# Brain–computer interface: Changes in performance using virtual reality techniques

* Nowadays, conventional systems of feedback are based on cursor control [14] and horizontal bar extension [9].
* this type of feedback could be tiring or somewhat boring, leading to a lack of motivation [12]
* Virtual reality is a powerful tool with graphical possibilities to improve BCI-feedback presentation. Virtual reality technology has the capability of creating immersive and motivating environments, which are very important in guaranteeing a successful training [7].
* **The system runs on PC compatible Pentium 4 operating at 2.53GHz and has been made in Visual C++, usingWorldToolKit to develop the virtual world.**

# Development of EEG Biofeedback System Based on Virtual Reality Environment

* **The VR environments are designed using 3D MAX. For the real time rendering we use Microsoft Visual C++ 6.0 and DirectX 9.0 SDK [8-9].**

# Effects of a Brain-Computer Interface With Virtual Reality (VR) Neurofeedback: A Pilot Study in Chronic Stroke Patients

* Research on BCIs for rehabilitation has shown that motor-related brain signals are reinforced by rewarding feedback so they can be used to strengthen key motor pathways that are thought to support motor recovery after stroke (Wolpaw, 2012).
* Our previous work using REINVENT with healthy individuals indeed showed that the combination of VR integrated into a BCI encouraged greater embodiment, and greater embodiment was related to greater neurofeedback performance (Anglin et al., 2019).
* In this version, the data acquisition and processing modules are also independent of the VR task, communicating bidirectionally over a network layer
* **We acquired the electrophysiological signals from the hardware using a set of “satellite” clients (EEG, EMG) and sending them to the processing module(s) and a logger via the Lab Streaming Layer (LSL) protocol**
* **After signal processing, the extracted features (i.e., EEG bands, EMG flexion detection) were sent through the same protocol to VR.**
* The VR training environment streamed back to the network the following items: task score, task events (e.g., trial start, pause, complete), and rotational information of the VR hand controllers in three-dimensions.
* All VR elements were implemented in the Unity game engine (Unity Technologies, San Francisco, CA, United States) and rendered through an Oculus Rift HMD using the Oculus SDK (Oculus VR, Menlo Park, CA, United States).
* Moreover, the Oculus Rift HMD also included two Oculus touch controllers with 6-DoF, delivering vibrotactile feedback to the users.
* EEG Acquisition and Online Processing
  + the EEG system was connected via Bluetooth to the dedicated desktop computer for raw signal acquisition and processing.
  + The EEG signals were first acquired through the Neuroelectrics NIC-2 client before sending them to OpenVibe platform for online processing.
  + **Finally, the output was sent via LSL to the VR client**

# The Mind-Mirror: See Your Brain in Action in Your Head Using EEG and Augmented Reality

* “Neurofeedback”
  + which consists in progressively learning to control a brain pattern while continuously observing a real-time feedback about this pattern [4].
  + is considered today in the medical field for treating different kinds of pathology, such as attention deficits [11]
  + In most Neurofeedback applications, the feedback used is visual and consists in basic graphics such as 2D gauges increasing or decreasing over time
* In a recent study on Neurofeedback Hwang et al. used a realtime visualization of brain activity to train the user to BCI control [6].
  + Participants could visualize their cortical mu (8-12 Hz) rhythm activity in real-time, improving the BCI training and thus the performance when using the motor imagery paradigm.
  + In this desktop setup participants were able to have a direct view of their brain activity using a simple 2D colored image of a virtual brain.
* **System**
  + EEG data acquired with OpenViBE software [20] and head movement data from the Kinect are retrieved and processed within a Unity3D-based application that simulates and displays the virtual brain
  + Virtual brain activity visualizations are displayed in real-time (framerates between 25 and 80 Hz depending on the visualization type).
* Visualization Tools
  + Brain Topography: The brain topography visualization enables the display of the EEG signal power over the brain surface, as shown in Figure 3-left. This representation allows for a quick overview of the most active brain areas, i.e., the areas with the largest EEG signal power
  + 3D Volumetric Representation Using Inverse Solution: EEG signals correspond to brain activity at the surface of the scalp. Fortunately, it is possible to estimate the brain activity in the whole brain volume using algorithms known as inverse solutions [17]. The volumetric brain activity hence estimated can then be displayed with a 3D model of the brain using voxels. This visualization allows for a comprehensive 3D view of the brain activity, as shown in Figure 3-right.
  + Visualization Integrating Mental State Classification