Mining Event-related Brain Dynamics II

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Many tools now available -- but still (?) a **two-cultures** problem.
What is EEG?

- Brain electrical activity
- A small portion of *cortical* brain electrical activity
- An even smaller portion of *total* brain electrical activity

- **But which portion?**
- Triggered and modulated *how*?
- **With what functional significance?**
The very broad EEG point-spread function

Simulated parietal effective source

Very broad projected scalp potentials

Akalin Acar & Makeig 2010
The generation and modulation of EEG is COMPLEX and not well studied.
Phase cones (Freeman)

Avalanches (Plenz)
One emergent, spatially coherent effective source

1 million independent minicolumns

Summed scalp projection

Change in spatial coherence only – not in power or power spectrum
The **effective sources** of the scalp EEG & MEG are emergent islands of local synchrony / near-synchrony.
Sleep spindles
Information-based Signal Processing
ICA separates *non-brain* effective source processes
... and *also* separates cortical brain IC processes.
Independent Component Dipolarity

Measured by residual variance
not accounted for by the best fitting single (or dual) equivalent dipole model.
ICA in practice

Onton & Makeig, 2006
Blind EEG Source Separation by ICA

Flanker Task
Trial-by-Trial Analysis

erpimage()
regression

aw minus regression
Blind EEG Source Separation by ICA

Spatial Navigation
Tunnel Task – A Passive Spatial Navigation Paradigm
Tunnel Task – A Passive Spatial Navigation Paradigm
Tunnel Task – A Passive Spatial Navigation Paradigm
‘Turner’ and ‘Nonturner’ subjects use different spatial orienting styles.
Two parietal component clusters

Klaus Gramann et al., 2010
Medial prefrontal component cluster

Klaus Gramann et al., 2010
Clusters distinguishing Turners & Nonturners

Klaus Gramann et al., 2010
Clinical Research

Data Analysis
ADHD Working Memory

Lenartowicz et al., J. Neurosci., 2014
Can ICA reveal subject differences?

Multidimensional Landscape of Individual Differences
Blind EEG Source Separation by ICA

High-Resolution EEG Source Imaging
Effects of Mis-Estimating Skull Conductivity

Akalin Acar & Makeig, 2013
## SCALE-returned BSCR values for 9 subjects

SCALE applied to data from 9 subjects between 18-25 years old. Four-layer head models (scalp, skull, CSF, and brain) were derived from whole head MR images. Assumed conductivities: Scalp: 0.33S/m, CSF: 1.79S/m, Brain: 0.33S/m

The numbers of ICs used to run SCALE are shown in parentheses. *Skull conductivity and brain source patch distributions* were learned from the data. Skull conductivities are expressed as Brain/Skull Conductivity Ratio (BSCR):

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**Skull conductivity**

- **BD**: 12%
- **FR**: 8%
- **AV**: 16%
- **RB**: 34%
- **LH**: 12%
- **GV**: 8%
- **AS**: 33%
- **JH**: 56%
- **SE**: 5%

**Brain/Skull Conductivity Ratio (BSCR):**

- **3:1**
Topological source clustering – 2-D measure projection
Brain imaging during movement – How?

- Current advances in miniaturization, computer power, and information-based signal processing make possible a new imaging modality:

  Mobile Brain/Body Imaging (MoBI)

Concept:

Combine whole-head EEG, eye-gaze tracking, and whole-body motion capture recording in a real-world 3-D environment.
MoBI

Mobile Brain/Body Imaging

Record what the brain does,
What the brain experiences,
And what the brain organizes.
Lab Streaming Layer software for synchronous multi-stream, multi-platform recording and feedback – freely available online (paper in progress):
github.com/labstreaminglayer

Extensible Data Format (xdf) for multimodal data collection and storage.

SNAP – a python-based framework running on Unity for control of simple or complex MoBI experiments.

MoBILAB – a Matlab-based multimodal data browser and pre-processing app.
Measuring Musical Engagement Through Expressive Rhythm

How can we measure listeners’ engagement?

HBM 2014
Poster #1538 online

G Leslie & S Makeig,
EEG Result

Right TPJ
- Theory of Mind
- Sense of Agency
- both Action & Emotion Inhibition
Spatial Navigation Experiment – the Audiomaze
1st Pass Navigation
1st Pass Navigation
2nd Pass Navigation
3rd Pass Navigation
3rd Pass Navigation
Central Posterior Independent Component Effective Source Cluster

Low-frequency increase  Alpha suppression

Audio ‘Wall Touch’
Alpha/theta increase
High beta suppression
The Visiomaze

Subject’s L- and R-eye 3-D visual feedback views
Brain imaging **natural cognition** -- *actions & interactions*

**Imaging Human Agency and Social Interactions**
Gedeon Deak Lab @ UCSD Cognitive Science

“Development of Shared Attention” –
A Mother and Toddler MoBI Experiment

Gedeon Deak et al., 2011
3-yr old child – Reward Observation

Mother Pops the Bubble!

Activity power spectrum

Yu Liao, T Mullen, S Makeig, G. Deak 2011
Now feasible – Low-cost MoBI Systems

Any EEG System

Low-Cost MoBI

< $500 Emotiv Neuroheadset
< $500 Kinect motion capture
< $500 Touchscreen

< $1000 Full Body Wireless Inertial Motion Capture

< $100 Eye Tribe eye tracker
< $100 Leap Motion hand/finger tracker

LSL software drivers exist for all these (and more) devices
New EEGLAB Portal project

1. **Add multimodal data processing capabilities to the core EEGLAB environment** by adding support for joint processing of other time series information collected concurrently with EEG signals including appropriate data preprocessing for several modalities to allow direct comparisons to source-resolved EEG measures. We will also extend the EEGLAB General Linear Model framework to allow hypothesis testing on multimodal data.

2. **Make available high-performance computing within EEGLAB through the Neuroscience Gateway.** The Neuroscience Gateway ([nsgportal.org](http://nsgportal.org)) now provides public HPC access for eight popular neuroscience software environments. Adding an Open EEGLAB Portal will hasten the development of human 3-D electrophysiological brain imaging, and will also allow researchers to run custom EEGLAB processing pipelines for the first time on collections of datasets for *meta-analysis* purposes.
Brain processes have evolved and function to optimize the outcome of the behavior the brain organizes in response to perceived challenges and opportunities.

Brains seize the opportunity of the moment!

Who am I?
The Beginning

fEEG, BCI, MoBI, NFB, BrainStim ...