hiVE
HYPER INTERACTION VIABILITY EXPERIMENTS

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Starlab Living Science

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YEAR 4 NEWSLETTER - Summer 2012

HIVE is a 4 year project

[2008-2012] funded by the European Commission and coordinated by Starlab under the Future Emerging Technologies (FET Open) - ICT program nursery of novel and emerging scientific ideas.

Our Mission

Our mission is to research new stimulation paradigms and create a new generation of non-invasive brain stimulation technologies.

The Team

The HIVE consortium spans researchers from several countries in Europe, including Spain, Portugal, Germany, France, Greece and the United Kingdom. The coordinator is [Starlab](), an SME with the specific company mission of transforming science into technologies with a clear positive impact on society.

Challenge 1

Improve our understanding of the effects of stimulation at the neuron and neuronal ensemble level.

The project has investigated the biophysics of stimulation at the theoretical, computational and experimental level — both in humans and animals.

Challenge 2

Find solutions for currently unfocused, un-precise stimulation technologies.

Develop new multisite current stimulation paradigms to implement more controllable and effective stimulation technologies and applications and subsequently explore related applications.

Challenge 3

Investigate fundamental mechanisms and clinical applications of tCS through animal and human stimulation experimental work.

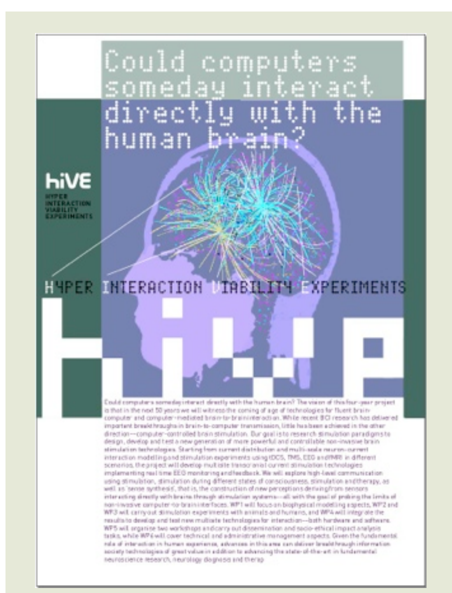
The project has and continues to explore new stimulation paradigms to communicate and interact with neural ensembles and the human brain.

COULD COMPUTERS SOMEDAY INTERACT DIRECTLY WITH THE HUMAN BRAIN?

The HIVE project (2008-2012) is now near its closing. HIVE's vision is to explore the potential of non-invasive brain stimulation to realize the concept of "hyperinteraction". By **hyperinteraction** we mean technology mediated brain-to-brain communication, that is, the computer mediated transmission of information from a brain directly to another via brain monitoring of the sender (BCI) and non-invasive, transcranial current stimulation (tCS) in the receiver (CBI). HIVE targets brain to computer information transmission (CBI).

EXPERIMENTAL PROGRESS (end of Y3)

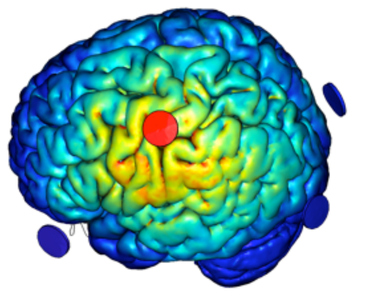
Animal studies have been conducted illuminating the fundamental mechanisms of tDCS plasticity (the after effects of stimulation), and provided a new model to study the effects of stimulation in learning. In addition, the concept of "**hyperinteraction**", that is, the direct generation of perceptions and, hence, transmission of information, by transcranial stimulation of the cortex, has been **demonstrated in the rabbit.**

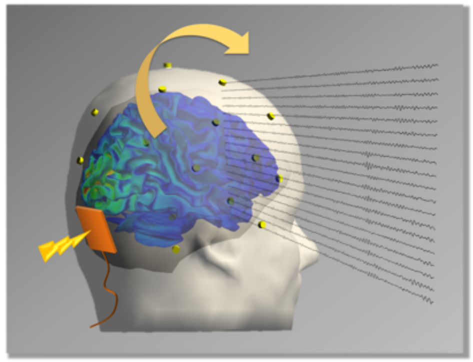


Technologies such as EEG or MRI give important insights into the brain areas that are involved in mental functions. However to prove the necessary involvement of a brain region it is necessary to perturb its activity during a task. We have combined tCS with brain monitoring (EEG and MRI) to **further our understanding of the neural bases of functions such as object manipulation and mental rotation.** By combining the skills of several partners we have contributed to our scientific knowledge in ways that will eventually translate into strategies for aiding people with neurological disorders.

Human studies from researchers worldwide have shown that tDCS ha significant potential for treatment of chronic neuropathic pain, major depression and for stroke rehabilitation. In this project we investigated the effects of tDCS in patients diagnosed with **Persistent Vegetative State (PVS) or Minimal Consciousness State (MCS)** and secondly we sought to explore the effects of tDCS and tACS in patients with **Cervical Dystonia (CD)**. The first study provides encouraging results for patients who are in MCS for less than a year and the second study gives promising outcomes for the tACS as a possible therapeutic tool for CD in the future. With regards to **sleep applications**, we have found that if stimulation is done shortly before sleep onset or during the first hour of sleep there seem to be some effects on **sleep** and **memory** functions – confirming earlier reports. This will be investigated further with the new device - which was designed for this kind of investigations.

In the next few months, the project’s final experiments on hyperinteraction will be completed.



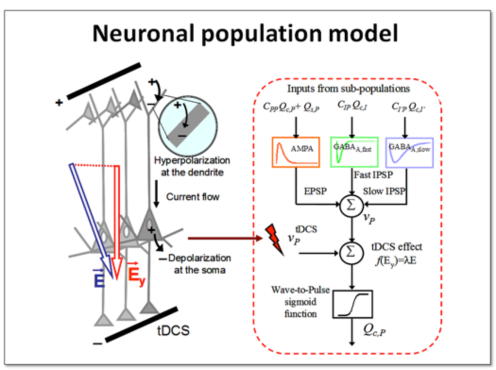


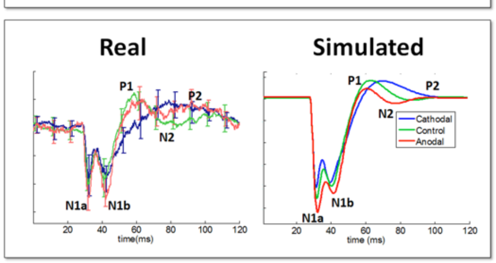
ELECTRIC FIELDS IN THE BRAIN

In HiVE, we have developed a realistic head model for the calculation of the **electric field in the brain during tCS.** Magnetic Resonance images were used to define the various surfaces in the model, with special attention being paid to the representation of the cortical surface.

Using this model we were able to demonstrate the significant impact of tissue geometry and heterogeneity on the electric field in the brain. We also computed the normal and tangential components of the electric field on the cortical surface. This information is needed to model the interaction between the electric field and the neuronal populations in the cortex.

The model was also used to investigate the advantages of multi-electrode stimulation over the traditional bipolar montage, a key aspect of the technology developed in the project.





This neuronal population model contributes to a major issue of HIVE: better understanding of the local response of cortical circuits to externally-applied electric fields induced by direct stimulation of the cortex.

NEURAL MODELS

Another important aim has been to provide neurophysiological models describing the local effect of stimulation on the cerebral cortex (as reflected in local field potentials) and its global effects on brain neurodynamics (as reflected in scalp EEG signals). These weak fields, turns out, couple rather efficiently with neurons, affecting population dynamics and, in turn, giving rise to plastic phenomena. In the project an end-to-end numerical model of electrical stimulation to electric fields to neuronal dynamics and measurable EEG has for the first time been implemented. A neural mass model was developed based on a literature review about the cytoarchitecture of the cerebral cortex. Model parameters were identified based on real signals recorded in rabbits from the somatosensory cortex (SSC). This model is capable of accurately replicating actual evoked potentials (EPs) obtained by stimulation of the rabbit's whiskers and, in addition, it reproduces the effects of tDCS. The model provides insights about i) the respective contribution of the subpopulations of cells to the SSC EPs, ii) the effect of the stimulation on main cells and on interneurons and iii) the interpretation of real responses with respect to stimulation parameters.

As far as the **impact of tCS at global level** is concerned, we developed a brain model that can reproduce EEG signals as recorded in human subjects. This model starts from the aforementioned neuronal population model that was extended in order to describe the activity generated over the entire neocortex. Based on i) this realistic representation of neocortical sources which activity can be influenced by externally-applied electric fields, ii) a description of the volume conductor (the head) properties and iii) the distribution of the electric fields within this volume conductor, we could solve the forward problem in order to simulate EEG data at the level of scalp electrodes. In a first step, we focused on alpha EEG activity recorded during rest and have provided some testable predictions of the effects of tCS in EEG.

TECHNOLOGY

The second challenge tackled by HIVE is technological. As of date, only rather coarse, unfocused current stimulation technologies are available. An important objective of this project has been to develop new multisite current stimulation system to implement more controllable and effective stimulation applications. The project has now developed a groundbreaking multisite transcranial current stimulation and monitoring system for finer control of current flows in the brain and for subsequent exploration of related applications. The system will soon be released as a product - named **StarStim** – by **Neuroelectrics**, a newly founded Starlab spin-off dedicated to the commercialization of advanced electrophysiological medical devices. StarStim is a unique wireless device for transcranial stimulation research and clinical practice, capable of EEG recording and current stimulation using arbitrary current programmable waveforms from 8 independent channels.

Recent project publications

TRANSCRANIAL DIRECT-CURRENT STIMULATION MODULATES SYNAPTIC MECHANISMS INVOLVED IN ASSOCIATIVE LEARNING IN BEHAVING RABBITS, Márquez-Ruiz et al., Proc Natl Acad Sci U S A. 2012 Apr 9.

TRANSCRANIAL CURRENT BRAIN STIMULATION (TCS): MODELS AND TECHNOLOGIES, Ruffini et al., To appear in IEEE TNSRE Special Issue - 2012.

PERIPHERAL SENSORY STIMULATION CAN BE SUCCESSFULLY SUBSTITUTED BY TRANSCRANIAL ALTERNATING CURRENT STIMULATION (TACS) OF THE SOMATOSENSORY CORTEX FOR ASSOCIATIVE LEARNING IN BEHAVING ANIMAL, Márquez-Ruiz et al., submitted to J. of Neuroscience.

EFFECTS OF TRANSCRANIAL DIRECT CURRENT STIMULATION (TDCS) ON CORTICAL ACTIVITY: A COMPUTATIONAL MODELING STUDY, Molaee-Ardekani et al., Brain Stimul. 2012.

tACS REDUCES SYMPTOMS IN IDIOPATHIC CERVICAL DYSTONIA, Angelakis et al., Submitted to Movement Disorders.

STIMULUS-SPECIFIC SLOWING OF MENTAL ROTATION WITH CATHODAL TRANSCRANIAL DIRECT CURRENT STIMULATION OF MOTOR CORTICAL AREAS, Davis et al., Submitted to J. of Neuroscience.

EFFECT OF ELECTRODE SIZE ON FOCALITY OF TRANSCRANIAL CURRENT STIMULATION: A MODELLING STUDY USING REALISTIC ELECTRODE AND HEAD MODELS, Salvador et al., CLIN NEUROPHYSIOL, 2011; 122(S1): S34

See http://hive-eur.org for a complete list of publications