Psychology Research and Behavior Management

Dovepress

open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

Longitudinal Examination of the Relationship Between Virtual Companionship and Social Anxiety: Emotional Expression as a Mediator and Mindfulness as a Moderator

Zehang Xie, Zeyu Wang

School of Media and Communication, Shanghai Jiao Tong University, Shanghai, People's Republic of China

Correspondence: Zeyu Wang, School of Media and Communication, Shanghai Jiao Tong University, No. 800 Dongchuan Road, Minhang District, Shanghai, 200240, People's Republic of China, Email zeyuwang@sjtu.edu.cn

Purpose: As the interweaving of human interaction and Artificial Intelligence (AI) intensifies, understanding the psychological impact, especially regarding social anxiety, of engaging with AI-driven virtual companionship becomes crucial. While a substantial body of research on social anxiety has concentrated on interactions between individuals, both online and offline, there is a noticeable deficit in explorations concerning how human-computer interactions influence social anxiety. This study offers a comprehensive, longitudinal examination of this underinvestigated relationship, intricately dissecting the roles of emotional expression and mindfulness within the context of AI-based interactions.

Methods: We use social support theory and emotion regulation theory as our theoretical foundation. Data were collected from 618 undergraduate students in Eastern China over two intervals (May 15, 2023 and September 15, 2023). We utilized SPSS 26.0 to conduct descriptive statistics, while AMOS 25.0 facilitated multi-group confirmatory factor analysis (CFA) and the cross-lagged panel modeling.

Results: Our findings indicate that as the frequency of virtual companionship use increases, there's a decline in online social anxiety but a rise in offline social anxiety. Emotional expression emerges as a significant mediator, with heightened emotional expression leading to reduced social anxiety in both contexts. Mindfulness serves as a potent moderator, suggesting its protective role against the potential pitfalls of frequent virtual interactions.

Conclusion: This research not only deepens our theoretical understanding of the dynamics between virtual interactions and social anxiety but also serves as a cornerstone for future endeavors aimed at optimizing AI and devising therapeutic interventions tailored for the digital generation.

Keywords: virtual companionship, social anxiety, emotional expression, mindfulness, longitudinal study

Introduction

In an increasingly digital world, the way we interact and form relationships has evolved significantly. Virtual companionship, characterized by artificial entities such as robots or agents that establish social relationships, create emotional bonds, and provide emotional support. Virtual companionship might be perceived as "a special form of friendship" or "having someone familiar".[1] Previous research has discussed the relationship between social media use and well-being on various levels, such as the relationship among media use, anxiety, and well-being among Chinese people during Covid-19,[2] and the correlation between social media usage and psychological well-being among university students in Pakistan.[3] AI offers unprecedented opportunities for interaction, especially for those who may experience barriers in face-to-face settings. However, the implications of these virtual interactions on people's social anxiety, remain an area of burgeoning interest and debate.

Received: 31 October 2023
Accepted: 8 February 2024
Published: 26 February 2024

Social anxiety, characterized by a fear of social situations and interpersonal interactions, can have profound implications on an individual's quality of life.[4] Recent studies, such as the piecewise growth mixture model analysis by Liu, et al [5] highlight that mental health issues like social anxiety exhibit varying developmental trajectories among college students. This variability underscores the dynamic nature of social anxiety during the university stage, where factors such as personality, relationships, and lifestyle play significant roles in shaping its progression. Traditionally, face-to-face social interactions have been the primary focus of research in this area.[6] However, as interactions with AI become an integral part of our social fabric, it is crucial to understand how virtual companionship influences, and is influenced by, social anxiety. One pivotal aspect that emerges in this context is emotional expression. Virtual platforms provide unique avenues for emotional expression, often allowing individuals a degree of anonymity or distance they might not experience in face-to-face interactions.[7] The anonymity inherent in interactions with AI might encourage individuals to be more forthcoming with their emotional expressions towards the technology. This open emotional dialogue with AI entities could serve as a safe space for expressing emotions without the fear of judgement or backlash, potentially mitigating levels of social anxiety in users. Therefore, interactions with AI might inadvertently assist users in navigating through their social anxiety by offering an alternative, non-threatening platform for emotional expression. Emotional expression could serve as a mediating factor, potentially influencing the relationship between virtual companionship and social anxiety. Furthermore, mindfulness, a state of active, open attention to the present moment, has garnered interest in recent years for its potential in modulating various psychological outcomes.[8] Within the context of virtual companionship and social anxiety, mindfulness may serve as a crucial moderating factor. By enhancing self-awareness and reducing automatic, habitual reactions to emotional stimuli,[9] mindfulness might shape the way an individual perceives and engages in virtual social interactions, possibly tempering or amplifying their effects on social anxiety.

The existing literature presents gaps that our study aims to address. Much of the research on social anxiety has centered around human-to-human interactions.[10,11] However, as noted by D'Alfonso,[12] the patterns of AI are diversely associated with mental health outcomes, emphasizing the significance of the AI domain in influencing mental well-being. Furthermore, as highlighted by Cao and Liu, AI-based technologies are increasingly being applied in psychiatric research and practice. They emphasize the application of AI in screening for psychosis risk, employing methods like chatbots and large-scale social media data analysis, which underscores the growing importance and potential of AI in detecting and addressing mental health issues at an early stage. However, they also emphasize the potential negative impacts of AI on individuals in the field of mental health.[13] With the advent of advanced GPT-model chatbots, human-computer interactions have elevated to unprecedented levels.[14] Thus, an imperative question arises: While social anxiety has commonly been examined within the context of human-human interactions, does interaction with computers induce social anxiety, and if so, what is the underlying mechanism, particularly when incorporating emotional expression?

This paper aims to provide a longitudinal examination of the intricate relationship between virtual companionship and social anxiety. By dissecting the mediating role of emotional expression and exploring the moderating role of mindfulness, we hope to offer a comprehensive understanding that could pave the way for better therapeutic interventions and digital engagement strategies in the future.

Literature Review

Theoretical Foundation: Social Support Theory and Emotion Regulation Theory

Social Support Theory

Social support theory postulates that the presence and quality of support systems in an individual's life, be it familial, friendship, or from a broader community, play a pivotal role in moderating the stress and anxiety they experience.[15] Essentially, social support acts as a buffer against the negative impacts of stressors on an individual's well-being.[16] The theory categorizes social support into two main types: instrumental support (tangible assistance like financial help or physical aid) and emotional support (empathy, care, love, and trust).[17]

In the realm of virtual companionship, the application of social support theory offers intriguing prospects. The interaction with AI might replicate or substitute some aspects of human-based social support, especially emotional support. AI can offer consistent, non-judgmental support. This is especially pivotal for those grappling with social anxiety. Traditional human interactions may be riddled with potential pitfalls for them: fear of judgment, worries about saying the wrong thing, or just the

overwhelming nature of face-to-face communication. Virtual companions, in contrast, offer a safe emotional support space. AI-based companions can uniquely offer empathy and understanding without biases or preconceived notions, allowing users to express themselves freely. They can engage in active listening, provide comforting responses, and even offer personalized advice or encouragement. This virtual form of emotional support can be particularly beneficial in helping individuals manage their feelings of anxiety and stress, offering a sense of understanding and validation that is free from the complexities of human judgment.

Emotion Regulation Theory

Emotion regulation theory, initially forwarded by Gross,[18] focuses on the processes by which individuals influence, experience, and express their emotions. The theory identifies various strategies for emotion regulation, such as cognitive reappraisal, attentional deployment, and situation modification. Each strategy acts as a conduit that individuals utilize to fine-tune their emotional reactions to different circumstances. As a result, they can reshape the emotions they experience, the manner in which they communicate these feelings, and even the accompanying physiological manifestations.[19]

In the context of virtual companionship, chatbots designed to offer such companionship serve as a novel tool for individuals to regulate emotions. These AI-driven entities provide an environment where individuals can more freely and securely navigate their emotional landscape. As they engage with these virtual companions, individuals might find it easier to manage and adjust their emotions, which, in turn, could influence their subsequent emotional states and overall psychological well-being.

In summary, the theoretical foundations of social support theory and emotion regulation theory provide a robust framework to delve deeper into the intricacies of virtual companionship and its implications for social anxiety. Understanding these foundational theories is paramount in contextualizing the broader scope of virtual interactions and their impact on mental well-being.

Relationship Between Virtual Companionship and Social Anxiety

In the modern landscape of interpersonal interactions, where digital platforms have become central to communication, the traditional understanding of social anxiety needs expansion. Social anxiety, by its classical definition, focuses largely on face-to-face or "offline" social interactions.[6] However, as online platforms have proliferated and become deeply integrated into our social lives, a new dimension of social anxiety has emerged—one that manifests in online or virtual settings.[20] To grasp the full spectrum of social anxiety in today's context, it's essential to delineate between these two arenas: online and offline.

Offline social anxiety typically manifests in physical settings like social gatherings, public speaking events, or casual face-to-face conversations. Such anxiety is driven by concerns about being negatively judged, scrutinized, or evaluated in real-time, with immediate, palpable feedback from others. The physical presence, direct eye contact, body language, and immediate reactions form a complex web of stimuli that can exacerbate feelings of anxiety for some individuals.[21] On the other hand, online social anxiety emanates from interactions on social media platforms, chat rooms, online forums, or even during video calls. While one might assume that the virtual barrier may lessen anxiety, the online environment presents its own unique set of challenges. For instance, the permanence of online posts, the potential for virality, and the vast, often faceless audience can create intense pressure for individuals. Moreover, the delay in feedback, the ambiguity in textual communication devoid of tone and non-verbal cues, and the potential for misinterpretation can also fuel anxiety.[22,23] Our study distinguishes between these two specific forms of anxiety: offline anxiety and online social anxiety. In examining virtual companionship, which primarily involves online interactions, it is imperative to delve into its impacts on both offline anxiety and online social anxiety separately and distinctly. Ignoring this distinction risks oversimplifying the multifaceted relationship between our digital lives and our mental well-being.

Offline social anxiety has historically been a prevalent concern among many individuals, leading to avoidance of physical social situations and a sense of isolation. The social support theory posits that support systems in an individual's life act as a buffer against the negative impacts of stressors on an individual's well-being.[15] In line with this, the advent of virtual companionship offers a potential means for alleviating this anxiety. The ability to engage with AI can provide instrumental and, more crucially, emotional support, akin to human interaction without the accompanying immediate stressors of physical presence, direct eye contact, and real-time scrutiny. This is exemplified in Zhu and Deng's study, which found that university students with higher social anxiety preferred robotic training partners over human ones, citing a sense of relaxation with robotic partners as a mediating factor.[24] Research by Nomura et al supports this, showing that people with social anxiety

experience less anticipatory anxiety when expecting to interact with a robot compared to a human.[25] This indicates a reduced level of tension in interactions with AI, which could be a significant factor in alleviating offline social anxiety. Park et al [26] further reinforce this perspective by highlighting the satisfaction and intention to reuse anthropomorphic chatbots in mental health counseling. Their findings suggest that a human-like presence in a virtual setting can significantly alleviate feelings of loneliness and anxiety experienced in offline contexts. This suggests that the qualities of AI, especially those that mimic human characteristics, can create a comforting virtual space for individuals. Additionally, studies by Ali et al [27] and Hu et al [28] emphasize that individuals with pronounced offline social anxiety may find solace and comfort in virtual companionship. These studies indicate that as these individuals increase their engagement with AI platforms, they experience a decrease in their anxiety levels. Drawing from these insights, it becomes apparent that virtual companionship, enabled by AI, holds potential as a tool for managing and possibly reducing offline social anxiety. Therefore, we propose:

Hypothesis 1: The frequency of use of virtual companionship is correlated with offline social anxiety.

When exploring online social anxiety, the digital context introduces a layered complexity that intertwines user experience with virtual interactions and the nuanced manifestations of anxiety within this sphere. Although research specifically focusing on the relationship between AI-based virtual companionship and online social anxiety is still in nascent stages, prevailing studies mapping internet use and online social anxiety delineate a multifaceted connection between the two. There is documented evidence that suggests a relationship between problematic social networking sites use and the development of social anxiety in users, highlighting an intriguing pathway where the online medium may become a catalyst for anxiety rather than a refuge for those with online social anxiety.[29] Conversely, certain studies present a view, asserting that no significant correlation exists between general internet use and social anxiety.[30] Such disparities underscore the requisite to delve deeper into specific user interactions and platforms to unearth more targeted insights. Pertinently, new research on AI elucidates the role it can play in alleviating forms of social anxiety, especially in scenarios where online consumption are concerned. For consumers anxious about negative evaluations from others in social environments, AI emerges as a preferred service provider, sidestepping the potential stressors that accompany human interaction. An exploration into the consumer cognitive model investigating this phenomenon evidenced that when fear of negative evaluation escalates, social anxiety is elicited, thereby swaying consumers towards a non-subjective preference for AI services. This demonstrates the role of AI in alleviating online social anxiety.[31] Albeit acknowledging the complex relationship, we propose:

Hypothesis 2: The frequency of use of virtual companionship is negatively correlated with online social anxiety.

Mediating Role of Emotional Expression

Emotional expression serves as a pivotal intermediary, linking the adoption of virtual companionship to the experiences and manifestations of social anxiety.

Emotion regulation theory posits that individuals utilize various strategies to influence and modulate their emotional experiences.[18] In the digital realm, the frequent engagement with virtual companionship acts as a novel strategy for emotion regulation, enabling users to navigate and articulate their emotional landscape more effectively. Chatbots, evolving in their design, now incorporate a semblance of natural emotions to enrich user interactions.[32] When these chatbots are emotionally resonant, users tend to feel more understood, leading to a heightened level of emotional expression. Evidence from Liu et al [33] elucidates that chatbots that exhibit sympathy and empathy, over mere information dispensation, are perceived more favorably by users, thereby encouraging users to express their emotions more freely. In a similar vein, Han et al [34] underscore that AI agents expressing positive emotions during customer interactions can significantly influence users' emotional perceptions and emotional expression. Collectively, these findings underscore that frequent interactions with emotionally attuned chatbots can amplify users' emotional expression.

Drawing from Emotion Regulation Theory, the relationship between emotional expression and social anxiety can be illuminated in various dimensions. According to this theory, the manner in which individuals express or suppress their emotions can directly impact their psychological well-being. Specifically, effective emotional expression can serve as a coping mechanism, potentially attenuating feelings of anxiety. Dijk et al [35] delve into the intricate behaviors of those

with social anxiety. Their research indicates that individuals with heightened social anxiety exhibit a specific pattern when reacting to others' emotional displays. Despite being more susceptible to negative emotions from their surroundings, socially anxious individuals often suppress these feelings by outwardly showing positive emotions. Their predilection to mask genuine feelings with positive displays might be driven by an intrinsic urge to avoid potential conflicts or fear of rejection. Essentially, the more adept they are at expressing positive emotions, the lower their social anxiety tends to be. Spokas et al [36] further substantiate the link between emotional suppression and heightened social anxiety. Their findings suggest that those who retain negative emotions, rather than expressing them, often experience amplified levels of both online and offline social anxiety. These individuals also harbor ambivalent feelings about emotional expression and are more likely to perceive it as a sign of vulnerability or weakness. This aligns with Emotion Regulation Theory's assertion that suppressing emotions can compound psychological distress. Kivity and Huppert[37] offer a complementary perspective by focusing on individuals' reactions to facial expressions. Their meta-analysis discerns that individuals more willing to express their genuine selves tend to experience lower levels of social anxiety. This openness not only decreases their own anxiety but also renders them more approachable to others. In sum, Emotion Regulation Theory provides a compelling framework to understand the inverse relationship between emotional expression and social anxiety. As evidenced by the cited research, individuals who adeptly navigate and express their emotions experience reduced social anxiety, underscoring the therapeutic potential of fostering genuine emotional expression.

In light of the above, we propose:

Hypothesis 3: Emotional expression mediates the relationship between the frequency of use of virtual companionship and offline social anxiety.

Hypothesis 4: Emotional expression mediates the relationship between the frequency of use of virtual companionship and online social anxiety.

Moderating Role of Mindfulness

Mindfulness, characterized by a non-judgmental awareness of the present moment, has been widely acknowledged for its influence on psychological health and well-being.[38] Recent studies have delved deep into the intricate relationships between social anxiety, mindfulness, and other psychological constructs. For instance, Parsons et al [39] identified specific facets of mindfulness that could predict reactions to social anxiety stressors beyond the foundational effects of social anxiety schemas. Furthermore, Wang et al [40] highlighted that trait mindfulness can moderate the indirect effect of perfectionism on social anxiety through perceived stress. Furthermore, Yang et al [41] highlighted the moderating role of mindfulness in the association between mobile phone addiction, a modern form of digital companionship, and mental health problems such as anxiety and depression in adolescents. Their study indicated that for individuals with lower levels of mindfulness, the negative impacts of mobile phone addiction on mental health were intensified. This ability of mindfulness to act as a moderator suggests its potential in other realms, such as the interactions between individuals and virtual companionship.

Building upon these insights, and considering the increasing integration of virtual companionship in our daily lives, it becomes pertinent to understand how mindfulness might influence the outcomes of these interactions. Specifically, in the realm of virtual companionship, individuals with heightened mindfulness could potentially perceive and respond to their engagements differently. This heightened awareness could amplify the effects of their virtual interactions on psychological constructs such as social anxiety. With this in mind, one might surmise that the direct relationship between the frequency of use of virtual companionship and online and offline social anxiety could be influenced by the level of mindfulness. Thus, for individuals with a greater inclination towards mindfulness, their engagements with virtual companionship could have more pronounced effects on their experiences of social anxiety.

Based on the synthesis of the aforementioned literature and the overarching theme of mindfulness's moderating role, we propose:

Hypothesis 5: Mindfulness moderates the direct relationship between the frequency of use of virtual companionship and offline social anxiety. Specifically, for individuals with elevated mindfulness, the effects of virtual companionship's frequent use on offline social anxiety are more potent compared to those with diminished mindfulness levels.

Hypothesis 6: Mindfulness moderates the direct relationship between the frequency of use of virtual companionship and online social anxiety. Specifically, for individuals with higher levels of mindfulness, the impact of the frequency of use of virtual companionship on online social anxiety is more pronounced than for those with lower mindfulness levels.

Method

This study collected data by distributing online surveys in the WeChat course groups of elective computer classes at three universities. The study was approved by the Institutional Review Board at the authors' institution (code B2022328I), and the participation of all subjects was based on informed consent. Participants who completed all two surveys were compensated with 10 yuan each, via WeChat Pay or Alipay.

Participants and Procedure

The longitudinal study engaged 618 undergraduate students from three universities located in Eastern China through a convenience sampling strategy. Given the technological focus of our study, participants were specifically chosen from elective computer courses, as students enrolled in these courses are more inclined to be early adopters of new technological advancements, making them a particularly apt demographic for our research. This choice of sampling was primarily driven by the convenience and accessibility of this particular student population, who are not only facile with the technology but also readily available and willing to participate in such studies. This approach enabled us to efficiently collect data while also ensuring that our sample was representative of a demographic that is particularly relevant to our research focus.

In May 2022, as an effort to alleviate the psychological pressures and social anxiety faced by university students during campus closures due to the pandemic, the three universities collaboratively introduced a virtual companionship service based on chatbot technology. The earliest version of this chatbot was built on Microsoft's Xiao Bing, which is commonly referred to as the Avatar Framework. Students were provided with a guide on utilizing the chatbot for various applications – such as asking questions related to health concerns, seeking general companionship, or using the chatbot as an emotional support tool. Recognizing the potential of advancing AI technology, the universities swiftly updated their systems in March 2023, upon the release of the GPT-4 model. Subsequently, students were offered an enhanced virtual companionship experience powered by GPT-4.

Data collection proceeded in two main phases. The first measurement was conducted on May 15, 2023. This was roughly a month post the incorporation of the GPT-4 model into the virtual companionship service. By this juncture, students had engaged with the updated virtual companion for a month, offering us an initial glimpse into their experiences and the psychological nuances they faced. Subsequent to this, a second round of measurement was administered on September 15, 2023. This allowed for an assessment over an extended duration, offering a window into potential long-term effects or shifts in student perceptions concerning their interactions with the virtual companion. The chatbots provided in two rounds were based on the contemporary artificial intelligence models, offering both text and voice virtual companionship.

Across these two data collection intervals, students were evaluated based on several parameters: the frequency of use of virtual companionship, their mindfulness levels, manifestations of online and offline social anxiety, and patterns of emotional expression during their interactions with the chatbot. Through this data, our study aimed to unpack the intricacies of how emotional expression could mediate the relationship between virtual companionship and social anxiety, and how mindfulness might play a moderating role in this dynamic.

Over the course of the study, there was a decrease in the number of participants, with a retention rate of 89.48% in the second wave (553 participants). The reduction was mainly due to the graduation of some students in June 2023, which made it challenging to collect data from them. Despite the decrease, the participant retention rate was relatively high, providing robust longitudinal data for our analysis.

To handle the missing data, we first conducted a Little's Missing Completely at Random (MCAR) test. The results indicated that the missing values were randomly distributed ($\chi 2 = 88.73$, $p = 0.30$). Subsequently, to address the issue of missing data in our longitudinal study, we employed the Full Information Maximum Likelihood (FIML) method, which is particularly suited for handling missingness in complex, multi-wave data sets like ours.[42] FIML works under the assumption that the data are missing at random, which is a reasonable assumption in our context given the primary reasons for dropout were graduation and loss of contact, rather than factors related to the study variables. In the application of FIML, each participant's available data,

regardless of the wave, was utilized to estimate the model parameters. This means that even if a participant did not complete two waves of the study, their responses from the completed waves were still included in the analysis.[43]

For our data analysis, we utilized SPSS 26.0 to conduct descriptive statistics, while AMOS 25.0 facilitated multi-group confirmatory factor analysis (CFA) and the cross-lagged panel modeling.[44]

Measures

The scales of this study are adapted from mature research. Survey questions can be viewed in Appendix.

Virtual Companion

The predominant forms of virtual companionship are conveyed through AI-generated text and voice. To discern the frequency with which participants engaged with these companions, we posed the question, "What is your frequency of use of virtual companions in the forms of AI-generated text and AI-generated voice?" Response options ranged from 1 to 5, where 1 represents "Less than once a week", 2 denotes "Once to twice a week", 3 signifies "Three to six times a week", 4 indicates "Once a day", and 5 corresponds to "Multiple times a day". Participants who chose "never" for either form of companionship were excluded from the study.

In the questionnaire, we clarified the purpose of using chatbots as seeking companionship. Instances where chatbots were only used as question-answer tools were excluded from the results. Additionally, participants were asked whether they used chatbots other than those provided by the school. To better control for variables, those who indicated using external chatbots were also excluded.

In subsequent analysis, we found a strong correlation between interactions with AI-generated text and AI-generated voice companionship (In two waves of the analysis, the Pearson correlation between AI-generated text and AI-generated voice companionship was greater than 0.75, with a p-value less than 0.05.) This correlation can be attributed to the fact that AI-generated voice fundamentally operates on text recognition before converting it into speech, thus aligning it closely with AI-generated text. Given this strong correlation, we combined the frequency of interactions with both types of virtual companions into a single score by calculating their mean value for further analysis.

The internal consistency of the frequency of use of virtual companionship measure was high across two waves, with Cronbach's alphas of 0.893 (T1), 0.887 (T2), demonstrating a strong degree of reliability over time. The CFA showed acceptable model fit across two waves ($\chi 2/df$ ranged from 2.40 to 2.79, CFI ranged from 0.95 to 0.97, TLI ranged from 0.95 to 0.96, RMSEA ranged from 0.03 to 0.04).

Social Anxiety

The measure for online social anxiety was adapted from Alkis et al.[45] Participants were asked to ponder their experiences while participating in online activities and respond to a series of statements based on a 5-point Likert scale, where 1 represents "Never" and 5 stands for "Always". The statements targeted various aspects of online social interactions, including concerns about personal information exposure, the potential for negative judgments from peers, apprehensions about the impression they leave in online communities, and the general anxiety of interacting with unfamiliar individuals online. The overall score for online social anxiety was computed by taking the mean score of the items, with a higher score indicating greater levels of anxiety associated with online social interactions.

The online social anxiety scale exhibited commendable internal consistency across the two waves, with Cronbach's alpha values of 0.920 and 0.909 (T2). Additionally, to ascertain the structure of our measure, a confirmatory factor analysis (CFA) was undertaken. The resulting CFA showed satisfactory model fit indices: $\chi 2/df$ ranged from 1.83 to 2.04, CFI ranged from 0.97 to 0.99, TLI ranged from 0.96 to 0.98, and RMSEA ranged from 0.04 to 0.06.

Offline social anxiety was assessed using a scale adapted from Mattick & Clarke.[46] Participants reflected on their offline interactions and were required to rate their level of agreement with a variety of statements using a 5-point Likert scale. This scale ranged from 1 (Never) to 5 (Always). The statements covered diverse facets of face-to-face social interactions, such as nervousness when speaking to authoritative figures, difficulty in establishing eye contact, apprehensions about social mingling, and concerns over potentially embarrassing social situations. An aggregate score was derived from the mean of these items, with a higher score indicating an elevated level of offline social anxiety.

The offline social anxiety scale consistently demonstrated high internal reliability throughout the two waves, supported by the obtained Cronbach's alpha values of 0.898 (T1) and 0.893 (T2). A confirmatory factor analysis (CFA) was also conducted to verify the construct validity of our offline social anxiety measure. The model fit indices from the CFA attested to the measure's structural validity and reliability over time: $\chi 2/df$ ranged from 1.78 to 1.99, CFI ranged from 0.96 to 0.98, TLI ranged from 0.95 to 0.97, and RMSEA ranged from 0.03 to 0.05.

Emotional Expression

The measure for emotional expression was derived from Gross & John.[47] Participants were prompted to reflect on their personal experiences and rate their level of agreement with various statements concerning their emotional expressiveness. The ratings were given on a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Several items in the scale were reverse-coded (R) to ensure accurate interpretation and response differentiation. These items encompassed a range of emotional experiences, from the transparency of emotional displays to the intensity of emotional reactions and the tendencies to suppress or manifest emotions in different situations. To ensure accurate interpretation during analysis, reverse-coded items were appropriately re-scored before the computation of the overall emotional expression score. The final score was determined by calculating the mean of these items, with higher scores suggesting a greater degree of emotional expressivity.

The emotional expression scale exhibited strong internal consistency across both waves, with Cronbach's alphas of 0.812 (T1) and 0.804 (T2). To further substantiate the construct of our emotional expression measure, a confirmatory factor analysis (CFA) was conducted. The CFA for both waves produced acceptable model fit statistics: $\chi 2/df$ ranged from 1.75 to 2.07, CFI values fluctuated between 0.97 and 0.99, TLI values varied from 0.96 to 0.98, and RMSEA values ranged from 0.03 to 0.05.

Mindfulness

The measure for mindfulness was adapted from Brown & Ryan.[48] Participants were instructed to consider their typical experiences and indicate the frequency with which each statement applies to them. Responses were given on a 5-point Likert scale, from 1 (Never) to 5 (Always). The items in this scale predominantly capture inattentive or mindless behaviors and tendencies, and thus higher scores on the original scale might suggest lower mindfulness. It's important to note that this scale is reverse-scored to accurately interpret higher scores as indicative of higher mindfulness.

The mindfulness scale showcased solid internal consistency across the two waves, with Cronbach's alphas of 0.893 (T1) and 0.879 (T2). To further authenticate the construct validity of our mindfulness measure, we executed a confirmatory factor analysis (CFA). The CFA results across both waves displayed satisfactory model fit indices: $\chi 2/df$ values ranged from 1.68 to 2.01, CFI values were between 0.96 and 0.98, TLI fluctuated from 0.95 to 0.97, and RMSEA values varied between 0.02 and 0.04.

Results

Common Method Bias Test

Prior to delving into the outcome of our hypothesis tests, we first mitigated the possible issue of common method bias as our data was gathered from a single source. Common method variance could potentially pose a risk in studies like ours where self-report measures are employed for both the predictor and criterion variables. To examine this potential bias, we executed Harman's single-factor test, a broadly acknowledged method for scrutinizing common method bias.[49] This test administers an exploratory factor analysis where all survey items are included. If a solitary factor emerges or one factor is accountable for the majority of the covariance among the variables, it is suggestive of common method bias.[50]

In our evaluation, the exploratory factor analysis was conducted separately for Time 1 and Time 2 to rigorously inspect potential variations in common method bias across the two phases. At Time 1, the principal factor explained 20.7% of the variance, while at Time 2, it explained 23.2% of the variance—both percentages are considerably below the critical threshold of 50%,[51] indicating that no single factor dominated the variance (Chin et al 2012). Consequently, these results suggest that common method bias does not pose a significant concern in our data at either of the two time points.

Descriptive Statistics and Correlations

The results of the descriptive statistics and correlations are presented in Table 1. This table includes the means and standard deviations of all variables at two time points, along with the correlations between these variables.

Regarding the age of the participants, the average was 20.781 years with a standard deviation of 1.461. In terms of gender distribution, coded as 0 for females and 1 for males, the mean was 0.584 with a standard deviation of 0.112, indicating a relatively balanced gender distribution in the sample.

Across two waves, the frequency of use of virtual companionship (VCF), emotional expression (EE), offline social anxiety (OFSA), online social anxiety (ONSA), and mindfulness (MI) showed considerable consistency over time, as evidenced by the significant correlations between the same constructs measured at different time points.

The correlations between VCF and ONSA were negative and statistically significant, indicating that participants who used virtual companionship more frequently experienced significantly lower levels of online social anxiety. Conversely, the statistically significant positive associations between VCF and OFSA suggest that a higher frequency of use of virtual companionship was notably linked with increased levels of offline social anxiety. Furthermore, the positive and statistically significant correlations between VCF and EE imply that individuals who used virtual companionship more frequently also exhibited a significant increase in emotional expression. The statistically significant negative associations between EE and both ONSA and OFSA indicate that participants who expressed their emotions more robustly were markedly less likely to experience high levels of both online and offline social anxiety.

These results provide a comprehensive overview of the data, offering preliminary insights into the relationships between the key variables in our study.

Cross Lagged Analysis of Frequency of Use of Virtual Companionship, Emotional Expression, and Social Anxiety

Initially, we assessed the baseline model (M1), which only encompassed the autoregressive paths of VCF, EE, and both ONSA and OFSA, devoid of any cross-lagged regression paths. The errors of the aforementioned variables at T1 were correlated in this model. The goodness of fit indices for M1 were: $\chi^2(df) = 320.154$ (90), $p < 0.001$, AGFI = 0.862, NFI = 0.891, RFI = 0.860, IFI = 0.903, TLI = 0.875, CFI = 0.884, RMSEA = 0.064.

Subsequently, we hypothesized that VCF can predict EE, and EE, in turn, can predict both ONSA and OFSA. With this hypothesis, the second model (M2) was developed based on M1, integrating the cross-lagged paths from VCF to EE, and from EE to both ONSA and OFSA. The fit indices for M2 were: $\chi^2(df) = 220.124$ (85), $p = 0.001$, AGFI = 0.906, NFI = 0.921, RFI = 0.908, IFI = 0.931, TLI = 0.925, CFI = 0.933, RMSEA = 0.057. The chi-square difference tests revealed that M2 offered a superior fit as compared to M1 ($\Delta\chi^2 = 100.030$, $\Delta df = 5$, $p < 0.001$).

Next, we evaluated if ONSA and OFSA could forecast VCF and EE. Therefore, the third model (M3) was formulated rooted in M1, incorporating cross-lagged paths from both ONSA and OFSA to VCF, and from them to EE. The fit indices for M3 were: $\chi^2(df) = 200.090$ (83), $p = 0.001$, AGFI = 0.912, NFI = 0.930, RFI = 0.912, IFI = 0.949, TLI = 0.938, CFI = 0.941, RMSEA = 0.050. The chi-square difference tests denoted that M3 was significantly more fitting than both M1 ($\Delta\chi^2 = 120.064$, $\Delta df = 7$, $p < 0.001$) and M2 ($\Delta\chi^2 = 20.034$, $\Delta df = 2$, $p < 0.05$).

To provide a comprehensive view, we amalgamated M1, M2, and M3 to devise the fourth model (M4), considering the stability of relationships among VCF, EE, ONSA, and OFSA across both time points and all cross-lagged paths. Following established conventions, the fit indices for this saturated model, M4, were not reported. Thus, M4 was adopted as the conclusive cross-lagged analysis model for our research (refer to Figures 1 and 2).

Figure 1 represents the significant paths of our definitive model across the two waves. Our results pinpointed that VCF at T1 notably predicted ONSA at T2 ($\beta = -0.177$, $p < 0.05$). VCF at T1 notably predicted EE at T2 ($\beta = 0.134$, $p < 0.05$). Concurrently, EE at T1 also exhibited significant predictive capacity for ONSA at T2 ($\beta = -0.213$, $p < 0.001$).

Figure 2 represents the significant paths of our definitive model across the two waves. Our results pinpointed that VCF at T1 notably predicted OFSA at T2 ($\beta = 0.109$, $p < 0.05$). VCF at T1 notably predicted EE at T2 ($\beta = 0.136$, $p < 0.05$). Concurrently, EE at T1 also exhibited significant predictive capacity for OFSA at T2 ($\beta = -0.173$, $p < 0.05$).

Table 1 The Results of Descriptive Statistics and Correlations (N=618)

Variables	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1 Age	20.781	1.461											
2 Gender	0.584	0.112	0.087										
3 VCF (T1)	2.931	0.879	0.042	−0.121*									
4 VCF (T2)	3.171	0.793	0.081	−0.108*	0.678***								
5 EE (T1)	2.955	0.630	0.064	−0.092	0.205***	0.195***							
6 EE (T2)	2.903	0.614	0.048	−0.081	0.208***	0.211***	0.570***						
7 ONSA (T1)	3.408	0.722	−0.050	−0.077	−0.245***	−0.208***	−0.298***	−0.280***					
8 ONSA (T2)	3.556	0.753	−0.039	−0.068	−0.238***	−0.215***	−0.276***	−0.274***	0.606***				
9 OFSA (T1)	3.082	0.802	0.022	−0.055	0.160**	0.173**	−0.222***	−0.236***	−0.129*	−0.137*			
10 OFSA (T2)	2.993	0.769	0.040	−0.059	0.167**	0.159**	−0.208***	−0.215***	−0.133*	−0.140*	0.543***		
11 MI (T1)	3.245	0.594	0.091	0.048	0.101*	0.130*	0.103*	0.128*	−0.175**	−0.187**	0.125*	0.128*	
12 MI (T2)	3.330	0.582	0.078	0.060	0.123*	0.117*	0.116*	0.109*	−0.188**	−0.169**	0.143*	0.146*	0.500***

Notes: *p<0.05, **p<0.01, ***p<0.001.

Abbreviations: Gender, 0; Female, 1; Male; VCF, The frequency of use of virtual companionship; EE, Emotional expression; ONSA, Online social anxiety; OFSA, Offline social anxiety; MI, Mindfulness; SD, Standard deviation; T1, Time 1; T2, Time 2.

https://doi.org/10.2147/PRBM.S447487 DovePress

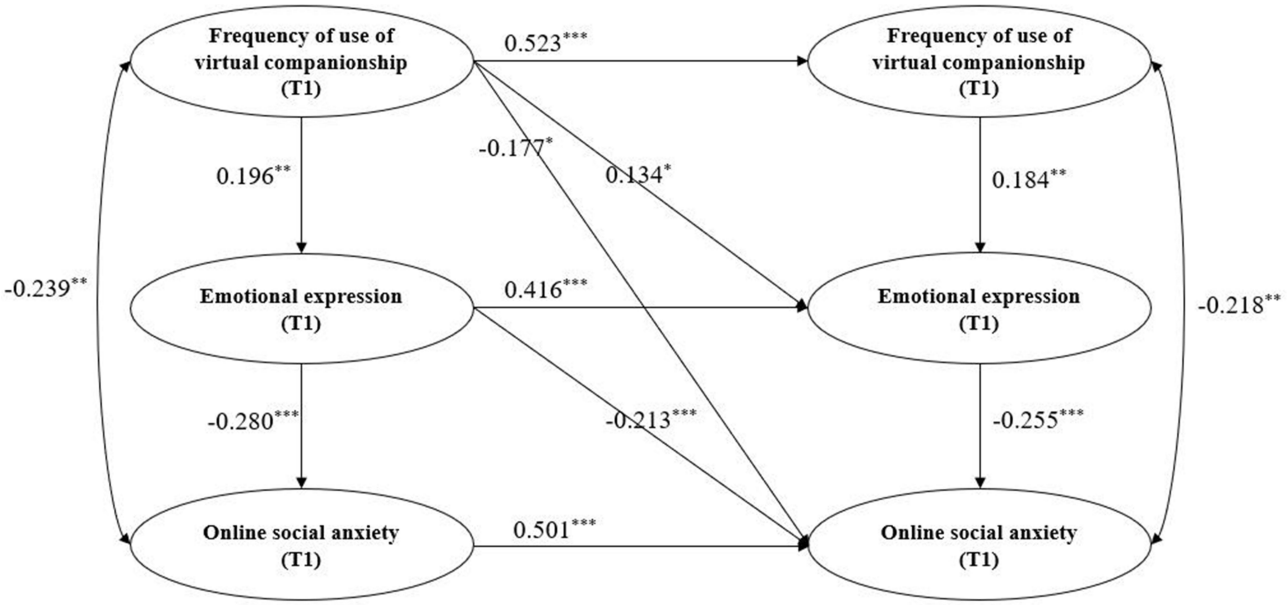

Figure 1 Two-wave cross-lagged model of the frequency of use of virtual companionship, emotional expression, and online social anxiety. The measurement error and non-significant paths were omitted to enhance the clarity of the figure. Only the main paths of interest for this study are retained.
Notes: *p<0.05, **p<0.01, ***p<0.001.

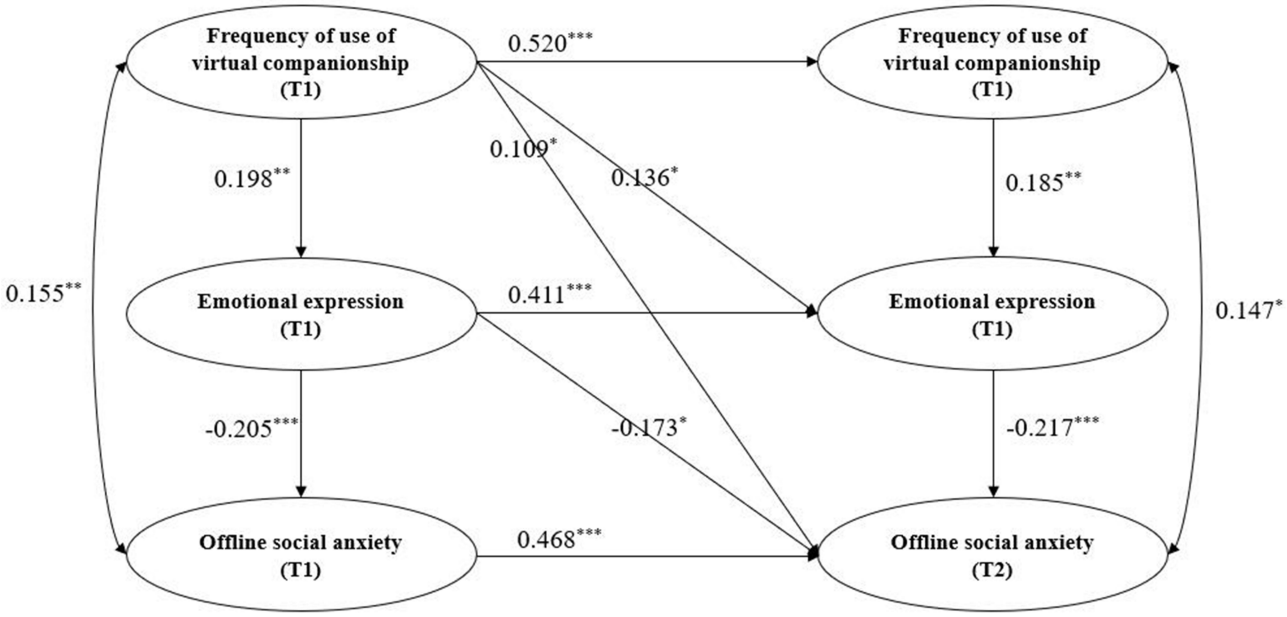

Figure 2 Two-wave cross-lagged model of the frequency of use of virtual companionship, emotional expression, and offline social anxiety. The measurement error and non-significant paths were omitted to enhance the clarity of the figure. Only the main paths of interest for this study are retained.
Notes: *p<0.05, **p<0.01, ***p<0.001.

Hypotheses 2, 3, and 4 were supported. However, the results were contrary to Hypothesis 1, indicating that a higher frequency of virtual companionship use actually led to increased offline social anxiety.

In summation, these outcomes illuminate that EE operates as a pivotal intermediary in our model. It channels the relationship between VCF and both forms of social anxiety, within the time frame. EE, influenced by VCF, subsequently impacts ONSA and OFSA, showcasing a clear temporal progression and the nuanced interrelation between VCF, EE,

ONSA, and OFSA over time. This corroborates the idea that those engaging more frequently in virtual companionship express their emotions more openly, which in turn affects their social anxiety levels, both online and offline.

Longitudinal Analysis of Mindfulness as a Moderator

The study investigated whether the influence of VCF at T1 on ONSA and OFSA at T2 was moderated by MI at T2. The results are presented in Table 2. Specifically, the interaction between VCF (T1) and MI (T2) significantly predicted ONSA at T2 (β=0.206, LLCI=0.173, ULCI=0.358) and OFSA at T2 (β=−0.187, LLCI=−0.207, ULCI=−0.098). This suggests that MI at T2 significantly moderated the direct path from VCF at T1 to both ONSA and OFSA at T2. Hypotheses 5 and 6 were supported.

Further examination of the moderation effect is displayed in Table 3. At a lower level of mindfulness (1 standard deviation below the mean), the influence of VCF at T1 on ONSA at T2 was −0.115 (SE=0.041, LLCI=−0.135, ULCI=−0.053), and on OFSA at T2 was 0.278 (SE=0.048, LLCI=0.038, ULCI=0.305). Conversely, at a higher level of mindfulness (1 standard deviation above the mean), the influence of VCF at T1 on ONSA at T2 intensified to −0.355 (SE=0.055, LLCI=−0.398, ULCI=−0.125), while its impact on OFSA at T2 reduced to 0.073 (SE=0.020, LLCI=0.012, ULCI=0.156).

This nuanced relationship was further elucidated by simple slope plots. Figure 3 illustrates the moderating effect of MI on the relationship between VCF and ONSA. From the figure, it's evident that as MI increases, the negative relationship between VCF and ONSA becomes more pronounced. Similarly, Figure 4 demonstrates the moderating

Table 2 Regression Analysis Results

Dependent Variables	Model 1				Model 2				Model 3			
	EE (T2)				ONSA (T2)				OFSA (T2)			
	β	*p*	LLCI	ULCI	*β*	*p*	LLCI	ULCI	*β*	*p*	LLCI	ULCI
Control variables												
Age	0.051	0.130	−0.095	0.108	−0.038	0.111	−0.067	0.085	0.044	0.099	−0.078	0.102
Gender	−0.079	0.090	−0.086	0.038	−0.070	0.065	−0.103	0.049	−0.058	0.071	−0.094	0.064
Independent variables												
VCF (T1)	0.239	0.001	0.143	0.335	−0.236	0.001	−0.244	−0.168	0.173	0.003	0.150	0.339
EE (T2)					−0.276	0.010	−0.373	−0.164	−0.208	0.008	−0.328	−0.112
MI (T2)					−0.162	0.043	−0.252	−0.079	−0.145	0.038	−0.286	−0.140
VCF (T1)×MI (T2)					0.206	0.013	0.173	0.358	−0.187	0.005	−0.207	−0.098
Constant	2.731	0.000	0.739	3.018	2.225	0.000	0.548	2.717	2.118	0.000	0.495	2.978
Model fit												
R^2	0.185				0.217				0.204			
F	17.632***				11.537***				12.089***			

Notes: We are using a 95% confidence interval, with the LLCI representing the lower limit and the ULCI representing the upper limit of this interval. β represents the standardized coefficient. ***p<0.001.

Abbreviations: Gender: 0, Female, 1, Male; VCF, The frequency of use of virtual companionship; EE, Emotional expression; ONSA, Online social anxiety; OFSA, Offline social anxiety; MI= Mindfulness; LLCI, Lower limit of the confidence interval; ULCI, Upper limit of the confidence interval; T1, Time 1; T2, Time 2.

Table 3 Examination of the Moderating Effect on the Direct Effects of ONSA and OFSA

MI	ONSA (T2)				OFSA (T2)			
	Effect	SE	LLCI	ULCI	Effect	SE	LLCI	ULCI
Low (M-1SD)	−0.115	0.041	−0.135	−0.053	0.278	0.048	0.038	0.305
High (M+1SD)	−0.355	0.055	−0.398	−0.125	0.073	0.020	0.012	0.156

Notes: We are using a 95% confidence interval, with the LLCI representing the lower limit and the ULCI representing the upper limit of this interval.

Abbreviations: ONSA, Online social anxiety; OFSA, Offline social anxiety; MI= Mindfulness; SE, Standard error; LLCI, Lower limit of the confidence interval; ULCI, Upper limit of the confidence interval; T2, Time 2.

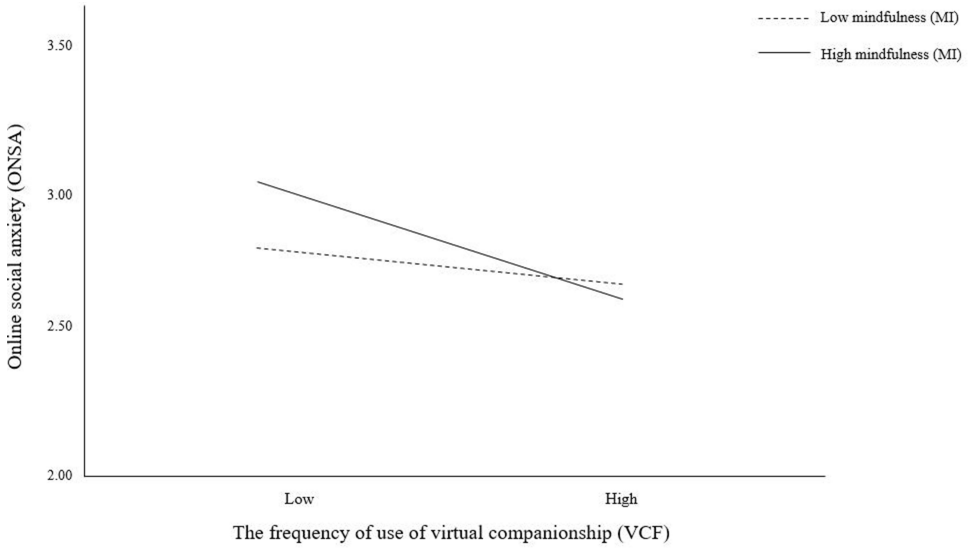

Figure 3 The moderating effect of MI on the relationship between VCF and ONSA.

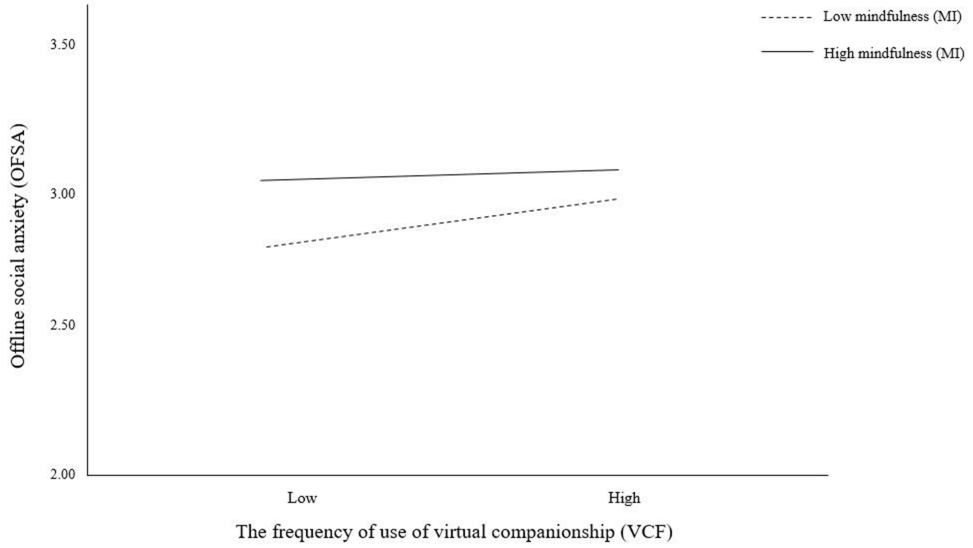

Figure 4 The moderating effect of MI on the relationship between VCF and OFSA.

effect of MI on the relationship between VCF and OFSA. The plot indicates that with a higher level of MI, the positive association between VCF and OFSA becomes less steep.

This suggests that individuals with higher levels of mindfulness experienced a more significant reduction in online social anxiety and a lesser increase in offline social anxiety in relation to the frequency of virtual companionship use. Conversely, those with lower levels of mindfulness showed a more muted decrease in online social anxiety and a greater increase in offline social anxiety. The findings underscore the protective role of mindfulness in the relationship between virtual companionship usage and social anxiety.

Discussion

The contemporary digital era has seen a surge in virtual interactions, making it pertinent to understand the dynamics of virtual companionship and its implications on social anxiety. Our study sheds significant light on these intricacies, revealing

compelling evidence of the relationships between frequency of virtual companionship use (VCF), emotional expression (EE), online social anxiety (ONSA), offline social anxiety (OFSA), and the moderating role of mindfulness (MI).

The Relationship Between Virtual Companionship and Social Anxiety

Central to our findings is the intricate link between virtual companionship and social anxiety. As the frequency of virtual companionship use increases, there is a noticeable decline in online social anxiety. This suggests that consistent engagement with virtual peers allows individuals to foster a sense of belonging and validation within the digital realm. Social Support Theory sheds light on this observation, emphasizing that perceived or actual support from others can mitigate stress and negative psychological experiences.[52] In the context of our study, virtual companionship potentially serves as a robust form of online social support. With more frequent virtual interactions, individuals might develop a reinforced sense of camaraderie and acceptance, making them feel less isolated and apprehensive about online engagements.

However, a twist emerges when we juxtapose this with offline scenarios. Contrary to our initial hypothesis, we observed that a higher frequency of virtual companionship corresponded to elevated offline social anxiety. This counterintuitive outcome may stem from a growing dependency on interactions with artificial companions, where users find solace in the predictable, controlled, and non-judgmental nature of AI platforms.[53] As users become more deeply entrenched in interactions with AI and perceive intensified social support in that realm, they might inadvertently neglect real-world interactions. Unlike human companions, AI does not exhibit emotions, unintentional biases, or complex interpersonal reactions, thereby providing an interaction that is both consistently positive and unambiguously supportive. However, human interactions, entailing a range of emotional responses and ethical considerations, can be intricate and multifaceted, often requiring adept social skills and emotional intelligence to navigate successfully. The profound comfort found in online engagements with AI might, therefore, render offline social scenarios more daunting, given their unpredictability, complexity, and the absence of digital buffers. Essentially, while the cocoon of virtual companionship with AI provides a sanctuary from online anxieties, it might paradoxically amplify sensitivities to real-world social stimuli.

This divergence between online and offline experiences accentuates the double-edged sword of virtual companionship. On the one hand, AI acts as a refuge, providing robust social support in the online domain due to its consistent and non-confrontational interactions. On the other, it might inadvertently establish barriers, making offline social engagements appear more intimidating and fraught with potential challenges. Thus, while virtual companionship with AI offers solace, it might simultaneously foster a sense of detachment from real-world social nuances, emphasizing the paramount importance of maintaining a balanced relationship between our digital and physical lives.[54]

Emotional Expression as the Mediating Mechanism

Another pivotal finding of our study centers on the mediating role of emotional expression between the frequency of virtual companionship use and social anxiety, both online and offline. Our results suggest that an uptick in virtual companionship usage fosters more pronounced emotional expression. This augmentation in emotional expression, in turn, contributes to reduced social anxiety in both online and offline contexts.

Emotion regulation theory provides a comprehensive lens through which to understand this mechanism. The theory suggests that people have the ability to consciously control and modify their emotional responses. This includes choosing the types of emotions they feel, determining the timing of these emotions, and managing the ways in which they experience and communicate their emotional states.[55] Virtual companionship might serve as a platform that facilitates emotion regulation by offering a safe space for individuals to articulate and process their feelings. The anonymity and distance inherent in online platforms might embolden users to express emotions more freely, especially emotions they might find challenging to convey in face-to-face settings.[19]

By providing a platform where individuals can explore and ventilate their emotions without immediate real-world repercussions, virtual companionship can assist users in gaining insights into their feelings and, subsequently, mastering emotion regulation strategies. Over time, this familiarity with one's emotional landscape and the ability to express emotions in a nuanced manner could foster resilience against social anxiety.[56] By developing a robust emotional vocabulary and understanding, individuals might feel more confident navigating social interactions, regardless of whether they are online or offline, and alleviate the social anxiety that are tethered to them.

Mindfulness as a Moderator

A particularly intriguing aspect of our study was the role of mindfulness in moderating the relationship between VCF and both forms of social anxiety. Mindfulness, a state of heightened awareness and presence, has been lauded for its potential in ameliorating psychological distress. Our results resonate with this, showcasing that individuals high in mindfulness are less susceptible to the negative impacts of frequent virtual companionship. Essentially, those with higher mindfulness levels seem to navigate AI more adeptly, experiencing reduced social anxiety. On the other hand, individuals with lower mindfulness levels appear more vulnerable, experiencing pronounced social anxiety, especially offline.

This emphasizes the protective capacity of mindfulness. It possibly buffers individuals from the overwhelming influx of information and emotions that AI often entail. By grounding individuals in the present and promoting a non-judgmental perspective, mindfulness might enable better emotional regulation, reducing susceptibility to anxiety.

Theoretical and Practical Significance

From a theoretical standpoint, our research bridges existing gaps by honing in on the unique and intricate relationships between virtual companionship with AI and social anxiety. The introduction of emotional expression as a mediating role and mindfulness as a moderating role not only deepens our comprehension of how AI-based virtual companionship directly influences social anxiety but also elucidates the subtle mechanisms underlying this relationship. Traditional models have largely centered around human-to-human interactions; this study, however, accentuates the essentiality of integrating digital and specifically AI-driven interactions into the foundational frameworks, acknowledging the evolution of social relationships in the contemporary digital era.

In a practical context, our research delineates key insights for enhancing the functionality of AI-driven virtual companionship platforms and therapeutic practices. For platform developers, implementing emotion-sensitive algorithms, which adeptly discern and respond to user emotional inputs, becomes paramount; along with the integration of mindfulness exercises and user-centric, intuitive design features to ensure an anxiety-minimizing user experience. Furthermore, emphasizing and transparently communicating data privacy measures will reassure users engaging in emotional expressions. Mental health professionals, concurrently, can weave these AI companions into therapeutic interventions, utilizing them as supplementary tools during and between sessions to bolster emotional expression and continuity of care. Integrating mindfulness-based interventions, and utilizing AI to remind clients to practice mindful exercises between sessions, not only sustain but amplify the impact of therapeutic practices. These strategic applications of AI-driven virtual companionship, embedded within our practical frameworks, not only attend to immediate emotional needs but also assure sustained, ethically, and privacy-respectful interactions, magnifying the pragmatic impact of our research findings in real-world settings.

Conclusion

In the contemporary digital era, examining the connection between virtual companionship and social anxiety assumes a critical relevance. Our longitudinal exploration, rooted in robust methodological underpinnings, has unveiled multi-faceted relationships between virtual companionship, emotional expression, and social anxiety, with mindfulness acting as a pivotal moderating factor.

Central to our findings is the dual nature of virtual companionship. On the one hand, it serves as a salve, assuaging online social anxiety and bolstering a sense of digital belonging. Conversely, an over-reliance on such platforms seems to beget heightened offline social anxiety, emphasizing the imperative for balance. Emotional expression emerges as a key mediating force, with AI offering a conducive environment for emotional exploration and articulation. Through this emotional navigation, users potentially harness strategies that mitigate social anxiety in both digital and real-world domains. Mindfulness accentuates this dynamic, acting as a protective bulwark. High mindfulness levels seem to counteract potential pitfalls of intensive virtual interactions, emphasizing the invaluable role of self-awareness in our digital engagements.

However, our study is not without its limitations. The specific demographic, undergraduate students from Eastern China enrolled in computer courses, may limit the generalizability of our findings. Additionally, the reliance on users' self-report data introduces another potential limitation regarding objectivity and behavioral accuracy. Future research could profit from not only broadening the participant spectrum, incorporating varied demographics and cultural contexts, but also integrating actual behavior data to affirm the veracity and applicability of the findings.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical Approval and Written Consent

The studies involving human participants were reviewed and approved by the Ethics Committee of Shanghai Jiao Tong (code B2022328I). The participants provided their written informed consent to participate in this study. The study complies with the Declaration of Helsinki.

Acknowledgments

Thanks to all the participants in the survey.

Disclosure

The authors declare no conflicts of interest in this work.

References

1. Strohmann T, Siemon D, Khosrawi-Rad B, Robra-Bissantz S. Toward a design theory for virtual companionship. *Hum-Comput Interact*. 2023;38:194–234. doi:10.1080/07370024.2022.2084620
2. Gong JK, Firdaus A, Said F, Aksar IA, Danaee M, Xu JH. Pathways linking media use to wellbeing during the COVID-19 pandemic: a mediated moderation study. *Soc Media Soc*. 2022;8:87390. doi:10.1177/20563051221087390
3. Aksar IA, Danaee M, Firdaus A, Gong JK. Moderating effect of gender between social media needs and psychological wellbeing: a case study of Pakistani adolescents. *J Hum Behav Soc Envi*. 2022;32(3):383–401. doi:10.1080/10911359.2021.1901823
4. Weeks JW, Heimberg RG, Rodebaugh TL. The fear of positive evaluation scale: assessing a proposed cognitive component of social anxiety. *J Anxiety Disord*. 2008;22:44–55. doi:10.1016/j.janxdis.2007.08.002
5. Liu XQ, Zhang YF, Gao WJ, Cao XJ. Developmental trajectories of depression, anxiety, and stress among college students: a piecewise growth mixture model analysis. *Hum Soc Sci Commun*. 2023;736:10. doi:10.1057/s41599-023-02252-2
6. Romano M, Moscovitch DA, Ma RF, Huppert JD. Social problem solving in social anxiety disorder. *J Anxiety Disord*. 2019;68:102152. doi:10.1016/j.janxdis.2019.102152
7. Abdul-Ghani E, Kim J, Kwon J, Hyde KF, Cui YY. Love or like: gender effects in emotional expression in online reviews. *Eur J Marketing*. 2022;56:3592–3616. doi:10.1108/Ejm-01-2021-0064
8. Poon KT, Jiang YF. Getting less likes on social media: mindfulness ameliorates the detrimental effects of feeling left out online. *Mindfulness*. 2020;11:1038–1048. doi:10.1007/s12671-020-01313-w
9. Meynadier J, Malouff JM, Loi NM, Schutte NS. Lower mindfulness is associated with problematic social media use: a meta-analysis. *Curr Psychol*. 2023. doi:10.1007/s12144-023-04587-0
10. Shabahang R, Aruguete MS, Shim H. Social media posting anxiety interpersonal trust, fear of negative evaluation, and hurt feeling proneness as predictors. *J Media Psychol-Ger*. 2022;34:49–54. doi:10.1027/1864-1105/a000300
11. Weeks JW, Heimberg RG, Rodebaugh TL, Norton PJ. Exploring the relationship between fear of positive evaluation and social anxiety. *J Anxiety Disord*. 2008;22:386–400. doi:10.1016/j.janxdis.2007.04.009
12. D'Alfonso S. AI in mental health. *Current Opinion in Psychology*. 2020;36:112–117. doi:10.1016/j.copsyc.2020.04.005
13. Cao XJ, Liu XQ. Artificial intelligence-assisted psychosis risk screening in adolescents: practices and challenges. *World J Psychiatr*. 2022;12:1287–1297. doi:10.5498/wjp.v12.i10.1287
14. Pack A, Maloney J. Using generative artificial intelligence for language education research: insights from using OpenAI's chatgpt. *TESOL Quart*. 2023;57(4):1571–1582. doi:10.1002/tesq.3253
15. Cobb S. Social support as a moderator of life stress. *Psychosom Med*. 1976;38(5):300–314. doi:10.1097/00006842-197609000-00003
16. Lee MS, Lee JJ, Park S, Kim S, Lee H. Is social support associated with postpartum depression, anxiety and perceived stress among Korean women within the first year postpartum? *J Psychosom Obst Gyn*. 2023;44:2231629. doi:10.1080/0167482x.2023.2231629
17. He S, Jiang SW, Zhu RL, Hu X. The influence of educational and emotional support on e-learning acceptance: an integration of social support theory and TAM. *Educ Inf Technol*. 2023;28:11145–11165. doi:10.1007/s10639-023-11648-1
18. Gross JJ. Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. *J Pers Soc Psychol*. 1998;74:224–237. doi:10.1037/0022-3514.74.1.224
19. Slovak P, Antle A, Theofanopoulou N, Roquet CD, Gross J, Isbister K. Designing for emotion regulation interventions: an agenda for HCI theory and research. *ACM T Comput-Hum Int*. 2023;30. doi:10.1145/3569898
20. Miers AC, Sumter SR, Clark DM, Leigh E. Interpretation bias in online and offline social environments and associations with social anxiety, peer victimization, and avoidance behavior. *Cognitive Ther Res*. 2020;44:820–833. doi:10.1007/s10608-020-10097-1
21. Purdon C, Antony M, Monteiro S, Swinson RP. Social anxiety in college students. *J Anxiety Disord*. 2001;15:203–215. doi:10.1016/S0887-6185(01)00059-7
22. Kuckertz JM, Strege MV, Amir N. Intolerance for approach of ambiguity in social anxiety disorder. *Cognition Emotion*. 2017;31:747–754. doi:10.1080/02699931.2016.1145105
23. Jensen D, Bruce LC, Heimberg RG, Matt LM, Morrison AS. Social anxiety and misinterpretation of the five facet mindfulness questionnaire subscale. *J Cogn Psychother*. 2016;30:168–176. doi:10.1891/0889-8391.30.3.168

24. Zhu DH, Deng ZZ. Effect of social anxiety on the adoption of robotic training partner. *Cyberpsych Beh Soc N*. 2021;24:343–348. doi:10.1089/cyber.2020.0179
25. Nomura T, Kanda T, Suzuki T, Yamada S. Do people with social anxiety feel anxious about interacting with a robot? *Ai Soc*. 2020;35:381–390. doi:10.1007/s00146-019-00889-9
26. Park G, Lee SY, Chung JY. Do anthropomorphic chatbots increase counseling satisfaction and reuse intention? The moderated mediation of social rapport and social anxiety. *Cyberpsych Beh Soc N*. 2023;26(5):357–365. doi:10.1089/cyber.2022.0157
27. Ali F, Zhang QY, Tauni MZ, Shahzad K. Social chatbot: my friend in my distress. *Int J Hum-Comput Int*. 2023. doi:10.1080/10447318.2022.2150745
28. Hu B, Mao YY, Kim KJ. How social anxiety leads to problematic use of conversational AI: the roles of loneliness, rumination, and mind perception. *Comput Hum Behav*. 2023;145:107760. doi:10.1016/j.chb.2023.107760
29. Marino C, Manari T, Vieno A, et al. Problematic social networking sites use and online social anxiety: the role of attachment, emotion dysregulation and motives. *Addict Behav*. 2023;138:107572. doi:10.1016/j.addbeh.2022.107572
30. Hutchins N, Allen A, Curran M, Kannis-Dymand L. Social anxiety and online social interaction. *Aust Psychol*. 2021;56:142–153. doi:10.1080/00050067.2021.1890977
31. Wang L, Chen J The influence of fear of negative evaluation on consumers' preference for AI services. 2022 2nd International Conference on Management Science and Software Engineering (ICMSSE 2022). Atlantis Press; 2013. 561–565.
32. Chang YC, Hsing YC. Emotion-infused deep neural network for emotionally resonant conversation. *Appl Soft Comput*. 2021;113:107861. doi:10.1016/j.asoc.2021.107861
33. Liu BJ, Sundar SS. Should machines express sympathy and empathy? Experiments with a health advice chatbot. *Cyberpsych Beh Soc N*. 2018;21:625–636. doi:10.1089/cyber.2018.0110
34. Han ELZB, Yin DZ, Zhang H. Bots with feelings: should ai agents express positive emotion in customer service? *Inform Syst Res*. 2022. doi:10.1287/isre.2022.1179
35. Dijk C, Fischer AH, Morina N, van Eeuwijk C, van Kleef GA. Effects of social anxiety on emotional mimicry and contagion: feeling negative, but smiling politely. *J Nonverbal Behav*. 2018;42:81–99. doi:10.1007/s10919-017-0266-z
36. Spokas M, Luterek JA, Heimberg RG. Social anxiety and emotional suppression: the mediating role of beliefs. *J Behav Ther Exp Psy*. 2009;40:283–291. doi:10.1016/j.jbtep.2008.12.004
37. Kivity Y, Huppert JD. Emotional reactions to facial expressions in social anxiety: a meta-analysis of self-reports. *Emot Rev*. 2016;8:367–375. doi:10.1177/1754073915594436
38. Iani L, Lauriola M, Cafaro V, Didonna F. Dimensions of mindfulness and their relations with psychological well-being and neuroticism. *Mindfulness*. 2018;9:670–671. doi:10.1007/s12671-018-0918-z
39. Parsons EM, Luebbe AM, Clerkin EM. Testing the relationship between social anxiety schemas, mindfulness facets, and state and trait social anxiety symptoms. *Mindfulness*. 2017;8:1634–1643. doi:10.1007/s12671-017-0738-6
40. Wang YZ, Chen J, Zhang XS, et al. The relationship between perfectionism and social anxiety: a moderated mediation model. *Int J Environ Res Public Health*. 2022;19: doi:10.3390/ijerph191912934
41. Yang XJ, Zhou ZK, Liu QQ, Fan CY. Mobile phone addiction and adolescents' anxiety and depression: the moderating role of mindfulness. *J Child Fam Stud*. 2019;28:822–830. doi:10.1007/s10826-018-01323-2
42. Graham JW, Olchowski AE, Gilreath TD. How many imputations are really needed? - Some practical clarifications of multiple imputation theory. *Prev Sci*. 2007;8:206–213. doi:10.1007/s11121-007-0070-9
43. Enders CK. A primer on maximum likelihood algorithms available for use with missing data. *Struct Equation Model*. 2001;8:128–141. doi:10.1207/S15328007sem0801_7
44. Su S, Larsen H, Cousijn J, Wiers RW, Van den Eijnden RJJM. Problematic smartphone use and the quantity and quality of peer engagement among adolescents: a longitudinal study. *Comput Hum Behav*. 2022;126:107025. doi:10.1016/j.chb.2021.107025
45. Alkis Y, Kadirhan Z, Sat M. Development and validation of social anxiety scale for social media users. *Comput Hum Behav*. 2017;72:296–303. doi:10.1016/j.chb.2017.03.011
46. Mattick RP, Clarke JC. Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behav Res Ther*. 1998;36:455–470. doi:10.1016/S0005-7967(97)10031-6
47. Gross JJ, John OP. Facets of emotional expressivity - 3 self-report factors and Their correlates. *Pers Indiv Differ*. 1995;19:555–568. doi:10.1016/0191-8869(95)00055-B
48. Brown KW, Ryan RM. The benefits of being present: mindfulness and its role in psychological well-being. *J Pers Soc Psychol*. 2003;84:822–848. doi:10.1037/0022-3514.84.4.822
49. Podsakoff PM, MacKenzie SB, Lee JY, Podsakoff NP. Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J Appl Psychol*. 2003;88:879–903. doi:10.1037/0021-9010.88.5.879
50. Viswanathan M, Kayande U. Commentary on "common method bias in marketing: causes, mechanisms, and procedural remedies". *J Retailing*. 2012;88(4):300–314. doi:10.1097/00006842-197609000-00003
51. Chin WW, Thatcher JB, Wright RT. Assessing common method bias: problems with the ulmc technique. *Mis Quart*. 2012;36:1003–1019. doi:10.2307/41703491
52. Eamiello ML, Reid AE. Does online social support uniquely buffer effects of stress during the COVID-19 pandemic?: a natural experiment. *Soc Personal Psychol*. 2023;17:doi:10.1111/spc3.12836
53. Katz Y. Interacting for Peace: rethinking peace through interactive digital platforms. *Soc Media Soc*. 2020;6:926620. doi:10.1177/2056305120926620
54. Barbareschi G, Oldfrey B, Xin L, et al. Bridging the divide: exploring the use of digital and physical technology to aid mobility impaired people living in an informal settlement. 22nd International ACM Sigaccess Conference on Computers and Accessibility (Assets '20). 2020.
55. Woodcock KA, Cheung C, Marx DG, Mandy W. Social decision making in autistic adolescents: the role of theory of mind, executive functioning and emotion regulation. *J Autism Dev Disord*. 2020;50:2501–2512. doi:10.1007/s10803-019-03975-5
56. Schodt KB, Mickelson KD. Emotion expressivity and regulation in romantic relationships: the role of social anxiety. *Couple Fam Psychol*. 2023. doi:10.1037/cfp0000249