

Networked Cognitive Training on Negative Emotions for People with Mild Cognitive Impairment: A Systematic Review and Meta-analysis

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Abstract: *Purpose:* Individuals with mild cognitive impairment (MCI) frequently experience negative emotions, which are closely correlated with an accelerated rate of cognitive decline and the subsequent transition to a state of dementia. Despite networked cognitive training has been demonstrated to enhance cognitive function in MCI, its effectiveness for negative emotions is still unknown. This review aimed to exam the influences of networked cognitive training on negative emotions and quality of life in people with MCI. *Methods:* Searches for eligible studies were conducted using PubMed, Web of Science, EMBASE, Cochrane Library, Psyc INFO, CNKI, Wanfang database, VIP database, and Sinomed. The retrieval time limit was set from their inception to 17 December 2025. The articles were reviewed and extracted by two researchers, and their quality was evaluated using the Cochrane risk-of-bias assessment tool. Subsequently, a meta-analysis was carried out utilizing RevMan 5.4 software. *Results:* The review comprised 13 randomized controlled trials with 626 individuals. The meta-analysis demonstrated that networked cognitive training significantly improved depression (SMD = -0.36; 95% CI [-0.73, -0.00]; $p = .050$), anxiety (SMD = -0.32; 95% CI [-0.57, -0.06]; $p < .050$), and quality of life (MD = 2.54; 95% CI [0.98, 4.10]; $p < .001$). In terms of the comparison of apathy, the effect of intervention was unclear. *Conclusions:* From these meta-analysis results, networked cognitive training may help patients for MCI with their anxiety, depression, and overall quality of life. However, because there are so few randomized controlled trials available, the evidence regarding apathy is still ambiguous. More thorough randomized controlled trials with larger samples are necessary to verify the significance of networked cognitive training on apathy and to consolidate the findings.

Registered number on PROSPERO: CRD42024593710.

Keywords: Cognitive training; Emotion; Mild cognitive impairment; Meta-analysis

Online publication: Mar 10, 2026

1. Introduction

Approximately 50 million people globally are believed to have Alzheimer's disease (AD), and as global population continues to age, it is projected that this figure will reach 152 million by 2050^[1]. In light of the irreversible nature

of Alzheimer's disease (AD) and the constraints of available treatments, there has been a shift in focus towards early detection and intervention as key strategies in the prevention and management of AD. Consequently, there is growing interest in Mild Cognitive Impairment (MCI).

MCI is thought to be a transitional state from the normal cognitive decline that occurs with aging to the cognitive impairment associated with dementia, manifested by cognitive decline and neuropsychiatric symptoms [2]. Negative emotions, including anxiety, depression, and apathy, are among the most common manifestations of psycho-behavioral symptoms in individuals with mild cognitive impairment, with prevalence rates ranging from 35.0% to 85.0% [3]. Negative emotions, which have been demonstrated to precipitate a decline in cognitive and functional abilities, are primary factors in the progression of MCI to dementia [4]. Moreover, they adversely impact the health-related quality of life of patients with MCI. Although pharmacological treatments have demonstrated efficacy in alleviating negative emotions, they are also linked to a considerable prevalence of undesirable events and side effects [5]. The management of negative emotions in patients with MCI should prioritize the implementation of efficacious non-pharmacological interventions.

Cognitive training holds great promise as a non-pharmacologic intervention to slow cognitive decline and improve behavioral symptoms in individuals with cognitive dysfunction [6,7]. In recent years, as computing technology continues to evolve, network technologies like computers and virtual reality have opened new directions for cognitive training in individuals with MCI. Networked cognitive training enhances usability, efficacy, and customization by providing more dynamic exercises, real-time feedback, and greater personalization compared to traditional methods [8]. Thus, networked cognitive training is becoming an increasing preferred alternative for enhancing cognitive functions [9]. Earlier systematic reviews and meta-analyses have confirmed that networked cognitive training, such as virtual reality technology and computerized training, is beneficial for improving the overall cognitive function. However, variability remains in the effectiveness of networked cognitive training for negative emotions. Several trials have indicated that networked cognitive training can have a positive impact in terms of reducing depression, whereas others have indicated a non-significant effect on depression [10,11]. Furthermore, there is inconsistency regarding the application effects of networked cognitive training on anxiety, apathy, and quality of life among individuals with MCI [12-16]. Given these considerations, it is imperative to synthesize the existing research evidence to assess the impact of networked cognitive training on negative emotions in individuals with MCI. Thus, this study performed a systematic review with the specific aim of examining the effects of networked cognitive training on negative emotions and quality of life in patients with MCI, to generate evidence for the expanded application of networked cognitive training in patients with MCI.

2. Method

This review was carried out according to the PRIMSA 2020 Guidelines.

2.1. Search strategy

Searches for eligible studies were conducted across nine digital databases from the beginning to December 17, 2025, including PubMed, Web of Science, EMBASE, Cochrane Library, PsycINFO, CNKI, Wanfang database, VIP database, and Sinomed. This study adopted the title/abstract or Medical Subject Headings (MeSH terms) such as “cognitive dysfunction/ mild cognitive impairment/mild cognitive disorder/mild cognitive dysfunction/ mild cognitive decline/ mild neurocognitive disorder/MCI, Information Technology*/ Digital Technology/ Virtual Reality/ Internet/ Augmented Reality/ computer, depression /anxiety/apathy/neuropsychiatric symptom*,”

randomized controlled trial*/RCT". In order to find any more relevant studies, this study also looked through the reference lists of linked studies. The search was limited to English and Chinese.

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

- (1) Population
Adults with mild cognitive impairment (MCI);
- (2) Intervention
Cognitive training using network technologies. Cognitive training using network technologies refers to an intervention delivery method that makes use of network technologies, including internet-based platforms, mobile devices, sensors, and robots.
- (3) Control
Any kind of comparator, such as usual care, health education or no intervention;
- (4) Outcome
Reporting psychological-related outcomes such as depression, anxiety, apathy;
- (5) Study design
Randomized controlled trials.

2.2.2. Exclusion criteria

- (1) Individuals with certain illnesses or conditions that impact cognitive function, such as vascular mild cognitive impairment;
- (2) Conference papers;
- (3) Repeated publication;
- (4) Incomplete research, such as continuing studies or study methods.

2.3. Study selection and data extraction

The literature results gathered from each search database were imported into NoteExpress management software to handle and remove duplicates. Initially, two independent reviewers (L.Z.Z and H.G) examined the titles and abstracts of the studies against the inclusion and exclusion criteria, and then downloaded the full articles of potentially suitable studies for further review. Any discrepancies were addressed by discussing with a third reviewer (F.Q) at each stage until an agreement was obtained. Subsequently, one reviewer (L.Z.Z) extracted the data from eligible studies, and another reviewer (H.G) confirmed the information. The extracted data included first author, year of publication, country of origin, sample size, age, intervention type and characteristics (components, technology, duration, and frequency), comparison, and outcome measures. When standard deviations were not reported in the papers, this study converted the data in accordance with the Cochrane Handbook for Systematic Reviews of Interventions.

2.4. Quality assessment

Two reviewers (L.Z.Z and H.G) separately evaluated the included papers' quality using the Cochrane risk-of-bias tool for randomized trials^[17]. The tool evaluates six areas: the process of randomization, allocation concealment, the blinding status of participant and staff, the completeness of outcome data, selective outcome reporting, and other bias. Based on the degrees of bias, each item's overall evaluation for each study was classified as "low," "high," or "unclear". In terms of general quality, research classified as high risk in at least one area was categorized

as high risk overall. When no high risks were identified, trials with one or multiple unknown risks were deemed unclear overall. Studies assessed as low risk in every domain were considered low risk overall. Discrepancies were addressed by discussing with a third reviewer (F.Q).

2.5. Data synthesis and analysis

When at least two trials presented the result of interest, meta-analyses were conducted using Review Manager (version 5.4) to aggregate effect sizes; otherwise, narrative synthesis was carried out. MD was applied to integrate the experiments which used the same measurement rating scales. The trials using various measurement rating scales were calculated by SMD with 95% CI to assess the effect size of various rating scales.

Heterogeneity testing was done and evaluated by I^2 . It was deemed to exist notable variation when $I^2 > 50\%$ with $p < 0.10$ [18]. In these situations, a random effects model was employed to compute pooled effect estimates. A fixed effects model was applied if the heterogeneity was negligible. To assess the results' stability and dependability, this study conducted sensitivity analysis using a leave-one-out approach for outcomes with substantial heterogeneity. Effect sizes were computed using available data in cases where the study did not give a mean or SD. Effect sizes were interpreted using Cohen's criteria, with an SMD < 0.2 considered negligible, 0.2–0.49 considered small, 0.5–0.79 considered medium and > 0.8 considered large [19].

3. Results

3.1. Study selection

The decision-making procedure for the research's ultimate inclusion is summed up in the PRISMA flow chart in **Figure 1**. The electronic search generated 4248 items, of which two were manually examined using the references to the involved publications and earlier released related reviews. There were 3173 articles left after removing duplicate entries. 3121 articles were eliminated after titles and abstracts were screened, leaving 52 for the whole text evaluation. Overall, thirteen papers satisfied the inclusion requirements and were included in the ultimate analysis.

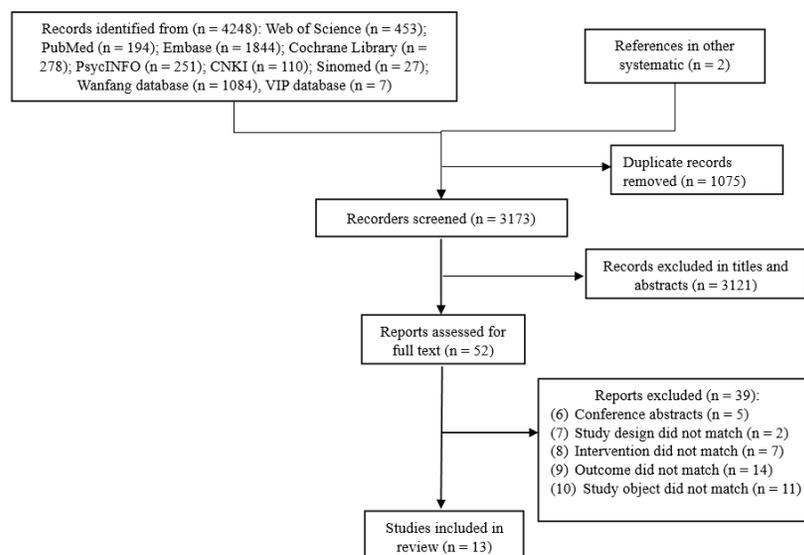


Figure 1. Flow chart of the selection process for this meta-analysis.

Note: CNKI=China national knowledge infrastructure; SinoMed = Chinese biomedical literature database; VIP = Chinese scientific journal database.

3.2. Quality of the studies

This study evaluated the quality of each study using the Cochrane criteria. In general, there was only one study with a low risk of bias, five with a high risk, and seven with an unknown risk. Among the included studies, only one study blinded the participant due to the nature of networked intervention; 9 (69.2%) reported details of the generated randomized sequence; 4 (30.8 %) provided details of allocation concealment; 9 (69.2 %) studies blinded the outcome assessor. The most prevalent types of bias risk were implementation bias and selection bias. According to the GRADE, the overall quality of the results was mediocre.

3.3. Study characteristics

The characteristics of the sample and the design of the individual studies were summarized in **Table 1**. Every study that was included was released between 2017 and 2024. Trails were performed in different countries: China (n = 4), Korea (n = 4), Italy (n = 1), Greece (n = 1), Spain (n = 1), England (n = 1), Iran (n = 1). There were 626 MCI participants in all who took part in this systematic review. The range of the mean age was 65.64 to 87.5. The networked cognitive training of the included studies were delivered using tablet (n = 2), computer (n = 3), virtual reality (n = 6), and robot (n = 2). Regarding the interventions for the control group: two studies applied traditional cognitive training, three conducted health education, two implemented usual care, five studies didn't use any kind of any intervention, and two studies continued with their regular routine. The duration of each dosage of the intervention varied from 24 minutes to an hour, and the number of instances of the intervention ranged from two to five times weekly. The overall duration of the intervention spanned anywhere from four to twenty-four weeks. The experiments that were included used a range of outcome measures. Two scales were utilized in eleven studies to measure depression: the Geriatric Depression Scale(GDS) and its abbreviated version, GDS-SF [11,12,20–28]. Two tools were employed in five studies to evaluate the impacts of the training on anxiety: the Geriatric Anxiety Inventory (GAI) and the Self-rating Anxiety Scale (SAS) [12,20,22,23,28]. Only one study using the Apathy Rating Scale measured apathy [24]. Quality of Life assessed in five studies, four of which utilized the Quality of Life in Alzheimer's Disease (QOL-AD) scale, while one utilized the 12-item Short-Form Health Survey (SF-12) [22,23,28–30].

Table 1. The characteristics of participants of included studies

No	First author, year	Country	N (I/C)	Mean age (I/C)	Device	Control group	Sessions	Outcomes
1	Savulich (2017)	England	21/21	75.2/76.9	Tablet	Waitlist control	Two 60-min sessions/week for 4 weeks	Depression: GDS-SF; Apathy: AES
2	Lee (2020)	Korea	20/21	73.6/74.5	Robot	Health education	Five 60-min sessions/week for 4 weeks	Depression: GDS
3	Park (2020)	Korea	10/11	71.80/69.45	VR	Maintained daily lifestyle	Two 30-min sessions/week for 12 weeks.	Depression: GDS-SF
4	Manenti (2020)	Italy	18/17	75.30/78.10	computer	Traditional cognitive training	Three 60-min sessions/week for 16 weeks.	QOL: QOL-AD
5	Goumopoulos (2023)	Greece	11/10	> 65	Tablet	Maintained daily lifestyle	Two 60-min sessions/week for 12 weeks.	Depression: GDS-SF

Table 1 (Continued)

No	First author, year	Country	N (I/C)	Mean age (I/C)	Device	Control group	Sessions	Outcomes
6	Baik (2024)	Korea	25/25	67.08/65.64	computer	Waitlist control	Three 24-min sessions/week for 8 weeks.	Depression: GDS
7	Sasaninezhad (2024)	Iran	20/20	70.3/69.1	VR	Waitlist control	Three 30-min sessions/week for 4 weeks.	Anxiety: GAI; Depression: GDS
8	Buele (2024)	Spain	14/12	75.41/77.35	VR	traditional cognitive training	Two 40-min sessions/week for 6 weeks.	Depression: GDS-SF
9	Park (2021)	Korea	45/45	75.5/75.6	Robot	Waitlist control	Two 60-min sessions/week for 6 weeks.	Depression: GDS-SF
10	Luo Yuting (2021)	China	38/35	70.18/70.40	computer	Health education	Two 60-min sessions/week for 12 weeks.	Anxiety: SAS; Depression: GDS; QOL: QOL-AD
11	Huang meizhen (2022)	China	41/41	69.54/71.12	VR	Health education	Three 30–45 min sessions/ week for 3 weeks.	Anxiety: SAS; Depression: GDS; QOL: QOL-AD
12	Ding Yiwen (2023)	China	21/21	82.81/82.95	VR	Waitlist control	Two 30-min sessions/week for 6 weeks.	Anxiety: GAI; Depression: GDS-SF; QOL: SF-12
13	Sun Zhicheng (2024)	China	32/31	77.18/78.03	VR	Usual care	Three 45-min sessions/week for 24 weeks.	QOL: QOL-AD

GDS = Geriatric Depression Scale, GDS-SF = Geriatric Depression Scale-Short Form, GAI = Geriatric Anxiety Scale, SAS = Self-rating Anxiety Scale, AES = Apathy Evaluation Scale, QOL = Quality of Life, QOL-AD = Quality of Life in Alzheimer's Disease Scale, SF-12 = 12-item Short-Form Health Survey.

3.4. Quantitative syntheses

3.4.1. Depression

Researchers evaluated the effect of networked cognitive training on MCI patients' depression levels in nine different research. The heterogeneity was large ($I^2=69.0\%$), and thus, a random effects model was performed. The result showed that networked cognitive training had a small but significant impact on reducing depression compared to the control treatment (SMD = -0.36; 95% CI [-0.73, -0.00]; $p = 0.050$; **Figure 2**). Sensitivity analysis found the study by Ding Yiwen was the main source of heterogeneity, and after deleting this study, the test for heterogeneity showed $I^2 = 0\%$ ^[28]. The result still indicated a statistically significant between networked cognitive training and control group (SMD = -0.19; 95% CI [-0.38, -0.00]; $p = 0.050$). Due to a lack of means and SD, two studies were not included in the data pool. According to Goumopoulos' study, the intervention group experienced a slight improvement in depression levels ^[25]. However, neither Savulich's nor Goumopoulos' investigation discovered any noteworthy differences between the groups ^[24,25].

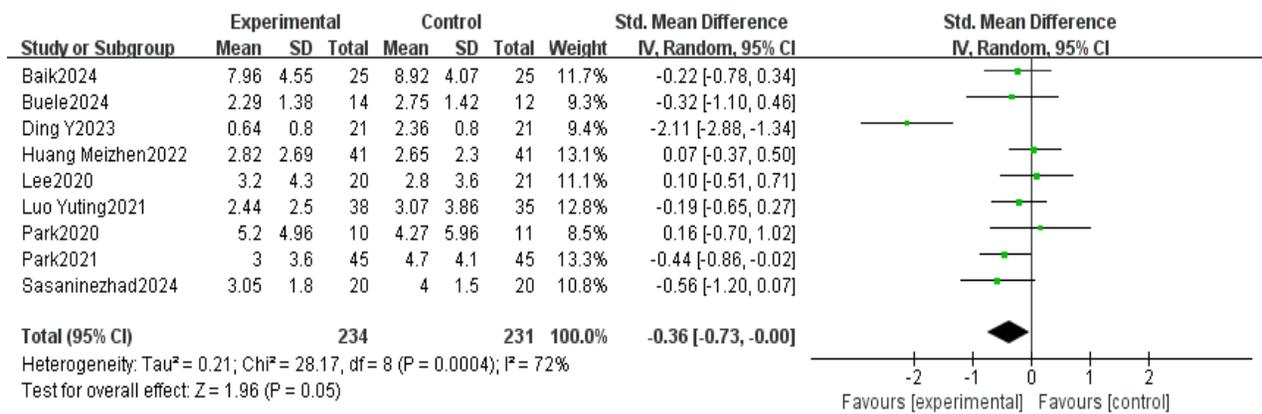


Figure 2. Forest plot of efficacy of networked cognitive training in reducing depression.

3.4.2. Anxiety

Data from five studies were utilized to assess the effectiveness of networked cognitive training on the anxiety level of patients with MCI. The heterogeneity was not significant ($p > 0.100$; $I^2 = 20.0\%$), and thus the fixed effects model was performed. The findings showed that participants who underwent networked cognitive training experienced a statistically significant decrease in anxiety measures (SMD = -0.32; 95% CI [-0.57, -0.06]; $p < 0.050$) when compared to the control group. Subgroup analyses of types of anxiety rating scales showed networked cognitive training did not show superiority over the control group when the GAI was used (SMD = -0.05; 95% CI [-0.48, 0.39]; $p > 0.050$; Figure 3).

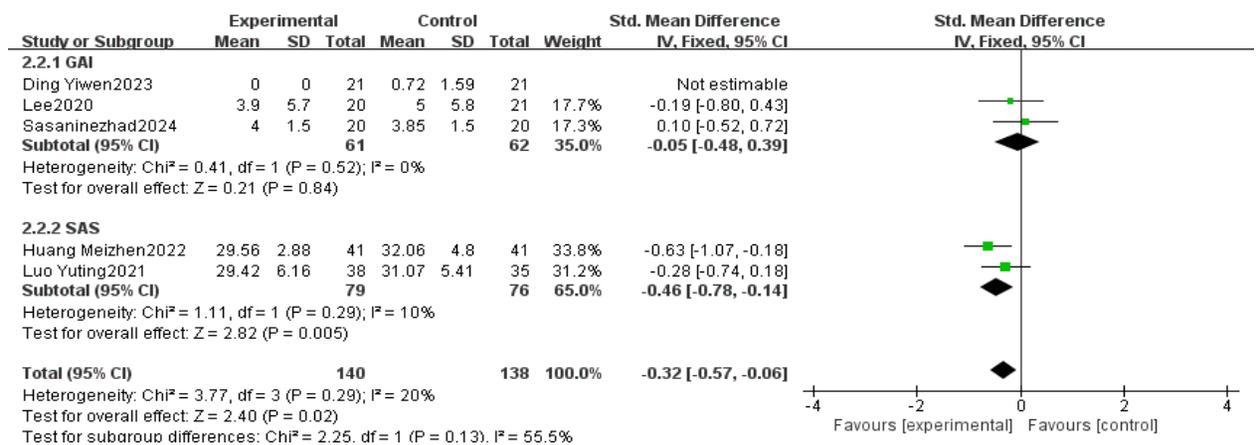


Figure 3. Forest plot of efficacy of networked cognitive training in reducing anxiety.

3.4.3. Apathy

The study by Savulich was the only one to assess the effectiveness of networked cognitive training on the apathy levels of patients with MCI [24]. To be specific, individuals in the networked cognitive training group exhibited a slight reduction in apathy, whereas the control group showed an increase. A notable difference was observed between the two groups.

3.4.4. Quality of life

Researchers conducted four studies to assess the effect of networked cognitive training on the quality of life of

patients with MCI. Since the heterogeneity test indicated a significant level of heterogeneity ($p < 0.100$; $I^2 = 53.0\%$), the random effects model was employed. The outcome shown that networked cognitive training had a positive and significant effect on quality of life in the immediate post-intervention period compared with control therapy (MD = 2.54; 95% CI [0.98, 4.10]; $p < 0.050$; **Figure 4**). One study, which was excluded from data pooling due to a lack of overall means and SD, demonstrated a considerable improvement in the quality of life for the intervention group, including physical and mental health ($p < 0.001$)^[28]. Sensitivity analysis failed to find any research that could alter the outcome. Only one study provided follow-up data, which indicated that there was no significant sustained effect at 4 and 7 months after the intervention ($p > 0.050$)^[29].

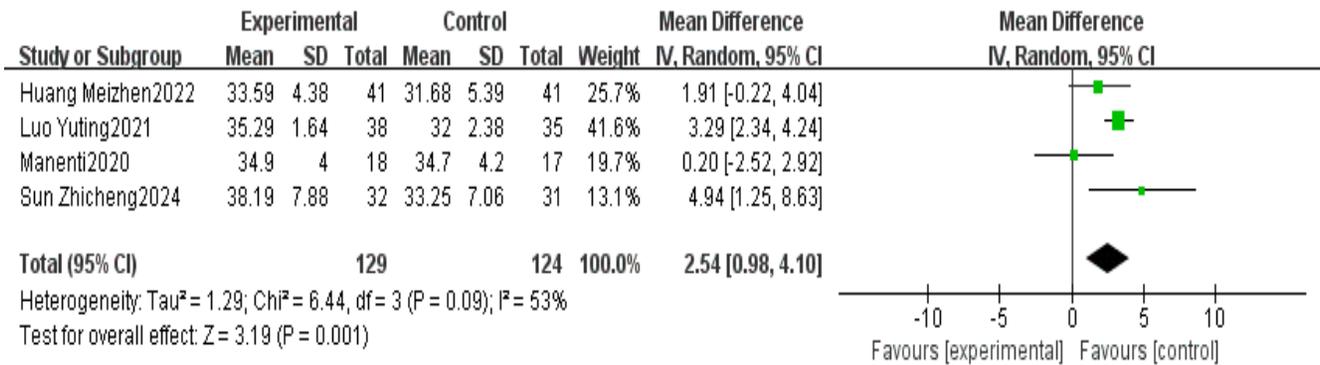


Figure 4. Forest plot of efficacy of networked cognitive training in improving quality of life.

3.5. Publication bias

For depression (n = 9), funnel plots were visually inspected, revealing indications of potential asymmetry.

4. Discussion

4.1. Summary and interpretation of results

This meta-analysis included 14 RCTs and assessed the impacts of networked cognitive training on patients with MCI. Immediate outcomes following the intervention demonstrated a remarkable betterment in depression, anxiety, and overall quality of life. Nevertheless, the evidence regarding apathy is uncertain because of the insufficient number of existing randomized controlled trials.

People with MCI experience declines in memory and executive function that gradually affect their ability to perform daily activities, leading to decreased satisfaction and confidence and increased feelings of meaninglessness that can lead to depression. This meta-analysis found that networked cognitive training effectively reduces depression in patients with MCI, which is similar to previous studies^[31]. A systematic review found that depression in MCI is closely linked to executive dysfunction in MCI, which is caused by disruption or weakened connectivity of the cognitive control network consisting of the dorsolateral prefrontal cortex, dorsal anterior cingulate gyrus, and precentral gyrus^[32,33]. Based on principles of neuroplastic reorganization, network cognitive training may improve patients' executive function by altering neural network function and modulating synaptic connections in the brain, which may alleviate depression. Furthermore, a cognitive neurophysiological model of depression suggests that networked cognitive therapy enhances the activity of higher-order frontal regions to control depression^[34,35]. Therefore, it indicates that networked cognitive training may be a viable therapy for relieving depression in individuals with MCI. Nevertheless, since few trails included ongoing observational

information after the training concluded, this study just able to retrieve information on the training endpoints from these studies. Consequently, our findings may only reflect a temporary impact on depression.

Anxiety is a negative emotional state characterized by worrying about an uncertain or unpredictable future^[36]. The findings of this meta-analysis showed that anxiety has significant yet modest effect. This may be explained by the training components utilized in this project, such as memory training. This training can effectively enhance memory capacity by frequently practicing cognitive activities that require high memory demands, thereby equipping individuals with more resources to manage anxiety. Meanwhile, cognitive training assists individuals in redirecting their attention away from negative stimuli and alleviating anxiety symptoms focusing on relevant knowledge^[37,38]. Furthermore, networked cognitive training can offer positive reinforcement when patients provide the correct answers. This positive feedback may enhance their self-confidence, foster a greater sense of accomplishment, and reduce negative interpretation biases. Unfortunately, the exact mechanism by which networked cognitive training reduces anxiety has not been precisely identified, even though this study offers unambiguous proof of its anxiety-reducing effects. Future research needs to utilize neuroimaging and other techniques to investigate the potential mechanisms through which networked cognitive training alleviates anxiety. Additionally, it has been found that the effects of the same technology-driven cognitive intervention appear to have variable effects with various anxiety assessment tools, which may be attributed to inconsistent focuses across the scales. This finding highlights the importance of choosing harmonized assessment tool for the same outcome, which can be a source of high quality and homogeneous evidence.

Apathy is one of the most prevalent and enduring behavioral and psychological disorders observed in individuals with cognitive disorders^[39]. It is a multidimensional syndrome characterized by motivational disorders, primarily manifested by a lack of interest, a significant reduction in goal-directed activities, and diminished affective responses^[4]. This study cannot determine the effect of networked cognitive training on apathy in individuals with MCI due to insufficient pooled data. The study by Savulich showed that there were no significant differences in apathy levels from the beginning to the end among the networked cognitive training group; however, a significant time-by-group interaction was noted^[24]. This indicates that utilizing networked cognition training to alleviate apathetic symptoms has demonstrated potential, aligning with the findings reported by Robert^[40]. Therefore, this study recommend the development of larger randomized controlled trials in the future to confirm the effects of networked cognition training on apathy, in order to draw more robust conclusions.

Quality of life is a comprehensive assessment of treatment outcomes and the health status of patients with MCI^[41]. Contrary to the insignificant findings of earlier meta-analyses regarding MCI and dementia, this meta-analysis showed a large impact of networked cognitive training ($MD = 2.54$) on improving quality of life^[16]. It is essential to understand that quality of life is a subjective concept encompassing people's impressions of physical, psychological, and social dimensions^[42]. Thus, qualitative analysis can be a valuable source of insight into the explanation of these positive effects. At somatic level, networked cognitive training has been demonstrated to enhance both cognitive and motor functions, which may have direct implications for enhancing abilities of daily living and overall physical well-being^[43]. At psychological level, participants often reported a decrease in negative emotions, along with an increase in self-confidence and well-being as a result of networked cognition training^[44]. Regarding social benefits, some participants reported that networked cognitive training can facilitate communication, aid in learning new skills, and enrich social interactions^[28]. These qualitative results supplement the quantitative research, offering a deeper perspective on the subjective experiences and perceived advantages of networked cognition training on quality of life. However, this meta-analysis concentrated on the short-term effects

on quality of life, while the tracking of long-term effects was limited. Therefore, future research could extend the follow-up duration or incorporate wearable devices for continuous health data monitoring to validate the prolonged effects of networked cognitive training on quality of life.

Just one study included in this meta-analysis investigated whether utilizing a network as a delivery method would have a greater impact on negative emotions compared to traditional manual delivery methods. Buele compared the effects of a cognitive training program delivered through a VR-based platform with traditional cognitive training methods^[26]. This study indicated that both treatment modes were efficient in alleviating depression; however, stronger effects were reported in the control group. This underscores the latent benefits of obtaining verbal and mental assistance from trained providers in reducing participants' depression. Nonetheless, compared to traditional cognitive training, patients showed higher engagement and satisfaction with networked cognitive training. And networked cognitive training offers a variety of formats, including patterns, games, videos, and virtual, which patients can select based on their personal preferences. This approach maximizes individual autonomy, facilitates self-directed training, and provides more efficient cognitive training. From this, both manual and technology-based training approaches have advantages and disadvantages. As a result, it is impossible to say with certainty whether one kind of intervention is better than the other in reducing unpleasant emotions.

4.2. Limitations

There are various restrictions on this study. Firstly, although the experimental groups in this review all received networked cognitive training, the control groups were subjected to various measures, including the use of blank, active, and routine controls, which resulted in a less consistent study design. Secondly, most of the eligible trials lacked blinding of participants or investigators, which raises the possibility of performance bias. Thirdly, the lack of research has led to uncertainty about the effects of networked cognitive training upon apathy. Therefore, it is essential to approach the findings regarding the interpretations of apathy with caution. Additionally, there were not enough trials to determine which types of networked technologies were most effective in alleviating specific symptoms, so this study was failed to perform a subgroup analysis. Lastly, the included studies primarily focused on improving the cognitive function, while negative emotions were only assessed as secondary evaluation indicators, highlighting the need for more relevant studies that specifically address emotional outcomes.

5. Conclusion

To summarize, our meta-analysis shows the effectiveness of networked cognitive training in alleviating depression and anxiety, as well as enhancing quality of life. However, there is currently insufficient evidence to determine whether this intervention approach is effective in managing apathy, leaving the results regarding apathy inconclusive. Stronger randomized controlled trials with larger populations are required to verify the significance of networked cognitive training on apathy and to consolidate the findings. Meanwhile, future designs can compare and evaluate the effectiveness of various networked cognitive training methods in managing each type of emotional conditions.

Registration

This systematic review and meta-analysis have been registered with PROSPERO (under registration number CRD42024593710).

Disclosure statement

The authors declare no conflict of interest.

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