Human-Computer Interaction Issues in Brain-Computer Interface and Virtual Reality

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Introduction

The brain-computer interface (BCI) community usually focuses on evaluating accuracy, and rarely goes into systematic evaluation of human-computer interaction (CHI) issues. While this is, of course, understandable for a relatively young and challenging field, it is also clear that when applications finally transfer into the real world, CHI issues will become critical.

Recently, there has been increasing interest in using BCI in 3D virtual environments. There are several reasons for using a brain-computer interface in virtual reality (VR); some of these are the same reasons for using VR in general: rehearsal of scenarios that are too dangerous in the real world (e.g., controlling a wheelchair); prototyping devices (e.g., robotic hand); prototyping new control methods; studying the effects of "watching virtual body part actions" (e.g., applied for stroke rehabilitation); and increasing motivation and/or mental effort in BCI feedback experiments.

Based on our research on the sense of presence (for a review of presence research see [1]), we stress that there is a significant difference between immersive and non-immersive VR. For some applications this difference might be critical; for example, if we want to train a paralyzed patient to use a new interface, we want to make sure there is a perfect transfer to reality, otherwise we risk of miss-training; research have shown that, at least for some applications, a highly-immersive interface is required to achieve such transfer. A possible hypothesis is that subjects would perform BCI better (in terms of effort and accuracy) in highly-immersive VR, because the sensory context is similar to the real world.

The Graz BCI in the Cave

Thus, in the course of EU projects Presencia and Presenccia, we have integrated the Graz-BCI [2]with the UCL Cave[3]-like VR system, and conducted a series of experiments.

The Graz BCI is based on EEG-based detection of motor imagery, such as the imagination of left hand, right hand, or feet movement. A Cave is a VR system where the participant is standing inside a small room, wearing shutter glasses, surrounded by stereoscopic projections on the floor and walls (see Figure 1). Interaction is typically achieved by a wand (essentially a tracked 3D mouse), which in this case was replaced by the BCI.

Figure 1: A subject connected to the Graz-BCI system, inside the UCL Cave.

In a first experiment we wanted to establish that subjects could use the Graz BCI successfully in the Cave[4-6]. Three healthy subjects were successfully able to perform two tasks: rotating in a virtual bar and navigating along a single axis in a virtual street. For the latter task we were able to compare performance among three display types: desktop VE, head-mounted display, and Cave. All subjects were successful in all conditions; performance in the Cave was better than the other conditions, but results are inconclusive [5, 6].

In two additional studies we have allowed subjects to control a virtual body (avatar) using BCI[7, 8], and compared BCI with and without "free choice" [7]. Additionally, a paraplegic patient was able to perform asynchronous BCI navigation in the virtual street in the Cave [9].

CHI Issues

Since BCI is still exclusively practiced in research labs, experiments typically do not go beyond subjects performing very basic tasks. Scaling BCI from a simple paradigm to a more realistic task is a major step. The two major constraints we see are: i) BCI is typically **synchronous**, or **cue based**, and ii) the **number of classes** is typically very small (this, of course, effects the information throughput, which then becomes very limited). We have demonstrated asynchronous BCI [9] in the Cave, but in this case the paradigm was very simple, and it is not clear if other subjects would be able to perform such BCI, even with significant training.

Wolpaw et al. highlight the importance of **feedback** for BCI [10]. One of the problems with motor-imagery based BCI is that classification accuracy in the first second after the trigger is very low. This means any feedback given in this duration is probably misleading. Still, we prefer to present feedback immediately following the trigger, rather than introducing a delay, which might be more disorienting to the subjects.

Of course, 3D environments are an excellent way to deliver rich feedback, and our findings, so far, indicate that BCI subjects are not too distracted by excessive audiovisual input. Such environments may have another simple, yet very important advantage: subjects are more motivated to perform tasks in VE, even if it is not explicitly put in the context of a video game. In our street navigation experiments subjects were very competitive, and were highly motivated to continue down the street as far as they could[4, 6]. This motivation may have a crucial role in BCI, since it may reduce the burden of the large amounts of **training** required.

Finally, can VR facilitate BCI not only by making it more entertaining, but also by providing a concrete, intuitive context? Our hypothesis is that highly-immersive VR, by inducing a high sense of presence[1], would, under the right circumstances, facilitate BCI performance, since it would provide the senses with appropriate feedback, as compared with non-immersive environments. Like many issues with BCI, we only have very partial results, and these are not conclusive either way. On the one hand, we have evidence that subjects perform best in highly-immersive VR [6]. On the other hand, when we compared BCI performance in a condition with an **intuitive mapping** between thought patterns and feedback, with another condition that included a very un-intuitive mapping, subjects did not perform better in the intuitive condition, contrary to our initial expectations [8].

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