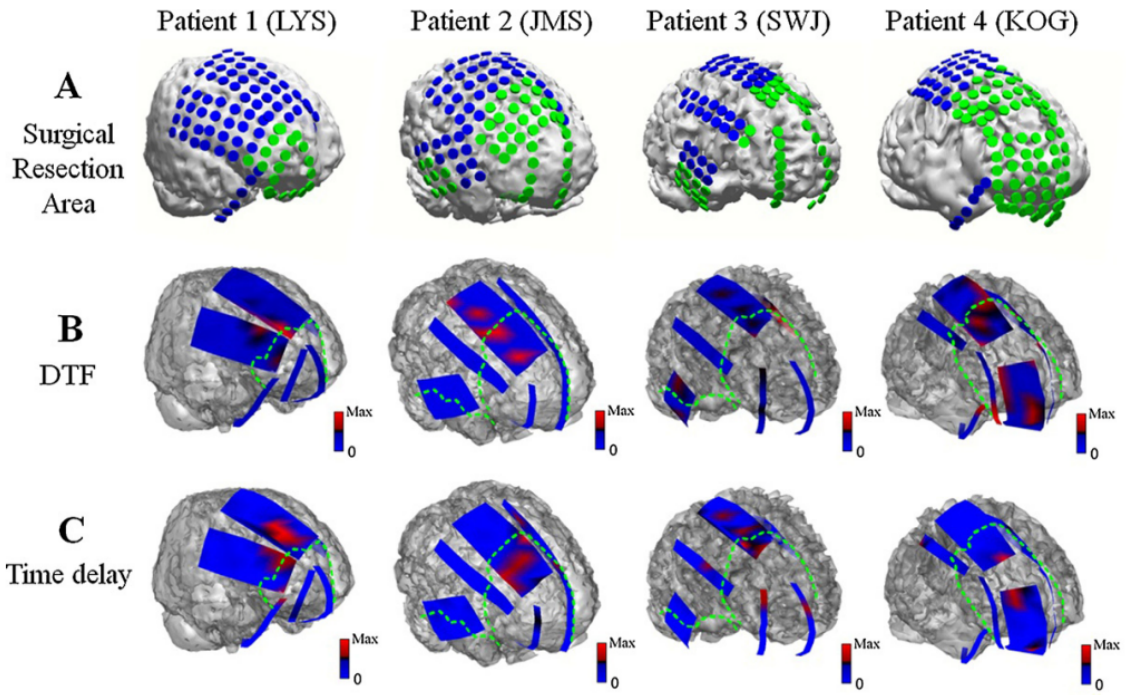
Computational Neuroengineering (CoNE) Laboratory

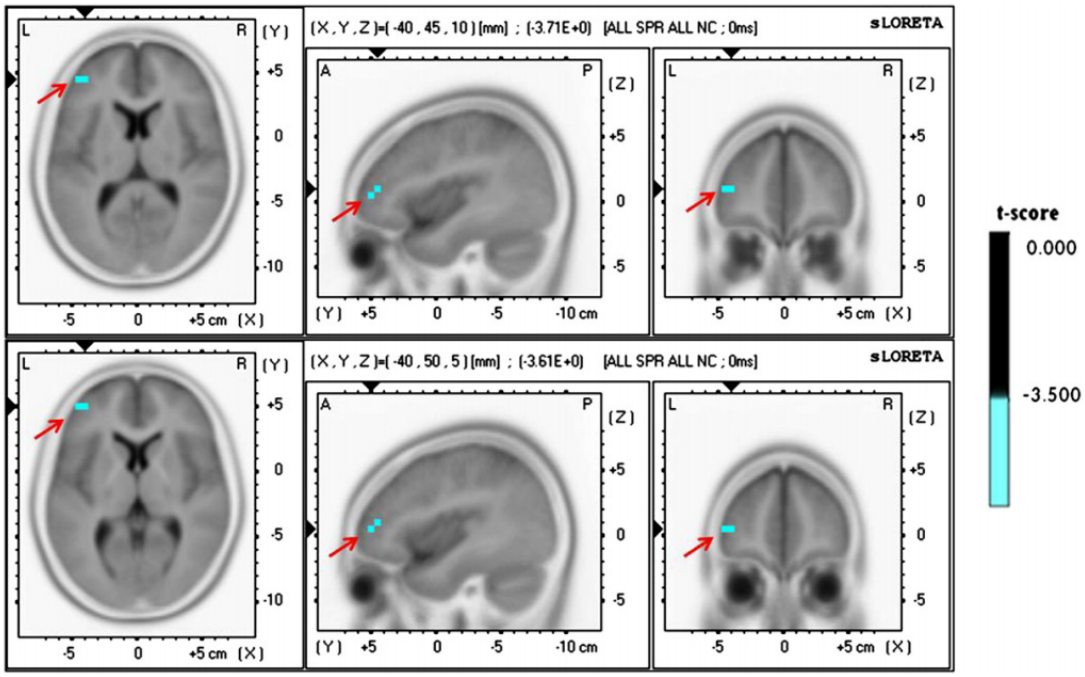
Localization of ictal onset zones in Lennox-Gastaut syndrome (LGS) based on information theoretical time delay analysis of intracranial electroencephalography (iEEG)

Precise localization of ictal onset zones is of great clinical importance for successful surgery in patients with intractable drug-resistant epilepsy. Time delay analysis has been one of the most reliable and most widely used computational electroencephalogram (EEG) analysis methods for localizing ictal onset zones. However, the majority of previous studies have only been applied to the localization of ictal onset zones in focal epilepsy. In the present study, we analyzed intracranial EEG (iEEG) recordings acquired from patients with Lennox—Gaustaut syndrome (LGS), which is a type of intractable, pediatric, secondary generalized epilepsies with bilaterally synchronous ictal epileptiform discharges. To estimate the ictal onset zones from ictal iEEG recordings, we estimated time delays among iEEG signals based on the information theoretical approach. The results of the time delay analysis applied to the iEEG data of four successfully treated LGS patients corresponded well with the surgical resection areas identified by experienced epileptologists and multiple neuroimaging modalities, suggesting that the time delay analysis may provide useful information on the precise locations of ictal onset zones prior to epilepsy surgery in LGS patients. [**published in Epilepsy Research, 2012**]



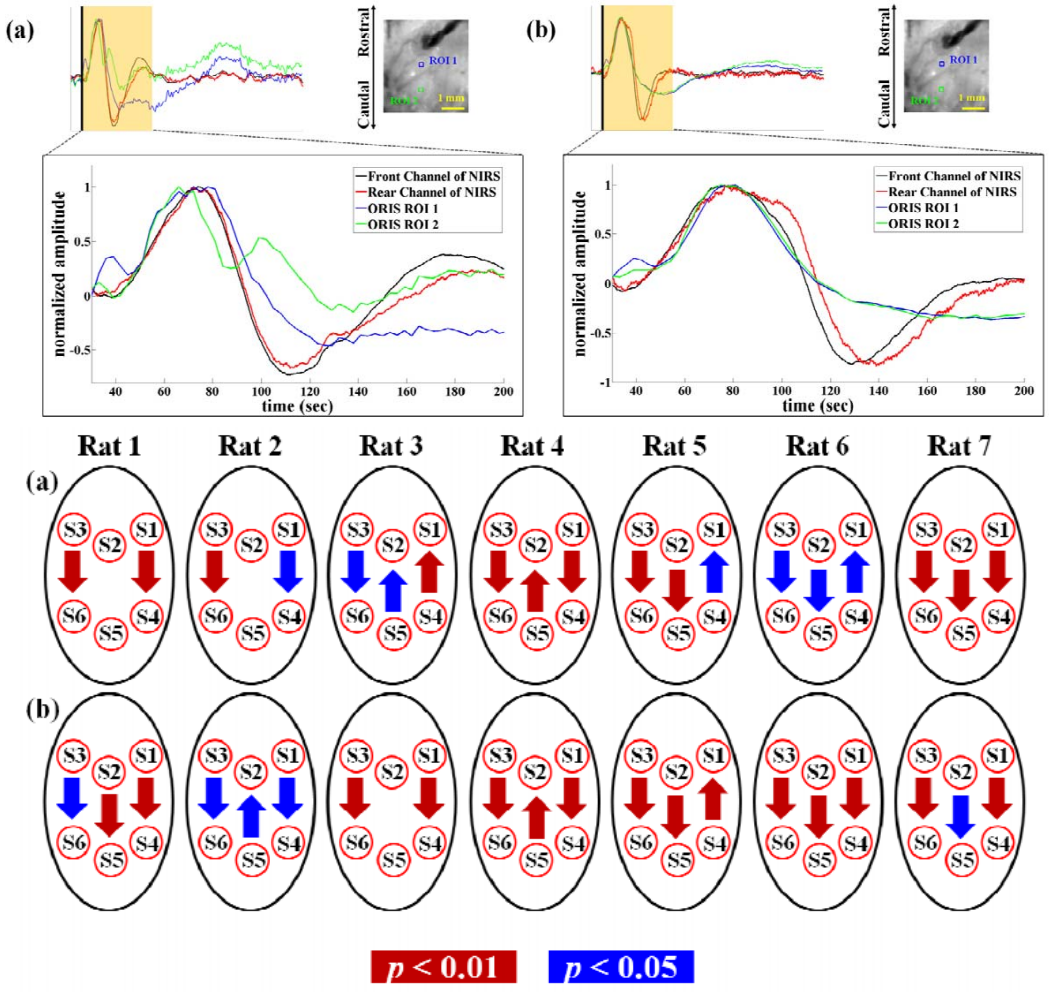
Reduced Source Activity of Event-Related Potentials for Affective Facial Pictures in Schizophrenia Patients

The ability to recognize facial affect is impaired in schizophrenia patients. This study compared source activities of the event-related potentials (ERPs) for affective facial pictures between schizophrenia patients and healthy controls. Twenty-three schizophrenia patients (11 females) and 24 healthy controls (12 females) were recruited. The standardized low-resolution brain electromagnetic tomography (sLORETA) source activities of four ERP components (P100, N170, N250, and P300) were compared between schizophrenia patients and healthy controls in response to fearful, happy, and neutral facial expressions. Group differences of sLORETA source activities were found only for the N170 component in response to the fearful face. Source activities in the middle frontal gyrus and inferior frontal gyrus were lower in schizophrenia patients compared to healthy controls. Source activity in the insula was lower in male schizophrenia patients compared to male healthy controls. Source activities in the superior temporal gyrus, middle temporal gyrus, insula and inferior frontal gyrus were lower in male compared to female schizophrenia patients. However, there was no gender difference on ERP source activities in the healthy controls. These results support the hypothesis that schizophrenia patients have reduced N170 current source density in response to fearful faces. The area exhibiting reduced current source density includes the frontal and temporal cortex. The present results suggest that there may be gender differences in facial affect processing in schizophrenia patients. [**published in Schizophrenia Research, 2012**]



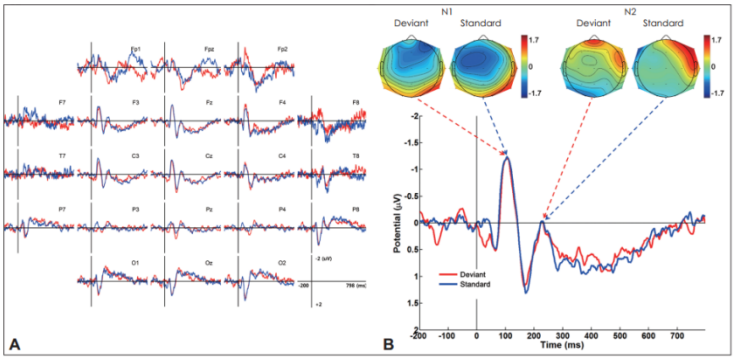
Depth-dependent cerebral hemodynamic responses following Direct Cortical Electrical Stimulation (DCES) revealed by in vivo dual-optical imaging techniques

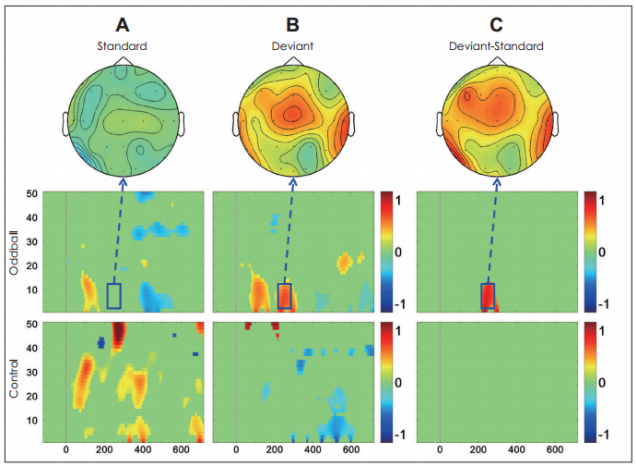
We studied depth-dependent cerebral hemodynamic responses of rat brain following direct cortical electrical stimulation (DCES) in vivo with optical recording of intrinsic signal (ORIS) and near-infrared spectroscopy (NIRS). ORIS is used to visualize the immediate hemodynamic changes in cortical areas following the stimulation, whereas NIRS measures the hemodynamic changes originating from subcortical areas. We found strong hemodynamic changes in relation to DCES both in ORIS and NIRS data. In particular, the signals originating from cortical areas exhibited a tri-phasic response, whereas those originating from subcortical regions exhibited multi-phasic responses. In addition, NIRS signals from two different sets of source-detector separation were compared and analyzed to investigate the causality of perfusion, which demonstrated downstream propagation, indicating that the upper brain region reacted faster than the deep region. [**published in Optics Express, 2012**]



Theta Oscillation Related to the Auditory Discrimination Process in Mismatch Negativity: Oddball versus Control Paradigm

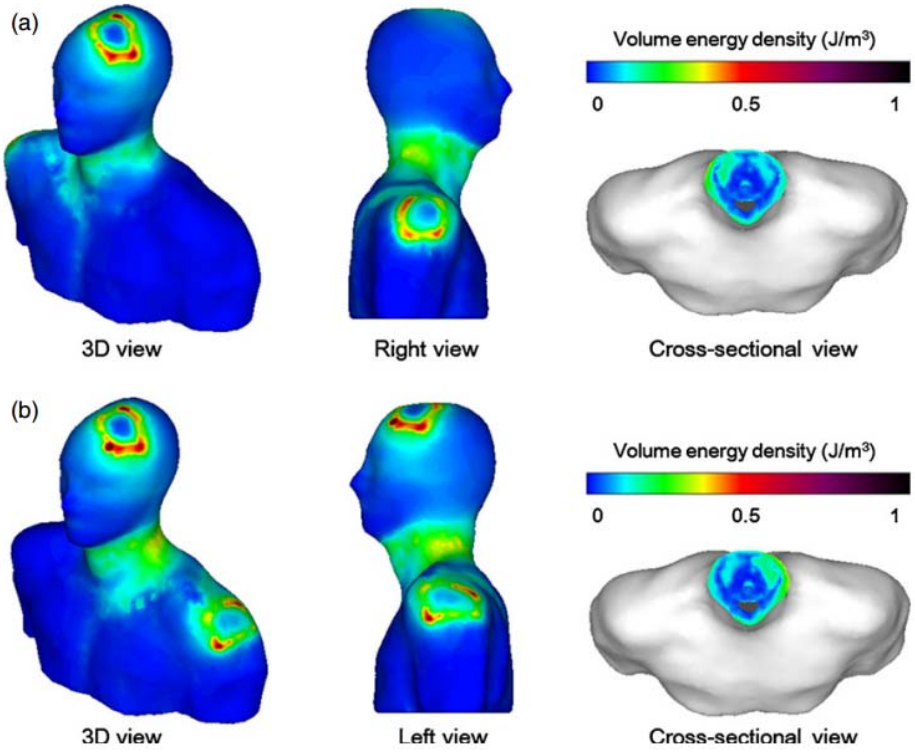
The aim of this study was to identify the mechanism underlying the auditory discriminatory process reflected in mismatch negativity (MMN), using time-frequency analysis of single-trial event-related potentials (ERPs). Two auditory tones of different probabilities (oddball paradigm) and the same probability (control paradigm) were used. The average dynamic changes in amplitude were evaluated, and the in-phase consistency of the EEG spectrum at each frequency and time window across trials, event-related spectral perturbations (ERSPs), and inter-trial phase coherence (ITC) were computed. Subtraction of the ERPs of standard stimuli from the ERPs of deviant stimuli revealed a clear MMN component in the oddball paradigm. However, no discernible MMN component was observed in the control paradigm. Statistical tests showed that in the oddball paradigm, deviant tones produced significant increases of theta ERSPs and ITC at around 250 ms as compared with the standard tone, while no significant difference between the two stimuli was observed in the control paradigm. Our results confirm that the auditory discriminatory process reflected in MMN is accompanied by phase resetting and power modulation at the theta frequency. [**published in Journal of Clinical Neurology, 2012**]





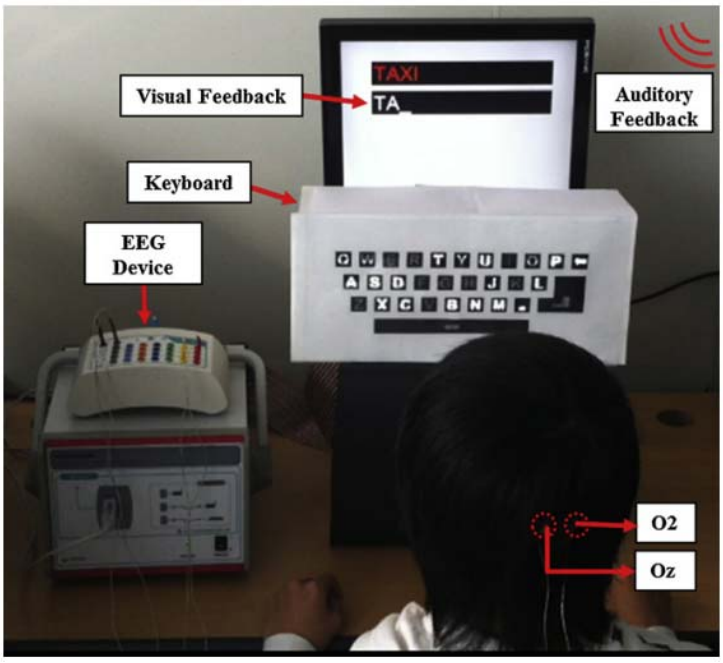
Evaluation of local electric fields generated by transcranial direct current stimulation (tDCS) with an extracephalic reference electrode based on realistic 3D body modeling

In this study, local electric field distributions generated by transcranial direct current stimulation (tDCS) with an extracephalic reference electrode were evaluated to address extracephalic tDCS safety issues. To this aim, we generated a numerical model of an adult male human upper body and applied the 3D finite element method to electric current conduction analysis. In our simulations, the active electrode was placed over the left primary motor cortex (M1) and the reference electrode was placed at six different locations: over the right temporal lobe, on the right supraorbital region, on the right deltoid, on the left deltoid, under the chin, and on the right buccinator muscle. The maximum current density and electric field intensity values in the brainstem generated by the extracephalic reference electrodes were comparable to, or even less than, those generated by the cephalic reference electrodes. These results suggest that extracephalic reference electrodes do not lead to unwanted modulation of the brainstem cardio-respiratory and autonomic centers, as indicated by recent experimental studies. The volume energy density was concentrated at the neck area by the use of deltoid reference electrodes, but was still smaller than that around the active electrode locations. In addition, the distributions of elicited cortical electric fields demonstrated that the use of extracephalic reference electrodes might allow for the robust prediction of cortical modulations with little dependence on the reference electrode locations. [**published in Physics in Medicine and Biology, 2012**]



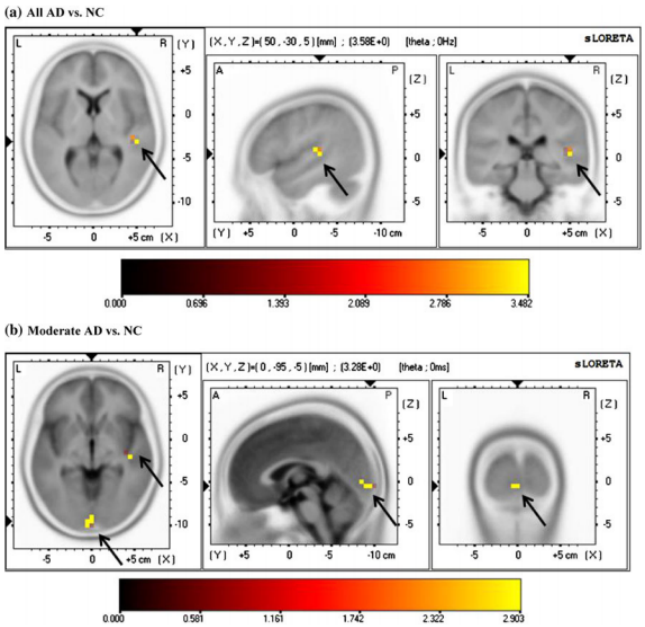
Development of an SSVEP-based BCI Spelling System Adopting a QWERTY-Style LED Keyboard

In this study, we introduce a new mental spelling system based on steady-state visual evoked potential (SSVEP), adopting a QWERTY style layout keyboard with 30 LEDs flickering with different frequencies. The proposed electroencephalography (EEG)-based mental spelling system allows the users to spell one target character per each target selection, without the need for multiple step selections adopted by conventional SSVEP-based mental spelling systems. Through preliminary offline experiments and online experiments, we confirmed that human SSVEPs elicited by visual flickering stimuli with a frequency resolution of 0.1 Hz could be classified with classification accuracy high enough to be used for a practical brain–computer interface (BCI) system. During the preliminary offline experiments performed with five participants, we optimized various factors influencing the performance of the mental spelling system, such as distances between adjacent keys, light source arrangements, stimulating frequencies, recording electrodes, and visual angles. Additional online experiments were conducted with six participants to verify the feasibility of the optimized mental spelling system. The results of the online experiments were an average typing speed of 9.39 letters per minute (LPM) with an average success rate of 87.58%, corresponding to an average information transfer rate of 40.72 bits per minute, demonstrating the high performance of the developed mental spelling system. Indeed, the average typing speed of 9.39 LPM attained in this study was one of the best LPM results among those reported in previous BCI literatures [**published in Journal of Neuroscience Methods, 2012**]



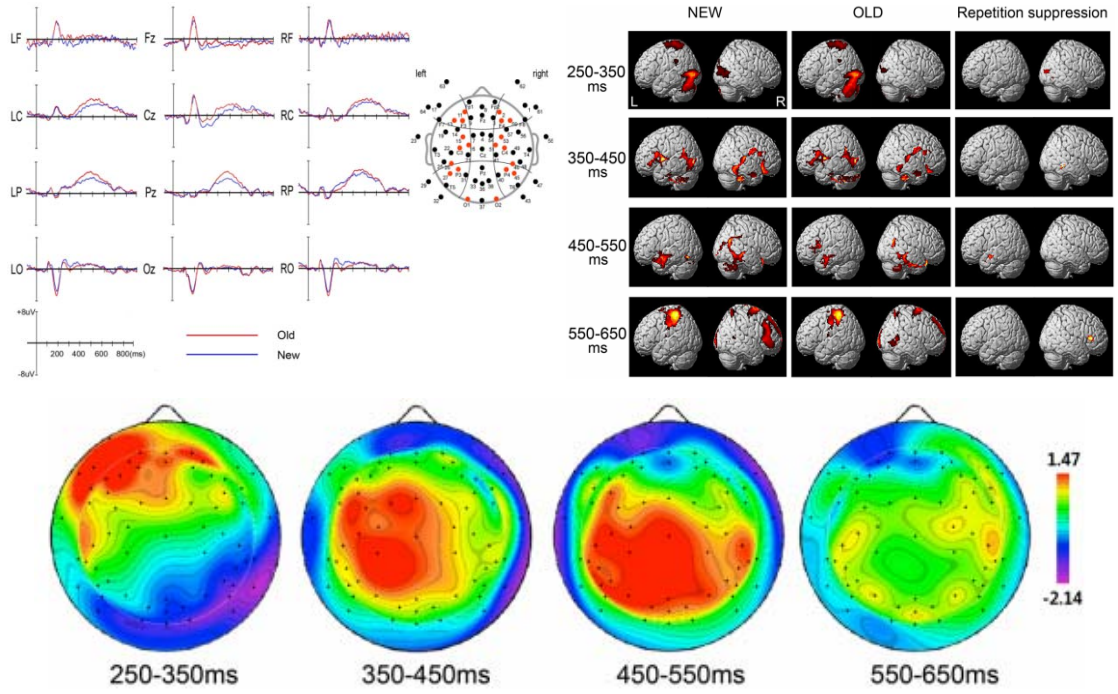
Clinical implications of quantitative electroencephalography and current source density in patients with Alzheimer's disease

This study examined whether quantitative electroencephalography (qEEG) and current source density (CSD) can be used to evaluate symptom severity in Alzheimer's disease (AD) patients. Thirty AD patients (13 mild and 17 moderate severity) and 30 normal control (NC) subjects were recruited. The Korean version of the Consortium to Establish a Registry for Alzheimer's Disease Assessment Packet and the Global Deterioration Scale were measured. qEEG and CSD data were analyzed in five frequency bands: delta (1–3 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta (13–25 Hz), and gamma (30–50 Hz). Compared with the NC subjects, the moderate AD patients had significantly increased theta and decreased beta power. Compared with the mild AD patients, the moderate AD patients had significantly decreased beta power. In the AD patients, the theta power was significantly correlated with a poor performance for global cognition; however, beta power was positively correlated with a good performance for global cognition, attention, memory, visuospatial function, and executive function. The CSD of the theta band in the superior temporal gyrus, transverse temporal gyrus, insula, postcentral gyrus, cuneus, and lingual gyrus was significantly different between NC subjects and moderate AD patients and between mild and moderate AD patients. The theta CSD of these regions was significantly correlated with a poor performance for global cognition, memory, visuospatial function, execution, and language. The results suggest that qEEG and the CSD of the theta and beta bands are useful biological markers in AD patients. [**published in Brain Topography, 2012**]



Electrophysiological correlates of object-repetition effects: sLORETA imaging with 64-channel EEG and individual MRI

We investigated the electrophysiological correlates of object-repetition effects using an object categorization task, standardized low-resolution electromagnetic tomography (sLORETA), and individual magnetic resonance imaging. Sixteen healthy adults participated, and a total of 396 line drawings of living and non-living objects were used as stimuli. Of these stimuli, 274 were presented only once, and 122 were repeated after one to five intervening pictures. Participants were asked to categorize the objects as living or non-living things by pressing one of two buttons. The old/new effect (i.e., a faster response time and more positive potentials in response to repeated stimuli than to stimuli initially presented) was observed at 350-550 ms post-stimulus. The distributions of cortical sources for the old and new stimuli were very similar at 250-650 ms after stimulus-onset. Activation in the right middle occipital gyrus/cuneus, right fusiform gyrus, left superior temporal gyrus, and right inferior frontal gyrus was significantly reduced in response to old compared with new stimuli at 250-350, 350-450, 450-550, and 550-650 ms after stimulus-onset, respectively. Priming in response time was correlated with the electrophysiological priming at left parietal area and repetition suppression at left superior temporal gyrus in 450-550 ms. These results suggest processing of repeated objects is facilitated by sharpening perceptual representation and by efficient detection or attentional control of repeated objects. [**published in BMC Neuroscience, 2012**]

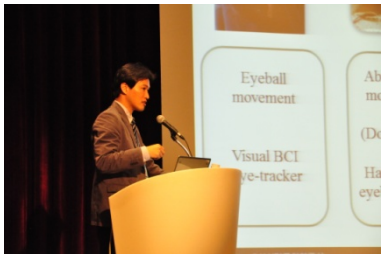


Highlights of the year

18th Annual Meeting of the Organization for Human Brain Mapping (2012.06.10)

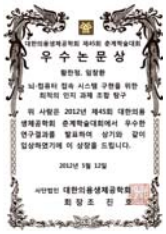
Members of CoNE laboratory attended the 18th Annual Meeting of the Organization for Human Brain Mapping from 10th to 14th of September, 2012, which was held in Beijing, China. The members presented their recent research results as poster presentation.

12th International Conference on U-healthcare (2012.10.27)



Prof. Im and Dr. Hwang from CoNE laboratory pariticpated in the 12th International Conference on U-healthcare. The conference provided a great opportunity for us to recognize the newest trend of the field. Prof. Im presented his recent works on brain-computer interface as an invited speaker.

45th Conference of Korean Society of Medical & Biological Engineering (2012.05.12)



Dr. Hwang from CoNE laboratory was bestowed on the Best Paper Award in the 45th Conference of Korean Society of Medical and Biological Engineering.

4th Conference of Korean Society for Computational Neuroscience (2012.08.20)

Dr. Hwang from CoNE laboratory was bestowed on the Best Poster Award in the 4th Conference of Korean Society for Computational Neuroscience.

46th Conference of Korean Society of Medical & Biological Engineering (2012.11.10)

Prof. Im from CoNE laboratoy was bestowed on the Biomedical Engineering Letters Award in 46th Conference of Korean Society of Medical & Biological Engineering.

Publications in 2012

International Journal

Yoon Kyum Shin, Dong Ryul Lee, Seung Guk Kang, Han Jeong Hwang, Sung (Joshua) Hyun You, Chang-Hwan Im, A Novel EEG-based Brain Mapping to Determine Cortical Activation Patterns in Normal Children and Children with Cerebral Palsy during Motor Imagery Tasks, NeuroRehabilitation, 2012, 31, 4, 349-355

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Dong-Hyun Baek, Chang-Hee Han, Ha-Chul Jung, Seon Min Kim, Chang-Hwan Im, Hyun-Jik Oh, James Jungho Pak, Sang-Hoon Lee, Soldering-based easy packaging of thin polyimide multichannel electrodes for neuro signal recording, Journal of Micromechanics and Microengineering, 2012, 22, art.no. 115017

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Nam G. Lee, Sung K. Kang, Dong R. Lee, Han J. Hwang, Ji H. Jung, Joshua H. You, Chang-Hwan Im, Dong A. Kim, Jung A. Lee, Ki S. Kim, Feasibility and Test-retest Reliability of an Electroencephalography-based Brain Mapping System in Children with Cerebral Palsy: A Preliminary Investigation, Archives of Physical Medicince and Rehabilitation, 2012, 93, 5, 882-888

Chang-Hwan Im, Ji-Hye Park, Miseon Shim, Won Hyuk Chang, Yun-Hee Kim, Evaluation of local electric fields generated by transcranial direct current stimulation (tDCS) with an extracephalic reference electrode based on realistic 3D body modeling, Physics in Medicine and Biology, 2012, 57, 2137-2150

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Jung, Theta Oscillation Related to the Auditory Discrimination Process in Mismatch Negativity: Oddball versus Control Paradigm, Journal of Clinical Neurology, 2012, 8, 35-42

Seungduk Lee, Dalkwon Koh, Areum Jo, Hae Young Lim, Young-Jin Jung, Choong-Ki Kim, Youngwook Seo, Chang-Hwan Im, Beop-Min Kim, Minah Suh, Depth-dependent cerebral hemodynamic responses following Direct Cortical Electrical Stimulation (DCES) revealed by in vivo dual-optical imaging techniques, Optics Express, 2012, 20, 7, 6932-6943

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Jae-Hyun Cho, Hoon-Chul Kang, Young-Jin Jung, Yong-Ho Lee, Ki-Young Jung, Heung Dong Kim, Chang-Hwan Im, Localization of ictal onset zones in Lennox-Gastaut syndrome (LGS) based on information theoretical time delay analysis of intracranial electroencephalography (iEEG), Epilepsy Research, 2012, 99, 78-86

Young-Jin Jung, Kyung Hwan Kim, Chang-Hwan Im, Mathematical Issues in the Inference of Causal Interactions among Multichannel Neural Signals, Journal of Applied Mathematics, 2012, 2012, 472036, 14

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Ki-Young Jung, Jae-Hyun Cho, Deokwon Ko, Hung Youl Seok, Ho-Kyoung Yoon, Heon-Jeong Lee, Leen Kim, Chang-Hwan Im, Increased corticomuscular coherence in idiopathic REM sleep behavior disorder, Frontiers in Neurology, 2012, 3, 60

Chang-Hwan Im, Special issue on neural engineering, Biomedical Engineering Letters, 2012, 2, 1, 1

Do-Won Kim, Jun-Chang Lee, Young-Min Park, In-Young Kim, Chang-Hwan Im, Auditory brain-computer interfaces (BCIs) and their practical applications, Biomedical Engineering Letters, 2012, 2, 1, 13-17

Myung-Sun Kim, Sung Hwa Oh, Kyoung Mi Jang, Huije Che, Chang-Hwan Im, Electrophysiological correlates of cognitive inhibition in college students with schizotypal traits, Open Journal of Psychiatry, 2012, 2, 68-76

Jong-Ho Choi, Feng Luan, Min-Hyuk Kim, Hyun-Kyo Jung, and Chang-Hwan Im, "Influence of orientation and area of the extended cortical current source on the magnetoencephalography (MEG) inverse problem, Biomedical Engineering Letters, 2012, 2, 2, 124-128

International Conference

Hyo-Jin Lee, Kyoung-Mi Jang, Chang-Hwang Im, Myung-Sun Kim, Electrophysiological correlates of working memory in college students with schizotypal traits, 18th Annual meeting of the Organization for Human Brain Mapping, 2012

Kyoung-Mi Jang, Myung-sun Kim, Chang-Hwan Im, Feedback-related negativity in the lowa gambling task: An event-related potential, 18th Annual meeting of the Organization for Human Brain Mapping, 2012

Seung-Hwan Lee, Sangrae Kim, Ji-Hye Park, Do-won Kim, Chang-Hwan Im, Preferential patterns of Gamma Band Activity to Socially-Relevant Stimuli in Schizophrenia Patients, 18th Annual meeting of the Organization for Human Brain Mapping, 2012

Miseon Shim, Chang-Hwan Im, An tDCS study with an extracephalic reference electrode based on realistic 3D body modeling, 18th Annual meeting of the Organization for Human Brain Mapping, 2012

Jeong-Hwan Lim, Han-Jeong Hwang, Chang-Hwan Im, Implementation of a standard-alone mental spelling system based on steady-state visual evoked potential, 18th Annual meeting of the Organization for Human Brain Mapping, 2012

Do-won Kim, Seung-Hwan Leem, Chang-Hwan Im, Source Activation during Face Emotional Processing Correlates with Symptom Severity in Schizophrenia, 18th Annual meeting of the Organization for Human Brain Mapping, 2012

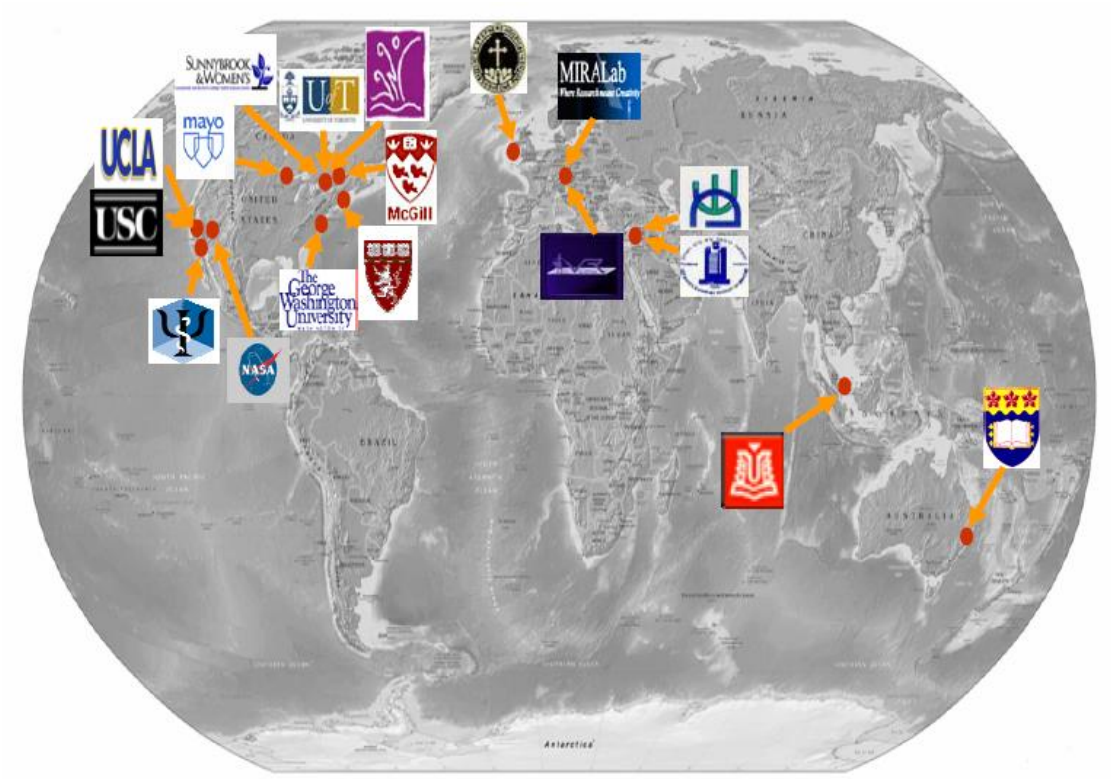
Han-Jeong Hwan, Chang-Hwan Im, A New Dual-Frequency Stimulation Method for SSVER-Based BCI and application to a mental keypad, 18th Annual meeting of the Organization for

Human Brain Mapping, 2012

Chang-Hwan Im, Classification of Selective Attention to Visual, Auditory, or Tactile Stimuli and Its Application to Brain-Computer Interfaces, 12th International Conference on U-healthcare, 2012

Chang-Hwan Im, Imaging of Functional Network Properties in Intractable Epilepsy Based on Neural Signal Analysis, 2012 12th International Conference on Control, Automation and Systems, 2012

Research Projects



Development of a mind reading system using real-time dynamic neuroimaging
[Ministry of Education, Science and Technology]
2009. 05~2012. 04

This project aims to develop a 'Mind Reading' system based on the proposed high-resolution brain-computer interface technology (HR-BCI), which can identify subjects' various intentions accurately to a level comparable to invasive BCI systems, thereby making a great contribution to the popularization of BCI technology. Topics include

- Development of fundamental technology to implement HR-BCI
- Optimization of various parameters to enhance the performance of HR-BCI
- Development of various techniques to enhance the reliability of HR-BCI.

Development of original technologies for brain-computer interfaces based on the spatiotemporospectral analysis of brain activity patterns
[Ministry of Education, Science and Technology]
2011. 07~2015. 06

The purpose of this project is to develop a high-performance brain-compute interface (BCI) system based on the spatiotemporospectral analysis of brain activity patterns, and apply the developed BCI system to the patients with locked-in syndrome. Topics include

- Development of the technology of decoding various human intentions based on spatiotemporaospectral analysis.
- Development of an asynchronous brain-computer interface system.
- Development of a rehabilitation assistive device based on brain-computer interface technology
- Development of a hybrid brain-computer interface system based on various experimental paradigms.
- Development of a customized brain-computer interface system for the patients with locked-in syndrome.

Development of a patient-specific image guided transcranical direct current stimulation (tDCS) system
[Ministry of Education, Science and Technology]
2010. 05~2013. 04

This project aims to develop an image-guided transcrainal direct current stimulation (tDCS) system, which can focally stimulate specific brain areas based on the individual anatomical images, thereby making a great contribution to the popularization of a tDCS system. Topics include

- Numerical analysis of conduction current during tDC stimulation.
- Development of an array-type tDCS system
- Validation of the efficiency of the proposed tDCS system

Development of a tDCS system specialized for the recovery of patients with chronic stroke
[Jeongwoo Medical, Co., Ministry of Knowledge and Economy]
2011. 12~2013. 11

This project aims to develop a tDCS system specialized for the recovery of patients with chronic stroke. Our laboratory takes a role to implement 3 dimensional electric field analysis software which can analyze and visualize local electric field distributions generated by tDCS. Our software will be incorporated with the tDCS hardware in order to increase the reliability and usability of the developed system.

Development of original technologies for the efficient communication of patients in completely locked-in state or persistent vegetative state based on neural signal decoding
[Ministry of Education, Science and Technology]
2012. 09~2015. 08

The aim of this study is to develop a novel mode of communication for individuals fallen into persistent vegetative state or completely locked-in state due to heart attack, external injury, and neurological disorders. We will develop new experimental paradigms, decoding algorithms, and training protocols for more accurate interpretation of the patients' intentions, thereby implementing a world first neural-signal-based communication system that can be applied to clinical applications.

Development of an efficient neurofeedback system using neurophysiological indices related to individual's intention
[Ministry of Education, Science and Technology]
2012. 05~2013. 04

The purpose of this project is to develop of a real-time neurofeedback system using neurophysiological indices related to individual's intention, and apply the developed neurofeedback paradigms to the user. Topics include

- Development of efficient feedback paradigms.
- Verification of optimal feedback methods using comparison of developed feedback paradigms.

- Improvement of developed real-time neurofeedback system using applying the feedback paradigm to the user.

Study on brain responses to different visual feedback delay using quantitative neural signal analysis
[LG electronics]
2012. 09~2012. 12

The aim of this project is to study brain responses to different visual feedback delay using quantitative neural signal analysis. We implement a visual feedback delay system and perform EEG experiments on 25 healthy participants. Using the quantitative neural signal analysis, we investigate the effect of visual feedback delay on neural signals.

Development of new current source imaging algorithms for precise measurement of brain activities
[KRISS]
2012. 02~2012. 11

The purpose of this project is to develop new current source imaging algorithms for precise measurement of brain activities. We develop current source imaging algorithms with excellent spatiotemporal resolutions, and investigate the mechanism of brain activities using functional connectivity analysis and network analysis.