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FULL-LENGTH REPORT

The effectiveness of an online acceptance and commitment therapy self-help course in reducing excessive gaming behavior through inhibitory control: A pilot randomized controlled trial

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ABSTRACT

Background and aims: Internet Gaming Disorder (IGD) has emerged as a significant mental health concern. However, a substantial number of young people exhibit excessive gaming behavior (EGB) without meeting the full criteria for IGD. Compared to IGD, studies on EGB are limited. On the basis of innovative design acceptance and commitment therapy (ACT) online self-help course, this study explored the mechanism of ACT self-help course improving inhibitory control ability and alleviating EGB. *Methods:* This study focused on college students with Internet Gaming Disorder-20 Test (IGD-20) scores between 55 and 70 and more than 21 h of weekly gaming time, representing individuals in the EGB stage who had not yet reached IGD. A total of 58 individuals with EGB (mean age = 20.5 ± 1.2 years) underwent an ACT self-help course (n = 30) or a routine education intervention (n = 28). The IGD-20, Behavior Rating Inventory of Executive Function-Adult Version (BRIEF-A), and Acceptance and Action Questionnaire (AAQ-II) were used to assess participants before and after the intervention. GO/NOGO tasks and electroencephalogram activities (N200, P300) were also recorded. *Results:* Compared to the control group, the ACT group exhibited significantly lower game addictive behaviors (IGD-20 score), reduced game time, and improved executive function (BRIEF-A) and cognitive flexibility (AAQ-II). Additionally, the ACT group demonstrated significantly improved NOGO task accuracy, increased N200 amplitude, and shortened P300 latency. Furthermore, correlation analyses and regression model identified that reduced gaming time, alongside improvements in executive function, psychological flexibility, and N200 amplitude, were significant predictors of treatment success. *Conclusions:* The online ACT self-help course effectively reduced excessive gaming (EGB) and enhanced Inhibitory control. Its efficacy appears driven by simultaneous improvements in psychological and neurocognitive processes, highlighting its clinical potential for treating EGB and IGD.

KEYWORDS

internet gaming disorder, excessive gaming behavior, acceptance and commitment therapy, inhibitory control

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INTRODUCTION

Internet Gaming Disorder (IGD) has been recognized as a significant mental health concern, with its prevalence rising globally (Montag et al., 2019). While most intervention studies target individuals diagnosed with IGD, a larger population engages in Excessive Gaming Behavior (EGB)—a pattern of use that poses significant health risks but does not meet the full diagnostic criteria for IGD. In this study, we conceptualize EGB as operationalizing the WHO's concept of 'hazardous gaming' (ICD-11, code QE22.1), which is defined as a pattern of gaming that appreciably increases the risk of harmful physical or mental health consequences to the individual or to others around them. This pattern of hazardous gaming represents a critical subclinical risk zone that often precedes the development of a full-blown disorder, making it a crucial target for early intervention.

The negative consequences of EGB are substantial. Neuroimaging research shows that even intensive gaming in novices can lead to reduced gray matter volume in the orbitofrontal cortex (Zhou et al., 2019)—a region pivotal for executive functions (EFs)—suggesting that detrimental structural changes can occur prior to a formal IGD diagnosis. Large-scale epidemiological studies, such as the ABCD study, further corroborate that excessive screen time is negatively correlated with cognitive performance in children (Walsh et al., 2018). Our own previous work has also demonstrated declines in EFs and retrospective memory among individuals gaming for more than 2–4 h daily, even in the absence of an IGD diagnosis (Xia et al., 2023; Zhao et al., 2021).

EFs are a set of higher-order cognitive processes essential for goal-directed behavior. A core component of EFs implicated in the development and maintenance of both EGB and IGD is inhibitory control—a specific facet of cognitive control responsible for suppressing dominant, automatic, or impulsive responses (D. Lee et al., 2021; J. Lee, Lee, Namkoong, & Jung, 2020; Li et al., 2020; Z. L. Wang et al., 2023). The role of inhibitory control deficits can be effectively understood within the comprehensive theoretical framework of the I-PACE model (Brand et al., 2019). This model posits that problematic internet-related behaviors, such as hazardous gaming, emerge from interactions between an individual's Predisposing factors (e.g., personality, psychopathology), Affective and Cognitive responses to triggers, and deficient Executive controls. Within this model, deficits in inhibitory control represent a key executive dysfunction ('E' component) that maintains maladaptive behavior. Specifically, these deficits weaken an individual's ability to resist gaming cues and regulate gaming behavior, thereby facilitating the transition from recreational to problematic use. Consequently, interventions that enhance inhibitory control may offer effective strategies for managing hazardous gaming, as demonstrated by studies showing that improving inhibitory control can reduce gaming cravings (Wu et al., 2021) and mitigate EGB (Ma, Xia, Zhao, & Zhao, 2024).

Acceptance and commitment therapy (ACT) is a third-wave behavioral therapy grounded in Contextual Behavioral Science. Its primary therapeutic goal is to enhance psychological flexibility—a dynamic meta-ability defined as contacting the present moment fully as a conscious human being, and based on what the situation affords, persisting in or changing behavior in the service of chosen values. This is achieved through six core processes: acceptance, cognitive defusion, present-moment awareness, self-as-context, values, and committed action (Hayes, 2025). By teaching skills such as acceptance, cognitive defusion, and values-based committed action, ACT has been shown to improve EFs, including inhibitory control, in individuals with substance use disorders (Svanberg, Munck, & Levander, 2017) and other conditions (H. Liu, Liu, Chong, Boon Yau, & Ahmad Badayai, 2023). Its efficacy and accessibility through self-help formats (Apolinário-Hagen, Drüge, Hennemann, & Breil, 2021; Cavanagh, Strauss, Forder, & Jones, 2014) make it a promising intervention for EGB.

In this study, we investigated whether an online ACT self-help course could reduce EGB by targeting its underlying mechanisms. Specifically, we proposed that ACT would enhance psychological flexibility and, consequently, improve inhibitory control. To effectively capture this proposed neurocognitive mechanism, it is critical to employ a sensitive paradigm capable of indexing the neural dynamics of inhibition, particularly in the presence of addiction-relevant cues. Cue-specific inhibitory control tasks, measured with electroencephalogram (EEG), offer a powerful tool for this purpose. In such paradigms, the N200 and P300 event-related potential components serve as well-established neural correlates of distinct inhibitory processes. The N200 component is thought to reflect an early conflict monitoring process, whereas the P300 is linked to the conscious, effortful allocation of neural resources towards successful response inhibition (Botvinick, Braver, Barch, Carter, & Cohen, 2001; A. Chen et al., 2008). Therefore, by examining these ERPs within a context that incorporates gaming-related stimuli, we can achieve a more nuanced and ecologically valid assessment of the proposed mechanism—specifically, whether ACT strengthens the ability to inhibit pre-potent responses when confronted with salient gaming cues.

We hypothesized that:

H1. Participants in the ACT group would show a greater reduction in gaming time and IGD symptoms compared to the active control group.

H2. The ACT group would demonstrate improved accuracy on the NOGO trials, particularly for gaming cues, and show increased N200 amplitude and decreased P300 latency, indicating a strengthening of cue-specific inhibitory control.

H3. The combination of these improvements (psychological flexibility, executive function, and inhibitory control neural markers (N200) would predict successful treatment outcome.

METHODS

Trial registration

This pilot randomized controlled trial serves as a preliminary investigation for the larger registered trial titled '[Mechanisms and Interventions of Social Reward on Cognitive Control in Internet Gaming Disorder]' (Trial ID: [NCT06957392]). It focuses on establishing the feasibility and initial efficacy of the ACT self-help intervention, which is a core component of the parent project.

Study design

This study was designed as a pilot randomized controlled trial (RCT). The pilot design was chosen for several reasons. First, the primary focus was on evaluating the feasibility and preliminary efficacy of a newly developed online ACT self-help course for reducing excessive gaming behavior (EGB). Second, a key aim was the initial exploration of the proposed mechanism of action—that the intervention works by improving inhibitory control—using a multi-method assessment (behavioral task and EEG). This mechanistic investigation is a core objective of pilot studies intended to generate hypotheses for future definitive trials. Finally, the sample size was determined based on feasibility to provide initial estimates of effect sizes, which will be crucial for powering a subsequent full-scale RCT.

Participants

We conducted an eligibility screening of 868 young adults from universities in Bengbu, China, using both online advertising and traditional poster campaigns. Sample size calculations were performed with the G-Power program. Assuming a Cohen's *f* moderate effect size of 0.25, with 95% power and an alpha of 5%, we determined that 44 participants were required for this study (Cohen, 2013). To account for potential dropouts, we recruited 72 adult participants aged 18–23 (mean age = 20.5 ± 1.2 years), ensuring they were not engaged in other gaming disorder treatment programs.

Participants were required to meet the following operational criteria, which align with the World Health Organization's concept of hazardous gaming (ICD-11, QE22.1)—a pattern of gaming that appreciably increases the risk of harmful consequences: 1) Time Investment: Playing the massively multiplayer online role-playing game "King of Glory" (a highly popular game among Chinese college students) for more than 12 months, with an average of at least 21 h of playing time weekly. 2) Functional Impairment and Subclinical Risk: Scoring within the range of 51–70 on the IGD-20 test, indicating clear functional impairment (e.g., academic decline, social isolation, neglect of personal well-being) and a high risk for negative consequences without meeting the full diagnostic threshold for Gaming Disorder (participants with scores above 71 were classified as having Gaming Disorder (Pontes, Király, Demetrovics, & Griffiths, 2014). Participants were excluded based on the following criteria: 1) Chronic conditions that compromise neurological, psychological, or physical wellbeing; 2) Recent medication use within the preceding three-month period; 3) High symptom severity of depression or anxiety, as indicated by a BDI score >28 (Steer, Rissmiller, & Beck, 2000) or a BAI score >25 (Beck, Epstein, Brown, & Steer, 1988); 4) Being unsuitable for EEG procedures; 5) Dependence on substances like nicotine and alcohol, or involvement in other behavioral addictions, such as gambling disorder; and 6) Left-handedness. The assessment of exclusion criteria commenced with an online self-report screening. Eligible participants from this screening subsequently underwent a brief clinical interview conducted by a trained researcher to verify and clarify the self-reported information. The data from this online screening were used as the baseline data for all subsequent analyses.

Procedure

This study employed a randomized, single-blind design to compare the effectiveness of two different intervention approaches. Participants were informed that the study aimed to compare the effects of two different online programs on gaming habits and well-being, without disclosure of the specific therapeutic models being tested. Upon registration, participants were randomly assigned, using a computer-driven system, to either the ACT group or a control group. After randomization, the ACT group consisted of 38 participants (26 males, 12 females), and the control group consisted of 34 participants (20 males, 14 females). Participants were blinded to the randomization and of the alternate group's specific intervention details, maintaining the single-blind nature of the study. The ACT group participants studied ACT self-help courses and courses on gaming disorders. Meanwhile, the control group participants focused only on gaming disorders. Before the study commenced, all participants provided written consent and received a completion fee of 120 RMB (approximately USD 17) upon completing all experimental sessions.

During the experiment, three participants were lost during the 27-day intervention, four were lost during the post-intervention testing, and seven were removed due to low EEG data quality. The primary analysis was conducted on a per-protocol (completer) basis, including only participants who completed the entire intervention and provided valid data at post-test. Both the ACT and control groups contained a higher number of males than females at randomization. This gender distribution was not significantly different between the two groups in the final sample ($p = 0.118$, Table 2), indicating that the post-randomization attrition did not create a significant gender imbalance between the groups. A CONSORT flow diagram is depicted in Fig. 1.

Intervention

The ACT self-help course intervention. The "SuperStarLearn" platform, a free application developed by Beijing Chaoxing Digital Library Information Technology Co. Ltd

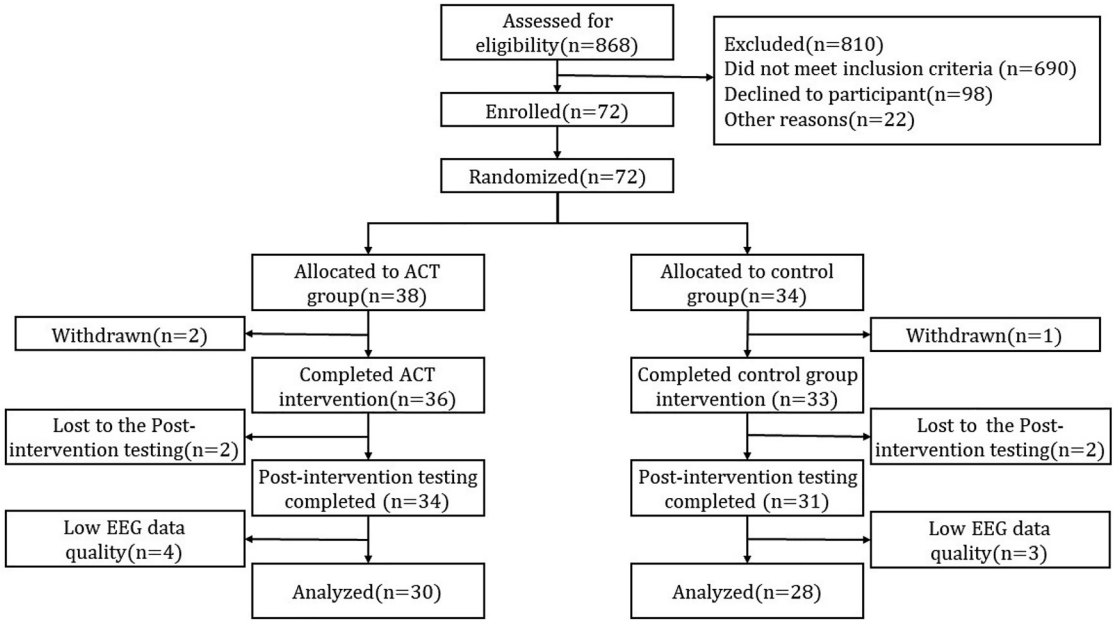

Fig. 1. CONSORT flow diagram. ACT group denotes ACT self-help course intervention

in 2016, integrates mobile teaching, learning, reading, and social communication functionalities. We established a structured ACT self-help course system on this platform, comprising nine sessions. The course architecture included the following components:

1) Self-paced Learning Materials

This component delivered theoretical content through various formats including text, audio, and video materials. It focused on two primary areas: The first part is ACT Theory and Case Studies: The curriculum was structured around the six core ACT processes (see Table 1). Rather than solely targeting and correcting specific cognitions related to gaming disorder, the course aimed to foster broader, more flexible, and effective coping strategies. In brief, the modules covered: a) Values: Clarifying life directions, recognizing pursuits more meaningful than gaming, and establishing motivation for change. b) Committed Action: Initiating effective actions to engage in a valuable and meaningful life. c) Mindfulness: Enhancing mindful awareness to alleviate anxiety and depressive moods and reduce cravings for excessive gaming. d) Acceptance: Accepting academic tasks and life pressures, and learning to reasonably allocate time between gaming and studies. e) Cognitive Defusion: Facilitating a more objective self-perception, building self-confidence, and avoiding fixation on gaming behaviors. f) Self-as-Context: Learning to create a buffer between stimuli and reactive behaviors, thereby reducing impulsive gaming. The second part is Psychoeducation on IGD: This segment covered: a) the concept and diagnostic criteria of IGD as defined by the DSM-5. b) the potential negative consequences of IGD on physical health, mental well-being, academic performance, and social relationships. c) the neurobiological mechanisms underlying addiction. d) general prevention strategies and tips for developing healthy gaming habits (e.g., setting time limits, taking breaks, engaging in alternative activities).

2) Teacher-led Online Sessions

Participants were required to complete one self-paced session every three days. Synchronized with this progress, a teacher facilitated an online group session every three days. These sessions were dedicated to practicing ACT techniques and conducting discussions related to the learned theory. This guidance aimed to enhance student engagement, ensure participants could effectively apply the techniques for self-adjustment, and help them derive tangible benefits.

3) Homework

Homework assignments were given to reinforce learning. The completion of these assignments was reviewed by the teacher during the subsequent online session.

Control condition intervention. Participants randomized to the control group also received an online course delivered via the "SuperStarLearn" platform. This was designed as an active control intervention to account for non-specific factors such as time spent, attention received, and the experience of online engagement. The course content for the control group was identical to the psychoeducational component provided to the ACT group (as detailed above in The ACT Self-help Course Intervention). To ensure parity with the ACT group in terms of structure and facilitator contact, the control group also participated in guided online discussions facilitated by a teacher every three days. These discussions were strictly focused on the psychoeducational topics. Participants in the control group were similarly assigned homework tasks, such as reading short articles on gaming addiction or reflecting on their personal gaming patterns.

Table 1. The ACT self-help course system

Number of Course	Self-help learn		Teacher online teaching		Self-help learn
	Theory courses	Case studies	Techniques training	Interaction and discussion	Homework
1	Introduction of ACT	Cases of ACT treating IGD	Mindfulness training	Tests understanding of the ACT	Study ACT-related books and Mindfulness practice
2	Introduction of IGD	Cases study of IGD	Mindfulness training	Test understanding of IGD	Study ACT-related books and Mindfulness practice
3	Values Clarification	Cases study of Values Clarification	Values Clarification techniques and Mindfulness training	Test mastery of knowledge and techniques	Mindfulness practice and considering the impact of the course on bad online game behaviors
4	Contact with the Present Moment	Cases study of Mindfulness therapy	Mindfulness training	Test mastery of knowledge and techniques	Mindfulness practice and considering the impact of the course on bad online game behaviors
5.	Cognitive Defusion	Cases study of Cognitive Defusion	Defusion techniques and Mindfulness training	Test mastery of knowledge and techniques	Mindfulness practice and considering the impact of the course on bad online game behaviors
6.	Acceptance	Cases study of Acceptance	Acceptance techniques and Mindfulness training	Test mastery of knowledge and techniques	Mindfulness practice and considering the impact of the course on bad online game behaviors
7	Self as Context	Cases study of Self as Context	Self-awareness techniques and Mindfulness training	Test mastery of knowledge and techniques	Mindfulness practice and considering the impact of the course on bad online game behaviors
8	Committed Action	Cases study of Committed Action	"Take One small step" techniques and Mindfulness training	Test mastery of knowledge and techniques	Mindfulness practice and considering the impact of the course on bad online game behaviors
9	Summarize knowledge		Summary techniques training	Discuss learning experience	Plan future actions

Measures

Before and after the intervention, each participant completed a demographic assessment and the Internet Gaming Disorder-20 Test (IGD-20), Behavior Rating Inventory of Executive Function-Adult Version (BRIEF-A) scale, Acceptance and Action Questionnaire (AAQ-II), GO/NOGO behavioral tasks, and the EEG, (Fig. 2).

Internet Gaming Disorder-20 test. The IGD-20 Test is based on the DSM-5 diagnostic criteria for IGD and assesses six core components of addiction: salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse (Shu, Ivan Jacob, Meng Xuan, & Anise, 2019). A score of 71 points or higher may potentially meet the criteria for IGD. At this cutoff, the IGD-20 Test has a specificity of 100% and a sensitivity of 96%, with a Cronbach's α coefficient of 0.910 obtained in this study.

Behavior Rating Inventory of Executive Function-Adult Version. Executive function was assessed using the Chinese Adaptation of the BRIEF-A, originally developed by Roth, Isquith, and Gioia 2005. This instrument comprises 75 items and generates an overall score known as the Global Executive Composite (GEC), derived from two composite scores: the Behavioral Regulation Index (BRI) and the Metacognitive Index (MI). The BRI encompasses four subscales: Inhibit, Shift, Emotional Control, and Self-Monitor. The MI includes five subscales: Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials. A 1–3 point rating system was used, with

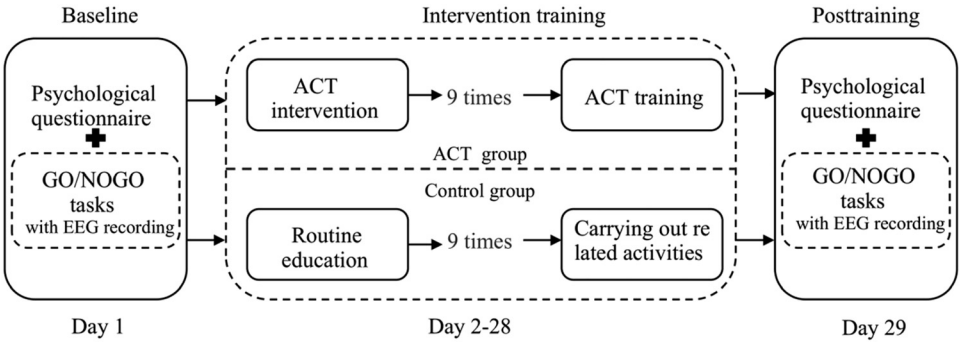

Fig. 2. Experiment timeline
On Day 1, participants underwent baseline assessments. From Days 2–28, participants were divided into two groups and received either ACT self-help course intervention or routine education intervention training. On Day 29, the participants underwent the same assessments administered on Day 1

1 representing "never," 2 signifying "sometimes," and 3 indicating "often." Higher GEC scores suggest greater impairment in executive function. In this study, the Cronbach's α coefficient was 0.931.

Acceptance and Action Questionnaire. The AAQ-II (Bond et al., 2011) is a psychometric instrument designed to assess psychological flexibility. It can also be used to evaluate the effectiveness of ACT psychotherapy (Khoramnia et al., 2020). This questionnaire consists of seven items. Each item is scored using a 7-point Likert scale, where 1 point represents "never true," a score of 7 is "always true," and a higher score indicates less mental flexibility. Previous studies have validated the reliability and validity of this scale, with a Cronbach's α coefficient of 0.85. In this study, AAQ-II had a Cronbach's α coefficient of 0.889.

GO/NOGO task. The GO/NOGO task (Fig. 3, adapted and revised from (G. C. Liu et al., 2014)) assessed an individual's cue-specific inhibitory control, specifically their ability to suppress a pre-potent motor response in certain situations. Before the experiment, participants were asked to refrain from playing games for 2 h. A brief 2-h abstinence period was required prior to testing to minimize any acute cognitive effects from recent gaming and to standardize baseline attention levels across participants. Participants then wore electrode caps to perform the GO/NOGO tasks, and their EEG data was recorded simultaneously. After reading the instructions and completing 40 practice trials, participants could press any button to start the official GO/NOGO tasks after confirming that they understood the procedure.

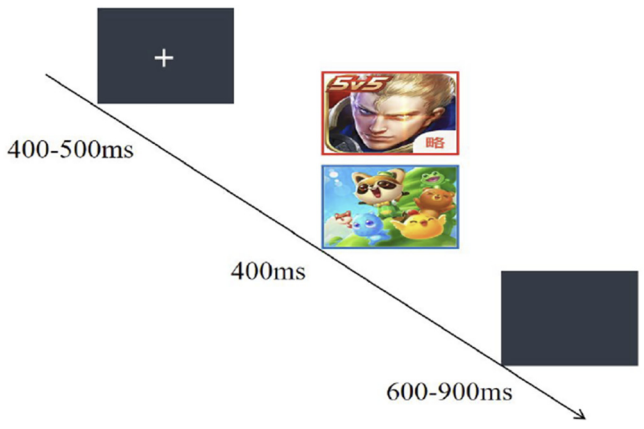

Fig. 3. GO/NOGO task procedure

The GO/NOGO task included four types of stimuli: neutral images using landscape pictures with a blue border, neutral images with a red border, game images using images from the "Kings of Glory" game with a blue border, and game images with a red border. Participants were instructed to press a button when they saw an image with a blue border (GO stimulus, including game and neutral images GO) and withhold their response when they saw an image with a red border (NOGO stimulus, including game and neutral images NOGO). The tasks consisted of 640 trials, including 480 GO and 160 NOGO stimulations, with short breaks after every 80 trials. At the beginning of each trial, a white "+" focus appeared on the screen for 400–500 ms, followed by an image stimulus for 400 ms, and then a blank screen of random duration (600–900 ms). The primary behavioral dependent variables were accuracy rates and reaction times. Crucially, accuracy was analyzed separately for: NOGO Accuracy: The proportion of correctly withheld responses to NOGO stimuli (red border images). This is the key measure of inhibitory control. We further separated this into Game NOGO accuracy (inhibition to gaming cues) and Neutral NOGO accuracy (inhibition to neutral cues) to assess cue-specific effects. GO Accuracy: The proportion of correct button presses to GO stimuli (blue border images), which served as a measure of general attention and task engagement. After completing the experiment, the E-Prime E-DataAid software was used to derive the participants' task performance data (accuracies and reaction times).

Physiological recording. EEG data were recorded using a SynAmps amplifier (NeuroScan, Charlotte, NC, USA) with an elastic cap containing 64 Ag/AgCl electrodes placed on the scalp at specific locations according to the extended international 10–20 system. Electrical activities were recorded over the left and right mastoids. Horizontal electrooculography (EOG) was recorded using a bipolar

channel placed lateral to the outer canthus of each eye, and vertical EOG was recorded using bipolar channels placed above and below the left eye. The reference electrode was attached to the bilateral mastoid process, and the ground electrode was attached to AFz. The impedance between the reference electrode and any recording electrodes was kept below 5 kΩ. Alternating current signals (0.03–100 Hz) were continuously recorded and digitized at a sampling rate of 500 Hz with a 24-bit resolution during data collection. Electrocardiography (ECG) and Skin Conductance Response (SCR) data were also recorded using a BIOPAC MP150 system (Goleta, CA, USA). ECG was assessed using three ECG clamps attached to both legs and the left wrist of the participants. SCR was evaluated using two Ag–AgCl electrodes attached to the first and second fingers of the left hand, between the first and second phalanges. The ECG and SCR data will be reported elsewhere.

EEG data analysis. ① Preprocessing. Offline analyses of the GO/NOGO tasks were conducted using MATLAB (2016a). EEG data were preprocessed using the EEGLab toolbox (Delorme & Makeig, 2004). The preprocessing steps for each participant included resampling the signal at 500 Hz and bandpass filtering (1–50 Hz) using a finite impulse response (FIR) filter. Electrodes with excessively noisy signals were interpolated from neighboring electrodes using spherical spline interpolation (Perrin, Pernier, Bertrand, & Echallier, 1989). Continuous EEG data were segmented into 1,000 ms epochs (−200 ms pre- and 800 ms post-stimulus). Independent component analysis was used to correct for ocular and muscle artifacts. Epochs with remaining artifacts were visually inspected and removed from subsequent analyses. ② ERPs. To examine the neural mechanisms of inhibitory control, we focused our analysis on the N200 and P300 components, as they are well-established neuroelectric indices of conflict monitoring and the conscious allocation of cognitive resources during response inhibition (Enriquez-Geppert, Konrad, Pantev, & Huster, 2010; Smith, Johnstone, & Barry, 2008), respectively. ERPs were grand averaged for each cue in the GO/NOGO tasks across participants. EEG signals were bandpass-filtered at 1–30 Hz, and only artifact-free and correct trials were included in the analysis. All ERPs were quantified using the mean amplitude measure relative to the −200 to 0 ms pre-stimulus baseline. We compared the N200 component at electrode site Cz, a commonly reported electrode site, for analysis in previous studies. The N200 amplitude was calculated by averaging the amplitude within the selected group peak time window (150–300 ms). The P300 latency was determined by calculating the average time of the selected group peak time window, which represents the interval between the onset of the stimulus and the appearance of the P300 crest.

Statistical analysis

A two-way mixed-design repeated measures analysis of variance (ANOVA) was conducted to analyze the measured variables. The intervention method (ACT and control groups) was a between-participants factor, while time (pre- and post-intervention) was a within-participants factor. Significant effects from the ANOVA were followed by Bonferroni correction. To quantify the individual change in symptom severity, a reduction rate was calculated for the IGD-20 score and other variables using the following formula: Reduction Rate (RR) = [(Baseline score - Post-intervention score)/Baseline score] × 100%. Student's *t*-tests were used to compare baseline and RR data. Spearman correlation analysis was conducted to examine correlations between variables. Stepwise regression analysis was performed with the RR of IGD-20 as the dependent variable to explore its effects on the other variables. All reported *p*-values were two-tailed, and a *p*-value below 0.05 was considered statistically significant. All analyses were performed using SPSS 24 and MATLAB (2016a).

Ethics

The study procedures were conducted in accordance with the Declaration of Helsinki. The Institutional Review Board of the Biomedical Ethics Committee of Bengbu Medical University approved the study (Ethics: 2023-347). All participants were informed about the study and provided informed consent.

RESULTS

Demographic and clinical characteristics

Independent sample *t*-tests revealed no significant differences in baseline demographic and clinical characteristics between the ACT and control groups (Table 2).

Testing hypothesis 1: effects on gaming behavior and clinical symptoms

To test our first hypothesis (H1) — that the ACT group would show a greater reduction in gaming time and IGD symptoms compared to the active control group — we compared the reduction rate (RR) of primary outcomes between groups. As predicted, following the intervention, the ACT group demonstrated a significantly higher RR of IGD-20 scores, RR of daily gaming time, RR of AAQ-II (psychological flexibility), and RR of BRIEF-A (executive function) compared to the Control group (Table 3). These results strongly support H1.

Testing hypothesis 2: effects on behavioral and neurophysiological indices of inhibitory control

Our second hypothesis (H2) proposed that the ACT group would demonstrate improved inhibitory control, as reflected by higher NOGO accuracy, increased N200 amplitude, and decreased P300 latency. We analyzed behavioral and EEG data from a cue-specific GO/NOGO task to test this hypothesis.

1. At the behavioral level, we analyzed the accuracy of the NOGO task and findings aligned with H2. Using

Table 2. Baseline demographic and clinical characteristics in the two groups (M ± SD)

		ACT group (n = 30)	Control group (n = 28)	Cohen's d (95% CI)	t/χ^2	p
Age(year)		20.55 ± 1.07	20.49 ± 1.35	0.05 [−0.58, 0.69]	0.18	0.862
Gender(male/female)		22/8	15/13	–	2.45	0.118
IGD-20	baseline	62.21 ± 1.26	61.92 ± 1.30	0.20 [−0.39, 0.85]	0.74	0.460
	post-intervention	35.78 ± 3.57	47.61 ± 3.85	−3.19 [−13.79, −9.89]	−12.16	<0.001
Time spent on game per day(h)	baseline	5.19 ± 0.32	5.14 ± 0.13	0.21 [−0.08, 0.18]	0.8	0.430
	post-intervention	2.30 ± 0.48	2.95 ± 0.42	−1.44 [−0.89, −0.42]	−5.5	<0.001
AAQ-II	baseline	24.59 ± 0.58	24.58 ± 0.84	−0.05 [−0.35, 0.30]	−0.16	0.871
	post-intervention	15.26 ± 2.38	17.59 ± 1.35	−1.20 [−3.36, −1.30]	−4.54	<0.001
BRIEF-A total scores	baseline	123.83 ± 8.28	125.33 ± 8.86	−0.05 [−4.97, 4.05]	−0.21	0.838
	post-intervention	88.38 ± 8.31	97.79 ± 9.85	−0.80 [−15.60, −3.21]	−3.04	0.004
NOGO task accuracy rate(%)	baseline	80.00 ± 3.02	81.00 ± 4.14	−0.28 [−0.85, 0.29]	0.03	0.981
	post-intervention	96.00 ± 5.35	83.00 ± 2.10	3.17 [2.30, 4.00]	12.04	<0.001
NOGO task N200 amplitude(μV)	baseline	−3.96 ± 0.69	−4.21 ± 0.78	0.35 [−0.17, 0.87]	1.16	0.259
	post-intervention	−5.43 ± 0.71	−4.39 ± 0.64	−1.54 [−2.12, −0.95]	−5.87	<0.001
NOGO task P300 latency(ms)	baseline	376.54 ± 11.98	368.49 ± 25.17	0.41 [−0.11, 0.93]	1.8	0.104
	post-intervention	340.22 ± 20.51	362.77 ± 14.32	−1.27 [−1.83, −0.70]	−4.88	<0.001

Data are presented as mean ± standard deviations. IGD-20, 20-item Internet Gaming Disorder Test; AAQ-II, Acceptance Action Questionnaire-II; BRIEF-A, Executive Function-Adult Version;

Table 3. Comparisons of the post-intervention RR of IGD-20, RR of daily gaming time, RR of AAQ-II, and RR of BRIEF-A in the ACT and Control groups (%, M ± SD)

	ACT group (n = 30)	Control group(n = 28)	t	p
RR of IGD-20	42.83 ± 5.76	23.11 ± 1.72	20.853	<0.001
RR of Time spent on gaming per day	56.52 ± 8.53	42.34 ± 8.30	6.113	<0.001
RR of AAQ-II	37.85 ± 7.28	28.43 ± 3.44	4.071	<0.001
RR of BRIEF-A	28.29 ± 2.38	21.34 ± 1.62	2.715	0.009

Data are presented as mean ± standard deviations. IGD-20, 20-item Internet Gaming Disorder Test; AAQ-II, Acceptance Action Questionnaire-II; BRIEF-A, Executive Function-Adult Version; RR, reduction rate.

2 (ACT group, Control group) × 2 (pre- and post-intervention) two-factor repeated measurement ANOVA, and compared the accuracy of the NOGO task of the game and neutral images. The results indicated that the between-group effect was not significant for the game image NOGO task's accuracy rate, and the within-group effect and the between-group × within-group effect were significant (Table 4). Further univariate analysis using an independent-samples t-test indicated that the post-intervention accuracy for the game images NOGO task in the ACT group (96.00 ± 5.35) was significantly higher than that in the control group (83.00 ± 2.10), $t(56) = 12.04$, $p < 0.001$.

Table 4. Repeated measurement ANOVA for game images NOGO task accuracy rate (%, M ± SD)

	Game images	
	Pre-intervention	Post-intervention
ACT group(n = 30)	80.00 ± 3.02	96.00 ± 5.35
Control group(n = 28)	81.00 ± 4.14	83.00 ± 2.10
Between-group effects (ACT group, control group)	$F = 0.001$, $p = 0.981$, Partial $\eta^2 = 0.002$	
Within-group effects (pre- intervention, post- intervention)	$F = 20.37$, $p < 0.001$, Partial $\eta^2 = 0.692$	
Between-group * within-group	$F = 4.377$, $p = 0.018$, Partial $\eta^2 = 0.144$	

2. At the neurophysiological level, the analysis of N200 amplitude provided further support for H2. Using same two-factor repeated measurement ANOVA, the N200 amplitude of the NOGO task of the game and neutral images was compared. The findings indicated that the between-group effect was not significant for the N200 amplitude of the game image NOGO task, the within-group effect and between-group × within-group effect were significant (Table 5). Further univariate analysis using an independent-samples t-test indicated that the post-intervention N200 amplitude for the game images NOGO task in the ACT group (−5.43 ± 0.71 μV) was significantly higher than that in the control group (−4.39 ± 0.64 μV), $t(56) = -5.865$, $p < 0.001$.

Figure 4C illustrates the topographic map of the NOGO-N200 amplitude (200–230 ms). Reflecting the significant Group × Time interaction (Table 5), the ACT group's post-intervention topography shows a larger and more intense blue area over the frontal lobe compared to their

Table 5. Repeated measurement ANOVA for game images NOGO task N200 amplitude (M ± SD)

	Game images	
	Pre-intervention(μV)	Post-intervention(μV)
ACT group(n = 30)	−3.96 ± 0.69	−5.43 ± 0.71
Control group(n = 28)	−4.21 ± 0.78	−4.39 ± 0.64
Between-group effects (ACT group, control group)	F = 1.335, p = 0.259, Partial η^2 = 0.032	
Within-group effects (pre-intervention, post-intervention)	F = 14.558, p = 0.001, Partial η^2 = 0.378	
Between-group * within group	F = 13.678, p = 0.001, Partial η^2 = 0.363	

pre-intervention state and the control group. This neurophysiological change, indicating increased N200 amplitude, is visually supported by Fig. 4A and statistically confirmed by the N200 amplitude data reported in Table 5.

Regarding the P300 component, findings also aligned with H2. Using same two-factor repeated measurement ANOVA, the P300 latency of the game and neutral images NOGO tasks were compared. The results revealed that the between-group effect was not significant for the P300 latency of the game image NOGO task, the within-group effect and between-group × within-group effect were significant (Table 6). Further univariate analysis indicated that after the ACT intervention, the ACT group exhibited significantly

Table 6. Repeated measurement ANOVA for game images NOGO task P300 latency (M ± SD)

	Game images	
	Pre-intervention (ms)	Post-intervention(ms)
ACT group(n = 30)	376.54 ± 11.98	340.22 ± 20.51
Control group(n = 28)	368.49 ± 25.17	362.77 ± 14.32
Between-group effects (ACT group, control group)	F = 3.246, p = 0.104, Partial η^2 = 0.256	
Within-group effects (pre-intervention, post-intervention)	F = 6.326, p = 0.005, Partial η^2 = 0.148	
Between-group * within group	F = 4.235, p = 0.034, Partial η^2 = 0.167	

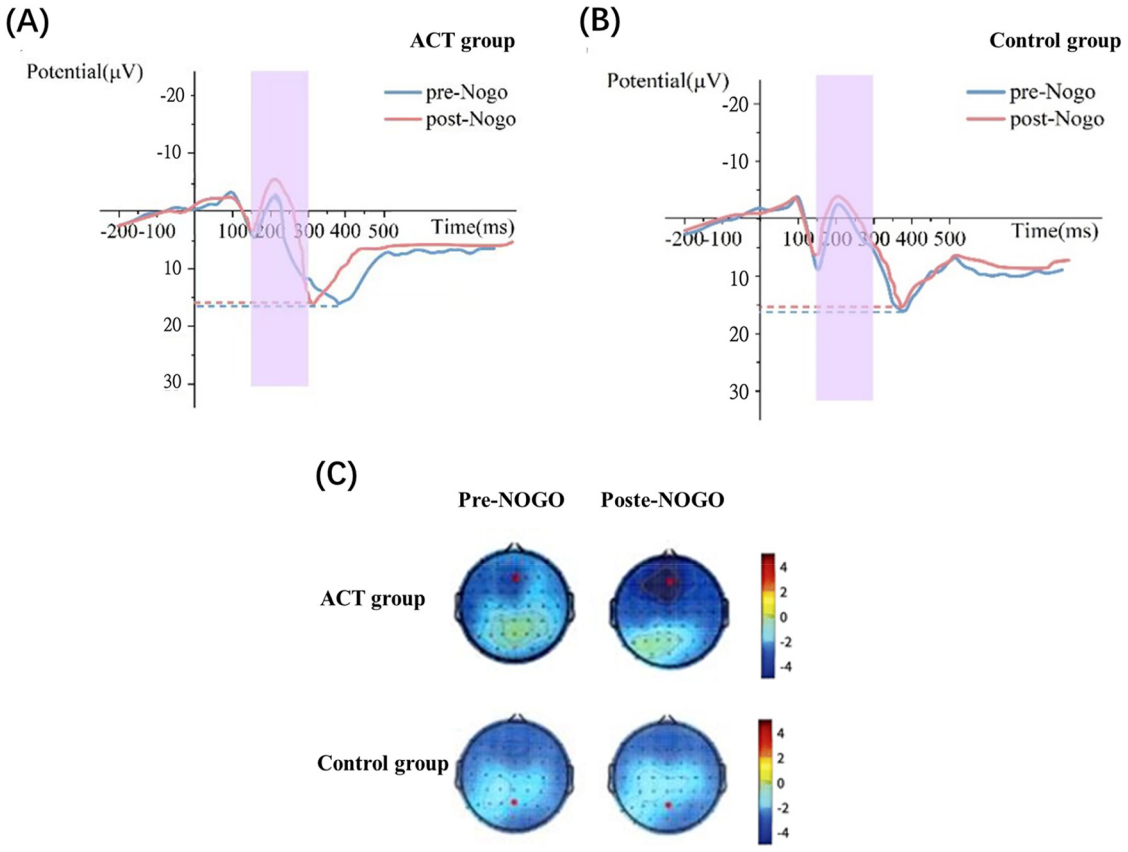

Fig. 4. Effects of intervention on N200 amplitude and P300 latency of game images during GO/NOGO tasks
(A) ACT group and (B) control group. NOGO-N200 (Cz) amplitudes were calculated by averaging the amplitudes between 150 and 300 ms (circled in purple). NOGO-P300 (Cz) latency was calculated by averaging the latency between the onset of the stimulus and the appearance of the P300 crest (circled in the dotted line). *p < 0.05. (C) Scalp topographies of NOGO-N200 (220 ms) components between the two groups

shorter P300 latency of the game images NOGO task than the control group ($p < 0.05$). Further univariate analysis using an independent-samples *t*-test indicated that the post-intervention P300 latency for the game images NOGO task in the ACT group (340.22 ± 20.51 ms) was significantly higher than that in the control group (362.77 ± 14.32 ms), $t(56) = -4.881$, $p < 0.001$.

Testing hypothesis 3: predictive model of treatment success

Our final hypothesis (H3) posited that the combination of improvements in psychological flexibility, executive function, and the neurophysiological marker of inhibitory control (N200 amplitude) would predict successful treatment outcome (i.e., reduction in IGD symptoms).

Initial Spearman rank correlation **within the ACT group** analysis showed a significant and positive relationship between the RR of IGD-20 and the RR of daily gaming time ($r = 0.436$, $p < 0.01$), RR of AAQ-II ($r = -0.352$, $p < 0.01$), RR of BRIE-A ($r = -0.374$, $p < 0.01$), RR of accuracy rate of game images NOGO tasks ($r = 0.456$, $p < 0.01$), RR of N200 amplitude in gaming images NOGO tasks ($r = 0.523$, $p < 0.05$), and RR of P300 latency in gaming images NOGO tasks ($r = 0.395$, $p < 0.05$) (Table 7).

To formally test H3, a stepwise regression analysis was conducted to identify the strongest unique predictors of treatment success (operationalized as the reduction rate of IGD-20 scores) within the ACT group. The predictor variables were selected a priori based on our theoretical model and included measures representing: (1) behavioral change (RR of daily gaming time), (2) psychological processes targeted by ACT (RR of AAQ-II and BRIEF-A), and (3) neurocognitive mechanisms (RR of N200 amplitude and accuracy on game-relevant NOGO trials). This approach allowed us to test which specific components of this theoretical pathway independently contributed to outcomes.

The results of the regression model supported H3 (Table 8). Firstly, the residuals of the regression model were assessed for normality using the Shapiro-Wilk test. The test indicated that the residuals were normally distributed ($W = 0.912$, $p = 0.437$). The stepwise multivariate regression showed that the RR of daily gaming time ($\beta = 0.225$, $t = 3.878$, $p < 0.001$), RR of AAQ-II ($\beta = -0.065$,

Table 7. Correlation analyses of reduction rates within the ACT group ($n = 30$)

		1	2	3	4	5	6	7
1	RR of IGD-20	–	0.436**	−0.352**	−0.374**	0.523*	0.456**	0.395*
2	RR of Time spent on game per day		–	0.304*	0.336*	0.335*	0.546**	0.426**
3	RR of AAQ-II			–	0.374**	0.325**	0.405***	0.387**
4	RR of BRIE-A				–	0.289**	0.215*	0.301*
5	RR of N200 amplitude in gaming images NOGO tasks					–	0.244**	0.237*
6	RR of accuracy rate in game images NOGO tasks						–	0.258**
7	RR of P300 latency in gaming images NOGO tasks							–

IGD-20, 20-item Internet Gaming Disorder Test; AAQ-II, Acceptance Action Questionnaire-II; BRIEF-A, Executive Function-Adult Version. RR, reduction rate.

Table 8. Stepwise multivariate regression analysis of RR of IGD-20 as a dependent variable to determine the effect of other variables within the ACT group ($n = 30$)

		B	SE	Beta	*t*	*p*
independent variable	RR of Time spent on game per day	0.360	0.170	0.225	3.878	<0.001
	RR of AAQ-II	−0.329	0.144	−0.065	−2.281	0.023
	RR of BRIE-A	−0.425	1.341	0.180	4.120	<0.001
	RR of accuracy rate in game images NOGO tasks	0.336	1.348	0.118	2.772	0.006
	RR of N200 amplitude in gaming images NOGO tasks	0.145	0.050	0.122	2.885	0.004
Covariate	Gender	2.188	1.086	0.076	2.014	0.044
	Age	−2.965	2.047	−0.021	−1.121	0.241
	R			0.652		
	R^2	0.425				
	Adjusted R^2	0.275				
	F (6,23)	21.036				
	p	<0.001				

IGD-20, 20-item Internet Gaming Disorder Test; AAQ-II, Acceptance Action Questionnaire-II; BRIEF-A, Executive Function-Adult Version. RR, reduction rate.

$t = -2.281$, $p = 0.023$), RR of BRIE-A ($\beta = 0.180$, $t = 4.120$, $p < 0.001$), RR of accuracy rate of game images NOGO tasks ($\beta = 0.118$, $t = 2.772$, $p = 0.006$), and RR of N200 amplitude in gaming images NOGO tasks ($\beta = 0.122$, $t = 2.885$, $p = 0.004$) were independently associated with the RR of IGD-20 data in the ACT group (Table 8).

DISCUSSION

An ACT online self-help course was implemented as the primary intervention for college students with EGB in this study. Following the intervention, the ACT group demonstrated significant reductions in game addictive behavior (IGD-20 scores) and game time compared with the control group. Additionally, EFs (BRIEF-A) and cognitive flexibility (AAQ-II) were significantly improved in the ACT group. Correlation analysis revealed significant correlations among the changes in IGD-20, BRIEF-A, and AAQ-II. Given the frequent use of AAQ-II to evaluate and study ACT psychotherapy effectiveness, these findings suggest that ACT self-help courses may reduce EGB and improve EFs. Moreover, improvements in EFs may contribute to reducing EGB. Previous studies have also shown that ACT can enhance EFs (H. Liu et al., 2023; Svanberg et al., 2017), aligning with the results of this study.

Inhibitory control is the core component of EFs implicated in the development and maintenance of both EGB and IGD (Kang, Hernández, Rahman, Voigt, & Malvaso, 2022; Kräplin et al., 2020). Previous research has indicated that IGD patients exhibit reduced inhibitory control ability and that improving inhibitory control ability can effectively reduce gaming behavior (Ko et al., 2015; Yao et al., 2015). Therefore, to investigate whether the ACT self-help course reduces EGB by improving inhibitory control, we employed the GO/NOGO task, a measure of inhibitory control. A key aspect of our GO/NOGO task design was the use of 'Kings of Glory'—a highly prevalent game among our participant population-pictures as NOGO stimuli. This was intentional to assess cue-specific inhibitory control — that is, the ability to suppress pre-potent responses in the presence of addiction-relevant cues. For individuals with EGB, gaming-related cues can trigger intense cravings and automatic approach tendencies, making inhibition particularly challenging and ecologically valid in this context (Kang et al., 2022; Kräplin et al., 2020). The significant improvements in accuracy and ERP components specifically in response to gaming cues suggest that the ACT intervention effectively enhanced this crucial cue-specific inhibitory ability, which is a core deficit in addictive behaviors.

The ACT intervention produced a specific pattern of neurophysiological changes: an increase in N200 amplitude and a shortening of P300 latency, which accompanied reduced EGB and improved accuracy on game picture NOGO trials. The N200 amplitude is a well-established indicator of inhibitory control, specifically reflecting the allocation of cognitive resources during conflict monitoring (A. Chen et al., 2008), a larger N200 signifies greater resource investment in this initial process (Dong, Yang, Hu, & Jiang, 2009). Furthermore, N200 impairment is a sensitive marker of inhibitory control deficits in addiction and IGD (Buzzell, Fedota, Roberts, & McDonald, 2014; Y. Chen, Yu, & Gao, 2022; D. Wang, Zhou, & Chang, 2015). Conversely, P300 latency indexes neural processing speed and efficiency (van Dinteren, Arns, Jongsma, & Kessels, 2014) and its shortening indicates accelerated information processing (Casali et al., 2016; Holm, Ranta-aho, Sallinen, Karjalainen, & Müller, 2006; Jiang et al., 2014; Park et al., 2005). This pattern of improvement contrasts with findings in IGD groups, which consistently show smaller N200s and altered P300s (Yu, Leong Bin Abdullah, & Binti Murad Mansor, 2024; Y. Chen et al., 2022; Fathi, Mazhari, Pourrahimi, Poormohammad, & Sardari, 2022), confirming their deficits in inhibitory control. The reversal of this pattern in our EGB participants following ACT suggests a targeted remediation of these underlying processes.

This specific pattern of results aligns with a two-stage inhibitory control model: an initial conflict monitoring phase (N200) followed by inhibitory execution (P300) (Botvinick et al., 2001; A. Chen et al., 2008). The increased N200 amplitude reflects enhanced detection of the conflict between the urge to respond to game cues and the goal to inhibit (Folstein & Van Petten, 2008). This enhanced conflict detection suggests a more efficient allocation of cognitive resources for early conflict monitoring after ACT. The shortened P300 latency indicates faster neural processing and resolution of this conflict, leading to successful behavioral inhibition (Smith et al., 2008). Enhanced monitoring (N200) thus enables quicker execution (P300). In summary, ACT specifically optimizes inhibitory control by strengthening initial conflict detection, which facilitates more efficient inhibitory execution, thereby improving task accuracy and reducing EGB.

The findings from the correlation and regression analyses provide crucial insights into the mechanistic pathways through which the ACT intervention ameliorates EGB. The pattern of significant correlations among the RR of all key variables reveals that improvements are interconnected across psychological, behavioral, and neural domains. Specifically, the reduction in IGD-20 symptoms was positively correlated with enhancements in executive function (BRIEF-A), psychological flexibility (AAQ-II), and the neural efficiency of inhibitory control (N200 amplitude). This interconnectedness suggests that the therapeutic process is not siloed; rather, gains in one domain (e.g., becoming more psychologically flexible) are associated with gains in another (e.g., improved brain-based inhibition). More importantly, the stepwise regression analysis allowed us to identify the strongest unique predictors of treatment success. A combination of reduced gaming time, improved executive function, heightened psychological flexibility, and enhanced neurocognitive monitoring (N200) collectively accounted for a substantial portion (42.5%) of the variance in IGD reduction. This result moves beyond correlation to suggest that successful outcomes are driven by a synergistic improvement in this specific set of processes. In conclusion,

the efficacy of the online ACT self-help course is likely mediated by its simultaneous positive impact on a network of related mechanisms.

Beyond their theoretical contributions, our findings carry significant clinical and practical implications. The demonstrated efficacy of a self-guided, online ACT program is particularly valuable for the treatment of, and especially the prevention of, IGD. Firstly, this modality overcomes critical barriers to care, such as limited access to specialized therapists, high cost, and the stigma associated with seeking help for gaming-related problems. This makes it a scalable intervention for the vast population of at-risk individuals with EGB who might otherwise go untreated. Secondly, our results speak directly to prevention. By successfully targeting a subclinical population (EGB) and demonstrating change in the core mechanisms (psychological flexibility and cue-specific inhibitory control) that underlie the disorder, our study provides a blueprint for preemptive intervention. ACT training equips individuals with transdiagnostic skills to manage internal experiences (cravings, negative emotions) and regulate behavior, potentially building resilience against the development of not only IGD but also other addictive and compulsive behaviors.

LIMITATIONS

This study has several limitations that should be acknowledged. First, this was a pilot study with a relatively small sample size, primarily designed to assess feasibility and generate preliminary efficacy estimates rather than to provide a definitive test of the intervention. The absence of a long-term follow-up assessment constitutes another significant limitation, as it remains unknown whether the observed post-intervention improvements were sustained over time. Second, the final analyzed sample exhibited a significant gender imbalance, which may affect the generalizability of our findings and warrants investigation in more gender-balanced cohorts. Third, our research employed a single-blind design; future studies should consider implementing a double-blind design to further minimize potential bias and confirm our results. Fourth, another limitation concerns the neurophysiological findings. The pre- and post-intervention N200 amplitude in response to neutral images during NOGO tasks did not change significantly, suggesting that general monitoring and inhibitory control abilities—without the interference of game-related cues—remained stable following the intervention. This may be because participants in this study were not formally diagnosed with IGD but rather exhibited EGB, and thus may not have significant impairments in domain-general inhibitory control. Therefore, the inclusion of a healthy control group in future research would help clarify whether these findings are specific to gaming-related stimuli or reflect broader cognitive profiles. Fifth, the identification of the at-risk (EGB) group was based solely on the IGD-20 screening questionnaire score, without verification through a clinical diagnostic interview. While the chosen cut-off score (51–70) is grounded in the instrument's validation study and aligns with the ICD-11 concept of hazardous gaming, future studies would benefit from incorporating structured clinical interviews to confirm the subclinical status of participants and enhance diagnostic precision. Sixth, we note that the randomization was performed at the individual level, not the cluster level. As a pilot study, this trial was not powered to detect anything other than large effects, and the results should be interpreted with caution until replicated in a larger, definitive trial. Seventh, the assessment of depression and anxiety was based on self-report screening measures (BDI and BAI) using standardized cut-off scores, rather than a structured clinical diagnostic interview. While this effectively identified and excluded individuals with severe symptomatology, it remains a limitation that formal diagnoses were not established. Eighth, the use of per-protocol analysis, while justified for assessing mechanism and feasibility in this pilot study, means that our estimates of efficacy are derived from a completer sample and must be interpreted with caution. The generalizability of the effect sizes may be limited, and future definitive trials should employ intention-to-treat analysis as the primary approach. Finally, it is important to note that this study is a pilot for a larger registered parent project. Consequently, the intervention description in the trial registry does not perfectly match the specific pilot component evaluated here.

CONCLUSIONS

This study is the first to demonstrate the efficacy of an online ACT self-help course for reducing excessive gaming behavior (EGB). Our results indicate that this intervention improves inhibitory control by specifically enhancing neurocognitive conflict monitoring, as evidenced by N200 changes. This modality offers a viable strategy for delivering effective early intervention to the large population of at-risk individuals who may not seek formal treatment, thereby helping to prevent the development of IGD.

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Methodology: X-YL, X-XG, L-LX. Formal analysis: P-PS, H-NL, W-BD. Data curation: L-JW, L-LM, P-PS. Supervision: J-Z, N-Z, X-CZ, D-LJ. Conceptualization: X-YL, Y-XG, L-LX, D-LJ. Project administration: J-Z, L-JW, L-LM, P-PS. Investigation: L-LX, X-ZT, Y-W, Z-YW. Validation: X-YL, X-ZT, Y-W, Z-YW. Resources: L-LX, X-ZT, Y-W, Z-YW. Funding acquisition: X-YL, N-Z, D-LJ. Writing – review & editing: N-Z, X-CZ, D-LJ. All authors read and approved the final manuscript.

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Data availability: The datasets analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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