Inter-Brain Connectivity: Comparisons between Real and Virtual Environments using Hyperscanning

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Abstract

Inter-brain connectivity between pairs of people was explored during a finger tracking task in the real-world and in Virtual Reality (VR). This was facilitated by the use of a dual EEG set-up that allowed us to use hyperscanning to simultaneously record the neural activity of both participants. We found that similar levels of inter-brain synchrony can be elicited in the real-world and VR for the same task. This is the first time that hyperscanning has been used to compare brain activity for the same task performed in real and virtual environments.

Keywords: Collaborative Virtual Environments, EEG, Brain-Computer Interface, Hyperscanning, Social Interactions

Index Terms: • **Human-centered computing~Collaborative and social computing devices** • Human-centered computing~Virtual reality

1 Introduction

This paper reports preliminary findings from a pilot study carried out to explore inter-brain connectivity between two users in real-world and VR environments. The aim is to explore whether VR is able to elicit similar levels of inter-brain connectivity among participants as demonstrated by previous studies in the real-world [1] [2]. The main contribution of this work is that it reports, to the best of our knowledge, on the first use of hyperscanning in VR. It is also the first comparative study assessing neural connectivity between people completing the same task in the real-world and VR.

2 Background

Social interactions among individuals form a vital component of being human. However, the neural mechanisms that underlie these interactions have remained largely unknown [3]. Until recently, studies exploring brain activity during social interactions tended to monitor one person at a time in unrealistic abstractions of a social scenario [3]. As expected, this provided results that were limited by the manner in which such studies were carried out. There was no way to correlate observed behavioural patterns of the second participant with the recorded neural activity of the first.

The introduction of low cost EEG hardware has enabled hyperscanning studies which involve the simultaneous recording of brain activity from two participants doing the same task [1] [3] [4]. A particularly result is the contrast between neural activities of participants engaged in a co-operative task versus a competitive one [5]. There is measureable evidence of inter-brain synchrony displayed between two participants engaged in a co-operative task with a mutually beneficial outcome. When this brain synchronisation occurs, people report feeling that they are collaborating better together, and perform more effectively.

We believe that Hyperscanning could also be used in VR to measure the quality of collaboration between people. However, the first step is to observe, via Hyperscanning, if the same task performed in the real-world and VR demonstrate similar levels of inter-brain synchrony between participants. This, to the best of our knowledge, has not been previously attempted. The remainder of the paper lays out the methodology adopted for the experiment, preliminary results, a brief discussion of the results, and directions for future research.

3 Methodology

We conducted a two-part study to evaluate our hypothesis that a virtual environment will be able to elicit the similar levels of inter-brain connectivity among participants as the real-world for a given task.

We decided to reproduce in VR a previous real-world experiment which used a combination of finger pointing and finger tracking to explore inter-brain synchrony [6]. A vital aspect underpinning this study was that social interaction between participants promotes inter-brain synchrony [6]. The social interaction in this case was the finger tracking exercise participants were subjected to during the experiment. The entire experiment was divided into three parts: (1) Pre-training finger pointing task (2) Hand tracking / training phase (3) Post-training finger pointing task (Figure 1).

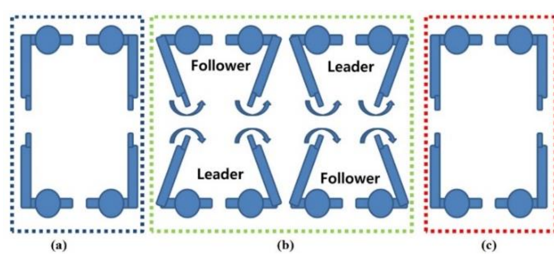

Figure 1: Experiment sequence: (a) Pre-Training finger pointing (b) Training – Finger tracking (c) Post-Training finger pointing [6]

Participants were seated opposite each other for the experiment (Figure 2). For each of the three parts of the experiment, participants were instructed to lift one of their arms in a manner such that it appeared to be a mirror image of the person sitting opposite them. For the sessions involving the finger pointing exercise, participants were required to raise their arms with their index finger pointed away from themselves. When given the instruction to begin the experiment, both participants looked at the tips of each other's fingers while trying to keep them aligned with each other. For the finger tracking / training exercise, participants were assigned the role of a leader at random, and told which hand to use. They then moved their hand around as they liked for one minute with follower trying to keep the finger tips aligned during the task. Each finger pointing and finger tracking task was run for

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978-1-7281-4765-9/19/$31.00 ©2019 IEEE
DOI 10.1109/ISMAR-Adjunct.2019.00-17

one minute, resulting in a total experimental run time of approximately 12 minutes. An additional 10 minutes was set aside for providing explanations and to complete the set-up.

Figure 2: Experiment Setup: (a) Virtual Reality (b) Real World

The same experimental protocol was followed for the real-world and VR parts of the study. In VR, participants saw a generic avatar of each other (Figure 3). The avatars' hand movements were mapped to the real users' had motions. Participants wore the Gear VR HMD with a mobile phone, and the users' head and hand movements were tracked using the NOLO CV1 tracker[1]

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Figure 3: Setup within a VR Environment: (a) Side view (b) Generic avatar seen by participants in VR

For the pilot study 4 pairs (8 participants: 6 male, 2 female) between the ages of 27 and 33 (Mean: 29, St. Dev: 1.9) took part in this study, with 2 of the 4 pairs being male-female pairs. The EEG activity from all participants was measured using the 16 channel openBCI Ultracortex MarkIV headset[2]. All EEG data was recorded and stored for off-line analysis using the OpenVibe [7].

4 Results

To analyze inter-brain synchrony between the two subjects, we used a Phase Locking Value (PLV) algorithm that produces values between 0 and 1 (0: no synchrony, 1: perfect synchrony). A visualization function for EEG lab developed by Perez et al. [8] was used to visualize the connections between the two brains. Connections that demonstrated a PLV correlation value above 0.9 were visualized using the function. The entire data set across all four pairs was then used to visualize the connections and provide an overall picture of inter-brain synchrony between all pairs (Figure 4).

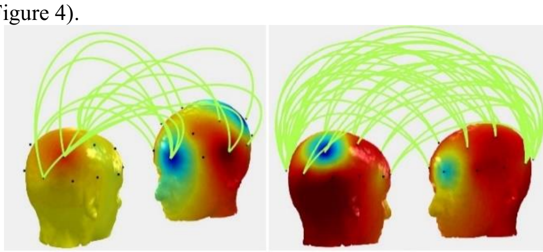

Figure 4: Inter-brain Synchrony measures: (a) Real-World (b) Virtual Reality (VR)

[1] https://www.nolovr.com/productDetails

[2] https://shop.openbci.com/collections/frontpage/products/ultracortex-mark-iv

As seen in Figure 4, both real-world and VR studies demonstrate that inter-brain synchrony can be elicited via some form of social interaction prior to a given task.

5 Discussion

This pilot study has been able to demonstrate that it appears possible to elicit comparable inter-brain synchrony among two individuals in real-world and VR using the same task. Interestingly, figure 4 shows that there may be more connections between two individuals in VR, but it remains to be seen how these connections are formed. We do not fully understand the reasons for a larger number of connections in the VR environment versus the real-world. None-the-less, these preliminary results demonstrate exciting findings that need further examination in order to be fully understood.

6 Conclusion

In this poster we have presented preliminary results that indicate that people working together in VR can experience the same inter-brain synchrony that sometimes occurs in the real-world. While this needs further study, one implication of our pilot study is that Hyperscanning could be used to measure the quality of collaboration in VR.

We are in the process of conducting a full study to confirm these preliminary results. There are also several directions for future research. For example, we will also explore the strength of the connections made between brains by means of studying how long the connections established between two interacting brains last. We are also interested in exploring if changing perspective will have an effect of inter-brain synchrony. VR has the ability to be able to deliver a real-time first-person perspective that is not possible with other forms of media, placing both people inside the same virtual body. We hypothesize that this first-person perspective could accelerate the rate at which inter-brain synchrony can be achieved, and maximize the number of connections that be established between two interacting brain in a collaborative environment.

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