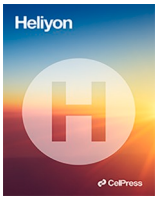
Heliyon 11 (2025) e42049

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Smartphone video games for cognitive functions and negative symptoms in male with chronic schizophrenia: A randomized controlled trial

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ARTICLE INFO

Keywords:
Schizophrenia
Video games
Cognitive functions
Negative symptoms
Overall functioning

ABSTRACT

Background: Video games have been extensively examined as a promising and innovative approach for addressing various psychiatric disorders. The primary objective of this study is to evaluate the effect of smartphone video games on cognitive functions, psychiatric symptoms and overall functioning in male with chronic schizophrenia.

Methods: We conducted a 6-week randomized controlled trial to compare the cognitive function, psychotic symptoms, overall functioning, and other outcomes of schizophrenic patients who engaged in smartphone video games (game group) with those who watched television programs (control group). We recruited schizophrenic patients who met the eligibility criteria from July 2021 to February 2022. The primary outcomes were the comparisons of various clinical scores between the two groups at baseline before interventions, the third and sixth weeks of the interventions, and the third and sixth weeks following the completion of interventions.

Results: Comparing the scores of the RBANS, PANSS, and GAF scales between the two groups, smartphone video games improved cognitive function, negative symptoms, and overall functioning. However, GSE and PHQ-9 scores did not reveal significant differences between the two groups. While there was a significant difference in PMGQ scores between the two groups, neither group reached the threshold for game addiction.

Conclusions: In this study, we emphasize the improvements of cognitive functions, psychiatric symptoms and overall functioning that brought by smartphone video games in male with chronic schizophrenia. Our findings indicate the need for more extensive research, future research should address what mechanisms of action underlie these effects of video games.

Trial registration: This study was registered in the Chinese Clinical Trial Registry (ChiCTR2100044113) and registered on 11/3/21.

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https://doi.org/10.1016/j.heliyon.2025.e42049
Received 6 June 2024; Received in revised form 29 October 2024; Accepted 15 January 2025
Available online 22 January 2025

1. Introduction

Schizophrenia is a severe psychiatric disorder with a global prevalence of 23.6 per 100000 persons [95 % UI 20·2–27·2]. A meta-analysis based on 73 trials reported that the median lifetime prevalence of schizophrenia was 7.49 per 1000 persons [1]. The clinical manifestations of schizophrenia mainly include positive symptoms (delusions, hallucinations, and disorganized speech), negative symptoms (blunted affect, alogia, anhedonia, asociality and avolition) [2,3], and cognitive functions (deficits in attention, working memory, episodic memory, processing speed and executive function) [4]. Schizophrenia causes 13.4 million years of disabled life to global disease burden [5].

The global games market reached $184.0 billion in revenue in 2023, the United States and China accounting for 49 % of all consumer spending on games [6]. The mobile games market is an important component of the global games market, whose growth rate has declined significantly in recent years, but it still generated $90 billion in 2023 [7]. As the gaming market flourished, there was increasing interest in the potential of video games, especially in treating various patient populations with mental illness. Video games, due to their accessibility [8], engaging nature, and high freedom to change game combinations or settings to specific symptoms, have emerged as a promising intervention for schizophrenia patients.

Currently, a diverse array of gaming options is being explored for improving cognitive functions and other symptoms in schizophrenic patients. Some of these games are uniquely tailored or independently developed, making them challenging to procure [9,10]. Others involve the use of specialized devices like Nintendo Wii [11], Xbox 360 Kinect [12], and devices for virtual reality [9], introducing a certain level of accessibility barrier. Moreover, certain games necessitate the coordination of multiple players, which can limit their convenience compared to individual therapy sessions. This experiment aims to explore the impact of a set of video games, which are easily downloadable and installable from gaming marketplaces on portable devices like smartphones, and feature simple rules and user-friendly interfaces, as an adjuvant approach during the pharmacological treatment of schizophrenic patients.

In clinical trials exploring the use of smartphone video games for treating chronic schizophrenia, male patients often present with higher research value. This is primarily attributed to several factors. Firstly, men tend to have a higher prevalence of schizophrenia [13] and lower cognitive functions [14], meaning a larger pool of potential subjects for studies. Secondly, the role of hormonal fluctuations in women may influence schizophrenia symptoms [15] and the response to treatment, making male patients an important subset to study.

1.1. Aims and hypotheses

This is a secondary analysis conducted on a randomized controlled clinical trial [16], which explores the clinical impact of a six-week combination of smartphone video games on the treatment of schizophrenia among male patients, and further investigates whether these observed improvements persist throughout the subsequent 6-week follow-up period.

We hypothesize that the game training will show the following outcomes.

Primary outcome

1. Improvements of the cognitive functions and psychiatric symptoms of participants with chronic schizophrenia will be observed at 3, 6, 9 and 12 weeks post-randomization.

Secondary outcomes

1. Overall functioning will improve at 3, 6, 9 and 12 weeks post-randomization.
2. Self-efficacy in daily life activities will improve at 3, 6, 9 and 12 weeks post-randomization.
3. None of the participants who completed all 6 weeks of game training are addicted to the games at 3, 6, 9 and 12 weeks post-randomization.
4. Depressive emotion will change at 3, 6, 9 and 12 weeks post-randomization.

2. Material and methods

2.1. Study design

As a secondary analysis of a randomized controlled trial of the game training for chronic schizophrenia which conducted from July 2021 to February 2022 in China [16], this study further focuses on exploring the influence of smartphone video games on male. This study was completed according to the CONSORT 2010 guidelines for randomized controlled trials. The research protocol has been completed following the WHO recommendation.

2.2. Sample size

The sample size was calculated using “Gpower”, based on previous studies using similar training interventions [17], type I error (α) was 0.05, effect size d was 0.85, and power was set to 0.8, resulting in a sample size of 23 cases per group.

2.3. Participants

Inclusion criteria: Individuals who met the inclusion criteria for schizophrenia in the psychiatric department of Chaohu hospital affiliated to Anhui Medical University were recruited for the study. Inclusion criteria: (1) the age of the participant should be between 18 and 60 years old; (2) the duration of schizophrenia has exceeded 5 years; (3) the participant has taken antipsychotics for at least 8 weeks, and the dose was stable within the past 3 months; (4) participant possesses the basic skills to operate smartphones independently.

Exclusion criteria: (1) the participant is diagnosed with comorbid psychotic disorders, bipolar disorder, or severe depression; (2) the participant has a history of seizures or brain trauma; (4) the participant is at serious risk of suicide or homicide; (5) the participant does not understand and sign informed consent. (6) the participant has neurological disorder or substance dependence.

Participants will be able to discontinue the intervention or withdraw from the study at their wishes.

2.4. Randomization

Following the completion of informed consents and baseline evaluations, participants were randomized into either the game group or the control group in a 1:1 allocation ratio by a computer-generated random numbers table. Although it is impossible to blind participants to their random allocation due to the nature of the game training, researcher-blinded diagnosis and assessments of the participants were used in this study.

2.5. Intervention

The research protocol is divided into several distinct stages.

2.5.1. Pre-intervention phase

Identify and recruit eligible participants based on the established inclusion and exclusion criteria. Participants accepted the baseline assessments and pre-game preparations.

2.5.1.1. Baseline assessments. The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), The Positive and Negative Syndrome Scale (PANSS), The General Self-Efficacy Scale (GSE), The Global Assessment of Function (GAF), The Problematic Mobile Gaming Questionnaire (PMGQ), The Patient Health Questionnaire-9 (PHQ-9). Baseline assessments were administered to measure cognitive functions, psychiatric symptoms and other relevant outcomes.

2.5.1.2. Pre-game preparations. Researcher provide participants with a detailed experiment scheme and game arrangement. Additionally, participants are instructed to familiarize with the rules and operation modes of the video games.

2.5.2. Intervention phase (6 weeks)

All participants consistently maintained their original medication regimens throughout the entire experiment. There was no statistical difference in the chlorpromazine equivalent dose between the two groups.

2.5.2.1. Interventions

2.5.2.1.1. Game-based intervention. The implementation of smartphone video games in the treatment of schizophrenia requires careful consideration and selection of appropriate games. Firstly, the game's simple rules and intuitive controls allow players to easily understand and engage with the game. Secondly, different types of games target different domains due to their distinct design, operation, and rationale [18]. This study selected three smartphone video games that require response and interaction abilities as the cognitive game training (Table 1). The participants received weekly game training sessions, conducted five times a week for 1 h each, spanning a total duration of six weeks.

2.5.2.1.2. Control intervention. The selection of news as the intervention measure for the control group is rooted in several

Table 1
Introduction and schedule of the different games.

Game name	Mechanics and tasks	Therapy goals	Schedule
Zuma	The player shoots colored balls at a line of balls of the same color, causing them to disappear. The goal is to eliminate all balls before they reach the end of the line.	Enhance players' visual perception, cognitive abilities, concentration skills, problem-solving capabilities, and quick decision-making.	Monday Friday
Happy Matching	The player matches three or more identical colors by swapping adjacent items, causing them to disappear. The objective is to clear all designated items in as few steps as possible.	Enhance players' visual perception, spatial reasoning, recognition matching, and problem-solving capabilities.	Wednesday
Talking Tom Gold Run	The player manipulates Tom to avoid obstacles and enemies while maximizing the collection of coins and rewards. The objective is to achieve the highest score possible before encountering an obstacle or being captured by enemies.	Enhance players' abilities in rapid response, quick decision-making, and hand-eye coordination.	Tuesday Thursday

rationales. Firstly, news programs are widely accessible and participatory, providing a neutral and familiar stimulus unlike Traditional Cinematherapy and Video Modeling that actively target specific cognitive or behavioral aspects, potentially altering patients' mental states or emotional responses [19]. Furthermore, to a certain extent, news programs mimic the visual stimuli found in video games, thereby minimizing the impact of confounding factors on the experimental outcome. The participants engaged in watching television programs five times weekly, with each session lasting approximately 1 h, spanning a total of six consecutive weeks.

2.5.2.2. Monitor and support. Researchers consistently prompt and motivate participants to maintain their engagement in the game training or television program, while overseeing their adherence to the designated duration and frequency of intervention. Moreover, Researchers provide timely support to address any issues encountered during the intervention.

2.5.2.3. Interim assessments. During the third and sixth weeks of intervention, the researchers administered assessments utilizing scales such as RBANS, PANSS, GSE, GAF, PMGQ, and PHQ-9 to closely observe and track alterations in patients' symptoms and associated outcomes.

2.5.3. Post-intervention phase (6 weeks)

2.5.3.1. Follow-up assessments. Establish regular contact with patients and inquire about their symptoms, feedback on the intervention, treatment adherence, and any adverse effects. At the third and sixth weeks after the completion of intervention, patients will undergo assessments using RBANS, PANSS, GSE, GAF, PMGQ, and PHQ-9 to quantify alterations in symptoms and other outcomes following the intervention. Compare these results with previously measured data from baseline and the third and sixth weeks of the intervention to assess the effectiveness of the game-based intervention.

2.5.3.2. Measures

2.5.3.2.1. The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS). The RBANS is a standardized rating scale used to identify the pathological decline in cognitive function in older adults. The RBANS consists of 12 subscales and evaluates the neuropsychological function in five factors: immediate memory, visuospatial, language, attention, and delayed memory [20]. The reliability and validity of the RBANS have been validated [21], including in China [22].

2.5.3.2.2. The Positive and Negative Syndrome Scale (PANSS). The PANSS is a standardized rating scale which commonly used to assess the severity of symptoms in patients with different types of schizophrenia, it can be divided into several subscales including positive symptoms, negative symptoms, and general severity of illness [3]. The PANSS has detailed scoring criteria, comprehensive scoring content, and verified reliability and validity in the population [23]. The PANSS has also been validated in Chinese population [24].

2.5.3.2.3. The General Self-Efficacy Scale (GSE). The self-efficacy in daily life activities in schizophrenia are assessed with GSE. The GSE involves 10 items to evaluate whether individuals have beliefs to adopt adaptive behaviors when faced with challenges in the environment. The reliability and validity of the GSE have been validated in China [25].

2.5.3.2.4. The Global Assessment of Function (GAF). The improvement in overall functioning of participants are assessed by the GAF [26]. It primarily encompasses three key domains: social function, occupational function, and psychological function. The GAF evaluates the extent of mental illness by assessing the psychological, social and occupational functioning of the participants, with good reliability and validity [27].

2.5.3.2.5. The Problematic Mobile Gaming Questionnaire (PMGQ). The users of smartphone video games have the certain risk of addiction which is assessed with the PMGQ. The PMGQ is modified from the Smartphone Addiction Inventory (SPAI), including six symptom criteria, four dysfunction criteria and one exclusion criteria, and its validity has also been confirmed in China [28].

2.5.3.2.6. The Patient Health Questionnaire-9 (PHQ-9). The game is designed based on the acquisition of pleasure, using the PHQ-9 scale to observe the emotional changes in schizophrenia. The PHQ-9 is one of the international universal depression testing scales and includes nine items to assess depression and symptom severity in the past two weeks, with good reliability and validity in China [29].

All participants completed above assessments at baseline before intervention, the third and sixth weeks of the intervention, and the third and sixth weeks after the completion of intervention. The clinical data interviews of the participants and the review of previous medical records were conducted by two professional psychiatrists to avoid potential rater bias. The assessments of RBANS, PANSS, and GAF were conducted by psychiatrists directly to the participants, and the self-rated scales of PHQ-9, GSE, and PMGQ were conducted by participants. Assessment data for each patient is collected through paper scales and stored in a special database to avoid private data leakage of patients.

2.6. Statistical analysis

The format "mean ± standard deviation (S.D)" is used to present the data. Comparisons of demographic data and disease characteristics between the two groups are performed by Mann-Whitney *U* test. The statistical method employed in this experimental design is Repeated Measures ANOVA, which evaluates the impact of intervention in male with chronic schizophrenia by calculating effects for treatment (game group vs. control group), time (baseline, weeks 3 and 6 of intervention, weeks 3 and 6 after post-intervention). We address indicators of baseline differences using analysis of covariance to avoid the interference of confounding factors. The significance level is set at $P < 0.05$. All data are analyzed by the statistical software SPSS 26.0.

3. Result

Fig. 1 summarizes the enrollment process of the participants for the study. Amongst the 62 schizophrenia participants assessed for eligibility, 41 participants met inclusion criteria and consented to participate in the study, and subsequently completed the initial baseline assessments. The participants were randomly assigned to watch television program (control group) or attend a 6-week game training (game group). Out of the 41 participants who began to receive game training or television program training, 1 participant withdrew consent and 4 participants dropped out. 17 participants completed the game training, 19 participants completed the television programs training. During the data analysis process, one individual was excluded from the control group due to abnormal duration of illness. To summarize, 35 participants successfully completed the full study protocol, with a final completion rate of 85.37 %.

3.1. Demographic data and disease characteristics

Demographic data and disease characteristics are summarized in Table 2, there were no significant differences in age, years of education, body mass index (BMI), duration of illness and chlorpromazine equivalent dose (Ps $>$ 0.05).

3.2. Smartphone video games on cognitive functions

After comparing the total score and five subscale scores of RBNAS between the game group and control group, we found that the language ($F_{group} = 4.73$, $P_{group} = 0.04$), attention ($F_{group} = 4.39$, $P_{group} = 0.04$), delayed memory ($F_{group} = 7.45$, $P_{group} = 0.01$), total scores ($F_{group} = 6.92$, $P_{group} = 0.01$) of RBANS showed significantly group effects (See Table 3). After using the U test to compare the indicators between the two groups at each time point, it was confirmed that the Delayed memory, and Total score of Rbans in schizophrenia patients showed significant improvement after 3 weeks, 6 weeks, 9 weeks, and 12 weeks of treatment compared to the control group. Language and Attention began to show significant improvement from the 6th week after treatment, and also maintained a good effect during the follow-up. However, the group effects of immediate memory and visuospatial were not observed (Ps $>$ 0.05). These results indicate that game training is effective on the improvement of cognitive functions in patients with chronic schizophrenia.

3.3. Smartphone video games on psychiatric symptoms

We evaluated the total score and three subscale scores of the PANSS, and we found that game training allowed significant improvement in negative symptoms in male with chronic schizophrenia compared to control group ($F_{group} = 4.14$, $P_{group} = 0.049$) (See

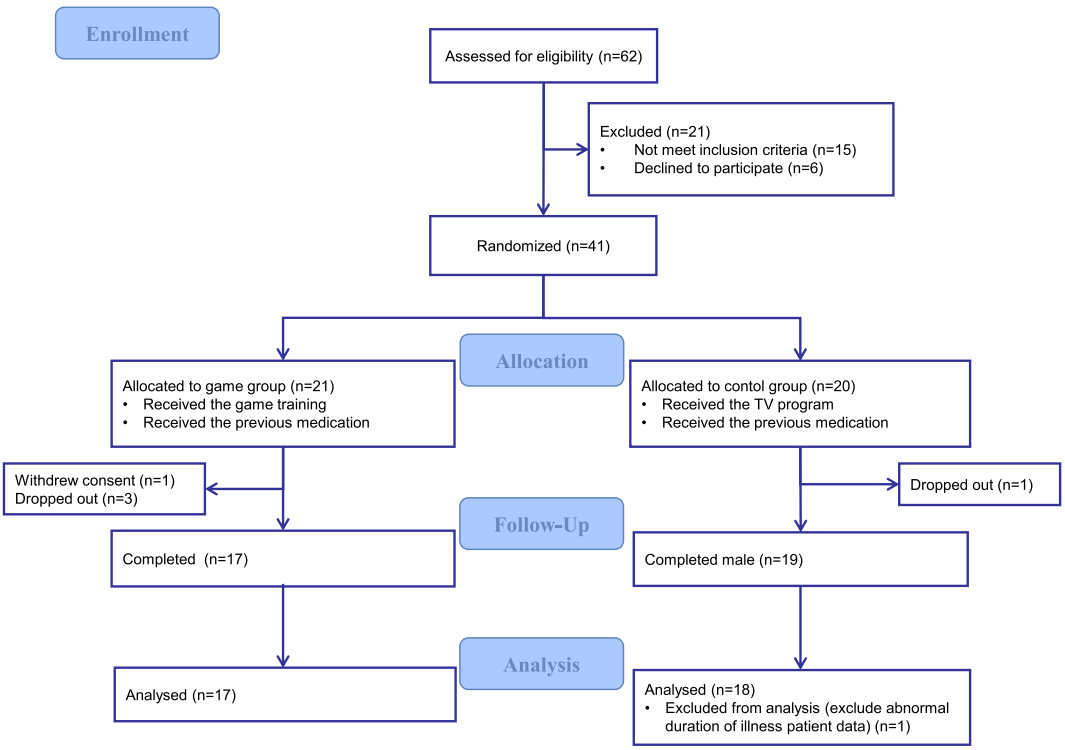

Fig. 1. CONSORT 2010 flow diagram.

Table 2
Comparisons of assessments of demographic data and disease characteristics between the game group and control group at baseline.

Male	Game group (n = 17)	Control group (n = 18)	*Z* value	*P* value
Demographic data				
Age, years	38.94 ± 9.53	43.00 ± 7.48	−1.60	0.11
Education, years	7.82 ± 2.94	6.94 ± 2.50	−0.95	0.34
BMI, kg/m2	24.70 ± 3.58	25.52 ± 5.10	−0.46	0.66
Disease characteristics				
Duration of illness, years	12.71 ± 6.39	17.17 ± 7.44	−1.84	0.07
Chlorpromazine equivalent dose, mg/day	588.24 ± 328.43	543.72 ± 350.86	−0.43	0.67

BMI, Body mass index.
Chlorpromazine equivalent dose, The basic scale for converting antipsychotic drug doses.

Table 3
Comparisons of assessments of RBANS between the game group and control group at different time points.

	Game group (n = 17)	Control group (n = 18)	F_{time}	P_{time}	F_{group}	P_{group}	$F_{time\times group}$	$P_{time\times group}$
RBANS Immediate memory			6.82	0.00	2.09	0.16	4.60	0.00
baseline	52.76 ± 12.41	52.56 ± 12.65						
3 weeks	62.59 ± 20.09	54.72 ± 14.91						
6 weeks	64.47 ± 20.88	53.83 ± 14.30						
9 weeks	63.65 ± 19.81	52.78 ± 13.37						
12 weeks	60.77 ± 18.87	52.78 ± 12.87						
RBANS Visuospatial			0.97	0.41	3.09	0.09	2.67	0.05
baseline	74.00 ± 10.05	71.05 ± 16.47						
3 weeks	77.59 ± 12.01	69.67 ± 14.93						
6 weeks	77.65 ± 9.97	70.33 ± 16.70						
9 weeks	81.06 ± 13.25	69.33 ± 15.42						
12 weeks	78.12 ± 13.31	69.39 ± 15.03						
RBANS Language			5.12	0.00	4.73	0.04	3.33	0.03
baseline	73.35 ± 14.51	71.28 ± 13.55						
3 weeks	77.82 ± 15.53	70.56 ± 13.80						
6 weeks	83.82 ± 11.73	70.83 ± 14.87[b]						
9 weeks	84.94 ± 8.13	72.11 ± 15.88[b]						
12 weeks	83.12 ± 10.86	74.00 ± 15.78[a]						
RBANS Attention			1.32	0.28	4.39	0.04	1.82	0.16
baseline	80.94 ± 13.78	75.50 ± 18.09						
3 weeks	85.12 ± 12.85	74.06 ± 19.22						
6 weeks	87.06 ± 12.30	74.56 ± 16.87[a]						
9 weeks	86.82 ± 15.29	74.94 ± 17.09[a]						
12 weeks	87.06 ± 14.59	75.28 ± 16.86[a]						
RBANS Delayed memory			3.70	0.02	7.45	0.01	4.93	0.00
baseline	55.59 ± 16.78	51.39 ± 16.49						
3 weeks	62.00 ± 19.52	48.67 ± 13.46[a]						
6 weeks	67.88 ± 21.76	50.28 ± 15.02[b]						
9 weeks	66.47 ± 21.89	48.94 ± 12.89[b]						
12 weeks	69.65 ± 17.34	50.17 ± 15.59[b]						
RBANS Total			8.39	0.00	6.92	0.01	9.87	0.00
baseline	336.65 ± 45.88	321.78 ± 57.29						
3 weeks	365.12 ± 54.13	317.67 ± 55.37[a]						
6 weeks	380.88 ± 59.18	319.83 ± 59.19[b]						
9 weeks	382.94 ± 66.35	318.11 ± 57.53[b]						
12 weeks	378.71 ± 60.82	321.61 ± 59.30[b]						

All P-values recorded as 0.00 in the table are approximate values, the actual P-values are less than 0.01, $P < 0.01$.
[a] Compared to the control group, $P < 0.05$.
[b] Compared to the control group, $P < 0.01$.

Table 4). It is peculiar that this improvement was only observed at the 9th and 12th week of follow-up, and not during the treatment process at the 3rd and 6th weeks. However, no significant group effects on the other subscales of the PANSS (positive scale, general psychopathology scale, and total score) were observed between the game group and control group at all time points (Ps > 0.05).

3.4. Smartphone video games on overall functioning and general self-efficacy

Compared with the control group, the GAF score of game group showed a significant difference in the 6th week of game training and maintained good curative effect during the follow-up periods at the 9th and 12th weeks (See Table 5) ($F_{group} = 4.78$, $P_{group} = 0.04$). After the game training, there was no significant group effects and time effect of self-efficacy observed at all time points (*Ps* > 0.05). Changes in the depressed emotion revealed a significant time effect ($F_{time} = 3.91$, $P_{time} = 0.02$), but the group effects were not

Table 4
Comparisons of assessments of PANSS between the game group and control group at different time points.

	Game group (n = 17)	Control group (n = 18)	F_{time}	P_{time}	F_{group}	P_{group}	$F_{time\times group}$	$P_{time\times group}$
PANSS Positive Scale			4.68	0.02	0.22	0.64	1.90	0.17
baseline	11.35 ± 5.48	12.72 ± 4.59						
3 weeks	11.24 ± 5.49	11.50 ± 4.50						
6 weeks	10.88 ± 5.36	11.78 ± 5.13						
9 weeks	10.94 ± 5.32	11.83 ± 5.39						
12 weeks	10.94 ± 5.32	11.61 ± 5.17						
PANSS Negative Scale			1.17	0.32	4.14	0.049	2.01	0.13
baseline	13.82 ± 5.60	16.33 ± 4.52						
3 weeks	13.12 ± 5.17	16.33 ± 5.17						
6 weeks	12.88 ± 5.21	16.28 ± 4.98						
9 weeks	12.18 ± 5.09	16.67 ± 5.37[a]						
12 weeks	13.12 ± 5.11	16.89 ± 5.97[a]						
PANSS General Psychopathology Scale			2.43	0.08	0.65	0.43	0.50	0.65
baseline	26.53 ± 5.71	28.61 ± 5.10						
3 weeks	26.00 ± 6.03	26.94 ± 6.10						
6 weeks	25.71 ± 6.15	27.11 ± 6.10						
9 weeks	25.24 ± 6.12	27.28 ± 6.38						
12 weeks	25.94 ± 6.97	27.50 ± 6.56						
PANSS Total Score			3.96	0.02	1.63	0.21	0.69	0.52
baseline	51.53 ± 13.87	57.67 ± 11.86						
3 weeks	50.18 ± 14.00	54.78 ± 13.47						
6 weeks	49.29 ± 14.13	55.17 ± 13.47						
9 weeks	48.94 ± 13.79	55.78 ± 14.70						
12 weeks	49.94 ± 14.03	56.00 ± 15.38						

PANSS, The Positive and Negative Symptom Scale.
[a] Compared to the control group, $P < 0.05$.

Table 5
Comparisons of assessments of GAF, GSE, PMGQ, PHQ-9 between the game group and control group at different time points.

	Game group (n = 17)	Control group (n = 18)	F_{time}	P_{time}	F_{group}	P_{group}	$F_{time\times group}$	$P_{time\times group}$
GAF			1.45	0.24	4.78	0.04	1.16	0.30
baseline	65.82 ± 11.20	61.94 ± 9.46						
3 weeks	67.53 ± 10.65	62.17 ± 9.46						
6 weeks	68.94 ± 10.31	59.00 ± 14.30[a]						
9 weeks	69.29 ± 9.74	63.11 ± 8.86[a]						
12 weeks	70.06 ± 9.40	63.17 ± 8.67[a]						
GSE			0.41	0.76	0.77	0.39	3.42	0.02
baseline	23.35 ± 7.28	27.06 ± 8.44						
3 weeks	22.77 ± 3.95	26.56 ± 7.52						
6 weeks	24.00 ± 5.29	25.00 ± 7.39						
9 weeks	24.18 ± 5.31	24.72 ± 7.32						
12 weeks	24.47 ± 5.40	24.78 ± 7.89						
PMGQ			0.76	0.50	5.17	0.03	0.31	0.78
baseline	5.65 ± 2.37	4.56 ± 1.20						
3 weeks	6.06 ± 2.56	4.78 ± 1.48						
6 weeks	6.06 ± 2.95	4.50 ± 1.04						
9 weeks	6.35 ± 3.04	4.72 ± 1.27						
12 weeks	5.77 ± 2.44	4.56 ± 1.20						
PHQ-9			3.91	0.02	0.00	0.95	0.87	0.44
baseline	5.88 ± 6.37	4.78 ± 4.18						
3 weeks	4.53 ± 4.14	4.33 ± 4.96						
6 weeks	3.24 ± 2.82	3.33 ± 3.03						
9 weeks	3.47 ± 2.90	4.22 ± 3.72						
12 weeks	3.00 ± 2.18	3.83 ± 3.54						

GAF: global assessment of function.
GSE: general self efficacy scale.
PMGQ: problematic mobile gaming questionnaire.
PHQ-9: patient health questionnaire-9.
All P-values recorded as 0.00 in the table are approximate values, the actual P-values are less than 0.01, $P < 0.01$.
[a] Compared to the control group, $P < 0.05$.

significant ($P > 0.05$). Despite the significant group effects of PMGQ ($F_{group} = 5.17$, $P_{group} = 0.03$), the PMGQ scores of both groups below the threshold for addiction at all time points.

4. Discussion

The experimental results indicate that the combination of these three smartphone video games (Zuma, Happy Matching, Talking Tom Gold Run) indeed demonstrates potential as an adjunctive treatment method, exhibiting significant appeal and effectiveness during the pharmacological treatment of patients with chronic schizophrenia. The retention rate of 85.37 % among the participants in this trial outperforms many current interventions based on cognitive training [30,31]. Moreover, these smartphone video games are capable of not only improving patients' cognitive functions but also effectively alleviating their negative symptoms, while simultaneously enhancing their overall functioning. Although various commonly used adjunctive treatments for schizophrenia patients undergoing pharmacotherapy, such as cognitive behavioral therapy (CBT) [32], physical exercise (PE) [33], Non-invasive brain stimulation (NIBS) [34], have individually demonstrated their therapeutic efficacy, there is currently no definitive consensus on which one is more effective, further extensive research is required to resolve this question conclusively.

It can be confidently stated that these treatments all possess certain limitations. CBT has been proven effective in improving positive symptoms of schizophrenia patients, yet its performance in alleviating negative symptoms and preventing disease relapse is not optimistic [35]. Additionally, the dropout rate is higher compared to conventional treatment [36]. PE demonstrates a favorable enhancement in cognitive function and negative symptoms [37], but it requires a longer course of treatment (>12 weeks) to achieve significant improvements [38]. NIBS exerts certain influences on cognitive function and negative symptoms, primarily focusing on attention and working memory [39,40].

The integration of smartphone video games with antipsychotic drug appears to be the most promising approach among adjunctive treatments, given its accessibility, ease of use, cost-efficiency, high engagement as well as good therapeutic efficacy. Video games can improve Attention, Visuospatial skills, and Cognitive control by influencing different regions and functional connections within the brains of healthy individuals [41]. Similar improvements have also been confirmed in schizophrenic patients [17,42], after the intervention of video games, the functional connectivity of the hippocampusprefrontal network in schizophrenia patients increased, and sustained attention, negative symptoms, and general psychopathology also improved. The observed effects of the game on cognitive function and negative symptoms in our study are similar to the results of this trial. However, the intergroup differences in negative symptoms in our study only appeared during the 9th and 12th weeks of follow-up, rather than throughout the treatment process, which may be due to the error caused by the smaller sample size included in this study. Further research with a larger sample size is needed to validate the feasibility of the study. Compared with the control group, individuals receiving video game therapy showed significant improvement in overall functioning, but their self-efficacy and depressive symptoms did not seem to change with the improvement of overall functioning. This could be attributed to the fact that their GSE and PHQ-9 scores were already within the normal limits, indicating little to no potential for further enhancement.

5. Study limitations

The sample size of this study did not reach the anticipated number, but we believe the following points can explain this discrepancy: Firstly, the game combinations we used have greater diversity and interactivity, which may have enhanced the data quality of individual participants. Secondly, extending the duration of each game session may have increased the richness and reliability of the data. Therefore, we believe that even with a smaller sample size, significant therapeutic effects could still be revealed. This study is limited by a small sample size, which restricts the broad application of the conclusions. Nonetheless, it still offers a valuable new perspective to the existing body of research.

6. Conclusion

The preliminary finding of improvements in cognitive functions and overall functioning following 6-week game training highlights the potential of smartphone video game as an effective and persistent intervention for male with chronic schizophrenia. Importantly, the majority of participants who completed all 6 weeks of game training were not addicted to the games. Future studies could focus on a larger range of serological indicators to explore the underlying mechanisms that video games improve chronic schizophrenia. Such study would further our understanding of the relationships between chronic schizophrenia and smartphone video games.

CRediT authorship contribution statement

Wenhui Wang: Writing – review & editing, Writing – original draft, Formal analysis. **Mengting Ye:** Data curation. **Yongjie Zhong:** Data curation. **Miaomiao Zhang:** Data curation. **Yue Wang:** Data curation. **Chuanchuan Chen:** Data curation. **Yitan Yao:** Data curation. **Ziqiao Feng:** Data curation. **Xiaoping Yuan:** Visualization, Validation, Supervision, Software. **Shenya Shi:** Methodology, Investigation, Conceptualization. **Xiaoqin Zhou:** Resources, Project administration, Conceptualization. **Kai Zhang:** Writing – review & editing, Funding acquisition.

Ethics declarations

This study was reviewed and approved by the Ethics Committee of the Chaohu Hospital of Anhui Medical University with the approval number: kyxm-202107-020, dated on July 10, 2021. All procedures performed in this trial conformed to the ethical standards and were conducted in accordance with the Declaration of Helsinki. The trial registration number was ChiCTR2100044113 (11/03/2021). All participants provided written informed consent to participate in the study and for their data to be published. Assent was obtained from minors in addition to consent from the legal guardians.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used AI in order to check grammar, spelling. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Funding sources

This study was supported by grants from the Anhui Province Outstanding Young Talents Support Program (gxyqZD2022022) (to KZ), the University Natural Science Research Key Project of Anhui Provincial Department of Education (2023AH050647) (to KZ), the Hengrui Innovative Drug Research Project of Anhui Provincial Health Commission (AHWJ2023BAc10004) (to KZ), the Counselor Project of Anhui Provincial Health Development Strategy Research Center (2023szk010) (to KZ).

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Reports a relationship with that includes:. Has patent pending to. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We appreciate all the participants and all those who helped us in this study.

Abbreviations

RBANS	The Repeatable Battery for the Assessment of Neuropsychological Status
PANSS	The Positive and Negative Symptom Scale
GAF	Global Assessment of Function
GSE	General Self Efficacy Scale
PMGQ	Problematic Mobile Gaming Questionnaire
PHQ-9	Patient Health Questionnaire-9

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