ORIGINAL RESEARCH

Problematic Internet Use in Early Adolescents: Gender and Loneliness Differences in a Latent Growth Model

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Purpose: Based on the Cognitive-Behavioral model and the Interaction of Person-Affect-Cognition-Execution model, this study examined the developmental trajectory of problematic Internet use (PIU) in early adolescents and explored whether there were gender differences in the onset level and rate of development of this developmental trajectory, and tested whether developmental changes in loneliness could have an impact on the developmental trajectory of problematic Internet use.

Participants and Methods: This longitudinal study collected data on PIU and loneliness from 296 early adolescents (*M*age=11.65, *SD*=0.58) in four waves. The development of PIU in adolescents and the effects of gender and loneliness development on PIU development were examined using a latent growth model.

Results: The results revealed that individuals' PIU development showed a nonlinear latent growth model, with PIU significantly higher than 0 in grade 6 and its growth rate slowing down as PIU increased. Individuals' PIU at low starting levels developed more rapidly later. Boys had higher initial levels of PIU but their PIU developed and increased at the same rate as girls'. Both the initial value and slope of loneliness had a significant effect on the initial value and slope of boys' and girls' PIU.

Conclusion: Interventions for PIU in early adolescents also need to consider loneliness at the same time, and intervention groups can focus on individuals with low initial levels of PIU, boys, and individuals with high levels of loneliness.

Keywords: problematic internet use, loneliness, latent growth model, gender, early adolescents

Introduction

As is well known, the internet is a "double-edged sword". On the one hand, people cannot live without the internet, whether for study and work (eg, searching and accessing information, sharing knowledge, communicating at work) or for entertainment and leisure (eg, online games, online videos, chat communities). On the other hand, internet addiction has negative effects on people's physical and mental health, such as negative emotional problems (depression, anxiety, loneliness, etc.) in adolescents, poor academic performance, poor social adjustment,[1–3] and negative career outcomes later.[4,5] Researchers define problematic internet use (PIU) as uncontrolled and unreasonable use of the internet that causes negative physical and mental effects, while some researchers call it internet addiction and compulsive internet use.

Among the negative outcomes associated with PIU, negative emotions have been one of the main focuses of researchers.[6–8] Loneliness is a subjective emotion of personal unhappiness that is associated with the lack or loss of companionship for individuals,[9] and individuals with loneliness are more likely to resort to internet socialization for the purpose of dissipating this negative emotion. That is, individuals with more lonely feelings may use the internet more frequently and trigger PIU.[1,10] Although loneliness was found to be a predictor of PIU by cross-lagged analysis in these two studies, both studies were followed for a short period of time (one or one and a half years), and additionally, the findings did not shed light on how PIU develops in adolescents. The present study focused on early adolescents and chose a longer follow-up period to reveal PIU's developmental trajectory and explore the relationship between it and loneliness.

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Literature Review

PIU in Early Adolescents

Adolescents are in the paradoxical stage of pursuing independence and not being able to break away from dependence, and they are eager to pursue independence because of their developing sense of self. However, at this stage, they are immature and have poor self-regulatory skills, so they are more likely to indulge in the internet, resulting in inappropriate and excessive internet use, ie, PIU.[11,12] Research has shown that PIU behavior exists from childhood through adolescence (ages 8 to 19).[10,12] That is, these studies demonstrate that PIU in adolescents is indeed prevalent. Regarding the development of PIU in early adolescents, a follow-up study by Zhang et al showed an overall upward trend in adolescents' PIU development,[13] and Shek and Yu surveyed junior high school students in Hong Kong and found that adolescents whose PIU had developed significantly on the first measurement had higher PIU on the second measurement.[14] A three-year longitudinal study of US adolescents also noted that adolescents' time spent using the internet increased significantly as the survey progressed.[15] The study by Li et al, on the contrary, showed that internet addiction among adolescents decreased significantly over time within six months.[16] Depending on the time of follow-up, PIU levels in adolescents were found to increase over time in studies longer than one year.

As is common knowledge, the main task of the adolescent developmental stage is to accomplish self-identity and foster self-concept development,[17] and the clearer the self-concept, the better the self-development.[18] Self-concept clarity has been found to be related to adolescents' social adjustment, with adolescents with higher levels of self-clarity having lower levels of depression,[19] anxiety,[20] and loneliness[21] and having fewer PIU behaviors.[22] That is, as adolescents age and their self-concept becomes clearer, their PIU behaviors may decrease.

In China, early adolescence corresponds to the sixth grade to junior high school stage. As junior high school students, achieving academic success is closely linked to their self-development.[16] In junior high school, their academic pressure is above the medium level.[16,23] Academic stress, on the one hand, can lead to the lower academic performance of middle school students, and on the other hand, it can also contribute to the academic performance of middle school students. It has been shown that students with good academic performance have lower PIU levels.[24] In other words, as they move up in grade level, and due to the gradual development of self-concept, they are able to perceive the increasing academic pressure on themselves, and at this time they devote more time to studying and thus less time to using the internet, so the trend of increasing PIU levels may gradually slow down.

Established longitudinal studies have shown the development of PIU in adolescents to be increasing over time, but the trend of increasing PIU has not been explored in the above studies. Based on the literature, the present study also concluded that PIU in early adolescents has developed and is developing an overall upward trend, but the rise in PIU in early adolescents might level off with the development of self-concept and increased academic stress. In summary, formulated in this study was Hypothesis 1: The initial level of PIU in early adolescence would be significantly greater than 0. Over time, PIU would show an increasing trend, but the increasing trend would gradually level off.

Gender Differences in PIU

Boys use the internet more for gaming entertainment, and girls resort more to internet socialization.[15,25] Lavoie et al investigated the PIU of gender-specific adolescents and found that individuals who reported themselves as girls had higher PIU-SM scores (ie, used the internet socially), individuals who reported themselves as boys had higher PIU-VG scores (ie, used the internet for video games), and participants in the PIU-VG group also spent significantly more time using the internet than the PIU-SM group.[26] However, some researchers have also measured PIU among middle school students (mean age 14.82 at the initial survey and 16.49 at the second survey) and found that the amount of time boys spent using the internet did not change between the two surveys, whereas girls' internet use decreased.[27] For boys, online gaming stimuli are highly attractive and can only be obtained through the internet, and their PIU levels are higher; girls, for whom the social satisfaction of the internet is available in the real world, have lower PIU levels than boys.[28,29]

Although boys and girls use the internet with different focuses, the experience of using the internet, whether for communication or gaming, brings them great satisfaction, and this is what drives them to continue using the internet. This is also the same as what is stated in the Interaction of Person-Affect-Cognition-Execution model (I-PACE model): in the early stages of PIU, the stimulation brought by the gaming experience for boys and the chatting process for girls drives

their emotional and cognitive changes, and they experience the great satisfaction brought by the internet to themselves.[30] However, as PIU develops, whether it is indulging in gaming or obsessing over online chatting, the satisfaction that individuals subjectively feel from the relevant stimuli gradually decreases, and the corresponding compensatory effects increase. That is, for both boys and girls, compensatory effects replace satisfaction as the main driver of later PIU behavior.[8,30] The role of this compensatory drive is consistent with what has been found in recent studies: both boys and girls reported that the idea of "not wanting to turn off the internet" after internet use was the most influential factor in PIU.[31] One researcher investigated PIU in Chinese subjects in early, middle, and late adolescence and found that "reluctance to stop using the internet" and "lack of control" were stronger in middle and late adolescence.[32]

According to the above, boys and girls have different concerns about the functional experience of the internet, which may explain their different levels of PIU. Studies have not focused on the development of PIU over time in boys and girls, and according to the I-PACE model, compensatory effects later become the main driver, and the later development of PIU may be the same in boys and girls. In this study, Hypothesis 2 was proposed: boys would have higher PIU than girls, but the trend of PIU development would be the same in boys and girls.

PIU and Loneliness

Researchers generally found a positive relationship between loneliness and PIU, with the same positive relationship obtained in investigations with American adolescents, Korean subjects, Chinese adolescents, Turkish subjects, and graduate students from India.[11,33,34] Researchers have not reached a consensus regarding the causal relationship between loneliness and PIU. Some researchers have suggested that PIU leads to an increase in loneliness. For example, a cross-lagged analysis showed that internet addiction among college students in Hong Kong leads to an increase in their loneliness over time,[35] and consistent results were obtained by Fang (2022) et al in a survey of adolescents in mainland China.[36] Partially similar results were found in the studies of Zhang et al and Tian et al,[1,10,36] both of which used Chinese junior high school and university students as subjects and showed that internet addiction at T1 predicted loneliness at T2 and internet addiction at T2 predicted loneliness at T3 through three tests (Tian et al study). As the displacement hypothesis suggests, because individuals' online socialization replaces offline socialization, they will experience more loneliness.[37]

Although their studies reported internet addiction as a predictor of loneliness, both Tian et al and Zhang et al results showed that loneliness at T2 positively predicted internet addiction at T3 and that loneliness had a greater effect on internet addiction than internet addiction on loneliness (Zhang et al study). Rachubinska et al also found that individuals with high levels of loneliness were more likely to suffer from PIU.[38] Loneliness triggering PIU may be consistent with both models: the cognitive-behavioral model states that loneliness, as a psychological factor, is a distal requisite for PIU, which triggers PIU by developing nonadaptive cognitions in individuals. That is, loneliness is associated with PIU and may trigger PIU.[5,8] Brand et al I-PACE model states that individuals' motivation to use the internet is related to the formation of PIU, such as lonely individuals' motivation to socialize.[30] Specifically, lonely individuals' motivation for social interaction drives them to want to establish social relationships with others, which also leads them to enhance or establish new relationships through offline and/or online avenues to reduce their loneliness;[1,39] therefore, lonely adolescents may be driven by social motivation to resort to the convenient and powerful internet to satisfy their social needs and devote much of their time to the internet, resulting in PIU.

Whether as a distal psychological factor or as a form of social motivation, loneliness can trigger PIU. It is of interest that loneliness in adolescents also changes over time,[1,36,40] but existing studies have not explored the effect of the dynamic development of loneliness on PIU. Based on the above theories and literature, in the present study it was also speculated that loneliness contributes to PIU in early adolescents and the role of loneliness development on PIU in adolescents was examined by using loneliness as a variable that changes over time. In this study, Hypothesis 3 was proposed: Early adolescents' loneliness would contribute to their PIU.

The Present Study

It is of great practical significance to explore PIU in early adolescents and to understand the development trend and related influencing factors of PIU. In this study, the latent growth model was chosen to explore adolescents' PIU development. In addition, as previously mentioned, there are gender differences in adolescents' motivation to use the

internet and in the content focus of internet use, and in this study PIU development was explored among adolescents of different genders. Finally, based on the cognitive-behavioral model and the I-PACE model, loneliness is associated with the development of PIU in adolescents, and the relationship between loneliness development and the development of PIU in adolescents was examined in this study.

Materials and Methods
Sample and Procedure

The data for this study were taken from a longitudinal study of PIU. The participants were all 6th-grade students in a primary experimental middle school in Shandong Province. In accordance with the voluntary principle, the participants were tested in a cluster sampling on a classroom basis. This study was conducted over three years with 4 tests (T1 to T4 corresponding to before the 6th-grade midterm exam, before the 7th-grade midterm exam, before the 8th-grade midterm exam, and before the 9th-grade midterm exam for students). A total of 296 students took the test, 135 (45.6%) boys and 161 girls, with a mean age of 11.56 years at the time of the first test ($SD = 0.58$).

All participants voluntarily participated in this study, and their guardians filled out informed consent forms before the first administration of the test. For data collection, a group questionnaire was administered in a classroom setting, and the administrator was a trained graduate student in psychology. When administering the test, the administrator briefly introduced the basic requirements of the test and told the participants to answer according to their real situation, and there was no distinction between "right" and "wrong" answers. The paper version of the data was entered into SPSS software for subsequent analysis.

Measures
Problematic Internet Use Scale

This study used the Chinese version of the Generalized Problematic Internet Use Scale (PIUS), which was developed by Gomez et al and revised by Li et al[41,42] The scale consists of 11 questions, such as "When you are online, you feel that time flies". The scale is scored on a 7-point Likert scale, with 1 representing "strongly disagree" and 7 representing "strongly agree", and the score of each question is added up to the scale score. The higher the total score, the higher the level of problematic internet use. The Cronbach's α for the four measurements of the problematic internet use scale in this study were 0.80, 0.87, 0.88, and 0.91, respectively.

Loneliness

The loneliness scale used in this study was developed by Russell and revised by Guo et al,[43] which consists of 20 questions, such as "Do you often feel harmonious in your relationships with others around you".[44] The scale is scored on a 4-point Likert scale, with 1 being "never" and 4 being "always". Nine questions on the scale were reverse scored, and all scores were summed to obtain a total score on the scale, with higher scores indicating higher levels of loneliness. The Cronbach's α of the loneliness scale in this study was 0.84, 0.87, 0.89, and 0.88 for the four measures, respectively.

Data Analysis

SPSS 21.0 and Mplus 7.0 were used to perform descriptive statistics, develop latent growth model (LGM), and examine the trajectory of adolescent PIU. In the construction of the LGM, an unconditional model was first constructed to form repeated measures of PIU at four time points. The intercept indicates the baseline state of the individual, ie, the observed level measured in the first measurement, and the slope is used to indicate differences in trajectories between individuals. This study first examined the trajectory of PIU and whether there were significant individuals at the starting level, the trend of change, and the quadratic change. Based on this, gender (a time-invariant covariate) was added to the model to examine whether there was a gender difference in the trajectory of PIU development in early adolescents. Later, loneliness (a time-varying covariate) was added to examine whether and to what extent PIU in early adolescents is affected by loneliness.

In terms of metrics to assess the model, this study used the commonly used goodness-of-fit indices: χ^2/df, the comparative fit index (CFI), the Tucker–Lewis Index (TLI), the root mean square error of approximation (RMSEA), and

the standardized root mean square residual (SRMR). For the criteria of the metrics, according to the consensus of researchers, $\chi^2/df \leq 5$ is reasonable,[45] CFI and TLI above 0.90 are adequate, and above 0.95 is excellent;[46] RMSEA less than 0.08 is acceptable and less than 0.06 is excellent;[47] SRMR less than 0.08 is acceptable.[48]

Missing Data Analyses

The data for this study were taken from a follow-up study at 4 time points over 3 years, and there were some missing data due to participants transferring to other schools and taking leave of absence. A review of the data revealed that the percentage of missing main variables ranged from 1.01% to 16.55%. Missing data were first analyzed using SPSS 21.0, which showed that χ^2 =1728.21, df=1646, p=0.078, indicating that the missing data type was missing completely at random (MCAR).[49] This implied that the probability of missing data occurring is not related to the variables in this study and that missing data is just a random event.[50] In Mplus 7.0, multiple imputation (MI) on missing data is performed in this study, which means that in the case of missing data at random, two or more values that reflect the probability distribution of the data itself are used to interpolate the missing data.[50]

Results
Preliminary Analysis

According to Table 1, from T1 to T4, early adolescents' PIU increased from a mean of 27.07 (SD=11.83) to 32.75 (SD=12.01), and loneliness increased from 40.47 (SD=9.43) to 43.67 (SD=10.32) at the first measurement. In addition, PIU was significantly and positively correlated with loneliness at four time points (r=0.23, p<0.001; r=0.36, p<0.001; r=0.35, p<0.001; r=0.26, p<0.001). Gender and PIU were significantly negatively correlated (r=−.20, p<0.001; r=−.13, p=0.04) (see Table 1).

Trajectories of Early Problematic Internet Use Among Early Adolescents

The unconditional growth model was tested. A comparison of the linear and quadratic LGMs showed that the quadratic model fit the data better than the linear model. The model fit of the quadratic LGM was χ^2=0.24, df=1, p=0.63, CFI=1.000, TLI=1.02, RMSEA=0.00, and SRMR=0.01. The model fit of the linear unconditional LGM model was χ^2 =12.84, df=5, p=0.02, CFI=0.96, TLI=0.96, RMSEA=0.07, and SRMR=0.04.

The quadratic growth model (see Figure 1) showed that the mean intercept of PIU for adolescents at T1 (grade 6) was significantly different from 0 ($M_{intercept}$=27.15, SE=0.66, p<0.001; $V_{intercept}$=81.65, SE=13.03, p<0.001). Consistent with the predictions of this study, PIU increased significantly from 6th to 9th grade (M_{slope} =1.74, SE=0.34, p<0.001; V_{slope} =16.33, SE=5.45, p=0.003). The quadratic change showed a significant negative change ($M_{quadratic}$ =−0.08, SE=0.03, p=0.02; $V_{quadratic}$

Table 1 Matrix of Means, Standard Deviations and Correlation Coefficients of Each Variable

Variables (N=296)	M±SD	I	2	3	4	5	6	7	8	9
I. Gender										
2. T1 PIU	27.03±11.83	−0.20**	1.00							
3. T2 PIU	28.68±12.01	−0.13*	0.47**	1.00						
4. T3 PIU	32.75±12.84	−0.11	0.29**	0.43**	1.00					
5. T4 PIU	36.41±13.80	−0.08	0.21**	0.26**	0.52**	1.00				
6. T1 Loneliness	40.47±9.43	0.05	0.23**	0.17**	0.16*	0.22**	1.00			
7. T2 Loneliness	39.22±10.44	−0.04	0.23**	0.36**	0.23**	0.15*	0.41**	1.00		
8. T3 Loneliness	42.84±11.19	0.05	0.13**	0.24**	0.35**	0.20**	0.37**	0.53**	1.00	
9. T4 Loneliness	43.67±10.32	0.05	0.12	0.10	0.23**	0.26**	0.36**	0.38**	0.53**	1.00

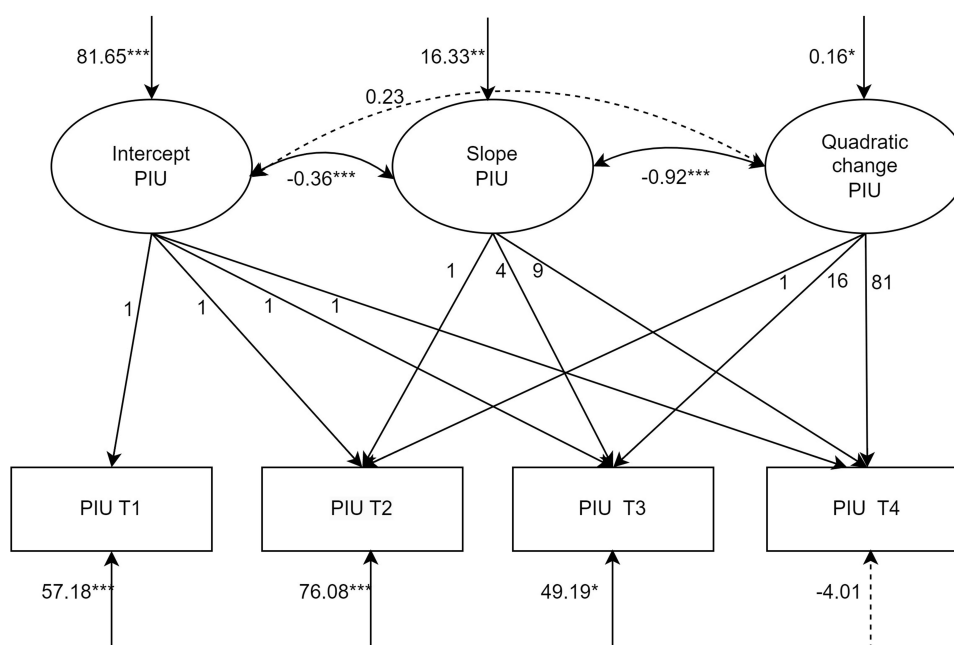**Notes**: T1–T4 for grades 6–9, respectively; *p<0.05, **p<0.01.

Figure 1 Nonlinear unconditional latent growth model for problematic internet use.
Note: T1–T4 for grades 6–9, respectively; *p<0.05, **p<0.01, ***p<0.001.

=0.16, *SE*=0.07, *p*=0.01), which indicated that the increase in PIU slows down and plateaus over time, ie, Hypothesis 1 was verified. In addition, the intercept and slope were significantly negatively correlated (*r*=−.36, *p*<0.001), meaning that the higher the starting level of PIU, the slower the increase; and the slope and quadratic change were significantly negatively correlated (*r*= −.92, *p*<0.001), meaning that the faster the primary growth rate of PIU in early adolescents, the slower the quadratic growth rate. There was no significant correlation between the intercept and the secondary slope (*r*=0.23, *p*=0.05), indicating that the starting level of PIU was not related to the secondary development rate.
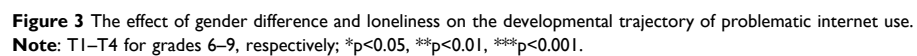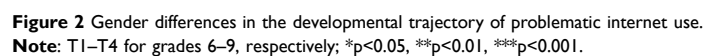
Gender Differences in the Developmental Trajectory of Problematic Internet Use Among Early Adolescents

To examine the differences in the developmental trajectory of adolescent PIU across gender groups, a new conditional latent growth model was constructed by adding gender (a time-invariant covariate) to the nonlinear model (see Figure 2). The model was found to fit well with χ^2 =1.49, df=2, *p*=0.47, *CFI*=1.00, *TLI*=1.01, *RMSEA*=0.00, and *SRMR*=0.01. Gender predicted the baseline level of PIU (β=−0.24, *p*<0.001) but not the increase in PIU (β=0.07, *p*=0.40) and quadratic change (β=−0.04, *p*=0.60). That is, there were significant gender differences in the onset levels of problematic internet use among individuals of different genders; specifically, girls had significantly lower onset levels of PIU than boys, and there was no significant difference in the rate of increase and change in PIU between boys and girls. In other words, Hypothesis 2 was verified.

Developmental Trajectories of Problematic Internet Use in Early Adolescents: The Influence of Gender and Loneliness

Latent Growth Model with Both Time-Varying and Time-Invariant Covariates

In this study, the effects of both loneliness and gender covariates on the development of PIU in adolescents were considered, and a new conditional latent variable model was constructed (see Figure 3). The model fit indicators were good, χ^2 =15.55, df=14, *p*=0.34, *CFI*=0.99, *TLI*=0.99, *RMSEA*=0.02, *SRMR*=0.04. Loneliness was associated with being able to predict PIU in grades 6–9 (β=0.24, *p*<0.001; β=0.31, *p*<0.001; β=0.31, *p*<0.001; β=0.16, *p*=0.01), suggesting that individuals with higher levels of loneliness had a significant contribution to the rise in PIU during the same period, ie,

Figure 2 Gender differences in the developmental trajectory of problematic internet use.
Note: T1–T4 for grades 6–9, respectively; *p<0.05, **p<0.01, ***p<0.001.

Figure 3 The effect of gender difference and loneliness on the developmental trajectory of problematic internet use.
Note: T1–T4 for grades 6–9, respectively; *p<0.05, **p<0.01, ***p<0.001.

individuals with higher levels of loneliness in early adolescence would have a more pronounced contribution to the rising trend in problematic internet use at that time.

Latent Variable Growth Model for Parallel Development Processes

To explore the effect of developmental changes in loneliness on the developmental trajectory of adolescent PIU, a latent variable growth model with parallel development of the two variables was proposed. In this process, first, the developmental change in loneliness was examined through linear and nonlinear models, and the linear model was found to better fit the developmental change in loneliness in early adolescents. The linear model had χ^2 =29.62, df=5, p<0.001, CFI=0.89, TLI=0.87, $RMSEA$=0.13, and $SRMR$=0.00, and the nonlinear model had χ^2 =9.17, df=1, p<0.001, CFI=0.96, TLI=0.78, $RMSEA$=0.17, and $SRMR$ =0.03, and the quadratic variation in the nonlinear model was found to be insignificant ($M_{quadratic}$ =−0.06, SE=0.03, p=0.06; $V_{quadratic}$=0.14, SE=0.05, p=0.01), so the linear model was used for the loneliness trajectory in the subsequent analysis.

Based on the previous nonlinear model of PIU and the linear model of loneliness, a new parallel developmental model (see Figure 4) was developed to examine the effects of developmental changes in loneliness on the developmental trajectory of adolescents' PIU. Each fitting index of the model was χ^2 =64.75, df=16, p<0.001, CFI=0.90, TLI=0.83, $RMSEA$=0.10, and $SRMR$=0.07, indicating that this latent developmental model of the parallel developmental process fit well.

According to scholars, the covariance between the intercepts of the two trajectories (PIU and loneliness) provides a coexistence relationship between the two variables at the beginning of the observation. A similar correspondence exists for slope and quadratic change. Consistent with expectations, loneliness in grade 6 positively predicted the intercept of PIU at that time (β=0.51, p<0.001), suggesting that adolescents with higher levels of loneliness onset tend to exhibit higher PIU. The slope of loneliness serves as a predictor of the slope of PIU (β=0.49, p=0.02), suggesting that
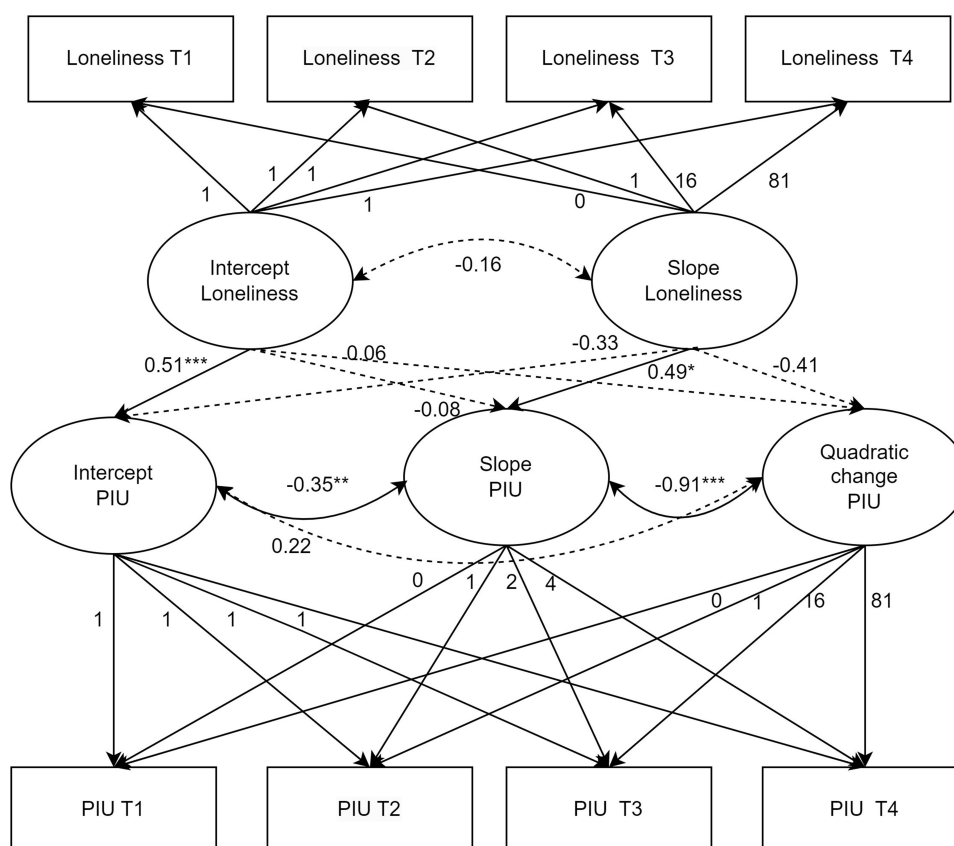

Figure 4 Latent variable growth model for the parallel development process.
Note: T1–T4 for grades 6–9, respectively; *p<0.05, **p<0.01, ***p<0.001.

adolescents with higher growth rates in loneliness also tend to show high rates of PIU growth. The slope of loneliness did not significantly predict the quadratic change in PIU (β=−0.41, p=0.05). Overall, Hypothesis 3 was partially tested.

Discussion

The purpose of this study was to investigate the developmental trajectory of PIU in early adolescents, to focus on the differences in PIU development between boys and girls and to investigate the effect of loneliness on PIU development. Therefore, this study analyzed the relationship between loneliness and PIU based on latent growth models based on 3 years of longitudinal data, and the results obtained and the main discussion are as follows.

The Trajectory of Problematic Internet Use in Early Adolescents

The development of PIU in early adolescents was modeled as a nonlinear latent growth model. The first measurement of PIU in this study was when the participants were in 6th grade, and it was found that their PIU intercept was significantly greater than 0 at that time, meaning that PIU had developed significantly in early adolescents. In 2007, Valcke et al mentioned that large surveys in many countries (eg, New Zealand, the United States, and the United Kingdom) reported individuals' PIU behaviors appearing at increasingly younger ages, with the age range involved in the survey being from 8 to 19 years old and the years of the survey being from 2000 to 2003;[12] in this study, PIU developed significantly among adolescents in the 6th grade (11 to 12 years old), supporting the existing findings. Compared with the year 2000, the development of the internet is not the same now, and the rich games and convenient online socialization on the internet are attractive enough to adolescents so that adolescents who are curious about the internet world are prone to PIU behavior.

The unconditional nonlinear model constructed in this study showed that the developmental slope of PIU was positive, but its quadratic change was negative. That is, the developmental trajectory of problematic internet use in early adolescents showed an overall upward curve, but its growth trend gradually slowed down. This is consistent with the report of Zhang et al that is, the overall PIU development of adolescents rises, but the upward trend becomes increasingly slower.[13] The above findings can be explained in two ways: on the one hand, when adolescents start to enter junior high school, many of them have their own computers or cell phones, so their time and access to the internet increases significantly; at the same time, they are still immature and less self-regulated during adolescence,[11,12] and because they have a need for independence, school and parental supervise on is not as seamless as in elementary school, and even many parents' own PIU can affect adolescents,[51] so they become increasingly immersed in internet use and may develop PIU.[15] In other words, the development of PIU in early adolescent individuals is on the rise.

On the other hand, based on the investigation and speculation mentioned in the introduction, this study showed that the increasing trend of PIU in early adolescence does slow down gradually, and this trend may be related to the development of adolescents' self-concept and the rise of academic pressure: adolescents are exploring and completing self-identity and developing self-concept at this time.[17] Researchers have also found that self-concept clarity negatively predicts PIU in adolescents, meaning that individuals with clearer self-concepts are less likely to have PIU.[22] Meanwhile, as grade level increases, early adolescents can clearly perceive the increase in academic pressure, and adolescents with clearer self-concept are well aware that one of their main tasks in middle school is to complete their education, so as grade level increases, coupled with the increase in academic pressure,[16,24,52] they increasingly take responsibility for themselves due to an awareness that they should do so and devote more and more time to their studies and correspondingly less time to the internet; ie, the increasing trend of time spent on the internet by early adolescent individuals slows down, making the rising trend of their PIU slow down.

In addition, this study showed that the slope of adolescent PIU was significantly negatively correlated with initial level and significantly negatively correlated with secondary change; this indicated that adolescents with low initial levels of PIU have faster growth than individuals with high starting levels, and the faster the primary growth of adolescents' PIU, the slower their secondary growth. This result has not been found in existing studies. It was speculated in the present study that this result may be related to adolescents' experience with the internet. Personal experience with internet use is also mentioned in the cognitive-behavioral model as a distal factor in the formation and development of PIU.[5] In other words, adolescents with high initial levels of PIU have fully explored internet use, and they seem to be "veterans" of internet use from the beginning, unlike adolescents with low initial levels of PIU, who have not fully

explored the internet and are like "novices" in internet use. These novices are much more attracted to the internet than the veterans, so the novices are more addicted to the internet, and their PIU grows faster.

In conclusion, the internet is attractive to adolescents, which makes them susceptible to PIU. Due to the influence of an underdeveloped mind and parents' PIU, adolescents' PIU tends to increase, but as their grade level increases, coupled with the gradual clarification of self-concept and the perceived increase in academic pressure, adolescents' PIU growth tends to slow down. Due to the different experiences gained when using the internet, adolescents with low initial levels of PIU develop PIU more rapidly in their later years.

Gender Difference in Problematic Internet Use Development

The present study demonstrated that boys had higher levels of PIU initiation than girls, but there was no significant difference in the development of PIU in boys and girls. The same finding has been obtained in existing cross-sectional studies in which PIU was investigated in adolescents from different countries (eg, Turkey, Iran, China, and India), all of which showed that PIU was more severe in boys.[11,53–55]

The same development of PIU in boys and girls can be explained in two ways. On the one hand, as researchers generally agree, internet use differs between boys and girls, which seems to explain the difference in the onset levels of PIU between boys and girls: girls' internet use is mostly focused on communication, whereas boys' internet use is dominated by information gathering and playing games.[15,25] Wang et al found in their longitudinal study that online gaming addiction disorder as a type of PIU started earlier and developed more quickly in adolescent boys than in girls,[25] and other researchers found the same in the adult population.[56]

On the other hand, compensatory drives can help to understand the lack of differences in PIU development between boys and girls: in Brand et al I-PACE model, it is noted that individuals use the internet in the early stages mainly to obtain satisfaction through some behaviors (eg, boys satisfy high competitive needs with the help of gaming behaviors, girls satisfy interpersonal needs through internet communication behaviors), and as their internet use becomes increasingly more involved, the level of satisfaction experienced by adolescents decreases and the corresponding compensatory effect increases.[8,30] That is, as adolescents' internet use gradually develops into PIU, the satisfaction brought by either boys' behavior based on game use or girls' behavior based on communication decreases, and the inability to use the internet leads to negative results for individuals. At this time, the use of the internet is more about compensation than satisfaction.[8]

In general, boys mostly like to play games on the internet, so their starting level of PIU is somewhat higher, and as individuals become more addicted to the internet, the satisfaction that the internet originally brought to individuals becomes greatly reduced, and both adolescent boys and girls use the internet as a compensatory behavior, so there is no significant difference in internet development between boys and girls.

Loneliness Predicts Problematic Internet Use

This study examined the relationship between loneliness as a time-varying covariate and adolescent PIU development and showed that loneliness at all 4 time points significantly and positively predicted adolescents' PIU during the same period, which meant that adolescents with higher levels of loneliness had higher levels of problematic internet use. In addition, by constructing a parallel developmental model, this study showed that the onset level and developmental slope of early adolescent loneliness significantly predicted the onset level and slope of PIU development; that is, adolescents with high levels of loneliness would have more PIU behaviors, and adolescents with greater changes in loneliness would also have greater changes in their PIU.

The present study supports existing findings: surveys of culturally diverse adolescents (eg, US, Korea, China, Turkey, India) have shown an association between loneliness and PIU,[11,33,34] and individuals with higher levels of loneliness have more PIU behavior.[40,57,58]

In addition, adolescents' loneliness predicted the development of their PIU, which occurs as described in the I-PACE model: lonely adolescents' social motivation drives them to use the internet to satisfy their social needs, which leads to the development of PIU.[8] This is because, on the one hand, the individual's social needs and the reinforcement obtained from the internet experience increase the individual's desire to become addicted to the internet. Furthermore, lonely adolescents use the internet more and want to use the internet to satisfy their social needs,[1,39] and since lonely individuals

are motivated to socialize and the internet has abundant online socialization options (eg, online chat rooms, discussion groups, in-game chat rooms, video pop-ups), this convenient online socialization can help satisfy individuals' social motivation,[59] and at the same time, online social behavior is reinforced; lonely individuals are more likely to socialize via the internet (ie, increase their internet use time), and the corresponding PIU increases. On the other hand, loneliness is a distal trigger of PIU,[5] which is an important predictor of individuals' PIU behaviors.[30] For example, Tian et al study used college students as study participants, and their loneliness, shyness, and PIU were measured within a year 3 times, and cross-lagged analysis revealed that previous loneliness was able to positively predict the next PIU situation.[1] In a longitudinal study with adolescents as subjects, it was found that adolescents' loneliness positively predicted four dimensions of their PIU.[10]

In general, early adolescents' loneliness triggers their social motivation, which leads them to socialize anonymously and conveniently via the internet. The satisfaction of their motivation leads them to overcommit to the internet, which further leads to an increase in their PIU.

Research Significance

This study examined the developmental trajectory of adolescent PIU and focused on its gender differences and the impact of loneliness on it, which has some practical implications. First, PIU in early adolescents is on the rise, and adolescents with low initial levels of PIU develop PIU more rapidly, which must be taken seriously by those involved (researchers, parents, teachers, etc.). The negative impact of the internet on the physical and mental health of adolescents should not be underestimated. Parents and school workers should pay attention to guiding adolescents to use the internet properly and to supervise their internet use time. Second, the PIU of boys is significantly higher than that of girls, which may be related to their internet use, which means that the relevant personnel must pay more attention to the PIU use of boys and can start by focusing on their internet use and then guide them to use the internet reasonably and correctly. Finally, adolescents' loneliness itself shows certain trends, and loneliness significantly predicts adolescents' PIU, ie, an increase in loneliness leads to an increase in PIU. That is, teachers and school-related workers also need to pay attention to the development of adolescents' loneliness and intervene as appropriate to prevent more serious PIU triggered by it. Overall, PIU in adolescents always needs attention, and in regard to PIU in adolescents, there is a particular need to focus on adolescents with low starting levels, boys, and adolescents with high levels of loneliness.

Limitations and Prospects

First, the sample is insufficient and lacks certain representativeness. The participants in this study were 6th-grade students in a primary experimental middle school in Shandong Province. The economic development of East, middle, and Western China is different, and there may be differences in the level of understanding and use of the internet among adolescents in different regions. Future studies need to improve the sampling scope and conduct sampling in a larger area of the country to improve the representativeness of the subjects and the generalizability of the study findings.

Second, there was an attrition of participants in the longitudinal study. This study used a longitudinal design and collected data four times over three years, and a small number of participants were inevitably lost due to leave of absence and school transfer. Future studies may consider selecting more suitable subjects to minimize subject attrition.

Third, different subgroups of possible developmental trajectories of problematic internet use were not analyzed. The study examined the developmental trajectory of problematic internet use and found significant individual differences in initial level and developmental speed but did not analyze different developmental trajectory subgroups due to participant size limitations. Future studies could select more participants to further examine the developmental trajectory of problematic internet use from different subgroups.

Fourth, the longitude period was relatively short. The adolescence period included students from upper elementary school to high school, and the PIU of the participants in high school was not tracked in this study because of the attrition of participants due to leave of absence and school transfer. In the future, a complete study of adolescence could be considered to understand the development of problematic internet use, which is significant for understanding the overall development of problematic internet use.

Fifth, this study examined the influence of gender differences in the development of PIU in early adolescents and developmental changes in loneliness on the developmental trajectory of problematic internet use based on the cognitive-behavioral model and the I-PACE model, and other models can be sought in the future for more in-depth research based on gender and loneliness.

Conclusion

The development of PIU in early adolescents showed a nonlinear LGM, and PIU in adolescents was already significant from the first measurement and showed an increasing trend of development, but the growth rate was gradual; moreover, adolescents with a low starting level of PIU had a faster later development. In addition, boys had higher initial levels of PIU, but their development and growth did not differ from those of girls. Finally, the initial level and development of loneliness predicted PIU in early adolescents. These findings revealed the development of PIU in early adolescents and suggested that researchers need to consider loneliness when focusing on interventions and that the focus group for interventions could be individuals with low initial levels of PIU, boys, and individuals with high levels of loneliness.

Ethics Statement and Informed Consent

This study was carried out in accordance with the recommendations of the World Medical Association's Declaration of Helsinki. The protocol was approved by the Ethics Committee of Shandong Normal University. All participants gave their informed consent for inclusion before they participated in this study.

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Disclosure

The authors report no conflicts of interest in this work.

References

1. Tian Y, Guo ZX, Shi JR, et al. Bidirectional mediating role of loneliness in the association between shyness and generalized pathological internet use in Chinese university students: a longitudinal cross-lagged analysis. *J Psychol*. 2018;152(8):529–547. doi:10.1080/00223980.2018.1468309
2. Lin M, Pang S, Hong Z, Meng D, Li X, Zhang X. College students' internet addiction and dependence on academic emotions: the mediating role of positive psychological quality. *Chin J Health Psychol*. 2018;26(8):1258–1262. doi:10.13342/j.cnki.cjhp.2018.08.037
3. Ioannidis K, Treder MS, Chamberlain SR, et al. Problematic internet use as an age-related multifaceted problem: evidence from a two-site survey. *Addict Behav*. 2018;81:157–166. doi:10.1016/j.addbeh.2018.02.017
4. Tian Y, Bian Y, Han P, Gao F, Wang P. Associations between psychosocial factors and generalized pathological internet use in Chinese university students: a longitudinal cross-lagged analysis. *Comput Human Behav*. 2017;72:178–188. doi:10.1016/j.chb.2017.02.048
5. Davis RA. A cognitive-behavioral model of pathological Internet use. *Comput Human Behav*. 2001;17(2):187–195.
6. Villanueva Silvestre V, Vázquez Martínez A, Isorna Folgar M, Villanueva Blasco VJ. Problematic Internet use, depressive symptomatology and suicidal ideation in university students during COVID-19 confinement. *Psicothema*. 2022;34(4):518–527. doi:10.7334/psicothema2022.40
7. Yurdagül C, Kircaburun K, Emirtekin E, Wang P, Griffiths MD. Psychopathological consequences related to problematic Instagram use among adolescents: the mediating role of body image dissatisfaction and moderating role of gender. *Int J Ment Health Addict*. 2021;19(5):1385–1397. doi:10.1007/s11469-019-00071-8
8. Moretta T, Buodo G. Problematic internet use and loneliness: how complex is the relationship? A short literature review. *Curr Addict Rep*. 2020;7:125–136. doi:10.1007/s40429-020-00305-z
9. Gierveld J. A review of loneliness: concept and definitions, determinants and consequences. *Rev Clin Gerontol*. 1998;8(1):73–80. doi:10.1017/S0959259898008090
10. Zhang S, Tian Y, Sui Y, et al. Relationships between social support, loneliness, and internet addiction in Chinese postsecondary students: a longitudinal cross-lagged analysis. *Front Psychol*. 2018;9:1707. doi:10.3389/fpsyg.2018.01707
11. Akgün Kostak M, Dindar İ, Zafer Dinçkol R. Loneliness, depression, social support levels, and other factors involving the internet use of high school students in Turkey. *Int J Ment Health Addict*. 2019;17:1521–1534. doi:10.1007/s11469-018-9927-3
12. Valcke M, Schellens T, Van Keer H, Gerarts M. Primary school children's safe and unsafe use of the Internet at home and at school: an exploratory study. *Comput Human Behav*. 2007;23(6):2838–2850. doi:10.1016/j.chb.2006.05.008
13. Zhang G, Dai B, Lei L. The development of pathological internet use and its relationship with self-esteem among junior high school students: the moderating role of classmate relationship. *Acta Psychol Sin*. 2013;45(12):1345–1354. doi:10.3724/SP.J.1041.2013.01345
14. Shek DT, Yu L. Internet addiction phenomenon in early adolescents in Hong Kong. *Sci World J*. 2012;2012:1.

15. Witt EA, Massman AJ, Jackson LA. Trends in youth's videogame playing, overall computer use, and communication technology use: the impact of self-esteem and the Big Five personality factors. *Comput Human Behav.* 2011;27(2):763–769. doi:10.1016/j.chb.2010.10.025

16. Li G, Hou G, Yang D, Jian H, Wang W. Relationship between anxiety, depression, sex, obesity, and internet addiction in Chinese adolescents: a short-term longitudinal study. *Addict Behav.* 2019;90:421–427. doi:10.1016/j.addbeh.2018.12.009

17. Erikson EH. *Identity Youth and Crisis (No. 7)*. WW Norton & company; 1994.

18. Campbell JD, Trapnell PD, Heine SJ, Katz IM, Lavallee LF, Lehman DR. Self-concept clarity: measurement, personality correlates, and cultural boundaries. *J Pers Soc Psychol.* 1996;70(1):141. doi:10.1037/0022-3514.70.1.141

19. Lee-Flynn SC, Pomaki G, DeLongis A, Biesanz JC, Puterman E. Daily cognitive appraisals, daily affect, and long-term depressive symptoms: the role of self-esteem and self-concept clarity in the stress process. *Pers Soc Psychol Bull.* 2011;37(2):255–268. doi:10.1177/0146167210394204

20. Van Dijk MP, Branje S, Keijsers L, Hawk ST, Hale WW, Meeus W. Self-concept clarity across adolescence: longitudinal associations with open communication with parents and internalizing symptoms. *J Youth Adolesc.* 2014;43:1861–1876. doi:10.1007/s10964-013-0055-x

21. Xu HH, Sun XJ, Zhou ZK, Niu GF, Lian SL. True self-expression on social network sites and loneliness: mediating of self-concept clarity. *Chin J Clin Psychol.* 2017;25(01):138–141+137. doi:10.16128/j.cnki.1005-3611.2017.01.03

22. Song JJ, Liu CL, Huang H. Effect of self-concept clarity and core self-evaluation on adolescences pathological internet use: the mediation role of social adaption. *Chin J Health Psychol.* 2020;28(03):409–414. doi:10.13342/j.cnki.cjhp.2020.03.021

23. Li BL, Deng LY, Chen JJ, Ni H. The relationship between class environment and academic stress among three middle schools: a multi-group SEM analysis of key, regular and migrant schools in Beijing. *J Educ Stud.* 2017;12(3):57–68. doi:10.14082/j.cnki.1673-1298.2017.03.007

24. Chi X, Hong X, Chen X. Profiles and sociodemographic correlates of Internet addiction in early adolescents in southern China. *Addict Behav.* 2020;106:106385. doi:10.1016/j.addbeh.2020.106385

25. Wang R, Yang S, Yan Y, Tian Y, Wang P. Internet gaming disorder in early adolescents: gender and depression differences in a latent growth model. *Healthcare.* 2021;9(9):1188. doi:10.3390/healthcare9091188

26. Lavoie C, Dufour M, Berbiche D, Therriault D, Lane J. The relationship between problematic internet use and anxiety disorder symptoms in youth: specificity of the type of application and gender. *Comput Human Behav.* 2023;140:107604. doi:10.1016/j.chb.2022.107604

27. Willoughby T. A short-term longitudinal study of internet and computer game use by adolescent boys and girls: prevalence, frequency of use, and psychosocial predictors. *Dev Psychol.* 2008;44(1):195–204. doi:10.1037/0012-1649.44.1.195

28. He N, Houmei H, Wang M, Li H. Problematic internet use and cyberbullying perpetration among Chinese adolescents: the mediating and moderating roles of negative emotions. *Int J Ment Health Addict.* 2022;1–19. doi:10.1007/s11469-021-00675-z

29. Joseph J, Varghese A, Vijay VR, et al. Problematic internet use among school-going adolescents in India: a systematic review and meta-analysis. *Indian J Community Med.* 2022;47(3):321–327. doi:10.4103/ijcm.ijcm_1129_21

30. Brand M, Young KS, Laier C, Wölfling K, Potenza MN. 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. *Neurosci Biobehav Rev.* 2016;71:252–266. doi:10.1016/j.neubiorev.2016.08.033

31. Liu S, Zhang D, Tian YX, B. Y, Wu XC. Gender differences in symptom structure of adolescent problematic internet use: a network analysis. *Child Adolesc Psychiatry Ment Health.* 2023;17(1):1–9. doi:10.1186/s13034-023-00590-2

32. Liu S, Xu B, Zhang D, Tian Y, Wu X. Core symptoms and symptom relationships of problematic internet use across early, middle, and late adolescence: a network analysis. *Comput Human Behav.* 2022;128:107090. doi:10.1016/j.chb.2021.107090

33. Shettar M, Karkal R, Kakunje A, Mendonsa RD, Chandran VM. Facebook addiction and loneliness in the post-graduate students of a university in southern India. *Int J Soc Psychiatry.* 2017;63(4):325–329. doi:10.1177/0020764017705895

34. Zeng W, Ye K, Hu Y, Ma ZW. Explicit self-esteem, loneliness, and pathological Internet use among Chinese adolescents. *oc Behav Pers.* 2016;44(6):965–972. doi:10.2224/sbp.2016.44.6.965

35. Yao MZ, Zhong ZJ. Loneliness, social contacts and Internet addiction: a cross-lagged panel study. *Comput Human Behav.* 2014;30:164–170. doi:10.1016/j.chb.2013.08.007

36. Fang X, Tian M, Wang R, Wang P. Relationships between depression, loneliness and pathological Internet use in adolescents: a cross-lagged analysis. *Curr Psychol.* 2022;1–11. doi:10.1007/s12144-022-03180-1

37. Kraut R, Patterson M, Lundmark V, Kiesler S, Mukophadhyay T, Scherlis W. Internet paradox: a social technology that reduces social involvement and psychological well-being? *Am Psychol.* 1998;53(9):1017–1031. doi:10.1037/0003-066X.53.9.1017

38. Rachubinska K, Cybulska AM, Grochans E. The relationship between loneliness, depression, Internet and social media addiction among young Polish women. *Eur Rev Med Pharmacol Sci.* 2021;25(4):1982–1989. doi:10.26355/eurrev_202102_25099

39. Morahan-Martin J, Schumacher P. Loneliness and social uses of the internet. *Comput Human Behav.* 2003;19(6):659–671. doi:10.1016/S0747-5632(03)00040-2

40. Jia Z, Wang Y, Yang Y, Yang L. Chinese university students' loneliness and generalized pathological Internet use: a longitudinal cross-lagged analysis. *oc Behav Pers.* 2018;46(5):861–870. doi:10.2224/sbp.6807

41. Gomez P, Harris SK, Barreiro C, Isorna M, Rial A. Profiles of Internet use and parental involvement, and rates of online risks and problematic internet use among Spanish adolescents. *Comput Human Behav.* 2017;75:826–833. doi:10.1016/j.chb.2017.06.027

42. Li H, Wang L, Wang J. Application of generalized pathological internet use scale in college students of China. *Chin J Clin Psychol.* 2008;2008(3):261–264.

43. Guo QK, Cai MH, Wang F, Li YJ. The influences of wording direction on the measurement of loneliness. *Chin J Clin Psychol.* 2017;25(1):116–119+131. doi:10.16128/j.cnki.1005-3611.2017.01.026

44. Russell DW. UCLA loneliness scale (version 3): reliability, validity, and factor structure. *J Pers Assess.* 1996;66(1):20–40. doi:10.1207/s15327752jpa6601_2

45. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equ.* 1999;6(1):1–55. doi:10.1080/10705519909540118

46. Marsh HW, Hau K-T, Grayson D. Goodness of fit evaluation in structural equation modeling. In: Maydeu-Olivares A, McArdle J, editors. *Contemporary Psychometrics. A Festschrift for Roderick P. McDonald*. Mahwah: Erlbaum; 2005:275–340.

47. Garland EL, Geschwind N, Peeters F, Wichers M. Mindfulness training promotes upward spirals of positive affect and cognition: multilevel and autoregressive latent trajectory modeling analyses. *Front Psychol.* 2015;6:15. doi:10.3389/fpsyg.2015.00015

48. Kovácsik R, Tóth-Király I, Egorov A, Szabo A. A longitudinal study of exercise addiction and passion in new sport activities: the impact of motivational factors. *Int J Ment Health Addict*. 2021;19:1511–1526. doi:10.1007/s11469-020-00241-z

49. Allison PD. *Quantitative Applications in the Social Sciences*. Thousand Oaks, Calif: Sage Publications; 2001.

50. Zhang S, Chen N, Liu H. LGM-based analyses with missing data: comparison between ML method and Diggle-Kenward selection model. *Acta Psychol Sin*. 2017. doi:10.3724/SP.J.1041.2017.00699

51. Liu QX, Fang XY, Zhou ZK, Zhang JT, Deng LY. Perceived parent-adolescent relationship, perceived parental online behaviors and pathological internet use among adolescents: gender-specific differences. *PLoS One*. 2013;8(9):e75642. doi:10.1371/journal.pone.0075642

52. Liu MY. *The Characteristics and Relationship Among Learning Stressors, Learning Burnout and Sleep Quality in Middle School Students* [Master's thesis]. Fujian Normal University; 2010.

53. Ahmadi K. Internet addiction among Iranian adolescents. A nationwide study. *Acta Med Iran*. 2014;52(6):467–472.

54. Wang L, Luo J, Bai Y, et al. Internet addiction of adolescents in China: prevalence, predictors and association with well-being. *Addict Res Theory*. 2013;21(1):62–69. doi:10.3109/16066359.2012.690053

55. Goel D, Subramanyam A, Kamath R. A study on the prevalence of internet addiction and its association with psychopathology in Indian adolescents. *Indian J Psychiatry*. 2013;55(2):140–143. doi:10.4103/0019-5545.111451

56. Mihara S, Higuchi S. Cross-sectional and longitudinal epidemiological studies of Internet gaming disorder: a systematic review of the literature. *Psychiatry Clin Neurosci*. 2017;71(7):425–444. doi:10.1111/pcn.12532

57. Alheneidi H, AlSumait L, AlSumait D, Smith AP. Loneliness and problematic internet use during COVID-19 lock-down. *Behav Sci (Basel)*. 2021;11(1):5. doi:10.3390/bs11010005

58. Prievara DK, Piko BF, Luszczynska A. Problematic internet use, social needs, and social support among youth. *Int J Ment Health Addict*. 2019;17:1008–1019. doi:10.1007/s11469-018-9973-x

59. Huang J, Sun H, Wang S, Zhang L. The research progress and prospects of overuse of social network. *Adv Psychol*. 2020;10(7):117. doi:10.12677/AP.2020.1071176