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Digital Detriment: The Impact of Online Gaming Duration on Non-Cognitive Abilities Development in Rural Chinese Children

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ABSTRACT
This study is based on the data of the China Education Panel Survey (CEPS). By adopting the multilevel linear model and instrumental variable approach, it systematically explores the impact of online game duration on the non-cognitive abilities of rural children and the underlying mechanism. The research findings are as follows: (1) After controlling for individual, family, and school characteristics, for every one-hour increase in the average daily online game duration, the social integration, openness ability, positive emotions, and learning perseverance of rural children decrease by 0.014, 0.007, 0.012, and 0.033 standard deviations respectively ($p<0.01$). (2) The heterogeneity analysis indicates that boys, non-boarding children, and heavy online game users (more than 2 hours per day) are more significantly influenced. (3) The mechanism test reveals that online games indirectly affect the development of non-cognitive abilities through three channels: reducing the frequency of parent-child interaction, squeezing out physical exercise time, and taking up homework time. This research provides a theoretical foundation and practical guidance for formulating digital behavior intervention policies for rural children.

KEYWORDS
Online games; Non-cognitive abilities; Rural children; Human capital; Mediating effect

1 Introduction

With the prevalence of the Internet in rural areas, an increasing number of rural children are getting access to the Internet and engaging in online gaming. According to the data from the "5th National Survey Report on the Internet Use of Minors" released in December 2023[1], by 2022, the number of minor Internet users in China had reached 193 million. Among them, the Internet penetration rate among rural minors was as high as 96.5%. Among these minor Internet users, 62.8% often play online games, a proportion that has surpassed half of the total number of minor Internet users. While online games offer entertainment and social functions, they may also exert complex influences on children's development. Most existing studies have concentrated on the direct impacts of online games on cognitive abilities or academic performance (Yue et al., 2024; Zhou et al.,2022). However, they have overlooked the mechanism through which online games affect non-cognitive abilities, an important element of human capital.

Non-cognitive abilities refer to psychological and behavioral traits that influence an individual's long-term development, beyond traditional cognitive capabilities. These include perseverance, emotional regulation, social skills, etc. (Heckman et al., 2014). A substantial amount of research has demonstrated that non-cognitive abilities have a significant predictive power for an individual's educational attainment, career development, and health-related behaviors (Kautz et al., 2015; Zhou et al., 2022). Due to the special circumstances such as the lack of parental supervision and insufficient educational resources, rural children face unique challenges in the development of non-cognitive abilities. Especially in the context of the digital economy, online games may reshape the development trajectories of children by altering time allocation and influencing family interactions.

Based on social cognitive theory and family system theory, this study utilizes nationally representative longitudinal survey data to systematically investigate the causal relationship between the duration of online gaming and the non-cognitive abilities of rural children for the first time, and to uncover the heterogeneous characteristics such as gender and boarding status. The contributions of this research are mainly manifested in three aspects: Firstly, theoretically, this study constructs an integrated "Digital Behavior-Family Environment-Individual Development" model, thereby expanding the connotations of human capital theory in the digital era. Secondly, methodologically, this study employs multilevel modeling to handle nested data structures and uses the instrumental variable approach to address endogeneity issues, enhancing the reliability of causal inference. Thirdly, practically, this study identifies high-risk groups (boys, non-boarding children, and heavy users), providing a scientific basis for formulating targeted intervention strategies.

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1 The information is sourced from the China Internet Society, available at https://www.cnnic.net.cn/n4/2023/1225/c116-10908.html

2 Theoretical framework and research hypotheses

Social cognitive theory accentuates the dynamic interplay among individuals, behaviors, and the environment. It posits that individuals acquire knowledge and mold their behaviors through observation, imitation, and social learning (Firmansyah et al.,2022).

Self-efficacy, goal setting, and social modeling are pivotal factors influencing this process.

In the context of online games, children may emulate the behavioral patterns of game characters. For example, violent or competitive elements in games may impact their emotional regulation and social behaviors. Moreover, the immediate feedback mechanism in games might erode their patience for long-term tasks (Huang et al.,2021). Additionally, the family environment (e.g., the quality of parent-child communication) and school resources (e.g., extracurricular activities) can moderate the influence of games on non-cognitive abilities. A favorable external support system can mitigate the adverse effects of gaming addiction.

Family systems theory perceives the family as a dynamic entity, where the interactions among family members collectively influence individual development. Parental supervision and the quality of family communication play a vital role in shaping children's gaming habits. Positive family interactions can effectively guide gaming behavior and minimize its negative impact on non-cognitive abilities (such as self-control and social skills). Conversely, in families with limited communication, detrimental gaming habits may be exacerbated. Different family structures (such as single-parent or boarding families) also exhibit variations. For example, boarding children may be more susceptible to addiction due to insufficient supervision, while a family environment characterized by strong cohesion is more conducive to cultivating self-management capabilities.

Non-cognitive abilities, a form of "psychological capital" distinct from traditional cognitive capabilities, encompass dimensions such as social skills, personality traits, emotional management, and soft skills. Existing research has shown that non-cognitive abilities are primarily evaluated through psychological scales such as self-efficacy and self-esteem, and are not easily measurable via intelligence tests or academic performance directly (Gutman et al.,2013). Specifically, social integration reflects a child's sense of belonging and interaction capabilities within a group, learning perseverance indicates their tenacity in the face of difficulties, positive emotions represent their daily emotional state, and openness measures their receptiveness to new things (Yue et al., 2019; Zhang et al., 2023).

Prior research has revealed that addiction to online games can curtail real-world social opportunities and impede the development of social skills (Lee et al., 2014). The virtual nature of online gaming environments may dampen the inclination to explore novel things (Newman et al., 2019). Moreover, violent elements and the instant feedback mechanisms within games are likely to evoke negative emotions and erode learning persistence (Loton et al., 2016). Grounded in these findings, this study posits the following:

Hypothesis 1a: The duration of online gaming among rural children has a significantly negative influence on their social integration.

Hypothesis 1b: The duration of online gaming among rural children has a significantly negative impact on their openness ability.

Hypothesis 1c: The duration of online gaming among rural children has a significantly negative effect on their positive emotion.

Hypothesis 1d: The duration of online gaming among rural children has a significantly negative bearing on their learning perseverance.

Parent-child interaction, being a crucial external resource for children's development, exerts a direct impact on their emotional regulation and socialization processes (Kautz et al., 2014). The prevalent issue of inadequate parent-child communication in rural areas may exacerbate children's reliance on online games, subsequently influencing their non-cognitive abilities (Zhou et al., 2022).

Simultaneously, physical exercise plays a positive role in fostering non-cognitive abilities such as psychological resilience and social competence (Smithers et al., 2018). The time consumed by online games directly diminishes the opportunities for physical activity (Melkevik et al., 2010). Additionally, an appropriate amount of time dedicated to homework contributes to the cultivation of self-discipline. However, excessive gaming can disrupt the time equilibrium, potentially giving rise to academic procrastination or emotional issues (Huang et al., 2023). Consequently, this study further advances the following hypotheses:

Hypothesis 2a: The duration of online gaming indirectly affects the development of non-cognitive abilities in rural children by decreasing the frequency of parent-child interaction.

Hypothesis 2b: The duration of online gaming indirectly impacts the development of non-cognitive abilities in rural children by squeezing the time available for physical exercise.

Hypothesis 2c: The duration of online gaming indirectly influences the development of non-cognitive abilities in rural children by reducing the time allocated to homework.

3 Methods

3.1 Data

This study utilizes the data from the China Education Panel Survey (CEPS) in 2014-2015. The CEPS employed a multi-stage stratified cluster sampling approach, covering 438 classes from 112 schools across 28 counties and districts nationwide. The questionnaire survey encompasses a diverse array of aspects. It includes students' family economic circumstances, demographic characteristics, the school environment, the availability of educational resources, and mental health conditions, among others. For the purpose of this research, 3,611 valid samples of children aged 10-18 years with rural household registration were selected. The data structure exhibits an evident hierarchical feature, where students are nested within classes and schools.

3.2 Variables

(1) Dependent Variable: Non-cognitive Abilities

This study measures non-cognitive abilities using four dimensions: social integration, openness ability, positive emotions, and learning perseverance, drawing on the Big Five personality theory model proposed by McCrae and Costa (1992) (Gutman et al., 2013). Each dimension consists of multiple measurement items. The original questionnaire is evaluated using a 4-point or 5-point Likert scale. Through mean-standardization of the items within each dimension, four standardized indices are finally constructed. A higher score on these indices indicates a stronger development level of non-cognitive abilities in the corresponding dimension. For the specific measurement items of each dimension, refer to Table 1.

Table 1 Introduction to the four indicators of non-cognitive abilities.

Indicator	Measurement Items
Social integration	In the past year, I have helped the elderly with various tasks.
	In the past year, I have followed the rules and queued up voluntarily.
	In the past year, I have been sincere and friendly to others.
Openness ability	I often participate in activities organized by the school or class.
	I can persist in my hobbies and interests.
	I have some adults whom I respect and admire.
Positive emotion	Have you felt that something bad might happen in the past seven days?
	Have you felt overly worried in the past seven days?
	Have you felt nervous in the past seven days?
	Have you felt sad or upset in the past seven days?
	Have you felt too tired to do things in the past seven days?
Learning perseverance	Even if I'm a little unwell or have other reasons to stay at home, I still try my best to go to school.
	Even if it's a subject I don't like, I still do my best to complete it.
	Even if it takes a long time to finish my homework, I still keep trying my best.

(2) Core Explanatory Variable: The duration of online gaming among rural children

This study synthesizes the survey data from two items: "Daily time spent on the Internet/playing games from Monday to Friday" and "Daily time spent on the Internet/playing games on weekends". By computing the weighted average of the game time on weekdays and weekends, a continuous variable representing the duration of online game usage is established (Chen et al., 2008). This measurement approach can comprehensively mirror the gaming behavior patterns of children over the course of a week.

(3) Control Variables

Individual Characteristics: Include gender (male=1, female=0), whether the child is a left-behind child (yes=1, no=0), self-evaluated family economic conditions (rated on a 1-5 scale, ranging from "extremely difficult" to "highly affluent"), and whether the child lives in a boarding school (yes=1, no=0).

Family Characteristics: Include family structure (two-parent family=1, single-parent or left-behind family=0) and parental occupation (professional/technical or managerial positions (including those in government agencies, public institutions, enterprises, and professional and technical posts) = 1, others = 0).

School Characteristics: Include the student-to-teacher ratio, the proportion of teachers with a bachelor's degree or higher, the gender composition of teachers (the proportion of male teachers), and the nature of the school (public school =1, private school =0).

(4) Mediating Variables

This study employs three key mediating variables to explore the mechanism through which online game usage affects the non-cognitive abilities of rural children. The quality of parent-child interaction is evaluated based on the frequency of communication reported by parents with their children (including school life, peer relationships, teacher-student

relationships, and worries and troubles), with each dimension rated on a three-point scale (1 = never to 3 = often), and the total score ranging from 4 to 12, where a higher score indicates more frequent parent-child interaction (Liu et al., 2023). The measurement of physical exercise integrates two indicators: the number of days exercised per week and the duration of exercise per day. The average weekly exercise time is calculated and converted into a binary variable (0 = no regular exercise, 1 = regular exercise) to reflect exercise habits (Zhou et al., 2025). The measurement of homework time uses a weighted average method, comprehensively calculating the homework time on weekdays and weekends to form a continuous variable that accurately reflects the time allocation pattern (Jara-Díaz et al., 2008). All these measurement methods have undergone standardization processing to ensure comparability among variables.

The descriptive analysis of the total sample is presented in Table 2. With respect to non-cognitive abilities, the measurement results of the four dimensions are as follows: The mean score of social integration ability is 0.636 (on a scale of 1), indicating a moderately above-average level. However, there remains substantial room for enhancement. The mean score of learning perseverance is 0.712; yet, there exists a notable degree of individual variation, as evidenced by a standard deviation of 0.244. The positive emotion dimension exhibits relatively weaker performance, with an average score of merely 0.449. The mean score of openness ability is 0.586, likewise suggesting significant potential for development.

Regarding the utilization of online games, the sample of children has an average daily gaming duration of 2.322 hours. Nevertheless, there is a marked degree of individual heterogeneity, with a standard deviation of 1.314 hours, and the usage time ranges from 0 to 6 hours. This implies that certain children may be engaging in excessive online gaming.

In terms of sample characteristics, the gender distribution is relatively balanced, with males accounting for 52% of the sample. Left-behind children constitute 21.8% of the total. The overall economic conditions of the families tend to be on the challenging side. Significantly, boarding students make up 47.1% of the sample. The vast majority (93.9%) of the children come from two-parent families. However, the occupational status of parents is generally at a lower level, with only 7.8% being engaged in managerial or technical occupations.

Table 2 Definition and statistical description of variables.

Variable	Definition	Obs.	Mean	SD
Dependent variables:				
Social integration	Standardized scores of social integration questions	3611	0.636	0.198
Openness ability	Standardized scores of openness ability questions	3611	0.586	0.225
Positive emotion	Standardized scores of positive emotion questions	3611	0.449	0.134
Learning perseverance	Standardized scores of learning perseverance questions	3611	0.712	0.244
Explanatory variables:				
Duration of online gaming	Weighted score of online game duration	3611	2.322	1.314
Control variables:				
Gender	Male = 1, Female = 0	3611	0.520	0.500
Left-behind status	Yes = 1, No = 0	3611	0.218	0.413
Family economic conditions	Very poor= 1, Rather poor= 2, Medium = 3, Rather wealthy = 4, Very wealthy = 5	3611	2.815	0.617
Boarding situation	Yes = 1, No = 0	3611	0.471	0.499
Hobbies and interests	None = 0, Exist = 1	3611	0.130	0.337
Family structure	Two-parent Family = 1, Single-parent Family=0	3611	0.939	0.240
Parental occupational status	High=1, Low=0	3611	0.078	0.269
Student-teacher ratio in school	Number of students / Number of teachers	3611	13.12	4.434
Proportion of teachers with bachelor's degrees	Proportion of teachers with a bachelor's degree or above	3611	0.651	0.345
Proportion of male teachers	Number of male teachers / Total number of teachers	3611	0.445	0.143
School type	Public School=1, Private School=0	3611	0.898	0.302

3.3 Empirical models

(1) Entropy Method

In line with the research requirements, this study employs the entropy method to assign weights to various indicators, aiming to calculate the standardized scores of each dimension of rural children's non-cognitive abilities. Prior to the application of the entropy method, assume that the statistical data consists of n samples and m evaluation indicators. Here, X'_{ij}(i=1, 2⋯n; j=1, 2⋯n) represents the value of the j-th indicator of the i-th sample. Then, the calculation is conducted in accordance with the following steps:

Step 1: Dimensionless transformation of data

To guarantee the comparability of data, it is essential to carry out dimensionless transformation on the data. Among them, the five items of the positive emotion indicator are reverse-coded indicators. Different treatment methods are applied to positive-coded indicators and reverse-coded indicators:

For positive-coded indicators, the treatment method is as follows:

$$X'_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}} \tag{1}$$

For negative indicators, the treatment is as follows:

$$X'_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}} \tag{2}$$

Step 2: Determine the weights of indicators, that is, calculate the proportion of the i-th case for the j-th indicator.

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}, j = 1,2\cdots m \tag{3}$$

Step 3: Compute the entropy value of the j-th indicator

$$e_j = -k * \sum_{i=1}^{n} P_{ij} \log(P_{ij}) \tag{4}$$

Here, $k > 0$, ln represents the natural logarithm, and $e_j \geqslant 0$. Additionally, if $k = 1/\ln m$, then $0 \leqslant e \leqslant 1$.

Step 4: Calculate the coefficient of variation of the j-th indicator

$$g_j = 1 - e_j \tag{5}$$

Step 5: Determine the weights of each indicator

$$W_j = \frac{g_j}{\sum_{j=1}^{m} g_j}, j = 1,2\cdots m \tag{6}$$

Step 6: Calculate the weights of individual indicators and the comprehensive score and obtain the scores for each dimension and the comprehensive score of non-cognitive abilities.

$$S_i = \sum_{j=1}^{m} W_j * P_{ij}, i = 1,2\cdots n \tag{7}$$

(2) Multilevel Linear Regression Model

The influencing factors of rural children's non-cognitive abilities demonstrate a distinct hierarchical nature. Among them, individual and family factors pertain to the individual level, while school-related factors fall into the school level. There exists a notable nested relationship between individual children and schools.

When dealing with these influencing factors of rural children's non-cognitive abilities that feature a two-tier structure, if traditional multiple linear regression analysis methods are employed, higher-level factors may be erroneously incorporated into the lower-level analysis. This can lead to the violation of the assumptions of independence and homoscedasticity in the residual terms (Zhou et al., 2024).

Consequently, this study will establish a multilevel linear model to elucidate the within-group and between-group variations in the influence of online gaming duration on rural children's non-cognitive abilities. By doing so, it becomes possible to differentiate between individual-level effects and school-level effects. This methodology enables a more precise understanding of the specific impacts exerted by factors at different levels on rural children's non-cognitive abilities. Specifically:

Level 1 (Individual) Model:

$$\text{ability}_{ij} = \beta_{0j} + \varepsilon_{ij} \tag{8}$$

Level 2 (School) Model:

$$\beta_{0j} = \gamma_{00} + \mu_{0j} \tag{9}$$

Combined Model:

$$\text{ability}_{ij} = \gamma_{00} + \mu_{0j} + \varepsilon_{ij} \tag{10}$$

Among them, ability_{ij} represents the non-cognitive ability score of the i-th child in the j-th school. β_{0j} and ε_{ij} are the intercept and error term in the first-level (individual) model respectively, while γ_{00} and μ_{0j} are the intercept and error term in the second-level (school) model respectively. It is precisely due to the presence of the random variable μ_{0j} that this equation constitutes a multilevel model. The subscript j indicates that each school has its distinct intercept, which is a crucial characteristic differentiating a multilevel model from an ordinary single-level model.

To delve deeper into the factors influencing the non-cognitive abilities of rural children at both the individual and school levels, this study will formulate a two-level multilevel linear model. Specifically, the random-intercept model within the multilevel linear model framework will be employed. This model posits that the intercept of rural children's non-cognitive abilities varies across different schools, yet the slope remains invariant within each school (Zhou et al., 2022). This implies that although the baseline levels of non-cognitive abilities of children in different schools may differ, the strength of influence exerted by factors on this ability is consistent across schools. By utilizing this approach, we can more precisely analyze which factors exert an impact on the non-cognitive abilities of rural children at the individual and school levels, and comprehend how these influences interact across different levels. Equation (11) pertains to the lower level, and Equation (12) pertains to the higher level. The model specifications are as follows:

Level 1 (Individual) Model:

$$ability_{ij} = \gamma_{0j} + \gamma_{10} G_{ij} + \varepsilon_{ij} \quad (11)$$

Level 2 (School) Model:

$$\gamma_{0j} = \gamma_{00} + \gamma_{01} W_j + \mu_{0j} \quad (12)$$

Combined Model:

$$ability_{ij} = (\gamma_{00} + \gamma_{01} W_j + \gamma_{10} G_{ij}) + (\mu_{0j} + \varepsilon_{ij}) \quad (13)$$

Based on the null model, this model incorporates independent variables from both levels. Here, $ability_{ij}$ denotes the non-cognitive ability of the i-th child in the j-th school. W_j represents the variable at the second-level (school level); γ_{01} is the coefficient of the impact of the second-level school-level independent variable on children's non-cognitive ability; G_{ij} is the variable at the first-level (individual level); γ_{10} is the coefficient of the impact of the first-level individual-level variable on the non-cognitive ability of rural children, and its effect remains consistent across different schools; μ_{0j} and ε_{ij} are the error terms.

(3) Two-Stage Least Squares (2SLS) Regression Model

To address the endogeneity issue that may arise from bidirectional causal relationships, this study designates "the number of friends who frequently visit internet cafes or gaming halls" as an instrumental variable. Subsequently, a two-stage least squares (2SLS) approach is adopted for estimation. The detailed models are presented as follows:

First stage:

$$x = \beta_0 + \beta_1 z + \upsilon \quad (14)$$

Second stage:

$$y = \alpha_0 + \alpha_1 \hat{x} + \varepsilon \quad (15)$$

In these equations, x denotes the endogenous explanatory variable, $\hat{x}$ represents the predicted value of the endogenous explanatory variable; z serves as the instrumental variable; y stands for the dependent variable; υ and ε are the stochastic disturbance terms.

4 Empirical results

4.1 Basic regression results

The results presented in Table 3 indicate that the duration of online gaming exerts a significantly negative influence on all four dimensions of rural children's non-cognitive abilities. Specifically, for each one-standard-deviation increase in the duration of online gaming, social integration decreases by 0.014 standard deviations ($P<0.05$), openness drops by 0.007 standard deviations ($P<0.1$), positive emotion reduces by 0.012 standard deviations ($P<0.01$), and learning perseverance weakens by 0.033 standard deviations ($P<0.01$). These findings confirm the research hypotheses H1a-H1d, indicating that excessive gaming hinders the improvement of children's social adaptability and comprehensive qualities by reducing real-life social opportunities and occupying time for developmental activities.

In terms of school characteristics, the study reveals that a higher student-to-teacher ratio can impede the development of children's openness ability. Additionally, a higher proportion of male teachers has a negative impact on social integration, openness ability, and learning perseverance ($P<0.05$). This outcome implies that female teachers may possess a comparative advantage in facilitating the development of students' non-cognitive abilities. These findings offer crucial insights into the factors influencing the development environment of rural children, thereby contributing to a more comprehensive understanding of this field.

Table 3 Baseline regression results.

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Duration of online gaming	-0.014***	-0.007***	-0.012***	-0.033***
	(0.003)	(0.003)	(0.002)	(0.003)
Gender	-0.025***	-0.030***	0.016***	-0.054***
	(0.006)	(0.007)	(0.004)	(0.008)
Hobbies and interests	-0.069***	-0.114***	-0.003	-0.041***
	(0.009)	(0.011)	(0.007)	(0.012)
Family economic conditions	0.004	0.008	0.019***	0.004
	(0.006)	(0.006)	(0.004)	(0.007)
Boarding situation	0.013	-0.008	-0.012**	-0.020*
	(0.009)	(0.010)	(0.006)	(0.010)
Left-behind status	-0.005	-0.018*	-0.008	-0.017
	(0.009)	(0.010)	(0.006)	(0.011)

Table 3 Baseline regression results. (Continued).

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Family structure	0.002	-0.008	0.021**	0.038**
	(0.015)	(0.017)	(0.010)	(0.018)
Parental occupational status	0.013	0.032**	0.002	0.010
	(0.012)	(0.014)	(0.008)	(0.015)
Student-teacher ratio in school	-0.002	-0.003**	-0.001	0.000
	(0.001)	(0.002)	(0.001)	(0.001)
Proportion of teachers with bachelor's degrees	0.010	0.026	0.012	0.022
	(0.019)	(0.020)	(0.011)	(0.018)
Proportion of male teachers	-0.232***	-0.180***	-0.011	-0.151***
	(0.041)	(0.044)	(0.024)	(0.040)
School type	-0.022	-0.049**	0.012	0.009
	(0.023)	(0.025)	(0.013)	(0.022)
Inter-group variation	-3.061***	-3.032***	-3.764***	-3.299***
	(0.109)	(0.117)	(0.140)	(0.149)
Intra-group variation	-1.682***	-1.551***	-2.043***	-1.459***
	(0.012)	(0.012)	(0.012)	(0.012)
Observations	3611	3611	3611	3611

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

4.2 IV estimates

To address potential endogeneity issues, this study adopts the approach of Glewwe et al. (2017) and selects "the number of friends who frequently visit internet cafes or game arcades" as an instrumental variable. This variable meets the two fundamental conditions of an instrumental variable: first, peer behavior significantly influences children's gaming behavior (relevance condition); second, friends' internet usage does not directly affect children's non-cognitive abilities (exogeneity condition).

The estimation results using two-stage least squares (2SLS) are presented in Table 4: In the first stage regression, the coefficient of the instrumental variable is significant (P < 0.01), and the robust F-statistic reaches 34.16, far exceeding the critical value of 10, ruling out the possibility of a weak instrumental variable. The second stage estimation reveals that the negative impact coefficients of online gaming duration on the four dimensions of non-cognitive abilities are -0.091 (social integration), -0.033 (openness ability), -0.078 (positive emotion), and -0.152 (learning perseverance), respectively. The absolute values of these coefficients are all greater than those from the benchmark regression, indicating that ordinary least squares indeed underestimate the negative effects of online gaming on non-cognitive abilities. This result further strengthens the reliability of the research conclusion.

Table 4 Instrumental variable (IV) estimation results.

Variables	First Stage Estimates	2SLS results			
	Duration of online gaming	Social integration	Openness ability	Positive emotion	Learning perseverance
Duration of online gaming		-0.087***	-0.034**	-0.070***	-0.139***
		(0.014)	(0.015)	(0.010)	(0.019)
Instrumental variable	0.536***				
	(0.046)				
Control variables	Yes	Yes	Yes	Yes	Yes
F-statistics			36.46		
Wald chi-square value		197.84	266.09	104.65	167.56
Observations	3611	3611	3611	3611	3611

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

4.3 Robustness checks

(1) Replacement of the Regression Model

In this study, a multilevel regression model was adopted as the benchmark regression approach to effectively account for the potential impact of school-level characteristics on the relationship between online gaming and the non-cognitive abilities of rural children. During the robustness testing stage, given that the dependent variables (social integration,

openness ability, positive emotion, and learning perseverance) are all standardized continuous variables, the study re-estimated the model using the ordinary least squares (OLS) method. The test results indicate that the direction and significance level of the regression coefficients in the OLS model are highly consistent with those of the benchmark regression results. Moreover, the impact effects across all dimensions have not undergone any substantial alterations. This effectively validates the robustness of the research conclusions.

Table 5 Robustness test results: OLS Regression.

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Duration of online gaming	-0.011***	-0.007**	-0.013***	-0.030***
	(0.003)	(0.003)	(0.002)	(0.004)
Control variables	Yes	Yes	Yes	Yes
Class fixed effects	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes
Observations	3611	3611	3611	3611
R2	0.183	0.178	0.121	0.150

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

(2) Mitigating Model Specification Bias

To mitigate potential model specification biases stemming from inappropriate selection of control variables, this study draws on previous research and employs a double-screened Lasso (Least Absolute Shrinkage and Selection Operator) regression approach to screen control variables prior to conducting OLS estimation (Wang et al., 2013). Initially, a Lasso regression is carried out with the dependent variable regressed against the control variables, thereby identifying a subset of control variables denoted as X_{c1}.

Subsequently, in a similar manner, the independent variable is regressed against the control variables using Lasso regression to select another subset of control variables, designated as X_{c2}. Subsequently, the two subsets of control variables are merged to form an effective set of control variables, where $X_c=X_{c1}\cup X_{c2}$. Finally, an OLS regression is performed on the selected effective set of control variables X_c. The estimation results, presented in Table 6, are consistent with those of the benchmark regression.

Table 6 Robustness test results: Lasso Estimation.

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Duration of online gaming	-0.012***	-0.007**	-0.013***	-0.030***
	(0.003)	(0.003)	(0.002)	(0.003)
The selected effective control variables	Yes	Yes	Yes	Yes
Class fixed effects	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes
Observations	3611	3611	3611	3611
R^2	0.183	0.178	0.121	0.149
F	3.783	3.621	2.296	2.947

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

4.4 Heterogeneity analysis

Firstly, the impact of online gaming duration on social integration shows significant gender differences (as shown in Table 7), with boys' social integration abilities being more negatively affected by online gaming. This phenomenon may stem from the fact that boys have a higher participation rate in online gaming and are more inclined to use game content as daily social topics, thereby suffering a more pronounced impact on their real-life social skills. Notably, no significant gender differences were observed in the influence of online gaming on openness ability and positive emotions, suggesting that the mechanisms of these dimensions may not be modulated by gender factors. This finding provides important evidence for understanding the group-specific effects of online gaming.

Table 7 The heterogeneity results 1: Heterogeneity in gender.

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Duration of online gaming*Gender	0.014***	0.000	0.001	0.003
	(0.004)	(0.005)	(0.003)	(0.005)
Duration of online gaming	-0.018***	-0.007	-0.009***	-0.026***
	(0.004)	(0.004)	(0.002)	(0.004)
Control variables	Yes	Yes	Yes	Yes

Table 7 The heterogeneity results 1: Heterogeneity in gender. (Continued).

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Inter-group variation	-3.047***	-3.049***	-3.785***	-3.226***
	(0.105)	(0.116)	(0.137)	(0.139)
Intra-group variation	-1.684***	-1.547***	-2.043***	-1.457***
	(0.012)	(0.012)	(0.012)	(0.012)
Observations	3611	3611	3611	3611

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

This study further examined the moderating effect of boarding status on the relationship between online gaming and non-cognitive abilities of rural children.

As shown in Table 8, boarding status exhibited significant heterogeneous effects on the positive emotion dimension. Specifically, the positive emotions of non-boarding children were more likely to be negatively affected by online gaming. This might be attributed to two factors: first, compared to the school environment, non-boarding children's families often lack systematic behavioral supervision and guidance (Carpenter et al., 2013); second, non-boarding children have fewer opportunities for peer interaction at home, making them more prone to developing a dependence on online gaming, which in turn leads to impaired emotional regulation abilities.

Notably, the moderating effects of boarding status on the dimensions of social integration, openness ability, and learning perseverance did not reach statistical significance. This finding indicates that the boarding school environment, by providing structured management and peer interaction opportunities, can to some extent buffer the negative impact of online gaming on children's development, but this protective effect is mainly manifested in the dimension of emotional development.

Table 8 The heterogeneity results 2: Heterogeneity in boarding conditions.

Variables	(1)	(2)	(3)	(4)
	Social integration	Openness ability	Positive emotion	Learning perseverance
Duration of online gaming* Boarding status	0.004	0.000	-0.005**	-0.001
	(0.003)	(0.003)	(0.002)	(0.004)
Duration of online gaming	-0.014***	-0.008**	-0.009***	-0.029***
	(0.003)	(0.003)	(0.002)	(0.004)
Control variables	Yes	Yes	Yes	Yes
Inter-group variation	-3.079***	-3.038***	-3.760***	-3.335***
	(0.109)	(0.118)	(0.139)	(0.156)
Intra-group variation	-1.686***	-1.550***	-2.043***	-1.463***
	(0.012)	(0.012)	(0.012)	(0.012)
Observations	3611	3611	3611	3611

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

This study, based on Lim (2021)'s research framework, delves into the nonlinear relationship between the duration of online gaming and the non-cognitive abilities of rural children. Empirical results (see Table 9) show that the impact of gaming duration varies significantly across different time periods. During weekdays (Monday to Friday), moderate gaming (0-1 hour per day) promotes children's social integration, positive emotion, and learning perseverance, possibly due to the cognitive stimulation and social interaction provided by gaming. However, when gaming time extends to 2-3 hours, this positive effect reverses, significantly negatively impacting social integration and emotional state. More notably, gaming for more than 3 hours damages all dimensions of non-cognitive abilities, including openness ability. The situation on weekends (Saturday to Sunday) is slightly different. The study found that gaming for up to 2 hours has a positive effect on all four non-cognitive ability indicators, possibly due to the more relaxed time arrangement and social environment on weekends. However, beyond this threshold, the positive effect of gaming also turns negative. These findings provide important evidence for formulating differentiated gaming time management strategies: on weekdays, children's gaming time should be controlled within 1 hour; while on weekends, it can be appropriately extended to 2 hours. Such differentiated time management can leverage the positive role of gaming in cognitive development while effectively avoiding the risks of excessive use.

Table 9 The heterogeneity results 3: Heterogeneity in game duration.

Variables	(1)	(2)	(3)	(4)	Observations
	Social integration	Openness ability	Positive emotion	Learning perseverance	
Monday to Friday					
0 hours	0.020***	-0.001	0.010**	0.041***	3611
	(0.007)	(0.008)	(0.005)	(0.008)	

Table 9 The heterogeneity results 3: Heterogeneity in game duration. (Continued).

Variables	(1) Social integration	(2) Openness ability	(3) Positive emotion	(4) Learning perseverance	Observations
0-1 hours	0.010	0.013	0.017***	0.008	3611
	(0.008)	(0.009)	(0.006)	(0.010)	
1-2 hours	-0.008	0.009	-0.002	0.003	3611
	(0.008)	(0.009)	(0.006)	(0.010)	
2-3 hours	-0.022*	0.003	-0.020**	-0.016	3611
	(0.011)	(0.013)	(0.008)	(0.014)	
3-4 hours	-0.044**	-0.051**	-0.033***	-0.066***	3611
	(0.018)	(0.020)	(0.012)	(0.022)	
More than 4 hours	-0.034**	-0.036**	-0.041***	-0.149***	3611
	(0.014)	(0.016)	(0.010)	(0.017)	
Saturday to Sunday					
0 hours	0.033***	0.003	0.013**	0.039***	3611
	(0.008)	(0.009)	(0.005)	(0.010)	
0-2 hours	0.017**	0.018**	0.017***	0.040***	3611
	(0.007)	(0.008)	(0.005)	(0.009)	
2-4 hours	-0.023***	-0.001	-0.003	-0.008	3611
	(0.008)	(0.009)	(0.005)	(0.010)	
4-6 hours	-0.027***	-0.014	-0.014*	-0.035***	3611
	(0.010)	(0.012)	(0.007)	(0.013)	
6-8 hours	-0.008	-0.010	-0.025**	-0.026	3611
	(0.015)	(0.017)	(0.011)	(0.019)	
More than 8 hours	-0.041***	-0.041***	-0.047***	-0.158***	3611
	(0.013)	(0.015)	(0.009)	(0.016)	

Note: Robust standard errors are reported in parentheses. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.

4.5 Mechanism analysis

Firstly, this study explored the mediating role of parent-child interaction in the relationship between the duration of online gaming and the non-cognitive capabilities of rural children. As presented in Column (1) of Table 10, after controlling for relevant variables and fixed effects, the duration of online gaming was found to have a significantly negative influence on parent-child interaction (β =-0.144, p<0.01), thus validating the research hypothesis H2a. Meanwhile, Liu et al. (2025) conducted research indicating that a "neglectful" parenting style characterized by a lack of effective communication can impede the development of children's non-cognitive capabilities. Gadaire et al. (2017) further demonstrated that the frequency of parent-child interaction is positively correlated with the time investment of parents. Zhou et al.(2022) found a decrease in this frequency can directly undermine the development of children's social-emotional capabilities. These research results collectively reveal the potential mechanism through which online gaming may negatively affect children's development by encroaching on parent-child interaction time.

Secondly, this research employed physical exercise as a mediating variable to delve into its intermediary role in the relationship between online gaming and the non-cognitive capabilities of rural children. The empirical findings, as presented in Column 2 of Table 10, indicate that upon controlling for relevant variables and fixed effects, the duration of online gaming exerts a significantly negative influence on the time allocated to physical exercise (β= -0.063, p<0.1). This result validates Research Hypothesis H2b. Li et al. (2024) conducted research that confirmed physical exercise can effectively facilitate the development of non-cognitive capabilities among adolescents, such as emotion management and self-efficacy. Moreover, studies by De et al. (2011), further revealed that regular physical activities not only enhance adolescents' social interaction capabilities but also boost their social trust and willingness to engage in social activities, thus expediting the process of socialization. Collectively, these research outcomes unveil a potential mechanism through which online gaming might impede the development of children's non-cognitive capabilities by usurping the time dedicated to physical exercise.

Finally, this research investigated the mediating role of homework time in the relationship between the duration of online gaming and the non-cognitive capabilities of rural children. The regression results in Column (3) of Table 10 suggest that the duration of online gaming has a significantly negative impact on homework time (β=-0.037, p<0.05), thereby validating Research Hypothesis H4. This discovery illuminates a potential pathway through which online gaming may influence the development of non-cognitive capabilities by encroaching on homework time. The process of completing homework holds multiple dimensions of value for the development of children's non-cognitive capabilities. Firstly, the completion of homework tasks necessitates children to engage in autonomous planning and management, which is instrumental in cultivating their self-discipline and sense of responsibility. Secondly, the act of independently completing homework can stimulate the development of critical thinking and creativity. More significantly, when

confronted with challenges in solving homework problems, children can gradually enhance their ability to withstand setbacks and refine their problem-solving skills, thereby fostering a positive psychological resilience to challenges (Caetano et al., 2023). The cultivation of these capabilities is of paramount importance for children in establishing self-confidence and enhancing their sense of self-efficacy. Consequently, the encroachment of online gaming on homework time may inadvertently undermine the opportunities for the development of these vital non-cognitive capabilities.

Table 10 Estimated results of mechanism analysis.

Variables	(1)	(2)	(3)
	Parent-child interaction	Physical exercise	Homework time
Duration of online gaming	-0.144***	-0.063*	-0.037**
	(0.033)	(0.035)	(0.015)
Control variables	Yes	Yes	Yes
Class fixed effects	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes
Observations	3611	3611	3611

Note: Robust standard errors are reported in parentheses. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5 Conclusion and implications

This study is grounded in the data from the China Education Panel Survey (CEPS) spanning 2014-2015. By adopting methods such as multilevel regression, two-stage least squares (2SLS), and ordinary least squares (OLS), it systematically examines the influence of the duration of online gaming on the non-cognitive abilities of rural children. The research findings are as follows: (1) The duration of online gaming has a significantly negative impact on rural children's social integration, openness capabilities, positive emotions, and learning perseverance. Among these, the negative impact on learning perseverance is the most substantial. (2) The reliability of this conclusion has been verified through the instrumental variable approach and various robustness tests. (3) There exists a notable heterogeneity in the impact effects: Boys' social integration and the positive emotions of non-boarding children are more vulnerable to negative influences. Moreover, when the gaming duration exceeds two hours, the negative effects become more evident. (4) Mechanism analysis indicates that online gaming indirectly undermines the development of non-cognitive abilities through mediating pathways such as reducing parent-child interaction, squeezing time for physical exercise and homework.

To enhance the development of rural children's non-cognitive abilities and effectively regulate the duration of online gaming, it is essential to establish a comprehensive governance system involving multiple stakeholders. Firstly, efforts should be made to strengthen family education guidance. This can be achieved by organizing specialized parental training programs, providing family education toolkits, and establishing village-level mutual-assistance networks, thereby elevating parents' capabilities in guiding children's internet use and cultivating their non-cognitive abilities. Secondly, school education provision needs to be optimized. This includes increasing investment in sports and cultural facilities, implementing after-school service improvement initiatives, and allocating professional psychological counseling teams. Simultaneously, the game supervision system should be refined. This involves strictly implementing real-name registration systems and time-limit regulations, establishing content classification and review mechanisms, and encouraging the development of educational game products. In addition, the construction of social support networks should be fortified. This can be accomplished through media campaigns, expert lectures, and the establishment of community activity centers to foster a conducive environment. Finally, a regular communication mechanism between families and schools should be established. A joint school-village management committee should be formed, and children's development indicators should be incorporated into the assessment of grass-roots work. By doing so, a long-term collaborative governance mechanism integrating "family, school, government, and society" can be established, thereby creating a healthier growth environment for rural children.

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