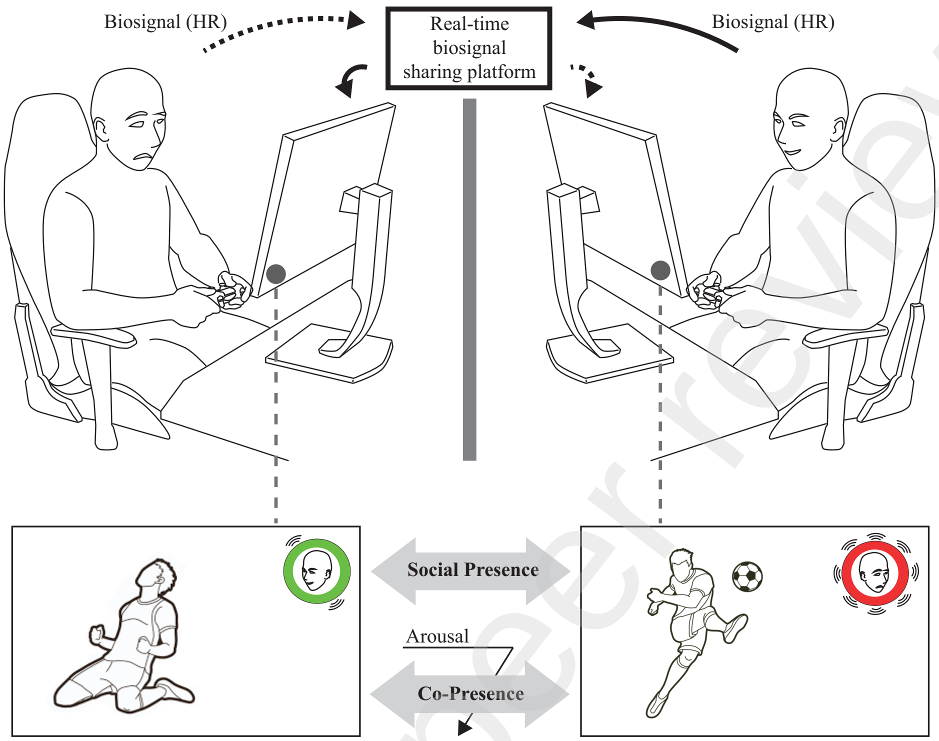

Graphical Abstract

Augmenting the Sense of Social Presence in Online Video Games Through the Sharing of Biosignals

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Highlights

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- The authors developed a real-time biosignal sharing platform to share biosignals between communication partners in online interactions. In this context, biosignals can be used to convey the physical and affect states between parties in online computer-mediated interactions.
- With the developed platform the authors investigated the augmentation of the sense of social presence between persons playing online video games. Questionnaire responses from 20 participants showed that displaying the opponent's face, a visual representation of their biosignal (heart rate), and a combination of the two improved the sense of social presence. The combination of the opponent's face and biosignal had the best performance, closest to the baseline condition in a co-located setting.
- Co-presence did not show a similar trend to social presence. However, when the participants were grouped based on emotional arousal the high-arousal group showed similar results to that of social presence, and the low-arousal group showed no significant differences between the experimental conditions. These results suggest emotional arousal as an interaction factor.

Augmenting the Sense of Social Presence in Online Video Games Through the Sharing of Biosignals

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Abstract

This study outlines the development of a platform that enables real-time biosignal sharing between gaming partners regardless of the game of choice. The platform's ability to augment social presence in an online environment was tested in a pilot study that included 20 participants. The biosignal was collected with the use of a wrist-worn heart rate monitor. Significant improvements were found in the sense of social presence when providing the players with video information or bio-information about their gaming partner. When both the bio and video information were provided simultaneously, the sense of social presence was closest to the baseline condition in which the players were co-located in the same physical environment. Similar trends were not observed in co-presence in the participants of this study. However, grouping the participants' scores by emotional arousal level showed a similar trend in the high-arousal group.

Keywords: Digital games, Social presence, Biosignals

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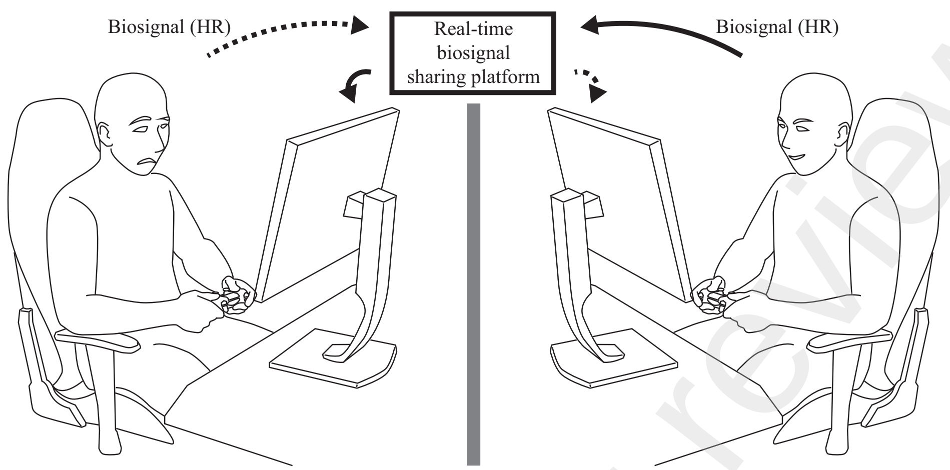

Figure 1: The concept of a real-time biosignal sharing platform for augmenting the sense of social presence in online gaming.

1. Introduction

Computer-mediated communication (CMC) is a continuously evolving technology that can include everything from simple text messages to virtual reality environments. As this technology grows it has been a growing topic of interest on how it brings people closer together. This sense of bringing people closer is often more technically defined as a sense of social presence or co-presence. Social presence refers to the degree to which a user feels present with another and their ability to interpret their emotional state and thoughts (Biocca; 1997 [1]). Co-presence is similar to social presence but focuses more on a sense of mutual presence between two users. One user is able to feel that someone else is present, and also understand that their own actions are visible to that someone (Nowak and Biocca, 2003 [2]). To summarize, social presence is the feeling that you can understand someone's intentions and co-presence is the feeling that you are in the presence of someone.

Video games as an interactive form of media provide ample opportunity for social interaction (Kort et al., 2007 [3]). In particular, multiplayer video games incorporate competition and/or cooperation into their core mechanics which incurs a social interaction between the players within and outside these contexts. Social presence is associated in the literature with increased enjoyment and engagement (Gajadhar et al., 2008; Cairns et al., 2013 [4, 5]). However, disregarding the social context of the specific games and prior interactions between the gaming partners, these games can be expected to benefit greatly from technology that can augment the sense of social presence in gameplay.

The magnitude by which a medium can afford social presence is believed to be proportional to the number of human senses for which the medium provides stimulation, and the quality of the stimuli (Lombard and Ditton, 1997[6]). However, in context-heavy interactions, even the most primitive forms of computer-mediated communications can elicit high levels of social presence (Bracken et al., 2005 [7]). Modern games can afford a high number of channels and fidelity for visual and auditory stimuli, however, these alone do not necessarily provide a higher level of social presence. The type and content of stimuli, especially those pertaining to the gaming partner or opponent should be investigated (Gajadhar et al., 2008; Cairns et al., 2013 [4, 5]).

We hypothesize that providing a gamer with visual, auditory, or tactile information that directly correlates with a gaming partner's physiological or psychological state will facilitate their perception of social presence in online gaming, regardless of the game's context, even without a history of prior interaction between the gaming partners. In this work, we set to investigate this hypothesis with empirical methods. We developed a platform for real-time sharing of biosignals between gaming partners playing an online video game (Figure 1), and we use this platform to conduct paired experiments in which we compare playing the same game in co-located settings and in remote settings with and without biosignal sharing. In this paper, we present the developed platform, the conducted experiments with 20 participants, the obtained results of a social presence survey, and discussions on the obtained results.

The objectives of this study are to (i) investigate methods of augmenting the sense of social presence in online games through the sharing of biosignals, (ii) investigate the presentation of different information of the communication partner on the perceived sense of social presence and co-presence.

2. Related Work

In the formulation of 'Networked Minds' Biocca and colleagues (Biocca et al., 2001,2002[8, 9]) argue that sensory awareness of bodily representations, psychological involvement with another intelligence, and behavioral engagement through interaction and synchronization are dimensions that characterize the social presence of a person in both mediated and unmediated settings. This formulation sustains that sensory information that conveys the physiological and psychological state of a communication partner can augment the social presence in computer-mediated communication.

Several studies have investigated methods to augment social presence with additional sensory information and stimuli. The use of synchronous web videoconferencing has been shown to lead a direct increase in social presence (Giesbers et al., 2009 [10]). Adding gestures in conversation with an interactive character also leads to an increase in social presence (Yamano et al., 2022 [11]). Other researchers successfully utilized mediated social touch with tactile stimulation to enhance social connectedness, sense of social presence, and co-presence (Hattum et al., 2022; Longa et al., 2022 [12, 13]).

Biosignals are temporal or spatial signals that include information about the physiological or psychological state of a bio-organism. Examples of biosignals include heartbeat, muscle activity, and brain wave signals (Escabi, 2012 [14]). In human-computer interaction (HCI), the information obtained from the biosignals can be used to interpret the physical, affective, and cognitive states of the user (Schultz et al., 2017 [15]). Various studies explored augmenting online interactions with heart rate and other biosignals. HeartChat is an application that was developed to improve context awareness and emotional expressiveness while texting (Hassib et al., 2017 [16]). The application alters the color of the chat bubble to reflect the heart rate of the sender at the time the message was sent. The study showed that sharing this biosignal increased empathy, curiosity, and awareness between the communicating parties. Heartefacts is another application that creates highlights of a video based on changes in the heart rate of the user while watching it (Vermeulen et al., 2016 [17]). The created highlight video was compiled of the clips that elicited a strong emotional and physiological response. This was later compared to the subjective highlights surveyed by the participants. They claimed one use of this program would be to help share these key moments with others to make it a more engaging experience. iFeel_IM! is an affective haptic platform that aims to influence a user's emotional state (Tsetserukou and Neviarouskaya, 2010 [18]). The platform consists of users wearing a variety of affective haptic devices while playing the online game, Second Life. From a preliminary user study, participants reported the platform evoking different emotions when the user could feel the heartbeat or hug from their online partner.

Research regarding biosignals and video games focuses on using this information as a metric to evaluate the interaction. Porter et al. used heart rate and blood pressure as a metric to measure the effects of video games on stress (Porter and Goolkasian, 2019 [19]). Similarly, Hong et al. measured the heart rate variability of participants to look for a link to addictive gaming habits (Hong et al., 2018 [20]). In this work, we aim to explore how biosignals can be used to augment the gaming experience. One of our earlier works suggested that a visual representation of a player's own biosignal, in the form of heart rate, could be used to improve their performance while playing a game (Kennard et al., 2020 [21]). The mentioned study used a mixed reality system to augment a physical game of curling.

In this work, we hypothesize that in the case of computer-mediated interaction, a biosignal from the communication partner that is presented in a comprehensible manner will facilitate the perception of their social presence. Instead of referencing one's own biosignals this work investigates using the biosignals of the gaming partner, building on the formulation of 'Networked Minds' (Biocca et al., 2001,2002 [8, 9]), in order to augment their mutual sense of social presence during gameplay.

3. Methodology

3.1. Biosignal Sharing Platform

We developed a platform that enables real-time biosignal sharing between gaming partners in online video games regardless of the game of choice. In this work, we elected to use Heart Rate (HR) as the biosignal to be shared between the players. The platform can measure the HR of each player, upload its value to a real-time database, read the HR value of the partner from the same database, create an animation overlay based on the partner's HR value, and display the animation on top of the gameplay screen.

3.2. Information Overlay

Different types of information overlays were developed with the biosignal sharing platform for the purposes of the experiments in this work. These are as follows:

1. Video information Overlay (ViO): The face video of each player is transmitted to the partner and displayed in real-time as an overlay on top of their gameplay screen.

Figure 2: The 3 different types of information overlay: Video information Overlay (ViO), Bio-information Overlay (BiO), Bio- and Video information Overlay (BViO).

2. Bio-information Overlay (BiO): The HR of each player is transmitted to the partner and displayed in real-time as an overlay on top of their gameplay screen.
3. Bio- and Video information Overlay (BViO): Both the HR and the face video of each player are transmitted to the partner and displayed in real-time as an overlay on top of their gameplay screen.

The different types of information overlay are shown in Figure 2. The ViO is shown as a circle containing the partner's face in the top-right corner of the gameplay screen. The BiO replaces the face video with a generic avatar image and adds a pulsating ring around it that conveys the HR information. The BViO combines the face video with the pulsating ring conveying the HR information. The color and pulsation intensity of the HR animation overlay in BiO and BViO are set based on the current HR and resting HR values of each player. The color is green for HR values below the resting HR +5 (in the range of 5 bpm), Orange for values between resting HR and resting HR +15 (in the range of 15 bpm), and red for any values above. The pulsation was set to slow when the color was green, moderate when the color was orange, and fast when the color was red. The animation parameters were determined experimentally by the authors to convey the state of nervousness/excitement of each player to their partner. The animation is illustrated in Figure 3.

3.3. System Overview

We implemented the Biosignal Sharing Platform for two players playing an online video game. The implementation consists of a gaming computer for each player that is connected to a heart rate sensor and running a suite of software. The software includes the game software, custom software to

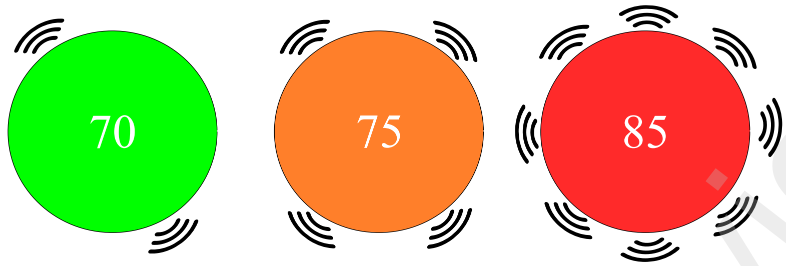

Figure 3: Heart rate animation states assuming a resting HR of 70 bpm.

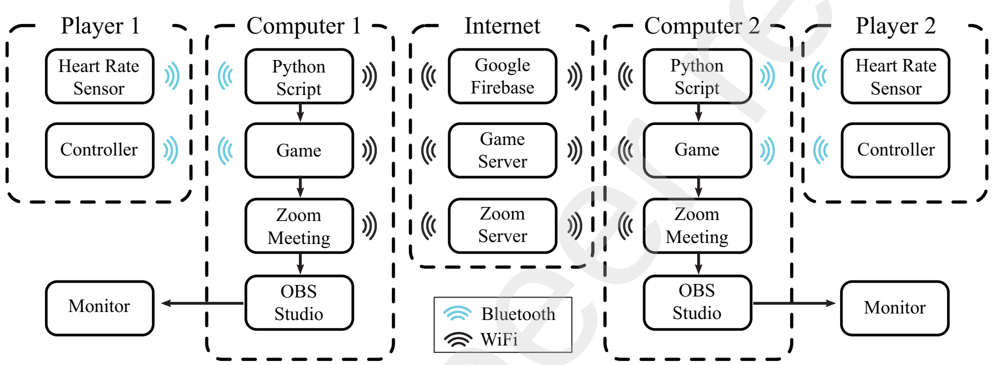

Figure 4: System overview of the biosignal sharing platform.

communicate with an online real-time database, video conferencing software, custom software to create the overlay and the HR animation, and broadcasting software to merge the overlay with the gameplay on one screen. The workflow of this system is as follows: The computer on each side collects the HR data from the HR sensor and uploads its value to a real-time database. At the same time, it collects the real-time HR values of the partner and creates the HR animation. The broadcasting software is then used to collect the partner's face video and/or the HR animation and display them as an overlay on top of the gameplay screen of the player. A block diagram of this system is shown in Figure 4.

3.3.1. Hardware and Software

The following hardware and software were used to implement the Biosignal Sharing Platform: a gaming computer (Alienware m17 R4, Intel Core i7-10870H CPU @ 2.20 GHz, 32 GB RAM, Alienware, US), heart rate sensor (Garmin Instinct Esports Edition, Garmin, US. and Polar verity Sense, Polar Electro Oy, Finland), desk, monitor (GigaCrysta EX-LDGC251UTB, IO-

DATA, Japan), headphones (ASTRO Gaming A10-PSGB, Logitech, Switzerland), game controller (Xbox Wireless Controller, Microsoft, US), web camera (Logicool HD Pro Webcam C920, Logitech, Switzerland), gaming chair (Striker EX, Okamura, Japan) with posture sensor (LifeChair, Lifeform AI, Australia) (Ishac and Suzuki, 2016; Bourahmoune et al., 2022 [22, 23]), eye tracker (Tobii Pro Nano, Tobii, Sweden), and thermal imaging camera (InfReC Thermo FLEX F50A-ONL, Nippon Avionics Co. Ltd., Japan). The posture sensor, eye tracker, and thermal imaging camera were used to record additional data for further analysis at a later stage in this research project.

We used OBS (Open Broadcaster Software) Studio to merge the gameplay and the overlay, and Zoom for video conferencing between the players (Zoom Video Communications, Inc., US). For collecting HR data we used either Garmin Instinct Esports Edition with STR3AMUP! (Garmin, US), or Polar verity Sense with a custom-made smartphone app to upload the HR data to the real-time database. We used the Firebase Realtime Database (Google LLC, US) for online real-time communication of the HR values. We created custom software using Python to interact with Firebase and create the HR animation.

3.3.2. Game Choice

The main objective of this research is to investigate methods of augmenting the sense of social presence in online video games through the sharing of biosignals. Therefore, we elected to use a game that does not influence the sense of social presence by itself, in order to measure the pure effect of the information overlay displayed on top of the gameplay screen. We searched for a game under the following criteria: i. does not contain social interactions between players as an in-game mechanic, ii. does not elicit a sense of spatial presence such as in first-person or third-person games, and iii. does not rely on text or voice communication as an in-game mechanic. In addition to the previous criteria, we also considered the game to be familiar to casual gamers so as to not require a long learning time. Based on these criteria we chose the games Pro Evolution Soccer (PES) (Konami Digital Entertainment, Japan), and FIFA22 (Electronic Arts Inc., US) for the experiments.

3.4. Experimental Setup

3.4.1. Participants

Participants of the experiments were recruited from the local municipality using a mediating recruitment company. The recruitment criteria were

Figure 5: Experimental setup for the remote (NO, ViO, BiO, BViO) conditions.

Figure 6: Experimental setup for the co-located (BL) condition.

as follows: i) age range from 20s to 30s, ii) prior or current video gaming experience, iii) playing video games once or more per week, iv) being able to use a standard, unmodified gaming controller, v) not at risk of epileptic seizures due to game graphics or eye tracker infrared light. We recruited 20 participants satisfying the mentioned criteria for the experiments.

3.4.2. Experimental Conditions

Two identical experimental sites were created and located in different buildings at the University of Tsukuba. Each environment started with a "Gaming Tent" that isolated the player from the experimenters. The experimental setup is shown in Figure 5. The participants were divided into two groups of 10 participants, and each group attended the experiments from one of the two sites. All the participants attended 5 experimental conditions: the three overlay conditions mentioned earlier: Bio, Vio, BViO, and two additional conditions which are a No Overlay (NO) condition, and a BaseLine condition (BL). The NO condition is identical to the other overlay conditions but without any overlay. The BL condition involved the two participants playing the game in a co-located setting within the visual and auditory distance of one another, Figure 6. The participants were randomized to 1) perform each condition exactly once, 2) never play the same opponent, and 3) perform the baseline condition last. Since some experimental conditions involved visual information, randomization was done to make sure that each participant played a "new opponent" to exclude the factor of familiarity with the partner from previous interactions. Additionally, a monetary reward was offered to all participants, and the reward was doubled for the winner of the match to motivate the participants and create a more dynamic and competitive environment.

3.4.3. Experimental Procedures

All the experimental procedures were approved by the University of Tsukuba internal review board (2021R521). Informed consent was obtained from each participant prior to each experimental condition.

The procedures for each of the experimental conditions were as follows:

- Welcome the participant, explain the experimental procedures, and obtain informed consent.
- Attach the heart rate sensor and watch a relaxing river scene video for 5 minutes. During this video, the resting HR is set by the experimenter.

- Collect a saliva sample after the relaxing video is finished.
- Move to the tent, take thermal images of the face and hands, and calibrate the eye tracker.
- Launch the game lobby and set the overlay condition.
- Play the match
- Take thermal images of the face and hands, move out of the tent
- Collect a second saliva sample after the match
- Answer the social presence survey
- Receive the reward, leave the experiment site

The saliva samples and thermal images were recorded for later investigation of the bio-chemistry-related factors in this research project, and they extend beyond the scope of this paper. The relaxing video at the beginning of the experiment was added to measure the resting HR of the participant and to ensure a relaxed state when collecting the first saliva sample. The overlay, or lack thereof, was set by the experimenter. The participant was only informed by the general outline of the experiment, and could only experience the overlay for each experimental condition at the time of the match. When selecting teams for the match, participants were instructed to choose a team with a star rating of 4 or more. Since the star rating is a measure of the overall strength of a team, this was to ensure there was not a large advantage for one player over the other regarding team selection. An example of two participants competing during the BViO condition is shown in Figure 7.

3.5. Survey

A survey was used to investigate the social presence and co-presence experienced by the participants under different experimental conditions. The survey items were adapted from those used in related studies (Nowak and Biocca, 2003; Bailenson et al., 2003 [24, 25]). In addition to the questions regarding social presence and co-presence, there were also questions relating to the overlay method for each task. The questionnaire is shown in Table 3.5.

Social Presence Questions
I perceived that I am in the presence of the opponent player in the room with me.
I felt that the opponent player was watching me and is aware of my presence.
The thought that the opponent player was not a real person crosses my mind often.
The opponent player appears to be sentient, conscious, and alive to me.
I perceive the opponent player as being only a computerized image, not as a real person.
I perceive the opponent player as being only a computerized image, not as a real person.
Co-Presence Questions
The opponent player was intensely involved in the match.
The opponent player seemed to find the match stimulating.
The opponent player communicated coldness rather than warmth.
The opponent player seemed detached during the match.
The opponent player was interested in the match.
The opponent player makes the match seem intimate.
The opponent player created a sense of distance between us.
The opponent player created a sense of closeness between us.
The opponent player acted bored by the match.
The opponent player showed enthusiasm while playing.
Additional Questions (only when applicable)
How often did you look at your opponent's face/vitals? (1 Never - 5 Always)
When did you look at your opponent's camera/vitals? (Multiple choice)
Was the camera/vitals distracting when playing: (1 Not at all - 5 Very distracting)
When your opponent's HR was GREEN, they seemed: (1 Relaxed - 5 Excited)
When your opponent's HR was ORANGE, they seemed: (1 Relaxed - 5 Excited)
When your opponent's HR was RED, they seemed: (1 Relaxed - 5 Excited)

Figure 7: Two players screens during the BViO condition

4. Results

4.1. Overlay Perception

The results from the surveys were compiled and analyzed. First, we will present the results regarding the players' perception of the information overlay system. The participants were first asked how often they looked at the overlay on a scale of 1 to 5 with 1 being "never" and 5 being "always". BViO ranked highest (3.75±0.7) followed by ViO (3±0.9), and then BiO (2.7±1.2), as shown in Figure 8a).

Next, the participants were asked if they felt the information overlay was distracting. Again this used a scale of 1 to 5 with 1 being "not at all" and 5 being "very distracting". The ViO ranked highest (2.8±1.2) followed by BViO (2.75±1.4) and then BiO (2.1±1.2), as shown in Figure 8b). There was no significant difference between the conditions. The participants were also asked at what time during the game did they check the information overlay. The options were "never", "when the HR indicator color changed" (only applicable for BiO and BViO conditions), "after a shot or goal", "after a penalty", "while on offense", "while on defense", or "other". Multiple options were allowed to be selected and the answers for the ViO, BiO, and BViO conditions were averaged and shown in Figure 9. Most participants reported checking the overlay after a shot on goal and when the Overlay color changed in BiO and BViO.

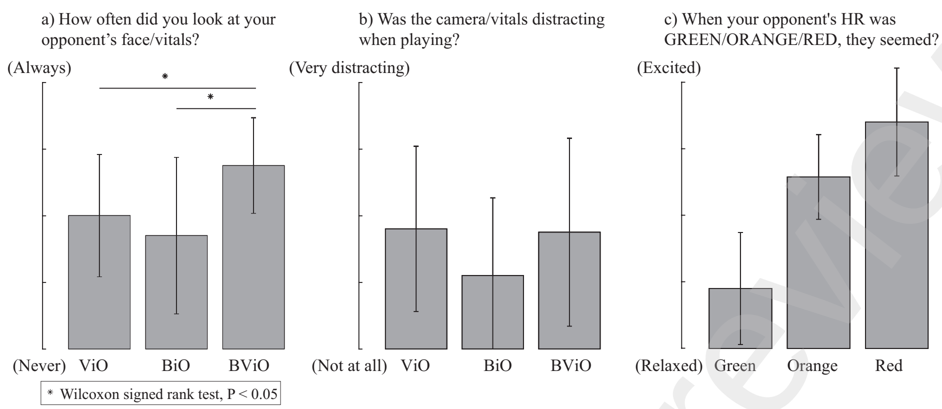

Figure 8: Responses to questionnaire items in the additional questions segment. a) How often did you look at your opponent's face/vitals? b) Was the camera/vitals distracting when playing? c) When your opponent's HR was GREEN/ORANGE/RED, they seemed? (ViO: Video information Overlay, BiO: Bio- information Overlay, BViO: Bio- and Video information Overlay).

Two additional questions were asked for only a specific condition. The first question was asked only for the BViO condition about which part of the overlay the user noticed the most; the heart rate (25%), video (45%), both (20%), or neither (10%). The second question was specific to the BiO and BViO conditions. The participants were asked to rate their perception of their opponent's mood based on the color of the heart rate overlay. They were ranked on a scale of 1 to 5 with 1 being "relaxed" and 5 being "excited". The results were averaged for both conditions and presented in Figure 8c).

4.2. Eye-Gaze

We analyzed eye gaze data from the experiments and calculated how often the participants looked at the overlay region compared to the total data points of the gameplay session. The calculated indices were: a) number of fixations on the overlay, b) total duration of fixations on the overlay (msec), and c) the percentage of the duration of fixations on the overlay (%), as shown in Figure 10. All these variables confirmed the trend reported by the participants in 9.a). The number of fixations, duration of fixations, and percentage of the duration of fixations on overlay were highest in the BViO condition, second in the ViO condition, and third in the BiO condition. Further, the BViO condition was significantly different from the BL and NO conditions.

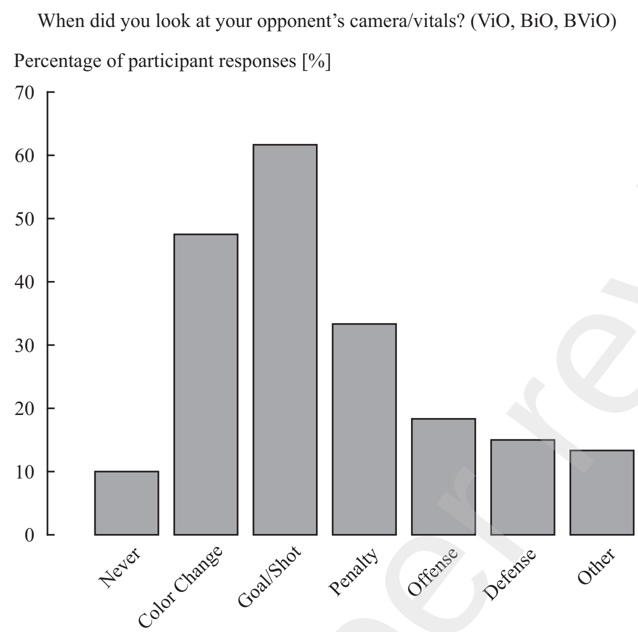

Figure 9: Participant responses to: When did you look at your opponent's camera/vitals?

4.3. Social Presence and Co-Presence

The social presence and co-presence scores were calculated from the corresponding questionnaire items. The results are shown in Figure 11. Statistically significant differences were tested using analysis of variance (ANOVA). The results of the social presence scores showed differences between ViO and BL ($p<0.01$), ViO and NO ($p<0.01$), BiO and BL ($p<0.01$), BViO and BL ($p<0.05$), and BViO and NO ($p<0.01$). In the co-presence scores differences were not found between the overlays and the no overlay condition. Differences between BL and NO are implicit in the above results thus they were omitted here to reduce clutter. These results showed that the overlays that included the opponent's face improved the social presence scores compared to the no overlay conditions, and the BViO was the closest to the baseline condition. This is consistent with the hypotheses of this work. However, the bio information overlay was not effective on its own, and only produced the intended effect when combined with the partner's face in the BViO condition. The co-presence scores, counter to the authors' hypothesis were not influenced by the overlay addition compared to the no overlay condition.

To investigate these results, we further hypothesized that the co-presence

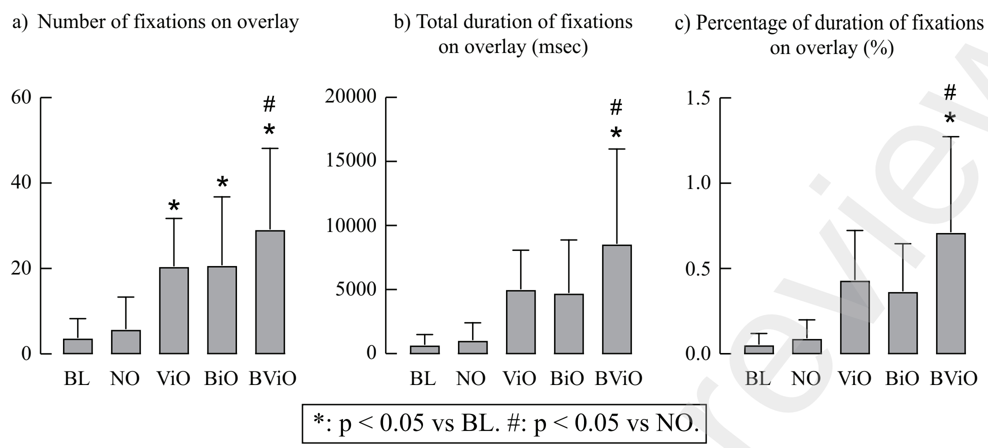

Figure 10: Eye gaze during the experiments: a) number of fixations on overlay, b) Total duration of fixations on overlay (msec), c) Percentage of duration of fixations on overlay (%). (BL: BaseLine, NO: No Overlay, ViO: Video information Overlay, BiO: Bio- information Overlay, BViO: Bio- and Video information Overlay).

scores could be influenced by another factor: emotional arousal. Based on the circumplex model of affect (Russell, 1980 [26]), we grouped the participants based on their arousal level during the matches. We calculated the arousal scores for each participant from video segments during the gameplay using facial expression analysis software (FaceReader 9, Noldus Information Technology, Netherlands). The software automatically recognized facial expressions and analyzed the level of arousal and valence of emotions from the videos. Arousal indicates how a person is activated by an event. For example, a low level of arousal can be classified as calm, and a high level of arousal can be classified as excited. Valence indicates if a person feels pleasant or unpleasant by an event. For example, a low level of valence can be classified as sad, and a high level of valence can be classified as happy (Barrett and Russell, 1999 [27]). In this study, we focused on arousal to figure out the group differences depending on how actively they were engaged in the matches with their opponents.

We selected two videos and 10-minute windows from each participant for the analysis to match the same amount of gameplay between participants. Considering that each participant experienced at least two matches and at most four matches except in the baseline conditions, we selected videos by two criteria: 1) excluding baseline conditions, and 2) earliest and latest matches of each participant. Considering that the shortest duration of gameplay

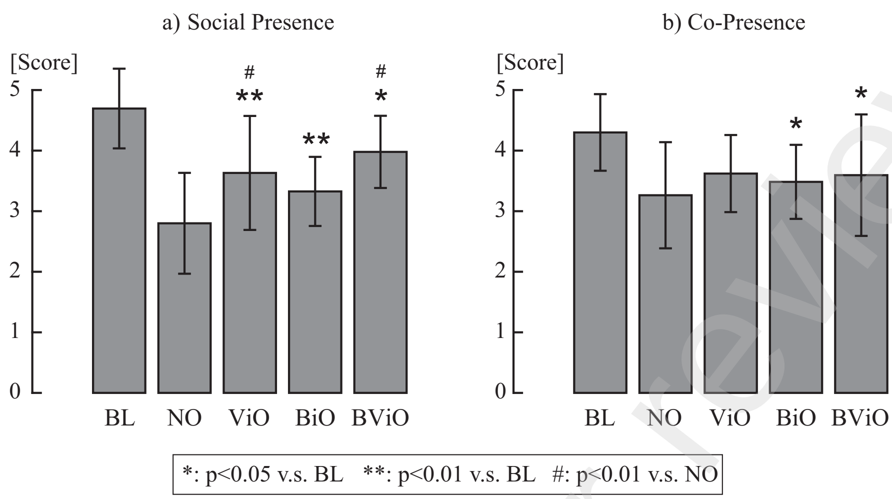

Figure 11: Calculated a) Social Presence and b) Co-Presence scores for each of the experimental conditions. (BL: BaseLine, NO: No Overlay, ViO: Video information Overlay, BiO: Bio- information Overlay, BViO: Bio- and Video information Overlay).

was around 10 minutes and participants showed more emotional responses during the second half of the matches, we selected 10-minute windows before the end of the game. Then the participants were grouped into High Arousal and Low Arousal groups using the median, and the co-presence scores were then plotted for each group, as shown in Figure 12.

The results showed that the Low Arousal group had similar scores for all the experimental conditions, while the High Arousal group scores showed a similar trend to that of the social presence. BViO and ViO were different from NO, and BiO was different from BL. These results imply that the participants' engagement level, which was indicated by emotional arousal in the matches, influenced the perceived sense of co-presence.

5. Discussions

The trend observed in the social presence scores, Figure 11, and the co-presence scores of the high arousal group, Figure 12, is as follows: BViO produced responses closest to the baseline, and furthest from no overlay, followed by ViO, and then BiO. This trend is supported by the frequency by which the participants looked at the overlay as shown in the participant responses (Figure 8), the calculated eye gaze indices (Figure 10), and the eye tracker heat map (Figure 13). Participants paid the most attention to the

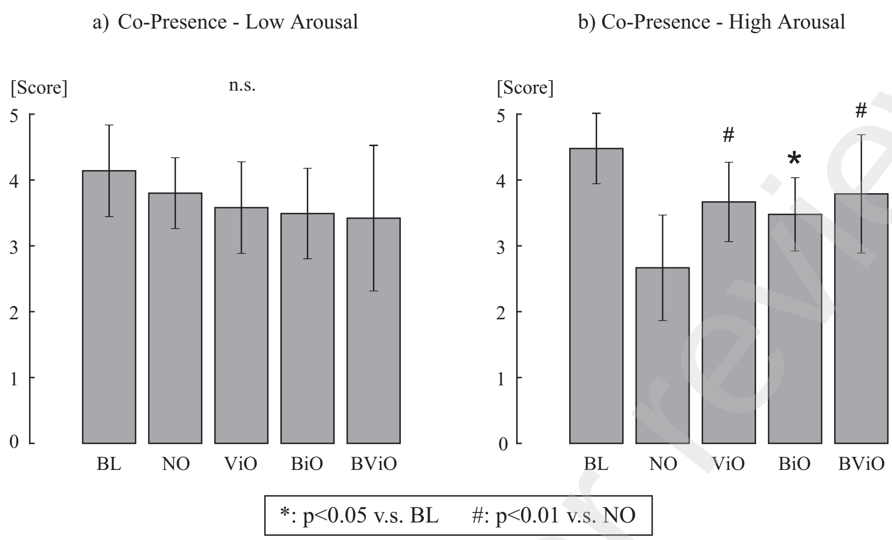

Figure 12: Calculated Co-Presence scores for a) Low Arousal Group and b) High Arousal Group for each of the experimental conditions. (BL: BaseLine, NO: No Overlay, ViO: Video information Overlay, BiO: Bio- information Overlay, BViO: Bio- and Video information Overlay).

BViO condition. Increased attention to the partners' visual and bio information can be linked directly to an improved sense of their social presence [8, 9].

The content of the overlay does not contain an indication of the mutual presence of the gaming partners in a common real or virtual space, which explains the diminished trend in the co-presence scores, Figure 11. The high arousal group revived the observed trend, Figure 12, which indicates that interaction with the partner in an excited or tense state might also improve the sense of co-presence. Further experiments with a higher number of participants and more controlled settings will be needed to investigate this interaction effect further.

An interesting observation is that BiO by itself did not produce the desired effect, but BViO marginally outperformed ViO in the social presence scores. A person's face contains the most information about their psychological or physiological state and is the natural means of communication between humans. The participants of this research were asked about their perception of the gaming partner with the different colors of the bio-information overlay: Green, Orange, and Red. Their responses showed that they perceived the

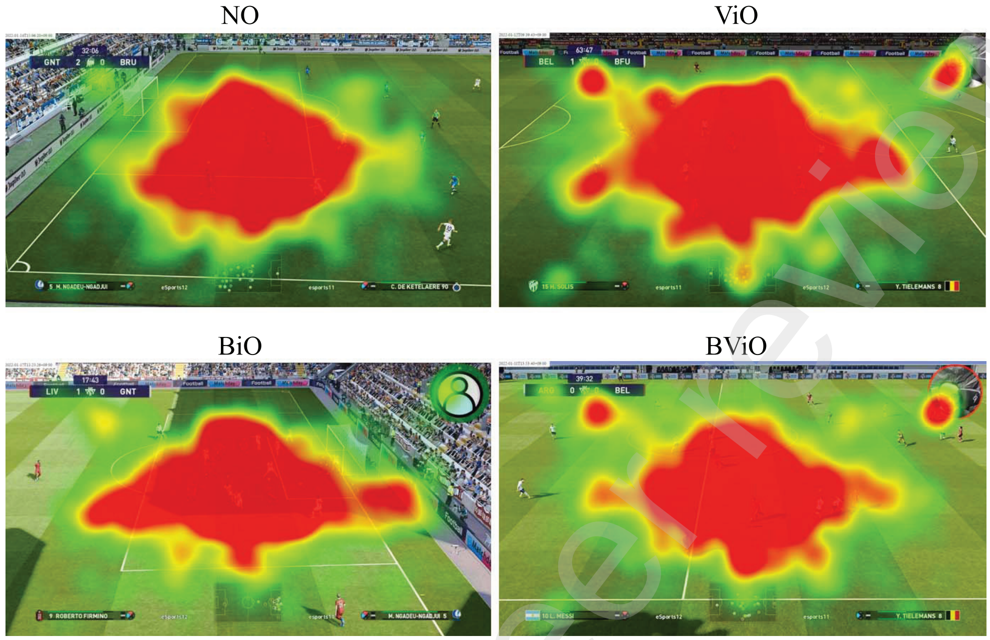

Figure 13: Eye tracker heat map. (NO: No Overlay, ViO: Video information Overlay, BiO: Bio- information Overlay, BViO: Bio- and Video information Overlay).

intended design of the HR overlay: Green for a relaxed state, Orange for a slightly excited state, and Red for an excited state, Figure 8.c. A longitudinal study can shed light on whether the presentation of the biosignal of a communication partner can, by itself, improve the sense of social presence as the ability to interpret the partner's state increases with increased familiarity with this information.

The authors were interested in whether the information overlay on top of the gaming screen was distracting to the gaming partners during gameplay. The participants responded that the overlay was slightly distracting in ViO and BViO, and less distracting in BiO, Figure 8.b. As to when the participants looked at the overlay, the participants answered that a goal or shot was the highest factor, the color change in BiO and BViO was the second highest factor, and other game events were lesser factors, Figure 9. The authors concluded from internal testing that the player looks at the overlay right after a salient game event. In future works, we plan to investigate this assumption from detailed coding of the gameplay and eye gaze data.

This study only explored the presentation of heart rate in visual form with the biosignal sharing platform. Exploring the sharing of various biosignals with alternate modalities, such as a haptic display, can further clarify the perception of the communication partner's physiological and psychological state, and how it influences the perceived sense of social presence. Although this study focused on the sharing of biosignals while playing a video game, it suggests that this platform can be applied to various types of CMC for real-time biosignal sharing to increase Networked Minds between communicators.

6. Conclusions

The developed biosignal sharing platform was able to improve the players' sense of social presence when playing an online game with a partner they had no prior history of interaction with. There was a similar improvement in the sense of co-presence, but only for participants that demonstrated a high level of arousal during the experiment. Further verified by the eye tracking data, the players interacted with the bio- and video information overlay the most and the sense of social presence was the closest to the baseline, co-located, condition among the tested settings.

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