nature neuroscience

Focus on human brain mapping

We present a special issue highlighting considerations and recent developments in noninvasive techniques that improve our understanding of neural measurements in humans, bridging the gap between human and animal research in neuroscience.

Neuroscientists endeavor to understand how the brain develops and controls our perception of the world and our interactions with it. Animal models enable investigations of the genetic, molecular, cellular, circuit-level and neurophysiological mechanisms underlying these processes. Noninvasive technologies such as magnetic resonance imaging (MRI), magnetoencephalography (MEG) and electroencephalography (EEG) complement these approaches by assessing human brain structure and neural responses to complex behaviors. In this issue, *Nature Neuroscience* presents a series of commissioned pieces that discuss recent progress in several noninvasive techniques and put forth conceptual frameworks under which we can examine neuroimaging data to deepen our understanding of these rich data sets. These advances may help connect findings from various species and achieve a more complete picture of the brain's structure and function.

In light of growing concerns about the robustness and reproducibility of functional MRI (fMRI) research findings, the Organization for Human Brain Mapping has created the Committee on Best Practices in Data Analysis and Sharing (COBIDAS) to delineate standards for reporting MRI methods, analyses and data sharing. On page 299, the COBIDAS comments on reproducibility pertaining to MRI-based research and on the sociological impediments to adopting their suggested practices. (For our editorial stance on recent concerns about fMRI research, please see our accompanying editorial http://dx.doi.org/10.1038/nn.4521.)

fMRI data are acquired in high resolution across three spatial dimensions and time, yet standard analysis methods do not always take advantage of the richness of these data. On page 304, Nicholas Turk-Browne and colleagues discuss advanced fMRI analysis techniques that uncover unique insight into neural computations in humans, enable shared inferences about neural processes across multiple humans and describe a computing infrastructure for performing these cutting-edge analyses.

MRI also provides an unparalleled opportunity to noninvasively measure brain structure. On page 314, Jason Lerch and colleagues present the next installment of *Nature Neuroscience's* series promoting data quality. This piece provides an overview of the structural and diffusion MRI methods used to examine neuroanatomy at macroscopic, mesoscopic and microscopic scales, accompanied by important considerations for acquiring, analyzing and interpreting MRI data. The authors also briefly cover studies of human structural neurodevelopment and MRI applications in population neuroscience, a field that examines epidemiological and genetic influences on human brain structure.

Moving from neuroimaging data acquired with magnetic fields of typically 3 Tesla or more to measurements at the femtotesla scale (10^{-15} Tesla), MEG enables the detection of magnetic inductions that are generated by neuronal activity. On page 327, Sylvain Baillet reviews several aspects of MEG that are advantageous for examining neural processing in humans relative to EEG, fMRI or positron emission tomography (PET). The review also discusses the application of machine-learning techniques to MEG data, developments in making MEG data available on a larger scale ('big data') and some major conceptual advances provided by MEG research so far.

The complexity of neuroimaging data sets allows researchers to examine properties of collective neural activity at the level of networks. On page 340, Michael Breakspear provides an essential introduction to models of large-scale brain dynamics for neuroscientists. In his paper, he outlines core theoretical concepts for examining neural activity using this framework, as well as considerations and insights that might arise when this framework is applied to different modalities of neuroimaging data (fMRI, EEG, etc.). On page 353, Danielle Bassett and Olaf Sporns discuss parallel efforts in examining networks at the genetic, molecular, neuronal, regional and behavioral scale, and they encourage the neuroscience community to consider network-level research questions that bridge across scales and species.

Neuroimaging data are often used as 'biomarkers' for particular behavioral traits or disordered processes in the brain. On page 365, Tor Wager and colleagues provide a critical review of translational research in which neuroimaging data are used to predict clinical outcomes. Based on their survey of the published literature, they propose general recommendations for building better neuroimaging biomarkers for health and disease.

Given the breadth of human brain mapping techniques available in neuroscience research, it is difficult to cover each of these approaches in one journal issue. The methodologies highlighted in this focus issue are by no means intended to define the scope of neuroimaging work considered for publication at *Nature Neuroscience*. Rather, these pieces were commissioned to inform our readers about exciting advances in the field and to highlight some of the areas in which the field is rapidly developing. It is our hope that the neuroscience community at large will consider these noninvasive approaches as essential tools that provide substantial insights into brain structure and function, when combined with strong research questions, experimental rigor in study design and informed choices in data acquisition and analyses. With this issue, we celebrate the valuable neuroscientific contributions from human brain mapping, and we look forward to working closely with the neuroimaging community to develop and publish new, exciting neuroscience research using these techniques. ■