



Measuring Functional Connectivity of the Brain from Electrophysiological Signals

Sergul Aydore

Biomedical Imaging Group
Advisor: Prof. Richard M Leahy

Measuring Electrical Activity of the Brain



Magnetoencephalography (MEG)

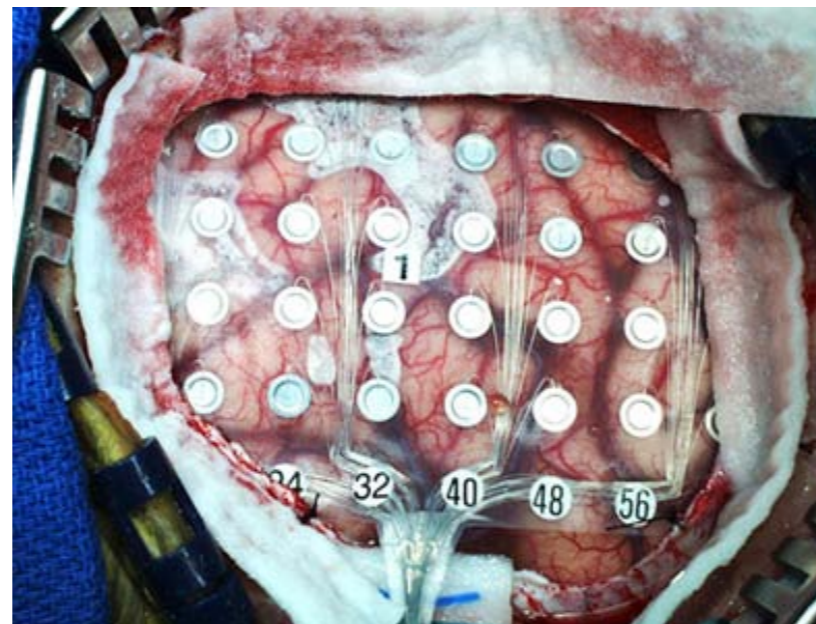


University of Washington (2009, July 19). Learning Is Both Social And Computational

Electroencephalography (EEG)



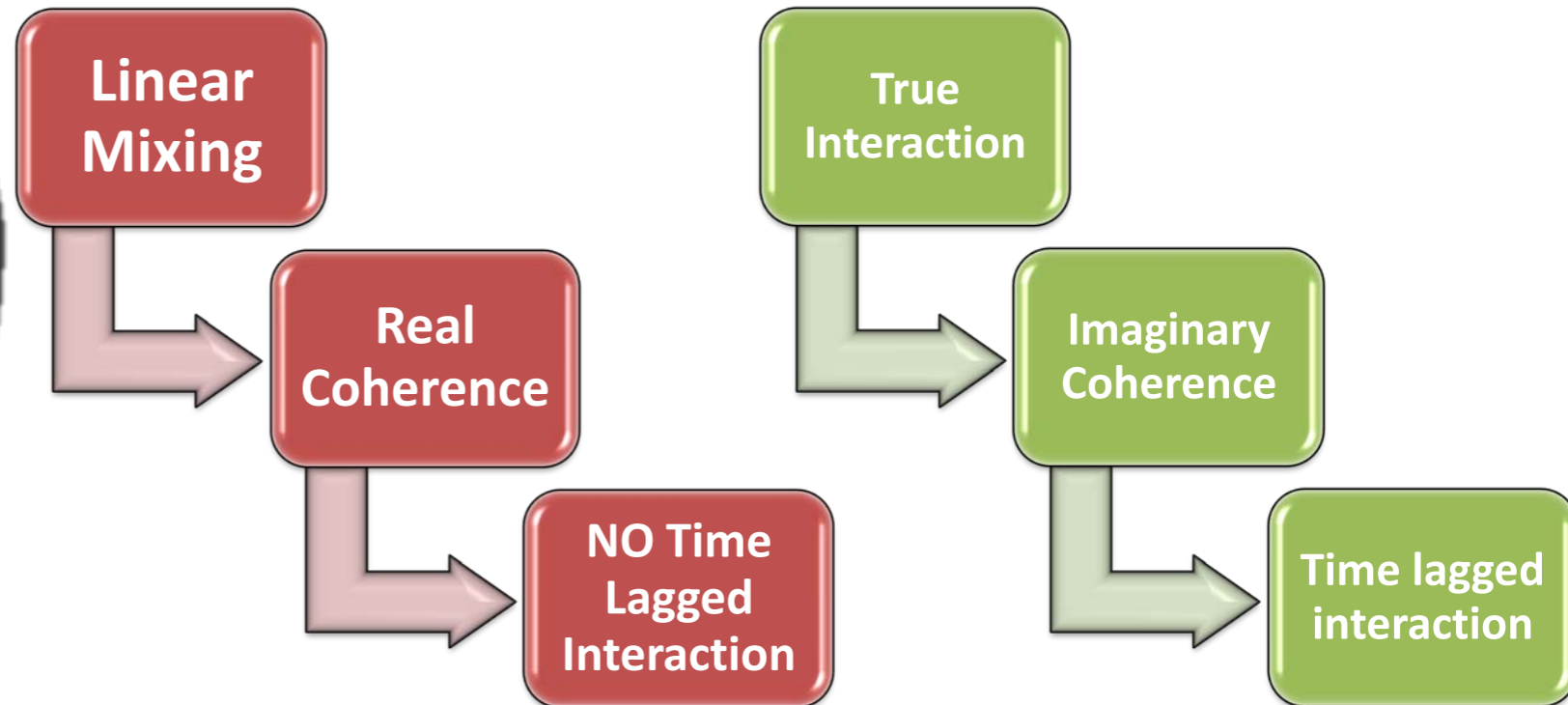
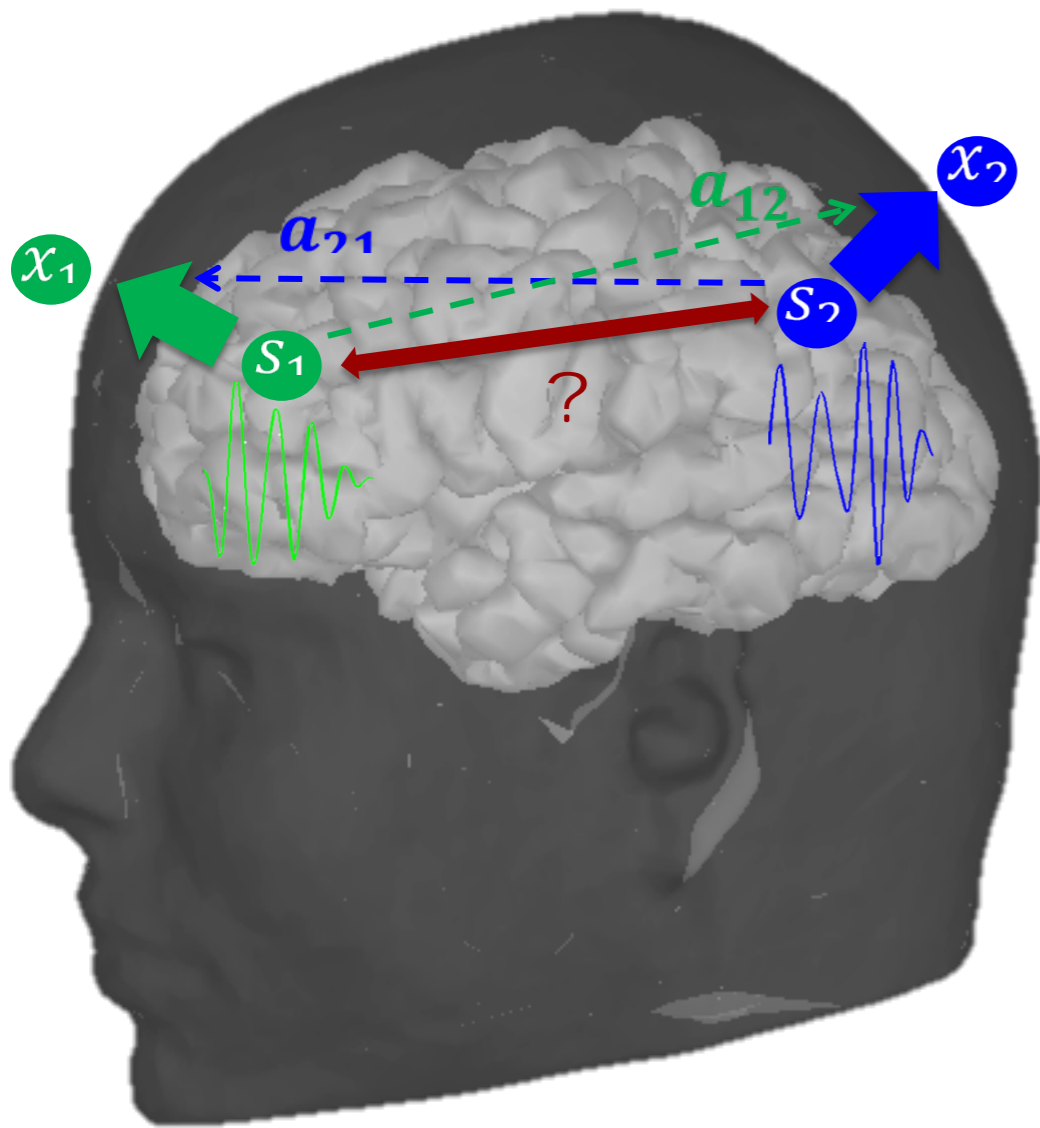
Invasive EEG



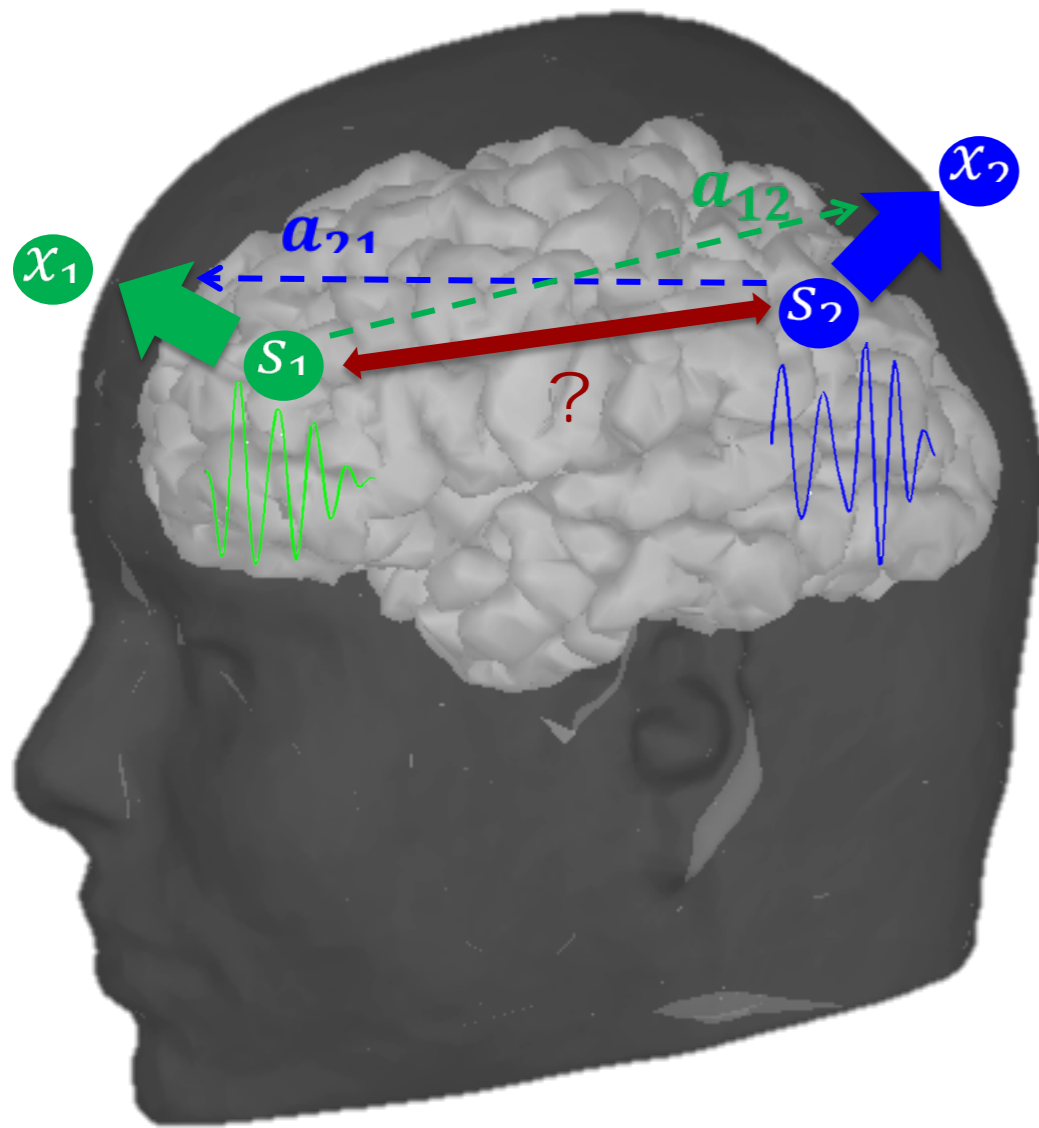
Connectivity between two areas in Presence of Linear Mixing



Coherence:
$$C(x_1, x_2) = \frac{|E[z_1 z_2^*]|}{\sqrt{E[|z_1|^2]E[|z_2|^2]}}$$



Connectivity between two areas in Presence of Linear Mixing



Coherence: $C(x_1, x_2) = \frac{|E[z_1 z_2^*]|}{\sqrt{E[|z_1|^2]E[|z_2|^2]}}$

Imaginary Coherence: $IC(x_1, x_2) = \frac{|Imag\{E[z_1 z_2^*]\}|}{\sqrt{E[|z_1|^2]E[|z_2|^2]}}$

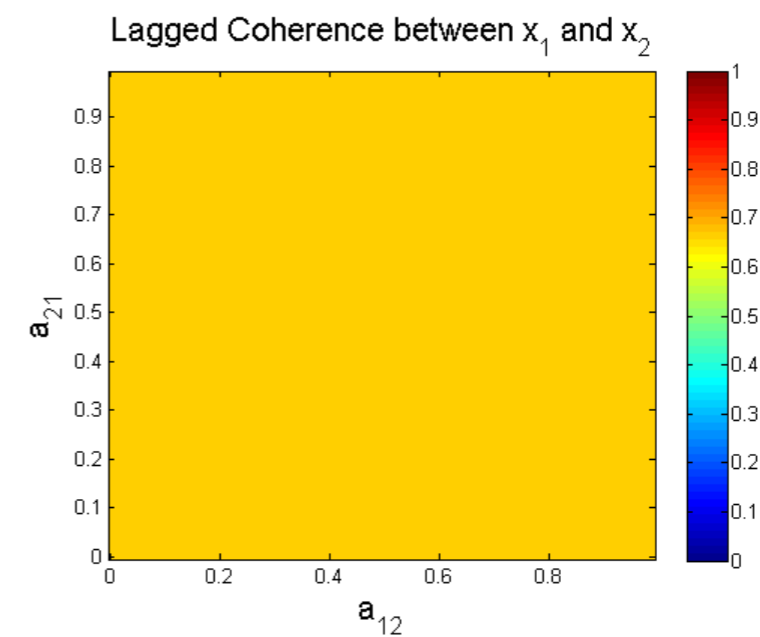
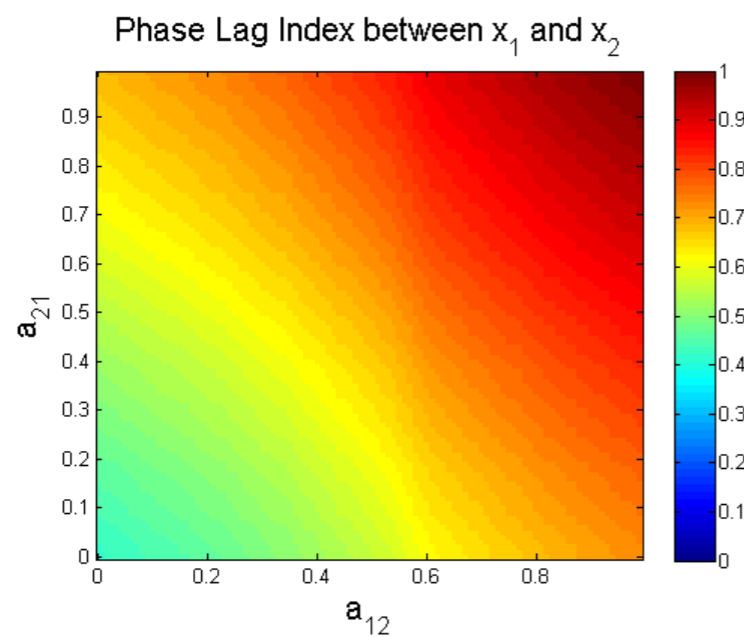
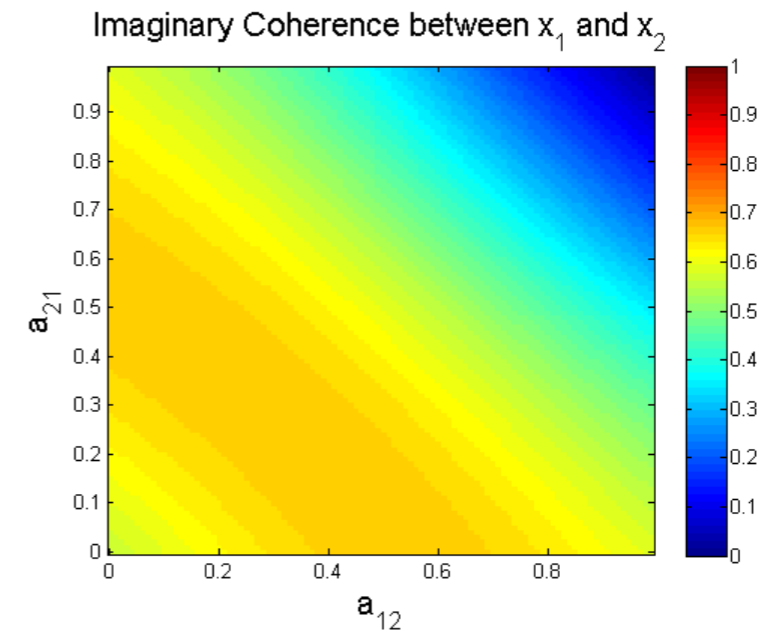
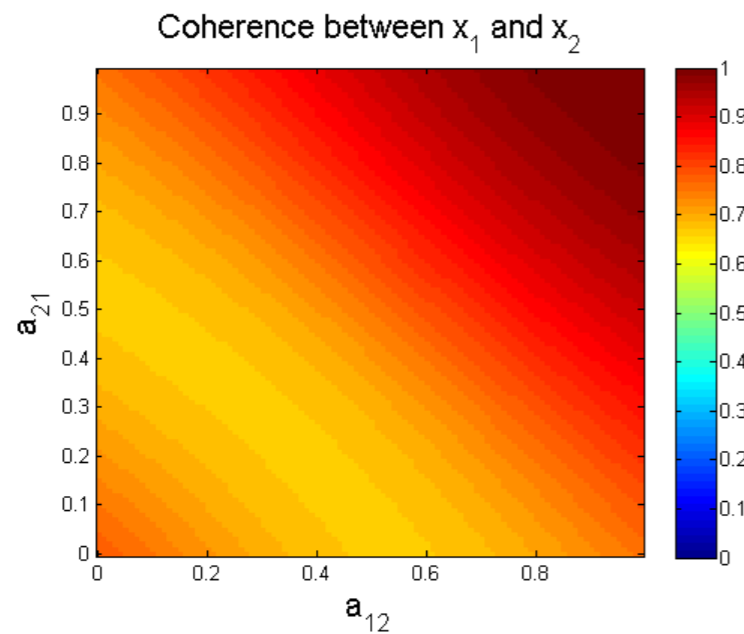
Phase Lag Index: $PLI(x_1, x_2) = |E[sign(\phi_1 - \phi_2)]|$

Lagged Coherence: $LC(x_1, x_2) = \frac{|Imag\{E[z_1 z_2^*]\}|}{\sqrt{E[|z_1|^2]E[|z_2|^2 - |Real\{E[z_1 z_2^*]\}|^2]}}$

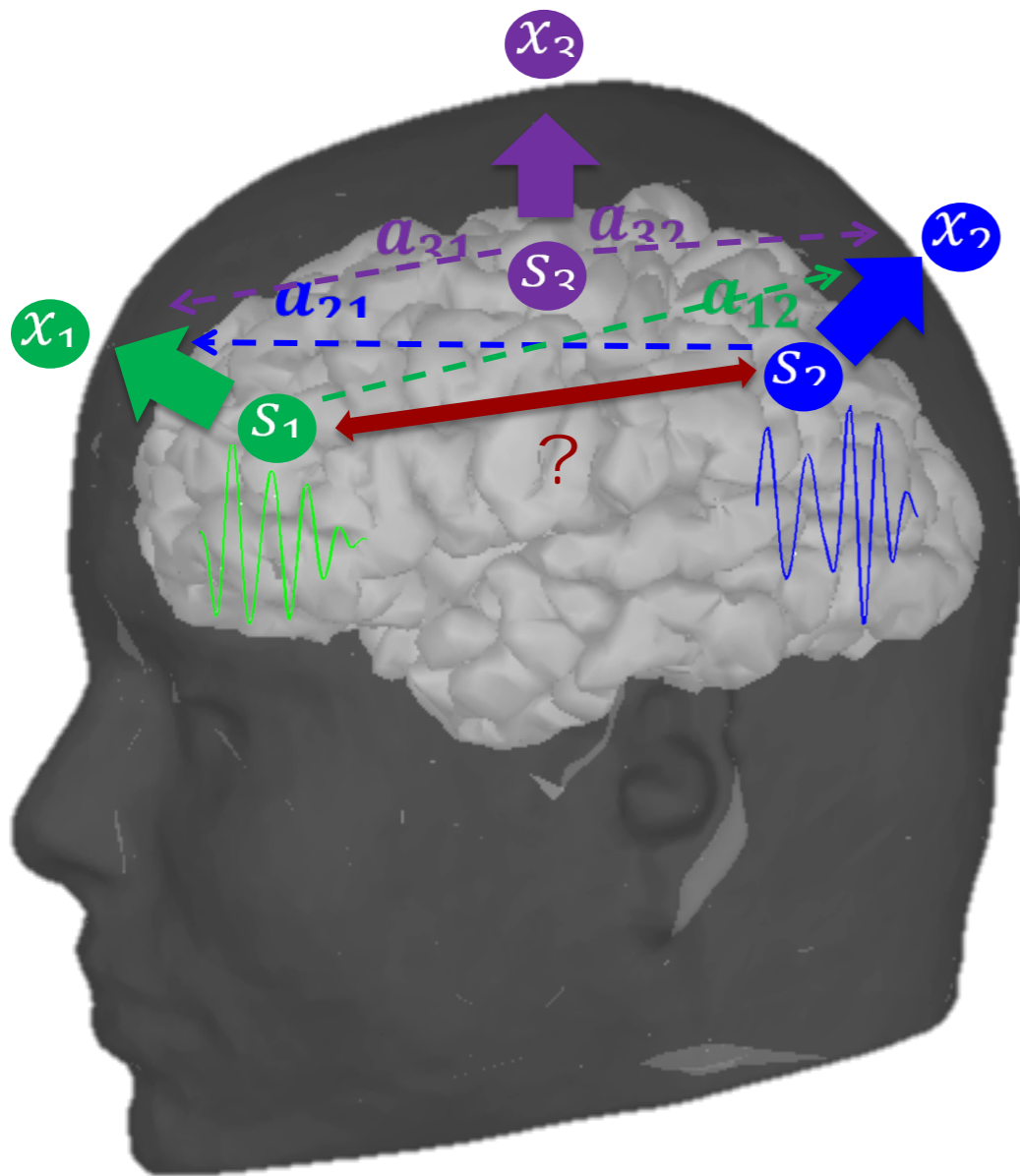
$LC(x_1, x_2) = LC(s_1, s_2)$

Aydore 2013, Asilomar Conf.

Interaction Measures as a Function of Linear Mixing



Connectivity between two areas in Presence of Linear Mixing and Interference



Lagged Coherence

$$\hat{x}_1 = ax_2$$

$$LC(x_1, x_2) = 1 - \frac{E[|x_1 - ax_2|^2; a \in C]}{E[|x_1 - ax_2|^2; a \in R]}$$

Partial Coherence

$$\hat{x}_1 = ax_2 + bx_3$$

$$LC(x_1, x_2) = 1 - \frac{E[|x_1 - ax_2 - bx_3|^2; a \in C, b \in C]}{E[|x_1 - ax_2|^2; a \in C]}$$

Partial Lagged Coherence

Aydore 2013,
in preparation

$$\hat{x}_1 = ax_2 + bx_3$$

$$LC(x_1, x_2) = 1 - \frac{E[|x_1 - ax_2 - bx_3|^2; a \in C, b \in R]}{E[|x_1 - ax_2 - bx_3|^2; a \in R, b \in R]}$$

Local Field Potentials from Macaque Monkey



Coherence

Imaginary
Coherence

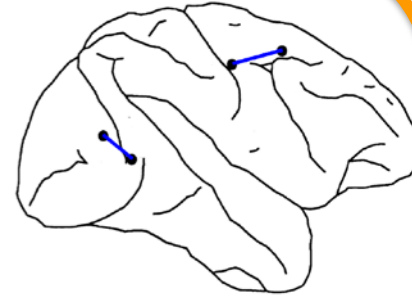
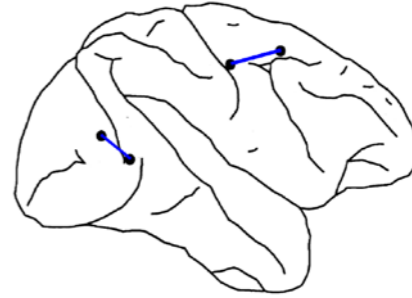
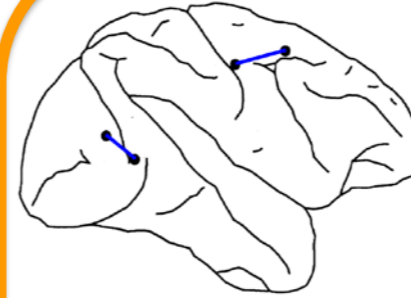
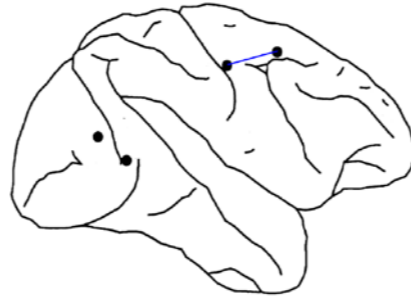
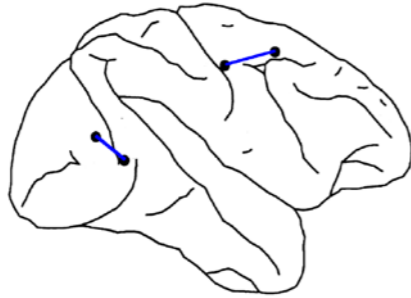
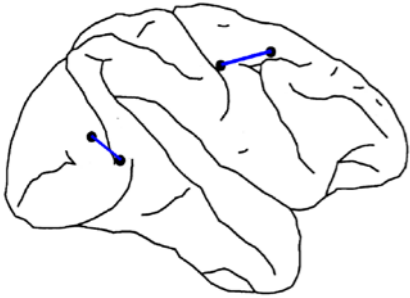
Phase
Lag Index

Lagged
Coherence

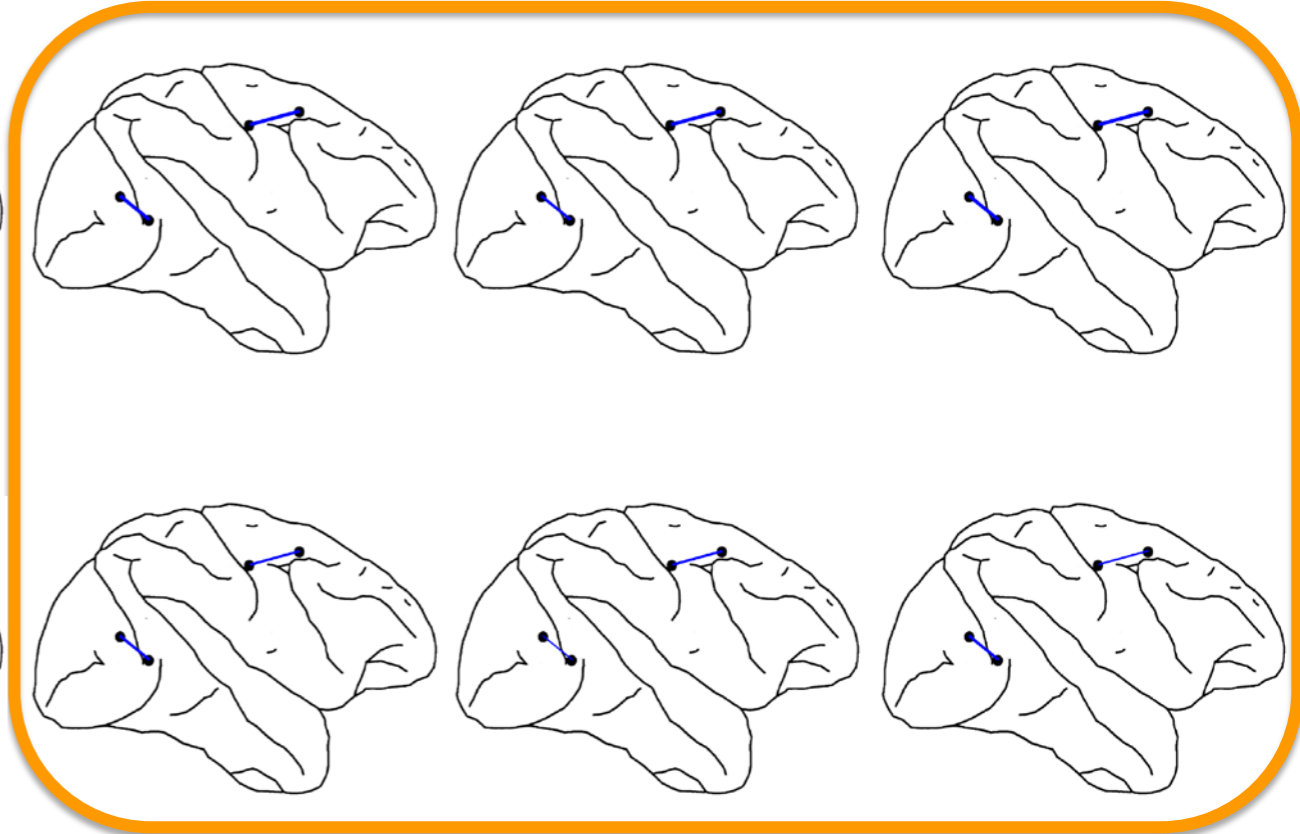
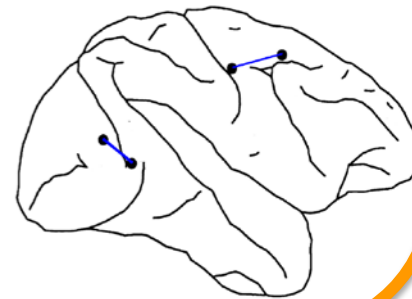
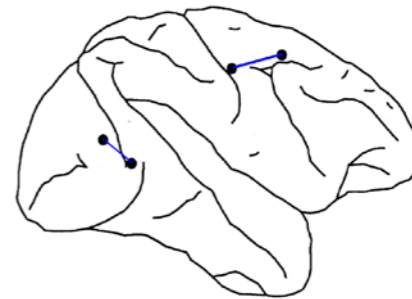
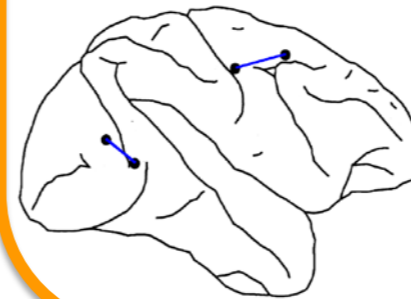
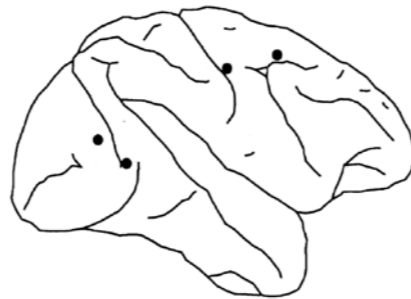
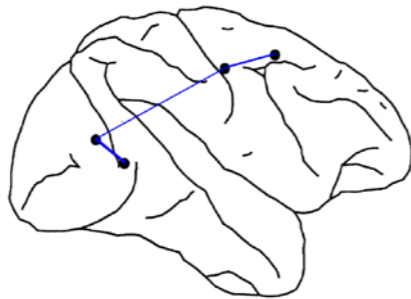
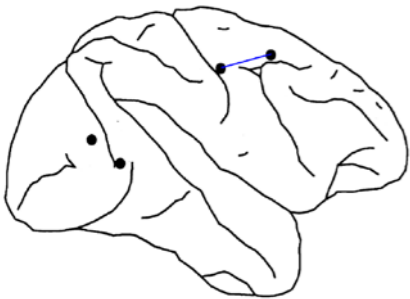
Partial
Coherence

Partial
Lagged
Coherence

No Linear
Mixing



Linear Mixing Increases



Local Field Potentials from Macaque Monkey



Coherence

Imaginary
Coherence

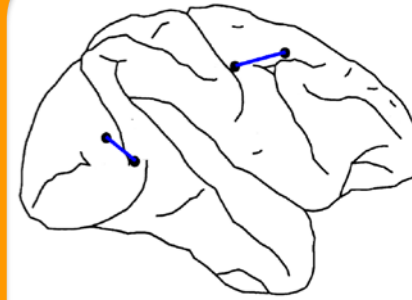
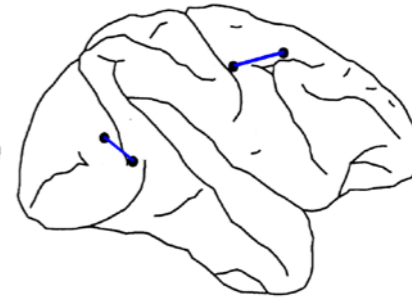
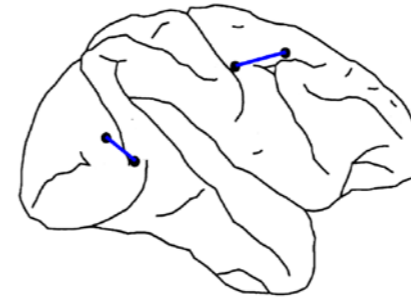
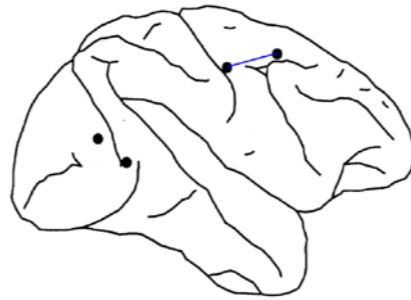
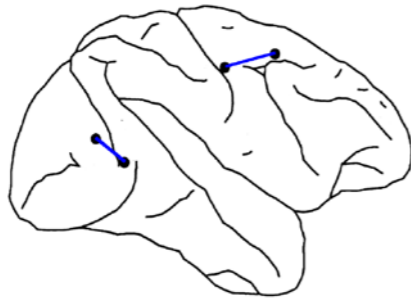
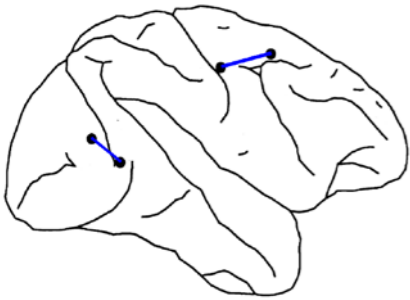
Phase
Lag Index

Lagged
Coherence

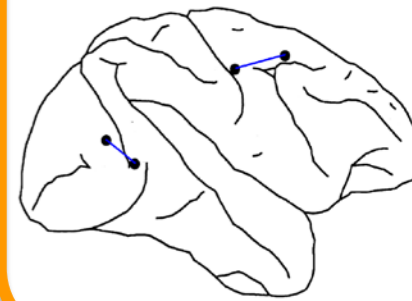
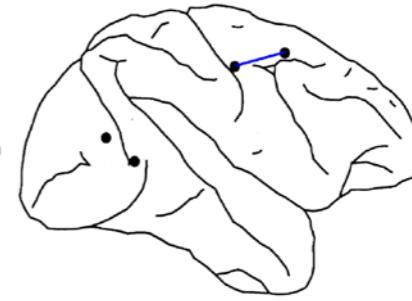
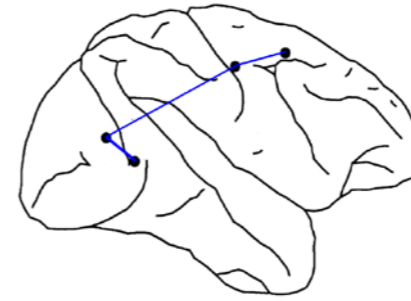
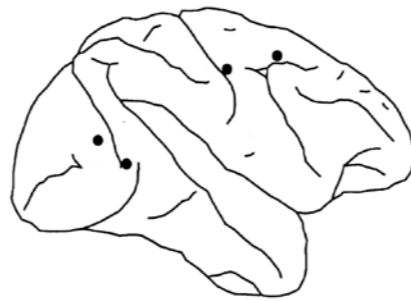
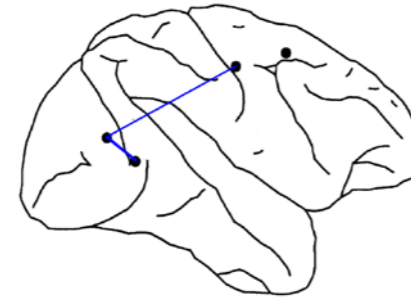
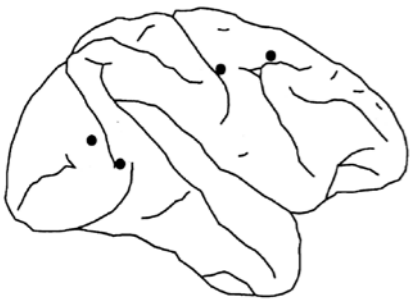
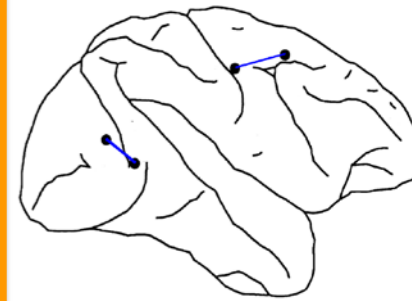
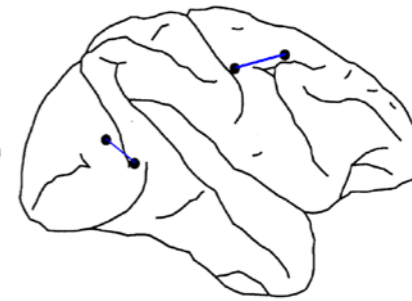
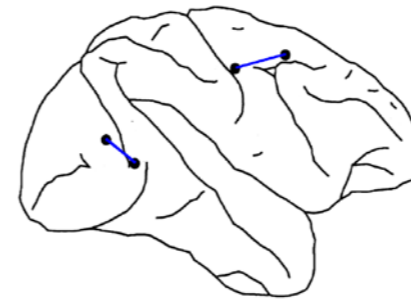
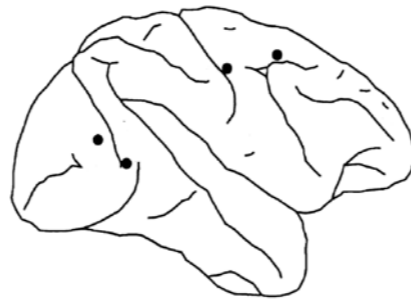
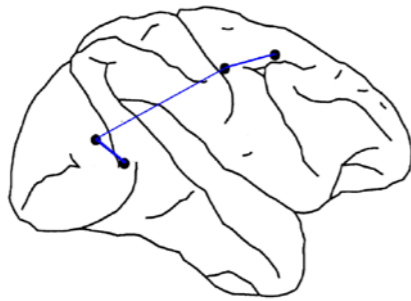
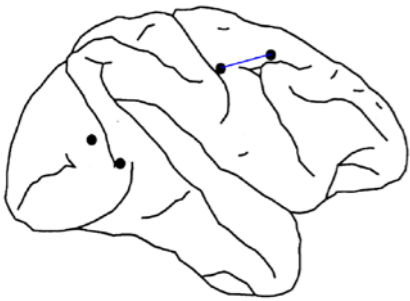
Partial
Coherence

Partial
Lagged
Coherence

No Linear
Mixing



Linear Mixing Increases



Publications



S. Aydore, D. Pantazis, R.M. Leahy, "A Note on the Phase Locking Value and its Properties" , Neuroimage 74, 231-244, 2013.

S. Aydore, M.K. Mihcak, A. Akin, R. K. Ciftci, "On Temporal Connectivity of PFC via Gauss-Markov Modeling of fNIRS Signals" , IEEE Transactions on Biomedical Engineering, vol. 57, no. 3, pp. 761-768, 2010.

S. Aydore, D. Pantazis, R. M. Leahy, "Phase Synchrony in Multivariate Gaussian Data with Applications to Cortical Networks" , ISBI 2012, Barcelona, Spain.

S. Aydore, I.Sen, M. Kivanc Mihcak, Y. P. Kahya, "Classification of Respiratory Signals by Linear Analysis" , 31st Annual International IEEE EMBS Conference, September, 2-6, 2009, Hilton Minneapolis, Minnesota, USA.

S. Aydore I. Sen, M. K. Mihcak, Y. P. Kahya, "Classification of Wheeze in Respiratory Sounds by Linear Discriminant Method" , IEEE 17th Signal and Image Communications Applications, Antalya, Turkey, April 9-11, 2009.

S. Aydore, M. K. Mihcak, A. Akin, "System Identification of Prefrontal Cortex in the Presence of Cognitive Tasks" , Biomedical Optics Topical Meeting (BIOMED) St. Petersburg, Florida, USA, March 2008.

S. Aydore, S. Ashrafulla, A. A. Joshi, R. M. Leahy, "A Measure of Connectivity in the Presence of Crosstalk" , Asilomar Conference on Signals, Systems and Computers, November 3-6, 2013, Pacific Grove, CA, USA.

S. Dery, **S. Aydore**, S. Ashrafulla, Esther Florin, E. Both, R. M. Leahy, S. Baillet, F. Tadel, "Functional Connectivity using Brainstorm" , Human Brain Mapping (HBM), June 16-20, 2013, Seattle, USA.

S. Aydore, R. M. Leahy, "The Partial Phase Locking Value for Circular Gaussian Processes" , BIOMAG 2012, France. (Best PhD poster award).

S. Aydore, D. Pantazis, R. M. Leahy, "Measuring Partial Phase Locking Value to Detect Synchronization in Multivariate Gaussian Systems" , Neuroinformatics 2011, Boston, MA, USA.

S. Aydore, D. Pantazis, J. Mosher, R. M. Leahy, "Statistical Analysis of Phase and Amplitude via Partial Coherence in Hilbert Transform Domain" , Human aBrain Mapping (HBM), June, 26-30, 2011, Quebec City, Canada.