Towards Augmenting IVR Communication with Physiological Sensing Data

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ABSTRACT

Immersive Virtual Reality (IVR) does not afford social cues for communication, such as sweaty palms to indicate stress, as users can only see an avatar of their collaborator. Prior work has shown that this data is necessary for successful collaboration, which is why we propose to augment IVR communication by (1) real-time capturing of physiological senses and (2) leveraging the unlimited virtual space to display these. We present the results of a focus group (N=7) and a preliminary study (N=32) that investigate how this data may be visualized in a playful interaction and the effects they have on the performances of the collaborators.

KEYWORDS

Virtual and augmented reality; Collaboration; Physiological Sensors; HMD

BACKGROUND

Spoken words are immediately associated with natural communication, however, humans also communicate through physiological signals, such as sweaty palms or a red face. In immersive virtual reality (IVR) with head mounted displays (HMD), these unintentional social cues are currently absent.

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Users are only represented by avatars or real world projections of themselves and consumer devices are limited to tracking hand and head movements.

Prior work has shown that real-time physiological sensing [11]to inform digital communication is beneficial, which is why we propose to augment IVR communication with this type of data. The human body generates a multitude of physiological data, thus different technologies focus on various parts of the body to obtain this data [15]. For example, brain activity is captured with Electroencaphalography (EEG)and heart activity with Electrocardiography (ECG). Additionally, many current trackers also display heart rate (HR). Related work in this area is twofold:

Firstly, it has reviewed the effects of displaying users own data back to them, for example to alter the game according to their level of arousal [13]. Nacket et al. [14] used physiological sensors as input devices, for example by tracking EMG.

Secondly, prior work has shed light on the advantages of displaying physiological sensor data in remote social interactions. Results revealed an increased level of affection towards the avatar that was augmented with visualizations from physiological sensor data [4, 11]. Additionally, applications such as BioShare [3] and HeartChat [7] showed an increased feeling of connectedness towards the collaborators. Similarly, Hassib et al. revealed that there was a higher interest in receiving physiological signals rather than providing them, especially when it was conveying negative emotions [8].

Contrary to prior work where data from physiological sensors could only be shared within a limited space (e.g. mobile phone chat) or solely displayed for once own benefit, IVR offers an unlimited virtual space to communicate this data in a social context to all participants in real-time.

In this pre-liminary work, we focus on augmenting gaming scenarios with physiological signals, whereby both users are based in IVR but remote in the real world. In this context, we want to explore which effects physiological sensor based visualizations from HR have on the performance. We present the results of a focus group (N=7), where we generated ideas for visualizations, followed by a user study (N=32), where we evaluated four visualizations based on real-time HR tracking. Our results show that users prefer visualizations where only one type of data is displayed (e.g. traffic light) and that, in agreement with prior work, they provoke empathy amongst collaborators.

FOCUS GROUP

To understand (1) which tasks could benefit from the additional information provided by physiological signals and (2) how these signals may be visualized in IVR, we conducted a focus group (N=7, between 20-30 years and with prior HMD experience). After a general introduction to physiological sensing, they were asked to brainstorm on each of the goals mentioned above. For the second goal, participants had to sketch out their ideas. The whole session lasted one hour and ended with an open discussion.

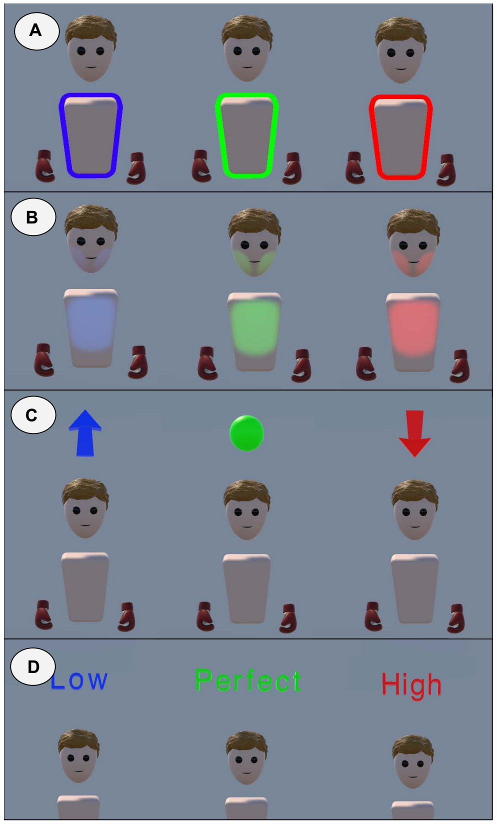
Sidebar 1: Focus Group Results

Summary of Tasks. The first part of the focus group, where participants had to brainstorm tasks that would benefit of physiological sensing, resulted in the following ideas.

Bluff games Participants have to guess if their counterpart is telling the truth with the aid of physiological sensing.
Fitness trainer Trainer can adapt their coaching style and training according to the trainees real-time physiological feedback.
Balance game Both participants have to balance their physiological data within a given level to win the game.
Dating app Partners meet in IVR with visualiazations of their physiological data.
Heart rate heat map
Behavioural Therapy
Adpative (Horror) Game
Trust Game
Fake Heart Beat
Defuce bomb

Summary of Ideas from Sketches. In the second part they had to brainstorm ideas for visualizations and sketch them. Below is a summary of most popular visual ideas.

Plot/Graph
Beating Heart
Text with color/size or states, e.g. calm
Beating heart changing size/color
Heat vision on body parts, e.g. cheeks
Colored arrows
Thermometer-like scale/fills up&changes color



Sidebar 2: Visualizations used for the main study: (A) aura, (B) glow, (C) arrow, (D) text

Take Aways for Main Study

A summary of tasks and sketches that were created during the focus group can be found in sidebar 1.

Tasks. We decided to focus on a trainee-trainer scenario for the main study, as it provoked the most discussion during the brainstorming exercise and the follow-up discussion.

Visualizations. The follow-up discussion highlighted that participants indicated a preference for labels rather than detailed quantitative information, such as a plot. Additionally, they mentioned that dynamic data, in form of a beating heart, would be difficult to interpret. "I really think, to identify the beating heart with the naked eye is hard - you need a while to be able to estimate [...] (P3)." "I am not able to read anything here, only if the person is alive or dead" (P2). Based on the follow-up discussion and the low-fi sketches that were produced during the discussion, we decided to test four traffic-light based visualizations in the main study: (A) Glowing avatar (*glow*), (B) Avatar with an aura (*aura*) (C) Coloured arrows that indicate in which direction the pulse needs to go in order to be balanced (*arrows*) and (D) coloured text (low, perfect, high) (*text*) - see sidebar 2.

Type of Physiological Data. Although not specifically questioned during the focus group, experimenters observed that the heart rate was a prominent topic when discussing how to visualize physiological data. As such, heart rate was chosen as dependent variable for the main study.

MAIN STUDY

We completed a within subjects study (N=32, female=8, Age: Mean=25, SD=3.8) to test the effect of four different physiological-sensing based visualizations on performance in gaming scenarios.

Independent Variables

games: To observe the effect of varying types of interactions and space, four different games were completed, namely boxing, baseball, archery and dodgeball. Each game lasted 5 min.
visualization: Four visualizations were presented, namely *aura*, *glow*, *arrow* and *text* - see sidebar 2.

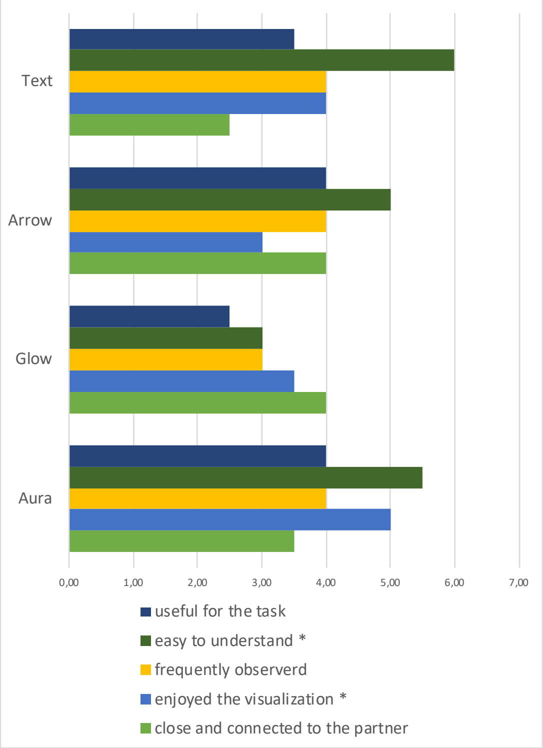
Dependent Variables

We captured participants hear rate (HR) and obtained qualitative data through demographic and post-study questionnaires (7-point Likert scale: 7=strongly agree). The latter questioned "I felt close and connected with my partner", "I enjoyed the visualization", "I frequently observed the visualization", "visualization was easy to understand", and "visualization was useful for the task".

Apparatus

We connected two remote desktops and HTC Vives with Photon Cloud. Each user had to wear a Polar H7 HR tracker that was sending real-time data to a BLE Antenna on the desktop device. The

[1]Note, due to copyright reasons, images of the games can only be retrieved from the original website



Sidebar 3: Summary (Median) of post-study questionnaire (7-point Likert scale: 7=strongly agree).

virtual reality games were created with Unity (https://unity3d.com/) and open source code [5, 12] [1]. Participants were wearing noise-cancelling headphones and they could not communicate verbally.

The aim of the game was to keep the collaborator within a pre-defined target heart rate zone. The zones were visualized with the designs mentioned in sidebar 2. Hence, participants had to adjust the intensity of their own game-play based on the real-time physiological data visualizations of their counterparts. The target heart rate zone was calculated using the Karvonen method [9], who use the resting heart rate, an intensity factor and the theoretical maximum heart rate in their formula. The latter was predicted using Tanaka's formular [17], which uses participants age. The intensity factor was derived from prior work that suggest 0.59-0.76 for aerobic exercises [2].

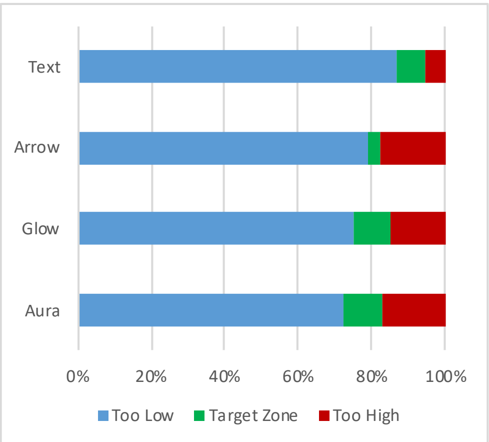
Procedure

Participants were recruited in pairs. After an introduction to the study and the hardware, participants were asked to sign a consent form. Subsequently, they put the HR tracker on - which they could either do in-front of the experimenter or in separate rooms. Next, the experimenter obtained the resting heart rate over a 2 min time frame, which was followed by the completion of a demographics questionnaire. Before they entered IVR, participants were randomly appointed as trainer/trainee and introduced to the aim of the games and the visualizations by using print-outs and drawings. Then they put the HMDs on and were encouraged to speak out loud during game play. Each pair took part in all [counterbalanced] games, they completed individual follow-up questionnaires at the end of the study.

RESULTS & DISCUSSION

The data was not normally distributed and two participants data had to be excluded due to missing captures. A Friedman test showed a significant difference for "enjoyment of visualization" ($x^2 = 10.07, p = 0.01$)and "easy to understand" ($x^2 = 24.71, p = 0.01$) - see sidebar 3 for more details. This was also reflected in the qualitative data captured during game play. A thematic analysis on this data revealed that *aura* was the overall favourite, as 12 participants referred to it as "intuitive and always visible". This was followed by *text* and *arrow*, as 13 participants pointed out that it was "easy to understand". *Glow's* unpopularity was pointed out by 17 users. They referred to it as their "least favourite visualization" and "hardest to understand".

Another emerging theme was that participants put themselves in deadlock situations, whereby the trainer would try to decrease the effort in order to lower the trainees increasingly unbalanced HR but the trainee would try to increase their own effort, as the trainers HR was decreasing below the desired zone. "I don't know how to bring him up! He is the personification of being calm." (A7) Enabling oral communication between the players may reduce this phenomenon, however, this may



Sidebar 4: Overview of time spent in each hear rate zone over the total amount of game play.

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not be necessary as some participants revealed a learning effect. "She's throwing too fast and is red. But I think she's trying to increase my movement." (B14).

Adding the HR data seems to provoke empathy among the players rather than the natural urge to win. "I tried to make him sweat even more until I remembered that the goal was to keep him green." (A6) B8 was concerned but then changed their opinion, for example "It might be good when he moves much and has a low heart rate [...] indicates a healthy and athletic body.

A review of time spent in each HR zone highlights that *arrow* provoked the least success amongst participants and that *aura*, whilst achieving a similar time spent in a balanced target zone as *glow* and *text*, was also the condition where participants spent the most time in a high HR zone. Although our qualitative data showed that *arrow* was a popular choice, the quantitative data contradicts participants feedback. This may be explained by the fact that *arrow* was the only condition that provided 2 pieces of information, state and direction, whereas for the other ones the direction was inferred. The latter seems to perform better in the context of balancing heart rates for game purposes. We also see a similarity here with the real world, where humans see physiological signals (e.g. red face) and decide how to act upon it, which may have influenced how users interpreted the visualizations in our study.

CONCLUSION & FUTURE WORK

We present the results of a focus group (N=7) and a follow-up study (N=32) to investigate how physiological sensing based visualizations may be included in remote social interactions for IVR. In this preliminary study, we focused on playful interactions and presented visualizations of the HR to both participants. In agreement with prior work, we found that it provoked empathy with the collaborator [4, 11]. Additionally, we found that displaying more than one piece of information in the visualization seems to be unfavourable during game play.

Future work may explore whether one-directional display of visualizations, for example only for the trainer rather than the trainee, have an affect on the performance of the trainee over time. This approach would also avoid *deadlock situations*, which were common in our study. In our context both collaborators were in IVR, however, there are also collaborative situations were one person is in the real world and the other in the virtual world, such as in military training [16]. In this scenario, the co-located person in the real world may be able to see the IVR user's physiological responses (e.g. sweat, heated face), whereas the immersed IVR user does not see any of these signals. To overcome this imbalance, it may be beneficial to visualize the co-located real-world collaborators physiological data to the IVR user. For example, to improve performance and support communication. Based on prior work [6], displaying physiological data in this context may also affect social presence, which is a subjective measure of how real the interaction with another person in IVR is face to face [1, 10].

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