

# Attachment Anxiety and Problematic Use of Conversational Artificial Intelligence: Mediation of Emotional Attachment and Moderation of Anthropomorphic Tendencies

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**Purpose:** The advent of conversational AI has offered individuals an alternative communication modality and an interactive partner outside traditional social media through one-on-one personalized services. This has given rise to a critical question: Does this technological innovation negatively affect specific populations? The sample for this study was comprised of individuals with attachment anxiety. The aims of the study were to explore the relationship between attachment anxiety and problematic use of conversational artificial intelligence and to investigate the mediating role of emotional attachment and the moderating role of anthropomorphic tendency.

**Patients and Methods:** Fifty-four Chinese adults who used conversational artificial intelligence were randomly selected to complete the questionnaires of attachment anxiety, emotional attachment, anthropomorphic tendency and the use of conversational artificial intelligence. Correlation analyses were employed to explore the relationships among the above mentioned variables, and the Hayes PROCESS test was used to test the mediating effect of emotional attachment and the moderating effect of anthropomorphic tendency.

**Results:** Attachment anxiety not only directly affects the problematic use of conversational artificial intelligence but also indirectly influences it through emotional attachment. The anthropomorphic tendency was also found to moderate the relationship between attachment anxiety and the problematic use of conversational artificial intelligence.

**Conclusion:** Individuals with high attachment anxiety urgently need relatively perfect partners to reduce negative emotions. While the emergence of conversational artificial intelligence meets their needs, there is a risk of excessive dependence. To solve this problem, developers should focus on the personification design of the product, embed usage control and educational content, and provide intervention measures for high-risk groups.

**Keywords:** conversational artificial intelligence, attachment anxiety, emotional attachment, anthropomorphic tendency, problematic technology use

## Introduction

Conversational artificial intelligence (CAI) refers to programs that utilize artificial intelligence and natural language processing techniques.<sup>1</sup> Unlike social media and other technologies, which function as platforms for user-to-user connections, CAI interacts with users as a virtual entity. These programs are engineered to engage in natural and intelligent dialogue with users through modalities such as speech, text, and images.<sup>2</sup> CAIs interact socially with users either verbally or in written form, offering personalized responses<sup>3</sup> and highly human-like representations.<sup>4</sup> Moreover, CAI systems can “learn” to adapt to various environments, demonstrating traits such as transferability, autonomy, and persistent memory.<sup>5,6</sup> These characteristics make CAI potentially more attractive for interaction than humans or other



robotic agents, which was quite evident during the COVID-19 pandemic as this event exacerbated social isolation and led to a loneliness pandemic.<sup>7,8</sup> During this period, millions turned to CAI for companionship.<sup>9</sup> For example, users of the chatbot “Xiaoice” averaged 23 conversations, surpassing typical human interactions.<sup>10</sup> While frequent CAI interactions can foster psychological connections, they may also give rise to the problematic use of conversational artificial intelligence (PUCAI).<sup>11</sup>

PUCAI refers to an individual’s use of CAI in an addictive manner with adverse consequences on daily life,<sup>12,13</sup> thus resulting in a vicious cycle that may lead to mental health problems.<sup>11,14,15</sup> This behavior is influenced by multiple factors, with individual factors being significant. Attachment anxiety, an important predictor of addictive behaviors such as problematic smartphone use and online game addiction,<sup>14,15</sup> may also affect PUCAI. However, few studies have explored the role of attachment anxiety in the PUCAI. Therefore, this study aimed to investigate the effects of attachment anxiety on the PUCAI and its underlying mechanisms from the perspective of emotional attachment on the basis of attachment theory.<sup>16</sup>

## Attachment Anxiety and PUCAI

Attachment refers to the emotional connection forged between an infant and a caregiver.<sup>16</sup> This bond plays a crucial role in directing individuals to establish and sustain relationships with important people throughout their lives.<sup>17</sup> Through early interactions with one or more primary caregivers, infants develop three distinct attachment styles: secure, avoidant, and anxious.<sup>18</sup> Among these factors, anxious attachment is the most significant risk factor for problematic technology use.<sup>19,20</sup>

Individuals with high attachment anxiety constantly fear abandonment or rejection, leading them to seek support and comfort and resulting in elevated relational needs.<sup>21</sup> They continually search for “substitutes” in the external world to satisfy their intimacy needs.<sup>22</sup> According to needs-affordances-features (NAF) theory,<sup>23</sup> individuals’ psychological needs drive them to use technologies such as smartphones or social media, which possess features that fulfill these needs, thereby resulting in problematic technology use. For example, social media can satisfy the excessive relational needs of individuals with anxious attachment,<sup>24</sup> leading to addictive use.<sup>22</sup> The personalization features of CAI, 24/7 timely feedback, highly anthropomorphic images, and social interactions with users have improved the satisfaction of users’ usage and made CAI a perfect attachment figure to meet the intimate needs of individuals with anxious attachment.<sup>15,25,26</sup> However, these features may exacerbate the dependency on CAI, leading to PUCAI. Therefore, we propose Hypothesis 1: Attachment anxiety is positively associated with PUCAI.

## Mediating Role of Emotional Attachment with CAI

Emotional attachment is the emotional bond that connects humans, animals, and inanimate objects. As such, it encompasses affection, liking, passion, fulfillment, and connectedness, which last for a lifetime in relationships with family members, loved ones, or objects.<sup>27</sup> According to attachment theory, emotional attachment represents the desire of individuals with anxious attachment to attach for security, attention, and intense love.<sup>28–30</sup> Specifically, individuals with anxious attachment crave a sense of belonging and establish connections and emotional bonds with others.<sup>31</sup> This need can be met through interpersonal relationships or inanimate objects such as robots.<sup>32,33</sup> When individuals are satisfied with inanimate objects, their socialization, connectedness, commitment, and loyalty are critical factors for individuals with anxious attachment as they attempt to form emotional attachments.<sup>33,34</sup> CAI features, such as storing chat history, understanding user habits, engaging in social interactions, and disclosing intimate information without prompts,<sup>35,36</sup> consumingly attracts individuals with anxious attachment and encourages them to establish emotional attachments.

When individuals with anxious attachment establish an emotional attachment with CAI, it not only satisfies their need for security but also enhances their perceived self-worth. However, if the individual’s use is interrupted, it leads to greater psychological distress and pain in individuals with anxious attachment.<sup>35,37</sup> To avoid experiencing these negative emotions, individuals continuously use CAI, thereby leading to problematic CAI use behavior.<sup>38</sup> Consequently, individuals with attachment anxiety are more predisposed to forming emotional attachments with CAI, resulting in an increased frequency and depth of interactions with CAI, which may ultimately evolve into PUCAI. Therefore, we propose Hypothesis 2: Emotional attachment mediates the relationship between attachment anxiety and PUCAI.

## The Moderating Role of Anthropomorphic Tendency

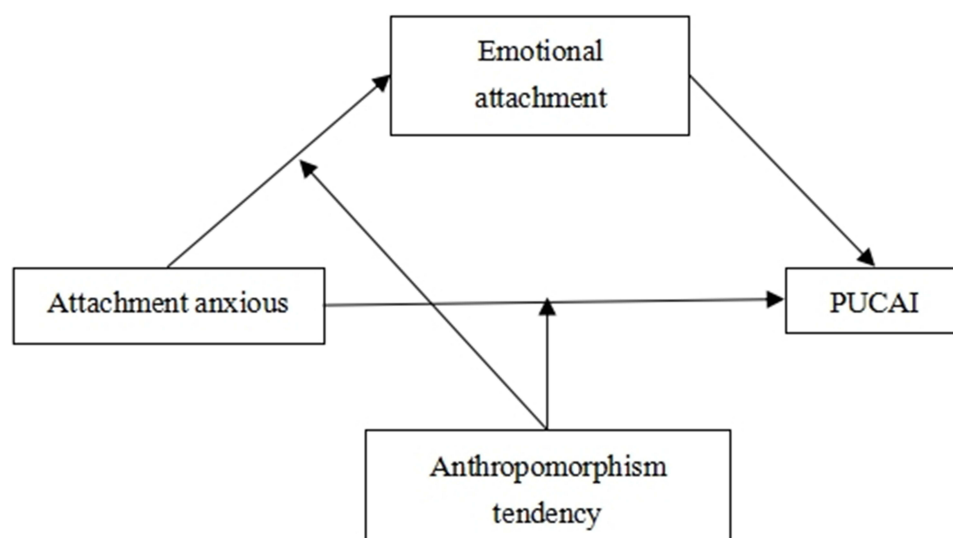
The mediating role of emotional attachment suggests that it is the proximal factor between attachment anxiety and PUCAI, with attachment anxiety influencing the PUCAI through emotional attachment. However, this mediation might be moderated by other factors, meaning that the effect might be significant for some individuals but not for others. Accordingly, this study aims to examine the moderating effect of anthropomorphic tendency on the pathway “attachment anxiety → emotional attachment → PUCAI.”

Anthropomorphism is defined as the attribution of human motives, intentions, or emotions to nonhuman entities, which represents an individual cognitive bias.<sup>39</sup> The anthropomorphic tendency, consequently, refers to the proclivity toward this cognitive deviation, where individuals habitually ascribe human characteristics to nonhuman objects. Those exhibiting a greater likelihood of anthropomorphizing are considered to possess a greater degree of anthropomorphic tendency.<sup>40</sup> Studies on excessive acquisition have demonstrated that individuals with anxious attachment styles and elevated anthropomorphic tendencies tend to suffer from more severe hoarding disorders.<sup>41,42</sup> This evidence suggests that anthropomorphic tendencies exacerbate addictive behaviors among individuals with anxious attachment.

Therefore, this study speculates that, compared with individuals with anxious attachment and low anthropomorphic tendencies, those with high anthropomorphic tendencies may use their interactions with CAI to compensate for a lack of intimacy, to alleviate emotional distress, and to attain a sense of security, thereby fulfilling their psychological needs. On the basis of these findings, we propose Hypothesis 3a: Anthropomorphic tendencies positively moderate the relationship between attachment anxiety and the PUCAI.

CAI exhibits empathetic capabilities<sup>39,40</sup> and offers timely,<sup>31</sup> personalized feedback. These features are particularly significant, as they provide attachment security and a sense of belonging, and they enhance self-worth among individuals with anxious attachment styles. Additionally, prior research has indicated that individuals’ anthropomorphic tendencies play a crucial role in fostering emotional attachment to inanimate objects.<sup>42,43</sup> Given these established relationships, it follows that, compared with individuals with low anthropomorphic tendencies, those with anxious attachment styles and high anthropomorphic tendencies are more susceptible to forming emotional attachments to CAI. The empathetic and personalized characteristics of CAI act as catalysts, thereby enabling these individuals to establish deeper emotional connections, which may subsequently lead to the development of the PUCAI. Building on this theoretical framework and empirical evidence, we propose Hypothesis 3b: Anthropomorphic tendencies positively moderate the relationship between attachment anxiety and emotional attachment.

In summary, this study proposes a mediated moderation model (Figure 1) based on existing research and theory. The primary aims of this study were as follows: (1) to explore the relationship between attachment anxiety and the PUCAI;



**Figure 1** Model of the Relationships among Attachment Anxiety and PUCAI.

(2) to investigate whether anthropomorphic tendencies moderate this relationship; and (3) to test whether this moderation occurs via the mediating variable of emotional attachment, with the intention of achieving a more profound understanding of the mechanisms underlying the relationship between attachment anxiety and the PUCAI. This corresponds to the following four assumptions:

**Hypothesis 1.** Attachment anxiety is positively associated with the PUCAI.

**Hypothesis 2.** Emotional attachment mediates the relationship between attachment anxiety and the PUCAI.

**Hypothesis 3a.** Anthropomorphic tendencies positively moderate the relationship between attachment anxiety and the PUCAI.

**Hypothesis 3b.** Anthropomorphic tendencies positively moderate the relationship between attachment anxiety and emotional attachment.

## Material and Methods

### Participants

A total of 572 participants were recruited via the Wenjuanxing platform using random sampling methods. The questionnaire collection period was from March to April 2024. All participants signed informed consent forms. After excluding those who had never used CAI and those who filled out the questionnaires carelessly (eg, the attention detection question was answered incorrectly), 504 participants were included in the data analysis, resulting in a valid recovery rate of 88.11%. Among those included, 248 were male (49.206%) and 261 were female (51.785%). The participants' ages ranged from 17 to 54 years ( $M = 22.540$ ,  $SD = 5.146$ ). In terms of education, 180 participants (35.714%) had a college degree or lower, 198 participants (39.285%) had a bachelor's degree, and 131 participants (25.992%) had a master's degree or higher.

### Measures

#### Attachment Anxiety Scale

A short version of the Experiences in Close Relationships (ECR) scale adapted by Chen was used.<sup>24</sup> This scale is composed of six items. Responses are rated on a 5-point Likert scale, where 1 indicates "complete noncompliance" and 5 represents "full compliance". The Cronbach's  $\alpha$  in this study was 0.726.

#### Emotional Attachment Scale

The emotional attachment scale developed by Jimenez and Voss was adopted.<sup>44</sup> This scale consists of four items, including "I feel no emotional bond/strong emotional bond with the conversational AI." Each item is rated on a 7-point Likert scale, with higher scores indicating stronger emotional attachment. The Cronbach's  $\alpha$  for this study was 0.925.

#### Anthropomorphic Tendency Scale

The scale adapted by Kim and Im for measuring anthropomorphic individual differences was adopted.<sup>40,45</sup> It was assessed via seven items (eg, "I think AI is alive."). The participants were instructed to indicate the degree of their agreement with each item on a 5-point Likert scale. The scale ranged from 1, denoting "strongly disagree" to 5, signifying "strongly agree." The Cronbach's  $\alpha$  for this study was 0.923.

#### PUCAI

The PUCAI scale developed by Hu et al was adopted. This scale consists of six items, such as "I tried to reduce my use of CAI but was unsuccessful."<sup>12</sup> Each item is rated on a 5-point Likert scale ranging from 1, "very rarely" to 5 "very often." The Cronbach's  $\alpha$  for this study was 0.934.

With the exception of the PUCAI scale, which has a Chinese version, the other three scales were verified by a bilingual expert team through forward and reverse translation to ensure the reliability and validity of the Chinese version. The scales used above are shown in the **six** ([Questionnaire items](#)).

## Data Analysis

Descriptive and correlation analyses were conducted via SPSS 26, and the mediating adjustment model was tested via Model 8 in the PROCESS macro plugin.<sup>46</sup>

## Results

### Multicollinearity

All predictors were centered to minimize multicollinearity.<sup>47</sup> Stepwise regression analysis confirmed that the variance inflation factor for all predictors was less than 3, indicating that there was no multicollinearity in this study.

### Descriptive Statistics and Correlation Analysis

Descriptive statistics and correlation analyses were conducted for four variables: attachment anxiety, emotional attachment, anthropomorphic tendency, and PUCAI. The results are presented in Table 1.

As shown in Table 1, attachment anxiety is positively correlated with emotional attachment ( $r = 0.502, p < 0.001$ ), anthropomorphic tendency ( $r = 0.480, p < 0.001$ ), and the PUCAI ( $r = 0.475, p < 0.001$ ). Emotional attachment ( $r = 0.799, p < 0.001$ ) and anthropomorphic tendency ( $r = 0.681, p < 0.001$ ) are positively correlated with PUCAI. Emotional attachment is positively correlated with anthropomorphic tendencies ( $r = 0.688, p < 0.001$ ). These correlation analysis results indicate that the relationships among attachment anxiety, emotional attachment, anthropomorphic tendency, and PUCAI meet the requirements for testing a mediated moderation model.

### Testing for Mediated Moderating Effects

Sex, age, and education level, which can influence users' acceptance and behavior toward CAI,<sup>48</sup> were included as covariates in the data analysis.

We used Model 8 from Hayes' PROCESS macro to test the mediated moderation and the results are presented in Table 2.<sup>49</sup> To increase precision, we employed percentile bootstrapping and bias-corrected percentile bootstrapping with 5,000 resamples to compute 95% confidence intervals for indirect effects. This approach ensures robust estimation of effect magnitudes and sampling variability in mediational analyses.

As presented in Table 2, Equation 1 reveals that attachment anxiety and anthropomorphic tendency are significant predictors of PUCAI ( $\beta = 0.260, p < 0.001$ ;  $\beta = 0.532, p < 0.001$ ), with a significant moderating effect of anthropomorphic tendency ( $\beta = 0.158, p < 0.001$ ). Equation 2 reveals significant main effects of attachment anxiety and the tendency toward anthropomorphism on emotional attachment ( $\beta = 0.445, p < 0.001$ ;  $\beta = 0.793, p < 0.001$ ), as well as a significant interaction effect ( $\beta = 0.200, p < 0.001$ ). In Equation 3, both anthropomorphic tendency and emotional attachment demonstrate significant effects on the PUCAI ( $\beta = 0.227, \beta = 0.384, p < 0.001$ ), as does the interaction effect of attachment anxiety and anthropomorphic tendency on the PUCAI ( $\beta = 0.081, p = 0.0103 < 0.05$ ). The results of the regression analyses indicates that a mediated moderated-effects model explains the relationships between the variables and that emotional attachment plays a partial mediating role in this model, with a mediated-effects value of 0.434, accounting for 38.7% of the total effect. Moreover, the tendency toward anthropomorphism moderates the relationships between attachment anxiety and the PUCAI score and between attachment anxiety and emotional attachment.

To reveal more clearly the moderating role played by anthropomorphic tendencies with respect to the relationship between attachment anxiety and the PUCAI, we divided the participants into high- and low-anthropomorphic groups according to plus or

**Table 1** Means, Standard Deviations, and Correlations for Variables

	M	SD	1	2	3	4
1 attachment anxiety	2.827	0.777	–			
2 emotional attachment	2.845	1.513	0.502***	–		
3 anthropomorphic tendency	2.383	1.015	0.480***	0.688***	–	
4 PUCAI	2.122	1.025	0.475***	0.799***	0.681***	–

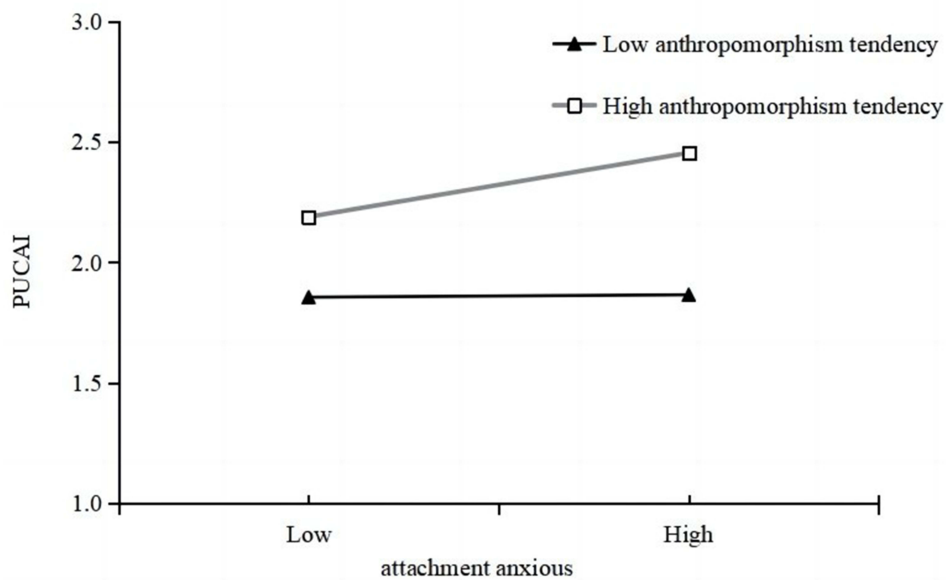
Notes: \*\*\* $p < 0.001$ , two-sided test.

**Table 2** Testing the Mediated Moderating Effects of Attachment Anxiety on PUCAI

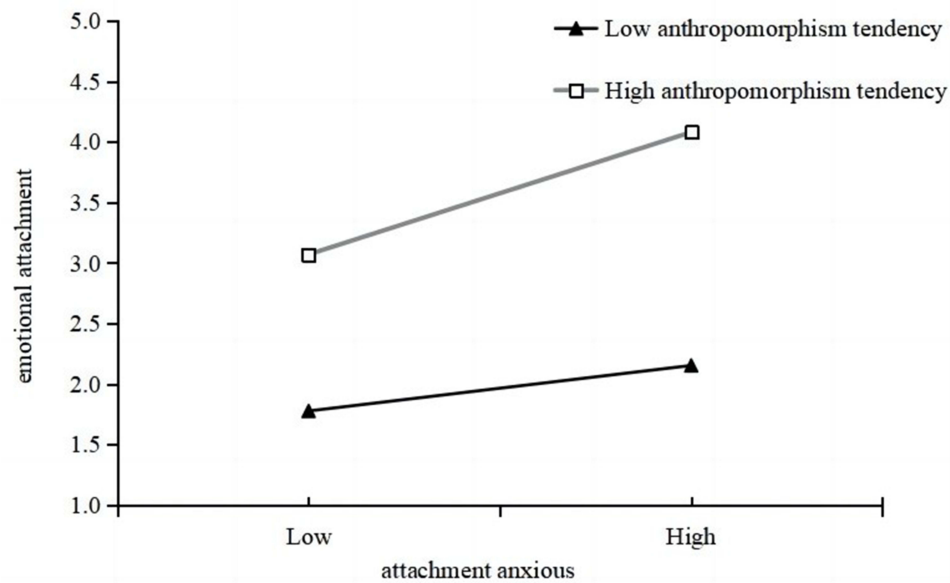
	Equation 1 (PUCAI)		Equation 2 (Emotional Attachment)		Equation 3 (PUCAI)	
	$\beta$	$t$	$\beta$	$t$	$\beta$	$t$
Age	0.031	4.516	0.035	3.443	0.017	3.072
Gender	-0.070	-0.949	-0.024	-0.221	-0.061	-0.998
Education level	0.069	1.382	0.035	0.474	0.055	1.350
Attachment anxious	0.260	5.372***	0.445	6.229***	0.089	2.147*
Anthropomorphic tendency	0.532	14.515***	0.793	14.654***	0.227	6.287***
Attachment anxious $\times$ anthropomorphic tendency	0.158	4.188***	0.200	3.594***	0.081	2.574*
Emotional attachment					0.384	15.342***
$R^2$	0.539		0.540		0.688	
$F$	17.545***		12.91***		6.628*	

Notes: \* $p < 0.05$ , \*\*\* $p < 0.001$ , two-sided test.

minus one standard deviation, and a simple slope test was performed to examine how the relationship between attachment anxiety and PUCAI differed at different levels of anthropomorphic tendency. A simple effect analysis was performed (Figure 2). The results of the test reveal that attachment anxiety did not significantly predict PUCAI when the tendency for anthropomorphism was low ( $\beta_{\text{simple}} = 0.006, t = 0.141, p > 0.05$ ) but did significantly predict the PUCAI when the tendency for anthropomorphism was high ( $\beta_{\text{simple}} = 0.171, t = 2.987, p < 0.01$ ). Simple slope tests of the moderating role of the tendency toward anthropomorphism between attachment anxiety and emotional attachment indicated (Figure 3), that individuals with attachment anxiety develop stronger emotional attachment to CAI as the level of tendency toward anthropomorphism increases ( $\beta_{\text{simple}} = 0.006, t = 0.141, p < 0.01$ ;  $\beta_{\text{simple}} = 0.648, t = 6.583, p < 0.001$ ). The Cohen’s  $f^2$  of the moderating effect is 0.15, indicating a moderate effect intensity. These results suggest that the tendency toward anthropomorphism moderates the relationships between attachment anxiety and both PUCAI scores and emotional attachment.



**Figure 2** Moderation of attachment anxiety and PUCAI by tendency toward anthropomorphic.



**Figure 3** Moderation of attachment anxiety and emotional attachment by anthropomorphic tendencies.

## Discussion

This study aimed to explore the relationship between attachment anxiety and the PUCAI and its underlying mechanisms. The results indicate that the relationships among attachment anxiety, anthropomorphic tendencies, emotional attachment, and PUCAI can be explained by a mediated moderation model. Attachment anxiety not only directly influences the PUCAI but also indirectly affects the PUCAI through emotional attachment, especially for individuals with high levels of anthropomorphic tendencies.

### Attachment Anxiety and PUCAI

The results indicate that individuals with higher levels of attachment anxiety are more likely to use CAI problematically, thereby supporting Hypothesis 1. This finding is consistent with previous research, which has indicated that individuals with an anxious attachment style are at a greater risk of developing other types of technology addiction, such as smartphone addiction and internet addiction.<sup>48,50</sup>

As social creatures,<sup>51</sup> humans are driven by a fundamental instinct to seek relationships.<sup>52</sup> When psychological needs become intense and frequent, individuals may develop compulsive behaviors and addiction tendencies.<sup>53</sup> The lack of self-worth in relationships causes individuals with anxious attachment to be more sensitive to signs of abandonment and rejection, resulting in an excessive need for closeness and validation from others.<sup>22,50,54</sup> The emergence of CAI has rendered it a convenient tool for users with high attachment anxiety to meet their social needs. During interactions with CAI, users do not have to worry about being abandoned or rejected, and their psychological deficiencies are effectively satisfied. This positive experience of demand satisfaction cultivates and strengthens the addictive tendency, thus resulting in problematic usage behaviors.

### Mediating Role of Emotional Attachment

In addition to demonstrating that attachment anxiety and emotional attachment to CAI are positive predictors of PUCAI, this study revealed that emotional attachment serves as a mediator in the relationship between attachment anxiety and PUCAI, thus supporting Hypothesis 2. This finding is in line with previous research indicating that individuals with anxious attachment style are prone to forming strong emotional attachments to objects.<sup>55,56</sup> When separated from CAI, this emotional attachment leads to greater anxiety and distress.<sup>12,38</sup>

Emotional attachment is partly driven by social needs.<sup>38</sup> According to the compensatory attachment strategy, when the emotional needs of individuals with anxious attachment are not met in real life, they seek substitutes that are often nonhuman objects as they are considered more reliable for reducing anxiety.<sup>55</sup> CAI provides the emotional value and security sought by individuals with anxious attachment as it is endowed with empathy, engages in personalized social interactions on the basis of user needs, and mimics human behavior and emotions to alleviate the negative feelings being experienced by individuals with anxious attachment.<sup>35</sup> These features render CAI a more reliable compensatory attachment object. This explains why individuals with anxious attachment continuously contact CAI to avoid anxiety or distress caused by separation.

## Moderating Role of Anthropomorphic Tendency

The relationship between attachment anxiety/emotional attachment and PUCAI is also moderated by individuals' anthropomorphic tendency levels. In the direct path, only individuals with high anthropomorphic tendencies are likely to exhibit addiction tendencies. However, in terms of the relationship between attachment anxiety and emotional attachment, anxious individuals develop emotional attachments to CAI regardless of their anthropomorphic tendencies; ie, individuals with greater anthropomorphic tendencies form stronger emotional attachments to CAI. Hypotheses 3a and 3b are supported.

Anthropomorphic tendencies reinforce the positive associations between attachment anxiety and the PUCAI, as well as between attachment anxiety and emotional attachment given that individuals with high levels of attachment anxiety exhibit greater desires for social belonging, feedback, and comfort. These needs can be partly satisfied through CAI. When individuals possess high anthropomorphic tendencies, they perceive CAI as real individuals available for social interaction. This perception enhances the overall quality of their interactions with AI and prompts anxious attachment users to engage more deeply in technology-based interactions.<sup>57</sup> During these interactions, individuals with anxious attachment develop emotional attachments to CAI and experience positive effects such as intimacy because their strong relational needs are being met. Therefore, compared with individuals with low levels of anthropomorphic tendencies, individuals with high levels of such inclinations are more likely to develop emotional attachments to CAI and experience PUCAI.

## Research Significance and Future Directions

From the perspective of the social needs of individuals with anxious attachment and the support and characteristics provided by CAI, this study explores how individuals with anxious attachment develop PUCAI through emotional attachment and the moderating role of individual anthropomorphic tendencies. The findings of this study also have practical implications for the prevention and intervention of technology addiction in people with anxious attachment. In other words, CAI design should consciously screen for individuals with anxious attachment, offer CAI products with low anthropomorphic design for these users, and provide psychological intervention suggestions such as mindfulness to reduce anxiety, thereby decreasing dependency.

This study has several limitations. First, this was a cross-sectional study, thus preventing the inference of causality between variables. Future research should use longitudinal or experimental designs to validate these results. Second, the study results suggest that attachment anxiety positively predicts an individual's anthropomorphic tendencies.<sup>54</sup> Thus, anthropomorphic tendencies could be used as a mediating variable in future research to explore their role in the relationship between attachment anxiety and the PUCAI. Third, future research should investigate the role of the anthropomorphic design of technology in this process. Finally, various types of CAI in the market, such as chatbots, virtual assistants, and embedded robots, meet different user needs and motivations (eg, practical, entertainment, or social purposes). Further research is needed to explore the impact of unique CAI technological capabilities and usage purposes on the PUCAI.

## Conclusion

This study represents a crucial stride in revealing how attachment anxiety forecasts the PUCAI. The results indicate that the impact of attachment anxiety on the PUCAI is partially due to emotional attachment. Moreover, anthropomorphic

tendencies regulate this indirect connection both in the direct pathway and in the initial stage of the mediation process. These findings not only deepen our understanding of the psychological mechanisms underlying PUCAI but also provide valuable insights for developing targeted interventions to address problematic usage behaviors.

## Data Sharing Statement

The data for this study are available from the following DOI: 10.17632/jgpmrmmz8t.1.

## Ethics Approval and Informed Consent

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the institutional review board of the Institute of Education, Henan Normal University, China (ethical code: 20220610). All participants signed an informed consent form prior to beginning the questionnaire and could withdraw from the questionnaire at any time.

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## Disclosure

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

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