Development of Complex Curricula for Molecular Bionics and Infobionics Programs within a consortial* framework**

Consortium leader

PETER PAZMANY CATHOLIC UNIVERSITY

Consortium members

SEMMELWEIS UNIVERSITY, DIALOG CAMPUS PUBLISHER

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**Molekuláris bionika és Infobionika Szakok tananyagának komplex fejlesztése konzorciumi keretben

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NEURAL INTERFACES AND PROSTHESES

Neurális interfészek és protézisek

Perspective of Brain-Machine Interface

(Agy-gép kapcsolat perspektívája)

BALÁZS DOMBOVÁRI & GYÖRGY KARMOS

IN THIS LECTURE YOU'LL LEARN:

- Future direction of invasive and non-invasive BCI development
- What are the issues to improve neural recordings
- What is a hybrid BCI
- Today's commercially available BCI systems

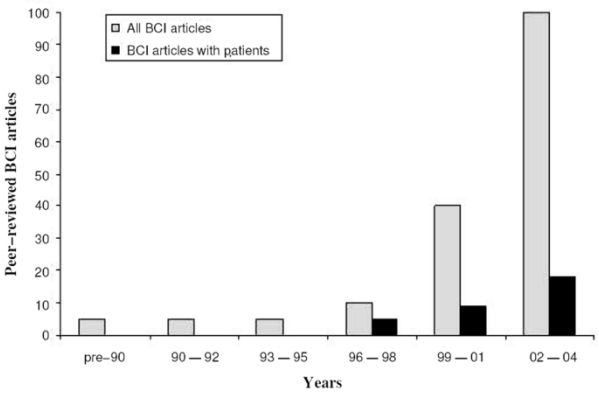
INTRODUCTION

BCI research became a very popular research area in the recent years. The number of BCI related papers has been extremely multiplied thanks to the fast evolution of the technology.

Most of the BCI research groups are focusing on the restoration of communication and control of severely paralyzed patients.

But BCI communication is becoming useful for healthy people too.

The goal of this lecture is to show some possible opportunities of future BCI research.



Dornhege,G. (ed.) Toward Brain-Computer Interfacing, MIT Press, 2007

CRUCIAL ISSUES FOR DEVELOPING BCIS IN THE FUTURE

- BCI independence from normal neuromuscular communication channels and dependence on internal aspects of normal brain function;
- Selection of signal acquisition methods, signal features, feature extraction methods, translation algorithms, output devices, and operational protocols;
- Development of user training strategies;
- Attention to psychological and behavioral factors that affect motivation and success of the users;
- Adoption of standard research methods and evaluation criteria;
- Choice of applications and user groups;
- Reveal largely unknown capacities and limitations of non-muscular communication channels.

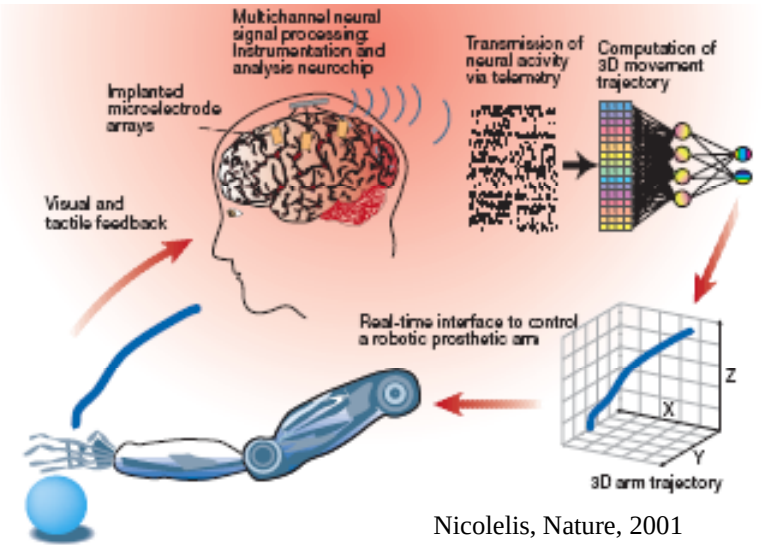
FUTURE DIRECTIONS OF INVASIVE BCIS

All of the present BCIs are „investigational devices”.

According to Miguel Nicolelis (Duke University), in the next 10-20 years brain-computer and brain-machine interfaces (BMIs):

- include fully implantable recording system
  - wirelessly transmit multiple streams of electrical signals, derived from thousands of neurons
- capable of decoding spatial and temporal characteristics of movements

These BMIs would utilize a combination of high-order motor commands and peripheral low-level control signals.



Nicolelis, Nature, 2001

FUTURE DIRECTIONS OF INVASIVE BCIS

To achieve the ambitious goal of creating a clinically useful invasive BMI for restoring limb mobility, one has to pass the following key bottlenecks:

- Develop a new type of 3D probe array with thousands of channels to obtain stable, very long-term recording of large population of neural ensembles from multiple brain areas.
- Develop computational efficient algorithms into BCI software which translate the neural activity into command signals for artificial actuators.
- Implement new type of limb prosthetics which are capable to accept above mentioned command signals.

ISSUES TO IMPROVE NEURAL RECORDINGS

Currently chronically implanted probe arrays offer the best compromise to operate invasive BCIs.

Several significant improvements are required before they become fully applicable for clinical applications in humans:

- Biological compatibility
- Wireless headstages to reduce the risks of infection

Many new ideas of how to improve neuronal recordings have been proposed recently.

These range from ceramic-based multi-electrode arrays to nanotechnology probes that access the brain through the vascular system.

HYBRID BCI

Conventional BCIs rely on only one signal (e.g. ERD/ERS, steady-state evoked potentials, P300 evoked potentials, etc).

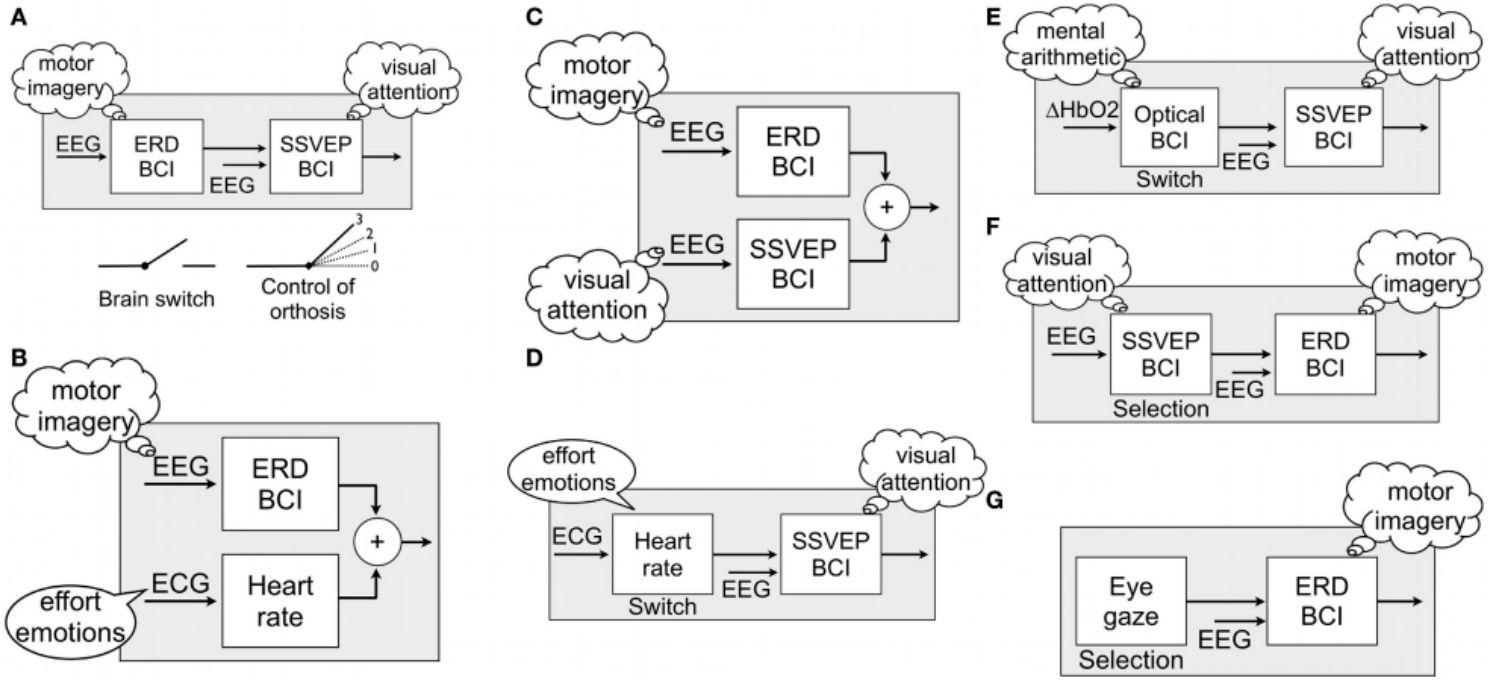
Hybrid BCIs exploit the advantages of different approaches.

A typical hybrid BCI is composed of one BCI and another system (which might be another BCI), and must achieve specific goals better than a conventional system.

The hybrid BCI can either have more than one input and the inputs are typically processed simultaneously.

One of the great challenges in hybrid BCI research is identifying the best combinations of signals to accomplish desired goals.

HYBRID BCIS



Hybrid BCI can have two inputs and the inputs are typically processed *simultaneously* (B,C), or can operate two systems *sequentially*, whereby the first system can act as a "brain switch" (A,D,E) or as "selector" (F,G).

Pfurtscheller et al. Frontiers in Neuroscience 2010

H-BCI CONTROLLED ARM FES-ORTHOSIS

As an example, a hybrid-Brain Computer Interface (h-BCI), i.e. a combination of a brain switch and a shoulder position sensor, for control of an arm neuroprosthesis based on Functional Electrical Stimulation (FES) and a mechanical orthosis, can be helpful for spinal cord injured hemiparetic patients.

For setup of the brain switch a special pattern in the recorded EEG signals (beta rebound) after imagination of foot movements is being analyzed. When the BCI-output (classifier) exceeds certain thresholds, two different brain-switch signals are generated, which select predefined control modes. They controls the degree of elbow flexion / extension or the degree of hand opening / closing, depending on the movements of the shoulder.

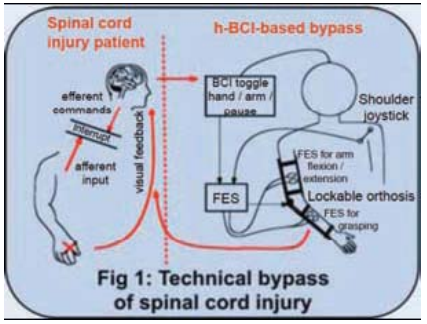


Fig 1: Technical bypass of spinal cord injury

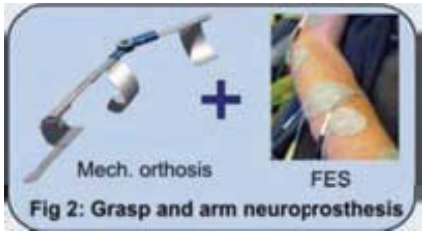


Fig 2: Grasp and arm neuroprosthesis

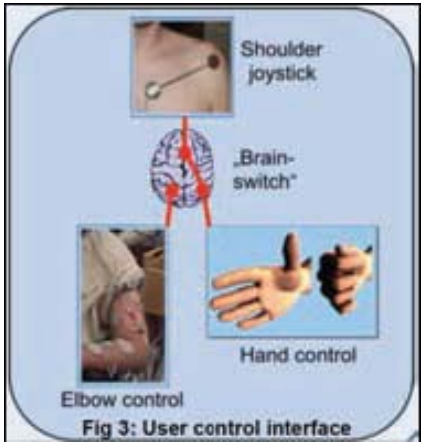


Fig 3: User control interface

TOBI-Newsletter, ISSUE Nº 2 May 2011 www.tobi-project.org

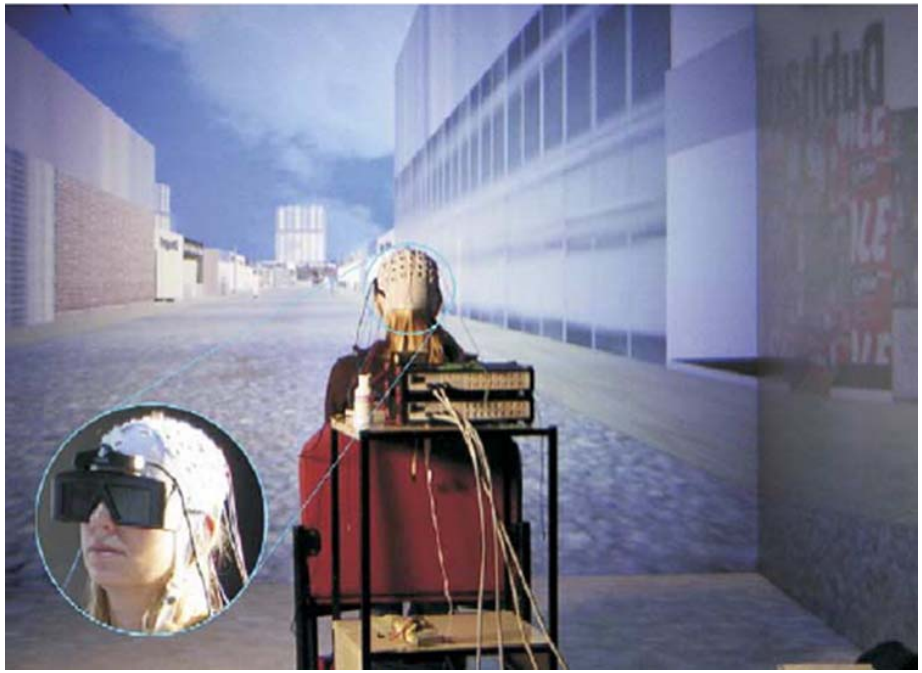
BCI AND VIRTUAL REALITY

Combining BCI with virtual environment (VE) was found to improve performance of the subjects. They made fewer errors, reported that BCIs were easier to learn and use, and they enjoyed BCI use more.

VEs enhanced vividness and mental effort, which led to more distinct brain patterns and improved pattern recognition performance.

Leeb et al., Comput. Intell. Neurosci, 2007

Leeb et al., IEEE Rehabilitation, 2007



Participant during the experiment. In the background, the virtual street with shops and animated avatars is projected in stereo view so that the participant has the illusion of being in the street. In reality, the subject is sitting on a comfortable chair, wearing shutter glasses and an electrode cap (see zoomed picture).

Pfurtscheller et al., Brain Res., 2006

INTERNATIONAL BCI RESEARCH PROJECTS

Effective BCI research and development require efforts of scientists of different fields. A series of international collaborative projects are in progress:

TOBI is a European integrated project which will develop practical technology for brain-computer interaction (BCI). (2008-2012) http://www.tobi-project.org/

DECODER is a European project that will deploy BCI for the detection of consciousness in non-responsive patients. (2010-2012) http://www.decoderproject.eu/

BETTER is a European project that will develop a new approach for gait training in which assistive technologies (ATs) might be improved if combined with non-invasive BNCI. (2010-2012). http://www.iai.csic.es/better/

BrainAble is a 7th Framework Programme „Autonomy and social inclusion through mixed reality Brain-Computer Interfaces: Connecting the disabled to their physical and social world" http://www.brainable.org/en/Pages/Home.aspx

Walk Again is a multinational collaborative program to develop high performance brain-controlled prosthetic device. http://www.walkagainproject.org/

Future BNCI is a project funded by the Seventh Framework Programme, exploring future directions with BCIs. http://future-bnci.org/

COMMERCIALLY AVAILABLE BCI SYSTEMS

In the recent years a series of companies producing electrophysiological instruments developed BCI systems. These are using the results of the research laboratories. These BCI systems may be used in further research applications but at the same time they intend to simplify research-grade EEG for everyday use for the people.

Since the idea of BCI became very popular companies are advertising these systems as tools using thoughts, feeling, emotion to be more creative or to relax. Games are developed using BCI to direct ball or so. Even it is suggested for market research to get true insight about how people respond and feel about material presented to them.

The BCI technology is moving to toys, games. It may get important role in sports as well as in alertness control in cars etc. In this way BCIs are going to become part of our everyday life.

EMOTIV EPOC NEUROHEADSET

14 channel high resolution, neuro-signal acquisition and processing wireless neuro-headset.

The Emotiv Software Development Kit includes a TestBench software which provides real-time display of the Emotiv headset data stream, including EEG, contact quality, FFT, gyro, wireless packet acquisition/loss display, marker events, headset battery level.

Affective suite can reportedly measure the emotional states of the user. Anger, fear, frustration. Emotiv puts forth the example that this could be used to have games increase or decrease the difficulty level depending on the player's state of mind.

The Cognitive Suite is the control mechanism that allows players to control objects, and the

Expressive suite which measures and interprets facial expressions of the user. The descriptions and demos are vivid, for example: You smile and thus your avatar smiles.

http://www.emotiv.com http://www.emotiv.com/corporate/media.php

BCI SPELLER OF G.TEC MEDICAL ENGINEERING

The **intendiX**® system is based on visually evoked EEG potentials (P300).

It enables the user to sequentially select characters from a keyboard-like matrix on the screen just by paying attention to the target for several seconds.

Spelling rate of 5 to 10 characters per minute can be achieved by the majority of healthy users at their first trial.

To control external devices a special extension tool called **"extendiX"** serves as an interface.

Video here

http://www.gtec.at/ http://www.intendix.com

THE NEUROSKY BCI

The Neurosy company defines the mission of the company to create a paradigm shift in biosensors and make them accessible for a broad market outside the laboratory. They intend to simplify research-grade EEG for everyday use for real people.

Their systems are combining EEG (brain waves), EMG (muscle activity), EOG (eye movement) and ECG (heart) biosensing. The Neurosky systems are developed for research, education, sport and entertainment applications.

There are currently over a dozen games and educational applications available for download.

Mattel partnered with NeuroSky to release the Mindflex game in 2009.

http://www.neurosky.com

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REVIEW QUESTIONS:

Which are the crucial issues for developing future BCIs?

What is hybrid BCI?

What is the advantage of the hybrid BCI?

How can be used virtual reality in a BCI?

What are the trends in the present BCI researc projects ?

For what can be used the commercially available BCIs?