

ARTICLE

Exploring the trajectories of problematic smartphone use in adolescence: Insights from a longitudinal study

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Abstract

The goal of the present study was to investigate the trajectories of problematic smartphone use among adolescents and its predictors, including self-regulation, fear of missing out (FoMO), depression, and anxiety among Canadian adolescents. A total of 2549 participants (1025 girls; $M_{\text{age}} = 14.10$ years, $SD = 0.96$ years) from grades 8 to 12 in Southern British Columbia, Canada, took part in the study. Self-reported problematic smartphone use was collected annually over 4 years. At Time 1, adolescents provided self-reports on self-regulation, depression, anxiety, and FoMO. Growth mixture modelling was used to examine the trajectories of problematic smartphone use. The results revealed three distinct trajectories: low-increasing-decreasing (35.5%), moderate-increasing (60.9%), and high-stable (3.6%). Multinomial logistic regression revealed that higher FoMO and depression were significant predictors of membership in the high-stable problematic smartphone use group, while better self-regulation predicted lower problematic smartphone use. These findings highlight the dynamic nature of problematic smartphone use and the importance of self-regulation and mental health in understanding problematic smartphone use trajectories among Canadian adolescents.

KEYWORDS

adolescents, anxiety, depression, fear of missing out, problematic smartphone use, self-regulation

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Statement of contribution

- Identified three trajectories of adolescent problematic smartphone use over four years.
- High-stable users showed consistently high use; most followed a moderate-increasing pattern.
- Depression and FoMO predicted higher risk; self-regulation was protective.

INTRODUCTION

The pervasive use of smartphones among adolescents has become a defining feature of contemporary youth culture, presenting both opportunities and challenges (Vaterlaus et al., 2021). Specifically, while smartphones offer various benefits, including instant access to information and social connectivity, there is a growing concern about problematic smartphone use, characterized by excessive and compulsive usage patterns that interfere with daily life (Gioia et al., 2021). The heightened sensitivity to social influences and ongoing maturation of self-regulatory capacities that are characteristic of adolescence makes this developmental stage particularly vulnerable to the development of problematic smartphone use (Xiao et al., 2024). For example, as youth increasingly orient towards their peers, they may spend more time online connecting with and checking in on their peers. Additionally, as their self-regulation skills are still developing, it may be particularly difficult for youth to effectively manage their device use (Pandey et al., 2018). Indeed, rates of problematic smartphone use increase drastically in adolescence, with the global prevalence of problematic smartphone use among adolescents ranging from 10% to 30%, with higher rates observed in regions with greater smartphone penetration, such as East Asia and Europe (Kuss et al., 2018; Wu & Siu, 2020). Additionally, recent work has identified profound links between internalizing problems and problematic smartphone use in adolescence (Wang et al., 2020; Zhou et al., 2023), suggesting that this may function as another important risk factor. While recent work has begun identifying how developmental characteristics such as self-regulation and peer relations may act as key predictors of problematic smartphone use in adolescence (e.g., peer relationships; Wang et al., 2023); fear of missing out (FoMO; Xiao et al., 2023), low self-control, and high impulsivity (Montag et al., 2015; Van Deursen et al., 2015), the majority of these studies have been cross-sectional, offering only a snapshot of these relationships at a single point in time, which limits our understanding of how problematic smartphone use develops and changes during adolescence. To this end, this study explored the longitudinal trajectories of problematic smartphone use among Canadian adolescents and identified key predictors—such as self-regulation, fear of missing out, depression, and anxiety – that influenced these trajectories over time.

The developmental trajectories of problematic smartphone use in adolescence

Problematic smartphone use encompasses a range of compulsive and potentially harmful behaviours online, including excessive engagement with social media, gaming, and impulsive online activities (Elhai et al., 2016; Fineberg et al., 2018; Gioia et al., 2021). Problematic use has been associated with various challenges in adolescents' lives, including academic difficulties and both physical and mental health issues (Hughes & Burke, 2018; Sourander et al., 2010). For example, Li et al. (2019) identified a link between problematic smartphone use and low self-esteem among children. Similarly, a study by Demirci et al. (2015) found that problematic smartphone use was associated with increased levels of depression and anxiety among adolescents.

Adolescents' increased access to smartphones, driven by their widespread availability, has led to heightened concerns about dependency on these devices (Marciano et al., 2021). The COVID-19 pandemic further intensified these concerns, as lockdowns and social distancing measures necessitated

greater reliance on digital devices for socializing, education, and entertainment (Lai et al., 2022; Yang et al., 2021). This shift likely contributed to an increase in problematic smartphone use among adolescents, as prolonged screen time became more prevalent during extended periods of remote learning and restricted social interactions (Freitas et al., 2023; Serra et al., 2021). Studies exploring the general trajectory of problematic smartphone use suggest heterogeneous patterns across different populations and age groups (Lai et al., 2022; Xiao et al., 2024; Yoo, 2024a, 2024b). For example, research among Chinese university students indicates that problematic smartphone use tends to stabilize during late adolescence and early adulthood, showing little significant change over time (Yang et al., 2021). Conversely, studies focusing on Swiss adolescents suggest a potential decline in problematic smartphone use as they mature, reflecting possible improvements in smartphone usage habits among older adolescents (Marciano et al., 2021). That said, the variability in problematic smartphone use trajectories becomes more apparent when considering different cultural contexts and societal norms (Billieux et al., 2015; Montag & Reuter, 2017). Canada's sociocultural landscape offers a distinct context that may influence the development and trajectories of PSU among adolescents. With a smartphone penetration rate of 87% among Canadians in 2021 and ~88% of youth aged 15–24 reporting that they check their phones at least once every hour, Canadian adolescents are among the most digitally connected globally (Statista, 2023). Moreover, Canada's multicultural population introduces diverse cultural norms and social expectations that can intensify adolescents' sensitivity to social comparison and social pressure (Haight et al., 2016). Specifically, youth navigating multiple cultural identities may rely more on social media for social integration and identity formation, making them more susceptible to FoMO and validation-seeking behaviours (Ogibi, 2015). By examining PSU within this unique Canadian context, the current study contributes to a nuanced understanding of how cultural, technological, and educational factors intersect to influence adolescent digital behaviour.

In addition, research from the Korean Children and Youth Panel Survey highlights this complexity, identifying diverse trajectories among school students, including both increasing trends and cohort-specific variations in problematic smartphone use (Son et al., 2021; Yoo et al., 2021). These findings underscore the influence of environmental factors and technological landscapes on adolescent behaviours related to smartphone use. Moreover, longitudinal studies among Chinese college students reveal distinct patterns in problematic smartphone use over time, with some individuals showing a decrease in problematic usage over time while others exhibited an increase (Wang et al., 2022). This variability suggests that initial levels of problematic smartphone use and individual differences play significant roles in shaping developmental trajectories.

To effectively capture and understand these diverse patterns, growth mixture modelling (GMM) offers a robust methodological approach (Jung & Wickrama, 2008; Muthén, 2004). GMM allows researchers to identify latent subgroups within a population that follow distinct trajectories of problematic smartphone use (Ram & Grimm, 2009). By categorizing individuals based on their developmental paths of problematic smartphone use, GMM enables a more nuanced analysis of why certain adolescents may be more prone to developing problematic usage habits than others (Yoo, 2024a, 2024b). Accordingly, we explored the longitudinal trajectories of problematic smartphone use among Canadian adolescents using GMM.

Predictors of problematic smartphone use trajectories

Guided by the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, this study investigated the trajectories of problematic smartphone use by examining the roles of FoMO, self-regulation, and internalizing symptoms such as depression and anxiety. The I-PACE model posits that specific Internet-use disorders emerge from the interaction of personal predispositions (e.g., emotion regulation difficulties), affective responses (e.g., anxiety, depression), cognitive biases (e.g., FoMO), and reduced executive functioning (e.g., poor self-regulation) (Brand et al., 2016). In line with this framework, FoMO was conceptualized as a cognitive bias that may heighten sensitivity to social rewards, while depression

and anxiety reflect affective responses that may drive maladaptive coping behaviours. Self-regulation was examined as an indicator of executive control capacity, which may buffer or exacerbate problematic use. By integrating these psychological factors, we aimed to clarify how individual vulnerabilities shape the progression of problematic smartphone use during adolescence, a developmental period marked by heightened susceptibility to digital overuse (De-Sola Gutiérrez et al., 2016). This approach supports a theory-driven understanding of risk factors and informs the development of targeted interventions to reduce harm and promote adolescent well-being.

Fear of missing out (FoMO)

FoMO has emerged as a significant psychological factor driving problematic smartphone use, particularly among adolescents (Elhai et al., 2018). FoMO refers to the pervasive apprehension that others might be having rewarding experiences from which one is absent (Przybylski et al., 2013). This anxiety can lead to compulsive behaviours, such as constantly checking smartphones to avoid missing out on social interactions or updates (Elhai et al., 2020). The literature indicates that high levels of FoMO are associated with increased problematic smartphone use and can contribute to its escalating trajectory over time (Coco et al., 2020; Xiao et al., 2023). Adolescents who experience FoMO are likely to develop maladaptive coping strategies that reinforce smartphone overuse, thereby deepening their dependence and increasing the likelihood of experiencing negative consequences (Coco et al., 2020). Therefore, we expected that adolescents with higher levels of FoMO are more likely to fall into the group with an increasing trajectory of problematic smartphone use compared with those with lower levels of FoMO.

Self-regulation

Self-regulation, the ability to manage one's thoughts, emotions, and behaviours in pursuit of long-term goals, plays a crucial role in determining an individual's susceptibility to problematic smartphone use (Novak & Clayton, 2001). Deficits in self-regulation are consistently linked to various forms of behavioural addictions, including problematic smartphone use (Brand et al., 2016). Adolescents with poor self-regulation may struggle to control their smartphone use, particularly when faced with stressors or emotional challenges, leading to a faster increasing trajectory of problematic smartphone use (Xiao et al., 2024). On the other hand, those with strong self-regulatory skills are better equipped to set limits on their smartphone use, resist temptations, and maintain a balanced digital lifestyle (Gökçeşlan et al., 2016). Therefore, we expect that adolescents with higher levels of self-regulation are less likely to fall into the group with an increasing trajectory of problematic smartphone use compared with those with lower levels of self-regulation.

Mental health

Mental health is a critical factor in the development and progression of problematic smartphone use, yet it remains underexplored within the I-PACE model context. Psychological conditions such as depression and anxiety have been identified as predictors of faster growing problematic smartphone use trajectories (Do & Kim, 2024). Adolescents with poor mental health may use smartphones excessively as a coping mechanism, seeking solace or distraction from their distress (Crowhurst & Hosseinzadeh, 2024). This maladaptive coping strategy can lead to a vicious cycle, where increased smartphone use exacerbates mental health issues, which in turn fuels further smartphone dependency (Wang & Ma, 2024). Therefore, we expected that adolescents with higher levels of depression and anxiety would be more likely to fall into the group with an increasing trajectory of problematic smartphone use compared with those with lower levels of depression and anxiety.

The present study

The goal of the present study was to investigate the trajectories of problematic smartphone use among adolescents and its predictors, including self-regulation, FoMO, depression, and anxiety among Canadian adolescents. This study aimed to address the following research questions: (1) What are the distinct trajectories of problematic smartphone use among adolescents over time? (2) How do self-regulation, FoMO, depression, and anxiety predict membership in different problematic smartphone use trajectory groups? We hypothesized that there would be multiple distinct trajectories of problematic smartphone use, such as increasing, stable, and decreasing patterns. Additionally, we hypothesized that higher levels of FoMO and depression would be associated with higher and more stable problematic smartphone use trajectories. In contrast, better self-regulation would be associated with lower problematic smartphone use trajectories.

METHOD

Participants

Participants in this 4-year longitudinal study were recruited from five public schools in Southern British Columbia, Canada, and included 2549 participants from grade 8 to grade 12 (1025 girls; $M_{\text{age}} = 14.10$ years, $SD = 0.96$ years) at Time 1. Approximately, 65.4% of participants were born in Canada. The sample was ethnically diverse, with approximately 41.8% self-identifying as East Asian; 30.4% White/Caucasian; 4.6% South Asian; 17.8% Southeast Asian; 3.7% West Asian; 4.5% Latin American; 3.6% Indigenous, and 1.4% Other (e.g., Caribbean).

Follow-up data were collected in the same schools once a year in (T2–T4). At T2–T4, 2023, 1522, and 1346 participants provided data, respectively. Little's (1988) MCAR test was not significant, $\chi^2(2945) = 3019.25$, $p = .132$, suggesting that the pattern of missingness was not systematic. To further confirm that the pattern of missingness was not systematic, we conducted a series of tests comparing characteristics of adolescents who dropped out of the study to those who remained in the study. Results indicated no significant differences on the main study variables at Wave 1, including problematic smartphone use ($t = -1.16$, $p = .24$), depression ($t = -1.73$, $p = .08$), anxiety ($t = -0.69$, $p = .49$), FoMO ($t = 1.67$, $p = .09$), and self-regulation ($t = -1.08$, $p = .28$). Additionally, no gender differences were observed between groups ($\chi^2 = 3.97$, $p = .41$). However, there was a significant age difference at Time 1, with adolescents who dropped out being slightly older ($M = 14.48$, $SD = 0.93$) than those who remained in the study ($M = 13.68$, $SD = 0.78$; $t = -10.63$, $p < .001$). Thus, full information maximum likelihood was used to estimate missing data in Mplus 7.2 (Muthen & Muthen, 1998–2012).

Procedure

The present study received ethical approval from the institutional review board of The University of British Columbia. Written consent was obtained from all participants at all three time points, with passive consent from parents through their schools. To show appreciation for participation, all students from each school were entered into a draw for a chance to win a smartphone at each time point. Data collection took place separately at each school between October 2020 and March 2021. Follow-up data were collected once a year in (W2–W4) within the same schools. All self-report questionnaires were completed online through Qualtrics (www.qualtrics.com) on participants' personal devices during school hours.

Measures

Self-regulation

Participants completed the Self-Regulation Questionnaire (Novak & Clayton, 2001). The scale contained 13 items on 4-point Likert scale, ranging from 1 (Never true for me) to 5 (Always true for me), which comprised three subscales: emotional self-regulation (five items, e.g., 'I have a hard time controlling my temper'), behavioural self-regulation (four items, e.g., 'As soon as I see things that are not working, I do something about it'), and cognitive self-regulation (three items, e.g., 'I develop a plan for all my important goals'). A composite variable was created by calculating the average score across all items. This measure has demonstrated evidence of reliability and validity among Western adolescents (Novak & Clayton, 2001). In the present sample, this measure also demonstrated good internal reliability ($\alpha = .79$).

Problematic smartphone use

Smartphone addiction was measured using the Smartphone Addiction Scale – Short Version (SAS-SV; Kwon et al., 2013). The measure is comprised of 10 items that are rated on a 6-point Likert scale, ranging from 1 (Strongly disagree) to 6 (Strongly agree). Sample items included 'I use my phone longer than intended'. A composite variable was created by calculating the average score across all items. This measure has been shown to have good psychometric properties (De Pasquale et al., 2017). In the present sample, this measure also demonstrated high internal reliability ($\alpha = .83, .84, .84, .86$) at each time point.

Internalizing problems

To assess their mental health, adolescents completed the Depression, Anxiety, and Stress Scale (DASS- 21, Lovibond & Lovibond, 1995). For this analysis, we focused on two subscales: depression (seven items; e.g., 'I couldn't seem to experience any positive feeling at all') and anxiety (seven items; e.g., 'I was aware of dryness of my mouth'), that are rated on a 4-point Likert scale, ranging from 1 (Did not apply to me at all) to 4 (Applied to me very much or most of the time). Sum scores are computed by adding up the scores on the items per (sub)scale and multiplying them by 2. These cut-off scores are derived from a set of severity ratings, proposed by Lovibond and Lovibond (1995). Specifically, scores = 0–14 are labelled as 1 (Normal), scores = 15–18 are labelled as 2 (Mild), scores = 19–25 are labelled as 3 (Moderate), scores = 26–33 are labelled as 4 (Severe), and scores >34 are labelled as 5 (Extremely Severe). This measure has been shown to have reliable psychometric properties (Zanon et al., 2021).

Fear of missing out (FoMO)

FoMO was measured using the fear of missing out scale (FoMO; Przybylski et al., 2013). The FoMO scale is comprised of 10-items (e.g., 'I get worried when I find out my friends are having fun without me') rated on a 5-point Likert scale, ranging from 1 (Never) to 5 (All of the time). A composite variable was created by calculating the average score across all items. This measure has demonstrated evidence of reliability and validity among Canadian adolescents (Parent et al., 2021). In the present sample, this measure also demonstrated good internal reliability ($\alpha = .86$).

Statistical analytic strategy

Both latent growth curve modelling (LGCM) and growth mixture model (in Mplus 7) were used to examine the trajectories of problematic smartphone use. We first used LGCM to explore the general trajectory of problematic smartphone use among adolescents. To evaluate the absolute model fit, we used the following fit indices: comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), and χ^2 -test of significance (see Hu & Bentler, 1999). A close fit is indicated by CFI and TLI values >0.90 (Hu & Bentler, 1999). In addition, a close fit is indicated by RMSEA values <0.06, whereas an adequate fit is indicated by values between 0.06 and 0.08. SRMR values <0.08 indicate a good fit.

We employed the ‘3-step’ method for GMM estimation (Vermunt, 2010), which supports the integration of predictors into the analysis. This approach maintains the integrity of the initial class structure (from the unconditional model) by mitigating the potential effects of covariates using the auxiliary variable feature in Mplus (Muthén, 2003). The decision on model fit incorporated a variety of criteria, including the Akaike information criterion (AIC) and Bayesian information criterion (BIC) to balance model fit and complexity, the Lo–Mendell–Rubin adjusted likelihood ratio test (LMR) and bootstrapped parametric likelihood ratio test (BLRT) to compare models with different numbers of classes, entropy, and classification probabilities to assess the distinctness and clarity of class assignments, and indicators of model instability such as any class containing fewer than 10% of the sample. Additionally, the evaluation of the classes based on theoretical considerations and researcher judgement was essential to ensure that the identified classes made sense in the context of existing literature and conceptual frameworks (Muthén & Muthén, 2000). Next, we examined if self-regulation, FoMO, depression, and anxiety could predict which of the identified latent classes adolescents would fall into. This was done using the R3STEP auxiliary function, which employs multinomial logistic regression for analysis.

RESULTS

Preliminary analyses

Descriptive statistics and intercorrelations among study variables are presented in Table 1. Measured invariance of problematic smartphone use over the four time points was then assessed. The fully constrained model (i.e., equal loadings and intercepts across time) had adequate levels of fit (CFI = 0.90, TLI = 0.90, SRMR = 0.029, Δ CFIs = −0.003–0.001, Δ RMSEAs = −0.001–0.000). These results indicated that the measurement of problematic smartphone use displayed strong invariance across time in our

TABLE 1 Descriptive statistics and intercorrelations among study variables.

	1	2	3	4	5	6	7	8
1. PSU T1	1							
2. PSU T2	.58**	1						
3. PSU T3	.31**	.34**	1					
4 PSU T4	.47**	.43**	.36**	1				
5. FoMO T1	.36**	.23**	.16**	.13**	1			
6. Self-regulation T1	−.39**	−.26**	−.16**	−.21**	−.35**	1		
7. Depression T1	.37**	.29*	.14**	.20**	.39**	−.46**	1	
8. Anxiety T1	.33**	.19**	.05	.11	.32**	−.34**	.55**	1
<i>M</i>	2.38	2.63	2.66	2.62	2.33	2.78	3.89	4.46
<i>SD</i>	.82	.84	.83	.86	.76	.50	.89	.74

* $p < .05$. ** $p < .01$.

study. Strong invariance ensures that changes over time reflect true developmental differences rather than measurement inconsistencies. This provides a reliable foundation for interpreting the identified trajectories of problematic smartphone use. Next, we conducted both linear and quadratic LGCM analyses for problematic smartphone use. The results showed that the quadratic model provided good data fit (model fits see Table 2). The general developmental trajectory of problematic smartphone use increased first and then decreased over 4 years (see Table 2).

Additionally, a series of independent *t*-tests were conducted to investigate gender differences in all study variables. The results indicated that there were no significant gender differences in any of the variables (p s = .07–.45).

GMM of PSU

Results from a GMM of problematic smartphone use indicated three distinct trajectories of problematic smartphone use. The corresponding trajectories of estimated means and estimated individual values are depicted in Figure 1. The trajectories contained (a) a low-increasing-decreasing trajectory (905 students, 35.50% of the sample, intercept = 1.72, SE = 0.06, t = 27.41, p < .001; linear slope = 0.45, SE = 0.11, t = 3.90, p < .001; quadratic slope = -0.12, SE = 0.04, t = -2.99, p = .003): this trajectory started low at T1, showing gradual increases through subsequent time points; (b) a moderate-increasing trajectory (1552 students, 60.89% of the sample, intercept = 2.62, SE = 0.14, t = 18.89, p < .001; linear slope = 0.23, SE = 0.10, t = 2.27, p = .02; quadratic slope = -0.05, SE = 0.03, t = -1.44, p = .15): students in this trajectory presented a moderate level of problematic smartphone use at T1 that increased during this period; and (c) a high-stable trajectory (92 students, 3.61% of the sample, intercept = 3.88, SE = 0.29, t = 13.45, p < .001; linear slope = -0.17, SE = 0.29, t = -0.58,

TABLE 2 The means and variances of intercept, linear slope, and quadratic slope in LGCM of PSU.

Model	Model fit					Mean			Variance		
	$\chi^2(df)$	p	CFI	RMSEA	SRMR	Intercept	Linear slope	Quadratic slope	Intercept	Linear slope	Quadratic slope
Linear LGCM	55.91 (5)	.000	0.80	0.06	0.08	2.45***	0.07***	—	0.36***	0.02	—
Quadratic LGCM	3.20 (5)	.07	0.99	0.03	0.02	2.35**	0.29***	-0.07***	0.93***	0.58**	0.01

** p < .01. *** p < .001.

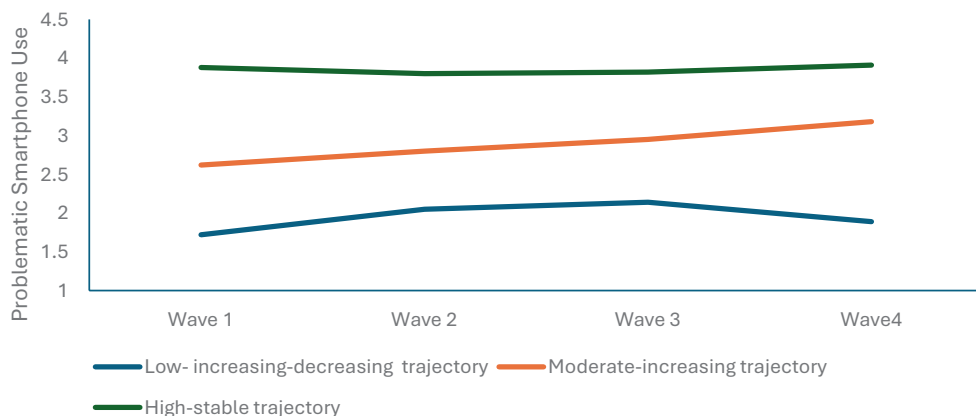


FIGURE 1 Three class model for PSU trajectories.

$p = .56$; quadratic slope = 0.07, $SE = 0.08$, $t = 0.81$, $p = .42$) in which problematic smartphone use was high at T1 and stable over 4 years.

Conditional GMM with covariates predicting class membership

The next set of analyses explored the roles of self-regulation, FoMO, depression, and anxiety as predictors of problematic smartphone use latent class membership using multinomial logistic regression. Results are displayed in Table 3. Compared with the low-increasing-decreasing and moderate-increasing groups, both FoMO and depression significantly predicted an increased likelihood of membership in the high-stable group. In addition, compared with the moderate-increasing group, self-regulation significantly predicted a decreased likelihood of membership in the high-stable group. Furthermore, compared with the moderate-increasing group, self-regulation significantly increased the likelihood of belonging to the low-increasing-decreasing group, while depression significantly decreased the likelihood of membership in this group. There were no significant effects on anxiety (Table 4).

DISCUSSION

The present study aimed to investigate the developmental trajectories of problematic smartphone use among adolescents and identify key predictors such as self-regulation, FoMO, depression, and anxiety. Our findings identified three distinct problematic smartphone use trajectories: low-increasing-decreasing, moderate-increasing, and high-stable. These trajectories underscore the dynamic nature of problematic smartphone

TABLE 3 Results of different latent class growth analyses.

Class	AIC	BIC	ABIC	Entropy	VLMR-LRT	LMR-LRT	BLRT	Class probability
1	10,796.69	10,837.59	10,815.35	N/A	N/A	N/A	N/A	1
2	10,596.43	10,596.70	10,561.75	0.40	<0.001	<0.001	<0.001	0.651/0.349
3	10,447.83	10,535.48	10,487.82	0.59	0.035	0.037	<0.001	0.355/0.609/0.036
4	10,420.21	10,531.24	10,470.87	0.58	0.044	0.048	<0.001	0.053/0.003/0.638/0.306
5	10,411.56	10,545.96	10,472.88	0.46	0.300	0.307	<0.001	0.003/0.022/0.216/0.518/0.240

Note: $N = 2549$. Model fit indices for 1- to 5-class solutions. Bolded values indicate the best-fitting model based on a combination of information criteria (AIC, BIC, ABIC), entropy, and likelihood ratio tests (VLMR-LRT, LMR-LRT, and BLRT). The 3-class solution demonstrated a strong balance of model fit, parsimony, and classification accuracy and was selected as the optimal model.

Abbreviations: ABIC, sample-size adjusted BIC; AIC, Akaike information criterion; BIC, Bayesian information criterion; BLRT, bootstrap likelihood ratio test; LMR-LRT, Lo-Mendell-Rubin likelihood ratio test; VLMR-LRT, Vuong-Lo-Mendell-Rubin likelihood ratio test.

TABLE 4 Multinomial logit analysis of the associations between problematic smartphone use trajectory class membership and predictors at Time 1.

Covariate	Low-increase-decreasing vs. high-stable			Moderate-increasing			Low-increase-decreasing vs. Moderate-increasing		
	Est.	SE	OR	Est.	SE	OR	Est.	SE	OR
FoMO	-0.81**	0.32	2.5	-1.36**	0.46	2.9	-0.55	0.33	1.6
Self-regulation	0.43	0.67	0.64	1.94*	0.75	2.6	1.51***	0.41	3.6
Depression	-1.23**	0.46	2.66	-1.60**	0.49	3.3	-0.37*	0.19	1.9
Anxiety	0.20	0.49	0.54	-0.61	0.89	0.68	-0.61	0.33	1.8

Note: All values are unstandardized estimates.

Abbreviations: Est., estimate; OR, odds ratio; SE, standard error.

* $p < .05$. ** $p < .01$. *** $p < .001$.

use during adolescence, highlighting periods of both escalation and decline. Higher levels of FoMO and depression were significant predictors of membership in the high-stable problematic smartphone use group, suggesting that these factors play a crucial role in maintaining high levels of smartphone use. Conversely, better self-regulation was associated with lower problematic smartphone use, emphasizing the protective effect of self-regulatory abilities. These results align with the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, which posits that individual predispositions, affective and cognitive responses, and executive functioning interact to influence the development and maintenance of specific Internet-use disorders. The insights gained from this study highlight the importance of addressing FoMO, depression, and self-regulation in interventions aimed at reducing problematic smartphone use among adolescents.

The developmental trajectories of problematic smartphone use in adolescence

First, our results indicated that the general trajectory of problematic smartphone use increased initially and then decreased over the 4 years. This quadratic trend could be explained by the novelty and excitement associated with early smartphone use, which may lead to increased engagement and subsequent problematic behaviours (Billieux et al., 2015). Over time, as adolescents become more familiar with their devices and develop better self-regulation strategies, the novelty wears off, leading to a decrease in problematic smartphone use (Yang et al., 2021). Indeed, previous studies, including one that examined 2548 Chinese adolescents, identified a clear increasing trend in problematic smartphone use during early adolescence, followed by a potential decrease in late adolescence and early adulthood (Lai et al., 2022). This finding highlights the adaptability of most adolescents and their capacity to integrate smartphone use into their lives without long-term adverse effects.

The second trajectory depicted a moderate level of problematic smartphone use that gradually increased over the study period. This trend indicates a persistent and rising engagement with smartphones that may not abate over time. Adolescents in this group might be at a higher risk for developing more entrenched problematic behaviours, which could be attributed to various factors such as peer influence, the increasing utility of smartphones for social and academic purposes, or a lack of effective monitoring and guidance from parents and educators (Chen et al., 2017). For example, a survey conducted in a Canadian adolescent population depicted a rising trend in problematic smartphone use throughout the 2-year follow-up (Xiao et al., 2024). The persistence of this trajectory underscores the need for ongoing interventions that focus on promoting healthy smartphone habits and providing resources for adolescents to manage their usage.

The third trajectory exhibited consistently high levels of problematic smartphone use with little variation over the 4 years. Representing only 3.6% of the participants, adolescents in this group are of particular concern as their stable high use suggests a significant struggle with managing smartphone behaviours. This trajectory may reflect underlying issues, such as compulsive use patterns, susceptibility to smartphone addiction, or other co-occurring mental health conditions like anxiety or depression (Demirci et al., 2015; Elhai et al., 2016). Indeed, the Korean Children and Youth Panel Survey revealed that adolescents in the fourth grade exhibited a high level of problematic smartphone use at the baseline, which remained consistently elevated in subsequent years (Yoo, 2024a, 2024b). Although only a small subset of the study participants were in this group, interventions need to be more intensive and tailored, potentially incorporating cognitive-behavioural strategies and involving parents, teachers, and mental health professionals to address the multifaceted nature of their problematic smartphone use. Specifically, adolescents in this trajectory may represent a population with entrenched behavioural patterns and heightened psychological distress, making them less responsive to universal prevention strategies. As such, intervention efforts targeting this group should be intensive, individualized, and sustained. These may include cognitive-behavioural therapy (CBT) focused on impulse control and emotion regulation, psychoeducation on digital habits, and the involvement of parents, teachers, and mental health professionals to provide coordinated support across settings.

The identification of distinct problematic smartphone use trajectories underscores the heterogeneous nature of adolescent smartphone use, emphasizing the need for flexible, personalized engagement plans. Early and continuous education on responsible smartphone use, incorporating digital literacy and self-regulation strategies, is essential for adolescents (Anthonysamy et al., 2020). Open communication between parents and adolescents about smartphone habits and setting appropriate boundaries can mitigate the risk of problematic behaviours (Lauricella et al., 2016). Policymakers should support public health initiatives that promote healthy digital habits and fund research on effective interventions. Understanding the dynamics of problematic smartphone use, especially in light of increased smartphone dependency during the COVID-19 pandemic, is crucial for addressing its potential impacts on adolescents' mental health, academic performance, and overall well-being (Ellis et al., 2020).

Predictors of problematic smartphone use trajectories

In addition to identifying trajectories of problematic smartphone use among adolescents, we explored the roles of self-regulation, FoMO, depression, and anxiety in predicting these trajectories. Findings from these analyses provide valuable insights into how these factors influence different patterns of problematic smartphone use over time.

Fear of missing out (FoMO)

The results indicate that FoMO significantly predicted membership in the high-stable problematic smartphone use group compared with both the low-increasing-decreasing and moderate-increasing groups. That is, adolescents with higher levels of FoMO were more likely to exhibit consistently high levels of problematic smartphone use. This relationship can be understood through the psychological mechanism where FoMO, a pervasive concern of missing out on rewarding experiences that others might be having, compels individuals to frequently check their smartphones to stay connected and updated (Elhai et al., 2018; Przybylski et al., 2013). FoMO-driven behaviour creates a reinforcing loop whereby the more adolescents engage with their smartphones to mitigate their fear of missing out, the more entrenched their problematic smartphone use becomes (Elhai et al., 2020). This need for constant social validation and fear of social exclusion can lead to a compulsive pattern of smartphone use, which becomes difficult to break and stabilizes at a high level of usage (Elhai et al., 2018). Therefore, programmes that focus on helping adolescents develop healthier relationships with social media—by promoting the understanding that missing out is a normal part of life—could be effective. Additionally, teaching coping strategies that help manage FoMO, such as mindfulness and cognitive restructuring, might reduce the compulsion to constantly check smartphones, thereby lowering the risk of developing problematic smartphone use.

Self-regulation

In addition, self-regulation emerged as a significant predictor of problematic smartphone use trajectories. Compared with the moderate-increasing group, higher self-regulation was associated with a decreased likelihood of belonging to the high-stable group and an increased likelihood of membership in the low-increasing-decreasing group (Wilmer & Chein, 2016). This suggests that self-regulation acts as a protective factor against the development of persistent and high levels of problematic smartphone use. Adolescents with strong self-regulatory skills can effectively manage their smartphone use, preventing it from becoming problematic (Gökçeşlan et al., 2016). The protective role of self-regulation highlights its importance in interventions aimed at mitigating problematic smartphone use. Teaching adolescents self-regulation techniques, such as mindfulness practices, goal-setting, and time-management strategies

could empower them to use their smartphones more responsibly (Burleigh et al., 2018). By enhancing these skills, schools and parents can play a crucial role in helping adolescents maintain a balanced approach to technology use, reducing the likelihood of it becoming problematic.

Mental health

The study also explored the impact of mental health factors, specifically depression and anxiety, on problematic smartphone use trajectories. Depression significantly predicted an increased likelihood of membership in the high-stable group compared with the low-increasing-decreasing and moderate-increasing groups. Conversely, higher levels of depression decreased the likelihood of belonging to the low-increasing-decreasing group. This is in line with previous work which has consistently linked depression with heightened levels of problematic smartphone use (Elhai et al., 2018; Xiao et al., 2023). Indeed, adolescents experiencing depressive symptoms may turn to their smartphones as a form of escape from negative emotions or as a means of temporary relief from feelings of sadness, loneliness, or hopelessness (Elhai et al., 2016). This reliance on smartphones for emotional regulation can lead to a progressively increasing pattern of problematic smartphone use.

However, anxiety did not predict problematic smartphone use trajectory memberships. Interestingly, previous studies have also suggested that adolescents with anxiety may use smartphones to manage their fears and worries, seeking comfort through constant connectivity or reassurance from social interactions (Lachmann et al., 2018). However, this pattern was not observed in our study. It is possible that adolescents experiencing anxiety may seek out alternative coping strategies beyond smartphones, such as engaging in repetitive behaviours or avoiding social interactions altogether (Cao et al., 2025). Further research is needed to explore the nuanced relationship between anxiety and smartphone use.

Limitation and future direction

While the present study provides valuable insights into the trajectories of problematic smartphone use among adolescents, several limitations should be considered. First, the exclusive reliance on self-report questionnaires, such as the smartphone addiction scale-short version (SAS-SV) and the Depression, Anxiety, and Stress Scale (DASS-21), may have introduced bias due to participants' subjective perceptions and potential issues with social desirability or recall accuracy (Stone et al., 2000). These limitations may have led to distorted assessments of both smartphone use and mental health symptoms. Future research should incorporate objective data, such as screen time tracking, app usage patterns, and contextual information about smartphone interactions to enhance measurement precision and ecological validity (Andrews et al., 2015).

Moreover, while the study focused on psychological predictors of PSU trajectories – namely, self-regulation, FoMO, depression, and anxiety – it did not control for important contextual factors, such as socio-economic status (SES), parental control, peer influence, and access to technology. Prior research shows that lower SES is linked to different patterns of smartphone use (Rideout & Katz, 2016), parental monitoring can reduce the risk of problematic use (Lauricella et al., 2016), and peer pressure can reinforce excessive engagement (Nesi & Prinstein, 2015). Future research should incorporate these contextual influences to offer a more comprehensive and ecologically valid understanding of adolescent PSU trajectories.

Lastly, we did not examine outcomes associated with different trajectories of problematic smartphone use. Understanding the impact of these trajectories on academic performance, social relationships, and overall well-being is crucial for developing effective interventions (Twenge & Campbell, 2018). Future research should investigate these outcomes to provide a more comprehensive understanding of the consequences of problematic smartphone use trajectories.

Despite the limitations, this study revealed three distinct trajectories of PSU among adolescents, emphasizing the significant roles of self-regulation, FoMO, depression, and anxiety. Higher levels of

FoMO and depression predicted high-stable PSU, while better self-regulation was associated with lower problematic smartphone use. These findings underscore the dynamic nature of problematic smartphone use and its predictors, offering critical insights for stakeholders. Policymakers should develop mental health support policies and regulations to encourage healthier smartphone use in schools. Teachers can integrate digital literacy and self-regulation skills into their curricula and provide support for students showing signs of high problematic smartphone use (Gui et al., 2023). Parents should model healthy smartphone behaviour, set usage boundaries, and address mental health issues at home (Lauricella et al., 2016). Interventions should focus on enhancing self-regulation and providing mental health support to address FoMO, depression, and anxiety.

AUTHOR CONTRIBUTIONS

Bowen Xiao: Conceptualization; formal analysis; writing – original draft; writing – review and editing. **Haoyu Zhao:** Writing – original draft; writing – review and editing. **Claire Hein-Salvi:** Writing – original draft; writing – review and editing. **Natasha Parent:** Methodology; writing – review and editing; conceptualization. **Jennifer D. Shapka:** Conceptualization; methodology; supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors report no conflicts of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT

Approval was obtained from the ethics committee of The University of British Columbia. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

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REFERENCES

- Andrews, S., Ellis, D. A., Shaw, H., & Piwek, L. (2015). Beyond self-report: Tools to compare estimated and real-world smartphone use. *PLoS One*, 10(10), e0139004. <https://doi.org/10.1371/journal.pone.0139004>
- Anthonyamy, L., Koo, A. C., & Hew, S. H. (2020). Self-regulated learning strategies in higher education: Fostering digital literacy for sustainable lifelong learning. *Education and Information Technologies*, 25(4), 2393–2414. <https://doi.org/10.1007/s10639-020-10201-8>
- Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D. J., & Griffiths, M. D. (2015). Can disordered mobile phone use be considered a behavioral addiction? An update on current evidence and a comprehensive model for future research. *Current Addiction Reports*, 2(2), 156–162. <https://doi.org/10.1007/s40429-015-0054-y>

- Brand, M., Young, K. S., Laier, C., Wölfling, K., & Potenza, M. N. (2016). Integrating psychological and neurobiological considerations regarding the development and maintenance of specific internet-use disorders: An interaction of person-affect-cognition-execution (I-PACE) model. *Neuroscience & Biobehavioral Reviews*, 71, 252–266. <https://doi.org/10.1016/j.neubiorev.2016.08.033>
- Burleigh, T. L., Stavropoulos, V., Liew, L. W., Adams, B. L. M., & Griffiths, M. D. (2018). Depression, internet gaming disorder, and the moderating effect of the gamer-avatar relationship: An exploratory longitudinal study. *International Journal of Mental Health and Addiction*, 16(1), 12–25. <https://doi.org/10.1007/s11469-017-9806-3>
- Cao, H., Wang, S., Zhou, N., & Liang, Y. (2025). From childhood real-life peer victimization to subsequent cyberbullying victimization during adolescence: A process model involving social anxiety symptoms, problematic smartphone use, and internet gaming disorder. *Psychology of Violence*, 15(1), 106–120. <https://doi.org/10.1037/vio0000548>
- Chen, B., Liu, F., Ding, S., Ying, X., Wang, L., & Wen, Y. (2017). Gender differences in factors associated with problematic smartphone use: A cross-sectional study among medical college students. *BMC Psychiatry*, 17(1), 341. <https://doi.org/10.1186/s12888-017-1503-z>
- Coco, G. L., Salerno, L., Franchina, V., La Tona, A., Di Blasi, M., & Giordano, C. (2020). Examining bi-directionality between fear of missing out and problematic smartphone use. A two-wave panel study among adolescents. *Addictive Behaviors*, 106, 106360. <https://doi.org/10.1016/j.addbeh.2020.106360>
- Crowhurst, S., & Hosseinzadeh, H. (2024). Risk factors of smartphone addiction: A systematic review of longitudinal studies. *Public Health Challenges*, 3(2), e202. <https://doi.org/10.1002/puh2.202>
- De Pasquale, C., Sciacca, F., & Hichy, Z. (2017). Italian validation of smartphone addiction scale short version for adolescents and young adults (SAS-SV). *Psychology*, 8(10), 1513–1518. 110.4236/psych.2017.810100.
- Demirci, K., Akgönül, M., & Akpinar, A. (2015). Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students. *Journal of Behavioral Addictions*, 4(2), 85–92. <https://doi.org/10.1556/2006.4.2015.010>
- De-Sola Gutiérrez, J., Rodríguez de Fonseca, F., & Rubio, G. (2016). Cell-phone addiction: A review. *Frontiers in Psychiatry*, 7, 175. <https://doi.org/10.3389/fpsy.2016.00175>
- Do, K.-Y., & Kim, C.-B. (2024). Predicting smartphone addiction trajectories in Korean adolescents: A longitudinal analysis of protective and risk factors based on a National Survey from 2018 to 2020. *Asia-Pacific Journal of Public Health*, 36, 550–557. <https://doi.org/10.1177/10105395241259243>
- Elhai, J. D., Levine, J. C., Alghraibeh, A. M., Alafnan, A. A., Aldraiweesh, A. A., & Hall, B. J. (2018). Fear of missing out: Testing relationships with negative affectivity, online social engagement, and problematic smartphone use. *Computers in Human Behavior*, 89, 289–298. <https://doi.org/10.1016/j.chb.2018.08.020>
- Elhai, J. D., Levine, J. C., Dvorak, R. D., & Hall, B. J. (2016). Fear of missing out, need for touch, anxiety and depression are related to problematic smartphone use. *Computers in Human Behavior*, 63, 509–516. <https://doi.org/10.1016/j.chb.2016.05.079>
- Elhai, J. D., Yang, H., Fang, J., Bai, X., & Hall, B. J. (2020). Depression and anxiety symptoms are related to problematic smartphone use severity in Chinese young adults: Fear of missing out as a mediator. *Addictive Behaviors*, 101, 105962. <https://doi.org/10.1016/j.addbeh.2019.04.020>
- Ellis, L. A., Dumas, T. M., & Forbes, M. K. (2020). The role of social media during COVID-19: The importance of online social connections and support for wellbeing. *Translational Behavioral Medicine*, 10(5), 1171–1180.
- Fineberg, N. A., Demetovics, Z., Stein, D. J., Ioannidis, K., Potenza, M. N., Grünblatt, E., Brand, M., Billieux, J., Carmi, L., King, D. L., Rumpf, H. J., Lee, H. K., Chamberlain, S. R., & Yücel, M. (2018). Manifesto for a European research network into problematic usage of the internet. *European Neuropsychopharmacology*, 28(11), 1232–1246. <https://doi.org/10.1016/j.euroneuro.2018.08.004>
- Freitas, B. H. B. M., Gaíva, M. A. M., Diogo, P. M., & Bortolini, J. (2023). Factors related to self-reported smartphone addiction among Brazilian adolescents in the face of the COVID-19 pandemic: A mixed-method study. *Journal of Child and Adolescent Psychiatric Nursing*, 36(2), 124–133. <https://doi.org/10.1111/jcap.12401>
- Gioia, F., Rega, V., & Boursier, V. (2021). Problematic internet use and emotional dysregulation among young people: A literature review. *Clinical Neuropsychiatry*, 18(1), 41–54. <https://doi.org/10.36131/cnfioritieditore20210104>
- Gökçeşlan, Ş., Mumcu, F. K., Haşlamam, T., & Çevik, Y. D. (2016). Modelling smartphone addiction: The role of smartphone usage, self-regulation, general self-efficacy and cyberloafing in university students. *Computers in Human Behavior*, 63, 639–649.
- Gui, M., Gerosa, T., Argentin, G., & Losi, L. (2023). Mobile media education as a tool to reduce problematic smartphone use: Results of a randomised impact evaluation. *Computers & Education*, 194, 104705. <https://doi.org/10.1016/j.compedu.2022.104705>
- Haight, M., Quan-Haase, A., & Corbett, B. A. (2016). Revisiting the digital divide in Canada: The impact of demographic factors on access to the internet, level of online activity, and social networking site usage. In J. Earl & K. Kimport (Eds.), *Current research on information technologies and society* (pp. 113–129). Routledge.
- Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, 6(1), 1–55. <https://doi.org/10.1080/10705519909540118>
- Hughes, N., & Burke, J. (2018). Sleeping with the frenemy: How restricting ‘bedroom use’ of smartphones impacts happiness and wellbeing. *Computers in Human Behavior*, 85, 236–244. <https://doi.org/10.1016/j.chb.2018.03.047>

- Jung, T., & Wickrama, K. A. (2008). An introduction to latent class growth analysis and growth mixture modeling. *Social and Personality Psychology Compass*, 2(1), 302–317. <https://doi.org/10.1111/j.1751-9004.2007.00054.x>
- Kuss, D. J., Kristensen, A. M., & Lopez-Fernandez, O. (2018). Internet addictions outside of North America: A systematic review. *Computers in Human Behavior*, 83, 347–358. <https://doi.org/10.1016/j.chb.2020.106621>
- Kwon, M., Kim, D. J., Cho, H., & Yang, S. (2013). The smartphone addiction scale: Development and validation of a short version for adolescents. *PLoS One*, 8(12), e83558. <https://doi.org/10.1371/journal.pone.0083558>
- Lachmann, B., Sindermann, C., Sariyska, R. Y., Luo, R., Melchers, M. C., Becker, B., Cooper, A. J., & Montag, C. (2018). The role of empathy and life satisfaction in internet and smartphone use disorder. *Frontiers in Psychology*, 9, 398. <https://doi.org/10.3389/fpsyg.2018.00398>
- Lai, X., Huang, S., Nie, C., Yan, J. J., Li, Y., Wang, Y., & Luo, Y. (2022). Trajectory of problematic smartphone use among adolescents aged 10–18 years: The roles of childhood family environment and concurrent parent–child relationships. *Journal of Behavioral Addictions*, 11(2), 577–587. <https://doi.org/10.1556/2006.2022.00047>
- Lauricella, A. R., Wartella, E., & Rideout, V. J. (2016). Young children's screen time: The complex role of parent and child factors. *Journal of Applied Developmental Psychology*, 42, 57–65. <https://doi.org/10.1016/j.appdev.2014.12.001>
- Li, C., Liu, D., & Dong, Y. (2019). Self-esteem and problematic smartphone use among adolescents: A moderated mediation model of depression and interpersonal trust. *Frontiers in Psychology*, 10, 2872. <https://doi.org/10.3389/fpsyg.2019.02872>
- Little, R. J. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association*, 83(404), 1198–1202. <https://doi.org/10.1080/01621459.1988.10478722>
- Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the depression anxiety stress scales (DASS) with the Beck depression and anxiety inventories. *Behaviour Research and Therapy*, 33(3), 335–343. [https://doi.org/10.1016/0005-7967\(94\)00075-U](https://doi.org/10.1016/0005-7967(94)00075-U)
- Marciano, L., Schulz, P. J., & Camerini, A. L. (2021). How smartphone use becomes problematic: Application of the ALT-SR model to study the predicting role of personality traits. *Computers in Human Behavior*, 119, 106731. <https://doi.org/10.1016/j.chb.2021.106731>
- Montag, C., Blaszkiewicz, K., Lachmann, B., Sariyska, R., Andone, I., Trendafilov, B., Eibes, M., & Markowetz, A. (2015). Correlating personality and actual phone usage: Evidence from psychoinformatics. *Journal of Individual Differences*, 36(4), 217–225. <https://doi.org/10.1027/1614-0001/a000139>
- Montag, C., & Reuter, M. (2017). *Internet addiction* (pp. 143–150). Springer International Publishing.
- Muthén, B. (2004). Latent variable analysis: Growth mixture modeling and related techniques for longitudinal data. In D. Kaplan (Ed.), *Handbook of quantitative methodology for the social sciences* (pp. 345–368). Sage.
- Muthén, L. K., & Muthén, B. O. (1998–2012). *Mplus user's guide* (7th ed.). Muthén & Muthén.
- Muthén, B. (2003). Statistical and substantive checking in growth mixture modeling: Comment on Bauer and Curran (2003). *Psychological Methods*, 8(3), 369–377. <https://doi.org/10.1037/1082-989X.8.3.369>
- Muthén, B., & Muthén, L. K. (2000). Integrating person-centered and variable-centered analyses: Growth mixture modeling with latent trajectory classes. *Alcoholism: Clinical and Experimental Research*, 24(6), 882–891. <https://doi.org/10.1111/j.1530-0277.2000.tb02070.x>
- Nesi, J., & Prinstein, M. J. (2015). Using social media for social comparison and feedback-seeking: Gender and popularity moderate associations with depressive symptoms. *Journal of Abnormal Child Psychology*, 43, 1427–1438. <https://doi.org/10.1007/s10802-015-0020-0>
- Novak, S. P., & Clayton, R. R. (2001). The influence of school environment and self-regulation on transitions between stages of cigarette smoking: A multilevel analysis. *Health Psychology*, 20(3), 196–207. <https://doi.org/10.1037/0278-6133.20.3.196>
- Ogibi, J. D. (2015). Social media as a source of self-identity formation: Challenges and opportunities for youth ministry. <https://scholar.sun.ac.za/handle/10019.1/97862>
- Pandey, A., Hale, D., Das, S., Goddings, A. L., Blakemore, S. J., & Viner, R. M. (2018). Effectiveness of universal self-regulation-based interventions in children and adolescents: A systematic review and meta-analysis. *JAMA Pediatrics*, 172(6), 566–575. <https://doi.org/10.1001/jamapediatrics.2018.0232>
- Parent, N., Dadgar, K., Xiao, B., Hesse, C., & Shapka, J. D. (2021). Social disconnection during COVID-19: The role of attachment, fear of missing out, and smartphone use. *Journal of Research on Adolescence*, 31(3), 748–763. <https://doi.org/10.1111/jora.12658>
- Przybylski, A. K., Murayama, K., Dehaan, C. R., & Gladwell, V. (2013). Motivational, emotional, and behavioral correlates of fear of missing out. *Computers in Human Behavior*, 29(4), 1841–1848. <https://doi.org/10.1016/j.chb.2013.02.014>
- Ram, N., & Grimm, K. J. (2009). Methods and measures: Growth mixture modeling: A method for identifying differences in longitudinal change among unobserved groups. *International Journal of Behavioral Development*, 33(6), 565–576. <https://doi.org/10.1177/0165025409343765>
- Rideout, V., & Katz, V. S. (2016). Opportunity for all? Technology and learning in lower-income families. In *Joan Ganz Cooney center at sesame workshop*. Joan Ganz Cooney Center at Sesame Workshop. 1900 Broadway, New York, NY 10023.
- Serra, G., Lo Scalzo, L., Giuffrè, M., Ferrara, P., & Corsello, G. (2021). Smartphone use and addiction during the coronavirus disease 2019 (COVID-19) pandemic: Cohort study on 184 Italian children and adolescents. *Italian Journal of Pediatrics*, 47(1), 1–150. <https://doi.org/10.1186/s13052-021-01102-8>

- Son, H. G., Cho, H. J., & Jeong, K. H. (2021). The effects of Korean parents' smartphone addiction on Korean children's smartphone addiction: Moderating effects of children's gender and age. *International Journal of Environmental Research and Public Health*, 18(13), 6685. <https://doi.org/10.3390/ijerph18136685>
- Sourander, A., Rihko, M., Ristkari, T., Juvonen, J., Jantunen, H., & Helenius, H. (2010). Internet use, abuse, and suicidal behavior among Finnish adolescents: A cross-sectional study. *Archives of Suicide Research*, 14(2), 166–176.
- Stone, A. A., Bachrach, C. A., Jobe, J. B., Kurtzman, H. S., Cain, V. S., & Dietz, D. K. (Eds.). (2000). *The science of self-report: Implications for research and practice*. Psychology Press.
- Statista. (2023). Share of children with an electronic device in their home in the United States in 2019 and 2021, by type. <https://www.statista.com/statistics/1324245/children-owning-an-electronic-device-at-home-by-type-us/#:%E2%88%BC:text=During%20a%202021%20survey%20conducted,percent%20recorded%20two%20years%20before>
- Twenge, J. M., & Campbell, W. K. (2018). Associations between screen time and lower psychological well-being among children and adolescents: Evidence from a population-based study. *Preventive Medicine Reports*, 12, 271–283. <https://doi.org/10.1016/j.pmedr.2018.10.003>
- Van Deursen, A. J., Bolle, C. L., Hegner, S. M., & Kommers, P. A. (2015). Modeling habitual and addictive smartphone behavior: The role of smartphone usage types, emotional intelligence, social stress, self-regulation, age, and gender. *Computers in Human Behavior*, 45, 411–420. <https://doi.org/10.1016/j.chb.2014.12.039>
- Vaterlaus, J. M., Aylward, A., Tarabochia, D., & Martin, J. D. (2021). “A smartphone made my life easier”: An exploratory study on age of adolescent smartphone acquisition and well-being. *Computers in Human Behavior*, 114, 106563. <https://doi.org/10.1016/j.chb.2020.106563>
- Vermunt, J. K. (2010). Latent class modeling with covariates: Two improved three-step approaches. *Political Analysis*, 18(4), 450–469.
- Wang, A., Wang, Z., Zhu, Y., & Shi, X. (2022). The prevalence and psychosocial factors of problematic smartphone use among Chinese college students: A three-wave longitudinal study. *Frontiers in Psychology*, 13, 877277. <https://doi.org/10.3389/fpsyg.2022.877277>
- Wang, W., Liu, J., Liu, Y., Wang, P., Guo, Z., Hong, D., & Jiang, S. (2023). Peer relationship and adolescents' smartphone addiction: The mediating role of alienation and the moderating role of sex. *Current Psychology*, 42(26), 22976–22988. <https://doi.org/10.1007/s12144-022-03309-2>
- Wang, Y., & Ma, Q. (2024). The impact of social isolation on smartphone addiction among college students: The multiple mediating effects of loneliness and COVID-19 anxiety. *Frontiers in Psychology*, 15, 1391415. <https://doi.org/10.3389/fpsyg.2024.1391415>
- Wang, Y., Yang, H., Montag, C., & Elhai, J. D. (2020). Boredom proneness and rumination mediate relationships between depression and anxiety with problematic smartphone use severity. *Current Psychology*, 41, 1. <https://doi.org/10.1007/s12144-020-01052-0>
- Wilmer, H. H., & Chein, J. M. (2016). Mobile technology habits: Patterns of association among device usage, intertemporal preference, impulse control, and reward sensitivity. *Psychonomic Bulletin & Review*, 23(5), 1607–1614. <https://doi.org/10.3758/s13423-016-1011-z>
- Wu, J., & Siu, A. C. (2020). Problematic mobile phone use by Hong Kong adolescents. *Frontiers in Psychology*, 11, 551804. <https://doi.org/10.3389/fpsyg.2020.551804>
- Xiao, B., Parent, N., Rahal, L., & Shapka, J. (2023). Using machine learning to explore the risk factors of problematic smartphone use among Canadian adolescents during COVID-19: The important role of fear of missing out (FoMO). *Applied Sciences*, 13(8), 4970. <https://doi.org/10.3390/app13084970>
- Xiao, B., Zhao, H., Hein-Salvi, C., Parent, N., & Shapka, J. D. (2024). Examining self-regulation and problematic smartphone use in Canadian adolescents: A parallel latent growth modeling approach. *Journal of Youth and Adolescence*, 54(2), 1. <https://doi.org/10.1007/s10964-024-02071-x>
- Yang, X., Hu, H., Zhao, C., Xu, H., Tu, X., & Zhang, G. (2021). A longitudinal study of changes in smart phone addiction and depressive symptoms and potential risk factors among Chinese college students. *BMC Psychiatry*, 21(1), 252. <https://doi.org/10.1186/s12888-021-03265-4>
- Yoo, C. (2024a). Problematic smartphone use and adolescent's depression trajectory patterns. *Asia Pacific Journal of Social Work and Development*, 1–17. <https://doi.org/10.1080/29949769.2024.2397982>
- Yoo, C. (2024b). What makes children aged 10 to 13 engage in problematic smartphone use? A longitudinal study of changing patterns considering individual, parental, and school factors. *Journal of Behavioral Addictions*, 13(1), 76–87. <https://doi.org/10.1556/2006.2024.00002>
- Yoo, J. H., Chun, J. W., Choi, M. R., Cho, H., Kim, J. Y., Choi, J., & Kim, D. J. (2021). Caudate nucleus volume mediates the link between glutamatergic neurotransmission and problematic smartphone use in youth. *Journal of Behavioral Addictions*, 10(2), 338–346. <https://doi.org/10.1556/2006.2021.00024>
- Zanon, C., Brenner, R. E., Baptista, M. N., Vogel, D. L., Rubin, M., Al-Darmaki, F. R., Gonçalves, M., Heath, P. J., Liao, H. Y., Mackenzie, C. S., Topkaya, N., Wade, N. G., & Zlati, A. (2021). Examining the dimensionality, reliability, and invariance of the depression, anxiety, and stress scale–21 (DASS-21) across eight countries. *Assessment*, 28(6), 1531–1544. <https://doi.org/10.1177/1073191119887449>

Zhou, J., Zhang, L., & Gong, X. (2023). Longitudinal network relations between symptoms of problematic internet game use and internalizing and externalizing problems among Chinese early adolescents. *Social Science & Medicine*, 333, 116162. <https://doi.org/10.1016/j.socscimed.2023.116162>

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