Multi-Brain BCI Games: Where to Go from Here?

Anton Nijholt

University of Twente, the Netherlands & Imagineering Institute, Iskandar, Malaysia, anton@imagineeringinstitute.org

Abstract

In this extended abstract we look at some issues associated with multi-brain computing. They concern the position of this field of research in Brain-Computer Interface (BCI) research in general, as seen in various BCI roadmaps. The issues concern various kinds of competition and collaboration in multi-brain computing, observations on social interaction and multi-brain computing, and observations on multimodal interaction and multi-brain computing. Illustrations of these issues will be taken from BCI game examples. In addition we introduce this BCI field of research with some historical notes on early artistic applications.

Introduction

Clinical research on brain-computer interaction has focused on patients and assistive technology for disabled users. How can we provide an ALS (amyotrophic lateral sclerosis) patient with the possibility to communicate with the outside world using his or her brains only? Or, how can an artificial limb or prosthetic device be controlled by thoughts only. In the early years of brain-computer interface research many other applications were considered. Artists used EEG (electroencephalography) devices to audify and visualize brain activity and gave it a role in real-time performances. Rather than having just one person's brain activity measured and used, they also thought of, designed, and implemented artistic applications where brain activity of two users was required in order to produce a desired result. An example is a situation where two persons have to synchronize their brain activity with the help of visual feedback in order to produce an aesthetically pleasing visualization or a command to activate a device. But it is as well possible that two persons explore an audio-visual landscape and discover how it can be changed by modulating their brain activity, playing with sounds and visualizations, discovering effects of joint actions and discovering effects of contrasting actions.

These activities took place in the late 1960s and early 1970s [1]. At that time there were already papers on EEG recording of intended movement ('Bereitschaftspotential' [2], intended modulation of alpha activity [3] and externally evoked brain activity [4]. Vidal mentioned several BCI controlled applications, including the navigation of a spaceship. In the years that followed interest in BCI for artistic applications decreased. What else could be added to what was already done? And, EEG detecting devices were costly and not that easily available. In the decades that followed we can see the further recognition in neuroscience and BCI research of various BCI paradigms that are now well-known and systematically used in BCI applications: event-related potentials (ERPs), evoked potentials (visual, auditory, touch, smell, taste) and intended modulation of brain activity by a user (trying to relax, pay attention to, focus on or perform a mental task, imagine a movement).

Although there are some examples after the 1970s of artistic use of BCI and having multiple users involved, only in the 21st century we see again a growing interest. Obviously, this was stimulated by the introduction of cheap BCI devices and accompanying software that produces (black box) results of detecting and interpreting brain activity, whether it is about affective state or intended command detection. Multi-brain computing became an issue in BCI game research, in neuro-marketing, group decision making, and evaluation of group performance. In this extended abstract we look at some issues associated with multi-brain computing. They concern the position of this field of research in BCI research in general, as seen in various BCI roadmaps. But more importantly, they concern observations on various kinds of competing and collaborating in multi-brain computing, on social interaction and multi-brain computing, and multimodal interaction and multi-brain computing. Illustrations of these issues will be taken from (BCI) game examples.

A.J. Spink *et al.* (Eds.): Measuring Behavior 2016, ISBN 978-1-873769-59-1
Dublin, Ireland, 25-27 May 2016

Multi-Brain BCI: Applications

Slightly adapted from [5], we have the following applications of research on multi-brain computing: (1) Joint decision making in environments requiring high accuracy and/or rapid reactions or feedback, (2) Joint/shared control and movement planning of vehicles or robots, (3) Assess team performance, stress-aware task allocation, rearrange tasks, (4) Characterization of group emotions, preferences, appreciations. (5) Social interaction research (two or more people), (6) Arts, entertainment, games. In [6] we gave an arts and games biased survey of these applications. It is interesting to see how road maps for BCI research look at such multi-brain BCI applications. They are not or hardly mentioned, which is understandable since researchers who represent the BCI field look at clinical applications only and focus on solutions to problems of individuals (patients) [7]. Neuro-marketing is one of the fields that is sometimes mentioned, but clearly, this is not about (real-time) interaction, collaboration or competing.

Apart from multi-brain games that now are being developed [6] there is much interest by artists, often musicians, in having one or more persons' brain activity take part in creating or adapting a piece of life media art. This can be done in a performance that requires interaction with the artist/performer who is coordinating the joint life performance [8]. It is also possible that the artist delivers an interactive piece of art and it is up to the public to discover how to interact with it and possibly control the created interactive audio-visual (virtual or physical) environment [9]. Measuring audience responses with BCI is less well known than with more traditional physiological sensors (heart rate and skin conductivity sensors), but with the more recently developed EEG wireless headsets with dry electrodes this will certainly change. In games it is usually not about multiple players discovering interesting and entertaining properties of an environment. They are more aimed at competition (with one or more other players), collaboration (with one or more other players) or social interaction (with one or more other players) that is not or less task oriented than we see in interactions related to task or game collaboration and task or game competition.

Cooperation and Competition Using BCI

Whether it is about cooperation or competition, we think it is useful to distinguish between the following situations. Our examples address entertainment game interactions. We think these issues are important in non-game interactions as well, whether they are cooperating, competing or social.

First we distinguish between comparative and interactive games. In a comparative game there is no interference between the players. The performance of one player has no impact on the other player. When the game is played together or in the presence of an audience there may be social aspects that have impact. Consider for example playing with a pinball machine using imagery movement for pin control [10]. There is turn taking between players, but apart from score announcements and issues such as engagement and frustration, after each turn the game situation is neutral again.

This is different from turn taking in the Connect Four game. Players have a vertical grid of 6x7 positions and, taking turns, they can drop a coin in a chosen column. The game end when a player has four of his coins connected, either vertically, horizontally or diagonally. In [11] an event-related potential (P300) is used to let players choose a column. Once a coin is dropped the game state has changed, the opponent faces a new situation. This can be compared with playing chess and have your pieces moved by P300 or imagery movement [12]. The outcome of the Connect Four or chess game is not dependent on your BCI skills (unless we introduce time constraints).

BCI skills play an essential role in the game of Pong. There is turn taking, as in a tennis game, but it is turn taking with a time constraint (determined by the game, that is, the time it takes for the ball to move from one player to the other). Moreover, while your opponent is taking his turn, you can already prepare and in fact start your turn by predicting the ball's position when it returns from your opponent. There is a continuous change of the game state, but no control interference. Each player has its own bat to move. In [13] Pong players use motor imagery to move the bats.

Finally we mention games where there is BCI control interference and continuous change of the game state. A simple example is the BrainBall game where we have two competing players and BCI control through relaxation [14] is about the control of the ball and have it moved in the direction of your opponent. Other examples are mentioned in [6]. We think that especially this category of games, whether competitive, cooperative, or both, should be called BCI games. The outcome of the game is determined by the BCI skills of the participants.

Multi-Brain, Multi-Modal and Social Interaction

There are a three more observations we want to make when considering the future of BCI games (and more generally, the use of BCI in competitive and cooperative situations). Firstly there is the issue of fusion of information (brain activity) to be detected and interpreted from multiple players. It is an issue nicely discussed in [15], distinguishing between fusion at signal, feature and decision or application level. Obviously, possibilities are also dependent on whether players use the same BCI paradigm. In multimodal interaction research these issues have been investigated and in future multi-brain research we can profit from the knowledge that has been obtained there [16]. The second issue we want to mention is the impact of the cognitive or affective state of the participants on the issuing of BCI commands. The affective state of a user influences intended brain activity. In [17] two scenarios are mentioned: (1) accounting for the user's emotional state to adapt the algorithms that identify the user's intent in the ongoing EEG signals, and (2) purposefully eliciting emotion to enhance EEG features that are relevant for BCI. In a competitive situation we can also think of a scenario where we purposefully elicit emotion to weaken EEG features. Whatever scenario, we need to consider brain processes that concurrently occur. The final issue we want to mention is current neuroscience research on social interaction [18,19]. This research aims at the study of brain patterns that emerge during social interaction. This interaction can, for example, be a conversation, joint music making, or more generally, having a task that needs cooperation and joint attention. Again, as in the previous remark on concurrent occurring brain processes, here we have concurrent and often synchronized brain processes related to the interaction that takes place and that provide a context of interpreting intended and evoked modulations of brain waves.

Conclusions

In this short paper we had a look at issues that can play a role in future BCI games. They mainly concern how to deal with various concurrent brain processes in the players' brains. How can they enhance the players intentions during cooperation or how can they be employed to weaken players' intentions during competition? It is clear that the challenging issues addressed here are not yet at the foreground of current BCI and neuro-social interaction research. A longer version of this paper will appear in [20].

References

1. Rosenboom, D. (ed.) (1976). Biofeedback and the Arts: results of early experiments. A.R.C. Publications, Vancouver.
2. Kornhuber, H.H., Deecke, L. (1965). Hirnpotentialänderungen bei Willkürbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiale. *Pflügers Arch* **284,** 1–17.
3. Kamiya, J. (1968). Conscious control of brain waves. *Psychology Today* **1**(11), 56-60.
4. Vidal, J. (1973). Toward direct brain-computer communication. *Annual Review of Biophysics and Bioengineering*, **2**, 157-180.
5. Stoica, A. (2012). MultiMind: Multi-Brain Signal Fusion to Exceed the Power of a Single Brain. Proceedings Third International Conference on Emerging Security Technologies, 94-98.
6. Nijholt, A. (2015). Competing and Collaborating Brains: Multi-Brain Computer Interfacing. Chapter 12: Brain-Computer Interfaces: Current trends and Applications. A.E. Hassanieu & A.T. Azar (Eds.), Springer,

Switzerland, 313-335.

7. Brunner, C., Birbaumer, N., Blankertz, B., Guger, C., Kübler, A., Mattia, D., Millán, J. del R., Miralles, F., Nijholt, A., Opisso, E., Ramsey, N., Salomon, P., Müller-Putz, G.R. (2015). BNCI Horizon 2020: Towards a Roadmap for the BCI Community. *Brain-Computer Interfaces* 2(1), 1-10.
8. Zioga, P., Chapman, P., Ma, M., Pollick, F. (2014). A Wireless Future: performance art, interaction and the brain-computer interfaces. Proceedings ICLI 2014 - Interface: Intern. Conf. on Live Interfaces, 220-230.
9. Wadeson, A., Nijholt, A., Nam, C.S. (2015). Artistic Brain-Computer Interfaces: Current State-of-Art of Control Mechanisms. *Brain-Computer Interfaces* **2**(2-3), 70-75.
10. Tangermann, M.W., Krauledat, M., Grzeska, K., Sagebaum, M., Vidaurre, C., Blankertz, B., Muller, K.R. (2008). Playing Pinball with non-invasive BCI. In: Proceedings Advances in Neural Information Processing Systems 21 (NIPS 2008), D. Koller, D. Schuurmans, Y. Bengio, L. Bottou (Eds.), Curran Associates, Inc., 1641-1648.
11. Maby, E., Perrin, M., Bertrand, O., Sanchez, G., Mattout, J. (2012). BCI Could Make Old Two-Player Games Even More Fun: A Proof of Concept with "Connect Four". *Advances in Human-Computer Interaction*, Article ID 124728.
12. Maruthappan, N., Iyengar, N., Sudip Patel, P. (2011). Brain Chess – Playing Chess using Brain Computer Interface. In: ICBMG 2011 workshop, *IPCSIT* **20**, 183-191. IACSIT Press, Singapore.
13. Krepki, R., Blankertz, B., Curio, G., Müller, K.R. (2007). The Berlin brain-computer interface (BBCI)—towards a new communication channel for online control in gaming applications. *Multimed Tools Appl.* **33**(1), 73–90 (2007)
14. Hjelm, S.I., Browall, C. (2000). Brainball: using brain activity for cool competition. In: Proceedings of the First Nordic Conference on Computer-Human Interaction (NordiCHI 2000), Stockholm, Sweden.
15. Wang, Y., Jung, T.-P. (2011). A Collaborative Brain-Computer Interface for Improving Human Performance. *PLoS ONE* **6**(5): e20422, 1-11.
16. Turk, M. (2014). Multimodal interaction: A review. *Pattern Recognition Letters* **36**, 189-195.
17. Garcia Molina, G., Tsoneva, T., Nijholt, A. (2009). Emotional Brain-Computer Interfaces. In: Proceedings 3rd International Conference on Affective Computing and Intelligent Interaction - ACII 2009, IEEE Computer Society Press, 138-146.
18. Babiloni, F., Astolfi, L. (2012). Social neuroscience and hyperscanning techniques: past, present and future. *Neurosci Biobehav Rev.* **44**, 76-93.
19. Mattout, J. (2012). Brain-computer interfaces: a neuroscience paradigm of social interaction? A matter of perspective. *Front. Hum. Neurosci.* **6**, Article ID 114.
20. Nijholt, A., Poel, M. (2016). Multi-Brain BCI: Characteristics and Social Interactions. In: 10th International Conference on Augmented Cognition, 17-22 July 2016, Toronto, Canada. Lecture Notes in Computer Science. Springer Verlag, Berlin, to appear.