Empathy Toward Virtual Humans Depicting a Known or Unknown Person Expressing Pain

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Abstract

This study is about pain expressed by virtual humans and empathy in users immersed in virtual reality. It focuses on whether people feel more empathy toward the pain of a virtual human when the virtual human is a realistic representation of a known individual, as opposed to an unknown person, and if social presence is related to users’ empathy toward a virtual human’s pain. The 42 participants were immersed in virtual reality using a large immersive cube with images retro projected on all six faces (CAVE-Like system) where they can interact in real time with virtual characters. The first immersion (baseline/control) was with a virtual animal, followed by immersions involving discussions with a known virtual human (i.e., the avatar of a person they were familiar with) or an unknown virtual human. During the verbal exchanges in virtual reality, the virtual humans expressed acute and very strong pain. The pain reactions were identical in terms of facial expressions, and verbal and nonverbal behaviors. The Conditions by Time interactions in the repeated measures analyses of variance revealed that participants were empathic toward both virtual humans, yet more empathic toward the known virtual human. Multivariate regression analyses revealed that participants’ feeling of social presence—impression that the known virtual character is really there, with them—was a significant predictor of empathy.

Introduction

There is an increase in the use of virtual humans in experimental research. For example, studies have shown that users immersed in virtual reality (VR) can effectively recognize emotions expressed by a three-dimensional (3D) virtual representation of humans, including happiness, fear, anger, and sadness, as demonstrated by.1 Men also modify their posture, hand movement, and head movements when they interact with a virtual female character.2 Rossen et al.3 found that negative skin-tone biases toward people are transferred from the physical to the VR. In that study, reactions toward dark skin-tone virtual humans were predicted by biases toward African-Americans. Slater et al.4 reproduced the classical social psychology experiment from Stanley Milgram and illustrated quite effectively that users react strongly to the pain experienced by an unknown virtual person receiving electric shocks.

In the field of pain, a few studies have used virtual humans to standardize how pain is expressed by a “patient” and assess differences in how people rate pain in others. Hirsh et al.5 conducted an experiment with 75 young adults who watched videos of various virtual humans expressing their pain through facial expressions. Participants rated the unpleasantness and intensity of virtual human’s pain. They were able to differentiate accurately the level of pain experienced by virtual humans. Results of this experiment5,6 and others by the same group have consistently shown that, even if the expression of pain is similar for male and female virtual humans, virtual human females are rated as having higher pain intensity, unpleasantness, negative mood, and worse coping than virtual human males.7 Similar biases have also been reported in these studies toward African-American and older people expressing pain.

If virtual humans in pain can elicit reactions in the user, can they elicit empathy? Would a user immersed in VR react more strongly to the virtual human if the user is an acquaintance of the person depicted in VR (its avatar) than if it is an unknown stranger. Literature on empathy8–11 suggests that people are more likely to react to someone experiencing pain given that they can relate positively to that person (e.g., a member of the same race, a friend). Research on the use of

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virtual humans and avatars should test empirically if empathy toward pain expressed by an acquaintance also extends to the virtual world.

There is a growing body of evidence showing that the relationship between people’s emotional reactions toward virtual human’s appearance and behavior is not linear and simple. Two different types of evidence can be identified. Concerning theoretical issues, an early theory by Morii suggested that in a graph depicting how observers are increasingly empathic toward synthetic humans as the latter become more humanlike, the response of the observer will suddenly drop just before the synthetic reaches a very human look, forming an “uncanny valley” caused by sensitivity and revulsion to perceived imperfections in near-humanlike forms. Concerning empirical support, some studies brought nuances to Mori’s theory, notably that many factors influence how observers react to the realism of a synthetic human. Experimental research on virtual human and avatars now shows the existence of a non-linear relationship between realism of virtual characters and the consequence of imperfections and mismatch in their behavior and appearance. It would appear that people are able to tolerate well significant imperfections in behavioral realism when the virtual humans are not considered realistic. However, as virtual humans become more realistic, anthropomorphic and behavioral realism set up higher expectations, which in turn could lead to more disenchantment when small imperfections are perceived, either because of behavioral or physical discrepancies. Because of this “clash against expectations,” a more realistic yet imperfect avatar of an acquaintance may lead to less empathy when expressing pain.

Also, using virtual humans to study empathy may not be straightforward because, despite that facial expression of pain can elicit empathy, empathy is also affected by other complex processes. Craig et al. argued that an observer’s reaction to the pain of someone else does not only depend on perceiving pain cues. The observer’s reactions are moderated by how pain is interpreted. Manifestations of pain that are perceived as automatic, involuntary, and spontaneous lead to different reactions in the observer than expressions of pain that are perceived to be voluntarily controlled. If the observer’s reactions to painful stimuli are modulated by how they perceive the sufferer, then the fact that virtual humans are not real and programmed may influence the observer’s reactions. Also, empathy could be significantly increased if the observer has a personal connection with the person in pain (e.g., being a friend, a relative, an acquaintance or, more generally, someone known by the observer). When immersed in VR, the interactions and relationship with virtual humans or avatars is influenced by social presence. Social presence reflects how users immersed in VR feel that virtual humans are really there, in the room, with them. As Bailenson and colleagues have argued, social presence could be assessed from two standpoints: the users’ subjective feeling that they are not alone in the virtual environment (referred to as co-presence), or the user’s social behaviors being influenced by the virtual human. They therefore proposed to refine our assessment of social presence by measuring co-presence and social responses.

The current study investigated two research questions related to whether pain experienced by a virtual human can induce empathy in a user immersed in VR: (a) Is the empathy stronger when observing the avatar of a known individual than by observing a virtual human depicting an unknown person? (b) Does social presence play a role in users’ empathy toward virtual human’s pain?

Methods

Participants

The sample is composed of 42 adults (18 to 60 years old, 13 women per experimental condition) in good mental and physical health, as verified during a telephone prescreening. Because the goal of the study was to document people’s reactions to the avatar of a person the participants are familiar with, it was considered feasible to recruit participants that were familiar with one physical person (in this case, Stéphane Bouchard) but impossible to spend months developing and animating realistic avatars tailored to the image of a friend of each participant. Despite the risk of potential biases, it was decided to favor feasibility and proceed with recruitment based on familiarity with one virtual human rather than wait years for the technology to catch-up with our needs to build and animate highly realistic friends of randomly selected participants. Recruitment was therefore conducted on the university campus among students, university staff, friends, colleagues, and relatives of members of the research team. To be eligible for the study, participants must (a) have directly talked at least once with the person who was used as a model to create the Known Virtual Human (Stéphane Bouchard), but (b) have never seen the virtual humans used for the project nor been aware that the virtual humans would express pain during the experiment. The study followed a repeated measures design with a first control immersion (Immersion 1) identical for every participant and a counterbalanced presentation of experimental conditions at Immersion 2 and Immersion 3. Participants were randomly assigned (i.e., not matched based on demographic properties) to two virtual humans conditions: (a) Known Virtual Human First (KVHF; i.e., Immersion 2 was with the known virtual human, followed by Immersion 3 with the unknown virtual human, n = 22) or (b) Unknown Virtual Human First (UVHF; i.e., Immersion 2 was with the unknown virtual human, followed by Immersion 3 with the known virtual human, n = 20).

The following exclusion criteria were set a priori for ethical reasons and, if met, would have led to the rejection of the participant showing signs of suffering from schizophrenia, psychotic disorder, or PTSD. This was assessed using the respective sections of the SCID-NP. These criteria were assessed by research assistants (PhD candidates in psychology who had experience in administering the SCID-NP, including assessing these criteria, who had been trained in handling clinical cases, and who were not relatives of the participant). In addition, people suffering from the following physical problems would have been excluded given the risk of having significant cybersickness during the immersion: vestibular or inner ear problems, recurrent migraines, epilepsy, balance, cardiac or ocular problems, and frequent and intense motion sickness in transports. No participants were excluded on the basis of any of the criteria mentioned above. People with no stereoscopic vision (as assessed with the Randot stereoscopic test) were excluded since people with this condition cannot perceive depth in stereoscopic immersions. This criterion was used to exclude one potential candidate.
All participants were informed about ethical considerations relative to the study and the risks associated with the experimental protocol. Before being asked for their written informed consent, they were told they were free to refuse to participate and could withdraw their consent without prejudice or hard feelings at any time. No financial compensation was provided. Experimenters insisted that the principal investigator would not have access to their personal information or details about their personal experience. Participants were not informed that the virtual characters would express pain. This information and the real objective of the study (i.e., study user’s reactions to the pain of a known individual or a stranger) were not disclosed (see the Procedure section for details of the information actually provided). After the study, participants were fully debriefed and informed about the aim of the study and the reasons motivating this deception. The present study had been approved by the ethics review board of Defence Research and Development Canada Valcartier and the Ethics committee of the Université du Québec en Outaouais before initiating the recruitment. All individual participants in this study gave written informed consent prior to their participation and none withdrew it after the debriefing.

Measures

Demographic and personal information

A list of questions was presented to each participant for information on age, gender, socio-economical status, on average how often they meet Stéphane Bouchard during a year, etc. This demographic information and the score on the measure of attachment were collected to (a) describe the sample, and (b) statistically control for potential biases that may be induced by the randomization.

Adult attachment questionnaire. This instrument measures adult attachment style. It consists of 13 items using a scale from 1 (strongly disagree) to 7 (strongly agree). Administering this questionnaire once at the start of the study allowed controlling for potential individual differences in attachment styles that may arise after randomization and may lead to a greater sensitivity to a virtual human’s pain reactions.

Psychological measures

Empathy. Empathy toward the pain of the virtual human was assessed with two items rated on a 1 to 7 scale: “I was empathic to the pain of the virtual person” and “the pain of the virtual character was credible.” These items were not used after the control immersion because no pain was involved in Immersion 1 (see method section below).

Social presence questionnaire. The original version contains 17 questions about the feeling of presence and interactions with virtual characters. Nine items were dropped from the original scale because they were irrelevant to our virtual environment (e.g., “How aware were you of the existence of your own avatar?”; “How natural was the mechanism which controlled the actions of your avatar?”; “How responsive were the avatars of other participants to nonverbal communication that you initiated?”). This measure is used as a global measure of presence, without the distinction proposed by Bailenson et al. between feeling co-present and behaving in accordance to the presence of virtual humans.

Co-presence questionnaire. It contains six items measuring the subjective impression of being there in the virtual environment and to which extent the person treats the virtual humans as if they are real people. The format was adapted and worded specifically for each immersion by referring explicitly to the cat, the known virtual character of Stéphane Bouchard, or the unknown virtual human.

Likability. This variable was measured with three of the four items developed by Bailenson et al. to assess to what extent the participants liked the virtual human they met during the immersion. The end of each item was modified to adapt the question to the character encountered during the immersion (i.e., the cat, the Known Virtual Human or the Unknown Virtual Human). Bailenson et al.’s approach to the general concept of social presence was to differentiate how participants respond to virtual humans and from the subjective impression of being co-situated. As with embarrassment, likability fits in the category of social dimensions of social presence, as opposed to co-presence.

Embarrassment. This instrument contains four items measuring the participant’s willingness to perform embarrassing acts in front of the virtual character. Embarrassment addresses the participant’s perception of the social influence exerted by the virtual character and the participant’s social response toward the virtual character. In conjunction with co-presence, it provides a refined view of social presence. The format was adapted and worded specifically for each immersion and character by referring explicitly to the cat, the Known Virtual Human or the Unknown Virtual Human. Some items were modified because the context of the current study would make them implicitly embarrassing (e.g., willingness to change clothes in front of the known virtual human).

Measures relevant to VR

Immersive tendencies questionnaire. The Immersive Tendencies Questionnaire was administered at the intake interview to statistically control for potential biases, if needed. The ITQ has 18 items rated on a 7-point scale (1: Never, 7: Often) which provide a Total score and four subscale scores: Focus (the ability to concentrate and to ignore distractions), Involvement (the feeling of being caught up by stories and movies), Emotion (the intensity of the emotions evoked by stimuli such as movies), and Play (the frequency of playing video games).

Simulator sickness questionnaire. This questionnaire assesses the level of discomfort before and after the immersions, using 16 different items related to symptoms (headache, eye strain, nausea, etc.). It was administered at baseline and after each immersion to document potential side effects induced by the experiment. Only the raw (unweighted) scores are reported (see Ref. for details).

Physiological and behavioral measures

Stereoscopic vision for depth perception. In order to test the ability to perceive binocular disparity in distance from static stimuli, the participant performed a stereopsis test (Randot).
Galvanic skin response. Electrical conductivity is commonly used to assess immediate response to stressors.\(^{28}\) This consisted in observing various geometric shapes (between 400 and 20 seconds of arc in apparent size) and animals (between 400 and 100 seconds of arc) in front of random dot backgrounds while wearing polarizing glasses. Participant must recognize the stimuli they perceived as 3D (i.e., floating above the test board). A PD-5 Topcon pupillometer (Topcon Medical Systems, www.topconmedical.com) was used to measure interpupilar distance and individually tailor the stereoscopy to each participant immersed in the virtual environments.

Distance and change in distance relative to the virtual humans. This information allowed documenting interpersonal distance and the behavioral reactions of participants when the virtual humans expressed pain. Data from the InterSense IS-900 VET for participant’s head position and the position of the virtual humans was recorded at every visual frame displayed (with a frame rate ranging on average between 40 to 50 per second, depending on the processing of information at each instant) during the immersions. The interpersonal distance during the discussion with the virtual human is reported in actual distance in meters. To capture the range of movements of the users relative to the virtual humans expressing pain, change in distance from was recorded at the previous visual frame was calculated by averaging movements during 12-second segments before and during the acute pain animation. Change in distance describes the average amplitude of movements away from the virtual human, in meters.

Equipment and material

Hardware. All immersions were performed in the CAVE-like system at the Laboratoire de Cyberpsychologie de l’Université du Québec en Outaouais (see Fig. 1). This immersive system, nicknamed Psyche because of its dedication to psychological studies and mental health, consists of six projector surfaces: four sides, a ceiling, and a floor. The back wall is mounted on a railing and can be fully closed once the participant is inside the cube. Each screen of 8.6’ receives images from a VizTek 1 projector located 15’ away. Each CRT projector displays 225 ANSI lumens images at a native resolution of 1280 × 1024 at a frame rate of 100 Hz and delivers active stereoscopy (in active stereoscopy, the maximum frame rate is 50 unique images displayed per second per eye, or lower if an important amount of data must be processed to render the visual frame). Psyche is driven by a cluster of six slave computers and one master computer, all running Virtual reality environment (VRE) software, VR Publisher Unlimited 5.0 and built with the following specs: Intel® Core 2 Quad Q6600@2.40 GHz with 4Go of RAM, NVidia® graphics card Quadro FX 5500G with 1024 MB of VRAM, Intel D975XBX2 motherboard, and Windows® XP Pro 32 Bits Service Pack 2. The rendering library uses OpenGL 2.0 Stereo. The master computer also has a Creative® SoundBlaster X-Fi sound card. The cluster of PC includes an additional computer to link the Intersense® tracker to the virtual environment on VRPN 7.18 with a Pentium 4 3.20 GHz CPU and 512 Mo of RAM. All computers are linked in a network using a CISCO® Catalyst 2950S Series 100MBIt/s/sec switch.

The viewer’s head position is tracked by a wireless Intersense IS-900 VET system at 256 Hz to correct for the perspective in real-time since the position of the viewer in relation to the screens change based on the user’s movement within Psyche. The user wears active 3D shutter glasses (NuVision®), wireless stereo headphones (Sennheiser® RS146), and a Shure® L3 wireless lapel microphone. The experimenter wears a set of Bose QuietComfort® 15 noise cancelling headphones and can talk to the participant via a microphone. Before starting the immersions, the participants were positioned in the middle of the back wall/door, two feet inside the cube. They were allowed to physically move freely within the virtual environment.

The experimenter was controlling Psyche, and the computer running the psychophysiological assessment, from outside the room hosting Psyche. The participant was thus left alone either (a) sitting close to a table with ambient lights turned-on but dimmed, for completing questionnaires and baseline physiological monitoring, or (b) standing-up in Psyche, all participants at the exact same location, with the ambient lights turned off, for starting the immersion.
A PC was used to monitor physiological responses continuously during the study (computer with Intel Core 2 Duo CPU @ 3 GHz, 1.96 Go of RAM, with a NVidia GeForce 9800 GTX PCI Express with 512 Mo of RAM, running on Windows XP Service Pack 3). GSR was monitored using a ProComp Infinity® and a wireless-enabling Tele-Infiniti® Compact Flash T9600, both from Thought Technology (www.thoughttechnology.com). GSR electrodes were strapped on the index and the annular fingers of the nondominant hand. Physiological data were sampled at 256 Hz. While data were acquired and recorded, the research assistant put markers in the series of physiological data at the same time she triggered specific events during the experiment, defining blocks of physiological data to be analyzed later.

Software and visual content. Two virtual environments were used, a training environment used as a baseline/control immersion and an experimental environment. The virtual training environment consisted of an empty room with three windows, a glass door, and a cat waiting on a table behind the glass door. The participant can hear a relaxing breeze and bird songs through the windows. The purpose of the control immersion in this training environment was twofold. First, it allowed participants to become familiar with being immersed in a CAVE-like system, including moving close to a virtual human and talking to a virtual stimulus. Second, data recorded during and after this immersion served as a baseline controlling for the effect of being immersed in VR as well as for seeing and interacting verbally with a virtual character.

The virtual experimental environment was a sports bar measuring 8.5 m in width by 13.5 m in depth, with a pool table, several tables and chairs, posters on the walls, alcoholic beverages on the counter, sports games playing on TV monitors, and rhythmic music playing in the background. The bar was empty, except for a virtual human standing near the pool table. The virtual human was in a waiting position, looking vaguely at the incoming participant. Quantitatively, both human characters were built with 59,644 polygons and the virtual cat with 3036 polygons. The experimental environment, including the virtual human, displayed about 259,339 polygons while the training environment was much lighter, with 53,234 polygons. The polygon counts fluctuated depending on the visible information at any given time, but the above information gives an idea of the complexity and richness of the scenes.

The three virtual characters used were a cat, Stéphane Bouchard (see Fig. 2), and a virtual human created without using the picture of a real person. Stéphane Bouchard’s avatar (referred to as the Known Virtual Human and dubbed MiniMe) was developed using pictures, videos enactments, and voice recordings of the various behaviors and facial expressions needed for the study (see Figs. 2 and 3). The Unknown Virtual Human was designed on the same bone structure as the Known Virtual Human, allowing using the same animations. The audio recordings were modified (increasing the higher frequencies in the voice, raising the pitch by eight percent and removing audio artifacts induced by the modifications), so the voice of the Unknown Virtual Human could carry the same emotions yet sound different from the Known Virtual Human. The two virtual humans therefore appeared different because different textures were applied on the bone structure, but they had the same verbal and non-verbal behaviors as well as facial expressions and lip synchronization.

Five animations were created for the human humans (see Fig. 3): (a) waiting in an idle position, (b) welcoming the participant and inviting him or her to describe one of the best things that had happened in his/her life, (c) idle/listening, (d) asking for more details, and (e) pain.

The virtual environments were created using 3D Studio-Max® version 2009 (Autodesk; http://en.autodesk.ca), the cat was adapted from the Vizard Complete Animals® set (WorldViz; www.worldviz.com) and the virtual humans were developed using the Evolver® software (Darwin Dimensions, Inc.; www.evolver.com). Stéphane Bouchard’s clone biped was created by Darwin Dimensions (see Fig. 2 rendered in Maya®) and preliminary facial animations with blend shapes were tested with the Evolver software. The
Unknown Virtual Human was also developed using Evolver, but only with the tools available on the web version of the software. Import into 3D Studio Max, final facial and biped animations and synchronization of lips movements with the audio files were performed by FacePro® (FacePro LLC; http://facepro.net). Animations were transferred from the known to the unknown virtual character by FacePro. Each step of the characters creation and animation processes actively involved the development team at UQO, who also used the above software to work on all stimuli. Integration of visual stimuli, avatars, sounds and animations, as well as real-time rendering was performed using 3DVia Virtools® 5.0 (Dassault Systemes; www.3ds.com). During the development of the animations, several pilot tests were performed in Psyche with staff and relatives to improve the realism of the virtual humans and animations.

Procedure

After completing the selection process, questionnaires (all French versions), and consent form in the experimenter’s office, participants were brought in Psyche’s room. The
experimenter installed the physiological monitoring and gave the first set of instruction to the participant. As instructions, participants were told they would have to visit the training environment and the experimental environment twice for a total of three immersions in VR. The two experimental immersions in VR would take place in a bar where a virtual human (known or unknown to them) would initiate a conversation with the participant. Participants were told to prepare describing the nicest thing that has occurred to them in their life because the virtual human would ask them to do so. Then, the experimenter left the participant in the room for baseline physiological assessment during 2 minutes.

After the baseline, participants received instructions specific to the training environment. The experimenter invited the participant to walk into the virtual room, open the glass door, and interact with the virtual cat (see Fig. 3), including talking to him.

The immersion in the first experimental environment began after repeating the instructions on telling the story of their best souvenir. The immersion was initiated according to the same sequence as for the training environment. In the virtual bar, the events occurred in the following sequence (see Fig. 3): (a) participants had up to 30 seconds to explore the surroundings and approach the virtual human who was slowly looking around in the bar, (b) the participants were greeted by the virtual human and the virtual human invited the participant to tell his or her story and remained into a listening (idle) animation while holding a positive emotional expression, (c) if the participant paused, the experimenter could launch additional animations asking for more details about the story, (d) after talking with the virtual human for 60 seconds, the pain animation was launched (duration of 12 seconds), which caused the virtual human to have acute stomach cramps while the participant was still talking, excused himself and invited the participant to keep talking while he experienced even stronger and longer pain reactions (including screams, moaning, bending and stretching, putting hands on the stomach, facial expressions, etc.—see Figs. 2 and 3), (f) after the pain animation the virtual human went back to the idle position and the experimenter stopped the immersion.

Following the first experimental immersion, participants followed the same procedure to complete questionnaires, received instructions again (the content was identical, except for referring to meeting the other virtual human), and the second experimental immersion unfolded just like the previous one.

Results

Descriptive information was collected and subjected to two-way analysis of variances (ANOVAs) and chi-square tests in order to confirm that randomization did not introduce biases in sample characteristics. As a manipulation check, repeated measures ANOVAs were first conducted to assess the immediate impact of the stressor of observing a virtual human sampled at each frame (between 40 and 50 per second) and the experimenter ended the sequence as for the training environment. In the virtual bar, the events occurred in the following sequence (see Fig. 3): (a) participants had up to 30 seconds to explore the surroundings and approach the virtual human who was slowly looking around in the bar, (b) the participants were greeted by the virtual human and the virtual human invited the participant to tell his or her story and remained into a listening (idle) animation while holding a positive emotional expression, (c) if the participant paused, the experimenter could launch additional animations asking for more details about the story, (d) after talking with the virtual human for 60 seconds, the pain animation was launched (duration of 12 seconds), which caused the virtual human to have acute stomach cramps while the participant was still talking, excused himself and invited the participant to keep talking while he experienced even stronger and longer pain reactions (including screams, moaning, bending and stretching, putting hands on the stomach, facial expressions, etc.—see Figs. 2 and 3), (f) after the pain animation the virtual human went back to the idle position and the experimenter stopped the immersion.

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Table 1. Descriptive Information for Participants Randomly Assigned to the Known Virtual Human First or the Unknown Virtual Human First (N=42)

<table>
<thead>
<tr>
<th></th>
<th>KVHF</th>
<th>LVHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years)</td>
<td>38.05 (12.45)</td>
<td>36.05 (12.28)</td>
</tr>
<tr>
<td>Attachment questionnaire—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secured</td>
<td>21.86 (3.90)</td>
<td>22.35 (3.88)</td>
</tr>
<tr>
<td>Avoidant</td>
<td>12.23 (4.24)</td>
<td>12.10 (5.39)</td>
</tr>
<tr>
<td>Anxious ambivalent</td>
<td>11.82 (3.50)</td>
<td>11.00 (2.15)</td>
</tr>
<tr>
<td>Immersive tendencies</td>
<td>67.82 (13.99)</td>
<td>68.65 (12.29)</td>
</tr>
<tr>
<td>Simulator sickness</td>
<td>3.45 (2.89)</td>
<td>3.50 (2.74)</td>
</tr>
</tbody>
</table>

Mean, with standard deviations in parentheses. KVHF, Known Virtual Human First; LVHF, Unknown Virtual Human First.

Table 2. Immediate Physiological and Behavioral Reactions to the Pain Stressor (N=42)

<table>
<thead>
<tr>
<th></th>
<th>Immersion 2</th>
<th>Immersion 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prepain</td>
<td>During pain</td>
</tr>
<tr>
<td>Galvanic Skin Response (in micro-Siemens)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KVHF</td>
<td>8.10 (4.26)</td>
<td>8.40 (4.35)</td>
</tr>
<tr>
<td>UVHF</td>
<td>8.33 (5.88)</td>
<td>8.65 (5.98)</td>
</tr>
<tr>
<td>Change in distance from the virtual human (in meters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KVHF</td>
<td>0.04 (0.03)</td>
<td>0.10 (0.10)</td>
</tr>
<tr>
<td>UVHF</td>
<td>0.05 (0.06)</td>
<td>0.09 (0.11)</td>
</tr>
</tbody>
</table>

Mean, with standard deviation in parentheses. Recall that Immersion 1 did not involve pain reaction and, as a baseline control, was conducted with the virtual cat. Change in distance reflects the average amount of relative movements away from the virtual human sampled at each frame (between 40 and 50 per second) during 12 seconds.
Known Virtual Human. The mean age of the entire sample was 37 years ($SD = 12.26$). Age, attachment style, immersive tendencies, and side effects of the immersion are reported in Table 1. The mean interpersonal distance during discussions between the participants and the virtual humans were 1.1 and 1.2 m for the Known and Unknown Virtual Humans, respectively. Note that analyses comparing the conditions on all these descriptive variables did not detect any significant differences between the groups.

**Research question 1: comparison between known versus unknown virtual humans during immersion 2 and immersion 3**

Participant’s behavioral reactions to the pain of the virtual humans were confirmed (see Table 2). The stressful impact of observing pain expressed by a virtual human was documented with GSR by a significant Time effect comparing the 12 seconds prior to the pain reaction to the 12 seconds of the pain reaction during Immersion 2 [$F(1,40) = 7.26, p < 0.01$] and during Immersion 3 [$F(1,40) = 5.58, p < 0.05$], as well as for change in distance away from the virtual humans the first time pain was expressed [$F(1,39) = 8.87, p < 0.01$] (i.e., Immersion 2). Change in distance away from the virtual humans also occurred during Immersion 3 but was smaller and non-significant [$F(1,39) = 2.25, ns$, partial eta-squared = 0.05].

The following sets of analyses were performed to document participant’s empathy toward the two virtual humans’ pain (see Table 3 for average scores), and social presence. Participants were equally empathic to the pain of the first virtual human they encountered (see Table 4). However, participant’s reactions were quite different in the following immersion, as documented by the statistically significant interaction main effect between Immersions 2 and 3. Those who met the KVHF were significantly less empathic toward the pain of the Unknown Virtual Human and those who met the UVHF were significantly more empathic to the pain of the Known Virtual Human in the last immersion (see Fig. 4).

**Table 3. User’s Perception of the Virtual Characters (N=42)**

<table>
<thead>
<tr>
<th></th>
<th>Control immersion (cat)</th>
<th>Second immersion</th>
<th>Third immersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empathy</td>
<td>KVHF: N/A</td>
<td>9.09 (3.66)</td>
<td>7.36 (4.03)</td>
</tr>
<tr>
<td></td>
<td>UVHF: N/A</td>
<td>9.6 (2.7)</td>
<td>10.7 (3.02)</td>
</tr>
<tr>
<td>Social presence</td>
<td>KVHF: 35.45 (8.76)</td>
<td>36.18 (6.62)</td>
<td>33.32 (7.36)</td>
</tr>
<tr>
<td></td>
<td>UVHF: 38.32 (7.06)</td>
<td>38.0 (5.91)</td>
<td>42.16 (6.98)</td>
</tr>
<tr>
<td>Co-presence</td>
<td>KVHF: 6.42 (3.7)</td>
<td>7.86 (5.31)</td>
<td>7.41 (5.51)</td>
</tr>
<tr>
<td></td>
<td>UVHF: 7.65 (4.75)</td>
<td>11.1 (4.97)</td>
<td>13.65 (5.27)</td>
</tr>
<tr>
<td>Likability</td>
<td>KVHF: 16.86 (6.46)</td>
<td>20.36 (4.72)</td>
<td>11.64 (6.84)</td>
</tr>
<tr>
<td></td>
<td>UVHF: 11.15 (9.43)</td>
<td>18.25 (6.32)</td>
<td>20.20 (7.50)</td>
</tr>
<tr>
<td>Embarrassment</td>
<td>KVHF: 20.86 (11.12)</td>
<td>21.09 (11.03)</td>
<td>17.64 (10.86)</td>
</tr>
<tr>
<td></td>
<td>UVHF: 19.30 (11.31)</td>
<td>19.35 (10.78)</td>
<td>17.35 (12.31)</td>
</tr>
</tbody>
</table>

Mean, with standard deviations in parentheses.
N/A, not applicable.

**Table 4. Summary of F and p Values for the Repeated Measures Analysis of Variances and Contrasts for the User’s Perception of the Virtual Humans and Animal**

<table>
<thead>
<tr>
<th></th>
<th>Main effects</th>
<th>Immersion 1 vs. Immersion 2</th>
<th>Immersion 2 vs. Immersion 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>Condition</td>
<td>Interaction</td>
</tr>
<tr>
<td>Empathy</td>
<td>0.92</td>
<td>3.66</td>
<td>18.59***</td>
</tr>
<tr>
<td>Social presence</td>
<td>0.29</td>
<td>6.17*</td>
<td>5.32**</td>
</tr>
<tr>
<td>Co-presence</td>
<td>4.58*</td>
<td>8.74**</td>
<td>4.25*</td>
</tr>
<tr>
<td>Likability</td>
<td>7.93**</td>
<td>0.03</td>
<td>15.17***</td>
</tr>
<tr>
<td>Embarrassment</td>
<td>1.99</td>
<td>0.16</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001.
N/A = Not applicable for Immersion 1 versus Immersion 2 because the control immersion with the cat did not involve exposure to pain; hence, empathy was not measured; for Immersion 2 and Immersion 3, no contrast was required because the main effect compared only two times.
When looking at social presence measured with the global scale, results were relatively stable from the control immersion to the first experimental immersion with a virtual human (see Tables 3 and 4 and Fig. 4). The interaction between the two experimental immersions revealed a clear impact of prior immersion and knowing or not the virtual humans. The second time they witnessed the pain reaction, participants considered the Known Virtual Human as significantly more present (e.g., aware, responsive to the participant, as if physically there) than the Unknown Virtual Human enacting the exact same animations.

When refining our understanding of social presence by examining separately co-presence and social dimensions, results (see Table 4) for the subjective impression of co-presence revealed a significant increase in co-presence in both conditions when moving from the virtual cat to the virtual humans, and a Condition by Time interaction (see Fig. 4) when comparing the Known and Unknown Virtual Humans. Participants had the impression the Known Virtual Human was more physically there and aware of their existence than the Unknown Virtual Human although both virtual humans behaved identically.

The impact of pain on social dimensions of social presence was slightly different than co-presence. Willingness to perform embarrassing actions in front of the virtual agents decreased significantly between the first and second immersions and no significant interaction was found on embarrassment between Known and Unknown Virtual Humans. The partial eta-squared was 0.013 for the interaction between Immersion 2 and 3, which represents a small effect size as illustrated by the large number of participants (more than 350 per condition) required to find a significant difference at 0.05 with a power of 0.80.

Likability of the virtual character, the second social measure of social presence, led to results that were consistent with the general measure of presence and co-presence (see Fig. 4). The participants all considered the first virtual human they met as more likable than the virtual cat. However, after having encountered their first virtual human, participant’s reactions went in opposite directions during the following immersion. Participants in the KVHF condition found the Unknown Virtual Human clearly less likable, whereas those in the UVHF condition rated their second immersion the Known Virtual Human as more likable.

Research question 2: relationship between presence and empathy

The standard multiple regression predicting empathy toward the Known Virtual Human using (a) the immersive tendencies and the average number of time they have met Stéphane Bouchard as control predictor variables, and (b) the social presence measure as main predictor, was significant \( \left[ F(5, 41) = 20.57, p < 0.001 \right] \). Only two of the three variables contribute significantly to the regression, the Immersive Tendencies Questionnaire \( t = 2.35, p < 0.05, r^2 = 0.24 \), and the Social Presence Questionnaire \( t = 6.6, p < 0.001, r^2 = 0.66 \). Actually, the number of time they have met Stéphane Bouchard correlated at 0.13 \( p = ns \) with empathy and at 0.27 \( p = ns \) with social presence. When refining the concept of social presence by using co-presence and social dimensions (embarrassment and likability) instead of a global assessment of social presence, the regression equation was again significant \( F(8, 41) = 6.6, p < 0.001 \) and only co-presence emerged as a significant predictor \( t = 3.56, p < 0.01, r^2 = 0.43 \) of empathy. Familiarity, estimated by the number of time they have met Stéphane Bouchard correlated at 0.1 \( p = ns \) with embarrassment and at 0.16 \( p = ns \) with social presence. Only co-presence correlated significantly with familiarity \( r = 0.37, p < 0.05 \).

Discussion

The aim of this study was to test if empathy toward a virtual human experiencing pain was stronger when the virtual human was a copy of someone familiar to the observer. To begin with, proxemics (the distances between people when they interact) were normal for social interactions. There was no difference whether the participants were discussing with the Known Virtual Human or the Unknown Virtual Human. All participants reacted with a surge in arousal, moved backward when the virtual human first expressed acute pain reactions. They also reacted with an increase in skin conductance during the pain reaction of the following immersion, although they did not significantly moved away from the virtual humans. Analyses controlling for potential biases (e.g., differences in age, gender, attachment style, immersive tendencies) did not show any influence of these factors on the results.

Participants also subjectively reported feeling empathy for the virtual humans expressing pain. The average scores were high on the first immersion and remained above the middle of the scale when participants felt less empathy for the unknown character during the final experimental immersion. Before discussing the results, one limit to this study must be highlighted. There was only one known and one unknown virtual human. Therefore, it is difficult to tease out to what extent the results are due to idiosyncratic effects involving these two virtual humans (e.g., body size), or to what extent they are really due to the “known-ness” of the virtual character. In further studies, instead of recruiting participants based on their relation to researchers on the team, investigators could model several known virtual human after professors in different departments and recruit participants in all of these departments. Nevertheless, empathy was indeed found during immersions in VR.

It is interesting to note that subtle imperfections and unavoidable mismatch in behaviors and appearances between the MiniMe avatar and the live reference model did not have a detrimental effect. It is difficult to believe that no one noted the discrepancies, and comments heard by the research assistants support the impression that discrepancies were observed. Level of familiarity with the reference model was not significantly correlated with empathy, and only moderately correlated with co-presence. The study was not designed to assess the relationship between imperfections in avatar’s realism, user’s expectations, and their impact on users’ reactions. Therefore, more studies should be conducted with highly realistic avatars and with intended and controlled lack of physical and behavioral realism to test if there is a nonlinear impact of small imperfections.

Despite the fact that the expression of pain was identical in terms of facial and verbal expressions as well as nonverbal behaviors, after users’ had met a virtual human expressing pain once, they reported significantly more empathy toward
the Known Virtual Human compared to the Unknown one. The general measure of social presence assessed the extent to which the participants felt that the virtual humans were really there, in the room with them, and revealed that after a first encounter with a virtual human presence was stronger with the Known Virtual Human than the Unknown Virtual Human. Refining our definition of presence by distinguishing between feeling that the virtual person is real and how this realism would translate in social behavior by the participants revealed interesting information. Co-presence was higher with the virtual humans than with a virtual animal, and after a first contact with virtual human it became higher with the Known Virtual Human than the Unknown Virtual Human. This dimension of social presence was the strongest predictor of empathy when facing virtual humans in pain, over and above immersive tendencies, and how familiar participants were with the person depicted by the virtual character. Participants also considered the virtual humans as more likable than a virtual animal, and the Known Virtual Human as more likable than the Unknown Virtual Human. Likability was also equally high toward the virtual human and higher than with the virtual animal, and scores went in opposite directions after the first encounter with a virtual human. The encounter with the Known Virtual Human led participants to consider the Unknown Virtual Human as less likable than those who encountered the Unknown Virtual Human first. In sum, on a first encounter with a virtual human people feel socially present, no matter how familiar they are with the original model that looks like the avatar copy. Social presence becomes affected by familiarity after participants have some experience with interacting with virtual humans, at least when the virtual humans are realistic and express strong pain.

Familiarity with the virtual humans did not have the same impact on users’ willingness to perform socially embarrassing behaviors in front of the virtual humans than other measures of social presence. Participants were as socially embarrassed during the immersion with the virtual animal as with the virtual humans. Although this measure was used successfully to assess perceived social impact of virtual humans, it is doubtful that a cat would induce the same level of shyness than a human. In addition, the second immersion with a virtual human led to a reduction in the perceived social impact of both virtual humans. These unexpected findings may be explained either by the strong pictorial realism of the virtual animal or the impact of seeing virtual humans in pain. However, it is most likely caused by social desirability. Participants were aware they were monitored by research assistants, which may have inflated the social pressure against respondents, which may have inflated the social pressure against participants, have some experience with interacting with virtual humans, at least when the virtual humans are realistic and express strong pain.

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The intensity and duration of the pain expressed by the virtual humans deserve to be addressed briefly. It is possible that using pain animations depicting excruciating pain for a long time, with cries, complaints, and begging for help expressed directly to the user would have elicited stronger reactions in the user and different reactions with the Known Virtual Human and the Unknown Virtual Human. Aside from the potential ethical questions raised by immersing people in situations where a friend is agonizing and they cannot help, given that empathy was felt toward the Unknown Virtual Human and the strong realism expectations that come with highly realistic virtual humans in general, it may not be necessary for most researchers to use virtual humans that replicate people that are familiar or known by the participants—at least, unless people have prior experience with virtual characters. After seeing realistic 3D representations of their acquaintances, people may react with less empathy and less social presence to virtual humans depicting people they do not know. Reversely, given equal level of realism, experience with generic virtual humans may increase empathy and social presence toward avatar of people we are familiar with.

What are the implications of finding that being familiar with a person depicted by a realistic virtual human has an impact on empathy when observing painful behaviors? For one, it opens the possibility to study how health professionals react when performing painful procedures with patients with whom they have developed an emotional bond (e.g., acquaintance, regular patients, popular and unpopular people). It could also provide a reference point in studies examining biases on how pain is perceived by observers, for example by allowing to compare reactions to the pain expressed by friends or loved ones with the pain expressed by people from different culture and races, age group, or gender. Experimentally controlling and manipulating how people relate to the person in pain can also be used to study top-down and bottom-up influences on empathy, or the relative contribution of observer’s reactions versus the expression of pain.

However, in these studies, the order of presentation of familiar and unfamiliar virtual characters should be carefully controlled. Finally, if social presence is an important factor in multisensory integration leading to the illusion of presence, researchers on empathy toward 3D characters should consider using more frequently immersive technologies than simply displaying virtual characters on computer monitors.

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