Investigating Social Distances between Humans, Virtual Humans and Virtual Robots in Mixed Reality

Socially Interactive Agents Track

Christopher Peters
KTH Royal Institute of Technology
Stockholm, Sweden
chpeters@kth.se

Chengjie Li
KTH Royal Institute of Technology
Stockholm, Sweden
chengjie@kth.se

Fangkai Yang
KTH Royal Institute of Technology
Stockholm, Sweden
fangkai@kth.se

Vanya Avramova
KTH Royal Institute of Technology
Stockholm, Sweden
avramova@kth.se

Gabriel Skantze
KTH Royal Institute of Technology
Stockholm, Sweden
gabriel@speech.kth.se

ABSTRACT

Mixed reality environments offer new potentials for the design of compelling social interaction experiences with virtual characters. In this paper, we summarise initial experiments we are conducting in which we measure comfortable social distances between humans, virtual humans and virtual robots in mixed reality environments. We consider a scenario in which participants walk within a comfortable distance of a virtual character that has its appearance varied between a male and female human, and a standard- and human-height virtual Pepper robot. Our studies in mixed reality thus far indicate that humans adopt social zones with artificial agents that are similar in manner to human-human social interactions and interactions in virtual reality.

KEYWORDS

Mixed reality; virtual characters; proxemics; interpersonal distances

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1 INTRODUCTION

People may have social relationships with computers, treating them in some ways and in some contexts as social partners [13]. Improving our understanding of the factors that underlie these social relationships is paramount if we are to be able to construct companions, physical or virtual, that are capable of interacting with humans in an unobtrusive and socially acceptable manner. This paper investigates one aspect underlying social interactions: proxemics [6], the study of how humans use and manipulate distances with others in the context of social behaviour. Mixed reality environments, which anchor and embed virtual objects into the real environment, offer new potentials for the design of compelling social interaction experiences in which virtual companions provide a heightened sense of presence while still enabling the user to maintain important contact with the surrounding environment. Since one is free to move around the environment, as in virtual reality, the issue of social distance is fundamental and paramount. If mixed reality interactions share similarities with their purely physical counterparts, there is the potential for the design of real interactions without the need for physical objects, which may be expensive or susceptible to breakdown (i.e. in the case of complex social humanoid robots). Our initial research studies have focused on establishing similarities between proxemics in mixed reality environments with real human-human interactions and in virtual reality.

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2 BACKGROUND

In relation to human-human proxemics, Hall [6] defines four zones: *intimate* (<0.45m), *personal* (0.45m-1.2m), *social* (1.2m to 3.6m) and *public* (>3.6m). Summarising this, Lambert [10] provides more precise values for *intimate* (0m to 0.15m) and *close intimate* (0.15m to 0.45m) zones to provide the generally recognised personal space zones. Proxemics is a significant factor in a variety of modelling and interaction attempts taking place in virtual environments, whether displayed on screen or through virtual reality equipment. For example, models of personal distance are fundamental to setting the social formations of small groups of virtual characters, an important requirement for creating plausible looking crowd scenes [4].

Recently Zibrek et al. [16] used a proximity task and different rendering styles in immersive VR to investigate the perceived realism, co-presence and agency for both agents and avatars (i.e. computer and user controlled characters, respectively). Interpersonal distances also have the potential to play an important in learning and feedback involving virtual characters, as demonstrated by Jeong et al. [9]. A number of studies (see for example [1], [2] and [8]) have focused on interpersonal distances in virtual reality under different circumstances, attempting to compare these interactions with the human-human situation and to elucidate the factors that may explain variations in interpersonal distances. Human Robot Interaction literature has also considered proxemics in relation to interactions with physical systems; see for example [5] and [7]. These have included studies on the impact of factors such as voice

styles [15], body postures [12], gaze and preference on interpersonal distances [11].

3 EXPERIMENT

The *Microsoft Hololens* was used to display mixed reality characters (referred to as *holograms*) that were rendered in the Unity 3D game engine. The Hololens integrates four cameras, a depth camera and an inertial measurement unit for environment understanding which includes a mixed reality coordinate system that has meaning in the physical world. This system allows the display to keep the positions of objects near the user stable relative to the world even when they make head movements. The coordinate system also allows world-locked objects i.e. objects that stay in the same position even when the user walks around.

The stimuli consisted primarily of the four virtual characters: virtual robots at two scales, a female human and a male human. The robot resembles the Pepper robot by *SoftBank Robotics* and was chosen due to its humanoid appearance. The male and female characters were predefined assets generated from Adobe Fuse CC, a 3D computer character software developed by Mixamo. Characters were imported into the Unity 3D game engine for real-time display and animation during the study.

These stimuli were used to investigate the main research hypothesis that human-character distances in mixed reality would be comparable to those found for human-human interpersonal distances [6]. 30 participants recruited from the local student population took part in the study. The experiments started with participants being given a verbal introduction to the study and written instructions before signing a consent form. Prior to the experiment, participants wore the Hololens and were shown the four different appearances used in the experiment. They rated each appearance in terms of height, gender, likability and realism on a five point Likert scale.

In each trial of the experiment, a character was placed 3 meters in front of the participant, facing directly towards them and maintaining mutual gaze with them. Participants walked towards the character until they felt that they were within a comfortable distance of it. When they stopped, their distance to the character was measured via the Hololens. They then walked back to the start point of the experiment and commenced the next trial. The character was varied in each trial between one of the four appearances.

4 OVERVIEW OF RESULTS

Results were obtained in relation to the perception of the appearance of the characters and comfortable stopping distances for participants. In terms of perceived gender, the male character was rated to be male and the female was rated to be female. Both the standard sized and human height robot characters were rated neutral in terms of gender. Both robot characters were rated as being less realistic but more friendly than the human characters.

In the main experiment, the mean overall stopping distance across all appearances and participants was 1.23m from the character. While no significant effect of appearance was found on distance, a post-hoc analysis indicated a significant difference between the large and small robot appearance types. While median comfortable stopping distances were generally the same across appearances, they appeared to vary more in relation to the comfortable distance with respect to the small robot. In 49% of trials, participants stopped within the social zone of the character, while in 42% of the trials, they stopped within the personal zone of the character. Notable are a small number of cases in which participants moved into the intimate zone of the character (i.e. within 0.15m): A number of participants had not only moved toe to toe with the characters, but also tried to hug or move through the holograms. This was consistent across character appearances, although the overall number of cases were low (10/464 trials).

5 DISCUSSION

Overall the mean comfortable stopping distance of 1.23m in the experiment falls within the boundaries of the personal and social zones and generally fits the hypothesis that social distances within mixed reality environments with virtual characters are comparable to those found for human-human interpersonal distances [10]. Participants maintained expected social and personal distances with the characters, although there were individual cases of violations of personal space that would not be expected in human-human interactions. While previous studies have noted differences in comfortable distance based on the appearance of characters (see for example [8]), this experiment did not find a strong effect of appearance on distance overall. This could explained by the use of mechanical appearances for robots in previous studies, while in this study the two virtual robots are quite human-like and participants rated them high in terms of their likability. Therefore the appearance of characters may have been too homogeneous to produce effects.

Despite this, participants tended to maintain a slightly larger distance from the small robot when compared to the others. This may be due to the height of the robot, which is shorter than an average human adult, although previous studies did not find an impact of the height of the stimulus on comfortable distance (see for example [14]). A number of participants described the robot as being child-like. One possibility is that participants were adopting social distances similar to those with a child, since social distances are known to change across age groups [3].

6 CONCLUSIONS

In a task in which users moved as close as they felt comfortable to virtual characters of varying appearances, we observed that most participants generally moved within the social (49% of trials) and personal (42% of trials) zones of the characters and moved closer in far fewer trials. Participants adopted significantly different distances to the shorter virtual robot than to the other appearances (male, female, full-sized robot). Overall, the results are consistent with previous research findings that humans generally adopt social zones with artificial characters. Our ongoing work involves investigating the impact of different gaze behaviours, visual perspectives and full-body behaviours on comfortable distances for virtual and physical human-human and human-robot interactions.

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