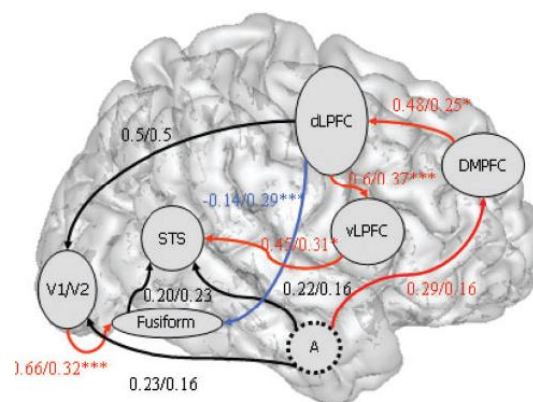
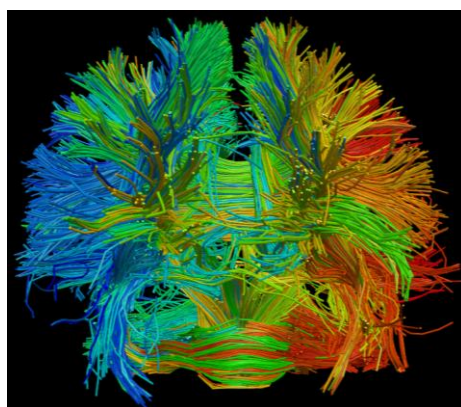


# New Horizons in Human Brain Imaging: A Focus on Brain Networks and Connectivity - Executive Summary

In this executive summary we describe our efforts to convene a 3-day international meeting of researchers from North America and Pacific Rim regions entitled “*New Horizons in Human Brain Imaging: A Focus on Brain Networks and Connectivity*” to examine and critique the future of brain imaging using MRI and related modalities of examining *in vivo* human brain connectivity. The meeting, being planned for December 2010, will be comprised of key themes important to the next era of neuroimaging science and address the research and clinical motivations for the next 20 years of research using rapidly evolving neuroimaging technologies. For instance, an important element will concern the better understanding of cognitive networks and their contributions to individual differences in functional activity seen across subjects. In particular, the meeting will focus specifically on attainable means by which investigators from Pacific Rim nations may maximize collaborative effort in addressing the scientific and clinical challenges facing this dynamic and multi-disciplinary field. We envision endorsement and support from federal funders, major scientific organizations, and corporate and private sponsors for this meeting which will help to attract attention to the meeting as well as demonstrate the interest in international imaging research.

**Introduction:** In the early 1990’s, several highly influential developments occurred that revolutionized the study of the human brain: 1) the accelerated use of PET to map human brain activity *in vivo*, 2) the proliferation of magnetic resonance imaging scanners in medical centers and academic departments in



**Figure 1:** The mapping of brain connectivity includes structural (left) as well as functional (right) neuroimaging approaches.

the North America and Europe made it possible to obtain exquisitely high resolution images of the brain, 3) the discovery of the blood oxygenation level dependent (BOLD) magnetic susceptibility effect of hemoglobin (Ogawa, Tank et al. 1992) enabled the moment to moment measurement of brain blood flow related signal using MR, and 4) the manipulation of BOLD signal over time using sensory, cognitive, and behavioral stimulation enabling the localization of fundamental brain functions (Bandettini, Wong et al. 1992). In the ~20 years that has elapsed since the first studies appeared in the literature, the number of neuroimaging studies of brain anatomy and cognitive function, in healthy subjects and patients, has increased dramatically. Considerable advancement has been made over that period, ranging from those involving improvements in technology (Bellgowan, Bandettini et al. 2006), development of sophisticated computational methodologies (Yamashita, Sadato et al. 2005), and better understanding into and interpretation of blood flow-related MR signals (Buxton 2001). Newer methodologies have also emerged in recent years, such as diffusion tensor imaging (DTI), that permit the assessment and mapping of white fiber tractography (Golay, Jiang et al. 2002; Bammer, Acar et al. 2003). In addition, the range and depth of the scientific questions that functional and structural MRI is addressing continues to grow. Indeed, nearly 2500 peer-reviewed articles appear in the literature each year that used MR brain imaging to examine the human brain in health and disease.

While initially a discipline largely motivated by scientists based in North America and Europe, as evident by the highly successful *International Consortium for Brain Mapping* (ICBM; see Mazziotta, Toga et al. 2001), the field of brain imaging has experienced increasingly important participation from researchers in Asia and Australia. Several recent meetings of the Organization for human Brain Mapping (OHBM) have been held in Japan and Australia. And yet, apart from specific *ad hoc* interactions, ongoing international collaborations and consortia between researchers from these countries concerning human neuroimaging have been relatively infrequent.

The field of neuroimaging is now at a juncture where clear vision is required to chart the course for the next 20 years of imaging research that focuses a directed research effort in the cognitive sciences, maximizes clinical efficacy, inspires new innovation, and leverages emerging methods and technology to fully utilize collected data. New thinking has emerged that suggests that individual variability of functional activity evoked during cognitive tasks is not an effect that should be “averaged out” but can be examined more closely in relation to differences in cognitive strategy and task performance (Miller, Van Horn et al. 2002). This is mirrored by recent developments in neuroimaging for tracing white matter fiber pathways which make it possible to identify individual-specific patterns of structural connectivity that underlie and support efficient distributed cognitive activity. Functional genomics is increasingly becoming an important way to understand how patterns of brain activity or spectroscopic signals contribute to a person’s cognitive abilities (Glahn, Paus et al. 2007). To analyze these increasingly large datasets, new computational approaches, such as grid computing (Van Horn, Dobson et al. 2006), are being examined. Now is the time to examine these issues as a whole and learn how to take advantage of emerging new biotechnologies for understanding what may be a characteristic of brain networks as opposed to the simple computing of average activity in health and disease. Additionally, examination of brain connectivity and the underlying network structure of cortical and sub-cortical pathways have recently emerged as topics of much interest. Inter-regional patterns of correlation underlie distributed cognitive networks responsible for higher-order thought, motor representation and action, social perception, and memory as well as during non-activated resting state (Grafton 2009; Greicius et al. 2009; Murphy et al. 2009). Such connectivity is believed to be disrupted in diseases such as multiple sclerosis (Bonzano et al. 2009), Alzheimer’s Disease (Buckner et al. 2009), and schizophrenia (Kim et al. 2009). Therefore, examination of the past, present, and most importantly, the future of multi-modal neuroimaging research with respect to understanding brain connectivity will form an exciting avenue for international interaction.

We are now working to convene an international meeting on the characterization, measurement, and analysis of human brain networks to include emergent fMRI technologies, recent advances in MRI scanner capabilities, research and clinical applications, and novel data processing methods for mapping brain networks. This meeting will focus on the future of BOLD, diffusion tensor imaging (DTI), positron emission tomographic (PET) and structural human brain imaging. High resolution imaging, cognitive, behavioral, pharmacological, and genomic neuroimaging will be topics of discussion in addition to their integration with related methods such as electroencephalography (EEG), magnetoencephalography (MEG), and optical approaches. Speakers will be asked to describe their current research into the characterization of brain networks but to contemplate where their research using these technologies will be in 5, 10, and 20 years from the present. Additionally, we will scrutinize some of the most cutting edge clinical and basic neuroscience applications of newly available imaging methodologies and what these mean for future studies of brain structural and functional connectivity. This event will build on an earlier event held in April 2009 which specifically focused on Pacific Rim neuroimaging interactivity. Further information can be found at <http://www.pacificrimneuroimaging.net>.

We expect this meeting to have an advanced educational aspect involving the latest advice on how to

best integrate recent methodologies into a useful and collaborative research program. Outcomes from the meeting will include a featured article in a leading peer-reviewed journal. We are confident that several productive and useful collaborations between meeting participants will result and that these outcomes will speak directly to governmental research agendas, provide insights into scientific directions for future industry technological R&D, and to how international researchers can interact more closely in the study of health and disease of the human brain using emerging neuroimaging techniques. In particular, we expect those in the medical imaging, high performance computing, and related industries to take particular interest in this meeting and the new markets it provide for their products. We have approached several vendors with ties to neuroimaging data collection, analysis, and computing also requesting their support. We are grateful to the National Institutes of Neurological Disorders (NINDS) and to Canada's Advanced Research and Innovation Network (CANARIE) for their generous support.

### Expected Meeting Outcomes

The expected outcomes of the “*New Horizons in Human Brain Imaging: A Focus on Brain Networks and Connectivity*” meeting will be in serving to: provide context and understanding for basic cognitive processes that depend upon the integration of neural information from disparate brain regions; insight into disruptions of connectivity in debilitating diseases such as Alzheimer’s and schizophrenia; how best to computationally model brain networks and make predictions; providing a refined vision for the utility of *in vivo* human brain imaging for the measurement of brain connectivity; encouraging and facilitating international interactions around the Pacific Rim; as well as providing a highly interactive means for enhancing neuroscience education.

We are confident that this meeting will prove to be a watershed moment in the development of neuroimaging science: fostering greater cooperation between Pacific Rim and North American scientists will enable us to meet the challenges that are expected in this field in the coming decades. The past 20 years have demonstrated remarkable productivity in the study of the human brain using MRI and this meeting will provide a useful vision for the next exciting epoch of experimental and clinical MRI research into brain networks.

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