Towards multiplayer BCI games

Hayrettin Gürkök, Danny Plass-Oude Bos, Michel Obbink,
Gido Hakvoort, Christian Mühl and Anton Nijholt
Human Media Interaction Group
University of Twente, the Netherlands
{h.gurkok@cs, d.plass@cs, m.obbink@student,
g.hakvoort@student, c.muhl@cs, a.nijholt@cs}.utwente.nl

ABSTRACT
Traditional brain-computer interface (BCI) research has forked to consider not only disabled patients but able-bodied users as well. Among various biosignals, electroencephalogram (EEG) is a cheap, portable and popular means of accessing brain activity. As a result, EEG-based BCIs are gradually being used in everyday applications, including games. Just as any computer product, human-computer interaction (HCI) aspects of BCI games deserve attention. In this paper, we describe our previous work on multiplayer and multimodal BCI games based on EEG along with possible future research directions.

Author Keywords
Brain-computer interface, social interaction, games, multiplayer, multimodal interaction

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies; B.4.2 Input/Output Devices: Channels and controllers

INTRODUCTION
Brain-computer interfaces (BCIs) are no more used solely in clinical applications for restoring communication and mobility of the disabled, but also for improving the interaction and enriching the experience of the able-bodied users. Example applications include cognitive and affective state monitors, virtual reality navigators and games [3]. Today, BCI applications need to compete against traditional human-computer interaction (HCI) applications to be used regularly in home environments. This requires investigating the extent to which BCI applications can sustain the multiuser setups and multimodal interaction.

Games are predominant computer applications attracting users from a broad range of age, personality and background. Thus, the field of computer games has been a popular investment and research domain. There already exist BCI games for entertainment purposes but they are mainly for the single player [6]. We conduct research on multiplayer, multimodal and multi-paradigm BCI games for able-bodied users, as opposed to patients. This not only includes developing user interfaces, signal processing and classification methods but also evaluating the usability of the system, user experience and social interaction. Below we describe the BCI games we have produced for our research. All of the systems use electroencephalography (EEG) to record the user's brain activity, as it is easy to employ, and has a high temporal resolution [8].

Figure 1. Stress changes the users character into a bear. To change back into their natural elf form they try to enter a relaxed state.

BCI IN WORLD OF WARCRAFT
One example of a popular multiplayer game currently on the market is World of Warcraft (R), a massively multiplayer online roleplaying game developed by Blizzard Entertainment (R), Inc. In this game, the user can play an elf druid who can shape-shift into animal forms. In bear form, for example, the druid is better protected against physical attacks by the thick skin, and is also quite the fighter with sharp claws and teeth. In their normal elf form, they are much more fragile, but can cast effective spells for damage to knock out enemies from a distance as well as to heal oneself. This game was used as a platform in a couple of prototypes, showing how BCI could be applied as an additional modality in an application that is up to par with what is currently on the market.

AlphaWoW
In AlphaWoW, one of our prototypes, this shape-shifting is controlled by the user's parietal alpha activity. Conventional mouse and keyboard input is still used for the other game controls. According to Cantero et al. [1], high alpha mea-

Submitted for BioS-Play 2010.

Figure 2. A user playing World of Warcraft using both conventional controls and brain activity to control her character in the game.

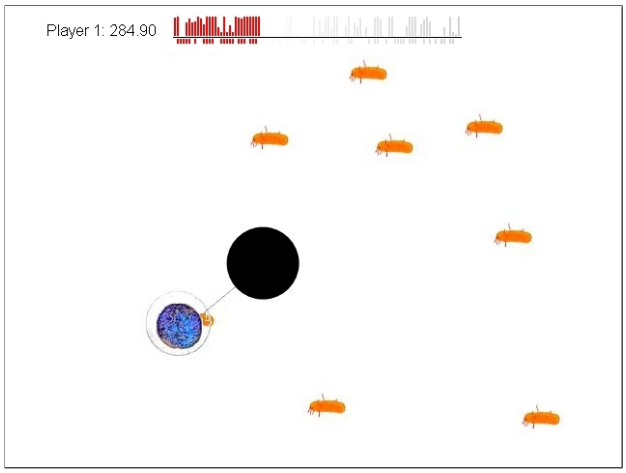

Figure 3. Screenshot from the Bacteria Hunt game. Eight targets (bacteria), one player avatar (amoeba) and the circular SSVEP stimulus are present. The player's score is shown at the top left. The histogram above the line depicts recent alpha band power, below the line the SSVEP classification results are marked.

sured at the parietal lobe is related to a relaxed alertness. The premise for mapping alpha to shape shifting in the game was that the opposite of this relaxed state would be some kind of sense of stress or agitation. Agitation would have a natural relation to the bear form, as the bear is eager to fight. Now the emotional state of the player is coupled to the avatar in the immersive game environment (see Figure 1).

The amount of control the user actually has over this alpha activity, and how well this measure reflects the user's affective state, will probably influence the user experience as well as the communication with others. Generalized to all possible input modalities, the more concentration and effort the input requires, the less mental processing is available for gameplay and social interaction.

IntuiWoW

In order to examine the influence different mental tasks have on the user experience, another BCI prototype was developed using the same game: IntuiWoW (see Figure 2). The in-game task controlled by BCI was still the shape-shifting action of the druid. Three different mental task pairs were compared: (1) stressing to bear versus relaxing to elf form, similar to the task used in AlphaWoW, (2) mentally reciting a spell (a different text for each of the two shapes), and (3) feeling like a bear or elf, depending on what you want to change into.

Results seem to indicate that in this particular situation the users based their preference for mental tasks mainly on how well they were recognized by the system. A second important aspect was the amount of effort involved in executing the mental task [5].

BACTERIA HUNT

After our work with alpha activity, the question arose whether people could actually control this feature well enough to even notice if it was really their activity. Additionally, we became interested in what the effect would be of using multiple BCI paradigms at the same time. To answer such issues, Bacteria Hunt was developed.

Bacteria Hunt is a multimodal, multi-paradigm game. In this game, the player controls an amoeba which is trying to eat the fleeing bacteria (Figure 3). Movement direction is controlled by the keyboard and is also influenced by the relative alpha power, which is a correlate of relaxed alertness. So the more relaxed the player is, the easier it is to control the amoeba. When the amoeba is on a bacterium, a flickering circle appears on the screen which stimulates an steady-state visually evoked potential (SSVEP) response [7]. If the user is able to produce the desired response, the bacterium gets eaten.

The study conducted using this game has two main goals [4]. Firstly, the game is used to test the effects of BCI with subjective and objective means. Sham feedback was used to examine the affect that the perceived control over the BCI has on the game experience. It was expected that real feedback would subjectively lead to a more relaxed state and greater feeling of confidence. Furthermore, we expected difference of objective indicators of relaxation. The analysis showed no difference in subjective and objective indicators of relaxation or control. Several possible factors for the inefficacy of the neurofeedback were suggested.

Secondly, the interaction between different, simultaneously used BCI paradigms, namely neurofeedback and SSVEP, were studied. Due to the antagonistic nature of these two mental tasks, relaxation and focused attention, and due to the blockage of the alpha rhythm during visual stimulation, a decrease of alpha was expected during SSVEP. However, an increase in alpha power was found. Further analysis suggested that the increase was due to the increase of the power in the first harmonic of the SSVEP stimulation (7.5 Hz), which is close to the alpha band (8-12 Hz).

MIND THE SHEEP!

Most recently, we decided to start looking into the influence of adding BCI input on collaboration in a multiplayer game. Mind the Sheep! is a BCI game where the player needs to herd a flock of sheep across a field by commanding a group of herding dogs (Figure 4). The aim is to fence in all the sheeps as quickly as possible. The game can be played by single player as well as by two players collaboratively.

In the non-BCI version of the game, the dogs are highlighted in random order with a decreasing speed as the player presses the mouse button. The player stops the highlighting by releasing the mouse button and the selected dog moves to the target where the mouse pointer was located. In this way the longer the user waits, the higher is the chance that he selects the correct dog to command. But, of course, the positions of the sheeps change meanwhile so the player needs to trade off between speed and accuracy.

In BCI version of the game, dogs are highlighted in constant speed so as to evoke an SSVEP or P300 response [2]. As in the non-BCI version, the user decides when to start and end the stimulation (the highlighting) and select the dog. So similarly, the longer the user waits, the higher is the accuracy of EEG classification. This makes the BCI and non-BCI versions of the game comparable.

We would like to use this game to investigate the social interaction between the players in BCI and non-BCI situations. There are challenges associated with this study. BCI acquisition methods, such as the EEG in this game, are intolerant to noise caused by movements or speech. Too much noise degrades classification performance and may introduce frustration. Therefore subjects would try to avoid extensive movements or speaking to the other player in order to improve their performances. On the other hand, they would be required to talk to each other for cooperation and, perhaps unwittingly, show bodily reactions during gameplay. Understanding players' tendencies and designing games accordingly is essential for realistic BCI games.

Figure 4. The Mind the Sheep! game. Eight sheeps, three herding dogs one of which is highlighted, various obstacles and on the top right corner the place to gather the sheeps.

We are also interested in finding out how different modalities and BCI paradigms (SSVEP and P300) affect user experience. The mouse in the non-BCI version of the game provides predictable and fast control in contrast to the paradigms in BCI version which have much inferior information transfer rates and latencies [6]. Therefore, being relatively an unreliable interface, the BCI version of the game could cause negative emotions such as frustration. Still, the BCI version could increase user's level of engagement and result in a positive user experience as it offers a novel interaction style. Similarly, players might have a preference among the BCI paradigms. For instance they might be disturbed by constantly flickering stimuli as is the case with SSVEP, or perhaps they might find one requiring less concentration.

Another direction of research for us is the trade off between performance and appeal in BCI games. To offer a high level of engagement and presence, BCI games need pleasant and realistic components. In traditional BCI research, the visual stimuli are usually in forms of regular shapes such as squares or circles and in large sizes that are expected to yield a good performance. However these shapes or sizes are not necessarily the most appealing ones in a game setting. In our case, we would like to find out whether dog-shaped stimuli in realistic sizes would evoke an SSVEP or P300 response at all or perhaps better than a regularly shaped stimulus. The number, inter-stimulus interval and duration of stimuli might also cause a clash between the performance and user experience. For example, longer exposure to stimulation could lead to annoyance while improving classification performance by the more amount of data available.

Recently, we have witnessed the release of wireless, easy-to-use, dry-electrode BCI hardware. With this game, we want to shift from using heavy research systems to portable devices for home use. We think that players would express themselves more freely when using light, wireless devices, and only then it would be possible to make a conclusion about real user experience.

ACKNOWLEDGEMENTS

This work has been supported by funding from the Dutch National SmartMix project BrainGain on BCI (Ministry of Economic Affairs), the GATE project funded by the Netherlands Organization for Scientific Research (NWO) and the Netherlands ICT Research and Innovation Authority (ICT Regie).

REFERENCES

1. J. Cantero, M. Atienza, C. Gómez, and R. Salas. Spectral structure and brain mapping of human alpha activities in different arousal states. *Neuropsychobiology*, 39(2):110–116, 1999.

2. L. A. Farwell and E. Donchin. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. *Electroencephalography and Clinical Neurophysiology*, 70(6):510–523, 1988.

3. M. M. Jackson and R. Mappus. Applications for brain-computer interfaces. In D. Tan and A. Nijholt,

editors, *Brain-Computer Interfaces: Applying our Minds to Human-Computer Interaction*, Human-Computer Interaction Series, pages 89–103. Springer-Verlag London Ltd., UK, 2010.

4. C. Mühl, H. Gürkök, D. Plass-Oude Bos, M. E. Thurlings, L. Scherffig, M. Duvinage, A. A. Elbakyan, S. Kang, M. Poel, and D. Heylen. Bacteria Hunt: Evaluating multi-paradigm BCI interaction. *Journal on Multimodal User Interfaces*, 4(1):11–25, 2010.

5. D. Plass-Oude Bos, M. Poel, and A. Nijholt. A study in user-centered design and evaluation of mental tasks for BCI. In *Advances in Multimedia Modeling, 17th International Multimedia Modeling Conference, MMM 2011*, Lecture Notes in Computer Science. Springer-Verlag, Berlin/Heidelberg, Germany, 2011. To appear.

6. D. Plass-Oude Bos, B. Reuderink, B. van de Laar, H. Gürkök, C. Mühl, M. Poel, A. Nijholt, and D. Heylen. Brain-computer interfacing and games. In D. Tan and A. Nijholt, editors, *Brain-Computer Interfaces: Applying our Minds to Human-Computer Interaction*, Human-Computer Interaction Series, pages 149–178. Springer-Verlag London Ltd., UK, 2010.

7. D. Regan. Steady-state evoked potentials. *Journal of the Optical Society of America*, 67(11):1475–1489, 1977.

8. M. van Gerven, J. Farquhar, R. Schaefer, R. Vlek, J. Geuze, A. Nijholt, N. Ramsey, P. Haselager, L. Vuurpijl, S. Gielen, and P. Desain. The brain-computer interface cycle. *Journal of Neural Engineering*, 6(4):041001, 2009.