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Brain Tangible Interfaces for Multimodal Rehabilitation

Introduction

Tangible User Interfaces (TUI) are rapidly becoming widespread and are proving to be a promising new platform for both individual and collective neurorehabilitation applications. While standard repetitive motor and cognitive training procedures can clearly lead to behavioral improvement as a result of increased integrity of the dysfunctional system (restitution), such approaches can alter brain function solely indirectly. Based on previous studies carried out at MTG-UPF (Mealla et al., 2011), we propose to design and develop a prototype of a Brain Tangible User Interfaces (BTUI) that will account for both physical, gesture-based interaction and for displaying user's physiological signals via tangible agents.

In order to achieve such implicit (physiological) and explicit (tangible) multimodal interaction, our BTUI will incorporate wireless, non-invasive, multichannel electroencephalographic (EEG) devices and heart-rate sensors for physiological signal acquisition, and the Reactable framework (Jordà et al., 2007) for music creation and collaboration. Such design can account for physiological state monitoring and biofeedback in domestic and clinical settings, both individually and collaboratively.

Through this project we aim at fostering new neurorehabilitation applications incorporating the latest neuroscientific results. In this regard, we believe BTUIs can be successfully applied in two concrete scenarios: the treatment of traumatic brain injuries (TBI) patients and therapies for children with autism spectrum disorder (ASD) based on mu-rhythm neurofeedback. Such implementation of BTUIs will require the designing of new tasks for improving motor-cognitive responses, attention and memory capacities and skills for social interaction in various patient groups.

Tangible User Interfaces

In the past decade we have seen a proliferation of interactive surface and tabletop user interfaces. Several tabletops allow indeed users to interact not only with their fingers (i.e. today's ubiquitous multi-touch interaction), but also through physical objects, which can be identified and tracked (position and angle). Such objects can represent abstract concepts or real entities; they can relate to other objects on the surface; they can be moved and turned around on the table surface, and all these spatial changes can affect their internal properties and their relationships with neighboring objects. Toolkits such as reacTIVision (Bencina et al., 2005) allow the tracking of fiducial markers and combined multi-touch finger tracking, and is nowadays widely used among the tabletop developers community (both academic and industrial).

The suitability of interactive tables as a support for collaboration and social learning has been highlighted by recent research (e.g. Marshall, 2007), and has been explored in several fields such as Computer-Supported Collaborative work (CSCW) (Scott et al., 2003), learning (Price et al., 2008), collaborative design (Kim et al., 2008), interactive storytelling (Stanton et al., 2001) and collaborative scenarios for children (Stanton et al., 2002). Here subjects share a physical space in which communication during all creative, experimental and reflexive processes are more physical and direct than communication via traditional personal computers and Graphic User Interfaces (GUI). Furthermore, it has been also shown that interactive table applications, with their ability for simultaneous action and visibility to collaborators, are ideal for exploratory and creative activities, and can allow and facilitate outputs that would be extremely difficult to obtain using more conventional interfaces.

The Reactable

The Reactable is a musical instrument designed for both novices and professionals, with the aim of creating an intuitive and non-intimidating musical instrument appropriate for single-user and collaborative performances. The Reactable has accomplished worldwide recognition both in the academic and musical worlds and an unparalleled mass popularity if considered its academic origin, turning into one of the very few new digital music instruments that have successfully passed the research prototype state. Recent studies carried out by the coordinating team with children with ASD have also started to show very promising results (Villafuerte and Jordà, 2012).

TUIs for rehabilitation

During the past decade the field of technology for rehabilitation has developed new programs of cognitive, behavioral, social and educational treatments, to address cognitive, behavioral and social deficits following traumatic brain injury. These new arrays of technologies and methods commonly involve specialized, highly expensive laboratory equipment, such as the case of the exoskeletons for functional upper extremity rehabilitation therapy (e.g. Hocoma's Armeo), or functional electrical stimulation (FES) to activate nerves innervating extremities affected by paralysis resulting from neurological disorders (Peckham et al., 2005). In parallel, non-hospital based technologies has been also developed in recent years. Commercial devices such as the Nintendo Wii Fit and Microsoft Kinect, originally designed for entertainment purposes, have been adapted to rehabilitation applications due its ergonomics, portability and inexpensiveness, and have proven the potentialities of such interfaces for out-of-the-hospital treatments. In a similar direction (Anette et al., 2009; Sharlin et al., 2002) have explored the use of multi touch, tabletop screen and tangible objects for cognitive restoration and motor rehabilitation. They stress on the fact that many individuals with disabilities enter into rehabilitation programs where many activities and exercises to be performed are monotonous and do not inspire patients to perform to the best of their abilities. Since the usage of traditional exercises can also make it difficult for therapists to objectively measure and track patient progress, the integration of interactive technologies into rehabilitation programs has the potential to benefit both patients and therapists.

To summarize, some of the expected benefits of applying TUI for rehabilitation purposes include their potential (i) for incrementing the speed of information processing and response at both cognitive and motor levels, (ii) for improvement attention-concentration, memory and executive capacities, and (iii) for enhancing capacities for social interaction. TUIs seem thus promising therapeutic tools for different types of populations, as adults and children with neurological diseases or congenital disorders.

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