LOC Symposium
Brain Machine Interfaces: Foundations and Perspectives

Organizers:
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How can the brain interface with computers, with prostheses, with avatars, or – in new ways - with the "own" body? In order to achieve this, new communication channels between the brain and these external devices (or the own body) have to be established. It will be important to get some – ideally real time – information about the status of the brain and to transfer this information to the respective device. It is also crucial to identify the "relevant" information of the brain and to be able to translate this info into something that can be "understood" and "translated" into some "action". This research field encompasses basic neuroscience, brain imaging, as well as clinical aspects. International leaders will inform us about the cutting edge of these developments.

Speakers:

Rainer Gobel
University of Maastricht Brain Imaging Centre, Maastricht University, The Netherlands
Real-Time fMRI Brain Computer Interfaces at 3 and 7 Tesla: From Basic Research to Clinical Applications
Recent progress in computer hard- and software allows the sophisticated analysis of fMRI data in real-time. Advanced online fMRI data analysis provides the basis for brain-computer Interface (BCI) applications such as neurofeedback and motor-independent communication. In neurofeedback studies, subjects observe and learn to modulate their own brain activity during an ongoing fMRI measurement. Because of its high spatial resolution, fMRI allows to provide content-specific feedback information from circumscribed cortical and subcortical regions. Many neurofeedback studies have demonstrated that with little practice, subjects are indeed able to learn to modulate brain activity in specific brain areas or networks using cognitive tasks, such as mental imagery or recalling emotional memories. The provided feedback information from task-relevant brain regions enables participants to adjust ("fine-tune") chosen mental tasks. We have recently shown that fMRI neurofeedback training not only enhances voluntary control over brain regions but that it also may have a significant therapeutic effect for patients suffering from neurological and psychiatric diseases. The selection of relevant brain regions as well as the emerging experience of self-control seem to be critical factors for therapeutic effects lasting beyond the real-time fMRI training sessions. Note that provided feedback needs not to be limited to mean activity levels from targeted bran areas: Recent developments calculate feedback signals from distributed activity patterns using machine learning classifiers or from functional connectivity measures reflecting the instantaneous coupling strength between brain areas or networks.

Besides neurofeedback applications, real-time fMRI can also be used to differentiate activation patterns evoked by participants engaging in various mental tasks. We have exploited this to build a hemodynamic communication BCI that decodes 27 distinct states from single-trial spatio-temporal activity patterns. By decoding these states online as letters of the alphabet, the developed system provides the possibility for patients with severe motor impairments to 'write' words on the screen letter-by-letter with high accuracy. While such hemodynamic BCI applications are successful, fMRI currently targets a level of resolution that does not allow inferring the sub-categorical feature representations used by the brain forcing subjects to engage in distinct mental tasks to encode different choices instead of directly imagining specific content such as the letters of the alphabet. We will present preliminary work towards novel BCI applications that exploit ultra-high field (UHF) scanners (7 Tesla and higher). These devices allow to study the human brain at a mesoscopic level discriminating cortical columns and cortical layers.

Andrew B. Schwartz
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Recent Work Towards High-Performance Brain-Computer Interface
A better understanding neural population function would be an important advance in systems neuroscience. The change in emphasis from the single neuron to the neural ensemble has made it possible to extract high-fidelity information about movements that will occur in the near future. This ability is due to the distributed nature of information processing in the brain. Neurons encode many parameters simultaneously, but the fidelity of encoding at the level of individual neurons is weak. However, because encoding is redundant and consistent across the population, extraction methods based on multiple neurons are capable of generating a faithful representation of intended movement. The realization that useful information is embedded in the population has spawned the current success of brain-controlled interfaces. Since multiple movement parameters are encoded simultaneously in the same population of neurons, we have been gradually increasing the degrees of freedom (DOF) that a subject can control through the interface. Our early work showed that 3-dimensions could be controlled in a virtual reality task. We then demonstrated control of an anthropomorphic physical device with 4 DOF in a self-feeding task. Currently, monkeys in our laboratory are using this interface to control a very realistic, prosthetic arm with a wrist and hand to grasp objects in different locations and orientations. Our recent data show that we can extract 10-DOF to add hand shape and dexterity to our control set. This technology has now been extended has been extended to patients who are paralyzed and cannot move their arms or hands.
Hansjorg Scherberger
German Primate Center, Gottingen, Germany
Coding and decoding of hand grasping movements
Hand function plays an important role in all primate species, and its loss is associated with severe disability. Grasping movements are complex motor acts for which the brain needs to integrate sensory and cognitive signals to generate behaviorally meaningful actions. To achieve this computation, specialized brain areas in the primate parietal (anterior intra-parietal area, AIP), premotor (area F5), and primary motor cortex (M1 hand area) are functionally connected. This presentation highlights recent experimental results in non-human primates to characterize how AIP, F5, and M1 generate grasping movements and how such movements can be decoded from spiking activity of these areas using permanently implanted electrode arrays while animals are grasping objects of various shape, size, and orientation. Besides understanding the underlying network structure and function, such characterizations are useful to evaluate the suitability of these preparatory and motor areas for the development of neural interfaces that aim to restore hand function in paralyzed patients.