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# Intolerance of uncertainty and internet addiction among college students in China post-pandemic era: the mediating role of future anxiety

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Due to the repeated changes in the COVID-19 pandemic, we live in an era of various uncertainties that raise future anxiety and behavioral addiction problems. According to the Protection Motivation Theory (PMT), the present study attempted to explore the impact of COVID-19 intolerance of uncertainty (COVID-19 IU) on internet addiction (IA) among college students and the mediating role of future anxiety (FA) by constructing a mediating model. A questionnaire survey was conducted on 679 Chinese college students and PROCESS 3.5 was utilized to test the hypotheses. The results indicated that the COVID-19 IU was significantly positively correlated with IA and FA, and FA was significantly positively correlated with IA. COVID-19 IU had a significant positive predictive effect on IA; FA played a complementary partial mediating role between COVID-19 IU and IA. The results supported the PMT, which not only enriched our understanding of FA under uncertain life circumstances, but also deepened our understanding of the potential mechanisms of the effects of IA. Finally, discussions and suggestions were presented based on the results.

**Keywords** COVID-19 intolerance of uncertainty, Internet addiction, Future anxiety, College Students

Based on the current development of the COVID-19 pandemic, the Chinese government announced on December 7, 2022, an adjustment to the policy for the prevention and control of epidemics, with less emphasis on social control<sup>1</sup>. However, the number of COVID-19 infections in China rose sharply after the relaxation of the policy. According to the Chinese Center for Disease Control and Prevention, the number of positive novel coronavirus infections reached a daily peak of 6.94 million on Dec 22 and the currently prevalent variant of Omicron continues to mutate<sup>2</sup>. Recent research also indicated that novel coronavirus had undergone multiple mutations and rapid evolution, resulting in more infectious new variants<sup>3</sup>. As a chronic and highly infectious disease with repeated multiple outbreaks<sup>4</sup>, COVID-19 poses a significant risk to all facets of human life<sup>5</sup>. With the continuous emergence of novel coronavirus variants, scientists are uncertain about the long-term efficacy of vaccines<sup>6</sup>. Consequently, the public risk and uncertainty posed by novel coronavirus continue to exist<sup>7</sup>.

Freeston et al.<sup>8</sup> defined uncertainty intolerance (IU) as “cognitive, affective, and behavioral responses to negative events of everyday uncertainty.” It is a sort of individual personality trait resulting from negative beliefs about uncertainty and its effects<sup>9</sup> and an inability to tolerate adverse reactions caused by perceived uncertainty due to a lack of critical or sufficient information<sup>10</sup>. Previous research indicates that the continuous mutation of COVID-19 induces the greatest degree of uncertainty in various facets of daily life<sup>5,6</sup>. This perception of uncertainty may elicit fear, worry, anxiety, vulnerability, avoidance of decision-making, and excessive information-seeking to reduce uncertainty in individuals<sup>4,11</sup>. Luo et al.<sup>4</sup> showed that COVID-19 intolerance of uncertainty (COVID-19 IU) may lead individuals to seek excessive information from the Internet, use the Internet to escape reality, and eventually spend more time online than offline, thereby increasing the risk of Internet addiction

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(IA). A cross-sectional study of 561 participants in Mexico found that 62.7% showed some degree of IA during the COVID-19 epidemic<sup>12</sup>.

Meanwhile, previous studies indicated that individuals with high IU are more likely to be overly anxious about their future life<sup>13–15</sup>, while anxiety had been proven to be an essential risk factor for IA in recent studies<sup>12,16,17</sup>. Therefore, this study focuses on how COVID-19 IU affects IA among college students through future anxiety (FA) in uncertain periods following the adjustment of the Chinese epidemic policy.

### The protective motivation theory

Rogers<sup>18</sup> proposed the Protective Motivation Theory (PMT), a robust theoretical framework for predicting the protective behaviors of individuals. PMT clarifies individuals' intention and motivation to perform protective behaviors and explains the behavior change process through individuals' assessment of threats and capacity to respond<sup>19,20</sup>. The theory focuses on exploring the human behavioral response from the perspective of intrinsic motivational factors<sup>18,21</sup>. Previous research has shown that when individuals perceive a severe threat, their intention to protect themselves increases<sup>22</sup>. Specifically, when individuals recognize that they are susceptible to a severe health threat, fear is heightened, increasing their motivation to engage in protective behaviors<sup>20</sup>.

The PMT provides a more comprehensive and in-depth analysis of the mechanisms and processes underlying individual behavioral change with a more comprehensive consideration of the influence of environment and social norms on individual behavior<sup>21</sup>. This framework is currently applicable not only for predicting individual health behaviors<sup>23,24</sup> but also for explaining, predicting, and intervening in individual unhealthy addictive behaviors in various contexts<sup>19,21</sup>. For example, based on PMT, Wang et al.<sup>21</sup> found that competitive stress and anxiety were important factors influencing smoking addiction among college students through interviews and questionnaire analysis. Webb et al.<sup>19</sup> demonstrated that PMT could be applied to propose intervention measures for addictive behaviors by correcting individuals' assessment of threats and coping ability.

Previous research indicates that an individual who feels their health is threatened may experience high levels of anxiety, resulting in a variety of negative behavioral responses to coping with threat-related anxiety, such as denial and avoidance<sup>20,25,26</sup>. The COVID-19 pandemic is an ongoing crisis accompanied by long-term uncertainty<sup>27</sup>. Individuals' perceived uncertainty may trigger fear, worry, and anxiety, and they may reduce uncertainty through behaviors such as decision avoidance or excessive information-seeking<sup>4,11,26</sup>. These behaviors may increase the risk of IA. Consequently, based on PMT, the present study considered college students' COVID-19 IU and future anxiety (FA) as intrinsic drivers of their behavior of IA. A mediation model was proposed to determine whether college students' COVID-19 IU and FA could significantly influence their IA.

### COVID-19 intolerance of uncertainty and internet addiction

IA is defined as the psychological dependence on the Internet<sup>28</sup>. Specific Internet addictive behaviors include preoccupation with the Internet and the use of the Internet to escape or alleviate negative emotions<sup>4</sup>. It is primarily characterized by excessive usage and access or inadequate control over the Internet<sup>29</sup>. Previous research has indicated that with the outbreak of the COVID-19 pandemic, college students' internet penetration has increased, thereby heightening the risk of IA<sup>30</sup>.

Previous studies have suggested that the Internet can be used to escape from uncertain reality when people are faced with intolerable uncertain events<sup>25</sup> and to find relevant information to reduce this uncertainty<sup>31</sup>. For instance, Starcevic et al.<sup>11</sup> found that individuals with a high level of IU frequently seek information online to increase their certainty, such as medical information, to reduce the uncertainty associated with potential health problems. In addition, past research suggests that the recurrent threat and high level of uncertainty posed by the COVID-19 pandemic may strengthen the connection between IU and IA<sup>4,32</sup>. Recent research also suggests that individuals with a high level of IU may spend more time on the Internet than others and are especially susceptible to addictive behaviors such as cell phone addiction<sup>33</sup> and IA<sup>4</sup>. A survey of 1006 adolescents in China revealed that IU significantly and positively predicted IA<sup>34</sup>. This result was supported by a study of Turkish adolescents, which demonstrated that IU directly and positively influenced IA during the COVID-19 epidemic<sup>35</sup>. Moreover, a survey of 1137 Chinese adults revealed that their COVID-19 IU was a significant predictor of IA<sup>4</sup>. Therefore, the present study attempted to investigate whether college students' COVID-19 IU could significantly and positively affect their IA during the Post-pandemic Era in China.

### The mediating role of future anxiety

Past research has tended to view future anxiety (FA) as a conscious state related to other forms of anxiety<sup>36–38</sup>. FA is a condition in which a person worries about negative changes in the distant future<sup>38</sup>. It is a cognitive trait that relates to actual social and political processes and events that lead individuals to anticipate future threats rather than an immediate present<sup>39</sup>.

According to previous research, the COVID-19 pandemic creates great public uncertainty<sup>32</sup>, which can lead to anxiety<sup>15</sup>. In addition, empirical studies have established a link between the COVID-19 pandemic and intrinsically harmful psychological states, such as anxiety<sup>40,41</sup>. Chen et al.<sup>42</sup> confirmed that IU was a crucial cognitive vulnerability factor and antecedent of anxiety. Individuals with a high level of IU display excessive anxiety and avoidant behavior<sup>13</sup> and may even increase their anxiety levels<sup>15</sup>. Previous research has shown that IU is significantly and positively related to greater anxiety in adults during the COVID-19 pandemic<sup>14</sup>. A study with 88 participants in Beijing revealed that IU predicted anxiety significantly and positively<sup>42</sup>. Miranda et al.<sup>43</sup> demonstrated a significant effect of IU on generalized anxiety. However, the current literature lacks direct evidence of the relationship between IU and FA. Based on the preceding literature, COVID-19 IU may trigger college students' anxiety about their future health status, studies, and employment situation. Therefore, the present study attempted to determine whether college students' COVID-19 IU can significantly influence their FA.

Past research has suggested that individuals with anxiety typically cope with or avoid associated distress by engaging in undesirable behaviors<sup>44</sup>, such as IA<sup>12</sup> and new media addiction<sup>16</sup>. According to previous research, anxiety has been proven to be linked to IA<sup>12,45,46</sup>. Recent studies have shown that individuals with higher levels of FA may exhibit greater addictive tendencies<sup>47</sup>. Shabahang et al.<sup>16</sup> noted that FA significantly predicted online news addiction (internet addiction) among Iranian university students. According to a study of 478 university students<sup>47</sup>, FA was significantly and positively associated with problematic new media use, which might alleviate their negative feelings and increase their addictive tendencies. A recent research involving 840 college students in China revealed that FA significantly and positively predicted college students' cell phone addiction<sup>48</sup>. During the COVID-19 epidemic, a survey of 482 graduate students discovered that graduate students' anxiety had a significant and positive effect on IA<sup>17</sup>. Based on the previous findings, FA may significantly impact IA among Chinese college students during uncertain times.

FA has frequently been reported as a mediation factor that predict addictive behaviors in previous research conducted during the COVID-19 pandemic<sup>47–49</sup>. A survey of 711 Spanish university students discovered that FA mediated the relationship between perceived COVID-19 threat on mental health<sup>49</sup>. Przepiorka et al.<sup>47</sup> found that procrastination of college students has an indirect impact on problematic new media use (addictive behavior) through FA. Another recent study of Chinese university students demonstrated that FA mediated the relationship between COVID-19 victimization Experience and cell phone addiction<sup>48</sup>. Hence, the present study considered FA as a mediator between COVID-19 IU and IA to examine the relationship between the three variables.

### The present study

Based on the PMT, the present study attempted to explain the personal motivations underlying college students' IA from the perspective of motivational factors. The characteristic of PMT is that the motivation of human behavior can ultimately be reduced to coping patterns, such as adaptive responses (e.g., changing unhealthy behaviors) and maladaptive responses (e.g., continuing to maintain unhealthy behaviors)<sup>21</sup>. When people experience COVID-19 IU in response to health threats (threats in the current environment), they may have high anxiety about the future<sup>15</sup>. Therefore they may engage in negative behaviors, such as going online to cope with threat-related anxiety. In light of PMT, the present study attempted to investigate the predictive roles of COVID-19 IU and FA (internal motivational factors) on IA (an unhealthy behavior) among college students.

Previous research has investigated the effects of IU on Internet addiction<sup>34,35</sup>, IU on generalized anxiety<sup>43</sup>, and FA on other addictive behaviors, including cell phone addiction, problematic new media use<sup>47,48</sup>. However, there is a lack of empirical evidence on the influence of IU on FA and FA on IA. Based on previous research, the present study attempted to extend the previous finding by investigating the influence of college students' COVID-19 IU on IA through FA by constructing a mediation model.

In addition, most previous studies on PMT have investigated individuals' healthy behaviors triggered by threats (adaptive responses). In contrast, few studies have explored the possibility of maintaining unhealthy behaviors (maladaptive responses) due to threats. Therefore, the present study attempted to extend PMT by developing a mediating model to further investigate the internal mechanisms of COVID-19 IU on IA among college students. The research findings would provide college educators with effective interventions for students' IA problems. Correspondingly, the following hypotheses were proposed and the hypothetical models were shown in Figs. 1 and 2:

H1: COVID-19 IU significantly positively affects IA.

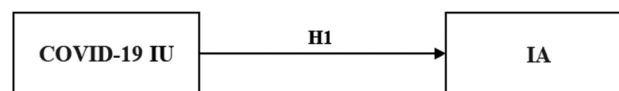


Fig. 1. Hypothetical model 1.

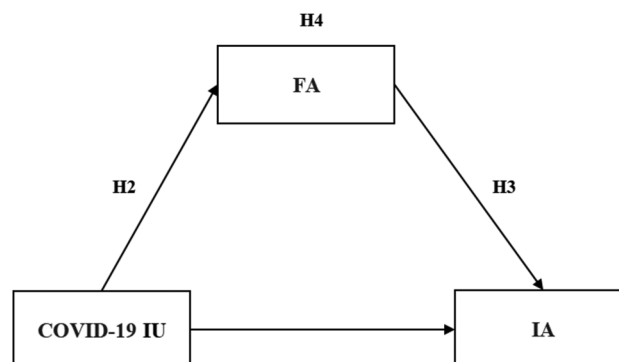


Fig. 2. Hypothetical model 2.

- H2: COVID-19 IU significantly positively affects FA.  
 H3: FA significantly positively affects IA.  
 H4: FA mediates the relationship between COVID-19 IU and IA.

## Methods

### Ethics approval

The present study was ethically reviewed and approved by the committee of Hainan Vocational University of Science and Technology (HKD-2022-25). Participants had the right to refuse and withdraw without any adverse consequences. The present study was conducted with full consideration of the rights and privacy of the participants, and the data were collected anonymously with the participants' consent.

### Data collection and participants

Participants were recruited online from a university in southern China by convenience sampling method. The data were collected online with e-questionnaires distributed by the university faculty through Questionnaire Star APP (participants could scan the QR code to complete the questionnaire). The purpose of the study and the use of the questionnaire were explained to the participants online before distribution. A total of 779 college students interested in IA were recruited in the present study. After screening the data, 679 valid questionnaires remained after excluding the invalid questionnaires with incomplete answers, with a return rate of 87.16%. The valid sample demographics are shown in Table 1. The ages of participants ranged from 18 to 25. There were 304 (44.8%) first-year students; 157 (23.1%) second-year students; 147 (21.6%) third-year students; 28 (4.1%) fourth-year students; and 43 (6.3%) graduate students. 163 were male (24%), and 516 were female (76%). 224 (33%) were only children, and 455 (67%) were non-only children.

### Measurement scale

According to the design and purpose of this study, in order to validate the study hypothesis, the following three unidimensional scales are employed in the present study, none of which have inverse items.

#### *Independent variable: COVID-19 IU*

The COVID-19 Intolerance of Uncertainty Scale, modified by Luo et al.<sup>4</sup>, was used to assess the COVID-19 IU of college students. This scale was chosen because it was based on the Intolerance of Uncertainty Scale<sup>50</sup> and revised according to the epidemic background. The expressions of items included pandemic-related elements<sup>4</sup>. Moreover, the reliability and validity of this scale in adults have been tested in empirical study, with better reliability and validity<sup>4</sup>. The scale has four items. An example of the aforementioned items is, "Confronted with the uncertainty of the pandemic, I cannot function very well in my studies, work and life." It is a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree), the higher score indicating a higher level of COVID-19 IU. The Cronbach's  $\alpha$  for this scale was 0.918.

#### *Mediating variable: FA*

The Dark Future Scale (also known as the Future Anxiety scale) developed by Zaleski et al.<sup>39</sup> was used to assess FA among college students. This scale was chosen because it thinks and predicts the future from the perspective of uncertainty, and has shown relatively stable reliability and validity in adult groups after revision<sup>39</sup>. The scale has five items. An example of the aforementioned items is, "I am afraid that changes in the economic and political situation will threaten my future." The scale is a 7-point Likert scale (0 = Decidedly false; 6 = Decidedly true), with a higher score suggesting a higher level of FA. The Cronbach's  $\alpha$  for this scale was 0.937.

Variable	Options	<i>n</i>	Percentage (%)
age	18–22 years	636	93.67%
	22–25 years	43	6.33%
Gender	Male	163	24%
	Female	516	76%
Grade	First grade	304	44.8%
	Second grade	157	23.1%
	Third grade	147	21.6%
	Fourth grade	28	4.1%
	Postgraduate	43	6.33%
Only-child (OC) /Non-only-child (NOC)	OC	224	33%
	NOC	455	67%

**Table 1.** Valid sample demographics.

*Dependent variable: IA*

The COVID-19-related Internet Addiction Scale adapted by Luo et al.<sup>4</sup> was employed in the present study. This scale was chosen because it has been revised by researchers in the context of pandemics, requires participants to answer the information about Internet use during a pandemic, and has shown relatively stable reliability and validity<sup>4</sup>. The scale has four questions. An example of the aforementioned items is, “During the pandemic, surfing the Internet became a way for me to get rid of negative emotions.” It is a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree), with a higher score representing more serious IA of college students. The Cronbach’s  $\alpha$  for this scale was 0.867.

**Data analyses**

SPSS 21.0 was employed to perform descriptive statistics, correlation analysis, and reliability tests. AMOS 21.0 was used to perform confirmatory factor analysis (CFA) and fitness tests of the measurement instruments. PROCESS 3.5 was utilized to test the hypotheses of the present study. In addition, the Bias-corrected percentile method was used to test whether the confidence interval (CI) for each hypothesized path coefficient contains 0 (5000 bootstrapped re-samples and a bias-corrected percentile confidence level of 95%). Not containing 0 indicated a significant effect<sup>51</sup>.

**Results****Measurement model***Convergence and discriminant validity*

CFA was conducted for each of the three measurement instruments using AMOS 21.0, and the results are shown in Table 2. The factor loading of all question items of the three measurement instruments ranged from 0.617 to 0.944 (> 0.5)<sup>52</sup>. The composite reliability (CR) values for each dimension were 0.919, 0.937, and 0.870, respectively, all greater than 0.7<sup>53</sup>. The average variance extracted (AVE) values were 0.738, 0.750, and 0.633, respectively, all greater than 0.5<sup>53</sup>. The above findings indicated that the convergence validity of the three measurement instruments in the present study was good<sup>53</sup>. Table 3 illustrates that the square root of the AVE of each construct was higher than its correlation coefficient with any other two constructs, indicating good discriminant validity of the measurement instruments<sup>53</sup>.

*The fitness of the measurement model*

The fitness indices of the three measurement models in the present study are shown in Table 4, satisfying the criteria proposed by Marsh et al.<sup>54</sup> (RMR < 0.08; GFI > 0.85; CFI > 0.85; NFI > 0.85; TLI > 0.80 and IFI > 0.85). The results indicated that the measured model fitness of COVID-19 IU, FA, and IA was satisfactory.

Measurement Model	No.	Factor Loading (>0.5)	CR (>0.7)	AVE (>0.5)
COVID-19 IU	1	0.846	0.919	0.738
	2	0.842		
	3	0.890		
	4	0.858		
FA	1	0.797	0.937	0.750
	2	0.893		
	3	0.925		
	4	0.854		
	5	0.857		
IA	1	0.894	0.870	0.633
	2	0.944		
	3	0.617		
	4	0.678		

**Table 2.** Convergence validity.

Variable	M	SD	COVID-19 IU	FA	IA_
COVID-19 IU	5.172	1.337	<b>0.859</b>		
FA	4.671	1.389	0.706***	<b>0.866</b>	
IA	4.685	1.265	0.464***	0.472***	<b>0.796</b>

**Table 3.** Descriptive statistics, Correlation Analysis and discriminant validity. Note:  $n = 679$ ; \*\*\* $p < 0.001$ ; Square root of AVE in bold on diagonal.

Model Fitness	RMR	GFI	CFI	NFI	TLI	IFI
<b>Standard</b>	<b>&lt;0.08</b>	<b>&gt;0.85</b>	<b>&gt;0.85</b>	<b>&gt;0.85</b>	<b>&gt;0.80</b>	<b>&gt;0.85</b>
COVID-19 IU	0.066	0.940	0.961	0.960	0.883	0.961
FA	0.040	0.972	0.984	0.983	0.969	0.984
IA	0.069	0.940	0.944	0.943	0.833	0.944

**Table 4.** Model fit summary.

### Descriptive statistics and correlation analysis

The results of descriptive statistics and bivariate correlation analysis of the three variables in the present study are shown in Table 3. The results showed that: COVID-19 IU had a significant positive correlation with FA ( $r=0.706$ ,  $p<0.001$ ), a significant positive correlation with IA ( $r=0.464$ ,  $p<0.001$ ); FA had a significant positive correlation with IA ( $r=0.472$ ,  $p<0.001$ ). In addition, the correlation coefficients between the study variables were all below the threshold value of 0.9, indicating no multicollinearity between the bivariate variables<sup>55</sup>. Hence, the hypothesis testing could be carried out in the next step.

### Hypothesis testing

To illustrate the rationality of the regression framework in this study, the research data had to satisfy normal distribution. In this study, the skewness absolute values for the 13 items were between 0.108 and 0.597, and the kurtosis absolute values for the 13 items were between 0.131 and 0.794. The results satisfied the standards of the absolute value for skewness  $<2$  and kurtosis  $<7$ <sup>56</sup>. Therefore, The data used in this study satisfied normal distribution.

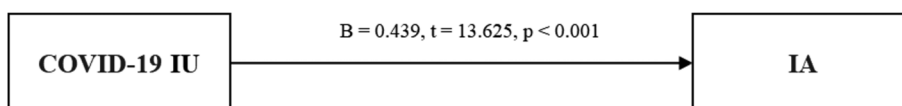
Model 4 in the PROCESS was selected for the present study to test the hypotheses. The results are shown in Tables 5 and 6 as well as Figs. 3 and 4. COVID-19 IU had a significant positive predictive effect on IA ( $B=0.439$ ,  $t=13.625$ ,  $p<0.001$ , 95% CI=0.363–0.513), and H1 was supported. COVID-19 IU had a significant positive predictive effect on FA ( $B=0.733$ ,  $t=25.944$ ,  $p<0.001$ , 95% CI=0.676–0.791), and H2 was supported. When COVID-19 IU and FA together predicted IA, FA had a significant positive predictive effect on IA ( $B=0.262$ ,  $t=6.140$ ,  $p<0.001$ , 95% CI=0.167–0.359), and H3 was supported. Meanwhile, the predictive power of COVID-19 IU on IA decreased from  $B=0.439$  ( $t=13.625$ ,  $p<0.001$ ) to  $B=0.247$  ( $t=5.571$ ,  $p<0.001$ ), indicating a partial mediating effect of FA between COVID-19 IU and IA.

Variable	Model 1 IA		Model 2 FA		Model 3 IA	
	B (t)	SE	B (t)	SE	B (t)	SE
COVID-19 IU	0.439 (13.625 <sup>***</sup> )	0.032	0.733 (25.944 <sup>***</sup> )	0.028	0.247 (5.571 <sup>***</sup> )	0.044
FA					0.262 (6.140 <sup>***</sup> )	0.043
$R^2$	0.215		0.499		0.257	
$F$	185.646 <sup>***</sup>		673.070 <sup>***</sup>		116.708 <sup>***</sup>	

**Table 5.** Mediation model analysis. Note: B = unstandardized coefficients; <sup>\*\*\*</sup> $p<0.001$ .

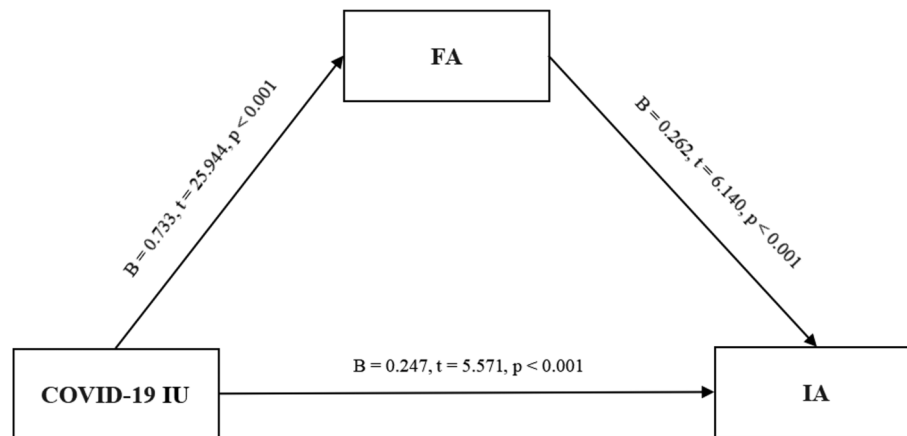
Path		B	Boot SE	Bootstrap 95%CI		Results
				Lower	Upper	
Total effect	H1: COVID-19 IU→IA	0.439	0.039	0.363	0.513	Supported
Direct effect	COVID-19 IU→IA	0.247	0.051	0.145	0.347	–
	H2: COVID-19 IU→FA	0.733	0.029	0.676	0.791	Supported
	H3: FA→IA	0.262	0.049	0.167	0.359	Supported
Indirect effect	H4: COVID-19 IU→FA→IA	0.192	0.036	0.124	0.263	Supported

**Table 6.** Bootstrap results for regression model parameters.



**Fig. 3.** The total effect model of COVID-19 IU on IA.





**Fig. 4.** Mediation model.

As presented in Table 6, the indirect effect value was  $B = 0.192$  with 95% CI ranging from 0.124 to 0.263 (not contain 0), indicating the significant indirect effect, and H4 was supported. The direct effect value was  $B = 0.247$  with 95% CI ranging from 0.145 to 0.347 (not contain 0), indicating the significant direct effect. Both direct and indirect effects of COVID-19 IU on IA were positive (same direction), validating that the hypothetical model in this study was a complementary partially mediated model<sup>57,58</sup>. The total effect value was  $B = 0.439$  with 95% CI ranging from 0.363 to 0.513, and the mediating effect accounted for 43.74%.

## Discussion

The present study confirmed that COVID-19 IU significantly and positively affected IA among college students. Consistent with previous research<sup>34,35</sup>, it is suggested that IU is a crucial predictor of IA among college students<sup>4</sup>. The possible reasons for this finding may be the following. First, the continuous emergence of novel coronavirus variants<sup>6</sup>, accompanied by chronic uncertainty<sup>27</sup>, makes college students in the state of IU. The Internet may become a way for them to seek relevant information<sup>4</sup> and to alleviate the fear, worry, anxiety, and sense of vulnerability triggered by the uncertainty of the epidemic<sup>4,11,26</sup>. Second, the pandemic recurred as China adjusted its epidemic prevention and control policy in December 2022. Many universities again shifted their teaching activities from offline to online, increasing the risk of IA among college students<sup>4</sup>.

Similar to previous studies<sup>14,42,43</sup>, it was confirmed that COVID-19 IU significantly and positively predicted FA among college students. Besides, it was also discovered that FA significantly and positively influenced college students' IA, consistent with recent studies<sup>17,48</sup>. The present study extends previous research by demonstrating a direct relationship between COVID-19 IU and FA, as well as between FA and IA. Moreover, this study found a complementary partially mediated model, FA was found to partially mediate the relationship between COVID-19 IU and IA among college students, similar to previous findings<sup>48</sup>. The findings indicated that COVID-19 IU and FA could jointly promote the IA of college students. The possible explanation for the findings may lie in the following. First, dangers and uncertainties persist due to ongoing COVID-19<sup>7</sup>, which may increase anxiety among college students<sup>15</sup>. Previous research has shown that one-third of the Chinese population experienced moderate to severe anxiety after the outbreak of the COVID-19 pandemic<sup>59</sup>. People with anxiety typically engage in misconduct to cope with or avoid the associated distress<sup>44</sup>. Therefore, college students' COVID-19 IU may trigger excessive anxiety about their future studies and lives, resulting in the need for interpersonal communication, access to relevant information, and escape from reality through excessive use of the Internet, thereby increasing the risk of IA<sup>4</sup>. Second, due to the evolving nature of the novel coronavirus, the vaccine's long-term effectiveness is uncertain<sup>6</sup>. College students can become uncertain about their future health status and employment and thus become anxious about the future. Higher levels of FA may show a stronger tendency to become addicted<sup>47</sup>. Therefore, the FA and COVID-19 IU form a complementary way, and more comprehensively explain the IA of college students.

In addition, most previous studies were based on the PMT to predict or intervene in individual health behaviors (adaptive responses). However, the present study extended PMT by exploring the possibility of maintaining unhealthy behaviors as maladaptive responses (IA) due to threats (COVID-19 IU and FA). The results highlight that COVID-19 IU and FA may be internal drivers of IA among college students. Two factors, COVID-19 IU and FA, are better predictors of IA behavior in college students.

## Conclusions and suggestions

The present study constructed a mediation model to explore the influential primary factors on IA among college students in the context of recurrent epidemics in China. The findings indicated that COVID-19 IU and FA were two key influences on IA among Chinese college students. Direct relationship between variables of COVID-19 IU, FA, and IA were discovered. Specifically, the present study confirmed that COVID-19 IU had a significant positive predictive effect on FA among college students; FA had a significant positive effect on IA; FA partially mediated between COVID-19 IU and IA. In addition, the present study extended the PMT by exploring the

internal mechanisms of COVID-19 IU on college students' IA. While most previous studies based on PMT have focused on threats triggering people to engage in healthy behaviors (adaptive responses), the present study explored the unhealthy behaviors (maladaptive responses) that threats may trigger. The study findings provide college instructors and administrators with empirical evidence to prevent and intervene in students' IA. The following recommendations are made in light of the study's findings.

First, college educators should master the ability to properly identify the psychological characteristics of college students' IU. The psychological characteristics of IU are reflected in the tendency of individuals to believe that negative events with low probability will inevitably occur, and they are overly worried about whether these negative events will occur in the near future and cannot accept them<sup>50</sup>. The intolerance of uncertainty is manifested in two main aspects: "desire for predictability" and "uncertainty paralysis"<sup>60</sup>. The performance of desire for predictability is always wanting to know the specific situation of one's future, always trying to eliminate all uncertain factors, excessive planning for the future, etc. In contrast, uncertainty paralysis manifests as restlessness, anxiety, or tension in the face of uncertainty, and even small uncertainties can make people stop working<sup>61</sup>. Therefore, it is recommended that college educators identify college students with higher levels of IU based on the above psychological characteristics and provide a scientific approach to cognitive modification of their IU. For example, cognitive behavioral therapy-intolerance of uncertainty (CBT-IU) may help college students to reassess the epidemic uncertainty correctly<sup>62</sup>. In particular, college students with high COVID-19 IU should be actively guided promptly to prevent their excessive negative emotions and adverse behavioral reactions.

Second, college educators should understand the most recent development of the COVID-19 epidemic, guide college students toward correct interpretation and scientific prevention, and alleviate the anxiety about future life, study, and work caused by college students' COVID-19 IU. In addition, experts in psychology could be invited to instruct college students through special lectures on effective methods for self-adjustment and anxiety relief during significant health events to prevent college students' IA caused by FA.

Finally, college educators should pay attention to addictive behaviors on the Internet. The specific manifestations of IA behavior are loss of control and social problems. Loss of control (also called time management) is specifically manifested in the fact that the Internet affects study or work, the time spent on the Internet is longer than originally planned, and the inability to control one's own online time, etc. Social problems include refusing social activities in order to surf the Internet, concealing the time of surfing the Internet, being angry when being interrupted when surfing the Internet<sup>63</sup>. College students who behave in the manner described should be brought to the attention of educators at the college or university. College educators should promptly intervene at an early stage, and instruct students about the adverse effects of IA. Safety education of college students' IA should be strengthened so that they can correctly understand IA and carry out self-prevention.

### Limitations and future research directions

There are several shortcomings and limitations of the present study.

First, we only examined students at one university in southern China during the sampled period. The study subjects could only represent individual cases, and the findings could not comprehensively cover the study of IA among college student groups from different regions of China. Future research may consider exploring the prevalence of Internet addiction among college students from various regional and temporal perspectives.

Second, the present study was only cross-sectional research examining the correlation and influence relationship between variables in research content. The causal relationship between research variables could not be confirmed. Future research may include longitudinal studies and experiments to understand better the causal relationships among the research variables, thereby enhancing the validity of the present study's findings.

Thirdly, the present study only investigated the influencing factors of college students' IA from the perspective of their personal motivation, ignoring additional social factors such as family relationships and social support. Future research may investigate additional influences on IA among college students.

### Data availability

The data used in this study are available on request from the corresponding author.

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## Author contributions

Conceptualization, L.P., Z.H. and J.L.; methodology, J.L.; validation, L.P., W.Q., Z.H. and J.L.; investigation, Z.H. and J.L.; data curation, Z.H. and J.L.; writing—original draft preparation, L.P., W.Q., Z.H. and J.L.; writing—review and editing, L.P., W.Q., Z.H. and J.L.; supervision, J.L. All authors have read and agreed to the published version of the manuscript.

## Competing interests

The authors declare no competing interests.

## Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Academic Ethics Committee of Hainan Vocational University of Science and Technology (HKD-2022-25).

## Informed consent

Informed consent was obtained from all subjects involved in the study.

## Additional information

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