

The Strathclyde Brain Computer Interface (S-BCI): the road to clinical translation

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Abstract. In this abstract we summarise the state of development of the Strathclyde Brain Computer Interface (S-BCI) and what has been so far achieved. We also briefly discuss our next steps for translation to spinal cord injured patients and the challenges we envisage in this process and how we plan to address some of them. Projections of the S-BCI project for the coming few years are also presented.

Keywords: *Translational issues, brain computer interface, spinal-cord injured, assistive and augmentative devices*

1. Introduction

The interplay between neuroscience, technology and clinical drivers has created the realistic potential for human machine interactions to be formed around neural interfaces. These interfaces can be sensitive and reliable indicators of user intention and when matched with appropriate assistive technology can offer ways to provide functional capacity to the intended user. In this project we are developing a non-invasive brain computer interface for use by severely paralysed spinal cord injured patients. The Strathclyde BCI system and translational process we aim to follow are outlined here.

1.1 Aims and Objectives

Our goal has been to develop multidimensional BCI control derived from surface EEG potentials and apply it through a virtual environment (VE). This scenario offers, on one hand opportunities for safe motor rehabilitation through training with realistic visual feedback and opportunities for the development of assistive and augmentative devices for communication and control of external devices via the BCI.

1.2. Approach

The approach we have adopted¹⁻¹² comprises

1. the use of a high density electrode montage to record surface EEG,
2. the design of experiments to explore three movement paradigms based on rapid goal directed wrist movements (actual, imaginary and observed movements),
3. the development of robust signal processing methods to identify and classify signals,
4. the development of a Virtual Reality (VR) simulator of an electric wheelchair and VE to provide a training test-bed and a source of environmentally relevant visual feedback for BCI use (closed system) and
5. real-time analysis providing adaptation to learning through immersion within a VE

1.3. State of development of the S-BCI

The S-BCI has so far been tested on healthy volunteers, the system provides accurate decoding of movement intent related to direction of motion and subjects are able to steer a VR simulated electric wheelchair by thought¹.

2. Clinical Translation

We are currently poised to move the S-BCI into SCI user tests with the collaboration of the Queen Elizabeth national Spinal Injuries Unit (QENSIU) in Glasgow. The major objective is to provide patients who are paralysed new means to access their environment with a device that can be controlled by thought. Initially, we shall be focusing on wheelchair navigation with a

VE. We believe that we currently are in an ideal position to turn the performance that we achieved in the laboratory^{1,10-12} into functional gains for paralyzed patients.

2.1. Target population

Our target population will be recruited from the QENSIU. This is because of the experience of the investigators with this population and the long and established collaboration between the Bioengineering Unit of University of Strathclyde and the clinical centre. The clinical centre is an ideal base as many patients remain for significant periods as in-patients (6 months or more post injury) and are first introduced to and learn to use assistive technologies during their stay in hospital.

2.2. Challenges and Obstacles

We envisage three main technical challenges (1) Understanding the temporal and spatial resolution of coding mechanisms of intention, planning and execution of action in the brain of SCI patients in contrast to healthy volunteers (2) Information extraction from recorded data and (3) Feedback and adaptation of both the software implementation and the brain itself. The first challenge remains un-explored territory but is central to the translation of BCI technology to SCI patients..

2.3. Our Approach to Clinical Translation

We expect to make considerable changes in our system during the evolution from the laboratory experiments on healthy volunteers to clinical studies on SCI patients. Our inclusion/exclusion recruitment criteria will initially only allow patients with some level of residual movement and good cognition to be included. This is to potentially ensure subjects will understand instructions and will be able to train to use the S-BCI. We are encouraged by our preliminary experiments and results^{6,7} on extracting spatio-temporal features from spinal cord injured patients during imagined or attempted movements. Our experimental design will be simplified to binary cued tasks with visual feedback. The task initially will be to turn the wheelchair in the virtual environment in only one direction and to stop it. Increasing the number of degrees of freedom with the BCI control will follow.

3. Where we should be in the next few years

In the next few years, we will be focusing on our pilot clinical trials identifying a clear path for translation of S-BCI for use in clinical scenarios to achieve two inter dependent objectives (1) development of an assistive/augmentative system for people with severe motor disability (2) further our understanding of neural mechanisms responsible for generation and control of movement in healthy and motor impaired subjects.

As the world-wide burden of brain-related illness exceeds \$2 trillion/year, in the next decade there will be greater unmet need to develop assistive and augmentative devices for the motor disabled and ageing population. The role of BCI technologies for use as brain training tools and systems to encourage plasticity and brain re-organisation will attain greater significance. In addition to clinical applications, we foresee a role for non-invasive BCI in pervasive and embedded control systems.

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