Computer-Assisted Cognitive Training for Patients with Severe Mental Illness: a Retrospective Study

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Abstract

Objectives: To investigate the effectiveness of eight 45-minute sessions of computer-assisted cognitive training programme (CCTP) on improving the cognitive and functional performance of patients with Severe Mental Illness (SMI).

Methods: Medical records of 16 women and 13 men aged 26 to 62 (mean, 46.34) years who participated a CCTP were reviewed. The CCTP lasted a total of 6 hours in eight sessions over 8 weeks and comprised a series of mobile applications customised to patients' specific impaired cognitive domains. Pre- and post-test performance of cognition and functioning were assessed using the Montreal Cognitive Assessment Hong Kong version (HK-MoCA) and the Brief Assessment of Prospective Memory (BAPM), respectively.

Results: After the CCTP, the mean HK-MoCA score increased significantly (23.62 ± 5.34 vs 25.48 ± 3.75 , $d = 0.403$, $p = 0.001$), with a significant increase in delayed recall (3.14 ± 1.75 vs 3.93 ± 1.44 , $d = 0.493$, $p = 0.003$), and the mean BAPM score decreased significantly (1.44 ± 0.47 vs 1.26 ± 0.23 , $d = 0.486$, $p = 0.012$). The improvement was greater in participants with primary-level education than in participants with secondary- or tertiary-level education in terms of the HK-MoCA score (3.83 ± 3.06 vs 1.35 ± 2.12 , $d = 0.942$, $p = 0.046$) and the BAPM scores (-0.49 ± 0.43 vs -0.10 ± 0.29 , $d = 1.063$, $p = 0.035$).

Conclusion: Our shortened CCTP effectively enhanced the cognitive performance and daily functioning of patients with SMI. Verbal episodic memory showed the most improvement. The improvement was greater in those with primary-level education than in those with secondary- or tertiary-level education.

Key words: Cognitive remediation; Mental disorders; Mobile applications

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Introduction

Cognition refers to the mental processes involved in thinking and acquiring information.¹ The American Psychiatric Association identifies six key domains of cognitive function: complex attention, executive function, learning and memory, language, perceptual-motor function, and social cognition.²

Cognitive impairment is common in people with severe mental illness (SMI). People with schizophrenia often have cognitive deficits in memory, attention, verbal fluency, visual processing, and psychomotor skills,³ resulting in decreased functioning in daily activities, social participation, and vocational outcomes.⁴ In people with mood disorders, the impaired cognitive domains include attention, executive function, and memory; greater symptom

severity is associated with increased cognitive dysfunction.⁵

Cognitive rehabilitation for SMI includes pharmacological and behavioural approaches. Although new antipsychotic medications have a more positive effect than traditional medications in improving cognition,⁶ the efficacy is minimal in terms of functional outcome and community reintegration.⁷ Behavioural interventions based on the concept of drill and practice have been advocated since 1980s.⁸ These include mainly strategy-based methods delivered in a verbal or a paper-and-pencil format in group or individual sessions. Improvements in attention, memory, problem-solving, and processing have been observed.

Computer-assisted cognitive training programmes (CCTPs) have advantages of prompt and accurate presentation of stimuli and recording of responses, standardised format, and cost-effectiveness.^{9,10} CCTPs are effective remedial method for improving executive function, working memory, verbal episodic memory, spatial episodic memory, and processing speed.¹¹ CCTPs can promote neuroplasticity¹² (deficit of which may cause social dysfunction¹³) and foster development of new compensatory skills for tackling cognitive difficulties in daily living.¹¹ After participated in a CCTP, patients with chronic schizophrenia have greater activation in the left frontopolar and left dorsolateral prefrontal cortices, which

correspond to improvements in attention and working memory.¹⁴ Patients with SMI are reported to have improved functional ability after participating in CCTPs,¹⁵ in addition to greater engagement in social rehabilitation programmes and improved employment outcomes.¹⁶

Various licensed CCTPs have been developed to target global cognition, speed of processing, attention, working memory, verbal memory, visual memory, reasoning, and problem-solving.¹⁷ A 100-hour CCTP with CogRehab for 12 months was reported to improve all cognitive domains, especially working memory.¹¹ Similarly, a 24-hour CCTP with Cogpack was reported to improve verbal memory and processing speed within 12 weeks.¹⁸ Whereas 6 hours of training with the Neuropsychological and Educational Approach to Remediation was reported to enhance problem-solving skills.¹⁹ Nonetheless, the required licenses pose a barrier to their use. The long training periods may not be applicable to hospital settings in Hong Kong, where the average hospitalisation duration is 7 weeks.²⁰

Some CCTPs have been designed for Hong Kong users such as Six Arts²¹, Brain Gymnasium,²² and a computerised errorless learning-based memory training programme.¹⁰ These CCTPs have positive effects on generalised cognition and prospective memory in daily living but are designed for older patients with dementia and mild cognitive impairment. In adult psychiatric patients, a 12-session CCTP was reported to have no significant effect on cognitive or vocational outcomes.²³ This study aimed to investigate the effectiveness of eight 45-minute sessions of CCTP on improving cognitive performance and functional ability of patients with SMI.

Methods

This was a retrospective, single-group, pre-test post-test study. We retrospectively reviewed records of patients with SMI from the Adult Psychiatric Day Hospital in Shatin Hospital who completed the CCTP between May 2018 and May 2019. Inclusion criteria were patients aged ≥ 18 years with a diagnosis of SMI including schizophrenia (F20), schizoaffective disorder (F25), bipolar affective disorders (F31), and recurrent depressive disorder (F33), according to the ICD-10.²⁴ Exclusion criteria were those with severe auditory or visual impairment, evidence of mental retardation, neurocognitive disorder, traumatic brain injury with a sustained loss of consciousness, or presence or history of epilepsy. Of 31 patients completed the CCTP, two were excluded (one had a history of traumatic brain injury and one had mild neurocognitive disorder) and 29 were included.

Participants' global cognitive functioning was assessed using the Montreal Cognitive Assessment Hong Kong version (HK-MoCA),²⁵ which covers the cognitive domains of visuospatial ability, executive function, naming, memory, attention, language, abstraction, delayed recall, and orientation. Total score is 30; lower scores indicate greater impairment in cognitive functioning. The MoCA

has good reliability and sufficient concurrent validity in detecting cognitive impairment in patients with SMI. It is an effective bedside screening tool for patients with schizophrenia, psychosis, or mood disorders.^{26,27}

Daily functioning was assessed using the Brief Assessment of Prospective Memory (BAPM).²⁸ This self-report questionnaire is shortened from the Comprehensive Assessment of Prospective Memory. The BAPM has strong agreement with the comprehensive version and good test-retest reliability, internal consistency, and criterion validity.²⁸ The BAPM contains 16 items in two categories: basic activities of daily living (BADL) and instrumental activities of daily living (IADL). Each item is rated in terms of the frequency of forgetting in the last month on a 5-point scale from very often (5) to never (1). Lower scores indicate fewer episodes of forgetting.

Gamified training on personal computers or mobile devices has the advantages of increasing motivation, usability, long-term engagement, ecological validity, and brain stimulation owing to gaming features such as competition, narrative, leaderboards, graphics, and game design.²⁹

Our CCTP has been used in patients with cognitive defects since 2018. It consists of eight 45-minute sessions and uses mobile applications in tablets. The mobile applications were analysed and categorised by occupational therapists based on the cognitive domains of speed of processing, attention, working memory, verbal memory, visual memory, reasoning, and problem-solving, as suggested in a literature review.¹⁷ The activity analyses of all mobile applications are shown in the Figure. Therapists selected the mobile applications according to the deficit areas identified in pre-assessment. Participants were under the guidance and supervision of occupational therapists and trained staff. The training duration and performance were recorded to facilitate monitoring of the treatment progress. The HK-MoCA and BAPM scores before and immediately after the CCTP were compared.

The post-hoc power of the CCTP was computed using AI-Therapy Statistics BETA. The effect size (Cohen's d) was calculated according to the equation $d = \frac{(\mu_1 - \mu_2)}{SD_{pooled}}$, where $SD_{pooled} = \sqrt{\frac{SD_1^2 + SD_2^2}{2}}$.³⁰ The mean difference between the pre- and post-test HK-MoCA scores was 1.86, and the population standard deviation was 4.61, resulting in an effect size of 0.403. The statistical power was 0.568. The mean difference between the pre- and post-test BAPM scores was 0.18, and the population standard deviation was 0.37, resulting in an effect size of 0.486. The statistical power was 0.759. The main effects of the CCTP were calculated using Wilcoxon signed-rank tests. Non-parametric tests were chosen due to the non-normality and non-homogeneity of the distributions. The dataset of changes in the HK-MoCA scores had a skewness value of 1.063 and a kurtosis value of 1.168 and the Shapiro-Wilk test revealed a significant difference

($p = 0.022$). The dataset of changes in the BAPM scores had a skewness value of 0.990 and a kurtosis value of 1.151, and the Shapiro-Wilk test revealed a significant difference ($p = 0.022$). All statistical analyses were two-tailed with a significance level of 0.05, except for the multiple comparisons between the pre- and post-test sub-scores of the HK-MoCA and BAPM. The Bonferroni correction was applied according to the number of comparisons. The adjusted alpha value for the HK-MoCA

sub-scores was 0.007, and that for BAPM sub-items was 0.025. Participants were categorised into subgroups: sex, age, diagnosis, and educational level. The age range was determined with reference to a study³¹ that reported association of better work functioning with certain age groups and improved attention. Mann-Whitney U tests were performed to determine between-group differences in baseline, post-intervention, and changes in the HK-MoCA and BAPM scores.

Application	Description	Cognitive domains	Interface
Fruit Legend	<ol style="list-style-type: none"> 1. Connect three or more of the same fruits to score points. 2. Achieve the target points to level up. 3. Eliminate fruits quickly to score extra points. 	<ul style="list-style-type: none"> • Attention • Processing speed

Attention Test	Tap the numbers from 1 to 9/16/25/36 (depending on the level of complexity selected) in ascending order as fast as possible.	<ul style="list-style-type: none"> • Attention • Processing speed

1 to 50	Tap the numbers from 1 to 50 in ascending order as fast as possible.	<ul style="list-style-type: none"> • Attention • Processing speed

The Best Brain Training
Hidden Animals	<ol style="list-style-type: none"> 1. Memorise the images of the row above, then click "GO". 2. Select the images that have been hidden. 	<ul style="list-style-type: none"> • Immediate recall

Remember Square	<ol style="list-style-type: none"> 1. Memorise the positions of the marked squares. 2. After a few seconds, the marked squares will disappear. 3. Select the places where the marked squares were. 	<ul style="list-style-type: none"> • Immediate recall • Processing speed

Figure. Mobile applications used in our Computer-assisted Cognitive Training Programme

Application	Description	Cognitive domains	Interface
Simon Says	Remember the sequences of lightened bulb and repeat it later.	<ul style="list-style-type: none"> Immediate recall

Rock-paper-scissors	Select the hand that wins or loses depending on the colour of the picture shown: <ul style="list-style-type: none"> Red: Select the winning hand Green: Select the losing hand 	<ul style="list-style-type: none"> Flexibility Processing speed

Colors	Choose the square with the colour corresponding to the meaning of the word. Do not confuse the meaning of the word with the font colour.	<ul style="list-style-type: none"> Flexibility Processing speed

Math Machine	Select the board numbers that add up to the number in the upper box	<ul style="list-style-type: none"> Working memory Processing speed

Mathematical Pairs	Match the mathematical operation with the right result.	<ul style="list-style-type: none"> Working memory Processing speed

Mental Agility	1. Select the numbers in ascending order. 2. Select the sum of the numbers.	<ul style="list-style-type: none"> Working memory Processing speed

Peg Solitaire	Remove pegs from the board by jumping over the peg to be removed with another peg.	<ul style="list-style-type: none"> Problem-solving and planning

Wood Block Puzzle	Drag the blocks into the frame to fill it up.	<ul style="list-style-type: none"> Visual-spatial

Figure. (cont'd)

Application	Description	Cognitive domains	Interface
Animal Memory Game	Tap the buttons and memorise the pictures behind it to find matching pairs.	<ul style="list-style-type: none"> Working memory

Memory Game: Brain Training
Like Previous?	<ol style="list-style-type: none"> Remember the shape. When a new shape appears, choose 'yes' or 'no' to indicate whether it is the same as the previous shape. 	<ul style="list-style-type: none"> Working memory Flexibility

Flow Free	Connect matching colours with a line without crossing or overlapping other lines.	<ul style="list-style-type: none"> Problem-solving and planning

Fruit Sorter	Sort the fruits on the conveyor belt according to type as quickly as possible.	<ul style="list-style-type: none"> Problem-solving and planning Processing speed

Twenty	<ol style="list-style-type: none"> Drop the tiles onto tiles with the same value. Matching tiles will combine to form a new tile with a higher value. A new row will be generated when the player runs out of moves or time. Combine the tiles as quickly as possible to get a value of 20. 	<ul style="list-style-type: none"> Problem-solving and planning Processing speed

Button and Scissors	<ol style="list-style-type: none"> Select two or more buttons of the same colour to cut them off from the scrap of denim. Only buttons on the same horizontal, vertical or diagonal line can be selected. Cut off all of the buttons to complete the level. 	<ul style="list-style-type: none"> Problem-solving and planning

Figure. (cont'd)

Results

Medical records of 16 women and 13 men aged 26 to 62 (mean, 46.34 ± 12.83) years were reviewed. 16 were young adults or middle-aged adults and 13 were older adults. 16 were diagnosed with schizophrenia, schizotypal, or delusional disorders and 13 were diagnosed with mood disorders. Six had primary-level education and 24 had secondary- or tertiary-level education.

From baseline to post-CCTP, the mean HK-MoCA

score increased significantly (23.62 ± 5.34 vs 25.48 ± 3.75 , $d = 0.403$, $p = 0.001$), with a significant increase in delayed recall (3.14 ± 1.75 vs 3.93 ± 1.44 , $d = 0.493$, $p = 0.003$), and the mean BAPM score decreased significantly (1.44 ± 0.47 vs 1.26 ± 0.23 , $d = 0.486$, $p = 0.012$) [Table 1].

The pre-test HK-MoCA score was significantly better in those with secondary- or tertiary-level education than in those with primary-level education (24.91 ± 4.28 vs 18.67 ± 6.50 , $d = 1.133$, $p = 0.008$), as was the pre-test BAPM score (1.35 ± 0.41 vs 1.79 ± 0.56 , $d = 0.897$,

Table 1. Pre- and post-test scores of the Montreal Cognitive Assessment Hong Kong version (HK-MoCA) and Brief Assessment of Prospective Memory (BAPM) of participants (n = 29)

Tool	Total item score	Pre-test score*	Post-test score*	Effect size (d)	p Value†
HK-MoCA	30	23.62 ± 5.34	25.48 ± 3.75	0.403	0.001
Executive function	5	3.31 ± 1.42	3.59 ± 1.38	0.200	0.070
Naming	3	2.76 ± 5.77	2.72 ± 0.59	0.010	0.705
Attention	6	5.00 ± 1.31	5.17 ± 1.14	0.138	0.386
Language	3	2.83 ± 0.38	2.97 ± 0.19	0.466	0.046
Abstraction	2	1.00 ± 0.93	1.28 ± 0.80	0.323	0.033
Delayed recall	5	3.14 ± 1.75	3.93 ± 1.44	0.493	0.003
Orientation	6	5.48 ± 1.06	5.66 ± 0.55	0.213	0.427
BAPM	5	1.44 ± 0.47	1.26 ± 0.23	0.486	0.012
Basic activities of daily living	5	1.35 ± 0.47	1.16 ± 0.21	0.522	0.076
Instrumental activities of daily living	5	1.58 ± 0.74	1.16 ± 0.42	0.698	0.080

* Data are presented as mean $\pm$ standard deviation

† The adjusted alpha values for the HK-MoCA and BAPM sub-items are 0.007 and 0.025, respectively, after Bonferroni correction

Table 2. Pre-test scores of the Montreal Cognitive Assessment Hong Kong version (HK-MoCA) and Brief Assessment of Prospective Memory (BAPM) between different sexes, ages, diagnoses, and educational levels

Demographic group	HK-MoCA score			BAPM score		
	Pre-test score*	Group difference		Pre-test score*	Group difference	
		Effect size (d)	p Value		Effect size (d)	p Value
Sex		0.237	0.692		0.255	0.495
Female (n = 16)	23.06 ± 6.37			1.49 ± 0.48		
Male (n = 13)	24.31 ± 3.86			1.37 ± 0.46		
Age, y		0.661	0.165		0.387	0.226
18-50 (n = 16)	25.19 ± 3.62			1.36 ± 0.45		
51-65 (n = 13)	21.69 ± 6.56			1.54 ± 0.48		
Diagnosis		0.309	0.454		0.042	0.895
Schizophrenia, schizotypal, or delusional disorders (n = 16)	24.38 ± 4.49			1.43 ± 0.47		
Mood disorder (n = 13)	22.69 ± 6.30			1.45 ± 0.48		
Educational level		1.133	0.008		0.897	0.040
Primary (n = 6)	18.67 ± 6.50			1.79 ± 0.56		
Secondary or tertiary (n = 23)	24.91 ± 4.28			1.35 ± 0.41		

* Data are presented as mean $\pm$ standard deviation

Table 3. Post-test scores of the Montreal Cognitive Assessment Hong Kong version (HK-MoCA) and Brief Assessment of Prospective Memory (BAPM) between different sexes, ages, diagnoses, and educational levels

Demographic group	HK-MoCA score					BAPM score				
	Post-test score*	Group difference		Change in score		Post-test score*	Group difference		Change in score	
		Effect size (d)	p Value	Effect size (d)	p Value		Effect size (d)	p Value	Effect size (d)	p Value
Sex		0.102	0.877		0.358 0.593		0.125	0.808		0.256 0.345
Female	25.31 ± 4.35			2.25 ± 3.04		1.27 ± 0.25			-0.22 ± 0.41	
Male	25.69 ± 3.01			1.38 ± 1.61		1.24 ± 0.23			-0.13 ± 0.28	
Age, y		0.530	0.269		0.605 0.095		0.434	0.269		0.219 0.496
18-50	26.38 ± 2.78			1.19 ± 2.01		1.21 ± 0.24			-0.15 ± 0.27	
51-65	24.38 ± 4.56			2.69 ± 2.87		1.31 ± 0.22			-0.23 ± 0.44	
Diagnosis		0.047	0.947		0.608 0.182		0.390	0.401		0.305 0.469
Schizophrenia, schizotypal or delusional disorders	25.56 ± 3.63			1.18 ± 1.91		1.30 ± 0.25			-0.13 ± 0.33	
Mood disorder	25.38 ± 4.03			2.69 ± 2.95		1.21 ± 0.21			-0.24 ± 0.39	
Educational level		0.968	0.034		0.942 0.046		0.204	0.724		1.063 0.035
Primary	22.50 ± 4.46			3.83 ± 3.06		1.30 ± 0.26			-0.49 ± 0.43	
Secondary or tertiary	26.26 ± 3.21			1.35 ± 2.12		1.25 ± 0.23			-0.10 ± 0.29	

* Data are presented as mean ± standard deviation

$p = 0.040$) [Table 2]. Sex, age, and diagnosis had no significant effect on pre-test HK-MoCA or BAPM score. The post-test HK-MoCA score was significantly higher in those with secondary- or tertiary-level education than in those with primary-level education (26.26 ± 3.21 vs 22.50 ± 4.46 , $d = 0.968$, $p = 0.034$, Table 3), but post-test BAPM score did not differ significantly between the two subgroups. However, the improvement was greater in those with primary-level education than in those with secondary- or tertiary-level education in terms of the HK-MoCA score (3.83 ± 3.06 vs 1.35 ± 2.12 , $d = 0.942$, $p = 0.046$) and the BAPM scores (-0.49 ± 0.43 vs -0.10 ± 0.29 , $d = 1.063$, $p = 0.035$) [Table 3].

Discussion

After the CCTP, cognition, particularly the delayed recall component (involving working memory and verbal episodic memory), and functional performance improved significantly in patients with SMI; these improvements were greater in those with lower educational level. Consistently, other studies reported that 100 hours of CCTP significantly improved working memory and verbal episodic memory among patients with SMI in an outpatient clinic,¹¹ and that 24 hours of CCTP using Cogpack significantly improved overall cognition, learning, and memory in an outpatient setting,¹⁶ and that CCTP using Cogpack significantly

improved overall cognition and learning in an inpatient setting.¹⁸

However, in our study, no significant improvement was found in the other cognitive domains. This contradicts a meta-analysis and other studies that reported significant improvements in abstraction, executive function, attention, and verbal learning after CCTPs.^{11,12,32} One possible explanation is the small effect sizes of the HK-MoCA sub-scores. For the cognitive components, the meta-analysis obtained a medium effect size range of 0.39 to 0.52,³² whereas the other study had a medium effect size of 0.63.¹¹ In our study, the effect sizes for executive function, naming, attention, language, abstraction, delayed recall, and orientation were 0.20, 0.06, 0.14, 0.48, 0.32, 0.50, and 0.21, respectively. The powers of the sub-scores were 0.436, 0.065, 0.172, 0.533, 0.599, 0.903, and 0.139, respectively. This indicates that the effect sizes of the domains were small to medium, and the corresponding post-hoc powers were modest.

In a meta-analysis of cognitive remediation in schizophrenia, the average duration of cognitive training was 10.4 hours over 12.8 weeks.³² Our CCTP lasted a total of 6 hours over 8 weeks, which is more feasible in Hong Kong where the average hospitalisation is 7 weeks.²⁰ Our shortened CCTP could effectively improve the cognitive and functional performance of patients with SMI. The training content and components were prescribed to patients

according to their specific impaired cognitive domains. For studies with longer duration of CCTP, one reported that a 12-hour CCTP improved functional independence among older adults, but specific functional domains were not assessed.³³ Another reported that 12-hour CCTP improved attention and resulted in better work outcomes.³¹ Another reported that a 24-hour CCTP improved performance in competitive employment, including the ability to earn higher wages, increased work tolerance, and the ability to find employment in a broader variety of jobs.¹⁶

The improved cognitive performance and functional independence after CCTP may be due to enhanced neuroplasticity. After CCTP, neural imaging shows increases in activation in the left frontopolar and left dorsolateral prefrontal cortices, which is related to attention and working memory.¹⁴ The event-related potential components over the occipito-parietal cortex decrease after completion of the CCTP.³³ This finding suggests that patients develop an enhanced ability for automatic and spontaneous retrieval in various real-life situations. The effectiveness of cognitive training can extend to everyday tasks. Although neurological assessment tools were not used in our study, the behavioural improvements in cognitive and functioning aspects were evident, which suggests corresponding neurological change.

In our study, the effect of CCTP was similar between patients of different sexes, ages, or diagnoses. However, participants with a lower educational level tended to show a greater improvement in cognitive and functional performance than those with a higher educational level. In other studies, improvement in cognitive performance was greater in younger adults (<40 years) than older adults,^{34,35} and improved attention in both younger and older adults resulted in better work outcomes.³¹ However, a meta-analysis reported that older adults gained more than younger adults in terms of cognition and functioning.³² Similarly, older adults were reported to have more room for cognitive improvement.¹⁵

Intelligence and educational level are positively related.³⁶ Improvement in cognition and functioning is associated with higher pre-morbid IQ.^{36,37} In contrast, patients with worse baseline performance have more potential for improvement.¹⁵ In the present study, although patients with lower educational level had greater impairment in cognitive and functional performance, they could gain more from the CCTP. Patients with a higher intellectual ability may have a greater cognitive reserve to generalise the skills learnt from the CCTP to reality.³⁷ Nonetheless, the importance of motivation and insight should be emphasised.¹⁵ Those who have subjective cognitive complaints and lack compensatory strategies at baseline are more willing to learn and have more potential to improve. Individualised CCTPs focusing on specific cognitive deficits of participants can considerably enhance the related cognitive domains.¹¹ Therefore, the emphasis of CCTPs should be on patients' drive for training and the customisation of the programme rather than focusing on the

individual demographic differences.

This study has some limitations. First, the sample size was small, leading to a wide confidence interval for effect size. The effect sizes were medium (0.403 for HK-MoCA and 0.486 for BAPM) and the statistical powers were insufficient (0.568 for HK-MoCA and 0.759 for BAPM). Second, our patients received multi-disciplinary treatment including medication titration, physiotherapy, vocational rehabilitation, and counselling. Many confounding factors might have affected cognition and functioning, and a control group should have been used. Third, the present study was not blinded, so potential researcher biases were not eliminated. Fourth, the cognitive assessment instrument used might not have been the most appropriate. Although the HK-MoCA is an effective screening tool for SMI,^{26,27} it does not reveal in-depth and domain-specific neuropsychological information such as processing time and verbal learning, which are commonly impaired in patients with SMI.^{38,39} Further studies that evaluate long-term effects and include a control group are needed. The use of a greater variety of assessment tools and incorporation of home training elements are also needed. Long-term studies with a control group in various settings are warranted to determine the effectiveness of our CCTP and specifically on symptoms, work outcomes, and social functioning. The levels of motivation and subjective opinions should have been measured. Home training after discharge can be explored, especially most mobile applications are available for free.

Conclusion

Our shortened CCTP effectively enhanced the cognitive performance and daily functioning of patients with SMI. Verbal episodic memory showed the most improvement. The improvement was greater in those with primary-level education than in those with secondary- or tertiary-level education.

Contributors

CML designed the study, acquired the data, analysed the data, and drafted the manuscript. WKT critically revised the manuscript for important intellectual content. CML had full access to the data. All authors contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

All authors have disclosed no conflicts of interest.

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Data Availability

All data generated or analysed during the present study are available from the corresponding author on reasonable request.

Ethics approval

The study was approved by the Joint Chinese University of Hong Kong-New Territories East Cluster Clinical Research Ethics Committee (Ref: 2019.593). The patients were treated in accordance with the tenets of the Declaration of Helsinki. The patients provided written informed consent for all treatments and procedures.

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