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Abstract

Background: Impairments in affective cognition are part of the neurocognitive profile and possible treatment targets in bipolar disorder (BD), but the findings are heterogeneous. The International Society of Bipolar Disorder (ISBD) Targeting Cognition Task Force conducted a systematic review to (I) identify the most consistent findings in affective cognition in BD, and (II) provide suggestions for affective cognitive domains for future study and meta-analyses.

Methods: The review included original studies reporting *behavioural* measures of affective cognition in BD patients versus controls following the procedures of the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) statement. Searches were conducted on PubMed/MEDLINE, EMBASE and PsychInfo from inception until November 2018.

Results: A total of 106 articles were included (of which nine included data for several affective domains); 41 studies assessed emotional face processing; 23 studies investigated reactivity to emotional words and images; 3 investigated explicit emotion regulation; 17 assessed implicit emotion regulation; 31 assessed reward processing and affective decision-making. In general, findings were inconsistent. The most consistent findings were trait-related difficulties in facial emotion recognition and implicit emotion regulation, and impairments in reward processing and affective decision-making during mood episodes. Studies using eye-tracking and facial emotion analysis revealed subtle trait-related abnormalities in emotional reactivity.

Conclusion: The ISBD Task Force recommends facial expression recognition, implicit emotion regulation and reward processing as domains for future research and meta-analyses. An important step to aid comparability between studies in the field would be to reach consensus on an affective cognition test battery for BD.

Keywords: Affective cognition, social cognition, emotional cognition, reward processing, bipolar disorder

Introduction

Cognitive impairments within non-emotional aspects of cognition in bipolar disorder (BD) have been the focus of research interest as a novel treatment target. Indeed, there is a growing recognition of the need for treatments targeting patients' persistent cognitive deficits to improve their psychosocial and vocational function[1] and reduce societal costs related to lost work productivity[2]. Research into the pattern of cognitive impairments has identified substantial heterogeneity with 10-40% of patients displaying *broad* cognitive deficits across verbal memory, attention, executive

function and psychomotor speed, 30-40% showing a *selective* decline in attention and psychomotor speed, and another 30-50% being relatively *cognitively intact* in comparison with norms of healthy age-matched individuals[3-6]. Notably, the cognitively impaired subgroups present reduced functional capacity, poorer quality of life and more perceived stress[4]. A large number of treatment trials targeting cognition with biological or behavioural interventions are therefore underway and will likely reveal novel effective treatments within the next few years[7].

Impairments in affective cognition are increasingly recognised as part of the neurocognitive profile and possible treatment targets in BD[8]. Affective cognition is often referred to as 'hot' (i.e., emotion-laden) cognition[9,10] and includes measures of emotion processing, emotion regulation, perceptual and attentional biases, feedback sensitivity, emotional decision making[9], and reward and punishment processing a key component of emotional decision making[11]. As such, affective cognition may partially reflect neurocognitive functioning in social contexts and moderate the association between neurocognitive impairments and socio-occupational difficulties in BD[12-14]. Indeed, impairments in affective cognition, including emotional intelligence and regulation, seem to have a negative impact on interpersonal and vocational functioning in BD[15-18]. Conversely, better affective cognition is related to favourable functional outcome and quality of life and lower levels of mood symptoms[19,20]. This highlights the functional relevance of affective cognitive difficulties in BD, although these are generally subtler than non-emotional cognition deficits [21], with an estimated 0.3-0.5 standard deviation (SD) decline in affective cognition for every 1 SD decline in non-affective cognition[22]. This has led to an increasing focus on the need to assess and address impairments within affective cognition in clinical management of BD and new treatment development strategies.

State- and trait-related affective cognitive impairments in BD have been observed across the three phases of bipolar disorder[23] and within several domains; facial expression recognition[24,25], reward processing and decision making[26,27] and emotional regulation[28,29]. However, findings are conflicting, with several studies showing no abnormalities[14,30-33] or even enhanced performance in some aspects of affective cognition in patients relative to controls[34,35]. The discrepant findings may partially reflect heterogeneity in patients' affective cognitive abilities that is similar to the heterogeneity within non-affective cognition[36]. Indeed, a study recently identified three distinct affective cognitive subgroups of patients with either general problems in decision making and reward processing, a combination of normal decision-making and high punishment sensitivity, or low sensitivity to punishment[37]. However, the conflicting evidence may also reflect methodological

inconsistencies between studies, including differences in affective cognition tests, sample sizes and clinical characteristics of patient populations, and whether studies used objective performance-based or subjective self-report measures. Another major consideration is that most affective cognition tests use complex visual stimuli, such as faces, with short exposure times. It therefore remains unclear whether deficits in affective cognition are truly unique, or nearly a manifestation of general (non-emotional) cognitive problems in attention and processing speed[33,38,39]. In addition, many studies are of an explorative nature and statistical issues such as lack of adjustment for multiple testing may affect conclusions from the various studies. It is therefore unclear which abnormalities in affective cognition are most consistent across illness stages and phases in BD and which tests are most sensitive to these abnormalities.

The International Society of Bipolar Disorder (ISBD) Targeting Cognition Task Force therefore conducted this systematic review to: (I) identify the most consistent trait-related deficits in affective cognition that deserve attention in cognition treatment trials and delineate which domains may only be impaired during mood episodes and, based on this, (II) propose specific affective cognition domains for future study and meta-analysis of effect sizes for deficits in these domains. The review does not include studies of higher-order, multidimensional social cognitive functions, such as empathy, trait attribution, social skills, stereotyping, or theory of mind (ToM). Indeed, there are several comprehensive reviews and meta-analyses of ToM[40,41], ToM, emotion processing, and attribution bias[42], and ToM and emotion processing[23,43] in BD. Instead, this systematic review serves as an update of the affective cognition literature in BD that distinguishes itself from previous reviews and meta-analyses by providing a comprehensive integration of findings from multiple affective cognitive domains across both symptomatic and remitted states of the disorder.

Methods

Search strategy

This systematic review followed the procedures of the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement[44]. A comprehensive systematic computerized search was performed on the PubMed/MEDLINE, EMBASE and PsychInfo databases from inception up until November 2018. The search profile included two elements “Bipolar disorder” and “Affective/social/emotional cognition” with each of their combinations and alternative key words in the respective databases (see Supplementary Material for details on the search profile).

Two authors (IS and HLK) independently performed a primary title/abstract screening for potentially eligible articles and, following this, a secondary full text screening was conducted. A hand-search was performed as well by tracking and screening citations in the included articles for eligible articles. In all phases, all articles were considered in accordance with inclusion/exclusion criteria (see Supplementary Material for details). Agreement between the two authors was high (primary screening: 97%; secondary screening: 87%). Disagreements were discussed, and consensus was reached in all cases through discussions with a third author (KWM).

Selection criteria

The initial search criteria were defined in accordance with PICO framework (Population, Intervention, Comparison, Outcome). We only included original peer-reviewed articles involving (a) individuals (age>18) meeting either ICD or DSM diagnostic criteria for BD I or II (confirmed through a validated structured diagnostic interview) and a healthy control (HC) comparison group; (b) investigation of affective cognition with *objective* performance-based measures or self-report measures *in the context* of emotional stimulus presentation; (c) articles published in English only. We excluded articles that: (I) included samples with several diagnoses (unless data for BD was reported separately); (II) studies in which BD was not directly compared to HC; (III) studies in which the HCs had an axis 1 disorder; (IV) studies of purely self-reported affective cognition (i.e., with questionnaires/interviews); (V) meeting abstracts, reviews, and case reports.

Results

The comprehensive search, together with the additional hand-search, identified 1063 articles (after removal of duplicated hits), and all these were included for title/abstract screening (primary screening). Out of these, 263 were evaluated for eligibility via a full-text reading (secondary screening). This resulted in 106 articles that met inclusion criteria and were included in this review – with several studies reporting data on different affective cognition domains; 41 studies assessed processing of emotional faces; 23 studies investigated processing of emotional words, speech and pictures; 3 investigated explicit emotion regulation; 17 assessed implicit emotion regulation as reflected by attentional interference by emotional stimuli; and 31 assessed reward and punishment

processing and emotional decision-making (See Figure 1: PRISMA flowchart; see an overview of the studies in Figure 2).

Emotion processing

Emotional processing of faces

Forty-one studies investigated facial emotional processing with different paradigms involving either (i) facial expression recognition/identification (from now on referred to as facial expression recognition), in which the participants are required to identify the emotions depicted (i.e., assessing ability to correctly identify emotional facial expressions); (ii) facial expression discrimination, in which the participants are required to match a target face with other faces (i.e., assessing ability to correctly discriminate emotional facial expressions); or (iii) methodologies including subjective ratings of perceived traits by looking at faces.

Studies of facial expression recognition

Forty-one studies examined facial expression recognition in samples with either *remitted* patients (k=20 studies; n=1026 BD, n=1144 HC)[16,24,33,34,38,45-59], *symptomatic* patients (k=3 studies; n=97 BD, n=93 HC)[33,60,61], *mixed* patient groups (i.e., patients in different episodes) with a separate analysis on each patient group (k=4 studies; n=243 BD, n=221 HC)[32,35,62,63], *mixed* patient groups (i.e., patients in different episodes) with no separate analysis for each patient group (k=8 studies; n=277 BD, n=400 HC)[25,64-70], or where current episode was *not specified* (k=6 studies; n=364 BD, n=231 HC)[71-76]. The total sample size was n=1969 BD and n=2039 HC, with samples of individual studies ranging from n=34-628 (see Table 1). Different paradigms were used in the studies assessing facial emotion recognition and affect labelling; the most common ones used a version of a facial expression recognition test (e.g., The Facial Expression Recognition Task (FERT), The Penn Emotion Recognition Task-40 (ER-40), The Ekman-60 Test (EK-60)), the Emotional Hexagon Test, or dynamic facial emotion labelling tasks. In the FERT, ER-40 and EK-60, participants view a series of facial expressions that displayed one of the six basic emotions anger, disgust, fear, happiness, sadness, and surprise and are instructed to select which of these emotions is expressed. In the Emotional Hexagon Test, two commonly confused, emotions are merged, and participants are required to indicate which emotion they identify. Finally, in the dynamic facial emotion labelling tasks, participants are required to view dynamic facial images/videos and identify the emotion being expressed.

Twenty-two studies examined facial expression recognition in *remitted* BD patients (of which three studies included mixed samples but conducted separate analyses for each mood state). Of these, seven studies found *generally impaired* performance in remitted patients; that is, lower accuracy and/or slowed responses during facial expression recognition[16,24,46,48,50,52,56,62]. Another eight studies found only *selective deficits* in the recognition of either happy faces[45,49,53,59], disgusted faces[38,45,59], sad faces[38], fearful faces[49,54,57], angry faces[55,57], or surprised faces[57]. In contrast, two studies found that patients displayed *better than normal* performance accuracy for disgusted[34] and fearful faces[35], respectively. Finally, five studies found no aberrant facial expression recognition in remitted patients[32,33,47,51,58]. In addition to these impairments in the recognition of facial expressions, seven studies found that remitted patients tend to *misinterpret* emotional expressions[50-53,55,57,59], with the facial expressions that were misinterpreted differing between studies.

Seven studies of facial expression recognition in *symptomatic* BD patients yielded mixed results (of these, four included a mixed patient sample but conducted separate analyses for each mood state)[32,33,35,60-63]. Two studies found that *depressed* patients required more intense emotional displays to identify all emotional expressions[61,63], and one also found specifically increased recognition of disgust[61]. In contrast, two other studies showed no performance deficits during depressed states of BD[33,62]. The five identified studies of *manic* patients all found broad impairments in facial expression recognition[32,35,60,62,63].

Finally, fourteen studies were conducted in *mixed* samples (i.e., patients presenting with either manic or depressive symptoms or who were in remission) with no separate analysis of each patient group or where the current mood episode was not specified[25,64-76]. Of these, eight found a *broad* facial emotion recognition deficits[25,64,65,68-70,72,75], while two studies reported *selectively* impaired recognition of fearful, sad[66], or surprised expressions[74]. In contrast, four studies found no facial expression recognition impairments in BD[67,71,73,76].

Studies of facial affect matching

Eleven studies examined facial affect matching in either *remitted* patients (k=4 studies; n=113 BD, n=115 HC)[47-49,77], *symptomatic* patients (k=2 studies; n=76 BD, n=72 HC)[33,60], a *mixed* sample (k=3 studies; n=133 BD, n=204 HC)[25,64,67], or a sample in which patients' mood states were *not specified* (k=2 studies; n=32 BD, n=50 HC)[71,78] (in total: n= 335 BD, 411 HCs) (see Table 2) with sample sizes ranging from n=30-155. Eight studies found impairments in facial emotion matching across both symptomatic and remitted states[25,33,48,60,64,67,71,77], whereas three studies of which two were

conducted in remitted patients yielded no deficits[47,49,78]. Notably, possible methodological limitations that may have impeded the detection of group differences in the three negative studies included test ceiling effects and lack of control for the effects of different psychotropic medications.

Other studies of facial emotion processing

Two studies examined perception of face dominance and trustworthiness. These studies were conducted in *remitted* patients (k=2 studies; n=86 BD, n=96 HC)[79-81], (in total: n=86 BD and 96 HC) with study sample sizes ranging from N=38-90 (see Table 3). The two studies of patients' perception of facial dominance and trustworthiness, respectively, found that remitted patients perceived angry, fearful, and neutral faces as less socially dominant[80] or less trustworthy[81] - possibly indicating a negative bias.

Interim summary of facial emotion processing

Processing of emotional faces was the most thoroughly investigated aspect of affective cognition in BD (k=41 studies). The most consistent evidence for face processing deficits across all illness phases was within the domain of facial expression recognition. Specifically, global or selective facial emotion recognition deficits were observed in 17 out of 22 (77%) studies of remitted patients and in 10 out of 14 (71%) studies of symptomatic patients. In contrast, affect matching does not seem to be consistently impaired – at least not during remission – and thus seems suboptimal for assessment of trait-related deficits in face processing. Among studies of facial expression recognition, discrepant findings are likely due to the differences in the employed paradigms. That is, some paradigms involve the presentation of statically morphed facial expressions (i.e., facial expressions morphed from neutral to full-intensity emotion) or dynamic morphing whereas others involve static images of high-intensity facial expressions. Paradigms with greater difficulty and sensitivity (e.g., Emotional Hexagon test and paradigms using morphed facial expressions) seem to provide the most consistent evidence for facial expression recognition deficits in BD. Indeed, a general characteristic of the negative studies was their use of a version of the *classic* facial expression recognition task involving pictures of (unambiguous) full emotions. These tests thus seem to be suboptimal for detection of subtle difficulties with facial expression recognition in BD. Notably, the findings must be interpreted with caution and often regarded as hypothesis-generating as a great part of the included studies did not correct for multiple comparisons (e.g. Bonferroni adjustment).

Reactivity to and decoding of emotional information

Twenty-three studies investigated emotion processing using emotional pictures of scenes, film-clips, auditory sentences, written sentences, or autobiographical memories in either *remitted* patients (k=14 studies; n=673 BD, n=728 HC)[16,20,30,31,46,82-90], a *mixed* sample (k=3 studies; n=249 BD, n=84 HC)[91-93], or patients for whom mood state was *not specified* (k=6 studies; n=342 BD, n=265 HC)[71-73,75,78,94] (in total: n=1168 BD, 1001 HCs), with sample sizes ranging from n=30-299 (Table 4).

Reactivity to emotional stimuli

Eleven studies involved emotion reactivity to emotional stimuli (i.e., emotional pictures, autobiographical memories, criticism induction or film-clips)[30,31,84,85,87-93].

Eight studies investigated emotional processing in *remitted* patients. Two studies found a *positive bias*, as reflected by ratings of neutral pictures as more pleasant and arousing[89] or a specific reduction in maintenance of negative emotions after viewing aversive images[31]. In contrast, two other studies of which one included a relatively large sample (n=110) showed *no abnormality* in self-reported emotional reactions to unpleasant or neutral images[30,87]. Notably, three studies using physiological responses and sensitive behavioural measures such as patients' facial emotion and eye-movements found subtle emotion processing abnormalities: one study found that neutral images triggered excessive startle reflexes[89], while the two other studies found that patients exhibited more *incongruent* facial expressions in response to emotional film-clips or pictures (i.e., expressions that did not match the valence of these stimuli)[85,87]. One eye-tracking study also showed that patients gazed more *away from* both unpleasant and neutral images[87]. Despite these positive findings, four studies found no abnormal emotional reactivity in BD[84,88,90,92]. More specifically, one study found no aberrant emotional reactions to criticism[88], while two other studies found no exaggerated emotional response during recall of autobiographical events[84,92].

Of the three studies of emotional reactivity in *symptomatic* or *mixed* patient samples, two eye-tracking studies showed that patients spent more time looking at and fixating on threatening aversive images across all mood states[91,93], and that depressed patients with BD fixated less frequently and for a shorter time on pleasant images[93]. One study found that manic (but not depressed or remitted) patients recalled fewer specific negative memories, suggestive of a state-related mood-congruent positive bias[92].

Decoding the emotional gist of scenes, speech and text

Twelve studies investigated the ability to decode the emotional gist from film-clips of social scenarios, speech or written text (i.e., paradigms using either auditory or written sentences)[16,20,46,71-73,75,78,82,83,86,94]. One study found that patients with BD in the latter stages of acute hospitalisation were impaired at identifying sad scenes in emotional film-clips[71], while another study showed that mildly depressed and remitted patients had problems with identifying emotions from body language[94]. Four studies found that remitted patients were impaired at identifying the emotional content of speech[20,82,83,86], while four studies showed no deficits[16,73,75,78]. Further, two studies showed difficulties with identifying negative emotional content in written descriptions of real-life situations in patients where current episode was not specified and remitted patients, respectively[46,72].

Interim summary of reactivity to and decoding of emotional information

Taken together, the evidence regarding reactivity to emotional stimuli is sparse and mixed. Self-reported emotional states in response to pleasant or aversive stimuli generally show no difference from controls in emotional reactivity, particularly studies of reactivity to criticism and autobiographical events. These aspects of emotional cognition may therefore not be affected consistently in BD – at least not to a degree that can be captured by self-report measures. In contrast, more sensitive behavioural measures of emotional reactivity, such as facial emotion and eye-movements, revealed subtle trait- and state-related abnormalities in reactivity to emotional film clips and pictures. Further, patients seem to have state-related difficulties with *decoding* the emotional content from film-clips and from written descriptions of emotional scenarios (whereas the findings in remitted patients were mixed). In contrast, the findings regarding ability to identify the emotional expression from speech are conflicting.

Emotion regulation

Explicit emotion regulation

Only three studies to date investigated behavioural measures of explicit (conscious) emotion regulation[87,95,96]. These were conducted on fully or partially remitted patients in a total of n=76 BD and n=78 HC participants with samples ranging from n=33-75 (see Table 5). One study revealed no deficits in cognitive reappraisal of affective and neutral film clips[95], while another study showed

impaired ability to down-regulate emotional reactions to both emotional and neutral films[96]. The third more recent study of patients' eye-movements and facial expressions in response to aversive images[87] revealed that patients in full or partial remission were more likely to gaze away from aversive images when instructed to dampen their negative emotions.

Implicit emotion regulation

Seventeen studies investigated *implicit* emotion regulation, measured by the degree of attentional interference of task performance by emotional distractor stimuli. The most common tests were the Affective go/no-go task (AGN) and the Emotional Stroop test (EST). The overall rationale behind the different tasks is that task-irrelevant emotional stimuli create an interference with the task by capturing attentional resources. The studies included either *remitted* patients (k=9 studies; n=222 BD, n=313 HC)[79,97-104], *symptomatic* patients (k=4 studies; n=118 BD, n=110 HC)[105-108], or *mixed* patient samples (k=4 studies; n=129 BD, n=77 HC)[109-112]. The total number of included participants was n=469 BD and n=500 HCs, with study samples ranging from n=18-203 (see Table 6).

Nine studies examined implicit emotion regulation in *remitted* patients. Six studies found broad attentional interference by all emotional stimuli independent of valence[97-100,103,104], while one study found specific attentional interference of positive stimuli[111]. In contrast, three studies reported no attentional interference by emotional distractor stimuli[79,102,112]. Finally, a study using a subliminal and supraliminal emotional face priming task found that patients (but not controls) displayed a negative judgment shift after supraliminal priming (i.e. consciously processed negative faces), indicating impaired cognitive control of negative emotional processing in these patients[101].

Eight studies examined implicit emotion regulation in *symptomatic* patients (of these, four studies included separate analyses for each mood state). Two studies of *depressed* patients revealed *mood-congruent* attentional interference by negative stimuli[105,110]. while four studies demonstrated more *general* attentional interference by all emotional stimuli independent of valence[105-107,111]. Further, two studies found that *manic* patients displayed general attention interference by all emotional stimuli, which was most pronounced for negative stimuli[108,110]. Only one study found no differences between groups in implicit emotion regulation, possibly due to a small sample size[112].

Studies of implicit emotion regulation using eye-tracking

Four studies examined implicit emotion regulation using eye-tracking in (i) a facial emotion pro/anti saccade (i.e., looking toward vs. away from faces) paradigm, or (ii) a free-viewing task of

emotional faces. These studies were conducted in *remitted* patients (k=3 studies; n=69 BD, n=70 HC)[113-115], or a *mixed* sample (k=1 study; n=71 BD, n=28 HC)[116]. Three of the eye-tracking studies found oculomotor abnormalities including slower inhibitory control during facial emotion processing in remitted and symptomatic patients[113,114,116]. In contrast, a free-viewing eye-tracking study revealed no abnormal viewing patterns in patients[115] despite a modest sample size (BD: N=29, HC: n=28).

Interim summary of explicit and implicit emotion regulation

In summary, the evidence from the three studies of *explicit* emotion regulation in remitted patients is inconsistent and thus this aspect of affective cognition in BD needs further investigation. There is some, albeit inconsistent, evidence for trait-related abnormalities within *implicit* emotion regulation and emotional bias in BD. Specifically, the majority (10 of 17) of studies revealed deficits within attentional interference for all emotional stimuli independent of valence across all illness states. There was also some indication of a negative bias in depressive phases. Nevertheless, the studies are sparse and conflicting, possibly due to differences in clinical characteristics and small sample sizes. In contrast, studies using eye-tracking methodology revealed relatively consistent abnormalities, indicating that this may be a sensitive measure to detect subtle behavioural differences in implicit emotion processing.

Reward processing and affective decision making

Reward and punishment processing as well as affective decision-making abilities were assessed in 31 studies using simulated gambling paradigms, of which the most common ones were the Iowa Gambling Task (IGT) and the Cambridge Gambling Task (CGT). The studies included either *remitted* patients (k=15 studies; n=475 BD, n=528 HC)[14,98,117-129], *symptomatic* patients (k=2 studies; n=46 BD, n=69 HC)[130,131], a mixed patient sample (k=12 studies; n=724 BD, n=503 HC)[92,112,132-141], and or patients for whom current mood state was not specified (k=2; n=64 BD, n=141 HC)[142,143]. In total these studies included n=1309 BD and n=1241 HCs, with study samples ranging from n=33-317 (see Table 7).

Fifteen studies examined reward sensitivity in *remitted* patients, of which six found a reduction in reward sensitivity[98,117,119,124,127,128]. Specifically, three of the studies found slower deliberation times prior to making a bet, indicating that risk choices were experienced as relatively difficult[98,119,128]. In keeping with this, two studies found impaired decision-making ability[117,124].

Another study showed reduced and delayed acquisition of response bias toward the more frequently rewarded stimulus that was partially due to enhanced sensitivity to single rewards of the disadvantageous stimulus[127]. In contrast, nine studies found no aberrant reward sensitivity in these remitted patients[14,118,120-123,125,126,129].

Sixteen studies investigated reward sensitivity in *acute illness phases*, of which ten studies showed pronounced risk-taking tendencies and suboptimal betting strategies across all illness phases, as indicated by poorer decision-making, slower deliberation times prior to making a bet and increased delay aversion[112,131-134,136-139,141]. In contrast, one study found evidence for state-related changes, with depressed patients displaying more risk-avoidance and manic patients showing more risk-seeking behaviour[132]. Nevertheless, six studies found no reward processing abnormalities in symptomatic BD patients[92,130,135,140,142,143].

Interim summary of reward processing and affective decision making

Taken together, the majority (10 out of 16; i.e., 63%) of the studies in symptomatic patients but the minority studies in remitted patients (6 out of 15; i.e., 40%) showed reward processing abnormalities. The most consistent findings were thus that patients displayed *state-related* impairments in reward-sensitivity and affective decision making, as reflected by pronounced risk-taking tendencies and suboptimal betting strategies during manic and depressed episodes.

Discussion

Impairments within affective cognition constitute an emerging treatment target in BD but findings are heterogeneous. This systematic review by the ISBD Targeting Cognition Task Force aimed to (I) identify the most consistent trait-related deficits in affective cognition and reward processing that deserve attention in treatment trials and which domains are only impaired during mood episodes, and (II) provide suggestions for affective and reward processing domains for future study and meta-analyses. We identified 106 behavioural studies of affective cognition in BD with a healthy control comparison group. These examined processing of emotional faces, words, pictures and speech, explicit and implicit emotion regulation, or reward processing and affective decision-making. The most extensively investigated affective cognition domains were face processing and reward processing. Aberrant processing of emotional faces across all illness states was the most

consistent finding in 77% of studies. Specifically, both remitted and symptomatic patients showed difficulties in facial emotion recognition (but not always affect matching), indicating that this may be a trait-related impairment in BD. In addition, there was some evidence for trait-related abnormalities in implicit emotion regulation as reflected by attentional interference by all emotional stimuli as well as state-related mood-congruent attention interference by negative stimuli during depressive states. Studies of reward processing and affective decision making generally reported state-related abnormalities including pronounced risk taking and more hesitation during response selection in symptomatic patients, whereas only half of studies detected such abnormalities during remission. There is a scarcity of studies of emotional reactivity and explicit emotion regulation and the findings for these domains are contradictory. Among these studies, those using highly sensitive behavioural measures like eye-tracking and facial emotion analysis found subtle abnormalities in emotional reactivity across acute and remitted states.

The observation of trait-related facial recognition impairments in more than two-thirds of studies of remitted and symptomatic patients suggests that this domain of affective cognition could be worth addressing in future cognition treatment trials. Notably, it is unclear whether aberrant face recognition is merely secondary to impairments in non-emotional cognition including attention and executive functions and would thus disappear if these primary impairments were treated. Indeed, there is some evidence to indicate that facial expression recognition and ToM problems in BD are at least partially mediated by non-emotional neurocognitive impairments[33,54]. However, even if these affective cognitive deficits may be secondary, they can still have direct negative impact on social functioning in remitted BD patients as seen in patients with schizophrenia[144]. It thus seems feasible in future cognition trials to include a measure of facial expression recognition as a secondary outcome in addition to a primary non-emotional cognition outcome as previously recommended by this task force[7].

The lack of a consensus test battery for assessment of affective cognition in BD may partially reflect the diversity of abilities within affective cognition, the conflicting findings regarding which aspects of affective cognition are affected across symptomatic and remitted states, and the only recent recognition of this domain as important for psychosocial function in BD. In this review, we found that the cognitive tests with greatest sensitivity to aberrant affective cognition in BD were characterised by high difficulty levels that circumvented ceiling effects. Within face processing the most thoroughly investigated domain the most sensitive tests seem to be (i) facial expression recognition tests that involve presentation of static faces with emotional expressions

across various intensity levels, (ii) video clip paradigms with dynamically morphed faces, and (iii) the Emotional Hexagon Test, in which two commonly confused emotions are merged. While facial emotion recognition tests with morphed faces involve presentation of 'pure' emotional expressions across different intensities, the Emotional Hexagon Test involves presentation of mixed expressions. The former may thus provide a better assay of deficits in the recognition of *specific* facial expressions. Further, presentation of *static* faces may provide greatest sensitivity to subtle deficits in facial expression recognition since motion (as in dynamically morphed faces in videoclips) facilitates emotion recognition and could therefore introduce ceiling effects in BD[22].

In studies of implicit emotion regulation, the most commonly used attention interference tests were the Affective Go/No-Go and the Emotional Stroop tasks. The Affective Go/No-Go is a target detection task with a superimposed affective processing component (typically words), in which a high number of commission errors reflects poor ability to inhibit unwanted responses to emotionally salient stimuli[99,112] and faster responses to emotional words reflect more emotional bias[109]. In the Emotional Stroop Task, greater cognitive interference by the emotional valence of words (i.e., poor ability to inhibit processing of task-irrelevant emotional information) is reflected by longer delays in reading emotional than non-emotional word cards. Both tests have shown sensitivity to impairments across illness states and thus seem feasible for future studies of the interplay between emotional and non-emotional cognition in BD. However, the Affective Go/No-Go task includes a more direct measure of emotional bias in addition to the attention interference measure than the Emotional Stroop Task[109] and may thus provide better insight into how cognitive performance is impacted by emotional content.

Within the domain of reward processing and affective decision-making, the most commonly used tests were the Iowa Gambling Task (IGT) and the Cambridge Gambling Task (CGT). Both tests involve simulated gambling and require participants to weigh short-term gains against long-term losses. Both tests have shown sensitivity to deficits during symptomatic states across almost all studies and in some cases during remission. They differ in that the CGT provides participants with explicit information about their odds of winning or losing at each trial while the IGT does not[145]. Further, the CGT includes measures of decision-making abilities that enable assessment of the different aspects of decision-making separately, whereas the IGT does not differentiate between different decision-making components. The CGT may therefore be more sensitive to more subtle abnormalities within single aspects of affective decision-making that could go undetected in a global measure[146]. Finally, tests that showed sensitivity to patients' subtle abnormalities in emotion

reactivity and -regulation involved eye-tracking and facial emotion analysis. Indeed, these sensitive behavioural measures could detect abnormal responses in cases where subjective self-report measures showed no differences between BD and controls. Eye-tracking and facial emotion analysis may therefore be included to assess not only emotion reactivity and -regulation but also other affective cognitive domains.

Based on this comprehensive review, the task force concluded that the *domains* of affective cognition to be assessed in future studies and meta-analyses are (i) facial expression recognition, (ii) implicit emotion regulation, and (iii) reward processing and affective decision making. Specifically, meta-analyses will be able to clarify the effect sizes of abnormalities in these domains across remitted and symptomatic states of BD as well as subtle differences in sensitivity between the implemented affective cognition tests. The *types of tests* to be implemented in future work assessing the respective domains are: (i) facial expression recognition tests using static presentations of morphed faces at various intensity levels to assess face processing, (ii) the Affective Go/No-Go task or, alternatively, the Emotional Stroop Task that assess attentional interference and emotional bias, and (iii) the Cambridge Gambling Task or Iowa Gambling Task that probe affective decision making and reward processing. Although ToM was not reviewed here, several meta-analyses indicate impairments in this multidimensional aspect of social cognition domain that builds on affective cognitive functions. The task force therefore recommends that a ToM test, such as Reading the Mind in the Eyes Test or the Hinting Task, is included in future studies of affective cognition in BD. Finally, an important consideration when selecting the specific type of affective cognition tests is their cognitive demand and complexity, as it may well be that deficits in affective cognition are secondary to deficits in non-emotional cognition[33].

Important goals for future *observational* studies including these types of tests would be (i) to examine which affective domains are most closely linked to psychosocial disability and prognosis in BD, (ii) to deepen our understanding of the interplay between non-emotional and affective cognitive deficits, (iii) to explore whether there exist distinct affective cognitive subgroups of BD patients similar to the observed non-emotional neurocognitive subgroups, and (iv) to examine affective cognition at early stages of BD and longitudinally. For future *intervention* trials targeting cognition, the recommendation would be to include a facial expression recognition using presentation of static morphed faces with varying intensities given the sensitivity of these tests to trait-related impairments during remitted states of BD.

A limitation of the review was that it did not refer to effect sizes of the differences between BD and HC groups and so the weighting of the deficits in each domain is unknown. However, it was not feasible to conduct meta-analyses due to the heterogeneous nature of the reviewed studies that included different affective cognition tests and samples with different mood states and age ranges. Further, it was a limitation that the review did not include a systematic quality assessment of the included studies. Many studies included in the review were of an explorative nature and statistical issues, such as lack of adjustment for multiple testing, may have affected conclusions from the various studies. Thus, some results from individual studies may be chance findings due to multiple testing (either testing several domains or several different tests within the same domain) without Bonferroni adjustment. Another limitation was that the included studies did not consistently report clinical characteristics including depression severity, illness chronicity, types and dose of medications, and whether samples included in- or outpatients. These factors were therefore not always controlled for and may have confounded the results. Further, the differences between studies in the affective cognitive paradigms used, in patients' mood states and illness stages and in sample sizes are likely to have contributed to the heterogeneous results. Finally, it was a limitation that the review did not cover ToM, which was due to the existence of several comprehensive meta-analyses for this aspect of affective cognition in BD[40,41]. The present recommendations for types affective cognition tests should therefore not be regarded as complete but merely as a first step towards a consensus battery.

In conclusion, the most consistent trait-related impairments in BD were facial expression recognition and implicit emotion regulation, although the latter was less thoroughly investigated. In contrast, impaired reward processing and affective decision-making were more related to affective episodes. The recommended affective cognition domains for future study and meta-analyses in BD are facial expression recognition, implicit emotion regulation, and reward processing and affective decision-making. The types of tests that seem most sensitive to deficits in these domains are facial expression recognition tasks using presentation of static morphed facial expressions across various intensity levels, an Affective Go/No-Go task or Emotional Stroop Task, and the Cambridge Gambling Task or Iowa Gambling Tasks, respectively. A measure of ToM should also be included. An important next step to aid consistency and comparability of findings in the field would be to reach consensus on which tests to include in an affective cognition test battery for BD. Further, implementation of eye-tracking and facial emotion analysis measures may aid detection of subtle affective cognitive abnormalities. Future cognition treatment trials should include a facial

expression recognition task as a secondary outcome given the functional importance of this aspect of affective cognition and frequent trait-related deficits in this domain. Finally, studies should ideally be conducted in homogenous samples of either remitted or symptomatic groups to increase insight into which affective cognition changes are state-related and trait-related, respectively.

Disclosures

KWM reports having received consultancy fees from Lundbeck, Allergan and Janssen. **KEB** has served on advisory boards for Sunovion, Sumitomo Dainippon, Takeda-Lundbeck, and Neuralstem and received funding from R01 MH100125 and I01CX000995. **AMA** has received funding for research projects and/or honoraria as a consultant or speaker for the following companies and institutions: Otsuka, Pfizer, AstraZeneca, Bristol-Myers Siquibb, Lundbeck, Brain and Behaviour Foundation (NARSAD Independent Investigator), the Spanish Ministry of Economy and Competitiveness and Instituto de Salud Carlos III. **CRB** has been a consultant or advisor for BoehringerIngelheim, Lundbeck, Otsuka, and Takeda and has received grant money from Pfizer and Takeda. **RSM** is a consultant and/or receives honorarium from speaking from Sunovian, Johnson & Johnson, Otsuka, Lundbeck, Pfizer, Allergan, BMS, Shire, and Purdue. **CLJ** has received grafrom: COLCIENCIAS, Universidad de Antioquia-CODI, NIMH. He has served as a consultant, advisor or Continuing Medical Education (CME) speaker for the following companies: AstraZeneca, Eli Lilly, Glaxo-SmithKline, Janssen, Lundbeck and Pfizer. **SEP** currently holds an investigator-initiated grant from Janssen and has received speaking honoraria from Lundbeck within the past 3 years. **AS** has been a consultant or received honoraria from Allergan, BMS, Lundbeck, Otsuka, and Sunovion. **IJT** has received consultant fees from Lundbeck and Sumitomo Dainippon. **RJP** uses Software for research at no cost from Scientific Brain Training Pro. **TS** has received honoraria for advisory board, consultations, and/or speaker's role from Dainippon Sumitomo Pharmaceutical, Meiji Seika Pharma, Novartis, Otsuka Pharmaceutical and Takeda. **LNY** has been on speaker/advisory boards for, or has received research grants from Alkermes, Allergan, AstraZeneca, Bristol Myers Squibb, CANMAT, CIHR, Dainippon Sumitomo Pharma, Janssen, Lundbeck, Otsuka, Sunovion, and Teva. **AHY** is employed by King's College London, is honorary Consultant for SLaM (NHS UK). He has given paid lectures and is on advisory boards for all major pharmaceutical companies with drugs used in affective and related disorders. He has no

shareholdings in pharmaceutical companies. He has investigator-initiated studies from AZ, Eli Lilly and Lundbeck. **LVK** has within the preceding three years been a consultant for Lundbeck and Sunovion. **EV** has received grants, CME-related honoraria, or consulting fees from AB-Biotics, Abbott, Almirall, Allergan, Angelini, AstraZeneca, Bristol-Myers Squibb, Cephalon, Eli Lilly, Ferrer, ForestResearch Institute, Gedeon Richter, GlaxoSmith-Kline, Janssen, Janssen-Cilag, Jazz, Johnson & Johnson, Lundbeck, Merck, Novartis, Organon, Otsuka, Pfizer, Pierre-Fabre, Qualigen, Roche, SAGE, Sanofi-Aventis, Servier, Shire, Solvay, Takeda, Teva, CIBERSAM, the Seventh European Framework Programme (ENBREC) and Horizon 2020, the Stanley medical Research Institute, United Biosource Cooperation, and Wyeth. All other authors report no biomedical financial interests or potential conflicts of interest. **AFC, TVR** and **GH** have no conflicts of interest to declare.

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Table 1: Facial expression recognition									
Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
REMITTED									
Thaler et al.	2013	Facial emotion processing	The Bell-Lysaker Emotion Recognition Test (BLERT)	48 BD, 24 HC	24 remitted with history of psychotic features; 24 remitted with no history of psychotic features	48 BD-I	67	36	BD remitted patients with psychotic features performed ↓ than the BD remitted patients without psychotic features and HCs for auditory, visual, and audio-visual items, with particularly ↓ performance in identifying angry stimuli compared to BD remitted patients without psychotic features and HCs and also ↓ performance in identifying surprise and fear stimuli compared to HCs only. The BD remitted patients with psychotic features also had a trend towards misattributing more neutral visual stimuli as negative.
Soeiro-de-Souza et al.	2012b	Facial emotion processing	The Ekman 60 Faces Test (EK-60)	39 BD, 40 HC	39 remitted	39 BD-I	62	33	BD remitted patients generally performed ↓ than HCs on total score, and performed specifically ↓ than

									HCs on anger and sadness.
Martino et al.	2011	Facial emotion processing	The Ekman 60 Faces Test (EK-60)	81 BD, 34 HC	81 remitted	45 BD-I, 36 BD-II	67	40	BD remitted patients showed ↓ recognition of fearful faces relative to HCs
Harmer, Grayson & Goodwin	2002	Facial emotion processing	The Ekman 60 Faces Test (EK-60) (morphed)	20 BD, 20 HC	20 remitted	?	50	38	BD remitted patients showed ↑ accuracy at identifying expressions of disgust compared to HCs.
Soeiro-de-Souza et al.	2012b	Facial emotion processing	The Emotional Hexagon Test (FEEST) (morphed)	39 BD, 40 HC	39 remitted	39 BD-I	62	33	BD remitted patients generally performed ↓ than HCs on total score, and performed specifically ↓ than HCs on disgust, happiness, sadness and surprise.
Altamura et al.	2016	Facial emotion processing	A facial expression recognition task (morphed faces)	16 BD, 20 young HC, 20 older HC	16 remitted	16 BD-I	56	46	BD remitted patients showed ↑ reaction time to all (happy and angry) faces compared to older and younger HCs.
Bora et al.	2005	Facial emotion processing	A facial expression recognition task	43 BD, 30 HC	43 remitted	43 BD-I	47	39	ns

Lawlor-Savage, Sponheim & Goghari	2013	Facial emotion processing	A facial expression recognition task	17 BD, 50 HC	17 remitted	?	18	47	BD remitted patients performed worse when judging happy expressions under time constraints compared to HCs. Also, BD remitted patients showed ↓ accuracy when differentiating neutral faces from happy faces compared to HCs.
Seidel et al.	2012	Facial emotion processing	A facial expression recognition task	21 BD, 21 UR, 21 HC	21 remitted	10 BD-I, 11 BD-II	43	46	BD remitted patients generally showed ↓ accuracy at identifying emotional facial expressions than HCs. Also, BD remitted patients were slower at identifying emotional facial expressions than HCs.
Van Rheenen et al.	2017	Facial emotion processing	A facial expression recognition task	28 BD, 28 HC	28 remitted	28 BD-I	32	42	BD remitted patients showed ↓ accuracy on whole-face recognition compared to HCs.
Ryan et al.	2013	Facial emotion processing	A facial expression recognition task	156 BD, 143 HC	156 remitted	133 BD-I, 23 BD-II	41	39	Not working BD remitted patients showed ↓ accuracy compared to working BD remitted patients and HCs. Not working BD remitted patients showed ↓ reactionstimes compared to working BD remitted patients and HCs.

Venn et al.	2004	Facial emotion processing	A facial expression recognition task (morphed faces)	17 BD, 17 HC	17 remitted		41	44	ns
Branco et al.	2017	Facial emotion processing	A facial expression recognition task (unambiguous facial expressions, not morphed)	30 BD, 45 HC	30 remitted	17 BD-I, 13 BD-II	80	43	BD remitted patients rated expressions of sadness more intensely compated to HCs. BD remitted patients showed ↓ accuracy in identifying expressions of disgust compared to HCs. When sadness were shown for shorter periods of time (200 ms), BD remitted patients showed ↓ accuracy.
Robinson et al.	2015	Facial emotion processing	The Facial Expression Recognition Task (FERT-static images)	38 BD, 28 HC (Study 1)	38 remitted	?	55	45	ns
Hoertnagl et al.	2011	Facial emotion processing	The Facially Expressed Emotion Labeling (FEEL) test	47 BD, 45 HC	47 remitted	47 BD-I	38	42	BD remitted patients showed ↓ accuracy when recognising happiness, disgust, and total score compared to HCs.

Yalcin-Siedentopf et al.	2014	Facial emotion processing	The Facially Expressed Emotion Labeling Test (FEEL)	57 BD, 50 HC	57 remitted	57 BD-I	65	42	BD remitted patients exhibited ↓ accuracy of recognition of disgusted and happy facial expressions compared to HCs. BD remitted patients more often misinterpreted disgusted faces as surprised or angry expressions, and sad faces as happy expressions compared to HCs.
de Brito et al.	2016	Facial emotion processing	The Penn Emotion Recognition Test	23 BD, 22 UR, 27 HC	23 remitted	23 BD-I	30	37	BD remitted patients showed ↓ accuracy when recognizing fearful faces, and ↑reaction times to happy faces, compared to HCs.
Goghari & Sponheim	2013	Facial emotion processing	The Penn Emotion Recognition Test	16 BD, 30 HC	16 remitted	16 BD-I	19	46	BD remitted patients showed ↑ accuracy when judging age (but not the emotion) from an angry facial expression compared to HCs. Also, BD remitted patients mislabeled more angry facial expressions as fear compared to HCs.
Ruocco et al.	2014	Facial emotion processing	The Penn Emotion Recognition Test	248 BD, 380 HC	248 remitted	248 BD-I	63	36	BD remitted patients showed ↓ accuracy in identifying neutral and angry faces compared to HCs. They also were more likely to misclassify

									neutral faces as sad and neutral faces as happy relative to HCs.
de Brito et al.	2016	Facial emotion processing	The Penn Emotional Acuity Test	23 BD, 22 UR, 27 HC	23 remitted	23 BD-I	30	37	BD showed ↓ reactiontimes to very happy faces compared to HCs.
Derntl et al.	2009	Facial emotion processing	The Vienna Emotion Recognition Tasks (VERT-K)	62 BD, 62 HC	62 remitted	26 BD-I, 36 BD-II	60	39	BD-I remitted patients showed ↓ general accuracy when recognizing emotional faces compared to HCs, whereas BD-II remitted patients did not differ from HCs in their ability to recognize emotional expressions. Moreover, sad faces were mistaken for fear by BD-I remitted patients significantly more often than by HCs, and again, BD-II remitted patients did not differ from HCs.
SYMPTOMATIC									
Getz, Shear & Strakowski	2003	Facial emotion processing	A facial expression recognition task	25 BD, 25 HC	25 manic/mixed	25 BD-I	52	25	BD manic patients showed ↓ accuracy and ↑ reactiontimes compared to HCs.

Schaefer et al.	2010	Facial emotion processing	A facial expression recognition task (morphed faces)	21 BD, 21 HC	21 depressed	9 BD-I, 12 BD-II	62	47	BD depressed patients required a more intense emotional display to correctly identify the facial emotion when compared to HCs. BD depressed patients exhibited ↑ accuracy on recognition of faces with disgust.
Robinson et al.	2015	Facial emotion processing	The Emotional Hexagon Test (FEEST) (morphed)	26 BD, 25 HC (study 2)	26 depressed	?	?	?	ns
Robinson et al.	2015	Facial emotion processing	The Facial Expression Recognition Task - Dynamic Images (FERT-dynamic)	51 BD, 47 HC (study 2)	51 depressed	?	38	47	ns
MIXED SAMPLE with a separate analysis on each patient group									
Pan, Tseng & Liu	2013	Facial emotion processing	The DANVA facial emotion recognition task (not morphed)	45 BD, 40 HC	29 manic; 16 remitted	?	44	41	BD manic patients performed ↓ than HCs in correctly categorizing total emotions, negative emotions and anger. BD remitted patients had

									comparable affect recognition performances with HCs.
Soeiro-de-Souza et al.	2012a	Facial emotion processing	The Ekman 60 Faces Test (EK-60)	64 BD, 75 HC	39 manic; 25 depressed	64 BD-I	?	28	BD manic and depressed patients showed ↓ performance on totalscore compared to HCs.
David et al.	2014	Facial emotion processing	The Emotional Hexagon Test (FEEST) (morphed)	110 BD, 96 HC	38 remitted, 41 manic, 31 depressed	110 BD-I	68	30	BD manic patients showed ↓ identificaiton of fear, happiness, surprise, and total score compared to HCs. BD remitted patients showed ↓ performance on fear and total score compared to HCs.
Soeiro-de-Souza et al.	2012a	Facial emotion processing	The Emotional Hexagon Test (FEEST) (morphed)	64 BD, 75 HC	39 manic; 25 depressed	64 BD-I	?	28	BD manic and depressed patients showed ↓ performance on totalscore compared to HCs.
Lembke & Ketter	2002	Facial emotion processing	A facial expression recognition task (not morphed)	24 BD, 10 HC	16 remitted, 8 manic	16 BD-I, 8 BD-II	?	?	BD manic patients correctly identified fewer fearful, disgust, and total facial expressions compared to BD remitted patients and HCs. BD-II remitted patients were better at recognising fearful facial expressions than HCs.

MIXED SAMPLE with no separate analysis on each patient group									
Wegbreit et al.	2015	Facial emotion processing	The DANVA facial emotion recognition task (not morphed)	27 BD, 42 HC	23 remitted, 3 depressed, 1 unknown	23 BD-I	37	21	BD patients made ↑ total errors when recognising facial expressions (angry, sad, fearful, happy) compared to HCs.
Van Rheenen & Rossell	2014b	Facial emotion processing	A dynamic and static facial emotion labeling task	50 BD, 52 HC	17 remitted, 4 (hypo)manic, 17 depressed, 12 mixed	38 BD-I, 12 BD-II	68	38	BD patients were generaly less accurate at labeling dynamic and static facial expressions (happy, fear, angry, sad) compared to HCs.
Van Rheenen & Rossell	2014a	Facial emotion processing	A facial emotion labelling task	50 BD, 52 HC	18 remitted, 16 depressed, 4 (hypo)manic, 12 mixed	38 BD-I, 12 BD-II	66	38	BD patients showed ↑ reactiontimes when presented with incongruent and congruent visual and auditory emotional information compared to HCs
Addington & Addington	1998	Facial emotion processing	A facial expression recognition task	40 BD, 40 HC	30 remitted, 1 depressed	?	75	38	BD patients generaly performed more poorly on the facial discrimination task compared to HCs.
Baez et al.	2013	Facial emotion processing	A facial expression recognition task (morphed faces)	15 BD, 30 HC	5 remitted; 4 depressed; 6 remission with subsyndromal symptoms	?	73	36	BD patients performed ↓ than HCs on fear and sadness recognition. BD patients had significantly ↓ reaction times compared to HCs for the emotions of disgust, anger, surprise

									and sadness.
Vierck, Porter & Joyce	2015	Facial emotion processing	A facial expression recognition task (morphed faces)	36 BD, 40 HC	19 remitted, 1 mixed, 16 depressed	32 BD-I, 4 BD-II	75	41	BD patients generally exhibited ↓ accuracy and ↑ reactiontimes during recognition of facial expressions (anger, sad, disgust, happy, fear) compared to HCs.
Rossell et al.	2014	Facial emotion processing	Name Affect subtest from the Comprehensive Affective Testing System (CATS)	43 BD, 112 HC	11 remitted, 32 depressed	43 BD-I	63	40	ns
Rossell et al.	2014	Facial emotion processing	Select Affect subtest from the Comprehensive Affective Testing System (CATS)	43 BD, 112 HC	11 remitted, 32 depressed	43 BD-I	63	40	ns

Daros et al.	2014	Facial emotion processing	The Penn Emotional Acuity Test	16 BD, 32 HC	8 manic, 3 mixed, 5 depressed	16 BD-I	44	24	BD patients were less accurate at recognising moderately sad faces and mildly/moderately happy expressions - all of which they rated more intense than HCs. BD patients continued to have difficulties identifying mild/moderately happy facial expressions after treatment relative to HCs. BD patients exhibited ↑ reactiontimes overall, also after treatment.
CURRENT STATUS NOT STATED									
Quide et al.	2018	Facial emotion processing	The Emotional Hexagon Test (FEEST) (morphed)	84 BD, 75 HC	Not stated	BD-I	64	38	ns
Summers et al.	2006	Facial emotion processing	The Emotional Hexagon Test (FEEST) (morphed)	36 BD, 30 HC	9 depressed; 27 NOS	25 BD-I, 11 BD-II	59	39	BD patients performed worse than HCs on surprise recognition.
Derntl et al.	2012	Facial emotion processing	A facial expression recognition task	24 BD, 24 HC	Not stated	BD-I: 13, BD-II: 11	50	44	BD patients generally exhibited ↓ accuracy compared to HCs.

Bellack, Blanchard & Mueser	1996	Facial emotion processing	A facial expression recognition task	11 BD, 19 HC	Not stated	Not stated	64	39	ns
Vaskinn et al.	2007	Emotion processing	A facial expression recognition task	21 BD, 31 HC	Not stated	21 BD-I	48	38	ns
Ryan et al.	2017	Facial emotion processing	The Facial Emotion Perception Test (FEPT)	90 BD, 17 HC	Not stated	Not stated	74	42	ns
Vederman et al.	2012	Facial emotion processing	The Facial Emotion Perception Test (FEPT)	119 BD, 66 HC	Not stated	Not stated	66	37	BD patients were ↓ accurate at fear, sadness, and total facial expression recognition compared to HCs.

Table 2: Facial affect matching

Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
REMITTED									
Bora et al.	2005	Facial emotion processing	The Benton Facial Recognition	43 BD, 30 HC	43 remitted	43 BD-I	47	39	ns

			Test (short form)						
Joshua et al.	2016	Facial emotion processing	Featural and second-order configural face processing	28 BD, 28 HC	28 remitted	28 BD-I	32	42	BD remitted patients showed ↓ accuracy on spacing and featural tasks compared to HCs. BD remitted patients also displayed a lack of an inversion effect on second-order configular face processing.
Bozikas et al.	2006	Facial emotion processing	Kinney's Matching Test	19 BD, 30 HC	19 remitted	19 BD-I	58	39	BD remitted patients showed ↓ accuracy when matching photographs with facial expressions (happy, sadness, fear, anger, disgust, surprise) compared to HCs.
de Brito et al.	2016	Facial emotion processing	The Penn Emotion Discrimination Test	23 BD, 22 UR, 27 HC	23 remitted	23 BD-I	30	37	ns
SYMPTOMATIC									
Robinson et al.	2015	Facial emotion processing	The Benton Facial Recognition Test (short	51 BD, 47 HC	51 depressed	Not stated	38	47	BD depressed patients performed overall worse than HCs.

			form)						
Getz, Shear, & Strakowski	2003	Facial emotion processing	A facial emotion discrimination task	25 BD, 25 HC	25 manic/mixed	25 BD-I	52	25	BD manic patients generally exhibited ↑ reactiontime compared to HCs.
MIXED SAMPLE (i.e. no seperate analysis on each patient group)									
Rossell et al.	2014	Facial emotion processing	Affect Discrimination subtest from the Comprehensive Affective Testing System (CATS)	43 BD, 112 HC	11 remitted, 32 depressed	43 BD-I	63	40	ns
Addington & Addington	1998	Facial emotion processing	The Benton Facial Recognition Test	40 BD, 40 HC	30 remitted, 1 depressed	Not stated	75	38	ns
Addington & Addington	1998	Facial emotion processing	A facial emotion discrimination task	40 BD, 40 HC	30 remitted, 1 depressed	Not stated	75	38	BD patients performed overall more poorly compared to HCs.

Rossell et al.	2014	Facial emotion processing	Match Affect subtest from the Comprehensive Affective Testing System (CATS)	43 BD, 112 HC	11 remitted, 32 depressed	43 BD-I	63	40	BD patients generally exhibited ↓ accuracy compared to HCs.
Van Rheenen & Rossell	2014b	Facial emotion processing	The static facial emotion discrimination task	50 BD, 52 HC	17 remitted, 4 (hypo)manic, 17 depressed, 12 mixed	38 BD-I, 12 BD-II	68	38	BD patients generally exhibited ↓ accuracy compared to HCs to all faces (happy, sad, angry, fear, and neutral faces).
CURRENT STATUS NOT STATED									
Bellack, Blanchard & Mueser	1996	Facial emotion processing	The Benton Facial Recognition Test	11 BD, 19 HC	Not stated	Not stated	64	39	BD patients performed worse overall compared to HCs.
Bellack, Blanchard & Mueser	1996	Facial emotion processing	A facial emotion discrimination task	11 BD, 19 HC	Not stated	Not stated	64	39	ns
Vaskinn et al.	2007	Emotion processing	A facial emotion discrimination task	21 BD, 31 HC	Not stated	21 BD-I	48	38	ns

Table 3: Other studies of facial emotion processing									
Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
Kim et al.	2016	Facial emotion processing	A facial expression recognition task on social dominance	35 BD, 45 HC	35 remitted	35 BD-I	43	36	BD remitted patients showed ↓ perception of social dominance based on anger, disgust, fear, and neutral facial emotional expressions compared to HCs.
Mansell & Lam	2006	Facial emotion processing	A facial rating task	32 BD, 32 HC	32 remitted	32 BD-I	66	45	BD remitted patients rated faces as less trustworthy compared to HCs.

Table 4: Reactivity to and decoding of emotional information									
Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
STIMULI: PICTURES									

Broch-Due et al.	2018	Emotion processing and regulation	An affective picture viewing task	16 BD, 17 HC	16 full/partial remission	5 BD-I, 11 BD-II	53	33	BD remitted patients gazed less at neutral and negative images when viewing and down-regulating affect compared to HCs. When viewing images, BD remitted patients exhibited stronger facial expressions to neutral pictures, a lack of facial expressions to unpleasant pictures, and more surprised facial expressions to both neural and unpleasant pictures relative to HCs.
Gruber et al.	2013	Emotion processing	An affective working memory task	29 BD, 30 HC	29 remitted	29 BD-I	66	30	BD patients exhibited a selective deficit in maintaining negative—but not positive—emotions compared to HCs.
Garcia-Blanco et al.	2014	Facial emotion processing	An emotional pictures free-viewing task	66 BD, 20 HC	23 remitted, 20 depressed, 23 manic	Not stated	40	45	BD depressed patients spent less time looking at, and fixated less at, happy images compared to HCs. Patients in remitted, depressive, and manic states spent more time looking at, and fixated more on, threatening images compared to HCs.

Garcia-Blanco, Salmeron & Perea	2015	Emotion processing	An emotional pictures free-viewing task	76 BD, 23 HC	26 remitted, 24 depressed, 26 manic	76 BD-I	42	45	BD patients exhibited more first-pass fixations, and longer and more fixations to threatening images compared to HCs.
Purcell et al.	2018	Emotion processing	An emotional pictures free-viewing task	24 BD, 25 HC	24 remitted	BD-I	58	34	ns
Aminoff et al.	2011	Emotion processing	A picture emotion processing task	110 BD, 135 HC	110 full/partial remission	64 BD-I, 41 BD-II	60	33	ns
M'Bailara et al.	2009	Emotion processing	A picture emotion processing task	55 BD, 90 HC	55 remitted	Not stated	Not stated	39	BD remitted patients rated neutral images as more pleasant and inducing higher level of arousal compared to HCs, and neutral images also triggered stronger startle reflexes compared to HCs.
STIMULI: AUDITORY STIMULI									
Derntl et al.	2012	Emotion processing	An affective responsiveness task	24 BD, 24 HC	Not stated	BD-I: 13, BD-II: 11	50	44	BD patients showed ↓ accuracy on situations eliciting disgust, neutral and sad emotions compared to HCs.
Bozikas et al.	2007	Emotion processing	The Affective Prosody Test (APT)	19 BD, 22 HC	19 remitted	19 BD-I	58	39	BD patients exhibited ↓ overall accuracy for all emotions (happiness, sadness, surprise, fear, anger,

									neutral) compared to HCs.
Zenisek et al.	2015	Emotion processing	An auditory-visual affect recognition task adapted from The Bell-Lysaker Emotion Recognition Test (BLERT)	46 BD, 24 HC	46 remitted	Not stated	67	36	BD patients with a history of psychosis performed worse on both the auditory and the auditory-visual condition of the emotion recognition task compared to HCs. BD patients without a history of psychosis did not show any significant impairment.
Ryan et al.	2017	Emotion processing	The Emotion Perception Test (EPT)	90 BD, 17 HC	Not stated	Not stated	74	42	ns
Vederman et al.	2012	Emotion processing	The Emotion Perception Test (EPT)	119 BD, 66 HC	Not stated	Not stated	66	37	ns
Ryan et al.	2013	Emotion processing	The Emotion Perception Test (EPT)	156 BD, 143 HC	156 remitted	133 BD-I, 23 BD-II	41	39	ns
Van Rheenen et al. (2013)	2013	Emotion processing	An emotional prosody labelling task	50 BD, 52 HC	50 remitted	38 BD-I, 12 BD-II	64	33	BD male patients showed ↓ emotional prosody accuracy for the labelling of happy intonations.

Van Rheenen et al. (2013)	2013	Emotion processing	A linguistic prosody labelling task	50 BD, 52 HC	50 remitted	38 BD-I, 12 BD-II	64	33	ns
Hoertnagl et al.	2014	Emotion processing	*Name Emotional Prosody* subtest from the Comprehensive Affective Testing System (CATS)	58 BD, 85 HC	58 remitted	58 BD-I	66	42	BD remitted patients generally performed ↓ than HCs on total score, and exhibited specifically ↓ score than HCs in identifying anger. BD remitted patients more often misintepreted anger as neutral prosody compared to HCs.
Van Rheenen et al. (2013)	2013	Emotion processing	A tone discrimination task	50 BD, 52 HC	50 remitted	38 BD-I, 12 BD-II	64	33	BD patients were ↓ sensitive in discriminating amplitude and durational cues but not pitch cues compared to HC.
Vaskinn et al.	2007	Emotion processing	The Voice Emotion Test of the Face/Voice Emotion Identification and Discrimination Test	21 BD, 31 HC	Not stated	21 BD-I	48	38	ns

STIMULI: WRITTEN SENTENCES									
Derntl et al.	2012	Emotion processing	An affective responsiveness task	24 BD, 24 HC	Not stated	BD-I: 13, BD-II: 11	50	44	BD showed ↓ accuracy on situations eliciting disgust, neutral and sad emotions compared to HCs.
Seidel et al.	2012	Emotion processing	An affective responsiveness task	21 BD, 21 UR, 21 HC	21 remitted	10 BD-I, 11 BD-II	43	46	BD remitted patients were generally worse at identifying emotional (fearful, disgusting, sad) situations compared to HCs.
STIMULI: OTHER									
Van der Gucht et al.	2009	Emotion processing	An autobiographical memory task	107 BD, 41 HC	43 remitted, 34 (hypo)manic/mixed, 30 depressed	Not stated	64	46	BD manic patients (but not depressed or remitted BD patients) recalled fewer specific negative memories than HCs.
Cuellar, Johnson & Ruggero	2009	Emotion processing	A criticism analog task	35 BD, 35 HC	35 remitted	35 BD-I	59	40	ns
Vaskinn et al.	2017	Emotion processing	Emotional Biological Motion Test (EmoBio)	53 BD, 84 HC	23 remitted; 30 NOS	29 BD-I, 24 BD-II	68	34	BD patients generally performed ↓ than HCs in the ability to perceive emotions (angry, happy, sad, fear, neutral) from body movement.

Bersani et al.	2013	Facial emotion processing	The Facial Action Coding System (FACS) to emotional film clips	15 BD, 15 HC	15 remitted	BD-I	53	48	BD remitted patients presented incongruent emotive feelings and facial expressions, compared to HCs.
Gruber et al.	2011	Emotion processing	A rumination induction task	39 BD, 34 HC	39 remitted	39 BD-I	71	38	ns
Bellack, Blanchard & Mueser	1996	Facial emotion processing	The Videotape Affect Perception Test (VAPT)	11 BD, 19 HC	Not stated	Not stated	64	39	BD patients were less accurate at identifying sad (but not angry or happy) scenes compared to HCs

Table 5: Explicit emotion regulation

Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
Broch-Due et al.	2018	Explicit emotion processing and regulation	An affective picture viewing task	16 BD, 17 HC	16 full/partial remission	5 BD-I, 11 BD-II	53	33	BD remitted patients gazed less at neutral and negative images when down-regulating affect compared to HCs.

Gruber, Harvey & Gross	2012	Explicit emotion regulation	An emotional film clips task	37 BD, 38 HC	37 remitted	34 BD-I; 3 BD-II	71	36	BD remitted patients were more likely to use cognitive reappraisal and suppression as explicit emotion regulation strategies, but with greater effort and less success, to negative, positive, and neutral film clips compared to HCs.
Gruber, Hay & Gross	2014	Explicit emotion regulation	An emotional film clips task	23 BD, 23 HC	23 remitted	23 BD-I	74	39	ns

Table 6: Implicit emotion regulation

Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
REMITTED									
Degabriele & Lagopoulos	2012	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	18 BD, 18 HC	18 remitted	18 BD-I	Not stated	40	BD remitted patients showed ↓ accuracy compared to HCs.

Gopin et al.	2011	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	59 BD, 144 HC	59 remission/partly remission	59 BD-I	43	41	BD remitted patients were generally slower and showed ↓ accuracy during positive conditions, and exhibited ↑ response bias during negative conditions, compared to HCs.
Rubinsztein et al.	2000	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	18 BD, 18 HC	18 remitted	18 BD-I	?	42	BD remitted patients were generally slower compared to HCs.
Barbosa et al.	2018	Implicit emotion regulation of emotional stimuli	Affective processing test	20 BD, 25 HC	20 remitted	BD-I	75	44	BD remitted patients showed ↓ performance on immediate and delayed affective memory recall compared to HCs

Gul & Khan	2014	Implicit emotion regulation of emotional stimuli	An emotional task-switching paradigm	40 BD, 40 HC	40 remitted	BD-I	50	32	BD remitted patients showed asymmetries between emotion and gender categorizations compared to HCs, and specifically, there was a larger switch cost (i.e., higher reaction times on switch as compared to no-switch trials) for the gender than the emotion categorization compared to HCs.
Lex et al.	2008	Implicit emotion regulation of emotional stimuli	The Emotional Stroop Task (EST)	19 BD, 19 HC	19 remitted	19 BD-I	63	40	ns
Sokhadze et al.	2011	Implicit emotion regulation of emotional stimuli	A modified emotional gender categorisation oddball task	9 BD, 10 HC	9 remitted	6 BD-I, 3 BD-II	67	42	BD remitted patients were generally slower than HCs when responding to positive (happiness, contempt) and negative (sadness, digust) facial expressions.

Kim et al.	2011	Implicit emotion regulation of emotional stimuli	Priming task of emotional faces	20 BD, 20 HC	20 remitted	20 BD-I	50	32	In subliminal tasks, both BD remitted patients and HCs judged the neutral target face as significantly more unpleasant (negative judgement shift) when presented with negative emotion primes compared with positive primes. In supraliminal tasks, BD remitted patients showed significant negative judgment shift, whereas HCs did not.
Berchio et al.	2017	Implicit emotion regulation of emotional stimuli	Two-back working memory task with neutral faces stimuli	19 BD, 19 HC	19 remitted	Not stated	42	35	ns
SYMPTOMATIC									
Holmes et al.	2008	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	65 BD, 52 HC	65 depressed	13 BD-I, 52 BD-II	65	38	BD depressed patients who were taking medication were generally slower and exhibited ↓ accuracy during positive conditions (i.e. missed more happy targets than sad targets) compared to unmedicated

									BD depressed patients and HCs.
Murphy et al.	1999	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	18 BD, 18 HC	18 manic	18 BD-I	50	36	BD manic patients were slower to respond to sad but not happy targets compared to HCs. BD manic patients exhibited ↑ task-irrelevant reponse bias (i.e. made generally more commission errors) and ↓ accuracy during positive conditions (i.e. missed more happy targets than sad targets) compared to HCs.
Rubinsztein et al.	2006	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	24 BD, 26 HC	24 depressed	24 BD-I	Not stated	44	BD depressed patients were generally slower compared to HCs.

Leyman, De Raedt & Koster	2009	Implicit emotion regulation of emotional stimuli	A pictural spatial cueing task including emotional modification	14 BD, 14 HC	14 depressed	14 BD-I	43	46	BD depressed patients generally showed enhanced attention (i.e. ↑ cue validity effect) for angry faces and experienced more difficulties disengaging attention away from angry and positive facial expressions compared to HCs.
MIXED SAMPLE (i.e. no separate analysis on each patient group)									
Bauer et al.	2018	Implicit emotion regulation of emotional stimuli	Affective Go/No-Go task (AGN)	28 BD, 15 HC	9 remitted; 10 depressed; 2 manic; 1 hypomanic; 1 mixed	19 BD-I, 6 BD-II, 3 BD-NOS	57	56	ns
Kerr, Scott, & Phillips	2005	Implicit emotion regulation of emotional stimuli	The Emotional Stroop Task (EST)	42 BD, 18 HC	14 manic, 13 depressed, 15 remitted	Not stated	52	47	BD patients were slower than HCs on all (positive, negative, neutral) conditions.
Lyon, Startup & Bentall	1999	Implicit emotion regulation	The Emotional Stroop Task (EST)	30 BD, 15 HC	15 manic, 15 depressed	Not stated	63	46	BD manic patients were overall slower than HCs. BD depressed and manic patients showed more overall

		of emotional stimuli							interference and specific interference for depression-related cards compared to HCs.
Jongen et al.	2007	Implicit emotion regulation of emotional stimuli	Spatial cueing task including emotional modification	29 BD, 29 HC	16 mildly depressed, 13 remitted	Not stated	Not stated	45	BD mildly depressed patients directed their attention away from depression-related words, whereas both BD groups (mildly depressed and remitted) directed their attention away from positive words compared to HCs.
Other studies measuring implicit emotion regulation using eye-tracking									
Garcia-Blanco, Perea & Salmeron	2013	Facial emotion processing	A facial emotion pro/-antisaccade task	71 BD, 28 HC	22 manic, 25 depressed, 24 remitted	Not stated	42	44	BD patients in manic and depressive episodes committed more antisaccade and prosaccade errors than HCs and BD remitted patients during presentation of neutral, happy, and sad facial expressions. BD manic patients committed more antisaccade errors on happy faces than neutral and sad faces compared to HCs. BD depressed, manic, and remitted patients had higher antisaccade latencies compared to

									HCs. BD depressed and manic patients had higher prosaccade latencies compared to HCs.
Soncin et al.	2016	Facial emotion processing	A facial emotion pro/-antisaccade task	20 BD, 21 HC	20 remitted	8 BD-I, 12 BD-II	50	37	BD remitted patients made ↑ direction errors and ↑ saccadic reactiontimes during fearful, sad and neutral antisaccade trials compared to HCs.
Yep et al.	2018	Facial emotion processing	A facial emotion pro/-antisaccade task	20 BD, 21 HC	20 remitted	Not stated	45	38	BD remitted patients made more direction errors on happy, neutral, sad, and angry facial expressions on antisaccade tasks compared to HCs. BD remitted patients had lower microsaccade rate than HCs for neutral faces preceding prosaccade trials.

Peckham, Johnson & Tharp	2016	Emotion processing	A free-veiwing task	29 BD, 28 HC	29 remitted	BD-I	52	37	ns

Table 7: Reward processing

Authors	Year	Measure	Paradigm	N	BD mood state	BD subtype	Sex (% female) for BD	Age (BD mean)	Finding
REMITTED									
Peckham & Johnson	2016	Reward	Anagrams reward task	31 BD, 28 HC	31 remitted	BD-I	52	38	ns
Jaracz, Drozdz & Borkowska	2010	Reward	Cambridge Gambling Task (CGT)	30 BD, 25 HC	30 remitted				ns
Roiser et al.	2009	Reward	Cambridge Gambling Task (CGT)	15 BD, 19 HC	15 remitted	15 BD-I	67	44	Following mood induction, BD remitted patients showed slower deliberation times compared to HCs. Notably, not significant on risk adjustment or quality of decision making.

Rubinsztein et al.	2000	Reward	Cambridge Gambling Task (CGT)	18 BD, 18 HC	18 remitted	Not stated	Not stated	42	BD remitted patients showed slower deliberation times compared to HCs, although accuracy on the task was not impaired.
Chandler et al.	2009	Reward	Framed Risky-Choice Task	20 BD, 20 HC	20 remitted	BD-II or BD-NOS	55	19	BD remitted patients showed slower deliberation times to select the safe options than risky choices in the positively framed dilemmas (i.e. oportunities to gain rewards) compared with HCs
Brambilla et al.	2013	Reward	The Iowa Gambling Task (IGT)	70 BD, 140 HC	70 remitted	70 BD-I	47	45	BD remitted patients showed ↓ decision making ability compared to HCs, and they were more likely to attend to gains or losses (motivational parameter).
Caletti et al.	2013	Reward	The Iowa Gambling Task (IGT)	18 BD, 18 HC	18 remitted	10 BD-I, 8 BD-II	78	42	ns
Clark, Iversen & Goodwin	2002	Reward	The Iowa Gambling Task (IGT)	30 BD, 30 HC	30 remitted		43	36	ns
Ibanez et al.	2012	Reward	The Iowa Gambling Task	13 BD, 25 HC	13 remitted	13 BD-II	38	40	ns

			(IGT)						
Malloy-Diniz et al.	2009	Reward	The Iowa Gambling Task (IGT)	39 BD, 53 HC	20 remitted	39 BD-I	59	41	BD remitted patients showed ↓ decision making ability compared to HCs.
Martino et al.	2011	Reward	The Iowa Gambling Task (IGT)	85 BD, 34 HC	85 remitted	48 BD-I, 37 BD-II	70	40	ns
Horan et al.	2016	Reward	A motivational gradient task	33 BD, 31 HC	33 remitted	33 BD-I	42	44	ns
Duek et al.	2014	Reward	Probabilistic Classification Task (PCT)	40 BD, 42 HC	40 remitted	40 BD-I	45	42	ns
Pizzagalli et al.	2008	Reward	Probabilistic Reward Task (PRT)	13 BD, 25 HC	13 remitted	11 BD-I, 2 BD-II	38	39	BD remitted patients showed ↓ response bias compared to HCs.
Saunders Goodwin & Rogers	2016	Reward	Risky Choice Task	20 BD, 20 HC	20 remitted	Not stated	100	36	ns
Ibanez et al.	2012	Reward	The Rapid-Decision Gambling Task (RDGT)	13 BD, 25 HC	13 remitted	13 BD-II	38	40	ns

Ibanez et al.	2012	Reward	The Rational Decision-Making Under Risk Task (RDMUR)	13 BD, 25 HC	13 remitted	13 BD-II	38	40	ns
SYMPTOMATIC									
Murphy et al.	2001	Reward	Cambridge Gambling Task (CGT)	18 BD, 26 HC	18 manic	18 BD-I	56	36	BD manic patients showed slower deliberation times, ↓ quality of decision making, overall failure to accumulate as many points as HC, as well as suboptimal betting strategies compared to HCs.
Hershenberg et al.	2016	Reward	Progressive Ratio Task	28 BD, 43 HC	28 depressed	Not stated	64	34	ns
MIXED SAMPLE (i.e. no separate analysis on each patient group)									
Holmes et al.	2009	Reward	Balloon Analogue Risk Task (BART)	55 BD, 25 HC	24 remitted; 28 depressed; 3 (hypo)manic	48 BD-I, 7 BD-II	62	41	BD patients across all phases showed aberrant risk-taking behaviour compared to HCs, though only in subjects with a prior history of alcohol abuse or dependence.
Hayden et al.	2008	Reward	A card-sorting task	59 BD, 44 HC	16 remitted; 8 manic; 7 hypomanic; 18	59 BD-I	61	43	BD remitted patients sorted more cards to win money than the BD symptomatic patients and the HCs.

					mixed; 10 depressed				
Bauer et al.	2018	Reward	Cambridge Gambling Task (CGT)	28 BD, 15 HC	9 remitted; 10 depressed; 2 manic; 1 hypomanic; 1 mixed	19 BD-I, 6 BD-II, 3 BD-NOS	57	56	BD patients across all phases showed ↓ quality of decision making, ↓ risk adjustment and ↑ delay aversion compared to HCs.
Van der Gucht et al.	2009	Reward	The Card Arranging Reward Responsitvity Objective Test (CARROT)	107 BD, 41 HC	43 remitted, 34 (hypo)manic/mixed, 30 depressed	Not stated	64	46	ns
Chase et al.	2018	Reward	Cued Reinforcement Reaction Time (CRRT) task	65 BD, 44 HC	35 remitted; 30 depressed	65 BD-I	72	33	Only BD remitted patients showed a relative increase in commission errors during the high reward compared to low reward condition compared to HCs.

Strakowski et al.	2009	Reward	Delayed reward task (DRT)	70 BD, 34 HC	50 manic; 20 mixed	70 BD-I	59	30	BD manic and mixed patients exhibited ↑ impulsive responses, slower deliberation times, and were more likely to choose a smaller, but more quickly obtained reward compared to HCs. In addition to this, BD manic patients showed ↑ impulsive responding than BD mixed patients.
Barch et al.	2017	Reward	Explicit Probabilistic Incentive Learning Task (EPILT)	43 BD, 55 HC	13 remitted; 8 manic; 10 mixed; 4 hypoamnic; 7 depressed; 1 unknown	43 BD-I	56	35	ns
Barch et al.	2017	Reward	Implicit Probabilistic Incentive Learning Task (IPILT)	43 BD, 55 HC	13 remitted; 8 manic; 10 mixed; 4 hypoamnic; 7 depressed; 1 unknown	43 BD-I	56	35	ns
Adida et al.	2011	Reward	The Iowa Gambling Task (IGT)	167 BD, 150 HC	32 depressed, 45 manic, 90 remitted	167 BD-I	59	40	BD patients across all phases selected significantly more cards from the risky decks than HCs, i.e. ↓ decision making ability. In addition,

									like HCs, BD patients preferred decks offering low-frequency penalties.
van Enkhuizen et al.	2014	Reward	The Iowa Gambling Task (IGT)	16 BD, 17 HC	9 manic, 7 hypomanic	Not stated	44	34	BD patients showed ↓ decision making ability compared to HCs.
Yechiam et al.	2008	Reward	The Iowa Gambling Task (IGT)	28 BD, 25 HC	14 remitted, 7 manic, 3 hypomanic, 2 depressed, 2 mixed	28 BD-I	54	43	ns
Lewandowski et al.	2016	Reward	Probabilistic Reward Task (PRT)	42 BD, 29 HC	42 BD with psychotic features	BD-I	55	30	BD patients with psychotic features showed ↓ discriminability (i.e. ability to perceptually distinguish between two stimulus types / task difficulty) compared to HCs.
Ryu et al.	2017	Reward	Probabilistic Reward Task (PRT)	44 BD, 24 HC	20 remitted; 24 manic	BD-I	57	35	BD patients showed ↓ response bias in the early stage compared to HCs, but not in the late learning stage (block 2 or block 3) of the task.
CURRENT EPISODE NOT STATED									

Harmon-Jones et al.	2008	Reward	Anagrams reward task	41 BD, 53 HC	Not stated	32 BD-II; 9 cyclothymic	61	22	ns
Brown et al.	2018	Reward	Delay-discounting task (DD)	23 BD, 88 HC	Not stated	Not stated	48	47	ns

Abbreviations: ns = Not statistically significant; BD = bipolar disorder; HC = Healthy control;

Figure 1: PRISMA flowchart

Figure 2: Overview of included studies

Figure 1: PRISMA flowchart

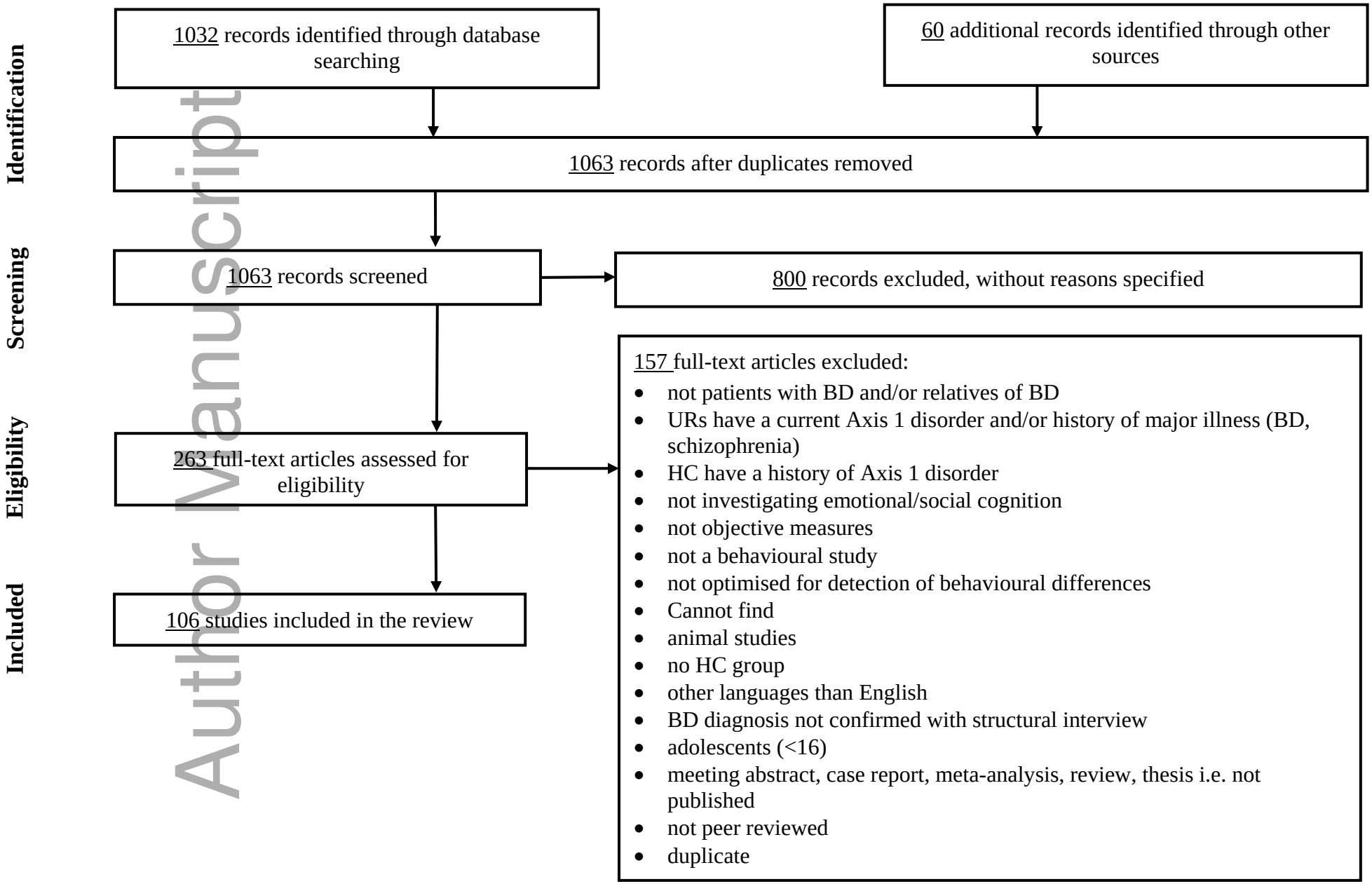

Figure 2: Overview of included studies