Simultaneous MRI-PET Imaging: Recent developments and future directions

Gary Egan Co Organizer
Monash University
Melbourne, Vic
Australia

Sharna Jamadar, PhD Organizer
Monash University
Monash University
Melbourne, VIC
Australia

Symposium

Commercial MRI-PET systems are now available, and it is estimated that about 70 such systems exist world-wide (Shah, 2019, The Royal Society of Chemistry, UK). One of the first applications of simultaneous MRI-PET, which aimed to exploit the complementary nature of MRI and PET (Villien et al., 2014), was published six years ago, and progress in this area is rapidly developing.

As with any multimodal imaging method, the combination of modalities brings unique opportunities and challenges. The increased inferential power of multimodality imaging is often offset by unique methodological challenges. The presenters in this symposium are uniquely positioned to providing a practical overview of this area to interested researchers.

The emergence of MRI-PET is of particular interest to members of OHBM, as it provides a unique window into brain function. We will explore three broad topics: haemodynamic & glucose uptake mapping, haemodynamic & dopamine mapping, and trimodal EEG-MRI-PET. Jamadar and Hahn will discuss simultaneous BOLD-fMRI and [18F]-FDG-PET, which simultaneously measure haemodynamic and glucose metabolic responses to neuronal activity. fMRI/FDG-PET not only provides a unique insight into the haemodynamic and metabolic responses, but also offers an opportunity to disentangle these components of neurovascular coupling. Sander will demonstrate how simultaneous BOLD-fMRI and dopaminergic PET can be used to localise brain activity and simultaneously capture the underlying molecular and receptor-specific dynamics. Lastly, Shah, the editor of the only book on this method, will demonstrate how MR-PET can be further extended with EEG-MR-PET trimodal imaging, as well as recent work pushing the boundaries of the method in 7T MRI.

Objective

- Understand the opportunities and challenges of simultaneous MRI-PET imaging for studying human brain function
- Gain an appreciation of the recent discoveries about electrophysiological, glucose metabolic, haemodynamic, and dopaminergic neural function using MRI-PET
- Gain a practical understanding of MRI-PET acquisition, methods, and applications

Target Audience

Researchers interested in using simultaneous MRI-PET for imaging human brain function
- Researchers who want to understand the increased inferential power of simultaneous MRI-PET and/or multimodality imaging
- Researchers interested in using multimodal imaging to disentangle neurovascular coupling.

Presentations

Introduction to Simultaneous MR-PET: Opportunities, challenges, and applications

Magnetic resonance imaging (MRI) and positron emission tomography (PET) are two of the most widely used measures for in vivo imaging of the brain, and provide complementary information about neural anatomy and physiology. MRI has excellent sensitivity for imaging the structure of the brain, and functional MRI provides a haemodynamic-based surrogate index of neuronal activity. PET is highly specific for imaging numerous molecular targets in the brain, including glucose and oxygen metabolism, and neurotransmitter distribution and concentration. However, the unsurpassed ability of PET to image molecular targets is offset by the poor spatial and anatomical information of the method. Thus, the combination of these two very flexible, but complementary imaging modalities opens up numerous opportunities for studying the normal and pathological physiology of the brain. In this symposium, we bring together experts who have developed novel simultaneous MRI-PET acquisition and imaging approaches for mapping the function of the human brain. In this presentation, I will provide an overview of simultaneous MRI-PET methodology, and the opportunities and challenges of the dual-modality approach. I will also discuss recent advances in radiotracer administration, and its application to an [18-F] fluorodeoxyglucose (FDG)-based measure of neural connectivity. At the completion of this symposium, audience members will have a practical, yet wide-ranging, introduction to the current state-of-play and future directions for this nascent hybrid imaging technique.

Presenter
Sharna Jamadar, PhD, Monash University, Monash University, Melbourne, VIC, Australia

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Mapping Task-based Responses using Simultaneous fMRI-fPET

The prevailing method to assess the neuronal response of task-induced stimulation is fMRI based on BOLD imaging. However, the BOLD signal represents a non-specific proxy of neuronal activation mediated by hemodynamic factors. Thus, it may only provide limited insight into the underlying energy metabolism. In this talk I will present novel techniques for mapping task-induced neuronal activation using simultaneous PET/MR imaging. In particular, a recently introduced approach to assess task-specific changes in glucose metabolism with a single [18F]FDG PET scan will be described. This approach enables the truly simultaneous acquisition of multiple parameters, each reflecting different aspects of brain energy metabolism (cerebral metabolic rate of glucose, cerebral blood flow and the BOLD signal). I will demonstrate that the combination of these modalities provides additional complementary information that cannot be assessed with each method alone. Such a combination yields a thorough picture of energetic demands at resting conditions as well as changes induced by cognitive task performance. Considering that numerous brain disorders are causally related to pathological alterations in energy metabolism, the joint investigation of complementary imaging data may serve as a relevant future tool to improve patient care. The talk will cover methodological aspects regarding the implementation of such a design, multimodal data analysis including advantages and pitfalls as well as examples of recent findings, thus supporting researchers to exploit the full potential of simultaneous PET/MR imaging

Presenter
Andreas Hahn, Medical University of Vienna, Austria

Dopaminergic Mapping using Simultaneous MRI-PET

Advances in simultaneous positron emission tomography (PET) and magnetic resonance imaging (MRI) have enabled novel approaches for in vivo functional brain mapping. The complementary nature of the imaging signals acquired by PET and functional MRI (fMRI) permits new insights into the molecular mechanisms of neurotransmission of the living brain: fMRI localizes changes in brain activity, whereas PET captures the underlying molecular and receptor-specific dynamics. One of the potentials of this technology is to provide new clinical biomarkers for the evaluation of dynamic receptor function and therapeutic interventions. This talk will describe how simultaneous functional imaging with PET/fMRI leads to novel mechanistic insights through drug-induced modulation of brain function. The focus will be on interventions that target the dopamine receptor system using pharmacological challenges. I will show that neurovascular coupling to receptors as identified by PET/fMRI can be used to classify drug properties in vivo. Together with biological and pharmacokinetic models, mechanistic insight into receptor adaptations over time can be gained. Specifically, our approach using PET/fMRI to evaluate the effects of stimulants drugs of abuse shows how excitatory and inhibitory dopamine receptors can differentially contribute to modulation of receptor signaling. Throughout, I will present on how the combined use of experimental and methodological approaches allows us to unravel receptor contributions to observed functional signal changes.

Presenter

Christin Sander, Harvard Medical School Boston, MA, United States

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Trimodal EEG-MRI-PET and Future Directions for MR-PET

Simultaneous MR-PET-EEG is a new tool for the investigation of neuronal networks in the human brain enabling assessment of structural-functional-metabolic information with high spatial resolution and its combination with temporal measures via EEG in a given brain. For example, it allows characterization of the brain's default mode network using multimodal fingerprinting by quantifying energy metabolism via FDG-PET, the inhibition-excitation balance of neuronal activation via MR spectroscopy, its functional connectivity via fMRI and its electrophysiological signature via EEG. The trimodal approach thereby reveals a unique fingerprint. Further, a comparison of EEG microstates with rs-fMRI metrics and neurometabolic measures in the DMN measured simultaneously as a trimodal data set will be reported and discussed. The hope is that analysis of these multimodal measures, which represent diverse physiological information, will pave the way for understanding the complex behaviour of the brain in the resting condition and will help in developing new image-based biomarkers for the early detection and treatment monitoring of various neuropsychiatric disorders. The vast majority of the work reported in triple modal imaging has been done at 3T. In this presentation, the prospects for simultaneous, triple-modal imaging at 7T will be presented and critically discussed.

Presenter

N. Jon Shah, Forschungszentrum Juelich GmbH Juelich, Germany