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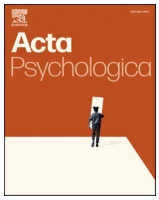

How self-efficacy influences Chinese university students' GenAI dependency: A study of the mediating roles of social anxiety and rumination and the moderating role of mindfulness

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ABSTRACT

With the recent, rapid advancement of artificial intelligence (AI) technology, an increasing number of university students are relying on generative artificial intelligence (GenAI) in their daily academic and personal lives. Although self-efficacy is known to influence dependency on GenAI, the mechanism through which this transpires remains insufficiently explored. Working from an I-PACE model, this study collected 758 valid survey responses from Chinese university students and subjected that data to quantitative analyses. The objective was to assess self-efficacy, social anxiety, rumination, mindfulness, and GenAI dependency. The findings indicate that students' dependency on GenAI is positively associated with their self-efficacy, rather than negatively, as predicted. This unexpected relationship is attributed to the distinctive context of higher education in China, which is characterized by high academic pressure, collectivist cultural norms (including tendencies toward conformity), and the illusion of self-efficacy produced by GenAI use. Further analyses reveal that social anxiety and rumination jointly mediate this association through a significant sequential mediation pathway. Specifically, diminished self-efficacy intensifies social anxiety, which subsequently triggers rumination, ultimately increasing GenAI dependency. This is the opposite of the main path result, in which mindfulness exerted a significant moderating effect on this mediation process. Together, these results elucidate a systematic pathway through which self-efficacy shapes university students' GenAI dependency within a specific cultural context. Therefore, the results offer theoretical foundations and practical implications for timely interventions by higher education practitioners from the perspectives of psychological traits and psychological processes.

1. Introduction

Artificial intelligence (AI) technology has had a significant impact at societal, organizational, and individual levels (Dwivedi et al., 2023). The ongoing development of AI has led to generative artificial intelligence (GenAI), a category of AI model that replicates the configuration and properties of input data with the objective of producing derived synthetic content, including images, videos, audio, text, etc. (Booth et al., 2024).

A significant number of studies have, with varying degrees of success, attempted to investigate how GenAI technology (i.e., chatbots) has been integrated into higher education (Essel et al., 2022; Fryer et al., 2019; Huang et al., 2024). Some studies have indicated that a range of psychological factors – including psychological perceptions, cognitive attitudes, and behavioral intentions – influence university students' use of GenAI (Chan & Hu, 2023; Huang et al., 2024; Urban et al., 2024). Moreover, a proliferation of studies over recent decades have identified self-efficacy as a key predictor of achievement in university students (Bartimote-Aufflick et al., 2016; Freire et al., 2020). In particular, there has been a significant impact on university students in terms of academic performance, entrepreneurship education, and smartphone addiction, especially when students are faced with enormous academic and life pressures (Chiu, 2014; Honicke & Broadbent, 2016; Richardson et al., 2012; Wilson et al., 2007; Zhao et al., 2005; Zimmerman et al., 1992). Several studies have also shown that, in the wake of rapid advancements in GenAI, a considerable number of university students have, to varying degrees, become dependent on GenAI (Darvishi et al., 2024; Fan et al., 2025; Wang et al., 2024). The interplay between self-efficacy and other

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factors is known to exert an influence on the extent of this dependency (Liao et al., 2025; Zhang et al., 2024). In other words, self-efficacy may exert a direct effect on the degree of GenAI addiction, or self-efficacy may exert an indirect effect by acting upon other psychological factors. Therefore, this study examines the differences among psychological variables (such as cognitive perception, motivation, anxiety, and self-efficacy) in university students and explores the relationship between these psychological factors and the students' use of GenAI. In doing so, this study aims to uncover the internal psychological mechanisms involved when students use GenAI and the pathways leading to their dependency on GenAI.

An official report from China has stated that, among Internet users, those aged 20–29 have the highest usage rate of GenAI products of any age group (40.5%), while, in terms of education, Internet users with a university degree or higher have the highest usage rate of GenAI products of any group (44.0%) (China Internet Network Information Center, 2024). These data suggest that university students constitute the primary demographic of GenAI users in China, a finding that underscores the value of research on the relationship between the psychological traits of Chinese college students and their use of GenAI.

This paper presents a quantitative study that was conducted using questionnaire surveys and data analysis to systematically explore how self-efficacy influences the degree of GenAI dependency among Chinese college students. A particular focus is placed on the dual mediating pathways of negative cognitive processing (rumination) and emotional experience (social anxiety). The aim of this study is to provide theoretical support and practical guidance for educational practices in institutions of higher education in the digital age. This study also explores the dynamic regulatory mechanisms by which mindfulness serves as an endogenous regulatory resource in the "cognitive assessment-emotional response-behavioral choice" process, thereby providing a scientific basis for the accurate identification of high-risk groups prone to developing GenAI dependency in the university student population. An additional objective is to inform the development of integrated intervention programs based on enhancing self-efficacy and mindfulness training.

2. Theoretical foundations, research hypotheses, and models

2.1. The I-PACE model

Brand et al. (2016) proposed the interaction of person-affect-cognition-execution (I-PACE) model. In 2019, the model was updated to expand its applicability to a broader range of addictive behaviors and to distinguish between the early and late stages of addiction. The I-PACE model has been validated through empirical research and is applicable to a wide range of addictive behaviors, and thus, the model provides a theoretical foundation for related research and clinical practice (Brand et al., 2019). The I-PACE model reflects the fact that addictive behaviors result from interactions among predisposing factors, emotional-cognitive responses to specific stimuli, and executive functions. Alternatively, such behaviors can stem from the dynamic interactions among individual core characteristics and multiple moderating and mediating variables (Brand et al., 2019). Specifically, in the I-PACE model, individual perceptions influence individuals' states and cognitions, ultimately altering their behavioral decisions (Nong et al., 2023). Additionally, the "person" component in the model represents core characteristics that may act as susceptibility variables in the addiction process (Brand et al., 2016). Moreover, given that this model is a general research method targeting the underlying processes of addictive behaviors, the model does not specify the precise roles or positions of cognitive and emotional processes (Brandtner et al., 2021). Consequently, researchers have broad leeway to incorporate any necessary elements into the I-PACE model. In summary, the I-PACE model is useful for the construction and validation of hypotheses concerning the interaction of specific variables, including variations in the severity of behavioral addiction symptoms (Brand et al., 2019). This model has been applied to research on various addictive behaviors and the problematic use of substances (Antons & Brand, 2018; Elhai et al., 2020; Young & Brand, 2017; Zhang et al., 2021).

2.2. Research hypotheses

2.2.1. The relationship between self-efficacy and GenAI dependency

Bandura (1977) defined self-efficacy as an individual's perceived beliefs about their possession of the capabilities required to achieve a goal. Thus, self-efficacy is a psychological concept that determines the extent to which an individual is willing to invest effort in achieving a goal. Prior studies have primarily concentrated on Internet addiction behaviors that are induced by excessive Internet use; researchers have established the existence of a robust negative correlation between Internet addiction and self-efficacy (Berte et al., 2021). In recent years, Internet use has developed to include the use of GenAI, and thus, the relationship between GenAI and self-efficacy has become a new topic of active research interest. These sustained **research efforts have revealed a** negative correlation between self-efficacy and GenAI dependency (Liao et al., 2025; Zhang et al., 2024). This finding suggests that, until now, the question of whether self-efficacy negatively predicts university students' GenAI dependency may have been underexamined. According to self-efficacy theory, individuals with low expectations of their own capabilities tend to exhibit weaker resilience in the face of setbacks. They are more likely to avoid situations they perceive as being threatening or beyond their coping capacity, and this avoidance behavior hinders their successful completion of goal-directed tasks (Bandura, 1977). Consequently, when college students with low self-efficacy are required to accomplish tasks that they perceive as exceeding their competence, they will be more inclined to seek external assistance, such as GenAI, to directly obtain solutions or answers (Zhang et al., 2024). In addition, multiple studies have shown that GenAI use can effectively enhance college students' performance, thereby strengthening self-efficacy in specific domains (e.g., learning English and nursing training) and even their general self-efficacy (Chang et al., 2022; Huang et al., 2024; Xu et al., 2024; Zhang & Xu, 2025). However, these studies also indicate that this enhanced self-efficacy is **illusory. Specifically,** individuals internalize GenAI's capabilities as their own and neglect the contribution of GenAI to their performance. In some cases, this can lead to an increase in technology dependency (Rodríguez-Ruiz et al., 2025; Skulmowski, 2024; Zhang & Xu, 2025). Moreover, Liao et al. (2025) analyzed data from 1928 university students and discovered that both parents' and peers' screen-gazing behaviors were positively correlated with university students' dependency on GenAI, with loneliness and self-efficacy acting as parallel mediators in this relationship. Thus, a decrease in self-efficacy has been found to lead to an increased reliance on GenAI in university students. Furthermore, scholars analyzing the formation of problematic AI usage behavior have discovered that college students with lower academic self-efficacy are more inclined to seek assistance from GenAI, potentially exacerbating their dependence on this technology (Zhang et al., 2024).

Based on the above, the following hypothesis is proposed:

H1. : Self-efficacy negatively predicts GenAI dependency.

2.2.2. The mediating effects of social anxiety and rumination on university students' GenAI dependency

Social anxiety (SA) is a common phenomenon that manifests as an acute fear of being evaluated by others in social contexts (Morrison & Heimberg, 2013). Typically, social anxiety results from the prospect or presence of interpersonal evaluation in real or imagined social settings (Schlenker & Leary, 1982). Social anxiety has been found to be correlated with a wide range of psychological variables, such as self-esteem, dependency, and self-criticism (Iancu et al., 2015; Spence et al., 1999; van Tuijl et al., 2014). A significant negative relationship between self-efficacy and social anxiety has also been well established. Specifically,

individuals with lower levels of self-efficacy tend to exhibit higher levels of social anxiety (Schlenker & Leary, 1982). Moreover, severe levels of social anxiety are closely linked to low self-efficacy. Thomasson and Psouni (2010) found that enhancing individuals' self-efficacy may be a potential strategy for alleviating social anxiety. In the I-PACE model, social anxiety is a predisposing variable for the addiction process (Brand et al., 2019). Socially anxious people are more likely to withdraw and avoid interpersonal interaction (Heerey & Kring, 2007). Hence, they may isolate themselves from the rest of the world and decrease their engagement in social activities (Sloan Jr. & Solano, 1984). In such cases, GenAI makes it possible for socially anxious people to more easily deal with social difficulties. For instance, Sartorato et al. (2017) found that interaction with interactive robots positively influenced the verbal communication skills of individuals with autism spectrum disorders. Some AI technologies are designed to satisfy individuals' sense of belonging and need for happiness (Skjuve et al., 2021). However, the gratification offered by GenAI may further aggravate psychological dependency on that technology to the point of emotional over-reliance (Drouin et al., 2022). Thus, low self-efficacy may increase GenAI dependency by increasing levels of social anxiety. However, empirical research examining this possible mediating role of social anxiety is limited. In light of these known associations among self-efficacy, social anxiety, and GenAI dependency, this study posits that social anxiety plays a mediating role in the link between self-efficacy and GenAI dependency. People with low self-efficacy tend to feel more socially anxious, and thus, they are more likely to turn to GenAI, leading to an over-dependency on that technology.

The concept of “rumination”, introduced by Nolen-Hoeksema et al. (2008), is defined as repeated, non-adaptive reflections on the symptoms, causes, and consequences of negative affective experiences. In one experimental study, Morrison and O'Connor (2008) found that the induction of rumination in the context of negative mood leads to a reduction in positive attentional bias. This consequent intensification of negative attentional bias causes individuals to persistently focus on their negative emotions, which in turn perpetuates rumination (Morrison & O'Connor, 2008). An empirical study by Elhai et al. (2018) further supports the positive correlation between social anxiety and high levels of rumination. A study on Japanese undergraduate nursing students revealed that rumination was negatively correlated with all sub-scales of the general self-efficacy scale, except for the Effort subscale. Thus, the study provided preliminary validation of the negative correlation between rumination and self-efficacy (Takagishi et al., 2013). Similarly, van Seggelen-Damen and van Dam (2016) study of Dutch workers found that rumination mediated the relationship between self-efficacy and fatigue, with rumination being negatively correlated with self-efficacy. Zhang et al.'s (2025) study on patients following pituitary adenoma surgery found a negative correlation of self-efficacy with rumination. These findings offer valuable insights into the relationship between self-efficacy and rumination in specific populations and thus further suggest a negative correlation between rumination and self-efficacy. Additionally, the samples present case examples for studies that treat rumination as part of a mediation chain. Other scholars have conducted surveys relating to the emotional regulation self-efficacy of Chinese university students, and their rumination. A quantitative analysis of the collected data confirmed the existence of a significant negative correlation between emotional regulation self-efficacy and rumination in Chinese university students (Su et al., 2025; Wu et al., 2023). This finding provides a foundation for the claim that self-efficacy and rumination are negatively correlated in university students, thereby offering theoretical support for the claim that subsequent research should shift from examining emotional regulation self-efficacy in particular to examining self-efficacy in general.

According to the cognitive-behavioral model of Rapee and Heimberg, individuals with social anxiety tend to concentrate on potential threats, including negative evaluations of their behaviors. Such individuals tend to rely on dysfunctional coping strategies to deal with their anxiety in social situations (Thomasson & Psouni, 2010). While the I-PACE model does not explicitly identify rumination as a central element, one can posit that rumination may exacerbate the overuse of technology. Within the framework of the model, problematic GenAI use can be understood to be a dysfunctional mechanism used to cope with negative feelings (Hu et al., 2023). More significantly, empirical studies grounded in the I-PACE model have established that rumination is a mediator in the link between individual traits and the excessive use of technology (Stanciu & Calugar, 2022). Foo et al. (2025) observed that a vital application of GenAI technology in virtual reality/augmented reality (VR/AR) is the rapid creation of high-quality, 3D virtual environments that can represent either entirely fictional scenes or digital replicas of the real world. People with a high degree of rumination are more likely to choose forms of GenAI that can create ideal and safe interaction zones for them. Although obtaining social stimulation through technology may provide short-term relief or satisfaction, in the long run, such stimulation may lead to dependency on GenAI (Kardefelt-Winther, 2014). Moreover, Hu et al. (2023) demonstrated that rumination significantly predicted problematic use of conversational AI, suggesting that rumination may similarly have a positive influence on individuals' reliance on GenAI.

Based on the above, this study posits that individuals who engage in more ruminative thinking about their behaviors will subsequently be driven to GenAI dependency. Thus, the following hypotheses are proposed:

H2. : Rumination mediates the relationship between self-efficacy and GenAI dependency.

H3. : Social anxiety mediates the association between self-efficacy and GenAI dependency.

H4. : Social anxiety and rumination serially mediate the association between self-efficacy and GenAI dependency.

2.2.3. The moderating effect of mindfulness on university students' GenAI dependency

“Mindfulness” has been defined as a state of consciousness whereby an individual maintains clear and focused awareness of what is happening in the present moment and of everything that occurs within oneself and one's mind over successive moments of perception (Nyanaponika Thera, 1972). Mindfulness also represents enhanced attention to and awareness of current experiences and reality, with core characteristics of open, accepting awareness and attention, manifested in a more regular or sustained consciousness of ongoing events and experiences (Brown & Ryan, 2003).

Moreover, Wolkin (2015) proposed that mindfulness promotes metacognition through “decentering” (i.e., awareness of one's own thoughts) and thus enables individuals to recognize that they are engaging in and actively disengage from rumination. Additionally, an experience sampling study by Brown and Ryan (2003) showed that individuals with high mindfulness, rather than passively relying on external tools, tend to make autonomous choices in their daily behaviors. Such individuals are also better able to detect their own tendency toward excessive dependency on technology, enabling them to proactively reduce their GenAI usage. Raes and Williams (2010) found that mindfulness moderates the relationship between analytical rumination and uncontrollable rumination. In individuals with high mindfulness, the association between the two forms of rumination is significantly weakened. This implies that, even if self-efficacy affects GenAI dependency through analytical rumination, mindfulness can weaken this mediating pathway by reducing uncontrollable rumination.

In addition, a meta-analysis of studies on social anxiety disorder (SAD) by Liu et al. (2021) revealed that mindfulness interventions can significantly reduce SAD symptoms. The mechanism of this benefit has foundations in the fact that, by enhancing present-moment awareness and a non-judgmental attitude, mindfulness reduces individuals'

tendency toward excessive rumination on their social performance and lessens catastrophic interpretations of negative evaluations (Brown & Ryan, 2003). In addition, Rasmussen and Pidgeon (2011) found that a significant negative correlation exists between mindfulness and social anxiety, which is partially mediated by self-esteem. However, the direct effect of mindfulness on social anxiety is also significant, and this means that mindfulness can alleviate social anxiety independently of other variables. By positioning mindfulness at the influential point between self-efficacy and social anxiety, one can find that mindfulness enhances individuals' emotional regulation abilities (Namaziandost & Rezai, 2024), making the emergence of social anxiety less dependent on the individual's level of self-efficacy. Rather, social anxiety is alleviated more through the direct regulatory effect of mindfulness itself. An experience sampling study by Brown and Ryan (2003) found that the state of mindfulness is negatively correlated with immediate social anxiety. When mindfulness levels are high, even if self-efficacy is low, individuals can reduce their anxiety reactions through present-moment awareness. A high level of mindfulness enables individuals to have a clearer awareness of social situations. Thus, mindfulness can reduce excessive worries about having insufficient self-efficacy, thereby directly reducing social anxiety (Liu et al., 2021) and thus weakening the strength of the "self-efficacy → social anxiety" association. This further supports the weakening effect of mindfulness on this path. Based on these findings, the following hypotheses are proposed:

H5. : When mindfulness levels are high, the indirect effect of self-efficacy on GenAI dependency through rumination is weakened.

H6. : When mindfulness levels are high, the indirect effect of self-efficacy on GenAI dependency through social anxiety is weakened.

2.3. Research model

The I-PACE model posits that susceptibility variables, cognitive and affective responses to external or internal stimuli, and executive and inhibitory control all contribute to decision making and the subsequent behavioral outcomes (Brand et al., 2016). The I-PACE model can also be used to explain Internet use and the outcomes of such use (Nong et al., 2023). In this study, the "person" component in the model is self-efficacy, which in turn serves as the core susceptibility variable in the GenAI addiction process. The two mediating variables in this study – social anxiety and rumination – correspond to the "affect" and "cognition" components of the model, respectively, while GenAI **dependency** is the "execution" component. In the early stages of the formation of GenAI dependency, individuals may perceive external or internal triggers (e.g., academic tasks assigned by teachers) in specific contexts. These triggers can then induce emotional and cognitive responses, namely social anxiety and rumination. Those responses then interact with behavioral decisions and reward expectations. The aforementioned correlations gradually become consolidated, contributing to the progression of GenAI **dependency** (Brand et al., 2019). In theory, mindfulness is related to the "execution" component, because mindfulness contributes to individuals' emotional regulation abilities (Namaziandost & Rezai, 2024). Mindfulness is also known to enhance present-moment awareness (Brown & Ryan, 2003). Therefore, mindfulness can be integrated into the I-PACE model to further explain the interaction of "person, affect, cognition, and execution". To summarize, in this study's model, these elements are defined based on their functional roles within the I-PACE model.

Serving as this study's theoretical foundation, the I-PACE model enables this study to investigate how self-efficacy influences GenAI dependency through affective and cognitive responses. Moreover, the influence of self-efficacy is dynamic and recursive, in that emotional and cognitive reactions interact with behavioral decisions and gradually consolidate into dependency. As a result, this study's model should be regarded as a processual and mutual pathway toward specifying a psychological mechanism.

This empirical study is principally based on the I-PACE model; the aim is to further explain the core process of GenAI dependency. However, mindfulness is introduced into this model as a moderator and not as a constituent within the original framework. Studies to date have stressed the significance of meta-cognitive factors that influence individuals' technology-related behavior (Aldbyani et al., 2025; Fendel et al., 2025). Therefore, in this study's model, mindfulness is considered to be a moderator of the affective and cognitive pathways. This study's model thus preserves the core mechanism of the I-PACE model and extends that model to examine the relationship between a meta-cognitive factor and GenAI dependency.

3. Research method

3.1. Participants

Data were collected using an online questionnaire administered via *Wenjuanxing* (www.sojump.com), a widely used online survey platform in China. The questionnaire incorporated all measurement scales relevant to this study and was disseminated through QR codes and web links. The links were distributed to students by their university instructors, as well as by student WeChat groups, DingTalk groups, QQ groups, and groups on other Chinese social media platforms. Each participant who completed the questionnaire received a monetary incentive of two yuan upon submission of a completion screenshot. Prior to participation, all students were informed that the purpose of the study was to examine dependencies related to GenAI and the technology's associations with psychological factors. The participants were assured that there were no correct or incorrect responses and were encouraged to answer based on their actual experiences. To secure their trust in the security and confidentiality of their data, all participants were explicitly assured that the entire data collection process strictly adhered to principles of anonymity and that their personal information would not be used for purposes beyond this study. The questionnaire screenshots they submitted only showed their completed responses and did not contain any personal information. Also, all monetary incentives were distributed through the platform to ensure anonymity. To ensure response quality, three attention-check items (e.g., "Please select 'Agree'") were embedded in the questionnaire. Data were collected between June 4 and June 24, 2025, yielding a total of 942 responses. After exclusion of cases failing any of the three attention checks, a final sample of 758 valid responses was retained for subsequent analyses.

3.2. Measurement items

All items in the questionnaire were based on questions from existing scales that were modified to fit this study's objective, namely exploring the factors that influence GenAI dependency. The distributed survey forms were written in Chinese; all survey forms were Chinese versions. The scales with previously validated translations were adopted. Scales without a Chinese version were translated by this study into Chinese. To make sure that the Chinese version could be understood, a pre-test was carried out. Meanwhile, a reliability analysis was conducted for all variables in this study.

3.2.1. Social anxiety

In this study, the Social Interaction Anxiety Scale (Mattick & Clarke, 1998), designed for evaluating levels of anxiety experienced before and during situations of social interaction, was used to measure fears of more general social interaction. The scale comprises 19 items rated on a 5-point Likert scale, ranging from 0 = *not at all* to 4 = *extremely*, with two positively-worded items being reverse-scored. The overall score is calculated as the sum of the scores for the individual items; higher scores represent higher levels of social anxiety.

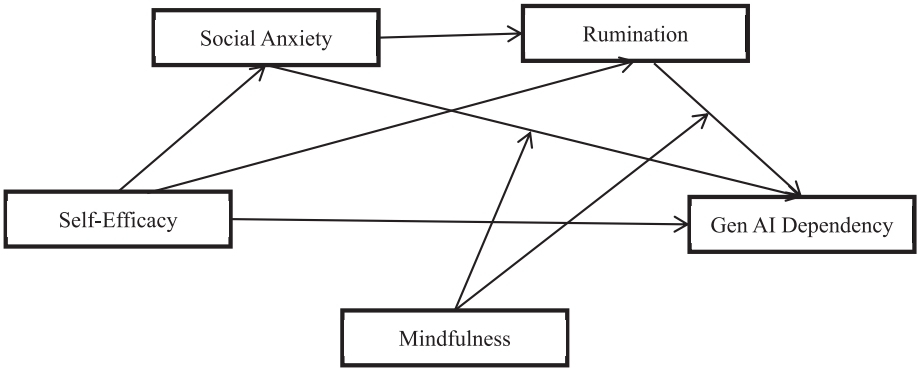

Fig. 1. The proposed model.

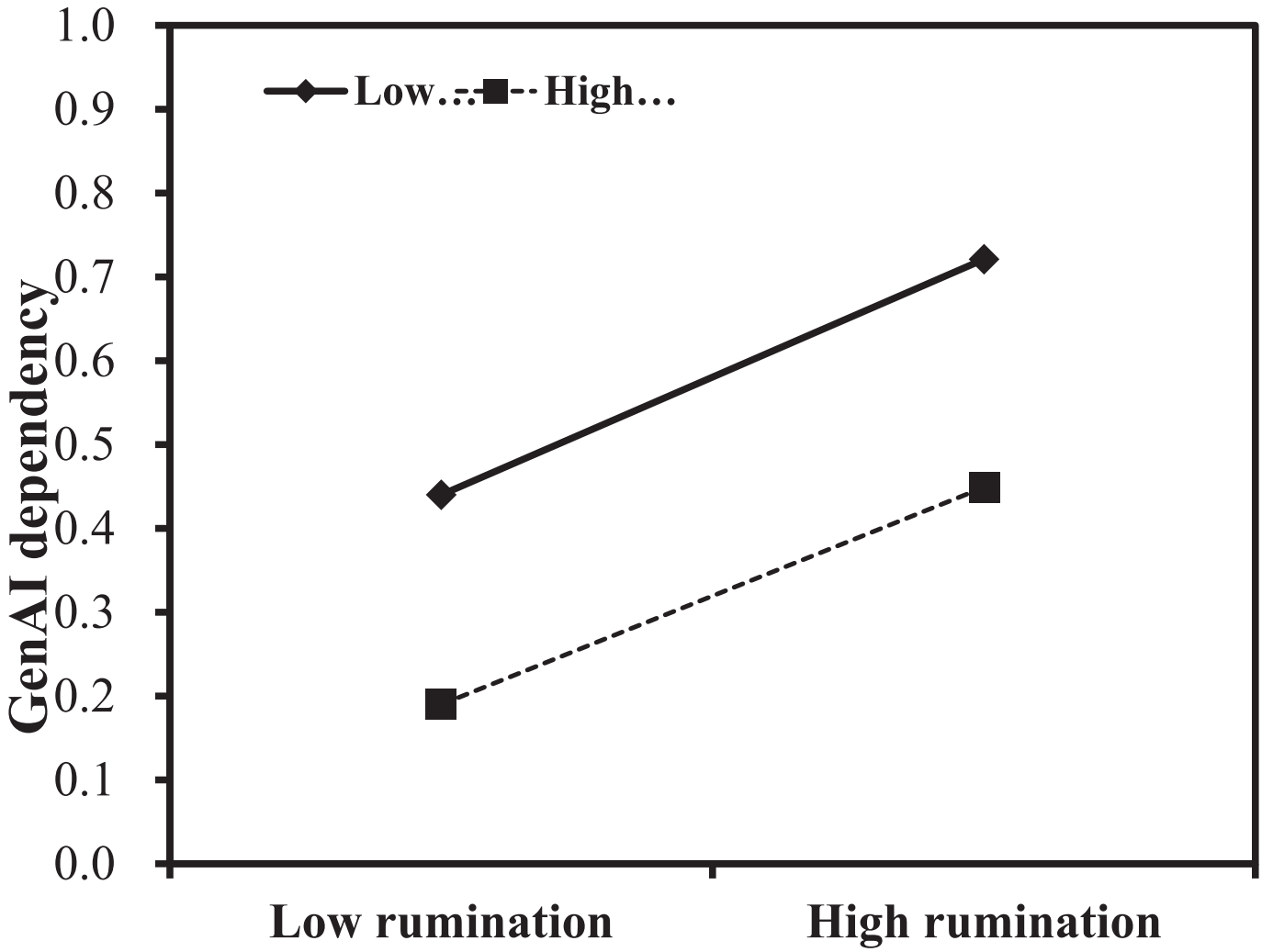

Fig. 2. Moderating effect of rumination.

3.2.2. Self-efficacy

Social cognitive theory posits that perceived self-efficacy is a key determinant of human motivation, affect, and action (Bandura, 1977). Working from this premise, Schwarzer and Jerusalem (1995) developed the Generalized Self-Efficacy (GSE) scale to operationalize a domain-unspecific belief in one's ability to mobilize cognitive, motivational, and behavioral resources when confronted with novel or challenging demands. All items in this case are scored on a 4-point Likert scale (from 1 = *not at all true* to 4 = *exactly true*) and no items are reverse-coded. The total score is calculated by simple summation and ranges from 10 to 40 (Schwarzer & Jerusalem, 1995). Psychometric studies conducted across 23 nations have yielded Cronbach's alpha (Cronbach's α) values for this scale ranging from 0.76 to 0.90, indicating uni-dimensionality and high internal consistency (Schwarzer & Jerusalem, 1995). Subsequent cross-cultural validations with Chinese, Indonesian, Japanese, and Korean respondents have replicated the single-factor structure and yielded Cronbach's α coefficients above 0.80, confirming the scale's metric and structural equivalence across Asian populations (Schwarzer et al., 1997). In addition, the scale has demonstrated satisfactory test-retest reliability (r = 0.83 over 10 days) and criterion-related validity

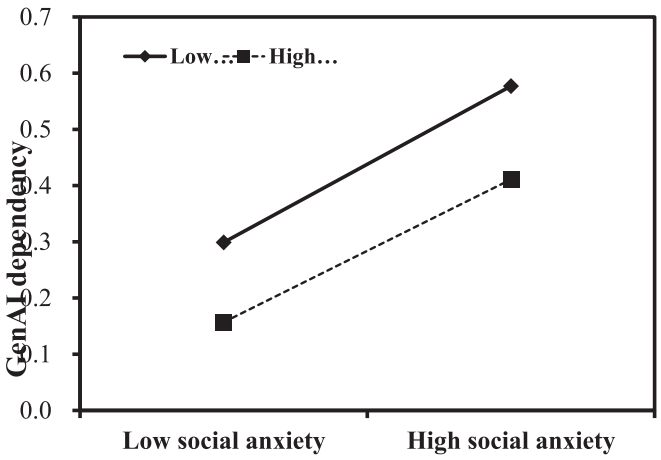

Fig. 3. Moderating effect of social anxiety.

through negative correlations with anxiety and positive associations with optimism and work satisfaction (Schwarzer & Jerusalem, 1995; Wang et al., 2001). Therefore, the GSE scale is used here to conduct relevant tests on university students, so as to determine their current level of self-efficacy. On this basis, the GSE model is further applied to conduct in-depth exploration of various factors that affect university students' dependency on GenAI.

3.2.3. *Mindfulness*

The Mindful Attention Awareness Scale (MAAS) (Brown & Ryan, 2003) assesses respondents' present attention and awareness. The scale consists of 15 items (e.g., "I find myself doing things without paying attention."), distributed across cognitive, emotional, physical, interpersonal, and general domains. Participants rate the items on a 6-point Likert scale, ranging from 1 = *almost always* to 6 = *almost never*, with higher scores indicating greater mindfulness. The MAAS has been found to have good reliability and validity (Black et al., 2012). The Chinese version by Chen et al. (2012) was used in this study to measure mindfulness in university students.

3.2.4. *Rumination*

The Ruminative Responses Scale (RRS) was originally developed by Nolen-Hoeksema and Morrow (1991) within the framework of response styles theory, which posits that individuals exhibit stable cognitive–affective strategies in response to negative moods. This scale comprises 22 items rated on a 4-point Likert scale, with higher aggregate scores indicating more severe ruminative tendencies (Nolen-Hoeksema & Morrow, 1991). Extensive psychometric work has shown that the RRS possesses strong internal consistency (α = 0.90) and acceptable test–retest reliability (r = 0.80) when used with English-speaking populations (Bagby et al., 2004). In addition, cross-cultural adaptations such as the Chinese RRS-CV produced by Han and Yang (2009) have replicated these properties with comparable Cronbach's α coefficients (0.85–0.93) and validated factor structures via confirmatory factor analysis. Consequently, the RRS has become a standard tool for assessing ruminative response styles in both clinical and non-clinical samples (Nolen-Hoeksema et al., 2008). The RRS is thus used in this study to explore the mediating role of modern university students' rumination in the link between their self-efficacy and GenAI dependency.

3.2.5. *GenAI dependency*

The ChatGPT dependency scale was specifically developed to quantify instrumental dependency on GenAI within academic settings (Ye et al., 2024). Based on the conceptual definition whereby dependency arises when "an individual feels unable to accomplish tasks without the specific technology, experiences discomfort when access is restricted, and repeatedly chooses the tool despite awareness of potential drawbacks" (Brand et al., 2019), this scale comprises six items rated on a 5-point Likert scale, with values ranging from 1 to 5, where 1 = *total disagreement* and 5 = *total agreement* (Ye et al., 2024). The stem of each item embeds behavioral, cognitive, and affective indicators that jointly reflect a unidimensional construct (King and ChatGPT, 2023). The items were developed using a deductive–inductive mixed approach: the research team first translated the DSM-5 criteria for substance-related disorders into technology-neutral language and then mapped them onto observable behaviors that are specific to GenAI use (Morales-García et al., 2024). Exploratory factor analysis on a pilot sample of 212 Taiwanese undergraduates produced a single-factor solution with loadings between 0.68 and 0.77 and an eigenvalue of 3.08, explaining 51.3% of the variance (Ye et al., 2024). The internal consistency of the scale has been found to be excellent (Cronbach's α = 0.86; composite reliability = 0.86), with the average variance extracted (0.51) exceeding the 0.50 threshold (Fornell & Larcker, 1981). Discriminant validity is supported: the square root of average variance extracted (AVE) (0.71) surpassed all inter-construct correlations, and metric invariance tests showed no significant degradation of fit across gender or usage-

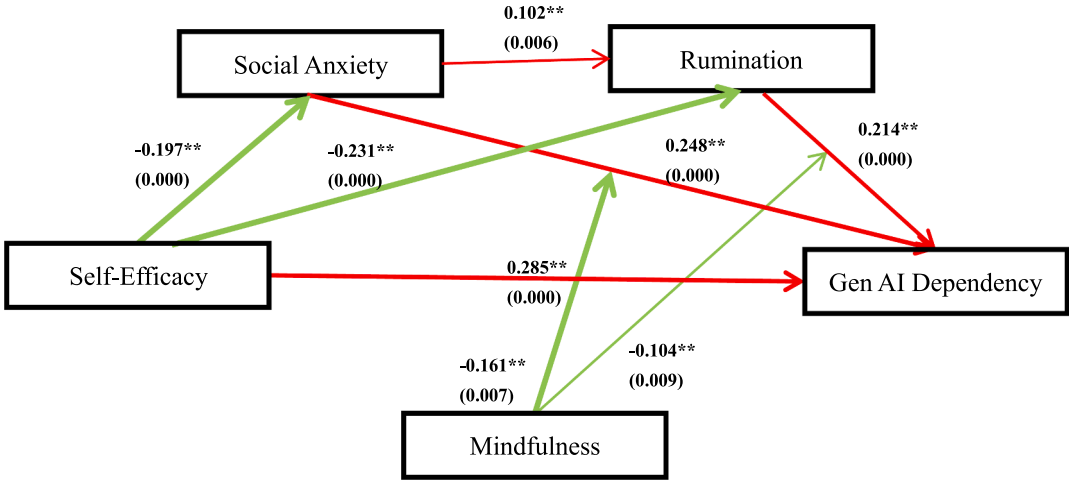

Fig. 4. Model adjustment mediating effect pathway diagram
Note: * $p < 0.05$, and ** $p < 0.01$. Line thickness represents the magnitude of the coefficient. Solid lines indicate statistically significant effects, while dashed lines indicate non-significant effects. Red lines denote positive effects, and green lines denote negative effects. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

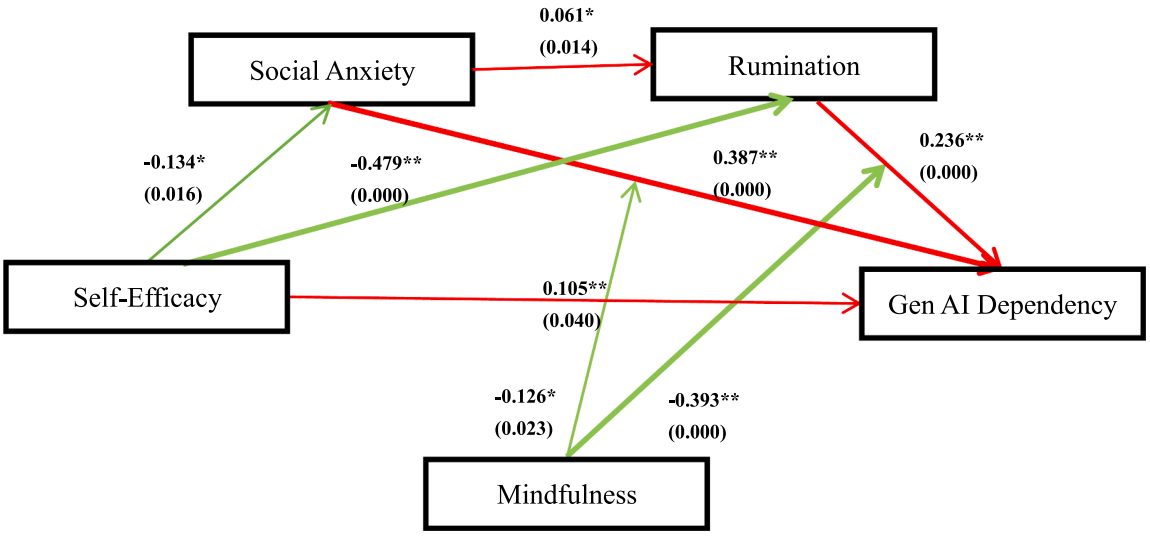

Fig. 5. SEM model path diagram
Note: * $p < 0.05$, and ** $p < 0.01$. Line thickness represents the magnitude of the coefficient. Solid lines indicate statistically significant effects, while dashed lines indicate non-significant effects. Red lines denote positive effects, and green lines denote negative effects. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Respondents' demographic information (n = 758).

Variables	*N*	%
Gender		
Male	380	50.13
Female	378	49.87
Education		
Freshman	116	15.30
Sophomore	231	30.47
Junior	285	37.60
Senior	106	13.98
Postgraduate or above	20	2.65
Monthly living expenses (¥)		
≤1000	18	2.37
1001–2000	387	51.06
2001–3000	284	37.47
>3000	69	9.10

experience groups (Chen, 2020). Thus, the ChatGPT dependency scale is used here to explore university students' dependency on GenAI and the association between such dependency and their self-efficacy.

3.3. Data analysis

The research model was subjected to thorough analysis with the aid of the PROCESS macro in SPSS (version 4.1) (Hayes, 2013). To rigorously examine the various paths and relationships within the model, the bootstrap resampling method was implemented with 5000 samples to create a robust estimate of the model's parameters and their associated uncertainties. The extensive use of samples in this manner was aimed at ensuring the reliability and validity of the findings, providing a solid foundation for further interpretation and conclusions.

Table 2
Reliability analysis results.

Constructs	*N*	Cronbach's α
Self-efficacy (SE)	10	0.886
Social anxiety (SA)	19	0.948
Rumination (RUM)	22	0.955
Mindfulness (MIND)	15	0.961
GenAI dependency (GAID)	6	0.837
Scale	72	0.970

Table 3
Model AVE and CR indicator results.

Factor	AVE	CR
Self-efficacy	0.536	0.953
Social anxiety	0.443	0.888
Rumination	0.499	0.956
Mindfulness	0.621	0.961
GenAI dependency	0.463	0.838

4. Results

4.1. Descriptive statistics

A total of 758 Chinese university students participated in the survey. The gender distribution was balanced, with males accounting for 50.13% and females 49.87%. In terms of education level, freshmen accounted for 15.30%, sophomores 30.47%, juniors 37.60% (the highest proportion), seniors 13.98%, and those with graduate degrees or above 2.65%. The majority of respondents reported living expenses in the range of 1001 to 2000 yuan per month, accounting for 51.06%, while the range of 2001 to 3000 yuan accounted for 37.47%. The proportions of students with living expenses below 1000 yuan or above 3000 yuan were relatively small, at 2.37% and 9.10%, respectively. The overall sample thus covers students from a wide range of different educational stages and family economic backgrounds.

4.2. Reliability analysis

A reliability analysis was conducted for all variables in this study. The Cronbach's α coefficients for all major constructs exceed 0.8, with self-efficacy at 0.886, social anxiety at 0.948, rumination at 0.955, mindfulness at 0.961, and GenAI dependency at 0.837. The overall scale achieves a high reliability coefficient of 0.970, demonstrating the excellent internal consistency and reliability of the measurement instrument.

4.3. Factor analysis

4.3.1. Confirmatory factor analysis

Table 3 presents the convergent validity results for the measurement

Table 4
Discriminant validity: Pearson correlation and AVE square root value.

Factor	Self-efficacy	Social anxiety	Rumination	Mindfulness	GenAI dependency
Self-efficacy	0.732				
Social anxiety	−0.143	0.666			
Rumination	0.723	−0.219	0.706		
Mindfulness	0.667	−0.205	0.700	0.788	
GenAI dependency	0.092	0.291	0.133	0.053	0.681

Table 5
Model fitting indicators.

Common indicators	χ^2	*df*	*p*	χ^2/df	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judgment criteria	–	–	>0.05	<3	>0.9	<0.10	<0.05	>0.9	>0.9	>0.9
Value	6371.401	2474	0.000	2.575	0.766	0.046	0.073	0.895	0.839	0.891
Other indicators	TLI	AGFI	IFI	PGFI	PNFI	PCFI	SRMR	RMSEA 90% CI		
Judgment criteria	>0.9	>0.9	>0.9	>0.5	>0.5	>0.5	<0.1	–		
Value	0.891	0.752	0.895	0.721	0.812	0.866	0.060	0.041–0.048		

Note: For the default model, x^2 (2556) = 39,656.057, p = 1.000, AIC = 291.189, and BIC = 1004.314.

Table 6
Total variance explained.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
1	26.029	36.152	36.152	26.029	36.152	36.152	10.988	15.261	15.261
2	5.982	8.309	44.460	5.982	8.309	44.460	10.545	14.645	29.906
3	3.542	4.920	49.380	3.542	4.920	49.380	10.503	14.587	44.493
4	3.339	4.637	54.017	3.339	4.637	54.017	5.560	7.722	52.216
5	2.594	3.602	57.619	2.594	3.602	57.619	3.337	4.635	56.851
6	1.390	1.930	59.550	1.390	1.930	59.550	1.514	2.103	58.954
7	1.224	1.699	61.249	1.224	1.699	61.249	1.362	1.891	60.845
8	1.070	1.486	62.735	1.070	1.486	62.735	1.361	1.890	62.735
9	0.856	1.189	63.924						
10	0.779	1.081	65.005						

Note: KMO = 0.977, Chi-square = 38,304.542, degrees of freedom, and p-value<0.001; extraction method: principal component analysis.

model. The constructs demonstrate strong composite reliability (CR), with all CR values exceeding the recommended threshold of 0.7, ranging from 0.838 to 0.961. The AVE values are all above 0.4, indicating acceptable convergent validity for the research context and confirming that the constructs adequately capture variance in their respective indicators. (See Figs. 1–5.) (See Tables 1 and 2.)

Table 4 presents the results of discriminant validity testing using the Fornell-Larcker criterion. The square roots of the AVE for each construct, shown on the diagonal, are in all cases greater than its correlations with other constructs. This confirms that each construct shares more variance with its own indicators than with other constructs, thereby establishing adequate discriminant validity for the measurement model. (See Tables 9–12.) (See Tables 14–17.)

The model fitting index results from confirmatory factor analysis are presented in Table 5. The model shows an acceptable fit with χ^2/df = 2.575, RMSEA = 0.046, and CFI = 0.895. Although the goodness-of-fit (GFI) and adjusted goodness-of-fit (AGFI) values are slightly below the common threshold, other key indices such as standardized root mean square residual (SRMR) at 0.060 and RMR at 0.073 generally support the model's acceptable fit to the data.

All loadings are statistically significant, and most exceed 0.6, demonstrating strong relationships between the items and their respective latent constructs. The SMC values indicate that a substantial portion of each item's variance is explained by its underlying factor, confirming the robustness of the measurement model.

4.3.2. Exploratory factor analysis

The exploratory factor analysis results support the robust psychometric properties of the measurement model. As presented in Table 6, eight factors emerged with eigenvalues exceeding 1, of which the first factor accounts for 36.152% of the total variance, which is below the 40% threshold that would indicate common method bias. This finding, combined with the excellent KMO value of 0.977 and a significant Bartlett's test result, confirms the data's suitability for factor analysis, while demonstrating the absence of substantial common method variance.

The rotated factor loading matrix reveals a clear and theoretically coherent structure. Most items load strongly on their intended constructs with coefficients above 0.6, with minimal cross loadings on other factors. Self-efficacy and GenAI dependency are found on different loading patterns of projects, which clearly cluster together on their respective factors without significant overlap with other factors.

The discriminant validity is further supported by the HTMT ratios (see Table 7), which are below the conservative threshold of 0.85 across all construct pairs. The highest observed value is that between self-efficacy and rumination, which at 0.752 falls within acceptable limits, providing strong evidence that the constructs are empirically distinct despite the theoretical relationships that connect them.

Additional evidence for the validity of the model can be seen in Table 8, where all constructs demonstrate AVE values exceeding both the maximum shared variance and the average shared variance. This pattern, coupled with the fact that the CR scores are all above 0.83, confirms that the measurement model adequately captures the intended theoretical constructs with sufficient reliability and discriminant validity.

4.4. Correlation analysis and multicollinearity test

Self-efficacy was found to be significantly positively correlated with GenAI dependency (r = 0.287, p < 0.01), contradicting the initial

Table 7
HTMT results.

Factor	Self-efficacy	Social anxiety	Rumination	Mindfulness	GenAI dependency
Self-efficacy	–				
Social anxiety	0.276	–			
Rumination	0.752	0.257	–		
Mindfulness	0.700	0.228	0.731	–	
GenAI dependency	0.171	0.343	0.194	0.141	–

Table 8
Distinguishing between the MSV and ASV validity indices.

Factor	AVE	CR	MSV	ASV
Self-efficacy	0.536	0.953	0.587	0.282
Social anxiety	0.443	0.888	0.107	0.067
Rumination	0.499	0.956	0.587	0.305
Mindfulness	0.621	0.961	0.548	0.271
GenAI dependency	0.463	0.838	0.107	0.034

hypothesis of a negative relationship. Social anxiety was significantly negatively correlated with both self-efficacy ($r = -0.205$, $p < 0.01$) and rumination ($r = -0.219$, $p < 0.01$), while displaying a negative correlation with GenAI dependency ($r = -0.291$, $p < 0.01$); H1 is thus supported. The strongest relationship observed in the analysis is the positive correlation between rumination and mindfulness ($r = 0.700$, $p < 0.01$). Demographic variables were generally only weakly correlated with the main constructs, although education level was significantly correlated with multiple variables, including social anxiety and GenAI dependency.

The collinearity diagnosis results revealed no severe multicollinearity concerns among the study variables. All variance inflation factor (VIF) values are well below the conservative threshold of 3, and the highest VIF (2.057) was observed for rumination and the second-highest (2.047) for mindfulness. Similarly, the tolerance values all exceed 0.4, substantially above the critical level of 0.1. These findings demonstrate that the variables are sufficiently independent for subsequent regression analyses, ensuring the stability and reliability of the parameter estimates in the proposed theoretical model.

4.5. Chain mediation effects testing

The coefficient of the path from self-efficacy to rumination was -0.231 ($p < 0.001$), and the coefficient of the path from rumination to GenAI dependency was 0.214 ($p < 0.001$). Both of these reach the level of significance, and thus, H2 is supported. The influence of self-efficacy on GenAI dependency through the mediator of social anxiety was also significant; H3 is thus supported. At the same time, the path coefficient linking self-efficacy to social anxiety was -0.197 ($p < 0.001$), the path coefficient linking social anxiety to rumination was 0.102 ($p = 0.006$), and the path coefficient linking rumination to GenAI dependency was 0.214 ($p < 0.001$). Together, these three consecutive, significant pathways constitute a complete chain mediation mechanism. Note in particular the significant positive correlation ($\beta = 0.102$) between social anxiety and rumination, which is essential to the continuity of the mediation chain and thus strongly supports H4.

A chain mediation analysis revealed that self-efficacy significantly affects GenAI dependency through multiple pathways involving social anxiety and rumination. The path coefficients linking self-efficacy to social anxiety, social anxiety to rumination, and rumination to GenAI dependency all reached significant levels, and the bootstrap confidence intervals did not include 0, thus providing statistical support for the chain mediation effect and validating H4.

4.6. Adjustment effect test results

The moderation effect analysis revealed the interaction coefficient between the key indicators of social anxiety and mindfulness to be -0.161 ($p = 0.007$). This significant negative value clearly indicates that mindfulness has a weakening effect on the social anxiety pathway. Moreover, the bootstrap confidence interval [0.038, 0.101], with an indirect effect value of 0.067, does not contain 0, confirming the existence of moderated mediation effects and further supporting H6. When the level of mindfulness rises from low to high, the direct effect value decreases by about 35%, from 0.438 to 0.284. This clear relationship reinforces the findings presented in Table 13, indicating that the regulatory effect of mindfulness has practical significance and further supporting H6.

The coefficient of the interaction term for rumination and mindfulness is -0.104 ($p = 0.009$) and statistically significant, while the bootstrap confidence interval of the indirect effect value -0.077 [-0.116, -0.042] is completely in the negative range. This coherent chain of evidence clearly demonstrates that mindfulness effectively weakens the mediating effect of the contemplative pathway; H5 is thus supported. As mindfulness levels increased from -1SD to +1SD, the direct effect value decreased by 45%, from 0.581 to 0.320. This significant change confirms the existence of substantially strong regulatory effects, and H5 is thus supported.

The moderation analysis indicates that mindfulness attenuates the association between rumination and GenAI dependence. Specifically, when mindfulness levels are low, rumination shows a stronger positive association with GenAI dependence (simple slope = 0.281). In contrast, under high levels of mindfulness, this association becomes weaker (simple slope = 0.259). The converging pattern of the two simple slopes suggests that higher levels of mindfulness buffer the maladaptive impact of rumination on GenAI dependence. Overall, the results indicate that mindfulness reduces the strength of the rumination–GenAI dependence link, supporting the role of mindfulness as a protective regulatory resource.

A similar moderating pattern can be observed for social anxiety. When mindfulness levels are low, social anxiety exhibits a relatively stronger positive association with GenAI dependence (simple slope = 0.278). This association is attenuated at higher levels of mindfulness (simple slope = 0.254). The divergence between the simple slopes indicates that mindfulness mitigates the influence of social anxiety on GenAI dependence. These findings suggest that individuals with higher levels of mindfulness are less likely to translate social anxiety into excessive dependency on GenAI, highlighting the potential of mindfulness as a buffering factor in technology-related dependence.

4.7. Structural equation modeling validation

The overall fit of the structural equation model is good, and all key indicators meet the evaluation criteria. The χ^2/df value is 2.575; RMSEA is 0.046; the CFI, normed fit index (NFI), non-normed fit index (NNFI) and other indicators all exceed 0.9, and AGFI is 0.923, indicating an ideal match between the theoretical model and the observed data. The research hypothesis is thus supported.

The path coefficients presented in Table 18 reveal the structural relationships among the variables, with self-efficacy significantly negatively affecting both social anxiety and rumination, and both social anxiety and rumination significantly positively affecting GenAI dependency. Particularly noteworthy is that mindfulness had a significant negative impact on both mediator variables, consistent with the

Table 13
Moderated mediation model (rumination).

	GenAI dependency				Social anxiety			
	β	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
Constant	0.661	0.616	1.073	0.284	2.379	0.394	6.043	0.000**
Self-efficacy	0.776	0.136	5.684	0.000**	−0.276	0.042	−6.615	0.000**
Mindfulness	0.289	0.124	2.339	0.020*				
Rumination*Mindfulness	−0.104	0.040	−2.624	0.009**				
Gender	−0.070	0.052	−1.351	0.177	0.058	0.046	1.244	0.214
Age	0.017	0.022	0.781	0.435	0.018	0.020	0.911	0.362
Education	0.019	0.033	0.573	0.567	0.043	0.029	1.459	0.145
Living expenses	0.022	0.038	0.590	0.555	−0.018	0.034	−0.527	0.598
Rumination	0.279	0.055	5.041	0.000**				
N	758				758			
R^2	0.140				0.063			
Adjusted R^2	0.130				0.056			
F	$F(8,747) = 15.207, p = 0.000$				$F(5,750) = 10.118, p = 0.000$			

Note: * $p < 0.05$, and ** $p < 0.01$.

Table 18
SEM model regression coefficients.

X	→	Y	*B*	*SE*	CR	*p*	*β*
Self-efficacy	→	Social anxiety	−0.061	0.025	−2.409	0.016	−0.134
Self-efficacy	→	Rumination	−0.365	0.030	−11.968	0.000	−0.479
Self-efficacy	→	GenAI dependency	0.103	0.047	−0.075	0.040	0.105
Social anxiety	→	Rumination	0.103	0.042	2.451	0.014	0.061
Social anxiety	→	GenAI dependency	0.640	0.081	7.906	0.000	0.387
Rumination	→	GenAI dependency	0.232	0.063	3.676	0.000	0.236
Mindfulness	→	Social anxiety	−0.042	0.019	−2.270	0.023	−0.126
Mindfulness	→	Rumination	−0.223	0.021	−10.532	0.000	−0.393

Table 9
Pearson correlation.

Variable	Mean ± SD	1	2	3	4	5	6	7	8	9
1. Gender	1.499 ± 0.500	1								
2. Age	21.09 ± 1.559	0.058	1							
3. Education	2.606 ± 1.069	0.077*	0.674**	1						
4. Living expenses	2.533 ± 0.692	0.010	0.130**	0.142**	1					
5. Self-efficacy	0.634 ± 0.272	0.142**	0.096**	0.112**	0.135**	1				
6. Social anxiety	2.861 ± 0.564	0.020	0.028	0.033	0.134**	0.205**	1			
7. Rumination	2.125 ± 0.651	0.019	0.068	0.078*	−0.038	−0.219**	−0.093*	1		
8. Mindfulness	3.132 ± 1.259	0.024	0.080*	0.058	−0.092*	−0.205**	−0.200**	0.700**	1	
9. GenAI dependency	3.828 ± 0.748	0.010	0.099**	0.108**	0.062	0.291**	0.287**	0.133**	0.053	1

Note: * $p < 0.05$, and ** $p < 0.01$. The self-efficacy scores were normalized to a range of 0–1.

Table 10
Collinearity diagnosis.

Item	VIF	Tolerance
Gender	1.030	0.971
Age	1.847	0.542
Education	1.859	0.538
Living expenses	1.056	0.947
Self-efficacy	1.250	0.800
Social anxiety	1.169	0.856
Rumination	2.057	0.486
Mindfulness	2.047	0.488
GenAI dependency	1.234	0.811

aforementioned moderation analysis and confirming the important moderating role of mindfulness in the model.

A comparison of the results from the structural equation model and the aforementioned mediation model reveals that the two models are highly consistent in terms of their core path coefficients and significance patterns. The direction and magnitude of the path coefficients for self-efficacy being linked to GenAI dependency through social anxiety and rumination in the SEM model are consistent with the results from the mediation analysis. Moreover, the inhibitory effect of mindfulness on the two mediating variables is significant under both analysis methods, confirming the robustness and reliability of the research conclusions.

5. Discussion

The findings of this study show that self-efficacy positively predicted GenAI dependency, with social anxiety and rumination playing central mediating roles in this relationship. Furthermore, this study focuses on a high-frequency GenAI user group, namely Chinese university students, so the results underscore the potential risks associated with GenAI use in a higher education context. By combining quantitative research with the I-PACE model, this study elucidates the mechanisms by which individual psychological traits and their interactions influence GenAI addiction in a specific cultural context. This study further explores the mechanisms through which self-efficacy influences GenAI dependency, examining the sequential mediating effects of social anxiety and rumination within that framework. Mindfulness is also included as a moderator of these mediating effects, thereby revealing a systematic pathway of influence. This research extends the existing corpus of studies on GenAI dependency, offering insights for future investigation. In addition, a

Table 11
Mediation effect model testing.

	Social anxiety				Rumination				GenAI dependency				GenAI dependency			
	β	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
Constant	–	0.165	1.755	0.080	–	0.394	6.106	0.000**	–	0.446	5.235	0.000**	–	0.434	3.579	0.000**
Gender	−0.009	0.020	−0.244	0.808	0.044	0.046	1.234	0.218	−0.035	0.053	−1.005	0.315	−0.043	0.050	−1.281	0.201
Age	−0.008	0.008	−0.165	0.869	0.043	0.020	0.905	0.366	0.035	0.023	0.752	0.452	0.028	0.021	0.629	0.529
Education	0.006	0.012	0.129	0.897	0.070	0.029	1.464	0.144	0.054	0.033	1.140	0.255	0.037	0.031	0.834	0.405
Living expenses	0.105	0.014	2.901	0.004**	−0.015	0.034	−0.402	0.688	0.011	0.038	0.319	0.750	−0.011	0.036	−0.317	0.751
Self-efficacy	−0.197	0.018	−5.425	0.000**	−0.231	0.043	−6.265	0.000**	0.285	0.047	7.998	0.000**	0.287	0.047	8.145	0.000**
Social anxiety					0.102	0.087	1.161	0.006**					0.248	0.093	7.324	0.000**
Rumination													0.214	0.039	6.284	0.000**
N	758				758				758				758			
R^2	0.055				0.065				0.092				0.189			
Adjusted R^2	0.049				0.057				0.086				0.182			
F	*F* (5,750) = 8.745, *p* = 0.000				*F* (6,749) = 8.660, *p* = 0.000				*F* (5,750) = 15.269, *p* = 0.000				*F* (7,748) = 24.947, *p* = 0.000			

Note: * p < 0.05, and ** p < 0.01.

substantial body of research has reported significant negative correlations linking self-efficacy to both Internet addiction and problematic smartphone use (Berte et al., 2021; Chiu, 2014; Li et al., 2021; Odacı, 2013). As an extension of Internet and smartphone applications, GenAI and the mechanisms of addiction to GenAI are incorporated here into existing theoretical frameworks and tested using empirical evidence.

First, the relationship between self-efficacy and GenAI identified in the present study contradicts both prior research (Liao et al., 2025; Zhang et al., 2024) and Hypothesis 1. Prior studies on GenAI dependency have either examined domain-specific self-efficacy, or they have treated self-efficacy as a mediating variable. Those studies have consistently demonstrated a negative association between self-efficacy and GenAI dependency, framing technology reliance as a compensatory response to low self-efficacy (Liao et al., 2025; Zhang et al., 2024). The explanation of such dependency as a "compensatory response" indicates that individuals may develop a dependency on the Internet or related technologies as a form of escapism or as a compensatory mechanism for perceived deficits in their own capabilities for dealing with the real world (Kardefelt-Winther, 2014; Tokunaga, 2017). In contrast, the present study focuses on the effect of general self-efficacy and finds that general self-efficacy positively predicts GenAI dependency. This finding suggests that the nature of this relationship may be more instrumental than compensatory. Individuals with high levels of self-efficacy may view dependence on GenAI as an empowered and strategic form of reliance, rather than a loss of autonomy. Such individuals are likely to possess greater confidence in their ability to manage tasks, and they will incorporate technological tools into their work, enabling them to proactively use GenAI to enhance their efficiency and performance (Bandura, 1977b; Bandura, 2001; Compeau & Higgins, 1995; Shu et al., 2011; Venkatesh et al., 2003). From this perspective, higher dependency does not necessarily imply reduced self-regulation or competence but rather deliberate engagement with GenAI as a cognitive and productivity-enhancing resource (Dell'Acqua et al., 2023; Raisch & Krakowski, 2021). Thus, one can infer that GenAI dependency may assume qualitatively different meanings across different levels of self-efficacy. This underscores the need to reconceptualize dependency as a context-sensitive and agency-driven construct, rather than a uniformly maladaptive outcome.

The positive correlation of self-efficacy and GenAI dependency could also be explained by mental health challenges, such as academic stress and anxiety, cultural factors, such as collectivism and peer influence, and **a greater propensity for habitually developing and using GenAI competencies**. Prior studies have shown that prolonged perceived time pressure, heavy academic workloads, high reward sensitivity, and emphasis on performance quality can substantially increase the likelihood of GenAI addiction. As highly-engaged students tend to bear the greatest pressure, they also face the highest risk of GenAI overuse (Abbas et al., 2024; Li & Jiang, 2025; Wang et al., 2025; Zhang et al., 2024). Moreover, related studies have shown that students with higher levels of self-efficacy generally demonstrate greater engagement in learning (Alemayehu & Chen, 2023; Ma et al., 2025). Therefore, in the context of higher education in China, which is characterized by intense academic pressure and widespread anxiety, hopelessness, and depressive symptoms among university students, students with higher levels of self-efficacy may paradoxically be at heightened risk of GenAI addiction.

Furthermore, this correlation may be more pronounced in the Chinese cultural context, which is collectivist (Bond & Smith, 1996; Triandis, 1989). In a society where collectivism is culturally salient, individuals tend to emulate the behaviors of other members of their social group. They also exhibit a greater tendency toward conformity, compared to individuals from individualistic cultures (Bond & Smith, 1996; Triandis, 1989; Triandis et al., 1988). This implies that even students with high levels of self-efficacy may be inclined to use GenAI when they observe widespread adoption of that technology among their peers, thereby increasing their own reliance on GenAI. Related studies have also shown that peer influence significantly affects the use of GenAI

Table 12
Summary of chain-based mediating effects analysis.

Effect	Item	Effect	*SE*	*t*	*p*	LLCI	ULCI
Direct effect	Self-efficacy⇒GenAI dependency	0.382	0.047	8.145	0.000	0.290	0.473
	Self-efficacy⇒Social anxiety	−0.095	0.018	−5.425	0.000	−0.130	−0.061
	Self-efficacy⇒Rumination	−0.266	0.043	−6.265	0.000	−0.350	−0.183
Indirect effect	Social anxiety⇒Rumination	0.101	0.087	1.161	0.006	0.070	0.271
	Social anxiety⇒GenAI dependency	0.684	0.093	7.324	0.000	0.501	0.867
	Rumination⇒GenAI dependency	0.246	0.039	6.284	0.000	0.169	0.323
Total effect	Self-efficacy⇒GenAI dependency	0.379	0.047	7.998	0.000	0.286	0.471

Table 14
Conditional direct effect and indirect effect (rumination).

	Level	Horizontal value	Effect	*SE*	*t*	*p*	*LLCI*	*ULCI*
Conditional Direct effect	Low level (-1SD)	1.875	0.581	0.072	8.096	0.000	0.440	0.721
	Average	3.132	0.450	0.048	9.426	0.000	0.357	0.544
	High level (+1SD)	4.389	0.320	0.066	4.837	0.000	0.190	0.449
Indirect effect			−0.077	0.020			−0.116	−0.042

for academic misconduct among university students (Nguyen & Goto, 2024; Teunissen et al., 2012; Zhao et al., 2022). In other words, when students with high self-efficacy observe their peers completing academic tasks more easily or more effectively by using GenAI, they may also adopt GenAI as an efficient means of coping with heavy workloads and time pressure. This then elevates the frequency of their GenAI use and ultimately increases their GenAI dependency (Abbas et al., 2024; Li & Jiang, 2025). The key point to note is that the usage of GenAI by students is not only motivated by a desire for study efficiency but also by the need to establish friendships, integrate into peer groups, and promote interpersonal compatibility. This fact underscores how social conformity shapes individuals' decision-making in GenAI adoption (Laursen & Veenstra, 2021).

Beyond these explanations, prior studies have suggested that individuals with higher levels of general self-efficacy also tend to develop stronger self-efficacy in specific task domains (Agarwal et al., 2000; Brashi, 2022; Gardner & Pierce, 1998; Tetri & Juujärvi, 2022). Specifically, individuals with higher levels of general self-efficacy tend to exhibit stronger Internet self-efficacy and computer self-efficacy. This, in turn, increases their propensity to use digital services and computers for academic purposes (Brashi, 2022; Tetri & Juujärvi, 2022). Building on this line of reasoning, one can plausibly infer that individuals with higher levels of general self-efficacy are also more likely to develop higher levels of GenAI self-efficacy. Prior empirical studies have also shown that individuals with higher levels of GenAI self-efficacy engage in more frequent use of GenAI technologies (Schutte & Li, 2025). Furthermore, sustained and high-frequency engagement with GenAI systems has been found to increase users' susceptibility to developing dependence on these technologies (Robayo-Pinzon et al., 2025).

This study's results regarding the relationship between rumination and self-efficacy, and that between rumination and GenAI, are in accordance with the results of previous scholarly research (Hu et al., 2023; Stanciu & Calugar, 2022; Su et al., 2025; Takagishi et al., 2013; van Seggelen-Damen & van Dam, 2016; Wu et al., 2023; Zhang et al., 2025). Prior studies on rumination have primarily focused on the emotional self-efficacy of university students (Su et al., 2025; Wu et al., 2023). In contrast, this study extends the scope to general self-efficacy and places greater emphasis on behavior and outcomes, rather than

Table 15
Moderation mediation model (social anxiety).

	GenAI dependency				Social anxiety			
	β	*SE*	*t*	*p*	*β*	*SE*	*t*	*p*
Constant	1.200	0.597	2.010	0.045*	0.290	0.165	1.755	0.080
Self-efficacy	0.553	0.135	4.101	0.000**	0.095	0.018	5.425	0.000**
Mindfulness	0.280	0.121	2.309	0.021*				
Social anxiety*Mindfulness	−0.161	0.039	−3.571	0.007**				
Gender	−0.063	0.051	−1.246	0.213	−0.005	0.020	−0.244	0.808
Age	0.013	0.022	0.602	0.547	−0.001	0.008	−0.165	0.869
Education	0.029	0.032	0.921	0.357	0.002	0.012	0.129	0.897
Living expenses	0.001	0.037	0.025	0.980	0.041	0.014	2.901	0.004**
Social anxiety	0.709	0.096	7.381	0.000**				
N	758				758			
R^2	0.171				0.055			
Adjusted R^2	0.161				0.048			
F	$F(8,747) = 19.292, p = 0.000$				$F(5,750) = 8.745, p = 0.000$			

Note: * $p < 0.05$, and ** $p < 0.01$.

Table 16
Conditional direct effect and indirect effect (social anxiety).

	Level	Horizontal value	Effect	*SE*	*t*	*p*	*LLCI*	*ULCI*
Conditional Direct effect	Low level (-1SD)	1.875	0.438	0.071	6.167	0.000	0.299	0.577
	Average	3.132	0.361	0.047	7.651	0.000	0.269	0.454
	High level (+1SD)	4.389	0.284	0.065	4.378	0.000	0.157	0.411
Indirect effect			0.067	0.016			0.038	0.101

Table 17
SEM model fit indices.

Common indicators	χ^2	*df*	*p*	χ^2/df	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judgment criteria	–	–	>0.05	<3	>0.9	<0.10	<0.05	>0.9	>0.9	>0.9
Value	6372.416	2475	0.000	2.575	0.766	0.046	0.037	0.925	0.931	0.928
Other indicators	TLI	AGFI	IFI	PGFI	PNFI	PCFI	SRMR	RMSEA 90% CI		
Judgment criteria	>0.9	>0.9	>0.9	>0.5	>0.5	>0.5	<0.1	–		
Value	0.919	0.923	0.909	0.813	0.867	0.854	0.060	0.041–0.048		

Note: For the default model, $\chi^2(1596) = 39{,}656.057$, and $p = 1.000$; AIC = 289.186, and BIC = 997.681.

emotions and feelings. This approach provides a more appropriate perspective for exploring the mechanisms underlying GenAI dependency as a form of behavioral addiction. In other words, students with low self-efficacy are more likely to engage in rumination during their daily behaviors and decision-making processes. Rumination is known to be a mediator in the relationship between individual traits and excessive technology use, particularly in the context of problematic smartphone use and internet addiction (Elhai et al., 2020; McNicol & Thorsteinsson, 2017; Peng et al., 2022; Stanciu & Calugar, 2022). Furthermore, a previous study has demonstrated a substantial positive correlation between rumination and problematic use of conversational AI (Hu et al., 2023). Consequently, when university students with low levels of self-efficacy encounter negative emotions due to their academic tasks and life challenges, they engage in rumination that makes them more inclined to overuse GenAI as a compensatory mechanism (Gao et al., 2022), ultimately leading to GenAI dependency. Within the framework of the I-PACE model, one can posit that individuals may develop (possibly erroneous) expectations that engaging with the Internet can serve as a successful means of stress relief (Brand et al., 2016). Additionally, GenAI can create high-quality virtual environments (Foo et al., 2025) that can serve as ideal and relatively safe interactive spaces (Hu et al., 2023) and can assist university students in addressing issues in their studies and daily lives. As such, GenAI can temporarily enhance their self-efficacy (Chang et al., 2022; Huang et al., 2024; Xu et al., 2024; Zhang & Xu, 2025) and thereby temporarily alleviate rumination. However, this phenomenon has also been observed to lead to a decline in cognitive engagement and a heightened reliance on GenAI (Ye et al., 2024).

Moreover, this study finds that social anxiety mediates the link between self-efficacy and GenAI dependency. This finding is consistent with cognitive theory, which holds that low levels of self-efficacy can maintain or intensify anxiety (Bandura, 1977). Prior studies have also provided sufficient evidence to show that the severity of social anxiety is closely linked to self-efficacy. Specifically, individuals with lower levels of self-efficacy tend to exhibit higher levels of social anxiety (Aune et al., 2021; Schlenker & Leary, 1982; Thomasson & Psouni, 2010). One of the contributions of this study is to clarify how this mediating mechanism operates in the context of GenAI. Prior studies on GenAI chatbot use have largely focused on the benefits of that technology for enhancing learning and improving self-efficacy (Chang et al., 2022; Jeilani & Abubakar, 2025; Liang et al., 2023). However, the findings of this study refine the theoretical framework by suggesting that such outcomes may not generalize across populations, particularly with regard to individuals with high levels of social anxiety. While not a human entity, GenAI can convincingly simulate interpersonal impressions. In addition, human–machine interaction has been shown to be able to alleviate social anxiety (Hu et al., 2023). Thus, for individuals with low self-efficacy and high social anxiety, GenAI may serve less as a tool for overcoming social challenges than as a means of avoiding demanding tasks or negative feelings. Furthermore, when high social anxiety mediates this process, the usage of GenAI may reinforce social avoidance and foster over-reliance. This finding is consistent with the relevant discussions regarding coping mechanisms in terms of the I-PACE model. These discussions emphasize that maladaptive or impulsive coping strategies in response to stress may significantly contribute to the development and maintenance of Internet-use disorders (Brand et al., 2016). This pattern also accords with previous studies that have shown that GenAI may provide users with emotionally supportive interactions and thereby become an appealing alternative to human interaction as a means to compensate for social deficits (Hu et al., 2023). Notably, GenAI provides accurate comprehension of instructions, timely responses, and personalized interactions (Liao et al., 2025), making GenAI attractive to socially anxious students who perceive interpersonal interactions as demanding. Accordingly, when university students encounter challenges such as high social anxiety, they are more inclined to rely on GenAI. In turn, this reliance may further direct their attention toward their own underlying emotional vulnerabilities (Hu et al., 2023) and consequently increase their willingness to use GenAI to cope with their current challenges. The potential risk of this behavioral pattern lies in the associated long-term developmental implications. For university students with elevated social anxiety, excessive reliance on GenAI may reduce opportunities for real-world interpersonal interaction. Unfortunately, this could potentially contribute to the maintenance or even aggravation of offline social difficulties (Hu et al., 2023; Xie & Wang, 2024). Furthermore, many academic tasks inherently require collaboration, discussion, and active participation. As such, avoidance-motivated GenAI use may weaken students' academic engagement and ultimately compromise their academic performance (Mou et al., 2024). Therefore, the overall risk does not arise from the use of GenAI itself but from a substitution pattern in which GenAI use may replace rather than complement authentic social and academic involvement.

The results of this study also align with prior research that has shown that social anxiety contributes to the problematic use of conversational AI and that this process is mediated by rumination (Zhang et al., 2025). This finding also agrees with the viewpoint proposed by Brand in terms of the I-PACE model (Brand et al., 2016; Brand et al., 2019). Brand argued that predisposing variables may not directly impact the development of a specific Internet use disorder but are instead associated with certain Internet use expectancies and dysfunctional coping styles. Excessive technology use may thus represent an action taken to seek reassurance and relieve the distress of persistent negative thoughts (Hu et al., 2023). Therefore, individuals with a high level of rumination are more likely to develop GenAI dependency as an avoidance strategy for relieving stress, precisely as shown in this study. Specifically, this study's results demonstrate that low levels of self-efficacy increase social anxiety, which further exacerbates rumination tendencies and ultimately leads to greater dependence on GenAI. This conclusion agrees with the results of an empirical study that suggested that social anxiety can significantly predict higher levels of rumination in adolescents (Jose et al., 2012; Zou & Abbott, 2012). This mechanism shows that the internal and external stimuli involved in the addiction process can be conditioned, thereby initiating affective and cognitive processes that culminate in the decision to engage with a particular Internet application, exemplified here by GenAI. Such a view is fully consistent with the theoretical propositions of the I-PACE model (Brand et al., 2016; Brand et al., 2019).

Finally, this study's findings on mindfulness are consistent with the hypotheses and results of previous studies. The results of this study indicate that mindfulness significantly moderates the effect of self-efficacy on GenAI dependency through two pathways, namely

rumination and social anxiety. For the rumination-mediated pathway, mindfulness fosters metacognition through "decentering", which enables individuals to recognize and then actively disengage from rumination (Wolkin, 2015). This finding agrees with those of Raes and Williams (2010), who found that mindfulness weakens the link between analytical and uncontrollable rumination, thereby weakening the pathway through which self-efficacy drives rumination and thus fueling GenAI dependency. This finding is also consistent with the results of a study by Yu et al. (2021) on Chinese adolescents, which found that mindfulness not only directly affected negative outcomes but also indirectly improved related issues by reducing rumination. Those results further confirm the core role of rumination in the mindfulness moderation pathway.

With regard to the social anxiety-mediated pathway, a meta-analysis by Liu et al. (2021) on social anxiety disorder found that mindfulness interventions can reduce seasonal affective disorder (SAD) by curbing excessive rumination on social performance and negative evaluations. Moreover, that study also showed that high levels of mindfulness promote autonomous behavioral choices, enabling individuals to proactively detect and regulate their excessive GenAI use while also enhancing present-moment awareness to mitigate their social anxiety, even when their self-efficacy level is low (Brown & Ryan, 2003). Notably, the role of mindfulness is not limited to moderating effects. A study on Chinese adolescents by Li et al. (2018) found that perseverance also enhances subjective well-being through the mediating role of mindfulness. This finding complements the moderating function of mindfulness revealed in this study. Collectively, the results confirm the core role of mindfulness in multiple psychological pathways, with the mechanism of mindfulness essentially stemming from its role in focus and the awareness of current experiences.

5.1. Theoretical implications

Prior studies have primarily focused on Internet addiction and smartphone addiction (Balakrishnan & Griffiths, 2017; Iskender & Akin, 2010; Özdemir et al., 2014). Differently, this study makes theoretical contributions by extending the I-PACE model to the emerging domain of GenAI use by university students (Liao et al., 2025). As a group inclined to adopt emerging technologies, college students undoubtedly have both greater opportunities and more motivation to engage with GenAI (Chen et al., 2024). This study offers a novel perspective for understanding the relationship between psychological factors and GenAI dependency in university students and the underlying mechanisms involved. This research not only provides an empirical foundation for understanding students' digital development and interaction with AI but also contributes to the advancement of theoretical frameworks in this emerging field.

The positive association between self-efficacy and GenAI dependency found in this study contradicts conventional assumptions that self-efficacy negatively predicts digital addiction (Berte et al., 2021; Iskender & Akin, 2010). However, this result accords with culturally contextualized interpretations. The Chinese academic environment is characterized by high academic pressure and social conformity. In this environment, students with higher self-efficacy have a stronger perceived ability to utilize GenAI as an efficient problem-solving tool, which reinforces their GenAI dependency. Therefore, these findings extend the I-PACE model by illustrating how sociocultural factors interact with psychological factors to influence technology dependency.

Moreover, this study enriches the understanding of the affective and cognitive pathways proposed in the I-PACE model. Social anxiety and rumination, representing the affective and cognitive components of the model, respectively, function as sequential mediators in a chain linking self-efficacy to GenAI dependency. While rumination has been examined within a digital addiction framework (Bağatarhan & Siyez, 2022), few studies have explored rumination's role in GenAI dependency. This study's finding thus provides a novel, empirical perspective on the cognitive mechanism by which the cognitive factor – rumination – functions in GenAI dependency.

Finally, the moderating role of mindfulness discovered in this study offers a new insight into the execution component of the I-PACE model. The results show that higher mindfulness weakens the effects of self-efficacy on GenAI **dependency** through the mediating effects of social anxiety and rumination. They also indicate that mindfulness can temper the negative effects of affective and cognitive factors in **human-computer interactions.** By demonstrating the moderating effect of mindfulness in a specific, AI-related context, this study integrates mindfulness firmly into the I-PACE model as an established mediating factor in human-AI interaction pathways.

This study identifies the underlying psychological factors that drive GenAI dependency and the boundary conditions imposed by individual characteristics in human-computer interactions. The results underscore the critical roles of self-efficacy, social anxiety, and rumination in shaping college students' engagement with GenAI. This study also addresses the need to further investigate the factors that influence users' behavioral intentions toward AI-based technologies (Chi et al., 2020). The results also extend the understanding of the determinants of human-AI interaction and offer theoretical implications for moderating users' mindsets. The need to develop better strategies to promote AI adoption is also highlighted.

5.2. Practical implications

These findings indicate the critical role of school-based interventions in mitigating dependency on GenAI, thereby offering new practical implications for higher education. First, university administrators should establish mechanisms for faculty collaboration within institutional work systems. This would enable instructors to coordinate their assignment schedules and thereby avoid clustering major student tasks within the same period. Such coordination would allow teachers to guide students in managing their time more effectively, thereby alleviating the intensity of academic pressure on students and reducing their frequency of rumination. Moreover, when assigning coursework and projects, instructors should shift the evaluative standards from an emphasis on quantity and comprehensiveness to a focus on originality and critical thinking. Students should be encouraged to develop novel perspectives grounded in existing research, rather than simply replicating prior studies (Abbas et al., 2024).

In addition, universities could offer more practice-oriented career development courses. Experienced alumni could be invited to deliver lectures that would help students pursue diversified personal and academic growth based on their individual interests and needs. By reducing students' exclusive focus on academic achievement, such initiatives could help alleviate academic stress, diminish rumination and related psychological issues, and enhance students' self-efficacy over the long term. Ultimately, these initiatives would lower the likelihood of excessive GenAI use.

The results of this study further underscore the obligation of higher education practitioners to cultivate authentic, inclusive, and psychologically safe environments for dialogue. When planning to invite students to participate in discussions, instructors should communicate beforehand with those who experience low self-efficacy or social anxiety so that they have sufficient time to prepare. This simple solution would help prevent inadvertently driving such students to turn to GenAI in moments of stress. When these students share their ideas, teachers should engage with them positively, providing affirmation and trust. This would help to create a caring classroom atmosphere that strengthens genuine interpersonal interaction as opposed to AI-mediated communication (Doğan et al., 2025; Noddings, 2012). This approach could reduce students' social anxiety and, in turn, diminish their tendencies toward rumination and metacognitive inertia (Fan et al., 2025; Ye et al., 2024), thereby ultimately curbing overreliance on GenAI.

Moreover, university instructors should promote their students' digital literacy, their awareness of the risks associated with AI dependency, and their self-efficacy. Given the heterogeneity of students' psychological characteristics, educators could design customized AI-assisted learning strategies that guide students, step-by-step, to organize, analyze, and critically evaluate GenAI-generated content. By offering appropriate encouragement and objective feedback, teachers can reduce students' overconfidence in GenAI outputs and prevent superficial gains in self-efficacy. Again, this would help to decrease their students' reliance on GenAI (Jia et al., 2025; Zhang & Xu, 2025).

Finally, institutions of higher education can systematically integrate mindfulness training into mental health courses or freshmen orientation programs. This could be done quite effectively by guiding students to engage in 10 to 15 min of daily focused awareness exercises, such as breath meditation and awareness of present-moment experience. Such exercises can enhance students' ability to regulate their rumination and social anxiety, thereby helping them reduce their reliance on technology and instead develop healthy emotional regulation patterns (Yu et al., 2021). Combined with the conclusions of a prior study by Li et al. (2018) on "grit" and subjective well-being that found that "mindfulness enhances present-moment focus", such an initiative would help students maintain their physical and mental engagement when pursuing long-term goals. This would not only alleviate the excessive technology usage caused by academic anxiety but would also improve students' overall well-being by enhancing their psychological flexibility.

6. Conclusion

In conclusion, this study finds that self-efficacy influences university students' dependency on GenAI through both direct and indirect pathways. Low self-efficacy results in increased social anxiety and rumination, which in turn then intensify GenAI dependency both independently and in a sequential chain. This result highlights the cumulative impact of emotional strain and maladaptive cognition. This study also identifies a small but significant positive direct effect of self-efficacy on GenAI dependency. That effect may result from the effects of academic pressure and collectivist norms in the Chinese context, as well as the illusion of competence fostered by GenAI use. Moreover, mindfulness is found to act as a key moderator, weakening the effects of self-efficacy on social anxiety and rumination, as well as the influence of these factors on GenAI dependency. Overall, these findings establish an integrated model that links self-efficacy, emotion, cognition, and behavioral dependence, emphasizing the central roles of social anxiety, rumination, and mindfulness in shaping GenAI dependency.

7. Limitations and directions for future research

This study explores the factors that influence university students' GenAI dependency. This is done by verifying the chain mediating role of social anxiety and rumination in the relationship between self-efficacy and GenAI dependency. However, this study also has some limitations worth noting, as they point to directions for future research.

The size and insufficient regional and academic diversity of the sample may reduce the statistical power and representativeness of the multi-variable serial mediation model. This limitation limits the authors' ability to exclude the possibility of regional interference and to explore the moderating effect of academic level on the core path. The sample's characteristics also limit the generalizability of the conclusions. Future research should use a larger sample size, multi-regional sampling, more refined academic classification, and integrated academic performance indicators.

Furthermore, this study lacks any in-depth exploration of the possible influences of age and gender. University students' age groups were not subdivided, and gender differences were not examined. This creates difficulty in identifying variations in self-efficacy fluctuations, GenAI dependency motivation, and rumination triggers. Age and gender could have as yet undetected moderating effects, limiting the comprehensiveness of the explanatory power of the mechanisms identified in this article. Future research should subdivide age groups and consider gender differences to improve the applicability of the results.

This study only examines the chain mediating effect of social anxiety and rumination while ignoring other possible moderating variables, such as family background and "phubbing" (phone-snubbing) behavior (Liao et al., 2025; Liu et al., 2025). Future research should incorporate these variables and verify their potential roles through moderated mediation analysis. Specifically, such analysis could be used to determine whether: (1) differences in family background affect the positive impact of social anxiety on GenAI dependency and (2) whether the generalization of phubbing behavior weakens the negative impact of self-efficacy on rumination (Liao, J., et al., 2025). This would define the boundary conditions of this mechanism and provide targeted theoretical support for AI dependency intervention strategies.

The link between self-efficacy and GenAI use by college students may be significantly influenced by the specific context, such as educational expectations and the sociocultural environment. Therefore, this link cannot be tested separately while disregarding students' academic pressure and other sociocultural factors. Future studies can fully consider these variables and incorporate cultural factors into the model.

Moreover, the current study uses a cross-sectional design with self-reports, an approach that limits the ability to make causal inferences. To address this limitation and mitigate possible common method bias, future research should adopt a longitudinal or time-lagged design. This would address these concerns by creating a temporal separation between the measurement of predictor and criterion variables, as suggested by Podsakoff et al. (2003).

CRediT authorship contribution statement

Yirui Li: Writing – review & editing, Writing – original draft, Conceptualization. **Huang Zhou:** Writing – review & editing, Writing – original draft, Data curation. **Wenbin Quan:** Writing – review & editing, Writing – original draft, Investigation. **Liu Yang:** Writing – review & editing, Supervision, Data curation. **Liang He:** Writing – review & editing, Supervision, Formal analysis, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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Glossary

Brooding (BRO): *A subdimension of rumination, representing a passive and negative form of repetitive thinking where individuals focus on their shortcomings, helplessness, and the unfairness of their situations without seeking solutions (Han & Yang, 2009; Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008).:*

ChatGPT dependence scale: *A scale specifically developed to quantify instrumental dependence on GenAI in academic settings, with items reflecting behavioral, cognitive, and affective indicators of dependence. This scale has excellent internal consistency and construct validity (Ye et al., 2024).:*

Depressed-symptom rumination (DSR): *A subdimension of rumination, referring to the repeated and non-adaptive cognitive focus on symptoms, causes, and consequences related to depressed moods (Han & Yang, 2009; Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008).:*

GenAI dependency (GAID): *A behavioral tendency defined as "an individual feeling unable to accomplish tasks without GenAI, experiencing discomfort when access is restricted, and repeatedly choosing the tool despite awareness of potential drawbacks" (**Brand, M., et al. 2019**; Ye, J.-H., et al. 2024).:*

Generalized self-efficacy scale (GSE): *A measurement tool developed by Schwarzer and Jerusalem to assess domain-unspecific self-efficacy, i.e., individuals' belief in their ability to mobilize cognitive, motivational, and behavioral resources when facing novel or challenging demands (Schwarzer, R., & Jerusalem, M. 1995; Schwarzer, R., et al. 1997).:*

I-PACE model: *The Interaction of Person-Affect-Cognition-Execution model, proposed and updated by Brand et al., which explains addictive behaviors as the dynamic interaction between predisposing factors (person), emotional-cognitive responses (affect-cognition), and executive functions (execution) (**Brand, M., et al. 2016**; **Brand, M., et al. 2019**).:*

Mindful attention awareness scale (MAAS): *A scale developed by Wolkin to assess individuals' present-moment attention and awareness across cognitive, emotional, physical, interpersonal, and general domains (Chen et al., 2012; Wolkin, J. R. 2015).:*

Mindfulness (MIND): *A state of consciousness characterized by maintaining focus and awareness of present-moment experiences, with core traits of open and accepting attention to ongoing events within oneself and one's mind (Nyanaponika Thera, 1972; Wolkin, 2015).:*

Reflective pondering (RP): *A subdimension of rumination, characterized by a more adaptive form of repetitive thinking that involves purposeful consideration of one's thoughts, feelings, and experiences to gain insight or solve problems (Han & Yang, 2009; Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008).:*

Rumination: *A repeated and non-adaptive cognitive process focusing on the symptoms, causes, and consequences of negative affective experiences, first introduced by Nolen-Hoeksema et al. Rumination corresponds to the "cognitive component" in the I-PACE model and has two subdimensions (reflective pondering, brooding) and a depressed-symptom rumination dimension (Nolen-Hoeksema, 1991; Nolen-Hoeksema et al., 2008).:*

Ruminative responses scale (RRS): *A scale developed by Nolen-Hoeksema and Morrow within the response styles theory to assess stable cognitive-affective strategies when individuals confront negative moods (Han & Yang, 2009; Nolen-Hoeksema, 1991).:*
Self-efficacy (SE): *A psychological concept described by Bandura as an individual's perceived beliefs about the capabilities required to achieve a goal, which determine the extent to which an individual is willing to invest effort in goal attainment (Bandura, 1977).:*
Social anxiety (SA): *A common psychological phenomenon manifested as an acute fear of being evaluated by others in social contexts, resulting from the prospect or presence of interpersonal evaluation in real or imagined social settings (Mattick & Clarke, 1998; Morrison & Heimberg, 2013; Schlenker & Leary, 1982).:*
Social Interaction Anxiety Scale (SIAS): *A scale designed by Mattick and Clarke to evaluate levels of anxiety experienced before and during social interactions, focusing on fears of general social interaction (Mattick & Clarke, 1998).:*

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