Virtual Humans with Pets and Robots: Exploring the Influence of Social Priming on One's Perception of a Virtual Human

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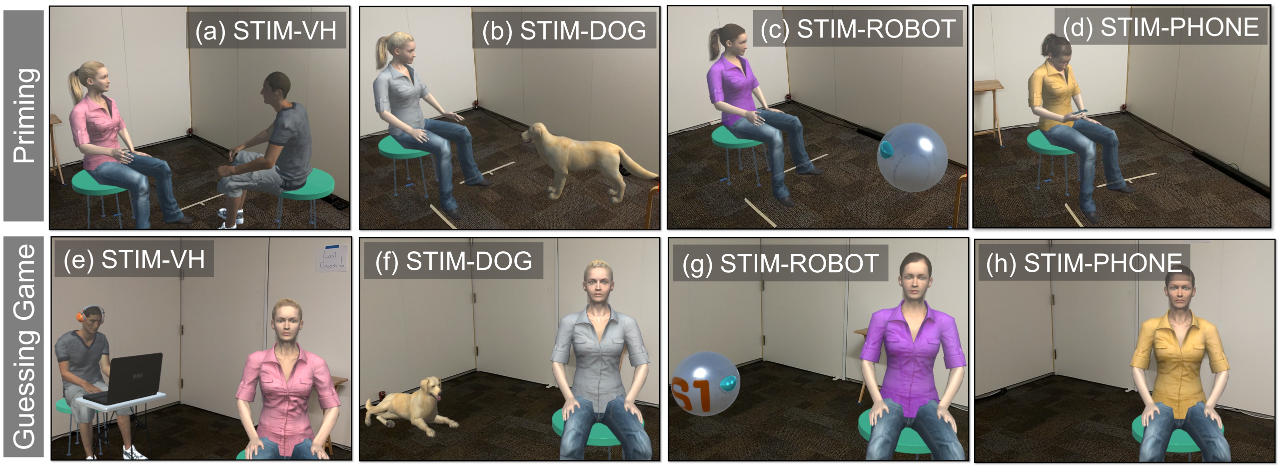

Figure 1: Screenshots showing the participants' view through an augmented reality head-mounted display. The top row shows the view they would see while standing at the doorway during the priming phase, for each of the four conditions shown in (a)–(d). The bottom row shows the view they would see while seated in the room during the 20-questions guessing game phase, for the same four conditions shown in (e)–(h).

Abstract

Social priming is the idea that observations of a virtual human (VH) engaged in short social interactions with a real or virtual human bystander can positively influence users' subsequent interactions with that VH. In this paper we investigate the question of whether the positive effects of social priming are limited to interactions with humanoid entities. For instance, virtual dogs offer an attractive candidate for non-humanoid entities, as previous research suggests multiple positive effects. In particular, real human dog owners receive more positive attention from strangers than non-dog owners.

To examine the influence of such social priming we carried out a human-subjects experiment with four conditions: three social priming conditions where a participant initially observed a VH interacting with one of three virtual entities (another VH, a virtual pet dog, or a virtual personal robot), and a non-social priming condition where a VH (alone) was intently looking at her phone as if reading something. We recruited 24 participants and conducted a mixed-methods analysis. We found that a VH's prior social interactions with another VH and a virtual dog significantly increased participants' perceptions of the VHs' affective attraction. Also, participants felt more inclined to interact with the VH in the future in all of the social priming conditions. Qualitatively, we found that the social priming conditions resulted in a more positive user experience than the non-social priming condition. Also, the virtual dog and the virtual robot were perceived as a source of positive surprise, with participants appreciating the non-humanoid interactions for various reasons, such as the avoidance of social anxieties sometimes associated with humans.

Index Terms: Human-centered computing—Interaction paradigms—Mixed / augmented reality; Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods—User studies; Computer graphics—Graphics systems and interfaces—Mixed / augmented reality

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1 Introduction

Over the past 20 years researchers have been studying social interactions between real humans and virtual humans (VHs) primarily by varying *VH-specific characteristics* or factors associated with a VH's *contextual existence* [41,44]. By contextual existence we mean factors that aim to create the illusion that the VH is associated with its environment, and give context to its presence. For example, if a VH is affected by (or exhibits awareness of) events in the real physical environment, or is able to affect (influence) that environment, that reinforces the VH's association with its environment [29, 34]. If a VH shares lifelike *backstories* with users [10], or *socially primes* users by engaging in social interactions with other real/virtual human actors [17–19], that reinforces the VH's contextual presence. Previous research has found that the addition of social priming and backstories before users' primary interaction with a VH influences their subsequent interactions by enhancing their mood, engagement, and social presence with the VH [10, 17–19]. Both mechanisms are also practical: they can be incorporated into a wide range of existing interactions users may have with VHs, and both mechanisms can often be implemented via "canned" (pre-scripted) sequences.

While previous research found that social priming involving real/virtual *humans* seen interacting with a primary VH can positively influence perceptions of the VH, similar to Figure 1 at (a), it is unclear whether *non-humanoid* virtual actors seen interacting with a primary VH can bring similar benefits. The possibility of social priming with non-humanoid virtual actors is motivated by several factors. For example, increasing the number of virtual human actors may add complexities to the social dynamics as users may expect these virtual humans to go beyond just acting, and expect to interact with them, which is not always possible. Furthermore, it may be the case that a non-humanoid social actor is already present in the primary VH's space, conveniently removing the need to add another VH just for the sake of social priming.

One particularly interesting example of a non-humanoid virtual actor to facilitate social priming is a virtual dog. The use of a dog is inspired by the fact that they are commonly associated with humans, and there is extensive evidence of positive associations between dogs and humans. For example, researchers have found that real dogs can create a "halo" effect for their owners (e.g., more friendly/likable) and act as a social catalyst resulting in dog owners receiving more positive attention compared to non-dog owners [9,24,36,56,58]. Another potential non-humanoid alternative is a virtual robot, motivated by the years of research in social robotics where researchers study and develop social robots in the real world aimed at different applications such as companionship [21,32]. Thus, we explored the following research questions:

- **RQ1** What are the subjective and objective influences of social priming compared to a non-social priming condition?
- **RQ2** Are the influences of social priming limited to VHs interacting only with other real/virtual humans?

In response to these research questions, we conducted a within-subjects study using augmented reality technology. In our study, participants were instructed to walk to the doorway of a physical room, and to wait there until a VH invited them in to play a round of "20 Questions," where one player thinks of a person, place, or thing, while the other asks up to 20 yes/no questions to guess the answer.

Prior to starting the game the participants were exposed to one of four randomly chosen conditions: one of three *social* priming conditions where a VH was interacting with either another VH, a virtual pet dog, or a virtual personal robot; or a *non-social* priming condition where a VH (alone) was intently looking at her phone as if reading something. These priming conditions occurred while the participants were standing in a doorway, waiting to be invited in by the VH, and ended prior to engaging with the VH in the guessing game, in which they had her full attention.

Our mixed-methods analysis found that participants attributed more positive affective characteristics to VHs in most of our social priming conditions, and felt more inclined to interact with the VHs in the future in all of our social priming conditions, compared to the non-social priming condition. Our qualitative analysis of our participants' post-study interview revealed a more positive overall experience in the social priming conditions with an appreciation of the non-humanoid virtual actors for various reasons, including making some of our participants feel more curious, and reducing anxiety for the few who experienced social anxiety with the VHs.

Our work makes the unique contribution of studying a variety of social priming stimuli, such as virtual dogs and robots in light of the positive influences of their real world counterparts while comparing them to a non-social priming condition to better characterize the potential benefits of priming, social and non-social, on future interaction of users with VH.

2 Related Work

This section presents previous work on the influence of priming stimuli, namely social priming and backstory, on users' perceptions of virtual humans and the social benefits of real dogs and robots motivating the potential of virtual ones as social priming stimuli.

2.1 Influence of Priming for Virtual Humans

Borrowing from social psychology, priming is defined as "the incidental activation of knowledge structures, such as trait concepts and stereotypes, by the current situational context" [8]. Several examples or previous work on VHs capture the concept of priming, such as *social priming*, which occurs when participants observe a VH engaged in short social interactions with a real or virtual human bystander and are therefore primed about the VH's social abilities [17–19]. Another example is the use of backstories to add more context for the interactions with the VH [10,15,53].

In one of the earliest examples of social priming in VH research, Daher et al. [18] exposed participants to an engaging conversation between a VH and a real human before playing the 20-questions guessing game with the same VH and compared this exposure to a control condition where participants directly played the game with the VH without any social priming. They found that participants in the social priming condition felt more affected by the VH's mood and found the VH to be warmer than the VH in the control condition. Later, Daher et al. [19] conducted a similar experiment and varied the social priming stimuli from a real human to a VH, and exposed participants to an engaging conversation between two VHs prior to playing a 20-questions guessing game with one of the VHs, while participants in the control group did not receive this exposure. Compared to the control condition, they found that participants in the social priming condition felt more excited and alert and experienced higher levels of copresence with the VH. In both experiments [18,19], the VH who facilitated the social priming exited the interaction space before the start of the game.

Separately, several researchers studied the influence of VHs with backstories. In order to design more engaging virtual museum guides for children, Swartout et al. [53] conducted a formative study and found that their target population wanted the guides to have a more contextual presence, such as having pets/jobs and spending time with their friends. Bickmore et al. [10] utilized the idea of backstories to keep users engaged for long-term interaction with a VH. Through a longitudinal study with a VH exercise counselor, they found that exposing participants to a VH that shared backstories in the first person format resulted in higher levels of user enjoyment and system usage than a VH that shared backstories in the third person format.

Motivated by the promising findings above, we studied the influence of a variety of social priming stimuli that are not simply there to facilitate the act of social priming and then leave but can be perceived as part of the VH's backstory.

2.2 Social Benefits of Real Dogs and Robots

Beyond the examples of social priming in virtual interactions mentioned above, similar notions exist in real-world interactions as well. For instance, human-animal interaction research has found that real pets and service animals, mainly dogs, act as a *social catalyst* for their owners by facilitating positive social interactions between their owners and other people [9,24,36,56,58]. For instance, McNicholas and Collis [36] found that a male adult accompanied by a dog increased the frequency of social interactions (e.g., verbal exchanges, smiles, and nods) with strangers. Interestingly, these findings persisted even when the dog handler was scruffily dressed than smartly dressed [36]. Similarly, Wells [56] studied the social catalyst effect of dogs by varying the dog's breed and comparing them to multiple controls such as dog handler alone, with a potted plant, or with a toy. In this study, the female dog handler received more positive attention when accompanied by a dog compared to all the other conditions; however, this effect was not generic to dogs with the age of the dog and the breed's perceived aggressiveness mediating this effect [56].

Researchers have presented multiple explanations for the social catalytic effect of dogs. For instance, McNicholas and Collis suggested that dogs act as a safe conversation starter [36]. Some researchers suggest that dogs create a *halo effect* for their human

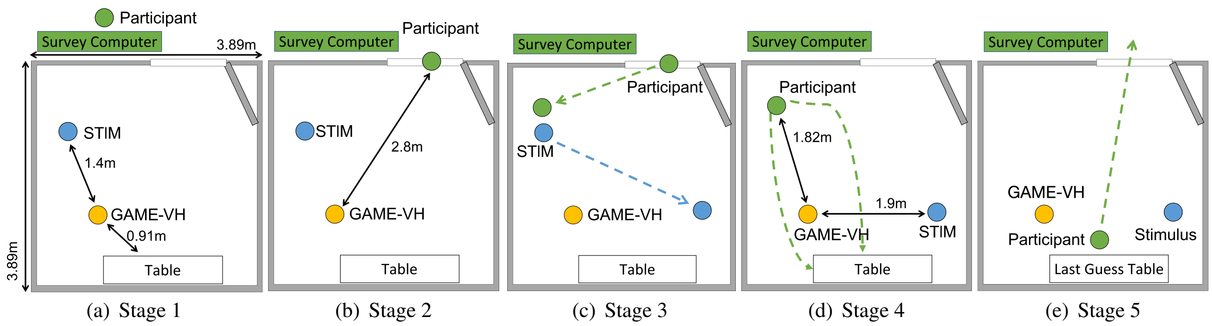


Figure 2: Illustrations of the physical setup with placement of the virtual entities at different stages of the interaction.

owner, meaning that because of the dog, the human owner is perceived more positively by others (e.g., more friendly, trustworthy, etc.) [16, 28, 49, 51, 54, 57]. For instance, Schneider and Harley [51] found that participants who watched videos of a psychotherapist with a dog were more satisfied compared to the one without a dog.

Although the range of the social interactions of many humans today is limited to other real humans and animals, robotics researchers have been investigating the potential of social robots for decades to facilitate various applications such as companionship, healthcare, education, and entertainment [21, 32]. Thus, the long history of the field and the promising findings of previous work regarding the positive social effects of these robots for different populations, such as children and older adults [26, 31, 55], motivated us to explore the influence of social robots in the context of social priming. The social benefits of real dogs noted above motivated us to study their virtual counterparts as social priming stimuli for VHs. Further, the successes of social robotics motivated us to explore whether interaction with virtual robots may have a similar effect as with virtual dogs. Since solely relying on the use of another real/virtual human as a social priming stimulus may add complexities to social interactions as users may expect all of the VHs in a given interaction to follow certain social norms, these expectations do not necessarily exist for non-humanoid robots and dogs.

3 Experiment

This section presents details of our human-subjects experiment, including our study participants, methods, and materials.

3.1 Methods

This section explains the study design and procedure we adopted to explore the influence of social priming with different stimuli on participants' perceptions of different VHs and their overall experience.

3.1.1 Study Design

We carried out a full-factorial within-subjects study using a 4×1 Latin Square design to counterbalance our conditions. Participants played a 20-questions guessing game with a different VH game partner (GAME-VH) across all four conditions. The specific GAME-VH and the answers for each round of the 20-questions guessing game were randomized, so no condition was associated with a specific GAME-VH or answer. In all of our conditions, participants walked to the doorway and waited until they were invited in by the GAME-VH. Participants experienced all four conditions:

- **Social Priming:** Upon reaching the door, participants observed an ongoing social interaction between GAME-VH and one of three different virtual actors. After 16 seconds the virtual actor moved to the side but remained in the room as shown in Figure 1 at (e)–(g), and the GAME-VH invited the participant inside to play the guessing game. There are three social priming conditions corresponding to the three virtual actors.
  - **Virtual Human Stimulus (STIM-VH):** A virtual human used as the virtual actor.
  - **Virtual Dog Stimulus (STIM-DOG):** A virtual dog used as the virtual actor.
  - **Virtual Robot Stimulus (STIM-ROBOT):** A virtual robot used as the virtual actor.
- **Non-Social Priming (STIM-PHONE):** Upon reaching the door, participants observed GAME-VH in the process of looking at her phone. After 16 seconds GAME-VH invited them inside to play the guessing game. The duration of this non-social priming was chosen to match the stimuli exposure time for the three social priming conditions (above).

In addition to previous literature (see Sec. 2), we chose our three social priming virtual actors based on three criteria: an expectation they would be perceived as capable of (a) interactivity and (b) locomotion; and (c) they would fall into distinct classes of entities.

3.1.2 Procedure

Participants were met in the lobby of our building and guided to the experimental space. After reading the informed consent document and consenting to take part in the study, the experimenter explained the general goal of the study, which is to evaluate the capabilities of augmented reality technology in facilitating social interactions with VHs, and noted that participants would play four rounds of the 20-questions guessing game in an augmented reality break room with four different VHs.

Next, the experimenter explained the five stages of the experiment shown in Figure 2: **(Stage 1)** don the head-mounted display (HMD) after the experimenter's cue and move towards the doorway after hearing a bell sound through the HMD's speakers, **(Stage 2)** wait for GAME-VH to invite you in and have a seat, **(Stage 3)** follow GAME-VH's cues and start asking questions when prompted by GAME-VH and a second bell sound, **(Stage 4)** ff the game ends without having guessed the item chosen by GAME-VH, follow GAME-VH's prompt to write your last guess on a post-it on the table in the back of the room, and **(Stage 5)** leave the room and then doff the HMD.

After each condition it was confirmed that the participants saw all the entities they were supposed to see, and they were asked to complete several subjective questionnaires. After the last condition, participants answered technology familiarity and demographic questionnaires, followed by a short post-study semi-structured interview. Lastly, the participants were thanked for their participation and compensated for their time.

3.1.3 Participants

We recruited 24 participants (7 female, 17 male, age 18–37, $M = 24.17$, $SD = 5.18$) for our study. The study protocol was approved by the institutional review board of our university. We asked our participants to assess their familiarity and expertise with related technology by answering six 7-point scale questions (1 = novice/not familiar, 7 = expert/very familiar) capturing expertise with computers ($M = 5.5$, $SD = 0.88$) and familiarity with VR ($M = 5.17$, $SD = 1.31$), AR ($M = 4.71$, $SD = 1.46$), VH agent/avatars ($M = 5.13$, $SD = 1.54$), virtual animals ($M = 4.71$, $SD = 1.68$), and virtual robots ($M = 4.42$, $SD = 1.64$). Nine participants were single or multi-pet owners (five cats and nine dogs in total). Eleven participants had normal vision, nine had corrected vision with glasses, and two had corrected vision with contact lenses.

3.2 Materials

This section describes the details of the physical space, virtual entities, and the 20-questions guessing game utilized in our augmented reality experiment. Figure 2 depicts the physical setup and the distances between things.

3.2.1 Experimental Setup

We used a HoloLens 2 HMD (frame rate: 60 Hz, diagnoal field of view: 54°, and resolution: 2048×1080 per eye [1, 27]) and two graphics workstations (Specs: Intel Xeon 2.4 GHz 16-core processor, 32 GB of main memory, and two Nvidia Geforce GTX 980 Ti graphics cards). The participants used one workstation to answer questionnaires and the recording of the post-study interview. The experimenter used the other workstation for running a server application that logged data and controlled the behavior of the virtual entities on a client application on the HMD. All the server/client applications were created using the Unity graphics engine version 2018.4.34f1. Participants played the 20-questions guessing game while seated on a stationary stool in a 3.89 m ×3.89 m experimental room with the door open. The black arrows in Figure 2 show the distance estimates between participants and the different virtual entities at different phases of each condition. It is important to note that given the field of view of the HMD, if participants were directly facing the VH game partner in Stage 3 of the interaction (see Sec. 3.1.2) they could only catch a glimpse of the social priming stimuli in the corner of the room by moving their head.

3.2.2 20-Questions Guessing Game Phase

We used a 20-questions guessing game as the context for the social interaction between participants and the GAME-VHs as this game has been effectively used in previous human-agent interactions [7, 19, 33]. To balance the conditions and make sure that participants' perception of a GAME-VH would not be influenced by whether or not they won the game against the GAME-VH, we structured the questions so that participants would *always* lose. Therefore, we randomly assigned one of four challenging final answers (difficult to guess) to each condition, and allowed the experimenter to adapt the GAME-VHs' responses throughout (see Table 1). The four final answers were: Brad Pitt as a famous actor, the Sydney Opera House as a place, Lasagna as a food item, and Condor as an animal.

3.2.3 Virtual Entities

This section details all the virtual entities that the participants observed and/or interacted with in each of the four conditions. For all of these virtual entities, we used a combination of pre-made animations from the original creators, Adobe Mixamo [3] animations, and custom animations created in Unity's animation window.

Virtual Human Game Partner (GAME-VH) We adopted four different female GAME-VH models from the Microsoft RocketBox Avatar Library library [37]. As we wanted to limit the influence of the GAME-VHs' facial features or clothing styles on the participants' perceptions, we used four different GAME-VHs that each had similar facial features, and were wearing similar clothing, but had different colored shirts as shown in Figure 1. We added blendshapes to the GAME-VHs using Autodesk Maya 2022 [6] to control their facial expressions and lip movements while talking. We used Rogo

Category	Speech Prompts
Social Priming, STIM-VH	STIM-VH: *"Matt won all the rounds yesterday, I'm so unlucky in this game, I only won 2 out of 10"*; GAME-VH: *"You'll get them next time"* STIM-VH: *"Hope you have better luck today"*; GAME-VH: *"thank you"*; STIM-VH: *"Oh you've got a visitor, I'll leave you two to play"* STIM-VH: *"Catch you later"*; GAME-VH: *"see you later"*
Social Priming, STIM-DOG	STIM-DOG sniffing sound; GAME-VH: *"You got it"*; STIM-DOG barking sound; GAME-VH: *"You're energetic today"*; STIM-DOG sniffing sound; GAME-VH: *"Who's a good dog'*
Social Priming, STIM-ROBOT	STIM-ROBOT: beep sound #1; GAME-VH: *"You got it"*; STIM-ROBOT: beep sound #2; GAME-VH: *"You're charged up today"*; STIM-ROBOT: beep sound #3; GAME-VH: *"Good job Robbie"*
Greeting & Game Start, GAME-VH	GAME-VH: *"Hi my name is Julie/Katie/Suzi/Stacy"*; GAME-VH: *"Nice to meet you"*; GAME-VH: *"that's my friend Remy/dog Bailey/robot Robbie"*; GAME-VH: *"how are you?"*; GAME-VH: *"I'm doing well, thank you"*; GAME-VH: *"Come on in, please have a seat"*; GAME-VH: *"I guess it's time to start"*
Game Responses, GAME-VH	GAME-VH: *"yes/yup/that's right"*;GAME-VH: *"no/nope/ that's not right"*; GAME-VH: *"kind of but try again, not quite but try again, that's close but try again"*
Game End, GAME-VH	GAME-VH: *"I think you ran out of questions/I think you ran out of time"*; GAME-VH: *"Don't forget to write your last guess on the paper back there"*; GAME-VH: *"It was nice playing with you, see you later"*

Table 1: The speech/sound prompts voiced by different virtual entities for each condition.

Digital Lip Sync Pro [48] to generate lip movements that matched the GAME-VHs' speech, and incorporated appropriate facial expressions. Throughout the experiment, the GAME-VHs were made to blink and vary their facial expressions and gestures, such as smiling, raising their eyebrows, waving, idle gesturing with either hand, nodding yes, and shaking their head no. Table 1 shows the different speech/audio prompts voiced by the GAME-VHs and the other stimuli. The GAME-VHs used a variety of prerecorded speech prompts for the different phases of the interaction. We recorded these speech prompts using the Audacity software [5] and the voice of a female native English-speaking research personnel from our group.

Virtual Human Stimulus (STIM-VH) We acquired a 3D model of a character named Remy from Adobe Mixamo [3] and made slight adjustments. The blendshapes of the Remy character were used to control its facial expressions and lip movements while talking. Similar steps to those of the GAME-VHs (above) were taken for STIM-VH for the blinking animation and its facial expressions, gestures, and lip movements, while in this case, the voice of a male native English-speaking co-experimenter was used. Figure 1 at (a) shows a snapshot of the interaction between a GAME-VH and the STIM-VH character, and at (e) shows the STIM-VH at its destination position after the social priming phase was over. Table 1 lists the speech prompts used between the GAME-VHs and STIM-VH during the social priming phase. The STIM-VH was facing the GAME-VH throughout the social priming phase, and only looked towards the doorway where the participants were standing just before saying the phrase *"Oh you've got a visitor, I'll leave you two to play."* At that point the STIM-VH slowly looked back, stood up from its stool, walked to the stimuli destination position where his desk was placed, sat behind his computer, and looked at his computer the whole time with headphones on his ears as shown in Figure 1 at (e).

Virtual Dog Stimulus (Stim-Dog) We purchased a 3D rigged and animated model of a golden retriever dog from the Unity asset store [46]. We chose a golden retriever dog model as real-life examples of this breed were previously used in social catalyst studies with real dogs and real humans (see Sec. 2.2). Blinking animations were added to the Stim-Dog model. Figure 1 at (b) shows a snapshot of the interaction between the Game-VH and the Stim-Dog character, and at (f) the Stim-Dog at its destination position after the social priming phase was over. Table 1 lists the speech prompts used between the Game-VHs and Stim-Dogduring the social priming phase. During this phase, the Stim-Dog faced the Game-VH and wagged its tail while transitioning between three animations of four-legged idle, sniffing and scratching the ground, and playfully crouching while barking. At the end of the social priming phase, the Stim-Dog turned its head and looked at the doorway, where the participant was standing, turned back towards the Game-VH, stopped wagging its tail, and moved towards the stimuli destination position and idly lay on the floor as shown in Figure 1 at (f).

Virtual Robot Stimulus (Stim-Robot) We acquired a 3D rigged and animated model of a virtual robot from the Unity Asset Store [45] and made slight adjustments. Figure 1 at (c) shows a snapshot of the interaction between the Game-VH and the Stim-Robot character, and at (g) shows the Stim-Robot at its destination position after the social priming phase was over. We chose to avoid a human-like or animal-like robot appearance as we did not want our participants to perceive the Stim-Robot as a robotic version of a human or a dog, and to potentially look for animal-like or human-like qualities in the robot. We used a rolling animation for the Stim-Robot's movements, slight playful motions around the yaw axis, and blinking for the eyes. We removed the three legs of the 3D model and adjusted it to roll from one place to the next, as during our internal pilot testing we found that the robot's movements with its legs could make it seem aggressive or unsafe. Our choice for Stim-Robot's appearance was informed by the interactive mobile robots that have been on the market [50], such as Cozmo [20] and Sphero [52]. Also, this robot was closer to a form factor, such as the Qin robot [13] that was rated very highly on the warmth dimension [47]. Stim-Robot made short beep sounds during the game play as shown in Table 1. The beep sounds were acquired from Zapsplat [59]. During the social priming phase, Stim-Robot slowly motioned around its yaw axis, mostly facing the VH with its eyes indicating a happy emotion as shown in Figure 1 at (c). Before the end of the social priming phase, the robot rotated around to look back at the doorway, where the participants were standing, then rotated back towards the Game-VH with its eyes transitioning to normal mode and rolled towards the stimuli destination position in the corner of the room as shown in Figure 1 at (g).

3.2.4 Hypotheses

Our hypotheses were inspired by the positive influences of social priming and backstory on perceptions of virtual humans [10, 17–19], and the potential of real dogs in creating a positive image of the real human dog owners based on Halo Effect and Social Catalyst literature [28, 36, 49, 56]. We are further interested in exploring if the interaction with non-humanoid robots may have a similar effect as with dogs. We present the following hypotheses:

- **H1:** Social priming facilitated by another VH compared to non-social priming enhances participants' social interaction with the VH (i.e., increased *Social Presence*) and results in a more positive perception of the VH (i.e., enhanced *Affective Attraction*, *Inclination*, and *Inclusion of Other in the Self*).
- **H2:** The above benefits of social priming are not limited to humanoid entities and can be induced by non-humanoid entities.
- **H3:** The presence of social priming stimuli will influence participants' attention behavior during the social priming phase.

3.2.5 Measures

This section presents all of our subjective and objective measures and our post-study interview questions used to assess participants' perceptions of the social priming and non-social priming conditions. The choices for our measures were based on experiences with measures employed in previous studies with similar virtual entities [23, 30, 35, 40, 42].

Objective Measures

- **Head Gaze:** We logged head gaze as a basic approximation of our participants' attention during the experiment, indicating how often participants looked towards and brought the different visual stimuli in our experiment into their visual field. We used a ray originating from the center of the HMD (i.e., user's face) to measure how often participants' heads were oriented towards the stimuli, depending on the condition during Stage 2 as shown in Figure2 at (b), and before the start of the game.

Subjective Measures

- **Social Presence:** We used the 9-item social presence questionnaire utilized by Oh et al. [43] as an adaptation of the networked minds social presence questionnaire [11]. This questionnaire was to used to assess how together participants feel with the different Game-VHs on a 7-point scale (1 = strongly disagree, 7 = strongly agree). Following previous work [43], we computed an aggregated score for each condition.
- **Affective Attraction:** We used the 5-item affective attraction questionnaire devised by Herbst et al. [25] to evaluate participants' perceptions of the Game-VHs regarding the 5 factors of unpleasant/pleasant, cold/warm, positive/negative, friendly/unfriendly, and distant/close presented to participants on a 7-point scale (e.g., 1 = unpleasant, 7 = pleasant). Following previous work [25], we reversed the negative items and calculated and aggregated score for each condition.
- **Inclination:** We devised the question "How inclined do you feel to interact with your game partner more in the future?" to assess participants' inclination for future interactions based on the different conditions.
- **Inclusion of Other in the Self:** We used the single-item pictorial inclusion of other in the self (IOS) by Aron et al. [4], to assess how at one participants feel with the Game-VHs.

Post-Study Interview

At the end of the study, aligned with our research questions (see Sec. 1) we conducted a semi-structured interview and asked our participants to describe their experience including their thoughts/feeling while they were waiting at the doorway, how they felt during the game, and how they divided their attention in the social priming conditions where there was another stimulus in the room with them.

3.2.6 Data Analysis

We adopted a mixed-methods approach for the analysis of our quantitative and qualitative data. Two participants were removed from the analysis for technical issues, including one who did not see all of the entities. We used repeated measures ANOVA at the 5% significance level for the analysis of our objective and subjective quantitative data. This decision is aligned with recent findings in the domain of statistics suggesting the robustness of parametric methods for subjective scale data [38, 39]. T-tests were utilized for pair-wise comparisons using False Discovery Rate (FDR) to correct for family-wise error. After correction we adopted SPSS' approach of reporting the corrected p-values. Assumptions of normality were confirmed with Shapiro-Wilk tests and QQ plots. Degrees of freedom were corrected using Greenhouse-Geisser and Huynh-Feldt estimates following a significant Mauchly's test of sphericity.

Measure	Main Effect	Pair-Wise Comparison with FDR
Head Gaze at Stimuli	$F(2,42) = 5.84$, $\boldsymbol{p = 0.006}$, $\eta_p^2 = 0.22$	STIM-DOG vs. STIM-ROBOT: $t(21) = 4.29$, $\boldsymbol{p < 0.001}$, $d = 0.92$ STIM-DOG vs. STIM-VH: $t(21) = 1.95$, $p = 0.096$, $d = 0.42$
Head Gaze at GAME-VH	$F(3,63) = 44.52$, $\boldsymbol{p < 0.001}$, $\eta_p^2 = 0.68$	STIM-DOG vs. STIM-PHONE: $t(21) = -8.97$, $\boldsymbol{p < 0.001}$, $d = -1.91$ STIM-ROBOT vs. STIM-PHONE: $t(21) = 6.41$, $\boldsymbol{p < 0.001}$, $d = -1.37$ STIM-VH vs. STIM-PHONE: $t(21) = -11.36$, $\boldsymbol{p < 0.001}$, $d = -2.42$
Social Presence (0.91)	$F(2.22, 46.52) = 0.89$, $p = 0.427$, $\eta_p^2 = 0.041$	—
Affective Attraction (0.84)	$F(3,63) = 4.72$, $\boldsymbol{p = 0.005}$, $\eta_p^2 = 0.18$	STIM-DOG vs. STIM-PHONE: $t(21) = 3.06$, $\boldsymbol{p = 0.018}$, $d = 0.65$ STIM-ROBOT vs. STIM-PHONE: $t(21) = 2.29$, $p = 0.066$, $d = 0.49$ STIM-VH vs. STIM-PHONE: $t(21) = 3.23$, $\boldsymbol{p = 0.018}$, $d = 0.69$
Inclination	$F(3,63) = 6.15$, $\boldsymbol{p < 0.001}$, $\eta_p^2 = 0.23$	STIM-DOG vs. STIM-PHONE: $t(21) = 3.24$, $\boldsymbol{p = 0.012}$, $d = 0.69$ STIM-ROBOT vs. STIM-PHONE: $t(21) = 2.83$, $\boldsymbol{p = 0.02}$, $d = 0.60$ STIM-VH vs. STIM-PHONE: $t(21) = 5.374$, $\boldsymbol{p < 0.001}$, $d = 1.15$
Inclusion of Other in the Self	$F(3,63) = 3.18$, $\boldsymbol{p = 0.030}$, $\eta_p^2 = 0.13$	STIM-DOG vs. STIM-PHONE: $t(21) = 2.54$, $p = 0.075$, $d = 0.54$ STIM-DOG vs. STIM-ROBOT: $t(21) = 2.41$, $p = 0.075$, $d = 0.51$

Table 2: Summary of all of the subjective/objective quantitative results. Cronbach α values are presented in parentheses.

Themes	Code: Definition
Social Priming vs. Non-Social Priming (54%)	**Positive Feelings**: comparing the social priming and non-social priming conditions in relation to one's feeling (e.g., feeling pleasant or demotivated) **Attention Curiosity:** talking about the positive influences of the stimuli in garnering positive curiosity **Screensaver:** talking about uses of the stimuli similar to a "screensaver" that avoids idle scenes
Unexpectedness Benefits (45%)	**Normalcy:** Using words such as normal, natural, authentic, common, expected, realistic or their opposites to describe the general pre-game interactions and/or the presence of the different stimuli **Real-Life Comparison:** Talking about the conditions in relation to real-life experiences **Previous Technology Comparison:** Discussing the conditions in relation to past technological exposures
Variation Benefits (31%)	**Apprehension:** describing feelings of anxiety with VHs based on anxiety with real human strangers **Positive Feelings:** describing preference for the non-human stimuli

Table 3: Thematic Analysis Codebook.

For the analysis of our participant's post-study interview responses we adopted Braun and Clarke's thematic analysis approach [12], conducted by the first author of this manuscript. The thematic analysis started with the transcription of the post-study interview audio files, followed by multiple rounds of reading the transcriptions to get familiarized with the data. Next, the data was iteratively coded and through multiple revisions grouped into themes. Table 3 presents our code book devised for our qualitative analysis.

4 RESULTS

This section presents our quantitative (subjective and objective) results and the three themes that emerged from the qualitative analysis of our participants' post-study interview responses. Table 2 summarizes our quantitative results.

4.1 Objective Measures

This section presents the results of our objective measures summarized in Table 2.

Head Gaze at Stimuli: Figure 3 at (a) shows the results for the Head Gaze at Stimuli measure. A significant difference in pairwise comparisons indicate that participants' head gaze was directed towards the dog more often than the robot ($\boldsymbol{p = 0.002}$).

Head Gaze at GAME-VH: Figure 3 at (b) illustrates the results for the Head Gaze at GAME-VH measure. Significant differences in pair-wise comparisons indicate that participants' Head Gaze were directed at the GAME-VH less often when another stimuli was present in the room ($\boldsymbol{p < 0.001}$).

4.2 Subjective Measures

This section presents the results of our objective measures summarized in Table 2.

Social Presence: Figure 3 at (c) indicates participants' level of social presence experienced with the different GAME-VHs. We did not find a significant main effect of condition on the level of social presence experienced with the GAME-VHs. Considering also the magnitudes and variance, social priming may have had no effect on how present participants felt with the different GAME-VHs.

Affective Attraction: Figure 3 at (d) shows the level of affective attraction experienced towards the different GAME-VHs for each condition. Significant differences in pair-wise comparisons indicate that the two STIM-VH and STIM-DOG conditions positively influenced participants' levels of affective attraction towards the GAME-VHs in comparison to the STIM-PHONE condition ($\boldsymbol{p < 0.05}$).

Inclination: Figure 3 at (e) shows the differences between participants' inclination scores. Significant differences in pair-wise comparisons indicate participants were more inclined to interact with the GAME-VHs in all of the social priming conditions compared to the STIM-PHONE condition ($\boldsymbol{p < 0.05}$).

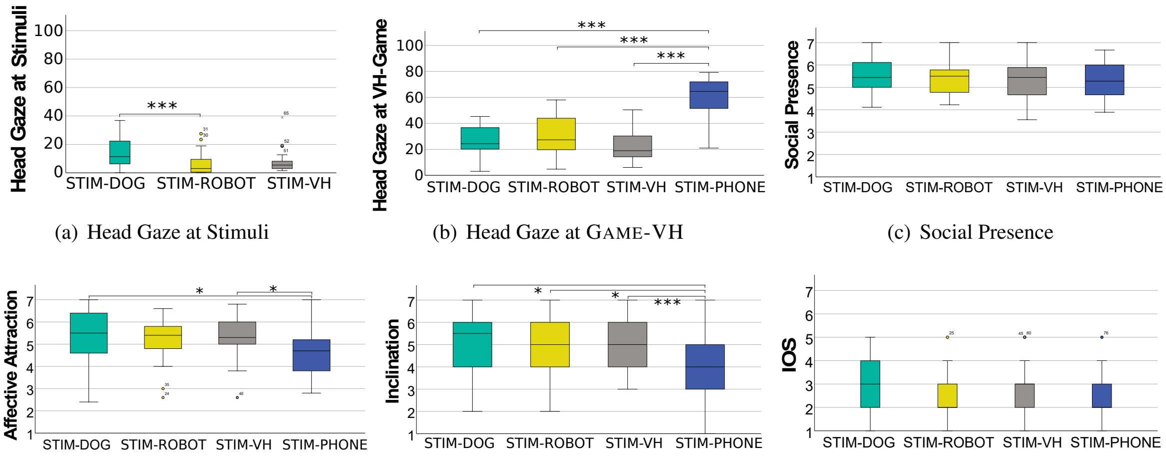
Inclusion of Other in the Self: Figure 3 at (f) shows the results for this measure. We only found trends in the pairwise comparisons, cautiously suggesting that participants may have felt more at one with the GAME-VHs with the virtual dog compared to the STIM-ROBOT and STIM-PHONE conditions.

4.3 Qualitative Results

This section presents the three themes that emerged from the qualitative analysis of our participants' post-study interview responses. For each theme, the total number of opinions presented for each condition can exceed the number of participants as each of them may have multiple opinions for each condition for a given theme.

Social Priming Enhanced User's Experience Compared to Non-Social Priming: Twelve of our participants (54%) described at least one positive benefit of the social priming conditions compared to the non-social priming condition.

For nine participants (41%), these positive benefits were more explicit as they found the social priming conditions to be more welcoming, pleasant, and contextual. The social priming conditions



(a) Head Gaze at Stimuli (b) Head Gaze at Game-VH (c) Social Presence

(d) Affective Attraction (e) Inclination (f) Inclusion of Other in the Self

Figure 3: Objective and subjective results (higher is better): (a) Head Gaze at Stimuli, (b) Head Gaze at Game-VH, (c) Social Presence, (d) Affective Attraction, (e) Inclination, (f) Inclusion of Other in the Self. Statistical significance: *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$).

being perceived as more welcoming is especially interesting, as all the Game-VHs had the same speech prompts, gestures, and facial expressions for welcoming the participants for each condition. On the other hand the non-social priming condition was described as unpleasant and demotivating. Overall, 12 positive mentions were recorded for the Stim-Dog condition followed by 10 positive mentions each for the Stim-VH and Stim-Robot conditions.

> *P15: "...last condition was very distant...they were looking at their phone and they did not realize that somebody is at the door first two conditions were really good because they were interacting with their in the first case robot and in the second case their pet but as soon as they realized they greeted and they wanted to welcome in and even the third condition I would say it was still pleasant because they were giving 100% of their attention to the person they were talking to..."*

Six participants (27%) noted that at least one of the social priming conditions garnered a positive sense of curiosity as they would glance at them to see what they would do next or get clues for the game. Three participants (13%) appreciated the presence of the stimuli during the game as they thought of them as "screensavers" that avoided idle scenes while in the presence of the Game-VHs.

> *P12: "...as I was talking and asking questions I kind of like used as a screen saver...I would look over to it [social priming stimuli] to give my mind a second thing to think about so it felt like some progress was being made..."*

Unexpected Social Priming Can Have Positive Benefits: Ten of our participants (45%) assessed the social and non-social priming interactions based on how closely it resembled their real-life experiences or their previous exposures to similar technology. Among this group, the Stim-VH condition was regarded as the most common and normal compared to the other conditions (six participants, 27%), followed by the Stim-Phone (four participants, 18%), and the VH-Dog (two participants, 9%).

> *P15: "...the one with the dog I felt the most comfortable with cause it seemed more authentic and the one where she was talking with that guy, just cause it seemed like real like situations that could happen...I felt like a little more like curious I guess [with] the robot one, but also it feels a bit more like not actually real because we don't have anything like that in real life...the one when she was on her phone...that felt authentic to me because that sometimes happens, you gotta have to wait for someone to notice you when you are standing at the door..."*

Interestingly, although being common was deemed as a positive quality for the above conditions, the opposite very rarely led to a negative experience. Eight participants in the Stim-Robot condition (36%) and six (27%) participants in the Stim-Dog condition did not find the social priming interactions in these conditions as common or expected. However, the unexpectedness resulted in an added sense of positive curiosity and amusement for most, with only two participants (9%) deeming the uncommonness of the Stim-Dog and Stim-Robot conditions as negative and weird.

> *P5: "...I felt that it was kind of cool that there was a dog there with the robot as well...I just thought they are more interesting because most AR avatars aren't dogs or robots..."*

Adding Variation to Social Priming Stimuli Can be Beneficial: The experience of seven of our participants (31%) was influenced by the presence or absence of non-human stimuli. In this group, three participants (13%) described their general feelings of anxiety and apprehension when interacting with strangers, which was brought to the fore when presented with the Stim-VH and Stim-Phone conditions. The remaining four participants (18%) noted feeling more social, happier, and comfortable in the Stim-Dog and/or Stim-Robot conditions due to liking dogs and the added curiosity and excitement brought about by these stimuli.

> *P20: "...with the robot I was curious cause I wasn't expecting to see a robot so I was more invested...in the dog too I don't have a dog but I like dogs I trust them...with the other person I get anxious around people so I wasn't as inclined to like having the other person there it almost felt like I was interrupting I guess since they already were in the middle of something cause I don't feel like I'm interrupting a dog but when it's a person-person interaction I was like oh maybe I'm interrupting something here and then when they were on their phone was probably the worst cause you just had to stand there and I guess I'm bothering her I felt bad like oh she's on her phone oh my bad..."*

5 Discussion

Our quantitative and qualitative findings show the promise of social priming to both positively influence participants' perceptions of the Game-VHs compared to the non-social priming, and to impact how participants divide their attention. Also, we found that some of the benefits of social priming can be induced by non-humanoid entities. However, we did not find any evidence for social priming enhancing the quality of social interaction between the participants and the Game-VHs. Here we provide a detailed discussion of the findings.

5.1 Potential Dual Benefits of Social Priming

Our quantitative and qualitative results suggest that social priming may have dual benefits: (a) enhancing participants' perceptions of the GAME-VHs, and (b) enhancing participants' user experience.

Regarding point (a), we found that participants attributed more positive affective characteristics to the GAME-VHs in the STIM-VH and STIM-DOG conditions, such as finding the GAME-VHs more warm and friendly than the non-social priming condition (trend for STIM-ROBOT). Also, participants felt more inclined to engage in future interactions with the GAME-VHs in all social priming conditions than the non-social priming condition. These findings also reveal that social priming can be facilitated with non-humanoid entities, with similar differences for the STIM-DOG and STIM-ROBOT conditions (trend for affective attraction in the STIM-ROBOT condition). These findings correspond to previous research on real dogs creating a halo effect for their owners [9, 24, 36, 56, 58]. We speculate that the positive findings for the virtual robot may be related to participants' positive curiosity and excitement resulting from its presence. These findings partially support **H1** and **H2**. This partial support is due to the fact that unlike previous work [17–19], we did not find higher Social Presence scores in the social priming conditions compared to the non-social priming condition, with relatively high Social Presence scores across all conditions, as shown in Figure 3 at (c). This finding may be explained by the fact that most of our participants mentioned being engaged in the game and finding the mechanics of the social interactions with the GAME-VHs to be similar across all conditions, leading to similar social presence scores. Interestingly, a few of our participants noted that seeing a VH on their phone seemed normal to them, which may explain the unaffected social presence scores.

Also, previous research looking at dyadic social interactions has found that using one's phone continuously during the social interaction negatively influences the other person's perceptions [2, 14, 22]. Although our STIM-PHONE condition did not include such a scenario—continuous phone usage during the interaction—some of our participants found it less pleasant than to the social priming condition. Based on our participants' feedback, we speculate that the negative perceptions in the STIM-PHONE condition is more associated with the their perception of having to wait longer at the doorway, while this point was not mentioned for the other conditions.

As expected, our participants paid more attention to the GAME-VHs in the non-social priming condition as no other stimuli was present in the room, supporting our hypothesis **H3** that participants divided their attention between the GAME-VHs and the different social priming stimuli in the social priming conditions. Separately, in response to **RQ1** and **RQ2**, our participants paid more attention to the virtual dog than the virtual robot at the beginning of the interaction—similar, but a trend was observed between STIM-DOG and STIM-VH conditions. This may be due to the virtual dog being perceived as pleasant and unexpected compared to the other stimuli. For instance, although only a trend, participants seemed to feel more at one with the GAME-VHs in the STIM-DOG condition compared to STIM-ROBOT and STIM-PHONE (see IOS in Table 2).

In response to **RQ1** and **RQ2**, we also found the influence of social priming on participants' overall experience captured in point (b) noted above. Our qualitative findings suggest that some of our participants found the social priming phase as a pleasant and interesting interaction to observe, adding to their sense of curiosity with some participants finding the virtual dog and the virtual robot to be unexpected in a positive way. Thus, we see benefits for giving context to interactions with VHs through social priming and exploring varying stimuli since interactions with virtual dogs or robots can provide novel background information about the VHs, their personality, and affective states that may facilitate longer-term engagement. For instance, VHs that share first-person perspective background information are found to be more engaging in the long run [10].

5.2 Limitations

First, we observed a limitation of our Head Gaze measure as participants tried to fit both entities in the social priming conditions in the field of view of the HMD, such that a single ray cast forward from participants' faces cannot entirely capture our participants' focus of attention. We plan to utilize eye tracking in future studies to pinpoint the differences in participants' division of attention.

Second, ideally, the interactions with GAME-VHs would have been identical in all conditions. While we aimed to create ecologically valid interactions that would make sense for each condition, we cannot rule out that differences in these interaction scenarios had an effect on participants' perception of GAME-VHs, such as seeming more empathetic or natural in some conditions, which may also be related to the novelty aspect of the stimuli and interactions.

Third, all GAME-VHs were involved in relatively positive interactions during the social priming phase, and future studies should explore the influence of more neutral interaction scenarios. That said, except for one participant, all attributed the influences of the social priming to the general interaction between the GAME-VHs and the different stimuli and not to the specific content of the interaction.

Lastly, while all GAME-VHs were designed to be similar, they varied in subtle features such as the shape and color of their clothes. Though effects of their appearance would likely be minute compared to the other stimuli, we cannot entirely rule out such influences.

6 CONCLUSION

In this paper, we presented a human-subjects user study to assess the potential of social priming through social interactions between different VH and virtual stimuli, which included another VH, a virtual pet dog, a virtual personal robot and compared it to a non-social priming condition. We found that social priming leads to a more positive perception of VHs than the non-social priming condition; however, participants experienced similar levels of social presence in all conditions. Additionally, our findings point towards benefits in adding variation to social-priming stimuli. For instance, some of our participants were positively surprised by the presence of the virtual dog and the virtual robot and a few experienced social anxiety with the VH stimuli.

Looking ahead, we see many opportunities to investigate other aspects of social influence. For example, we wonder whether a virtual human appearing to have a social conversation on a phone or over video could result in social influence. We also wonder about the potential influence of non-humanoid entities, both those that have real world counter parts and those that do not, e.g., fantasy characters. We see value in studying the potential influence of the mere *presence* of entities. A finding of influence by the mere presence of an entity could be valuable as it would be relatively easy to add non-interacting entities to a scene. Such findings could also open the door to investigations of the influence of longer-term presence. Finally, we wonder about the social influence of virtual entities associated with real people, e.g., whether a virtual dog associated with a real human can result in similar social influence.

ACKNOWLEDGMENTS

This material includes work supported in part by the National Science Foundation under Collaborative Award Numbers 1800961 and 1800922 (Dr. Ephraim P. Glinert, IIS) to the University of Central Florida and Stanford University respectively; the Office of Naval Research under Award Number N00014-21-1-2578 and N00014-21-1-2882 (Dr. Peter Squire, Code 34); and the AdventHealth Endowed Chair in Healthcare Simulation (Prof. Welch).

REFERENCES

[1] 4Experience. HoloLens 2 vs HoloLens 1: what's new? https://4experience.co/hololens-2-vs-hololens-1-whats-new/, 2020.

[2] M. M. V. Abeele, M. L. Antheunis, and A. P. Schouten. The effect of mobile messaging during a conversation on impression formation and interaction quality. *Computers in Human Behavior*, 62:562–569, 2016.

[3] Adobe Mixamo. Animate 3D characters for games, film, and more. https://www.mixamo.com/, 2021.

[4] A. Aron, E. N. Aron, and D. Smollan. Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of personality and social psychology*, 63(4):596, 1992.

[5] Audacity. Free, open source, cross-platform audio software. https://www.audacityteam.org/, 2021.

[6] Autodesk. 3D computer animation, modeling, simulation, and rendering software. https://www.autodesk.com/products/maya/, 2021.

[7] J. N. Bailenson, A. C. Beall, and J. Blascovich. Gaze and task performance in shared virtual environments. *The journal of visualization and computer animation*, 13(5):313–320, 2002.

[8] J. A. Bargh, M. Chen, and L. Burrows. Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of personality and social psychology*, 71(2):230, 1996.

[9] A. Beetz, K. Uvnäs-Moberg, H. Julius, and K. Kotrschal. Psychosocial and psychophysiological effects of human-animal interactions: the possible role of oxytocin. *Frontiers in psychology*, 3:234, 2012.

[10] T. Bickmore, D. Schulman, and L. Yin. Engagement vs. deceit: Virtual humans with human autobiographies. In *International workshop on intelligent virtual agents*, pp. 6–19. Springer, 2009.

[11] F. Biocca, C. Harms, and J. Gregg. The networked minds measure of social presence: Pilot test of the factor structure and concurrent validity. In *Annual International Workshop on Presence*, pp. 1–9, 2001.

[12] V. Braun and V. Clarke. Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2):77–101, 2006.

[13] BYD. BYD Qin plug-in hybrid car has an in-dash robot to keep you company. https://www.theverge.com/2012/4/23/2968502/byd-qin-robot-beijing-auto-show-aida-robotic-assistant, 2021.

[14] V. Chotpitayasunondh and K. M. Douglas. The effects of "phubbing" on social interaction. *Journal of Applied Social Psychology*, 48(6):304–316, 2018.

[15] A. Cordar, M. Borish, A. Foster, and B. Lok. Building virtual humans with back stories: training interpersonal communication skills in medical students. In *International Conference on Intelligent Virtual Agents*, pp. 144–153. Springer, 2014.

[16] P. Creary. *The influence of the presence of a dog or cat on perceptions of a psychotherapist*. PhD thesis, 2017.

[17] S. Daher, K. Kim, M. Lee, G. Bruder, R. Schubert, J. Bailenson, and G. Welch. [POSTER] Can Social Presence be Contagious? Effects of Social Presence Priming on Interaction with Virtual Humans. In *IEEE Symposium on 3D User Interfaces (3DUI)*, 2017.

[18] S. Daher, K. Kim, M. Lee, A. Raij, R. Schubert, J. Bailenson, and G. Welch. [POSTER] Exploring Social Presence Transfer in Real-Virtual Human Interaction. In *Proceedings of IEEE Virtual Reality (VR)*, 2016.

[19] S. Daher, K. Kim, M. Lee, R. Schubert, G. Bruder, J. Bailenson, and G. Welch. *Effects of Social Priming on Social Presence with Intelligent Virtual Agents*, vol. 10498, pp. 87–100. Intelligent Virtual Agents, Springer International Publishing, 2017.

[20] Digital Dream Labs. Cozmo. https://www.digitaldreamlabs.com/, 2021.

[21] T. Fong, I. Nourbakhsh, and K. Dautenhahn. A Survey of Socially Interactive Robots. *Robotics and Autonomous Systems*, 42(3-4):143–166, 2003.

[22] A. L. Gonzales and Y. Wu. Public cellphone use does not activate negative responses in others… unless they hate cellphones. *Journal of Computer-Mediated Communication*, 21(5):384–398, 2016.

[23] M. Gottsacker, N. Norouzi, K. Kim, G. Bruder, and G. F. Welch. Diegetic Representations for Seamless Cross-Reality Interruptions. In *Proceedings of the IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 1–10, 2021.

[24] N. Guéguen and S. Ciccotti. Domestic dogs as facilitators in social interaction: An evaluation of helping and courtship behaviors. *Anthrozoös*, 21(4):339–349, 2008.

[25] K. C. Herbst, L. Gaertner, and C. A. Insko. My head says yes but my heart says no: Cognitive and affective attraction as a function of similarity to the ideal self. *Journal of personality and social psychology*, 84(6):1206, 2003.

[26] L. Hung, C. Liu, E. Woldum, A. Au-Yeung, A. Berndt, C. Wallsworth, N. Horne, M. Gregorio, J. Mann, and H. Chaudhury. The benefits of and barriers to using a social robot paro in care settings: a scoping review. *BMC geriatrics*, 19(1):1–10, 2019.

[27] Immersiv.io. Hands-on Microsoft's HoloLens 2: Review by Immersiv.io' team. https://www.immersiv.io/blog/hands-on-hololens-2-review/, 2020.

[28] S. Isenstein. *Man's Best Friend is a Therapist's Best Friend: How the Presence of a Dog Influences Therapists and Others' Perceptions of Them*. PhD thesis, 2018.

[29] K. Kim, G. Bruder, and G. F. Welch. Blowing in the wind: Increasing copresence with a virtual human via airflow influence in augmented reality. In *Proceedings of ICAT-EGVE*, pp. 183–190, 2018.

[30] K. Kim, N. Norouzi, T. Losekamp, G. Bruder, M. Anderson, and G. Welch. Effects of patient care assistant embodiment and computer mediation on user experience. In *Proceedings of the IEEE International Conference on Artificial Intelligence & Virtual Reality (AIVR)*, pp. 17–24, 2019.

[31] S. C. Kramer, E. Friedmann, and P. L. Bernstein. Comparison of the effect of human interaction, animal-assisted therapy, and aibo-assisted therapy on long-term care residents with dementia. *Anthrozoös*, 22(1):43–57, 2009.

[32] A. Lambert, N. Norouzi, G. Bruder, and G. Welch. A systematic review of ten years of research on human interaction with social robots. *International Journal of Human–Computer Interaction*, 36(19):1804–1817, 2020.

[33] M. Lee, K. Kim, S. Daher, A. Raij, R. Schubert, J. Bailenson, and G. Welch. The wobbly table: Increased social presence via subtle incidental movement of a real-virtual table. In *Proceedings of IEEE Virtual Reality (VR)*, pp. 11–17, 2016.

[34] M. Lee, N. Norouzi, G. Bruder, P. Wisniewski, and G. Welch. Mixed reality tabletop gameplay: Social interaction with a virtual human capable of physical influence. *IEEE Transactions on Visualization and Computer Graphics (TVCG)*, 2019.

[35] M. Lee, N. Norouzi, G. Bruder, P. J. Wisniewski, and G. F. Welch. The physical-virtual table: Exploring the effects of a virtual human's physical influence on social interaction. In *ACM Symposium on Virtual Reality Software and Technology (VRST)*, pp. 25:1–25:11, 2018.

[36] J. McNicholas and G. M. Collis. Dogs as catalysts for social interactions: Robustness of the effect. *British Journal of Psychology*, 91(1):61–70, 2000.

[37] Microsoft. Microsoft Rocketbox Avatar Library. https://github.com/microsoft/Microsoft-Rocketbox, 2021.

[38] C. Mircioiu and J. Atkinson. A comparison of parametric and non-parametric methods applied to a likert scale. *Pharmacy*, 5(2):26, 2017.

[39] G. Norman. Likert scales, levels of measurement and the "laws" of statistics. *Advances in health sciences education*, 15(5):625–632, 2010.

[40] N. Norouzi, G. Bruder, A. Erickson, K. Kim, J. Bailenson, P. J. Wisniewski, C. E. Hughes, , and G. F. Welch. Virtual animals as diegetic attention guidance mechanisms in 360-degree experiences. *IEEE Transactions on Visualization and Computer Graphics (TVCG) Special Issue on ISMAR 2021*, pp. 1–11, 2021.

[41] N. Norouzi, K. Kim, J. Hochreiter, M. Lee, S. Daher, G. Bruder, and G. Welch. A Systematic Survey of 15 Years of User Studies Published in the Intelligent Virtual Agents Conference. In *International Conference on Intelligent Virtual Agents*, pp. 17–22, 2018.

[42] N. Norouzi, K. Kim, M. Lee, R. Schubert, A. Erickson, J. Bailenson, G. Bruder, and G. Welch. Walking your virtual dog: Analysis of awareness and proxemics with simulated support animals in augmented reality. In *Proceedings of the IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 253–264, 2019.

[43] C. Oh, F. Herrera, and J. Bailenson. The effects of immersion and

real-world distractions on virtual social interactions. *Cyberpsychology, Behavior, and Social Networking*, 22(6):365–372, 2019.

[44] C. S. Oh, J. N. Bailenson, and G. F. Welch. A systematic review of social presence: Definition, antecedents, and implications. *Frontiers in Robotics and AI*, 5(114), 2018. doi: 10.3389/frobt.2018.00114

[45] Razgrizzz Demon. . https://assetstore.unity.com/packages/3d/characters/robots/robot-sphere-136226, 2021.

[46] Red Deer studio. . https://assetstore.unity.com/packages/3d/characters/animals/dog-golden-retriever-187111, 2021.

[47] B. Reeves, J. Hancock, and X. Liu. Social robots are like real people: First impressions, attributes, and stereotyping of social robots. *Technology, Mind, and Behavior*, 1(1), 2020.

[48] Rogo Digital LipSync. A powerful lip-syncing and facial animation tool for Unity. https://lipsync.rogodigital.com/, 2021.

[49] K. A. Rossbach and J. P. Wilson. Does a dog's presence make a person appear more likable?: Two studies. *Anthrozoös*, 5(1):40–51, 1992.

[50] M. Rubagotti, I. Tusseyeva, S. Baltabayeva, D. Summers, and A. Sandygulova. Perceived safety in physical human robot interaction–a survey. *arXiv preprint arXiv:2105.14499*, 2021.

[51] M. S. Schneider and L. P. Harley. How dogs influence the evaluation of psychotherapists. *Anthrozoös*, 19(2):128–142, 2006.

[52] Sphero. STEAM Education for All Ages & Stages. https://sphero.com/, 2021.

[53] W. Swartout, D. Traum, R. Artstein, D. Noren, P. Debevec, K. Bronnenkant, J. Williams, A. Leuski, S. Narayanan, D. Piepol, et al. Ada and grace: Toward realistic and engaging virtual museum guides. In *International Conference on Intelligent Virtual Agents*, pp. 286–300. Springer, 2010.

[54] S. Tifferet, D. J. Kruger, O. Bar-Lev, and S. Zeller. Dog ownership increases attractiveness and attenuates perceptions of short-term mating strategy in cad-like men. *Journal of Evolutionary Psychology*, 11(3):121–129, 2013.

[55] E. J. Van Der Drift, R.-J. Beun, R. Looije, O. A. B. Henkemans, and M. A. Neerincx. A remote social robot to motivate and support diabetic children in keeping a diary. In *2014 9th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pp. 463–470. IEEE, 2014.

[56] D. L. Wells. The facilitation of social interactions by domestic dogs. *Anthrozoös*, 17(4):340–352, 2004.

[57] M. Wells and R. Perrine. Pets go to college: The influence of pets on students' perceptions of faculty and their offices. *Anthrozoös*, 14(3):161–168, 2001.

[58] L. Wood, K. Martin, H. Christian, A. Nathan, C. Lauritsen, S. Houghton, I. Kawachi, and S. McCune. The pet factor-companion animals as a conduit for getting to know people, friendship formation and social support. *PloS one*, 10(4):e0122085, 2015.

[59] Zapsplat. Free Sound Effects. https://www.zapsplat.com/, 2021.