The Effect of Cumulative Ecological Risk on Adolescent Smartphone Addiction: The Role of Psychological Capital and Self-Control

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Abstract

This study investigated the impact of cumulative ecological risk on adolescent mobile phone addiction and examined the mediating roles of psychological capital and self-control. Using a cluster sampling method, a one-year longitudinal survey was conducted with 1329 adolescents (M =13.59; SD = 0.49). The results revealed that: (1) the linear term of cumulative ecological risk significantly and positively predicted mobile phone addiction, and the quadratic term also significantly and positively predicted mobile phone addiction (demonstrating a "positive acceleration pattern"); (2) the linear term of cumulative ecological risk could significantly and positively predict mobile phone addiction through the parallel and chain mediating effects of psychological capital and self-control, whereas the quadratic term significantly and negatively predicted mobile phone addiction through the parallel and chain mediating effects of psychological capital and self-control (demonstrating a "negative acceleration pattern"). These findings provide important implications for interventions targeting adolescent mobile phone addiction.

Full Text

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Abstract

This study examined the impact of cumulative ecological risk on adolescent smartphone addiction and investigated the mediating roles of psychological capital and self-control. Using cluster sampling, 1,329 adolescents (M = 13.59; SD = 0.49) were surveyed in a one-year longitudinal design. The findings revealed: (1) both the linear and quadratic terms of cumulative ecological risk significantly and positively predicted smartphone addiction, demonstrating a "positive acceleration pattern" ; (2) the linear term of cumulative ecological risk significantly predicted smartphone addiction through parallel and chain mediating effects of psychological capital and self-control, whereas the quadratic term significantly and negatively predicted smartphone addiction through these same mediating pathways, exhibiting a "negative acceleration pattern." These results provide important implications for interventions targeting adolescent smartphone addiction.

Keywords: smartphone addiction, cumulative ecological risk, psychological capital, self-control, adolescents

As of December 2024, approximately 1.105 billion Chinese internet users engage in gaming, video streaming, social networking, and shopping via mobile devices, with smartphones representing the dominant access terminal (99.7%; China Internet Network Information Center, 2025). Research indicates that adolescents are more susceptible to smartphone addiction than adults (Zeng et al., 2025), with excessive mobile phone use negatively impacting academic performance and precipitating psychological and social adaptation problems (Zhang & Wu, 2020). Consequently, investigating the influencing factors and underlying mechanisms of adolescent smartphone addiction is critically important.

Numerous studies suggest that adolescent smartphone addiction is influenced by ecological risks across multiple domains. Ecological risk refers to adverse environmental factors that increase the likelihood of negative developmental outcomes (Wright & Masten, 2005), and examining the cumulative effects of multi-domain ecological risks on adolescent smartphone addiction more accurately reflects real-world conditions (e.g., Tian et al., 2023; Xie et al., 2024).

1.1 The Impact of Cumulative Ecological Risk on Smartphone Addiction

Drawing from bioecological theory (Bronfenbrenner & Morris, 1998), extensive research has demonstrated that adolescent smartphone addiction is affected by ecological risks in family, school, and social domains (Buctot et al., 2020; Peng et al., 2022). First, negative family environments elevate smartphone addiction risk. Children from families with adverse characteristics may turn to mobile phones for emotional fulfillment when they cannot obtain adequate emotional support and care (Xie & Xie, 2020), and insufficient parental monitoring can lead to excessive use and addiction (Geng et al., 2021). Additionally, poor parent-child relationships and family dysfunction may drive children to seek solace or

vent negative emotions through mobile phones, ultimately treating their devices as a psychological haven and developing addiction (Peng et al., 2022).

Second, the school domain also harbors risks for smartphone addiction. Poor teacher-student relationships and negative classroom environments can weaken students' connection to school, making it difficult for them to gain sufficient sense of belonging and emotional support from school, teachers, and peers (Xi & Hu, 2022), ultimately leading them to seek "help" through mobile phones and develop addiction (Sundaya et al., 2021). Finally, social factors play an important role in smartphone addiction risk. Research indicates that associating with peers who are addicted to mobile phones constitutes deviant peer affiliation, and individuals may develop smartphone addiction through observation and imitation (Xie et al., 2019). Furthermore, individuals who frequently experience social adversity or lack peer support may use mobile phones to release negative emotions or seek help, also showing higher risk for smartphone addiction (Chen et al., 2021).

However, with increasing online risks, individuals exposed to cyber social exclusion, cyberbullying, and violent online games also show elevated smartphone addiction risk (Kuss et al., 2014), yet few studies have explored the combined cumulative effects of online ecological risks alongside other ecological risks. Therefore, this study incorporates online ecological risk into the cumulative ecological risk model to further validate and enrich existing research.

The cumulative ecological risk model posits that risks across different domains are often synergistic; when an individual faces risk in one domain, the probability of risk in other domains increases accordingly. Examining the effect of a single risk in isolation may overestimate its impact (Evans et al., 2013). Therefore, only by simultaneously considering risks across multiple domains can we more accurately reflect individuals' real-life experiences. Although previous studies have explored the impact and mechanisms of cumulative ecological risk on smartphone addiction from various perspectives (e.g., Xie et al., 2024; Zhang, 2024), none have examined the mediating roles of psychological capital and self-control. This study employs a longitudinal design to validate and extend previous findings, providing a scientific basis for smartphone addiction interventions.

1.2 The Mediating Roles of Psychological Capital and Self-Control

Psychological capital refers to individuals' positive psychological development state, encompassing self-efficacy, optimism, hope, and resilience (Luthans et al., 2007), whereas self-control refers to the capacity to regulate cognition, emotion, and behavior to overcome impulses, habits, or automatic responses, consciously directing one' s behavior to align with social norms and long-term goals (Baumeister et al., 2007). The resource model of self-control posits that self-control is closely related to psychological resources (e.g., psychological capital), with self-control behavior execution depending on limited internal psychological

resources (Baumeister et al., 2007). This theory suggests that the upper limit of psychological resources determines self-control success; abundant resources enhance self-control, while resource depletion impairs it, indicating that psychological capital influences self-control. However, while the theory specifies this directional relationship, no empirical studies have validated it.

Since psychological resources are finite, depleted resources can be restored through rest and relaxation or replenished through external support, with support from family, school, society, and network being crucial pathways. However, individuals exposed to family, school, social, and online risks experience blocked external replenishment channels, leading to reduced psychological resources and consequently diminished self-control resources, resulting in self-control failure (Qu et al., 2017). Based on this, cumulative ecological risk may also lead to adolescent smartphone addiction by reducing psychological capital and lowering self-control levels.

1.3 Relationship Patterns Between Cumulative Ecological Risk and Smartphone Addiction

Rauer et al. (2008) identified three relationship patterns between cumulative ecological risk and problem behaviors. First, the "positive acceleration pattern" assumes that the effect of a single risk on problem behavior differs significantly depending on the presence of other risks, manifesting as "the total effect of risks being greater than the sum of individual risk effects."Second, the "linear pattern" assumes that each additional risk increases problem behavior by a constant unit. Third, the "negative acceleration pattern" assumes that the effect of each newly added risk on problem behavior diminishes over time.

Smartphone addiction, as a problem behavior, is subject to these relationship patterns. Li et al. (2016) examined the relationship pattern between cumulative ecological risk and internet addiction, finding a "negative acceleration pattern." Although previous research has investigated the relationship between adolescent cumulative ecological risk and smartphone addiction, the specific pattern remains unexplored (Xie et al., 2024). Following established procedures (Zhang, 2024), we examined relationship patterns by analyzing the linear and quadratic terms of cumulative ecological risk in relation to study variables. When both linear and quadratic terms are significant and directionally consistent, this indicates a "positive acceleration pattern" ; when significant but directionally inconsistent, a "negative acceleration pattern" ; and when only the linear term is significant, a "linear pattern."

Based on the above review, this study hypothesized: H1: Both linear and quadratic terms of cumulative ecological risk significantly and positively predict smartphone addiction. H2: Both linear and quadratic terms of cumulative ecological risk significantly and positively predict smartphone addiction through parallel and chain mediating effects of psychological capital and self-control.

2.1 Participants

Using cluster sampling, sixth-grade students from an elementary school in Tai' an, Shandong Province were selected for a one-year longitudinal survey. The first wave included 1,329 participants, and the second wave included 1,263 participants (attrition rate = 4.97%). Missing values for attrited participants were replaced using sequential mean imputation, yielding a final sample of 1,329. At the initial survey (December 2022), participants were born between 2009 and 2011, including 706 boys (53.1%) and 623 girls (46.9%); 423 were from urban areas (31.8%) and 906 from rural areas (68.2%), with 50% reporting annual family income above 30,000 RMB.

2.2.1 Cumulative Ecological Risk Scale

Cumulative ecological risk was measured using the Cumulative Ecological Risk Questionnaire revised by Wei (2022), comprising four dimensions (family, school, society, and network), 12 risk types, and 66 items. The questionnaire used a 7-point scale (1 = "completely disagree," 7 = "completely agree"). Following the cumulative ecological risk model, each risk type was dichotomously coded (1 = risk present, 0 = risk absent) using the 75th percentile as the cutoff, and the 12 coded risks were summed to create a cumulative ecological risk index. The scale demonstrated good internal consistency (Cronbach' s $\alpha = 0.89$) and structural validity: ^{2}/df = 1.88, TLI = 0.99, CFI = 0.998, RMSEA = 0.03, SRMR = 0.01.

2.2.2 Psychological Capital

Psychological capital was measured using the Positive Psychological Capital Questionnaire developed by Zhang (2010), consisting of 26 items rated on a 7-point scale (1 = "completely disagree,"7 = "completely agree"). The scale showed strong internal consistency (Cronbach' s $\alpha = 0.91$) and structural validity: ^{2}/df = 2.56, TLI = 0.97, CFI = 0.98, RMSEA = 0.03, SRMR = 0.03.

2.2.3 Self-Control

Self-control was measured using the Self-Control Scale developed by Tangney et al. (2004) and revised by Tan and Guo (2008), comprising 19 items rated on a 5-point scale (1 = "completely disagree," 5 = "very much agree"). The scale demonstrated adequate internal consistency (Cronbach' s $\alpha = 0.83$) and structural validity: ^{2}/df = 2.32, TLI = 0.97, CFI = 0.98, RMSEA = 0.03, SRMR = 0.02.

2.2.4 Smartphone Addiction

Smartphone addiction was measured using the Smartphone Addiction Scale for College Students developed by Su et al. (2014), consisting of 22 items rated on a 5-point scale (1 = "very much disagree," 5 = "very much agree"). The scale

showed excellent internal consistency (Cronbach' s $\alpha = 0.94$) and structural validity: ^{2}/df = 3.31, TLI = 0.97, CFI = 0.98, RMSEA = 0.04, SRMR = 0.02.

2.3 Common Method Bias Test

This study employed Harman' s single-factor test to assess common method bias across all variables (Podsakoff et al., 2003). The results revealed 19 factors with eigenvalues greater than 1, with the largest common factor explaining 17.23% of variance, below the critical threshold of 40%, indicating no significant common method bias.

2.4 Data Analysis

Gender, household registration, age, and socioeconomic status (SES) at T1 were included as control variables. Data analysis was conducted using SPSS 23.0 and AMOS 24.0.

3.1 Descriptive Statistics and Correlation Analysis

As shown in Table 1 , correlations between demographic and study variables were consistent with expectations.

Table 1 Descriptive Statistics and Correlation Analysis
Note: N = 1329. p* < 0.05, **p* < 0.01,** $p < 0.001$. The same applies below. Variables 1–4 are control variables. Gender and household registration are dummy variables (0 = female and rural, 1 = male and urban).*

3.2 Direct Effects

As illustrated in Figure 1 [Figure 1: see original paper], after controlling for gender, household registration, age, and SES, a structural equation model was constructed with T1 cumulative ecological risk and its quadratic term as independent variables and T2 smartphone addiction as the dependent variable. The model demonstrated good fit: ^{2}/df = 2.35, TLI = 0.99, CFI = 0.995, GFI = 0.99, RMSEA = 0.03, SRMR = 0.03. T1 cumulative ecological risk significantly and positively predicted T2 smartphone addiction ($\beta = 0.20$, SE = 0.33, p = 0.001), and the T1 quadratic term also significantly and positively predicted T2 smartphone addiction ($\beta = 0.26$, SE = 0.04, p < 0.001), indicating a "positive acceleration pattern" in the relationship between T1 cumulative ecological risk and T2 smartphone addiction.

Furthermore, under two reference standards, controlling for other ecological risk factors at T1 significantly changed the effect of T1 ecological risk on T2 smartphone addiction. Before controlling, all 12 ecological risk main effects were significant; after controlling, only 8 remained significant, with individual risk effects smaller than the cumulative ecological risk effect.

Figure 1 Direct Effects Model
Note: Solid lines indicate significant paths; dashed lines indicate non-significant paths.

3.3 Mediating Effects of Psychological Capital and Self-Control

Psychological capital and self-control were added as mediators to the direct effects model (see Figure 2 [Figure 2: see original paper]). The model showed good fit: ^{2}/df = 2.31, TLI = 0.989, CFI = 0.994, GFI = 0.99, RMSEA = 0.03, SRMR = 0.03. T1 cumulative ecological risk significantly and negatively predicted T2 psychological capital (β = -0.70, SE = 0.67, p < 0.001) and T2 self-control (β = -0.53, SE = 0.30, p < 0.001). The T1 quadratic term significantly and positively predicted T2 psychological capital (β = 0.21, SE = 0.07, p = 0.001), T2 self-control (β = 0.21, SE = 0.03, p = 0.002), and T2 smartphone addiction (β = 0.37, SE = 0.03, p < 0.001). T2 psychological capital significantly and positively predicted T2 self-control (β = 0.29, SE = 0.01, p < 0.001) and significantly and negatively predicted T2 smartphone addiction (β = -0.11, SE = 0.01, p < 0.001). T2 self-control significantly and negatively predicted T2 smartphone addiction (β = -0.30, SE = 0.03, p < 0.001). These results indicate "negative acceleration patterns" in the relationships between cumulative ecological risk and both psychological capital and self-control. Bootstrapping was used to test mediation effects, revealing six paths with 95% confidence intervals excluding zero, confirming the mediation pathways (see Table 2).

Note: Solid lines indicate significant paths; dashed lines indicate non-significant paths.

Figure 2 Mediation Effects Model

Table 2 Bootstrapping Tests of Mediation Path Effects

4.1 Impact of Cumulative Ecological Risk on Smartphone Addiction

The detrimental effect of cumulative ecological risk on adolescent smartphone addiction reflects that adolescent smartphone addiction results from the synergistic interplay of family, school, social, and online factors. For example, adolescents experiencing social adversity and cyberbullying who lack caring parents or teachers due to poor relationships may use mobile social networking to seek help, sympathy, or vent emotions through mobile games (Chen et al., 2021; Xie & Xie, 2020). Once they regard their phone as their closest "friend," they may develop addiction through excessive dependence (Qu et al., 2017). Additionally, bioecological theory posits that individuals are influenced not only by environments with which they directly interact but also by interactions among environmental factors (Bronfenbrenner & Morris, 1998). Although this study did not directly examine interactions among family, school, social, and online risks, the total effect of cumulative ecological risk far exceeding any single risk effect demonstrates that smartphone addiction is a product of multiple environmental factors working synergistically. Moreover, controlling for other risks

significantly reduced individual risk effects, indicating that examining a single risk in isolation may overestimate its impact.

4.2 Mediating Roles of Psychological Capital and Self-Control

Cumulative ecological risk significantly increased smartphone addiction through both parallel and chain mediating effects of psychological capital and self-control. First, results showed that cumulative ecological risk weakened self-control capacity, thereby increasing smartphone addiction risk, consistent with previous findings (Sun et al., 2017). Second, cumulative ecological risk depleted psychological capital, leading to increased smartphone addiction risk. As a chronic multiple stressor, cumulative ecological risk gradually consumes psychological capital, rendering individuals more vulnerable when coping with stress. They may increasingly rely on mobile phones to seek social support or release pressure, forming dependencies that lead to addiction (Zeng et al., 2025). Finally, cumulative ecological risk impaired self-control precisely because it reduced psychological capital. Psychological capital is crucial for self-control when facing external pressures and temptations, and cumulative ecological risk gradually depletes this capital through accumulated stressors, diminishing self-control and making individuals more susceptible to the vicious cycle of smartphone addiction (Peng et al., 2022). This suggests that support from family, school, society, and network functions as the "living water source" of psychological capital; when this source diminishes, psychological capital decreases significantly. Since self-control depends on abundant psychological capital, this "deficit model" reduces self-control levels, leading to uncontrolled mobile phone use and addiction. Furthermore, the parallel mediation of psychological capital and self-control indicates that, beyond psychological capital, cumulative ecological risk may deplete other potential psychological resources that cause self-control failure and ultimately smartphone addiction; additionally, psychological capital reduced by cumulative ecological risk does not entirely lead to smartphone addiction through self-control failure.

4.3 Relationship Patterns Between Cumulative Ecological Risk and Smartphone Addiction

This study found that the quadratic term of cumulative ecological risk directly and positively predicted smartphone addiction, showing a "positive acceleration pattern," indicating that each additional risk' s impact on smartphone addiction gradually intensifies. This suggests that interventions must minimize every possible risk, otherwise the situation may become irreversible, consistent with previous research (Tian et al., 2023). However, other studies have found "linear patterns" (e.g., Forehand et al., 1998) or "negative acceleration patterns" (e.g., Appleyard et al., 2005) between cumulative ecological risk and other problem behaviors, suggesting that relationship patterns vary across different problem behaviors. This study also found that the quadratic term of cumulative ecological risk influenced smartphone addiction through parallel and chain mediating

effects of psychological capital and self-control, both showing "negative acceleration patterns." This implies that the number of cumulative ecological risks needs to be controlled within a certain range; otherwise, interventions aimed at reducing smartphone addiction by increasing psychological capital and self-control may become less effective.

4.4 Limitations and Future Directions

First, the risks within family, school, social, and online ecosystems far exceed the 12 risks measured; thus, using only a 12-risk model may not fully represent the total cumulative risk across these four subsystems. Future research should continuously expand the cumulative ecological risk model for smartphone addiction to better reflect reality. Second, the dichotomous coding approach may result in loss of important information and cannot adequately capture interactions among ecological risks (Ellis et al., 2009). Future studies could employ big data analytics and machine learning to deeply explore interaction patterns among ecological risks and better reveal the true process of how cumulative ecological risk affects smartphone addiction.

This study yields the following conclusions: (1) Cumulative ecological risk significantly and positively predicts smartphone addiction, showing a "positive acceleration pattern"; (2) Cumulative ecological risk significantly and positively predicts smartphone addiction through parallel and chain mediating effects of psychological capital and self-control (both showing "negative acceleration patterns").

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Note: Figure translations are in progress. See original paper for figures.