

# Associations Among Depressive and Anxious Symptoms, Fear of Missing Out, and Problematic Smartphone Use Severity Among Chinese Adolescents: A Three-Wave Random-Intercept Cross-Lagged Panel Analysis

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**Purpose:** Previous research has documented that problematic smartphone use (PSU) is associated with various psychological symptoms among adolescents, but temporal ordering and underlying mechanisms remain unclear.

**Patients and Methods:** This three-wave longitudinal study examined bidirectional relationships among depressive and anxious symptoms, fear of missing out (FOMO), and PSU in a sample of 402 Chinese adolescents (49.6% girls;  $M_{age} = 12.33$ ,  $SD = 0.52$ ) assessed at six-month intervals (ie, T1, T2, and T3).

**Results:** The random-intercept cross-lagged panel modelling (RI-CLPM) results indicated a bidirectional relationship between FOMO and PSU, with each predicting subsequent increases in the other. PSU predicted increases in depressive symptoms over time ( $\beta_s = 0.19 - 0.21$ ,  $ps < 0.001$ ), but not vice versa ( $\beta_s = 0.05 - 0.06$ ,  $ps > 0.05$ ). Anxious symptoms predicted increased FOMO over time ( $\beta_s = 0.12 - 0.13$ ,  $ps < 0.01$ ), while FOMO did not predict anxious symptoms ( $\beta_s = 0.05$  and  $0.05$ ,  $ps > 0.05$ ). FOMO at T2 mediated the linkage between depressive/anxious symptoms at T1 and PSU at T3.

**Conclusion:** These findings identify FOMO as a critical mediating mechanism linking psychological symptoms to problematic digital behaviors. Interventions targeting FOMO may help disrupt these maladaptive patterns and prevent escalation of both PSU and psychological symptoms among adolescents.

**Keywords:** problematic smartphone use, fear of missing out, depressive and anxious symptoms, adolescents

## Introduction

Problematic smartphone use (PSU), characterized by excessive and uncontrolled use of smartphones that causes significant distress or impairment, has emerged as a significant public health concern among adolescents.<sup>1</sup> Research indicates that PSU is associated with numerous adverse psychological and behavioral factors in this population, including psychological distress (eg, depression and anxiety), sleep disturbances, poor academic performance, and diminished face-to-face social interactions.<sup>2-5</sup> Adolescents are particularly vulnerable to developing PSU due to their ongoing neurological development, heightened sensitivity to social rewards, and limited self-regulatory capabilities.<sup>6</sup> These developmental characteristics directly align with key theoretical frameworks: adolescents' identity formation processes may intensify compensatory use (CIUT) as they seek digital validation during identity uncertainty; their heightened peer sensitivity makes them particularly vulnerable to FOMO as social belonging becomes developmentally paramount; and their still-maturing cognitive control systems may exacerbate the impact of displacement effects on mental health outcomes. The confluence of these developmental vulnerabilities with increasingly sophisticated

digital environments creates a perfect storm for problematic digital engagement patterns during this critical period. Despite growing concerns about PSU prevalence among adolescents, which ranges from 14.0% to 31.2% globally,<sup>7</sup> the underlying developmental mechanisms remain incompletely understood. This underscores the necessity for longitudinal investigations aimed at elucidating the complex pathways leading to PSU during the critical developmental period.<sup>8</sup>

Relevant theory and prior empirical research have indicated that depressive and anxious symptoms may lead to more PSU severity. According to the Compensatory Internet Use Theory (CIUT),<sup>9</sup> individuals experiencing psychological distress may resort to excessive digital media use as a maladaptive strategy to alleviate negative emotions and escape from distressing realities. This linkage is well-supported by a substantial body of cross-sectional studies and a modest number of longitudinal investigations that have examined temporal precedence in these relationships.<sup>10–14</sup> For example, Zhou et al<sup>15</sup> found that depressive symptoms at earlier time points significantly predicted PSU severity at subsequent time points, while earlier PSU failed to predict later depressive symptoms. Similarly, Lapierre et al<sup>16</sup> demonstrated that higher anxiety levels prospectively predicted increased smartphone dependency six months later among adolescents. Notably, both studies employed two-wave short-term designs, which capture only a single temporal transition, limiting their ability to establish more stable patterns. In addition, the prevailing conceptualization posits that symptoms of mental health can precipitate excessive smartphone use, rather than the inverse.<sup>17,18</sup> These existing findings align with hypotheses suggesting that adolescents with psychological symptoms may be particularly vulnerable to developing PSU as they seek digital environments that offer emotional relief, social connection, and distraction from distress.

However, extant theoretical frameworks and empirical findings offer contradictory insights, suggesting that PSU may in fact exacerbate depressive and anxious symptoms. A recent meta-analysis demonstrated a moderate yet significant correlation between PSU and depressive and anxious symptoms, suggesting that PSU, conceptualized as a maladaptive coping mechanism, may exacerbate these symptoms.<sup>19</sup> The displacement hypothesis/model<sup>20,21</sup> provides a compelling framework for understanding this relationship, positing that excessive smartphone use displaces essential protective activities such as face-to-face social interactions, physical exercise, and adequate sleep - all vital buffers against psychological distress. Complementarily, Social Comparison Theory<sup>22,23</sup> explains how constant exposure to idealized representations on social media platforms accessed through smartphones triggers upward social comparisons that diminish self-esteem and intensify depressive and anxious symptoms, especially among developmentally vulnerable adolescents. Moreover, the frequent interruptions and notifications from smartphones may disrupt attention and cognitive processing, contributing to stress and anxiety.<sup>24</sup> Despite these theoretical propositions, most recent research employs cross-sectional designs with adult samples,<sup>25,26</sup> leaving temporal precedence unresolved and highlighting the need for rigorous longitudinal investigations with adolescent populations to disentangle these potentially complex bidirectional relationships.

Fear of missing out (FOMO) may serve as a crucial mediational mechanism linking depressive and anxious symptoms to PSU severity. It refers to a pervasive apprehension that others might be having experiences that are pleasurable and from which one is absent.<sup>27</sup> The Interaction of Person-Affect-Cognition-Execution (I-PACE) model<sup>17</sup> provides a theoretical framework for understanding this pathway, suggesting that predisposing factors such as psychopathology interact with affective and cognitive responses (including FOMO) to influence addictive behaviors. According to this model, individuals with elevated depressive or anxious symptoms may experience heightened sensitivity to social exclusion and increased desire for social connection, intensifying FOMO, which subsequently drives compulsive smartphone checking and usage patterns. Yuan et al<sup>18</sup> discovered robust evidence in support of this sequential relationship in a three-wave Chinese young adult sample; their findings indicated that depressive symptoms predicted increased FOMO, which subsequently predicted greater PSU severity. Liu et al<sup>28</sup> reported that anxious symptoms at baseline exhibited a positive influence on PSU through FOMO, in a two-wave Chinese adolescent sample.

However, across several years of research, contradictory findings have emerged regarding the associations among depressive and anxious symptoms, FOMO, and PSU across different cultural contexts and populations. Contrary to the findings above, using a two-wave Italian adolescent sample, Lo Coco et al<sup>29</sup> found no significant longitudinal cross-lagged associations between FOMO and PSU, suggesting potential cultural differences in these relationships. Numerous cross-sectional studies have yielded inconsistent results regarding the directionality and strength of associations among these variables.<sup>30–33</sup> This heterogeneity may stem from methodological variations, including differences in sample characteristics, cultural contexts, measurement instruments, and analytical approaches. Particularly when studying adolescents, longer

longitudinal designs with three or more waves are essential to capture the dynamic interplay among these factors and to establish temporal precedence with greater certainty.<sup>34</sup>

Traditional cross-lagged panel models (CLPM) often conflate between-person stable traits and within-person processes, potentially leading to biased estimates of bidirectional and cross-lagged relationships. To address this limitation, we employed random-intercept cross-lagged panel modeling (RI-CLPM), which disentangles between-person differences from within-person dynamics by including random intercepts that account for stable individual differences.<sup>35,36</sup> This approach may provide more accurate estimates of the temporal relationships among psychological symptoms, FOMO, and PSU by examining how deviations from one's typical levels in one variable predict subsequent deviations in other variables.

The present study utilized a three-wave longitudinal RI-CLPM design with a sample of Chinese adolescents to investigate bidirectional relationships among depressive and anxious symptoms, FOMO, and PSU. We hypothesized that: (1) depressive and anxious symptoms would prospectively predict increases in FOMO; (2) FOMO would prospectively predict increases in PSU severity; and (3) PSU would prospectively predict increases in depressive and anxious symptoms, creating potential vicious cycles.

## Materials and Methods

### Participants and Procedure

Data in this study were obtained from a longitudinal research program exploring the relationship between electronic device use and psychological well-being among children and adolescents in southwest China. Using convenience sampling, students from 10 classes across two middle schools were recruited. This study complies with the Declaration of Helsinki and was approved by the Research Ethics Committee of Leshan Normal University, with informed consent obtained from all participants and their parents/guardians. All questionnaires were administered under the supervision of professionally trained psychology personnel.

Data were collected in 3 waves at 6-month intervals: wave 1 (October 2021;  $N = 496$ ; 51.4% girls;  $M_{\text{age}} = 12.32$ ,  $SD = 0.52$ ), wave 2 (April 2022;  $N = 478$ ; 51.5% girls;  $M_{\text{age}} = 12.32$ ,  $SD = 0.52$ ), and wave 3 (October 2022;  $N = 403$ ; 49.6% girls;  $M_{\text{age}} = 12.33$ ,  $SD = 0.52$ ). During the follow-up assessments, the main reasons for participant attrition included: voluntary withdrawal, school transfers, and other circumstances. The final analytical sample consisted of 403 participants who completed all assessments across all three waves. Following each assessment, participants received group psychological counseling sessions and small incentive gifts to acknowledge their contribution to the research.

## Measures

### PSU

The Chinese version of Smartphone Addiction Scale-Short Version<sup>37</sup> was used to assess participants' PSU within the past six months across three waves. This questionnaire includes ten items, each rated on a 6-point scale from 1 (strongly disagree) to 6 (strongly agree). Sample items include, "missing planned work due to smartphone use" and "using my smartphone longer than I had intended". A higher total score on this scale indicates a greater level of PSU. This questionnaire has been used in Chinese samples with good reliability and validity.<sup>38,39</sup> In this study, Cronbach's  $\alpha$  reliability for this scale was 0.90, 0.90, and 0.91 at T1, T2, and T3, respectively.

### Depressive and anxious symptoms

The Chinese version of nine-item Patient Health Questionnaire (PHQ-9)<sup>40</sup> and Generalized Anxiety Disorder Scale-7 Item (GAD-7)<sup>41</sup> were used to measure depressive and anxious symptoms within the past six months across three waves. Both scales are rated on a 4-point scale from 0 (not at all) to 3 (nearly every day). Sample items include, "poor appetite or overeating" and "trouble relaxing". Higher sum scores represent greater levels of depressive or anxious symptoms. They have showed good reliability and validity in Chinese samples.<sup>42,43</sup> In this sample, Cronbach's  $\alpha$  coefficients were great: for PHQ-9,  $\alpha = 0.88$  at T1, T2, and T3, while for GAD-9,  $\alpha = 0.90$  at T1 and  $\alpha = 0.91$  at both T2 and T3.

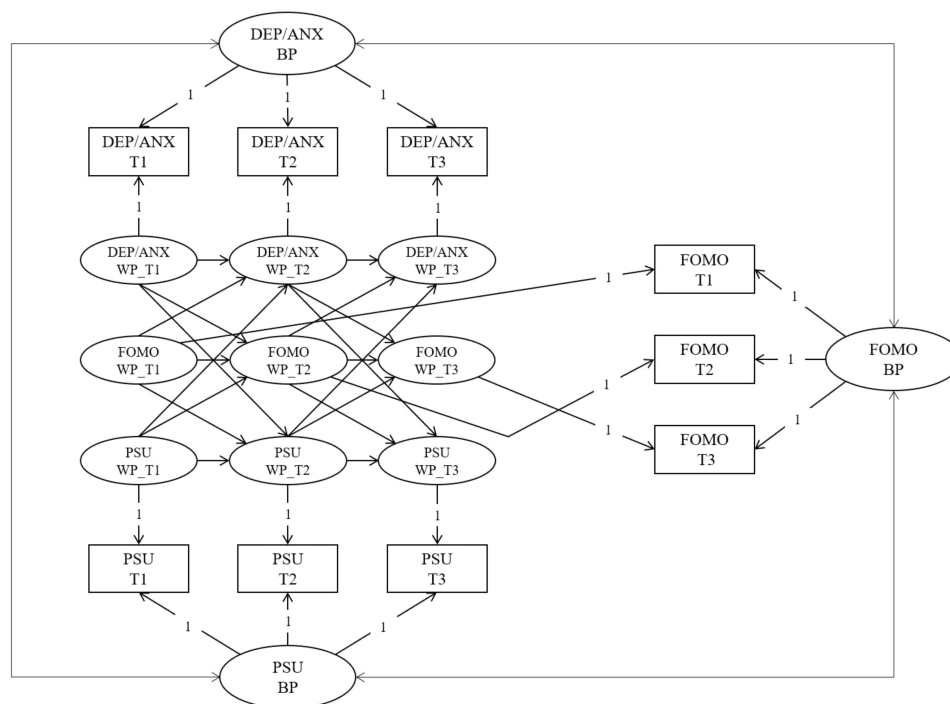
## FOMO

The Chinese version of FOMO scale<sup>27</sup> was used to measure participants' FOMO across three waves. It includes ten items, each rated on a 5-point scale from 1 (not at all of me) to 5 (extremely true of me). Sample items include, "I fear others have more rewarding experiences than me" and "when I miss out on a planned get-together it bothers me". The reliability and validity of this scale have been verified in previous Chinese samples.<sup>18,44</sup> In this study, Cronbach's  $\alpha$  reliability for this scale was 0.83, 0.87, and 0.84 at T1, T2, and T3, respectively.

## Data Analysis

We used SPSS 27.0 and R software version 4.2.2 to conduct analyses. The final analytical sample of 403 participants had complete data across all variables and time points, with no missing values observed in any of the study measures. Examination of distribution properties confirmed normality for all study variables through multiple methods. Descriptive indices showed absolute values for both skewness and kurtosis ranging from 0.02 to 0.86, which met the acceptable standards.<sup>45</sup> And both Shapiro–Wilk and Kolmogorov–Smirnov tests yielded non-significant results ( $ps > 0.05$ ), collectively supporting the appropriateness for further analyses. *T*-test results showed that no significant differences between study completers (403 respondents) and those lost to follow-up (93 respondents) on depressive and anxious symptoms, FOMO, and PSU ( $ps > 0.05$ ).

Descriptive statistics and Pearson's and partial correlations and were computed for all study variables (depressive and anxious symptoms, FOMO, and PSU) across three waves. To test our hypotheses, we employed RI-CLPM to examine bidirectional relationships between these variables (see Figure 1 for the hypothesized model). We implemented two distinct RI-CLPM analyses: one examining reciprocal relationships between depressive symptoms, FOMO, and PSU, and another investigating bidirectional associations between anxious symptoms, FOMO, and PSU. The RI-CLPM approach offers an advantage over traditional cross-lagged panel models by decomposing variance into between-person and within-person components.<sup>35</sup> The between-person component represents stable individual differences, while the within-person



**Figure 1** Hypothesized three-wave random intercept cross-lagged panel model.

**Notes:** For simplicity, the cross-sectional paths among three study variables at same wave are not displayed. T1 = wave 1, October 2021, T2 = wave 2, April 2022, T3 = wave 3, October 2022.

**Abbreviations:** DEP, depressive symptoms; ANX, anxious symptoms; FOMO, fear of missing out; PSU, problematic smartphone use; BP, between person, WP, within person.

component captures temporal changes occurring within individuals over time.<sup>36</sup> The RI-CLPM was implemented using structural equation modeling, with age and gender included as covariates due to their potential associations with the key study variables. To examine whether temporal patterns remained consistent across waves, we conducted model comparisons by systematically freeing within-person concurrent associations, cross-lagged effects, and stability paths across time points, evaluating whether each less constrained model yielded significantly improved fit, according to the suggestions by previous studies.<sup>46,47</sup> Model fit was evaluated using multiple indices: the ratio of  $\chi^2$  to degrees of freedom ( $\chi^2/\text{df} < 5.0$ ), comparative fit index and Tucker-Lewis index (CFI and TLI  $> 0.90$ ), root mean square error of approximation (RMSEA  $< 0.08$ ), and standardized root mean square residual (SRMR  $< 0.08$ ), with these thresholds indicating acceptable model fit.<sup>48</sup> Two-tailed  $p$ -values less than 0.05 were considered statistically significant, and all reported coefficients are standardized.

## Results

### Descriptive Findings

Table 1 presents descriptive statistics (means and standard deviations) and intercorrelations among study variables, revealing significant associations between depressive and anxious symptoms, FOMO, and PSU across all measurement waves. As expected, each variable measured at T1 was significantly correlated with its corresponding assessment at T2 and T3 ( $r_s = 0.48$  to  $0.64$ ,  $p_s < 0.001$ ), indicating considerable stability over time. Variables were also significantly and positively correlated with each other at the same time points and across time points. Notably, FOMO and PSU maintained consistent moderate associations both concurrently within each wave ( $r_s = 0.38$  to  $0.42$ ,  $p_s < 0.001$ ) and longitudinally across waves ( $r_s = 0.24$  to  $0.36$ ,  $p_s < 0.001$ ). Moreover, FOMO demonstrated significant correlations with both depressive symptoms ( $r_s = 0.28$  to  $0.51$ ,  $p_s < 0.001$ ) and anxious symptoms ( $r_s = 0.32$  to  $0.53$ ,  $p_s < 0.001$ ) across all three waves.

### RI-CLPM with Depressive Symptoms

We firstly tested the relationships among depressive symptoms, FOMO, and PSU in the hypothesized RI-CLPM that included age and sex as covariates. Figure 2 depicts the standardized coefficients of the RI-CLPM. The overall model fit of this RI-CLPM was acceptable,  $\chi^2/\text{df} = 4.172$ , CFI = 0.912, TLI = 0.907, RMSEA (90% CI) = 0.070 (0.062–0.081), SRMR = 0.064.

At the between-person level (the left side on Figure 2), depressive symptoms showed significant positive associations with both FOMO and PSU, while FOMO exhibited a significant positive correlation with PSU. At the with-in person level (the right side on Figure 2), the bidirectional paths between FOMO and PSU across three waves were significant ( $\beta_s = 0.10$ – $0.12$ ,  $p_s < 0.05$ ). PSU at the earlier time point exhibited a significant positive relationship with depressive

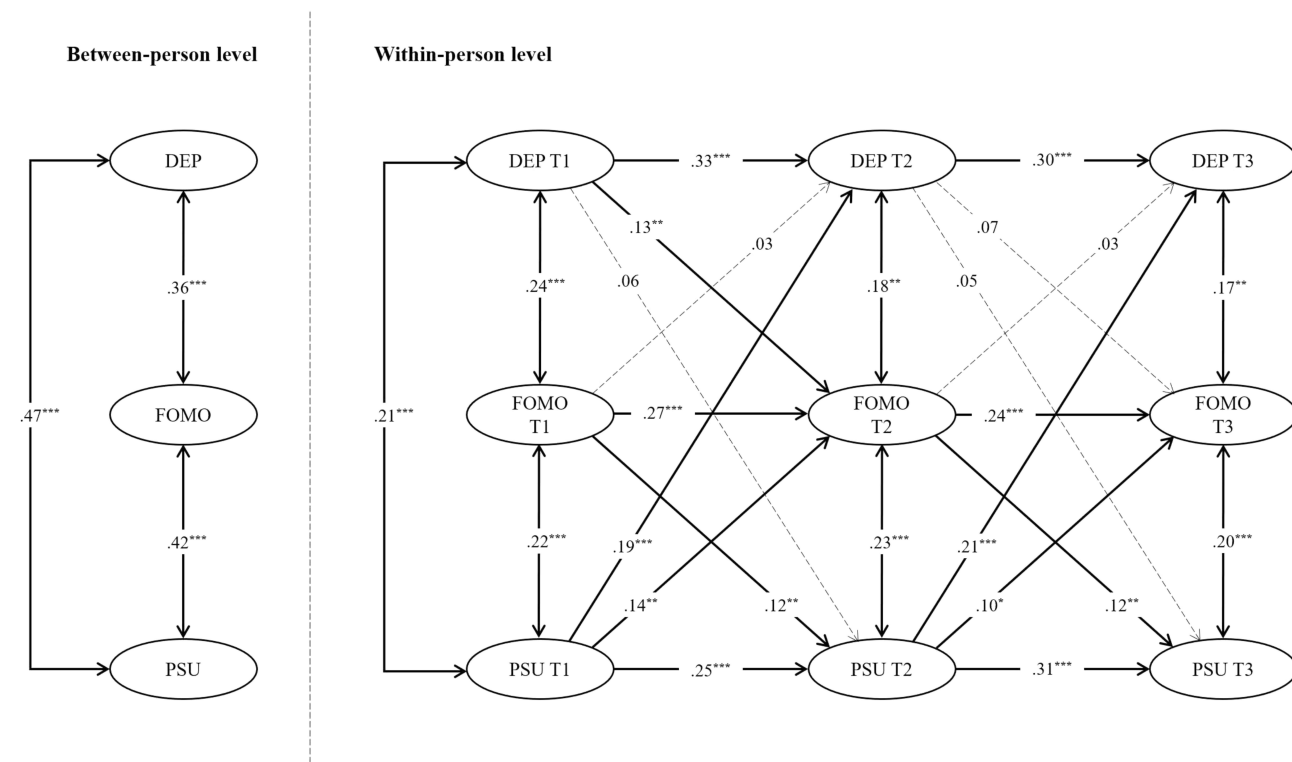
**Table 1** Means, Standard Deviations, and Correlations Among Study Variables at Three Waves ( $n = 403$ )

	M±SD	1	2	3	4	5	6	7	8	9	10	11	12
1. T1 DEP	8.14±6.31	—	0.79***	0.47***	0.45***	0.59***	0.52***	0.31***	0.31***	0.60***	0.54***	0.28***	0.27***
2. T1 ANX	6.57±5.25	0.80***	—	0.51***	0.42***	0.51***	0.54**	0.39***	0.29***	0.54***	0.64***	0.32***	0.27***
3. T1 FOMO	23.96±8.61	0.49***	0.52***	—	0.38***	0.38***	0.37***	0.48***	0.24***	0.34***	0.35***	0.56***	0.27***
4. T1 PSU	27.46±12.05	0.47***	0.44***	0.40***	—	0.33***	0.31***	0.29***	0.52***	0.31***	0.34***	0.25***	0.57***
5. T2 DEP	8.42±6.16	0.59***	0.53***	0.40***	0.36***	—	0.80***	0.51***	0.49***	0.64***	0.56***	0.32***	0.32***
6. T2 ANX	6.48±5.13	0.52***	0.55**	0.38***	0.32***	0.81***	—	0.53***	0.41***	0.55***	0.62***	0.31***	0.30***
7. T2 FOMO	24.54±9.24	0.31***	0.40***	0.49***	0.29***	0.52***	0.55***	—	0.42***	0.39***	0.43***	0.55***	0.33***
8. T2 PSU	29.23±11.58	0.34***	0.33***	0.28***	0.56***	0.52***	0.43***	0.43***	—	0.34***	0.34***	0.28***	0.64***
9. T3 DEP	7.93±6.01	0.61***	0.55***	0.36***	0.34***	0.65***	0.56***	0.40***	0.37***	—	0.80***	0.43***	0.43***
10. T3 ANX	6.43±5.20	0.54***	0.64***	0.37***	0.35***	0.56***	0.63***	0.44***	0.35***	0.80***	—	0.47***	0.42***
11. T3 FOMO	24.70±9.16	0.27***	0.33***	0.56***	0.24***	0.33***	0.33***	0.56***	0.28***	0.44***	0.47***	—	0.42***
12. T3 PSU	29.21±12.00	0.29***	0.30***	0.30***	0.60***	0.35***	0.32***	0.33***	0.66***	0.45***	0.43***	0.41***	—

**Notes:** Left/bottom triangle is the Pearson's correlations of all study variables, right/top triangle is the partial correlations of all the variables adjusted by age, sex, and weekly smartphone use time. T1 = wave 1, October 2021; T2 = wave 2, April 2022; T3 = wave 3, October 2022. \*\*\* $p < 0.001$ .

**Abbreviations:** DEP, depressive symptoms; ANX, anxious symptoms; FOMO, fear of missing out; PSU, problematic smartphone use.





**Figure 2** Simplified three-wave random intercept cross-lagged panel model – depressive symptoms.

**Notes:** Dashed lines represent statistically insignificant paths. All numbers in the figure are standardized path coefficients. For simplicity, we do not present the covariates (ie, age, sex, and weekly smartphone use time) and cross-sectional paths between depressive symptoms and problematic smartphone use for wave 2 and 3. T1 = wave 1, October 2021, T2 = wave 2, April 2022, T3 = wave 3, October 2022. \*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ .

**Abbreviations:** DEP, depressive symptoms; FOMO, fear of missing out; PSU, problematic smartphone use.

symptoms at the subsequent time point ( $\beta_s = 0.19 - 0.21$ ,  $p < 0.001$ ). Baseline depressive symptoms predicted increased FOMO at T2 ( $\beta = 0.13$ ,  $p < 0.01$ ), which subsequently predicted higher levels of PSU at T3 ( $\beta = 0.12$ ,  $p < 0.01$ ), suggesting that FOMO mediated the longitudinal relationship between depressive symptoms and PSU.

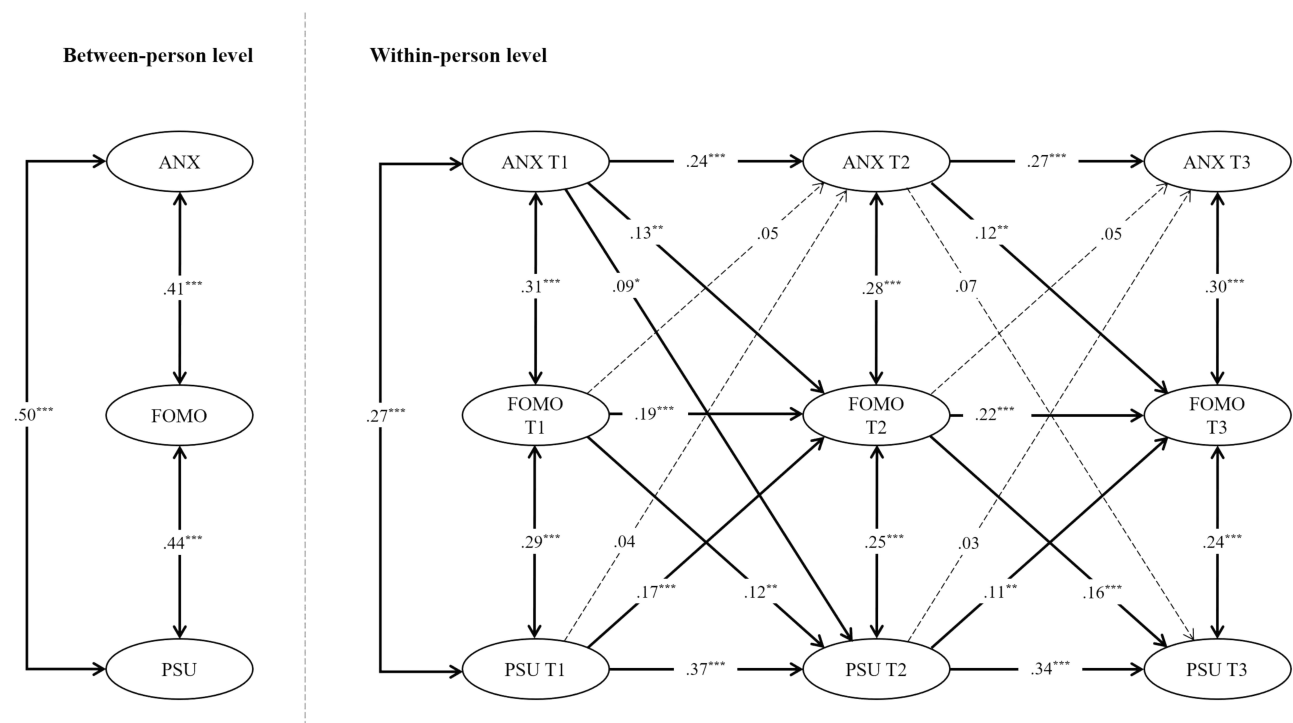
## RI-CLPM with Anxious Symptoms

We then tested the relationships among anxious symptoms, FOMO, and PSU in the hypothesized RI-CLPM that included age and sex as covariates. Figure 3 depicts the standardized coefficients of the RI-CLPM. The overall model fit of this RI-CLPM was acceptable,  $\chi^2/df = 3.756$ , CFI = 0.924, TLI = 0.917, RMSEA (90% CI) = 0.066 (0.051–0.080), SRMR = 0.051.

At the between-person level (the left side on Figure 3), anxious symptoms showed significant positive relationships with FOMO and PSU, with FOMO showing a significant positive association with PSU. At the within person level (the right side on Figure 3), the bidirectional paths between FOMO and PSU across three waves were still significant ( $\beta_s = 0.12 - 0.17$ ,  $p < 0.01$ ). Anxious at the earlier time point exhibited a significant positive relationship with FOMO at the subsequent time point ( $\beta_s = 0.12 - 0.13$ ,  $p < 0.01$ ). A similar mediational path (anxious symptoms → FOMO → PSU) was found where anxious symptoms at T1 were significantly related to FOMO at T2 ( $\beta = 0.13$ ,  $p < 0.01$ ), and FOMO at T2 was significantly related to PSU at T3 ( $\beta = 0.16$ ,  $p < 0.001$ ).

## Discussion

This three-wave longitudinal study examining bidirectional relationships among depressive and anxious symptoms, FOMO, and PSU among Chinese adolescents yielded several important findings. First, we observed significant bidirectional relationships between FOMO and PSU across all time points. Second, PSU predicted subsequent increases in depressive symptoms, but not vice versa. Third, anxious symptoms prospectively predicted increases in FOMO. Finally,



**Figure 3** Simplified three-wave random intercept cross-lagged panel model – anxious symptoms.

**Notes:** Dashed lines represent statistically insignificant paths. All numbers in the figure are standardized path coefficients. For simplicity, we do not present the covariates (ie, age, sex, and weekly smartphone use time) and cross-sectional paths between anxious symptoms and problematic smartphone use for wave 2 and 3. T1 = wave 1, October 2021, T2 = wave 2, April 2022, T3 = wave 3, October 2022. \*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ .

**Abbreviations:** ANX, anxious symptoms; FOMO, fear of missing out; PSU, problematic smartphone use.

we identified two mediational pathways: depressive symptoms at T1 predicted FOMO at T2, which subsequently predicted PSU at T3; similarly, anxious symptoms at T1 predicted FOMO at T2, which predicted PSU at T3.

These findings can be meaningfully interpreted through the lens of key developmental tasks central to adolescence. The bidirectional relationship between FOMO and PSU may reflect adolescents' heightened concerns about peer inclusion and social capital during a developmental period when peer relationships become increasingly salient for identity formation. Notably, the pathway from anxious symptoms to FOMO aligns with developmental challenges related to social identity consolidation, as heightened social anxiety during this period may amplify concerns about missing social opportunities crucial for identity exploration. Similarly, the finding that PSU predicts subsequent depressive symptoms may reflect interference with essential developmental tasks such as autonomy development and establishing healthy peer relationships. Excessive smartphone engagement might impede adolescents' opportunities to develop independence and self-regulation skills by providing constant external validation and distraction. Furthermore, the mediational role of FOMO in linking psychological symptoms to PSU highlights how normative developmental concerns about social belonging and peer acceptance can become maladaptive when intensified by underlying psychological vulnerabilities during this sensitive developmental period. These developmental considerations enhance our understanding of why adolescents may be particularly vulnerable to the cyclical patterns observed in our study and suggest that interventions should be tailored to address stage-salient developmental needs.

Our findings reveal a complex interplay among depressive and anxious symptoms, FOMO, and PSU that both supports and challenges existing theoretical frameworks. The identification of sequential pathways from psychological symptoms to PSU via FOMO underscores the importance of considering mediating mechanisms in digital media use research. These results align with the I-PACE model,<sup>17</sup> which posits that predisposing factors such as psychopathology interact with cognitive-affective responses (eg, FOMO) to influence problematic digital behaviors.

However, our observation that PSU predicted subsequent depressive symptoms, rather than the reverse, challenges traditional assumptions about the primacy of psychological symptoms in these relationships. The unidirectional

relationship from PSU to depressive symptoms contradicts the CIUT<sup>9</sup> but aligns with the displacement hypothesis.<sup>20,21</sup> While CIUT suggests that individuals with psychological distress use digital media to alleviate negative emotions, our findings indicate that excessive smartphone use may precipitate depressive symptoms among adolescents. This supports Twenge's hypothesis<sup>21</sup> that digital media use displaces essential protective activities such as face-to-face social interactions and physical activity. Similarly, Wacks and Weinstein<sup>3</sup> found that excessive smartphone use was associated with negative mental health outcomes through multiple pathways, including sleep disruption and reduced physical activity. This temporal pattern suggests that excessive smartphone use may serve as a risk factor that potentially erodes adolescents' psychological well-being over time, rather than merely being a consequence of existing depressive symptoms.

The prospective relationship between anxious symptoms and FOMO may extend our understanding of anxiety's role in digital media engagement. This finding suggests that anxiety sensitivity, characterized by heightened awareness of and concern about social evaluation,<sup>49</sup> may intensify fears about missing rewarding experiences. Adolescents with social anxiety exhibited greater social needs gratification through social media, potentially explaining the pathway to increased FOMO.<sup>50</sup> The subsequent link from FOMO to PSU supports Rozgonjuk et al's conceptualization of FOMO as a "vulnerability factor"<sup>51</sup> that drives compulsive checking behaviors. This pathway illuminates how pre-existing anxious tendencies may lead to problematic digital behaviors through social-cognitive mechanisms.

The bidirectional relationship between FOMO and PSU indicates a potentially self-reinforcing cycle that may be particularly problematic during adolescence. This finding contradicts Lo Coco et al's results<sup>29</sup> with Italian adolescents, where no significant cross-lagged associations between these variables were observed. This discrepancy highlights the complexity of these relationships across different populations and methodological approaches. Cultural differences may partially explain these divergent findings. Within the Chinese collectivist context, social harmony and group belonging are particularly valued, potentially intensifying FOMO's impact. Additionally, the intense academic pressure system in China, characterized by high-stakes examinations and competitive educational environments, may drive adolescents toward digital escapism while simultaneously heightening concerns about falling behind peers socially.<sup>52</sup> Furthermore, Chinese family dynamics often emphasize filial piety and academic achievement, creating tension between parental expectations and adolescents' digital social needs, potentially reinforcing the observed bidirectional relationship between FOMO and PSU. This reciprocal relationship suggests a potential amplification mechanism where heightened FOMO drives increased smartphone checking behaviors, which in turn exposes adolescents to more social comparison opportunities, thereby further intensifying their FOMO in a cyclical pattern that becomes increasingly difficult to disrupt over time.

The mediational pathways identified (psychological symptoms->FOMO->PSU) substantiate Yuan et al's findings<sup>18</sup> in young adults but extend them to an adolescent population during a critical developmental period characterized by heightened social sensitivity and identity formation. Our results align with Liu et al's finding<sup>28</sup> that anxiety predicted PSU through FOMO in Chinese adolescents, but our three-wave design provides stronger evidence for temporal sequencing. These mediational pathways suggest that psychological symptoms may create vulnerability to PSU not directly but through cognitive-affective mechanisms involving social comparison and belongingness needs. Specifically, depressive and anxious symptoms may heighten adolescents' sensitivity to social cues and intensify concerns about social exclusion, thereby amplifying fears of missing rewarding experiences or social opportunities. This heightened FOMO then drives compulsive checking behaviors to alleviate social uncertainty, ultimately leading to problematic patterns of smartphone use. FOMO represents a crucial bridge construct connecting emotional states to technological behaviors,<sup>53</sup> making it a promising target for preventive interventions.

Our findings also contribute to the broader digital well-being literature by elucidating specific pathways that may impede or promote healthy technology engagement among adolescents. While much of the existing research has focused on documenting problematic digital behaviors, our results help advance more nuanced conceptualizations of technological well-being that recognize both risk and protective factors. The bidirectional relationship between FOMO and PSU identified in our study aligns with emerging frameworks of digital citizenship that emphasize the importance of self-regulation and mindful engagement with technology. Furthermore, our findings on the mediational role of FOMO contribute to evolving theoretical perspectives that view digital well-being not as merely the absence of problematic use but as the development of adaptive cognitive-affective responses to digital environments. By identifying specific temporal pathways among psychological symptoms, FOMO, and PSU, our research helps bridge traditional



psychopathology frameworks with emerging models of technological well-being that emphasize the importance of fostering healthy digital engagement patterns rather than simply reducing screen time. These findings suggest that enhancing adolescents' capacity to manage social comparison concerns and developing their sense of social belonging outside digital contexts may represent key components of digital well-being interventions.

This study has some limitations. First, our sample consisted exclusively of Chinese adolescents, potentially limiting generalizability to other cultural contexts. Future research should examine these relationships across diverse populations to establish cross-cultural validity. Second, reliance on self-report measures may introduce response biases; incorporating behavioral assessments or smartphone usage data would enhance measurement precision. Third, while our three-wave design improves upon previous research, six-month intervals may not capture more rapid fluctuations in psychological symptoms and digital behaviors. Future studies should employ ecological momentary assessment approaches to examine these relationships at micro-temporal levels and extend follow-up periods to investigate longer-term developmental trajectories as adolescents transition into adulthood.<sup>54,55</sup> Our study also has theoretical limitations. While we employed specific conceptual frameworks (CIUT, displacement hypothesis, I-PACE model), alternative theories might offer different interpretations of our findings. For instance, media effects theories might better explain bidirectional relationships through reinforcement spirals. Additionally, our conceptualization of PSU may not fully capture its multidimensional nature, potentially overlooking important distinctions between different types of smartphone activities (gaming, social media, information-seeking) and their unique relationships with psychological symptoms. Further, our focus on individual-level processes may underemphasize broader systemic factors such as technological design features explicitly engineered to maximize engagement through psychological vulnerabilities.

Despite these limitations, our findings have valuable implications for addressing PSU among adolescents. The bidirectional relationship between FOMO and PSU suggests that interventions targeting either construct could potentially disrupt this self-reinforcing cycle. Since FOMO appears to function as a critical mediator linking psychological symptoms to PSU, cognitive-behavioral interventions specifically addressing social comparison concerns and belongingness needs may be particularly effective. Specific intervention components might include: (1) cognitive restructuring techniques targeting catastrophic thinking about missed social opportunities; (2) behavioral experiments challenging assumptions about social media content; (3) mindfulness-based attention training to reduce automatic checking behaviors; (4) scheduled "digital detox" periods with alternative engaging activities; (5) social skills training promoting fulfilling offline interactions; and (6) values clarification exercises helping adolescents prioritize meaningful engagement versus quantity of digital connections.<sup>56</sup> A tiered prevention approach could implement universal digital literacy education in schools while offering targeted interventions for adolescents demonstrating elevated FOMO and early signs of PSU. Clinicians working with adolescents experiencing depressive or anxious symptoms should routinely assess for FOMO and smartphone use patterns, as these may represent modifiable factors in treatment. Educational programs for adolescents could incorporate mindfulness techniques to reduce the emotional reactivity that often drives compulsive checking behaviors. Additionally, school-based initiatives promoting healthy digital media engagement and strengthening face-to-face social connections could help mitigate both FOMO and subsequent PSU, potentially preventing the development of more serious psychological symptoms over time.

## Conclusion

This three-wave longitudinal study provides important insights into the temporal dynamics among psychological symptoms, FOMO, and problematic smartphone use during adolescence. The bidirectional relationship between FOMO and PSU highlights a potentially self-reinforcing cycle that may escalate over time. Our findings that PSU predicts subsequent depressive symptoms, rather than the reverse, challenges compensatory use theories and supports displacement hypotheses. The identification of FOMO as a mediating mechanism linking psychological symptoms to PSU offers a promising target for intervention. These temporal relationships underscore the need for early prevention strategies that address both psychological vulnerabilities and promote healthy digital engagement patterns to protect adolescent well-being in an increasingly connected world. Future research should investigate how targeted FOMO-reduction interventions impact both PSU and psychological symptoms over time, examining specific components of FOMO as potential differential mediators while exploring these pathways across developmental periods from early adolescence through emerging adulthood. Experimental studies testing digital well-being interventions that specifically

target the bidirectional FOMO-PSU cycle will be particularly valuable for translating these findings into effective prevention strategies for adolescents.

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## Disclosure

The authors report no conflicts of interest in this work.

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