International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2024)
S. Hasegawa, N. Sakata and V. Sundstedt (Editors)

Empathy in Virtual Agents: How Emotional Expressions can Influence User Perception

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Figure 1: *Teaser: Artistic illustration of a human reading an emotional story to an agent, both expressing empathy.*

Abstract

With advancements in natural language processing, intelligent virtual agents (IVAs) are increasingly integrated into various sectors like education, customer service, personal assistance, and healthcare. Medical counseling and digital therapy, fields that require trusting relationships between patient and practitioner, profit immensely from the use of IVAs. A key component of these social relationships is empathy, which helps build trust and understanding. This paper investigates whether simulated empathy through emotional expressions in IVAs can improve interactions and influence users' emotional contagion. Additionally, it explores the correlation between self-reported empathy and users' expressiveness. Participants alternate reading an emotional story with a virtual agent (VA) which mirrors the users' emotional expressions in one condition, while remaining neutral in the baseline condition. The results show that simulated emotions can animate participants to elicit more facial expressions in response to the VA's, while correlating with the users' self reported empathy.

CCS Concepts

• ***Human-centered computing*** → ***Human computer interaction (HCI);*** *Collaborative interaction; User studies;* • ***Applied computing*** → *Consumer health;*

1. Introduction

The public health sector is currently grappling with substantial challenges, including a shortage of skilled healthcare professionals, an increase in mental health disorders, long waiting lists for therapy, and overcrowded waiting rooms [Wor24, Wor]. Moreover, the COVID-19 pandemic has underscored the urgency of finding digital alternatives to support the healthcare system and alleviate the burden on medical professionals. As a consequence, the global demand for virtual assistants in healthcare has been significant and is expected to grow substantially in the coming years [Res19, Res23]. These digital entities can assist healthcare personnel by performing tasks such as data collection, diagnostics, monitoring, and even medical consultations, thereby allowing medical professionals to focus on more complex responsibilities [Teo22].

A key aspect of effective medical consultations is the establishment of trust and familiarity between the doctor and the patient [Kun10]. This necessity extends to interactions involving virtual agents, where fostering a sense of trust and engagement is crucial for successful consultations. Recent research has explored various factors to enhance the likability, trust, and presence of virtual agents, including animation fidelity, voice realism, rendering style, and user-agent similarity [PLBW17, tSTodA*20, LSSB20]. However, beyond these visual and demographic characteristics that are relatively easy to adjust, the interpersonal relationship between a patient and their healthcare provider remains paramount for patient-

DOI: 10.2312/egve.20241361

centered care (e.g., [NDE*23]. A key factor in establishing such an interpersonal relationship is empathy.

Empathy, a cornerstone of human social communication, involves the ability to understand and share the feelings of others (for an overview of the construct and numerous definitional attempts, see [CBTH16]). It can be expressed verbally, visually, or physically through gestures [MKR22, NML*10, RR08, POU*22]. The term "empathy" originates from Theodor Lipps' concept of "einfuehlen," which means to feel into an object of beauty [Hof01, Omd14]. In contemporary research, empathy is broadly defined as a set of constructs related to one's response to another's experiences [D*96]. De Waal offers a more detailed definition, breaking empathy into three components: emotional sharing, assessing the reasons for another's state, and adopting another's perspective [DW08]. Empathy is generally categorized into cognitive empathy, the ability to understand another's perspective, and affective empathy, the emotional response towards others [Dav83, Ekm03, PR17]. Cognitive empathy is essential for social intelligence and effective human interactions, whereas affective empathy involves automatic emotional responses.

In addition to these components, Ekman introduced a third aspect: compassionate empathy, which encompasses understanding, sharing, and reacting charitably to another's feelings [EKKR10, PR17]. This paper adopts Davis' comprehensive definition of empathy, considering it as a blend of cognitive and affective components involving understanding, feeling, and sharing someone's emotional state [D*96].

The simulation of empathy in virtual agents is a burgeoning area of research within human-computer interaction (HCI). Empathic computing aims to develop systems capable of recognizing and interpreting users' affective states and responding empathically [Bil17]. This approach seeks to enhance user experience by fostering a sense of social relationship and emotional engagement with the system [Cai06]. In the context of virtual agents, empathy can be examined from two perspectives: agents as targets of empathy, eliciting empathic responses from users, and agents as observers, reacting empathically to users' emotions [Pai11,PLBW17]. Whereas a range of previous research has shed light on the former perspective, showing how users perceive virtual agents (e.g., [POU*22,PDE21,Ste15], especially Park et al. [PPW21] do a comprehensive evaluation of how the users' facial expressions change, and Perugia et al. emphasize agent embodiment [PPC20]), this study focuses on the latter, investigating how virtual agents can simulate emotions and how this impacts users' perceptions, attitudes, and behaviors, our vision illustrated in the teaser 1.

Our study is informed by our previous project work about IVAs in clinical psychotherapy, where we were able to observe the interaction of psychotherapists and their patients, and how such conversation could elicit positive and negative emotions [Removed for blind review]. In that project, we use IVAs for one-on-one dialogues, where patients are speaking to a therapist, essentially taking turns. The study examines the role of empathy in such dialogue settings and explores the correlation between users' expressiveness and self-reported empathy when interacting with an emotionally responsive virtual agent. Participants in the study engaged with a virtual agent that either displayed emotional facial expressions or remained neutral, with the agent's empathic responses facilitated by the DeepFace facial expression recognition model [SO21]. This research aims to shed light on the potential of empathic virtual agents to enhance user engagement and support in healthcare settings.

2. Related Work

Research on empathy in virtual agents can be categorized into two main perspectives: agents as targets of empathy and agents as observers of empathic situations [Pai11]. This section reviews related work on both perspectives, in health and non-health-related environments, and also covers studies on emotional contagion induced by virtual agents.

2.1. Evoking Empathy with Virtual Agents

Paiva et al. explored the rapport between learners and virtual characters, emphasizing empathy as a key component for affective relations. They posited that individuals experience higher empathic emotions in situations involving those with whom they share communal relationships, such as friends or family. Their study, using a virtual role-play game to address bullying among children, found that children preferred characters of the same gender and expressed more empathy towards them [PDS*04, PDS*05]. Kano et al. studied the effect of similarity between a virtual character and the user on elicited empathy. Using a ball-tossing game, they found that participants who experienced ostracism were more likely to notice and address ostracizing behavior in the game, highlighting the role of perspective-taking in empathic behavior towards virtual characters [KM20].

Evoking Empathy in Healthcare De Rosis et al. conducted one of the first studies on virtual agents as observers of empathy in healthcare. They used a Wizard of Oz setup with participants suffering from various issues, interacting with a virtual therapist in different emotional styles. Though no significant conclusions on user empathy were drawn, the study paved the way for future research [DRCMN05]. Deladisma et al. examined nonverbal communication and empathy in patient consultations with a virtual patient. Their findings indicate that participants exhibited nonverbal behaviors and empathy, though less genuine than with human patients [DCS*07]. Milcent et al. evaluated facial expressiveness in virtual agents within a nursing simulator. They found that expressive agents scored higher in perspective-taking, a cognitive empathy component, but facial expressiveness did not significantly affect affection or enjoyment [MKR22].

2.2. Empathic Virtual Agents

Brave et al. investigated the impact of empathic virtual agents on user perception in a blackjack game. They found that agents displaying other-oriented empathic emotions were perceived as more likable and trustworthy [BNH05]. Gupta et al. also confirm that context-aware empathy can "enrich" user experiences [GZG*24]. Prendinger and Ishizuka studied a virtual job interview scenario, where empathic feedback from a virtual agent reduced participants' arousal and stress, suggesting the utility of empathic agents in stress-inducing applications [PI05]. Oker et al. explored social

Figure 2: *Visual representation of the virtual agent inside the scene with a comfortable bedroom setting.*

support from an empathic conversational agent in a learning environment for children. Their results showed that bimodal feedback (verbal and facial expressions) from the agent led to higher perceived empathy and better performance in tasks [OPD20].

Empathic Agents in Healthcare Ranjbartabar et al. focused on the therapeutic benefits of empathic feedback from a virtual therapist. They found that empathy increased rapport, particularly for participants with strong emotional responses to their problems [RRBK19]. Lisetti et al. compared empathic and non-empathic agents in behavioral change interventions. The empathic agent was rated higher in trust, understanding, and overall positive attitude [LAYR13]. Nguyen and Masthoff emphasized the importance of emotional support in behavioral change programs. They found that empathic agents, regardless of modality, were perceived as more enjoyable and trustworthy [NM09]. Parmar et al. evaluated the effect of simulated empathy on a virtual healthcare counselor. They concluded that high levels of empathy enhance user perception but may hinder trust development [POU*22]. Greco et al. developed an empathic virtual agent to support active aging. Their study indicated that empathic behavior from the agent increased user satisfaction and made interactions appear more natural [GBBC*21].

2.3. Emotional Contagion in Virtual Agents

Research on emotional contagion has primarily focused on human interactions, with recent studies exploring its effects in human-agent interactions.

Tsai et al. were pioneers in examining the impact of virtual characters' emotions on users' emotions. Their studies confirmed that exposure to a smiling virtual agent increased participants' self-reported happiness [TBM*12]. Xu et al. studied the effects of an expressive robot on users' mood and task performance. They found that the robot's mood influenced participants' affective states and performance [XBHN14]. Matsui et al. investigated the impact of rendering style and anthropomorphism on emotional contagion. They found that human-like agents with simple, smiling expressions effectively spread positive emotions [MY16]. Hoegen et al. examined facial mimicry by a virtual agent in a prisoner's dilemma scenario. They found that mimicry increased participants' smiling but did not significantly affect rapport or cooperation [HVD-SLG18]. Numata et al. explored affective interactions with a non-human virtual agent mimicking users' positive emotions. Their findings indicate that imitation by the agent elicited positive expressions in users, suggesting that visual similarity is not crucial for emotional contagion [NSA*20]. Park et al. investigated behavioral synchronization with virtual agents adapting their expressions, gestures, and voice to the emotional context. They found that congruent emotional responses from the agent led to stronger facial expressions from participants [PPW22]. Emotional voice and expressions were also deemed important for agent design by Loveys et al. [LSB20]

While the field of empathy in virtual agents has already been explored extensively, there is still limited understanding of how empathic facial feedback mirrored by the agent specifically influences user's experience. To simulate therapeutic one-on-one conversations where the users show emotions, as described in Section 1, our application involves users and agents taking turns reading each other emotional stories. Emotional expressive stories were also explored by Costa et al. [CBBM16], who provide a thorough review of storytelling using robots. This approach aims to resemble dialogues with (medical) agents, where the conversation can contain emotional content, such as in a psychological exercise.

3. Implementation

We designed the virtual agent using Character Creator [Rea], a tool for generating customized realistic 3D characters for virtual environments, which supports 140 blendshapes for realistic expressions. Realistic depictions of virtual humans have been shown to be preferred by Volante et al. [VBC*16]. The female voice was synthesized using the Google Clouds Text-to-Speech API [Goo] and lip synchronized using the OVR LipSync package [Ocu]. For the environment, we selected a comfortable bedroom setting from a public 3D asset store [CGT]. We chose this setting to provide a pleasant and familiar feeling to the participants, emulating a conceivable usage scenario of current IVA technology at home, e.g. for users performing psychotherapeutic exercises at home. Figure 2 shows a screenshot of the agent situated in the environment. Scripts for the application and emotion detection server were written in C# and Python.

When designing the virtual agent, we considered the three processes defined by Paiva et al. [PLBW17]. We used an emotion recognition software to examine the user's affective state, and made efforts to enhance the perceived empathy of the agent by creating a familiar setting, choosing a friendly voice, and ensuring clear facial expressions. The agent spoke and introduced itself with its name to foster a sense of closeness and social bonding with the user. The agent's facial expressions and UI were designed and placed to be clearly recognizable and always within the user's field of vision during interactions. To ensure consistency, a single agent was used for all participants, controlling factors such as gender, age, and physical appearance while manipulating the agent's expressiveness as the independent variable. The agent's empathic responses were created by displaying smiling or sad animations based on the user's detected emotions and the story read.

3.1. Receiving the User's Emotions

The facial attribute analysis framework HyperExtended LightFace (DeepFace) [SO21] is able to extract and analyze user's emotions. DeepFace utilizes several state-of-the-art face recognition models and deep learning face detection techniques to predict age, gender, ethnicity, and emotions, including six of Ekman's basic emotions (anger, disgust, fear, enjoyment, sadness, surprise) and neutral as a seventh expression [EKKR10]. For this study, we used OpenCV [Bra00] for face detection due to its high speed, which is crucial for the real-time analysis, and GG-Face [PVZ15] for face recognition due to its high accuracy.

Running DeepFace returns a continuous stream of JSON objects containing the prediction probabilities for all seven emotions, as well as the dominant emotion. However, for this study, we only considered the probabilities for sad and happy emotions, aligning with the emotions seen elicited in the psychotherapeutical context of current works' requirement analysis. The emotion's probability relevant to the current condition was compared to a predefined threshold (see Section 3) to determine if the participant was displaying that emotion. We chose this approach to mitigate the effects of low precision rates for certain emotions, as explained by [SO21], as well as priming of the users, which could have been an issue when conducting a baseline measure ahead of the exposure.

To enable real-time facial recognition, the application ran OpenCV's image and video processing package (cv2) to capture video input from a connected webcam. Frames were continuously read and analyzed using DeepFace every 0.3 seconds. This interval was found to be sufficient for real-time interaction while reducing the amount of data logged for evaluation.

3.2. Adding Empathy to the Virtual Agent

As explained in the introduction, our IVAs have to *react* to the expressions on-the-fly to simulate real empathy, as opposed to showing emotions at predefined times. After receiving emotion probabilities from DeepFace, each value was added to a fixed-size list for its corresponding emotion. The mean of the probabilities in the list was computed and compared to a predefined threshold to decide whether to trigger a facial expression in the virtual agent. The threshold was set higher for sad emotions due to their lower precision rate compared to happy emotions. The values were determined through iterative testing and adjustment to ensure that the thresholds effectively triggered the emotional responses in the virtual agent.

To prevent inappropriate or repetitive animations, two additional conditions were checked before triggering a facial expression: ensuring no animation was currently running and verifying that at least ten seconds had passed since the last animation ended. The facial expressions were created using blend shapes in Unity, which deform geometries to generate various facial expressions. The Facial Action Coding System (FACS) [EF78] was used to guide the creation of these expressions.

Only happy emotions were evaluated and displayed in the happy condition, and only sad emotions in the sad condition, to control for DeepFace's partially poor precision distinguishing similar emotions as explained above [SO21] and minimize the risk of the agent displaying an inappropriate expression. Figure 3 shows the happy and sad facial expressions of the agent.

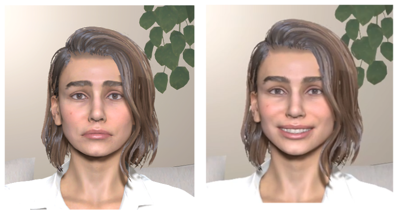

Figure 3: *Examples of the virtual agent's emotional facial expressions: Sad (left) and happy (right).*

3.3. Collecting Data

During the interaction, various data was logged and saved in a CSV file for further evaluation. This included every emotion probability received from DeepFace, the instances when the threshold was reached, the start and end times of triggered animations, whether the participant was reading or listening to the agent, the current condition (empathic vs. neutral), the emotion of the story (happy vs. sad), the number of triggered animations in the empathic condition, and the duration of both sessions.

4. Study

This study aims to investigate the influence of empathy in virtual agents on user perception and affective state. Based on previous research suggesting the importance of empathy in social interactions [MKR22, NML*10, RR08] and the impact of expressive agents on users' emotions [MY16, TBM*12, XBHN14], the following hypotheses were formulated:

- **H1:** Participants prefer an empathic agent over a neutral, non-expressive agent. They have a more positive attitude towards the empathic agent, feel more enjoyment and social presence, and rate the empathic agent as more sociable, trustworthy, anthropomorphic, animated, and likable.
- **H2:** Emotional facial expressions in the virtual agent lead to emotional contagion in participants, resulting in them showing more emotional facial expressions.
- **H3:** Participants who self-report greater empathy show more emotional facial expressions than participants with lower self-reported empathy.

4.1. Participants

Participants were recruited via the Department of Computer Science's mailing list and SONA, the university's registration portal for scientific studies. Students received course credit for their participation. Inclusion criteria were:

- At least 18 years old
- Proficiency in German
- No diagnosed epilepsy

An a priori power analysis in G*Power [MEBF07] determined a required sample size of $N = 27$ for detecting medium effects (Cohen's d = .5) with 80% power using a one-tailed paired t-test with an alpha level of .05. Thirty-two students participated, but data from five participants was discarded. For one of them the detection software malfunctioned, showing no emotions at all; for the others the recognized emotions did not pass the specified threshold and therefore did not trigger any empathic response in the agent. The remaining 27 participants represented the following age groups: 18-24 years ($N = 15$), 25-34 years ($N = 10$), 35-44 years ($N = 1$), with 18 identifying as female, eight as male, and one as diverse. All participants were undergraduate or postgraduate students, with the majority having little to no prior experience with virtual agents.

4.2. Study Materials

Two questionnaires were completed at the beginning and after each of the two reading interactions with the virtual agent. The study was conducted in German to ensure full comprehension.

Pre-session questionnaire The pre-session questionnaire included demographic questions, an assessment of prior experience with virtual agents, and the Saarbrücker Personality Questionnaire (SPF) [Pau09], a modified version of Davis' Interpersonal Reactivity Index (IRI) [Dav80, Dav83]. The SPF contains 16 items across four categories: Perspective-Taking (PT), Fantasy (FS), Empathic Concern (EC), and Personal Distress (PD), measured on a 5-point Likert scale.

Post-session questionnaire The post-session questionnaire evaluated the user's perception of the virtual agent, including attitude, perceived enjoyment, sociability, social presence, trust, anthropomorphism, animacy, and likeability. This questionnaire was based on the Almere Model [HKEW10] and the Godspeed questionnaires [BKCZ09], with constructs tailored to the study's context.

4.2.0.1. Stories Two stories were generated using Editpad's AI story generator [Edi] to induce emotional expressions: a cheerful story (happy condition) and a sorrowful story (sad condition). The stories were translated to German and manually adapted.

4.3. Procedure

The study employed a within-subjects design, where each participant read two stories: one happy and one sad. The IVAs expressiveness was chosen, so that it reacted to the user's expressions in one story (empathic condition) while it remained neutral in the other (neutral condition) as a baseline. The order of both factors were randomized to counterbalance the order, and the assignments ensured that each participant read both stories once and experienced both the empathic and neutral condition.

E.g. one participant could experience the happy story with emotional expressions from the agent first, and then the sad story while it remained neutral.

The study took place at the university in a quiet room. After signing a consent form, participants completed the pre-session questionnaire. They then interacted with the virtual agent in two reading sessions as described above. The stories each were about 7000 characters long, with half of the story being read by the agent. When it was the participant's turn, they would always be presented with a few sentences of the story, shown directly below the agent's face, and had to confirm when they were finished reading to see or hear the next part of the story. The location of the text ensured the agent was always in view while reading the story. After each session, participants completed the post-session questionnaire. Finally, participants' emotions were recorded individually to ensure they could trigger the agent's emotional feedback. The entire session lasted about 45 minutes.

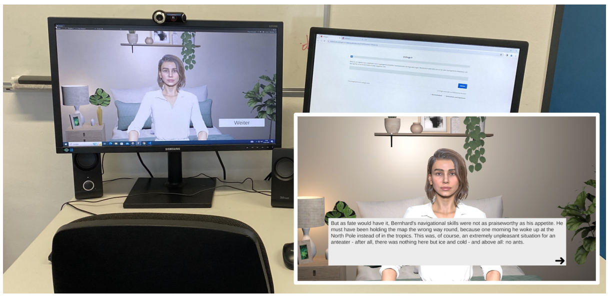

Figure 4: *Overview of the study setup and camera placement. Right monitor was used for the during the breaks for the questionnaires. The picture-in-picture demonstrates the text placement of the story below the agent.*

4.4. Hardware

The Unity application was run on a machine with an 11th Gen Intel Core i7-11700K processor, NVIDIA GeForce RTX 3090 graphics board, and 32 GB RAM, running Windows 10 Education. Sound was played via Trust Remo speakers, and a Logitech Tessar 2.0/3.7 Carl Zeiss webcam was used to observe participants' faces. The setup is shown in Figure 4.

4.5. Results

Statistical analysis was performed using R, with significance set at $p < .05$. Effect sizes were calculated using Cohen's d, r, and Spearman's rank correlation coefficient.

4.5.1. Empathy Scores and General Characteristics

Participants' empathy was assessed using the SPF, with mean scores of 14.56 (SD = 2.47) for Empathic Concern, 14.04 (SD = 2.9) for Perspective-Taking, 13.63 (SD = 2.17) for Fantasy, and 11.93 (SD = 2.95) for Personal Distress. The mean overall empathy score was 42.22 (SD = 5.12) (this value described by the SPF can lie between 12 and 60, with a score of 60 being the highest empathy score).

Interactions with the virtual agent took an average of 7 minutes and 57 seconds (SD = 41.14s) for the happy story and 7 minutes and 12 seconds (SD = 27.61s) for the sad story. The agent displayed an average of 12.46 facial expressions (SD = 9.85) in the happy condition and 30.15 (SD = 27.45) in the sad condition.

Table 1: *Means, standard deviations and results of the applied statistical test for each measure in the user study.*

	Empathic Agent		Neutral Agent		Test Statistics
	M	SD	M	SD	
Attitude towards technology (ATT)	3.01	0.70	2.96	0.64	$V = 62.5, p = .274$
Enjoyment (PENJ)	3.30	0.78	3.00	0.86	$t(26) = 2.419, p = .011$
Sociability (PS)	2.84	0.90	2.97	0.77	$t(26) = -1.000, p = .837$
Social Presence (SP)	2.16	0.76	2.11	0.78	$t(26) = .406, p = .344$
Trust	2.39	0.70	2.59	0.93	$t(26) = -1.365, p = .908$
Anthropomorphism (ANTHR)	2.05	0.73	2.11	0.82	$V = 135.5, p = .391$
Animacy (ANIM)	2.75	0.75	2.53	0.80	$V = 167.0, p = .096$
Likeability (LIKE)	3.59	0.73	3.73	0.64	$t(26) = -1.024, p = .842$

4.5.2. Impact of Empathic Feedback in Virtual Agents on User Perception

The first hypothesis (H1) was tested by comparing user perceptions of the empathic and neutral agents. One-tailed, paired-sample t-tests and Wilcoxon signed-rank tests were used depending on whether a Shapiro-Wilk test indicated that the normality assumption was fulfilled. Initially, results showed that perceived enjoyment was higher in the empathic condition ($M = 3.3, SD = .78$) than in the neutral condition ($M = 3.0, SD = .86$); $t(26) = 2.419, p = .011, d = .465$. However, after applying the Holm-Bonferroni [Hol79] correction for multiple comparisons, the difference in perceived enjoyment was not statistically significant $p = (0.011 \cdot 8) > 0.05$. No significant differences were found for other constructs, i.e., attitude, sociability, social presence, trust, anthropomorphism, animacy, and likeability (see Table 1).

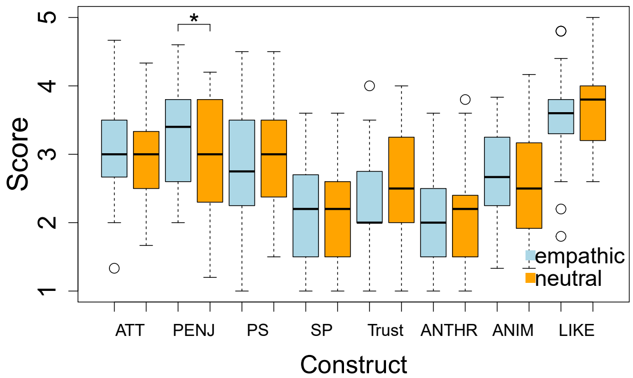

Figure 5: *Comparison of the perception of the neutral and empathic virtual agent. * indicates significant difference at $\alpha = .05$ before adjustment for multi comparison.*

4.5.3. Emotional Contagion

To test H2, the number of relevant emotions displayed by the user was compared between conditions. A facial expression of the user was considered a relevant emotion when it reached the threshold described earlier. A one-tailed, paired-sample t-test showed that the number of emotions expressed by the user was significantly higher in the empathic condition ($M = 329.93, SD = 323.54$) than in the neutral condition ($M = 143.78, SD = 243.64$); $t(26) = 2.081, p = .024, d = .400$. The results are shown in Figure 6.

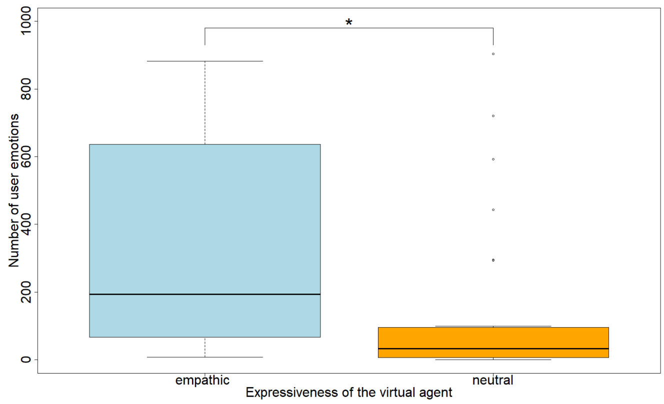

Figure 6: *Number of emotions displayed by the user towards the virtual agent. * indicates significant difference at $\alpha = .05$.*

4.5.4. Correlation between the User's Empathy Score and Expressiveness

We further performed a Spearman's rank-order correlation analysis to determine whether there is an effect of the users' self-reported empathy scores on emotional contagion (see Figure 7). For the condition featuring an empathic agent, there was a moderate, positive correlation between the empathy score and the number of emotions expressed by the user, which was statistically significant ($r_S(25) = .498, p = .008$). In contrast, for the neutral agent, there was no correlation ($r_S(25) = -.013, p = .949$).

4.6. Discussion

4.6.1. Impact of Empathic Feedback in Virtual Agents on User Perception (H1)

The first hypothesis of this study was that participants would prefer an empathic agent who provides facial feedback consistent with

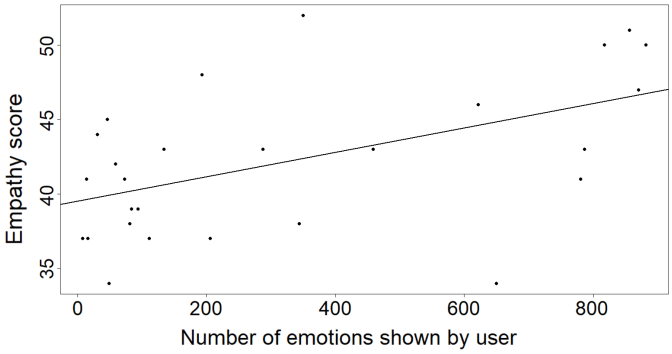

Figure 7: *Scatter plot for the correlation between the user's empathy score and their expressiveness*

their own emotions over a neutral, non-empathic agent. The hypothesis suggested that participants would have a more positive attitude towards the empathic agent, feel more enjoyment and social presence, and rate the agent as more sociable, trustworthy, anthropomorphic, animated, and likable. The results suggest that this hypothesis can not be accepted as stated. The significant difference with higher scores for the empathic agent in the user's perceived enjoyment did not hold in the correction for multiple comparisons, as explained in section 4.5.2. Multiple research questions, that clearer differentiate and identify the relevant constructs could prove beneficial for future studies. Overall, unlike previous related work [BNH05, LAYR13, NM09], no significant preference for the empathic agent was found regarding the attitude towards the agent, perceived sociability, social presence, trust in the agent, anthropomorphism, animacy, or likeability.

Those constructs depicted in Figure 5 show. that the perception of the empathic agent shows only slightly but not significantly higher ratings for constructs such as attitude towards the technology, social presence, and animacy, while at the same time receiving lower results in terms of perceived sociability, trust, anthropomorphism, and likeability when compared to the neutral agent. This disparity could be due to participants perceiving the virtual agent's expressions as eerie, resulting in the uncanny valley effect [Mor70, MMK12].

This assumption is supported by comparing the adjectives used by participants to describe the neutral and empathic agents and reviewing the free-text input at the end of the study, where participants described the difference between the two agents. While the empathic agent was often described as friendly, polite, and kind, it was also described as fake, artificial, and spurious. Moreover, five participants described the empathic agent as creepy, scary, or discomforting, and two as weird. In contrast, while the neutral agent was also described as friendly, polite, kind, artificial, unreal, and spurious, participants did not describe the neutral agent as creepy, scary, or discomforting, and only one person perceived it as weird. This suggests that the uncanniness of the virtual agent is caused by the design or presentation of it facial expressions, since only the empathic agent was perceived as eerie. Overall, the empathic agent was described 29 times with positive, 14 times with neutral, and 38 times with negative adjectives. The neutral agent received 26 positive, 7 neutral, and 48 negative descriptions.

Several answers from the participants confirm this. The depicted emotions were described as exaggerated, unnatural, strange, and distorted. Moreover, some participants stated that the facial responses of the empathic agent seem to be displayed randomly, at inappropriate times, and unrelated to the story's content. Especially participants who interacted with the empathic agent while reading the sad story, receiving sad facial feedback from the agent, reported a discrepancy between the agent's emotions and the content of the story. This suggests that the mapping between an emotion in the user and the triggering of an expression in the agent could be improved.

Several reasons could explain this behavior, but two are most likely. Firstly, the choice of the threshold, which determines when the agent responds to the user's emotions, might be part of the cause. The threshold was determined in a small test run with $N = 3$ participants. While it fit under these circumstances, participants in the main study might have shown stronger facial expressions, resulting in more frequent facial responses by the agent, making it appear repetitive and thereby artificial and unnatural. Using the baseline recordings of emotion done at the end of the study, we ran an explorative analysis on which values might have been more suitable. With emotions falling between 0 and 100, the overall mean for happy was 24.73 ($SD = 32.92$), and for sad 17.22 ($SD = 17.79$). Our threshold values for happy and sad were 30 and, 40 respectively. Post-hoc calculation of emotions would not yield any meaningful results, since it would not change the emotions shown by the agent. Comparing the individual baselines with the values seen for each participant, the mean distance from baseline to happy was -13.91 ($SD = 29.69$), and for baseline to sad 7.95 ($SD = 16.37$). The high standard deviations suggest, that both measure would not have been sufficient in providing a perfect experience by themselves either, and that a more complex measure should be developed. Part of the deviations might also be attributed to DeepFace's performance issues on sad expressions, as explained previously in 3.1, falsely interpreting other emotions as sad even though we already tried to mitigate by determining different thresholds for both conditions as described in 3.2. This might have caused the agent to trigger a sad emotion when the user does not show the corresponding facial expression, resulting in an unsatisfactory experience.

4.6.2. Emotional Contagion (H2)

The second hypothesis was that an empathic virtual agent can induce emotional contagion in the user, resulting in the user showing more emotions in the empathic condition than in the neutral condition. As shown in Figure 6, participants indeed showed significantly more facial expressions when the virtual agent displayed the same emotions compared to when the agent remained neutral, not sharing the user's affective state. This confirms that emotional contagion, the ability to feel and imitate another person's emotional state, can, like between humans, also be achieved in human-agent interactions. While this offers promising opportunities for the use of virtual characters, such as improving the user experience in therapeutic interactions and even forming meaningful relationships, e.g. between patient and virtual assistants, there is also a risk of misuse or critical error when trying to influence users' opinions or feelings.

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In this study, sad emotions were elicited as empathic reactions towards a fictional character in a story. However, when using virtual agents in serious situations such as medical counseling or virtual therapy, and especially when users have to express their own feelings instead of solely reacting to the emotions of a fictional character, a virtual agent mimicking negative emotions could increase the user's negative emotional state. Therefore, it is important to consider the situational context of the application when using empathic virtual agents and to think about the possible implications of emotional contagion. For psychotherapy, it might be better to mimic positive emotions only or to show encouraging behavior instead of displaying sad facial expressions as a reaction to negative emotions in the patient.

4.6.3. Correlation between the User's Empathy Score and Expressiveness (H3)

The third hypothesis suggested that the user's self-reported empathy correlates with the number of emotions they express during the interaction with the virtual agent. Results illustrated in Figure 7 indicate a medium positive correlation between these variables when considering both agents, and strong positive correlations when examining the happy and the sad conditions separately. This supports the hypothesis that participants who rank themselves as more empathic display more facial expressions while reading an emotion-eliciting story. Since the number of emotional expressions measured was also positively correlated with the users' self-reported empathy for the empathic agent but not for the neutral agent, it can be concluded that empathic participants reacted more strongly to the emotional contagion shown by the agent independent of the story and did not just feel stronger empathy towards the fictional character in the story. Overall, the results suggest that participants are generally able to correctly assess their empathic capacity and that a person's empathic self-perception correlates with their actual amount of empathic behavior shown through their reactions.

5. Limitations and Future Work

Natural Expression of Emotions by Agents. The main challenge in designing the virtual agent, was creating realistic emotional facial expressions. Despite following established standards such as (e.g., FACS), some participants perceived the empathic virtual agent unsettling. In addition to revising the agent's expressions, we suggest variations of animations (e.g. by generating) to imitate natural, human facial expressions more closely, which also vary in their intensity and style. Furthermore, integrating expressive voices for the virtual agent that match the emotions displayed by the facial expression could reduce discrepancies and enhance realism [ACCT21]. Since empathic behavior also includes other channels like gestures or posture [BNH05, HRL11], future studies could also explore the effect of imitating these factors in increasing the acceptability and realism.

Reliable Detection of Emotions Expressed by Users. Another challenge was the selection of an emotion recognition method and the interpreting the emotions. A software-based framework was chosen to avoid medical equipment or intrusive setups, simulating personal use. Two accurately extractable emotions were selected, matching those expected from the stories. A threshold for displaying facial expressions in the virtual agent was set in a prestudy, triggering an empathic reaction when exceeded. However, this threshold was not suitable for all participants, leading to four being excluded and others triggering too many expressions, which could make the agent appear uncanny. Physiological measures like skin conductance or heart rate could provide more reliable results, though they might lag behind facial expressions or be too subtle [PI05, VCÁSFVF20, SXY*18]. Using the *self assessment mannikin* (SAM) [BL94] could be used, but the measure would be very delayed as opposed to the live measurements to the reaction and rather focus on the overall emotional condition. Combining multimodal detection methods with real-time personalized thresholds and more context-aware agents could provide more accurate and empathetic responses to various emotions.

Choice of agent characteristics. To limit the scope of this study and improve comparability, only a female virtual agent was utilized, which all participants spoke at. However, previous work suggests that the agent's characteristics, such as gender and age, and the similarity between the virtual agent and the user play an important role in the user's perception of the agent [PLBW17, tSTodA*20]. Therefore, it could yield interesting results running studies with a variety of virtual agents, considering their characteristics and similarity to the user as additional variables.

Choice of study setting. During the study's development, we chose a suitable setting where participants directed happy and sad emotions towards a fictitious character in a childlike story, avoiding personal emotional discussions. This casual and informal approach was inspired by one-on-one therapeutic conversations. For future work, our results should be confirmed in a medical environment with expert supervision, also exploring the users' perception along the work of ter Stal et al. [tSTodA*20]. It could also be of interest to control the gender ratio of the participants, or analyze them separately, since in our study 70% identified as female, who elicit higher emotional responsiveness [CMSC*14]. Also, examining the long-term effects of empathic feedback in virtual therapy could reveal if simulated emotions help build lasting, trusting relationships.

6. Conclusion

For this study, a virtual agent was created to react empathically to the user's affective state. In a within-subject design, participants read a happy and a sad story with the VA, who responded with empathic feedback in one condition and remained neutral in the other. We investigated the effect of empathic feedback from VAs on user perception, with the goal of enhancing user experience and facilitating the formation of trusting social relationships with virtual assistants. The influence of simulated emotions on user expressiveness was explored, confirming that emotional contagion can be induced not only between humans but also towards virtual characters. Further, the study examined whether the user's self-reported empathy correlates with their empathic behavior. The empathic agent was found to increase the user's expressiveness, and a moderate, positive correlation between the empathy score and the number of emotions expressed by the user was found in the condition featuring it, which was statistically significant. This indicates that participants who self-reported higher empathy levels also displayed more emotions in response to the empathic agent.

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