New Methods for Brain Imaging and Stimulation

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Human brain activity can be monitored with magnetoencephalography (MEG) by measuring extracerebral magnetic fields produced by neuronal currents. Because these fields are extremely weak, being in the femtotesla range, superconducting SQUID magnetometers are used. On the other hand, the structure of the brain can be determined with magnetic resonance imaging (MRI), where the applied fields may be 15 orders of magnitude higher than the smallest neuromagnetic signals, normally ruling out simultaneous MEG. However, it has been demonstrated recently that simultaneous MRI and MEG is possible: the trick is prepolarization at about 0.1 tesla and MRI at about 50 microtesla. At Aalto University, we have built a hybrid multichannel helmet-shaped MEG-MRI prototype capable of ultra-low-field MRI and MEG using the same sensors. The main benefit of measuring MEG and MRI with the same detectors is superior registration and thereby improved source localization accuracy and reliability. In addition, MRI at ultra-low fields offers its own unique benefits such as quiet operation, lack of projectile hazard and improved safety when people with metallic implants or cardiac pacemakers are studied. Furthermore, the T1 contrast at low fields is superior to that at high fields.

Another focus of interest at Aalto University is transcranial magnetic stimulation (TMS) combined with multichannel electroencephalography (EEG). We use so-called navigated brain stimulation (NBS), which allows 3-mm accuracy in targeting the neuron-stimulating electric field. When the TMS-evoked EEG is recorded, one obtains direct measures of cortical excitability and time-resolved area-to-area connectivity. One can also monitor changes in excitability and connectivity in the course of treatment, medication, or rehabilitation.

Another technique under study and development at Aalto University is near-infrared spectroscopy or NIRS. In NIRS, infrared light is directed through the scalp and skull into the brain; the light that comes out informs us about the amount and oxygenation of blood in the path of the light. We are in the process of combining NIRS with both MEG and TMS studies.