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Acceptability and impact of computerised cognitive training on mental health and cognitive skills in schizophrenia: a double-blind controlled trial

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ABSTRACT

Background Schizophrenia is characterised by pervasive cognitive deficits that significantly impair daily functioning and quality of life. Pharmacological treatments have limited efficacy in addressing these deficits, highlighting the need for adjunctive interventions like computerised cognitive training (CCT).

Aims This study aimed to evaluate the effects of a 30-session CCT programme on mental well-being and cognitive performance in individuals with schizophrenia. Additionally, it assessed the usability and acceptability of CCT in this population.

Methods A double-blind, randomised clinical trial was conducted with 54 participants assigned to intervention and control groups. Cognitive and mental health outcomes were assessed using validated tools such as the Depression Anxiety Stress Scale 21, the Warwick-Edinburgh Mental Wellbeing Scale and the Cambridge Neuropsychological Test Automated Battery. Usability was measured with the System Usability Scale (SUS). Assessments were conducted at baseline, post-intervention and 3 months post-follow-up.

Results The CCT intervention significantly improved mental well-being, reduced stress and enhanced working memory (paired associate learning, spatial working memory and spatial span) compared with controls. However, no significant effects were observed for anxiety, depression or executive function. Usability scores were high (SUS=83.51), and compliance rates were strong (92.7%), indicating favourable participant engagement.

Conclusion CCT demonstrated potential as an adjunctive treatment for schizophrenia, with significant improvements in targeted cognitive and mental health domains. The high usability and compliance rates support its feasibility for broader implementation. Further research is needed to optimise protocols and explore long-term benefits. CCT offers a promising approach to addressing mental health and cognitive challenges in schizophrenia, particularly for stress and working memory. Its

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Cognitive deficits are a core feature of schizophrenia, significantly affecting quality of life and daily functioning.
⇒ Computerised cognitive training (CCT) has shown mixed efficacy in improving cognitive skills, with limited research on its effects on mental health in schizophrenia.
⇒ Usability and acceptability of CCT in schizophrenia remain unexplored.

WHAT THIS STUDY ADDS

⇒ This study demonstrated significant improvements in mental well-being (stress and overall mental health) and cognitive skills (working memory) after a 30-session CCT intervention.
⇒ It also provided evidence of high usability (System Usability Scale score of 83.51) and strong adherence (92.7%) among participants.
⇒ The findings highlighted the need for prolonged interventions to achieve broader cognitive and mental health benefits.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study could inspire future research on integrating CCT with other therapeutic modalities, such as brain stimulation and group-based interventions, to improve social engagement, cognitive abilities and mental well-being.
⇒ Proving the effectiveness of CCT in people with schizophrenia may support its integration into routine psychiatric rehabilitation services, leading to better patient outcomes and reduced long-term treatment costs through personalised treatment plans.
⇒ The findings encourage policy shifts towards integrating cognitive remediation programmes into standard schizophrenia care, with a focus on long-term evaluation and broader cognitive benefits.

usability and acceptability suggest it could be seamlessly integrated into clinical practice.

INTRODUCTION

Cognitive deficits are one of the main and primary features of schizophrenia and adversely affect patients' quality of life, functional skills and activities of daily living.[1] Neurocognitive impairment affects 80% to 90% of individuals with schizophrenia.[2] Verbal memory, visual memory, attention, working memory, problem-solving and processing speed are among the most commonly impaired cognitive functions in patients with schizophrenia.[2] All approved pharmacological treatments for schizophrenia target the dopamine D2 receptor, effectively reducing symptoms such as hallucinations and delusions caused by excess dopamine signalling in the striatum. However, these medications have little effect on cognitive impairments, likely due to the fact that these deficits are driven by different underlying biological processes.[3] Therefore, investigating complementary forms of treatments that can be used alongside pharmacotherapy becomes highly significant.

Cognitive remediation/rehabilitation techniques (computerised and paper-pencil) have received considerable interest in the last years. Computerised cognitive training (CCT), also known as computer-assisted cognitive remediation, is a type of cognitive remediation that employs structured computer-based games and exercises to enhance cognitive processes.[4] Computer-assisted cognitive remediation approaches offer a flexible, interactive and dynamic method for enhancing cognitive domains. Furthermore, computers enable automatic task adjustments based on the patient's performance, providing personalised and adaptive training with immediate feedback.[5] Recent studies examining the effectiveness of CCT in schizophrenia have yielded varying results regarding improvements in general cognition and other cognitive skills.[6]

Previous studies have shown a positive link between neurocognitive skills and various mental health indicators, including quality of life, anxiety, depression and self-esteem.[1] Cognitive processes and emotional regulation have similar neural circuits.[7] The dorsolateral prefrontal cortex is thought to be important for controlling emotions by bringing together the resources needed for executive control, as well as activating areas of the brain that are involved in suppressing emotional responses in ventromedial parts of the prefrontal cortex.[8] Enhancing prefrontal executive control may help manage emotional processing issues in anxiety and depression, potentially leading to better mental health outcomes. Neuroimaging results also suggest that cognitive training can boost activity in frontal and prefrontal brain regions.[9]

Psychiatric comorbidities such as depression and anxiety are highly prevalent and may be integral to schizophrenia. These comorbidities can impose a huge burden on older individuals and societies with ageing populations.[10] However, few studies have explored the mental health effects of CCT in schizophrenia,[11 12] leaving a gap in knowledge about its potential as an effective adjuvant treatment for mental health conditions. Therefore, it is critical to continue evaluating the role of CCT in mental health. Given the potential impact of mental well-being and cognitive skills on daily functioning, enhancing both mental health and cognitive skills should be a primary focus of therapy. Many of the published intervention studies had flaws in their design or analysis, preventing definitive conclusions about the efficacy of the training. Additionally, none of the cited studies fully adhered to best practice guidelines for CCT[13] (online supplemental table 1).

This study aimed to use the guidelines and evaluate the impact of a 30-session computer-assisted cognitive training intervention on the mental health and cognitive performance of individuals with schizophrenia. We hypothesised that CCT would lead to significant improvements in mental health and cognitive skills. Additionally, treatment disengagement, such as dropping out, low attendance in individual or group therapy, and poor medication adherence, continues to be a challenging problem. Digital interventions can improve mental health outcomes and reduce dropout rates while increasing patient adherence to treatment plans.[14] Therefore, understanding user perspectives is crucial for developing effective and well-accepted cognitive remediation interventions for patients. Given the absence of research on the acceptability of CCT among individuals with schizophrenia, we also investigated the usability and acceptability of CCT.

METHODS

The present study is a randomised, double-blind clinical trial with a 1:1 allocation ratio, a pretest–post-test design and a 3-month follow-up. The study was registered in the Iranian Registry of Clinical Trials with the following code IRCT20180317039116N2 and reported in accordance with Consolidated Standards of Reporting Trials guidelines.[15] Data described in this report were obtained in compliance with the Helsinki Declaration.[16] The design of the present study was based on updated best practice guidelines for using CCT.[13] Written informed consent was obtained from each study participant prior to his or her inclusion in the study. Participants were compensated financially for each session to acknowledge their time and effort in completing the study tasks.

Design and participants

Participants were recruited from three different psychiatric hospitals in Tehran between October 2022 and November 2023 using random sampling. Inclusion criteria required participants to (1) be aged between 18 and 60 years; (2) meet the criteria for schizophrenia disorder as specified in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, assessed by a psychiatrist; (3) obtain a Mini-Mental State Examination

score higher than 18 to assess the cognitive ability for learning and following commands; and (4) be able to provide written consent. Exclusion criteria included: (1) changes in drug regimen within the past month or during the intervention; (2) presence of chronic neurological diseases, including epilepsy, Parkinson's disease and Alzheimer's disease; (3) musculoskeletal disorders in the upper limb; and (4) below-average intelligence quotient.

Fifty-four participants diagnosed with schizophrenia were recruited and randomly allocated to either the CCT group or the control group using the randomisation tool Random.org.[17] The randomisation sequence was generated by an independent researcher who was not involved in enrolment or outcome assessments. Allocation concealment was ensured by using sealed opaque envelopes to assign participants to groups by the principal investigator, and both the outcome assessor and participants were blinded to group allocation. All participants were evaluated at baseline (T0), after intervention (T1) and after 3 months (T2).

Assessment tools

As a primary outcome measure, mental health was assessed using the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) and the Depression Anxiety and Stress Scale 21 (DASS-21). The WEMWBS assesses overall mental health, with 14 items rated on a 5-point Likert scale from 1 (never) to 5 (always). The score ranges from 14 to 70, with higher scores indicating better mental health.[18] The DASS-21 is a self-report questionnaire for measuring the severity of symptoms in three subscales, namely, depression (DASS-D), anxiety (DASS-A) and stress (DASS-S). The individual is required to indicate the presence of symptoms over the previous week. Each item is scored from 0 (did not apply to me at all) to 3 (applied to me most of the time).[19]

To evaluate various cognitive domains such as memory, executive functions and planning, five subtests of the Cambridge Neuropsychological Test Automated Battery (CANTAB) were selected, including Spatial Recognition Memory (SRM), Paired Associate Learning (PAL), Spatial Working Memory (SWM), Stockings of Cambridge (SOC) and Spatial Span (SSP). Lower scores in PAL and SWM indicate improvements in cognitive skills, while higher scores in SRM, SOC and SSP indicate better performance. A description of each test and its change criterion is presented in online supplemental table 2.

The usability aspect of CCT was evaluated by the System Usability Scale (SUS) after the intervention. All participants were asked to complete the SUS questionnaire. It consists of 10 items with five response options ranging from 1 (strongly disagree) to 5 (strongly agree), and results in a possible minimum score of 0 and a maximum score of 100. In this study, higher scores indicate better usability of CCT. Furthermore, to calculate the therapy compliance rate of each participant, the researcher reviewed the number of completed training sessions.

Procedures

The intervention group received 30 sessions of CCT over 10 weeks, with sessions held three times a week using CANTAB software. To minimise practice effects, various cognitive tasks were used. Various modes of four subtests were employed for cognitive practice in the intervention group: Match to Sample Visual Search, One Touch Stockings of Cambridge, Pattern Recognition Memory and Delayed Matching to Sample. The characteristics of selected CANTAB tasks used for cognitive training are described in online supplemental table 2.

The active control condition was designed to control for non-specific treatment effects. Participants in the control group attended the same number of computer sessions with the same therapists as the intervention group, following an identical schedule. To match the challenge levels across both groups, the control condition included a computer game with increasing difficulty focusing on naming, a cognitive skill that is mildly affected in schizophrenia,[20] which was not assessed after the intervention. Additionally, other games included in the control condition had low cognitive demands or relied primarily on chance, such as progressive adult colouring activities and simple dice games. All participants received two 30-minute sessions of computer games or cognitive training, with a 20-minute interval between sessions, in addition to their conventional treatments, which included medication, occupational therapy and psychological services. Feedback was provided for all participants as needed after finishing each task. Post-test follow-up assessments were conducted 1 day after the completion of the intervention and 3 months later. To complete the programme, participants were required to attend at least 80% of the planned sessions.

Statistical analysis

Data analysis was carried out using SPSS V.25 (IBM Corp). Numerical variables were summarised using mean (standard deviation (SD)), and categorical variables were presented as the number of patients and percentages. The Shapiro-Wilk test was performed to check the normality of the baseline data. Given the non-normal distribution of the baseline data, the Mann-Whitney U test was used to compare baseline cognitive and mental health scores between the two groups. The mean values of the research variables in all three stages in the two intervention and control groups were compared with the Mann-Whitney test, and then the generalised estimating equations (GEE) model was used to investigate the effect of the group and the intervention and the interactive effects of

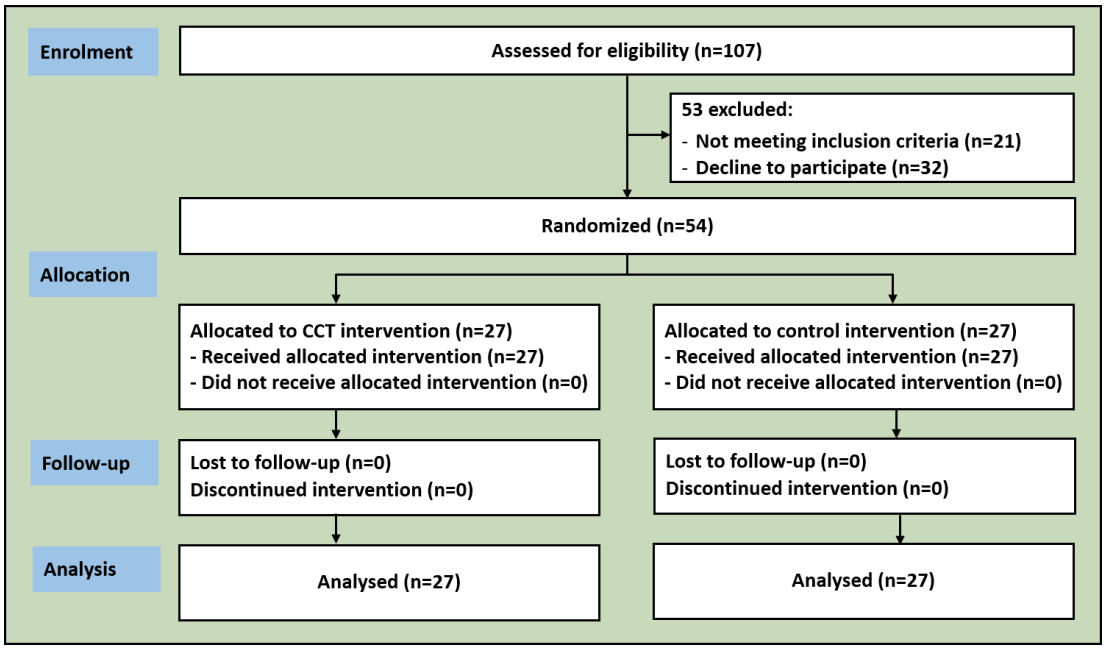

Figure 1 Consolidated Standards of Reporting Trials flowchart of the trial. CCT, computerised cognitive training.

the two. To confirm where the differences occurred between groups, Bonferroni's post hoc analysis was used for pairwise comparison of significant variables. P value ≤0.05 was considered at a significant level. Improvements between T0 and T1 in both groups were determined as the intervention's effectivenesses.

RESULTS

Baseline characteristics

Out of the 107 individuals screened for the trial, 54 patients met the inclusion criteria and were subsequently randomised into two groups: the intervention group (cognitive training, n=27) and the control group (computer games, n=27). All participants completed the trial and follow-up assessments (see figure 1). The average age of the participants was 41.23 (6.78) years, with 33 male and 21 female enrolled. Most participants in both the intervention group (48.1%) and the control group (40.7%) had a primary education. Additionally, the majority of participants in both groups (intervention: 44.4%, control: 51.9%) were single. Baseline characteristics between the two groups, as shown in table 1, did not exhibit significant differences (p>0.05).

Effects of CCT on mental health

Table 2 presents the mean scores for mental health variables along with the results from the GEE analysis. The GEE method for DASS-D identified significant main effects of time and time×group interaction (p<0.05). To further explore changes across different time points, a post hoc analysis was performed. Based on the Bonferroni test, no significant differences were found between the two groups at either T1 or T2. Although the mean depression score in the intervention group significantly decreased after the intervention (mean difference (MD) (95% CI)=−1.85 (−1.90 to 0.42), p=0.005), this difference was not significant when compared with the control group at both T1 and T2. Therefore, while the intervention had a positive impact on depression, it did not lead to significant improvements in depressive symptoms compared with the control group. Regarding the GEE model for DASS-A, the intervention showed no significant effect on anxiety at any time point (p>0.05), and thus, no post hoc analysis was conducted.

In the DASS-S variable, the main effects of time, group and the time×group interaction were all significant (p<0.001). Further analysis showed a significant difference between the two groups at both T1 and T2 (MD (95% CI)=2.15 (0.69 to 3.61), p<0.001; MD (95% CI)=−1.93 (−3.27 to −0.59), p<0.001). Additionally, within the intervention group, mean scores at T1 and T2 were significantly lower than at T0 (MD (95% CI)=2.96 (1.54 to 4.38), p<0.001; MD (95% CI)=2.67 (1.18 to 4.16), p<0.001). Moreover, the difference between the intervention and control groups was significant (MD (95% CI)=4.30 (1.38 to 7.22), p<0.001), with the positive effects of the intervention persisting up to 3 months post-intervention (MD (95% CI)=−3.70 (−6.54 to −1.18), p=0.001).

The average WEMWBS scores in the intervention group increased after the intervention but declined at T2. No significant changes were observed in the control group throughout the study. The GEE analysis revealed significant main effects of time, group and the time×group interaction (p<0.05). Post hoc analysis showed a significant increase in the intervention group's average scores at both T1 and T2 compared with T0 (MD (95% CI)=−2.07 (−2.86 to −1.29), p<0.001; MD (95% CI)=−1.81 (−2.45 to −1.18), p<0.001), as well as a significant difference between the intervention and control groups (MD

Table 1 Baseline characteristics of participants

Variable	Intervention group	Control group	Z/χ^2	P value
Age (years), mean (SD)	41.78 (5.22)	40.67 (8.04)	−0.208	0.835*
Sex (F), n (%)	11 (40.7%)	10 (37.0%)	0.078	0.780†
Duration of illness, mean (SD)	4.59 (2.45)	4.63 (2.11)	−0.096	0.923*
MOT, mean (SD)	0.23 (0.50)	0.17 (0.53)	−0.208	0.835*
MMSE, mean (SD)	28.59 (2.42)	29.59 (28.30)	−0.790	0.430*
PANSS, mean (SD)				
Positive	10.11 (1.21)	10.41 (1.33)	−0.911	0.362*
Negative	9.89 (1.34)	10.41 (1.15)	−1.547	0.122*
General	25.59 (1.15)	26.07 (1.63)	−0.880	0.379*
Total	45.59 (2.48)	46.89 (2.00)	−1.858	0.066*
Education, n (%)			0.567	0.753†
Below diploma	23 (85.2%)	21 (77.8%)		
Diploma or higher	4 (14.8%)	6 (22.2%)		
Marital status n (%)			1.487	0.475†
Single	12 (44.4%)	14 (51.9%)		
Married	5 (18.5%)	7 (25.9%)		
Divorced/widowed	10 (37.0%)	6 (22.2%)		

*t test.
†χ^2 test.
F, female; MMSE, Mini-Mental State Examination; MOT, motor screening task; PANSS, Positive and Negative Syndrome Scale; SD, standard deviation.

(95% CI)=−1.48 (−4.8 to −1.12), p<0.001). In contrast, the control group did not show any significant changes after the intervention or during the follow-up. Overall, the intervention had a significant positive impact on general mental well-being, with these effects lasting for at least 3 months (MD (95% CI)=1.04 (0.36 to 3.80), p=0.006) (see online supplemental figure 1).

Contrast analysis further confirmed that the intervention group experienced significantly greater improvements in WEMWBS scores compared with the control

Table 2 The result of GEE model analysis and effect sizes for mental health variables

	Time	Groups		GEE (time×group interaction)			Partial eta squared (effect size)
Variable		Intervention, mean (SD)	Control, mean (SD)	Df	Wald χ^2	P value	
DASS-Depression	T0	23.56 (3.10)	23.56 (2.84)				
	T1	21.70 (2.92)	23.63 (3.14)	2	12.388	0.002	0.014
	T2	22.44 (2.56)	23.56 (3.29)				
DASS-Anxiety	T0	13.04 (2.79)	12.30 (2.86)				
	T1	12.37 (3.04)	12.44 (3.15)	2	2.259	0.323	0.004
	T2	12.74 (3.09)	12.44 (3.15)				
DASS-Stress	T0	25.11 (4.75)	23.33 (4.57)				
	T1	19.48 (2.80)	23.78 (4.44)	2	35.668	<0.001	0.042
	T2	20.22 (3.25)	23.93 (3.65)				
WEMWBS	T0	36.15 (1.13)	36.60 (1.25)				
	T1	38.22 (1.48)	36.74 (0.76)	2	57.833	<0.001	0.144
	T2	37.96 (1.16)	36.93 (1.04)				

DASS, Depression Anxiety Stress Scale; GEE, generalised estimating equations; SD, standard deviation; WEMWBS, Warwick-Edinburgh Mental Wellbeing Scales.

Table 3 The result of GEE model analysis and effect sizes for cognitive variables

		Groups		GEE (time×group interaction)			Partial eta squared (effect size)
Variable	Time	Intervention mean (SD)	Control mean (SD)	Df	Wald χ^2	P value	
PAL	T0	38.41 (13.77)	39.93 (12.00)				
	T1	26.67 (12.47)	37.56 (11.66)	2	17.29	<0.001	0.058
	T2	28.85 (11.14)	38.56 (13.16)				
SRM	T0	67.04 (9.12)	65.93 (11.85)				
	T1	73.70 (12.67)	65.74 (11.41)	2	25.84	<0.001	0.013
	T2	70.04 (12.72)	64.63 (11.34)				
SOC	T0	3.78 (1.42)	3.59 (0.88)				
	T1	4.52 (1.57)	3.70 (0.86)	2	17.61	<0.001	0.020
	T2	4.56 (1.47)	3.44 (0.89)				
SSP	T0	4.00 (1.07)	4.04 (0.75)				
	T1	5.26 (1.48)	3.85 (1.32)	2	49.34	<0.001	0.031
	T2	5.22 (1.28)	5.22 (0.96)				
SWM	T0	28.81 (7.39)	29.07 (8.20)				
	T1	22.78 (7.36)	30.07 (7.02)	2	32.15	<0.001	0.019
	T2	25.33 (6.85)	31.22 (6.55)				

GEE, generalised estimating equations; PAL, Paired Associate Learning; SD, standard deviation; SOC, Stockings of Cambridge; SRM, Spatial Recognition Memory; SSP, Spatial Span; SWM, Spatial Working Memory.

group, particularly between T0 and T1 (contrast estimate F=−1.111, p<0.001).

Effects of CCT on cognition

Table 3 presents the mean scores for cognitive variables and the results of the GEE analysis. The intervention group demonstrated significant improvements in performance on the PAL, SSP and SWM tasks following the intervention. For all three variables, the main effects of time, group and the time×group interaction were significant (p<0.001). Post hoc analysis revealed that the intervention group's mean scores at T1 and T2 significantly improved compared with T0 (MD (95% CI)=6.04 (2.87 to 9.20), p<0.001; MD (95% CI)=3.48 (0.71 to 6.25), p=0.003). Additionally, at the T1 stage, significant differences were observed between the intervention and control groups in SSP (MD (95% CI)=−1.41 (−2.51 to −0.31), p=0.003), PAL (MD (95% CI)=10.89 (1.42 to 20.36), p=0.011) and SWM (MD (95% CI)=7.30 (1.65 to 12.94), p=0.002). These differences remained stable through the 3-month follow-up assessments (see online supplemental figure 2).

The contrast analysis revealed statistically significant differences for the PAL (contrast estimate F=7.056, p=0.004) and SSP (contrast estimate F=−0.537, p=0.036) between T0 and T1. However, no significant differences were found between T1 and T2 for either PAL (F=−1.593, p=0.560) or SSP (F=0.111, p=0.660). The GEE analysis for the SRM variable revealed significant main effects of time and the time×group interaction (p<0.001). However, post hoc analysis showed no significant differences between the intervention and control groups at either T1 (MD (95% CI)=−7.96 (−17.42 to 1.49), p=0.202) or T2 (MD (95% CI)=7.41 (−2.04 to 16.86), p=0.321). In contrast, for the SOC test, a significant difference between the two groups was observed only at the T2 stage (MD (95% CI)=1.11 (0.16 to 2.07), p=0.010).

Usability and acceptability of CCT

Figure 2 presents the participants' average SUS score, along with the corresponding acceptability and adjective rating ranges. The mean SUS score for the CCT was 83.51 out of 100, indicating an 'above average' usability rating and an 'excellent' level of acceptability.[21] This high usability score suggests that participants found the system intuitive and easy to use. Furthermore, the participants achieved a mean compliance rate of 92.7%, which reflects a high level of adherence to the intervention. The combination of strong usability and compliance underscores the system's effectiveness in engaging participants and promoting consistent use throughout the study.

DISCUSSION

Main findings

This double-blind randomised controlled trial investigated the efficacy of CCT as an adjunctive treatment for improving mental health and cognitive skills. In addition, for the first time, this study explored the usability and acceptability of CCT in people with schizophrenia. The 30-session CCT programme significantly improved mental well-being (WEMWBS), stress and working memory (PAL, SWM and SSP). However, it did not lead to

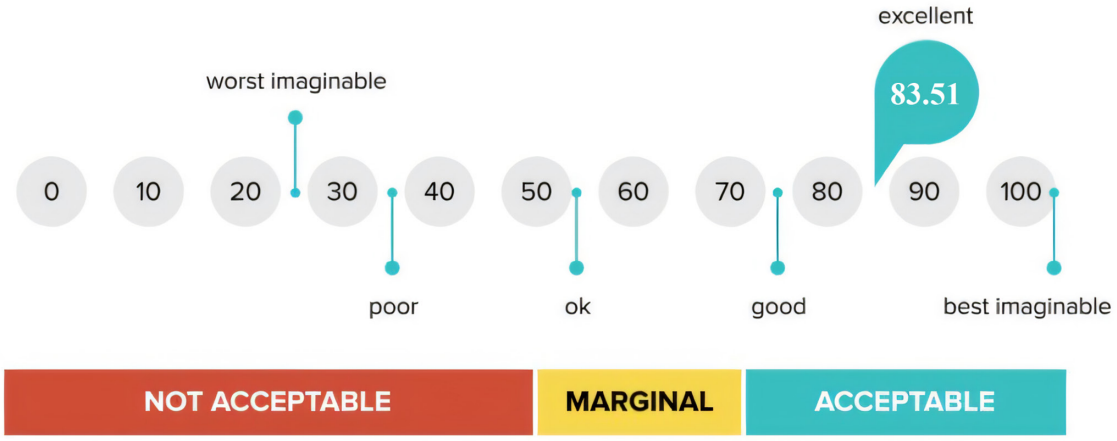

Figure 2 System Usability Scale mean scores.

significant improvements in anxiety, depression or executive function between groups. Despite this, in the intervention group, the CCT positively impacted depression, SOC and SRM, with changes persisting up to the 3-month follow-up, as evidenced by significant differences at both T1 and T2 stages compared with T0. Nevertheless, these changes were not significant when compared with the control group. In other words, our study design improved mental health and cognitive skills (working memory), but we need a more extended intervention period or adjustments in the intervention's protocol to achieve significant improvements in all aspects of mental well-being and cognition compared with the control group.

The first hypothesis of the present study was that CCT would lead to significant improvements in the mental health of individuals with schizophrenia by activating frontal and prefrontal brain regions and enhancing prefrontal executive control.[8] Accordingly, in this investigation, we selected four cognitive practice tasks targeting cognitive domains regulated by the dorsolateral prefrontal cortex, including memory, executive function and attention.[22] The findings of the present study align with previous research on CCT in individuals with schizophrenia. Despite some improvements in self-esteem and depression, no significant changes were observed in quality of life, depression, anxiety or self-esteem when compared with the control group.[11 23 24] In contrast to the present study's findings, one study reported significant improvements in depressive symptoms after 12 sessions (four times per week) of CCT in individuals with schizophrenia.[25] This discrepancy may be due to differences in the intensity and frequency of the interventions, as well as other factors such as the measurement tools used and participants' characteristics, such as average age and baseline scores, which could have contributed to the differing outcomes.

Glenthøj *et al* investigated the effects of 20 CCT sessions combined with social cognitive training in individuals at ultra-high risk for psychosis, delivered in a group format, compared with treatment as usual. Their study found no significant improvements in cognitive skills or depressive symptoms,[23] which aligns with the findings of the present study. However, they did observe a significant treatment effect in emotion recognition processing speed in the 12-month follow-up assessments. This suggests that while CCT may not directly impact overall cognitive function or mood in this population, it could have a more targeted effect on specific cognitive processes, such as social cognition. Group-based interventions may have greater potential to impact anxiety compared with individual-based approaches.[26] Group-based CCT may also have a greater potential to reduce depression and anxiety than individual interventions, due to the added benefits of positive social interactions and peer support. Research indicates that social support plays a crucial role in mental health outcomes, helping to reduce feelings of isolation and fostering emotional well-being.[26] Future research should explore the potential benefits of group-based CCT interventions and assess whether the addition of social components can enhance both cognitive and mental health outcomes in people with schizophrenia.

The results of the current study reveal significant enhancements in general mental well-being, as indicated by scores on the WEMWBS, along with reductions in stress levels, outcomes that have not been examined in prior research. The WEMWBS offers a multifaceted perspective on well-being, encompassing psychological functioning, emotional stability, affective experiences and cognitive

engagement.[18] These findings suggest that while CCT may not directly address specific symptoms of depression or anxiety, it can facilitate improvements in overall mental well-being. This aligns with the growing body of literature that emphasises the importance of a holistic approach to mental health, where fostering general well-being is viewed as equally vital as alleviating specific symptoms.[27] The findings of this study underscore the importance of targeting general mental well-being through CCT, as this may yield long-term benefits for individuals, even in the absence of immediate anxiety and depression symptom relief.

Regarding cognitive skills results, participants' performance on three of five cognitive tests improved significantly in the intervention group compared with the control group. In accordance with the present study's results, previous literature has demonstrated the effectiveness of CCT in improving cognitive skills in individuals with schizophrenia, such as attention and memory.[12 28] The average score for SOC in the intervention group was only significant at the T2 stage. This can be attributed to a slight increase in the intervention group and a slight decrease in the control group during the follow-up phase, leading to a notable difference between the two groups. Contrary to our results, one study reported significant improvement in SOC after 10 sessions of CCT using COGPACK software for remediation. However, this study was not a randomised controlled trial, and there were only 20 participants in one group.[28]

A recent randomised trial study used 24 sessions of CCT using RehaCom software in the intervention group and the MATRICS Consensus Cognitive Battery for cognitive assessments. They found no significant differences in processing speed, attention, working memory, verbal and visual learning, problem solving and social cognition between the experimental and control groups at post-training and 6-month follow-up assessments.[29] One potential explanation for the different results could be that the participants in the previous study had experienced their first episode of schizophrenia, whereas we did not apply this criterion in the present study. Another factor could be that in the present study, we used the CANTAB software for both remediation and assessments. Computers provide more precise measurements, especially for complex cognitive skills. Tests are administered in an entirely consistent manner for all participants, which enhances the reliability of measurement. The test outcome is not influenced by the subjective judgement of the assessor.

Regarding acceptability and usability results, this study demonstrated a positive user experience for CCT in people with schizophrenia. The participants' high SUS scores and strong compliance rates indicated that the CCT programme was well-received. This high level of acceptability has important clinical implications, as positive user experiences are crucial for ensuring adherence to interventions, which is key to achieving therapeutic benefits in long-term treatments for schizophrenia. In contrast, a related study involving individuals at ultra-high risk for psychosis reported a low attendance rate, with participants in the CCT intervention group attending an average of just 11 out of 20 sessions.[23] Their low attendance and insignificant cognitive results may be attributed to both low intrinsic and extrinsic motivation, as participants might not have found the intervention personally meaningful or rewarding.

In the present study, participants received monetary compensation for each session they attended, which could have increased their extrinsic motivation to attend. Moreover, all participants in this study were first-time users of CCT, and, according to Gartner's Hype Cycle, initial enthusiasm for new technologies may wane with repeated exposure, potentially affecting long-term engagement and outcomes.[30] This suggests that while initial user experience and compliance were high, future clinical applications of CCT should account for potential shifts in user motivation over time. Adjusting training protocols and offering continued incentives or engagement strategies may be necessary to sustain participation and ensure the intervention's ongoing effectiveness.

Limitations

The present study had several major strengths, including a double-blind controlled design and a complete lack of dropouts up to the follow-up assessment. However, it is important to acknowledge and address certain limitations. First, due to ethical considerations, we did not include a no-treatment group, making it impossible to isolate the effects of CCT from those of conventional treatments. Second, a longer follow-up period is necessary to evaluate the long-term effects of CCT. Finally, another limitation of this study is the small effect sizes. Future studies should explore whether this effect remains consistent across larger or more diverse samples, conditions or implementation strategies to better assess its real-world applicability.

However, given the statistical significance of our findings, CCT remains a promising tool, particularly in clinical settings where even incremental improvements in cognition or psychological well-being can enhance daily functioning and quality of life for individuals with schizophrenia.

Implications

The findings of this study suggest that CCT holds promise as a supplementary intervention for schizophrenia, particularly in addressing key areas such as stress reduction and working memory improvement. Its high usability and compliance rates make it a practical option for clinicians aiming to improve patient engagement with therapy. While the observed benefits were domain-specific, these results underscore the potential of CCT to complement traditional pharmacological and psychosocial treatments by targeting cognitive deficits that medications may not adequately address. To maximise its clinical utility, future efforts should focus on refining intervention protocols, exploring group-based formats and integrating CCT with real-world skill training to enhance functional outcomes and long-term mental health recovery.

Future research could investigate the effectiveness of combining CCT with real-world functional skills training,

such as vocational rehabilitation or independent living skills. Additionally, exploring the impact of delivering CCT in a group format may provide valuable insights into its therapeutic potential. Furthermore, incorporating brain imaging techniques, such as functional magnetic resonance imaging or electroencephalography, in a group-based CCT could demonstrate the neural mechanisms driving the observed changes, enhancing our understanding of how CCT influences cognitive, social and functional outcomes.

CONCLUSION

This double-blind clinical trial shows that CCT can lead to significant improvements in mental well-being, stress and working memory (PAL, SWM, SSP). However, no significant changes were observed in anxiety, depression or executive function. The study also demonstrated high usability, with an SUS score of 83.51 and a compliance rate of 92.7%. These findings suggest that CCT is a promising adjunctive treatment for enhancing mental health and cognitive abilities in individuals with schizophrenia, with strong acceptance among participants. Further research is recommended to explore the long-term benefits of CCT, including its sustained impact on mental health and social participation.

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