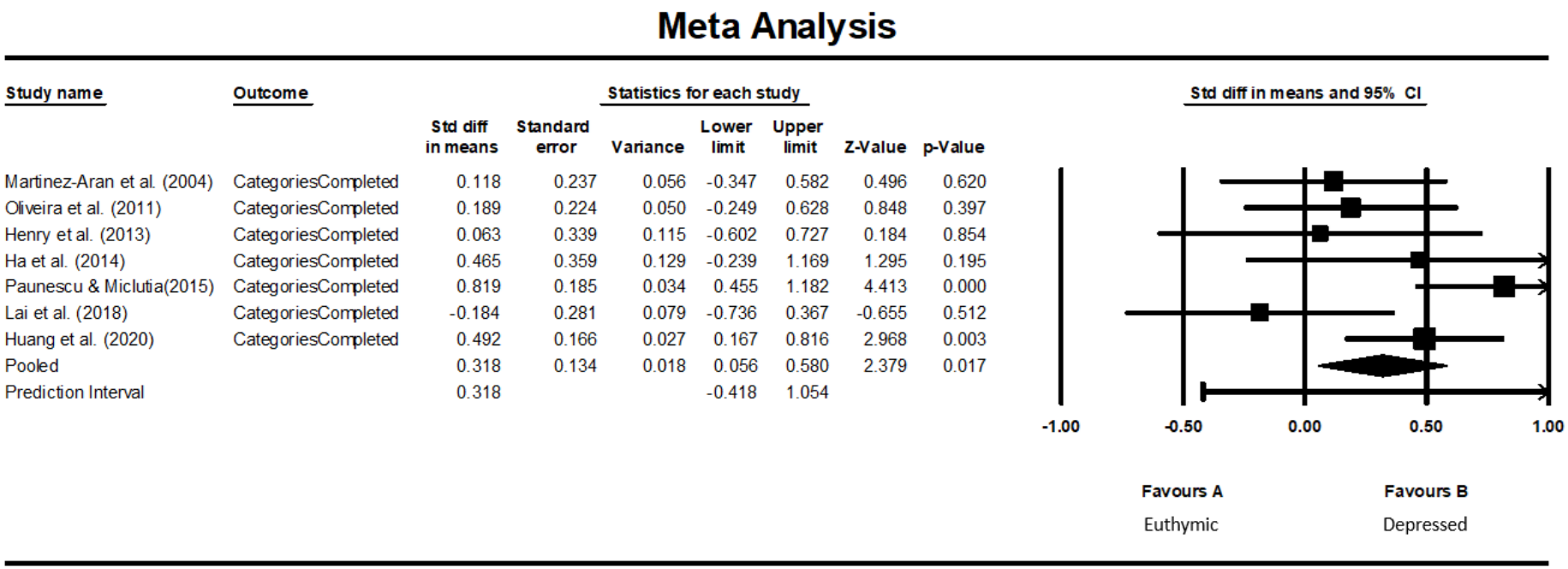
Set-shifting measure	Studies	Participants		Effect size				Heterogeneity				Egger's test	
	Number	Group 1 (*n*)	Group 2 (*n*)	*d*	95% C.I.	*z*	*p* (*z*)	[a]*Q*$^{(df)}$	*p* (*Q*)	I^2	T^2 (*d* units)	[c]*t* $^{(df)}$	*p* (*t*) (one-tailed)
Euthymic (group 1) vs. depressed (group 2)													
WCST: Completed Categories	7	319	252	0.32	0.06, 0.58	2.38	.02*	12.95$^{(6)}$	.04*	54%	0.06	1.59$^{(5)}$	.09
WCST: Perseverative Errors	8	330	264	-0.28	-0.59, 0.00	-1.97	.049*	18.85$^{(7)}$	.01*	63%	0.10	1.43$^{(6)}$	.01*
WCST: Total Errors	5	258	207	-0.33	-0.74, 0.09	-1.53	.13	17.54$^{(4)}$	.00*	77%	0.17	1.26$^{(3)}$	.15
TMT-B: Completion Time	5	196	196	-0.28	-0.48, -0.07	-2.68	.01*	[b]0.92$^{(4)}$	NR	0	0	0.45$^{(4)}$	.34

Set-shifting measure	Studies	Participants		Effect size				Heterogeneity				Egger's test	
	Number	Group 1 (*n*)	Group 2 (*n*)	*d*	95% C.I.	*z*	*p* (*z*)	[a]*Q*$^{(df)}$	*p* (*Q*)	I^2	T^2 (*d* units)	[c]*t* $^{(df)}$	*p* (*t*) (one-tailed)
	(Hypo)manic (group 1) vs. euthymic (group 2)												
WCST: Completed Categories	4	232	217	-0.38	-0.57, 0.19	-3.92	<.00*	[b]2.02$^{(3)}$	NR	0	0	0.93$^{(2)}$	.23
WCST: Perseverative Errors	6	268	250	0.08	-0.31, 0.47	0.41	.68	19.27$^{(5)}$	.00*	74%	0.16	0.85$^{(4)}$	.22
TMT-B: Completion Time	3	146	114	0.30	-0.04, 0.65	1.71	.09	3.87$^{(2)}$	.14	48%	0.05	1.54$^{(1)}$	.18

Note: [a]interpret with caution, tests of heterogeneity are likely to be unreliable when based on fewer than 10 studies. [b]*Q*-value is less than the degrees of freedom, observed effect was less than expected based on sampling error alone. *p* value was therefore not computed and indices of heterogeneity were set to 0. Euthymic vs. (hypo)manic WCST Total Errors excluded from meta-analysis, *k*<3. [c]interpret with caution; reliability of Egger's test with fewer than 10 studies is unknown and underpowering is likely.
*Significance values (*p* (*z*) criterion α =.05), *p* (*Q*) criterion α = .1, *p* (*t*) criterion α =.05.

Figure 2

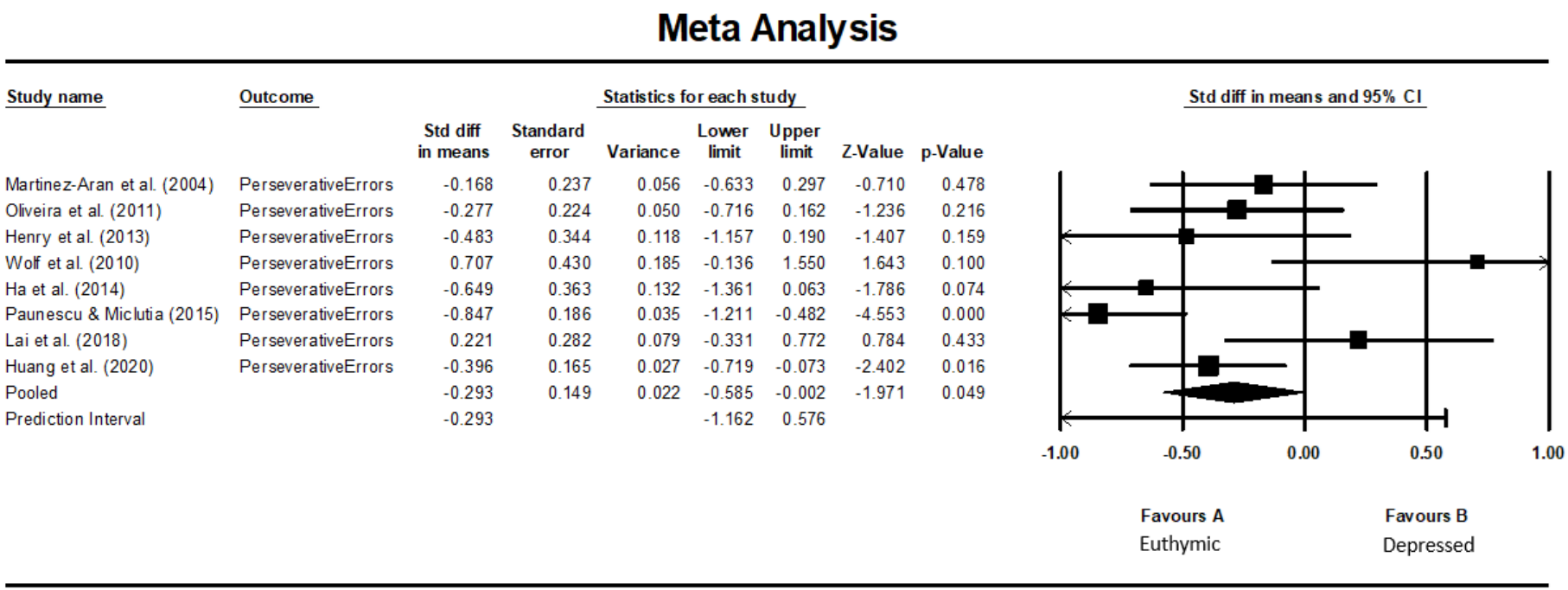
Euthymic vs. depressed groups, forest plot for WCST completed categories



Note: Higher number of categories completed indicates better performance

Figure 3

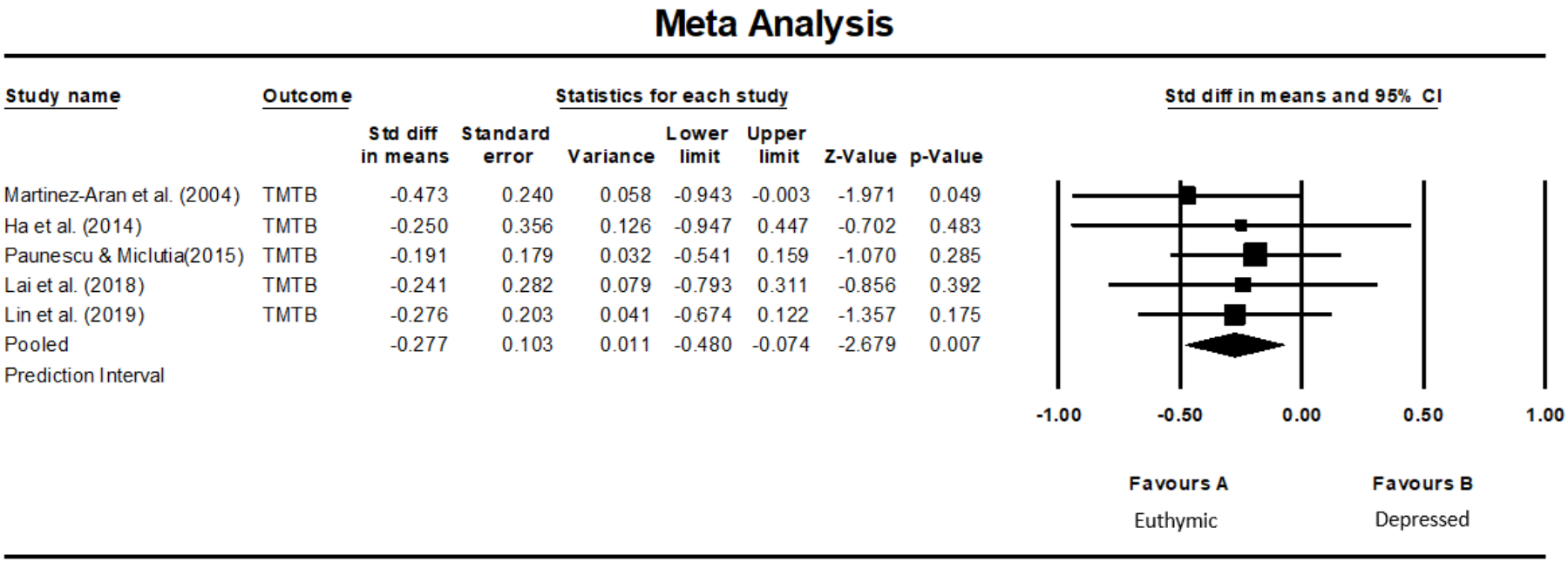
Euthymic vs. depressed groups, forest plot for WCST perseverative errors



Note: A higher number of perseverative errors indicates poorer performance

Figure 4

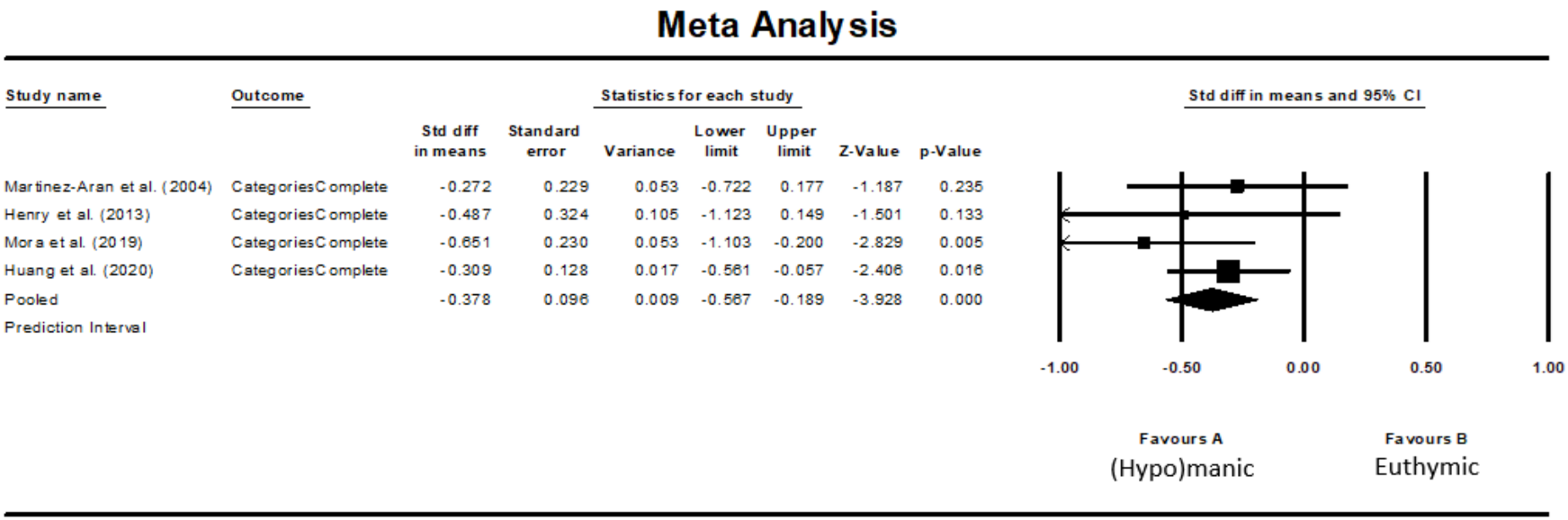
Euthymic vs. depressed groups, forest plot for TMT-B completion time



Note: A higher completion time indicates poorer performance

Figure 5

(Hypo)manic vs. euthymic groups, forest plot for WCST categories completed



Note: More categories completed indicates better performance

1.4 Discussion

This paper aimed to determine whether performance on set-shifting tasks varies depending on mood state in bipolar disorder and compared (hypo)manic and depressed groups, euthymic and depressed groups, and (hypo)manic and euthymic groups.

There was no evidence of differences between set-shifting scores for (hypo)manic compared to depressed states from meta-analysis. It must be noted that David et al. (2014) and Soeiro-de-Souza et al. (2012) both reported significant differences between (hypo)manic and depressed groups for the variable 'perseverative errors,' but data was unobtainable and could not be included in the meta-analysis. There was little evidence of a trend for difference in performance from wider variables not included in meta-analysis.

Meta-analysis provided some evidence that set-shifting tasks vary significantly between euthymic and depressed groups, with significant effect sizes for three of the compared variables (WCST 'perseverative errors' and 'categories completed', and 'TMT-B Completion Time'), all of which were suggestive of poorer performance from the depressed groups. The general trend when considering other variables compared, that were unable to be included within the meta-analysis, was also suggestive of this pattern. These results differ from Kurtz & Gerraty (2009) who reported similar set-shifting between depressed and euthymic patients.

Meta-analysis for comparisons between the (hypo)manic and euthymic groups supported some variation in performance between groups. Significantly better performance by the euthymic group was revealed for the variable 'categories completed' on the WCST, with no evidence of heterogeneity. Evidence from Paunescu and Miclutia (2015), which could not be included in the meta-analysis due to missing data, also reported significantly better performance from the euthymic group for the variable 'perseverative errors'; it must be borne in mind that this missing data has left the analysis vulnerable to bias. Results for measures of the WCST differ from findings by Kurtz and Gerraty (2009), who reported no difference between (hypo)manic and euthymic groups. However, results of similar effect sizes between these groups on the TMT-B are consistent with Kurtz & Gerraty (2009).

1.4.1 Clinical and research implications

The evidence from the present paper indicates poorer set-shifting during affective states than when euthymic, with a trend for weakest set-shifting ability when (hypo)manic. As set-shifting has a known relationship with certain behaviours that are common in BD (Yang et al., 2017; Linke et al., 2013; Johnson et al., 2015), further research is needed to characterise this role whilst in different affective states. Understanding this role, and its interaction with affective states as indicated in this review, would enable the integration of tailored cognitive strategies within psychoeducation and intervention. The efficacy of an integrative approach that includes strategies for cognitive enhancements has been evidenced in a randomised control trial (Valls et al., 2021). Furthermore, a recent review suggested the benefit of integrating cognitive rehabilitation training with other methods such as mindfulness and individual or group CBT sessions (Razavi et al., 2024); it is likely that understanding interactions of cognition with affective states would increase efficacy of such approaches, but further research is needed.

Only four studies included in this review were longitudinal; there is a need to fill this gap, with research by Gruber et al. (2007) highlighting the importance. Their research showed that cross-sectional comparison indicated little difference in cognitive performance between depression and manic groups, but 6-8 weeks later, the depression group showed greater cognitive recovery than the manic group. This gave important information regarding the interaction of mood state, cognition and longer-term impairment. It further highlights the difficulty in defining affective states, particularly euthymia, according to scores on measures of mood alone. The residual mood symptoms of both groups at follow-up in Gruber et al., (2007) were within the range classified as euthymic by most studies within this review, yet seemingly due to the nature of recent affective states (manic or depressed 6-8 weeks previously), their results on set-shifting tasks differed with large effect sizes. This is suggestive of a need for future research to account for duration since and nature of previous affective episodes when comparing between groups; this criteria was not commonly considered in definitions of euthymia in studies within this review. It also highlights difficulty with a categorical approach to affective states, which negate the context of presentation and varying levels of different symptoms that may co-occur. Whilst there are evidenced distinctions between mood states in BD, the challenge of categorisation was further indicated by the variance in cut-off scores used on measures of mood such as the YMRS and HAMD when classifying participants, which revealed the resulting difference in magnitude of mood-symptoms within classifications. When making comparisons between categorical mood states in BD, a standardised definition is needed when using cut-off scores, and consistency is required for an accepted level of residual symptoms to classify euthymia.

Consideration of the nature of exclusion criteria is needed. Studies within this review excluded people with substance misuse, poor physical health and other comorbidities that are common in BD (Amann et al., 2017; Kemp et al., 2009); it must be considered that this limits the generalisability of study data with misrepresented BD populations. This further suggests a need for more longitudinal studies, where variance can be minimised with the use of within-subject designs rather than strict exclusion criteria.

The number of different variables of the WCST measured by studies within this review was striking and impacted the amount of comparable data. Although the WCST is one of the most used measures of set-shifting clinically and in research, there are common discrepancies in scoring approaches and definitions of variables (Miles et al., 2021). This study therefore only included data from variables given the same descriptor, e.g. 'perseverative errors,' to minimise the risk of bias; 'perseverative responses' may be interchangeable with 'perseverative errors,' but may have an alternative meaning (Miles et al., 2021). However, it is also possible that these variables are scored differently, with different published scoring methods produced by Grant and Berg (1948) and Heaton and Staff (1993). In future research, to allow comparison between studies, an agreed approach to administering and scoring the WCST is recommended; researchers are advised to refer to Miles et al. (2021) who has made further recommendations on this issue. This adds support to the development of an agreed standardised assessment tool for BD, as discussed in (Rossetti et al., 2023).

1.4.2 Limitations

The risk of unreliable meta-analysis results must be acknowledged; missing data from three studies may have biased the results. Heterogeneity was significant for many comparisons and was likely increased by small study sizes (IntHout et al., 2015), with $n < 40$ in most groups and $n < 20$ in some, although poor reliability of heterogeneity analysis should be noted with inclusion of a small number of studies (Hardy & Thompson, 1998). Egger's tests indicated low risk of publication bias for all variables except for the variable 'perseverative errors' within the euthymic vs. depressed comparison, but reliability and power is likely to be limited with fewer than 10 studies for comparison (Ioannidis & Trikalinos, 2007). Examination of quality assessment did not indicate concern of undue bias, and further to this, published data for this variable reached statistical significance in only one of the eight examined studies. However, it is acknowledged that future research would benefit from including unpublished studies and grey literature to minimise risk of publication bias.

Further sources of bias may result from inclusion of publications available in English-language only. On the other hand, the nature of this study may have reduced risk of bias; studies

included in the review used cognitive test batteries to investigate a broad range of research questions, resulting in inclusion of set-shifting data when this was not the research focus.

Risk of bias from variation in the country of study must also be considered. Set-shifting scores were expressed with raw data rather than standardised scores based on countries' own normative data. It is therefore likely that variation in performance occurred, based on cultural and geographical differences in approach to such tasks, alongside educational differences (Ardila, 2018). Furthermore, the large number of variables produced by the WCST limited the usefulness of the data collected in this study, and introduced vulnerability to inconsistencies and bias, despite steps previously discussed to minimise this.

1.4.3 Conclusion

This systematic review and meta-analysis has provided evidence of difference in set-shifting ability during affective states of BD, with higher rates of perseveration during depression and mania than euthymia. There are implications of these findings for further research regarding the role of set-shifting in expressed symptoms during affective states. There is also a need for further research investigating the efficacy of intervention tailored to integrate appropriate cognitive rehabilitation. The review has highlighted a need for more research adopting within-subjects longitudinal designs. Furthermore, this review recommends standardised definitions of mood states and a standardised approach to the use of the WCST.

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Chapter 2 Empirical Paper

Title: Does Executive Function Predict Impulsive Financial Behaviours in Bipolar Disorder?

Journal Specifications: This chapter has been prepared for submission to The Journal of Neuropsychology, which specifies a word limit of 6000 for empirical papers (excluding the abstract, reference list, tables and figures). See Appendix G for full journal specifications.

Word Count: 5,994

Abstract

Impulsive spending behaviours, including compulsive buying and gambling, are known to be elevated in bipolar disorder and contribute to increased financial hardship. This has implications for mental health, functional ability and quality of life. Research has evidenced impairment of executive function in bipolar disorder, but there is a lack of literature investigating a relationship between executive function and impulsive spending behaviour. The present study aimed to examine this relationship across two time points one month apart, after controlling for mood symptoms. Computerised performance-based measures of executive function were completed at baseline only (n = 119), in addition to self-reported mood symptoms and measures of compulsive buying, gambling and debt. Follow-up questionnaires were completed four weeks later (n = 82). Hierarchical regression models revealed compulsive buying to be predicted by measures of inhibition and planning at both time points when controlling for current mood and the length of time since diagnosis. Level of debt was also predicted by a measure of inhibition. Pathological gambling could not be predicted by executive function measures. Participants reporting worsening compulsive buying over one month had more severe manic symptoms. The findings have implications for intervention and the possibility of identifying vulnerability for impulsive spending, with a view to deter or prevent the behaviour. The study was limited by a lack of verified diagnosis and bias resulting from opportunity sampling and online methodology.

Keywords:

Bipolar disorder, executive function, impulsivity, response inhibition, planning, compulsive buying, impulsive spending, gambling, debt, finance

2.1 INTRODUCTION

Bipolar Disorder (BD) is characterised by disturbances of mood and energy, resulting in episodes of mania, hypomania or depression, alongside changes in cognition (World Health Organisation [WHO], 2019). BD is ranked worldwide as the 18th most prevalent debilitating health condition (National Institute for Health and Care Excellence [NICE], 2023).

In BD populations, financial instability is common. A recent survey has shown 22% of a sample reported bankruptcy following manic impulsive spending, and a further 37% have considered bankruptcy (Brozena et al., 2024). A large recent study (*n* = 46,167), showed a 50% higher rate (12% of BD population) of bankruptcy filing compared to a general health cohort (Nau et al., 2023). Impulsive spending behaviours can include compulsive buying, which refers to spending an excessive or unreasonable amount of money or feeling compelled to buy things that are not needed (Cheema et al., 2015). Compulsive buying has been reported in 8% of BD cases (Kesebir et al., 2012), compared to 3% of the general population (Mueller et al., 2009), and 'unrestrained buying sprees' are associated with BD in the DSM-5 (American Psychiatric Association [APA], 2013). Gambling is a further contributor to financial difficulty and is thought to be a problem in approximately 10% of people with BD, four times more than in the general population (Jones et al., 2015).

Compulsive buying and gambling can be emotionally devastating, leading to interpersonal conflict and feelings of shame and remorse (Fletcher et al., 2013). Richardson et al. (2018) reported that depression, anxiety and stress can predict compulsive buying, and in addition, financial difficulties and poor mental health produce a vicious cycle, where each contributes to maintain the other. Risky behaviours, such as impulsive spending, have been linked to mania; 71% of a bipolar sample reported spending money excessively when hypomanic (Fletcher et al., 2013). Evidence supports a relationship between mood and problem gambling; a systematic review reported 41% comorbidity with anxiety disorder, 23% with manic episodes and 5% with hypomanic episodes (Varo et al., 2019). Kennedy et al. (2010) reported BD participants classified as 'problem gamblers' had more depressive symptoms than non-gamblers, and a BD group was more likely to gamble as a coping mechanism for negative affect compared to a major depression group (Quilty et al., 2017).

Cognitive deficits in BD, relative to healthy controls, have been evidenced in numerous cross-sectional and longitudinal studies e.g. (Fleck et al., 2008; Gruber et al., 2007; Luo et al., 2020; Oliveira et al., 2011; Switalska, 2016), with particular attention given to executive function. Executive function implicates the prefrontal cortex of the brain, and is an umbrella

term for general-purpose 'control mechanisms' that regulate the dynamics of human cognition and action (Miyake & Friedman, 2012). Cognitive tasks measuring executive function attempt to capture different domains, six of which were identified by Dickinson et al. (2017) as commonly used in the study of BD: set-shifting, working memory, inhibition, planning, attention and verbal fluency. However, task impurity is challenging when measuring executive function and evidence focuses importance on set-shifting (or cognitive flexibility), working memory (or updating) and inhibition (Diamond, 2013; Miyake et al., 2000).

A systematic literature review reported poorer performance on all examined measures of executive function in BD participants relative to controls (Dickinson et al., 2017). A general deficit in executive function has been evidenced in different phases of BD, with worse inhibitory control in hypomanic/mixed states compared to depressed or euthymic states (Dixon et al., 2004; Ryan et al., 2012). Poor executive function in BD has been associated with worse everyday functional ability (Cotrena, Branco, Kochhann, et al., 2016; Henry et al., 2013), an increased probability of occupational dysfunction (Drakopoulos et al., 2020; O'Donnell et al., 2017; Tabares-Seisdedos et al., 2008), poorer quality of life (Cotrena, Branco, Kochhann, et al., 2016; Mackala et al., 2014) and has been found to predict disability in social relationships (Wingo et al., 2009).

Despite the high prevalence of impulsive spending behaviours in BD, a relationship with executive function has been little studied. In one study, Cheema et al. (2015) reported a relationship between increased levels of impulsivity on an emotional go/no-go task and poorer management of finances in a BD population. Comparisons of compulsive buyers and controls within the general population have shown inconsistent results. There is support from several studies for a relationship between poorer executive function and compulsive buying, specifically for decision-making (Derbyshire et al., 2014; Trotzke et al., 2015), inhibitory control (Arıcan & Kafadar, 2022; Derbyshire et al., 2014; Vogt et al., 2015), working memory (Adams, 2019) and planning (Arican & Kafadar, 2022). However, Vogt et al. (2015) reported no difference between groups for a decision-making task and Trotzke et al. (2015) did not support a relationship between inhibition or planning and compulsive buying. Relationships with pathological gambling and poorer executive function have been supported in the general population, in particular weaker set-shifting ability, difficulty with problem-solving, poorer working memory and higher impulsivity (Marazziti et al., 2008; Zhou et al., 2016).

2.1.1 The present study

The relationship between impulsive spending behaviours and executive function has received little attention in BD, yet impulsive spending behaviours are known to be prevalent and

problematic, and executive function is known to be impaired. This informs the two main aims of this study.

2.1.1.1 Aims and hypotheses

1. The first aim of this study is to investigate whether there is a relationship between executive function and indicators of impulsive spending (compulsive buying, gambling and debt) in BD, and if so, whether any domains of executive function characterise this relationship. The relationship will be examined cross-sectionally and longitudinally.
   Hypothesis 1: Based on previous literature, a relationship between measures of executive function with compulsive buying, gambling or debt was hypothesised at both time points.
   Hypothesis 2: The role of inhibitory control was hypothesised to be of importance to the relationship between executive function and impulsive spending, based on findings by Cheema et al. (2015).
2. The second aim focuses on the longitudinal design of the study, and is to investigate whether executive function or mood differ between people who report an increase in compulsive buying, gambling or debt over a four-week follow-up.
   Hypothesis 3: Due to the reported relationship between mood and anxiety with impulsive spending behaviours, in studies by Richardson et al. (2018) and Varo et al. (2019), it was hypothesised that there would be a difference in mood in people who experience an increase in compulsive buying, gambling or debt, in the month following initial testing.
   Hypothesis 4: It was further hypothesised that there would be a difference in executive function between people with and without increased compulsive buying, gambling or debt during this month.

To the author's knowledge, this is the first study investigating these relationships.

2.2 MATERIALS AND METHODS

2.2.1 Design and participants

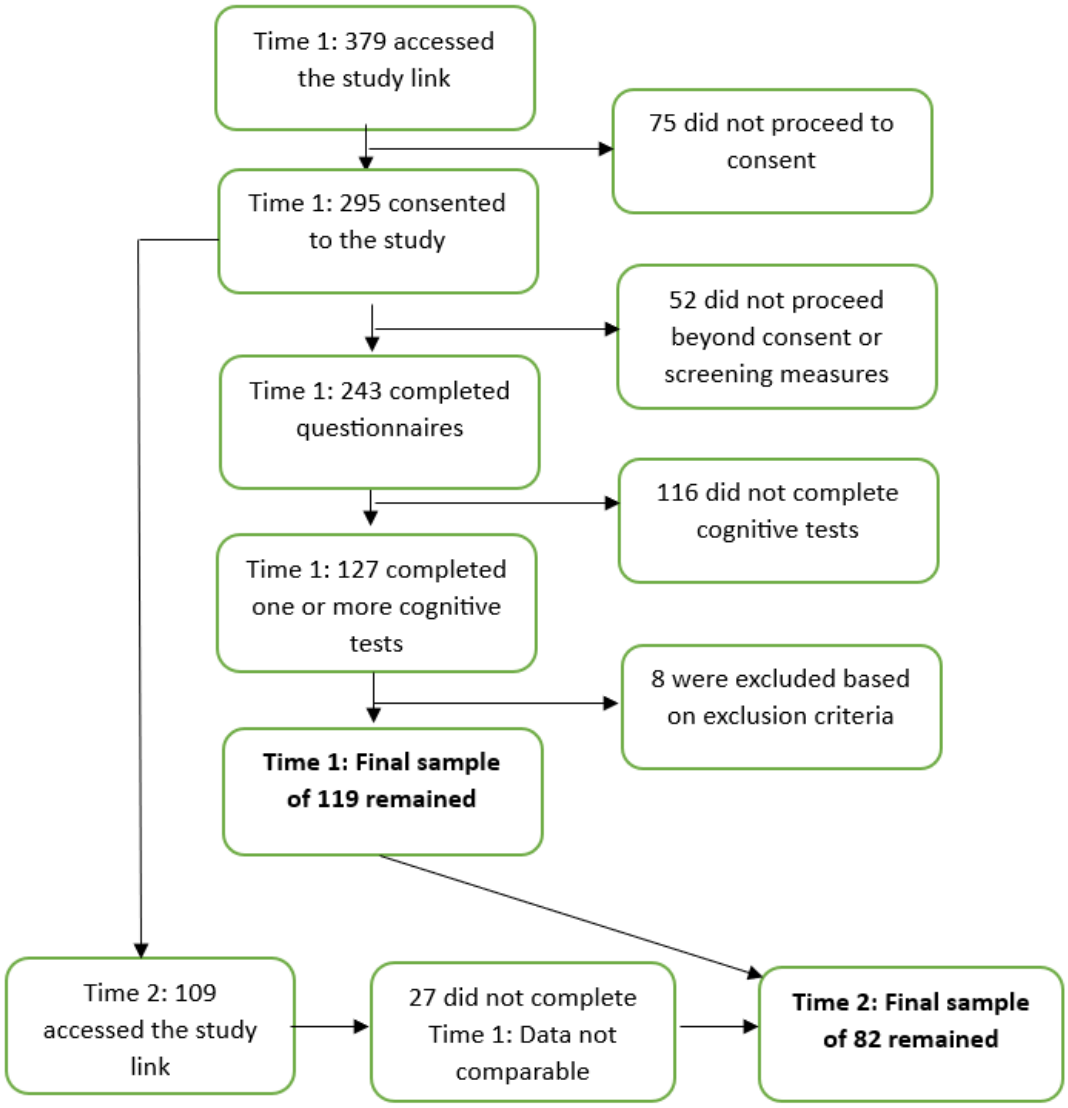
In this longitudinal online study, a sample of 243 participants were recruited internationally (UK: 77% (Appendix H.1: **Table S 1**); White British 74%, (**Table 6**)) via social media (Twitter, Instagram, LinkedIn, TikTok and Facebook), advertising from Bipolar UK, Crest BD, the Money and Mental Health Policy Institute newsletter and Prolific between July 22nd 2023 and November

22nd 2023. Five participants (non-Prolific) were randomly selected to receive an Amazon voucher. Participants recruited via Prolific (*n* = 33) were paid at both time-points.

Inclusion criteria were: 1) self-reported diagnosis of BD by a mental health professional; 2) aged 18+; 3) English as first language (due to the cognitive tests used) and 4) capacity to give informed consent (assumed in the absence of conditions outlined in the exclusion criteria that affect the functioning of the brain). Exclusion criteria were: 1) diagnosis of cyclothymia; 2) diagnosis of or current investigation for a neurodegenerative disease of the brain; 3) uncorrected visual impairments likely to affect test results, or 4) intellectual or cognitive disability. Financial difficulty was not a requirement of participation. Participants were excluded as follows: four without English as a first language; two with significant uncorrected visual impairment; one with a brain injury affecting cognition and one due to self-diagnosis of BD. Participants were included in analysis if they completed at least one cognitive test at Time 1. Participants who completed questionnaires only were subsequently excluded from the study (**Figure 6**). A final sample of 119 remained at Time 1, and 82 at Time 2.

Figure 6

Participant flow diagram



A sample size of at least 112 was targeted, from a G*Power version 3.1 (Faul et al., 2009) calculation based on the assumption of a medium effect size (from similar studies in the general population, e.g. (Arican & Kafadar, 2022)) of R^2 = 0.13 and power at 0.8 (Cohen, 1988) to test a two-tailed hypothesis with an estimated eight predictors (with expectations of confounding demographic/clinical characteristics, mood variables and measures of executive function).

The study was approved by the University of Southampton ethics committee (ERGO-ID:79095) prior to commencement. Participants read a detailed study description and gave informed consent (via an online form) prior to participating (Appendices C and D).

Patient Public Involvement (PPI) aided the study design. A focus group, advertised on social media (Twitter and Facebook), was held for one hour, with eight people with a diagnosis of BD, to discuss the measures and procedure. Changes to the study design and author-constructed financial questionnaire were made accordingly. The final study procedure was piloted on four acquaintances of the author, resulting in slight amendments.

2.2.2 Measurement of mood and current clinical presentation

Author-constructed demographic and screening questionnaire

An author-constructed questionnaire was used to gather demographic and eligibility information and to allow the consideration of clinical and confounding variables (Appendix E).

The Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2001)

A self-rated, widely used 9-item clinical measurement of depression. It scores each of the nine DSM-IV criteria on a 4-point Likert scale, ranging from 0 (Not at all) to 3 (Nearly every day). Sensitivity and specificity are both reported at 88% when using a cut-off score of ≥10 (Kroenke et al., 2001). Internal consistency in the current sample at baseline was excellent, α = .93.

The Patient Mania Questionnaire (PMQ-9) (Cerimele et al., 2022)

A self-rated, 9-item questionnaire designed to assess mania symptoms. It is recently developed and designed to be used alongside the PHQ-9, with the same Likert scale, in the clinical assessment and monitoring of mood symptoms in patients with BD. High manic symptom burden is considered to be a score of ≥10, although more research is required to determine construct and criterion validity. In the current sample at baseline, α =.91.

The Generalized Anxiety Disorder (GAD-7) (Spitzer et al., 2006)

A 7-item anxiety scale, developed as a brief, self-reported clinical measure to assess Generalised Anxiety Disorder (Spitzer et al., 2006). It uses the same Likert scale as the PHQ-9 and PMQ-9. A score of ≥10 indicates GAD, with 89% sensitivity and 82% specificity. In the current sample at baseline, α = .93.

2.2.3 Measurement of impulsive spending behaviours

The Compulsive Buying Scale (CBS) (Valance et al., 1988)

An 11-item measure with a 5-point Likert scale to assess compulsive buying habits, with a cut-off total of ≥36 indicating problematic compulsive buying. In the current sample at baseline, α = .93.

The South Oaks Gambling Scale (SOGS) (Lesieur & Blume, 1993)

20 problem items are identified on the SOGS, with a sum of ≥5 from these items indicating probable pathological gambling. In the current sample at baseline, α = .93 for problem items.

Author-constructed financial, compulsive buying and gambling questions

A questionnaire regarding participant finances and debt (developed with PPI), including loan details and amount of debt from different sources (excluding mortgage and student loan). Five-point Likert scales measured whether participants felt they lived within their means generally and over the past month. Six-point Likert scales were used to measure occurrence and frequency of, and amount of money spent on compulsive buying and gambling habits over the past month (Appendix F).

2.2.4 Measurement of executive function

The Stroop Task (Stroop, 1935) by Millisecond Software (2022)

The task presents a colour name (e.g. blue) printed in different colour ink. Participants indicate the ink colour and not its meaning; presentations are either congruent or incongruent. Accurate performance results from successful selective inhibition, which has a dampening effect on the automatic activation produced by word-reading (Khng & Lee, 2014). The variables used for this task were total errors, mean response latency (ms) and the difference between incongruent and congruent errors.

Corsi Block Tapping Task Forwards and Backwards (Kessels et al., 2000) by Millisecond Software (2022)

Corsi-Forwards measures simple item span by recall of sequences of illuminated squares. Corsi-Backwards measures working memory capacity, requiring manipulation of the sequence by recalling it in reverse. Variables produced for the forwards and backwards tasks individually are block span (the number of illuminated squares correctly recalled), total score (summary score as proposed by Kessels et al. (2000): block span*number of correctly recalled sequences) and mean response latency (ms).

Trail Making Test (A and B) (Armitage, 1946; Reitan, 1955) by Millisecond Software (2022)

This test is in two parts; Part A requires sequencing of numbered circles, measuring motor speed and information processing speed. Part B requires alternation between numbered and lettered circles, adding a measurement of set-shifting. Variables used were the difference between completion times (Part B - Part A) and the difference between errors (errors made on

Part B – errors made on Part A); use of these variables is recommended to measure central executive functioning (McMorris, 2016).

Iowa Gambling Task (Bechara et al., 1994) by Millisecond Software (2022)

This task is considered to be a measure of decision-making and risk-taking processes, although some research has suggested higher involvement from attentional systems (Gansler et al., 2011). Participants are presented with four decks of cards and are required to make 100 choices from these decks, which result in gaining or losing fictional money. Two decks are generally advantageous and two are generally disadvantageous (unbeknownst to the participant). Variables used were 'number of advantageous picks – number of disadvantageous picks' (Bechara et al., 1994), mean response latency (ms), mean gain, mean loss, mean total and final total.

Tower of London Task (Anderson et al., 1996; Krikorian et al., 1994; Shallice et al., 1982) by Millisecond Software (2022)

This task measures different levels of planning (Georgiou et al., 2017). Participants are required to rearrange displays of coloured balls on poles, according to rules, to copy a 'target arrangement' in as few moves as possible. Variables used were total score, mean initiation time (the time it took for participants to take their first move) (ms), mean number of problem attempts and mean solution time (time elapsed between starting and ending a problem) (ms).

2.2.5 Procedure

Participants completed the online questionnaires and rating scales (using Qualtrics, Provo, UT) in a randomised order, followed by computerised tests of executive function (Inquisit Web 6.6.1, 2022). Time 2 follow-up included the PHQ-9, PMQ-9, GAD-7, CBS, SOGS and author-constructed questionnaire.

2.2.6 Statistical Analysis

Data was analysed using Statistical Package for Social Sciences (SPSS) software, version 28.1.1.0 (IBMCorp., 2021). Missing data was not substituted; this was deemed inappropriate due to measurement of different facets of executive function.

Measures were assessed for normal distribution, (defined by kurtosis and skewness within the -2 to +2 range). Univariate and bivariate outliers were identified and deleted where values were >3 SDs from the mean, and were deemed implausible (likely due to poor effort or technical difficulties with the computer software). Corsi-Backwards results were '0' in 23 cases,

where participants did not follow reverse sequencing rules. This data was excluded from analysis.

Relationships between executive function, mood, compulsive buying and demographic variables were analysed with bivariate Pearson's or Spearman's correlation (as appropriate). The South Oaks Gambling Scale Problem Total was unsuitable for correlation analysis due to floor effects. Dichotomous classification of 'Pathological Gambler (total problem items ≥5) /Not' was therefore used. Relationships between pairs of dichotomous variables were analysed using Chi-Square. MANOVAs were used to examine differences in mood scores (anxiety, depression and mania) grouped by primary dichotomous variables of interest (SOGS Pathological Gambler/Not and Total Debt High/Low [split by median; Time 1: Low < $3236.50 < High, Time 2: Low < $2687.00 < High]). Further MANOVAs were planned to examine differences in executive function scores between these groups, but due to multiple violations of assumptions (multicollinearity, missing data, a high number of variables) independent samples t-tests were used for normally distributed variables. For non-parametric data, bootstrapping was used when examining Level of Debt, and Mann Whitney U tests when examining differences between Pathological/Non Pathological Gamblers (due to small sample size). The significance level was $p < .05$.

Relevant predictors, assessed by statistical significance (as in Aminoff et al. (2013)), were entered into multiple hierarchical regression models (linear or binary logistic as appropriate) to predict impulsive spending measures. The difference in reported debt was calculated between Times 1 and 2, and participants were classified dichotomously as Debt Increase or Debt Decrease/Stable. Participants reported compulsive buying or gambling to be more or less frequent at Time 2, and were classified dichotomously as Better/Stable or Worse. The difference in executive function (from Time 1) and mood at Time 2 was subsequently examined using independent t-tests or Mann Whitney U tests, using Bonferroni correction. MANOVAs were used to examine difference in mood variables at Time 2 between: 1) participants reporting worse compulsive buying and better/stable compulsive buying over the past month 2) worse gambling and better/stable gambling and 3) an increase in debt and a decrease in/stable level of debt. All analyses were two-tailed.

2.3 RESULTS

2.3.1 Demographic and clinical characteristics

Demographic and clinical characteristics are displayed in **Table 6**. Of the 119 participants at Time 1, over three-quarters were female, with BD diagnosis most commonly given by a

Psychiatrist. Nearly half of the sample had a comorbid mental health or personality disorder diagnosis and over half were under the care of a mental health team. Over a quarter of the sample previously used recreational drugs and over 1 in 10 reported current use of recreational drugs. One hundred percent of the sample were currently taking psychiatric medication.

Table 6

Demographic and clinical characteristics of the sample at Time 1: Means (M), standard deviations (SD) or population size (N) and corresponding percentages (%)

Continuous variable	***M***	***SD***
Age (*n* = 119)	38.29	10.92
Number of years diagnosed (*n*=117)	9.45	8.31
Categorical variable	***N***	**%**
Gender (male/female/non-binary)	22/94/3	18.5/79/2.5
Ethnicity:		
Asian (British/Indian/Other)	5	4.2
Black (British/African/Caribbean/Other)	4	3.3
Mixed or Multiple Ethnic Groups	8	6.7
White British	88	73.9
White: Any other White Background	9	7.5
Other Ethnic Group	4	3.3
Undisclosed	1	0.8
Bipolar Type (i/ii/unknown)	30/58/31	25.2/48.7/26.1
Diagnosed by (Psychiatrist/Psychologist/GP/Other Mental Health Professional)	103/11/15/12	86.6/9.2/12.6/12
Current recreational drug use (yes)	14	11.8
Previous recreational drug use (yes)	39	32.8
Currently taking medication (yes)	119	100.0
Under care of Mental Health team (yes)	78	65.5
Other Mental Health/Personality Disorder (yes)	53	44.5
Sleep Disorder	10	8.4
ADHD/ASC/Tics	13/10/1	10.9/8.4/0.8

2.3.2 Impulsive spending measures and executive function tests

Table 7 displays information regarding mood and impulsive spending measures. Mean scores and standard deviations of executive function measures are presented in **Table 8**.

Table 7

Mood and impulsive spending measures from times 1 and 2: Means (M), standard deviations (SD) or number of participants (N) and corresponding percentages (%)

Mood or Impulsive Spending Measure	Time 1 *M*/n	Time 1 *SD*/%	Time 2 *M/n*	Time 2 *SD*/%
Mood:				
PMQ-9 Score (*M, SD)*	8.13	6.53	8.29	5.95
GAD-7 Score (*M, SD)*	10.31	6.12	9.16	6.07
PHQ-9 Score (*M, SD)*	12.47	7.85	11.97	7.24
Compulsive Buying:				
CBS Total Score (*M, SD)*	42.34	10.56	41.00	10.88
CBS Criteria Met (Yes/No, *n*, %)	95/23	80.5/19.5	61/20	75.3/24.7
†Compulsive Spending Irresistible Past Month (Yes/No *n*, %)	68/39	57.6/33.1	46/29	57.5/36.3
†Compulsive Spending Emotional/Mentally Unwell Past Month (Yes/No, *n*, %)	68/40	57.1/33.6	46/31	38.7/26.1
†Compulsive Spending: Amount Spent Past Month ($) (*M, SD*)	889.70	1126.43	744.75	1463.90
Gambling:				
SOGS Problem Total (*M, SD*)	2.29	3.92	2.96	4.17
SOGS Pathological Gambler Criteria Met (Yes/No, *n*, %)	24/95	20.2/79.8	17/63	21.8/78.8

†Gambled in the past month (Yes/No, *n*, %)	34/83	28.6/69.7	27/52	33.8/65.0
†Gambling: Amount Spent Past Month ($) (*M, SD)*	185.59	357.00	187.59	390.75
Debt:				
†Total Debt ($)	13,651.15	25,456.97	12,386.86	27,296.31
†No debt (*n,* %)	27	23	20	25
†Debt < $1000 (*n,* %)	42	36	29	36

Note: PMQ: Time 1: *n* = 118, Time 2: n = 80, GAD-7: Time 1: *n* = 82, PHQ-9: Time 1: *n* = 118, Time 2: *n* = 80, Compulsive Buying Scale (CBS) Time 1: *n* = 118, Time 2: *n* = 81, 'CBS Total Score' = Compulsive Buying Scale Total Score, 'CBS Criteria Met' = Criteria for problematic compulsive buying met (score ≥ 36/55), South Oaks Gambling Scale (SOGS) Time 1: *n* = 119, Time 2: *n* = 80, 'SOGS Pathological Gambler Criteria Met' = total score on problem items ≥ 5. 'Total Debt': Time 1: *n* = 118, Time 2: *n* = 81, debt includes total amount owed on loans, credit cards and overdraft (excluding mortgage and student loan). Compulsive Buying Amount Spent Past Month (Time 1: *n* = 81, Time 2: *n* = 56), Gambling Amount Spent Over Past Month: (Time 1: *n* = 34, Time 2: *n* = 27). Unaccounted for *n* in 'yes/no' questions are due to responses of 'unsure'.

†Information obtained from author-constructed Financial Questionnaire

Table 8

Means (M) and standard deviations (SD) resulting from executive function tests, and population (N) for each measure

Executive Function Measure	*M*	*SD*	*N*
Stroop Total Errors	3.58	4.46	110
Stroop Mean Response Latency (ms)	1484.86	518.11	109
Stroop Correct Congruent	27.66	0.62	110
Stroop Correct Incongruent	25.35	3.30	109
Stroop Difference Between Congruent and Incongruent Responses	2.32	3.16	109
Corsi-Forwards Block Span	5.81	1.02	107
Corsi-Forwards Total Score	48.84	17.40	107
Corsi-Forwards Mean Response Latency (ms)	855.80	304.83	105
Corsi-Backwards Block Span	5.66	1.04	87
Corsi-Backwards Total Score	46.70	18.45	87
Corsi-Backwards Mean Response Latency (ms)	710.72	254.42	87
Iowa Gambling Mean Response Latency (ms)	769.29	263.62	108
Iowa Gambling Mean Gain	77.17	9.05	110
Iowa Gambling Mean Loss	81.04	17.83	110
Iowa Gambling Mean Total	1631.53	441.01	110
Iowa Gambling Final Total	1614.83	951.37	110
Iowa Gambling Advantageous Deck Choices-Disadvantageous Deck Choices	-8.63	36.54	110
Trails A Number of Errors	1.17	1.41	100
Trails A Total Time (ms)	54699.28	25758.82	100
Trails B Number of Errors	2.45	2.51	100

Executive Function Measure	*M*	*SD*	*N*
Trails B Total Time (ms)	72698.86	32880.92	100
Trails Errors Difference (B-A)	1.27	2.49	97
Trails Time Difference (B-A) (ms)	17381.82	12984.00	97
Tower of London Mean No. of Problem Attempts	1.33	0.17	105
Tower of London Total Score	29.11	5.06	105
Tower of London Initiation Time (ms)	8061.49	3835.84	106
Tower of London Mean Solution Time (ms)	15321.29	5421.17	106

2.3.3 Aim 1: The relationship between executive function and impulsive spending behaviours (compulsive buying, gambling and debt) at two time-points

Hypotheses 1 and 2: Compulsive buying at time 1

Significant negative correlations were revealed at Time 1 between executive function measures Corsi-Backwards (Corsi B) Mean Latency Time (r (84) = -.24, p = .03, 95% C.I. [-0.44, -0.03]), Tower of London (ToL): Initiation Time (r (104) = -.31 , p = .001, 95% C.I. [-0.47, -0.12]) and ToL Total Solution Time (r (104) = -.24, p = .01, 95% C.I. [-0.42, -0.06]) and the total score on the Compulsive Buying Scale (CBS score) (Appendix H.2: **Table S 2**), indicating that those with higher CBS scores took less time to respond to or complete these measures. CBS score significantly positively correlated with all three measures of mood (PMQ: r (116) = .36, p < .001, 95% C.I. [0.19, 0.51]; GAD-7: r (116) = .34, p < .001, 95% C.I. [0.17, 0.49]; PHQ-9: r (116) = .37, p < .001, 95% C.I. [0.21, 0.52]), indicating greater anxiety, depression and mania alongside higher CBS scores. There was a significant negative correlation between CBS score and the number of years since diagnosis and therefore, a shorter time since diagnosis was related to greater impulsive spending scores (r (114) = -.22, p = .017, 95% C.I. [-1.0, -0.07]).

Table 9 displays results of hierarchical multiple linear regression using blockwise methods to enter significant variables to predict CBS score, controlling for 'years since diagnosis' and PMQ-9, GAD-7 and PHQ-9 scores, to finally examine the contribution of significant executive function measures. Due to high correlation between ToL: Initiation Time and ToL: Total Solution Time, r (104) = .80, p = < .001, 95% C.I. [0.72, 0.86], and therefore violation of the assumption of no multicollinearity, the most significant correlation with CBS score (ToL: Initiation Time) was used for further analysis. Assumptions of linear regression were met. The two executive function measures predicted CBS score, explaining a significant proportion of variance (13%) over and above mood variables and the number of years since diagnosis, with 34% of the variance in CBS score accounted for by the model.

Hypotheses 1 and 2: Compulsive buying at time 2

Variables found to predict compulsive buying at Time 1 were entered into a hierarchical linear regression model to predict compulsive buying at Time 2, controlling for mood scores from Time 2 (**Table 9**), with assumptions of regression met. The same executive function variables significantly correlated with CBS Time 2 score. Executive function at Time 1 was found to predict CBS score one month later, when current mood was controlled for, explaining 15% of the

variance over and above other variables, with 33% of the variance in CBS score accounted for by the model.

Table 9

Hierarchical linear regression models predicting Compulsive Buying Scale total at times 1 and 2

	Final Model						Summary Model			
Variables	**β**	**β *SE***	**β**	***t***	***sr²***	**Coeff.*p***	***R²***	***Δ R²***	***SE***	***p***
DV: CBS Score										
Time 1 (*n* = 81)										
Block 1:							**.02**	**.02**	**10.88**	**.19**
No. Yrs. Diagnosed	0.02	0.14	0.02	0.16	0.00	.87				
Block 2:							**.21**	**.19**	**9.97**	**<.001**
T1 PMQ-9	0.26	0.21	0.16	1.20	0.01	.23				
T1 GAD-7	0.28	0.28	0.16	1.01	0.01	.32				
T1 PHQ-9	0.16	0.23	0.11	0.68	0.00	.50				
Block 3:							**.34**	**.13**	**9.22**	**.001**
Corsi B: Mean Latency Time	-0.01	0.01	-0.13	-1.15	-0.01	.25				
ToL: Initiation Time	-0.00	0.00	-0.32	-3.10	-0.09	.003				
Time 2 (*n* = 62)										
Block 1:							**.12**	**.12**	**10.64**	**.005**
No. of Yrs. Diagnosed	-0.30	0.19	-0.20	-1.60	-0.03	.16				
Block 2:							**.18**	**.06**	**10.53**	**.24**
T2 PMQ-9	0.03	0.26	0.02	0.10	0.00	.92				
T2 GAD-7	0.59	0.35	0.27	1.42	0.02	.16				
T2 PHQ-9	-0.23	0.30	-0.15	-0.78	-0.01	.44				

	Final Model						Summary Model			
Variables	**β**	**β *SE***	**β**	***t***	***sr²***	**Coeff.*p***	***R²***	***Δ R²***	***SE***	***p***
Block 3:							**.33**	**.15**	**9.72**	**.005**
Corsi B Mean Latency Time:	-0.01	0.01	-0.23	-1.73	-0.04	.09				
ToL: Initiation Time	-0.00	0.00	-0.27	-2.13	-0.06	.04				

Note: Corsi B = Corsi-Backwards, ToL = Tower of London

Hypotheses 1 and 2: Gambling

Mann Whitney U tests revealed a significant difference between pathological gamblers (PG) and non-pathological gamblers (NPG) for Trail Making Difference in Errors (B-A) (PG: n = 22, Mdn = 0.00, NPG: n = 75, Mdn = 1.00, U (68) = 590.50, p = .040), with a smaller difference in errors for pathological gamblers. T-tests and Mann Whitney U tests did not reveal significant differences on any other measures of executive function between PG (n = 17-23) and NPG (n = 70-87), p > .05. MANOVA did not reveal significant main effects of mood (mania, anxiety or depression) on classification as a pathological gambler (PG: n = 24. NPG: n = 94), using Hotelling's Trace statistic, T = 0.43, F (3,114) = 1.64, p = .18, η_p^2 = .041.

Binary logistic regression was used to explore whether categorisation as a pathological gambler or not on the SOGS was predicted by Trail Making Difference in Errors. The model was not significant: χ^2 (df = 1, n = 97) = 3.53, p = .06, Nagelkerke R^2 = .05, Hosmer and Lemeshow χ^2 (df = 5) = 4.96, p = .42, and therefore executive functioning measures were not found to predict SOGS Pathological Gambling.

Hypotheses 1 and 2: Debt at Time 1

Independent samples t-tests revealed significant differences between high debt (HD) and low debt (LD) for: Corsi-Forwards Mean Response Latency (HD: M = 751.09, LD: M = 903.45, t (50.10) = 2.42, p = .03 , d = 0.57), Corsi-Backwards Mean Response Latency, (HD: M = 612.24, LD: M = 780.10, t (48.16) = 3.20, p = .008, d = 0.76), Tower of London Initiation Time (HD: M = 6848.72, LD: M = 8751.33, t (60.16) = 2.45, p = .017, d = 0.56) and Tower of London Mean Solution Time (HD: M = 13886.65, LD: M = 16755.93, t (89.40) = 2.81, p = .006, d = 0.58). Those with HD were faster to respond, with smaller mean response latencies for each of these variables. There were no other significant differences in executive function between HD and LD (p > .05). MANOVA did

not reveal significant main effects of mood on level of debt (HD: n = 59, LD: n = 59), using Hotelling's Trace statistic, T = 0.18, F (3,114) = 0.70, p = .56, η_p^2 = .018.

Blockwise methods were used to enter variables one-by-one in a binary logistic regression model to predict Level of Debt. Again, due to the high correlation between ToL Initiation Time and Mean Solution Time, the variable with the most significant difference between level of debt was selected for further analysis (Mean Solution Time). The overall model was significant (p = .01), accounting for 17% of the variance in level of debt (Cox & Snell R^2 = .13, Nagelkerke R^2 = .17), with non-significant contributions from each variable in the overall model. Blockwise contributions showed 16% of the variance was accounted for by Corsi-Backwards Mean Response Latency. The model was refit with this variable alone (**Table 10**) and was significant: χ^2 (1,86) = 11.88, p < .001, Cox & Snell R^2 = .13, Nagelkerke R^2 = .17, accounting for 17% of the variation. This indicates that level of debt could be predicted from mean latency on the Corsi-Backwards task in this population. The population value of the odds ratio lies between 0.994 and 0.999 and therefore as Corsi-Backwards Mean Latency Time increases, the odds of high debt decrease.

Hypotheses 1 and 2: Debt at Time 2

Corsi-Backwards Mean Response Latency was entered into a binary logistic regression model to examine whether it could continue to predict Debt at Time 2. The model was not significant (p = .08), with 6% of the variance in level of debt accounted for.

Table 10

Coefficients of the model predicting Level of Debt at Times 1 and 2 (95% BCa bootstrap confidence intervals based on 1000 samples in brackets)

Predictor	*b*	*SE*	Wald	Odds Ratio Exp (*b*)	*p value*	95% CI for Odds Ratio	
						Lower	Upper
Time 1 (*n* =86):							
Constant	2.61 (1.05, 4.79)	0.89	8.56	13.58	.003		
Corsi B: Mean Response Latency	-0.004 (-0.007, -0.002)	0.001	8.34	.996	.004	.994	.999
Time 2 (*n* =66):							
Constant	1.20 (-0.37, 4.30)	0.83	2.11	3.33	.15		
Corsi B: Mean Response Latency	-0.002 (-0.006, 0.00)	0.001	2.70	.998	.10	.996	1.000

Note: Time 1: Assumptions of logistic regression were met; the model was a good fit with no evidence of overdispersion: Hosmer and Lemeshow (χ^2 (8,86) = 2.28, p = .97). The interaction of Corsi B: Mean Response Latency with its logit was non-significant (p >.05)). Inspection of residuals, including Cook's distance, leverage, normalized residuals and DFBeta values indicated no influential cases.

Drop out

No significant differences were found between participants lost to drop out and those who completed Time 2 tests on measures of mood, impulsive buying or executive function measures (Appendix H.3).

2.3.4 Aim 2: Exploring differences in executive function and mood with increased compulsive buying, gambling and debt

Hypothesis 3: MANOVA revealed a significant effect of mood on the difference in self-reported compulsive buying severity between Times 1 and 2, using Hotelling's trace statistic, $T = 0.16$, $F(3, 75) = 4.06$, $p = .01$, $\eta_p^2 = .14$. Univariate tests on GAD-7, PHQ-9 and PMQ-9 showed significant effects of mania (PMQ-9 score) $F(1,77) = 9.29$, $p = .003$, $\eta_p^2 = .11$. Participants reporting better or equivalent compulsive spending over the past month had a lower mania score at Time 2 ($M = 7.23$, $n = 60$) than participants reporting worse compulsive spending over the past month ($M = 11.79$, $n = 19$). Effects of depression (PHQ-9 score) and anxiety (GAD-7 score) on self-reported change in severity of compulsive buying were non-significant, (PHQ-9: $F(1,77) = 0.43$, $p = .052$, $\eta_p^2 = .005$, GAD-7: $F(1,77) = 3.73$, $p = .06$, $\eta_p^2 = .05$).

When examining change in levels of debt (Debt Increase $n = 35$, Debt Decrease/Stable: $n = 44$) and change in self-reported gambling frequency (More Frequent Gambling: $n = 7$, Less Frequent/Equivalent Gambling: $n = 64$), MANOVAs did not reveal significant effects of mood variables, (Levels of Debt: $T = .01$, $F(3, 75) = 0.27$, $p = .85$, $\eta_p^2 = .01$, Gambling frequency: $T = .006$, $F(3, 67) = 0.13$, $p = .94$, $\eta_p^2 = .006$).

Hypothesis 4: Independent t-tests revealed no significant differences between executive function measures for debt change between the two groups (Debt Increase: $n = 25$-35, Debt Decrease/Stable: $n = 38$-46), $p > .05$, or for self-reported change in compulsive buying severity (Compulsive Buying Worse: $n = 15$-20, Compulsive Buying Better or Stable: $n = 41$-59), $p > .05$. T-tests and Mann Whitney U tests did not reveal significant differences in executive function scores between participants who reported an increase in gambling frequency over the past month ($n = 5$-7) and those who reported a decrease in or equivalent gambling frequency ($n = 54$ - 65). The range in n in these comparisons is due to differences in the number of cognitive tests completed between participants. Comparisons are underpowered with only a small number of participants reporting an increase in gambling frequency.

2.4 DISCUSSION

2.4.1 Executive function and impulsive spending

This is the first study to investigate the relationship between measures of executive functioning, mood and impulsive spending in a BD population. The main finding was that quicker response on a working memory task (Corsi-Backwards Block Tapping Task) and spending less time before

initiating the first move on a planning task (Tower of London) predicted higher compulsive buying behaviours at two different time points, one month apart, when controlling for mania, depression, anxiety and number of years since diagnosis. Faster response on a working memory task also predicted level of debt cross-sectionally, supporting a relationship between this measure and impulsive financial behaviours. These findings support a relationship between executive function and measures of impulsive spending (hypothesis 1). The analysis was under-powered longitudinally and the mean level of debt decreased in the four-week follow-up; it was not possible to examine predictors of an increase in spending. Furthermore, against hypotheses (hypothesis 4), no difference was found in executive function scores between people who experienced an increase in compulsive buying, gambling or debt compared to those who did not; these analyses were also underpowered, with a particularly small sample size for participants experiencing an increase in gambling behaviours. Research with a longer follow-up would aid investigation, in addition to recruitment of a larger sample.

As hypothesised, and consistent with Cheema et al. (2015), the executive function measures predictive of impulsive spending were related to inhibitory control (hypothesis 2). 'Initiation time' on the Tower of London task is a specific measure of action planning (Georgiou et al., 2017) and is likely to be heavily influenced by inhibition (Miyake et al., 2000). It follows that response latency on Corsi-Backwards may relate to underlying inhibition. Findings supported a relationship with these measures of inhibition only (and not others, e.g. the Stroop task), contradicting hypotheses of a general relationship with inhibitory control. The tasks which produced problematic inhibitory control in people with higher compulsive buying were those with a higher cognitive load (Sweller, 1988), i.e. Corsi-Backwards but not forwards, and a complex measure of planning on the Tower of London. This pattern may therefore result from an interaction of inhibitory control with working memory processes or high attentional demands. Similar findings, of an association between poorer working memory and poorer self-regulatory behaviours on simulated purchasing tasks were reported in Adams (2019), in the general population.

Other studies examining impulsive buying and executive function in the general population report both contradictory and similar results to this study. Arican and Kafadar (2022) also found significant relationships with Tower of London variables (solution time and total time) and an Impulsive Buying Scale (IBS) (Youn & Faber, 2002); however, participants with higher impulsive buying took longer to complete the Tower of London task and not less time, as this study found. This may suggest differences in the underlying cognitive processes in BD compared to the general population, although both populations require further research. Arican and Kafadar (2022) found a relationship between Stroop scores and IBS scores, which was not found in this study, or in other studies of the general population (Adams, 2019; Black et al.,

2012; Voth et al., 2014). Similar to this study, research examining set-shifting variables (such as Trail Making) has not reported a relationship with compulsive buying (Arican & Kafadar, 2022; Trotzke et al., 2015). This study found no relationship between the Iowa Gambling Task (a measure of decision-making) and measures of impulsive spending. Reports from research in the general population differ; poorer performance from compulsive buyers on the Iowa and Cambridge Gambling Tasks were found in Trotzke et al. (2015) and (Derbyshire et al., 2014). This again suggests a need for further research.

This study did not support a relationship between executive function measures and pathological gambling, which differs from hypotheses (hypothesis 1), and findings in the general population (Marazziti et al., 2008; Zhou et al., 2016). Only 20% of participants were classified as 'pathological gamblers' according to the SOGS, and it was therefore likely that analyses were underpowered. It is also possible that the mechanisms underlying compulsive buying and gambling differ, discussed further below.

2.4.2 Impulsive spending and mood

As hypothesized, it was found that higher levels of depression, anxiety and mania, occurred alongside higher compulsive buying scores (hypothesis 3). This is consistent with Richardson et al. (2018) and suggests that mood plays an important role in compulsive buying. The role of mania was highlighted in this study, with significantly higher mania in participants who reported worse compulsive buying over a one month follow-up compared to those who did not, consistent with Fletcher et al. (2013) and Brozena et al. (2024), who found participants reported frequently over-spending when hypomanic.

Contradicting hypotheses (hypothesis 3), aspects of mood were not found to characterise pathological gambling or level of debt at Time 1. Varo et al. (2019) reported comorbidities of anxiety, (hypo)mania and depression with problem gambling in BD. Findings in the present BD sample do not necessarily contradict comorbid mood symptoms, but suggest that mood symptoms cannot differentiate between pathological and non-pathological gamblers. At follow-up, comparisons could not be made due to few participants reporting a gambling increase. Mood was not found to differentiate participants with 'high debt' from those with 'low debt'. However, different values of debt are potentially significant for different individuals, and most participants were in debt (77% at Time 1). Mood therefore may have exacerbated debt (Richardson et al., 2018) for too many participants in 'low debt' to create distinct mood profiles.

Findings differed for compulsive buying and pathological gambling, suggesting different underlying mechanisms. The profiles of pathological gamblers and compulsive buyers have

been defined as distinct (Granero et al., 2016). Pathological gambling has been reclassified within the 'substance-related and addictive disorders' group in the DSM-5 (APA, 2013). Currently, 'compulsive buying-shopping disorder' features within the coding tool of the ICD-11 for 'other specified impulse control disorders' (Thomas et al., 2023). A review by Fauth-Bühler et al. (2017) reports impulse control disorders to be strongly related to impairment in motor response inhibition, which has an ambiguous relationship with pathological gambling. Conversely, both pathological gambling and compulsive buying have been reported to involve the ventral striatum (Fauth-Bühler et al., 2017; Raab et al., 2011). However, these studies have largely concerned the general population; the interaction of cognition in BD with these behaviours is unknown.

2.4.3 Limitations

This study was exploratory, with a large number of variables. This limited the analysis; when conducting regression models, it is preferable to select variables based on theoretical knowledge or to investigate all variables. However, in the absence of theory, and without a sample size large enough to provide statistical power to investigate all variables, a funnel down approach was used to identify variables of interest. Due to the exploratory nature of the study, the level of significance was not adjusted in accordance with multiple comparisons. The risk of Type 1 errors is therefore acknowledged and this highlights the importance of validating these findings with further research.

The CBS classified 81% of participants in this study as 'Compulsive Buyers'. This is 10 times the number reported by (Kesebir et al., 2012). The number of pathological gamblers was twice as high (20%) as reported in other BD populations (Jones et al., 2015). Although this study requested participants with or without financial difficulties, this presentation may result from opportunistic sampling, which likely attracted participants with a vested interest in this research. Participants in this study were from a range of countries, each of which with its own differing financial context at the time of the study. The wider financial context at the specific time of the study must be borne in mind in the interpretation of these results. These factors, in addition to an absence of verified bipolar disorder diagnosis, are limitations likely to bias the results and limit generalisability. Completing cognitive tests online, rather than face-to-face with a qualified professional, produced limitations; some participants reported software difficulties, others did not follow instructions (resulting in a large number of invalid Corsi-Backwards cases) and participants were relied on to complete the tests alone, in a suitable environment, and make their best effort. It limited the sample to participants who had access to a computer and could navigate the technology, introducing further bias. Nonetheless, online

testing enabled a viable sample size and access to international participants, with further benefits discussed below.

2.4.4 Implications

This study has treatment and intervention implications for people with BD with problematic impulsive spending behaviours, in particular, compulsive buying, and adds to the evidence base that a large number of people with BD experience this problem (Fletcher et al., 2013; Kesebir et al., 2012). Following replicated and more widely generalised findings, screening for the cognitive profile found to predict impulsive spending behaviours (i.e. inhibitory control difficulties on tasks with high cognitive load) may provide useful information early in diagnosis. Cognitive remediation therapy, which has been suggested to be effective in BD (Strawbridge et al., 2021), may be able to target inhibitory control. The importance of tailored intervention for BD patients, rather than generalising from the general population, was highlighted by the qualitative difference in findings from the Tower of London task between Arican and Kafadar (2022) and this study.

Awareness of risk of compulsive spending could result in safeguards such as financial literacy training, tailored psychoeducational family or individual intervention (e.g. (Marone et al., 2022)), or the use of technology as a preventative measure (e.g. (Evans et al., 2020)). This research also found an association of higher levels of anxiety, depression and mania with compulsive buying, supporting the importance of addressing poor mental health in the treatment of compulsive buying, for example with CBT based interventions such as *'Space from Money Worries'* (Richardson et al., 2022).

There are further implications for methods of data collection in BD. Paper and pencil cognitive tests would not have produced the variables predictive of compulsive buying in this study, nor would most neurocognitive assessment batteries for BD, e.g. the International Society for Bipolar Disorders Battery for Assessment of Neurocognition (ISBD-BANC) (Yatham et al., 2010). This supports the use of digitalized cognitive testing to allow more sensitive measurement (Björngrim et al., 2019; Brunetti et al., 2014), with added weight given by the relationship of compulsive buying with similar digital variables in Arican and Kafadar (2022). In future studies, it is recommended that cognitive load and digitalized measures are considered in test selection, to ensure sensitivity to the impairments potentially revealed in this study.

2.5 CONCLUSION

This study suggests that faster response on inhibition tasks with high cognitive load predicts greater compulsive buying behaviours at two time points. There is some evidence for a similar relationship with levels of debt. Executive function did not predict pathological gambling, which may indicate differences in underlying mechanisms between gambling and compulsive buying; further research is needed. There is evidence of a relationship between mood and compulsive buying, with particular implication of mania. Further research is needed to confirm findings and investigate differences between cognitive profiles of compulsive buyers with and without BD.

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Appendix A Systematic Literature Review: Quality Assessment Tool

Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (National Lung, Heart and Blood Institute, 2019, retrieved from https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.

Criteria	Yes	No	Other (CD, NR, NA)*
1. Was the research question or objective in this paper clearly stated?			
2. Was the study population clearly specified and defined?			
3. Was the participation rate of eligible persons at least 50%?			
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?			
5. Was a sample size justification, power description, or variance and effect estimates provided?			
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?			
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?			
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?			

Criteria	Yes	No	Other (CD, NR, NA)*
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?			
10. Was the exposure(s) assessed more than once over time?			
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?			
12. Were the outcome assessors blinded to the exposure status of participants?			
13. Was loss to follow-up after baseline 20% or less?			
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?			

Appendix B Systematic Literature Review: Journal of Affective Disorders: Guidelines for Submission

This paper is prepared for submission to the Journal of Affective Disorders. Below are submission guidelines for authors. See: https://www.sciencedirect.com/journal/journal-of-affective-disorders/publish/guide-for-authors

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http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ (accessed 13 March 2003).

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Appendix C Empirical Paper: Participant Information Sheets

C.1 Non-Prolific Version

Participant Information Sheet

Study Title: Does Executive Function Predict Impulsive Financial Behaviours in Bipolar Disorder?

Researcher: Hannah Coman h.k.coman@soton.ac.uk

ERGO number: 79095

You are being invited to take part in the above research study. To help you decide whether you would like to take part or not, it is important that you understand why the research is being done and what it will involve. Please read the information below carefully and ask questions if anything is not clear or you would like more information before you decide to take part in this research. You may like to discuss it with others but it is up to you to decide whether or not to take part. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

This is a doctoral project as part of the Doctorate in Clinical Psychology (DClinPsy). I am interested in conducting research that combines mental health conditions with knowledge about the brain and how it works, to contribute towards developing practical interventions.

This research is examining impulsive spending behaviour in people diagnosed with bipolar disorder and how this relates to a certain aspect of brain function, called executive function. Executive function involves the front part of your brain and is an umbrella term for a collection of abilities including working memory (being able to hold information in mind and do something with

it), monitoring (keeping track of what you are doing) and being able to inhibit (stop yourself doing something). It can also involve planning, organisation and decision-making.

Looking at adults who have been diagnosed with bipolar disorder only, the study aims to find out if there is a relationship between a person's score on tasks that measure different parts of executive function and the likelihood that someone will spend money impulsively. Spending money impulsively can cause lots of problems, such as bankruptcy or relationship break downs and can impact your mental health. If scores on executive function tests can help to tell us who is most likely to end up spending money impulsively, then something could be done to prevent this from happening. This could include doing some psychological work with someone and raising their awareness of the problem, or it could include practical intervention involving their bank.

To add to the understanding of this issue, the study also aims to find out whether executive function differs between mood states (i.e. euthymic, manic/hypo, mixed or depressed) and if so, whether this has an effect on any relationship between executive function and impulsive spending. Lastly, the study aims to find whether there is a difference on tests of executive function between individuals who have an increase in compulsive buying, gambling or debt a month after being tested compared to those who do not.

The study is funded by the University of Southampton.

Why have I been asked to participate?

You have been approached to take part in the study as you are an adult who has a diagnosis of bipolar disorder. At least 140 adults with a diagnosis of bipolar disorder are needed for the study.

Who is eligible to take part?

To be eligible for the study:

- Have a diagnosis of bipolar disorder
- Be 18 years of age or older
- Speak English as a first language

You would **not** be eligible for the study if you:

- Have a diagnosis of Cyclothymia
- Have a diagnosis of or are under investigation for a neurodegenerative disease of the brain (due to the effects on tests of cognitive function).
- Have an acquired brain injury (including stroke or brain tumour) that you believe to affect your cognitive function (e.g. your attention, concentration, speed of processing information, or memory).
- Have significant visual or hearing difficulties that cannot be corrected, for example with glasses or hearing aids (due to the effects on tests of cognitive function).

Please do not proceed with the study if you are not eligible. If you have any doubts or questions and would like to discuss these, please email the researcher (details at the top of this page).

What will happen to me if I take part?

The study is all online and asks for you to participate at two different time points, one month apart.

At time point one:

1. You will be asked to complete three short questionnaires regarding demographic and health information, the amount of alcohol you drink, and traits of bipolar disorder. These questionnaires will take around **10 minutes** to complete and are to enable data comparison within subsets of the population and are to confirm eligibility for the study.

   The eligibility criteria are detailed above. If you are deemed ineligible from the results of these questionnaires, your data will be excluded from the study.

2. Main Study Questionnaires: These are scales and questions regarding your mood, spending habits and finances. These will take around **15 minutes** to complete.

3. Executive Function tests: You will also be sent a link to complete online tests of Executive Function. It's really important to complete these on your own with no disturbances. There are five of these to complete, ranging from two minutes to ten minutes in duration. Overall, this section will take around **50 minutes** to complete (allowing for reading time).

You may be asked to complete Main Study Questionnaires and Executive Function tests in either order, but you do not have to complete them in one sitting. You may have a break of up to 24 hours between completing the Main Study Questionnaires and Executive Function tests.

At time point two (one month later)

1. Main Study Questionnaires: You will be asked to repeat the four short questionnaires again (regarding mood, spending habits and finances), but not the tests of Executive Function.

Questionnaires at time point two are likely to take around **15 minutes** to complete.

Are there any benefits in my taking part?

Five people will be randomly selected to receive £50 in Amazon vouchers as a thank you for taking part in the study. Taking part has no other direct benefits to you, but the research findings will contribute to our understanding of bipolar disorder and it is possible that interventions to prevent or reduce risky spending behaviour will be developed as a result of the study.

Are there any risks involved?

There are no physical risks during this research. It is possible that you may feel some level of psychological discomfort or distress when answering personal questions about topics that can be understandably sensitive for some people, such as your substance use, medical history or finances. If you become concerned as a result of taking part in this study, you may wish to seek help from the following charities:

Mind: www.mind.org.uk

Gamblers Anonymous: www.gamblersanonymous.org.uk

Alcoholics Anonymous: www.alcoholics-anonymous.org.uk

It is also possible that you may experience some level of psychological discomfort when completing tests of Executive Function; the tests are not designed to be distressing, but it is possible to feel anxiety regarding your performance.

This study is for research purposes only and no clinical interpretation of test results will be made. No feedback regarding performance will be provided to any individual. If you are concerned about your performance on these tests, it is recommended that you seek advice from your GP. It is worth noting however, that such tests are designed to challenge you in order to measure performance.

What data will be collected?

All data will be collected online and will consist of your responses to questionnaire items or scores assigned by computer software, based on your performance on tests of Executive Function. Demographic information collected will include some special category data under Article 9 of GDPR, as information regarding a health diagnosis and information regarding ethnicity is asked for. This information is required as it is essential for the purpose of the research that participants have a diagnosis of bipolar disorder. Ethnicity provides important contextual information for performance on tests of executive function and may be controlled for as part of data analysis.

Research data will be digital and stored on the University's networked storage, in accordance with University of Southampton regulations. Data will be encrypted/password protected when being stored or transferred. It will be kept on University networks only and will not be stored locally. Should any data require transferring, this will not be done via email, rather the University's secure system 'SafeSend' will be used. Data will be stored and used in accordance with GDPR law. At the end of the research project, data will be stored in a discipline specialist data repository.

ID numbers will be used in place of participant names on databases containing test scores and survey results; names and email addresses (needed for one month follow up contact of participants) will be stored separately.

Will my participation be confidential?

Your participation and the information we collect about you during the course of the research will be kept strictly confidential.

Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

Do I have to take part?

No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to sign a consent form to show you have agreed to take part. Consent will be requested online prior to the collection of eligibility information and will be asked for again, prior to completing online questionnaires and tests of executive function.

What happens if I change my mind?

You have the right to change your mind and withdraw at any time without giving a reason and without your participant rights being affected.

If you wish to withdraw from the study at any time, please contact the researcher and provide your participant number, stating whether you wish to discontinue participation only or whether you would like all information already obtained from you to be removed from the study.

What will happen to the results of the research?

The project will be written up as part of the qualification requirements for the DClinPsy at the University of Southampton. It is also likely to be submitted with the aim of publication in an

academic journal. Participants will be not routinely receive a copy of the results as email addresses will not be stored once data is collected and Amazon vouchers have been distributed. However, participants may indicate on the Debriefing Form following completion of the study if they would like to receive a copy of the thesis.

Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent.

At the end of the research project, all data with the exception of names and email addresses will be stored in a discipline specialist data repository, and therefore anonymized data is publicly available. Under the University of Southampton Research Data Management Policy, this is for a minimum of 10 years.

If you have any concerns about the storage of your data, please contact the researcher (Hannah Coman).

Where can I get more information?

If you have any questions after reading this information sheet, please contact the researcher (Hannah Coman).

What happens if there is a problem?

If you have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions.

If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Head of Ethics and Clinical Governance. (023 8059 5058, rgoinfo@soton.ac.uk).

Data Protection Privacy Notice

The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team if you have any questions or are unclear what data is being collected about you.

Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at

http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. The University of Southampton will keep identifiable information about you for 10 years after the study has finished after which time any link between you and your information will be removed.

To safeguard your rights, we will use the minimum personal data necessary to achieve our research study objectives. Your data protection rights – such as to access, change, or transfer such information - may be limited, however, in order for the research output to be reliable and accurate. The University will not do anything with your personal data that you would not reasonably expect.

If you have any questions about how your personal data is used, or wish to exercise any of your rights, please consult the University's data protection webpage (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page) where you can make a request using our online form. If you need further assistance, please contact the University's Data Protection Officer (data.protection@soton.ac.uk).

Thank you for taking the time to read this information sheet and for considering taking part in the research.

C.2 Prolific Version

Participant Information Sheet (Prolific Version)

Study Title: Does Executive Function Predict Impulsive Financial Behaviours in Bipolar Disorder?

Researchers: Hannah Coman h.k.coman@soton.ac.uk

Thomas Richardson t.h.richardson@soton.ac.uk

Warren Dunger w.n.dunger@soton.ac.uk

ERGO Number: 79095

You are being invited to take part in the above research study. To help you decide whether you would like to take part or not, it is important that you understand why the research is being done and what it will involve. Please read the information below carefully and ask questions if anything is not clear or you would like more information before you decide to take part in this research. You may like to discuss it with others but it is up to you to decide whether or not to take part. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

This is a doctoral project as part of the Doctorate in Clinical Psychology (DClinPsy). I am interested in conducting research that combines mental health conditions with knowledge about the brain and how it works, to contribute towards developing practical interventions.

This research is examining impulsive spending behaviour in people diagnosed with bipolar disorder and how this relates to a certain aspect of brain function, called executive function. Executive function involves the front part of your brain and is an umbrella term for a collection of abilities including working memory (being able to hold information in mind and do something with it), monitoring (keeping track of what you are doing) and being able to inhibit (stop yourself doing something). It can also involve planning, organisation and decision-making.

Looking at adults who have been diagnosed with bipolar disorder only, the study aims to find out if there is a relationship between a person's score on tasks that measure different parts of executive function and the likelihood that someone will spend money impulsively. Spending money impulsively can cause lots of problems, such as bankruptcy or relationship break downs and can impact your mental health. If scores on executive function tests can help to tell us who is most likely to end up spending money impulsively, then something could be done to prevent this from happening. This could include doing some psychological work with someone and raising their awareness of the problem, or it could include practical intervention involving their bank.

To add to the understanding of this issue, the study also aims to find out whether executive function has a relationship with mood state or anxiety in a bipolar disorder population, and if so, whether this has an effect on any relationship between executive function and impulsive spending. Lastly, the study aims to find whether there is a difference on tests of executive function between individuals who have an increase in compulsive buying, gambling or debt a month after being tested compared to those who do not.

The study is funded by the University of Southampton.

Why have I been asked to participate?

You have been approached to take part in the study as you are an adult who has a diagnosis of bipolar disorder. At least 140 adults with a diagnosis of bipolar disorder are needed for the study.

Who is eligible to take part?

To be eligible for the study:

- Have a diagnosis of bipolar disorder
- Be 18 years of age or older
- Speak English as a first language

You would **not** be eligible for the study if you:

- Have a diagnosis of Cyclothymia
- Have a diagnosis of or are under investigation for a neurodegenerative disease of the brain (due to the effects on tests of cognitive function).
- Have an acquired brain injury (including stroke or brain tumour) that you believe to affect your cognitive function (e.g. your attention, concentration, speed of processing information, or memory).
- Have significant visual or hearing difficulties that cannot be corrected, for example with glasses or hearing aids (due to the effects on tests of cognitive function).

Please do not proceed with the study if you are not eligible. If you have any doubts or questions and would like to discuss these, please email the researcher (details at the top of this page).

What will happen to me if I take part?

The study is all online and asks for you to participate at two different time points, one month apart.

At time point one:

4. You will be asked to complete three short questionnaires regarding demographic and health information, the amount of alcohol you drink, and traits of bipolar disorder. These questionnaires will take around **10 minutes** to complete and are to enable data comparison within subsets of the population and are to confirm eligibility for the study.

   The eligibility criteria are detailed above. If you are deemed ineligible from the results of these questionnaires, your data will be excluded from the study.

5. Main Study Questionnaires: These are scales and questions regarding your mood, spending habits and finances. These will take around **15 minutes** to complete.

6. Executive Function tests: You will also be sent a link to complete online tests of Executive Function. It's really important to complete these on your own with no disturbances. There are five of these to complete, ranging from two minutes to ten minutes in duration. Overall, this section will take around **40 minutes** to complete (allowing for reading time).

You may be asked to complete Main Study Questionnaires and Executive Function tests in either order, but you do not have to complete them in one sitting. You may have a break of up to 24 hours between completing the Main Study Questionnaires and Executive Function tests.

At time point two (one month later)

2. Main Study Questionnaires: You will be asked to repeat the short questionnaires again (regarding mood, spending habits and finances), but not the tests of Executive Function.

Questionnaires at time point two are likely to take around **15 minutes** to complete.

Are there any benefits in my taking part?

The research findings will contribute to our understanding of bipolar disorder and it is possible that interventions to prevent or reduce risky spending behaviour will be developed as a result of the study.

In line with Prolific's policies you will be paid for your time.

How will I be paid?

All payments will be made through Prolific.

Payment requirements

Session	**What I need to do to get paid?**	**Pay per hour (£)**	**Estimated time to complete**
Pre-Screening	Complete pre-screening questions regarding eligibility	9	5 minutes
Part 1	Complete the survey and the cognitive tasks	9	65 minutes
Part 2	Complete the survey	9	15 minutes

Are there any risks involved?

There are no physical risks during this research. It is possible that you may feel some level of psychological discomfort or distress when answering personal questions about topics that can be understandably sensitive for some people, such as your substance use, medical history or finances. If you become concerned as a result of taking part in this study, you may wish to seek help from the following charities:

Mind: www.mind.org.uk

Gamblers Anonymous: www.gamblersanonymous.org.uk

Alcoholics Anonymous: www.alcoholics-anonymous.org.uk

It is also possible that you may experience some level of psychological discomfort when completing tests of Executive Function; the tests are not designed to be distressing, but it is possible to feel anxiety regarding your performance.

This study is for research purposes only and no clinical interpretation of test results will be made. No feedback regarding performance will be provided to any individual. If you are concerned about your performance on these tests, it is recommended that you seek advice from your GP. It is worth noting however, that such tests are designed to challenge you in order to measure performance.

What data will be collected?

All data will be collected online and will consist of your responses to questionnaire items or scores assigned by computer software, based on your performance on tests of Executive Function. Demographic information collected will include some special category data under Article 9 of GDPR, as information regarding a health diagnosis and information regarding ethnicity is asked for. This information is required as it is essential for the purpose of the research that participants have a diagnosis of bipolar disorder. Ethnicity provides important contextual information for performance on tests of executive function and may be controlled for as part of data analysis.

Research data will be digital and stored on the University's networked storage, in accordance with University of Southampton regulations. Data will be encrypted/password protected when being stored or transferred. It will be kept on University networks only and will not be stored locally. Should any data require transferring, this will not be done via email, rather the University's secure system 'SafeSend' will be used. Data will be stored and used in accordance with GDPR

law. At the end of the research project, data will be stored in a discipline specialist data repository.

ID numbers will be used in place of participant names on databases containing test scores and survey results; names and email addresses (needed for one month follow up contact of participants) will be stored separately.

Will my participation be confidential?

Your participation and the information we collect about you during the course of the research will be kept strictly confidential.

Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

Do I have to take part?

No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to indicate your consent to show you have agreed to take part. Consent will be requested online, further below, prior to the collection of any information.

What happens if I change my mind?

You have the right to change your mind and withdraw at any time without giving a reason and without your participant rights being affected.

If you wish to withdraw from the study at any time, please contact the researcher and provide your participant number, stating whether you wish to discontinue participation only or whether you would like all information already obtained from you to be removed from the study.

What will happen to the results of the research?

The project will be written up as part of the qualification requirements for the DClinPsy at the University of Southampton. It is also likely to be submitted with the aim of publication in an academic journal. Participants will be not routinely receive a copy of the results as email addresses will not be stored once data is collected and Amazon vouchers have been distributed. However, participants may indicate on the Debriefing Form following completion of the study if they would like to receive a copy of the thesis.

Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent.

At the end of the research project, all data with the exception of names and email addresses will be stored in a discipline specialist data repository, and therefore anonymized data is publicly available. Under the University of Southampton Research Data Management Policy, this is for a minimum of 10 years.

If you have any concerns about the storage of your data, please contact the researcher (Hannah Coman).

Where can I get more information?

If you have any questions after reading this information sheet, please contact the researcher (Hannah Coman).

What happens if there is a problem?

If you have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions.

If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Head of Ethics and Clinical Governance. (023 8059 5058, rgoinfo@soton.ac.uk).

Data Protection Privacy Notice

The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team if you have any questions or are unclear what data is being collected about you.

Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at

http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. The University of Southampton will keep identifiable information about you for 10 years after the study has finished after which time any link between you and your information will be removed.

To safeguard your rights, we will use the minimum personal data necessary to achieve our research study objectives. Your data protection rights – such as to access, change, or transfer such information - may be limited, however, in order for the research output to be reliable and accurate. The University will not do anything with your personal data that you would not reasonably expect.

If you have any questions about how your personal data is used, or wish to exercise any of your rights, please consult the University's data protection webpage (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page) where you can make a request using our online form. If you need further assistance, please contact the University's Data Protection Officer (data.protection@soton.ac.uk).

Thank you for taking the time to read this information sheet and for considering taking part in the research.

Appendix D Empirical Paper: Consent Form

Study title: Does Executive Function Predict Impulsive Financial Behaviours in Bipolar Disorder?

Researcher name: Hannah Coman

ERGO number: 79095

Please tick the box(es) if you agree with the statement(s):

I have read and understood the information sheet (*21.04.2023 /version no. 4 of participant information sheet*) and have had the opportunity to ask questions about the study.	
I agree to take part in this research project and agree for my data to be used for the purpose of this study.	
I understand if I should only take part in this study if I believe I am eligible. If I am not deemed eligible based on my responses to questions regarding my demographic information and health, my data will be excluded.	
I understand my participation is voluntary and I may withdraw at any time for any reason without my participation rights being affected.	
I understand that my data will be confidential and will not identify me personally.	
I understand that my data may be looked at for other research questions and that anonymized data will be publicly available.	

Appendix E Empirical paper: Author-Constructed Demographic Questionnaire

1) Please enter your email address (free text)

2) Which gender do you identify with? [drop down]

   Male

   Female

   Non-binary/third gender

   I use another term to describe my gender (please specify)**.**

3) What is your age? You must be 18 or over to take part in this study. [drop down 18-100]

4) Which best describes your ethnicity? [Drop down]

   Asian or Asian British

   - **Indian**
   - **Pakistani**
   - **Bangladeshi**
   - **Chinese**
   - **Any other Asian background**

   Black or Black British

   - **African**
   - **Caribbean**
   - **Any other Black background**

   Mixed or multiple ethnic groups

   - **White and Black Caribbean**
   - **White and Black African**
   - **White and Asian**
   - **Any other mixed background**

White

- **British/English/Welsh/Scottish/Northern Irish**
- **Irish**
- **Gypsy/Traveller (including Roma)**
- **Any other White background**

Other Ethnic Groups

- **Arab**
- **Hispanic**
- **Latino**
- **Native American**
- **Pacific Islander**
- **Any other ethnic group**

5) What country do you live in? [free text]

6) What is your first language? [free text]

7) What is your diagnosis? [drop down]

Bipolar I

Bipolar II

Bipolar (not specified/ not sure)

8) Who were you diagnosed by? [drop down]

General Practitioner/ Family Doctor

Psychiatrist

Psychologist

Other Mental Health Service Practitioner

Myself

Other (please state – free text for inputting)

9) What year did you receive your diagnosis? [free text]

10) Are you currently under the care of a mental health service? [drop down]

Yes

No

11) Are you currently taking any medication for either mental or physical health? [drop down]

Regularly

As needed

None

If so, please list your current medication including dosage [free text].

12) Have there been any recent changes to your medication? [drop down and free text]

Yes (please specify nature of change and date of change)

No

13) Do you have a diagnosis of any other mental health difficulty or personality disorder? [drop down]

Yes (please specify)

No

Currently under investigation (please give details)

14) Have you been diagnosed with a traumatic brain injury (TBI) or acquired brain injury (ABI), including stroke? (drop down)

Yes

No

Currently under investigation (please specify)

If yes, do you believe or have you been told that your cognitive function has been affected by your brain injury? [drop down]

Yes

No

15) Have you been diagnosed with any of the following [tick box]

Alzheimer's Disease

Frontotemporal Dementia

Vascular Dementia

Posterior Cortical Atrophy

Other dementia (please specify)

Parkinson's Disease

Huntington's Disease

Multiple Sclerosis

Encephalitis

Epilepsy

Brain tumour

Other disease known to affect the functioning of the brain (please specify)

Currently under investigation (please give details of what is being investigated)

None

16) Have you been diagnosed with any of the following? [tick box]

ADHD

Autistic Spectrum Condition

Tics

Tourette's Syndrome

Other Neurodiversity (please specify)

Currently under investigation (please give details of what is being investigated)

None

17) Have you been diagnosed with an Intellectual Disability? [drop down]

Yes

No

Currently under investigation (please give details)

18) Have you been diagnosed with a Sleep Disorder? [drop down]

Yes (please specify)

No

Currently under investigation (please give details)

19) How many hours of sleep do you have per night, on average? **[drop down 1-20]**

20) Have you previously undergone 'Neuropsychological testing,' 'Cognitive testing' or 'Psychometric testing'? [drop down]

Yes (please give details – free text)

No

21) Do you have any sensory impairments, such as visual impairment or hearing loss? [drop down and free text option]

Visual impairment – corrected with glasses or contact lenses as required

Visual impairment – uncorrected

Hearing loss – corrected with hearing aids

Hearing loss – uncorrected (please give details regarding severity)

Other sensory impairment (please give details regarding nature and severity)

22) Do you currently take recreational drugs? [drop down]

Yes (please specify drug type and amount taken – free text)

No

23) Have you previously taken recreational drugs? [drop down]

Yes (please specify drug type and amount taken – free text)

No

Appendix F Empirical paper: Author-Constructed Financial Questionnaires

F.1 Author-Constructed Financial Questionnaire Time 1

The information obtained by asking the following questions will be used solely to help us meet our research aims; this is to work out whether there is a relationship between executive function and the way that money is spent in a population of people diagnosed with bipolar disorder. We understand these questions may feel very personal to answer and are very appreciative of your help. It is really important for our study that you answer the questions as honestly as you are able to and that you respond to every question.

1. **Loans:** Do you currently have any of the following? (Please tick *all that apply*)

   - I do not have any loans
   - Loan from bank and/or building society (excluding mortgage and overdrafts)
   - Loan from company that collects payments from home (e.g. Provident)
   - Loan from a finance company (e.g. Ocean Finance)
   - Goods bought in instalments from mail order catalogue
   - Goods bought on ‘hire purchase’ (HP) or on credit (including
   - Goods bought on a 'buy now, pay later' service (e.g. Klarna)
   - Social Fund or Crisis Loan
   - Loan from a payday lender (e.g. Wonga, cash converters)
   - Loan from a credit union
   - Loan from friends and family
   - Loan from an individual (not friends or family)
   - Student loan
   - Other type of loan
   - Unsure

2. With the exception of a **mortgage, overdraft** and **student loan**, please indicate on the sliding scale how much you owe altogether **in loans**? (It is fine to estimate if you are unsure). Please visit Xe Currency Converter - Live Exchange Rates Today to convert your currency into USD.

$0 $100,000+

3. **Credit Cards and Store Cards:** Approximately how much do you owe on **credit cards or store cards** in total? (It is fine to estimate if you are unsure)

   Please visit Xe Currency Converter - Live Exchange Rates Today to convert your currency into USD.

$0 $100,000+

4. Are you currently using an overdraft on your bank/building society account?
   - Yes
   - No
   - Unsure

   If yes, what amount are you overdrawn?

$0 $10,000+

5. Do you feel as though you are living within your means?
   5= I always earn more than I spend
   4= I earn more than I spend most of the time
   3= I spend what I earn
   2= I spend more than I earn most of the time
   1= I always spend more than I earn

6. Have you lived within your means over the past month?
   5= I earned much more than I spent
   4= I earned a little more than I spent
   3= I spent what I earned
   2= I spent a little more than I earned
   1= I spent much more than I earned

7. Over the **past month**, have you spent money *compulsively*, **where spending money felt irresistible?**
   - Yes
   - No
   - Unsure

8. Over the **past month**, have you spent money *compulsively*, **where you spent more than you wanted to due to feeling emotional or mentally unwell?**

- Yes
- No
- Unsure

If yes to either of these, how often have you compulsively spent money?

6= More than once a day

5= Most or all days

4= A couple or a few times a week

3= Once a week

2= A couple or a few times a month

1= Once a month

If yes, how much did you *compulsively* spend in total over the past month?

$0 $10,000+

9. Over the **past month**, have you gambled? This includes playing the lottery, buying lottery scratch cards and all gambling, whether online or any form of physical gambling, i.e. betting shops, casinos, racetracks, sport events etc.?
   - Yes
   - No
   - Unsure

   If yes, how often have you gambled?

   6= More than once a day

   5= Most or all days

   4= A couple or a few times a week

   3= Once a week

   2= A couple or a few times a month

   1= Once a month

If yes, how much did you spend in total over the month (not taking account of winnings)?

$0 $10,000+

F.2 Additional Questions on Author-Constructed Financial Questionnaire at Time 2

How has your **compulsive spending** been compared to one month ago, when you completed Stage 1 of this study?

5= It has been much better

4 =It has been better

3= It has stayed the same

2= It has been worse

1= It has been much worse

How has your **gambling** been compared to one month ago, when you completed Stage 1 of this study?

5= I have gambled much less frequently

4 = I have gambled a bit less frequently

3= It have gambled about the same amount as last month

2= I have gambled a bit more frequently

1= I have gambled much more frequently

Appendix G Empirical Paper: Journal of Neuropsychology: Guidelines for Submission

Requirements for submission of a manuscript to the Journal of Neuropsychology

https://bpspsychub.onlinelibrary.wiley.com/hub/journal/17486653/homepage/forauthors.html#_3._MANUSCRIPT_CATEGORIES

JNP AUTHOR GUIDELINES

Sections

1. SUBMISSION

Authors should kindly note that submission implies that the content has not been published or submitted for publication elsewhere except as a brief abstract in the proceedings of a scientific meeting or symposium.

New submissions should be made via the Research Exchange submission portal. You may check the status of your submission at any time by logging on to submission.wiley.com and clicking the "My Submissions" button. For technical help with the submission system, please review our FAQs or contact submissionhelp@wiley.com.

All papers published in the *Journal of Neuropsychology* are eligible for Panel A: Psychology, Psychiatry and Neuroscience in the Research Excellence Framework (REF).

Data protection:

By submitting a manuscript to or reviewing for this publication, your name, email address, and affiliation, and other contact details the publication might require, will be used for the regular operations of the publication, including, when necessary, sharing with the publisher (Wiley) and partners for production and publication. The publication and the publisher recognize the

importance of protecting the personal information collected from users in the operation of these services, and have practices in place to ensure that steps are taken to maintain the security, integrity, and privacy of the personal data collected and processed. You can learn more at https://authorservices.wiley.com/statements/data-protection-policy.html.

Preprint policy:

This journal will consider for review articles previously available as preprints. Authors may also post the submitted version of a manuscript to a preprint server at any time. Authors are requested to update any pre-publication versions with a link to the final published article.

2. AIMS AND SCOPE

The Journal of Neuropsychology publishes original contributions to scientific knowledge in neuropsychology including:

- clinical and research studies with neurological, psychiatric and psychological patient populations in all age groups
- behavioural or pharmacological treatment regimes
- cognitive experimentation and neuroimaging
- multidisciplinary approach embracing areas such as developmental psychology, neurology, psychiatry, physiology, endocrinology, pharmacology and imaging science

The following types of paper are invited:

- papers reporting original empirical investigations
- theoretical papers; provided that these are sufficiently related to empirical data
- review articles, which need not be exhaustive, but which should give an interpretation of the state of research in a given field and, where appropriate, identify its clinical implications
- brief reports and comments
- case reports
- fast-track papers (included in the issue following acceptation) reaction and rebuttals (short reactions to publications in JNP followed by an invited rebuttal of the original authors)
- special issues.

3. MANUSCRIPT CATEGORIES AND REQUIREMENTS

- Research papers should be no more than 6000 words (excluding the abstract, reference list, tables and figures). Multiple citations for a single point are usually duplicative and authors are urged to cite the best reference. In exceptional cases the Editor retains discretion to publish papers beyond this length where the clear and concise expression of the scientific content requires greater length (e.g., explanation of a new theory or a substantially new method). Authors must contact the Editor prior to submission in such a case.
- Brief communications are short reports of original research or case reports. They are limited to a maximum of 1500 words (excluding the abstract, reference list, tables and figures) and have a total of up to three tables or figures, and no more than 10 references.
- Theoretical or review articles are full-length reviews of, or opinion statements regarding, the literature in a specific scientific area. They should be no more than 4000 words (excluding the abstract, reference list, tables and figures) and have no more than 45 references. Multiple citations for a single point are usually duplicative and authors are urged to cite the best reference. In exceptional cases the Editor retains discretion to

publish papers beyond this length where the clear and concise expression of the scientific content requires greater length (e.g., explanation of a new theory or a substantially new method). Authors must contact the Editor prior to submission in such a case.
- Please refer to the separate guidelines for Registered Reports.
- All systematic reviews must be pre-registered and an anonymous link to the pre-registration must be provided in the main document, so that it is available to reviewers. Systematic reviews without pre-registration details will be returned to the authors at submission.

4. PREPARING THE SUBMISSION

Free Format Submission

Journal of Neuropsychology now offers free format submission for a simplified and streamlined submission process.

Before you submit, you will need:

- Your manuscript: this can be a single file including text, figures, and tables, or separate files – whichever you prefer. All required sections should be contained in your manuscript, including abstract, introduction, methods, results, and conclusions. Figures and tables should have legends. References may be submitted in any style or format, as long as it is consistent throughout the manuscript. If the manuscript, figures or tables are difficult for you to read, they will also be difficult for the editors and reviewers. If your manuscript is difficult to read, the editorial office may send it back to you for revision.
- The title page of the manuscript, including a data availability statement and your co-author details with affiliations. *(Why is this important? We need to keep all co-authors informed of the outcome of the peer review process.)* You may like to use this template for your title page.

Important: the journal operates a double-anonymous peer review policy. Please anonymise your manuscript and prepare a separate title page containing author details. *(Why is this important? We need to uphold rigorous ethical standards for the research we consider for publication.)*

- An ORCID ID, freely available at https://orcid.org. *(Why is this important? Your article, if accepted and published, will be attached to your ORCID profile. Institutions and funders are increasingly requiring authors to have ORCID IDs.)*

To submit, login at https://wiley.atyponrex.com/journal/JNP and create a new submission. Follow the submission steps as required and submit the manuscript.

If you are invited to revise your manuscript after peer review, the journal will also request the revised manuscript to be formatted according to journal requirements as described below.

Revised Manuscript Submission

Contributions must be typed in double spacing. All sheets must be numbered.

Cover letters are not mandatory; however, they may be supplied at the author's discretion. They should be pasted into the 'Comments' box in Editorial Manager.

Parts of the Manuscript

The manuscript should be submitted in separate files: title page; main text file; figures/tables; supporting information.

Title Page

You may like to use this template for your title page. The title page should contain**:**

- A short informative title containing the major key words. The title should not contain abbreviations (see Wiley's best practice SEO tips);
- A short running title of less than 40 characters;
- The full names of the authors;
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Appendix H Empirical Paper: Supplementary Materials

H.1 Table S 1 Participant countries of residence

Table S 1

Participant countries of residence

	N	*%*
Country of Residence:		
United Kingdom	92	77.3
United States of America	14	11.8
Canada	4	3.4
Guernsey	1	0.8
Germany	1	0.8
Italy	1	0.8
Sweden	1	0.8
Kenya	1	0.8
India	1	0.8
Malaysia	1	0.8
Hong Kong	1	0.8
Australia	1	0.8

H.2 Table S 2 Correlation matrix for executive function measures, mood variables, impulsive spending measures and relevant demographics

Table S 2

Correlation matrix for executive function measures, mood variables, impulsive spending measures and relevant demographics

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.
1.																												
2.	.36***																											
3.	.34***	.65***																										
4.	.37***	.56***	.70***																									
5.	-.06	-.21*	-.16	-.05																								
6.[a]	-.22**	-.08	-.19*	-.24**	.37***																							
7.[a]	.14	-.11	-.01	-.00	-.04	-.11																						
8.	-.05	-.15	-.19*	-.20*	-.01	.06	.17																					
9.	.06	.16	.12	.01	.16	.04	.18	.25																				
10.	.01	.05	.07	.02	-.11	.07	.08	.31**	.67***																			
11.	-.07	-.17	-.11	-.10	.36***	.15	-.01	.03	-.09	-.10																		
12.	.16	.08	.06	.09	-.17	.02	.04	.02	.14	.17	-.13																	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.
13.	.13	.13	.06	.05	.07	.10	-.00	-.13	.01	.21 *	-.06	.94 ***																
14.	-.02	.00	.04	.04	.14	-.07	.09	-.03	-.09	-.16	.12	-.75 ***	-.80 ***															
15.	-.07	-.06	-.08	-.07	.06	-.13	-.03	.03	-.22	-.25	-.02	-.78 ***	-.92 ***	.75 ***														
16.	-.14	-.09	-.07	-.08	.20*	-.01	-.04	-.01	-.15	-.16	.11	-.98 ***	-.92 ***	.75 ***	.76 ***													
17.	-.07	-.08	.00	-.12	-.15	-.10	-.07	-.15	-.06	-.09	-.21 *	-.05	-.03	.00	.02	.03												
18.	-.01	-.05	.03	-.07	-.21 *	-.11	-.05	-.14	-.06	-.06	-.25 *	-.03	-.04	.02	.04	.02	.95 ***											
19. [a]	-.02	-.19	-.17	-.08	.44 ***	.16	.01	.07	-.13	-.08	.65 ***	-.19	-.09	.15	-.01	.14	-.38 ***	-.41 ***										
20.	.11	.07	-.04	-.01	-.29 **	-.24 *	.00	-.18	-.10	-.04	-.33 **	-.11	-.20	.03	.29 **	.12	.27 *	-.38 ***	.33 **									
21.	.08	.08	-.05	-.02	-.26 *	-.18	.01	-.16	-.10	-.05	-.31 **	-.06	-.15	-.01	.24	.09	.28 *	-.30 **	.34 **	.94 ***								
22. [a]	-.24 *	-.25 *	-.17	-.22 *	.41 ***	.24 *	-.00	.09	-.06	.03	.55 ***	-.25 *	-.18	.20	.06	.18	-.26 *	-.33 **	.77 ***	-.32 **	-.32 **							
23. [a]	.05	.05	.08	.11	.14	.05	.08	.12	.08	.06	.09	.05	.07	.01	-.10	-.01	-.11	-.15	-.01	-.17	-.22	.10						

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.
24.[a]	.04	-.18	-.20	-.09	.27**	-.04	-.04	-.02	-.05	-.03	.54***	-.26**	-.17	.24*	.06	.23*	-.06	-.09	.34***	-.33**	-.33**	.35***	.14					
25.[a]	-.05	-.05	-.01	.02	.14	.04	.17	.13	.05	.02	.10	.01	.04	.00	-.07	.03	-.00	-.07	.10	-.08	-.10	.16	.80***	.20*				
26.	.09	-.12	.08	.06	.04	.03	.14	.10	-.00	.10	.02	.10	.13	-.03	-.08	-.09	-.10	-.15	.01	-.23*	-.32**	.01	.11	.14	.12			
27.	.08	.13	.09	-.01	.03	-.01	-.08	-.08	-.02	-.03	.03	-.04	-.05	.07	.02	.03	.24*	.28**	-.04	.27*	.34**	-.06	-.20	-.14	-.19	-.52***		
28.	-.31***	-.23*	-.20*	-.18	.20*	.16	-.22*	-.03	-.16	-.04	.38***	-.14	-.09	.04	.01	.10	.09	.04	.35***	-.07	-.02	.35***	-.12	.33	-.04	-.28**	.17	
29.	-.25**	-.29**	-.29**	-.18	.40***	.21*	-.13	.06	-.08	-.00	.41***	-.12	-.05	.03	-.03	.13	-.05	-.15	.40***	-.26*	-.22*	.46***	.14	.48***	.17	-.10	-.14	.80***

Note: *$p < .05$, **$p \leq .01$, ***$p \leq .001$ two tailed. Correlation coefficients resulting from bivariate Pearson's correlation for parametric variables, [a]Bivariate Spearman's correlation coefficients for nonparametric variables. See Table S2b below for key

H.2.1 Table S 3 Key for Table S 2 and population (*n*) for each variable

Table S 3

Key for Table S 2 and population (n) for each variable

Variables: Key for Table S 2	*n*
1. Compulsive Buying Scale Total Score	118
2. Patient Mania Questionnaire-9	118
3. Generalized Anxiety Disorder-7	118
4. Patient Health Questionnaire-9	118
5. Age (years)	118
6. Years since diagnosis	116
7. Gender	118
8. Sleep (mean hours)	118
9. Trail Making Error Difference (B-A)	97
10. Trail Making Completion Time Difference (B-A)	97
11. Iowa Gambling Task: Mean Response Latency	109
12. Iowa Gambling Task: Mean Gain	109
13. Iowa Gambling Task: Mean Loss	109
14. Iowa Gambling Task: Mean Total	109
15. Iowa Gambling Task: Final Total	109
16. Iowa Gambling Task: Advantageous-Disadvantageous Deck Choices	109
17. Corsi-Forwards: Block Span	107
18. Corsi-Forwards: Total Score	107
19. Corsi-Forwards: Mean Response Latency	105
20. Corsi-Backwards: Block Span	86
21. Corsi-Backwards: Total Score	86
22. Corsi-Backwards: Mean Response Latency	86

23. Stroop: Total Errors	109
24. Stroop: Mean Response Latency	108
25. Stroop: Errors Difference	108
26. Tower of London: Mean no. of Problem Attempts	105
27. Tower of London: Total Score	105
28. Tower of London: Time to Take First Move	106
29. Tower of London: Mean Solution Time	106

H.3 Statistics for participant drop out analysis

MANOVA did not reveal significant main effects of mood (mania, anxiety or depression) on whether participants dropped out between Times 1 and 2 (No drop out: $n = 81$, Drop out: $n = 37$), using Hotelling's Trace statistic, $T = 0.02$, $F(3,114) = 0.57$, $p = .63$, $\eta_p^2 = .015$. Independent samples t-tests showed no significant difference in CBS score for drop out status ($t(116) = -0.97$, $p = .34$, $d = -0.19$) and Chi-squared analyses did not reveal significant differences for SOGS classification as a pathological gambler/not ($\chi^2(1, N = 119) = 1.70$, $p = .19$) or Level of Debt ($\chi^2(1, N = 118) = 3.12$, $p = .07$). Independent samples t-tests did not show significant differences in scores on any of the 21 executive function measures, with Bonferroni correction applied ($p > .0024$).