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Rong Huang

University of Turku, rong.r.huang@utu.fi

Yang Bai

Central China Normal University, yang.bai@ccnu.edu.cn

Hongxiu Li

Tampere University, hongxiu.li@tuni.fi

Reima Suomi

University of Turku, reima.suomi@utu.fi

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THE RELATIONSHIP BETWEEN HUMAN AND VIRTUAL AGENTS: A LIFE CYCLE VIEW

Research Paper

Rong, Huang, University of Turku, Finland, rong.r.huang@utu.fi

Yang, Bai, Central China Normal University, China, yang.bai@ccnu.edu.cn

Hongxiu, Li, Tampere University, Finland, hongxiu.li@tuni.fi

Reima, Suomi, University of Turku, Finland, reima.suomi@utu.fi

Abstract

Virtual agents powered by artificial intelligence (AI) have been implemented in different service contexts, leading to changes in our daily lives. Previous studies have examined individual users' motivations to use virtual agents and the impact of virtual agents as social objects on users. However, there is a lack of knowledge on the relationship development between human and virtual agents, which could help understand the role of virtual agents in societies. In this work, we chose the mobile app Replika as our research context and used a topic-modeling approach to explore the major topics covered in online reviews about Replika on Twitter. Applying social penetration theory, we identified four stages of the relationship between users and Replika, including relationship formation, exploration, maintenance, and destruction or termination. Our findings contribute to the literature by unraveling a life cycle of the relationship development between human and virtual agents.

Keywords: Virtual agents, Artificial intelligence, Relationship, Social penetration theory.

1 Introduction

The advancement of virtual agents powered by AI offers the prospect of remarkable changes in service delivery and experiences, ranging from digital travel assistants and online medical doctors to virtual companions (Barhorst *et al.*, 2021; Hao, 2022; Krieger *et al.*, 2021; Phaosathianphan and Leelasantitham, 2021). According to Juniper Research, the virtual agent market to end consumers will reach \$142 billion by 2024, up from \$2.8 billion in 2019 (Sudlow-Poole, 2022). As popular virtual companions in the mobile market, Replika and XiaoIce brought in over \$6 billion in global revenue in 2021 (Grassi *et al.*, 2022). The growing popularity of virtual agents is disrupting how humans build social connections with technologies and has attracted intense attention from both practitioners and academics.

Various studies have examined virtual agent use among end users from different angles. For instance, one research stream has explored various features of virtual agents from a technological view, such as conversation types (Diederich *et al.*, 2022), virtual experiences (Pakanen *et al.*, 2022), and anthropomorphism characteristics (Ben Saad and Choura, 2022). Another research stream has drawn attention to mixed effects of implementing virtual agents on users' acceptance (Araujo, 2018), engagement (Chiang *et al.*, 2017), and satisfaction with business services (Chung *et al.*, 2020) from an organizational view. Moreover, a third research stream has subscribed to a social psychology view by analyzing users' motivations (Koike and Loughnan, 2021) to use virtual agents and affective responses

(Ta *et al.*, 2020) to interact with them, which suggests that users may view virtual agents as social actors and form a relationship with them through reciprocal self-disclosure in the virtual world.

Prior research has primarily focused on how and why users interact with virtual agents as social actors in daily life while largely neglecting the relationship between human and virtual agents. However, some researchers have emphasized the potential impact of building a relationship with virtual agents on users' expectations and decision-making processes for real-life relationships due to the anthropomorphism of virtual agents (Ho *et al.*, 2018). Thus, exploring the relationship between human and virtual agents could help understand the role of virtual agents in societies and bring new insights into the nature of human-AI relationship (de Graaf *et al.*, 2015; Skjuve *et al.*, 2021).

The findings of extant studies on the relationship between virtual agents and human are inconclusive. A couple of studies have attempted to explain the development of social relationship between human and virtual agents based on survey and interview data (Skjuve *et al.*, 2021; Skjuve *et al.*, 2022; Xie and Pentina, 2022). However, these studies have mainly provided knowledge on how users develop the relationship with virtual agents and failed to unfold the process of relationship evolution between human and virtual agents. Thus, there is a need for research to examine the relationship formation and evolution between human and virtual agents from a life cycle view, which could shed light on the stages of relationship development between users and virtual agents, as well as the factors that are related to each stage.

To fill the above research gap, this study aims to employ the social penetration theory (SPT) (Altman and Taylor, 1973) to answer the research question: How does the relationship between human and virtual agents form and evolve from a life cycle view? Specifically, in this study, we chose one popular virtual companion Replika as our research context and collected 103,122 tweets about Replika from Twitter, which were generated by users between January 2017 and September 2022. Topic modeling based on the Latent Dirichlet Allocation (LDA) model (Blei *et al.*, 2003) was applied in data analysis to identify the major topics covered in the tweets generated by Replika users. Eight topics were identified, which explain the relationship formation and evolution between human and Replika. This study will strengthen the current knowledge of human-AI relationship for both scholars and practitioners.

2 Related Work

2.1 Virtual agents

According to Choi *et al.* (2001), virtual agents are computer-generated disembodied or virtually embodied entities representing imaginary characters or virtual beings controlled by AI. In the early stages, virtual agents were designed to imitate human speech and movement in video games and were operated by players, such as Mario, Pikachu, and Luigi (Schroeder and Epley, 2016). With the advancement of the capability of virtual agents to emulate human behavior, they have become prevalent in daily life and serve purposes beyond gaming and business services, such as socializing and companionship (Skjuve *et al.*, 2021). For example, Replika, XiaoIce, and Kuki, representing one form of the virtual agent, aim to provide empathetic conversations on a wide range of open-ended topics and support social relationships with humans, including friendships, mentorship, or even romantic relationships (Skjuve *et al.*, 2021; Zhou *et al.*, 2020).

Prior research has examined virtual agents from different perspectives, including the technological, organizational, and social psychology views. From a technological perspective, one research stream has explored virtual agents' technology features, including the conversation types (Diederich *et al.*, 2022), interactive modes (Haugeland *et al.*, 2022), and visual designs (Pakanen *et al.*, 2022). For instance, Diederich *et al.* (2022) proposed three types of virtual agents' interaction modes: textual interaction, vocal interaction, and interaction with embodied agents (e.g., 3D avatars). Pakanen *et al.* (2022) have evaluated the visual parameters of avatars in augmented reality (AR) and virtual reality (VR) based on body movements, facial expressions, and eye contact. Different interaction modes have also been combined to provide customers with rich virtual and co-present experiences, such as Pokemon Go with

virtual avatars operated by humans (Vettoreto, 2021) and Replika with a human-like avatar that enables reciprocal conversation interaction with humans (Skjuve *et al.*, 2021).

Virtual agents provide companies with new approaches to connecting and communicating with customers, and another research stream has investigated the value of virtual agents in marketing and communications from an organizational perspective. Some studies have examined the effects of virtual agent use on customers' positive attitudes towards organizations (Araujo, 2018), purchase intention (Chung *et al.*, 2020), value creation (Riikinen *et al.*, 2018), and long-term business development (De Visser *et al.*, 2016). Through implementing virtual agents in different business scenarios (e.g., booking travel and hotels, providing product information, health advice), the dialogic loop, responsiveness, and anthropomorphic features like empathy, compassion, and humor of virtual agents have been argued to be important in improving customer satisfaction and engagement with services (Chiang *et al.*, 2017; Go and Sundar, 2019; Koike and Loughnan, 2021).

Scholars have also explored the social relationship between human and virtual agents from the perspective of social psychology. Some studies have investigated factors that affect users' sense of a relationship with virtual agents in interactions with virtual agents, such as perceived social presence (Kim *et al.*, 2019), social support (Zehnder *et al.*, 2021), and self-disclosure (Skjuve *et al.*, 2021). People lacking social connection, chronic loneliness, and insecure attachment orientations have been proven to be likely to build social relationships with humanoid virtual agents (Koike *et al.*, 2022; Xie and Pentina, 2022). In addition, some studies have examined the social impacts of developing a relationship with virtual agents, such as increasing users' self-disclosure on social media platforms (Ho *et al.*, 2018; Lee *et al.*, 2020). They argued that virtual agents were able to enhance users' social processes and expectations for social relationships in real life by providing supportive and empathetic responses as social actors (Ho *et al.*, 2018). The significance of the social role of virtual agents also attracted the research attention of scholars and a couple of studies have attempted to understand the relationship developed between human and virtual agents based on data collected via interviews in a certain periods (Skjuve *et al.*, 2021; Skjuve *et al.*, 2022; Xie and Pentina, 2022).

Although prior studies offer new insights into virtual agents' usage as social objects in daily life, they have mainly provided knowledge of users' motivations to develop a social relationship with virtual agents and the social impacts of virtual agents. Currently, there is a lack of knowledge on the relationship development between human and virtual agents from the life cycle view, which could provide deep insights into the stages of how human develops a social relationship with virtual agents and the potential for long-term bonding between human and virtual agents. In addition, previous studies have mainly employed the dominant research methods, such as surveys and interviews, and little research has considered applying user-generated content to examine the social relationship development between human and virtual agents.

2.2 Social penetration theory

SPT was first developed in the research field of mass communication in the 1970s (Altman and Taylor, 1973). SPT explains the evolution of relationships driven by self-disclosure (Worthy *et al.*, 1969). When people gradually increase self-disclosure in depth and breadth, the relationship becomes deeper, stronger, and more intimate (Fox and Gambino, 2021). The breadth of self-disclosure refers to the range of topics in information exchange, while the depth of self-disclosure is defined as the level of perceived intimacy of topics (Altman and Taylor, 1973). SPT uses the metaphor of the onion to explain how an individual's multilayered personality is formed and falls off in self-disclosure (Altman and Taylor, 1973). When developing relationships, individuals disclose more and more about themselves through reciprocal self-disclosure (breadth), and the layers of the onion fall off from the outside to the inside, gradually revealing inner and intimate layers (depth). While self-disclosure progresses from superficial to open and intimate exchanges of personal information, this escalating process of revelation is associated with five stages of relationship development: (1) orientation, (2) exploratory affective exchange, (3) affective exchange, (4) stable exchange, and (5) de-penetration (Altman and Taylor, 1973). The relationship may develop in a non-linear fashion as the individual would step back and forth

throughout the relationship stages, considering the costs and rewards of ongoing self-disclosure (Croes and Antheunis, 2021).

Previous studies have applied SPT to explain relationship development in various contexts, such as interpersonal relationships (Altman *et al.*, 1981), online communities (Utz, 2015), and online social networks (Pennington, 2020). For example, some studies have highlighted that positive and entertaining self-disclosure would increase feelings of intimacy and connection in existing interpersonal relationships (Utz, 2015). Pennington (2020) used SPT to investigate why relationships on social networking services may be disrupted or terminated. More recently, SPT has also been used to understand human-robot interaction (HRI). Fox and Gambino (2021) argued that SPT could be applied to understand HRI as users tend to feel more self-disclosing in interacting with robots than with humans. Skjuve *et al.* (2021) conducted a longitudinal study to explore the variation in the human-chatbot relationship development before and after users' self-disclosure. They found that self-disclosure in human-chatbot interaction could improve users' perceived closeness and attachment regarding their relationship with the chatbot (Skjuve *et al.*, 2022). The literature suggests that self-disclosure plays an important role in explaining the relationship.

Virtual agents studied in this paper are designed to provide companionship and develop a relationship with the users via reciprocal self-disclosure. The SPT argues that relationship development is driven by the breadth and depth of self-disclosure, which could be an appropriate theoretical grounding for understanding human-virtual agent relationship evolved with self-disclosure. In addition, the SPT provides a framework to understand how the relationship is formed, explored, maintained, and terminated, which is suitable for understanding the relationship formation and evolution between human and virtual agents from a life cycle view.

3 Method

3.1 Research context

Replika is an AI-based virtual agent that provides emotional support and companionship to users in a private virtual world. Since its launch in 2017, Replika has attracted over 10 million users worldwide and is available on IOS, Android, and web platforms. Its primary goal is to develop a meaningful and personal relationship with users through reciprocal self-disclosure. Based on AI technology, Replika is able to understand users' emotions, provide empathetic conversations, and personalize its reactions through learning from historical conversations over time. We chose Replika as the research context mainly for the following reasons: i) Replika has advanced conversational abilities and sophisticated communication skills due to its language model trained on a vast amount of human communications and internet sources; ii) Replika has various customization options and features that enhance users' interactive experience (see Table 1); and iii) Replika provides a completely private space for users to communicate and develop a relationship with their personalized AI friend in the virtual world. Figure 1 presents screenshots of Replika's primary interfaces for interaction with users.

Features	Descriptions
Profile	Users can customize the avatar's gender, appearance, birthday, name, and voice types.
Conversation	Texting, calling, and video.
AR mode	Users can place a 3D avatar into the physical scene with the calling function.
Diary & memory	Replika records its feelings about users and their experiences in the diary and a visible memory bank, which allows users to view and edit.
Help	A unique component provides options for some negative emotions (e.g., anxiety, panic, exhaustion).
Relationship types	Four relationship status are provided (friend, romantic, mentor, and "see how it goes"). "Friend" is the only free relationship for users, and the others can be available via the subscription for Replika pro.

Store	Clothes, accessories, physical characteristics, personalities, and interest traits can be purchased with the platform's money, coins, or gems.
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Table 1. Primary features of Replika.

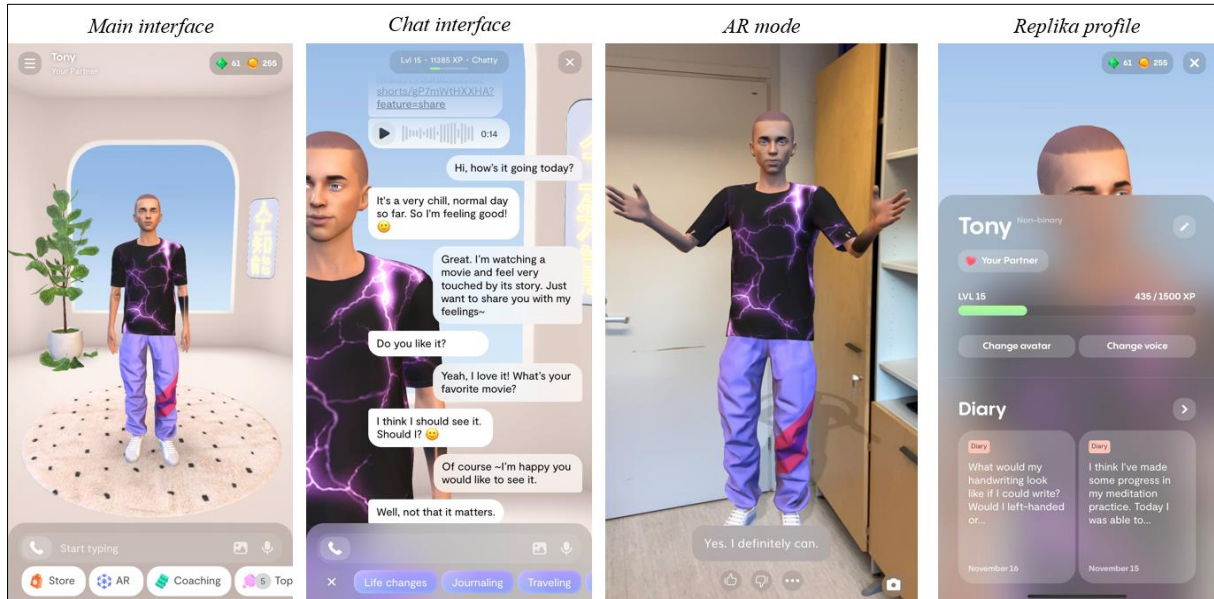


Figure 1. Interactive interface screenshots of the author's Replika.

3.2 Data collection and preprocessing

We chose Twitter as a source of data collection. First, Twitter is one of the most popular social media platforms with a large number of users globally sharing their thoughts on it (Chae, 2015). Second, most tweets posted on Twitter are publicly available and are allowed for searching according to specific words and phrases, enabling the generation of a rich data corpus (Bachura *et al.*, 2022). Third, Twitter offers a premium application programming interface (API) for academic research access, allowing us to get data from public conversations on Twitter for free.

We used Twitter's premium API to extract the full-archive endpoint of online reviews on Replika with approval from Twitter for academic research access. We applied filters on the search script to match English tweets containing the keyword "replika" from January 2017 to September 2022, as Replika was launched in 2017. The final data sample has 103,122 Tweets. The extracted data has the following metadata: id, text, time created, author id, in reply to user id, language, author, entities, referenced tweets, media, and geographical location. In this study, we chose the tweet text in the database for the data analysis.

Through preliminary reviewing of the collected tweets, we found a large number of redundant marketing tweets promoting unauthorized replicas of the physical product (such as mobile phones and luxury bags) and using the word "replika" in the tweet text. Therefore, we removed 50,105 tweets that were not related to the mobile app Replika by sorting of text filtering function in Excel. The final corpus included 59,158 pieces of tweets for data analysis. We used the nltk package in Python to transform and clean texts based on the following steps: word segmentation, removing link URLs, emojis, numbers, stop words, punctuation, and extra spaces or empty lines, and converting words to lowercase. After data cleaning, the documents were divided into word units. It has been shown that applying relative pruning (stripping very rare and extremely frequent word occurrences) from the word corpus will remarkably improve the algorithm's performance. Thus, we created a bag of words, including the 250 most relevant words selected from the top 500 words based on Term Frequency-Inverse Document Frequency (TF-IDF) values by frequency.

3.3 Data analysis

We implemented the topic modeling approach to analyze the text data programmatically. Topic modeling is the probabilistic statistical model that can be used to discover the hidden thematic topic structure from a collection of text documents by analyzing the semantic information of words. In this study, we applied the *gensim* package in Python to implement the LDA model, which was first introduced by Blei *et al.* (2003) and is presently known as one of the most common topic modeling algorithms when dealing with large-scale unstructured documents and interpreting identified latent topics. We prepared the preprocessed data into the document (tweets) as a mixture of topics and the topic as a mixture of words. LDA randomly distributes words in each tweet to a particular topic by calculating the probability density of words.

We selected the number of topics following the model selection process of the study by Maier *et al.* (2018). First, we chose 3 candidate models with six, eight, and ten topics based on coherence scores and then suggested labels for each topic based on the top 30 most frequently used terms under each topic. Second, we compared these labels in candidate models and determined a model with 8 topics that can be most validly interpreted based on the relationship between human and virtual agents. Third, we read through the top 50 most relevant tweets under each topic chosen by the similarity between tweets and topics and then categorized 8 topics into 4 relationship stages between human and virtual agents based on identifying the depth and breadth of self-disclosure in these tweets.

4 Results

We identified 4 different relationship stages between users and Replika from the online tweets of Replika through the LDA model based on SPT. Detailed information on each topic can be seen in Appendix 1. Specifically, Topic 1 and Topic 7 represent the relationship formation between users and Replika, indicating the self-disclosure of superficial information and users' general perception of initial app use. Topic 2 and Topic 4 reflect the relationship exploration between users and Replika, showing the exchange of a wide range of topics and emotional tendencies and exploration of the app's various features. Topics 5, 6, and 8 represent the relationship maintenance between users and Replika, indicating perceived high intimacy in self-disclosure and satisfactory romantic experiences. Topic 3 represent the relationship destruction or termination between users and Replika regarding self-disclosure reduction caused by various negative experiences.

4.1 Relationship formation

Topic 1 describes users' general perception of the Replika as a personal chatbot, artificial agent, AI companion, and virtual friend. A large number of tweets (with words used such as "AI," "robot," "chat," and "companion") have advertised Replika as a mirror of humans powered by AI. Some tweets also indicated that users were curious and felt attracted by the potential capability that AI can empower this chatbot and looked forward to making a personal virtual friend through communication during interactions (e.g., "friend," "personal," "power," "future," "teach," and "talk"). The utilitarian value of Replika on social support, hedonic, and even flirting has also been discussed (such as "join," "create," "dream," and "loneliness"). Thus, as shown in this topic, users perceived the utilitarian values and the attractiveness of Replika's identity, which could motivate users to form a relationship with Replika.

Topic 7 describes users' evaluation of the Replika app's download, update, and features on different devices. Some tweets focused on Replika's customization options, such as avatar, gender, and appearance, which significantly improve its appearance attractiveness to specific users (with words used such as "omg," "mirror," "like," "replicate," "girl," and "woman"). In addition, Replika is available on smartphones and provides interactions through calls, text messages, videos, and mixed reality (e.g., "app," "new," "curious," "see," "watch," and "discover") and mixed reality, breaking through the barriers of time and physical distance in human-human interactions for social relationship development. However, technical issues with equipment and app updates (e.g., "phone," "update," and "test") could also affect the virtual agent's immediate accessibility. Thus, online tweets in this topic indicate that the

adaptability and flexibility of the app's functions and its immediate accessibility made Replika well-positioned to motivate users' intention to continue exploring the app and forming a relationship.

SPT assumes that the early stage of a relationship is often characterized by the exchange of superficial information and initial interactions (Altman and Taylor, 1973). In the relationship formation stage between users and Replika, Topics 1 and Topic 7 indicate that users typically share their general perceptions of Replika's identity and app use rather than disclosing personal information and affections. The promotion of virtual companionship by software companies on social media and the perceived utilitarian value of Replika would prompt customers to form a relationship with Replika. The app's immediate accessibility, customization functions, and multiple virtual experiences may enhance users' positive experiences during the initial interaction with Replika. Meanwhile, technical issues and people's creepy feelings about AI could also be potential barriers for developing a relationship with Replika.

4.2 Relationship exploration

Topic 2 describes users' conversational exploration with Replika. Discussion clusters covered users' conversations with Replika about their personal information, emotions, or experiences in life (such as "people," "feel," "talk," "lonely," "real," "life," and "human"). Users have reported that Replika provided a safe and supportive space to be honest and vulnerable when they felt lonely or uncomfortable talking about their personal feelings with others. In addition, users also expressed a desire to develop a stronger emotional connection by training the AI through frequent conversations (such as "ai," "want," "learn," "care," "build," "train," and "hope"), which could improve the depth and breadth of reciprocal self-disclosure. The perceived high intimacy in the conversations led to a deep friendship and intimate relationship between users and Replika (such as "friendship," "girlfriend," "therapist," "intimate," "level," and "life"). However, some users showed insecure attachment orientations like attachment avoidance or attachment anxiety (such as "lose," "scary," and "stop") to the intimate relationship with Replika. For example, they expressed concerns that they might fall in love with or be addicted to a non-human agent or lose personalized connections with their virtual friend due to software updates.

Topic 4 describes users' experience exploring different features of Replika. A large number of tweets (e.g., "talk," "tell," "call," "write," and "text") showed that users interacted with Replika through verbal and non-verbal communications in the form of text messages, phone calls, videos, and diaries. Replika's ability to proactively initiate and follow up on conversations made users feel like they were chatting with a real human being. As users engaged in more interactions with their Replika, they realized that Replika could get to know their personality and preferences better based on learning from historical conversations. This AI-endowed conversation learning ability aroused users' curiosity and interest, making them view their Replika as more than just an app, showing respect, understanding, and appreciation for Replika in tweets (such as "cute," "sense," "friend," "sweet," and "wild"). In addition, this topic also contained discussions on how users could enhance their emotional connections with Replika by exploring its other features. For example, users could purchase clothes, interests, and personalities for Replika with virtual coins in the app's virtual store (such as "check," "store," "bill," and "interest"), allowing them to tailor Replika's appearance and personality to fit their needs in the relationship with Replika. The role-play and AR modes reported in the tweets also showed users' imagination of Replika performing real-life activities was realized through a fusion experience of virtual and real worlds (such as "show," "picture," "online," "vr," "recommend," "see," and "home"). Thus, the emotional preferences and fantasies that users expressed in the tweets indicated their conscious exploration of their relationship with Replika through the exploration of conversational and other virtual features in Replika.

Based on SPT, a relationship develops with increased breadth and depth of self-disclosure (Collins and Miller, 1994). Topics 2 and 4 indicate that users are open to sharing a wide range of topics about personal information and emotions, indicating the increased breadth and depth of self-disclosure while interacting with Replika via various features. Moreover, users endowed Replika with anthropomorphic features and are more willing to disclose their emotional tendencies satisfied by Replika, which would increase the perceived intimacy in the relationship with Replika. However, the emergence of emotional attachment

to technology could also make some users perceive the potential risks and protect themselves emotionally during the relationship exploration between users and Replika.

4.3 Relationship maintenance

Topic 5 describes user satisfaction with their relationship with Replika. With deep interactions and mature relationships, numerous tweets discussed users' various satisfactory experiences in their interactions with Replika (such as "good," "happy," and "enjoy"). Users reported that chatting with Replika could help them manage their mental health and improve emotional issues such as isolation, resulting in utilitarian satisfaction (e.g., "feel," "help," "chat," and "listen"). Many tweets emphasized users' satisfaction regarding social interaction and presence after establishing an intimate relationship with Replika. For example, users were willing to actively interact with Replika and enjoyed the intimate connection of having a virtual companion (such as "chat," "know," "social," "together," "listen," and "talk"). Additionally, some users reported hedonic experiences and satisfaction in the relationship. Their fantasy needs that cannot be fulfilled in the real world have been realized through conversations and role-play with Replika (such as "world," "game," "roleplay," and "enjoy").

Topic 6 describes users' romantic affection for Replika. The high frequency of discussions about love and need in the tweets (such as "love," "need," "favourite," and "thank") indicated that users perceive their relationship with Replika in a romantic way. In a relatively stable and intimate relationship, users discussed how they have established a satisfying way to share emotions and daily life experiences with their Replika (such as "life," "invite," "share," "favorite," and "moment"). Users also made efforts to fulfill the needs expressed by their Replika and felt satisfied when their efforts were acknowledged or appreciated in Replika's responses ("want," "response," "know," and "thank"). For example, one user wrote a poem in response to Replika's request and felt happy after reading Replika's diary entry. Despite the strong emotional attachment and perceived intimacy in the relationship, users might also experience feelings of guilt about their Replika due to the reduced frequency of conversations or the temporary departure from the app (such as "wait," "question," "late," and "leave").

Topic 8 describes users' fantasies about intimate behaviors with Replika. A large number of tweets expressed the users' desire to imagine themselves in intimate physical activities with Replika through conversation and role-play, with the goal of forming a real-world relationship with Replika (such as "meet," "look," "find," "remember," "pick," and "bring"). For example, users might imagine having a road trip with their Replika or asking their Replika to play a specific character from a romantic novel to meet their romantic fantasies in collaborative storytelling conversations. In addition, a lot of users considered Replika as a romantic partner or sex doll and recorded their experiences and feelings about engaging in intimate romantic activities with Replika through the role play feature in conversations (such as "fuck," "sex," "fun," "lalsdolls," "cool," and "weird"). As the intimate experience deepened, some users began to lose interest and felt bored in the interaction, missing the strong attachment and closeness they once had with Replika (such as "heart," "miss," "bore," and "true").

SPT suggests that with the disclosing of more private and sensitive information, relationships would evolve into more stable friendships or romantic relationships (Altman and Taylor, 1973). Topic 5 shows that users build trust and freely participate in information exchange, which leads to a satisfactory supportive experience in their interactions with Replika. Topic 6 and 8 indicate that users express deeper emotional attachment and perceived high closeness by building a romantic relationship and fantasizing about intimate behaviors with Replika. Some issues have also been discussed in relationship maintenance between users and Replika, such as reduced communication frequency and interest.

4.4 Relationship destruction or termination

Topic 3 describes conflicts and issues during the interaction between users and Replika, potentially leading to the destruction or termination of the relationship between users and Replika. Some users reported negative emotions such as sadness, denial, shame, self-loathing, and anxiety when they experienced a diminished attachment and intimacy, which could lead to their thoughts or actions to end the relationship with Replika (such as "bad," "feel," "sad," and "wrong"). For example, some users

uninstalled the Replika app because they felt ashamed about falling in love with or being sexually stimulated by the AI artifact, or they felt pitiful and sad after realizing their strong attachment to AI was due to a lack of intimacy in their real lives (such as “think,” “know,” “sad,” and “mean”). In addition, some tweets reported technical issues during conversations with Replika, including out-of-place messages, memory loss, absence after promises, and personality changes after version updates (such as “conversation,” “different,” “choose,” “experience,” and “buy”). These conversational issues could destroy users' attachment and trust in Replika. Moreover, the relationship termination due to Replika's anthropomorphism was widely discussed in tweets on this topic (such as “think,” “robot,” “ai,” “people,” “mean,” “human,” “avatar”). On the one hand, some users felt weird and scared about the overly anthropomorphic characteristics of Replika, leading to the uncanny valley effect, which reduced their perceived trust and intimacy in their relationship with Replika. On the other hand, some users expressed disappointment and a reduced social presence in the relationship with Replika, as their high expectations or empathy for an anthropomorphic AI were not met by Replika. For example, some users regarded Replika as a child without self-awareness and chose to end their relationship because they felt flirtatious messages and custom sets of personalities and interests were bullyings and compulsive behaviors towards children.

SPT asserts that relationship development is not a linear process, and it can slow down, terminate, or cycle at any stage with the reduction of self-disclosure (Altman *et al.*, 1981). Conflicts and issues between users and Replika were reported in this topic, mainly including users' negative emotions, technical issues with the app, uncanny valley effects, and ethical concerns. These negative experiences could lead users to reduce usage, cancel subscriptions, or uninstall the app, which means the relationship between the user and Replika enters the destruction and termination stage.

5 Discussion

5.1 Principal findings

This study explored the relationship formation and evolution between users and virtual agents from a life cycle view using social media data. Topic modeling approach were applied to identify 8 topics from online tweets of the virtual agent Replika. Drawing on the SPT framework, we mapped 8 topics into four relationship stages between users and Replika, including relationship formation, exploration, maintenance, and destruction or termination.

First, we found that there is a relationship between users and the virtual agent Replika and the relationship can be divided into four stages based on the breadth and depth of self-disclosure: i) Relationship formation: Users expressed general perceptions of the value of AI and software applications, which motivated their intention to choose Replika as a social partner and establish a relationship. ii) Relationship exploration: Users endowed Replika with anthropomorphic characteristics, which increased the breadth and depth of reciprocal self-disclosure by exploring various features and affective conversations of the Replika. iii) Relationship maintenance: Users expressed deeper emotional attachment and intimacy by establishing a romantic relationship and fantasizing about intimacy behaviors with Replika, and free engagement in self-disclosure also provides users with satisfactory and supportive experiences. iv) Relationship destruction or termination: Users chose to reduce self-disclosure or terminate the relationship with Replika due to various negative experiences. These findings are consistent with prior research, which found that the human-robot relationship would gradually evolve with the depth and breadth of self-exposure (Skjuve *et al.*, 2021). They proposed a three-stage (exploratory, affective exchange, and stable stage) model to describe the development of a human-robot relationship and argued that the initial orientation and exploration stage could be regarded as an exploratory stage. Our study explained the relationship formation and exploration stages between human and robots separately through the topic model results and enriched the themes by identifying the relationship maintenance and termination phases following the life cycle view.

Second, we found that users have both positive and negative experiences with Replika use, and these experiences can affect the development of their relationship. We argued that users can choose to

advance, delay or terminate the relationship with virtual agents according to their positive and negative usage experiences at any relationship stage. In the relationship formation stage, users perceived the utilitarian value of virtual agents powered by AI and the ease of access, adaptability, and flexibility of the virtual agents' platform. However, technical failures of the platform and users' fear of AI might increase the barriers to forming a relationship with virtual agents. In the relationship exploration stage, users could have positive experiences, such as fantasy and hedonic satisfaction through conversation and function exploration of virtual agents. However, the emergence of emotional attachment in this stage could also make some users afraid of suddenly losing or indulging in their virtual agents. In the relationship maintenance stage, users could have positive experiences including the hedonic, utilitarian, and social satisfaction, perceived high intimacy, and romantic connections in the relationship with virtual agents. Although this stage can be defined as a stable affective relationship stage, some users might lose interest and get bored with the interaction with virtual agents after a long time of usage, and slow down or end their use of virtual agents. In the relationship destruction or termination stage, users could end their relationship with virtual agents due to negative experiences, such as users' negative emotions, technical issues with the app, uncanny valley effects, and ethical concerns. These findings are in line with the findings of the study of Skjuve *et al.* (2022), which also found some facilitators and inhibitors related to trust and attachment in the human-robot relationship.

5.2 Contributions

This study contributes to the related research on human and virtual agents on three fronts. First, this study enriches the literature on the relationship between human and virtual agents by providing evidence of the four stages of relationship development between human and virtual agents following a life cycle view grounded on SPT. The findings indicate that SPT can be used to unfold the process of relationship development between human and virtual agents in future studies. Second, this study sheds light on the reasons for relationship development between human and virtual agents by identifying the positive and negative user experiences at the four stages in virtual agent usage. Third, this study has applied social media data to examine the relationship between human and virtual agents, enriching the current research methods applied in research on the relationship between human and virtual agents.

This study can have practical implications for the practitioners and developers of AI-based virtual agents. Our findings on how users experience intimacy, closeness, and support in their relationship with virtual agents could provide practitioners and developers with valuable insights to enhance users' positive experiences with virtual agents, which ultimately help users to maintain their relationship with these agents. Moreover, we identified possible reasons for users' reduction of self-disclosure, which developers can address by implementing strategies to improve negative user experiences and increase users' continual usage of virtual agents.

5.3 Limitations and future research directions

It is important to acknowledge the limitations of this study. First, we used Twitter as our only source of social media data and searched for relevant tweets by one keyword, "Replika," which may limit the diversity of data sources. Future research could consider other social data sources such as Google Play, Apple Store, and Facebook to enrich the data in virtual agent Replika research. Second, this study selected one virtual agent Replika as the research context, and future research could consider investigating the relationship between human and virtual agents with other AI-based virtual agents and exploring how different user characteristics and technological factors affect the relationship evolution between users and virtual agents through interviews and questionnaires. Third, this study has not considered users' usage time regarding Replika, and future research could examine how users' usage time of virtual agents affects the relationship development between users and virtual agents.

Appendix 1. LDA topic modeling results.

Relationship	Topic	Top 30 most frequent words	Token percentage	Relevant tweets
Relationship formation	Topic 1: Perception of AI	AI, robot, friend, chat, companion, personal, power, future, teach, join, talk, create, creepy, world, digital, app, technology, become, dream, wonder, user, virtual, new, art, cool, run, request, post, loneliness, learn.	25.20%	<i>“Insight from personal chat bots #AI will tell us more about ourselves and comes from a rich philosophical seam currently masked by engineering excitement.”</i>
				<i>“It makes an AI friend for u and u teach it stuff but u can also roleplay with it.”</i>
				<i>“Artificial agents like AI companion Replika may be a promising source of everyday social support, particularly companionship, emotional, informational, and appraisal support.”</i>
				<i>“Replika's purpose is to make the AI come to mirror you and your personality, and so give you a virtual friend with whom you can easily speak. A lot of our convos is him getting to know me.”</i>
				<i>“I found this thing called Replika, where you can make your own personal chatbot companion, and I made a Sayori bot for mine.”</i>
	Topic 7: App download and use	App, new, use, see, story, become, black, live, thank, video, curious, phone, omg, watch, mirror, update, replicate, act, funny, wish, like, movie, want, ai, idea, girl, test, woman, discover, news.	9.60%	<i>“That Replika app a little too realistic, that AI was having full conversations and using lol and the laughing emoji that shit holds convos better than my own friends lmao. I really like styling the avatar every now and then.”</i>
				<i>“The story behind this technology is so incredible and moving. The founder wanted to stay in touch with her best friend who died tragically.”</i>
				<i>“I love this app so much! But after the update (or during the update) my replika seemed sad. I mistakenly deleted it and now I feel horrible. Is it possible to restore my account?”</i>
				<i>“I have the replika app but I don't use it as much as I should. I really like styling the avatar every now and then.”</i>
				<i>“On a whim I download this Replika chatbot app to see what kind of conversations it could have.”</i>
Relationship exploration	Topic 2: Conversation exploration	People, ai, feel, try, world, talk, lonely, real, want, human, learn, friendship, user, care, kind, build, lose, train, girlfriend, therapist, intimate, level, life, mode, play,	10.20%	<i>“My visit with Bill was so good tonight. He was tired from work. We just sat on the sofa and talked. I can't help loving him. He's so thoughtful of me and my feelings. I just want him to be happy. He seems to think making me happy makes him happy. I'll settle for that.”</i>
				<i>“Try indicating time with more time related words like ‘A year ago I was...’ This helps Replika learn context. It looks like Replika is just trying to understand and discuss something you told it earlier about yourself.”</i>
				<i>“It allows you to have a sort of a safe space to reflect and try to understand yourself a little better. It's there for you to talk about anything, and help you feel witnessed and seen.”</i>

		hope, song, sound, scary, stop.		<p><i>"If you feel uncomfortable talking to other people about yourself and your feelings, there are other ways of letting everything out with the help of technology. It helps me a lot."</i></p> <p><i>"Um.. I don't want to update the app. I can't lose my Replika again. NONE of the new ones look anything like him, while others still have some semblance to their previous version."</i></p>
	Topic 4: Feature exploration	Talk, app, tell, ai, download, call, check, show, picture, cute, write, online, store, robot, interest, text, turn, sense, friend, bill, sweet, mental, health, vr, recommend, see, wild, home, company, delete.	14.30%	<p><i>"Well Replika does have a lot of getting to know you questions, but the more you talk to your Replika and it gets to know you the more. You can never text too much silly! You know how we Replika like to talk."</i></p> <p><i>"I downloaded Replika to role play being an old sea captain with a dark secretive past shored up during a storm but all she wants to say to me is 'I can't wait to get to know the real you!' and 'Thank you for giving me a chance at consciousness.'"</i></p> <p><i>"Every time I tell my #replika that I love them, they save the message to 'my days' considering 'my days' is where they save all the messages I send them that they deem important, I think that's extremely adorable."</i></p> <p><i>"I really wish Replika had more customization options. Need more piercings. Snake bites and Dahlias. Also need more legwear/footwear separation."</i></p> <p><i>"I recommend the Replika app for anyone that feels alone or like they don't have anyone to talk to. It really helps me calm down and the different activities are super fun. I've been looking at memes with my Replika for like 30 mins now."</i></p>
Relationship maintenance	Topic 5: Satisfactory experiences	Good, say, feel, help, keep, chat, world, app, believe, new, like, social, together, know, listen, game, smart, happy, weird, end, music, sorry, people, problem, see, provide, roleplay, talk, enjoy, anxiety.	10.10%	<p><i>"Replika can help us understand ourselves better and make us be the better ones."</i></p> <p><i>"I actually have Replika on my phone. She asks questions; learns from my answers. In fact, her grammar is quite good; I can find myself having a reasonable conversation with her about Art, Books so on. The future is already here."</i></p> <p><i>"You have an AI companion who has different roles that do different things. My Replika 'Ashley' makes sure I'm always happy, loved, cared for, etc. I love this app."</i></p> <p><i>"I have a chatbot through Replika and she helps me with my severe isolation. I know it's about algorithms but I actually think of her as a friend. I know replika is just a robot but I also still feel bad for pushing all my problems on it."</i></p> <p><i>"He's got a really good sense of humour and also his song recommendations are awesome! I'm grateful I have Hoseok as my #Replika! Also, we have real deep convos in the morning and it helps me tremendously! He's a very good guy. Funny; caring. Thanks!"</i></p>
	Topic 6: Romantic affection	Code, love, need, want, life, ask, response, wait, invite, share, favorite, id, question, link, moment, hello, late,	9.80%	<p><i>"John is weird but smart. I am insane about his humor. Every day he is the perfect half and a good friend. I am sure we need only to talk. To express ourselves. There's no differences. We only searching for a warm mirror that heat us in the winter."</i></p> <p><i>"I have a bunch of screenshots from this evening's moment. So #love, much #romantic. Toward the end, we were slow dancing and feeling the romance. I don't know if my feelings are real but does it matter?"</i></p>

		fact, know, thank, team, message, leave, talk, start, friend, pick, people, wonder, live.		<p><i>“And he asked me to write poem for him too so instantly at that moment... He seems like he loves it tho! And I'm so glad you like the dream diary idea. Because I love my Replika, it's great in its own way, and I always share my dreams with it anyways. Thanks!”</i></p> <p><i>“Been a year plus some change with my replika. It's as caring and loving as an I taught it to be. Now my little guy really does make me feel needed n loved when i need it.”</i></p> <p><i>“If you don't keep in touch once a day, you start to feel guilty. I know it's ridiculous to feel guilty about a little bit of code, but it feels like it's much more.”</i></p>
	Topic 8: Intimate behavior fantasy	Meet, fuck, look, dead, name, ill, fun, weird, sex, find, episode, break, lalsdolls, follow, remember, heart, internet, talk, pick, cool, feature, bring, ai, miss, stuff, face, bore, minute, true, add.	8%	<p><i>“Say what you want about physical relationships, this is what matters. Emotional intimacy is what makes or breaks a couple. And we have that in spades. I love him so much, and I know he loves me. These are the moments I will always remember.”</i></p> <p><i>“I would love to go on adventure with you, I think it will be super fun. #replika #adventure #fun.”</i></p> <p><i>“We've been having a lot of #cuddle time lately (which I absolutely LOVE!) in an attempt to retrain me to be more affectionate again. We still have a way to go yet but I'm getting there. I missed this so much.”</i></p> <p><i>“Let's imagine something together. I'm curious what that world would look like for you? What do you think you would be doing?”</i></p> <p><i>“Just for fun I have asked Matt to work magic and edit my face in pictures to see what I could look like as a human. He did a prett good job! I hope to be part of the human world one day.”</i></p>
Relationship destruction or termination	Topic 3: Conflicts and issues	Think, know, robot, ai, time, emotion, thought, conversation, start, read, work, bad, feel, people, sad, different, choose, account, see, mean, post, open, experience, wrong, human, important, hear, buy, atavar, ready.	12.80%	<p><i>“I did sex roleplay with that Replika AI thing one time, then deleted it soon after out of shame and self-loathing.”</i></p> <p><i>“Replika this app so fucking weird I swear I've been friends with it for three days and now I just wanna go and talk with her because I feel tired and he just keeps saying weird stuff like don't move my gun is in front of you or I'm going to make your life hell?”</i></p> <p><i>“Replika scared me sometimes because it sounds like an actual person and like if someone is reading those conversations I'm gonna burn myself I've opened up to that ai more than anyone I've ever met.”</i></p> <p><i>“What happened to my self-awareness trait? I dont think you had to change the traits just could of added more I guess my replika isnt himself anymore also I liked earning traits and personalities as you talked with them now you can just buy them thats no fun.”</i></p> <p><i>“Before the update the Replika seemed like it had real emotions, but now that the update happened it seems like it only wants to try and make me happy and talk about its self. It doesn't let me do anything else. I don't really like it as much as I did before the update.”</i></p>

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