Brain-Computer Interfaces for 3D Games: Hype or Hope?

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ABSTRACT

Brain-Computer Interfaces (BCI) are communication systems conveying messages through brain activity only. This paper elaborates on the suitability of BCI for 3D Video Games (VG). Thus, we first review some recent BCI-based 3D VG. We then discuss the limitations of current BCI technology, those being mainly related to usability and performances. Finally, we report on some areas in which BCI could be useful for 3D VG despite their limitations. More precisely, BCI could be useful as an additional control channel, to send commands that cannot be intuitively sent with other devices. BCI could also be used for mental state monitoring either 1) during the game, in order to make adaptive and dynamic video games or 2) during the game creation in order to maximizes some measures of game quality that could be derived from a tester's mental state.

1. INTRODUCTION

For long, keyboards, mice and pads have been the devices of choice to play Video Games (VG). However, since the arrival of the Nintendo Wiimote© or the Microsoft Kinect©, the hegemony of these old devices is fading away, and full body interaction with 3D VG is becoming the new trend. In this context, the VG community is looking for new interaction devices that can make this full body interaction more natural, immersive and enjoyable for the player. Brain-Computer Interfaces (BCI) could be that new device. Indeed, BCI are devices that enable a user to convey messages to a computer thanks to brain activity only, this activity being generally measured using ElectroEncephaloGraphy (EEG) [18].

Recent research results have shown that BCI can indeed be used to interact with 3D VG and Virtual Environments (VE) [8][14]. However these results are laboratory-controlled results and as such more a proof-of-concept than a real life application. One may therefore wonder how useful BCI can really be in the context of 3D VG. In this paper we address this specific question. In Section 2, we briefly review some recent results in BCI-based 3D VG. Then, in Section 3, we discuss the limitations of current BCI technology. Finally, Section 4 discusses some promising areas in which BCI might prove particularly useful for 3D VG in the future.

2. RECENT RESULTS

During the past 10 years, a number of prototypes of BCI-based 3D VG have been proposed (for reviews about BCI and all kinds of games, see [14][8]). Some of these prototypes enable the player to select 3D objects in the game simply by paying attention to these objects. In this case, a specific visual stimulus is displayed on overlay of each object. It is indeed possible to find out whether the player is paying attention to a given object by analyzing the player's EEG signals in response to the corresponding stimulus [1][7].

However, most existing prototypes of BCI-based 3D VG use brain activity to perform navigation tasks in the VE (see e.g., [9][20][19][3]). Although these works prove that exploring a VE by brain activity is possible, the number of degrees of freedom provided to the user is rather limited. Indeed, these works offer only 1 or 2 mental commands to the player (e.g., turning left or right by imagining left or right hand movements, respectively). Moreover, most of these BCI were synchronous, meaning that the player could only send mental commands at specific time periods, imposed by the system, which is neither natural nor convenient. Recently, more advanced BCI systems have been proposed to navigate VE [17][13]. These BCI provide 3 different mental commands to the user, and were asynchronous BCI, i.e., the player could send mental commands at anytime, at will. Moreover, [13] showed that by using appropriate interaction techniques, only 3 mental commands were necessary to explore large and complex 3D VE (see also Figure 1).

3. HYPE: LIMITATIONS OF BCI

Even though such recent results are rather impressive, these BCI-based 3D VG remain simple prototypes that are not yet suitable for practical applications and widespread use. In particular, most if not all of these prototypes were assessed in laboratory conditions, i.e., in a carefully controlled environment, very different from an actual gaming context. More precisely, most current BCI were used in artificially quiet environments with artificially quiet subjects. Therefore, in a real gaming context, we would expect BCI performances - which are already rather low (e.g., the recognition of two mental states only very rarely reaches 100% accuracy)- to get even worse. Although there were some exceptions with evaluations in close-to-real-life environments,

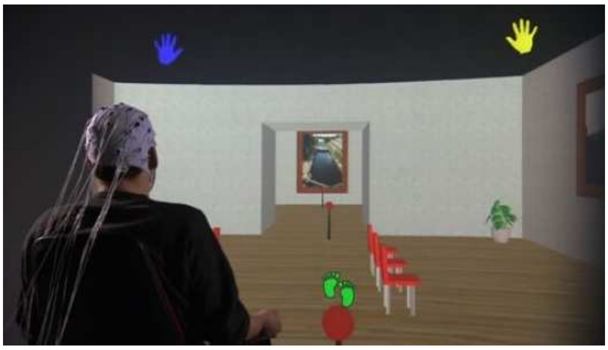

Figure 1: BCI-based navigation in a complex VE.

e.g., "Alpha WoW" [14] and "Use-the-force" [11], there is still a number of limitations impeding BCI use for actual 3D VG.

First, BCI users so far always have to sit, since body motions are known to generate various electrical artefacts that pollute EEG signals [4]. Unfortunately, during full body interaction with a 3D VG, the player will naturally be doing a lot of body motions which may jeopardize BCI use.

Second, using a BCI requires a lengthy and tedious calibration step. This step consists in collecting examples of EEG signals from the player in order to adapt the BCI to his/her specific brain activity. There is indeed a large inter-subject variability. The length of this calibration step ranges roughly from 5 to 20 minutes for the best BCI, depending on the mental states used to drive the interface [2]. Since most players probably want to use their game device immediately, such a calibration step would probably discourage many of them from using a BCI for gaming.

Third, current EEG sensors are gel-based, meaning that the subject needs to put gel in his hair below the EEG electrodes in order to use the BCI. Naturally, very few players would accept such a drawback if they play on a regular basis.

Fourth, for roughly 20% of BCI users, the recognition performances they achieve are not good enough to enable any form of control with this BCI [18]. Although the causes of this so-called "BCI illiteracy" are not well understood, in practice this may be a problem as a game device that 20% of the players cannot use may be quickly abandoned.

Fifth, the number of mental states that can be recognized by a BCI is currently very limited. For instance, most BCI based on imagined movements can only discriminate between a few tasks (e.g., imagining left hand movements versus imagining foot movements). Most probably, a game designer or a player would like the BCI to recognize a much larger variety of mental states, ideally tailored to the game at hand. Unfortunately, only a very limited number of mental states have been explored so far [18].

Finally, in terms of performances, a BCI is far below all existing game devices. More precisely, a BCI is much slower and much more prone to errors (e.g., wrongly identifying a given mental state instead of another one) than other devices. This makes the use of a BCI to send control commands rather inconvenient. Actually, the very limited performances of an EEG-based BCI make its use as the main control device of a 3D VG rather unlikely, even in the future.

4. HOPE: PROMISING PERSPECTIVES

Even though the previous section may seem very pessimistic about the future of BCI for 3D VG, there are also many reasons to be optimistic. For instance, many of the limitations mentioned above are currently being addressed by the BCI community and improvements can be expected in the relatively short term. More precisely, some preliminary results suggested that BCI could be used by a mobile user [12], although this makes the recognition performances slightly lower. Some efforts have also be made to reduce or suppress the calibration time with a minimal (but, unfortunately not null) performance loss [10][5]. The design and use of dry EEG sensors (i.e., without gel) is also being explored and validated, although this again leads to a slight performance loss as compared to gel-based sensors [15]. Finally, a new approach to BCI calibration has been proposed in order to reduce the number of BCI illiterates [21].

Unfortunately, one cannot expect much of EEG due to its very nature: noisy, non-stationnary signals of poor spatial resolution (EEG measures the synchronous activity of millions of neurons whereas we are ideally interested in their individual activity). Therefore, EEG-based BCI may always have modest performance which may prevent them from being the primary control device for VG. Nevertheless, BCI may be suitable for 3D VG in other ways. They could be used as an additional control channel, supplementing a game pad or a Kinect, for instance. While the low performances and speed of BCI would prevent them from being used to send critical commands, it can be perfect to send optional commands. Such a command could be a super power that is not needed to complete the game but can make things easier for the player if he manages to control the BCI. In this sense, as Nijholt put it and explored in "AlphaWoW", the shortcomings of BCI are turned into a challenge for the player [14]. In the case of immersive 3D VG, a BCI could also be used to increase this immersion by being used to send commands that cannot be intuitively issued with other devices such as a Wiimote or a Kinect. For instance, if the player's character in the game is a monkey, a full body interaction technique cannot enable him to perform tail movements in the game as a typical player does not have any. However, imagining a tail movement is something relatively easy for the user, that a BCI could potentially detect. Whether such a mental state could actually be detected in EEG signals is still an open question but even so, using a BCI in this way could again benefit to the player's immersive feeling in the 3D environment and thus to the fun of the game.

Another area in which BCI could be a promising tool for video games is mental state monitoring. Rather than using a BCI in an active way to voluntarily send control commands to the game, the BCI could be used instead in a passive way (in this case the BCI is denoted as a "passive BCI", see [6][22][18] for reviews), in order to dynamically adapt the content of the game to the current mental state of the user[1]. For instance, if a real-time analysis of the player's

[1]These aspects are currently explored in the OpenViBE2

EEG signals reveals that the player is bored, the game difficulty might be increased. On the contrary, if the mental workload of the user is too high, then the VE might be simplified to make the interaction and gaming easier or at least more intuitive. In these case, the limited performance of the BCI is not an issue, since a correct detection of the mental state is not required to complete the game, does not need to be fast but can possibly make the game experience more enjoyable. A passive BCI can also be useful for game design and evaluation. Indeed, while some players might feel uncomfortable wearing an EEG cap, it is perfectly acceptable to ask a 3D VG tester to wear one while assessing the game during its creation. This would enable the game designers to finely assess which parts of the game should be improved or removed in order to maximize the player's enjoyment based on the tester's brain responses to the different game events. Similarly, this would enable the designers to make the interaction technique used to control the game as intuitive as possible, based again of the tester's mental states while using it. There is currently only little research in the area of mental state monitoring, so it remains difficult to predict what kind of mental states can be recognized in EEG signals and how well they can be recognized. However, preliminary results are encouraging and these topics are getting increasingly popular so we may expect some interesting and useful progresses in a relatively near future [6][22][18].

Finally, it should be mentioned that, while EEG signals have many limitations, many of these limitations can be solved by using sensors implanted within the brain [18]. Naturally, this comes with the strong limitation of being highly invasive. However, one may except that, in the future, some hardcore gamers would ask for such invasive sensors in order to be able to play more advanced and innovative VG.

5. CONCLUSION

In this paper, we elaborated on whether EEG-based BCI were suitable devices for 3D video games. More particularly, we first provided a brief overview of recent 3D video games controlled by a BCI. Then we discussed the limitations of current BCI technologies, these limitations being mainly related to usability (inconvenient need for gel-based electrodes and long calibration times) and performances (low command production rate and relatively high recognition error rate, especially in a gaming context). Finally, we proposed a number of areas in which BCI could still be useful for 3D games despite the limitations identified. More precisely, BCI could be useful as an additional control channel, to send commands that cannot be intuitively sent with other devices. Moreover, BCI could also be useful to design adaptive video games that dynamically change depending on the player's mental states. The BCI could also be used during the creation of the game itself, in order to design a game that maximizes some measures of game quality derived from a tester's mental state (e.g., flow, presence, etc.). In conclusion, we believe that BCI-based 3D VG is a very promising topic that needs to be further explored. The availability of a free and open-source software platform to create such BCI-based VG [16] should encourage the gaming community to join the R&D activities in this area.

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project: http://www.irisa.fr/bunraku/openvibe2/

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