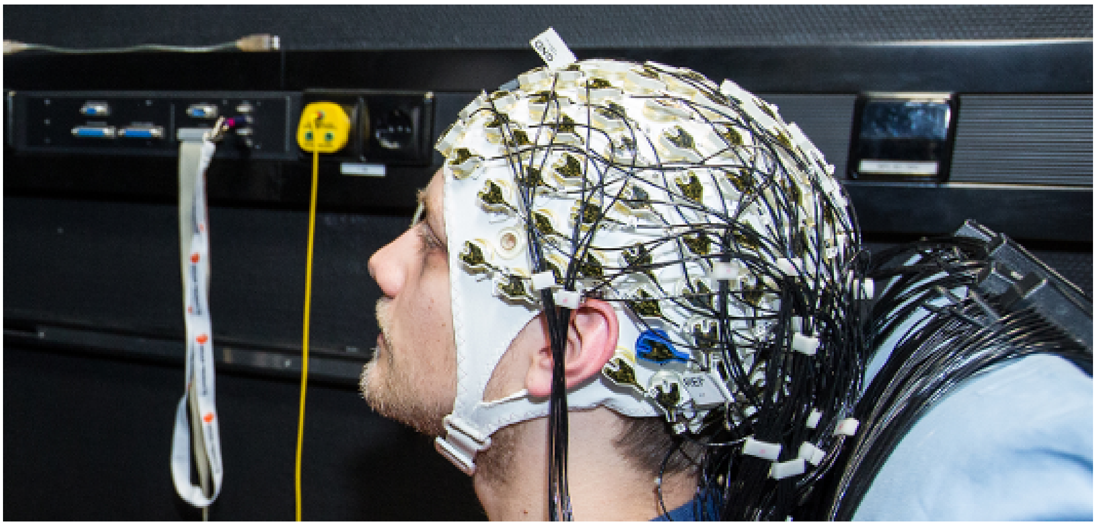
Brain-computer interfacing



Brain-computer interfaces (BCIs) translate neural recordings into signals that may be used for communication and/or the control of neuroprosthetic devices. Research in this domain poses interesting challenges to machine learning, because data is typically scarce, noisy, and non-stationary [186]. Furthermore, good decoding algorithms are contingent on domain knowledge that is not readily available and difficult to incorporate into traditional statistical methods. Accordingly, we employ machine-learning methods to study neural processes involved in BCI-control and use these insights to develop novel decoding algorithms and enhance experimental paradigms.

Machine learning algorithms for brain-state decoding A crucial aspect of our work is the development of algorithms for real-time brain-state decoding. We have developed a graphical model decoding framework for ERP-based visual speller systems [187]. Furthermore, we were the first to successfully apply the framework of multi-task learning to the domain of BCIs [560]. As the signal characteristics used by subjects to control a BCI share common aspects, the incorporation of data from previously recorded subjects substantially decreases calibration time and enhances overall decoding performance [13]. Besides working on methods for real-time decoding, we also develop tools to investigate the neural basis of disorders of cognition [14, 46]. This is essential to understand how the diseased brain differs from the one of healthy subjects, which has implications for the design of BCI systems for patient populations.

Brain-computer interfaces for communication Building upon our machine-learning methods, we have investigated the neural basis of the ability to operate a BCI in healthy subjects and in patient populations. We were able to show that the configuration of large-scale cortical networks, as represented in high-frequency gamma-oscillations of the brain's electromagnetic field, influences a subject's ability to communicate with a BCI [149, 174]. Building upon these insights, we have developed a novel class of BCIs for patients in late stages of amyotrophic lateral sclerosis [81, 346].

Brain-computer interfaces for rehabilitation While BCIs were initially conceived as communication devices for the severely disabled, we have argued that they can also be used for stroke rehabilitation [183]. By combining a BCI with a seven degrees-of-freedom robotic arm, serving an exoskeleton, we developed a brain-controlled rehabilitation robot supporting patients with chronic stroke in self-regulation of sensorimotor brain rhythms [194]. The concept of brain-controlled rehabilitation robotics can be extended to systems that monitor patients' learning progress to adapt the rehabilitation exercise in real-time [65].

More information: https://ei.is.tuebingen.mpg.de/project/brain-computer-interfaces