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FULL-LENGTH REPORT

Trajectory of problematic smartphone use among adolescents aged 10–18 years: The roles of childhood family environment and concurrent parent–child relationships

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ABSTRACT

Background and aims: Adolescence is a period of high incidence of problematic smartphone use. Understanding the developmental trajectory of problematic smartphone use in adolescence and its influencing factors could guide the choice of timing for prevention and intervention. This study fitted the growth trajectory of problematic smartphone use among adolescents and examined its associations with the childhood family environment and concurrent parent–child relationships. *Methods:* Using a cohort sequential design, we investigated 2,548 Chinese adolescents and their parents three times in three years. Multiple group multiple cohort growth models were used to fit the growth trajectory. *Results:* The quadratic growth trajectory of problematic smartphone use in adolescents aged 10–18 years showed a clear increasing trend, with a possible decreasing trend in late adolescence or early adulthood. Early life socioeconomic status, childhood family unpredictability, and the concurrent parent–child relationship had unique impacts on the development of problematic smartphone use during adolescence. *Discussion and conclusions:* Early adolescence is a favorable time for problematic smartphone use prevention and intervention. A supportive family environment should be maintained throughout the different developmental stages of children and adolescents.

KEYWORDS

problematic smartphone use, developmental trajectory, childhood family environment, parent–child relationship

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INTRODUCTION

Smartphones are increasingly used in today's world. In 2021, the number of smartphone users worldwide is estimated to exceed 6.37 billion (Statista, 2021). In China, 986 million people had used smartphones to surf the internet, accounting for 99.7% of all Chinese internet users (CNNIC, 2021b). In the United States, more than 90% of 18-year-old adolescents have their own smartphones (Rideout & Robb, 2019). Smartphones are the most widely used smart devices among Chinese youth, providing important support for flexible learning during the COVID-19 pandemic (CNNIC, 2021a; Huang et al., 2020). While smartphones bring many conveniences to adolescents' lives and education, they also pose some potential risks to users' physical and mental health (UNICEF, 2017). One of these is problematic smartphone use (PSU), which refers to an uncontrolled overuse of smartphones that leads to impaired interpersonal and social functioning and psychological and behavioral problems (Billieux, 2012; Busch & McCarthy, 2021). Some researchers have argued that PSU shares many similarities with behavioral addictions, such as gambling and internet game disorders (Felt & Robb, 2016). Previous studies have found positive associations between PSU and symptom severity of anxiety and depression in adolescents (Chen et al., 2016; Lapierre, Zhao, & Custer, 2019; Sohn, Rees, Wildridge, Kalk, & Carter, 2019; Thomée, 2018; Yang et al., 2021) and negatively correlated with academic achievement and interpersonal relationships (Herrero, Urueña, Torres, & Hidalgo, 2019; Huang, Lai, Li, Luo, & Wang, 2021; Samaha & Hawi, 2016; Zhang et al., 2021). Thus, it is important to explore the development of PSU, identify the reasons adolescents become overdependent on smartphones, and find appropriate ways to resolve the problem.

Development of PSU across adolescence

Adolescence is a period of high incidence of PSU (Gutiérrez, de Fonseca, & Rubio, 2016). More specifically, adolescents aged 17–19 years have the highest prevalence of PSU (Sohn et al., 2019). According to the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, reduced executive functioning and reduced inhibitory control contribute importantly to the development and maintenance of specific Internet-use disorders (Brand, Young, Laier, Wölfling, & Potenza, 2016). During adolescence, the brain's social-emotional and cognitive control systems develop asynchronously (Steinberg, 2008). This brain development pattern may make mid-adolescence a period of heightened vulnerability to PSU. Also, PSU may decline between adolescence and adulthood because of changes in the brain's cognitive control system that improve an individual's executive functioning and inhibitory control. Considering adolescents' vulnerability to PSU, it is important to explore the developmental trajectory of PSU in adolescents. Understanding the developmental trajectory could guide the development of intervention strategies (Tóth-Király et al., 2021). If PSU follows a progressive trend consistent with the development of stable psychological traits, early preventive measures to avoid PSU at the beginning of children's smartphone use are necessary. Conversely, if the developmental trajectory of PSU does not follow a fixed pattern and shows a high degree of malleability and environmental reactivity, then a strategy of ongoing prevention and intervention should be implemented. Additionally, the trajectory of PSU could provide a reference for assessing the severity of PSU in adolescents at different ages. Accordingly, this study assessed the development of PSU throughout adolescence.

Currently, few studies address the developmental trajectory of PSU in adolescents. Existing studies cover a limited age range, and different studies have failed to reach a consensus on key issues such as the direction of change. Researchers measured PSU in Chinese freshmen four times over two years and found that the extent of PSU among 18- to 20-year-old adolescents fluctuated but did not show significant trends (Yang et al., 2021). Using a linear function to fit the developmental trajectory of PSU in Swiss adolescents aged 12–15 years, a decreasing trend was found for this group (Marciano, Schulz, & Camerini, 2021). The Korean Children and Youth Panel Survey found that the PSU of students showed an upward trend between 4th to 7th and 5th to 8th grades (Cho, 2019; Kim, Park, & Park, 2021), while the PSU of students from different cohorts showed different trends between 7th grade and 10th grade (Yoo, 2021). The traditional single cohort longitudinal design takes a long time, suffers from severe subject loss, is contaminated due to repeated measures of the same individuals, and confounds the developmental and cohort effects with each other (Duncan, Duncan, & Hops, 1996; Preacher, Wichman, MacCallum, & Briggs, 2008). Therefore, it is difficult to study the developmental trajectory of adolescents' PSU using a single cohort longitudinal design. A cohort sequential design is an accelerated longitudinal design that can effectively integrate age and developmental effects to fit the developmental trajectory over a longer age span with limited follow-up times (Duncan, Duncan, & Strycker, 2006; Moerbeek, 2011). The accuracy of the developmental trajectories fitted by this approach is very close to that of a single cohort longitudinal design (Duncan et al., 1996). Therefore, this study used a cohort sequential design for the investigation and multiple group multiple cohort growth models to fit the developmental trajectory of PSU among adolescents aged 10–18 years.

Family factors and PSU

The family environment is the most important developmental environment for children and adolescents. According to the I-PACE model, both biopsychological constitution (e.g., early childhood experiences) and social cognitions (e.g., perceived social support) are antecedents of specific Internet-use disorders (Brand et al., 2016). Early life adversity refers to the lack of stimuli and the presence of harmful and threatening stimuli during normal development early in life, which can be detrimental to an individual's physical and mental health throughout life (Moreira et al., 2020; Pine & Fox, 2015; Sonuga-Barke et al., 2017; Turner, Thomas, & Brown, 2016), and it includes PSU (Forster, Rogers, Sussman, Watts, et al., 2021; Forster, Rogers, Sussman, Yu, et al., 2021; Liu, Zhang, & Chen, 2020; Zhang & Wu, 2022). In human societies, poverty and the unpredictability of living and parenting environments are important aspects of early life adversity (Ellis, Figueredo, Brumbach, & Schlomer, 2009). The parent–child relationship is a two-way interpersonal relationship between parents and children. It is not only a reflection of the outcomes of parent–child interactions but also an important reflection of parental social support, which has important implications for adolescents' behavioral problems and ICT use (Laursen & Collins, 2009; Smetana, Campione-Barr, & Metzger, 2006). As a behavioral problem, PSU may be associated with poor parent–child relationships. The social skill model of problematic internet use suggests that individuals with social skill defects and poor offline interpersonal relationships may have a preference for online social interactions and use ICT to meet their needs of relatedness, which may lead to uncontrolled ICT use, problematic ICT use and other negative results (Caplan, 2003, 2010). The negative correlation between the parent–child relationship and PSU has also been confirmed in empirical studies (Huang et al., 2021; Xie, Chen, Zhu, & He, 2019; Zhang et al., 2021).

Few studies have examined the impact of both early life and concurrent family factors on adolescents. Some researchers argue that adolescents who experience early life adversity are more likely to be hindered in their early attachment behaviors and have difficulty establishing strong and lasting emotional connections with others, such as good parent–child relationships (Thompson, 2016; Umberson, Williams, Thomas, Liu, & Thomeer, 2014). They emphasize the role of adolescents' current family interpersonal relationships. Other researchers suggest that early life adversity may cause individuals to develop a series of cognitive and behavioral tendencies to enjoy the present moment while ignoring future risks (Del Giudice, Gangestad, & Kaplan, 2016; Ellis & Del Giudice, 2019; Zhang & Wu, 2022), of which PSU is only one. Concurrent family interpersonal relationships did not assume a particular role in the framework of their studies.

In summary, it is unclear whether early life adversity and concurrent family interpersonal relationships have a unique role in the development and maintenance of PSU in adolescents. This study used a growth model with time-invariant and time-varying covariates to examine the relationships between early life socioeconomic status (SES), childhood family unpredictability, concurrent parent–child relationships, and PSU. Considering that some studies have found that gender is an influencing factor of adolescents' PSU (Fischer-Grote, Kothgassner, & Felnhofer, 2019), this study also included gender as a covariate.

METHOD

Participants

In this longitudinal study, 10-, 13-, and 16-year-olds from 61 classes of 12 randomly selected basic education schools in four cities of central China were surveyed. Participant recruitment advertisements were distributed to all students in these classes, and formal invitations were sent to students who expressed interest in participating in the study, including themselves and their legal guardians. Participants were surveyed at three time points (April 2019, July 2020, and April 2021). A total of 2,582 adolescents were invited to participate in the longitudinal study. Among them, 2,548, 2,168, and 2,261 adolescents participated in Waves 1 to 3, respectively. One of the participants' parents reported family information (e.g., parental education, annual family income, early life SES, and childhood unpredictability).The retention rate of Wave 2 was affected because it was difficult to reach some adolescents during that time. The demographic information of the participants is shown in Table 1.

Measures

Problematic smartphone use. The smartphone addiction proneness scale developed for adolescents by Kim, Lee, Lee, Nam, and Chung (2014) was used to measure PSU. This scale has gained popularity among researchers (Harris, Regan, Schueler, & Fields, 2020). We used a revised Chinese version of the scale (Lai et al., 2022), which consists of 16 items and includes four dimensions: (1) disturbance of adaptive functions; (2) withdrawal; (3) tolerance; and (4) virtual life orientation. Students were asked to rate the frequency of the described events on a 4-point Likert scale ranging from 1 = *never* to 4 = *always*. Higher scores indicated a higher propensity for PSU. In this study, the Cronbach's α was 0.94.

Early life SES. The childhood SES scale developed by Griskevicius and colleagues was adapted to measure early life

Table 1. Demographic information of participants

Variables	Groups	Cohort 1	Cohort 2	Cohort 3
Age in Wave 1	–	10.37±0.38	13.50±0.50	16.02±0.38
Gender	Female	48.3%	49.0%	56.3%
	Male	51.7%	51.0%	43.7%
Residence	City	50.5%	48.7%	51.5%
	Township	18.6%	21.9%	26.2%
	Rural region	30.9%	29.4%	23.3%
Only child	Yes	93.9%	96.9%	76.3%
	No	6.1%	3.1%	23.7%
Mother's education	< College	74.2%	90.5%	80.7%
	≧ College	25.8%	9.5%	19.3%
Father's education	< College	69.6%	89.3%	76.7%
	≧ College	30.4%	10.7%	23.3%
2018 Annual income	< ¥50,000	53.4%	73.8%	54.2%
	¥50,000–100,000	26.3%	15.7%	30.3%
	> ¥100,000	20.3%	10.5%	15.5%

Note. ¥ = CNY.

SES (Griskevicius, Delton, Robertson, & Tybur, 2011; Griskevicius, Tybur, Delton, & Robertson, 2011; Griskevicius et al., 2013). We used the Chinese version (Jiaying Wang & Chen, 2016), consisting of four items (e.g., "In the first few years after the child's birth, our family usually had enough money for things"). Parents were asked to indicate their level of agreement with the four statements on a 5-point scale with anchors ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicated higher levels of early life SES. In this study, the Cronbach's α was 0.86.

Childhood unpredictability. The childhood unpredictability scale and family unpredictability scale were adapted to measure childhood unpredictability (Mittal, Griskevicius, Simpson, Sung, & Young, 2015; Luo, Niu, & Chen, 2020; Ross & Hill, 2000; Ross & McDuff, 2008). This measure consists of nine items (e.g., "Things were often chaotic in my house"). Parents were instructed to "Think back to your life before the child started third grade." Then, they were asked to rate their level of agreement with nine statements on a 5-point scale with anchors ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicated higher levels of childhood unpredictability. In this study, the Cronbach's α was 0.86.

Parent–child relationship. The network of relationships questionnaire was used to measure parent–child relationships (Furman & Buhrmester, 1985). We used the short form in Chinese (Zhang et al., 2021), which includes 13 items and two dimensions: (1) support and (2) negative interaction. Students were asked to rate the frequency of the described events on a 5-point Likert scale ranging from 1 = *never* to 5 = *always*. Higher scores indicated higher levels of parent-child relationships. In this study, the Cronbach's α was 0.86.

Procedure

The procedure in Waves 1 & 3 was for the adolescents to fill out the questionnaire independently, and one parent of each participant reported some information related to the parent and family environments, such as parental education and annual household income. In Wave 2, the link to the online questionnaire was sent to the participants via WeChat, a popular communication application that is easily accessible to Chinese adolescents.

Statistical analysis

We conducted descriptive statistics and missing value analysis in SPSS (version 25) and SPSS Missing Value Analysis software. In this study, the average missing rate for each variable was 3.35%. Little's MCAR (missing completely at random) test showed that the missing data (χ^2 = 309.214, *df* = 110, $P < 0.001$) were not MCAR. We used a maximum likelihood (ML) estimation procedure to estimate missing item-level data and an expectation-maximization imputation method for missing case-level data (Little & Rubin, 2020). Then, we fitted the trajectories of PSU and identified the predictors by multiple group multiple cohort growth models in Mplus 7.4 (Muthén & Muthén, 2015). The robust maximum likelihood estimator (MLR) was used to account for the non-normality of the data (Jichuan Wang & Wang, 2020). In general, growth models do not have to be assessed using fit indices as structural equation models do, and inadequate model fit does not diminish the growth modeling results. The primary use of the fit indices in this study is not to objectively assess model fit, but to make comparisons between models. We used the following indices (Bentler & Bonett, 1980; Bentler, 1990; Hu & Bentler, 1999; MacCallum, Browne, & Sugawara, 1996): the chi-square statistic (χ^2), the comparative fit index (CFI; acceptable >0.90, good >0.95), Tucker–Lewis index (TLI; acceptable >0.90, good >0.95), and the root mean square error of approximation (RMSEA; mediocre fit <0.10, fair fit <0.08, close fit <0.05). The final model with time-invariant and time-varying covariates is illustrated in Fig. 1.

Ethics

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Institutional Review Board (IRB) of the State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, China (CNL_A_0003_003). Electronic or written informed consent was obtained from all adolescents, guardians, teachers, and school administrators in this study.

RESULTS

Preliminary findings

First, the scores of the three cohorts in the three waves were analyzed by repeated measures ANOVA. The results showed that there were significant differences in PSU among cohort 1 ($F = 15.27$, $df = 2$, $P < 0.001$, $\eta^2 = 0.02$) and cohort 2 ($F = 12.87$, $df = 2$, $P < 0.001$, $\eta^2 = 0.01$) but not cohort 3 ($F = 1.79$, $df = 2$, $P = 0.168$, $\eta^2 < 0.01$). Repeated measures ANOVA showed significant differences in the parent–child relationship in cohort 1 ($F = 31.64$, $df = 2$, $P < 0.001$, $\eta^2 = 0.03$), cohort 2 ($F = 248.56$, $df = 2$, $P < 0.001$, $\eta^2 = 0.18$) and cohort 3 ($F = 90.10$, $df = 2$, $P < 0.001$, $\eta^2 = 0.16$). Figure 2 shows the levels of PSU and the parent–child relationship among adolescents of different ages in this study. As shown in Fig. 2, the means of adolescents' PSU showed an increasing trend with little fluctuation. The means of the adolescent parent–child relationship fluctuated noticeably, but it is difficult to identify a clear trend from the figure.

Trajectories of PSU

Linear and quadratic growth models without covariates were used to explore the trajectories of PSU, respectively. The

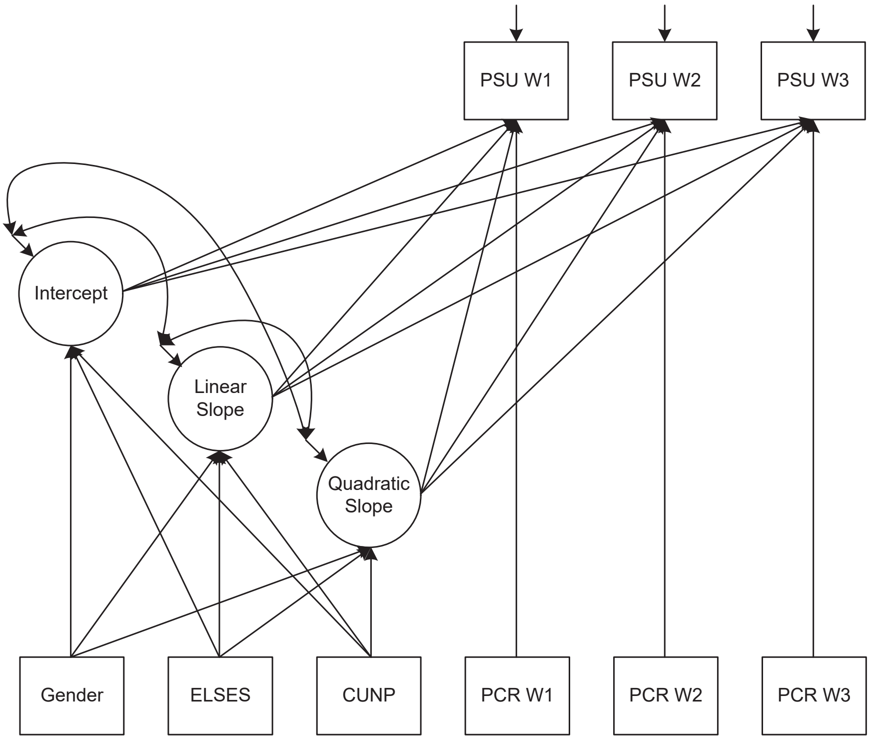

Fig. 1. Growth model with time-invariant and time-varying covariates
Note. ELSES = Early life SES; CUNP = Childhood unpredictability; PCR = Parent–child relationship; W1 = Wave 1; W2 = Wave 2; W3 = Wave 3

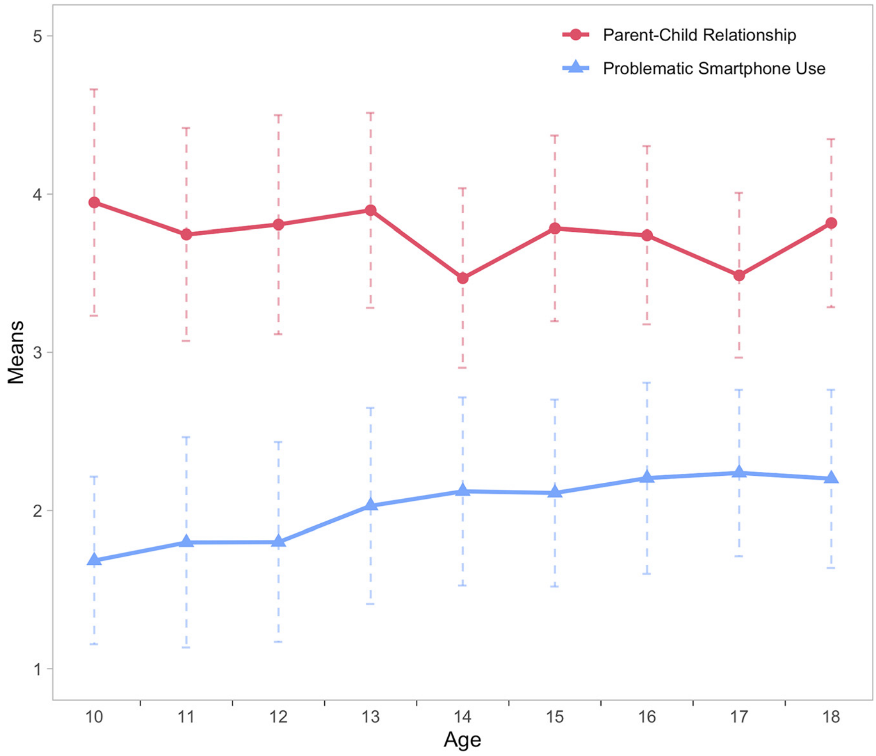

Fig. 2. PSU and parent–child relationship by age
Note. Error bars represent standard deviations

model fit of the linear growth trajectory of PSU was inadequate ($\chi^2(13) = 109.648$, $P < 0.001$, CFI = 0.839, TLI = 0.888, and RMSEA = 0.094, with 90% CI [0.078, 0.110]). The analysis suggested that the intercept ($M = 1.74$, $P < 0.001$) and the linear slope ($M = 0.70$, $P < 0.001$) were different from zero. Unlike the linear growth trajectory, the quadratic growth trajectory had an adequate model fit ($\chi^2(9) = 54.094$, $P < 0.001$, CFI = 0.925, TLI = 0.925, and RMSEA = 0.077, with 90% CI [0.058, 0.097]). The analysis suggested that the intercept ($M = 1.70$, $P < 0.001$), the linear slope ($M = 1.23$, $P < 0.001$), and the quadratic slope ($M = -0.73$, $P < 0.001$) were different from zero. In the quadratic growth model, the variances of the linear slope were statistically significant ($P = 0.032$), while those of the intercept ($P = 0.105$) and the quadratic slope ($P = 0.664$) were not. Although the intercept and quadratic slope variances were nonsignificant, it is known that the Wald test (a standard measure in Mplus) has low power to detect variance when only three time points are used (Hertzog, Von Oertzen, Ghisletta, & Lindenberger, 2008). Adding covariates may increase power, and thus pick out variance more effectively (Burns, Martin, & Collie, 2019). The χ^2 difference test based on loglikelihood values and scaling correction factors obtained with the MLR estimator was computed (Satorra & Bentler, 2010). The quadratic growth model was found to fit significantly better than the linear growth model ($\Delta\chi^2 = 55.447, \Delta df = 4, P < 0.001$). Changes in CFI and RMSEA values between these nested models were also monitored with combination of cut-offs: ΔCFI <0.01, ΔRMSEA <0.015 (F. F. Chen, 2007; Cheung & Rensvold, 2002). There were definite differences between the two models (ΔCFI = 0.086, ΔRMSEA = 0.017). Therefore, the quadratic growth model was used as the basis for the subsequent analysis. Based on the model-estimated trajectory parameters, we plotted linear and quadratic growth trajectories of PSU among adolescents aged 10–18 years (see Fig. 3). Using the formula for the vertex coordinate of the univariate quadratic function, it could be estimated that the PSU scores of adolescents might peak at the age of 18.43. The PSU of adolescents older than age 18 may show a decreasing trend.

Roles of gender, childhood family environment, and concurrent parent–child relationships

First, a quadratic growth model with early life SES, childhood family unpredictability, and gender as time-invariant covariates was used to explore the role of the childhood family environment. This model had an adequate model fit ($\chi^2(27) = 83.483$, $P < 0.001$, CFI = 0.937, TLI = 0.916, and RMSEA = 0.050, with 90% CI [0.038, 0.062]). Then, concurrent parent–child relationship was added into the model as time-varying covariate. This model also had an adequate model fit ($\chi^2(45) = 119.297$, $P < 0.001$, CFI = 0.948, TLI = 0.927, and RMSEA = 0.044, with 90% CI [0.035, 0.054]). Table 2 displays the association between PSU growth trajectories and covariates. The results showed that the initial level of PSU was lower in male adolescents, while it increased at a slower rate. The early life SES of adolescents did not significantly predict the initial level of PSU, but

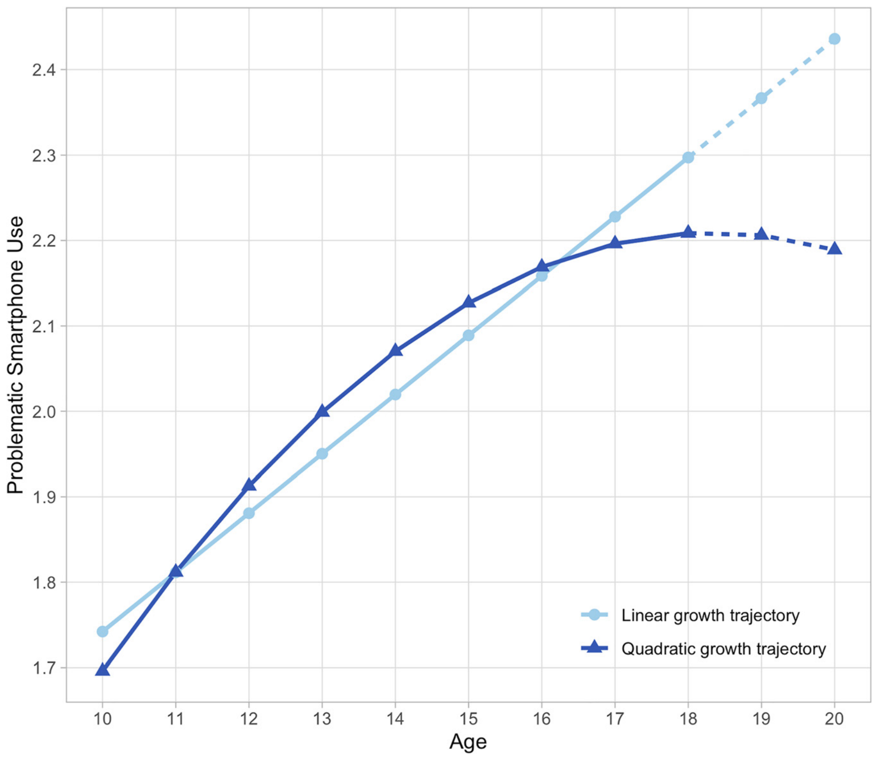

Fig. 3. Linear and quadratic growth trajectories of PSU
Note. Trajectories after age 18 predicted by the models are presented with dashed lines

Table 2. Association between PSU growth trajectory and covariates

	Model 1			Model 2		
	b	*SE*	*p*	*b*	*SE*	*p*
Gender → Intercept	−0.11	0.03	0.001	−0.09	0.03	0.004
Gender → Linear slope	0.53	0.18	0.003	0.42	0.17	0.015
Gender → Quadratic slope	−0.64	0.22	0.004	−0.49	0.22	0.025
Early life SES → Intercept	0.00	0.02	0.888	0.00	0.02	0.878
Early life SES → Linear slope	−0.29	0.10	0.003	−0.23	0.10	0.019
Early life SES → Quadratic slope	0.38	0.13	0.004	0.31	0.13	0.015
Childhood unpredictability → Intercept	0.10	0.03	<0.001	0.09	0.03	<0.001
Childhood unpredictability → Linear slope	0.12	0.14	0.395	−0.13	0.14	0.366
Childhood unpredictability → Quadratic slope	0.07	0.18	0.683	0.32	0.19	0.081
PCR → PSU (age 10)				−0.16	0.02	<0.001
PCR → PSU (age 11)				−0.22	0.02	<0.001
PCR → PSU (age 12)				−0.28	0.02	<0.001
PCR → PSU (age 13)				−0.26	0.01	<0.001
PCR → PSU (age 14)				−0.29	0.02	<0.001
PCR → PSU (age 15)				−0.27	0.02	<0.001
PCR → PSU (age 16)				−0.24	0.02	<0.001
PCR → PSU (age 17)				−0.22	0.03	<0.001
PCR → PSU (age 18)				−0.17	0.04	<0.001

Note. Gender was coded as: 1 = male; 2 = female. PCR = Parent–child relationship.

adolescents with high early life SES had slower PSU growth. Childhood unpredictability significantly and positively predicted the initial level of PSU. Although the impact of the childhood family environment on adolescents' PSU development was reflected in the model, there was still a clear association between PSU and the concurrent parent–child relationship. For adolescents of each age, the parent–child relationship had an effect on PSU: the worse the parent–child relationship was, the higher the propensity for PSU. Additionally, the inclusion of the concurrent parent–child relationship as a time-varying covariate did not meaningfully change the role of the childhood family environment.

DISCUSSION

Trajectories of PSU

Unlike the parent–child relationship pattern, the developmental trajectory of PSU in adolescents aged 10–18 years shows a clear increasing trend, with a possible decreasing trend in late adolescence or early adulthood. This trend is consistent with previous research on adolescent addictive behaviors and PSU development (Cousijn, Luijten, & Feldstein Ewing, 2018; Fischer-Grote et al., 2019; Sohn et al., 2019). This result can be explained by the I-PACE model: decreased executive function and reduced inhibitory control resulting from the asynchronous development of the social-emotional and cognitive control systems of the adolescents' brain may make late adolescence a period of high PSU prevalence (Brand et al., 2016; Steinberg, 2008). Towards the end of adolescence, the growth of PSU slows and potentially begins to decline, implying that adolescents may be a major risk group for PSU. Prevention and interventions for PSU should focus on adolescents. However, this does not mean that PSU in adulthood does not warrant the attention of researchers. First, although PSU may show a decreasing trend in adults, adults with high PSU are at risk. For example, adults who drive cars may be involved in traffic accidents and incur significant physical and financial losses due to excessive smartphone use (Nguyen-Phuoc, Oviedo-Trespalacios, Su, De Gruyter, & Nguyen, 2020). Second, this study found that the variation in the linear slope in the quadratic model was significant, indicating that there were individual differences in this parameter among the adolescent population. The variation of this parameter in the equation affects the estimation of the age of peak PSU, indicating that although the trend of PSU is consistent among the adolescent population, there may be some individual differences in the age of peak PSU. Therefore, this result should be interpreted with caution.

Roles of childhood family environment and concurrent parent–child relationships

This study found that early life SES and childhood family unpredictability have impacts on the development of PSU during adolescence. This finding provides supporting evidence for the I-PACE model. Early life adversity may make adolescents more inclined to satisfy their short-term needs through excessive smartphone use while ignoring its long-term damage on their education and interpersonal relationships (Del Giudice et al., 2016). After considering the impact of the childhood family environment on PSU development, this study still found significant correlations between a negative parent–child relationship and PSU in adolescents of all ages. This result further emphasizes the importance of the family social support on adolescent development and provides support for the I-PACE model and the social skill model of problematic internet use (Brand et al., 2016; Caplan, 2003, 2010). Overall, the above results show that the family environment has an important impact on the development of adolescent PSU, both in childhood and adolescence. Although adolescents have a high degree of developmental plasticity (Foulkes & Blakemore, 2018), the influence of the family environment and experience from childhood and even early life continues. However, adolescents with early life adversity should not feel depressed, and they can still reduce the risk of PSU by improving their current family interpersonal relationships. Additionally, for adolescents who are unable to change their family environment, PSU may also be a strategy for coping with stress (Kardefelt-Winther, 2014). Evolutionary psychologists believe that while behavioral problems caused by early life adversity may be harmful to adolescents, they may also increase adolescents' adaptability to developmental environments (Ellis, Bianchi, Griskevicius, & Frankenhuis, 2017).

Implications, limitations, and future directions

The main contribution of this study is its novel description of the trajectory of PSU development in adolescents aged 10–18 years in a Chinese population. This trajectory may provide an important reference for evaluating the severity of PSU levels in adolescents of the same age group. Based on the trend in adolescent PSU identified in this study, PSU follows a stable, increasing trajectory consistent with the development of a rigid psychological trait. Researchers should devise early intervention strategies to prevent the emergence of PSU. The favorable time for PSU prevention and intervention is more likely to be early adolescence rather than late adolescence, although late adolescence is the most severe period for PSU, which is relevant to policy-makers and educators. In addition, this study explored the impact of family factors on adolescent PSU at different developmental stages and suggested that educators and parents should pay attention to creating a family environment that is conducive to the development of children and adolescents at different ages.

Although this study presented several important findings regarding the development of adolescent PSU, some limitations need to be considered. First, the study was conducted in China, thus our conclusions cannot be generalized to other countries. Future research should include cross-cultural samples in prospective studies. Second, we used a single method (survey) to collect data from two different sources (adolescents and their parents), which might be affected by social desirability and common method biases. In further studies, multi-informative data collection methods are needed, such as field observation. Third, because there were no subjects aged 19–21 years, this study cannot directly make conclusions about the development of PSU in early adulthood. Future research could focus on this developmental stage to further clarify whether the PSU in this age group shows a decreasing trend. Fourth, this study adopted only three time points follow-up, which might limit the power to detect individual variance. Future research could take more time points to detect individual variance more effectively.

CONCLUSIONS

This study found that PSU in adolescents aged 10–18 years showed an increasing trend, slowing down with age. Family environmental factors during childhood and adolescence were related to adolescent PSU. A supportive family environment should be maintained throughout the different developmental stages of children and adolescents.

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Authors' contribution: X-XL: study concept and design, data curation, analysis and interpretation of data, writing of the original draft, review and edit the draft. S-SH: data curation, review and edit the draft. CN: statistical analysis, writing of the original draft, review and edit the draft. J-JY: study supervision, review and edit the draft. Y-JL: data curation. YW: study concept and design, obtained funding, study supervision, review and edit the draft. Y-HL: study supervision, review and edit the draft. All authors contributed to and approved the final manuscript.

Conflicts of interest: None.

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