Towards Understanding the Influence of a Virtual Agent's Emotional Expression on Personal Space

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Abstract

The concept of personal space is a key element of social interactions. As such, it is a recurring subject of investigations in the context of research on proxemics. Using virtual-reality-based experiments, we contribute to this area by evaluating the direct effects of emotional expressions of an approaching virtual agent on an individual's behavioral and physiological responses. As a pilot study focusing on the emotion expressed solely by facial expressions gave promising results, we now present a study design to gain more insight.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

1 Introduction

A deep understanding of human behavior is of prime importance for different research disciplines. In psychology, the insight can be applied in therapeutic contexts, e.g., in mental health care. In computer science, especially in the realm of social virtual reality (VR), the understanding is required to accurately simulate human behavior of advanced (emotional) human interfaces. These represent human interaction partners in the form of embodied, computer-controlled, human-like, intelligent and conversational virtual agents (VAs).

Investigating social human behavior by means of VR-based experiments is increasingly common [5–8]. These studies provide maximal experimental control, while obtaining a natural frame for social interactions. Thus, participants tend to respond realistically when experiencing a plausible scenario [17]. Furthermore, using VAs as interaction partners allows us to measure non-confounded interaction effects as the reflection problem [14] is avoided.

The work in progress presented here focuses on human personal space adaptations in response to emotional expressions. To this end, we have developed an experimental VR setup [19] that allows evaluating the direct effects of a VA's emotional expressions on a participant's behavioral and physiological responses. This setup was already successfully used in a pilot study (see Section 3 and [6]). Findings acquired from this setup will advance core theoretical knowledge on personal space and approach-avoidance behaviors between individuals, stimulating further translational research. Ultimately, the use of VR in clinical settings may promise new avenues for potential interventions regarding altered social motivational behavior, i.e., avoidance or aggression.

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The remainder of this paper is structured as follows: We will give more details on personal space in Section 2, summarize the results of our pilot study in Section 3, discuss the within-subject design of our planned follow-up study in Section 4 and give a short summary and outlook in Section 5.

2 Personal Space

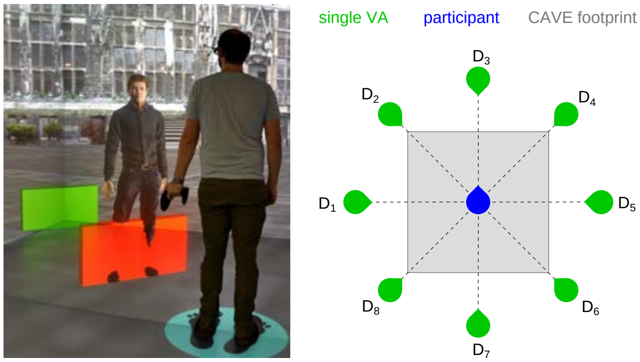
The non-verbal behavior of choosing an appropriate distance to others in social environments is a key element of social interactions. Although a lot of research on interpersonal distance (proxemics) was conducted in the past, the personal space, an area individuals try to maintain around themselves [10], is not yet fully understood. This is due to the fact, that this dynamically regulated, elliptical safety zone [1] depends on numerous social and personal characteristics. Among many more, examples of influencing factors are environmental aspects such as obstacle movements [9], interpersonal factors like the interaction partner's sex and age (e.g., [1, 12]), but also personality traits such as social anxiety. Individuals with high social anxiety, e.g., reveal complex avoidance behaviors and prefer a larger distance from strangers [16, 25]. The impact of affective contexts and expressions on personal space preferences is also evident in larger distances to others in threatening situations [11] or when confronted with angry-looking individuals [23].

In general, violations of the personal space evoke discomfort and physiological arousal in the individual [11]. These are evident in, e.g., changes in heart rate [18] and skin conductance [21]. Furthermore, personal space intrusions may trigger avoidant or aggressive reactions [15]. Being able to consciously violate an individual's personal space thus opens up new research areas in the field of social behavioral studies on aggressive behaviors.

We are interested in the influence of emotions expressed by an approaching person on an individual's personal space preferences. Real-life observations already showed that individuals keep a larger distance to people with angry facial expressions compared to those with a happy expression [22, 23]. While previous research showed, that the concept of personal space is also applicable in VR settings (e.g., [2–4]), we are the first to investigate the influence of emotions in a VR setting.

3 Insights From Our Pilot Study

In a pilot study, 27 German males in the age range of 18 to 30 years conducted a *Sample* task. They were asked to stand still in the center of our CAVE and to explicitly sample their personal space preferences (see Figure 1(a)) while being approached by either a single VA or a group of three VAs with matching age, gender and cultural background. Two distances had to be specified per participant: a so-called comfortable distance, defined as the distance when he feels most comfortable for interacting with the VAs (shown as green barrier in Figure 1(a)) and a so-called uncomfortable distance by which the



(a) (b)

Figure 1: A male participant samples his personal space preferences (a), while being approached by a male VA from eight directions (b) in a randomized order. (Images adapted from [6].)

participant felt the urgent need to step aside as his personal space was already invaded by the VAs (shown as red barrier in Figure 1(a)).

The VAs were looking at the participants while approaching them with about 0.8m/s randomly from six directions (see D1 to D5 in Figure 1(b)), showing one of two emotions as facial expressions: angry (E_a) or happy (E_h). Some of our findings were in line with previous observations of real-world or VR-based studies: the elliptical form of the personal space was indicated (e.g., cp. [1]), a larger distance was kept to the single, angry VA compared to the happy one (cp. [23]), and single VAs were allowed to come closer compared to the group (e.g., cp. [13]). For more details, we refer the interested reader to [6].

4 Design of the Follow-up Study

Our pilot study is a reasonable foundation for further investigations on the impact of emotions on individuals' personal space preferences and reactions to personal space invasions. As the effect of the emotions was very pronounced for the single VA, gaining more insight in this condition is most promising. Thus, we plan to extend our measurements as well as the participant's tasks.

Sampling the Complete Personal Space

While our pilot study only focused on the frontal and the lateral personal space preferences, our follow-up study will also take the personal space behind the participants into account. Thus, the directions of approaching in the *Sample* task will be extended by D6 to D8, as shown in Figure 1(b). To this end, we will embed footstep sounds as auditory cues to account for the fact that the VA approaching the participant's back is not in his field of view.

In order to allow the participants to perceive the correct emotion without seeing the body posture or the facial expression, different sounds for the footsteps will be used. For E_a, the sound will indicate a stomping individual. For E_h, a softer sound indicating light-footedness will be used.

Emotional Expression

In our everyday life, we infer others' motivational and emotional states not only via their facial expressions, but also via a plethora of non-verbal cues, e.g., eye gaze and body posture. Thus, we plan to extend our setting by adding an appropriate body language to the facial expression. As done in our pilot study, the gaze is oriented towards the participant, while blinking avoids an unnatural starring in the about 9s of approaching.

In order to obtain a personal space baseline, participants will be asked to conduct the *Sample* task first with a VA showing a neutral emotion (E_n), before facing the angry and the happy VA in a random order. Thus, each *Sample* task consists of 8 approaches repeated for 3 emotions, resulting in 24 runs.

Advancing from our pilot study, we will run a perception session as pre-study. To verify the perception of the emotions, we will combine our pilot study and the approach of Llobera et al. [13]: A VA will approach the individual's front and back in 3 fixed distances (one intimate, one personal, one social), showing different characteristics of E_a and E_h for the face, the body, and the footsteps. By collecting data on how strong the respective emotion was perceived, the best rated characteristic per emotion will be used in the final study.

To perceive E_n, E_a and E_h equally long, the agent's walking pace will be kept constant. Furthermore, no gestures will be embedded as their exact timing and form of presentation may add too many confounding factors to our design.

Physiological and Behavioral Indicators

As the pilot study focused on explicitly sampling the personal space, we favored a subjective indicator of proxemics. This will now be combined with implicit physiological measurements: heart rate by means of a heart rate sensor on a chest strap, skin conductance by means of a skin response sensor attached to the non-dominant hand. For the *Sample* task, this additional insight allows searching for correlating patterns in the gathered data.

Subsequent to the *Sample* task, we will obtain behavioral indicators by implicitly verify the participant's personal space preferences. In the so-called *PassBy* task, the participants will be approached from different directions by a VA showing either E_a or E_h, while knowing that the VA will pass by. Depending on the personal space areas gathered in the previous *Sample* task, the VA will adapt its trajectory to avoid collisions while passing sometimes close and sometimes more distant. During the VA's approach or pass by, participants are explicitly allowed to step aside or to turn at any time if they feel uncomfortable. The deviations to the participant's original position will be tracked, evaluated and compared with the implicit physiological measurements.

Display Devices

To be comparable to our pilot study, we will also conduct the follow-up study in our CAVE, using the acoustic system in it's ceiling for the footstep sounds. By means of a binaurale auralization simulating the natural hearing experience, the participants are able to localize the sound correctly in 3D space (cp., e.g., [24]).

Besides the CAVE, two additional displays will complete our study design:

As second device, the HTC Vive with headphones and a body-avatar will be used. By this, we hope to find indicators if and how the limited field of regard by an HMD influences the personal space preferences depending on the perceived VA's emotion. Furthermore, a comparison between HMD and CAVE will provide insights which display system to favor for future studies: while HMDs are affordable, wearing them for a longer period may be unfavorable or even not possible, especially for individuals with anxiety disorders. In contrast, CAVEs are high-priced and rare, however exclude less potential participants.

The third device will be a desktop. In order to compare our *Sample* results to previous findings from psychology, the common computerized stop-distance paradigm will be used. In a top-down view, participants drag a virtual space invader from all eight directions towards their own virtual representation. The *PassBy* task will not be conducted at the desktop.

Brief Study Procedure

While excluding participants of our pilot study, 60 German males in the age range of 18 to 30 will be recruited for our within-subjects study. To account for the age, gender and culture impact on personal space, they will face the virtual character of the single VA conditions

Table 1: Overview about the study components.

Task: \ Display:	Desktop	HMD	CAVE
Sample	1) all runs of E_n 2/3) all runs of E_a & E_h, E order randomized		
PassBy	—	mixed runs of E_a & E_h	

of our pilot study (see Figure 1 (a)). This model is taken from and animated by the virtual human toolkit SmartBody [20].

An overview about all tasks is given in Table 1. The desktop-based *Sample* task will be conducted first, beginning with the neutral VA, followed by a randomized order of the VA expressing E_a or E_h. Afterwards, the participant will conduct the *Sample* and *PassBy* task with each VR device. Whether HMD or CAVE will be tested first is counterbalanced. Furthermore, the order of E_a and E_h for *Sample* will be randomized, while both will be mixed up for *PassBy*. After finishing all tasks at one display device, participants will have a short break.

5 Summary

In this work, we presented the planned design for a two-step, VR-based evaluation of human personal space preferences: In the first step, the preferred personal space per participant will be explicitly sampled by means of an approaching VA, while investigating the influence of the emotional expression (neutral, angry, happy) and the direction of approaching. In the second step, these personal space measurements per participant will be verified implicitly by assessing the participant's behavior when a VA is passing by closely.

Based on the insights gained from our experiment, we intend to model different behavioral patterns for a VA by means of a generic, behavioral algorithm. Thereby, the patterns shall range from consciously respecting the personal space of a user or another VA to consciously violating it. By this, a first elementary basis for different research areas in the field of social VR is provided: respecting the personal space is a key element in crowd simulations or applications in which VAs fulfill the roles of assistants, guides or coaches; however the conscious violation opens up new and innovative research areas in the field of social behavioral studies and thus enables us to conduct VR-based research on aggressive or even violent offending behaviors.

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