Telepathic Play: Towards Playful Experiences Based on Brain-to-brain Interfacing

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ABSTRACT

Brain-to-Brain interfaces (BBIs) are systems that facilitate direct information transmission between two brains via a combination of neuroimaging and neuromodulation technologies. These systems can stimulate one user's brain based on the neural signals of another. While Brain-Computer Interfacing is often discussed in the Human-Computer Interaction (HCI) game and play community, BBI is underexplored. In this paper, we investigate the social play potentials of BBI systems by proposing three types of "telepathic play experiences" based on a wearable BBI system called "PsiNet" which we designed, engineered, and evaluated in a previous study. This system measures the neural activity of players via electroencephalogram (EEG) as the input to the system and stimulates associated brain activity in other users using transcranial electrical stimulation (tES) as the system output. We hope this work will inspire game design researchers to create novel play experiences using neurotechnology such as BBI systems.

CCS CONCEPTS

• **Human-centered Computing**; • **Human-computer interaction (HCI)**; • **Interaction paradigms**;

KEYWORDS

Brain-to-Brain Interface, EEG, tES, Neural synchrony, Inter-Brain Synchrony, BBI, BCI, Brain Stimulation

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1 INTRODUCTION

When playing games, communication is an essential part of the experience. This ability is usually enabled by information transmission using our sensory and motor systems to derive meaning from the external environment, such as by using language, body gestures, and facial expressions. However, with recent research in the fields of neuroscience and bioengineering, information transmission is now internally realizable; directly from one brain to another. These brain-to-brain interface (BBI) systems utilize neuroimaging technology to extract information from the neural signals of a sender's brain and then deliver it to a receiver's brain using brain stimulation [7, 8, 12, 22]. We believe there is potential to utilize these advancements to create novel play experiences.

Some of the neuroimaging and neurostimulation technologies that BBI systems use have been explored independent of each other in the research context of HCI. For example, neuroimaging methods such as electroencephalogram (EEG)-based BCI technology have already been applied in the game industry, generally by using players' brain activity as game controller inputs [21]. Neurostimulation methods such as transcranial electrical stimulation (tES) were also explored, such as enhancing the illusory touch perception in Virtual Reality (VR) games [26]and interactivity in general [25]. However, we find that BBI systems that combine electroencephalogram (EEG)-based BCI technology and transcranial electrical stimulation (tES) have been unexplored when it comes to games and play.

In this paper, we identify a new design space opened up by BBI systems within the field of CHI PLAY. To populate this design space, we will propose three types of play experiences afforded by BBI which we name as "Telepathic Play Experiences" through revisiting participant interviews from an earlier, boarder study we conducted, investigating a wearable BBI system named PsiNet [1]. This paper aims to begin filling the gap in our understanding of what role BBI can contribute to playful experiences. It might also be useful for researchers interested in understanding BBI applications in social contexts. Ultimately, we hope our work can inspire more discussion on neurotechnology's potential in social play.

2 RELATED WORK

We learned from prior work, especially direct BBI systems in bioengineering, BCI systems in the HCI game design field, and indirect BBI systems in interactive art.

2.1 BBI systems in bioengineering

One of the earliest human BBI systems was designed in the field of bioengineering. The system measures a sender's motor imagery (imagining the movement of hands or feet) from their EEG and encodes this as a binary number of "1", representing high motor imagery, or "0", representing low [22]. The system then sends this binary information to three 'receiver' participants as TMS-induced phosphenes (intrinsic visual sensations of a ring or spot of light), wherein a "1" from the sender results in a phosphene for the receiver, and a "0" results in no phosphene. This system was later applied to game-based collaborative decision-making, where the binary information represented a decision to either rotate Tetris-like blocks or not rotate them [12].

We acknowledge this first step in applying BBI to a gaming context, but also recognize the shortcomings of this system. Namely, these systems and their evaluation neglect the user experience. Although the latter example used a Tetris-like game in the experiment, the game's intention was not to produce a play experience but rather to establish a context for decision making. In addition, these systems were limited to transmitting binary information, which severely undermined the potential of BBI technology. With this in mind, our BBI system, PsiNet, is designed to communicate more complex state information, including the affective and cognitive states of users. Moreover, compared to these prior works' extensive lab equipment setups, PsiNet is a wearable system that can be used out of the lab in more naturalistic social settings.

2.2 BCI systems in the HCI game design field

We took inspiration from previous BCI games, especially in implementing how to consider multiple players' brain signals as game inputs. For example, "BrainBall" [10] collects the EEG data of two participants to measure levels of relaxation, then uses these levels to control the movements of a ball in a collaborative or competitive setting. Other similar examples that utilize EEG to contribute to gameplay include "MindBalance" [13], "BrainArena" [4], "Relax to Win" [19] and "Kessel Run" [6]. These examples provided insights into how to design playful experiences by integrating or comparing users' cognitive or affective states as game inputs. However, these multi-user BCIs can only read, but not directly impact other users' cognitive or affective states. Therefore, existing multi-user BCI systems are unable to support the brain-to-brain play that we are interested in.

2.3 Indirect BBI systems in the field of interactive art

Neurofeedback systems in the field of interactive art served as an inspiration to us on how to achieve brain-to-brain coupling. The art performance "Hivemind" [7], for example, used performers' EEG data to control rhythmic stimuli of light and sound in an immersive environment. The intention of altering the environment was to synchronize the brain oscillations of participants who were viewing the performance, altering their perceptions, memory formations, and reaction time. Similarly, "Telephone Rewired" [2] used exogenous pulses of light and sound in the environment to entrain the exogenous synchronization of participants' brain waves. To some extent, these artworks represented indirect BBI systems: the brain waves of performers affected the environment, which in turn affected viewers' cognitive states. Both Hivemind and Telephone Rewired provided insight as to how a brain-to-brain coupling may be used in social interactions to foster human connectedness, as play often does. However, these systems rely on mediation by the environment, as there was no direct interfacing between users' brains.

In summary, our examination of prior work revealed that brain imaging and stimulation technologies appear to have the potential for play experiences. However, the direct brain-to-brain interaction that BBI affords is unexplored in the CHI PLAY community. To begin our exploration, we formulated the following research question: "What kind of playful experiences can BBI afford?"

3 BBI SYSTEM

In our previous study [1], we designed, engineered, and evaluated a novel wearable BCI system called PsiNet (figure 1) to explore the user experience afforded by BBI systems in-the-wild, without a specific focus on the application domain or usage context. This wearable BBI system collects EEG data through 16 Ag/AgCI dry EEG electrodes on an OpenBCI headset with a Cyton EEG amplifier, processes and categorizes the EEG data using a battery-powered Raspberry Pi 4, then delivers corresponding tES brain stimulation using a "foc.us V3" tES device through two 2" x 2" sponge electrodes. The system categorizes users' brain states into 'concentrating', 'focused', 'motor activity', 'stressed', 'excited',' relaxed', and 'bored', considers the inputs of other users, and then delivers tES to either stimulate motor activity (mental imagery of performing movements), relaxation, increased focused attention, or a phosphene (perceptions of flashing lights in the periphery of the visual field). For example, when the system detects a user is exhibiting a high level of concentration (compared to each participant's baseline), the system will deliver tES stimulation to other users' left dorsolateral prefrontal cortex and supraorbital regions to increase the level of focused attention for all the other users.

4 THE STUDY

In PsiNet's evaluation study, 9 participants were recruited as three groups of 3 individuals who lived together, with close interpersonal

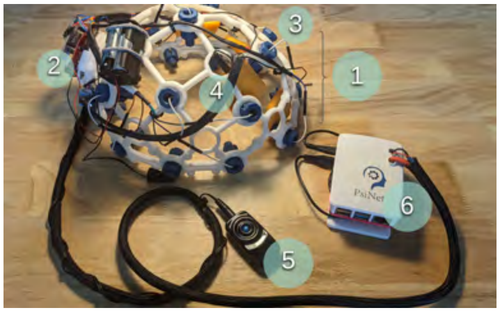

Figure 1: The components of PsiNet: 1 - Ultracortex, 2 - OpenBCI Cyton Board, 3 - EEG Electrodes (blue bolts), 4 - tES Electrodes (orange squares), 5 - tES Device, 6 - Raspberry Pi

relationships such as families, couples, and housemates (males = 4, females = 5, mean = 35 years, standard deviation = 14.34 years).

Each participant received their own PsiNet device with setup instructions. Participants in each household were required to wear the system at the same time for at least one hour daily over a period of three days. To reduce the possibility of a placebo effect occurring, participants were only generally informed about how the system works; they did not know about what user inputs relate to which outputs. To encourage participants to use the system in their day-to-day naturalistic social interaction context, there were no assigned tasks, but rather, participants had full discretion in deciding their activities with the system.

In the end, semi-structured interviews were conducted for approximately 30 minutes for each participant. The interviews were designed to obtain information about participants' experiences. Nvivo 12 was used to code the interview transcripts, adopting a grounded theory method approach [5]. In the previous study of PsiNet, thematic analysis was conducted on participant interviews to elucidate the general user experience afforded by wearable BBI systems in-the-wild. In conducting this analysis, we noticed that participants highlighted the potential for playful experiences while wearing PsiNet, inspiring us to pursue a separate line of enquiry into the collected data, focused on analyzing BBI's playful potential.

Figure 2: Participants playing a card game while wearing the system

5 RESULTS AND DISCUSSION

Participants used PsiNet in various social contexts, like watching TV together, playing video games, playing cards, cooking together, eating together, etc. Overall, 5 out of 9 participants used the word "fun" when reporting their experience with PsiNet, suggesting PsiNet's potential to afford a playful experience. Three themes emerged during the analysis of the interviews with a specific focus on the playful and game-based user experiences: closer connectedness through autonomous information transmission, 'mind guessing' through ambiguous information transmission, and a sense of control over others' minds.

5.1 Closer connectedness through autonomous information transmission

In the system evaluation study, participants felt more connected with other household members when using the system. The system made participants *"feel more connected in ways that we haven't before"* (participant 3) and *"make a group of people closer to each other"* (participant 5). Also, when asked whether they noticed any difference in their group's dynamic, participant 8 stated: *"We're on the same level. Like we're just closer, but usually, we're all in different vibes"*. The feeling of connection occurred even when participants were physically distant from each other: for example, participant 3 stated that using the system was like *"a bonding experience"* even when they were physically alone in a room. This feeling also occurred for Participant 2:*"Even when we were all doing our separate things at one time, it still felt like we were a bit closer"*. Similarly, participant 3 reported that *"when you're apart, it allows you to feel connected to them. But then I think it also allows you to feel connected in another way when you're actually together as well.* Participant 5 also described this feeling as *"awareness of the presence and potential of interaction with other minds"*.

Such connectedness could be attributed to the autonomous information transmission function of this BBI system. Unlike online instant messaging technologies, which usually have a required 'send' button to authorize the sending of information, the information transmission of this wearable BBI system is fully automated and triggered only by users' brain activity, which participants can not directly designate. This automatic information transmission links the users' brains without restrictions to location, time, and interaction contexts, and exhibits a high degree of transparency (users have low degrees of autonomy to 'hide a thought'). This connectedness-facilitation can be useful for play experiences, as connectedness is associated with engaging play experiences [17].

5.2 'Mind Guessing' Through ambiguous information transmission

The information transmitted using brain stimulation is highly ambiguous. However, players can infer insight into the cognitive state of others based on their environmental and social context. For example, a phosphene received when participants are playing video games together, or when they are having dinner together, have completely different meanings. Such 'ambiguities' can be useful for play experiences, as information with noises can be a valuable resource in play [24].

Participants in the experiments often make assumptions on other users' states of mind based on the ambiguous information they received through BBI as an assistant for their decision making. For example, when participants were playing card games together, they would guess what cards others had based on the simulations they got. Participant 3 also described a video gaming scenario: *"one time* *we were trying to do a puzzle in a game, and I worked it out with the simulations as hints [...]"* Participants also noticed other group members' performance and believed the ambiguous information delivered by the systems contributed to an improvement. For example, participant 1 reported: *"It might have made us, like, faster to hit the buttons on the controller when we were playing the game together."*

5.3 Sense of Control Over Other's Minds

Although the system mechanisms were not informed to the participants, 6 participants (P1, P2, P3, P5, P6, P8) mentioned that they figured out how their brain activities would influence other users through the system. Some participants further used this knowledge of the system to affect others. This sense of control over other users' states of mind appeared to contribute to the playfulness of the BBI experience. Participant 1, for example, mentioned how he intentionally maintained a higher level of concentration in order to trigger a phosphene to *"influence each other."* Participant 2, who was in the same group as participant 1, added: *"Using PsiNet is like having a fun gaming session together, or let's do something fun together [...] when my partner got stimulated, she was like 'oh, stop sending me phosphenes' [...] It was kind of funny. It was like a little playful moment."*

We attribute the playfulness of this sense of control over others' minds to two aspects. Firstly, the power of controlling itself is a playful element in games, which further refers to the feeling of dominating, commanding, and regulating [15]. Moreover, for the person whose mental states are influenced by others temporarily, this loss of control could also be a source of playfulness [18].

6 PROPOSED TELEPATHIC PLAY EXPERIENCES

Based on the study results, we now propose three types of "telepathic play" experiences afforded by the PsiNet system.

6.1 'I can feel you are with me' play experience

According to the study results, PsiNet appeared to strengthen the sense of connectedness among its users. As social bonding is a key source of joy in many social games [17], we believe that PsiNet can afford playful experience by enriching this source of joy through providing *"an awareness of presence and potential for interaction with other minds even when they are apart"*(P5) through autonomous information transmission. We therefore propose the 'I can feel you are with me' play experience.

Inspired by "Significant Otter" [14], a game on smartwatches that helps couples to communicate using animated otters that change based on their real-time sensed heart rates, our proposed BBI equivalent play experience may also aim to facilitate social bonding when people are apart. In this play experience, brain stimulation is used as 'emoji' and is triggered by the user's certain brain activities. For example, when the BBI system detects a user is exhibiting a high level of stress, a phosphene will be sent automatically to another user, which can be interpreted as an 'I need you' message. Or when the BBI system detects a user is in a state of highly focused attention, it can stimulate other users to improve their levels of attention, in communicating one's emotional states to another. We speculate such a play experience will establish strong bonding between the users since it provides a means of communication that traditional communication technologies can not afford. Similar to the game "Significant Otter", this play experience utilized biosignals to categorize users' current mind states to assist with interpersonal communication. Moreover, as outlined in the study results, compared with traditional communication technologies, such information transmission is highly autonomous and exhibits a high degree of transparency. We therefore speculate that such unique brain-to-brain communication among the players can be enjoyable and create a strong sense of connectedness between them even when they are apart.

6.2 'I know what you're thinking' Play Experience

Furthermore, the 'mind guessing' experience of interpreting ambiguous information from PsiNet to guess what is on other users' minds can also be enjoyable. Inspired by how participants used the stimulation as a hint to guess each other's cards, we speculate that PsiNet can be used in any social game setting when the interpretation of others' minds is needed. For example, in a social deduction game like Mafia or Werewolf, the information PsiNet provides can help players to reason and deduce one another's role.

The playfulness of such ambiguous information transmission is explained using the game example of 'Charades' by Salen and Zimmerman in the book "Rules of Play" [24]. In the game activity 'Charades', players use improvised gestures to convey a written word to their teammates. Framing games as systems of information, sometimes the entire pleasure of the game establishes the concept of adding noises and uncertainties to communication, making the information more ambiguous. The authors further illustrate the phenomenon of playful mind guessing or interpreting with noises to lusory attitude - the shared attitude that accepts an "inefficient" way to achieve the game's goal [24].

6.3 'I can control your mind' play experience

Control in games can refer to a player "dominating, commanding, regulating" the game [15]. Based on the study results, participants regarded a sense of control over another participant's state of mind as playful (as discussed in the study result section, participants tried to stay highly concentrated to trigger a phosphene for others).

In the 'I can control your mind' play experience, one player is designated as the "source", and the others are "targets". The source player's EEG signals control the tES stimulation administered to target players. For example, once a player wins a round in a competitive experience, they may be rewarded with the ability to act as the source to control another player's tES stimulations: the source player can think of moving their left hands or right hands to trigger corresponding tES stimulations on target players.

7 ETHICS

This research was approved by our university's ethics board. As neurotechnology is becoming increasingly popular outside the laboratory in real-world situations, there is a growing need to reflect on neuroethical practice [9]. Combining the tES technology with BCI makes direct brain-to-brain interfacing possible, but also raises ethical debates [11]. Some general ethical concerns are relevant to this nascent technology, including aspects of agency, responsibility, the potential influence on brain functioning, negative lasting effects on brain plasticity, and data privacy [20]. In response, we instituted strict safety protocols, data protocols, and exclusion criteria in our study. Since tES' precise working mechanisms remain unclear, the medicalization and regulations of tES are increasingly appealed by the science community[3, 16, 23]. We chose tES in this study since the application of low intensity tES in humans is mostly safe and adverse effects such as cutaneous perceptions, dizziness, and pressure sensations are mostly non-serious and not persistent [16]. We hope our research also encourages further discussions on the ethical aspects of such emerging neurotechnology.

8 LIMITATIONS AND NEXT STEPS

We acknowledge the limitations of this work. Our results are only preliminary as we only evaluated our system with a small cohort. Our data is limited as PsiNet's accuracy rate could be optimized, and a control group could be introduced. The next steps of this work include improving the PsiNet system and designing specific games based on the play experiences we proposed in order to validate our claims with regard to the potential of BBI for play.

9 CONCLUSION

In this paper, we proposed three types of 'telepathic play' experiences that are based on an in-the-wild study of a wearable BBI system called 'PsiNet' which enables brain-to-brain interaction using EEG and tES technology. We hope this work can inspire game designers to employ novel neurotechnology in the creation of brain-to-brain interfacing playful experiences.

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