Guest Editorial: Brain/Neuronal-Computer Game Interfaces and Interaction

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1. Brain-Computer Games Interaction

There have been many attempts to define the word game**.** The essential elements of a good game are play, non-trivial goals/challenges and rules and games often involve a pretended or virtual reality. Non-trivial gameplay requires a challenge but not so much of a challenge that the player becomes disinterested. Games, in general, have been around since ancient times to entertain us. Since the first electronic and video games appeared in the 1940s and 1950s there has been an increasing demand for enhancements to existing games and new ways of interacting with computer games. More recently games have been used to engage and stimulate us cognitively, help us learn and help us recover from illness (e.g., edutainment and serious games). Buttons, mice, joysticks, joypads and handheld devices have been the main human interfaces with games for many years, then came steering wheels, gear sticks, electronic musical instruments and all sorts of peripherals that represent real-life objects. Nowadays brainwave or electroencephalogram (EEG) controlled games controllers are adding new options to satisfy the continual demand for new ways to interact with games, following trends such as the Nintendo® Wii, Microsoft® Kinect and Playstation® Move which are based on accelerometers and motion capture.

EEG-based games interaction are controlled through brain-computer interface (BCI) technology which requires sophisticated signal processing to produce a relatively inaccurate and unstable control signal that provides a low communication bandwidth with only a few degrees of freedom. Extracting a reliable control signal from non-stationary brainwaves is a challenge being addressed by many researchers. Producing paradigms for training users to produce brain activity that is easily translated into a control is another key focus of BCI research. Another challenge is to develop games and games control strategies that can be operated using unstable and limited control signals and exploit the rich dynamics available in brainwaves. It is therefore important to engage those involved in games development to help develop new paradigms for not only enabling non-muscular game interaction but also for advancing the field of BCI in general.

Brainwave controlled computer games have been researched since the 90's with an emphasis on using video games to improve the user's performance in brain-computer interface experiments and maintaining motivation whilst learning to modulate brain activity, with the end goal of being able to use that ability to interact with and control technology and communicate, movement-free. More recently entertainment and gaming have become a popular application focus for BCI researchers and games developer have begun to engage the challenge that such a field proposes, with BCI games become increasingly more advanced; incorporating 3D environments, multiple user objectives and hybrid control systems incorporating both conventional input devices and multiple BCI techniques.

Brain controlled video games can be used in training users to intentionally modulate their brainwaves to 1) enable communication for those with severe movement impairment 2) enable those who are physically impaired to enjoy video games 3) for rehabilitation (e.g., post stroke rehab to encourage brain repair), and 4) for gamers, to augment and improve the game playing experience. A challenge is to train the users in paradigms which are not too simplified (e.g., simple cursor control) such that progressing from a training paradigm to a real-world communication/control situation significantly impacts on the performance of the subject. Video games provide such a learning environment, where increased cognitive load can be controlled by modulating the amount of stationary or moving objects/matter which may or may not need to be attended to by the BCI user. Controllable distraction to the user can help the user learn to cope with such distractions when using BCI in the real world.

While there has been successful research into brain-computer game interaction to date, the algorithms and techniques developed are limited in scope and may not utilise all available data in the appropriate contexts e.g., optimising for genre specific games. Whilst the importance of computer games, the challenge and the competition, provide key ingredients for motivating and engaging user whilst they learn to control a BCI, it must be emphasised that brainwave controlled games need to be developed to suit the end purpose or application. For entertainment this is obvious: keep the users engaged, excited, challenged (but not too much) and immersed where gamers must feel they are in control of the BCI. This may involve tailoring the difficulty to suit the players' ability, which is acceptable for gaming when positive feedback is important but may not be desirable for training when the end application requires precise and accurate selection such as commands for assistive robotics or communication. For example, when a BCI is used as an alternative communication device the objective is to maximise the probability of interpreting the users intent correctly therefore the games should maintain a person's motivation to perform better, try harder to produce the right brain activity/activate the correct area of brain and provide feedback to the user to enable learning whereas, if the BCI is aimed at inducing neuroplastic changes in specific cortical areas, i.e., in stroke rehabilitation (another application which involves games and brain-computer interface), the objective is to not only to provide accurate feedback but also to encourage the user to activate regions of cortex or produce oscillatory activities which do not necessarily provide optimal control signals in the context of BCI.

This special issue was therefore solicited to gain insights into new biosignal processing algorithms tested in gaming applications and gaming applications which exploit BCI and neural signals to enhance game play experience and player motivation, be the players able-bodied or physically impaired.

2. The papers

In this special issue a snapshot of the current trends in BCI controlled computer games is presented across 11 manuscripts. Marshall et al provide a review of the field to date, how it has grown over the past 20 years and what types of BCI control strategies are suited to particular games genres, for the first time categorising games used with BCIs into genres. The appropriateness of game genres (a category of games characterised by a particular set of gameplay challenges) and the associated gameplay challenges for different BCI paradigms are evaluated. Gameplay mechanics employed across a range of BCI games are reviewed and evaluated in terms of the BCI control strategy's suitability, considering the genre and gameplay mechanics employed. A number of recommendations for the field relating to genre specific BCI-games development and assessing user performance are also provided for BCI game developers. Interestingly, it was found that the action game genre was the most popular genre even though action games tend to require fast responses whilst motor imagery was the most used BCI approach for games, even though motor imagery based BCI normally requires training which would be unusual for general gaming. The breadth of topics covered in this special issue correlate with the findings of the review by Marshall et al, where motor imagery, steady state visual evoked potentials (SSVEP) and P300 based games interfaces are shown to be the most popular with aspects of how biofeedback, user states and emotions also being exploited to enhance gameplay.

Chumerin et al evaluated the use of Steady State Visual Evoked potentials in a maze game on a consumer grade EEG device (the Emotiv EPOC) and a traditional EEG cap. The game was then tested using the consumer grade headset with a broad audience (53 persons) in a real world setting. Most players enjoyed the game and had good control over it, yet a percentage of players found the stimuli difficult to concentrate upon. Recommendations for both BCI game design, the fitting of consumer grade EEG headsets on participants and the use of SSVEP stimuli in games are presented based on the findings from the study.

Legeny et al examine a context dependent approach for a SSVEP based BCI games controller. The controller uses two kinds of behaviour alteration. Commands may be added and removed if their use is irrelevant to the context or the actions resulting from their activation and may be weighted depending on the likeliness of the actual users' intention. The controller was integrated in a test spaceship shooting game for a pilot study using twelve subjects. Preliminary results obtained confirmed the possible benefits in terms of a context dependent controller workload reduction and performance improvement.

Leeb et al describe a multimodal approach using an asynchronous BCI in parallel with a manual joystick control signal, while playing a game in virtual reality. The subject controls a penguin character sliding down a mountain slope in which steering the game character left or right was achieved with a joystick whereas making the character jump was achieved using foot motor imagery. The BCI was built upon the so-called brain switch, which allowed for discrete and asynchronous actions. Results from fourteen subjects showed that the use of a secondary motor task in this case joystick control did not deteriorate the BCI performance during the game. These findings show that BCI may be used in a multimodal or hybrid BCI implementation where a user can perform two tasks in parallel. These are encouraging results suggesting that BCI can indeed be used as an additional control in computer games.

Thurlings et al studied a different aspect of multitasking, in particular dual-attentional tasks for Event Related Potentials (ERP)-based BCI, investigating if and to what extent event related potentials (ERPs) and ERP-BCI performance are affected in a dual task situation and if these effects are a function of the level of difficulty of a concurrent task. These two tasks consist in attending to tactile stimuli (for ERP-based BCI control) and performing a visual memory task. The study showed that when users are required to perform these two tasks simultaneously, the resulting ERP-based BCI performances drop significantly. While they are still higher than chance, they become lower than what would be necessary for effective control.

Overall, the studies on multitasking may suggest that using spontaneous BCI such as motor imagery-based BCI can be used in addition to other motor control commands (e.g., a joystick), but that ERP-based BCI may not be used in addition to other attentional tasks, hence constraining the types of games in which ERP-based BCI can be used.

A more specific look at BCI-games was provided by Kaplan et al in a review of BCI controlled games based on the P300 evoked potential. The shortcoming of the P300 BCI in gaming applications is reviewed and it is outlined how solutions for overcoming these shortcomings already exist in several different games. Problems such as static stereotyped stimuli, goal selection control instead of process control, repeated stereotyped mental actions required to control a single action in the game and that the P300 is a synchronous BCI. Solutions for these problems are found in existing BCI games as well as recommendations for making future P300 BCI games more practical.

Kosmyna and Bernard present an evaluation of a multimodal combination of BCI paradigms and eye tracking with consumer grade hardware in a game. The paper evaluates three combinations of BCI and Eye tracking used in the context of a simple puzzle game. The use of SSVEP, motor imagery and eye tracking are used in several different combinations to identify the extent to which the paradigms impact on the playability of the game. The paper presents preliminary results that indicate that BCI interaction is tiring and imprecise yet may be suited as an optional and complementary modality to other interaction techniques, yet that the combination of the eye tracker and SSVEP was the most well rounded and natural combination.

In terms of practical focus for brain-computer games interaction Scherer et al propose the use of games to enhance the user experience when collecting behavioural data for research. The rationale is that experimental paradigms used to collect behavioural trials from individuals are data-centred and not user-centred resulting in the experimental paradigms that are generally demanding for the user/participant, and not always motivating or engaging. An approach involving the use of the Kinect motion tracking sensor in a game based paradigm for non-invasive electroencephalogram-based (EEG) functional motor mapping is proposed to alleviate this problem by making the data collection experience more interesting for the user. Results from an experimental study with able-bodied participants playing a virtual ball-game suggest that the Kinect-sensor is useful for isolating specific movements during the interaction with the game, and that the computed EEG patterns for hand and feet movements are in agreement with results described in the literature.

Berta et al provides an electroencephalogram and physiological signal analysis for assessing flow in games. The paper defines flow in games as a measure of keeping the player fully immersed and engaged in the process of activity within the game. The evaluation of flow involves a 4 electrode EEG, using the low beta frequency bands for discriminating among gaming conditions. Using simple signals from the peripheral nervous system three levels of user states were branded using a Support Vector Machine classifier. The user states where identified using 3 levels of a simple plane battle game identifying states of boredom, flow and anxiety. The paper argues that a personalized system could be implemented in a consumer context allowing for more flowing gameplay in consumer games.

Van de Laar et al investigates if the incorporation of BCI into the popular game World of Warcraft affects the user experience. A BCI control channel based on alpha band power is used to control the shape and function of the avatar in the game. The character within AlphaWoW has two forms, an elf and a bear. The elf form allows them to attack enemies from a safe range and the bear allows them to attack from close range (the bear is also more resistant to attacks). The “shape shifting” in the game is controlled via the user’s parietal alpha activity. This study suggests that the use of BCI control can be as much fun and natural to use as conventional controls even if the player’s control is limited.

Finally, in the paper by Bonnet et al. we see a first step towards multi-brain games, that is, games where two (or more) players compete or collaborate to steer a ball displayed on the screen in the direction of goalposts left and right on the screen. Steering is done using motor imagery. In the collaborative version players make a joint effort to steer the ball in the same direction. In the competitive version their efforts are compared and the ball goes in the direction of the goalposts indicated by the strongest motor imagery control. The paper makes clear that multi-brain control of a BCI game is possible and enjoyable for the players.

3. Discussion/Conclusion

In recent years, many proof-of-concept investigations have shown that BCI can be used to control computer games. This special issue presents a variety of examples representing the latest developments in BCI-based game designs and outline progress in the field including designs and studies of more complex and more practical BCI-based games, not only as proof-of-concept investigations. The papers presented in this special issue have attempted to study issues related to multi-tasking with BCI control, multiplayer BCI gaming, BCI game design constraints, natural and efficient integration of the BCI system and its limitations in the game, use of commercial EEG devices, bio/neurofeedback for adaptive/passive gaming, BCI-games performance assessment, BCIs and BCI games categorization by genre and suitability to genre design among other interesting aspects that together render this special issue special.

The progress outlined herein will no doubt increase the interest in brain-computer games interaction (BCGI) and make BCI-based gaming a mainstream technology of the future, not only for entertainment but to enhance many of the applications that are linked with BCI and can provide assistive enabling technologies to the physically impaired as well as providing interesting and challenging activities to enable users to learn how to modulate brain activity more proficiently. Naturally, there are still a number of research problems that need to be solved to increase the market penetration of BCI games. These include completely suppressing BCI calibration or camouflaging it in the game design and story, or identifying the kind of BCI controls that are the most efficient in a gaming context and/or the most enjoyable for the players. This also includes finding seamless ways to train players during the course of the game. As Marshall et al suggested, to learn how best to tackle such challenges as BCI games evolve and further studies are conducted, it will be important for all investigators to consider and report the many different variables which dictate performances. For example, the players level of BCI control proficiency (measured as game performance and as BCI performance), the number of sessions a user has undertaken, types of control strategies, BCI setup including the number of electrodes used, types of assistance within the game and game AI, games distractions and environments along with other variables should be reported consistently. This will allow assessment of progress in the field on an on-going basis and to develop a clearer picture of the best practices and best designs for BCGI. There are exciting research problems ahead that BCI-based game designers will have to address whilst researchers can have fun with computer games as serious and beneficial research is being conducted.

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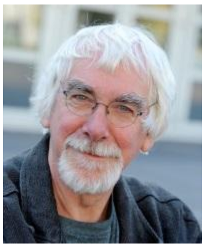

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