Mining
Event-related
Brain Dynamics
II

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Many tools now available -- but still (?) a **multicultural** problem.

- Psychology.
- Biology.
- Physics/Math.
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

Akalin Acar & Makeig 2010
The very broad EEG point-spread function

Single simulated parietal source → Very broad projected scalp potentials
The ‘receptive field’ of a bipolar EEG channel

Scalp EEG channel

Its cortical ‘receptive field’
The generation and modulation of EEG is COMPLEX and not well studied.
Phase cones (Freeman)
Avalanches (Plenz)
Delta band (1-4 Hz) in anesth. animals

Townsend et al., 2015
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
Skin
Electrodes
S. Makeig 2007
Relative Independence
phenomena
epiphenomena
Skin
Skull
Blind EEG Source Separation by ICA

Information-based Signal Processing
Surprising ‘dipolarity’ of Independent Component scalp projections

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

S. Makeig, A. Delorme, 2018
ICA separates *non-brain* effective source processes.
... and also separates cortical brain IC processes
ICLabel: A crowd-sourced AI independent component classifier

Fig. 1. An IC labeling example from the ICLabel website (https://iclabeleducsd.edu/tutorial), which also gives a detailed description of the features shown above. Label contributors are shown the illustrated IC measures and must decide which IC category or categories best apply. They mark their decision by clicking on the blue buttons below, and have the option of selecting multiple categories in the case that they cannot decide on one or believe the IC contains an additive mixture of sources. There is also a “?” button that they can use to indicate low confidence in the submitted label.

labeling.ucsd.edu/tutorial

Luca Pion-Tonachini, 2019
ICA in practice

Onton & Makeig, 2006
ICA decomposition finds dependent subspaces

Pairwise Mutual Information

B = brain
M = muscle
E = eye
? = other
SC = channel

S. Makeig, R. Martinez-Cancillo, 2018
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.
get_chanlocs – handheld 3-D electrode position recording

post hoc 3-D electrode location recording from a subject 3-D head image.
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:

- knowing
- feeling
- willing
EEG & feeling
Suggest the imaginative experience of 15 emotions:

- after Helen Bonny
- initial relaxation instruction
- alternate suggestions to imagine scenes engendering positive and negative emotions
- relaxation instructions between emotion episodes
- obtained 1-5 min periods of eyes-closed spontaneous EEG for each emotion from 33 subjects.
Independent Modulators

(a) Scalp electrodes
(b) Independent Components (ICs)
(c) Reference electrode
(d) Independent Modulators (IMs)

Onton & Makeig, Frontiers in Human Neuroscience ‘09
Independent Modulators
Independent Modulators

IC58

IC5

IC2

EMG (IM1)

Broadband (IM8)

Alpha rhythm (IM20)

Rel. Power (dB)

Frequency (Hz)
Changes in distribution of broadband high-frequency EEG power with imagined emotion
fMRI BOLD

EEG
fMRI BOLD

EEG

HFB

Mona Park et al., 2015

Onton & Makeig 2009

Makeig, 2016
Multi-model AMICA detects non-stationarity in source-level EEG

Model Probability

Emotion-Sorted Model Order (1-20)

Induction Experience

Time (sec)

Awe

Love

S Hsu, J Onton, T-P Jung, S Makeig, 2019
EEG & Willing

Imaging Human Agency
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.

Mobile Brain/body Imaging (MoBI)
MoBI

Mobile Brain/Body Imaging

Record what the brain does,
What the brain experiences,
And what the brain organizes.

S. Makeig 2007
Lab Streaming Layer software for synchronous multi-stream, multi-platform recording and feedback – freely available online (paper in progress): [github.com/labstreaminglayer](https://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.
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.
1st Pass Navigation
Central Posterior
Independent Component
Effective Source Cluster

Audio ‘Wall Touch’

Low-frequency increase
Alpha suppression
Frontal Midline
Independent Component
Effective Source Cluster

Alpha/theta increase
High beta suppression
Measuring Musical Engagement Through Expressive Rhythm

How can we measure listeners’ engagement?

G Leslie & S Makeig, 2013
Expressive gesturing task

The Heart is a Lonely Hunter (1968)

Two conditions:
- Fully engaged
- Less engaged

Conducting Experiment (2013)

Grace Leslie & S Makeig, 2013
The **TPJ** controls **representations of the self or of another individual** across a variety of low-level and high-level and socio-cognitive processes (mentalizing, empathy, agency discrimination, visual perspective taking, imitation) …

The **right TPJ** is a key cortical structure for both motor and emotional control – particularly of hand control. **rTPJ volume predicts level of emotional awareness of others** (in autistics) …
Brain imaging natural cognition -- actions & interactions

Imaging Human Social Interactions
Gedeon Deak Lab @ UCSD Cognitive Science

“Development of Shared Attention” –
A Mother and Toddler MoBI Experiment
3-yr old child – Reward Observation

Mother Pops the Bubble!

Yu Liao, T Mullen, S Makeig, G. Deak 2011
Brain processes have evolved and function to optimize the outcome of behavior the brain organizes in response to perceived challenges and opportunities.

Who am I?

Brains seize the opportunity of the moment!
The Beginning
fEEG, BCI, MoBI, NFB, BrainStim ...