ORIGINAL RESEARCH

The Impact of Problematic Internet Use on Adolescent Loneliness-Chain Mediation Effects of Social Support and Family Communication

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Purpose: To explore the relationship between adolescents' problematic Internet use and loneliness and the mediating roles of social support and family communication.

Methods: A questionnaire survey of 2483 adolescents aged 12–17 years in 148 cities in China was conducted using the Problematic Internet Use Scale, the Collaborative Social Support Scale, the Family Communication Scale, and the Loneliness Scale. The data were statistically analyzed by SPSS 26.0 and validated by AMOS 28.0. Structural equation modelling (SEM) was conducted to test the effects of problematic Internet use on adolescents' loneliness and the mediating effects of perceptions of social support and family communication.

Results: There was a significant positive effect of adolescents' problematic Internet use on loneliness (B-0.471, P<0.001), and the mediating effects of perceptual social support (0.003, 0.012) and family communication (0.008, 0.019) were found to play a chain effect between adolescents' problematic Internet use and loneliness, respectively. Use and feelings of loneliness played a chain mediating role (0.002, 0.006).

Conclusion: This study identified the effects of adolescent problematic Internet use on loneliness and its mechanism of action, emphasized the importance of social support and family communication, and provided practical insights for improving family parenting styles and preventing and intervening in adolescent loneliness problems.

Keywords: problematic internet use, adolescents, loneliness, perceived social support, family communication

Introduction

Internet use has become an integral part of daily life for many adolescents.[1–4] In the United States, almost all teenagers aged 13–17 own a smartphone.[2] In China, according to the 2022 Progress Report on the Protection of Minors in China's Gaming Industry, the size of Internet users under the age of 19 has reached 186 million in 2022, accounting for 17.6% of the total number of all Internet users, of which the rate of cell phone ownership among minors aged 9 years old and above has reached 97.6%.[5] Excessive use of the Internet may generate problematic Internet use.Gómez et al identified the population of Problematic Internet Use as primarily adolescents.[6] Problematic Internet use developed in adolescence is likely to persist into mid-adulthood.[7] With the increase of problematic internet use among adolescents, internet-related physical and mental health issues such as loneliness have become a hot topic of discussion.[8,9]

Academics are divided on the relationship between Internet use and loneliness.[10,11] On the one hand, online communication helps people to stay in touch with friends and family who can provide emotional support, facilitating communication and interaction with family and friends and ultimately reducing loneliness.[12,13] However, some researchers warn

people against overusing the Internet because their addiction to the Internet and replacing offline communication with off-domain interactions leads to a lack of necessary relationships or the inability to maintain long-term connections with others, thus making it difficult for them to receive positive emotional support and a sense of belonging, which ultimately leads to an increase in loneliness.[14,15] However, in a follow-up study with the same sample of participants, the link between the level of Internet use and loneliness was found to disappear.[16] This shows that the relationship between problematic Internet use and loneliness is more complex, and other influences may need to be tested with more empirical data. Moreover, compared with other groups, adolescents in puberty are more likely to experience loneliness than other age groups.[17] Loneliness is a painful emotional experience that is associated with various types of mental health problems, such as persistent loneliness increases the risk of depression and anxiety in adolescents.[18,19] Therefore, this study aims to establish a multilevel model of factors influencing adolescent loneliness that includes external information and internal cognition to explain the formation mechanism of adolescent loneliness and then provide a theoretical basis for the intervention of adolescent loneliness.

Literature Review and Research Hypotheses
Problematic Internet Use and Loneliness

Scholars have proposed a variety of terms and definitions to describe Problematic Internet Use (PIU), including Internet addiction,[20] Compulsive Internet Use[21] or pathological Internet use,[22] which are often used interchangeably.[23] However, at their core, these different designations all refer to the same underlying phenomenon.[24] Therefore, this study conceptualized PIU as problematic, excessive, and time-consuming Internet exposure and use. Similar to the phenomenon of "generalized Internet addiction" proposed by Brand et al[25] and Davis,[22] PIU encompasses all forms of Internet use and therefore reflects multi-dimensional overuse of the Internet. This study views problematic Internet use as a general psychological condition of varying severity.[8] The media displacement theory suggests that the disembedded online presence brought about by the media replaces offline interactions with friends and family members, which may disrupt real-life relationships and increase feelings of isolation, leading to mental health problems.[26] Adolescents are in a critical period of neurological development and have difficulty regulating emotions.[27] If they are addicted to the Internet, they are more prone to emotional problems.[28]

Loneliness has been defined as a painful feeling of sadness and emptiness that occurs when a person is cognitively aware that the number of social relationships he or she has is lower than the number of social relationships he or she aspires to.[29] However, some researchers have cautioned against overuse of the Internet as people tend to become addicted to the network, reducing or eliminating real-world connections, which can exacerbate social isolation and loneliness.[30,31]

Loneliness originates from the spiritual loss caused by the conflict between the spiritual needs of human subjects and their realization of possibilities, and it is the failure of outward connection.[32] Along with the development of the Internet, people envision a "freely connected" society and hope to "disconnect" to the open space of the virtual network to resolve the sense of loneliness in real life. However, the use of digital technology has gradually replaced deep face-to-face relationships with superficial online connections that lack intimacy.[33] This is because they are in a state of development, gradually becoming more independent from their families, seeking to build strong relationships with their peers, and developing their social and emotional skills.[34] For adolescents, they try to alleviate loneliness through virtual interactions, but they sink deeper and deeper into loneliness because of PIU.[35] Yao & Zhong[36] used cross-lagged analyses and found that, in terms of decreasing loneliness, online socialization wasn't an effective substitute for offline social interactions, and excessive and unhealthy online use behaviors increase individual loneliness. Based on this, this study proposed the hypothesis that.

H1: Adolescents with PIU positively predicted their loneliness.

Understanding the Relationship Between Social Support and PIU and Loneliness

The concept of social support has two dimensions: The support that the individual believes is available when needed (ie, perceived social support) and the support received.[37] Research has consistently shown that perceived social support has a more significant effect on loneliness than actual social support received.[38] Therefore, the focus of this study is on

perceived social support, which refers to an individual's perception and assessment of aspects from family, friends, and other essential sources.[39]

Excessive Internet use has been found to reduce the quality of real-life social support for individuals.[40] This is because the social connections and reinforcement gained on the Internet may increase adolescents' desire to maintain a "virtual" social life.As adolescents spend more time on the Internet, they will have less time and energy to actively maintain social connections in their daily lives actively, increasing their feelings of isolation.[15,41] As Shirley Turkle points out, "Humans are using mobile devices to convince themselves that even when we are all alone, we feel like we are with everyone, but when we are alone, we are alone".[42]

However, some scholars have argued that this claim implies a fear of "Internet witchcraft" and ignores the role of social support in the relationship between Internet use and loneliness.[43] Appreciating social support prevented risky behaviors and psychological distress in adolescents.[44] Highly supportive friendships were associated with less loneliness.[45] The Internet can help people stay connected to their close social relationships across time and physical space, resulting in positive associations with perceived social support.[46] Social capital theory is a well-established theoretical framework related to the establishment and maintenance of social relationships.[47] It consists of two aspects: bonding social capital and bridging social capital. Bonding social capital refers to social relationships with solid ties, such as relationships with family members and close friends who usually provide emotional support. Connective social capital comes from relationships with weakly connected people who often have diverse backgrounds and can provide a wide range of resources.[48] Networks help people learn about the current status of their family and friends, share events in their lives, and promote connectedness and closeness, thus enhancing bonding social capital. Networks provide opportunities for formal interactions not only with family and close friends, but also with acquaintances and community members, which can increase bonding social capital.Both forms of social capital can provide individuals with valuable support and reduce feelings of isolation.[12] Individuals shared their experiences, chatted and communicated with others, posted statuses and photos to show themselves through online platforms may gain attention from others and social support, which in turn reduced psychological problems among college students.[49] Song et al[50] argued that lonely individuals are likely to seek out social support on the Internet. Loneliness associated with PIU among adolescents can be improved by increasing social support.[51]

Thus, social support may be an important mediating mechanism in explaining the relationship between PIU and adolescent loneliness. Although this idea has not been directly tested, some evidence indirectly supports the mediating role of social support in this relationship. In summary, the hypotheses of this study were proposed.

H2: Perceived social support mitigated the effects of PIU on adolescent loneliness.

The Relationship Between Family Communication and PIU and Loneliness

Families can bring about profound effects and changes in the beliefs of individuals and their behavior.[52] Family communication, a way of transmitting affection and emotional bonds, is an important part of family functioning.[53,54] Studies have found that family environment characteristics are associated with adolescents' Internet use behavior.[55–57] On the one hand, parent-adolescent communication,[58] family cohesion,[59] and supportive parental supervision[60] are recognized as protective factors against PIU.On the other hand, rejection, overprotection, or negative parent-child relationships[58,60] etc. were identified as risk factors for PIU.

According to developmental psychology, lack of family communication is a predictor of adolescent loneliness.[61] When there are deficits in family functioning or relationships with parents, such as when parents are overly strict or neglectful and do not communicate positively with their children,[62,63] adolescents may become addicted to the Internet.[64] Research has found that family communication moderates the relationship between social media use and loneliness among young people; at the same time, its findings suggest that family communication remains at the center of social discourse when it comes to adolescent loneliness, mental health, and social media use.[65] Family communication reduced loneliness among family members by increasing spiritual identity.[66] Some scholars have further found that family communication plays a mediating role between problematic smartphone use and family well-being, thus advocating the promotion of family well-being through enhanced family communication.[67] Based on this, this study proposed the hypothesis:

H3: Family communication mediated the relationship between problematic internet use and loneliness.

Appreciating the Chain Mediation of Social Support and Family Communication

Appreciating social support and family communication as protective factors for adolescents' risky behaviors can mitigate their emotions of loneliness in PIU, and there is also a strong link between the two. Social support can be transmitted and influenced through family communication.[68] According to Family Systems Theory (FST), the family is a system characterized by patterns of emotional interactions between generations, viewing family members as elements in an interrelated structure and emphasizing that each member interacts with each other.[69]

Loneliness is a subjective feeling, a negative emotion of dissatisfaction with the level and quality of social interactions and a perception of limited social support and companionship.[70,71] When people do not feel supported in their family of origin and cannot express their thoughts and feelings freely, they may feel alienated, disconnected, and misunderstood, which are components of loneliness.A good family-of-origin environment is thought to prevent loneliness.[72]

Currently, some scholars have preliminarily demonstrated the relationship between PIU, perceived social support, and loneliness and have suggested that the key to increased social support is to strengthen family communication and protect adolescents from loneliness and PIU by practicing communication skills face-to-face.[51] However, research findings have not yet tested the hypothesis that comprehending social support and family communication mediates the relationship between PIU and adolescent loneliness.The advancement of this study will contribute to the deepening of the academic community's knowledge of the impact of problematic internet use on adolescent loneliness. Based on this, this study proposed the hypothesis:

Based on the above literature review, we formulate the following research hypotheses, And constructed a conceptual model of PIU, perceived social support, and family communication influencing adolescent loneliness, as shown in Figure 1.To explore the pathways through which problematic Internet use affects adolescents' loneliness.

H1: Adolescents with PIU positively predicted their loneliness.

H2: Perceived social support mitigated the effects of PIU on adolescent loneliness.

H3: Family communication mediated the relationship between problematic internet use and loneliness.

H4: Appreciating that social support and family communication chain-mediated the relationship between PIU and loneliness.

Method

Study Population and Recruitment

This study was a cross-sectional, face-to-face survey of adolescents aged 12–17 in 148 cities, 202 districts and counties, 390 townships/towns/streets, and 780 neighborhoods/villages in 23 provinces, 5 autonomous regions, and 4 municipalities directly under the central government of China, excluding Hong Kong, Macau, and Taiwan.Based on the data from the Seventh National Population Census, population ratios were obtained for 23 provinces, 5 autonomous regions, and 4 municipalities directly under the central government, and based on the population ratios, the sample size for each province, autonomous region, and municipality directly under the central government was calculated separately, and the sampling was gradually conducted at the level of cities, districts, counties, townships/towns/streets, and communities/villages.The study conducted two rounds of pre-surveys in mid-June and early July 2022, each with a sample size of 100 people.The sampling method used was quota sampling, in which the quota attributes were the same as those required for the formal survey. Based on the pre-survey, the presentation of
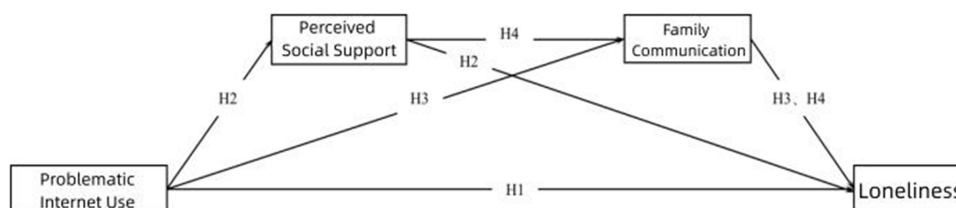

Figure 1 Research conceptual mode.

the questionnaire and the survey questions were modified and adjusted accordingly to the respondents' comprehension and cognitive levels.The formal survey was based on the Questionnaire Star platform (https://www.wjx.cn/), which distributed the questionnaire to respondents on a one-on-one, face-to-face basis, and respondented respond by clicking on the questionnaire link. Each questionnaire was numbered accordingly under the premise of informed consent of the respondents.If the respondent was unable to complete the questionnaire independently, the investigator explained the questionnaire and answered it instead of the respondent following their true wishes.After the questionnaires were recovered, logical checking and data screening were conducted by two people back to back.Finally, 2483 valid questionnaires were obtained, of which 1167 (46.9%) were male, 1316 (52.1%) were female, 1757 (70.8%) were urban, and 726 (29.2%) were rural, as shown in Table 1.

Measurements
Problematic Internet Use
This study used the Problematic Internet Use Scale developed by Demetrovics et al to measure the extent of PIU in an adolescent population.[73] The scale consists of three dimensions and six entries.The scale was measured using a Likert 5-point scale for scoring, with options ranging from never (0 points) to always (4 topics) and total scores ranging from 0–24, with higher scores indicating more severe PIU in adolescents.The Cronbach's alpha coefficient for this scale in this study was 0.922.

Loneliness
The Loneliness Scale (T-ILS) was used to measure adolescents' feelings of perceived loneliness.[74] The scale was developed by Russell et al. One dimension, three entries.The measure was scored using a Likert 3-point scale with options ranging from rarely (1 point) to often (3 points), and the total T-ILS score ranges from 3–9 points. The Cronbach's alpha coefficient for this scale in this study was 0.896.

Perceived Social Support
The present study used the Perceived Social Support Scale developed by Zimet et al to measure the level of perceived social support among the adolescent group.[75] The scale consists of three dimensions and three items.It measured the extent to which adolescents perceived social support from family, friends, and other people and reflected the total degree of perceived social support the individual feels in terms of a total score. The Cronbach's alpha coefficient for this scale in this study was 0.907.

Family Communication
The Family Communication Scale (FCS-10) was used to measure the level of family communication in the adolescent population.[76] The scale was developed by Olsen et al. One dimension, with ten entries, assesses family communication status. The measure was scored using a 5-point Likert scale with options ranging from strongly disagree (1 point) to strongly agree (5 points), with total scores ranging from 10 to 50, with higher scores indicating higher levels of family communication.The Cronbach's alpha coefficient for this scale in this study was 0.971.

Statistical Analysis
This study used SPSS 26.0 and AMOS 28.0 software for statistical data analysis and validation factor analysis, and structural equation modeling was developed through the latter. On this basis, the validity of the path hypothesis between

Table 1 Description of the Distribution of Sample Characteristics

Variant	Options (as in Computer Software Settings)	Frequency	Percentage (%)
Distinguishing between the sexes	Male	1167	46.9
	Women	1316	53.1
Current address	Cities and towns	1757	70.8
	Non-urban	726	29.2

the variables was tested, and the mediating effect of comprehending social support and family communication was further verified.According to previous studies, it was found that the bias-corrected percentile Bootstrap method has higher validity in the mediation effect test compared with the traditional Sobel method.[77] Therefore, this study used this method to validate further the mediating effect of comprehending social support and family communication.Therefore, the bias-corrected percentile Bootstrap method will be used in this study to estimate the 95% confidence interval of the mediation effect by taking 5000 times from the original sample with release. If the confidence interval did not contain a zero, the mediating effect was present; conversely, the mediating effect was absent.

Applicability Test

Principal component analysis was performed on the four variables to reduce the dimensionality of the dataset using SPSS 26.0, and a suitability test was performed, the results of which were shown in Table 2. In this analysis, a KMO test value of 0.949 was obtained, and the probability of significance of the $\chi 2$ statistic value of Bartlett's test of spheres < 0.001 suggested that the principal component analysis fully met the feasibility criterion.

Principal Component Analysis

Using SPSS26.0 software to analyze the variables in the measurement questionnaire as principal components, we finally obtained the results shown in Table 3. Table 3 shows that we have extracted four principal components, and their cumulative variance contribution reached 78.808%, indicating that these principal components can reflect the original data more adequately.The variance share of the first principal component was 36.247%, which was lower than the critical value of 40%, but this still indicated that the bias of the homology method was within an acceptable range and met the conditions for carrying out the next step of data analysis.

Reliability and Validity Test

As shown in Table 4, the internal consistency of each dimension was analyzed using the Cronbach coefficient reliability test. The results showed that the Cronbach's coefficients of the scales were between 0.8 and 1.Therefore, it indicated that all the scales used in this study have good internal consistency. The convergent validity (AVE) and combinatorial reliability (CR) of the dimensions of the scales were examined through a validation factor analysis of the convergent validity of the measurement model.The results of the study showed (Table 4) that the standardized loadings of the question items of the scales ranged from 0.781–0.903 were all higher than 0.5, the AVE ranged from 0.666–0.773 were

Table 2 KMO and Bartlett's Test

KMO Quantity of Sample Suitability		0.949
Bartlett's spherical test	Approximate chi-square	50,671.767
	Degrees of freedom	231
	Significance	<0.001

Table 3 Total Variance Explained by Each Scale

Component	Initial EIGENVALUE			Extract the Sum of the Squares of the Loads			Rotational Load Sum of Squares		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.490	43.135	43.135	9.490	43.135	43.135	7.974	36.247	36.247
2	4.502	20.465	63.600	4.502	20.465	63.600	4.439	20.175	56.423
3	1.840	8.363	71.963	1.840	8.363	71.963	2.511	11.414	67.837
4	1.506	6.845	78.808	1.506	6.845	78.808	2.414	10.971	78.808

Table 4 Results of Convergent Validity and Combined Reliability Tests for Each Dimension of the Scale

Pathway Relationship			Estimate	AVE	CR	AVE Square Root	Cronbach's α
WT1	—>	Problematic Internet Use	0.792	0.666	0.923	0.816	0.922
WT2	—>	Problematic Internet Use	0.854				
WT3	—>	Problematic Internet Use	0.831				
WT4	—>	Problematic Internet Use	0.791				
WT5	—>	Problematic Internet Use	0.781				
WT6	—>	Problematic Internet Use	0.845				
ZC1	—>	Perceived Social Support	0.871	0.765	0.907	0.875	0.907
ZC2	—>	Perceived Social Support	0.879				
ZC3	—>	Perceived Social Support	0.873				
GT1	—>	Family communication	0.866	0.773	0.972	0.879	0.971
GT2	—>	Family communication	0.891				
GT3	—>	Family communication	0.868				
GT4	—>	Family communication	0.869				
GT5	—>	Family communication	0.896				
GT6	—>	Family communication	0.903				
GT7	—>	Family communication	0.884				
GT8	—>	Family communication	0.899				
GT9	—>	Family communication	0.840				
GT10	—>	Family communication	0.885				
GD1	—>	Loneliness	0.873	0.743	0.897	0.962	0.896
GD2	—>	Loneliness	0.878				
GD3	—>	Loneliness	0.834				

all higher than 0.5, and the CR ranged from 0.897–0.972 were all higher than 0.7.Thus, the scales used in the present study have good convergent validity and combinatorial reliability.

With good convergent validity and combined reliability for each dimension of the scale, the test of differential validity was conducted based on the results of convergent validity of each scale.According to the analysis results, it can be found (Table 4) that the standardized phase coefficients between each dimension in this test of discriminant validity are less than the square root of the AVE corresponding to that dimension.Therefore, it can be stated that each dimension has an excellent discriminant validity between them.

Results and Findings
Main Effects Tests
In this study, the research model was analyzed by AMOS 28.0 for structural equation fitting to verify the model assumptions.The ratio of chi-square to degrees of freedom, CMIN/DF, root mean square of approximation error, RMSEA, goodness of fit index, GFI, non-standard fit index, TLI, value-added fit index, IFI, and relative fit index, CFI, were used for validation.After fitting corrections, the final model fit indices were shown in Table 5, where CMIN/DF = 4.891, greater than 1 and less than 5, and RMSEA (Root Mean Square of Error) = 0.040, within the range of < 0.05. The GFI, TLI, IFI, and CFI test results reached an excellent level of 0.9 or more. This showed that the critical fit indicators in this study were within the acceptable range of recommended values, and therefore, the model was well-fitted.The problem of multicollinearity may occur when there is a high correlation between independent variables. According to the formula VIFj=1/(1-Rj2)(Rj2 is the coefficient of determination obtained by doing a regression of independent variables on other independent variables) (Variance Inflation Factor, VIF. After the calculation, the VIF of the predictor variables used in this study was below 5, so it can be concluded that there is no problem of multicollinearity.

Based on the conceptual model, this study constructed a structural equation model of PIU, navigational social support, and family communication affecting adolescents' loneliness.In the relationship test of the path hypothesis of this study,

Table 5 Model Fitness Test Results

Norm	Reference Standard	Actual Results
CMIN/DF	1–3 is excellent, 3–5 is good	4.891
RMSEA	< 0.05 is excellent, < 0.08 is good	0.040
GFI	> 0.9 is excellent, > 0.8 is good	0.965
TLI	> 0.9 is excellent, > 0.8 is good	0.982
IFI	> 0.9 is excellent, > 0.8 is good	0.985
CFI	> 0.9 is excellent, > 0.8 is good	0.985

adolescents' PIU (β= −0.109, P < 0.001) significantly negatively affected their apprehension of social support;adolescents' PIU(β= −0.158, P < 0.001) significantly negatively affected their influence on family communication; adolescents' PIU (β= 0.471, P < 0.001) significantly positively affected their loneliness, the first research hypothesis of this study was proven; perceived social support (β= 0.501, P < 0.001) significantly positively affects their family communication; perceived social support (β= −0.128, P < 0.001) significantly negatively affected adolescents' loneliness; family communication (β= −0.122, P < 0.001) significantly and negatively affected adolescents' loneliness. The path coefficients between the variables and their significance were shown in Table 6 and Figure 2.

Mediation Effects Test

Based on the study's conceptual model, this paper hypothesized that there was a mediating effect of perceived social support and family communication between adolescents' PIU and loneliness, which was analyzed and validated by AMOS 28.0.And the mediating effect of perceived social support and family communication was verified by using the bias-corrected nonparametric percentile Bootstrap method, and Table 7 showed the standardized estimates of each indirect path and the 95% confidence intervals of the mediating effect, and the mediating effect was significant if the 95% confidence interval did not contain zero.According to the data in Table 7, Root showed that the 95% confidence intervals for all three indirect paths did not contain 0, indicating that the effects of perceived social support, family communication, and chain mediation were all significant.Specifically, the mediation effect value of perceived social support is 0.0067, the mediation effect value of family communication is 0.0128, and the mediation effect value of chain mediation is 0.0039.Therefore, this study's hypothesed 2, 3, and 4 are all valid.

Discussion

The finding that adolescents with PIU directly and significantly positively affects their loneliness is consistent with existing research.[51] As found in Katariina et al's study, problematic Internet use can trigger loneliness in adolescents.[78] Thanks to the Internet, adolescents are becoming obsessed with and addicted to it, becoming trapped in PIU and pseudo-techno relationships and using them as a substitute for lasting emotional connections, leading to loneliness.This symptom is echoing Freud's lament in Civilization and its Discontents: "If there had been no railroads, there would have been no

Table 6 Results of Model Path Relationship Hypothesis Testing

| Pathway Relationship	Estimate	S.E.	C.R.	P-value	Reach A Verdict
Problematic Internet Use→ Perceived Social Support	− 0.109	0.030	− 4.952	< 0.001	Be in favor of
Problematic Internet Use→ Family Communication	− 0.158	0.016	− 8.447	< 0.001	Be in favor of
Problematic Internet Use→ Loneliness	0.471	0.013	22.267	< 0.001	Be in favor of
Perceived Social Support → Family communication	0.501	0.013	24.609	< 0.001	Be in favor of
Perceived Social Support → Loneliness	− 0.128	0.010	− 5.572	< 0.001	Be in favor of
Family communication → Loneliness	− 0.122	0.016	− 5.356	< 0.001	Be in favor of
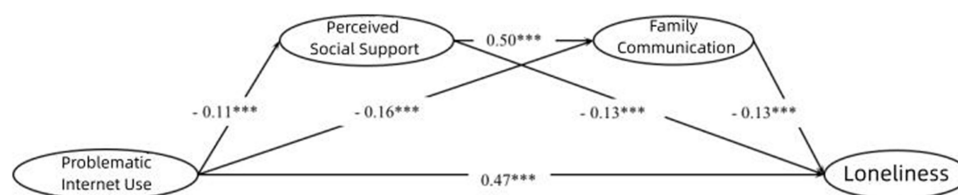
Figure 2 Path coefficients of structural equation modeling.
Notes: ***$P<0.001$.

need for my child to leave his home, and I would not have had to make telephone calls in order to listen to his voice; if there had been no invention of the ship that could cross the ocean, my friends would not have had to make plans for a voyage, and I would not have had to resort to the telegraph in order to alleviate my anxiety".[79] The essence of this issue is the question of the relationship between the subject and technology.While the Freudian rejection of technology is unnecessary, the attitude with which to confront technology, especially in the adolescent population, has become a more pressing topic than ever before.

Following the implications of technological ontology, adolescents are drawn into the logic of cybertechnology and become its objects, too deeply entangled to be extricated.Take Merleau Ponty's cane as an example, the cane is originally a tool for people who are blind, but through the act of constantly getting on the hand, the cane is gradually incorporated into the body of people who are blind, thus becoming a medium.[80] In the case of adolescents, the Internet is a virtual cane for them, through which they view the world as a "digital prosthesis". This would be a perfect example of technology for good, but the problem lies in the word "problem" in PIU. In the scale used in this study, the issue of PIU consists of three main dimensions: obsession, neglect, and control disorder. In PIU, adolescents as subjects are "alienated" as objects of Internet technology.

Elaborating on the problem of social alienation of people caused by network technology, Turkle concludes that "the online connection of digital technology replaces offline communication, reducing vivid and rich offline interpersonal interactions to simple digital connections; transforming embodied performative self-presentation into disembodied false performances; and evolving intimacy from weakening to alienation. Such results counter people's attempts to free themselves from genuine relationships through digital technology, ultimately deepening the uncertainty of communication and the experience of human loneliness".[81] Therefore, we have to guide adolescents to correctly face technological rationality, establish a reasonable way of communication and interaction, transcend the enslavement of technological rationality to the subject, and build a multidimensional and multifaceted mode of communication so that rationality does not overstep the bounds of reason and sensibility is not absent, and so that adolescents can return to the real world from the virtual world, and then improve the sense of loneliness of adolescents.

Although PIU predicted adolescents' loneliness, comprehending social support mitigated this relationship and acted as a social cure. This is consistent with previous research, such as problematic computer gamers receiving higher social support online and lower social support offline, both of which alleviate their loneliness.[82] However, unlike the studies by Wang et al (2018)[56] and Tian et al (2021),[83] who argued that overuse of the Internet may take away time that should be spent on social interactions with peers, thus making adolescents' relationships with peers deteriorate and decreasing social support from peers, which ultimately leads to adolescents sinking deeper into loneliness. The findings of this study

Table 7 Intermediate Path Relationship Test Results

Trails	Standardization Path Factor	Standard Error	95% Confidence Interval	
			Lower Limit	Limit
Problematic Internet Use → Perceived Social Support → Loneliness	0.0067	0.0022	0.0032	0.0116
Problematic Internet Use → Family Communication → Loneliness	0.0128	0.0028	0.0077	0.0187
Problematic Internet Use → Perceived Social Support → Family Communication → Loneliness	0.0039	0.0012	0.0019	0.0063

corroborate "the need to belong" theory and "social capital" theory.The Need to Belong theory suggests that people naturally desire to be connected to society, which in turn creates a sense of belonging and thus reduces loneliness.[84] Social capital theory suggests that social relationships contribute to the production of bonding and connective social capital, which are sources of social support.[48] Adolescence is a critical stage in the socialization process of individuals. With the awakening of self-consciousness, they crave freedom and independence like never before and begin to separate the "I" from the "we" gradually and try to obtain social support and make new connections on the Internet new connections.[85] Through Internet applications, adolescents can "see" and "be seen", share bits and pieces of their lives with their families and friends, and promote a sense of connection and belonging, strengthening interpersonal relationships.As expected by the "social capital" theory, more robust social relationships generate social capital, providing instrumental benefits and emotional support to adolescents and reducing the risk of loneliness.

Adolescents perceive that social support from others is essential in reducing their sense of isolation, making it particularly important to increase one's sense of belonging and connection with relevant others. This is contrary to the practices of some communities and families that keep an adolescent disconnected from the outside world to quit his Internet addiction, which may be counterproductive and, in line with the viewpoints derived from this study, negatively affect the adolescent as they contribute to loneliness, weaken the adolescent's abilities, and fragment the forms of social support. Therefore, we recommend that the relevant authorities provide social support to adolescents with problematic internet use, which will help them develop positive internet use and increase resilience, thus preventing them from falling into isolation.[86]

In addition, family communication has been found to mediate between PIU and adolescent loneliness, mitigating the effects of PIU on adolescent loneliness. Adolescents share their inner thoughts, personal feelings, experiences and information online.[87] These online self-representations can allow parents to grasp their adolescents' psychological trends for better communication and alleviate adolescents' loneliness.[88] For parents, open and positive communication about Internet use seems to be the most effective way to prevent adolescents' problematic Internet us.[89–91] The mediating effect of family communication is manifested in three aspects: firstly, family communication can bring a sense of stability that cyber society cannot give, generating spiritual value; secondly, family communication expresses and permeates meaning through collective and repetitive practices, constructs and maintains order, and thus forms and maintains community to counteract the effects of problematic cyber use and loneliness; finally, family communication can contribute to the chaos and confusion of cyber use; Finally, family communication can give a set of structural order to the chaotic and disordered reality and help the subject to better recognize and grasp reality.[92]

Therefore, this study recommends that government agencies, schools, and educators should also target parents to educate them about the importance of creating a positive communication climate in the home, and to instruct parents on how to communicate with their children about Internet use in an authoritative but non-judgmental manner that is characterized by support for and respect for the child's need for autonomy.[93]

Appreciating the chain mediating role of social support and family communication in the relationship between PIU and loneliness suggests that PIU collectively affects adolescents' loneliness through some specific mediating variables. The findings shed light on the internal mechanism of action by which PIU affects adolescents' loneliness, ie, family communication and social support mitigated the loneliness associated with adolescents' addiction to the Internet.These studies suggest that adolescents' PIU is not the result of their "inherently" vulnerable developmental characteristics.Instead, it is to be blamed on today's lack of family functioning and lack of social structure. A growing sense of uncertainty and ambivalence is the dominant feature of our times, often described as 'fluid modernity'.[94] Social structures - such as education, healthcare, social security, and the family - seem fluid and unable to hold their shape, and due to the lack of solid bonds adolescents are plunged into the abyss of the Internet, unable to extricate themselves.The path of "problematic Internet use-social support-family communication-loneliness" corresponds to the "individual-society-family-individual" communication pattern and influence mechanism.This mechanism of action is Habermas' prescription for alienation: to break the alienation of people by science and technology by establishing a reasonable mode of communication.Frequent social support and family communication for adolescents may reduce their need to seek solace in PIU and decrease feelings of isolation.

Conclusions

In summary, while past research has provided possible directions for the link between PIU and adolescent loneliness, the underlying mechanisms are unclear. Based on expanding and deepening the original research, this study found the indirect roles of perceived social support and family communication. We constructed a communication model for intervening loneliness with the help of family systems theory. In this regard, constructing a multi-level and multi-dimensional interaction model, promoting the return of adolescents from the virtual world to the physical world, enhancing adolescents' social support, and promoting their communication with family members are effective ways to inhibit the development of loneliness.

Limitations and Future Research

Although the sample size of the study is not tiny, it was only analyzed on cross-sectional data, so caution must be exercised when inferring causal relationships between variables, and subsequent studies will be based on longitudinal follow-up surveys to deepen the discussion of this issue, and then propose more targeted opinions, suggestions and strategies.

Data Sharing Statement

Data are available, upon reasonable request, by emailing: bjmuwuyibo@outlook.com.

Ethics Statement

This study was approved by the Ethical Review Committee of the Health Culture Research Centre of Shaanxi Province, China and the Second Xiangya Hospital of Central South University.All procedures performed in studies involving human participants were in accordance with the ethical standards and with the Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study (Minor participants have obtained informed consent from their parents or legal guardians).

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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