Elements: Art and Play in a Multi-modal Interactive Workspace for Upper Limb Movement Rehabilitation

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Introduction

This paper discusses an arts and science research collaboration to design a multi-modal interactive workspace titled *Elements*. The *Elements* workspace aims to aid clinicians rehabilitate upper limb movement in patients with Traumatic Brain Injury (TBI). TBI represents a significant health issue for Australians with approximately 2% of the population living with disabilities stemming from cerebral insult.[1] Young adults are at particular risk with the peak age of incidence in the 15-24 year range. The cost of disability is estimated to exceed $3 billion per year in Australia.

TBI refers to a cerebral injury caused by a sudden external physical force. Such physical trauma can lead to a variety of physical, cognitive, emotional and behavioral deficits that may have long lasting and devastating consequences for the victims and their families. The ability to enhance rehabilitative processes in the early stages following TBI is one of the great challenges for therapists. The use of interactive screen-based technology in neuro-rehabilitation may hold the potential to assist TBI patients regain basic functional skills.[2] The design of the *Elements* project is a direct response to these needs.

Conceptual Approach

Our conceptual development of the *Elements* system is consistent with emerging trends in Human Computer Interaction (HCI)[3] and the neuroscience of movement.[4] As reported elsewhere, our conceptual approach combines (ecological) motor learning theory with an embodied view of interaction design to inform the way we conceive of the relationship between performer and workspace.[5] The concept of *affordance* proposed by ecological theorist Gibson[6] is particularly instructive. Affordance refers to the opportunities for interaction that meaningful objects provide in our immediate environment and in relation to our sensorimotor capacities. The perceptual properties of different objects and events are, thus, mapped fairly directly to the action systems of the performer.[4,6]

The affordances offered by *tangible user interfaces* (TUIs) have been designed to engage the patient's attention to the movement context and the immediate possibilities for action. So, rather than embedding virtual objects in a virtual world, we use real objects and a direct mode of interaction. The ecological approach has a lot to commend itself by not drawing an artificial distinction between the performer and the natural constraints of his performance. Advances in interaction design also accord with this embodied view of performance.[3] Embodied computer user interaction capitalizes on our physical skills and our familiarity with real world objects. Our design is sensitive to the patient's sense of embodiment and how the environment might be presented to afford new opportunities for action and play. It seeks to provide an interaction aesthetic that is coupled to the individual's perceptual and motor capabilities, building a durable sense of agency.

Implementation

TBI patients frequently exhibit impaired upper limb function including reduced range of motion, accuracy of reaching, inability to grasp and lift objects, or perform fine motor movements.[7] The *Elements* system responds

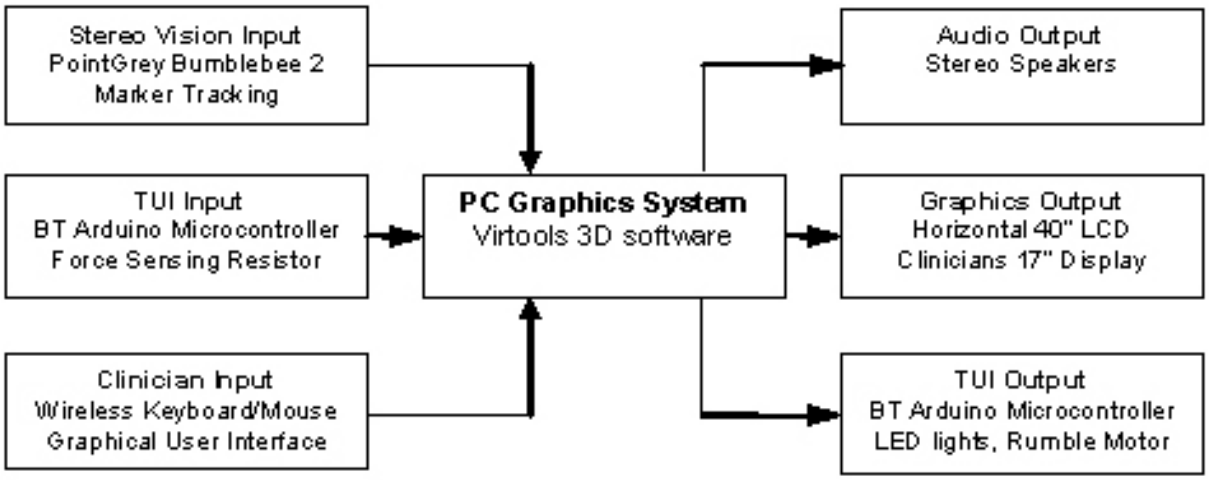

Figure 1: Hardware Functional Block Diagram

to this level of disability by using an intuitive desktop workspace that affords basic gestural control. The physical design of the *Elements* workspace consists of a 40-inch horizontal tabletop graphics display, a stereoscopic vision-based passive marker tracking system, TUI's and 3D computer game authoring software (Figure 1). The TUI is a graspable interface that incorporates low cost sensor technology to augment feedback that in turn, mediates the form of interaction between performer and the environment. The combination of 3D non-invasive technology is developed to empower TBI adults with moderate or severe movement disabilities. Audiovisual feedback can be used by patients to refine their gestural movements online and over time. In addition, patients can manipulate the feedback to create unique audio visual aesthetics. In short, the system design provides tactility, texture, and audio visual feedback to entice patients to explore their own movement capabilities in a directed and self-directed fashion.

There are two main aesthetic modes of user interaction which aim to exploit the potential of the *Elements* system. Each of these modes encourages a different aesthetic style of user interaction and consequently has different application potential. The first aesthetic mode of user interaction presents a task driven computer game of varying complexity that addresses the competence level of the patient. In this task, a patient places a TUI on a series of moving targets (Figure 2). The accuracy, efficiency, proximity and placement of the TUI is reinforced via augmented audio visual feedback. The patient can review their performance and test scores

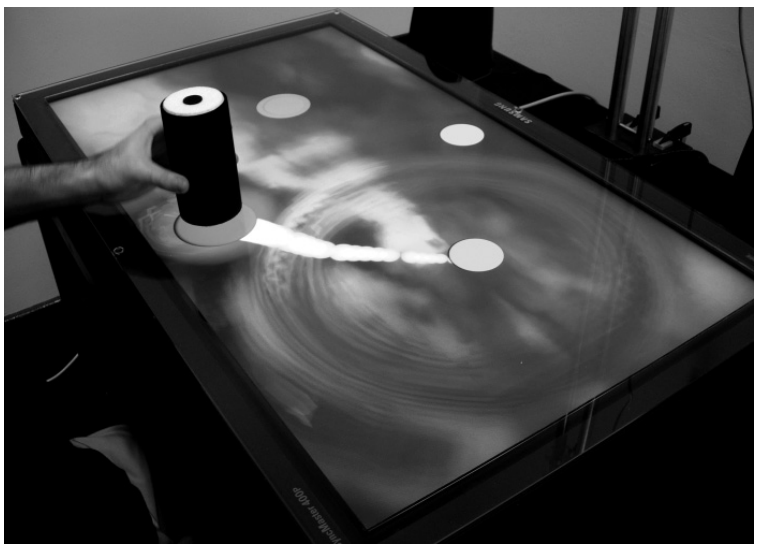

Figure 2: Patient places a TUI onto a series of moving targets.

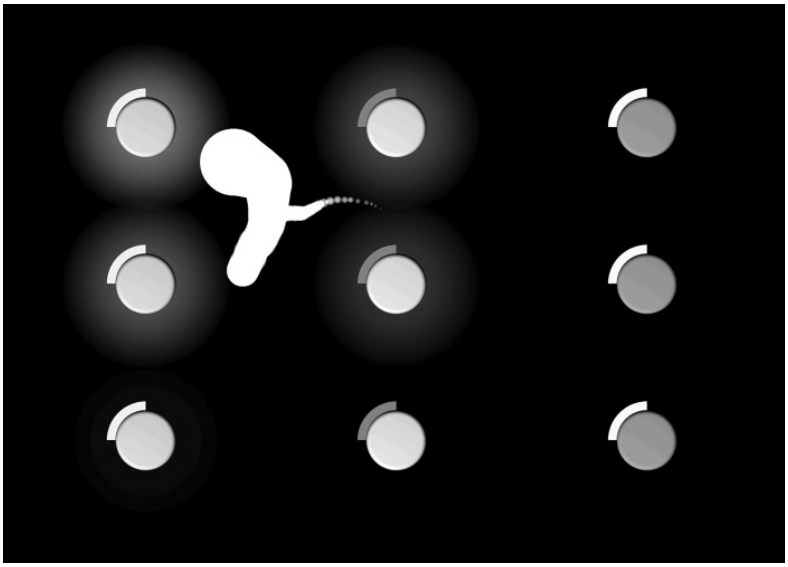

Figure 3: Screen image of audio mixing application.

as therapy progresses over time. The second mode of user interaction is an abstract tool for composing with sounds and visual feedback that promotes artistic activity. Painting and sound mixing is expressed through the patient's upper limb control of the TUI's (Figure 3). These environments are designed to evoke the patient's interests in practicing otherwise limited movement skills.

Discussion

Three male patients between the ages of 20 – 25 were recruited from the Epworth Hospital, Melbourne, Australia for a preliminary case study. The goal of this study is to measure and illustrate how our interactive environment can facilitate motor learning. The patient's upper limb performance and behavior are currently being evaluated and monitored overtime. Our preliminary observations show that significant improvements of movement accuracy, efficiency and attention to task have increased. All of the patients expressed a desire to interact with system in a creative capacity and have shown increased levels of motivation, engagement and enjoyment whilst undertaking the case study. These results suggest that applications that support creative and game style interaction tailored for TBI patients may improve their motor skills and sense of agency and control. These opportunities may be considered as a means to improve their quality of life in general using such a workspace. Further, it may be possible to tailor the system for a broader spectrum of people with mobility impairments.

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