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Dynamic virtual faces demonstrate deterioration in the recognition of facial emotion in bipolar disorder patients

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Abstract

Bipolar disorder (BD) impacts around 1–2.4% of the world's citizens, causing significant declines in life quality and psychosocial functioning for many individuals. The primary objective of our research was to assess facial emotion recognition by employing a unique collection of dynamic virtual faces (DVFs). Data from one-hundred and ten participants were analysed, consisting of fifty-five BD patients and an equally large number of healthy matched controls. Each participant completed a single session comprising sociodemographic and clinical assessments, as well as a task for the recognition of emotions. The task involved virtual non-immersive reality, where participants viewed DVFs displaying the neutral expression and the six basic emotions on a 27" computer screen. After each DVF presentation, enrollees had to identify the underlying emotion by choosing from seven possible responses that were displayed at the bottom of the screen. Patients with BD demonstrated impaired facial emotion recognition skills, exhibiting lower accuracy rates and longer reaction times compared to their healthy counterparts. The most substantial differences were observed in recognising fear, disgust and sadness. Interestingly, individuals with BD exhibited better recognition of positive emotions than negative ones. Notably, factors such as psychopathology (including bipolar symptomology and affectivity), level of functioning and life quality did not show significant correlations with emotion recognition in BD patients. The recognition of the most dynamic faces was superior in healthy controls, and the presentation angle had no discernible impact on either group. This study confirmed that people with BD have trouble recognising affect across the entire spectrum. While our validation of the DVFs tool was successful, it is worth noting that research employing virtual reality in this domain remains relatively scarce. Therefore, further investigations using virtual reality tools are encouraged to enhance the methodological consistency of studies and yield more conclusive findings.

Keywords Facial emotion recognition · Emotion processing · Social cognition · Bipolar disorder · Virtual humans

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Introduction

Bipolar disorder (BD) refers to a persistent mental health condition that is characterised by severe swings in mood, wherein individuals alternate between periods of intense euphoria, heightened activity, and elevated or irritable mood (referred to as manic episodes), and periods of deep depression and despair (known as major depressive episodes). BD can be categorised into two main types: BD I, which involves the experience of a manic episode, either with or not accompanied by a depressive episode, and BD II, where patients undergo a major depressive episode along with a hypomanic episode (American Psychiatric Association, 2013). Despite receiving treatment, many individuals with BD encounter significant deterioration in their overall life and psychosocial

functioning (Souto et al., 2023), a term that typically encompasses aspects such as social behaviours, social skills and social cognition. The investigation of social cognition in the context of BD is an emerging field, as evidenced by prior studies (Aparicio et al., 2017; Samamé et al., 2015; van Neerven et al., 2021). Social cognition encompasses a multi-faceted concept covering a range of mental processes that are associated with the capacity to recognise, perceive and interpret social clues and information accurately (Green et al., 2015). Within the realm of social cognition, four distinct theoretical domains are typically considered: social perception, attributional style, theory of mind and emotional processing (Fernández-Sotos et al., 2019; Ochsner, 2008).

Emotional processing can be described as the capacity to recognise, support, control and effectively manage feelings (Mayer et al., 2001). Such intricate process of emotional processing encompasses various components, including emotional facial recognition (which constitutes the lower perceptual level processing) and processes at a higher level like the understanding and management of emotions (Green et al., 2008; Gur et al., 2017). Specifically, emotional facial recognition represents the foundational and initial step within the broader framework of social cognition. It pertains to the skill of identifying and categorising emotional states based on facial expressions or other non-facial cues (Gago et al., 2022; Pinkham, 2014). Numerous studies have investigated emotion processing in people with BD compared to a healthy control group. These studies have consistently reported some degree of impairment in emotion processing among BD patients across different stages of the disorder (Dehelean et al., 2021; de Almeida Rocca et al., 2009; Yalcin-Siedentopf et al., 2014). This impairment is observed during manic episodes (Getz et al., 2003; Gruber, 2011; Lembke & Ketter, 2002), major depressive episodes (Peckham et al., 2010), and even during euthymia phases (Işık Ulusoy et al., 2020; Nigam et al., 2021; Van Rheenen & Rossell, 2014). These findings suggest that the difficulties in emotional processing persist throughout the course of BD (Korgaonkar et al., 2019; Martino et al., 2011).

Recognising the critical part that social relationships play in the process of recovery for people with BD (Schön et al., 2009), it becomes evident that enhancing social cognition, particularly in the realm of facial emotion recognition,), holds significant potential as an intervention target (Ruiz-Murugarren et al., 2011). However, it is worthy of note that our exploration uncovered only two studies specifically directed towards this objective. One of these studies employed Metacognitive Training and placed a specific focus on improving social cognition (Haffner et al., 2018). The other study applied the Social Cognition and Interaction Training (SCIT) in 37 euthymic BD patients (Fernández-Sotos et al., 2021). Encouragingly, this study reported moderate enhancements in the ER40 (Emotion Recognition 40 Faces test) and substantial improvements in the Face Emotion Identification Task (FEIT) and the Face Emotion Discrimination Task (FEDT). In addition to these two studies targeting social cognition, we identified two others that concentrated on improving BD patients' social functioning (Arman et al., 2018; Gomes et al., 2019). Their findings collectively underscore the importance of addressing social cognition and functioning as integral components of interventions to improve the overall wellbeing and recovery of individuals living with BD.

Furthermore, the growth of interest in researching social cognition, as demonstrated by recent studies (Fernández-Sotos et al., 2020; Monferrer et al., 2021), has spurred the development of updated assessment methods. Traditionally, studies on emotion recognition have predominantly relied on static, natural stimuli, often utilising facial photographs or images to represent basic emotions. A methodological progression in this field has involved the incorporation of dynamic stimuli, with videos used to convey facial expressions of emotion. It should be noted, however, that many of these video-based methods have not undergone comprehensive validation and possess certain limitations (Calvo & Nummenmaa, 2016; Dyck et al., 2008). In recent years, virtual reality (VR) has shown great promise as a clinical tool, by recreating practically real controlled environments (Maples-Keller et al., 2017; Sammer & Ruprecht, 2023; Zimmermann et al., 2023). VR has the unique capability to simulate highly controlled environments that closely resemble real-world settings, offering increased accessibility and enhanced ecological validity. VR serves not only as a valuable tool for assessment purposes (Espinós et al., 2019; Kim et al., 2009b), but also as a platform for developing innovative computerised interventions that facilitate interactive practice (Brito & Vicente, 2018; El-Qirem et al., 2023; Grabowski et al., 2019; Ioannou et al., 2020; Park et al., 2019; Riva & Serino, 2020). This evolving landscape highlights the increasing significance of VR technology in the field of social cognition research and intervention.

This study takes a major advance in the realm of social cognition through harnessing VR technology to create dynamic avatars that represent various emotional states. These avatars facilitate real-time social interactions and serve as a means to evaluate affective processing, aligning with previous works (Calvo & Nummenmaa, 2016; Geraets et al., 2021; Hørlyck et al., 2021; Muros et al., 2021). The construction of these avatar faces is grounded in the standardised Facial Action Coding System (FACS) (Ekman & Friesen, 1978). The FACS provides a set of normative data for cataloguing facial movements, quantifying muscle contractions using a unit of measurement known as an action unit (AU). Given these advancements, the primary objective of this investigation was to evaluate facial emotion recognition using DVFs among fifty-five stable patients diagnosed with BD and their carefully matched healthy controls. The study aimed to compare their performance and pinpoint

specific deficits, with the ultimate goal of informing the development of more effective, targeted interventions. To guide this investigation, these hypotheses were formulated:

- H1: BD patients show lower emotional recognition rates and higher recognition times than healthy controls.
- H2:. For the BD group, emotional recognition rates are lower for negative than for positive emotions.
- H3: Patients with BD show a relationship between emotional recognition and quality of life, level of psychopathology, and level of functioning.
- H4: In both groups, more hits are obtained with the most dynamic virtual faces (DVF) presented in frontal view than with the less dynamic in profile views.

The DVFs employed in this study had undergone validation in prior research conducted by the same authors (García et al., 2020), which involved a cohort of two-hundred and four healthy subjects. The favourable outcomes of this previous validation process on a healthy population lend credibility to the data used in the current study. Consequently, this validation supports the reliability of the data analysis in this study, particularly concerning the comparative assessment of facial affect recognition performance between BD and control groups.

Materials and methods

Design of study

The study participants, comprising individuals with BD and healthy control subjects, were actively recruited over a six-month period from June to November 2020. The recruitment process took place within the Mental Health Centre of the University Hospital of Albacete (CHUA), which caters for a local population of around three-hundred thousand. The research conducted in this study received ethical approval from the hospital's Clinical Research Ethics Committee, officially granted on September 24, 2019, under the reference code 2019/07/073. The authors of this study affirm that all procedures integral to this research adhered strictly to the ethical standards established by the competent national and institutional human experimentation committees. Furthermore, they ensure compliance with the principles outlined in the Declaration of Helsinki of 1975, as revised in 2008.

Participants

The study sample consisted of a total of one-hundred and ten participants, evenly divided between fifty-five stable subjects with a diagnosis of BD and fifty-five healthy volunteers from the same region. The size of the sample depended on the availability of stable BD subjects at the time of the study. For the purposes of this research, patient stability was characterised by a period of at least three months preceding enrolment during which no alterations were made to their pharmacological treatment, no hospitalisations were necessary, and no substantial psychopathological changes were evident.

A sensitivity test was conducted using the G*Power program, version 3.1.9.6, to verify that the sample size used in this study had adequate statistical power. The analysis determined that an effect size of $d = 0.640$ was necessary for a significance level of $alpha = 0.05$, a power level = 0.95 (1—*beta*), and two sample groups of $n = 54$. This calculation was based on a non-centrality parameter of $delta = 3.311$ and a critical value $t = 1.66$. Consistent with our previous research (Fernández-Sotos et al., 2021), the participants in this study were divided into different age groups (20 to 39, 40 to 59, and 60 to 79 years) and levels of education (basic, medium and high), according to the classification criteria of the Spanish National Statistics Institute.

Sociodemographic data for both patients and healthy controls are shown in Table 1. In the participant selection process, each patient was paired with a corresponding control possessing identical characteristics. Consequently, the gender and educational level data were identical in both groups, and the age data were closely matched.

Inclusion criteria were as follows for the BD group:

a) Confirmation of a diagnosis of BD as assessed by the DSM-5 Structured Clinical Interview (American Psychiatric Association, 2013).
b) Clinical stability maintained for a minimum of three months before completing the SCID assessment, characterised by the absence of hospitalisations, no alterations

Table 1 Sociodemographic and clinical data

	BD group	Healthy group
Sample [*n*]	55	55
Gender [female: male]	28:27	27:28
Age [mean (SD)]	49.8 (15.1)	48.0 (12.2)
Age [*n*]		
Young (20–39 years)	9	10
Middle age (40–59 years)	32	32
Elderly (60–79 years)	14	13
Education level [*n*]		
Basic	23	23
Medium	21	20
High	11	12
Clinical variables [mean (SD)]		
Onset age	30.6 (12.9)	n/a
Years of disease evolution	18.7 (12.6)	n/a
Number of hospitalisations	2.2 (2.6)	n/a

in pharmacological treatment, and no significant clinical changes.
c) Status as an outpatient.
d) Age falling within the range of 20 to 79 years.
e) A good knowledge of the use and understanding of Spanish.
f) Willingness to provide informed consent.

Exclusion criteria for the BD group were:

a) Fulfilment of diagnostic criteria for any other severe mental disorder in Axis I of the DSM-5, with the exception of dependence on nicotine.
b) Having a diagnosis of mental retardation.
c) Suffering from somatic illness that may affect facial affect recognition.

For healthy controls, the inclusion criteria were d), e) and f) described for the patient group. Exclusion criteria for the healthy control group were b) and c) as previously described for individuals with BD or those with a psychiatric illness history.

Procedure for data collection

The eligibility of the clinical sample for inclusion was determined by a preliminary screening assessment carried out by the treating psychiatrist during a clinical appointment. During the initial screening visit, both sociodemographic and clinical information was collected in a single thirty-minute individual session. Sociodemographic data encompassed details such as age, sex, ethnicity, marital status, place of residence (urban or rural), level of education, labour force status (including categories like employed, unemployed, temporarily incapacitated, retired, housekeeper, and student), and occupation. On the clinical front, the data included familial somatic and psychiatric history, personal somatic (including neurological) and psychiatric history, substance use history, diagnosis, disease duration, number of decompensations experienced, frequency of emergency department visits and hospitalisations, and current treatment regimens.

During the baseline visit for patients with bipolar disorder, several clinically relevant variables were assessed using the following instruments:

- **Affectivity:** The Positive and Negative Affect Scale (PANAS) (Watson et al., 1988), in Spanish (Sandín et al., 1999), was employed to evaluate affectivity. PANAS is a self-administered scale that gauges present affectivity by assessing the frequency of occurrence of twenty mood-related topics over the previous week.
- **Severity of bipolar psychopathology:**
  - **Depression.** The Montgomery-Asberg Depression Rating Scale (MADRS) (Borentain et al., 2022; Fredriksen et al., 2022; Montgomery & Åsberg, 1979), in Spanish (Lobo et al., 2002), measured symptoms of depression. The MADRS is a hetero-administered scale comprising ten items, with responses rated on a Likert scale ranging from 0 to 6. There is no specific cut-off point, but higher scores reflect more intense depressive symptoms.
  - **Mania.** The Young Mania Rating Scale (YMRS) (Samara et al., 2023; Young et al., 1978), in Spanish (Colom et al., 2002), was employed to assess manic symptoms. YMRS is a heterogeneously administered eleven-items scale, with responses scored on a Likert scale (from 0 to 4 for some items, and 0 to 8 for others). Higher values indicate greater manic symptoms, and there is no defined cut-off point.
- **Functionality:** The Functioning Assessment Short Test (FAST) measured various domains of functioning. FAST consists of twenty-four items grouped into six specific domains (leisure time, interpersonal relationships, financial issues, cognitive functioning, occupational functioning and autonomy), and responses use to be recorded on a Likert scale (from 0 to 3), with scores indicating the difficulty level (Rosa et al., 2007). Higher scores signify better at functioning, and no specific cut-off point is established.
- **Quality of life:** The WHOQOL-BREF scale (The WHOQOL Group, 1998), in Spanish (Espinoza et al., 2011), was a quality of life assessment tool. This scale comprises 26 items, with responses recorded on a Likert scale ranging from 1 to 5. When aggregated, these scores provide an evaluation of four domains: environmental health, social, psychological and physical relationships. Higher scores indicate better life quality. There is no fixed cut-off point.

Healthy controls were recruited from the same socioeconomic area and sociocultural background as people with BD. Similar sociodemographic and clinical data were collected for this group, except for the clinical scales.

To manage the data acquisition process, the researchers designed a notebook. When a participant met the inclusion criteria for the study, the facial stimulus was administered. All subjects provided their informed consent following a thorough explanation of the trial and prior to the start of the experiment. The collected data were anonymised and stored in dissociated databases.

Experimental procedure

Following the collection of sociodemographic and clinical data, the facial stimulus experiment was conducted during the same session. The entire session had a duration ranging from forty to fifty minutes. The experiment commenced with a short tutorial introducing the participants to the task they were about to

undertake. Subsequently a number of fifty-two DVFs were displayed to all participants via a 27" computer screen (examples of which can be seen in Fig. 1). Each stimulus was displayed for a duration of two seconds. The majority of these DVFs featured a facial transformation, starting from an initial neutral expression and transitioning to one of the basic emotions (surprise, disgust, fear, anger, sadness, joy) before returning to neutral. However, some DVFs did not depict any emotional change and maintained a neutral expression throughout the presentation.

Following the presentation of each DVF, the participants were tasked with identifying the underlying basic emotion displayed. To do so, they were presented with seven options, and they had to choose the one that best represented the emotion. Importantly, the level of facial movement in the stimuli was taken into consideration. Specifically, fifty percent of the stimuli were characterised as less dynamic, where movement was primarily exhibited through the most distinctive facial features associated with each emotion. Conversely, the remaining fifty percent of the stimuli were classified as more dynamic, incorporating movements not only in facial features but also in the neck and shoulders, providing a richer representation of the emotional expression.

The presentation perspective was also factored in as a variable to control for. Among the fifty-two DVFs presented, they were distributed as follows: fifty per cent were presented in a frontal view, twenty-five per cent were presented in a right-hand view and twenty-five per cent were presented in a left-hand view. In addition to perspective, other physical appearance attributes were considered, including age and race. Among the DVFs, two avatars were depicted as white, around thirty years old, each with distinct eye colour, skin tone, and hair features; two avatars were portrayed as black, around thirty years old; two avatars were depicted as elderly individuals. The category of Black race was represented by a total of eight avatars, while the elderly age group was also represented by eight avatars. For more detailed descriptions of the DVFs, the reader is referred to the earlier experiment in which these stimuli were tested on a healthy sample of two-hundred and four healthy subjects (García et al., 2020).

Statistical analysis

The statistical analyses were conducted using Microsoft Excel and IBM SPSS Statistics (version 28). Some descriptive statistics were used to summarise sociodemographic data. The Student's t-test analysed age (as a continuous variable), while chi-squared tests were applied for gender and educational level comparisons. For quantitative variables, descriptive statistics included the calculation of average and standard deviation, while qualitative variables were presented as percentage. Given that the data for hits and recognition times were not normally distributed, non-parametric tests were chosen for testing hypotheses, with statistical significance defined as a $p\text{-}value < 0.05$.

The comparison between two groups was conducted by means of the Mann–Whitney U test. The Wilcoxon Signed Ranks test was used to assess differences in performance within the same group of participants (e.g., DVF with lower versus higher dynamics). To examine associations between variables, Spearman's rank correlation coefficient was employed.

Results

The descriptive statistics for sociodemographic variables revealed no significant differences between the groups, indicating homogeneity and suggesting that age ($t(108) = 0.689$, $p = 0.493$), gender ($X^2(1) = 0.036$, $p = 0.849$), and educational level ($X^2(2) = 0.068$, $p = 0.967$) had no discernible influence on the study results.

Comparison of emotion recognition rates and recognition time between the healthy group and BD patients (H1)

A noticeable difference in emotion recognition rates between the two groups was evident, as shown in Table 2. On average, across all emotions, the recognition rate was 70.81%

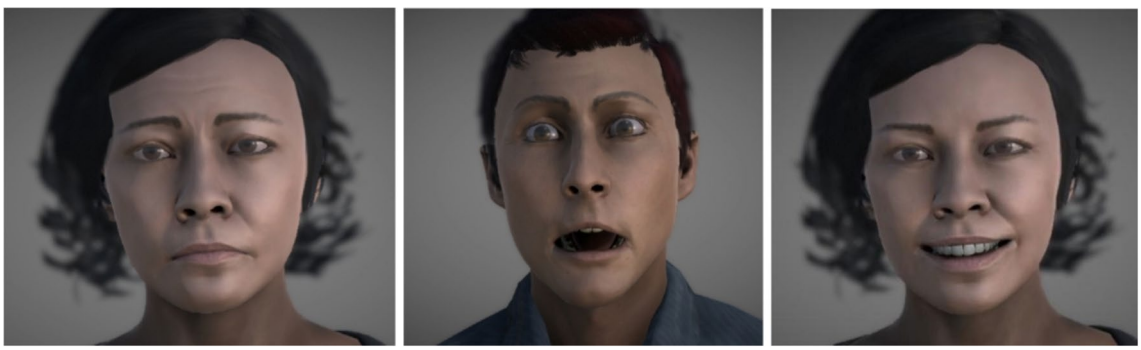

Fig. 1 Some DVF samples

for the BD group and 88.29% for the healthy control group. Importantly, this difference in recognition rates was statistically significant ($U = 396.5$, $p < 0.001$), with the healthy group demonstrating higher recognition rates. When examining individual emotions, the recognition rates consistently favoured the healthy control group, with the most pronounced differences observed for fear (44.3% vs 77.0%), disgust (62.0% vs 87.7%), and sadness (52.7% vs 83.6%).

Regarding detection time, as illustrated in Table 3, the results consistently favoured the BD group, although with greater variability as indicated by the standard deviation. The results of the Mann–Whitney test showed a statistically significant difference in the data ($U = 380.0$, $p < 0.001$). Similar to the analysis of recognition rates, the BD group exhibited poorer results in terms of detection time (i.e., longer recognition time), with the most significant differences observed in the case of neutral (6.29 s vs 3.23 s) and sadness (6.31 s vs 3.24 s) emotions.

Comparison of emotion recognition rates for negative and positive emotions in the BD group (H2)

The recognition rates for positive emotions (surprise and joy) stood at 88.4%, whereas for negative emotions (fear, anger, disgust, and sadness), the recognition rate was 78.3%. This distinction between positive and negative emotions in terms of recognition rates was statistically significant ($Z = -4.185$, $p < 0.001$),), indicating that positive emotions were recognised more effectively than negative emotions.

Influence of life quality, functioning and psychopathology levels on emotional recognition (H3)

The analysis of the results for the level of psychopathology (PANAS) using Spearman's rank test revealed no significant correlation between emotion recognition and the PANAS scores. Specifically, there was no significant correlation for both Positive-PANAS ($r = 0.088$, $p = 0.522$) and Negative-PANAS ($r = -0.043$, $p = 0.755$). Similarly, no significant correlations were found between the results of the MDRS and YMRS scores and emotion recognition ($r = 0.067$, $p = 0.628$ and $r = -0.027$, $p = 0.844$, respectively).

Regarding the level of functioning (FAST), no notable effect was observed on emotion recognition ($r = -0.103$, $p = 0.453$). Quality of life (WHOQOL-BREF) showed similar results, with no significant effect on emotion recognition detected across the test's four domains: environment ($r = -0.145$, $p = 0.290$); social relationships ($r = 0.032$, $p = 0.819$); psychological ($r = -0.119$, $p = 0.388$); physical health ($r = 0.091$, $p = 0.509$).

Table 2 Emotion recognition rates for each emotion shown for the bipolar group and healthy controls

		Recognised emotion						
BD group		Neutral	Surprise	Fear	Anger	Disgust	Joy	Sadness
Displayed emotion	Neutral	84.1%	2.3%	1.4%	2.3%	0.0%	3.6%	6.4%
	Surprise	2.5%	87.3%	5.7%	0.7%	0.7%	1.6%	1.6%
	Fear	2.0%	43.2%	44.3%	0.7%	2.0%	1.4%	6.4%
	Anger	3.0%	4.5%	4.5%	80.9%	3.9%	0.5%	2.7%
	Disgust	3.2%	4.1%	3.4%	23.9%	62.0%	0.9%	2.5%
	Joy	5.9%	3.6%	1.6%	2.0%	1.1%	84.3%	1.4%
	Sadness	10.9%	11.1%	9.5%	5.5%	8.2%	2.0%	52.7%
Healthy group		Neutral	Surprise	Fear	Anger	Disgust	Joy	Sadness
Displayed emotion	Neutral	96.4%	0.5%	0.0%	0.5%	0.0%	0.0%	2.7%
	Surprise	0.5%	90.0%	9.5%	0.0%	0.0%	0.0%	0.0%
	Fear	1.4%	16.6%	77.0%	0.0%	0.7%	0.0%	4.3%
	Anger	1.1%	1.6%	1.6%	90.9%	3.6%	0.0%	1.1%
	Disgust	0.5%	1.6%	0.9%	8.9%	87.7%	0.0%	0.5%
	Joy	3.0%	0.2%	0.0%	0.2%	0.2%	96.4%	0.0%
	Sadness	5.0%	4.5%	3.9%	0.2%	2.7%	0.0%	83.6%

Table 3 Mean reaction time and standard deviation (in seconds) per emotion for the bipolar and healthy groups

	Neutral	Surprise	Fear	Anger	Disgust	Joy	Sadness	Total
MDD group	6,29 (3.60)	4,39 (2.00)	4,91 (1.65)	4,94 (2.36)	4,77 (2.18)	4,44 (2.27)	6,31 (3.30)	36,06 (13.90)
Healthy group	3,23 (2.02)	2,69 (1.05)	2,96 (1.30)	2,94 (1.41)	2,74 (1.19)	2,55 (1.15)	3,24 (1.92)	20,35 (8.42)

Influence of the DVFs dynamics and presentation angles on emotion recognition for both groups (H4)

In relation to the level of dynamism, distinct results were observed in the two test groups. In the healthy control group, there was a significant difference in recognition rates (89.91% for high dynamics and 86.80% for low dynamics) as determined by the Wilcoxon Signed Rank Test ($Z = -2.160$, $p = 0.031$). Here, recognition rates were greater when using the more dynamic DVFs. In the BD group, however, there were no significant differences ($Z = -1.358$, $p = 0.174$) in the recognition rates for both types of DVFs. Recognition rates were similar for both the more dynamic DVFs (70.21%) and the less dynamic DVFs (69.21%) in this group.

In contrast to the dynamism factor, the presentation angles did not exhibit any major differences for the two groups of participants. For the healthy control group, the mean recognition rate was 88.98% for the frontal view and 88.74% for the side view ($Z = -0.192$, $p = 0.848$). Similarly, for the BD group, the recognition rates were 70.58% for the frontal view and 71.04% for the side view ($Z = -0.704$, $p = 0.481$). In both groups, presentation angle had no significant impact on recognition rates.

Discussion

This article has concentrated on evaluating facial emotion recognition in patients diagnosed with BD, juxtaposed with a healthy control group matched for key characteristics. To appraise this aspect of social cognition impairment, a non-immersive virtual reality tool featuring DVFs, which had been previously validated by the research team, was employed. The tool was designed with the aim of potential integration into a forthcoming rehabilitation program.

The results of this study consistently demonstrated deficit in emotion recognition among individuals with BD across all emotions assessed. These results aligned with our initial hypothesis and revealed lower recognition rates, particularly for fear, disgust, and sadness. Additionally, individuals with BD exhibited more variable and longer reaction times, especially in response to neutral and sadness emotions. These results are compatible with previous research conducted with euthymic BD patients using both natural static and dynamic stimuli. While some studies have reported more pronounced deficits in BD type I than BD type II (Bozikas et al., 2006; Derntl et al., 2009; Espinós et al., 2019), a generalised deficit in emotion recognition has been identified in the majority of studies. This transcends BD subtype distinctions (Darke et al., 2021; Dehelean et al., 2021; Işık Ulusoy et al., 2020; Nigam et al., 2021; Sharma et al., 2017; Tesli et al., 2015). Moreover, although the severity of the emotion recognition deficit in euthymic BD may vary between studies, meta-analytic findings reinforce the idea that impairments in facial emotion recognition are consistently observed across all mood states and phases of BD (Gillissie et al., 2022; Samamé et al., 2013).

To account for this deficit, some researchers have proposed that individuals with BD may require a higher intensity of emotional expression to accurately recognise emotions in comparison to individuals without BD (Brotman et al., 2008; Schaefer et al., 2010). However, other studies that have controlled for potentially confounding variables have not observed variations in the impairment based on specific emotions, tasks, or emotional intensity (Nigam et al., 2021; Van Rheenen & Rossell, 2014). Another key factor to consider in understanding the deficit in emotional cognition in BD is the well-documented cognitive impairment associated with the disorder. This cognitive impairment has been linked to factors such as antipsychotic medication use and comorbidity (Roux et al., 2019; Van Rheenen et al., 2020). There have even been correlations found in some research between non-social cognitive outcomes and emotion recognition deficits, particularly impairments in executive functioning (Varo et al., 2019). These findings highlight the complex relationship between cognitive functioning and emotion cognition in BD.

Neuroimaging has also made efforts to elucidate the underlying causes of this deficit in emotional processing. Some studies have suggested that there may be a persistent dysfunction in the mirror neuron system in individuals with BD (Kim et al., 2009a). Alternatively, others have proposed that there could be frontal dysfunction in BD, accompanied by compensatory strategies involving the parietal lobe (Hwang et al., 2021). These neuroimaging findings reveal the neural mechanisms that may contribute to the emotional processing deficit in BD.

In the context of the prolonged reaction times observed in individuals with BD, it is important to have in mind the influence of the pharmacotherapy commonly prescribed to these patients, which often includes medications like lithium or anticonvulsants. These medications have been associated with psychomotor retardation (Brodie et al., 1987; Elsass et al., 1981; Kasley et al., 1980), which could contribute to the slower reaction times observed in this population.

Regarding specific emotions, individuals with BD exhibited higher emotion recognition rates for positive emotions consistent with our second hypothesis. Surprise and joy were the most easily recognised positive emotions, while fear, disgust, sadness, and anger were recognised less accurately, with fear being the least recognised emotion. This pattern of emotion recognition aligns with previous research (Goghari & Sponheim, 2013; Lembke & Ketter, 2002). The finding that fear was the least recognised emotion is consistent with prior studies that have observed significant impairment in emotion recognition for fear in bipolar euthymic individuals versus healthy controls (Martino et al., 2011, 2016). This suggests that people with BD may face particular challenges

in recognising fear emotions, which could have implications for their social interactions and relationships.

Contrary to our third hypothesis, a significant influence of the level of psychopathology, including affectivity measured by the PANAS, or the severity of bipolar symptoms as measured by the MADRS and YMRS on emotion recognition in individuals with BD, was not observed. This finding diverges from a recent study that suggested a relationship between higher mania severity (YMRS scores) and poorer emotional processing in BD patients. On the one hand, regarding the level of psychopathology, although a recent study found that the higher the severity of mania (YMRS scores), the worse the emotional processing in patients with BD (Hwang et al., 2021), we did not replicate this result. However, our results align with other studies that have shown impaired emotion recognition in BD patients regardless of their mood state or affectivity (Van Rheenen & Rossell, 2014), even suggesting stability of performance across all phases of BD (Işık Ulusoy et al., 2020; Martino et al., 2016; Samamé, 2013).

Our study did not identify a significant impact of level of functioning, as assessed by the FAST scale, or the life quality, measured using the WHOQOL-BREF scale, on emotion recognition in BD patients. These results imply that the deficits in emotion recognition observed in BD patients may be relatively independent of their overall functioning and life quality. Thus, on the topic of the functioning level and quality of life, it is worth noting that other studies have described positive correlations between emotion recognition and functioning, particularly when using socio-occupational functioning scales (Thonse et al., 2018). Similarly, some research has found positive correlations between emotion recognition and quality of life, especially in the context of social and occupational functioning domains (Hoertnagl et al., 2011; Nigam et al., 2021; Vlad et al., 2018). It is possible that differences in the rating scales used, and their specific analyses may contribute to variations in study outcomes. While some studies focused on functionality within the socio-occupational domain, employing targeted and specific tools, our study utilised the FAST, which evaluates multiple domains of functioning (leisure, interpersonal relationships, financial issues, cognitive functioning, occupational functioning, and autonomy) without being restricted to the socio-occupational domain. In terms of quality of life, although most studies, including ours, employed the WHOQOL scale, they often analysed the results based on its specific domains (physical, psychological, social relationships, and environmental health) rather than solely examining the global score. These differences in measurement and analysis may explain the variation in findings regarding the association between emotion recognition, functioning and life quality in individuals with BD..

The fourth hypothesis yielded mixed results. On one hand, the influence of DVFs' dynamism on emotion recognition was confirmed for the control group, aligning with previous expectations (García et al., 2020). However, this hypothesis was not supported for the BD group, as no meaningful differences were found based on the degree of dynamism in the DVFs. On the other hand, the angle of presentation did not appear to impact emotion recognition, contrary to the initial expectations, with no discernible differences between frontal and profile views in either group. This study is among the first to present avatars in both frontal and profile views to individuals with BD. Nonetheless, two earlier studies conducted by our research team found that more dynamic DVFs and the frontal view led to more accurate recognition in healthy individuals and in a sample of patients with schizophrenia (García et al., 2020; Muros et al., 2021). These discrepancies in the healthy sample and previous findings may be due to several factors, including differences in factors, including differences in sample size, cultural and socioeconomic contexts, and the diversity of sociodemographic factors. It should be noted that the healthy controls were selected to match the clinical group, potentially resulting in a healthy group that differs in sociodemographic characteristics from those in other studies, which could account for variations in the outcomes.

Conclusion

The aim of this study was to evaluate facial emotion recognition using DVFs with fifty-five stable patients diagnosed with BD and compare their performance with that of matched healthy controls. The findings revealed that individuals with BD exhibited a deficit in recognising emotions, characterised by lower emotion recognition rates and longer recognition times compared to the healthy control group. Specifically, the BD group demonstrated better recognition rates for positive emotions but struggled with recognising negative emotions. Interestingly, factors such as the level of psychopathology, functioning and life quality did not greatly influence emotion recognition in BD patients. Additionally, the dynamism of DVFs only affected emotion recognition in the healthy control group, while the angle of presentation had no impact on either group. These results provide valuable insights into the emotional processing deficits associated with BD.

The study acknowledges a number of limitations that should be addressed in future research to enhance the comprehension of facial emotion recognition in patients with BD and its implications for treatment and intervention. By addressing these limitations, further research will contribute to a fuller understanding of the complex dynamics of facial emotion recognition in BD and provide valuable insights for the development of targeted interventions and treatments.

The study included a modest sample of 55 patients with BD without distinguishing between BD type I and type II. Future research with larger samples and differentiation between BD subtypes could help uncover potential differences in emotion recognition deficits between these groups. Another limitation

is that the BD group in this study were taking psychiatric medication, which could have affected emotion recognition. Investigating patients who are not on medication, while extremely complicated, could provide insights into the specific effects of psychopharmaceuticals on emotion processing. In addition, the study focused on facial emotion recognition but did not assess other cognitive domains related to social cognition. Further studies could investigate the relationship between emotion recognition, neurocognitive functions and other dimensions of social cognition in BD patients.

Moreover, this study suggests exploring novel theories of facial emotion recognition, including factors beyond recognition accuracy (hits) (Faith et al., 2022). Further research could delve into additional factors that may influence emotion recognition in BD, such as response time, emotional intensity, and the role of psychopathy. Lastly, while the study utilised DVFs as a novel assessment tool, ongoing research and development of virtual reality-based assessment tools are needed to standardise and improve their effectiveness in evaluating emotion recognition and related cognitive processes.

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Data availability The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval Clinical Research Ethics Committee of the Complejo Hospitalario Universitario de Albacete approved the study on 24 September 2019, with code number 2019/07/073. The authors confirm that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Consent All participants signed an informed consent after receiving a careful explanation of the study, and before conducting the experiment.

Competing interests None.

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