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Effects of Bright Light Therapy on Mood and Prospective Memory in Depressed Patients: A Randomized Controlled Trial

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Research Article

Keywords: Depression, Bright light therapy, Prospective memory, Cognitive function, Mood symptoms, Mood disorder

Posted Date: August 10th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10513068/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Depression is one of the leading causes of disability worldwide, and its associated cognitive impairments severely compromise patients' occupational and social functioning. This study aims to evaluate whether bright light therapy (BLT) can improve mood and cognitive function in individuals with depression.

Methods

In this double-blind, placebo-controlled, parallel-group study, a total of 100 patients were recruited, of whom 90 inpatients were ultimately randomized and assigned to either a 10,000-lux BLT group or a 100-lux dim light control group. Emotional symptoms were assessed using the Hamilton Depression Rating Scale and the Hamilton Anxiety Rating Scale. Cognitive function was evaluated through event-based prospective memory, time-based prospective memory, and digit blinking tasks.

Results

Intention-to-treat analysis revealed that BLT was significantly superior to placebo in reducing depressive symptoms (between-group difference = -8.81 points, $p = 0.003$, *Cohen's d* = 0.85) and anxiety symptoms (difference = -4.18 points, $p = 0.013$, *Cohen's d* = 0.53) in patients with depression. Additionally, the BLT group demonstrated significantly greater improvement in both event-based ($p < 0.001$, $d = 0.71$) and time-based prospective memory tasks ($p < 0.001$, $d = 0.82$) compared to the placebo group.

Conclusions

The results showed that BLT significantly improved mood symptoms and prospective memory in depressed inpatients compared with placebo. Meanwhile, the improvement in depressive symptoms was associated with enhanced prospective memory.

Trial registration

ChiCTR2500097364. Registered on 18 February 2025 at the Chinese Clinical Trial Registry (https//www.chictr.org.cn/).

1 Introduction:

Depression is a common and debilitating mental disorder that severely impacts patients' quality of life and social functioning, placing a heavy burden on both families and society(Lu et al., 2021). Studies indicate that a considerable proportion of patients with depression experience long-term recurrence, often accompanied by adverse mental health outcomes and significant cognitive impairment (Rock et al., 2014). Current primary treatment options for depression include pharmacotherapy and psychotherapy. Although existing research has confirmed that these therapies, whether administered alone or in combination, have certain efficacy, recent meta-analyses indicate that conventional treatments still face challenges such as high dropout rates and relatively low symptom remission rates(Haller et al., 2019). In light of this, exploring more innovative treatment approaches has become an important direction in clinical research.

Bright Light Therapy (BLT) is a non-invasive physical intervention that regulates the circadian rhythm system through timed exposure to high-intensity artificial light(Kosanovic Rajacic et al., 2023). Its antidepressant effects are primarily grounded in two core biological hypotheses: First, it resets the suprachiasmatic nucleus via the retinal-hypothalamic pathway, correcting circadian rhythm phase and thereby regulating the secretion of rhythm-related hormones such as melatonin(Roccaro & Smirni, 2020).Second, it enhances the activity of monoamine neurotransitters (particularly serotonin) in the prefrontal cortex and limbic system, improving emotional regulation(Harrison et al., 2015). In clinical practice, BLT has been recommended by multiple evidence-based guidelines as a first-line treatment for Seasonal Affective Disorder (SAD)(Rothenberg et al., 2024). In recent years, evidence has gradually accumulated for its application in treating non-seasonal depression. Multicenter randomized controlled trials indicate BLT significantly reduces depression severity(Menegaz de Almeida et al., 2025). However, most studies have predominantly focused on the improvement of core emotional symptoms, while a notable paucity of research has systematically evaluated its impact on cognitive function.

In addition to typical emotional symptoms, depression is often accompanied by multidimensional cognitive impairments(Fossati, 2018; Klojčnik & Bakracevic, 2023). These impairments are central factors contributing to impaired social functioning in patients and exhibit limited responsiveness to traditional pharmacological and psychotherapeutic interventions, posing significant challenges for clinical management(Klojčnik & Bakracevic, 2023). As a non-pharmacological intervention, BLT demonstrates theoretical potential for improving cognitive function. Its mechanisms may involve regulating prefrontal cortex function, enhancing functional connectivity between the midbrain and frontal cortex, and improving sleep quality.(Bajaj et al., 2021; G. Chen et al., 2024; Falck et al., 2020; Fernandez-Ruiz et al., 2018). Although observational studies have suggested that light therapy may improve cognition in diseases such as Alzheimer's disease(Hjetland et al., 2020; Roccaro & Smirni, 2020), and neuroimaging studies have indicated that its mechanism involves the regulation of prefrontal lobe function and network connectivity(Alkozei et al., 2021), evidence from high - quality randomized controlled trials in depressed patients remains limited and shows inconsistent conclusions. Furthermore, the specific pathways through which BLT enhances cognition have not been fully elucidated. Particularly in individuals with depression, complex bidirectional interactions exist between cognitive impairment and emotional symptoms(Brailean et al., 2019; Goldberg et al., 2023), limiting the

efficacy assessment of single-dimensional approaches. Therefore, it is crucial to systematically evaluate the effects of BLT on the emotional and cognitive states of individuals with depression while also delving into the underlying mechanisms linking these effects.

This study is designed as a double-blind randomized controlled trial. Enrolled patients with depression will be assigned to either a placebo group or a BLT group. After a two-week intervention, emotional scale points and cognitive function points will be assessed at baseline and post-intervention. We hypothesize that BLT will improve both emotional and cognitive function in patients with depression, and that improvements in mood will be correlated with changes in cognitive performance.

2 Materials and Methods

2.1 Design

This study is a randomized, double-blind, placebo-controlled, parallel-group trial registered with the China Clinical Trial Registry (ChiCTR2500097364) on 18 February 2025. It complies with the Declaration of Helsinki and was approved by the Ethics Committee of Anhui Medical University Mental Health Hospital (HFSY-IRB-YJ-KYXMZDM). All participants signed informed consent forms prior to enrollment. Participants were assessed at baseline (Week 0), after 2 weeks of treatment (Week 2), and at 8-week follow-up (Week 8). Selected indicators were collected weekly during Weeks 2 and 8.

2.2 Participants

The study recruited 100 participants between March 2025 and November 2025.Participants were patients with depressive disorders from the Sleep Disorders Department of the Affiliated Mental Health Hospital of Anhui Medical University in China. All participants were aged between 18 and 65 years and had completed at least primary education. Two mental health specialists assessed all participants with depressive disorders using DSM-IV criteria to confirm psychiatric diagnoses. The following exclusion criteria apply to this study: history of neurological disorders, head trauma, or other significant psychiatric conditions; Electroconvulsive therapy (ECT) or transcranial magnetic stimulation (TMS) within the preceding three months; severe physical illnesses that may interfere with study assessments; retinal disease; acute suicidal tendencies; bipolar disorder or schizophrenia; pregnancy or lactation.

2.3 Randomized Grouping and Blinded Design

An independent statistician, who was not involved in participant recruitment or assessment, generated the randomization sequence using computer software. The sequence employed a 1:1 allocation ratio with random block sizes of 2 and 4, and was not stratified. To ensure allocation concealment, the sequence was implemented using sequentially numbered, opaque, sealed envelopes. After obtaining written informed consent, an enrolling researcher determined a participant's eligibility. A treatment nurse, who was not involved in baseline or outcome assessments, then opened the next consecutively numbered envelope in the presence of the participant to reveal the group assignment (BLT or dim light placebo) and administered the corresponding intervention. Due to the perceptible difference in light

intensity between the two conditions (10,000 lux vs. 100 lux), blinding of participants was not feasible. Participants were informed that the study was comparing two different regimens of light exposure. However, all personnel responsible for outcome assessments (i.e., administering the Hamilton Depression Rating Scale (HAMD), Hamilton Anxiety Rating Scale (HAMA), and cognitive tests) and subsequent data analysis were kept fully blinded to group allocation throughout the study.

2.4 Procedures

After admission, participants were assessed by trained staff using relevant scales. Following baseline evaluation, participants were randomly assigned to receive BLT in either the treatment group (full-spectrum white light, 10,000 lux) or the placebo group (full-spectrum white light, 100 lux). Treatment required participants to undergo 30 minutes of light exposure daily between 9:00 AM and 10:00 AM. After two weeks of treatment, the same staff reassessed participants using identical scales. During the entire research period, the ward lighting was strictly controlled according to a fixed schedule. Ward lighting conditions were strictly controlled according to standard ward protocols: lights on from 06:00 to 22:00 daily (illuminance ~ 400 lux), lights off from 22:00 to 06:00 the following day (illuminance ≤ 20 lux). All curtains remained closed to prevent exposure to natural daylight.

2.5 Clinical Assessment

The HAMD and HAMA were widely used to assess depression and anxiety in patients, respectively. The HAMD consists of 24 items, and the HAMA consists of 14 items. Items are rated on a scale of 0 (never), 1 (mild), 2 (moderate), 3 (severe), and 4 (extremely severe). For the HAMD, a total score of 0–8 indicates no depression, 21–35 indicates mild to moderate depression, and a score ≥ 36 indicates severe depression. For the HAMA, the total score ranges from 0 to 56, with higher points indicating more severe anxiety symptoms(Williams, 2001). EBPM (Event-Based Prospective Memory) scales and TBPM (Time-Based Prospective Memory) scales are used to assess patients' prospective memory function (higher scores indicate better performance in the respective abilities), but they differ in their assessment dimensions: the EBPM scale primarily evaluates event-based prospective memory (e.g., executing a plan when a specific event occurs), while the TBPM scale focuses on time-based prospective memory (e.g., executing a plan at a designated time point)(Guo et al., 2019; Wang et al., 2020). All participants underwent the Continuous Performance Test (CPT) to assess sustained attention and impulse control functions (higher CPT scores indicate better attentional control). This test adopts a computerized neurocognitive task paradigm, evaluating an individual’s ability to maintain attention and inhibit responses to target stimuli over a fixed duration through a series of stimulus-response tasks. Task types include target detection (requiring rapid identification and response to specific symbols/letters) and interference tasks (measuring attentional allocation and inhibitory control in the presence of distracting stimuli)(Slobodin, 2020; Slobodin et al., 2020).

2.6 Statistical Analysis

The primary analysis was conducted based on the intention-to-treat (ITT) set, which included all participants who received at least one session of the assigned light therapy and completed at least one

post-baseline assessment. Sensitivity analyses were performed to evaluate the robustness of the study results. For continuous variables—including age, years of education, total disease duration, HAMD points, HAMA points, and standardized medication doses (converted uniformly to fluoxetine equivalent doses to enhance comparability)—independent-samples t-tests were used to compare differences between the BLT group and the placebo group. Data for each group were presented as mean (standard deviation, SD).Categorical variables, such as gender, were analyzed using the chi-square test, and the same method was applied to assess differences in the distribution of medication types (SSRIs vs SNRIs). All statistical analyses considered a *P*-value < 0.05 as indicating a statistically significant difference. The primary analysis of outcome measures included all randomized subjects. For continuous outcome measures, a mixed-effects model was used to analyze all scale measurement data from Week 0 to Week 2, with baseline values incorporated as a covariate to adjust for baseline differences. Additionally, we employed partial correlation analysis to explore associations between affect and cognitive function across all enrolled patients, adjusting for age, sex, education level, total disease duration, and medication dosage. Multivariate linear regression analysis was used to examine associations between affect and cognitive function in the BLT group and control group, respectively, after adjusting for age, sex, education level, total disease duration, and medication dosage. For the primary outcomes of depressive and anxiety symptoms (HAMD, HAMA), a two-sided $P < 0.05$ was considered statistically significant. Analyses of cognitive function (prospective memory and attention tasks) were considered exploratory.

3 Results

As shown in **Figure 1**, 100 participants were assessed for eligibility, and 90 were randomized (45 to each group). Of these, 12 participants (5 in BLT, 7 in Placebo) withdrew consent before receiving any treatment and were therefore excluded from the ITT population. Among the 78 participants who initiated treatment, 8 discontinued the intervention early (5 in BLT, 3 in Placebo) but were included in the ITT analysis as they had post-baseline data. Consequently, the ITT population comprised 70 participants (35 per group), which served as the primary analysis set for all efficacy outcomes.

3.1 Sample Characteristics

The BLT group consisted of 35 patients (14 males, 21 females), and the placebo light therapy (PLT) group consisted of 35 patients (8 males, 27 females). The mean ages of the BLT and PLT groups were 38.49 (13.25) years and 40.83 (12.06) years, respectively. There were no statistically significant differences between the two groups in demographic characteristics such as age, gender, years of education, and total illness duration ($P = 0.442$; $P = 0.126$; $P = 0.572$; $P = 0.330$). Regarding clinical variables, there were no statistically significant differences in HAMD and HAMA points between the two groups ($P = 0.524$; $P = 0.401$). The HAMD score was 34.26 (9.69) in the BLT group and 32.94 (7.32) in the PLT group. The HAMA points was 22.00 (7.08) in the BLT group and 23.43 (7.07) in the PLT group (**Supplementary Table 1**).

3.2 Changes in HAMA and HAMD Scale Points between the Control Group and the BLT Group

The linear mixed-effects model analysis revealed a significant Group × Time interaction effect for both HAMD (β = -8.79, SE = 2.24, p < 0.001) and HAMA points(β = -4.18, SE = 1.81, p = 0.022). This indicates that the trajectory of symptom improvement over the 2-week intervention differed significantly between the BLT and placebo groups. As shown in **Supplementary Table 2** (descriptive data), the BLT group showed a greater reduction from baseline to post-treatment in both HAMD (mean change: -22.69) and HAMA points (mean change: -14.10) compared to the placebo group (HAMD: -13.88; HAMA: -9.92). The model-estimated effect sizes and standard errors for the main and interaction effects are detailed in **Table 1**. Simultaneously, we employed linear mixed-effects models using HAMD and HAMA points as the primary outcome measures. The model-estimated effect sizes (*β*) with their 95% confidence intervals (*CIs*) are detailed in **Table 1**. The analysis revealed a significant main effect of Group, indicating that the treatment group had significantly higher HAMD (*β* = 8.18, 95% *CI* [5.02, 11.34], *p* < 0.01) and HAMA *(β* = 4.48, 95% *CI* [1.93, 7.03], *p* < 0.01) points at baseline compared to the control group. Furthermore, we observed a significant main effect of Time. In the control group, both HAMD (*β* = 22.73, *SE* = 1.51, *p* < 0.001) and HAMA (*β* = 14.12, *SE* = 1.21, *p* < 0.001) points increased substantially over the course of the study, suggesting a trend of symptom worsening in the absence of intervention. Most crucially, the Group × Time interaction term was statistically significant for both scales. For HAMD points, the interaction effect was negative and highly significant (*β* = -8.79, *SE* = 2.24, *p* < 0.01), demonstrating that, compared to the control group, light therapy significantly reduced the extent of increase in depressive symptoms over time. Similarly, a significant negative interaction effect was also observed for HAMA points (*β* = -4.18, *SE* = 1.81, *p* < 0.01), indicating that light therapy also had a definite mitigating effect on the progression of anxiety symptoms.

3.3 Longitudinal Changes in Mood and Cognitive Function

To visualize the temporal trajectories of symptom improvement, we plotted the changes in HAMD, HAMA, EBPM, and TBPM scores across the three assessment time points (Week 0, Week 2, and Week 8). As shown in **Figure 2**, the BLT group exhibited a progressive reduction in both depressive and anxiety symptoms from baseline to Week 2, with the improvement sustained through the Week 8 follow-up. In contrast, the placebo group showed only minimal changes over the same period. Similarly, improvements in both event-based and time-based prospective memory were observed in the BLT group, with gains maintained at follow-up. These findings suggest that the therapeutic effects of BLT on both mood and cognition persisted beyond the active intervention phase.

3.4 Changes in Cognitive Function between the Control Group and the BLT Group

For cognitive outcomes, the linear mixed-effects model showed significant Group × Time interaction effects for both EBPM (*β* = 2.14, *SE* = 0.78, *p* = 0.008) and time-based prospective memory (TBPM: *β* = 2.25, *SE* = 0.67, *p* = 0.001) (**Table 2**). These results indicate that BLT led to greater improvements in prospective memory over time compared to the placebo. Descriptive data in**Supplementary Table 3**

show that the BLT group increased their EBPM scores from 5.61 to 9.12 and TBPM scores from 4.97 to 6.96, while the placebo group showed minimal change (EBPM: 6.84 to 7.85; TBPM: 6.24 to 6.15).

3.5 Sustained Attention Function

Analysis of sustained attention, assessed by the CPT, revealed a domain-specific pattern. The linear mixed-effects model showed a significant Group × Time interaction for the CPT-4 task (β = 0.38, *SE* = 0.17, p = 0.031), indicating that BLT specifically improved performance in this vigilance maintenance component over time compared to placebo. No significant interaction effects were observed for the CPT-2 or CPT-3 tasks (both $p > 0.05$; see **Table 2** for full model estimates). Consistent with this, descriptive data (**Supplementary Table 3**) show that the BLT group exhibited an improvement in CPT-4 scores from 0.92 to 1.34, whereas the placebo group showed no change (0.98 to 0.97). For CPT-2 and CPT-3, both groups showed minimal and comparable changes from baseline. We constructed linear mixed-effects models using prospective memory (EBPM, TBPM) and CPT indicators as cognitive function assessment measures. The model parameter estimates (β) and corresponding standard errors (*SE*) are summarized in **Table 2**. Baseline analysis revealed significant differences between the treatment and control groups on several cognitive indicators. Specifically, the treatment group had significantly lower baseline points on EBPM(β = -2.04, *SE* = 0.58, $p < 0.01$) and TBPM(β = -2.02, *SE* = 0.50, $p< 0.01$), and also showed weaker performance on the CPT-4 task (β = -0.36, *SE* = 0.12, $p < 0.01$). Analysis of the main effect of Time indicated that the control group showed significant declining trends over the course of the study in points for EBPM (β = -3.32, *SE* = 0.52, $p < 0.01$), TBPM (β = -2.03, *SE* = 0.44, $p < 0.01$), and CPT-4 (β = -0.37, *SE* = 0.11, $p< 0.01$). Analysis of the key Group × Time interaction effects revealed that light therapy produced differential improvement effects across different cognitive domains. Regarding prospective memory, the treatment group showed significant improvement relative to the control group in both EBPM (β = 2.14, *SE* = 0.78, $p < 0.01$) and TBPM (β = 2.25, *SE* = 0.67, $p< 0.01$). For attention-related indicators, although the interaction effects for CPT-2 and CPT-3 were not statistically significant, CPT-4 showed a significant interaction effect (β = 0.38, *SE* = 0.17, $p < 0.01$), indicating that light therapy also had an improving effect on attentional function in this specific dimension. In conclusion, the results of this study indicate that light therapy can significantly improve prospective memory function and positively impact attentional function in specific dimensions, demonstrating a domain-specific pattern of improvement in cognitive functions.

After controlling for age, gender, education, illness duration, and medication dosage, partial correlation analysis revealed that the change in EBPM points in patients with depression was significantly negatively correlated with the changes in both HAMD and HAMA points ($p < 0.001$ for both). In contrast, the change in TBPM points showed no significant correlation with the changes in HAMD or HAMA points (p = 0.066， p = 0.106). This suggests that improvements in event-based prospective memory function are associated with changes in mood in patients with depression. The linear regression between changes in cognitive function points and mood points in depressed patients is shown in **Table 3**. In the BLT group model, the change in EBPM points was significantly negatively correlated with the change in HAMD points (Crude model: *B* = -0.147, p = 0.003) and also significantly negatively correlated with the change in

HAMA points (Crude model: B = -0.145, p = 0.026). Furthermore, after additionally adjusting for age, gender, education, total illness duration, and medication dosage, a similar association was observed between the change in EBPM points and the change in HAMD points (Adjusted model: B = -0.129 p = 0.039), while the correlation between the change in TBPM points and the change in HAMA points disappeared (Adjusted model: B = -0.120, p = 0.166). In the control group, however, no significant association was found between the change in EBPM points and the changes in mood scale points.

4 Discussion

The findings of this study support the observation that patients with depression exhibited significant improvements in both mood and cognitive function following BLT, with a correlation identified between mood changes and cognitive enhancement. After a two-week light therapy intervention, we observed significant differences in patients' scores on EBPM, time-based prospective memory, and the fourth part of the Continuous Performance Test, whereas no significant changes were detected in the scores of the second and third parts of the Continuous Performance Test. Furthermore, we found that changes in HAMD points among depressed patients after light therapy were correlated with changes in EBPM scores, and that improvements in patient mood could further enhance cognitive function.These results further support the role of light therapy in improving cognition. Consistent with previous evidence obtained in other populations, such as patients with dementia (Hjetland et al., 2020), this study systematically demonstrates for the first time in individuals with depression that BLT specifically improves prospective memory, which is closely linked to daily functioning. This finding suggests that regulating circadian rhythms and neuroplasticity may represent potential common mechanisms underlying light therapy's cross-diagnostic cognitive benefits.

4.1 Mood Improvement in Depressed Patients After BLT

The current results indicate that mood improved in depressed patients following BLT(Cuomo et al., 2023; Kosanovic Rajacic et al., 2023; Lam et al., 2016). Extensive previous literature has shown that BLT is an effective method for improving mood in depressed patients, with established clinical efficacy particularly for patients with seasonal affective disorder (SAD)(Z. W. Chen et al., 2024; Pjrek et al., 2020). For non-seasonal depression, including major depressive disorder and bipolar depression, BLT also shows positive effects, often used as an adjunctive treatment or, in specific circumstances, as a monotherapy. Its mechanism of action is primarily achieved by regulating circadian rhythms and influencing neurotransitter balance(Lam et al., 2016; Yorguner Kupeli et al., 2018). In our study, we employed a pre-test/post-test design. At the baseline period, before implementing the intervention, all participants were assessed using the HAMD and HAMA scales (pre-test). Immediately after the completion of the intervention protocol, the same scales were administered for the post-test. The timing and intensity of light exposure were strictly controlled to minimize the influence of other factors on the study outcomes, thereby ensuring result stability. BLT demonstrated a certain improvement in the mood of depressed patients, particularly in depressive symptoms, which aligns with the results of most studies.

4.2 Cognitive Function Improvement in Depressed Patients After BLT

Furthermore, we also found that BLT not only effectively alleviates the core mood symptoms of depressed patients but also shows significant potential in ameliorating their accompanying cognitive impairments, similar to previous research findings(Pail et al., 2011; Zhou et al., 2018). This finding is supported by recent studies confirming the positive effects of light therapy on cognitive function. For example, a systematic review and meta-analysis indicated that light therapy improved cognitive function in Alzheimer's disease patients, although its benefits for behavioral and psychological symptoms were not significant(Lu et al., 2023). Another review of dementia patients reached similar conclusions, linking light therapy to improvements in cognitive deficits(Zhu et al., 2022). This study further clarifies that its therapeutic effects exhibit domain specificity: improvements in executive function and attention domains were the most consistent and pronounced. This specific pattern of enhancement is difficult to fully explain as a secondary effect of mood elevation, suggesting that the cognitive benefits of BLT may not be merely incidental. Instead, it likely indicates that BLT exerts more direct neurotrophic and activating effects on brain circuits supporting these specific functions, such as the prefrontal-subcortical circuitry.

4.3 Association Between Improvements in Mood and Prospective Memory

In this study, we observed a statistically significant correlation between the reduction in depressive symptoms (HAMD) and the improvement in EBPM following BLT. This association suggests a potential link between the therapeutic processes underlying mood regulation and cognitive recovery in depression. However, it is crucial to emphasize that our correlational analysis cannot establish causality or its direction. Several plausible interpretations exist: (a) improvement in mood may facilitate cognitive enhancement by freeing up cognitive resources or increasing engagement; (b) improvement in cognitive function, particularly in prospective memory which is vital for daily functioning, may itself contribute to improved mood and self-efficacy; or (c) both mood and cognitive improvements may be independent yet parallel outcomes of BLT acting on shared neural substrates (e.g., prefrontal cortex function, monoaminergic neurotransmission, or neuroplasticity).Existing neuroimaging studies have indicated that BLT can enhance activity in brain regions such as the dorsolateral prefrontal cortex and anterior cingulate cortex in depressed patients, which are core hubs for higher-order executive functions and emotion regulation(Pail et al., 2011; Spies et al., 2018). Light therapy may work by modulating the activity of monoamine neurotransitters (e.g., serotonin, norepinephrine) and influencing brain-derived neurotrophic factor (BDNF) levels(Spies et al., 2018). This suggests that BLT might improve mood in depressed patients, thereby regulating the release of related neurotransitters and directly enhancing the efficiency of cognitive control circuits. This enables patients to better focus attention, inhibit interference, and perform flexible mental shifting(Maruani & Geoffroy, 2019). Therefore, while the association is intriguing, our findings should not be construed as evidence that mood improvement

causes cognitive gains. Future mechanistic studies employing longitudinal neuroimaging, mediation analysis, or experimental designs that selectively target mood or cognition are needed to disentangle the temporal and causal relationships between these domains.

4.4 Strengths and Limitations

Our findings provide new evidence that BLT can improve patients' mood and cognitive function, with a correlation observed between mood improvement and cognitive changes. Furthermore, our results suggest that investigating the effects of BLT on cognitive function in patients with depression may offer new directions for developing future treatments aimed at improving impaired cognitive function in this population.

This study has several limitations. First, due to ethical considerations, we recruited inpatients who were inevitably receiving medication. Although patients using drugs known to affect cognitive function, such as venlafaxine and vortioxetine, were excluded during recruitment, and medication dosage was controlled as a covariate in the analysis, potential subtle effects of medication on cognition may still persist. Second, the proportion of female patients in this study was relatively high. To address this, gender was included as a covariate in the statistical analysis to control for its potential influence; however, the possible confounding effect of gender imbalance on the results still warrants careful consideration.Third, the assessment of cognitive function relied on scales and testing tools, which inherently involve a degree of subjectivity. Future research should incorporate objective evaluation techniques, such as neuroimaging and neuroelectrophysiology, to further explore the biological mechanisms underlying the improvement of cognitive function in patients with depression through BLT. Fourth, the sample size of this study was relatively small (with 35 valid cases per group ultimately included in the analysis), which may limit the statistical power and external generalizability of the findings. Although a randomized controlled design and intention-to-treat analysis were employed, the small sample size could still result in insufficient power to detect certain effects, particularly in subgroup analyses or for cognitive dimensions with effect sizes below the moderate range.Future studies could expand the sample size, conduct multicenter collaborations, or perform meta-analyses to further validate and generalize the findings of this research.

5 Conclusion

In summary, BLT significantly improved both mood symptoms and prospective memory in patients with depression. Importantly, the improvement in depressive symptoms was associated with gains in event-based prospective memory. This correlation suggests that mood enhancement may facilitate, or create a more favorable groundwork for, subsequent cognitive improvement. Our findings indicate that phototherapy might target neural pathways where ameliorating emotional dysfunction paves the way for cognitive recovery.

Abbreviations

Abbreviation	Full Name
BLT	Bright Light Therapy
CI	Confidence Interval
CPT	Continuous Performance Test
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition
EBPM	Event-Based Prospective Memory
ECT	Electroconvulsive Therapy
HAMA	Hamilton Anxiety Rating Scale
HAMD	Hamilton Depression Rating Scale
ITT	Intention-to-Treat
PLT	Placebo Light Therapy
SAD	Seasonal Affective Disorder
SD	Standard Deviation
SE	Standard Error
SNRI	Serotonin-Norepinephrine Reuptake Inhibitor
SSRI	Selective Serotonin Reuptake Inhibitor
TBPM	Time-Based Prospective Memory
TMS	Transcranial Magnetic Stimulation

Declarations

6 Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Comittee of Psychological Hospital Affiliated to Anhui Medical University (HFSY-IRB-PJZDM). Written informed consent was obtained from all participants or their legal guardians before enrollment.

7 Consent for publication

Not applicable.

8 Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

9 Competing interests

The authors declare that they have no competing interests

10 Funding

This study was supported by the National Clinical Key Specialty Construction Project of China and the Hefei 7th cycle key specialty construction project , Anhui Provincial Health and Wellness Scientific Research Project (Grant Nos. AHWJ2023A20086 and AHWJ2024Aa20549.

11 Author contributions

QHH: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. XYL: Writing – review & editing, Software, Methodology, Formal analysis, Conceptualization. JF: Writing – review & editing, Data curation. TW: Writing – review & editing, Data curation. JKY: Writing – review & editing, Data curation. XMQ :Writing – review & editing, Supervision, Project administration, Methodology. DMZ: Writing –review & editing, Supervision, Project administration, Funding acquisition.

12 Acknowledgments

We acknowledge the support of participants and the staff of the Department of Sleep Disorders, Affiliated Psychological Hospital of Anhui Medical University, and the Institute of Physical Science and Information Technology at Anhui University.

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Tables

Table 1 Linear mixed effects of Light Therapy on HAMA and HAMD

	HAMD	HAMA
Group	8.18(1.61)***	4.48(1.30)**
Time	22.73(1.51)***	14.12(1.21)***
Group× Time	-8.79(2.24)**	-4.18(1.81))*

Values indicate the estimated effect (β) and corresponding standard error (SE). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2 Linear Mixed Effects of Light Therapy on Cognitive Scale Points

	EBPM	TBPM	CPT-2	CPT-3	CPT-4
Group	-2.04(0.58)***	-2.02(0.50)***	0.26(0.16)	0.16(0.14)	-0.36(0.12)**
Time	-3.32(0.52)***	-2.03(0.44)***	0.07(0.14)	-0.04(0.12)	-0.37(0.11)***
Group× Time	2.14(0.78)**	2.25(0.67)***	-0.28(0.21)	-0.17(0.18)	0.38(0.17)*
Values indicate the estimated effect (β) and corresponding standard error (SE). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.					

Table 3 The Relationship Between Mood and Cognitive Function in Patients with Depression

Scale score	Change in EBPM score			
	Bright Light Therapy, *B* (95% *CI*)		Placebo , *B* (95%*CI*)	
	Model 1	Model 2	Model 1	Model 2
Change in HAMD	-0.147(-0.24,-0.05)*	-0.129(-0.23,-0.03)*	-0.116(-0.27,0.02)	-0.104(-0.30,0.12)
Change in HAMA	-0.145(-0.27,-0.02)*	-0.120(-0.27,0.03)	-0.131(-0.28,0.02)	-0.145(-0.33,0.04)

Model 1: Unadjusted for confounding factors; Model 2: Adjusted for age, sex, education, total disease duration, and medication dosage. *Indicates $P < 0.05$.

Figures

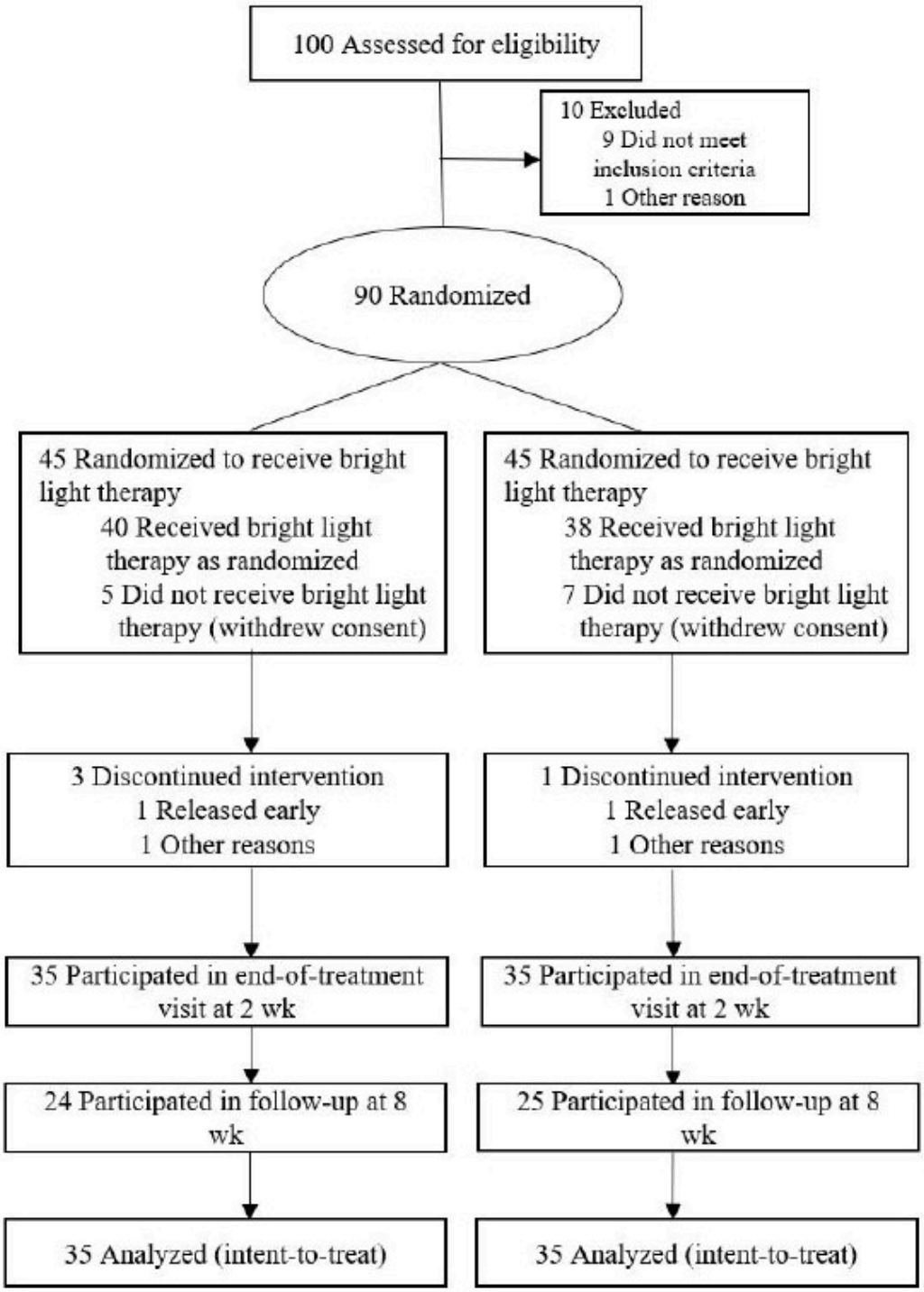


Figure 1

Patient Flow From Screening to Follow-Up Assessment Time Points

Intense light therapy comprised up to 14 sessions of morning light exposure at 10,000 lux intensity. The control condition included up to 14 placebo white light sessions at 100 lux intensity. Both groups received multimodal inpatient treatment as usual.

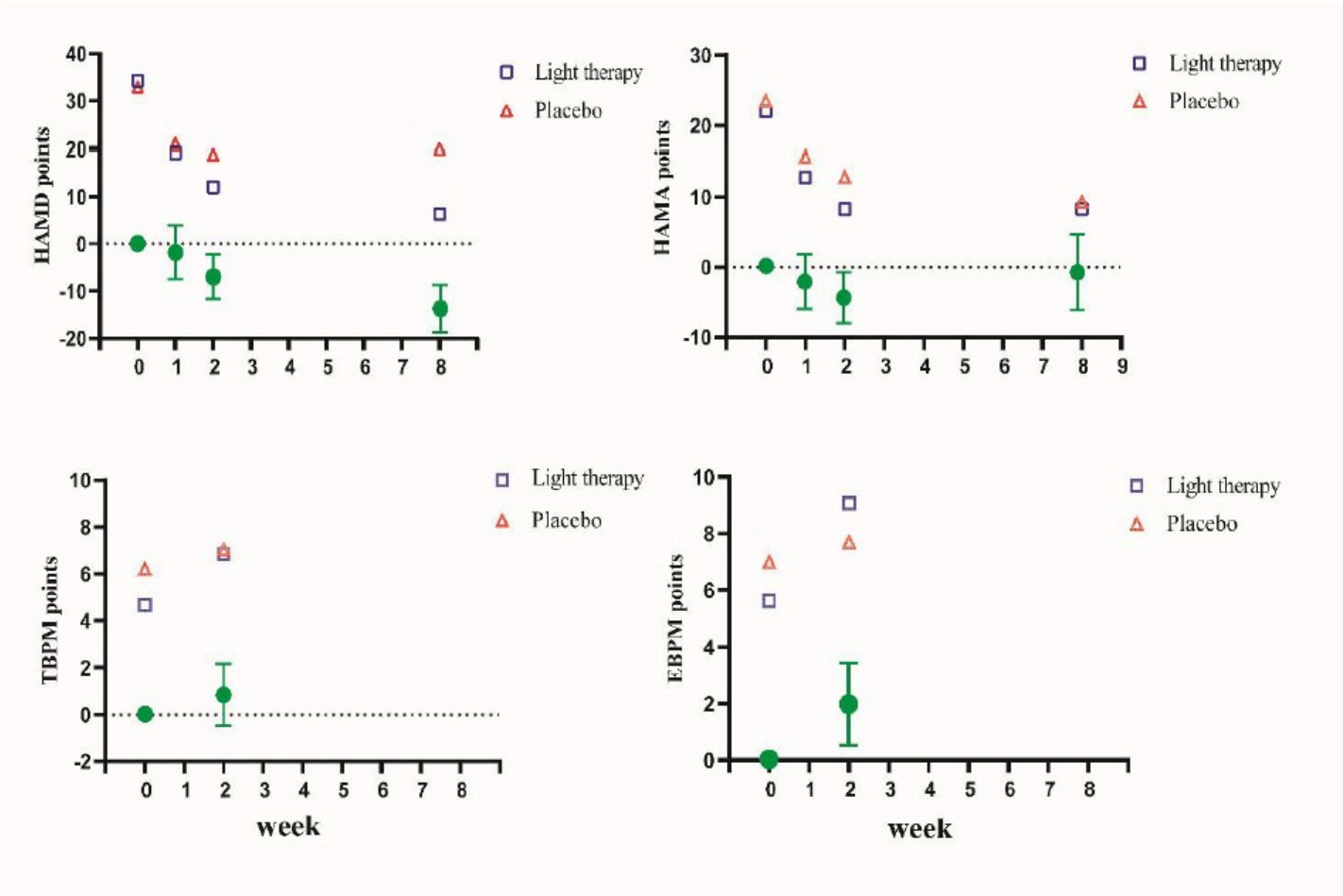


Figure 2

Effects of bright light therapy on depression and cognitive function.

Data points represent the means for bright light therapy (red triangles) and placebo (purple squares) conditions, along with the mean differences between conditions (bright light therapy minus placebo; baseline-corrected) (green circles). Error bars represent 95% CIs. Week 0 represents baseline; Week 2 represents the end of the intervention period; Week 8 represents follow-up.

Supplementary Files

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