Postprint: Intervention Effects and Mechanisms of Mobile Health App-Based Cognitive Compensation Training in Stable-Phase Schizophrenia Patients

Authors: Wenmin, Zhou Yongling, Liu Jingjing, Jiang Keqing, Liu Juan, Zhu Xiaodan, Xiaodan Zhu

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Abstract

Background Cognitive impairment constitutes one of the core symptoms in patients with schizophrenia. While cognitive compensation training represents an effective therapeutic approach for cognitive impairment, current intervention models in related research predominantly employ offline delivery, with limited studies investigating cognitive compensation training delivered via mobile medical applications.

Objective To examine the intervention effects of mobile medical application-based cognitive compensation training on patients with stable-phase schizophrenia and to elucidate its underlying mechanism of action.

Methods Fifty-eight patients with stable-phase schizophrenia treated at Ningxia Ning' an Hospital between June and December 2023 were enrolled and randomly allocated to a control group (n=29) or an intervention group (n=29). The control group received conventional treatment and regular follow-up, whereas the intervention group additionally underwent 12 weeks of mobile medical application-based cognitive compensation training. Cognitive function and quality of life were evaluated using the Brief Assessment of Cognition in Schizophrenia (BACS) and the Schizophrenia Quality of Life Scale (SQLS), respectively. Pre- and post-intervention BACS and SQLS scores were compared between groups, and the mediating effect of BACS scores on the relationship between group assignment and SQLS scores was tested.

Results Twenty-seven patients in each group completed the study. At the 12-week timepoint, the intervention group demonstrated significantly higher scores than the control group in total BACS score and the Number Sequence, Tower of London, Verbal Memory, Semantic Fluency, and Letter Fluency subscales

(P<0.05), along with significantly lower scores in total SQLS score and the Psychosocial and Motivation/Energy dimensions (P<0.05). Mediation analysis indicated that BACS scores partially mediated the association between group assignment and SQLS scores (indirect effect = -0.240, 95% CI = -0.556 to -0.050).

Conclusion Mobile medical application-based cognitive compensation training for patients with stable-phase schizophrenia can effectively improve cognitive function and quality of life, promoting enhanced perceived quality of life through improvements in overall cognitive function.

Full Text

Preamble

The Effect and Mechanism of Compensatory Cognitive Training Based on mHealth APP on Stable Schizophrenia Patients

WEN Min[1], ZHOU Yongling[2], LIU Jingjing[1], JIANG Keqing[1], LIU Juan[3], ZHU Xiaodan[1]*

[1]School of Nursing, Ningxia Medical University, Yinchuan 750004, China
[2]Department of Nursing, Ning An Hospital of Ningxia, Yinchuan 751400, China
[3]Office of Hospital Director, General Hospital of Ningxia Medical University, Yinchuan 750004, China

*Corresponding author: ZHU Xiaodan, Associate professor; E-mail: zhuxiaodan007@163.com

Abstract

Background Cognitive impairment is a core symptom in patients with schizophrenia, and compensatory cognitive training has been shown to be an effective intervention. However, most existing studies employ offline modes, with limited research on mobile health APP-based compensatory cognitive training. **Objective** This study aimed to evaluate the intervention effects and mechanisms of mobile health APP-based compensatory cognitive training in stable schizophrenia patients. **Methods** A total of 58 patients with stable schizophrenia from Ningxia Ning' an Hospital (June to December 2023) were randomized into a control group (n=29) and an intervention group (n=29). The control group received conventional therapy and regular follow-up, while the intervention group underwent additional mobile health APP-based compensatory cognitive training for 12 weeks. Cognitive function and quality of life were assessed using the Brief Assessment of Cognition in Schizophrenia (BACS) and the Schizophrenia Quality of Life Scale (SQLS), respectively. Pre- and post-intervention scores were compared, and mediation analysis was conducted to explore the relationship between group, BACS, and SQLS scores. **Results** Of the initial cohort, 27 patients in each group completed the study. At 12 weeks, the intervention group demonstrated significantly higher BACS total

scores and subscale scores (digit sequence, tower of london, verbal memory, semantic fluency, and word fluency) compared to the control group (P<0.05). Additionally, SQLS total scores and psychosocial and motivational-energetic dimension scores were significantly lower in the intervention group (P<0.05). Mediation analysis revealed that BACS scores partially mediated the relationship between intervention subgroups and SQLS scores (indirect effect was -0.240, 95%CI ranged from -0.556 to -0.050). **Conclusion** Implementing mHealth APP-based compensatory cognitive training for stable schizophrenia patients effectively enhances both cognitive functioning and quality of life. Moreover, it contributes to an individual' s perception of a higher quality of life by improving overall cognitive functioning.

[**Key words**] Mobile health APP; Compensatory cognitive training; Cognitive function; Quality of life; Randomized controlled trials; Mediating effect

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Cognitive impairment represents a core symptom of schizophrenia and is considered a primary contributor to high suicide rates, disability rates, disease burden, and poor prognosis among patients[1]. Previous studies have shown that 70%-80% of individuals with schizophrenia experience cognitive impairment[2]. Cognitive remediation therapy is a behavioral intervention designed to address deficits across multiple cognitive domains[3], with current approaches primarily classified into "compensatory" and "restorative" models. Compensatory cognitive training (CCT), as an important development in cognitive remediation, relies on patients' residual cognitive abilities to master specific strategies and develop sequential behaviors that reduce dependence on impaired cognitive functions, thereby effectively enhancing complex cognitive functions such as problem-solving and overall cognition[4]. Research has confirmed that this therapy can improve cognitive function, psychiatric symptoms, and quality of life in both outpatient and inpatient populations with schizophrenia[5–6]. However, existing studies have notable limitations. For instance, certain strategies in compensatory cognitive training for inpatients are constrained by the hospital environment, limiting their practical application and affecting intervention efficacy. Meanwhile, outpatients face challenges with time and transportation over the three-month intervention period, resulting in poor adherence, and the requirement for multiple therapists restricts both human resources and feasibility. With the widespread adoption of smartphones, mobile health APPs for disease management and intervention have proliferated. Numerous studies have demonstrated that mobile health APPs enable continuous treatment and nursing care for outpatients, improve treatment adherence through multiple functions, and exhibit good universality and acceptability in mental disorders, overcoming limitations of conventional health education regarding time, space, and human resources[7–8].

Quality of life represents a comprehensive measurement of health-related perceptions, encompassing physical, psychological, social, and role functioning[9]. The mild cognitive impairment (MCI) rehabilitation theoretical model indicates that cognitive stimulation activities can improve cognitive impairment, with cogni-

tive training directly targeting both cognitive deficits and quality of life[10]. Previous research has confirmed that compensatory cognitive training can promote improvements in certain cognitive functions and quality of life, though with high attrition rates, and the mechanism underlying its effects on patient outcomes remains unclear[11]. The neurodevelopmental model suggests that deficits across multiple subdomains of cognitive function are associated with patients' daily functioning and quality of life[12]. This study hypothesizes that the practice and application of strategic skills in compensatory cognitive training may stimulate improvements in specific cognitive subdomains, facilitate better self-care, and enhance individuals' perceived quality of life, though direct empirical evidence is currently lacking.

Based on the aforementioned theories and research, further refinement of intervention protocols and verification of intervention effects are warranted. Investigating the mechanism of action on the basis of confirmed efficacy will better enhance patient adherence to psychological treatment and outcomes. Therefore, this study integrated current domestic and international research on compensatory cognitive training, developed video-based cognitive compensatory training resources, and implemented interventions for stable schizophrenia patients through a self-developed mobile health APP. The study explored the intervention effects of mobile health APP-based compensatory cognitive training on cognitive function and quality of life in stable schizophrenia patients and further examined the mechanism through which this intervention improves cognitive function and quality of life.

1 Subjects and Methods

1.1 Study Subjects

Stable schizophrenia patients who regularly attended outpatient follow-up at Ningxia Ning' an Hospital from June to December 2023 were selected as study participants. Sample size was calculated using the formula for comparing means between two samples: $n=2[(Z\alpha+Z\beta)\sigma/\delta]^2$. Based on previous literature, cognitive function was selected as the key outcome indicator, with σ=8.8 and δ=6.4[6]. Setting significance level α=0.05 and β=0.2 yielded $Z\alpha$=1.645 and $Z\beta$=0.841. The estimated sample size was n=24 per group. Considering a 20% attrition rate, the final required sample size was at least 29 patients per group, totaling 58 participants. This study was approved by the Ethics Committee of Ningxia Medical University (Approval No.: 2021-N0011), and all participants and their families provided informed consent.

Inclusion criteria: (1) Age 18-60 years; (2) Diagnosis of schizophrenia according to the International Classification of Diseases, 10th Edition (ICD-10)[13]; (3) Brief Psychiatric Rating Scale (BPRS) score <35, indicating stable disease status[14]; (4) Montreal Cognitive Assessment (MoCA) score <26, indicating cognitive impairment[15]; (5) Intelligence quotient >70 as assessed by the Wechsler Adult Intelligence Scale[16]; (6) Ability to use a smartphone.

Exclusion criteria: (1) Severe physical or organic disease; (2) Receipt of modified electroconvulsive therapy (MECT) within 3 months; (3) Participation in other cognitive behavioral therapies; (4) Substance abuse within 6 months; (5) Pregnancy or lactation.

Withdrawal criteria: (1) Development of any exclusion criteria during the study; (2) Missing >3 intervention sessions[17].

1.2 Intervention Methods

1.2.1 Grouping Method All 58 enrolled patients were randomly assigned to either a control group (n=29) or an intervention group (n=29) based on their registration numbers. The control group received conventional antipsychotic medication and monthly telephone follow-up assessing disease status, medication adherence, self-care ability, and social functioning. The intervention group received additional mobile health APP-based compensatory cognitive training on top of the control group treatment.

1.2.2 Intervention Protocol 1.2.2.1 Establishment of research team: The research team comprised six members: one chief psychiatrist, one psychiatric nurse with psychological counselor qualifications, three nursing graduate students, and one engineer. Responsibilities were as follows: (1) The chief psychiatrist assessed participants' psychiatric symptoms; (2) The psychiatric nurse reviewed intervention video content and evaluated outcome measures; (3) Nursing graduate students implemented the intervention, regularly pushing intervention videos, answering questions, and providing homework feedback; (4) The engineer maintained and operated the APP platform.

1.2.2.2 Blinding: Patients and psychiatric nurses were blinded to group allocation. Nursing graduate students who implemented the intervention were aware of group assignments but did not participate in data collection.

1.2.2.3 Development of intervention videos: After registering on www.cogsmart.com, the research team obtained the English version of the *Compensatory Cognitive Training Manual* developed by Professor TWAMLEY and colleagues. Based on a previously translated Chinese version created through forward-backward translation, the team produced animated cognitive compensatory training videos following expert panel review and cultural adaptation, which were delivered via the mobile health APP.

1.2.2.4 Functions of the mobile health APP: The patient interface included: check-in reminders, daily check-ins, risk intervention, and consultation assistant (with attachments). Patients could set time reminders to facilitate daily check-ins, complete cognitive compensatory training video lessons in the risk intervention module, and interact with intervention staff regarding intervention content through the consultation assistant. The administrator interface included: information management, sample space, check-in tasks, information

push, and statistics (with attachments). After patient registration, administrators added them to the same sample space, established video and homework check-in tasks through check-in settings, uploaded cognitive compensatory training animated videos in information management, selected sample spaces for distribution in information push, and monitored patient learning and check-in completion through statistical functions.

1.2.2.5 Implementation of intervention protocol: (1) Patient contact information was added, basic APP operations were taught, and patients were enrolled in the same sample space; (2) Cognitive compensatory training animated videos were uploaded to information management; (3) Intervention group patients received two lessons per week, each with different training themes, with each lesson lasting 20 minutes over 12 weeks. Animated cognitive compensatory training videos were distributed via information push every Saturday and Sunday at 8:00, with viewing reminders and video/homework check-in plans configured. Patients logged into the APP' s "risk intervention" module to watch the videos and completed video and homework check-ins before 20:00 through the consultation assistant, submitting classroom exercises and homework in the form of pictures or videos; (4) Intervention staff checked completion of videos, check-ins, classroom exercises, and homework daily at 20:00. If patients failed to complete tasks for two consecutive days, staff contacted patients or their families to understand reasons, provide appropriate reminders, and encourage continued participation. Specific training content is shown in Table 1 .

1.3 Assessment Methods

Psychiatrists evaluated psychiatric symptoms to determine eligibility, while psychiatric nurses assessed cognitive function and quality of life at baseline and at 12-week follow-up.

1.3.1 Brief Assessment of Cognition in Schizophrenia (BACS) BACS is a neurocognitive test developed specifically for schizophrenia patients, with a total Cronbach' s α coefficient of 0.81[18]. The scale comprises seven subscales: (1) Digit sequencing: patients listen to a series of numbers and repeat them in ascending order, with correct responses scored; (2) Symbol coding: patients fill in numbers paired with different symbols within 90 seconds according to a template, with correct entries scored; (3) Token motor task: patients are given 100 tokens and must pick them up with both hands simultaneously and place them in a container within 60 seconds, with completed tokens scored; (4) Verbal memory: patients listen to 15 words read by the examiner and recall them, with correct words scored; (5) Tower of London: patients view two images simultaneously, each showing three differently colored balls on three pegs arranged differently, and must determine how many moves are required to make one arrangement match the other, with a perfect score of 20 points; (6) Semantic fluency: patients name as many words as possible in a specified category within 60 seconds, with correct words scored; (7) Word fluency: patients gen-

erate words using provided characters within 60 seconds, with correct words scored. The sum of all subscale scores constitutes the total score, with higher scores indicating better cognitive function.

1.3.2 Schizophrenia Quality of Life Scale (SQLS) The SQLS has a total Cronbach' s α coefficient of 0.87 and contains 30 items scored on a 1-5 scale, comprising three dimensions: psychosocial (15 items), motivation/energy (7 items), and symptoms/side effects (8 items). Lower scores on each dimension and total score indicate better quality of life[19].

1.4 Statistical Methods

Statistical analysis was performed using SPSS 26.0. Normally distributed continuous data were expressed as ($\bar{x}\pm s$) and compared between groups using t-tests; non-normally distributed continuous data were expressed as M(P_{25},P_{75}) and compared using Mann-Whitney U tests; categorical data were expressed as relative frequencies and compared using ^{2} tests. Mediation analysis was conducted using the Process plugin in SPSS, employing Hayes' Bootstrap method with 5,000 resamples and default 95% CI after standardizing continuous variables. The significance level was set at α=0.05.

2 Results

2.1 General Patient Characteristics

Two patients in the control group withdrew due to relapse, while one patient in the intervention group withdrew due to relapse and another due to unwillingness to continue. Ultimately, 27 patients in each group completed the study, with 23 patients (85.2%) in the intervention group completing all lessons. Baseline comparisons revealed no significant differences between groups in age, gender, total hospitalizations, total disease course, BPRS scores, chlorpromazine equivalents, family history, marital status, or education level (P>0.05), as shown in Table 2 .

2.2 Comparison of Cognitive Function Scores Between Groups Before and After Intervention

No significant differences were observed between groups in total BACS scores or subscale scores at baseline (P>0.05). At 12 weeks, the intervention group showed significantly higher BACS total scores and scores on digit sequence, Tower of London, verbal memory, semantic fluency, and word fluency subscales compared to the control group (P<0.05). However, no significant differences were found in symbol coding or token motor subscales between groups (P>0.05). Within-group comparisons showed that the intervention group had significantly higher BACS total scores and all subscale scores at 12 weeks compared to baseline (P<0.05), as detailed in Table 3 .

2.3 Comparison of Quality of Life Scores Between Groups Before and After Intervention

No significant differences were found between groups in total SQLS scores or subscale scores at baseline (P>0.05). At 12 weeks, the intervention group demonstrated significantly lower total SQLS scores and psychosocial and motivation/energy dimension scores compared to the control group (P<0.05). Within the intervention group, total SQLS scores and psychosocial and motivation/energy dimension scores were significantly lower at 12 weeks compared to baseline (P<0.05), while symptoms/side effects scores showed no significant change (P>0.05). No significant difference was observed in symptoms/side effects scores between groups at 12 weeks (P>0.05), as shown in Table 4 .

2.4 Mediating Effect of Cognitive Function Between Intervention and Quality of Life

Using group assignment (control group=0, intervention group=1) as the independent variable, BACS score as the mediator, and SQLS score as the dependent variable, mediation analysis was performed. Path coefficients for BACS scores between group and SQLS scores are presented in Figure 1 [Figure 1: see original paper]. Group assignment showed significant effects on BACS scores (β=0.817, P<0.01) and SQLS scores (β=-0.591, P<0.05), while BACS scores significantly negatively predicted SQLS scores (β=-0.294, P<0.05). The 95% CI for the mediating effect of BACS scores was -0.556 to -0.050, with an indirect effect β=-0.240 (P<0.05), accounting for 28.88% of the total effect, confirming the mediating role of cognitive function between intervention and quality of life, as detailed in Table 5 .

3 Discussion

3.1 Feasibility of mHealth APP-Based Compensatory Cognitive Training

Compensatory cognitive training promotes maintenance of social activities through learning information processing strategies for problem-solving. As these strategies gradually become daily habits, patients' self-esteem and confidence in participating in social life improve, leading to enhanced cognitive and overall functioning[20]. Previous research has confirmed that compensatory cognitive training has beneficial effects on cognition and quality of life in schizophrenia patients, with broad application prospects in cognitive rehabilitation[21–22]. However, limitations remain regarding intervention applicability and participant adherence. Most studies have targeted outpatients with schizophrenia using face-to-face group interventions, which are susceptible to limitations in treatment motivation, transportation, and time, significantly affecting adherence to outpatient participation. TWAMLEY et al.[23] reported that up to 30% of outpatients failed to complete compensatory cognitive training. Additionally, face-to-face interventions involving multiple interventionists

are subject to heterogeneity in strategy delivery due to individual differences in information processing and task performance capacity, potentially reducing study accuracy. ZHU et al.[22] implemented interventions in inpatient settings, achieving completion rates above 90%, but standardized hospital routines prevented timely practice and application of certain cognitive strategies, hindering establishment of cognitive habits and resulting in significant improvements only in overall cognition rather than most subdomains.

Building upon previous work, this study implemented compensatory cognitive training for stable schizophrenia patients via a mobile health APP, enabling online repeated viewing and learning, which resolved time and location constraints of face-to-face group interventions. Animated scenarios designed in the videos facilitated patient understanding, stimulated learning interest, and improved adherence. Furthermore, one interventionist could simultaneously manage multiple patients by simply publishing training videos in the system, substantially reducing inter-interventionist heterogeneity and workload. Patient usage records could be monitored through the backend, allowing interventionists to accurately track task completion and promptly contact patients when anomalies occurred, enabling better intervention management. Consequently, this study achieved an attrition rate of 6.9%, representing a significant improvement over offline treatments.

3.2 Effectiveness of mHealth APP-Based Compensatory Cognitive Training

The results demonstrated that mHealth APP-based compensatory cognitive training significantly improved cognitive function in stable schizophrenia patients, consistent with findings from MENDELLA et al.[6] and TWAMLEY et al.[11]. However, this study found no significant differences between groups in symbol coding and token motor modules. While compensatory strategies can help patients better engage in social life and improve cognitive function to some extent, certain subdomains such as processing speed and motor function emphasize reaction speed and coordination, potentially requiring other systematic operational training. This suggests that mHealth APP-based compensatory cognitive training could be combined with "restorative" cognitive remediation approaches to design more engaging, flexible, multi-level systematic game-based training targeting multiple cognitive domains. Scholars in cognitive remediation have proposed that integrated approaches, particularly combining "restorative" and "compensatory"models, may yield better functional outcomes for schizophrenia patients[4].

The study also revealed that mHealth APP-based compensatory cognitive training significantly improved quality of life in stable schizophrenia patients. This may be because personalized strategies in compensatory cognitive training help patients better plan for community reintegration, teach them to apply strategies for improved communication with others, enhance self-esteem and self-efficacy in social life, increase motivation and energy for social participation, and ulti-

mately improve post-discharge quality of life. However, no significant difference was observed between groups in symptoms/side effects scores (P>0.05), likely because schizophrenia patients require long-term antipsychotic medication, and adverse symptoms such as dry mouth, tremor, and somnolence cannot be addressed through cognitive training alone[24]. This highlights the importance of healthcare providers maintaining contact with outpatients, encouraging regular follow-up visits to monitor and evaluate medication side effects, and implementing specific management strategies to mitigate adverse effects.

3.3 Mechanism of mHealth APP-Based Compensatory Cognitive Training

Mediation analysis indicated that cognitive function partially mediated the relationship between intervention and quality of life, accounting for 28.88% of the total effect. Previous research has identified cognitive function as one of the strongest predictors of functional recovery in schizophrenia, directly influencing quality of life[25]. TWAMLEY et al.[23] and JAVED et al.[26] proposed that compensatory cognitive therapy may indirectly improve clinical symptoms and quality of life while correcting cognitive deficits, a hypothesis supported by the present findings. This may be because schizophrenia patients experience deficits across multiple cognitive domains including memory, attention, verbal function, cognitive flexibility, and problem-solving, resulting in poor performance and experiences in daily life, learning, and work. Compensatory cognitive training provides targeted skills and training for these domains, helping patients effectively manage problems caused by cognitive deficits, increase participation and satisfaction in social activities, and reinforce perceived quality of life. Therefore, compensatory cognitive training can improve overall quality of life by enhancing general cognitive functioning.

In conclusion, mHealth APP-based compensatory cognitive training effectively improves cognitive function and quality of life in stable schizophrenia patients, offering greater convenience, accessibility, and adherence compared to traditional interventions, with potential applications in continuous nursing care, disease management, and rehabilitation for mental disorders. Additionally, cognitive function partially mediates the intervention-quality of life relationship, indicating that the intervention both directly affects quality of life and indirectly enhances it through cognitive improvement. This study has limitations: first, as an initial exploratory study, the long-term effects of the intervention protocol remain unknown and require extended follow-up; second, mobile health APP usage may limit participation among older patients, restricting generalizability.

Author Contributions: WEN Min implemented the intervention protocol and drafted and revised the manuscript; ZHOU Yongling coordinated patients and assessed outcome measures; LIU Jingjing and JIANG Keqing organized data and performed statistical analysis; LIU Juan recruited participants; ZHU Xiaodan conceptualized the study, designed the research, guided and revised critical content, and assumed overall responsibility for the article.

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ORCID IDs:
WEN Min https://orcid.org/0009-0004-5680-1509
LIU Jingjing https://orcid.org/0000-0003-2954-1292
JIANG Keqing http://orcid.org/0009-0006-8660-1166
LIU Juan https://orcid.org/0000-0002-2434-3513
ZHU Xiaodan https://orcid.org/0009-0003-6228-1987

References

[1] LIU C, LANG X E, LI K W, et al. Effect of sex hormone levels on cognitive function in first-episode schizophrenia patients [J]. Chinese Nursing Research, 2023, 37(19): 3545-3549. DOI: 10.12102/j.issn.1009-6493.2023.19.024.

[2] LI G H, MENG L L, HUANG W, et al. Correlation between neurocognitive function and empathy in chronic schizophrenia patients [J]. Modern Preventive Medicine, 2022, 49(24): 4495-4499. DOI: 10.20043/j.cnki.MPM.202111497.

[3] MORIMOTO T, MATSUDA Y, MATSUOKA K, et al. Computer-assisted cognitive remediation therapy increases hippocampal volume in patients with schizophrenia: a randomized controlled trial [J]. BMC Psychiatry, 2018, 18(1): 83. DOI: 10.1186/s12888-018-1652-8.

[4] DARK F, NEWMAN E, GORE-JONES V, et al. Randomised controlled trial of compensatory cognitive training and a computerised cognitive remediation programme [J]. Trials, 2020, 21(1): 810. DOI: 10.1186/s13063-020-04743-y.

[5] ALLOTT K, VAN-DER-EL K, BRYCE S, et al. Compensatory interventions for cognitive impairments in psychosis: a systematic review and meta-analysis [J]. Schizophr Bull, 2020, 46(4): 869-883. DOI: 10.1093/schbul/sbz134.

[6] MENDELLA P D, BURTON C Z, TASCA G A, et al. Compensatory cognitive training for people with first-episode schizophrenia: results from a pilot randomized controlled trial [J]. Schizophr Res, 2015, 162(1/3): 108-111. DOI: 10.1016/j.schres.2015.01.016.

[7] ZHAI Q, YAN F. Research progress on digital technology in medication adherence for patients with severe mental disorders [J]. Journal of Neuroscience and Mental Health, 2023, 23(08): 583-592. DOI: 10.3969/j.issn.1009-6574.2023.08.009.

[8] KIDD S A, FELDCAMP L, ADLER A, et al. Feasibility and outcomes of a multi-function mobile health approach for the schizophrenia spectrum: App4Independence (A4i) [J]. PLoS One, 2019, 14(7): e0219491. DOI: 10.1371/journal.pone.0219491.

[9] WHO. Development of the World Health Organization WHOQOL-BREF quality of life assessment. The WHOQOL Group [J]. Psychol Med, 1998, 28(3): 551-558. DOI: 10.1017/s0033291798006667.

[10] HUCKANS M, HUTSON L, TWAMLEY E, et al. Efficacy of cognitive rehabilitation therapies for mild cognitive impairment (MCI) in older adults: working toward a theoretical model and evidence-based interventions [J]. Neuropsychol Rev, 2013, 23(1): 63-80. DOI: 10.1007/s11065-013-9230-9.

[11] TWAMLEY E W, THOMAS K R, BURTON C Z, et al. Compensatory cognitive training for people with severe mental illnesses in supported employment: a randomized controlled trial [J]. Schizophr Res, 2019, 203: 41-48. DOI: 10.1016/j.schres.2017.08.005.

[12] FABRE D, VEHIER A, CHESNOY-SERVANIN G, et al. From theory to PrACTice: a cognitive remediation program based on a neuropsychological model of schizophrenia [J]. Front Psychiatry, 2015, 6: 169. DOI: 10.3389/fpsyt.2015.00169.

[13] GAEBEL W, STRICKER J, KERST A. Changes from ICD-10 to ICD-11 and future directions in psychiatric classification [J]. Dialogues Clin Neurosci, 2020, 22(1): 7-15. DOI: 10.31887/DCNS.2020.22.1/wgaebel.

[14] CHEN S Y, ZHANG K, XIA X W, et al. Analysis of characteristics and influencing factors of social cognitive function impairment in stable schizophrenia patients [J]. Journal of Sun Yat-sen University (Medical Sciences), 2019, 40(6): 930-937. DOI: 10.13471/j.cnki.j.sun.yat-sen.univ(med.sci).2019.0128.

[15] YANG Z, ABDUL RASHID N A, QUEK Y F, et al. Montreal Cognitive Assessment as a screening instrument for cognitive impairments in schizophrenia [J]. Schizophr Res, 2018, 199: 58-63. DOI: 10.1016/j.schres.2018.03.008.

[16] KUO S S, EACK S M. Meta-analysis of cognitive performance in neurodevelopmental disorders during adulthood: comparisons between autism spectrum disorder and schizophrenia on the wechsler adult intelligence scales [J]. Front Psychiatry, 2020, 11: 187. DOI: 10.3389/fpsyt.2020.00187.

[17] O' REILLY K, DONOHOE G, O' SULLIVAN D, et al. A randomized controlled trial of cognitive remediation for a national cohort of forensic patients with schizophrenia or schizoaffective disorder [J]. BMC Psychiatry, 2019, 19(1): 27. DOI: 10.1186/s12888-019-2018-6.

[18] CUI J F, ZOU Y Z, LI Y, et al. Clinical reliability and validity of the Brief Assessment of Cognition in Schizophrenia [J]. Chinese Mental Health Journal, 2009, 23(3): 183-187. DOI: 10.3969/j.issn.1000-6729.2009.03.009.

[19] LUO H, LUO N, WANG Y Q, et al. Reliability and validity testing and application of the Schizophrenia Quality of Life Scale [J]. Chinese Mental Health Journal, 2003, 17(3): 179-182.

[20] MAHMOOD Z, CLARK J M R, TWAMLEY E W. Compensatory cognitive training for psychosis: effects on negative symptom subdomains [J]. Schizophr Res, 2019, 204: 397-400. DOI: 10.1016/j.schres.2018.09.024.

[21] DARMEDRU C, DEMILY C, FRANCK N. Cognitive remediation and social cognitive training for violence in schizophrenia: a systematic review [J]. Psychiatry Res, 2017, 251: 266-274. DOI: 10.1016/j.psychres.2016.12.062.

[22] ZHU X, SONG H, CHANG R, et al. Combining compensatory cognitive training and medication self-management skills training, in inpatients with schizophrenia: a three-arm parallel, single-blind, randomized controlled trial [J]. Gen Hosp Psychiatry, 2021, 69: 94-103. DOI: 10.1016/j.genhosppsych.2020.12.012.

[23] TWAMLEY E W, VELLA L, BURTON C Z, et al. Compensatory cognitive training for psychosis: effects in a randomized controlled trial [J]. J Clin Psychiatry, 2012, 73(9): 1212-1219. DOI: 10.4088/JCP.12m07686.

[24] WEI S F, MA D L, LI L, et al. Research progress on drug therapy for schizophrenia [J]. Chinese Journal of New Drugs and Clinical Remedies, 2023, 42(4): 209-215. DOI: 10.14109/j.cnki.xyylc.2023.04.01.

[25] WU Q, WANG X, WANG Y, et al. Developments in biological mechanisms and treatments for negative symptoms and cognitive dysfunction of schizophrenia [J]. Neuroscience Bulletin, 2021, 37(11): 1609-1624. DOI: 10.1007/s12264-021-00740-6.

[26] JAVED A, CHARLES A. The importance of social cognition in improving functional outcomes in schizophrenia [J]. Front Psychiatry, 2018, 9: 157. DOI: 10.3389/fpsyt.2018.00157.

Appendix

Figure 1. Patient interface main screen and cognitive compensatory training course videos

Figure 2. Administrator backend and information statistics interface [Figure 2: see original paper]

Note: Figure translations are in progress. See original paper for figures.