Specialty area: Title of session

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Highlights:

Historical perspective to the latest data driven neuroimaging

Latest tools for exploring ultrafast neuroimaging data

Future directions

Data driven and exploratory data analysis

TARGET AUDIENCE : neuroscientists, students, radiologists

OBJECTIVES

Learn critical and statistically sound ways to do data driven signal analysis on resting state/spontaneous brain activity changes.

PURPOSE

The purpose of this talk is to invite (neuro)scientists to think a little outside the common hypothesis driven scientific framework. As we are getting more and more accurate brain imaging data with faster fMRI sequences, we also need to have exploratory tools for mining the data. Even though we build on previous knowledge, we have to acknowledge that previously the methods have offered less accurate information than currently available. It is important to be able to explore the real human brain data with latest methods that add new views to the understanding of the human brain anatomy and function.

The exploratory nature of the data driven analyses adds further pressure on the soundness of the methodology as one is leaving conventional and more established grounds of data analytics. One has to acknowledge the risks of the new methods; new problems and issues surely arise. Therefore analyses need to be performed in a scientifically rigorous and critical manner. Sound mathematical/statistical approaches often facilitate the making of correct inferences from the data.

Data driven analysis tools and their origins:

Functional connectivity analytics have been on the scene for over twenty years. In spontaneously active resting brain it started from time domain signal analytics and moved to frequency domain methodology. Simultaneously signal source separation methods and clustering methods have gained strength. Recently the direction of analytics has moved into analyzing shorter and shorter time windows; analysis of variability in the signal dynamics and localizing of single event even with BOLD signal has emerged. Faster and more accurate scanners will continue to help us gain deeper understanding on brain activity mechanisms and diseases thereof.

The outline of this talk is to review some of the rationale and original ideas behind exploring spontaneous brain activity; we move from biswallian time domain correlation analysis into it's new realms such as dynamic small world network analytics. Correlation analysis is a strong tool in fast detection of network activity and real time usage should be implemented in pre/intraoperative surgical planning with methods like InstaCorr in AFNI.

Frequency domain analytics and it's latest derivatives such as ALFF and fALFF by Yu-Feng Zang are being increasingly used as a fast & repeatable way to analyze the spontaneous brain activity data. Fractal 1/f analytics have been somewhat used but currently they have not (yet) reached their full potential in fMRI.

Independent component analysis has become one of the most popular data driven methods for analyzing spontaneous brain activity since it can separate the noise sources from signal sources of interest by utilizing spatial information. A marked step forward from ICA-pioneers like Calhoun and Beckmann was the production of group level ICA that enabled us to recognize functional lego-blocks of the mind, i.e. the resting/intrinsic networks. Some see ICA having an issue with correct model orders but these 'issues' can be addressed mostly as parcellation levels of a hierarchical brain network system. Latest advances in ICA such as brain state analytics, temporal feature modes and spatial dynamics with sliding window ICA will be presented and possible new areas of interest will be discussed.

Future – citius, altius, fortius

New technological breakthroughs from ISMRM society have enables researchers to go faster, with higher accuracy and gain more statistical power. There are also new forms of ideas also emerging on the field partly stemming from being able to see clearer but

also from increases in theoretical understanding on how the brain funtions.

One new theoretical framework is avalanche analytics of singular neuronal activity propagation into the neuronal network. Co-activation patterns (CAP) are being recognized from single functional images with very accurate neuronal network presentations. Currently these may be also viewed in time making the avalanche analytics more at hand.

Also very interesting new approach is the detection of white matter connectivity structure using BOLD signal. Even though the white matter has some 30 % of the circulation of the grey matter, it seems to have some connectivity information that and it conveys signal along white matter tracts.

The new ultrafast neuroimaging systems offer critical sampling of physiological artifacts and enable very accurate modeling of the CAPs. Physiological signal imaging is one totally new concept that has arisen from the ultrafast imaging sequences like the MREG (magnetic resonance encephalography). Cardiac and respiratory cycles and vasomotor waves can now be imaged 4D from the brain and their clinical potential seems promising – although this has been the case with fMRI since it's dawn, there has been only marginal clinical implications.

One reason for not gaining the clinical foothold may have been the great sensitivity of BOLD based fMRI to multiple signal modulation factors. And the fact that not all us currently understood. A third issue has been the non-critical, aliased signal sampling combined to motion artifacts, which obscure the signal markedly.

But these hinders are dissipating away through scientific efforsts. Combining multimodal setups with ultrafast MRI is a good way of finding out exact signal source mechanism that shape the signals we measure. Once we know exactly what we are seeing with BOLD signal, then one is able to separate pathological mechanisms.

Putative multimodal information that can be critically sampled in synchrony with the fMRI BOLD signal produces massive amounts of data. Data mining and exploratory analyses become very important in understanding the interrelationships of these synchronous measures. The span of neuroimaging may be expanding from genomic populations level imaging into single cell analytics of activity. In such a span the exploratory and data driven tools may alter the way we see things and diagnose disease in the not-so-far future.

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