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for Brain, Cognition and Behaviour

Connectivity
Meaningful interpretations of networks

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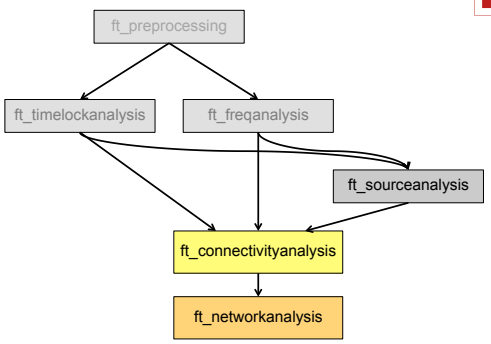
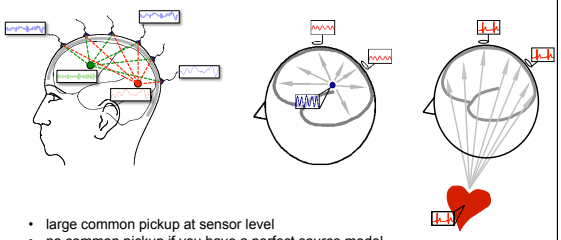
Talk outline

- Overview of connectivity methods
- Channel versus source connectivity
- Beamformer (recap)
- What is available in FieldTrip?
- What are oscillations (recap)?
- Influence of signal-to-noise ratio
- Suggested further reading

Connectivity and network analysis in FieldTrip



Common pick up



- large common pickup at sensor level
- no common pickup if you have a perfect source model
- some common pickup if source model is not perfect

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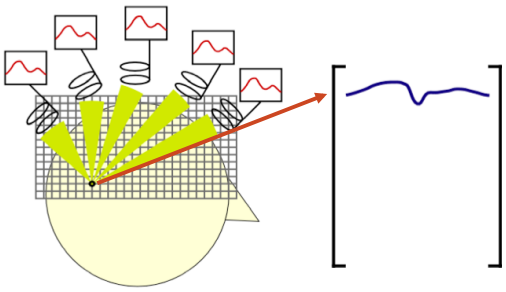
Beamformers: the concept



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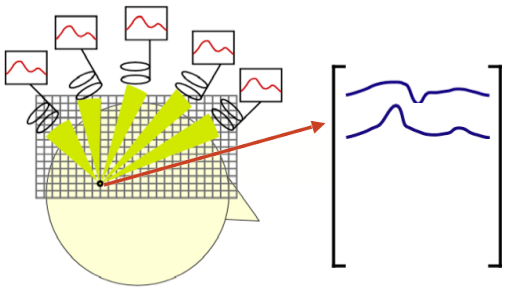
Beamformers: the concept



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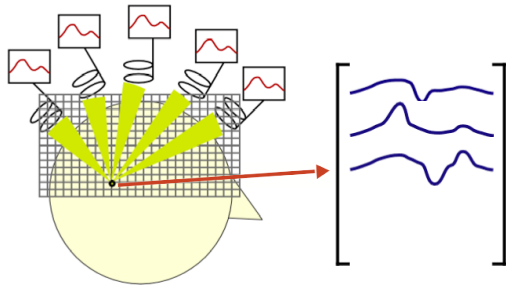
Beamformers: the concept



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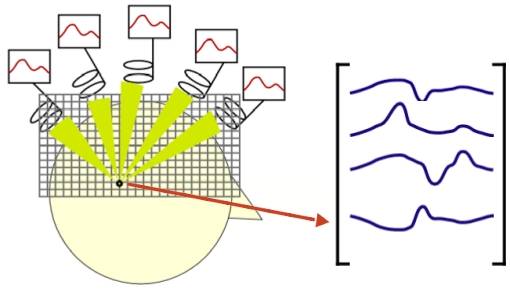
Beamformers: the concept



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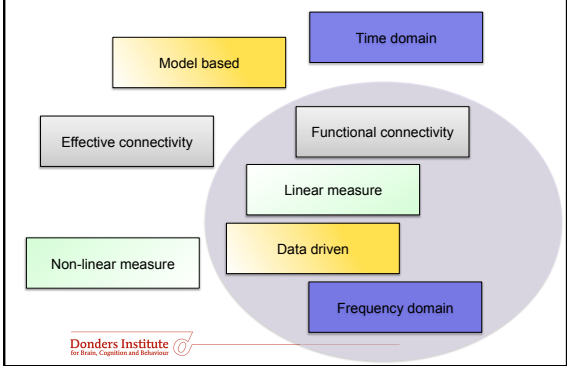
What measures of connectivity are available?



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Frequency domain connectivity measures

Coherence coefficient

Phase lag index

Phase synchronization

Partial directed coherence

Directed transfer function

Phase locking value

Imaginary part of coherency

Pairwise phase consistency

Phase slope index

Synchronization likelihood

Frequency domain granger causality

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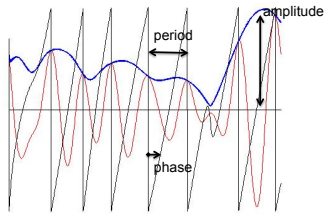
What constitutes an oscillation? (recap)



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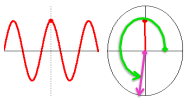
What constitutes an oscillation? (the movie)



$= Ae^{i\varphi}$

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What about 2 oscillations?

phase signal 1

phase difference

phase signal 2

Phase difference is scattered:
Low synchrony

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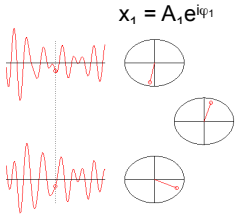
What about 2 oscillations?

$x_1 = A_1 e^{i\varphi_1}$



$x_2 = A_2 e^{i\varphi_2}$

phase signal 1

phase difference

phase signal 2

Phase difference is clustered:
High synchrony

$x_1 x_2^* = \langle A_1 A_2 e^{i(\varphi_1 - \varphi_2)} \rangle$

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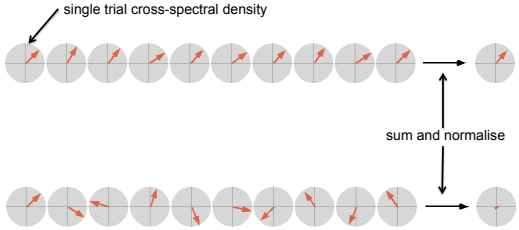
Coherence as measure of synchrony

Coherence is computed from the *cross-spectral density*, which is obtained by *conjugate multiplication* of the frequency domain representation of the signals

$x_1 x_2^* = A_1 e^{i\varphi_1} \times A_2 e^{-i\varphi_2} = A_1 A_2 e^{i(\varphi_1 - \varphi_2)}$

single trial cross-spectral density



sum and normalise

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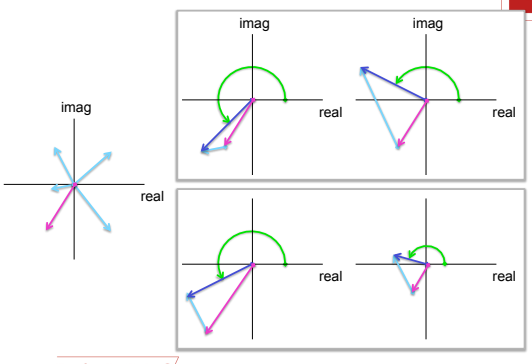
Signal, noise and phase



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Signal, noise and phase

- Differences in noise influence the phase estimate
  - more noise, less reliable estimate
  - less noise, more reliable estimate
- Differences in signal strength influence the phase estimate
  - stronger signal, more reliable estimate
  - weaker signal, less reliable estimate
- Differences in SNR affect phase estimates, and thereby affect connectivity measures

Note that something similar holds for Granger causality

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Summary

- Channel level connectivity difficult to interpret
  - common pickup of cortical and non-cortical sources
- Source level connectivity less problematic
- SNR influences reliability of phase estimate
- Quality of source reconstruction also affects the spatial filter
  - separation of different sources
  - separation of sources from noise
- Differences in signal and/or noise should be considered when interpreting and comparing connectivity

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Suggested further reading

Tutorials

http://fieldtrip.fcdonders.nl/tutorial/coherence
http://fieldtrip.fcdonders.nl/tutorial/connectivity
http://fieldtrip.fcdonders.nl/tutorial/connectivityextended
http://fieldtrip.fcdonders.nl/tutorial/beamformingextended

http://fieldtrip.fcdonders.nl/example/stratify

Papers

Source connectivity analysis with MEG and EEG.
Schoffelen JM, Gross J. Hum Brain Mapp. 2009

Nonparametric statistical testing of coherence differences.
Maris E, Schoffelen JM, Fries P. J Neurosci Methods. 2007

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