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A Comparison of the Effectiveness of Dialectical Behavior Therapy and Transcranial Direct Current Stimulation on Executive Functions, Emotional Dysregulation, Mania Severity, and Delusional Beliefs in Patients with Bipolar Disorder

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A B S T R A C T

Objective: This study aimed to compare the effectiveness of Dialectical Behavior Therapy (DBT) and Transcranial Direct Current Stimulation (tDCS) on executive functions, emotional dysregulation, mania severity, and delusional beliefs in patients diagnosed with Bipolar I Disorder.

Methods and Materials: The research employed a quasi-experimental design with pretest–posttest control groups and a four-month follow-up. The statistical population included all patients with Bipolar I Disorder in Isfahan during the final quarter of 2023. Forty-five eligible participants were selected through purposive sampling and randomly assigned to three groups: DBT (n = 15), tDCS (n = 15), and control (n = 15). The DBT group received eight 90-minute sessions based on Linehan's model, while the tDCS group underwent ten consecutive sessions targeting the dorsolateral prefrontal cortex. The control group received no intervention. Data were collected using Nejati's Executive Functions Questionnaire (2013), the Difficulties in Emotion Regulation Scale (Gratz & Roemer, 2004), the Young Mania Rating Scale (Young et al., 1978), and the Peters Delusions Inventory (Peters et al., 1999). Data analysis was performed using mixed-design repeated-measures ANOVA in SPSS-26 software.

Findings: The results revealed that both DBT and tDCS significantly improved executive functions and reduced emotional dysregulation, mania severity, and delusional beliefs compared to the control group ($p < 0.05$). Moreover, DBT demonstrated a greater effect than tDCS in enhancing executive functions, regulating emotions, and reducing delusional beliefs, while tDCS was more effective in decreasing mania severity. These effects were maintained at the four-month follow-up, confirming the stability of both interventions over time.

Conclusion: Dialectical Behavior Therapy and Transcranial Direct Current Stimulation are both effective interventions for improving cognitive and emotional functioning in patients with Bipolar I Disorder, though they operate through different therapeutic mechanisms—DBT through behavioral and cognitive restructuring and tDCS through neurophysiological modulation.

Keywords: *Dialectical Behavior Therapy (DBT); Transcranial Direct Current Stimulation (tDCS); Executive Functions; Emotional Dysregulation; Mania Severity; Delusional Beliefs; Bipolar I Disorder.*

1. Introduction

Bipolar disorder is a chronic, recurrent psychiatric condition that severely compromises emotional stability, cognitive integrity, and psychosocial functioning. Characterized by alternating episodes of mania, hypomania, and depression, the disorder involves multidimensional dysregulation across affective, cognitive, and behavioral domains (Oliva et al., 2025). The global prevalence of bipolar disorder has remained relatively stable over decades; however, the burden of disease is disproportionately high due to its early onset, high relapse rate, and significant contribution to suicide risk and functional disability (Arnone et al., 2024; Hansen et al., 2025). Recent neurobiological models highlight that bipolar disorder is not merely a mood disorder but a complex neurocognitive condition involving abnormalities in neural circuitry governing emotion regulation, executive control, and reward processing (Steardo Jr et al., 2025). These findings have spurred the development of integrated psychotherapeutic and neurostimulation-based interventions targeting both top-down cognitive regulation and bottom-up neurophysiological modulation.

The clinical course of bipolar disorder is marked by substantial inter-episode dysfunction. Even during euthymic periods, many patients exhibit deficits in executive functions—processes responsible for cognitive flexibility, inhibitory control, planning, and working memory (Cañada et al., 2024; Koene et al., 2022). Such impairments have been associated with fronto-striatal and fronto-limbic dysconnectivity, particularly in the dorsolateral prefrontal cortex (DLPFC), which underlies difficulties in goal-directed behavior, decision-making, and adaptive emotional responses (Ott et al., 2021; Wu et al., 2023). Neuroimaging meta-analyses indicate abnormal activation of prefrontal regions and disrupted large-scale brain network dynamics, including salience and default-mode networks, in patients with bipolar disorder (Wei et al., 2024; Zhang et al., 2024). These findings collectively emphasize that executive dysfunction constitutes a core cognitive endophenotype of the disorder, persisting across phases and contributing to poor functional outcomes (Gregersen et al., 2022).

Emotion dysregulation represents another fundamental dimension of bipolar pathology. Defined as the inability to monitor, evaluate, and modulate emotional responses to meet situational demands, it predicts mood instability and relapse risk (Paulet & Weiner, 2025). Neurocognitive models have revealed that emotion dysregulation in bipolar disorder is driven by altered interactions between limbic hyperactivity—particularly in the amygdala—and deficient prefrontal inhibitory control (Kim et al., 2025). These abnormalities manifest behaviorally as impulsivity, rapid mood shifts, and heightened reactivity to stressors (Chiu et al., 2025). Moreover, emotion dysregulation mediates the relationship between affective instability and interpersonal dysfunction, contributing to social impairment and reduced quality of life (Kouros et al., 2024). Chronic affective lability further undermines cognitive efficiency and amplifies manic or depressive polarity transitions, highlighting the importance of interventions that enhance emotional regulation skills and cognitive control (Goldstein et al., 2024).

Mania severity constitutes a crucial prognostic indicator in bipolar disorder, influencing hospitalization rates, treatment adherence, and suicidality (Placini et al., 2025; Sesso et al., 2024). Manic episodes are typified by euphoria, irritability, hyperactivity, racing thoughts, and impulsive decision-making, often accompanied by psychotic features and delusional ideation (Song et al., 2024). Neurobiologically, manic states are associated with dopaminergic hyperactivity, increased cortical excitability, and disruption of inhibitory GABAergic networks, leading to heightened reward sensitivity and reduced behavioral inhibition (Farr et al., 2024; Long et al., 2024). Functional imaging demonstrates that mania involves aberrant connectivity between the prefrontal cortex and limbic regions, resulting in reduced top-down modulation of emotional responses (Wei et al., 2024). Clinically, high mania severity correlates with diminished insight, increased risk behaviors, and poorer longitudinal outcomes (Bailey et al., 2024; Milic et al., 2025). Addressing manic symptoms therefore requires multimodal treatment strategies capable of concurrently modifying both neurobiological and behavioral components of the disorder.

Among cognitive–perceptual symptoms, delusional beliefs are particularly prominent during manic or mixed episodes. These fixed, false beliefs—often grandiose or persecutory in nature—reflect disturbances in reality testing and attributional biases (Barton et al., 2022). They frequently coexist with cognitive distortions and metacognitive deficits, such as “jumping-to-conclusions” reasoning styles and impaired error monitoring (Aydın et al., 2025). Recent evidence suggests that delusional ideation is not restricted to acute phases but may persist subclinically, contributing to chronic psychosocial impairment (Twigg,

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2024). Neuropsychological investigations have linked delusional beliefs in bipolar disorder to dysfunction in fronto-temporo-limbic networks and altered dopaminergic signaling, particularly within mesolimbic pathways (Ghosh, 2024; Steardo Jr et al., 2025). These insights have motivated the integration of cognitive–behavioral and neurostimulation approaches aimed at modifying dysfunctional belief systems and restoring prefrontal–limbic balance.

Historically, treatment for bipolar disorder has relied heavily on pharmacotherapy—mood stabilizers, antipsychotics, and antidepressants—but high relapse rates and partial recovery underscore the limitations of purely pharmacological interventions (Arnone et al., 2024; Salmerón et al., 2024). Consequently, there has been growing emphasis on adjunctive psychotherapeutic and neuromodulatory approaches that address cognitive and emotional dysfunction more directly. Dialectical Behavior Therapy (DBT) and Transcranial Direct Current Stimulation (tDCS) are two such evidence-based methods showing promising outcomes across mood and psychotic disorders (Jones et al., 2023; McClintock et al., 2020).

Dialectical Behavior Therapy, originally conceptualized by Linehan for borderline personality disorder, integrates cognitive–behavioral principles with mindfulness and acceptance-based strategies to improve emotion regulation and distress tolerance (Bailey et al., 2024). In the context of bipolar disorder, DBT has been adapted to target emotional instability, impulsivity, and interpersonal sensitivity, which are highly prevalent features (Wright et al., 2021). The therapy emphasizes four core modules—mindfulness, distress tolerance, emotion regulation, and interpersonal effectiveness—each aimed at reinforcing executive control over affective impulses (Jones et al., 2023). Empirical findings have demonstrated that DBT reduces mood fluctuations, self-harm, and maladaptive coping in adolescents and adults with bipolar spectrum disorders (Goldstein et al., 2024; Samadi et al., 2023). By enhancing metacognitive awareness and promoting acceptance of internal experiences, DBT strengthens prefrontal–limbic connectivity and thereby improves both cognitive and emotional functioning (Azevedo, 2024). Furthermore, DBT has shown beneficial effects on comorbid symptom clusters such as anxiety, aggression, and suicidality, suggesting transdiagnostic applicability (Tondo et al., 2021).

Mechanistically, DBT exerts its influence through structured behavioral activation and cognitive restructuring processes that facilitate the integration of emotional information into executive decision-making (Paulet & Weiner, 2025). Neuroimaging research indicates that mindfulness and emotion-regulation training enhance activity in the anterior cingulate and DLPFC—regions implicated in attention control and cognitive flexibility (Koene et al., 2022). These neurocognitive enhancements may translate into improved executive performance, including inhibitory control and planning, thereby mitigating impulsive or risky behaviors typical of manic episodes (Chiu et al., 2025). Moreover, by cultivating distress tolerance and adaptive coping, DBT reduces emotional reactivity to stressors that frequently precipitate manic or depressive episodes (Provost et al., 2024). Collectively, these findings position DBT as an integrative psychosocial intervention addressing both the cognitive deficits and emotional dysregulation characteristic of bipolar disorder.

Transcranial Direct Current Stimulation is a non-invasive neuromodulation technique that delivers low-intensity electrical current to the scalp to alter neuronal excitability in targeted cortical regions (McClintock et al., 2020). Stimulation of the left DLPFC, often implicated in cognitive control and emotion regulation, has shown beneficial effects on mood stabilization, attention, and executive functioning (Ott et al., 2021). tDCS operates through subthreshold modulation of resting membrane potentials, enhancing or inhibiting cortical excitability depending on electrode polarity (Steardo Jr et al., 2025). Studies report that anodal stimulation of prefrontal regions increases neuronal firing rates and improves synaptic plasticity, leading to more efficient top-down regulation of emotional and cognitive processes (Wei et al., 2024). Clinical trials have demonstrated tDCS efficacy in reducing depressive and manic symptoms and improving working memory and decision-making performance in bipolar and unipolar depression (Ghosh, 2024; McClintock et al., 2020).

Beyond its antidepressant and antimanic properties, tDCS has also shown promise in modulating aberrant neural network dynamics that underpin delusional beliefs (Barton et al., 2022; Twigg, 2024). By rebalancing excitatory–inhibitory mechanisms in prefrontal and temporoparietal cortices, tDCS can diminish aberrant salience attribution and promote cognitive insight. These neurophysiological effects position tDCS as a valuable adjunct to psychotherapeutic interventions, particularly when targeting cortical hypoactivation and impaired executive control (Aydın et al., 2025; Ghosh, 2024). The approach is safe, cost-effective, and well-tolerated, making it especially suitable for chronic psychiatric populations where pharmacological strategies may induce adverse effects or limited response (Milic et al.,

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2025). However, variability in response and short-term effects necessitate continued investigation of optimal protocols, including electrode placement, dosage, and combination with psychological interventions (Azevedo, 2024; Oliva et al., 2025).

Despite empirical support for both DBT and tDCS, the comparative evaluation of their effectiveness in bipolar disorder remains limited. Most studies have examined each modality in isolation, focusing on mood stabilization or emotion regulation rather than comprehensive cognitive-affective outcomes (Ghosh, 2024; Khashaba, 2023). Moreover, cultural and contextual variations—such as those in Iranian clinical populations—necessitate localized evidence regarding treatment efficacy and sustainability (Alidoosti & Mafi'an, 2023). Given that bipolar disorder entails overlapping disruptions in neural circuits governing executive and emotional regulation (Steardo Jr et al., 2025; Zhang et al., 2024), a direct comparison between DBT's top-down skill-training approach and tDCS's bottom-up neuromodulatory mechanism could elucidate their differential and complementary effects.

Integrative models propose that emotion dysregulation and executive dysfunction form a reciprocal feedback loop in bipolar disorder: deficits in cognitive control exacerbate emotional instability, while chronic affective dysregulation further impairs executive efficiency (Cañada et al., 2024; Koene et al., 2022). Both DBT and tDCS may interrupt this cycle but through distinct pathways—DBT through behavioral learning and cognitive restructuring, tDCS through modulation of cortical excitability and neural synchronization (McClintock et al., 2020; Wright et al., 2021). Furthermore, the presence of delusional beliefs adds an additional layer of cognitive distortion, where faulty reality testing undermines therapeutic engagement (Aydın et al., 2025; Barton et al., 2022). Addressing these beliefs requires both neurobiological correction and cognitive re-education, thereby justifying a comparative investigation of two interventions operating at different levels of the mind–brain interface.

Considering the complexity and multidimensionality of bipolar disorder, interventions that simultaneously target executive dysfunction, emotional dysregulation, mania severity, and delusional beliefs are of paramount importance. Dialectical Behavior Therapy, by virtue of its structured skill-building framework, aims to strengthen prefrontal regulatory mechanisms and improve emotional resilience (Goldstein et al., 2024; Samadi et al., 2023). Conversely, Transcranial Direct Current Stimulation aims to restore neurophysiological balance by directly modulating cortical excitability in executive and affective networks (McClintock et al., 2020; Wei et al., 2024). Although both approaches have demonstrated efficacy in specific domains, their relative effectiveness across cognitive, emotional, and psychotic symptom dimensions remains uncertain (Milic et al., 2025; Tondo et al., 2021).

Therefore, the present study seeks to compare the effectiveness of DBT and tDCS on executive functions, emotional dysregulation, mania severity, and delusional beliefs in patients with Bipolar I Disorder.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a quasi-experimental design with a pretest–posttest control group and a four-month follow-up. The statistical population comprised all patients with bipolar disorder in Isfahan city during the last quarter of 2023. The sample included 45 patients who were willing to participate and were selected via purposive sampling. Then, from within the study sample, 15 participants were randomly assigned to the control group and 30 to the intervention groups of Dialectical Behavior Therapy (DBT) and transcranial Direct Current Stimulation (tDCS). The first experimental group received DBT in eight sessions, held weekly, each lasting 90 minutes. The second experimental group received tDCS using a device administered by a physician over 10 consecutive sessions of 20 minutes each, while the control group received no training during the research process.

To enter the study, participants had to have a definitive diagnosis of bipolar disorder based on standard diagnostic criteria (DSM-5) and be experiencing active symptoms of the condition at enrollment, such as episodes of depression, mania, or mixed features. At least five years had passed since illness onset, and they had a history of prior treatment attempts, including pharmacotherapy or psychotherapy, without adequate symptom relief. Participants were 25–45 years old and able to provide informed consent and commit to adhering to treatment protocols. In addition, at entry to the treatment groups, they were required to have relatively stable mood and, as far as possible, be free of severe manic or depressive episodes. Exclusion criteria included failure to complete the treatment course and absence from more than three sessions. Any adverse events or side effects that made continuation impossible also led to exclusion. In the event of emergent active suicidal ideation with intent, immediate

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clinical intervention was required and the individual was promptly withdrawn from the study.

All participants were assured that their names would not be mentioned anywhere in the study and that only aggregated results would be used. A briefing session was held to conduct the research, informed consent forms were distributed, and to ensure anonymity and protect privacy, each participant was assigned a unique code. Before selecting and assigning participants—and prior to conducting the sessions—both treatment groups were assessed on executive functions. Then the first experimental group received DBT and the second received tDCS. After the intervention sessions ended, all three groups were reassessed with the study instruments, and at the follow-up stage—four months after the intervention—again all three groups were measured with the study instruments. It should be noted that after the study concluded, the control group also received DBT, and a number of them received tDCS.

2.2. *Measures*

Executive Functions Questionnaire: This questionnaire was developed by Nejati (2013/1392) and consists of 30 items and seven subscales: memory, inhibition, selective attention, decision-making, planning, sustained attention, social cognition, and cognitive flexibility. Items are rated on a 5-point Likert scale, with 1 to 5 points assigned per item. In the social cognition scale, scoring is reversed. Cronbach's alpha in Nejati (2013) was 0.83, and test–retest correlation was 0.86. In a study by Tousefian, Ghaderi Beghe Jan, Mahmoudi, and Khaledian (2017), Cronbach's alpha was 0.85 (Mohbi et al., 2020). In the present study, Cronbach's alpha was 0.87.

Difficulties in Emotion Regulation Scale (DERS): This 36-item scale was developed by Gratz and Roemer (2004). It assesses deficits and failures in emotion regulation on a 5-point Likert scale from 1 (almost never) to 5 (almost always) across six domains: non-acceptance of negative emotions; difficulties engaging in goal-directed behavior when distressed; impulse control difficulties when distressed; limited access to effective emotion-regulation strategies; lack of emotional awareness; and lack of emotional clarity. The total DERS score is the sum of the six subscales; higher scores on any subscale or the total indicate greater difficulty in emotion regulation (i.e., poorer emotion regulation). Gratz and Roemer reported external validity and reliability of 0.88, and overall internal consistency of 0.93. In Alidousti and Mafatian (2023), Cronbach's alpha was 0.92 (Alidoosti & Mafi'an, 2023). In the present study, Cronbach's alpha was 0.91.

Young Mania Rating Scale (YMRS): The Young Mania Rating Scale was created in 1978 to measure mania severity and has concurrent validity of 0.96, inter-rater reliability of 0.92, and Cronbach's alpha of 0.72. The 11-item scale rates symptom severity based on the patient's objective report of clinical status in the past 48 hours and the interviewer's observations during the interview. Completion takes about 15–30 minutes. Each item is scored 0–4, except for irritability, speech, thought content, and aggressive behavior, which are double-weighted and scored 0–8. Total scores range 0–44. A cut-off of 12—and in some studies 7 or below—has been used for hypomanic threshold. The Persian version was standardized at Roozbeh Hospital in Tehran in 2001 by Alipour and Nourbala; findings indicated the tool is useful for diagnosing and screening manic disorder among Iranian patients. In the Iranian validation, Cronbach's alpha was 0.72 for the patient group, 0.63 for the non-clinical group, and inter-rater reliability was 0.96. Diagnostic validity (canonical correlation of total scores with group membership) was 0.92, and item validity analyses showed high discriminative power across items. Concurrent validity with the International Diagnostic Interview was 0.87; for rater one, 0.89; and for rater two, 0.84 (Saberi et al., 2018). In the present study, Cronbach's alpha was 0.79.

Peters Delusions Inventory (PDI): The PDI was developed by Peters et al. (1999) to assess delusional beliefs. It has 40 items; when a positive endorsement is given, the respondent rates three subscales—distress, preoccupation, and conviction—on a 5-point Likert scale (1 = lowest to 5 = highest). The original instrument has strong validity and reliability. The Persian version has demonstrated acceptable properties, with reliability reported at 0.70 (Gharaeli & Saberi, 2020). In the present study, Cronbach's alpha was 0.71.

2.3. *Interventions*

The Dialectical Behavior Therapy intervention was implemented based on Marsha Linehan's theoretical framework and adapted from the protocol developed by Alijanzadeh et al. (2014; cited in (Samadi et al., 2023)). The program was delivered in a group format over four weeks, consisting of eight 90-minute sessions held twice weekly. During the first session, participants were introduced to the therapy's goals and rules and learned about the three mind

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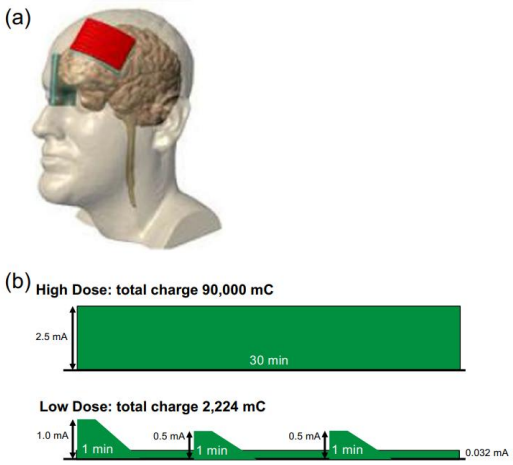
states—reasonable mind, emotional mind, and wise mind—as foundational mindfulness concepts. The second session focused on the "what" and "how" skills of mindfulness, including observing, describing, and participating (what skills), and cultivating a nonjudgmental stance, self-mindfulness, and effectiveness in action (how skills). In the third session, these mindfulness skills were practiced experientially through group exercises. The fourth session introduced the emotion-regulation module, explaining the definition and components of emotions, while the fifth session emphasized identifying and labeling emotions to enhance emotional control. The sixth session trained participants to accept emotions—especially negative ones—and to reduce vulnerability to emotional distress. The seventh session focused on distress-tolerance strategies, teaching crisis-survival techniques such as distraction and self-soothing through the five senses. Finally, the eighth session integrated all previous skills, emphasizing practical application of the "improve the moment" and "pros-and-cons" techniques for managing frustration and anger, while encouraging participants to generalize DBT skills to real-life situations beyond therapy sessions.

tDCS was administered with a medical device by a physician in 10 consecutive sessions of 20 minutes each.

Schematic of tDCS Configuration



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Schematic configuration of transcranial direct current stimulation (tDCS) electrodes and total charge-dose condition. (a) Shows the tDCS electrode montage on a three-dimensional rendering. The anode is centered over left dorsolateral prefrontal cortex at F3 (10/20 EEG system) and the cathode over right lateral prefrontal area at F8. The dose conditions, shown visually in (b), include a higher-dose tDCS at 2.5 mA and a lower-dose tDCS at 0.034 mA for 30 minutes.

2.4. Data Analysis

Data were analyzed using SPSS version 26 and mixed-design repeated-measures ANOVA.

3. Findings and Results

The study sample consisted of 45 patients with Bipolar I Disorder, including 12 females (26.7%) and 33 males (73.3%), with an overall mean age of approximately 33 years. Participants were evenly distributed across the three groups: Dialectical Behavior Therapy (DBT), Transcranial Direct Current Stimulation (tDCS), and control. The mean ages for the DBT, tDCS, and control groups were 33.1 (SD = 5.06), 33.06 (SD = 4.35), and 32.1 (SD = 2.66) years, respectively, with age ranges between 26 and 42 years. In terms of educational attainment, the majority of participants held a high school diploma (80%), while 15.6% had a bachelor's degree, and only a small proportion (4.4%) had postgraduate education. Statistical analyses using Fisher's exact test and one-way ANOVA indicated no significant differences among the groups in age, sex, or education level ($p > 0.05$), confirming demographic homogeneity across the study groups and ensuring that observed treatment effects could not be attributed to baseline differences.

Table 1

Comparison of means and standard deviations of variable scores across the three groups at three time points (pre-intervention, post-intervention, and follow-up)

Variable	Group	Pre-intervention Mean	Pre SD	Post-intervention Mean	Post SD	Follow-up Mean	Follow-up SD
Executive functions	DBT	66.5	5.80	99.6	13.8	98.7	13.2
	tDCS	67.4	5.47	79.4	7.82	78.9	8.11
	Control	68.4	6.97	69.3	5.25	68.4	5.24
Difficulties in emotion regulation	DBT	112.3	15.09	99.8	12.1	101.2	10.8
	tDCS	110.6	14.8	104.2	13.9	106	14.1
	Control	113.1	13.2	111.7	13.02	113.6	12.9
Mania severity	DBT	8.86	1.80	15.3	3.47	14.3	3.17
	tDCS	9.66	1.54	20.7	4.47	19.8	3.92
	Control	8.73	1.66	10.6	3.33	10.1	3.48
Delusional beliefs	DBT	52.2	2.78	41.5	2.32	42.5	2.32
	tDCS	49	2.97	43.2	2.73	44.2	2.83
	Control	51.2	3.88	50.6	3.67	51.1	3.77

As shown in Table 1, posttest and follow-up scores in the DBT and tDCS groups improved markedly relative to pretest across all variables—executive functions, difficulties in emotion regulation, mania severity, and delusional beliefs—while the control group's mean scores remained nearly unchanged. This pattern indicates the effectiveness of the interventions in the experimental groups. To determine statistical significance, appropriate tests were applied. Accordingly, assumptions of normality, homogeneity of variances, and homogeneity of covariance matrices were examined. Shapiro–Wilk tests for each variable in all three groups at all stages (pretest, posttest, follow-up) yielded p-values greater than 0.05; thus, the data were normally distributed and parametric assumptions held. Levene's tests indicated p-values > 0.05 for all variables, satisfying homogeneity of variances. Mauchly's test of sphericity showed the covariance matrix homogeneity assumption was not met; therefore, Greenhouse–Geisser corrections and adjusted degrees of freedom were used for within-subject interpretations. Overall, repeated-measures ANOVA demonstrated that the interventions had significant effects, improving the targeted psychological indices in the experimental groups relative to control.

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Table 2

Results of multivariate mixed ANOVA on executive functions, difficulties in emotion regulation, and mania severity

Source	Test	Value	F	df Hypothesis	df Error	Sig.	Eta²
Time of assessment	Pillai's trace	0.997	1145.8	11	32	0.001	0.997
	Wilks' lambda	0.003	1145.8	11	32	0.001	0.997
	Hotelling's trace	393.8	1145.8	11	32	0.001	0.997
	Roy's largest root	393.8	1145.8	11	32	0.001	0.997
Time × Group	Pillai's trace	1.59	11.7	22	66	0.001	0.796
	Wilks' lambda	0.022	16.8	22	64	0.001	0.853
	Hotelling's trace	16.9	23.8	22	62	0.001	0.894
	Roy's largest root	15.01	45.04	11	33	0.001	0.938

As seen in Table 2, all multivariate tests—Pillai's trace, Wilks' lambda, Hotelling's trace, and Roy's largest root—are significant, indicating significant differences in executive functions, cognitive emotion regulation, mania severity, and delusional beliefs by group, time of assessment, and the group × time interaction. Thus, the main hypothesis is supported: there are significant differences in the effectiveness and durability of DBT and tDCS on executive functions, difficulties in emotion regulation, mania severity, and delusional beliefs. To localize these differences and test secondary hypotheses, univariate analyses were conducted; results are presented in Table 3.

Table 3

Mixed-ANOVA results for the effects of group and time of assessment on dependent variables

Source	Dependent variable	SS	df	MS	F	p	Eta²
Within-subjects	Time	Executive functions	6724.4	1.03	6526.4	172.5	0.001
		Cognitive emotion regulation	1114.6	1.05	1059.3	112.4	0.001
		Mania severity	1126.6	1.15	975.7	100.3	0.001
		Delusional beliefs	846.5	1.04	813.3	321.2	0.001
	Time × Group	Executive functions	5340.7	2.06	2591.7	68.5	0.001
		Cognitive emotion regulation	649.6	2.10	308.7	32.7	0.001
		Mania severity	403.09	2.30	174.5	17.9	0.001
		Delusional beliefs	481.4	2.08	231.3	91.3	0.001
	Error	Executive functions	1636.8	43.2	37.8		
		Cognitive emotion regulation	416.3	84	4.95		
		Mania severity	471.6	48.4	9.72		
		Delusional beliefs	110.6	43.7	2.53		
Between-subjects	Group	Executive functions	8955.8	2	4477.5	24.6	0.001
		Cognitive emotion regulation	1663.6	2	831.8	9.59	0.043
		Mania severity	1080.9	2	540.4	29.1	0.001
		Delusional beliefs	929.7	2	464.8	17.9	0.001
	Error	Executive functions	7616.1	42	181.3		
		Cognitive emotion regulation	21973.4	42	523.1		
		Mania severity	778.8	42	18.5		
		Delusional beliefs	1090.5	42	25.9		

Given the mixed-ANOVA results in Table 3, the main effect of time and the time × group interaction are significant for all three dependent variables, and are examined in order. As reported in Table 3, the main effect of time is significant for all four dependent variables. This means that scores on executive functions, cognitive emotion regulation, and mania severity for all participants—regardless of group—differ significantly across pretest, posttest, and follow-up. To identify the sources of these differences, Bonferroni post-hoc tests were used; results are presented in Table 4.

Table 4

Bonferroni tests comparing the three groups on study variables

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Variables	Study phase	Group	Group	Mean difference	p
Executive functions	Pretest	DBT	tDCS	−0.933	1
		DBT	Control	−1.86	1
		tDCS	Control	0.933	1
	Posttest	DBT	tDCS	20.2*	0.001
		DBT	Control	30.3*	0.001
		tDCS	Control	10.1*	0.01
	Follow-up	DBT	tDCS	19.8*	0.001
		DBT	Control	30.3*	0.001
		tDCS	Control	10.5*	0.001
Difficulties in emotion regulation	Pretest	DBT	tDCS	1.66	1
		DBT	Control	−0.8	1
		tDCS	Control	−2.46	1
	Posttest	DBT	tDCS	6.40*	0.03
		DBT	Control	−11.8*	0.001
		tDCS	Control	−13.8*	0.001
	Follow-up	DBT	Control	−12.4*	0.001
		tDCS	Control	−9.46	0.03
		DBT	tDCS	−0.8	0.595
Mania severity	Pretest	DBT	Control	0.133	1
		tDCS	Control	0.933	0.404
		DBT	tDCS	−5.40*	0.001
	Posttest	DBT	Control	4.66*	0.005
		tDCS	Control	10.06*	0.001
		DBT	tDCS	−5.53*	0.001
	Follow-up	DBT	Control	4.20*	0.007
		tDCS	Control	9.73*	0.001
		DBT	tDCS	−0.466	1
Delusional beliefs	Pretest	DBT	Control	−0.866	1
		tDCS	Control	−0.466	1
		DBT	tDCS	22.7*	0.001
	Posttest	DBT	Control	27.8*	0.001
		tDCS	Control	5.08*	0.039
		DBT	tDCS	23.4*	0.001
	Follow-up	DBT	Control	28.2*	0.001
		tDCS	Control	4.83*	0.033

According to the Bonferroni results in Table 4, at pretest there were no significant differences among the three groups on executive functions, difficulties in emotion regulation, mania severity, and delusional beliefs ($p > 0.05$). At posttest, all variables showed significant differences between each intervention group and the control group ($p < 0.05$). Comparing the two treatments, DBT and tDCS differed significantly at posttest and follow-up across the study variables ($p < 0.05$): DBT outperformed tDCS on executive functions, difficulties in emotion regulation, and delusional beliefs, whereas tDCS outperformed DBT on mania severity. The most important source of effect in the mixed-ANOVA for testing the study hypotheses is the group × time interaction. As reported in Table 3, this interaction is significant for all three dependent variables—meaning that differences in participant scores across pretest, posttest, and follow-up depend on group. To examine the details of these effects, the corresponding interaction plots are reported sequentially for the dependent variables.

4. Discussion and Conclusion

The present study aimed to compare the effectiveness and durability of Dialectical Behavior Therapy (DBT) and Transcranial Direct Current Stimulation (tDCS) on executive functions, emotional dysregulation, mania severity, and delusional beliefs in patients with Bipolar I Disorder. The results demonstrated that both interventions significantly improved executive functioning, reduced emotion dysregulation, and decreased mania severity and delusional beliefs compared to the control group. However, the effects varied across domains: DBT was more effective in enhancing executive functions, regulating emotions, and reducing delusional beliefs, whereas tDCS had a stronger effect in alleviating manic symptoms. These findings reveal distinct but complementary therapeutic mechanisms underlying psychological and neurophysiological interventions for bipolar disorder, consistent with recent

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advances in understanding its multidimensional pathology (Aydın et al., 2025; Oliva et al., 2025; Steardo Jr et al., 2025).

The superiority of DBT in improving executive functions aligns with the theoretical model that executive dysfunction in bipolar disorder results from impairments in prefrontal-limbic connectivity and regulatory control over affective impulses (Cañada et al., 2024; Koene et al., 2022). DBT's structured skills training—focusing on mindfulness, emotion regulation, and distress tolerance—directly strengthens top-down cognitive regulation and enhances the functionality of the dorsolateral prefrontal cortex, a region consistently implicated in bipolar cognitive deficits (Ott et al., 2021; Wu et al., 2023). Prior studies have reported that patients undergoing DBT display improved planning, problem-solving, and inhibitory control, reflecting more efficient executive functioning (Goldstein et al., 2024; Jones et al., 2023). This enhancement may result from repeated cognitive rehearsal and behavioral activation during DBT sessions, which facilitate neuroplastic changes within the prefrontal networks (Paulet & Weiner, 2025). In contrast, tDCS operates primarily through neuromodulation—altering cortical excitability via weak electrical currents—thereby inducing more immediate but sometimes transient improvements in cognition (McClintock et al., 2020). Although tDCS increased executive function scores significantly relative to baseline, its effects were smaller and less durable compared to DBT, consistent with findings that behavioral interventions yield more sustained cognitive benefits due to active learning and self-regulation components (Azevedo, 2024; Milic et al., 2025).

The current study also found that DBT produced stronger and longer-lasting reductions in emotional dysregulation than tDCS. This outcome supports the conceptualization of DBT as an intervention fundamentally designed to modify emotion regulation mechanisms through skills training and experiential practice (Bailey et al., 2024; Wright et al., 2021). Emotional dysregulation in bipolar disorder is characterized by heightened reactivity and difficulties in modulating affective states due to dysfunctional prefrontal-limbic interactions (Kim et al., 2025). DBT mitigates these deficits by fostering mindfulness-based awareness, acceptance, and adaptive coping strategies, allowing patients to experience emotions without impulsive behavioral responses (Goldstein et al., 2024; Samadi et al., 2023). This aligns with evidence showing that DBT interventions in bipolar patients enhance emotion differentiation and tolerance, leading to decreased affective volatility and improved interpersonal functioning (Kouros et al., 2024; Paulet & Weiner, 2025). In contrast, although tDCS can reduce affective lability by modulating cortical excitability in the prefrontal cortex, its neurophysiological effects lack the cognitive restructuring and behavioral reinforcement components inherent in DBT (McClintock et al., 2020; Wei et al., 2024). Therefore, while both interventions influence emotional control systems, DBT achieves a more comprehensive change by addressing both neural mechanisms and cognitive-behavioral processes of regulation (Aydın et al., 2025; Steardo Jr et al., 2025).

Another major finding of this study was the significant effect of both DBT and tDCS on mania severity, with tDCS showing a larger immediate reduction. This observation supports neurophysiological models proposing that mania involves hyperactivation in dopaminergic and glutamatergic systems as well as hyperexcitability in cortical networks (Long et al., 2024; Song et al., 2024). By applying anodal stimulation over the left dorsolateral prefrontal cortex and cathodal over the right prefrontal region, tDCS normalizes abnormal cortical activity and restores balance between excitatory and inhibitory neuronal circuits (McClintock et al., 2020; Tondo et al., 2021). Similar reductions in manic symptoms following tDCS have been reported in clinical trials, highlighting its potential for rapid stabilization of mood during acute episodes (Ghosh, 2024; Milic et al., 2025). In contrast, DBT primarily addresses mania indirectly by increasing self-awareness and impulse control. This approach requires a longer time frame to achieve meaningful reductions in mania severity, since behavioral regulation develops gradually through repeated practice (Bailey et al., 2024; Jones et al., 2023). Nevertheless, the enduring stability observed in DBT-treated participants at follow-up indicates that once patients internalize emotion regulation skills, their susceptibility to manic relapse diminishes over time (Goldstein et al., 2024; Wright et al., 2021). Thus, DBT may provide long-term prophylaxis, whereas tDCS may serve as an effective adjunct during acute manic phases (Placini et al., 2025; Sesso et al., 2024).

Regarding delusional beliefs, both interventions produced significant reductions, but DBT's effect was more pronounced and sustained. This outcome can be interpreted through DBT's cognitive and metacognitive mechanisms, which emphasize mindfulness, reality testing, and balanced thinking (Bailey et al., 2024; Jones et al., 2023). Delusional ideation in bipolar disorder often stems from cognitive biases such as "jumping to conclusions" and overconfidence in false beliefs (Aydın et al., 2025; Gregersen et al., 2022).

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By increasing cognitive flexibility and meta-awareness, DBT helps patients question automatic thoughts and reappraise distorted interpretations of events (Paulet & Weiner, 2025). These effects parallel findings from cognitive-behavioral frameworks that target psychotic features through thought monitoring and behavioral experimentation (Barton et al., 2022; Twigg, 2024). Conversely, while tDCS influences cortical regions implicated in delusional processing—particularly the prefrontal and temporoparietal junctions—it primarily operates through biophysical modulation rather than cognitive restructuring (Steardo Jr et al., 2025; Wei et al., 2024). Consequently, its capacity to alter belief content is limited compared to DBT's skill-based reeducation of metacognitive processes. These findings are consistent with prior research emphasizing the necessity of psychotherapeutic interventions to achieve durable change in delusional cognition (Azevedo, 2024; Milic et al., 2025).

The convergence of DBT and tDCS effects observed in this study underscores the multidimensional nature of bipolar disorder, where cognitive, emotional, and neural dysregulations are interdependent (Oliva et al., 2025; Steardo Jr et al., 2025). The combined improvement across variables indicates that targeting prefrontal functioning—whether through structured psychological skill acquisition or neuromodulatory stimulation—enhances self-regulation capacity and cognitive integration. This aligns with the integrative neurocognitive model suggesting that interventions influencing both top-down (cognitive control) and bottom-up (neural excitation) pathways produce synergistic benefits (Wei et al., 2024; Zhang et al., 2024). The consistency of current findings with international literature strengthens their validity. For instance, Goldstein et al. (2024) demonstrated that DBT leads to significant improvements in emotion regulation and behavioral control in adolescents with bipolar disorder, while McClintock et al. (2020) reported cognitive enhancement following tDCS in both unipolar and bipolar depression. Collectively, these outcomes support a dual-mechanism hypothesis: DBT modifies cognitive and emotional schemas, whereas tDCS directly optimizes cortical processing efficiency.

Moreover, the findings align with evidence suggesting that psychotherapy and neurostimulation should not be viewed as competing but complementary interventions. Studies have recommended combined protocols—such as DBT-tDCS integration—to maximize treatment outcomes by harnessing both behavioral and biological mechanisms (Azevedo, 2024; Milic et al., 2025). In particular, DBT could be employed during maintenance phases to consolidate emotion regulation skills, while tDCS might serve as an acute-phase adjunct to stabilize neural hyperactivity. The integration of these modalities could potentially enhance neuroplasticity, improve self-regulation, and reduce relapse frequency. Additionally, recent neurobiological findings emphasize the heterogeneity of bipolar disorder subtypes and neuroinflammatory mechanisms, further supporting personalized multimodal treatment approaches (Long et al., 2024; Song et al., 2024). The present study's results contribute to this evolving framework by demonstrating that psychological and neurophysiological interventions converge on shared targets—executive control and emotion regulation—despite operating through different mechanisms.

The observed pattern of improvement across variables also underscores the role of self-regulation as a central therapeutic mediator. Patients who developed greater emotional awareness and tolerance during DBT sessions showed parallel gains in executive functions, suggesting bidirectional reinforcement between cognitive control and emotional stability (Cañada et al., 2024; Koene et al., 2022). This is consistent with the cognitive-emotional feedback model, which posits that strengthened executive control leads to enhanced emotion regulation, which in turn reinforces cognitive efficiency (Oliva et al., 2025; Steardo Jr et al., 2025). On the other hand, participants who received tDCS may have benefited from neural reorganization facilitating temporary executive improvements that indirectly improved mood stability. However, the decline of some tDCS effects at follow-up highlights the need for booster sessions or concurrent behavioral interventions to sustain cognitive and affective benefits (McClintock et al., 2020; Wei et al., 2024).

These findings also have implications for the treatment of psychotic and cognitive symptoms in bipolar disorder. Given that delusional beliefs and cognitive distortions are not only features of manic psychosis but also predictors of poor prognosis, the superior outcomes from DBT indicate that structured psychological training may help counteract dysfunctional belief systems through mindfulness and dialectical reasoning (Aydın et al., 2025; Twigg, 2024). In addition, the integration of mindfulness and acceptance-based strategies in DBT likely reduced rumination and intrusive thoughts, thereby attenuating cognitive distortions linked to delusional ideation (Bailey et al., 2024; Ghosh, 2024). This finding extends previous research demonstrating that enhancing metacognitive skills can lead to

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improvements not only in affective symptoms but also in perceptual reasoning and insight (Gregersen et al., 2022). Thus, DBT may serve a broader rehabilitative function by improving both affective and cognitive resilience in patients with bipolar disorder.

From a clinical standpoint, the complementary strengths of DBT and tDCS advocate for a multimodal treatment model. While DBT provides patients with long-term coping mechanisms, cognitive restructuring, and behavioral stability, tDCS offers rapid symptom relief and neurobiological recalibration. Integrating these approaches could be particularly advantageous in complex or treatment-resistant cases (Milic et al., 2025; Tondo et al., 2021). The convergence of behavioral and neurostimulation therapies reflects the growing movement toward personalized psychiatry, where interventions are tailored to specific cognitive and neural profiles (Hansen et al., 2025; Oliva et al., 2025). Ultimately, the results support the notion that sustainable recovery in bipolar disorder requires addressing both the neural substrates of dysregulation and the behavioral strategies for self-management (Goldstein et al., 2024; Steardo Jr et al., 2025).

5. Limitations & Suggestions

This study, while yielding significant and clinically meaningful findings, presents several limitations. First, the relatively small sample size (45 participants) limits statistical power and generalizability. The use of purposive sampling from a single geographic region (Isfahan) may have introduced selection bias and restricted cultural diversity. Second, although both interventions were carefully standardized, the study lacked a double-blind design—particularly relevant for the tDCS condition, where placebo effects may occur. Third, the follow-up period of four months, though informative for short-term durability, was insufficient to evaluate long-term maintenance of therapeutic gains. Additionally, self-report measures may have been influenced by subjective bias, especially in domains such as emotion regulation and delusional beliefs. Finally, the study did not account for potential pharmacological interactions, comorbidities, or lifestyle factors that might moderate treatment effects.

Future investigations should employ larger, randomized controlled designs encompassing diverse populations to validate the present findings. Longitudinal studies with extended follow-up intervals are essential to assess the persistence of therapeutic effects and to identify predictors of relapse or remission. Future research may also explore combined DBT–tDCS protocols to examine potential synergistic benefits. Neuroimaging techniques, such as fMRI or EEG, could elucidate the neural mechanisms underlying behavioral changes, clarifying how cortical modulation translates into cognitive–emotional improvement. Comparative studies across different bipolar subtypes (I, II, and cyclothymic) may also determine differential responsiveness to these interventions. Furthermore, examining mediating factors such as mindfulness, cognitive flexibility, or neuroplasticity could deepen understanding of the mechanisms driving treatment outcomes.

Clinicians are encouraged to consider DBT as a frontline psychotherapeutic intervention for improving emotion regulation, executive functioning, and cognitive insight in bipolar patients, while employing tDCS as an adjunctive tool for rapid stabilization of manic symptoms. Multidisciplinary treatment teams should integrate both behavioral and neurophysiological methods to address the multifaceted nature of bipolar disorder. Psychoeducation should emphasize the complementary benefits of these approaches, encouraging patient engagement and adherence. Regular monitoring, skill reinforcement, and booster neuromodulation sessions can enhance durability of effects. Ultimately, tailoring intervention selection to the patient's symptom profile—cognitive, affective, or psychotic—will likely yield the most effective clinical outcomes.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

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