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CLINICAL TRIAL REPORT

Examination on the Acceptability, Feasibility and Effectiveness of a Digital Cognitive Training Software in Patients With Stable Schizophrenia in China

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Objective: This single-arm study aimed to explore the acceptability and effectiveness of a digital cognitive training software (IBT-004) in patients with stable schizophrenia.

Methods: This study conducted an 8-week home-based cognitive training program, IBT-004, for patients with stable schizophrenia. Forty-seven participants were recruited from Peking University Sixth Hospital and Hebei Provincial Mental Health Center. IBT-004 focused on improving cognitive function through independent tasks. Cognitive function was assessed using the Chinese Brief Neurocognitive Suite of Tests (C-BCT) and self-report scales, with additional evaluation of the program's acceptability and feasibility.

Results: After 8 weeks of cognitive training, patients showed significant improvements in total cognitive scores, Digit Span, and Trial Making Test ($P < 0.05$). Subjective cognitive distress significantly decreased ($Z = -3.758$, $P < 0.001$). Age ($B = -0.532$, $\beta = -0.476$, $P < 0.05$) and training duration ($B = 0.273$, $\beta = 0.340$, $P < 0.05$) were significant predictors of Continuous Performance Test scores ($F = 3.884$, $P < 0.05$). Patients showed high acceptance of the software. Enjoyment scores (1–5 scale) ranged from 3.46 to 4.14, and difficulty scores (1–5 scale) ranged from 2.31 to 2.86, with no significant changes over time ($P < 0.05$). The average training time was 36.89 hours, and adherence reached 92.24%, indicating strong engagement and compliance.

Conclusion: This study showed that a home-based online cognitive training program improved cognitive function in patients with stable schizophrenia. Significant gains were seen in overall cognitive scores, processing speed, and attention. Participants also reported reduced cognitive distress. Younger age and longer training hours were linked to better outcomes. The program had high adherence, supported by personalized adjustments and engaging features. These results confirm the program's feasibility and effectiveness for cognitive improvement in schizophrenia.

Clinical Trials Registration: ChiCTR2200055930.

Keywords: stable schizophrenia, cognitive training, digital cognitive training software, Chinese brief neurocognitive suite of tests, C-BCT

Introduction

Schizophrenia is a severe and lifelong mental disorder. According to data from the 2019 national epidemiological survey, the lifetime prevalence of schizophrenia in China is 0.6%, indicating that there are over 8 million individuals with schizophrenia nationwide.[1] Typically emerging in adolescence or early adulthood, schizophrenia often requires medication, and many patients experience residual symptoms such as cognitive decline, lack of motivation, emotional apathy, or mood instability. As a result, many patients struggle to pursue education and employment. Some individuals with severe

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residual symptoms are unable to live independently and require long-term care from family members. A study published in 2019 revealed that the annual direct economic burden of schizophrenia for patients in China was 963 RMB, while the indirect economic burden primarily caused by absenteeism amounted to 11,724 RMB, exceeding the average annual household expenditure (11,641 RMB).[2]

It is increasingly recognized that cognitive dysfunction is a core dimension in schizophrenia, which occurs before the first psychotic episode and persists throughout the course of the illness.[3] With the establishment of MATRICS Consensus Cognitive Battery (MCCB), research on cognitive impairments in schizophrenia gained a huge progress. A meta-analysis in 2011 found that patients with stable schizophrenia show cognitive impairments in various domains, including speed of processing, attention or vigilance, working memory, verbal learning, visual learning, reasoning or problem solving, and social cognition, which are about 1–2 standard deviations below the average level.[4] In the clinic, we may often hear from our patients complaining that I cannot pay attention to read books, so I cannot continue my study or I cannot understand the word of others, so it is hard for me to build a friendship.

A meta-analysis in 2019 revealed that cognitive function in patients with schizophrenia is positively correlated with their social function.[5] Qualitative studies in patients with schizophrenia and their primary caregivers showed that social function and cognitive function are all regarded as important outcomes.[6] Especially, for young patients living in cities, they are eager to regain the ability to study and work. Therefore, nowadays, the treatment target of schizophrenia has been shifted from the control of clinical symptoms to the improvement of social function.[7] We believe that, by improving the cognitive function of patients with schizophrenia, we could improve their social function, and then improve their quality of life, alleviate caregiver burden, and reduce social strain.

Then, how to improve the cognitive function of patients with schizophrenia? Currently, there are two types of intervention: pharmacological and physical.[8] Examples of pharmacological interventions include atypical antipsychotics and cognitive enhancers, like cholinergic agents, dopaminergic agents and glutamatergic agents.[3] They are all promising treatment options, but their effect sizes tend to be small, and they may cause some possible adverse effects, like the sedation effect of antipsychotics, which restricted their clinical application. Therefore, researchers and doctors now turn to physical interventions. The most widely used ones include repetitive transcranial magnetic stimulation (rTMS), transcranial direct current stimulation (tDCS), as well as cognitive remediation training (CRT), which is the focus of our today's topic.[8]

So, what is cognitive remediation training? According to the definition of cognitive remediation experts working group, cognitive remediation is a behavioral training intervention targeting cognitive deficits, like attention, memory, executive function, social cognition or metacognition, using scientific principles of learning, with the ultimate goal of improving functional outcomes.[9] There are two main theories behind cognitive remediation, namely, neuroplasticity and effective learning. Neuroplasticity means that the structure and function of brain could be shaped by acquired experiences. For example, the number and connection of neurons might be changed by our behavior. Effective learning indicates that, through scientific learning, like repetitive learning and scattered learning, the efficiency and outcome of learning could be maximized.

The biological mechanisms behind cognitive remediation have been explored. A study in Chinese patients indicated that cognitive training may improve the activity of medial prefrontal cortex and anterior cingulate cortex.[10] A report in 2009 indicated that cognitive training may improve the function of dopaminergic receptor in prefrontal cortex.[11] Two studies in 2008 proved the transfer effect of cognitive training, indicating that the transfer effect might be mediated by the activation of brain regions shared by different cognitive tasks.[12,13] For example, the transfer effect from training on updating tasks to performance on working memory tasks was derived from their shared involvement of striatum.[12]

In patients with schizophrenia, the effectiveness of cognitive remediation has been proved by many clinical trials. The meta-analysis published in JAMA Psychiatry in 2021 indicated that cognitive training can not only improve cognition, with the effect size of 0.29 [95% CI, 0.24–0.34] but also improve social function and clinical symptoms, with the effect size of 0.22 [95% CI, 0.16–0.29].[14] More importantly, the effect of cognitive training may be maintained in follow-up assessments.[15] To conclude, cognitive training has multiple advantages. It is safe, without significant adverse effects; it is targeted, aiming at cognitive impairments; and its effect is sustained, which may last longer than 3 months.

Although the effectiveness of cognitive training has been proven, most studies above employed cognitive function training tasks conducted in a pen-and-paper format, with therapists present, within medical institutions.[14] The above elements mean that the traditional cognitive training demands substantial manpower and resources, requiring patients to make multiple weekly trips to the hospital, thereby limiting its accessibility. In China, due to the relatively late introduction of the rehabilitation treatment concept for schizophrenia and the lengthy training period for rehabilitation therapists, there exists a significant imbalance between the supply and demand of rehabilitation services for individuals with schizophrenia.[16] Therefore, conducting person-to-person type of training in clinical settings is quite challenging.

In comparison to traditional cognitive function training, the digitized format enables remote home-based training, helping to reduce the artificial costs of rehabilitation treatment, enhance the efficiency of healthcare professionals, and offer advantages such as low cost and high accessibility.[17] This makes it more user-friendly for the majority of stabilized schizophrenia patients in the community or at home. To meet the requirements of this group of patients, we developed IBT-004, a digital cognitive training software for patients with stable schizophrenia, which was set in a tablet and could be used at home.

As an important step for preliminary research and further improvement, in this study, we will use quantitative methods to examine the acceptability, feasibility, and effectiveness of IBT-004 in Chinese patients with stable schizophrenia. We will evaluate the acceptability of the intervention through participants' subjective reports and assess feasibility by analyzing participants' training implementation. Effectiveness will be assessed by comparing changes in subjective and objective cognitive levels before and after the intervention.

Methods

Study Design

This study was a single-sample, before-and-after controlled trial, where patients with stable schizophrenia were recruited to undergo a home-based online intervention with the digital cognitive training software (IBT-004). Cognitive function was measured before and after the intervention using the Chinese Brief Neurocognitive Suite of Tests (C-BCT). Clinically stable adults with schizophrenia were recruited from two sites: Peking University Sixth Hospital and Hebei Provincial Mental Health Center. In each institution, potential participants were informed about the study through referrals and information sheets posted in the outpatient department.

Participants were required to complete at least 5 days of home-based training per week, with each day consisting of 4 training tasks, each offering five difficulty levels. The training program lasted for 8 weeks, and participants were expected to complete 5 class hours (4tasks) per week. A post-training evaluation was conducted regardless of the amount of training completed. If a participant was unable to complete the training on time, a staff member would contact them to provide guidance and inquire about the reason for the delay. Participants were considered to have dropped out if they completed less than 80% of the required training during the trial.

Participants

Patients meeting the following criteria are included in the study: ① Meet the DSM-V criteria for a diagnosis of schizophrenia; ② Aged between 18 and 50 years; ③ Disease duration ≤20 years; ④ Capable of understanding the informed consent and research process and signing the informed consent form; ⑤ No significant medication adjustments within the past 8 weeks and no planned adjustments in the next 6 months; ⑥ No evidence of symptomatic fluctuations in the 2 months prior to enrollment, including no hospitalizations for schizophrenia or additional treatments due to illness exacerbation; ⑦ Positive and Negative Syndrome Scale (PANSS): P1 (delusions), P2 (conceptual disorganization), P3 (hallucinatory behavior), N1 (blunted affect), N4 (social withdrawal), N6 (lack of spontaneity and flow of conversation), G5 (mannerisms and posturing), and G9 (unusual thought content) scores ≤3.

Participants are excluded if they meet any of the following criteria: ① Have a medical condition that may affect cognitive function; ② Currently using methylphenidate, antidementia drugs, amphetamines, lithium salts, monoamine oxidase inhibitors, or tricyclic antidepressants; ③ Currently using first-generation antipsychotics (FGAs) or

clozapine; ④ At risk of suicide (suicidal behavior within the past year, suicidal ideation, or attempt within the last 3 months); ⑤ Received MECT or rTMS treatment within the past 6 months.

Participants receive 100 RMB for transportation for each study visit.

Interventions

The intervention is delivered through a WeChat applet and consists of 14 training tasks that target the major cognitive impairments commonly seen in individuals with schizophrenia: processing speed, attention, learning and memory, executive function, and logical reasoning (see Supplementary Table 1). Participants are required to complete 4 training tasks per day, with each task offering five difficulty levels. Each day's tasks are equivalent to one class hour (30 minutes). The difficulty of each training task is adjusted based on the participant's performance. At the start of the training, the difficulty level for each participant is the same, but as the training progresses, the difficulty is personalized according to the user's performance. If the participant performs well, the system gradually increases the difficulty to ensure an appropriate level of challenge; conversely, if the participant struggles, the difficulty is reduced to prevent frustration. This personalized adjustment ensures that each participant is working within their zone of proximal development, providing a balance between challenge and achievement. In the development of IBT-004, the guiding principle was patient-centered, which aligns with the FDA's recommendations for digital therapeutics.[18]

Furthermore, while focusing on cognitive training, the intervention also maintains an element of enjoyment. For example, in the interface design, all visual elements, including colors and icons, are specifically designed to be engaging and soothing. Additionally, the reward system, inspired by game design principles, shows an increase in points when participants successfully complete tasks. This is intended to stimulate participants' intrinsic motivation and improve adherence to the training program.

Moreover, each participant had a dedicated coordinator responsible for overseeing the training. The coordinator ensured that tasks were completed on schedule and that participants used the software correctly. They also offered support by answering questions and helping resolve any issues encountered during training.

Procedure

Participants were contacted via phone or WeChat and completed baseline assessments prior to the intervention. Baseline assessments included demographic information, an expectation questionnaire, and cognitive function evaluation (using the C-BCT). After each weekly intervention, participants evaluate the software's enjoyment and difficulty levels through an online questionnaire. At the end of the 8-week intervention, cognitive function was reassessed, followed by the post-intervention cognitive improvement evaluation questionnaire. This study follows a structured timeline, including baseline assessments, weekly assessments, and post-intervention follow-up assessments.

Outcomes

The study's primary outcome measure was cognitive function, assessed by the Chinese Brief Neurocognitive Suite of Tests (C-BCT). C-BCT consists of 4 subtests including Trail Making Test-A (TMT-A), Symbol Coding Test (SC), Continuous Performance Test (CPT), and Digit Span Test (DS), which evaluated the speed of information processing, attention, working memory, reasoning, and problem-solving ability. [19] The secondary outcome measure was subjective cognitive function, which is assessed by patients self-scored. The self-report measure used in this study consists of three sections: a pre-intervention expectation questionnaire, a during-intervention training acceptance questionnaire, and a post-intervention cognitive improvement assessment. The measure utilizes a Likert scale with predefined options to assess participants' cognitive distress, acceptance of training content, and perceived cognitive improvement. The expectation questionnaire includes: the degree of cognitive distress and confidence in the effectiveness of cognitive training and expectations of cognitive improvement. The second questionnaire focuses on training content acceptance, including the enjoyment and difficulty of the training. The third questionnaire evaluates post-intervention changes, including degree of cognitive improvement and changes in cognitive distress.

Sample Size

A review of previous studies revealed that cognitive training demonstrated small to moderate effect sizes on overall cognitive functioning (0.20 to 0.45) across all stages of schizophrenia. A one-sample before-and-after controlled trial was conducted using PASS 2021. The test level was set at 0.5 (α=0.5), the test efficacy of power was set at 0.9, and the effect size was calculated to be 0.45. This resulted in a required sample size of N=43, which was increased to 47 to account for a 10% dropout rate.

Data Analysis

The data were analyzed using SPSS Statistics 27. The *t*-test was used for measurement data, while the chi-square test was used for count data. The paired *t*-test was used for the total cognitive function score and each sub-score before and after the intervention. Regression analysis was performed to identify the relevant factors affecting cognitive function. We included variables such as marital status, education level, and age in the regression analysis to account for their potential influence on cognitive outcomes and to control for confounding factors, ensuring a more robust and comprehensive analysis.[20] The significant level was set at $P < 0.05$.

To compare the differences in enjoyment rating scores and difficulty rating scores across the eight time points, a repeated measures ANOVA was conducted. Post-hoc pairwise comparisons were performed using the Bonferroni correction method to control for Type I error due to multiple comparisons. The significance level for each comparison was adjusted to $p = 0.0018$ ($\alpha = 0.05/28$) to account for the total number of 28 pairwise comparisons.

Results

Demographic Characteristics

Of the 47 patients assessed for eligibility, 9 withdrew due to difficulties in consistently completing cognitive training, leaving a final sample of 38 patients. Table 1 summarizes the demographic and clinical characteristics. The average age was 28.63 years (range: 21–46 years), with a mean illness duration of 5.58 years (±4.26) and a PANSS score of 57.05 (±16.36). The sample included 18 females, 21 participants with a bachelor's degree or higher, and 16 employed individuals. Five participants were married, and the majority received monotherapy (mean antipsychotic type: 1.42 ± 0.5).

Difference in Cognitive Function After the Intervention

We conducted paired-samples t-tests to compare the cognitive function levels of patients before and after the intervention. The results are presented in Table 2 and Figure 1. The total scores were 44.20 ± 7.89 at baseline, while was 46.28 ± 8.16 at week 8. Trial Making Test score was 44.82 ± 8.77 at baseline. It was observed that the total scores ($P = 0.003$) and 2 dimensional scores including Trial Making Test ($P = 0.017$) and Digit Span ($P = 0.004$) of cognitive function were significantly improved after the intervention ($P < 0.05$). However, there was no significant difference in the Continuous Performance Test and Symbol encoding.

Table 1 Demographic Characteristics

Variable	Mean (SD) / n (%)
Age	28.63±7.91
PANSS	57.05±16.36
Length of illness (years)	5.58±4.26
Types of antipsychotic drugs	1.42±0.5
Gender (Female/Male)	18/20
Education (L/H)	17/21
Marital status (Married/Single)	5/33
Occupation (Employed/Unemployed)	16/22

Abbreviations: Education (L, Lower than a bachelor's degree; H, Higher than a bachelor's degree).

Table 2 Difference in Cognitive Function After the Intervention

Variable	Baseline	After	Stats	p-value	Effect Size
	Mean (sd)	Mean (sd)	t. Statistics		
Total scores	44.20	46.28	−3.15	0.003*	0.511
Trail Making Test-A (TMT-A)	44.82	46.97	−2.51	0.017*	0.400
Digit Span Test (DS)	45.00	48.47	−3.08	0.004*	0.500
Continuous-Performance Test (CPT)	44.34	45.32	−0.75	0.460	0.122
Symbol Coding Test (SC)	42.63	44.37	−1.32	0.196	0.213

Notes: *Compared to baseline, $P < 0.05$, paired *t*-test.

Factors Affecting the Effectiveness of Cognitive Intervention

To investigate the factors that may affect the effectiveness of cognitive intervention, we performed multifactorial linear regression analyses on several common clinical variables that may impact cognitive function. These clinical variables include gender, age, education level, marital status, occupation, training hours, and hospitalizations. Table 3 shows that age (B=−0.532, β = −0.476, P < 0.05) and training hours (B = 0.273, β = 0.340, P < 0.05) had a statistically significant effect on the cognitive function of CPT (F = 3.884, P < 0.05). Specifically, age negatively predicted cognitive scores of CPT, while training hours positively predicted it. No statistically significant effects of the clinical variables on the total scores and several subtests of TMT-A, SC, and DS were observed.

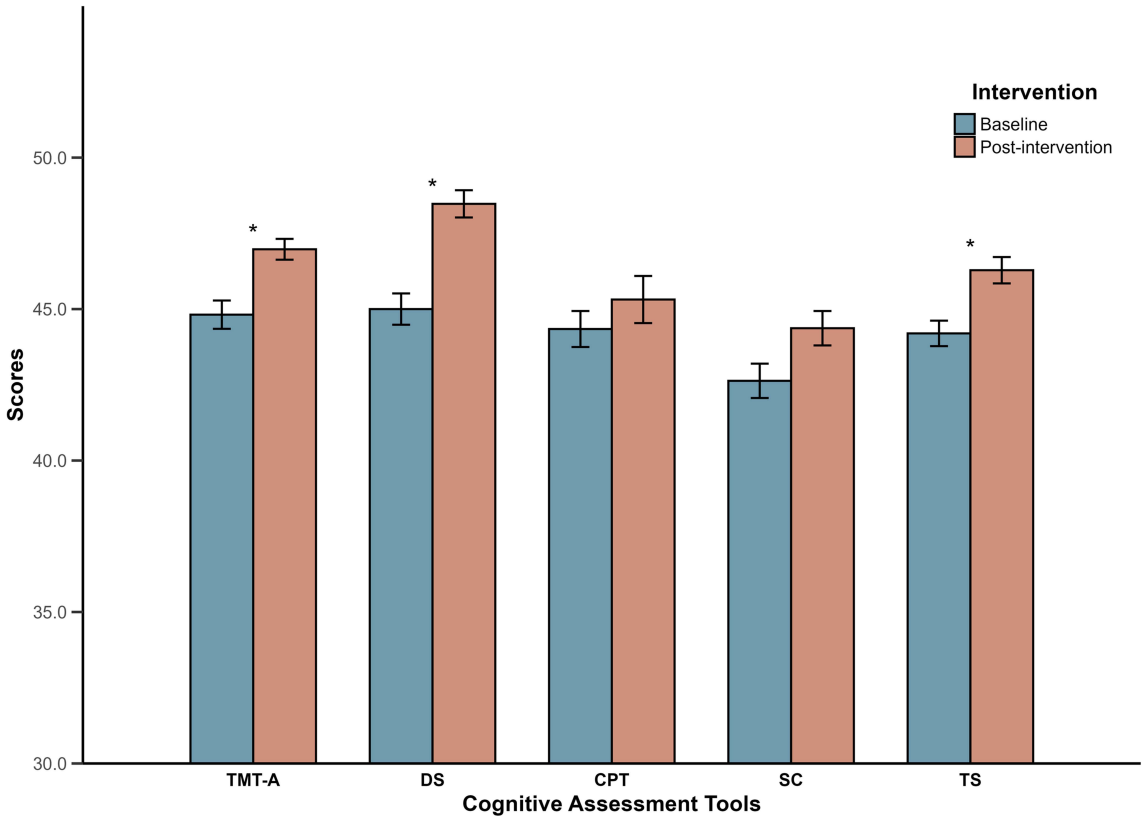

Figure 1 Comparison of Cognitive Function Before and After Training. *$P < 0.05$.
Abbreviations: TMT-A, Trail Making Test-A; DS, Digit Span Test; CPT, Continuous-Performance Test; SC, Symbol Coding Test; TS, total score.

Table 3 Continuous-Performance Test Influencing Factors

Variable	B	β	Std.Error	t	p-value
Gender	4.254	0.268	2.270	1.874	0.071
Age	−0.532	−0.476	0.165	−3.230	0.003*
Education	1.282	0.080	2.348	0.546	0.589
Marital status	−3.043	−0.130	3.540	−0.860	0.397
Occupation	0.458	0.029	2.475	0.185	0.854
Training hours	0.273	0.340	0.113	2.416	0.022*
Hospitalizations	−0.322	−0.116	0.430	−0.750	0.459

Note: *Significant level $P < 0.05$.

Improvements in Subjective Cognitive Function

To evaluate changes in patients' cognitive function, we also used objective measures: questionnaire scoring. The questionnaires were divided into pre-intervention expectation, during-intervention, and post-intervention surveys. We collected a total of 47 pre-intervention expectation questionnaires, and 38 valid post-intervention questionnaires. We analyzed the questionnaires and compared the pre- and post-intervention cognitive distress levels using the Wilcoxon rank-sum test for patients who completed the intervention. The results showed that the change in subjective cognitive distress was statistically significant ($P < 0.001$) (Table 4).

Participants' Acceptability of the Intervention

To evaluate participants' acceptability of the intervention software, we conducted weekly surveys. Participants rated the enjoyment and difficulty of the cognitive training program at eight time points, showing their dynamic perceptions. The results are presented in Table 5.

As shown in Table 5, enjoyment ratings fluctuated between 3.46 and 4.14, with the highest rating observed at Time 8. However, repeated measures ANOVA revealed no statistically significant differences across time points ($p = 0.298$). Similarly, difficulty ratings varied slightly, ranging from 2.31 to 2.86, with no significant differences detected across time points ($p = 0.062$).

Participants' Adherence of the Intervention

Table 6 shows the average class hours and adherence to cognitive training across eight weeks. The average class hours started at 3.89 hours in Week 1 and gradually increased, peaking at 4.92 hours in Week 3. It then stabilized between 4.47 and 4.82 hours, with the final week at 4.68 hours, for a total of 36.89 class hours. Adherence started at 77.89% in Week 1 and steadily increased, reaching 96.32% in Week 2. It remained around 94.74% in Week 4, decreased slightly to 89.47%

Table 4 Changes in Subjective Cognitive Distress

Variable	N	Z-value	p-value
Cognitive Distress (pre)	38	−3.758	<0.001*
Cognitive Distress (post)	38		

Note: *Significant level p< 0.05.

Table 5 Summary of Enjoyment and Difficulty Ratings (Mean (SD))

Rating	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	*P*
Enjoyment	3.87(0.84)	3.89(0.74)	3.74(0.86)	3.73(0.94)	3.59(0.95)	3.46(0.81)	3.50(0.82)	4.14(0.90)	0.298
Difficulty	2.68(0.78)	2.86(0.86)	2.47(0.75)	2.48(0.67)	2.31(0.76)	2.38(0.64)	2.50(0.52)	2.71(0.49)	0.062

Note: Significant level P < 0.018.

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Table 6 Average Participation Time and Adherence in Cognitive Training

Timepoint	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total
Average	3.89	4.82	4.92	4.74	4.55	4.47	4.82	4.68	36.89
Adherence	77.89	96.32	98.42	94.74	91.05	89.47	96.32	93.68	92.24

Note: Adherence is calculated as the number of participations divided by the required number of times (5 times per week).

in Week 6, but stayed above 90% in the later weeks. The final week had an adherence rate of 93.68%, with a total adherence rate of 92.24%. Overall, both class hours and adherence remained high throughout the training, with adherence showing a steady improvement.

Regarding feasibility and acceptability, the intervention showed high adherence, with participants completing an average of 36.89 hours over the 8-week period (92.24% adherence). Personalized difficulty adjustments and game-like elements helped maintain participant motivation and engagement. Overall, the intervention demonstrated strong feasibility and acceptability and provided an effective tool for improving cognitive function in individuals with schizophrenia.

Discussions

This study evaluated the effectiveness of remote digital cognitive training for patients with stable schizophrenia and explored the impact of individual differences on cognitive training outcomes. The results showed significant improvements in overall cognitive scores, Trail Making Test-A (TMT-A), and Digit Span (DS) scores. However, no significant changes were observed in Continuous Performance Test (CPT) and Symbol Coding (SC) scores. This suggests that the training enhanced cognitive functions such as information processing speed and attention but had limited effects on executive functions and higher cognitive abilities. The study also indicated that the short duration of the training period might be one reason for the lack of significant improvements in some areas.[21] Future research should consider extending the intervention duration to evaluate the long-term effects on executive functions.

Additionally, the study found that age and training time were important factors influencing cognitive function. Younger participants performed better on executive function tasks, and those who underwent longer training showed higher scores, indicating that age and training duration played a significant role in improving cognitive function, particularly in attention and executive control tasks.[6] Although clinical variables such as medication treatment and disease duration did not significantly impact cognitive improvement, individual differences such as age and training time had a notable effect on cognitive training outcomes. This highlights the importance of personalized and continuous cognitive training.

Regarding enjoyment and difficulty ratings, the study found that the training program maintained high acceptability and participant engagement over the eight-week intervention period. This successfully prevented a decline in interest and frustration among participants. Despite some fluctuations in the ratings, statistical analysis showed no significant differences in enjoyment and difficulty scores across different time points, indicating that the training was successful in maintaining participant interest and challenge. Future research could explore how other individual differences, such as baseline cognitive abilities or training preferences, affect these perceptions.

Although the cognitive training program demonstrated effectiveness, it has limitations compared to Cognitive Remediation Therapy (CRT). The intervention lacked therapist involvement and generalization mechanisms, focusing primarily on improving specific cognitive functions through digital tasks and personalized difficulty adjustments. Future research should consider integrating generalization strategies, such as functional rehabilitation, to achieve broader functional improvements.

The study also suggests that personalized cognitive training plays an important role in improving the prognosis of schizophrenia. Although the current program adjusted the training difficulty based on participant performance, incorporating biomarkers to guide personalized interventions could further enhance training outcomes. Biomarkers such as C-reactive protein (CRP), which is associated with decreased quality of life,[22] and miRNAs (eg, miR-1303 and miR-3131) that predict personality disorders,[23] could provide valuable insights for tailoring cognitive training. Future research should explore how these biomarkers can be integrated into cognitive training to optimize both cognitive and emotional outcomes.

In conclusion, this study provides evidence for the effectiveness of remote digital cognitive training in patients with stable schizophrenia, particularly in enhancing attention and information processing speed. The program demonstrated

good feasibility and acceptability, maintaining high engagement and challenge, despite some limitations in improving certain cognitive functions due to the short training duration. Future research should focus on extending the intervention period, exploring the impact of individual differences on training outcomes, and considering the integration of biomarkers to further personalize and optimize cognitive training methods.

Strengths and Limitations

This study's main strength is the use of digital training software, enabling home-based training, which reduces the burden of travel and enhances engagement for stable schizophrenia patients. The remote digital training demonstrated high acceptability and feasibility, with effect sizes similar to those of traditional methods, indicating it could be a viable or even superior alternative.

However, limitations include the lack of a control group, which makes it hard to compare the effects of remote training with other treatments and the small sample size, which limits statistical power. Future research should increase the sample size for more reliable results. Additionally, the short intervention period may have limited the capture of improvements in executive functions, suggesting the need for longer training durations. Individual differences, such as baseline cognitive abilities, were not explored but may influence training effectiveness. Future studies should include more diverse participants. While the program adjusted task difficulty, further personalization using biomarkers like CRP[22] and miRNAs[23] (eg, miR-1303, miR-3131) could improve outcomes. Notably, the C-BCT tasks were not designed for logical reasoning. The study did not include tests that directly assess logical reasoning. While the Backward Digit Span task may involve some reasoning (eg, reversing sequences), this is not its main focus. To comprehensively evaluate higher-order cognitive functions, future research should incorporate specific tests for reasoning. Another notable limitation of this study is the exclusion of participants using first-generation antipsychotics or clozapine. While this criterion was implemented to minimize variability and potential confounding effects due to the distinct pharmacological profiles and side effects of these medications (eg, extrapyramidal symptoms or cognitive impacts), it may limit the generalizability of our findings to individuals who use these treatments. Future research could explore the inclusion of these populations to enhance the applicability of cognitive-enhancing interventions across a broader spectrum of patients.

Conclusions

This study assessed the effectiveness, feasibility, and acceptability of a home-based online cognitive training intervention for patients with stable schizophrenia. The results showed significant improvements in cognitive function, particularly in total cognitive scores ($P = 0.003$), the Trial Making Test (TMT, $P = 0.017$), and Digit Span ($P = 0.004$). Although no significant differences were found in the Continuous Performance Test (CPT) and Symbol Encoding, the intervention still demonstrated positive effects on key cognitive domains such as processing speed and attention. Additionally, participants reported a significant reduction in subjective cognitive distress ($P < 0.001$), further supporting the effectiveness of the intervention.

Data Sharing Statement

Data are available upon reasonable request. Data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Statement

This study is conducted in strict accordance with the ethical principles outlined in the Helsinki Declaration, ensuring the protection of the rights and interests of all participants. On November 24, 2021, the protocol received approval from the Medical Ethics Committee of Peking University Sixth Hospital, with the approval number (2021) Ethics Review No. (64). The study involves individuals in the stable phase of schizophrenia, aged between 18 and 60 years, who have voluntarily consented to participate and have signed informed consent forms. All foreseeable risks associated with the study have been mitigated, and the potential benefits are deemed to exceed the risks. We pledge to safeguard the privacy and data security of all subjects with the utmost diligence.

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Disclosure

Lingzi Xu was a full-time employee at Infinite Brain Technologies during the data collection phase of this study. The authors report no other conflicts of interest in this work.

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