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AI Social Presence and College Students' Well-Being: The Mediating Role of Relatedness Need Satisfaction and the Moderating Role of Offline Social Support

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Received: Apr 03, 2026; Revised: Apr 29, 2026; Accepted: Apr 29, 2026; Published: Sep 29, 2026

Abstract: With the rapid development of artificial intelligence (AI), socially responsive AI systems are increasingly embedded in students' learning and daily life contexts, raising important questions about their associations with college students' psychological well-being. This study examined whether AI social presence was associated with loneliness and life satisfaction through relatedness need satisfaction and whether offline social support moderated this process. A cross-sectional survey was conducted among 536 Chinese college students, and the data were analyzed using partial least squares structural equation modeling (PLS-SEM). The results indicated that AI social presence was positively associated with relatedness need satisfaction, which was in turn associated with higher life satisfaction and lower loneliness. In addition, offline social support strengthened the positive association between AI social presence and relatedness need satisfaction. These findings suggest that AI interactions characterized by higher social presence may serve as a supplementary source of perceived social connection for some students, particularly when embedded within stronger real-world support systems. Given the cross-sectional design, all findings should be interpreted as correlational rather than causal. This study extends research on AI-mediated social interaction and well-being and provides practical implications for mental health education in higher education and the design of socially responsive AI systems.

Keywords: AI social presence; Relatedness need satisfaction; Life satisfaction; Loneliness; Offline social support

1. Introduction

The rapid proliferation of artificial intelligence (AI) is reshaping patterns of human-machine interaction, particularly in educational and social contexts. In recent years, conversational AI systems such as ChatGPT, DeepSeek, and similar platforms have become increasingly embedded in students' everyday lives. Beyond their instrumental functions, many of these systems are designed to display socially salient cues, including contextual responsiveness, emotionally toned feedback, and personalized interaction. As a result, some AI systems are not experienced merely as information tools, but as interaction partners that can evoke a sense of companionship or social presence during communication. For university students, who are active users of digital technologies and frequent adopters of AI for learning, problem-solving, and emotional expression, understanding how such AI-mediated experiences are associated with psychological well-being has become an important research issue.

Social presence is a core concept for understanding the psychological implications of mediated interaction. Originally proposed by Short et al. (1976), social presence refers to the extent to which a communication medium conveys the sense of interpersonal warmth, sociability, and psychological immediacy. In the context of human-AI interaction, AI social presence should not be understood as mere exposure to AI or frequency of AI use. Rather, it refers to a user's subjective perception that the AI interaction partner is socially present, responsive, warm, and psychologically available during communication. When AI systems provide contingent feedback, empathic language, and conversational continuity, users may experience a sense of being heard, understood, or accompanied (Banks et al., 2021). Importantly, such experiences do not imply that AI is equivalent to genuine interpersonal relationships. Instead, they suggest that AI may elicit a limited and perception-based sense of social connection that is psychologically meaningful to users.

However, existing research has not reached a consistent conclusion regarding how AI social presence is associated with psychological well-being. On the one hand, some studies have reported potentially beneficial associations. For example, De Freitas et al. (2025) found that AI companionship may alleviate loneliness, whereas Merrill et al. (2025) showed that human-centered AI

chatbots may help reduce anxiety and loneliness through emotionally validating communication. On the other hand, other studies have pointed to possible risks. Zhang et al. (2025) found that extensive emotional self-disclosure to AI was associated with lower well-being, while Fang et al. (2025) reported that high-frequency AI use was associated with greater loneliness, emotional dependence, and reduced real-world social interaction. These mixed findings suggest that the association between AI social presence and psychological well-being is unlikely to be uniform or straightforward. Rather, it may depend on specific psychological mechanisms and contextual boundary conditions. In addition, because AI systems vary substantially in their functions, ranging from task-oriented assistants to socially oriented companions, the psychological meaning of AI interaction may also differ across usage contexts.

To address these gaps, the present study extends the literature in two respects. First, drawing on Self-Determination Theory (Deci & Ryan, 2000), this study examines relatedness need satisfaction as a mediating variable. Self-Determination Theory posits that relatedness refers to the experience of feeling connected, understood, and accepted by others, and that satisfaction of this need is closely associated with psychological well-being (Reis et al., 2000). In the present study, we do not assume that AI can replace authentic, reciprocal human relationships. Rather, we propose more cautiously that when AI is experienced as socially present, it may contribute to a perceived and context-bound sense of relatedness during interaction, which may in turn be associated with higher life satisfaction and lower loneliness (Cacioppo & Hawkey, 2009). Second, this study introduces offline social support as a moderating variable. Social support theory suggests that support from family, friends, and significant others is an important protective factor for mental health (Cohen & Wills, 1985). At the same time, existing research offers divergent expectations regarding how offline support may shape AI-related experiences. One perspective suggests that stronger offline support may enable individuals to derive greater benefit from AI interaction because they possess more stable relational resources, whereas another suggests that individuals with insufficient offline support may rely more heavily on AI as a compensatory source of connection. Against this background, the present study examines whether offline social support conditions the association between AI social presence, relatedness need satisfaction, and psychological well-being.

1.1. AI Social Presence and Psychological Well-Being

With the rapid advancement of artificial intelligence (AI) technology, AI systems possessing social presence are increasingly being integrated into areas such as education, mental health, and social companionship. The concept of social presence was originally introduced by Short et al. (1976) to describe the extent to which communication partners subjectively perceive each other as socially present in mediated interaction. Lee and Nass (2003) further extended this concept to the field of human–computer interaction, showing that AI features such as voice, facial expressions, and emotional feedback can evoke anthropomorphic perceptions and emotional resonance, thereby generating a psychological sense of social presence.

The relationship between AI social presence and psychological well-being has become an important topic in recent research, yet the existing findings remain inconsistent. Some studies have documented positive effects of AI interaction. For example, De Freitas et al. (2025) found that AI companionship can reduce loneliness in the short term, with effects comparable to human interaction. Similarly, Merrill et al. (2025) reported that AI chatbots using highly person-centered communication can alleviate anxiety and loneliness through emotional validation. In contrast, other studies have identified potential adverse effects. Zhang et al. (2025) found that extensive emotional self-disclosure to AI was associated with lower levels of well-being, whereas Fang et al. (2025) showed that high-frequency AI use was linked to greater loneliness, emotional dependence, and reduced real-world social interaction.

These mixed findings suggest that the relationship between AI social presence and psychological well-being is unlikely to be a simple direct association. Rather, it may depend on specific mediating mechanisms and contextual boundary conditions. To better explain these inconsistent findings, the present study introduces relatedness need satisfaction as a mediating variable and examines the moderating role of offline social support.

Beyond the indirect pathway through relatedness need satisfaction, AI social presence may also be directly associated with well-being through affective mechanisms. Positive interactional experiences with socially present AI, such as feeling acknowledged or receiving emotionally toned feedback, may elicit immediate positive affect and reduce negative emotional states independently of relatedness need satisfaction per se (Lee & Nass, 2003). This reasoning supports the expectation of both direct and indirect associations between AI social presence and psychological well-being.

H1a: AI social presence is significantly and positively associated with life satisfaction.

H1b: AI social presence is significantly and negatively associated with loneliness.

1.2. Mediating Role of Relatedness Need Satisfaction

Self-Determination Theory (SDT) posits that psychological well-being depends on the satisfaction of three basic psychological needs: autonomy, competence, and relatedness (Deci & Ryan, 2000). Among these needs, relatedness refers to the experience of feeling socially connected, understood, accepted, and cared for by others. A large body of research has shown that relatedness need satisfaction is a critical psychological foundation for emotional adjustment and well-being (Reis et al., 2000). Individuals whose relatedness needs are better satisfied generally report higher life satisfaction and lower levels of loneliness (Cacioppo & Hawkley, 2009).

In the context of human–AI interaction, relatedness need satisfaction may be relevant because AI social presence primarily operates through social and affective cues rather than through instrumental functionality alone. Compared with autonomy and competence, relatedness is more directly activated when users perceive an interaction partner as warm, responsive, and socially available. AI systems with high social presence may simulate interpersonal features such as emotional responsiveness, empathic language, and contingent feedback, thereby eliciting subjective feelings of being heard, understood, and acknowledged during interaction (Banks et al., 2021). Importantly, the present study does not assume that such experiences are equivalent to fully reciprocal human relationships. Rather, we argue more cautiously that socially responsive AI may provide a limited, perception-based, and context-bound sense of connection that contributes to users' perceived relatedness experiences during interaction. In this sense, AI social presence may be linked to well-being not because AI replaces real relationships, but because it may partially support felt relatedness in specific interactional contexts.

From this perspective, AI social presence may influence psychological well-being not merely because users interact with AI more frequently, but because such interaction may partially fulfill their need for social connection. When users perceive AI as socially present, they may experience a stronger sense of connection and acceptance during interaction, which in turn enhances their relatedness need satisfaction. Once this need is better satisfied, individuals are more likely to experience positive psychological outcomes, such as greater life satisfaction, and less likely to experience negative states, such as loneliness. Thus, relatedness need satisfaction may serve as a key psychological mechanism linking AI social presence to psychological well-being.

Based on the above reasoning, the following hypotheses are proposed:

H2a: Higher levels of AI social presence are associated with greater relatedness need satisfaction among college students.

H2b: Greater relatedness need satisfaction is associated with higher life satisfaction among college students.

H2c: Greater relatedness need satisfaction is associated with lower loneliness among college students.

H3a: Relatedness need satisfaction mediates the relationship between AI social presence and life satisfaction.

H3b: Relatedness need satisfaction mediates the relationship between AI social presence and loneliness.

1.3. The Moderating Role of Offline Social Support

Although AI companionship may provide a certain degree of emotional comfort, support systems embedded in real-world social contexts remain a fundamental basis of psychological health. Social support theory suggests that support from family, friends, and significant others can buffer psychological stress and promote emotional stability (Cohen & Wills, 1985).

The role of offline social support in shaping the psychological effects of AI may be understood through two competing perspectives. The social compensation perspective suggests that individuals with fewer offline resources may turn to mediated interaction to compensate for unmet relational needs. In contrast, the social enhancement perspective suggests that individuals with stronger offline support may be better positioned to derive benefits from mediated social experiences because they possess greater relational security, trust, and social-cognitive resources. In the context of AI interaction, these perspectives lead to different expectations. Individuals low in offline support may rely more strongly on AI, but such reliance does not necessarily translate into stable psychological benefit (Nowak & Fox, 2018). By contrast, individuals high in offline support may be more capable of interpreting AI companionship as supplementary, safe, and relationally meaningful, thereby converting AI social cues into stronger perceived relatedness satisfaction (Fang et al., 2025). On this basis, the present study proposes that offline social support strengthens, rather than substitutes for, the positive association between AI social presence and relatedness need satisfaction.

Taken together, these findings indicate that the psychological effects of AI do not occur in isolation but are embedded in a broader social ecology. Drawing on the resource enhancement perspective, the present study proposes that higher levels of offline social support provide individuals with a more stable psychological foundation, enabling them to integrate virtual and real-world social experiences more effectively during AI interaction. As a result, offline social support may strengthen the positive association between AI social presence and relatedness need satisfaction. Therefore, the following hypothesis is proposed:

H4: Offline social support moderates the relationship between AI social presence and relatedness need satisfaction, such that the positive association between AI social presence and relatedness need satisfaction is stronger when offline social support is

higher. Accordingly, offline social support also moderates the indirect associations of AI social presence with life satisfaction and loneliness through relatedness need satisfaction, such that these indirect associations are stronger when offline social support is higher.

To present the hypothesized relationships more clearly, the theoretical model of this study is shown in Fig. 1.

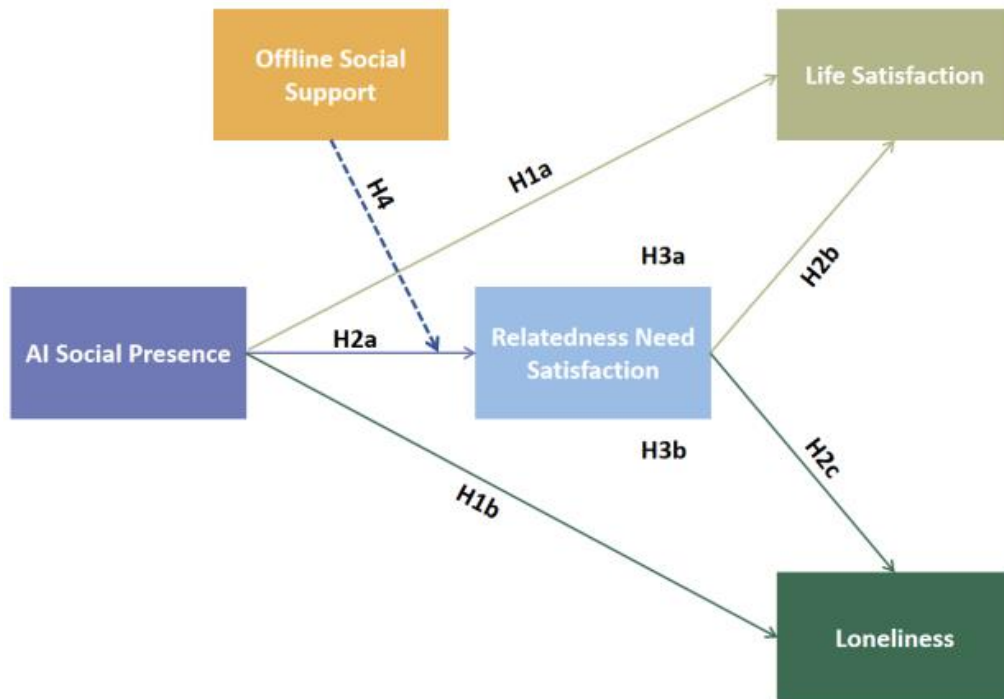


Fig. 1. Theoretical model of the study.

2. Materials and Methods

2.1. Participants and Data Collection

This study employed a cross-sectional questionnaire survey. Participants were undergraduate and postgraduate students from mainland China. Data were collected through an online survey platform using convenience and snowball sampling. To be eligible for participation, respondents had to meet the following criteria: (a) be 18 years of age or older; and (b) have used conversational AI tools, AI learning assistants, or other socially interactive AI applications within the past three months. In the survey instructions, AI use was described as interaction with AI systems that can provide text-based dialogue, feedback, suggestions, learning assistance, or emotionally toned responses. This criterion was intended to capture students' experiences of AI-mediated interaction rather than mere exposure to non-interactive digital technologies. A total of 536 valid questionnaires were obtained. Among the participants, 227 were female (42.4%) and 309 were male (57.6%). In terms of place of origin, 9.3% came from provincial capitals, 25.2% from prefecture-level cities, 25.2% from county-level cities, 18.7% from towns, and 21.6% from rural areas. To reduce the risk of spurious associations in this cross-sectional design, gender, age, place of origin, and degree level were included as control variables and linked to the endogenous constructs in the structural model.

2.2. Measurement Instruments

AI Social Presence. AI social presence was measured using an adapted version of the Networked Minds Social Presence Inventory developed by Biocca and Harms (2002). To fit the context of interaction with AI companions, the original wording referring to human interaction partners and media contexts was revised accordingly. Based on expert review and pilot feedback, the final scale consisted of seven items (SP1–SP7). All items were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Confirmatory factor analysis indicated an excellent model fit ($\chi^2/df = 0.897$; RMSEA = 0.000; SRMR = 0.014; CFI = 1.000; TLI = 1.001; NFI = 0.993), demonstrating that the measurement model exhibited strong structural validity. In the present study, the scale showed good internal consistency (Cronbach's $\alpha = 0.888$).

Relatedness Need Satisfaction. Relatedness need satisfaction was measured using items adapted from the Basic Psychological Need Satisfaction and Frustration Scale within the Self-Determination Theory framework (Deci & Ryan, 2000). In line with the purpose of the present study, only the items assessing relatedness need satisfaction were retained. The scale captured the extent to which participants felt understood, connected, and accepted in their experiences. Responses were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Confirmatory factor analysis indicated an excellent model fit for relatedness need satisfaction ($\chi^2/df = 0.620$; RMSEA = 0.000; SRMR = 0.017; CFI = 1.000; TLI = 1.011; NFI = 0.986), demonstrating that the revised measurement structure exhibited satisfactory construct validity. In the present sample, Cronbach's α was 0.854.

Life Satisfaction. Life satisfaction was assessed using the Chinese version of the Satisfaction with Life Scale developed by Diener et al. (1985). The scale consists of five items rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Higher scores indicate greater life satisfaction. Confirmatory factor analysis indicated an excellent model fit ($\chi^2/df = 0.855$; RMSEA = 0.000; SRMR = 0.009; CFI = 1.000; TLI = 1.001; NFI = 0.997), suggesting that the measurement model demonstrated strong structural validity. In this study, Cronbach's α was 0.887.

Loneliness. Loneliness was measured using the Chinese version of the UCLA Loneliness Scale–Short Form, which was derived from the UCLA Loneliness Scale developed by Russell et al. (1980). The scale includes six items rated on a 4-point scale ranging from 1 (never) to 4 (often), with higher scores indicating greater loneliness. Confirmatory factor analysis indicated a good model fit ($\chi^2/df = 2.040$; RMSEA = 0.044; SRMR = 0.023; CFI = 0.990; TLI = 0.984; NFI = 0.981), suggesting that the measurement model demonstrated satisfactory structural validity. In the present study, Cronbach's α was 0.829.

Offline Social Support. Offline social support was assessed using the Chinese version of the Multidimensional Scale of Perceived Social Support developed by Zimet et al. (1988). The scale includes 12 items rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), covering three subdimensions: family support, friend support, and significant other support. Higher scores indicate stronger perceived offline social support. Confirmatory factor analysis showed an acceptable model fit ($\chi^2/df = 1.695$; RMSEA = 0.036; SRMR = 0.029; CFI = 0.980; TLI = 0.974; NFI = 0.952), indicating that the measurement model demonstrated good structural validity. In the PLS model, the three subdimension scores were used as indicators of the latent construct. In this study, Cronbach's α was 0.856.

For reporting convenience, the following abbreviations are used throughout the paper: AI social presence (SP), relatedness need satisfaction (REL), life satisfaction (SWLS), loneliness (AL), and offline social support (SS).

3. Results

3.1. Common Method Bias

Given that the data were collected using self-report questionnaires, common method bias may be a potential concern. To assess this issue, Harman's single-factor test was performed. The results of the unrotated exploratory factor analysis indicated that multiple factors with eigenvalues greater than 1 emerged, and the first factor accounted for 24.43% of the total variance, which was below the commonly used cutoff of 40%. Therefore, common method bias was unlikely to pose a serious threat to the validity of the findings.

3.2. Descriptive Statistics and Correlation Analysis

The means, standard deviations, and correlations among the focal study variables are reported in Table 1. As shown in Table 1, AI social presence was significantly and positively correlated with relatedness need satisfaction and life satisfaction, and significantly and negatively correlated with loneliness. Relatedness need satisfaction was positively associated with life satisfaction and negatively associated with loneliness. Offline social support was also significantly correlated with all focal variables in directions consistent with the proposed hypotheses. These results provide preliminary support for the subsequent structural model analysis.

Table 1. Descriptive statistics and correlation coefficient matrix.

	1	2	3	4	5
AI Social Presence	1				
Loneliness	-0.288***	1			
Life Satisfaction	0.301***	-0.307***	1		
Relatedness Need Satisfaction	0.459***	-0.388***	0.365***	1	

	1	2	3	4	5
Offline Social Support	0.216***	-0.276***	0.291***	0.286***	1
M	3.755	2.329	4.838	2.615	6.463
SD	0.894	0.758	1.129	.576	.494
Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$	Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$	Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$	Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$	Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$	Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.3. Measurement Model Assessment

The results of the measurement model assessment indicated that all latent constructs demonstrated acceptable reliability and validity (Table 2). Cronbach's α values ranged from 0.829 to 0.888, and composite reliability (CR) values ranged from 0.875 to 0.917, both exceeding the recommended threshold of 0.70 (Hair et al., 2019). The standardized factor loadings ranged from 0.611 to 0.883. Most indicators exceeded or approximated the conventional threshold of 0.70. Several indicators of relatedness need satisfaction showed loadings between 0.60 and 0.70, which may be attributable to the contextualized adaptation of this construct to AI-mediated interaction. These items were retained because they represented theoretically important aspects of perceived understanding, connectedness, and acceptance, and because the construct still demonstrated satisfactory composite reliability (CR = 0.889) and average variance extracted (AVE = 0.533). In addition, the AVE values ranged from 0.533 to 0.776, exceeding the recommended minimum of 0.50, thereby supporting convergent validity. The variance inflation factor (VIF) values ranged from 1.436 to 2.322, indicating that multicollinearity was not a serious concern. As shown in Table 3, the heterotrait–monotrait ratio (HTMT) values were all below the recommended threshold of 0.85, supporting discriminant validity. Overall, the measurement model exhibited satisfactory psychometric properties and was therefore suitable for subsequent structural model analysis.

Table 2. Measurement model indicators.

Constructs	Code	Loading	VIF	Cronbach α	CR	AVE
Loneliness	AL1	0.762	1.680	0.829	0.875	0.540
Loneliness	AL2	0.746	1.633	0.829	0.875	0.540
Loneliness	AL3	0.728	1.554	0.829	0.875	0.540
Loneliness	AL4	0.718	1.558	0.829	0.875	0.540
Loneliness	AL5	0.751	1.609	0.829	0.875	0.540
Loneliness	AL6	0.701	1.482	0.829	0.875	0.540
Relatedness Need Satisfaction	REL1	0.729	1.773	0.854	0.889	0.533
Relatedness Need Satisfaction	REL2	0.717	1.738	0.854	0.889	0.533
Relatedness Need Satisfaction	REL3	0.675	1.602	0.854	0.889	0.533
Relatedness Need Satisfaction	REL4	0.637	1.460	0.854	0.889	0.533
Relatedness Need Satisfaction	REL5	0.710	1.696	0.854	0.889	0.533
Relatedness Need Satisfaction	REL6	0.617	1.436	0.854	0.889	0.533
Relatedness Need Satisfaction	REL7	0.692	1.625	0.854	0.889	0.533
Relatedness Need Satisfaction	REL8	0.611	1.451	0.854	0.889	0.533
Relatedness Need Satisfaction	REL9	0.712	1.702	0.854	0.889	0.533
Relatedness Need Satisfaction	REL10	0.721	1.767	0.854	0.889	0.533
Relatedness Need Satisfaction	REL11	0.674	1.572	0.854	0.889	0.533

Constructs	Code	Loading	VIF	Cronbach α	CR	AVE
Relatedness Need Satisfaction	REL12	0.680	1.579	0.854	0.889	0.533
AI Social Presence	SP1	0.785	2.016	0.888	0.912	0.598
AI Social Presence	SP2	0.769	1.872	0.888	0.912	0.598
AI Social Presence	SP3	0.797	2.049	0.888	0.912	0.598
AI Social Presence	SP4	0.775	1.875	0.888	0.912	0.598
AI Social Presence	SP5	0.781	1.873	0.888	0.912	0.598
AI Social Presence	SP6	0.755	1.787	0.888	0.912	0.598
AI Social Presence	SP7	0.751	1.739	0.888	0.912	0.598
Offline Social Support	SSFD	0.883	2.092	0.856	0.912	0.776
Offline Social Support	SSFS	0.881	2.221	0.856	0.912	0.776
Offline Social Support	SSSO	0.880	2.094	0.856	0.912	0.776
Life Satisfaction	SWLS1	0.802	1.895	0.887	0.917	0.690
Life Satisfaction	SWLS2	0.855	2.311	0.887	0.917	0.690
Life Satisfaction	SWLS3	0.821	2.134	0.887	0.917	0.690
Life Satisfaction	SWLS4	0.845	2.322	0.887	0.917	0.690
Life Satisfaction	SWLS5	0.828	2.094	0.887	0.917	0.690

Table 3. Discriminant validity: HTMT matrix.

	AL	REL	SP	SS	SWLS	SS x SP
AL						
REL	0.457					
SP	0.336	0.506				
SS	0.291	0.327	0.213			
SWLS	0.359	0.418	0.336	0.353		
SS x SP	0.028	0.139	0.077	0.269	0.107	

Note: SP = AI social presence, REL = relatedness need satisfaction, SWLS = life satisfaction, AL = loneliness, SS = offline social support.

3.4. Structural Model Assessment

Prior to hypothesis testing, the structural model fit and explanatory power were examined. The SRMR values were 0.042 for the saturated model and 0.054 for the estimated model, both below the recommended cutoff of 0.08, indicating an acceptable model fit. The NFI value of the estimated model was 0.876, suggesting an acceptable fit. Regarding explanatory power, the model accounted for 27.3% of the variance in relatedness need satisfaction ($R^2 = 0.273$, adjusted $R^2 = 0.268$), 15.8% of the variance in life satisfaction ($R^2 = 0.158$, adjusted $R^2 = 0.155$), and 17.8% of the variance in loneliness ($R^2 = 0.178$, adjusted $R^2 = 0.169$). These findings suggest that the structural model exhibits a limited but acceptable level of explanatory power for the key endogenous constructs. The control variables (gender, age, place of origin, and degree level) showed no significant associations with any of the endogenous constructs (all $p > 0.05$).

3.5. Hypothesis Testing

The path coefficient results are presented in Table 4. AI social presence was significantly and positively associated with life satisfaction ($\beta = 0.175$, $SE = 0.046$, $t = 3.842$, $p < 0.001$, 95% CI [0.088, 0.265]), supporting H1a. In addition, AI social presence

was significantly and negatively associated with loneliness ($\beta = -0.147$, $SE = 0.047$, $t = 3.094$, $p = 0.002$, 95% CI $[-0.242, -0.056]$), supporting H1b. AI social presence was also significantly and positively associated with relatedness need satisfaction ($\beta = 0.416$, $SE = 0.035$, $t = 11.841$, $p < 0.001$, 95% CI $[0.346, 0.485]$), supporting H2a. Relatedness need satisfaction was significantly and positively associated with life satisfaction ($\beta = 0.287$, $SE = 0.042$, $t = 6.907$, $p < 0.001$, 95% CI $[0.208, 0.369]$), supporting H2b, and significantly and negatively associated with loneliness ($\beta = -0.322$, $SE = 0.043$, $t = 7.431$, $p < 0.001$, 95% CI $[-0.408, -0.237]$), supporting H2c.

The mediation effects were tested using a bias-corrected bootstrap procedure with 5,000 resamples. As shown in Table 4, AI social presence exerted a significant positive indirect effect on life satisfaction through relatedness need satisfaction ($\beta = 0.120$, $SE = 0.021$, $t = 5.725$, $p < 0.001$, 95% CI $[0.081, 0.163]$), supporting H3a, and a significant negative indirect effect on loneliness through relatedness need satisfaction ($\beta = -0.134$, $SE = 0.022$, $t = 6.206$, $p < 0.001$, 95% CI $[-0.181, -0.095]$), supporting H3b. Overall, these findings suggest that AI social presence was associated with psychological well-being both directly and indirectly through relatedness need satisfaction. Because both the direct and indirect effects were significant, the pattern is more appropriately interpreted as complementary partial mediation rather than full mediation.

Table 4. Results of direct, indirect, and moderating effects testing.

Path	β	SE	T	P	LLCI	ULCI	Hypothesis
SP→SWLS	0.175	0.046	3.842	<0.001	0.088	0.265	H1a
SP→AL	-0.147	0.047	3.094	0.002	-0.242	-0.056	H1b
SP→REL	0.416	0.035	11.841	<0.001	0.346	0.485	H2a
REL→SWLS	0.287	0.042	6.907	<0.001	0.208	0.369	H2b
REL→AL	-0.322	0.043	7.431	<0.001	-0.408	-0.237	H2c
SP→REL→SWLS	0.120	0.021	5.725	<0.001	0.081	0.163	H3a
SP→REL→AL	-0.134	0.022	6.206	<0.001	-0.181	-0.095	H3b
SSxSP→REL	0.201	0.034	5.836	<0.001	0.134	0.269	H4
SSxSP→REL→AL	-0.064	0.015	4.305	<0.001	-0.096	-0.038	H4
SSxSP→REL→SWLS	0.058	0.012	4.662	<0.001	0.035	0.084	H4

To examine the moderating role of offline social support (SS) in the relationship between AI social presence (SP) and relatedness need satisfaction (REL), an interaction term ($SS \times SP$) was included in the structural model. As shown in Table 4, the interaction effect was significant ($\beta = 0.201$, $SE = 0.034$, $t = 5.836$, $p < 0.001$, 95% CI $[0.134, 0.269]$), indicating that offline social support significantly strengthened the positive association between AI social presence and relatedness need satisfaction. Thus, H4 was supported. Moreover, this interaction effect further extended to the indirect paths through relatedness need satisfaction. Specifically, the index of moderated mediation for life satisfaction was significant ($\beta = 0.058$, $SE = 0.012$, $t = 4.662$, $p < 0.001$, 95% CI $[0.035, 0.084]$), and the index of moderated mediation for loneliness was also significant ($\beta = -0.064$, $SE = 0.015$, $t = 4.305$, $p < 0.001$, 95% CI $[-0.096, -0.038]$). These results indicate that offline social support not only moderated the direct effect of AI social presence on relatedness need satisfaction, but also significantly shaped the indirect effects of AI social presence on loneliness and life satisfaction through relatedness need satisfaction.

To further interpret the moderating pattern, conditional effect analyses were conducted at high (+1 SD) and low (-1 SD) levels of offline social support. As shown in Table 5, the positive effect of AI social presence on relatedness need satisfaction was stronger under high offline social support ($\beta = 0.617$, $SE = 0.050$, $t = 12.289$, $p < 0.001$, 95% CI $[0.517, 0.713]$) than under low offline social support ($\beta = 0.216$, $SE = 0.048$, $t = 4.477$, $p < 0.001$, 95% CI $[0.121, 0.310]$). Similarly, the indirect effect of AI social presence on life satisfaction through relatedness need satisfaction was stronger at high levels of offline social support ($\beta = 0.177$, $SE = 0.030$, $t = 6.005$, $p < 0.001$, 95% CI $[0.123, 0.239]$) than at low levels ($\beta = 0.062$, $SE = 0.018$, $t = 3.530$, $p < 0.001$, 95% CI $[0.030, 0.099]$). The indirect effect on loneliness showed the same pattern, being more strongly negative under high offline social support ($\beta = -0.199$, $SE = 0.032$, $t = 6.139$, $p < 0.001$, 95% CI $[-0.265, -0.140]$) than under low offline social support ($\beta = -0.069$, $SE = 0.018$, $t = 3.849$, $p < 0.001$, 95% CI $[-0.108, -0.037]$). Taken together, these findings suggest that offline social support amplifies both the direct effect of AI social presence on relatedness need satisfaction and its indirect effects on psychological well-being.

Table 5. Conditional direct and indirect effects at different levels of offline social support.

path	level	β	SE	T	P	LLCI	ULCI	Hypothesis
SP→ REL	+1 SD	0.617	0.05	12.289	<0.001	0.517	0.713	support H4
SP→ REL	-1 SD	0.216	0.048	4.477	<0.001	0.121	0.31	support H4
SP→ REL→ SWLS	+1 SD	0.177	0.03	6.005	<0.001	0.123	0.239	support H4
SP→ REL→ SWLS	-1 SD	0.062	0.018	3.53	<0.001	0.03	0.099	support H4
SP→ REL→ AL	+1 SD	-0.199	0.032	6.139	<0.001	-0.265	-0.14	support H4
SP→ REL→ AL	-1 SD	-0.069	0.018	3.849	<0.001	-0.108	-0.037	support H4

4. Discussion

4.1. Main Research Findings

This study examined whether AI social presence was associated with college students' psychological well-being through relatedness need satisfaction and whether this pattern varied according to offline social support. Overall, the results were broadly consistent with the proposed model and provide evidence for understanding the psychological correlates of AI-based social interaction in the digital era. Given the cross-sectional design, these findings should be interpreted as associations consistent with the proposed framework rather than as evidence of temporal or causal effects.

First, this study found that AI social presence was significantly and positively associated with relatedness need satisfaction (H2a). This finding is broadly consistent with social presence theory (Short et al., 1976) and Self-Determination Theory (Deci & Ryan, 2000), suggesting that when AI systems are experienced as emotionally responsive and socially present, they may contribute to users' perceived sense of connection during interaction. This result is also in line with prior studies indicating that socially responsive technologies can evoke meaningful interpersonal-like experiences in mediated communication (Banks et al., 2021; Lee & Nass, 2003). For university students in particular, AI companionship may serve as a relatively low-threshold and accessible source of interactional support, especially in contexts involving academic pressure and social anxiety.

Second, relatedness need satisfaction was significantly and positively associated with life satisfaction and significantly and negatively associated with loneliness (H2b and H2c). This finding underscores the importance of relatedness need satisfaction as a key correlate of psychological well-being. The results are consistent with the view that relatedness is a fundamental psychological need closely linked to individual well-being (Deci & Ryan, 2000; Reis et al., 2000). Notably, the association between relatedness need satisfaction and loneliness ($\beta = -0.322$) was somewhat stronger in magnitude than its association with life satisfaction ($\beta = 0.287$), which may suggest that the relational experiences captured in this study were more closely linked to reduced negative emotional states than to broader positive evaluations of life. This pattern is also broadly consistent with recent studies suggesting that AI companionship may be associated with emotional relief or support under certain conditions (De Freitas et al., 2025; Merrill et al., 2025).

Third, relatedness need satisfaction showed a significant mediating role in the association between AI social presence and psychological well-being (H3a and H3b). This result suggests that the well-being-related correlates of AI social presence may be partly explained by whether users subjectively experience connection, understanding, and acceptance during interaction. At the same time, this interpretation should remain theoretically bounded: the present findings do not indicate that AI reproduces authentic interpersonal relatedness in a full sense, but rather that AI interaction may contribute to a perceived and limited form of relatedness experience relevant to users' well-being. This pattern underscores the importance of user perception in shaping the psychological meaning of human-machine interaction and provides implications for AI system design. Merely increasing technical sophistication or anthropomorphic cues may be insufficient to be associated with better psychological outcomes unless these features are translated into experiences of relatedness need satisfaction.

Fourth, and most importantly, offline social support significantly moderated the association between AI social presence and relatedness need satisfaction (H4). This pattern is more consistent with a social-enhancement or resource-enhancement interpretation than with a simple compensation account. Importantly, this finding should not be interpreted to mean that students with greater offline support need AI more. Rather, it suggests that stronger offline support may enhance users' capacity to interpret AI interaction as psychologically safe, supplementary, and relationally meaningful. In contrast, individuals with weaker offline support may rely on AI more strongly while still being less able to translate AI-mediated interaction into stable relatedness satisfaction, partly because such interactions may be approached with greater ambivalence, caution, or unmet relational need. Overall, the finding is more

consistent with a synergistic pattern in which offline social support strengthens the positive association between AI social presence and relatedness-related experiences.

This synergistic pattern may be interpreted in several ways. From a social-cognitive perspective, individuals with stronger offline social support may possess higher levels of social trust and more positive relational schemas, enabling them to approach AI with a more open attitude and to treat AI companionship as supplementary support rather than as a replacement for interpersonal relationships (Nowak & Fox, 2018). From a psychological resource perspective, offline social support may provide a foundation of emotional security that allows individuals to engage with AI interaction in a more stable and receptive manner and, in turn, to derive more positive relational experiences from it. By contrast, individuals with weaker offline support may approach AI more ambivalently, simultaneously desiring companionship while remaining cautious about virtual relationships, thereby limiting the extent to which AI interaction is associated with stable relatedness satisfaction.

The moderated mediation analysis was further consistent with a pattern in which offline social support not only moderated the association between AI social presence and relatedness need satisfaction but also was associated with stronger indirect associations between AI social presence and both life satisfaction and loneliness through this pathway. Under conditions of high offline social support, the indirect association between AI social presence and loneliness ($\beta = -0.199$) was nearly three times as large as that observed under low-support conditions ($\beta = -0.069$). This patterned result offers additional support for the idea that the associations observed in this study may vary across individuals and may be conditioned by the broader social ecology in which AI use is embedded.

4.2. Theoretical Contributions and Practical Implications

This study contributes to the growing literature on AI companionship and well-being by extending discussion of Self-Determination Theory into the domain of human–AI interaction in a more bounded manner. Rather than assuming that AI can substitute for human relationships, the present findings suggest that AI social presence may be linked to well-being, with users' perceived relatedness experiences during interaction serving as a plausible explanatory pathway. This framing helps clarify why AI interaction may be positively associated with well-being for some users while avoiding the stronger claim that AI fulfills relatedness in the same way as reciprocal interpersonal relationships.

Another notable contribution concerns the role of offline social support. The results suggest that real-world social support does not weaken the positive associations linked to AI social presence, but may instead strengthen them. This pattern challenges a simplistic assumption that technological interaction necessarily replaces interpersonal relationships. Rather, the findings suggest that virtual companionship and real-world support may operate in a complementary or synergistic manner. In addition, the association between AI social presence and lower loneliness appeared stronger than its association with higher life satisfaction, suggesting that the well-being-related correlates of AI interaction may differ across dimensions of well-being and should not be treated as a single undifferentiated outcome.

At the practical level, these findings have implications for AI product design. Because social presence was closely associated with users' psychological experiences in this study, improvements in emotion recognition, empathic response, conversational naturalness, and relational continuity may be especially important. At the same time, AI should still be positioned as a supplementary form of emotional support rather than as a substitute for human relationships. Embedding functions that encourage offline social interaction, such as contact reminders, peer-support prompts, or activity recommendations, may help better coordinate virtual and real-world support systems.

The findings also offer implications for university mental health services. AI companionship may have potential as a supplementary resource alongside traditional counseling because of its immediacy, accessibility, and low threshold for use. However, universities should continue to guide students to build diversified support networks in real life. Particular attention should be paid to students with weak offline support. The present findings suggest that such students may be less able to translate AI interaction into stable relatedness satisfaction, and may therefore be at greater risk of excessive AI dependence without corresponding psychological benefit. For these students, strengthening real-world social connections should be prioritized over AI-based support. In promoting AI-related mental health tools, higher education institutions should therefore simultaneously invest in opportunities for face-to-face communication and in the development of students' digital literacy and relational coping capacities.

4.3. Research Limitations and Future Directions

Although this study examined the associations among AI social presence, relatedness need satisfaction, and psychological well-being, several limitations should be noted. First, the cross-sectional design restricts causal inference because exposure and outcome variables were measured at the same time. Accordingly, the structural paths reported in this study should be interpreted as associations consistent with the proposed model rather than as evidence of temporal precedence or causal effects. Future research

should adopt longitudinal, diary-based, or experimental designs to examine the proposed relationships more rigorously. Second, the data were collected primarily through self-report questionnaires and may therefore have been influenced by common method bias and social desirability. Subsequent studies could integrate behavioral indicators, physiological measures, or multi-source data to improve objectivity. Third, the sample was limited to Chinese university students, which constrains the cultural and developmental generalizability of the findings. Future research should examine more diverse age groups and cultural contexts.

In addition, the present study did not examine the multidimensional structure of AI social presence in depth, nor did it distinguish different AI use contexts with sufficient precision, such as companion AI, learning assistants, and task-oriented AI tools. Because these forms of AI may differ substantially in their social functions and psychological implications, future studies should compare specific AI categories more explicitly and examine whether the associations proposed in this study vary across interaction contexts. It would also be worthwhile to investigate more refined characteristics of offline social support, including its sources, quality, and stability. Finally, future research could incorporate individual difference variables such as attachment style, personality traits, and motives for AI use, and integrate frameworks such as parasocial interaction or social identity theory to build a more comprehensive explanatory model of the psychological correlates of AI interaction.

5. Conclusions

This study proposed and examined a moderated mediation model linking AI social presence, relatedness need satisfaction, offline social support, and psychological well-being among Chinese university students. The results indicated that AI social presence was positively associated with relatedness need satisfaction; relatedness need satisfaction was, in turn, associated with higher life satisfaction and lower loneliness; and offline social support was associated with a stronger relationship between AI social presence and relatedness need satisfaction, as well as stronger indirect associations with well-being indicators. These findings suggest that AI companionship may serve as a supplementary source of perceived social connection for some users, particularly when embedded within stronger real-world support systems. At the same time, because the study was cross-sectional, these findings should be interpreted as correlational rather than causal. AI companionship may complement, but should not be understood as replacing, genuine interpersonal relationships.

Author Contributions: R. Shi contributed to conceptualization, formal analysis, and writing the original draft. C. Gao contributed to supervision and review and editing of the manuscript. D. Wu contributed to data curation. Tianfang Wang contributed to methodology and investigation. Q. Han contributed to validation and resources. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the General Project of Philosophy and Social Science Research for Universities in Jiangsu Province, China, titled “Research on the Path of Digital Transformation Promoting the Emergence of New Quality Productive Forces” (Grant 2024SJYB0957).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Changzhou College of Information Technology (approval code: CCIT-20251016, date of approval: March 2025).

Informed Consent Statement: Participation was voluntary, and informed consent was implied by survey completion.

Data Availability Statement: The data of this study are available from the corresponding author upon reasonable request.

Acknowledgments: The authors would like to thank all the students who participated in the survey and the colleagues who provided valuable suggestions during the preparation of this manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

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