Electroencephalography (EEG) with and without simultaneous fMRI

NIH MRI Summer Course

Peter J. Molfese, Ph.D. July 23, 2024

A quick recap

- On July 18, 2024 - Multimodal Neuroimaging Overview
  - Pros/Cons of doing Multimodal Neuroimaging
  - Design, Analysis, and Interpretation caveats and guides
  - Mostly a theoretical overview
- Today - July 23, 2024
  - All about EEG
  - Might have some overlap
  - Some introduction "Doing EEG at NIH"

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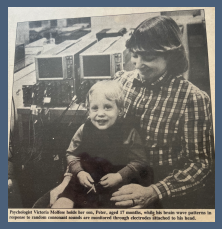

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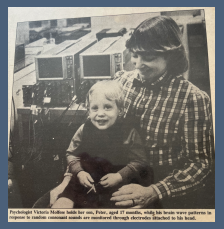
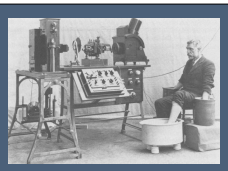


EEG Turns 100!

Hans Berger's 1924



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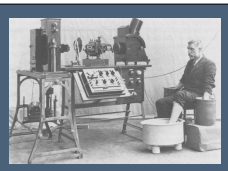

- Hans Berger 1873-1941

3-2

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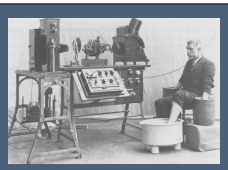

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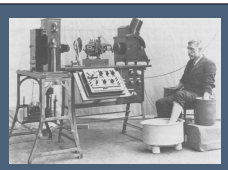

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  - Paper published in 1929
  - Did not go over well...
  - Replications from London in 1934

3-4

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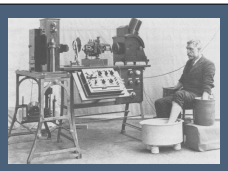

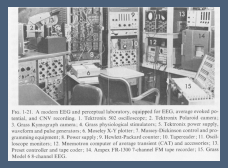

3-5

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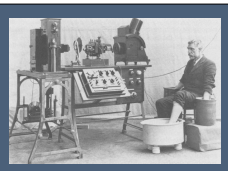
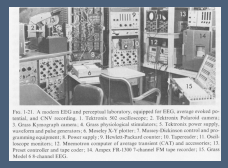
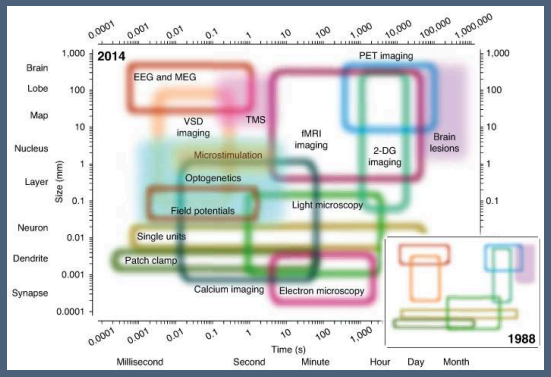




3-6

Spatial-Temporal Trade-offs



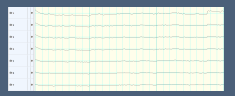
Sejnowski et al. (2014)

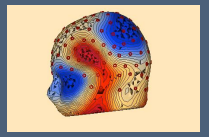
4

Neural Origins of EEG

From Neurons to Computers

Dipoles





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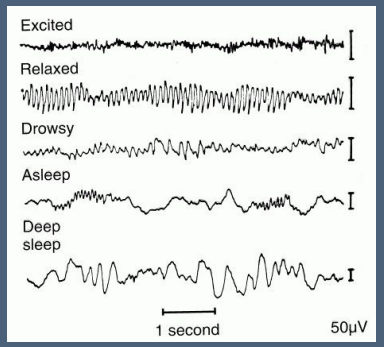
EEG Reflects Brain States



6

EEG is made up of various frequencies

Frequency Bands Thought to Reflect Certain Processes

Band	Frequency
Delta	0.5-4Hz
Theta	4-8Hz
Alpha	8-12Hz
Beta	12-35Hz
Gamma	>35Hz

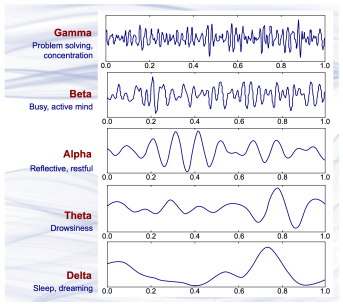


FIGURE 2.1 Brain wave samples with dominant frequencies belonging to beta, alpha, theta, and delta bands and gamma waves.

Abhang, Gawali, & Mehrotra (2016)
Introduction to EEG- and Speech-Based Emotion Recognition

7-1

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FIGURE 2.1 Brain wave samples v
gamma waves.

The theta band of EEG activity, which typically occurs in the frequency range of 4-7 Hz, is thought to be related to several important cognitive and behavioral functions:

1. Learning and memory: Theta waves are believed to play a crucial role in memory formation, encoding, and retrieval [2]. Studies have shown that theta oscillations may act as a switch between encoding and recall mechanisms in both rodents and humans.
2. Spatial navigation: Theta rhythm has been linked to mechanisms animals use to keep track of their location within the environment [2]. This is particularly evident in studies of hippocampal theta rhythm.
3. Cognitive control: Theta activity, especially from the midfrontal cortex, is specifically related to cognitive control processes [2].
4. Arousal and attention: Theta rhythm has been associated with states of arousal and attentional processes [2].
5. Emotional processing: Theta band activity has been observed in response to emotional expressions, particularly in areas such as the amygdala, visual cortex, and frontal cortex [3].
6. Sleep and drowsiness: In humans, theta waves tend to appear during meditative, drowsy, hypnotic or sleeping states, particularly during REM sleep [2].
7. Anxiety and personality traits: The amount of frontal midline theta has been found to negatively correlate with anxiety levels and positively correlate with scores on neurotic and extraversion scales [1].
8. Meditation: Increased theta power has been associated with meditative states [2].
9. Sensorimotor processing: Some researchers have argued that theta rhythm is related to sensorimotor integration [2].
10. Depression: Increased theta band power has been correlated with antidepressant treatment outcomes in patients with major depressive disorder [4].

It's important to note that theta activity can be observed in various brain regions, including both cortical and subcortical structures, and its specific function may vary depending on the location and context of its occurrence [2] [3].

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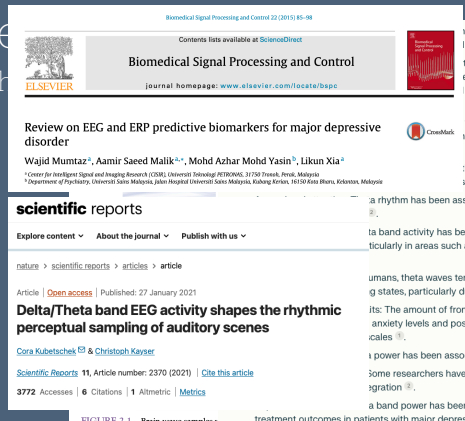

Biomedical Signal Processing and Control 22 (2015) 85–98

Contents lists available at ScienceDirect

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Review on EEG and ERP predictive biomarkers for major depressive disorder

Wajid Mumtaz, Aamir Saeed Malik, Mohd Azhar Mohd Yasin, Likun Xia

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Delta/Theta band EEG activity shapes the rhythmic perceptual sampling of auditory scenes

Cora Kubetschek & Christoph Kayser

Scientific Reports 11, Article number: 2370 (2021) | Cite this article

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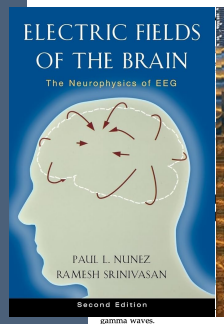

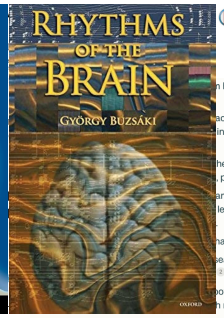

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The Event-Related Potential

Time/Event-locked EEG

8-1

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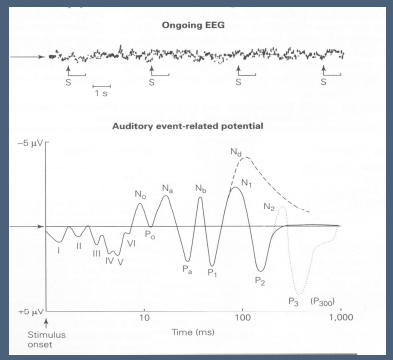
Time/Event-locked EEG



8-2

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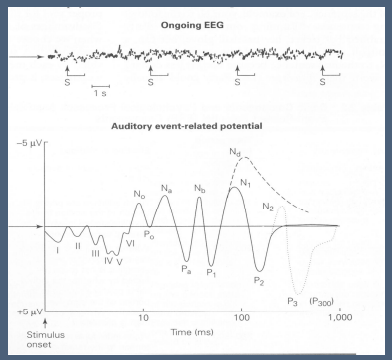
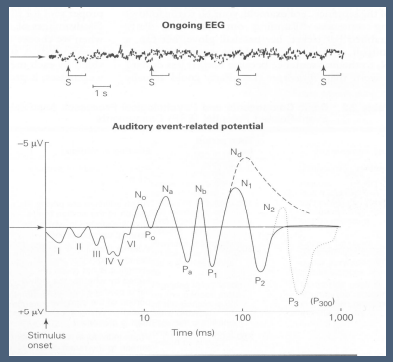


- Event-Related Potential or ERP

8-3

The Event-Related Potential

Time/Event-locked EEG



- Event-Related Potential or ERP
  - Never "ERRRP"

8-4

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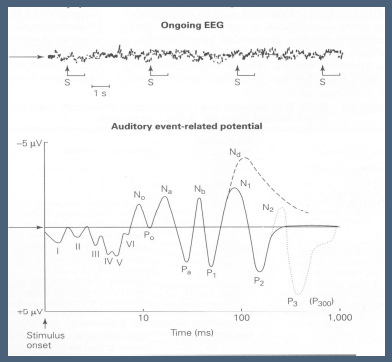

- Event-Related Potential or ERP
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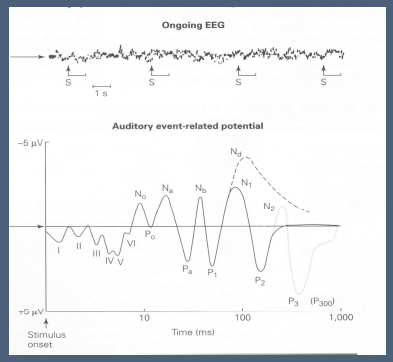
- Portion of the ongoing EEG

8-5

The Event-Related Potential

Time/Event-locked EEG



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8-6

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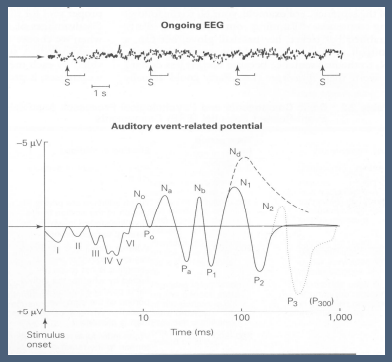

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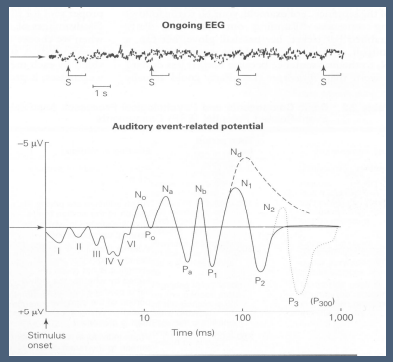


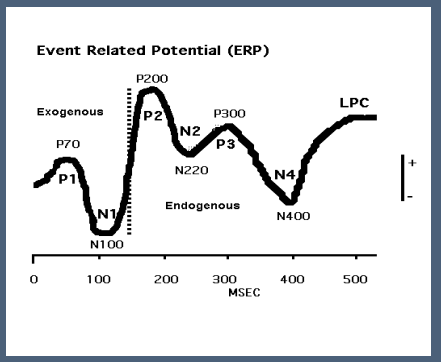
- Event-Related Potential or ERP
  - Never "ERRRP"
- Portion of the ongoing EEG
- Time-Locked to Stimulus Onset
- Strong Temporal Information
- Comparability across the lifespan

8-8

ERP

"Sequence of overlapping components, each perhaps representing activity of different populations of nerve cells and each sometimes standing in different, perhaps orthogonal, relations to experimental variables"

-Donchin, 1979, p24



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ERPs are comparable across lifespan

Can be used on all ages

- Predict later behavior and conditions
  - Reading ability
  - Accurate prediction of dyslexia as early as 1 day old infants

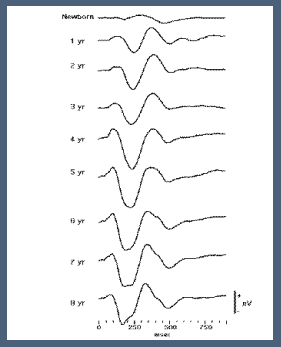
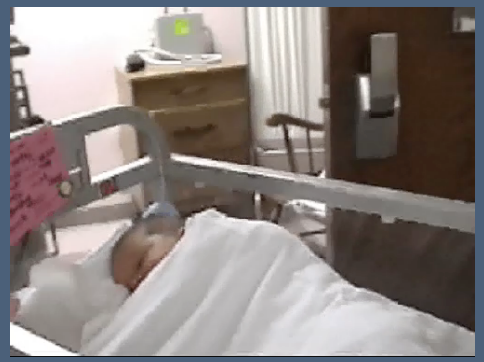


Figure courtesy Dennis Molfese

10

Infant EEG Recording

Infant is 24 hours old, testing in hospital nursery



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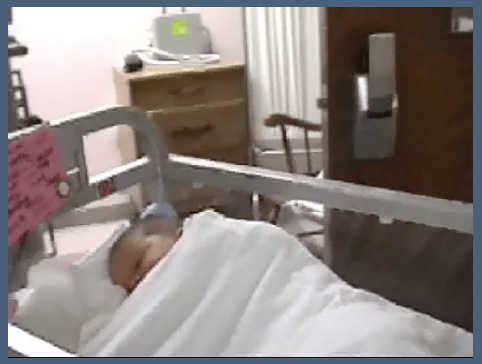

11-2

ERP Measures

Amplitude, Latency, Distribution

12-1

ERP Measures

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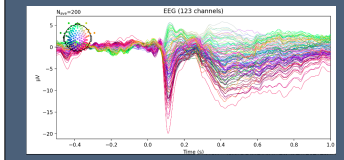

12-2

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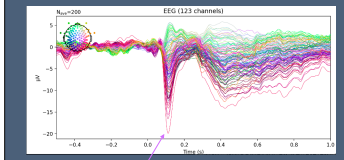

100ms
-18μV

12-3

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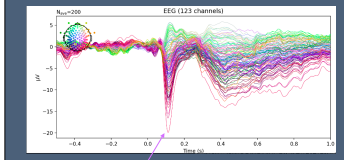

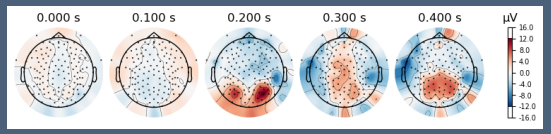

100ms
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12-4

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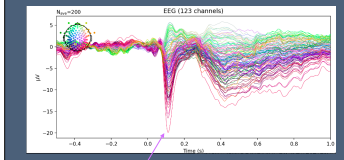
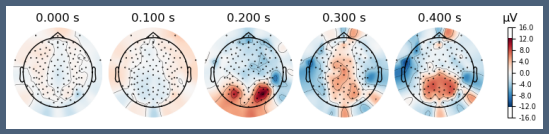




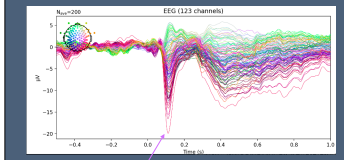
Infant Brain

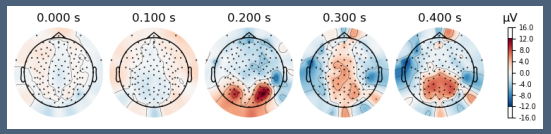
100ms
-18µV

12-5

ERP Measures

Amplitude, Latency, Distribution





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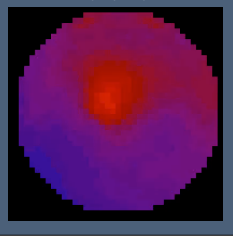

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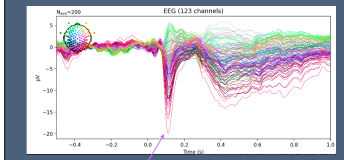
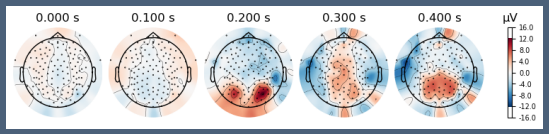
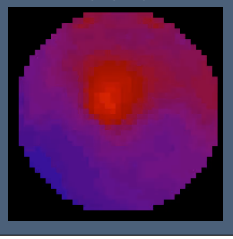




Infant Brain

Adult Brain

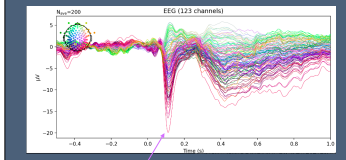


100ms
-18µV

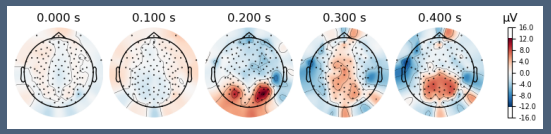
12-7

ERP Measures

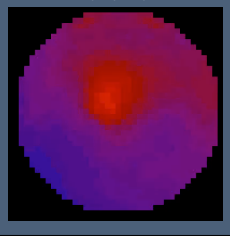
Amplitude, Latency, Distribution



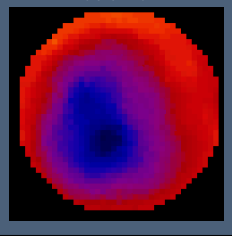
100ms
-18μV



Infant Brain

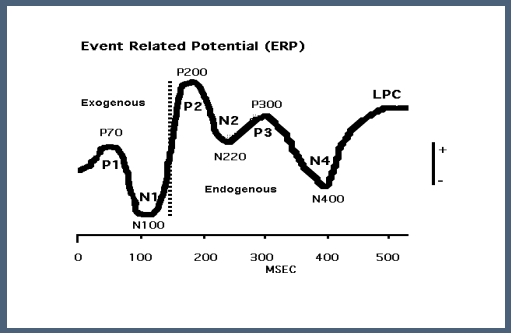


Adult Brain



12-8

ERP Nomenclature

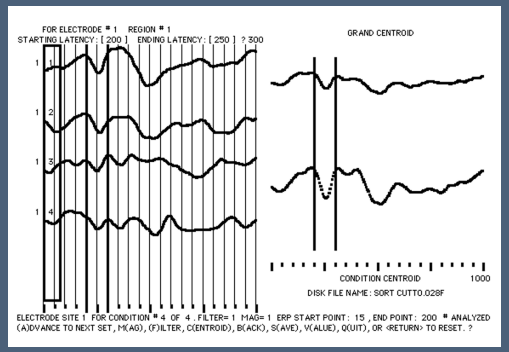


Exogenous = influenced by external factors
Endogenous = internal factors controlling

13

Amplitude & Latency Measures

"Peak Picking"



- Measure the amplitude of peak
  - Postive
  - Negative
- Measure the latency of peak
- Try to make search windows over the entire head
  - Latency and polarity may vary or even flip

Figure courtesy
Dennis Molfese

14

ERP Components

Part 1

Key, A. P., Dove, G. O., & Maguire, M. J. (2005). Linking brainwaves to the brain: an ERP primer. Developmental neuropsychology, 27(2), 183–215. https://doi.org/10.1207/s15326942dn2702_1

Peaks	Latency (ms)	Experiment Manipulation	Max Scalp Amplitude	Interpretation	Source
P1	50 Auditory	None Specific	Anterior	arousal level, suppression of unattended information	primary auditory cortex, superior temporal gyres, medial frontal
	100 Visual		Occipital		striate or extra-striate (posterior fusiform), posterior-parietal regions
N1	100 Auditory	None Specific	Temporal	selective filtering, basic stimulus characteristics, initial selection for later pattern recognition	Primary auditory cortex, superior temporal plane
	100-161 Visual		Central, Midline, Occipital		inferior occipital, occipito-temporal junction, inferior temporal lobe
P2	150-275 Auditory	None Specific	Central	selective attention, stimulus change, feature detection, short-term memory	primary auditory cortex, secondary auditory cortex
	200+ Visual		Occipital, Frontal		inferior occipital region

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ERP Components

Part 2

Key, A. P., Dove, G. O., & Maguire, M. J. (2005). Linking brainwaves to the brain: an ERP primer. Developmental neuropsychology, 27(2), 183-215. https://doi.org/10.1207/s15326942dn2702_1

Peaks	Latency	Experimental Manipulation	Max Amplitude	Interpretation	Source
N2	200 ms Auditory	None Specific	vertex, pre-occipital, and frontal	Detect changes in attended stimuli	supratemporal, auditory cortex
	156-189 ms (N170)	Face and Object Recognition	inferior temporal	Facial and Object Expertise	Fusiform Gyrus, lateral occipital-temporal
	100-300 ms	Go/No-Go	frontal, central	inhibition	caudal and astral anterior cingulate
MMN	100-250 ms Auditory	Physically different stimuli	frontal, central	early sensory memory	temporal lobe, right superior temporal gyrus and plane
P3	300 ms	oddball (P3b)	occipito-parietal	memory updating, stimulus discrimination	thalamus, hippocampus, superior temporal gyrus and junction
	300 ms	novel stimuli (P3a)	frontal	involuntary attention, inhibition	medial parietal lobe, left superior prefrontal cortex

16

ERP Components

Part 3

Key, A. P., Dove, G. O., & Maguire, M. J. (2005). Linking brainwaves to the brain: an ERP primer. Developmental neuropsychology, 27(2), 183-215. https://doi.org/10.1207/s15326942dn2702_1

Peaks	Latency	Experimental Manipulation	Max Amplitude	Interpretation	Source
N400	475 ms Visual	Sentence Processing with Semantic Violations	Parietal and Temporal	Higher-Order Language Processing	Parahippocampal, anterior fusiform, medial temporal, hippocampus, amygdala, lateral temporal regions
	525 ms Auditory				
P600	400-600 ms Memory	Learned vs. Novel	Left Temporal, Frontaocentral	Memory, Novel identification, can be cross-modal	Prefrontal, anterior temporal lobe, anterior cingulate, hippocampus, frontal and temporal cortex
	500 ms Language	Syntactic Violation	Frontocentral	Syntactic violation, phrase structure, subcategorization	Superior Parietal, Precuneus, Posterior Cingulate, Basal Ganglia

17

ERP Components

Part 4

Key, A. P., Dove, G. O., & Maguire, M. J. (2005). Linking brainwaves to the brain: an ERP primer. Developmental neuropsychology, 27(2), 183-215. https://doi.org/10.1207/s15326942dn2702_1

Peaks	Latency	Experimental Manipulation	Max Amplitude	Interpretation	Source
ERN	80-150 ms (Response Locked)	Forced Choice RT/ACC (e.g. Flanker)	Frontal & Central	Intent and Motivation	Anterior Cingulate Cortex, DLPFC
FRN	250-350 ms	Any reward feedback	Anterior Frontal Central	Expectation differs from feedback Feedback positive vs. negative	Anterior Cingulate Cortex
CNV	Pre-stimulus negative deflection	Go/No-Go Set ITIs	Vertex	Anticipation	Premotor (BA 6)

18

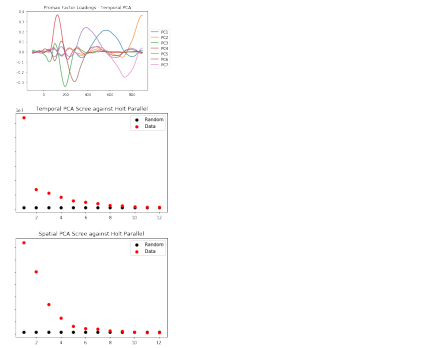
Multivariate Alternatives to Picking Peaks

PCA

19-1

Multivariate Alternatives to Picking Peaks

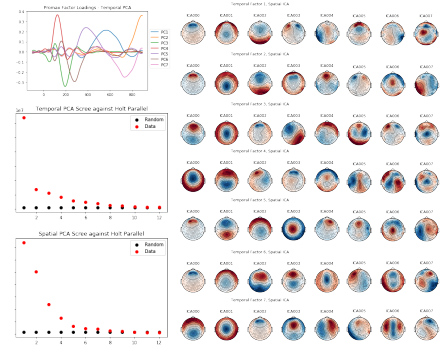
PCA



19-2

Multivariate Alternatives to Picking Peaks

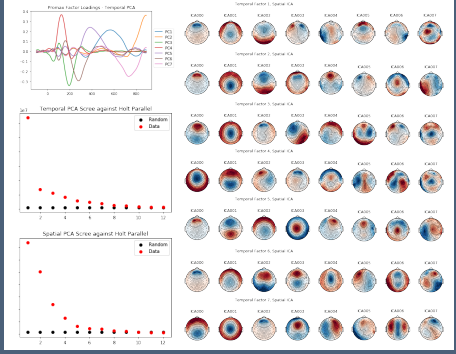
PCA

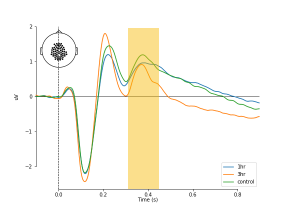


19-3

Multivariate Alternatives to Picking Peaks

PCA

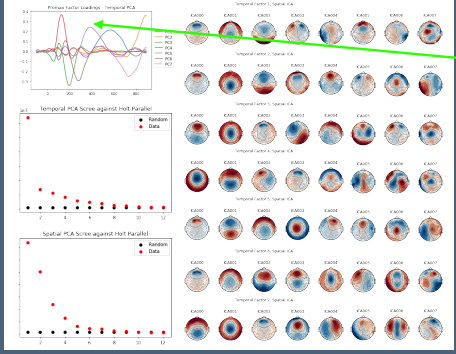


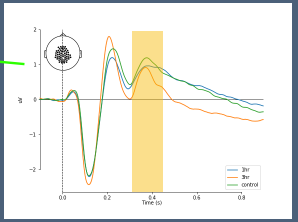


19-4

Multivariate Alternatives to Picking Peaks

PCA





19-5

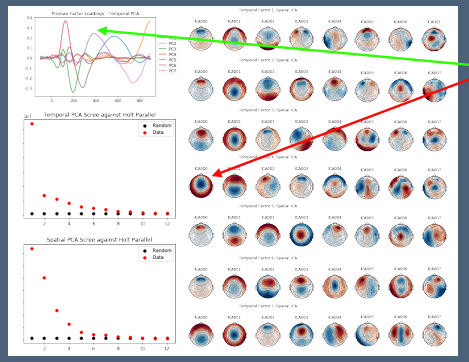
Multivariate Alternatives to Picking Peaks

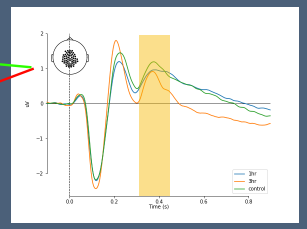
PCA

19-6

Multivariate Alternatives to Picking Peaks

PCA





PCA (Donchin, 1968; 1969)
PCA - discriminate function (Chapman, 1979)
PCA - ANOVA (Molfese, 1975; 1976)
PCA - MANOVA (Samar, 1986)
PCA - ANOVA - REGRESSION (Molfese & Molfese, 1986)
PCA - ANOVA - Canonical Correlation (Molfese & Molfese, 1979)
Growth curves (Molfese, Espy & Molfese)
Discriminante function

19-7

Multivariate Alternatives to Picking Peaks

PCA

PCA (Donchin, 1968; 1969)
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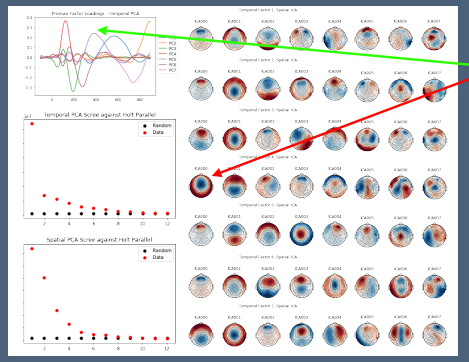
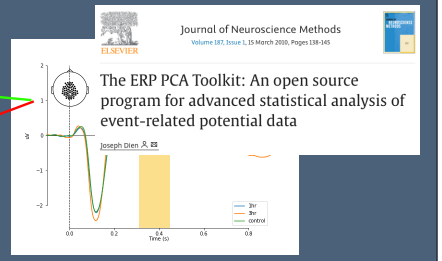
Growth curves (Molfese, Espy & Molfese)
Discriminante function

19-8

Multivariate Alternatives to Picking Peaks

PCA





Journal of Neuroscience Methods
Volume 187, Issue 1, 15 March 2010, Pages 138-145

The ERP PCA Toolkit: An open source program for advanced statistical analysis of event-related potential data

Joseph Dien

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PCA - discriminate function (Chapman, 1979)
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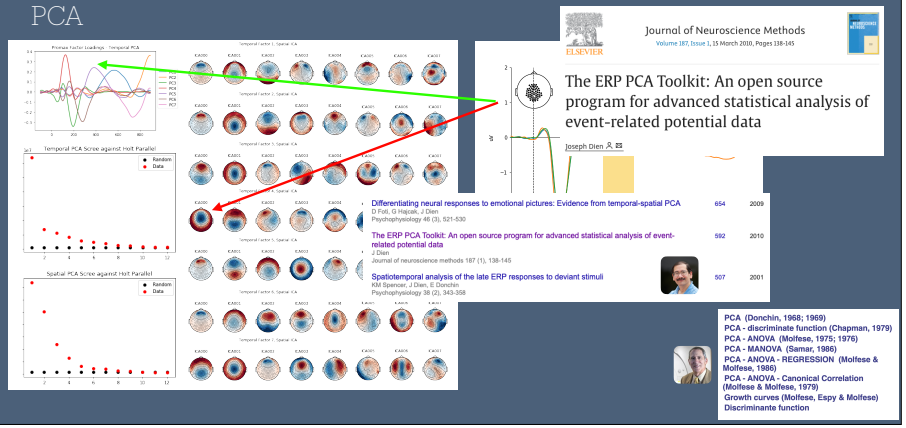
Discriminante function

19-9

Multivariate Alternatives to Picking Peaks

PCA



19-10

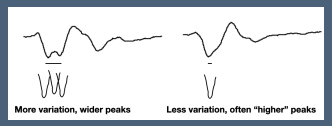
Caveats

Peaks are peaks, but are they really peaks?

20-1

Caveats

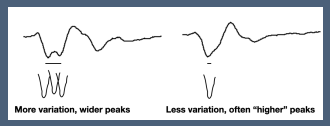
Peaks are peaks, but are they really peaks?

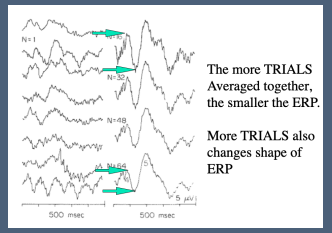


20-2

Caveats

Peaks are peaks, but are they really peaks?



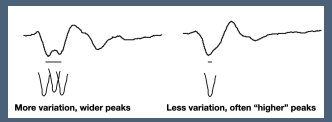


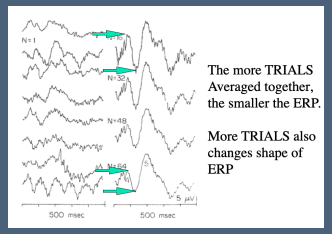
Goff, 1971

20-3

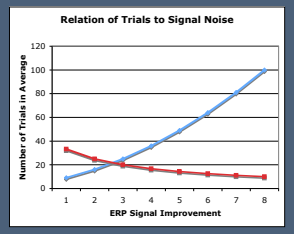
Caveats

Peaks are peaks, but are they really peaks?





Goff, 1971



Molfese, 1992

20-4

Do we really need that many...

Sampling Rate and Electrodes

21-1

Do we really need that many...

Sampling Rate and Electrodes

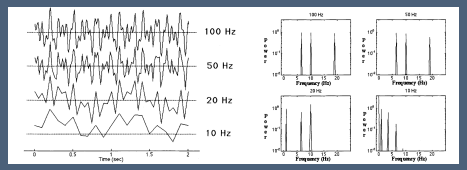
- More data is better!

21-2

Do we really need that many...

Sampling Rate and Electrodes

- More data is better!

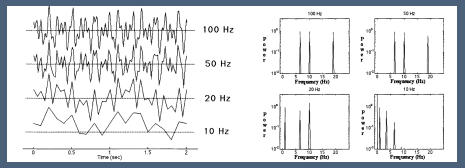


21-3

Do we really need that many...

Sampling Rate and Electrodes

- More data is better!
- Temporal Nyquist



21-4

Do we really need that many...

Sampling Rate and Electrodes

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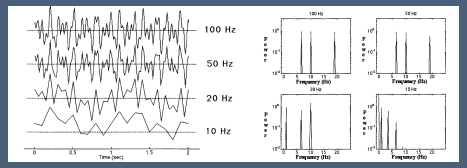
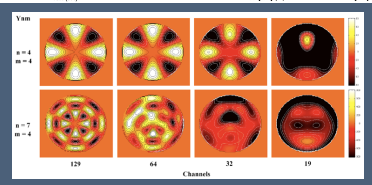
- Temporal Nyquist





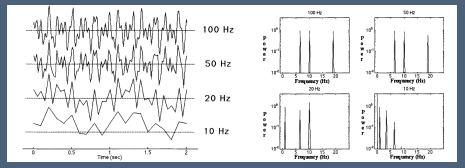
Srinivasan, Tucker, & Murias (1998)

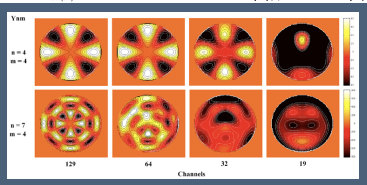
21-5

Do we really need that many...

Sampling Rate and Electrodes

- More data is better!
- Temporal Nyquist
- Spatial Nyquist





Srinivasan, Tucker, & Murias (1998)

21-6

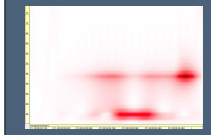
Time Frequency

Wavelets, FFTs, Oh My!

22-1

Time Frequency

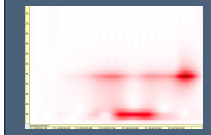
Wavelets, FFTs, Oh My!



22-2

Time Frequency

Wavelets, FFTs, Oh My!



- Measures of oscillatory dynamics
  - "Spectral Content" and how it changes over time
  - Brain oscillations at different frequencies can be associated with various cognitive functions / processes

22-3

Time Frequency

Wavelets, FFTs, Oh My!

- Measures of oscillatory dynamics
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- Transform from the time domain to the frequency domain
  - Wavelets allow us to keep some of the temporal information (similar to sliding window FFT)

22-4

Time Frequency

Wavelets, FFTs, Oh My!

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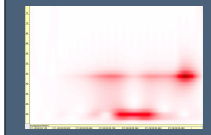
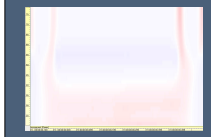
- Evoked - Phase locked oscillations

22-5

Time Frequency

Wavelets, FFTs, Oh My!





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Time Frequency

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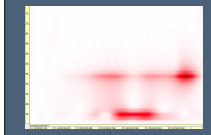

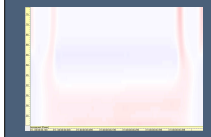

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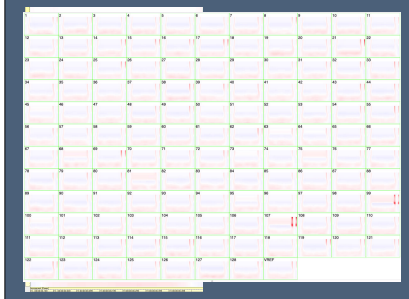
22-7

Time Frequency

Wavelets, FFTs, Oh My!



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- Transform from the time domain to the frequency domain
  - Wavelets allow us to keep some of the temporal information (similar to sliding window FFT)
- Evoked - Phase locked oscillations
- Induced - Not phase-locked

22-8

Source Analysis

Just show me some brains!

23

Best Practices for Source Analysis

- Adequate Number of Sensors
- Know the Geometry of Head & Sensors
- Accurate Head Model
- Know Conductivity of the head
- Choose a inverse solution model

24

Best Practices for Source Analysis

- Adequate Number of Sensors √
- Know the Geometry of Head & Sensors
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25

Best Practices for Source Analysis

- Adequate Number of Sensors √
- Know the Geometry of Head & Sensors
- Accurate Head Model
- Know Conductivity of the head
- Choose a inverse solution model

} Head Model

26

Forward Solution

EEG Sensor Geometry

27-1

Forward Solution

EEG Sensor Geometry

- Use some type of method for triangulating where the sensors are on the head

27-2

Forward Solution

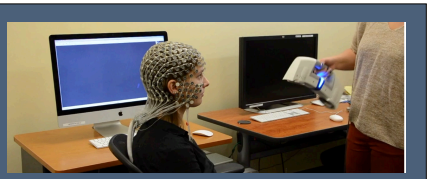
EEG Sensor Geometry

- Use some type of method for triangulating where the sensors are on the head
- Infrared NDI scanners

27-3

Forward Solution

EEG Sensor Geometry



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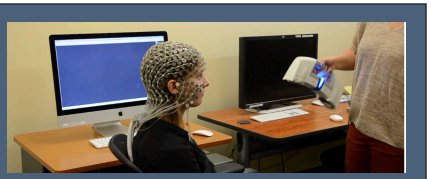
- Infrared NDI scanners

27-4

Forward Solution

EEG Sensor Geometry



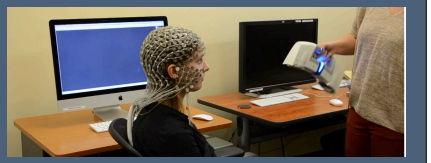
- Use some type of method for triangulating where the sensors are on the head
- Infrared NDI scanners
- Electrode Triangulation Systems

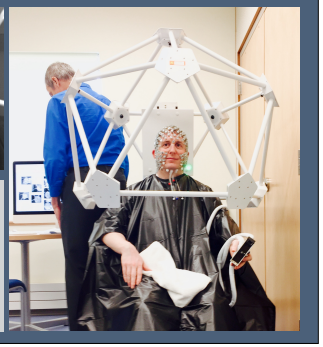
27-5

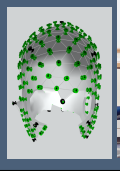
Forward Solution

EEG Sensor Geometry

- Use some type of method for triangulating where the sensors are on the head
- Infrared NDI scanners
- Electrode Triangulation Systems





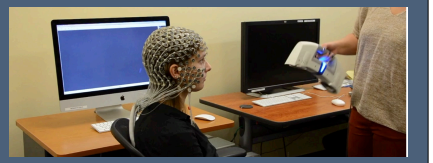


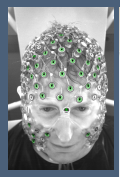
27-6

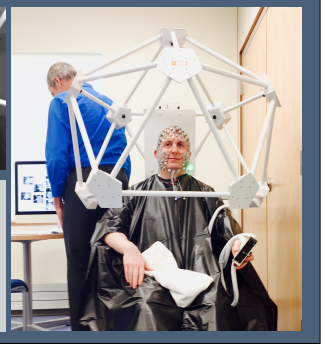
Forward Solution

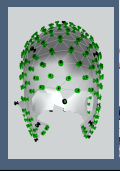
EEG Sensor Geometry

- Use some type of method for triangulating where the sensors are on the head
- Infrared NDI scanners
- Electrode Triangulation Systems
- Polhemus-like pen registration systems







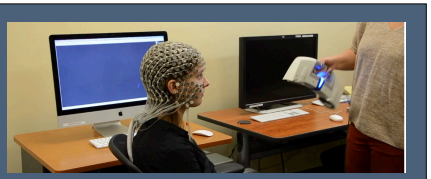


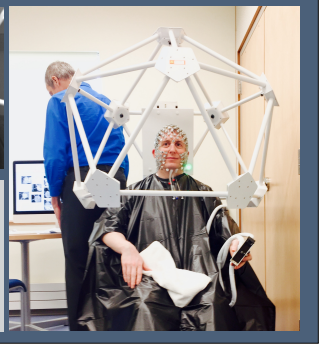
27-7

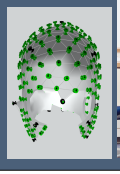
Forward Solution

EEG Sensor Geometry

- Use some type of method for triangulating where the sensors are on the head
- Infrared NDI scanners
- Electrode Triangulation Systems
- Polhemus-like pen registration systems







27-8

Source Analysis

The Problems

28-1

Source Analysis

The Problems

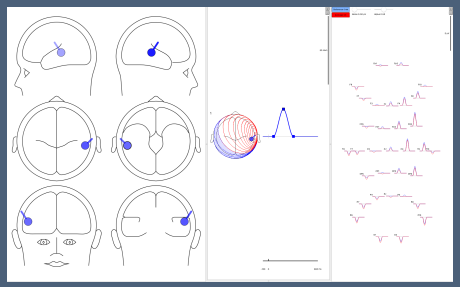
- Forward Problem: Given the sources and a propagation model, what does the scalp topography look like?

28-2

Source Analysis

The Problems

- Forward Problem: Given the sources and a propagation model, what does the scalp topography look like?

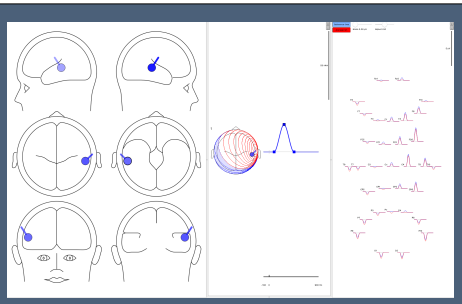


28-3

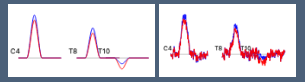
Source Analysis

The Problems

- Forward Problem: Given the sources and a propagation model, what does the scalp topography look like?



No Noise Low Noise

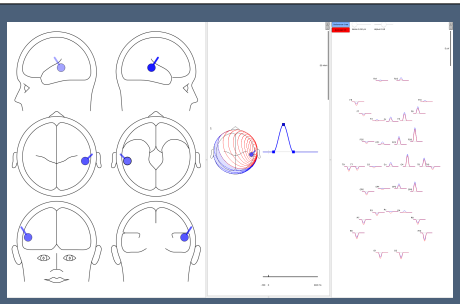


28-4

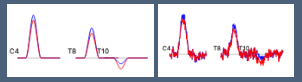
Source Analysis

The Problems

- Forward Problem: Given the sources and a propagation model, what does the scalp topography look like?
- Inverse Problem: Given scalp topography and propagation model, what are the generators?



No Noise Low Noise

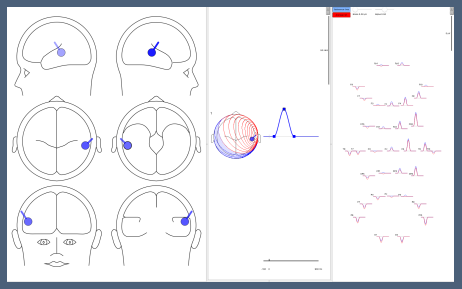


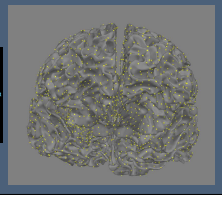
28-5

Source Analysis

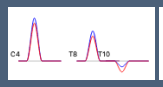
The Problems

- Forward Problem: Given the sources and a propagation model, what does the scalp topography look like?
- Inverse Problem: Given scalp topography and propagation model, what are the generators?

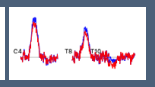




No Noise



Low Noise



BESA Simulator - FREE Download

28-6

Forward Solution

FEM / BEM - Head Volume Conduction

29-1

Forward Solution

FEM / BEM - Head Volume Conduction

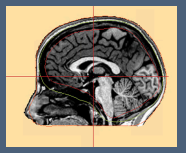
- BEM - Boundary Element Model
  - Typically uses a simple three-layer model (scalp, skull, brain) with isotropic conductivity

29-2

Forward Solution

FEM / BEM - Head Volume Conduction

BEM



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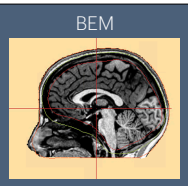
29-3

Forward Solution

FEM / BEM - Head Volume Conduction

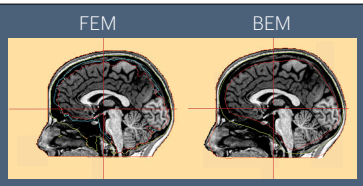


- BEM - Boundary Element Model
  - Typically uses a simple three-layer model (scalp, skull, brain) with isotropic conductivity
- FEM - Finite Element Model
  - Divide head volume into small elements (tetrahedral or hexahedral) with specific conductivity properties (e.g. brain, skull, scalp, CSF)
  - Allows for complex geometries to exist and be modeled & currents to vary by direction of flow (e.g. white matter tracts)

29-4

Forward Solution

FEM / BEM - Head Volume Conduction



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  - Allows for complex geometries to exist and be modeled & currents to vary by direction of flow (e.g. white matter tracts)

29-5

Inverse Models

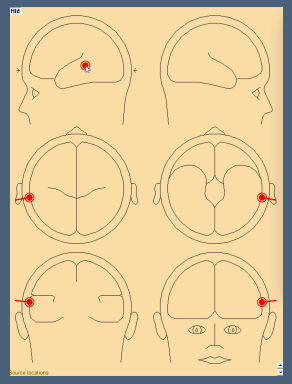
Often Underspecified and Under-Appreciated

- Single Dipoles
- Distributed Source Models
  - Minimum Norm Estimates (MNE)
- Beamforming

30

Single Current Dipoles

Equivalent Single Dipole

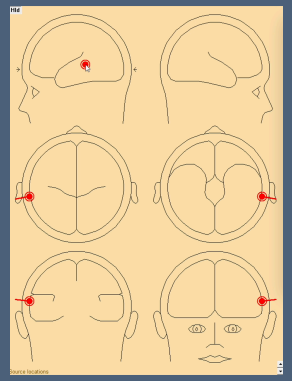


31-1

Single Current Dipoles

Equivalent Single Dipole

- Assume EEG signals are generated by a single equivalent current dipole source in the brain.

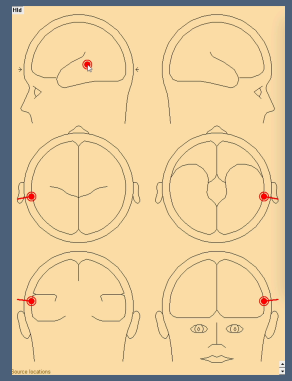


31-2

Single Current Dipoles

Equivalent Single Dipole

- Assume EEG signals are generated by a single equivalent current dipole source in the brain.
- Specifies location (XYZ), orientation, and strength

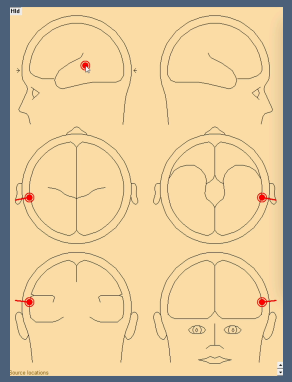


31-3

Single Current Dipoles

Equivalent Single Dipole

- Assume EEG signals are generated by a single equivalent current dipole source in the brain.
- Specifies location (XYZ), orientation, and strength
- The quality of the fit is assessed using measures like residual variance or goodness of fit

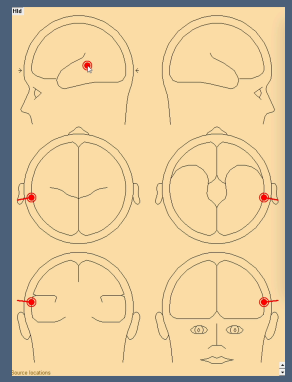


31-4

Single Current Dipoles

Equivalent Single Dipole

- Assume EEG signals are generated by a single equivalent current dipole source in the brain.
- Specifies location (XYZ), orientation, and strength
- The quality of the fit is assessed using measures like residual variance or goodness of fit
- Particularly useful for focal sources:
  - Early sensory evoked potentials or Epileptic spikes



31-5

Single Current Dipoles

Equivalent Single Dipole

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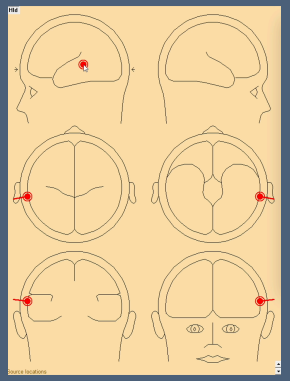
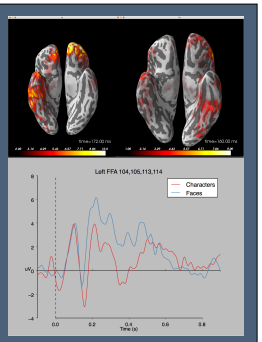
- Specifies location (XYZ), orientation, and strength
- The quality of the fit is assessed using measures like residual variance or goodness of fit
- Particularly useful for focal sources:
  - Early sensory evoked potentials or Epileptic spikes
- May not be appropriate for more complex or distributed brain activity patterns



31-6

Minimum Norm

Well implemented in many software



- Best fit of the sensor data while minimizing the overall amplitude of brain activity
- Variants: sLORETA, dSPM
- Pros
  - Computationally efficient, even for large datasets
  - Can handle complex source configurations
  - Provides a distributed estimate of brain activity
- Limitations
  - Tends to produce spatially smeared results (requires some regularization)
  - May have difficulty with deep sources

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Beamforming

Checkout the MEG talks for more info!

- Source Analysis by applying a spatial filter to sensor data
  - Spatial filters are adaptive and pass signals from a specific brain location while attenuating signals from other locations
- Common types: LCMV, DICS, and SAM
  - Can handle multiple simultaneous sources
  - No prior assumptions about number/location of sources
  - Good spatial resolution
- Cons
  - Difficulty with highly correlate sources

33

EEG / EEG-fMRI at NIH

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Our EEG Options

FMRI Facility Owned Equipment

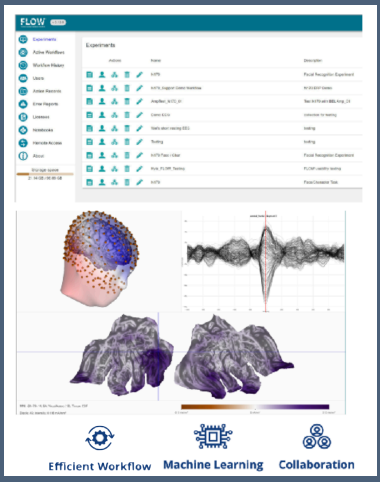
- 2x EGI MR-Conditional 256-Channel EEG Systems
- 1x EGI GTEN "Neuromodulation" 256-Channel EEG System
  - tACS/tDCS/tRNS
  - Can record EEG continuously
- GeoScan NDI Sensor for Electrode Triangulation
- Data Storage Node

35

Data Storage

Belco FLOW Server

- Sort of like XNAT for your EEG data
- Stores your EEG Data and assorted extras
  - Electrode location files
  - Screen captures
- Can also process your data on the node
  - Complete with basic source analysis



36

Design your Experiment

Currently supporting PsychoPy and E-PRIME

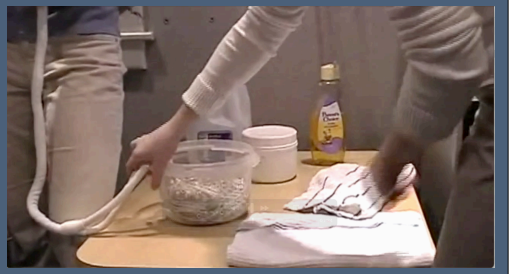
- CMN (Josh & Pete) wrote the Python package to communicate between PsychoPy and EGI's Net Station
- Millisecond accuracy timing
- Flexible using a range of stimuli
  - Visual
  - Auditory
  - Movies

```python
from egi_pynetstation import NetStation
# Set an IP address for the computer running NetStation as an IPv4 string
IP_ns = '10.10.10.42'
# Set a port that NetStation will be listening to as an integer
port_ns = 55513
ns = NetStation(IP_ns, port_ns)
# Set an NTP clock server (the amplifier) address as an IPv4 string
IP_amp = '10.10.10.51'
ns.connect(ntp_ip=IP_amp)
# Do whatever setup for your experiment here...
# Begin recording
ns.begin_rec()
# You can now send events; this one just says "HIYA" and automatically
# marks the time for you
ns.send_event(event_type="HIYA")
# You can include a data dictionary; perhaps you have a dog stimulus
my_data = {"dogs": "fido"}
# Send this data with the event type of "STIM"
ns.send_event(event_type="STIM", data=my_data)
# With the experiment concluded, you can end the recording
ns.end_rec()
# You'll want to disconnect the amplifier when your program is done
ns.disconnect()
```

37

Learn how use the system

- Net applications
  - Training offered 1-2 times a year
  - Ideal for when new folks join the lab
- Also learn how to hook system into MRI
  - Proper patient/subject prep
  - Recording good quality data
  - Cleaning / sanitizing



38-1

Learn how use the system

- Net applications
  - Training offered 1-2 times a year
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- Also learn how to hook system into MRI
  - Proper patient/subject prep
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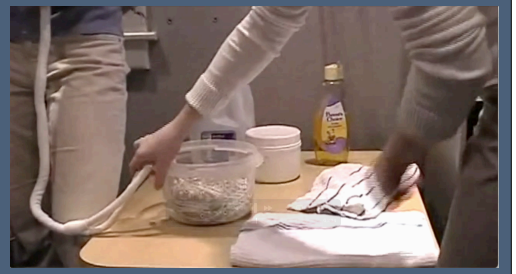


38-2

Learn how to analyze EEG/EEG-fMRI

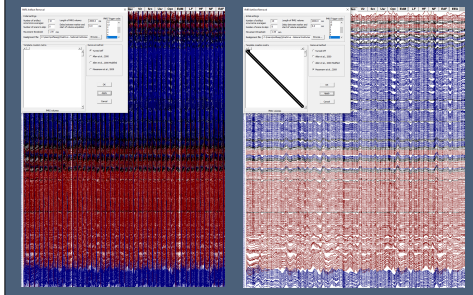
- Python notebooks available
- Processing nodes for Commercial Programs
- Guidance on analysis trajectory

Commercial		BESA
Python	MNE	
Matlab	BrainStorm	FieldTrip

39

MR Artifact Removal / Reduction

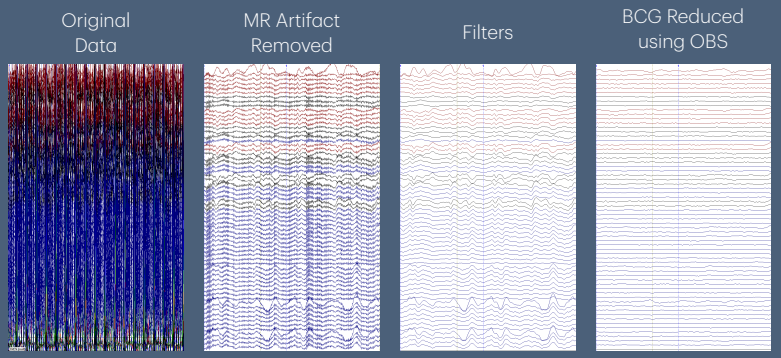
Gradient Artifacts



- AAS (Allen et al. 2000)
  - Average Artifact Subtraction
  - Possible problems if you have movement in scanner
- OBS (Mossmann et al. 2009)
  - Optimal Basis Sets to potentially model artifact
  - More flexible to changes in artifact over time
  - More complex, possible overfitting?

40

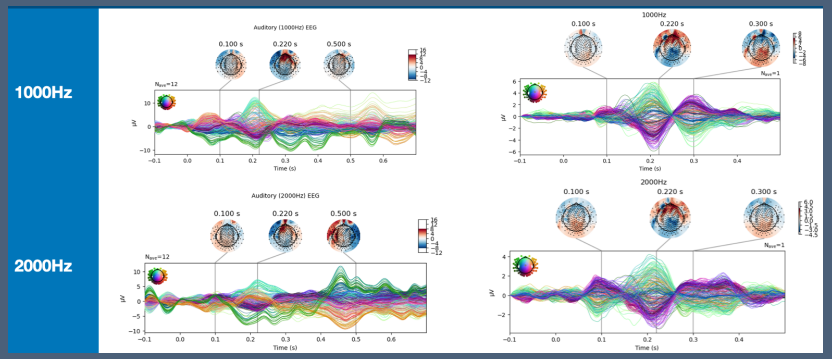
Subduing fMRI Artifacts



41

Comparing Preprocessing

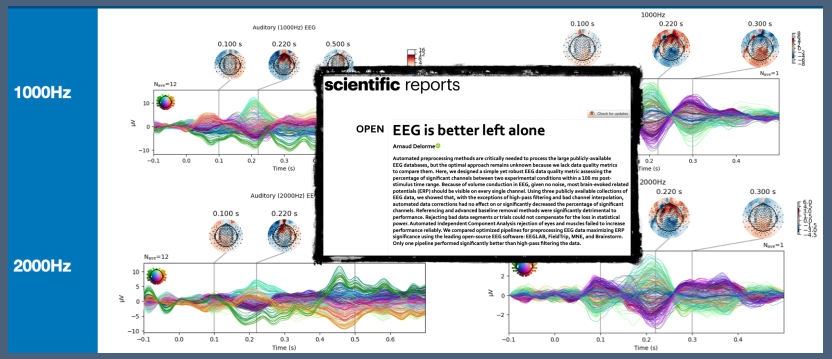
It can make a difference!



42-1

Comparing Preprocessing

It can make a difference!

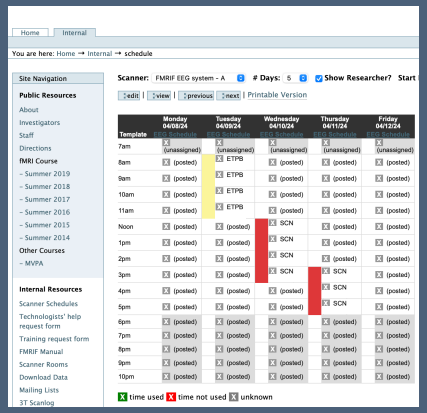


42-2

Scheduling

Just like MRI

- Scheduler can be accessed from our website
  - fmrif.nimh.nih.gov
- First come, first serve
- "Pre-wired" on most 3T scanners
  - 3Tb
  - 3Td
  - NIAAA 3T Prisma



43

Come Collect Awesome Data

44

Questions?

Peter.Molfese@nih.gov