Cross-frequency coupling mechanisms in the ongoing resting-state predict BOLD fluctuations

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Functional MRI and PET have demonstrated the existence of resting-state networks in the brain (Gusnard & Raichle, 2001; Raichle et al., 2001; Greicius et al., 2003). Yet the neural correlates and thereby the fine-scale temporal dynamics of the brain's intrinsic network activity remain elusive. A full understanding of the mechanisms at play cannot be achieved without input from electrophysiology, that directly assess the neuronal signature of the involved structures.

Recent findings from invasive recordings in DMN structures in monkeys (Hayden et al. PNAS 2009) and in human subjects (Ossandon et al. 2011; Dastjerdi et al., PNAS, 2011; Miller et al., PNAS, 2009; Jerbi et al. Front Syst Neurosci. 2010) provide novel insights into the neural correlates of the DMN. In particular, the invasive studies by Hayden et al. (2009), Dastjerdi et al (2011) and Ossandon et al. (2011) are critical because they bridge the gap between the role of neuronal firing, high-frequency activity ("Gamma-band" at 40Hz and above) and the fMRI BOLD signal in the brain's default-mode network, while also questioning the link between DMN deactivation and behavior. These invasive insights are crucial to validate the non-invasive identification of intrinsic brain networks using MEG.

A recent milestone in the non-invasive characterization of the electrophysiology of the resting brain was achieved using MEG source imaging to probe the dynamics of the default-mode and dorsal attention networks (de Pasquale et al., PNAS, 2010). A further significant MEG study by Brookes et al. recently identified multiple resting-state networks using an approach akin to fMRI resting-state data analysis (Brookes et al., PNAS, 2011). Both studies indicate that alpha and beta oscillatory fluctuations may provide a structural backbone for resting-state network dynamics.

We will feature recent results from our group using MEG source imaging to reveal cross-frequency coupling phenomena that appear to be at the origin of the slow fluctuations captured with fMRI during the resting-state. We investigated the dynamics of cross-frequency coupling between oscillatory fluctuations observed with MEG source imaging, across the cortex, in 6 subjects. We were able to identify that patterns of phase-amplitude couplings between low-frequency bands and high-gamma oscillations reveal the regions connected during resting-state. Based on these results, we synthesized time series at each cortical location, that essentially model the slow fluctuations observed with

BOLD. We verified that conventional correlation analysis based on these pseudo-BOLD time series revealed the expected resting-state networks.

Overall, our results suggest that the mechanisms that reveal the brain's resting-state networks with fMRI are based on the cross-frequency coupling between the phase of low-frequency components and the amplitude of high-gamma oscillatory fluctuations.

Our presentation will also feature recent results from our group featuring dynamic retinotopic mapping of the visual cortex, clinical applications of MEG source imaging and real-time cortical imaging with feedback to subjects.