ACCSCIENCE PUBLISHING

Journal of Clinical and Basic Psychosomatics

ORIGINAL RESEARCH ARTICLE

Improvement of effortful cognition through modified electroconvulsive therapy in treatment-resistant depression

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Abstract

Modified electroconvulsive therapy (MECT) is widely used in clinical practice and has become an indispensable treatment for treatment-resistant depression (TRD). This study explores the influence of MECT on effortful cognition in TRD using the face-vignette task (FVT). A total of 31 TRD patients and 30 healthy controls (HCs) were recruited. TRD patients were treated with MECT, and their depression severity was measured using the Hamilton depression rating scale (HAMD) and the FVT. Measurements were taken at 4 time points: baseline 1 (within 1 day before the first MECT session), baseline 2 (within 1 day after the completion of 12 MECT sessions), 2 weeks (after 2 weeks of MECT treatment), and 4 weeks (after 4 weeks of MECT treatment). HCs completed the FVT once. At baseline 1, all subjects completed the Basic Facial Emotion Identification Test; performance did not differ between the TRD and HC groups. However, MECT reduced HAMD scores in the TRD group. Additionally, at baseline 1, HCs showed a higher vignette-response proportion and a lower face-response proportion than TRD patients. In the TRD group, the face-response proportion at 4 weeks was lower, while the vignette-response proportion was higher than that at baseline 1, baseline 2, and 2 weeks. MECT improved FVT performance in the TRD group. TRD patients exhibited impairments in effortful cognition, which may improve following MECT. Effort cognitive indicators may serve as potential indices for evaluating the therapeutic effects of MECT in TRD.

Keywords: Treatment-resistant depression; Modified electroconvulsive therapy; Effortful cognition; Face-vignette task

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Citation: Wu L, Li W, Wang X, Sun Y, Wang W, Li Y. Improvement of effortful cognition through modified electroconvulsive therapy in treatment-resistant depression. *J Clin Basic Psychosom*. 2026;4(2):025360068. doi: 10.36922/JCBP025360068

Received: September 2, 2025

1st revised: September 24, 2025

2nd revised: September 25, 2025

Accepted: October 10, 2025

Published online: October 28, 2025

1. Introduction

Major depressive disorder (MDD) is a pervasive and debilitating mental health condition, affecting approximately 10–15% of the global population each year.[1] It is characterized by persistent low mood, anhedonia, cognitive impairments, and somatic symptoms that significantly interfere with daily functioning. Current treatment protocols primarily rely on pharmacotherapy, particularly the use of various classes of antidepressant medications, including selective serotonin reuptake inhibitors, serotonin–norepinephrine reuptake inhibitors, and tricyclic antidepressants. Despite the availability of these treatments,

clinical response remains suboptimal: Only about 65% of patients achieve a meaningful therapeutic benefit from first-line antidepressants.[2] Among non-responders, an estimated 25% meet the criteria for treatment-resistant depression (TRD), a condition defined by the failure to respond adequately to at least two different antidepressant regimens administered at appropriate dosages and for a sufficient duration, typically ranging from 4 to 6 weeks per trial.[3-5] TRD represents a significant clinical and public health challenge due to its high prevalence and association with persistent symptomatology, functional disability, reduced quality of life, and elevated healthcare costs. Moreover, patients with TRD often require complex, multimodal treatment strategies and are at greater risk for chronic illness courses and suicidality, necessitating ongoing efforts to improve diagnostic and therapeutic approaches.

The management of TRD necessitates a comprehensive, stepwise approach that integrates both pharmacological and non-pharmacological interventions. Pharmacological strategies often begin with switching to a different class of antidepressants or optimizing the current dosage to enhance therapeutic efficacy. Augmentation strategies are frequently employed, involving the addition of agents such as atypical antipsychotics, lithium, or thyroid hormones to existing antidepressant regimens. In recent years, novel therapeutics such as ketamine and its enantiomer, esketamine, have emerged as promising options due to their rapid antidepressant effects and unique mechanisms of action.[6] In parallel, non-pharmacological treatments are increasingly recognized as critical components of TRD management. These include evidence-based psychotherapies (e.g., cognitive behavioral therapy), neuromodulation techniques—such as electroconvulsive therapy (ECT) and deep brain stimulation—and complementary therapies such as light therapy, structured exercise programs, acupuncture, and yoga. Treatment plans are typically individualized, taking into account patient preferences, clinical profile, comorbidities, and prior treatment responses.[7]

Electroconvulsive therapy is a vital non-pharmacological intervention that has demonstrated robust efficacy in the treatment of several severe neuropsychiatric disorders, including schizophrenia, MDD, and acute manic episodes.[8] As a well-established brain stimulation technique, ECT is widely regarded by mental health professionals as one of the most effective and rapid-acting therapeutic modalities for achieving remission in patients suffering from severe depressive episodes, particularly when conventional pharmacological treatments prove insufficient.[9] In cases of TRD, where patients fail to respond to multiple adequate trials of antidepressants, ECT offers a critical alternative for symptom relief and functional recovery.[10] The introduction of modified ECT (MECT), which integrates the use of short-acting anesthetics, such as propofol or barbiturates, has significantly improved the safety and tolerability of the procedure. MECT enables rapid induction of anesthesia, minimizes the physiological stress associated with seizures, promotes faster postictal recovery, and reduces the likelihood of cognitive and cardiovascular side effects, all while maintaining the therapeutic efficacy of seizure induction.[11,12] Given these advancements, MECT has become a cornerstone intervention in the management of TRD and is routinely employed in modern psychiatric practice as a frontline strategy for severe, refractory depression.

Impairments in cognitive function are among the most prominent symptoms and clinically recognized features of TRD, contributing significantly to the overall disease burden and functional disability observed in affected individuals.[13,14] In recent years, a growing body of research has underscored the importance of cognitive measures not only as clinical correlates of depression but also as predictors of treatment outcomes. Specifically, cognitive deficits have been implicated as potential markers for identifying individuals at heightened risk for poor therapeutic response and long-term recurrence.[14] A prior investigation reported that patients with MDD typically present with negatively valenced emotional disturbances that are often paralleled by impairments in cognitive domains such as attention, memory, and executive function. These impairments have been closely linked to disrupted emotional processing within the prefrontal cortex, a brain region critically involved in affect regulation and cognitive control.[15]

Adaptive emotional functioning relies on the interplay between two distinct but complementary cognitive systems: Effortful and automatic processes.[16] Effortful cognition, a high-level neurocognitive function, encompasses controlled, deliberate, and goal-directed mental operations that facilitate the top-down modulation of emotional responses. Such processes are essential for tasks requiring reappraisal or inhibition of affect-laden stimuli and are commonly assessed using paradigms such as the face-vignette task (FVT).[16,17] In contrast, automatic cognitive processing operates more reflexively, requiring minimal attentional resources. It is initiated by specific stimulus configurations and proceeds without conscious intent or deliberate control, often shaping immediate emotional reactions through bottom-up mechanisms.[18]

Cognitive impairment plays a critical role in the pathophysiology and clinical presentation of TRD, highlighting the necessity of systematically assessing

cognitive function when evaluating the therapeutic outcomes of MECT. A growing body of evidence has demonstrated that MECT may induce alterations in neurocognitive performance. Among these, autobiographical memory loss appears to be the most persistent, with some studies reporting impairments lasting from one to 6 months post-treatment.[19,20] In contrast, other cognitive domains, such as working memory, processing speed, attention, and verbal fluency, tend to exhibit only transient disruptions and typically recover within a shorter timeframe.[21-26] Notably, the theoretical framework of effortful versus automatic cognition offers a nuanced perspective for understanding cognitive–emotional dysfunction in MDD. Investigating how MECT specifically affects effortful cognitive processes in TRD not only deepens insights into the neurocognitive mechanisms of action but also provides a clinically meaningful index of treatment efficacy and tolerability.

To date, no studies have specifically examined the impact of MECT on effortful cognition in TRD. In this study, participants included both patients with TRD and healthy controls (HCs), with the TRD group receiving MECT treatment. The Basic Facial Emotion Identification Test was employed to assess basic facial emotion recognition, while the FVT was used to evaluate effortful cognition. This study aimed to address this gap by investigating the influence of MECT on effortful cognition in patients with TRD. The study was guided by the following hypotheses: (i) patients with TRD exhibit impairments in effortful cognition; (ii) MECT improves effortful cognitive function in TRD; and (iii) effortful cognition may serve as an evaluative indicator of the effectiveness of MECT in treating TRD.

2. Materials and methods

2.1. Time and setting

This study was conducted in the Department of Psychiatry at the Yixing Fifth People's Hospital, Yixing, Jiangsu, China, from May 1, 2023, to December 1, 2024.

2.2. Study sample

A total of 31 patients who met the diagnostic criteria for MDD, as defined in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition,[27] were recruited into the TRD group. Initial screening was conducted in two stages. First, all participants underwent structured clinical interviews conducted by two senior psychiatrists to confirm the diagnosis of MDD and to exclude other psychiatric disorders (e.g., bipolar disorder, schizophrenia, schizoaffective disorder, or substance use disorders). When necessary, medical records and collateral information from family members were reviewed to support diagnostic accuracy.

Second, treatment history was carefully examined to determine TRD status. Patients were required to show documented failure to achieve response or remission after at least one adequate trial of an approved antidepressant, defined as treatment for a minimum of 8 weeks at an appropriate therapeutic dose. Nonresponse was assessed based on both clinical evaluation and standardized rating scales (e.g., Hamilton depression rating scale [HAMD]) as documented in the medical records.

For comparison, 30 HCs without a personal or family history of psychiatric disorders were recruited from the local community through advertisement and word of mouth. HCs were screened using the same structured clinical interview to confirm the absence of psychiatric conditions.

Patients were recruited from the Department of Psychiatry at Yixing Fifth People's Hospital, located in Yixing, Jiangsu, China. HCs were residents of the same region, recruited through online platforms and local community advertisements. Exclusion criteria for both groups included current daily smoking, a history of psychoactive substance use disorders, neurological conditions (e.g., head trauma or systemic illness affecting the central nervous system), and prior ECT or MECT within the past 6 months. All participants were of Chinese nationality and received compensation of 300 Chinese Yuan, in addition to reimbursement for transportation costs.

2.3. Neuropsychological test and measurements of effortful cognition

2.3.1. Basic facial emotion identification test

The Basic Facial Emotion Identification Test is a standardized assessment tool designed to evaluate an individual's ability to recognize fundamental emotional expressions. It comprises eight exemplars for each of the seven universally recognized basic emotions: happiness, anger, sadness, fear, surprise, disgust, and calm. All facial stimuli were sourced from the Chinese Affective Picture System, a culturally validated database developed for emotion research in Chinese populations.[28] To minimize potential gender bias in emotional recognition, the number of male and female faces was carefully balanced within each emotional category. This test provides a reliable measure of emotional perceptual processing in both clinical and non-clinical populations.

2.3.2. FVT

The FVT employed in the current study was adapted from an effortful cognitive paradigm[16] to investigate the distinction between effortful and automatic emotional

processing in individuals with schizophrenia. In the present study, the task was implemented using the E-Prime 2.0 software (Psychology Software Tools, United States), a widely used platform for experimental design in cognitive neuroscience.[29] The facial stimuli consisted of grayscale photographs with all external features (e.g., hair, accessories) removed to minimize perceptual distraction. These images depicted six basic emotional expressions—happiness, anger, sadness, fear, surprise, and disgust—and were selected from the culturally validated Chinese Affective Picture System.[28] For each emotion category, male and female faces were equally represented, and no individual identity was repeated within an emotion category, thereby ensuring variability and reducing familiarity effects.

The accompanying situational vignettes portrayed six non-basic, socially nuanced emotions: smugness, guilt, determination, pain, hopefulness, and insult. These vignettes were linguistically standardized and pre-validated by a group of seven undergraduate raters. The mean identification accuracy of the target emotion across raters was 0.91 (standard deviation [SD] = 0.08), with an inter-rater reliability κ of 0.75, indicating good consensus. In each stimulus pair, the emotional content of the vignette was deliberately incongruent with the facial expression—for instance, a vignette intended to elicit "smugness" was paired with a face expressing "happiness."

Each participant completed a total of 24 trials, each consisting of a face-vignette pair. As illustrated in Figure 1, the face and vignette were presented simultaneously, and participants were instructed to read the vignette aloud to enhance semantic processing. They were then asked to determine the emotional state of the person in the scenario and respond using a multiple-choice keypad with 13 labeled options: the six basic emotions, the six non-basic vignette emotions, and a "no emotion" option. Responses were categorized into three types: face-consistent, vignette-consistent, or random (neither), and were converted into proportional scores for subsequent statistical analysis to evaluate patterns of effortful emotional reasoning.

2.4. Electroconvulsive therapy procedure

Modified ECT was administered bilaterally at the temporal sites using a brief-pulse (pulse width = 1.0 ms), constant-current Thymatron DGx apparatus (Somatics LLC, United States) in the Department of ECT at Yixing Fifth People's Hospital, China. All patients received a total of 12 MECT sessions. The first three sessions were conducted on consecutive days, followed by sessions every other day, with breaks on weekends. Anesthesia was induced using intravenous propofol at a dose of 1.5–2.0 mg/kg. The initial

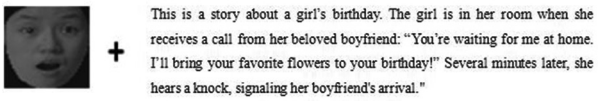

Figure 1. An example of a stimulus trial in the face-vignette task. The situational vignette in English is: "This is a story about a girl's birthday. The girl is in her room when she receives a call from her beloved boyfriend: 'You're waiting for me at home. I'll bring your favorite flowers to your birthday!' Several minutes later, she hears a knock, signaling her boyfriend's arrival." If the participant responds with "surprise" to the question, "What emotion is this person feeling?", it would be categorized as a face response. A response of "hopeful" would be categorized as a vignette response, while any other response would be coded as a random response.

stimulus intensity was set at one-quarter of the patient's age, based on a full-scale energy equivalent of 504 mC. Following previous guidelines,[30] stimulus intensity was adjusted in increments of 5% as needed to achieve an adequate seizure.

The seizure threshold was defined as the minimum electrical dose required to elicit an electroencephalographically confirmed seizure lasting at least 20 s. If the initial stimulus failed to induce a seizure, the output charge was increased by 5% increments, and stimulation was repeated after a 30-s interval, following age-adjusted titration protocols. A maximum of three stimulation attempts was allowed within a single treatment session.

2.5. Clinical assessment

Two qualified psychiatrists conducted structured clinical interviews with all participants to confirm or exclude a diagnosis of MDD according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. In addition to diagnostic confirmation, they collected detailed sociodemographic information and medication histories. The severity of depressive symptoms in patients was assessed using the 24-item version of the HAMD, a widely used clinician-rated instrument for evaluating depression severity.[31] For patients in the TRD group, both the HAMD and the FVT were administered at four distinct time points: Baseline 1 (within 1 day before the first MECT session), baseline 2 (within 1 day following the completion of the 12th MECT session), as well as at 2-week and 4-week follow-up intervals post-treatment. To minimize potential medication-related confounding effects, all patients were required to discontinue antidepressant or psychotropic medications at least 24 h before the first MECT session.

HCs underwent the FVT only at a single time point. Handedness in both patients and HCs was assessed using the Annett Handedness Scale.[32] to control for lateralization effects in cognitive processing. In addition, at baseline 1, all participants completed the Basic Facial Emotion

Identification Test to assess baseline emotion recognition ability.

All participants provided written informed consent to participate in the study. The study protocol was approved by the Ethics Committee of the Yixing Fifth People's Hospital, Yixing City, Jiangsu Province, China.

2.6. Statistical analysis

All data were analyzed using the Statistical Package for Social Sciences version 18.0 (SPSS Inc., United States). Comparisons of demographic data, handedness, Basic Facial Emotion Identification Test scores, and proportions of face, vignette, and random responses at baseline 1 between the TRD and HC groups were performed using independent samples *t*-tests or chi-squared tests, as appropriate. Within the TRD group, comparisons of HAMD scores and the proportions of face, vignette, and random responses across the treatment periods were conducted using one-way repeated measures analysis of variance (ANOVA). *Post hoc* analyses were performed using least-squares difference (LSD) tests when indicated. A significance level of 0.05 was used for all statistical tests.

3. Results

3.1. Participant demographics

The demographic characteristics of the TRD group and the HC group are shown in Table 1. There were no significant differences in sex, mean age, age range, mean education years, and handedness between the two groups.

3.2. Comparisons of Basic Facial Emotion Identification Test performances

An independent-samples *t*-test showed no significant difference in Basic Facial Emotion Identification Test performances (emotion identification accuracy) between the TRD (mean = 0.84, SD = 0.03) and the HC group (mean = 0.85, SD = 0.04) ($t = -0.579$, p=0.565).

3.3. Comparisons of Hamilton Depression Rating Scale scores before and after MECT

As shown in Figure 2, HAMD scores were analyzed using a repeated-measures ANOVA with session (baseline 1, baseline 2, 2 weeks, and 4 weeks) as a within-subject factor, which revealed a significant session main effect ($F = 111.729$, $df = 3$, p=0.000). MECT decreased HAMD scores at all follow-up periods. LSD tests were performed as *post hoc* analyses and demonstrated significant differences between HAMD scores at 4 weeks and those at baseline 1, baseline 2, and 2 weeks (all p=0.000). HAMD scores at 4 weeks were lower than those at baseline 1, baseline 2, and 2 weeks.

Table 1. The demographic characteristics of all participants

Variables	TRD group	HC group	Test statistic
n (M/F)	31 (17/14)	30 (16/14)	-
Mean age, years (SD)	38.8 (7.3)	39.2 (8.2)	t=0.151, P=0.880
Handedness (R/M/L)	10/10/11	11/9/10	χ^2=4.791, P=0.233
Age range	30–52	27–52	-
Education years (SD)	10.0 (2.2)	10.3 (2.3)	t=0.681, P=0.603
Onset duration (month, SD)	40.2 (9.2)	-	-

Note: Statistical significance determined at $P<0.05$.
Abbreviations: F: Female; HC: Healthy control; M: Male; R/M/L: Right-handed/mixed-handed/left-handed; SD: Standard deviation; TRD: Treatment-resistant depression.

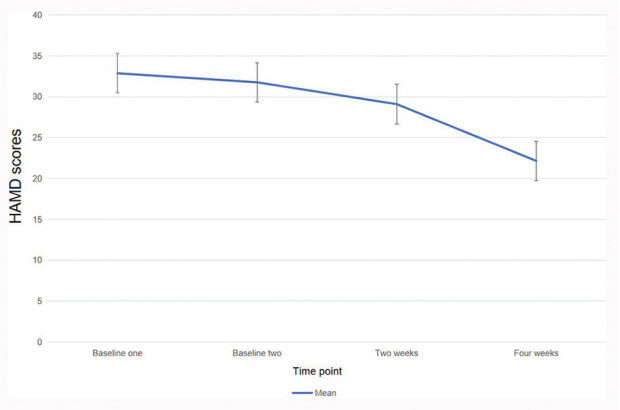

Figure 2. Comparisons of HAMD scores before and after MECT in the TRD group. HAMD scores at 4 weeks were lower than those at baseline 1, baseline 2, and 2 weeks.
Abbreviations: HAMD: Hamilton Depression Rating Scale; MECT: Modified electroconvulsive therapy; SD: Standard deviation; TRD: Treatment-resistant depression.

3.4. Comparisons of the FVT performances between groups

Independent-samples *t*-test revealed a significant difference in face-response proportions and vignette-response proportions between the TRD group at baseline 1 and the HC group ($t = 4.323, -3.847$; p=0.000). At baseline 1, the vignette-response proportions of the HC group were higher than those of the TRD group, while the face-response proportions were lower in the HC group. There were no significant differences in the random response proportions between the TRD group at baseline 1 and the HC group ($t = 0.448$, p=0.656) (Figure 3).

Face-response proportions, vignette-response proportions, and random response proportions in the TRD group were analyzed using a repeated-measure ANOVA with session (baseline 1, baseline 2, 2 weeks, and 4 weeks) as a within-subject factor. The analysis

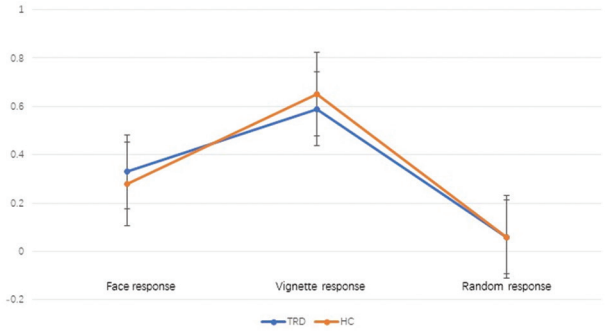

Figure 3. Comparisons of face-vignette task performances between the treatment-resistant depression (TRD) group at baseline 1 and the healthy control (HC) group. The vignette-response proportions of the HC group are higher than those of the TRD group at baseline 1, and the face-response proportions of the HC group are lower than those of the TRD group at baseline 1. There were no significant differences in the random response proportions between the TRD group at baseline 1 and the HC group.

revealed significant session main effect for the face-response proportions (F = 29.051, df = 1.77, p=0.000, η^2 = 0.492), the vignette-response proportions (F = 19.961, df = 1.265, p=0.000, η^2 = 0.400), and the random response proportions (F = 3.386, df = 1.717, p=0.048, η^2 = 0.101).

The LSD *post hoc* tests demonstrated significant differences between face-response proportions across all time points (baseline 1 vs. baseline 2, p=0.000; baseline 1 vs. 2 weeks, p=0.000; baseline 1 vs. 4 weeks, p=0.000; baseline 2 vs. 2 weeks, p=0.002; baseline two vs. 4 weeks, p=0.000; 2 weeks vs. 4 weeks, p=0.002). Significant differences were also found in vignette-response proportions (baseline 1 vs. baseline 2, p=0.000; baseline 1 vs. 2 weeks, p=0.000; baseline 1 vs. 4 weeks, p=0.000; baseline 2 vs. 2 weeks, p=0.040; baseline 2 vs. 4 weeks, p=0.000; 2 weeks vs. 4 weeks, p=0.000), and between random response proportions (baseline 2 vs. 4 weeks, p=0.025; 2 weeks vs. 4 weeks, p=0.047).

Face-response proportion at 4 weeks was lower than that at baseline 1, baseline 2, and 2 weeks. Moreover, the vignette-response proportion at 4 weeks was higher than that at baseline 1, baseline 2, and 2 weeks, while the random response proportion at 4 weeks was lower than that at baseline 2 and 2 weeks (Figure 4).

4. Discussion

To the best of our knowledge, this study is the first to examine the effects of MECT on effortful cognitive processing in patients with TRD, utilizing the FVT as an experimental paradigm. The discrepancy between face responses and vignette responses carries important clinical

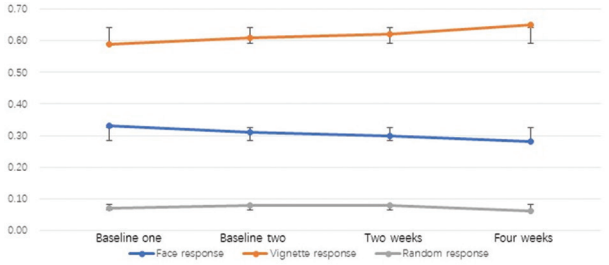

Figure 4. Comparisons of face-vignette task performances at baseline 1, baseline 2, 2 weeks, and 4 weeks in the treatment-resistant depression group. Face-response proportions at 4 weeks were lower than those at baseline 1, baseline 2, and 2 weeks; vignette-response proportions at 4 weeks were higher than those at baseline 1, baseline 2, and 2 weeks; and random response proportions at 4 weeks were lower than those at baseline 2 and 2 weeks.

implications. While face-based cues primarily reflect automatic emotional reactivity, vignette-based responses require effortful integration of contextual information. This suggests that patients may display relatively preserved automatic processing but impaired effortful processing, a pattern particularly relevant in depression and after MECT. Recognizing these differential effects may help refine cognitive assessment and guide interventions that specifically target effortful socio-emotional processing. The FVT combines facial expressions with contextual information, allowing for a more ecologically valid simulation of everyday social-emotional processing. This paradigm enables the simultaneous assessment of both automatic and effortful emotional processing. Furthermore, the FVT can be combined with behavioral and neurophysiological measures, such as functional magnetic resonance imaging or event-related potential, facilitating multimodal investigations and providing a robust framework for future research. The results revealed no significant differences between the TRD group and HCs in basic facial emotion recognition, as assessed by the Basic Facial Emotion Identification Test. However, during the FVT, which requires more complex, context-dependent emotional reasoning, patients with TRD demonstrated significantly lower accuracy compared to HCs, suggesting impairments in effortful emotional cognition. Notably, following a full course of 12 MECT sessions, patients in the TRD group exhibited a significant reduction in HAMD scores, indicating alleviation of depressive symptoms. Moreover, MECT was associated with improved performance on the FVT, suggesting partial restoration of effortful cognitive functioning and highlighting its potential role in enhancing higher-order emotional processing in TRD.

Modified ECT is widely recognized as a principal therapeutic modality for patients with TRD and is endorsed in clinical guidelines due to its robust antidepressant

efficacy.[33] However, growing evidence suggests that MECT may exert transient effects on specific domains of neurocognitive functioning in individuals with TRD, particularly working memory, processing speed, and verbal fluency. For instance, one study examining the trajectory of MECT-associated cognitive changes reported that patients with depression exhibited poorer working memory performance compared to HCs, and this impairment may be further exacerbated following MECT administration. Although these deficits often improve in parallel with the alleviation of depressive symptoms, subjective memory complaints can emerge even after the first MECT session and, in some cases, persist for up to 6 months post-treatment.[23] In contrast, other studies have shown a more favorable cognitive profile following MECT. For example, research has demonstrated that most MECT-induced cognitive impairments are limited to the initial 72 h after treatment. Cognitive performance generally returns to pretreatment levels thereafter, and in some cases, surpasses baseline within 2 weeks. Specifically, improvements have been observed in processing speed, working memory, anterograde memory, and selected components of executive function by day 15 post-treatment.[26]

A substantial body of research has demonstrated that cognitive processing in patients with MDD is particularly vulnerable to disruption by depressive symptomatology, especially when tasks demand sustained, controlled mental effort.[34-36] The degree of this interference is modulated by several factors, including the cognitive load of the task, the severity of depressive symptoms, and the emotional valence of the stimuli being processed. In contrast, automatic cognitive processes—those that operate rapidly and without conscious control—appear to be relatively preserved in individuals with depression.[37,38] Consistent with these observations, our study found that patients with TRD exhibited significant impairments in effortful cognition. Notably, while MECT is often associated with transient cognitive side effects, the improvements observed in effortful cognitive functioning following treatment were sustained across the entire study period. These findings suggest that effortful cognitive performance may serve as a sensitive and clinically meaningful index for evaluating the therapeutic efficacy of MECT in TRD populations.

Our findings confirmed the hypotheses of this study, i.e., the effects of MECT on effortful cognition are different from those on other cognitions, such as working memory, processing speed, and word fluency. The influence of MECT on working memory remains an area of concern due to its potential to induce transient cognitive deficits. Working memory processes are believed to be particularly susceptible to disruption by MECT, which may lead to difficulties in retaining and manipulating information immediately following treatment. These impairments are primarily associated with the neurobiological effects of MECT on the hippocampus and prefrontal cortex, both of which play crucial roles in working memory functions.[39] Research indicates that processing speed and verbal fluency are often impaired in the immediate aftermath of ECT, with patients displaying slower response times and reduced efficiency in performing cognitive tasks. These deficits are generally seen as a consequence of the neurobiological impact of seizures induced during MECT, which can disrupt cortical networks responsible for attention, executive functioning, and psychomotor speed.[22] Specifically, the prefrontal cortex, which regulates complex cognitive functions, and the hippocampus, critical for memory processing, are areas that may be affected by the electrical stimulation. Our findings also indicated that while effortful cognition overlaps with other cognitive functions, it is distinct in requiring conscious, deliberate mental exertion, in contrast to the more automatic and efficient processes underlying working memory, processing speed, and word fluency.

This study has two notable limitations. First, the relatively small sample size limits the statistical power and generalizability of the findings; thus, the results should be interpreted as preliminary and hypothesis-generating. Second, HCs were assessed using the FVT only once, whereas patients with TRD completed the task at multiple time points. This introduces the possibility that improvements in task performance among TRD patients may have been influenced by practice effects rather than genuine cognitive changes. Future research should employ larger sample sizes and repeated testing in control groups to better isolate the impact of MECT on effortful cognition in TRD.

Although the conventional statistical methods used in this study were appropriate and effective, it is important to note that machine learning techniques are increasingly valuable in health research. Recent literature indicates that machine learning methods (e.g., gradient boosting trees, natural language processing) can surpass conventional analyses in predictive accuracy for complex health datasets,[40,41] given their strength in modeling non-linear relationships. Therefore, integrating these advanced computational techniques with our experimental findings represents a promising avenue for future research to achieve a more comprehensive understanding.

5. Conclusion

Patients with TRD exhibited dysfunction in effortful cognition. Significantly, MECT enhanced effortful

cognitive function, which may serve as a valuable index for assessing its therapeutic effects in TRD.

Acknowledgments

We are grateful to everyone who generously participated in this study.

Funding

This study is supported by the General Scientific Research Program of Wuxi Municipal Health Commission (No. M202447).

Conflict of interest

The authors declare no conflict of interest.

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Project administration: Luoan Wu, Wei Li
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Software: Yu Li, Xinyu Wang, Yifan Sun
Supervision: Luoan Wu, Wei Li
Validation: Yu Li, Luoan Wu, Wei Li, Xinyu Wang, Yifan Sun
Visualization: Yu Li, Xinyu Wang, Yifan Sun
Writing–original draft: Yu Li, Xinyu Wang, Yifan Sun, Wenliang Wang
Writing–review & editing: Yu Li, Xinyu Wang, Yifan Sun, Wenliang Wang

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of the Yixing Fifth People's Hospital, Yixing, Jiangsu, China (Approval no.: WXMHCIRB2023LLky094). All participants provided written informed consent to participate in the study.

Consent for publication

Written informed consent was obtained from all participants, which explicitly included permission for the use of their anonymized data in publications.

Availability of data

Data used in this work is available from the corresponding author upon reasonable request.

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