Mining Event-related Brain Dynamics II

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Many tools now available -- but still (?) a **multicultural** 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 *a particular* portion.
- Triggered and modulated *in complex ways*.
- With *not well-understood* functional significance.
The very broad EEG point-spread function

Single simulated parietal source  →  Very broad projected scalp potentials
The very broad EEG point-spread function

Single simulated parietal source →

Very broad projected scalp potentials
The very broad EEG point-spread function

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Single simulated parietal source →

Very broad projected scalp potentials
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.
Cortex

Skull

Local Synchrony

Local Synchrony

Relative Independence

epiphenomena

phenomena

Skin

Electrodes

S. Makeig 2007
Information-based Signal Processing
Independent Component Dipolarity

Measured by residual variance *not* accounted for by the best fitting single (or dual) equivalent dipole model.
ICA separates *non-brain* effective source processes
... and also separates cortical brain IC processes

Single dipole component

Dual-symmetric dipole component

Equivalent dipoles
NEW! Handheld 3-D electrode position recording (aka ‘digitizing’ the electrode montage)

get_chanlocs() interface – post hoc 3-D electrode location recording from a subject 3-D head image.
Blind EEG Source Separation by ICA

Regress

Overlapping Event Responses
Trial-by-Trial Analysis

Trial-by-Trial Analysis

erpimage()
regression -- pMFC cluster

A) Raw
B) Regression
C) Raw minus regression
D) Raw minus regression
E) Raw minus average

Scott Burwell, unpublished
Blind EEG Source Separation by ICA

Spatial Navigation
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 & Individual Differences
Visual Working Memory Task – Trial Summary

Figure 1. Participants performed a Sternberg visual working memory task during EEG recordings. In each trial, appearance of an alerting fixation cross cued trial onset. Participants then viewed an encoding stimulus containing either 1 or 3 dots (low-load), or 5 or 7 dots (high-load), attending the spatial positions of the dots for 2 s. The dots then disappeared from screen, beginning a 3 s maintenance period. Upon presentation of the probe stimulus, participants were asked to indicate, by button press, whether or not the location of the probe disc matched the location of any of the encoding stimulus discs. During the ensuing intertrial interval (ITI) the screen was blank.

Lenartowicz et al., J. Neurosci., 2014
Canonical Correlation Analysis (CCA)
Linking EEG to Behavioral measures

Goal: Maximize correlation between these single values for each subject

EEG Measure Matrix

ADHD and Control Subjects

Need to Learn

EEG measure linear transform

Behavior Measure Matrix

ADHD and Control Subjects

Need to Learn
10 ERSP Canonical Correlation Filters

#1

#8
First Canonical Component, ERSP Filter

15 IC Clusters

Trial Latency (sec)

Stimulus

Probe

Fixation cue

50 Hz
10 Hz
3 Hz

Probe

Stimulus

Fixation cue

0

4

8
First Canonical Component, ERSP Filter

Trial Latency (sec)

-2 0 4 8

Probes
Fixation Cue
Button press
Stimulus
Probe
Maintenance
Stimulus

Cue 4 (157 Ms, 189 ICs)

Trial Latency (sec)
Blind EEG Source Separation by ICA

High-Resolution EEG Source Imaging
Figure 7: Estimated source distributions for independent component (IC) 5 of subject S1 using forward models incorporating BSCR values at various SCALE iterations when iterations start from $BSCR = 80$ (red plot) and from $BSCR = 25$ (blue plot). Color bar: normalized signal source density.
SCALE-applied 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):

<table>
<thead>
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<th>BD</th>
<th>FR</th>
<th>AV</th>
<th>RB</th>
<th>LH</th>
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Topological source clustering – 2-D measure projection

Arthur Tsai et al., NeuroImage, 2014
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.
MoBI Lab at SCCN, UCSD

Lab Streaming Layer software for synchronous multi-stream, multi-platform recording and feedback – freely available online (paper in progress): [github.com/labstreaminglayer](http://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?

Attention

Engagement

Action

G Leslie & S Makeig, 2013

HBM 2014
Poster #1538 online
EEG Result

Right TPJ
- Theory of Mind
- Sense of Agency
- both Action & Emotion Inhibition
Spatial Navigation Experiment – the *Audiomaze*

- Navigate an ‘invisible’ maze in the dark.
- Receive directional audio feedback, not tactile feedback.
- Task: Explore the maze and learn its configuration.
- Test: Draw the maze.
2nd Pass Navigation
3rd Pass Navigation
Central Posterior
Independent Component
Effective Source Cluster

Audio ‘Wall Touch’

Low-frequency increase

Alpha suppression
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!

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

Low-Cost MoBI

Any EEG System

< $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
Brain dynamics are inherently multi-scale. At each spatial recording scale, the signal is produced by active partial coherence of distributed activities at the next smaller scale.

Cross-scale coupling is bi-directional! Imaging Brain Support for Three Aspects of Consciousness

EEG (scalp surface fields)
ECOG (larger cortical surface fields)
Local Extracellular Fields
Intracellular and peri-cellular fields
Synaptic and other transmembrane potentials

Larger
Smaller
Knowing S. Makeig (2017)

Face Response ‘N170’
Willing

Imaging Human Agency

Mobile Brain/Body Imaging (MoBI)
Brains seize the opportunity of the moment!

Who am I?

Brains evolve and function to optimize the outcome of behavior the brain organizes in response to perceived challenges and opportunities.

Embodied Cognition & Agency

perception

action

evaluation
The Beginning
fEEG, BCI, MoBI, NFB, BrainStim ...
Can ICA reveal subject differences?

Multidimensional Landscape of Individual Differences