Going Beyond Human Communication Capabilities with Immersive Virtual Reality

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Abstract
Traditionally immersive virtual reality (VR) aims at providing communication tools that are as efficient as human interactions in the real world. We, however, believe that VR has the potential to be a space where communication not only matches the real world but provides amplified communication tools for remote collaboration [with avatars] that are otherwise not possible for humans. In this paper we present the results of a focus group (n=4) and a pre-study (n=30), which reveal that abstract representations of amplified communication tools, are recognized and effectively used in VR.

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human communication, immersive VR, social interaction

ACM Classification Keywords
I.3.7 [Three-Dimensional Graphics and Realism]: VR

Introduction
Effective communication is defined as one of the necessities for a successful social interaction. In the real world (RW) humans have a number of tools to support communication: speech, gesture, actions, haptic signals and physiological signals. However, in virtual reality (VR) the majority of these signals are either very limited (e.g., eye movement) or not available at all (e.g., sweating palm, turning red). Billinghurst et.al [2] claimed that in order for successful social interactions to occur, VR needs to provide experiences

Figure 1: Snapshot of brainstorming session with expert focus group during ideation phase. 2 out of approximately 18 ideas (excluding duplicate ideas) were tested in a pre-study (Fig. 2).

where communication tools and social interactions are as good as in the RW. We believe that VR has the potential to go beyond just matching the RW: Virtual environments can be a place where users and their avatars can experience and collaborate with amplified communication tools that are not available in the RW. In this paper we propose the first steps towards amplifying human communication tools in VR to achieve immersive remote interactions.

Communication tools

This section is organized according to the communication tools that humans use in the RW: gesture, actions, haptic signals and physiological signals. We do not review speech, as technologies to enhance it may be directly transferred from other domains, such Google Translate [15].

Gesture: Gestures can be divided into arm, body and head gestures, whereby the latter mostly comprises of facial expressions. It is an open research question what the best strategy (e.g., realistic or abstract) is to model face expressions into VR, especially due to the fact that emotions are mostly communicated through facial expressions. The recent focus has mainly been in how to display mouth and eye movements in order to improve social interactions in VR [10]. Head movements can already be tracked by tracking the location of the head mounted display (HMD, e.g., HTC Vive [13]), allowing a one-to-one mapping of the head in the physical and virtual world. Similarly, arm and body gestures can be tracked, enabling the visual representation, in form of an avatar, of a physical human in real-time. Previous research has also reviewed amplifying gestures by extending limbs: For example, prolonging the arms of avatars to facilitate pointing interactions of objects at distance [7, 14] or manipulation of body length for easier access to high and low level objects [1].

Action: There are a number of ways in which actions (e.g., walking) have been amplified in VR. The most popular one being the notion of teleportation, whereby upon destination selection a user is immediately transported into another virtual scene. Although it is a well-known method, there are known side effects such as visual fatigue, disorientation and cyber sickness [3]. Other modes of walking have been demonstrated in similar studies [11, 12], such as flying, however walking is still perceived to be the most favourable for achieving a high presence [17].

Haptic Signals: The lack of force feedback in VR, makes it difficult to communicate intention in social interactions. For example, one partner pulling the other in a specific direction is not obvious from the motion itself but may need another signal, such as pointing in the proposed direction. Studies in this area have shown promising results but challenges such as the weight of full-body suits for haptic feedback and the lack of a solution for imitating RW physics, makes this a demanding research area [5].

Physiological Signals: Physiological signals are used as a measure for arousal and approval [4]. These signals can be obtained from brain or muscle activity, heart rate and galvanic skin responses. In the RW, they would become visible (e.g., sweating palm, red face) and can therefore, be used for communicating effectively. As users are represented as avatars in VR, it is not possible to obtain this information in a similar fashion as in the RW. Previous research has reviewed how communication between remote users can be enhanced by providing biofeedback: Tan et.al. [16] showed that a visual stress indicator can improve remote collaboration and Lee et.al. [9] revealed that the display of emotional state to the video conferencing partner can foster continuous engagement in the communication.

Previous research has mainly focused on adapting RW human communication into VR. We believe VR has the potential to be an environment where humans can go beyond their RW experience, communicate with enhanced tools

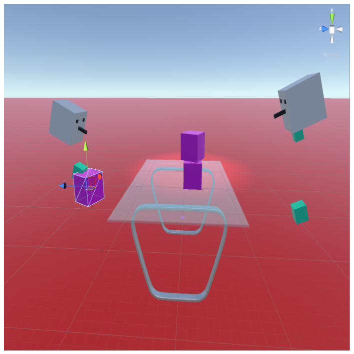

Figure 2: View of virtual scene used in pre-study. Participants were represented with avatars (white cubes with face and green hands) and were able to interact with each other in VR. They had the option to stack pink cubes.

Figure 3: View of RW room used in pre-study. Participants were using the HTC Vive HMD and controllers to navigate in VR [13].

and as a conclusion be more effective collaborators.

Ideation

To narrow our ideas and discuss them with experts from related fields, we conducted a focus group (n=4). Participants were chosen based on their expertise, namely in psychology, human robot interaction (HRI), brain computer interfaces, human computer interaction and VR. The aim of the focus group was twofold: (1) To discuss ideas for enhancing communication tools in VR based on our previously completed literature survey and (2) define possible measurement methods and their applicability for a study in VR. After obtaining participants consent for publication purposes, we conducted a brainstorming session. The session lasted for 60 min and consisted of multiple rounds of divergence and convergence of ideas. It was concluded by asking participants to agree on two promising ideas.

Results

The ideation resulted in a large number of ideas (Fig. 1), two were concluded to be the future research focus:

Eye gaze direction: We believe it would be beneficial for virtual partners, especially in a collaboration scenario, to see each others' gaze direction. In the RW humans derive the intention of their partners' action based on the focus of their eyes and head movements. In VR, this may be aided by casting a laser beam or a pointer on the object that the partner is currently focusing on. Similarly, we believe that it enhances the communication, when partners can get a real-time snapshot of the other persons' field of view. Based on our extensive literature review, we believe that this may aid collaboration scenarios in VR. For example while working on large sized 3D models and prototypes, such as cars and industrial machinery. Grounded on work by Kasahara et.al. [6], we are confident that the human brain is capable of processing these different views. To test this idea we (1) conducted a pre-study and (2) decided to continue our research towards eye tracking in VR.

Visualizing physiological signals: In virtual and mixed reality it is easily feasible to visualize additional information into the existing scene. As such we propose to visualize physiological signals to aid social interactions and enhance existing communication tools. In the RW this information is indirectly visible in some cases (e.g., sweating palm, red face) but virtual and mixed worlds enable us to see this information visualized while communicating, therefore allowing a more immersed remote communication.

Pre-study

To test one of our initial ideas, namely *Eye gaze direction*, we conducted a pre-study (n=30, male=16 and female=14). All participants had no prior experience with VR. The average age was 23 and the majority were students.

Apparatus

Two HTC Vives [13] and their gaming PCs were placed in two separate buildings, such that participants could meet over the internet in a virtual room. The virtual room was 36m² and a table was placed in the middle of the room with stackable cubes. As the focus of the pre-study was to test *Eye gaze direction*, participants were represented as avatars, whereby only head (white cube with eyes and nose) and hand movements (two green cubes) were visible (Fig. 2). Furthermore, the *Eye gaze direction* idea, we implemented as a continuously visible pointer (round red dot) in VR to indicate the gaze point of the avatar. For the purpose of this study, which was to get early user feedback, the gaze point was calculated based on the head tracking data of the head mounted display (HMD). In parallel we have been working on a solution with data from an HMD eye tracker. The following communication tools were made available in VR through the HTC Vive controllers: (1) walking and teleporting for movement, (2) pointing and fetching for hand gestures. All other communication tools were purposely not made available in our study (e.g., audio).

Procedure

Two participants took part in each session. They were separately recruited by the co-located experimenters, therefore it can be assumed that participants did not know each other. They were made aware that they would join an interaction in VR and given a training (approx. 3 min) on the previously mentioned communication tools (see Apparatus). Participants were not given any instructions on their virtual partner or the task (e.g., "please stack cubes"). On average they spent 10min in VR, including the training phase. After the study we asked 5 random participants to take part in a semi-structured interviews and obtained their consent for publication purposes.

Results

The results from the pre-study were obtained from semi structured interviews and observational data by the experimenters. Participants stated that they understood the avatar to be their virtual communication partner due to the gestures. "She was moving things around [...]" (P5). "[...] she is waving at me [...]" (P12). Without additional instructions, all participants eventually started stacking cubes on the table and some were playing catch with the cubes. Participants pointed out how easy they thought it was to interact in an abstract scene. "[...] so much [communication/collaboration] is possible with such a small amount of tools." (P1). However, they also made it clear that additional tools are necessary when difficult situations arose. "[...] she continuously threw over my stacked cubes. It would have been nice to tell her via audio/text to stop."(P3). "[...] sometimes the other person ignored me and stopped communicating with me. I wanted to ask them why they were doing that" (P1). 80% of participants noticed the gaze point (red dot) of the initial *Eye gaze direction* idea, however they only started using it intentionally for collaboration, after they were made aware of its purpose by the experimenter. Participants claimed that it was easier to derive their partners intentions when working with the eye gaze pointer. "[...] we would not grab the same cubes while stacking [...]" (P1).

Discussion and Conclusion

We gathered ideas for enhancing human communication tools in virtual and conducted a pre-study to test one of our ideas, namely *Eye gaze direction*. The pre-study revealed that abstract representations of [amplified] communication tools, such as the red dot for *Eye gaze direction*, are recognized and effectively used in VR. Due to the positive feedback from participants in the pre-study, we are currently enhancing the prototype to include alternative designs for displaying the eye gaze direction in VR (e.g., larger dot, only visible upon action by user). Furthermore, we are continuing the idea to enable sharing of snapshots of the field of view with communication partners and testing the concept of joint manipulation of virtual objects with gaze points. Based on our results, we believe that VR is a feasible test bed for future studies on enhancing human communication tools. Other ideas may include the amplification of (1) gestures, such as multiple limbs and (2) haptic signals, such as transferring heat signals upon touch through an avatar [8]. Finally, we believe that future research should review how communication can be enhanced in VR by [abstract or real] avatar representation.

Our study showed that abstract representations of amplified communication tools in VR achieve noticeable improvements in collaboration settings. In first instance it may seem as if only the virtual human is amplified, however by providing communication tools that are not available in the RW, the RW human experiences these amplifications identically.

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