23-Oct-2017

Introduction and Methodology of Evoked Potentials

Mahesh Jayachandra MD, PhD

Head, Bio-Engineering Group, NDRF-IEI

Director, Lab of Neurophysiology
St. John's Research Institute,
Bangalore 560 034

EEG and Event-Related Potentials (ERPs)

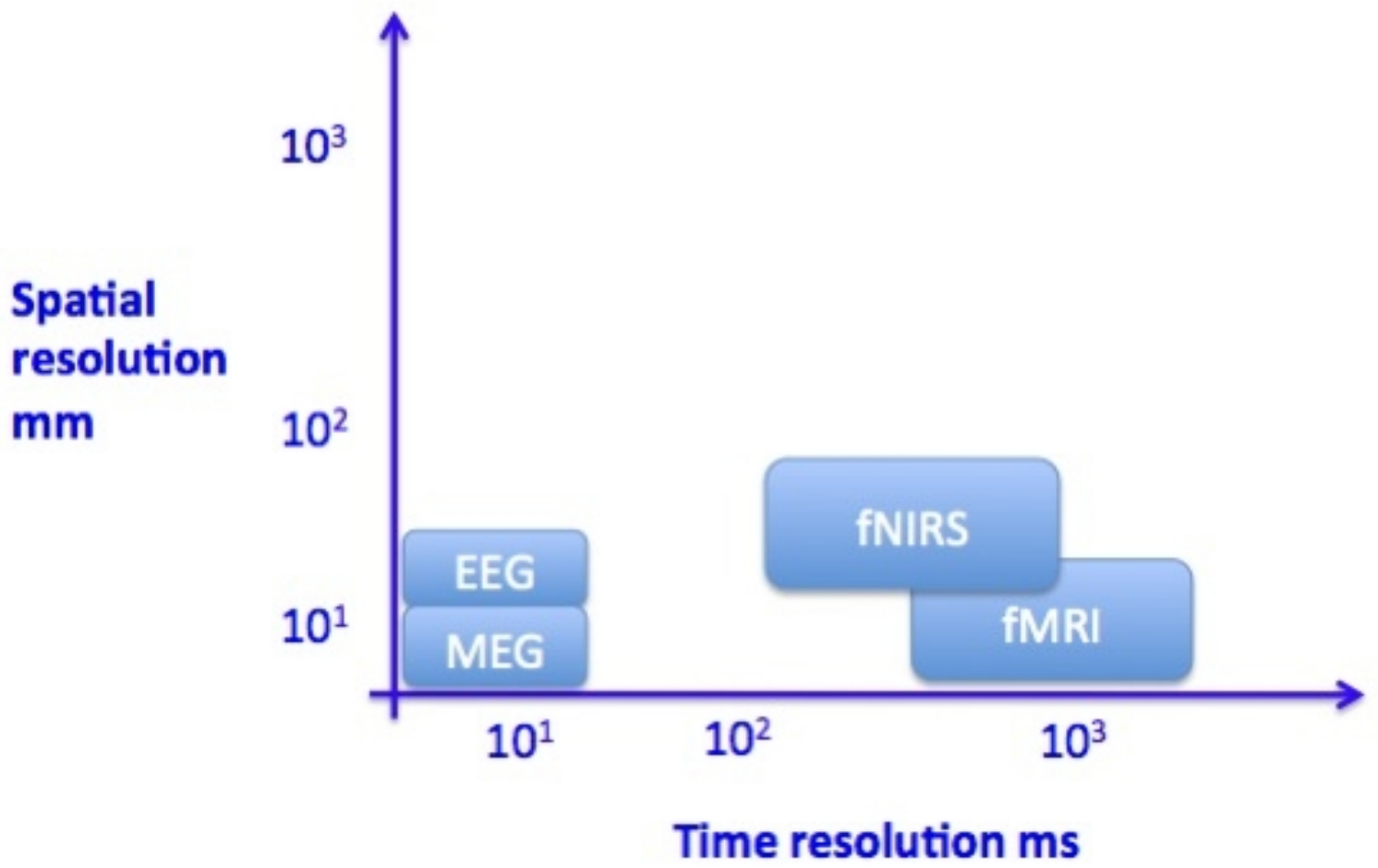
1. EEG is continuous electrical activity recorded from the scalp.

2. An Event Related Potentials (ERP) is the averaged electrical activity time-locked to a stimulus, e.g., click or flash. Evoked Potentials are a subset of ERPs.

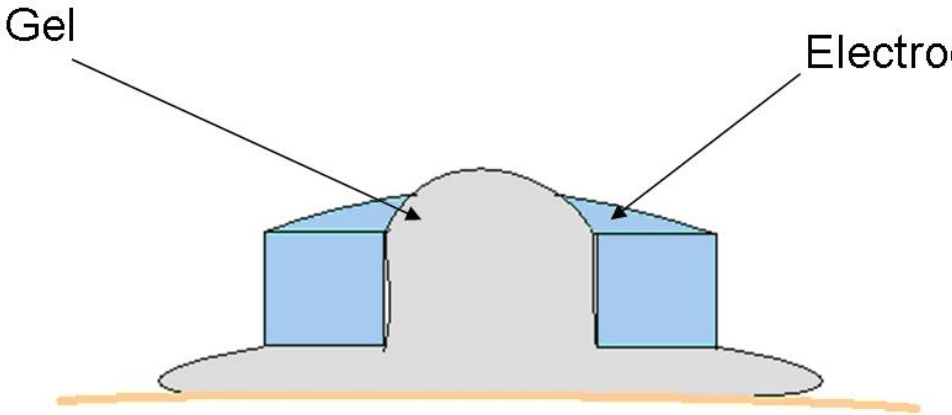
3. ERPs can be auditory, visual, or somatosensory

4. EEG/ERPs are easy to record, non-invasive and relatively inexpensive.

EEG/ERPs have the highest temporal resolution



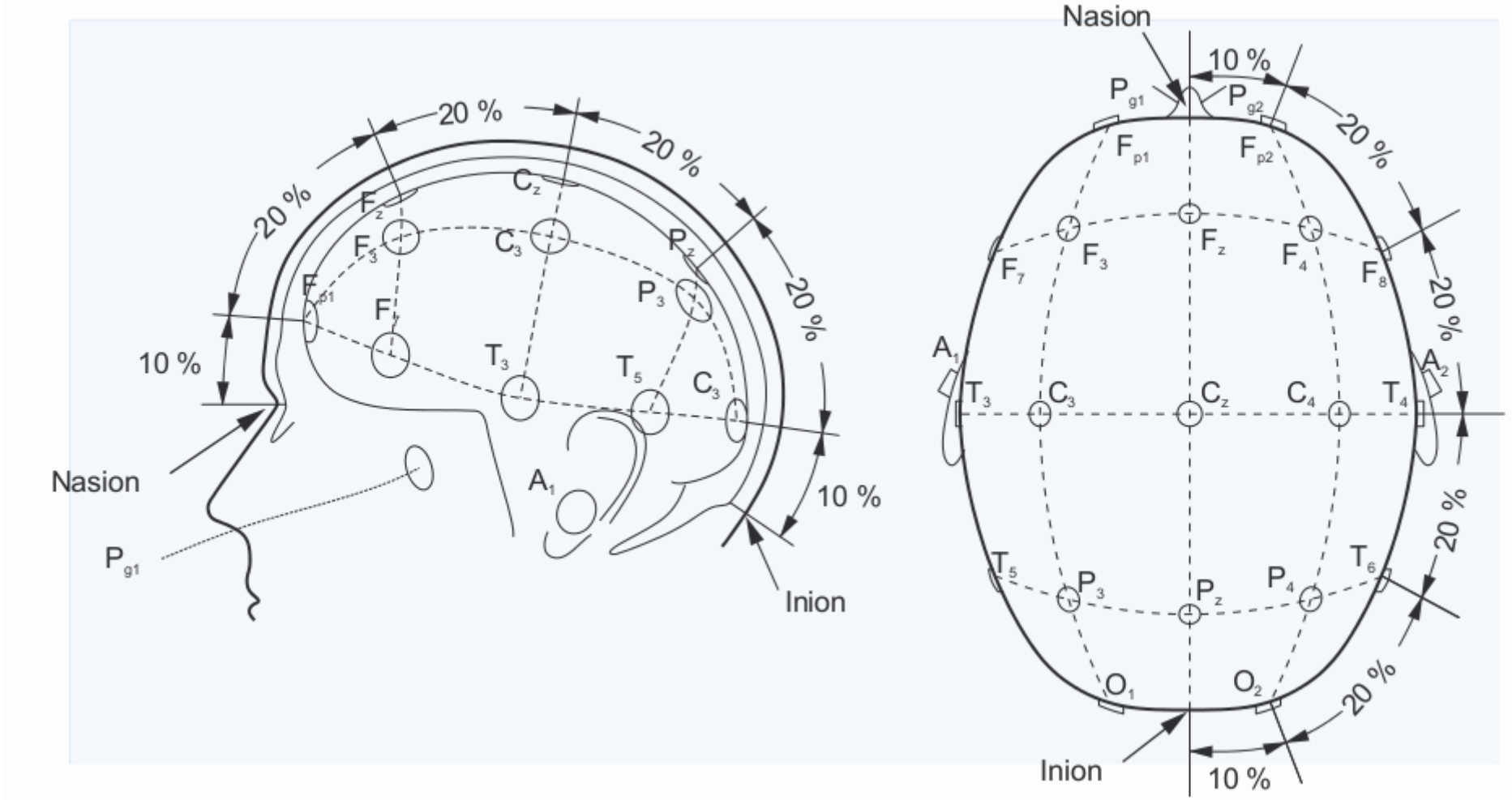
Scalp Recording Electrodes



Ag-AgCl Electrode give the best bio-potentials

- Achieved by abrading scalp a little; impedances <2000Ω
- Antiseptic conditions to be maintained against infection and disease transmission
- Input impedance of the amplifiers dictates optimal impedances at the scalp

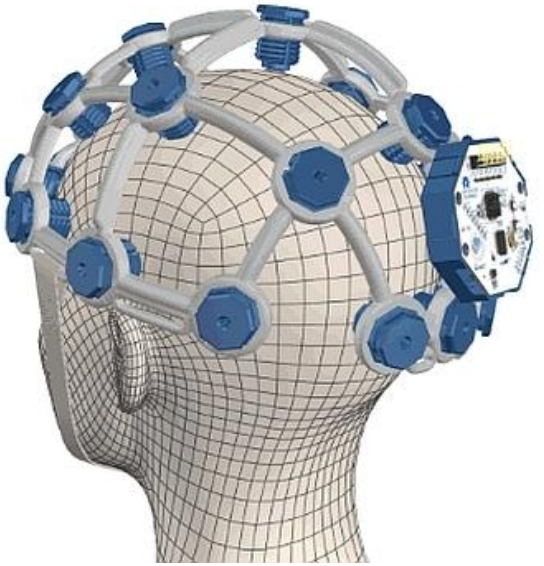
EEG electrode placement (10-20 system Jasper, 1956)



Advances in Electrode Technology: Caps & Dry Electrodes

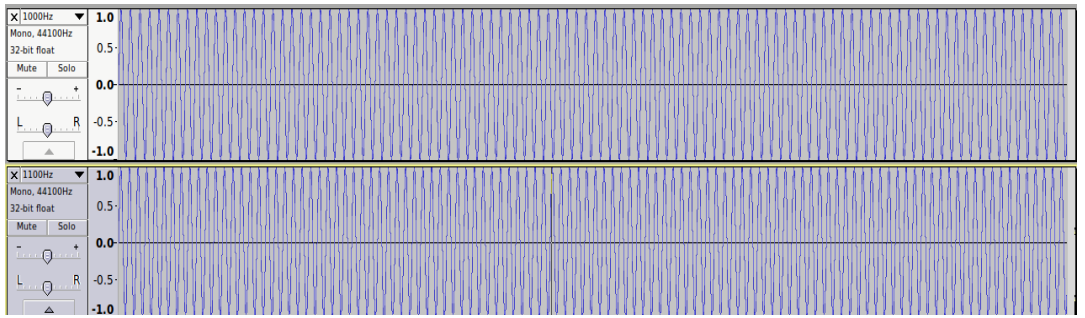
ENOBIO

Open-BCI

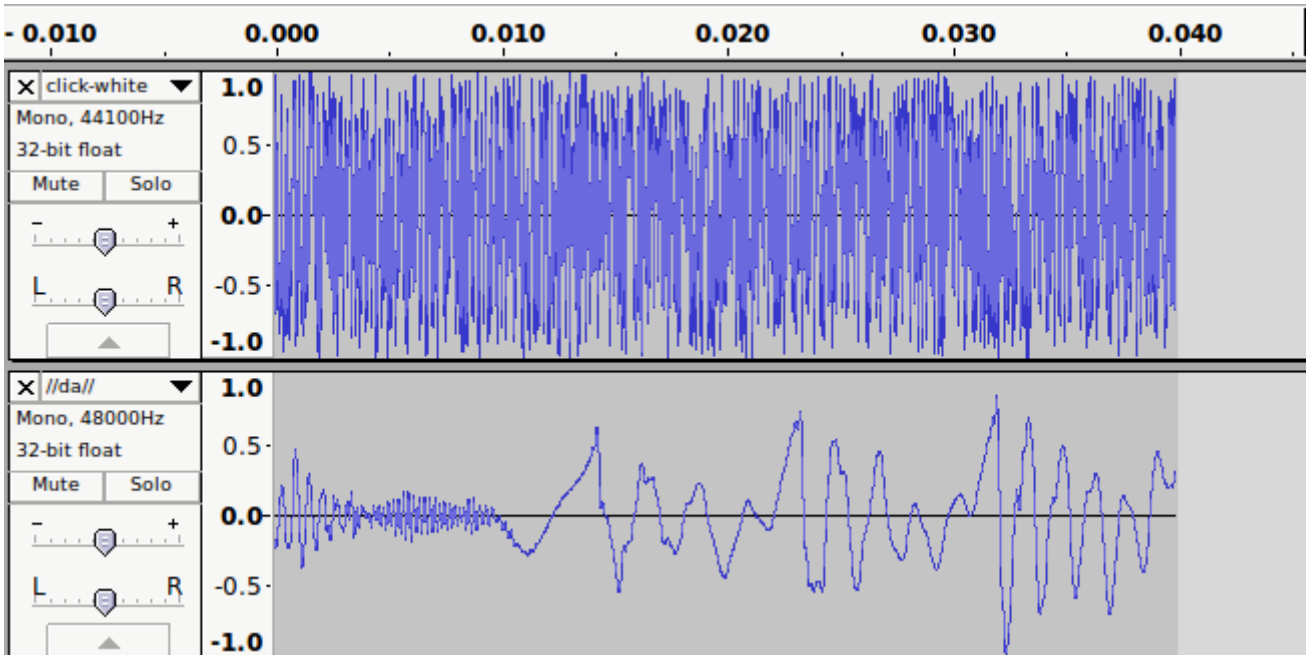


Gamer EEG systems, e.g. Emotiv

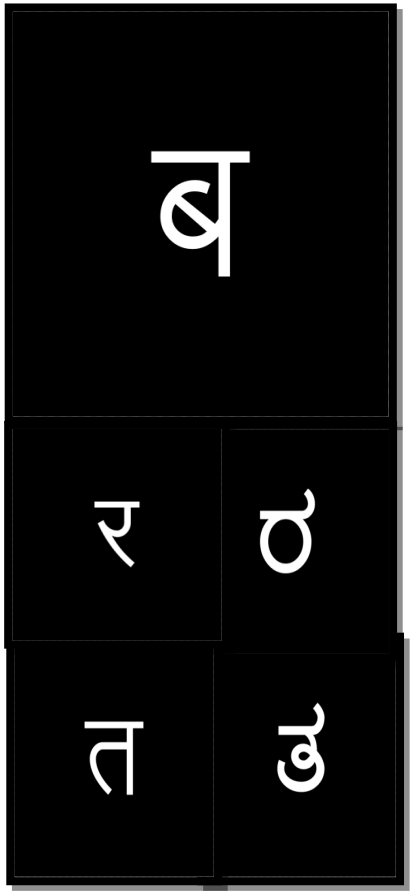
Auditory and Visual Stimulation



Pure tones 1000Hz (above) and and 1100Hz (below). Both 100ms.

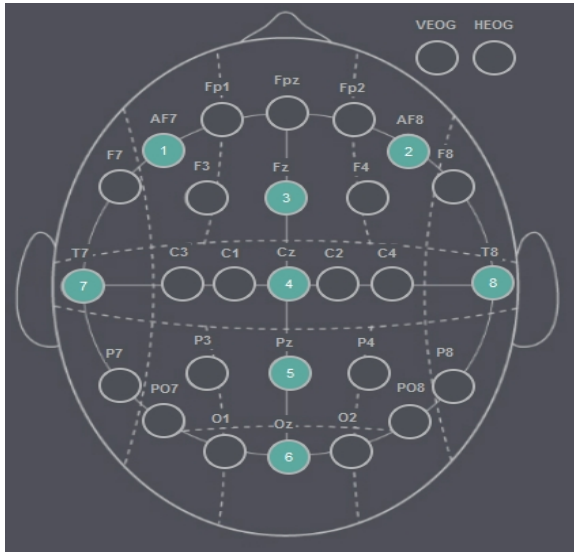


Broad Band White Noise burst (above), and (below), Vocalization //da// from the Kraus Auditory Neuroscience Lab, Northwestern University. Both 40ms.



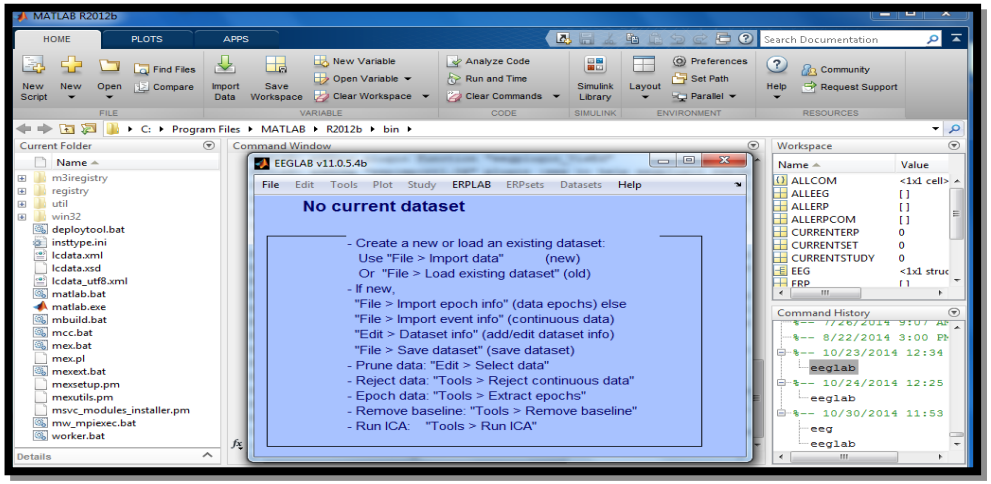
Visual stimuli with Hindi and Kannada alphabets

Recording, ATD Conversion, Matlab Analysis

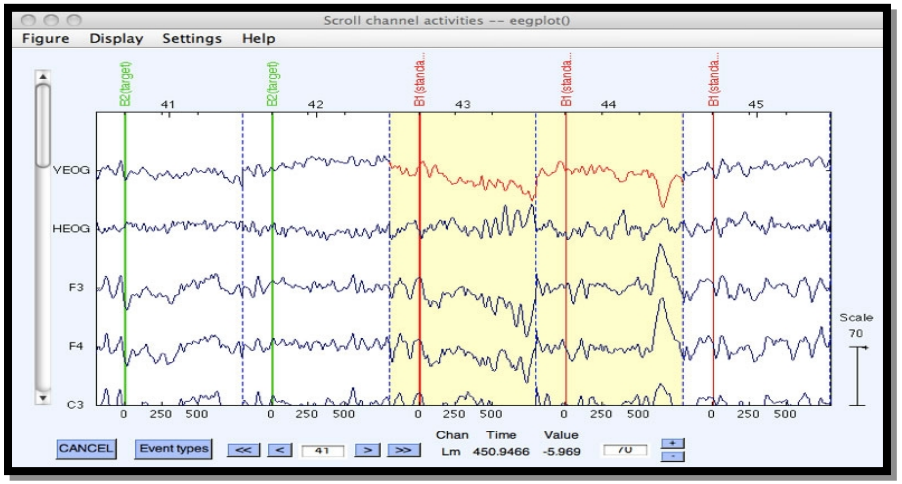


EEG Electrode montage

Free running EEG



EEGLAB/ERPLAB modules in *Matlab*



Processing ERPs, Artifact rejection

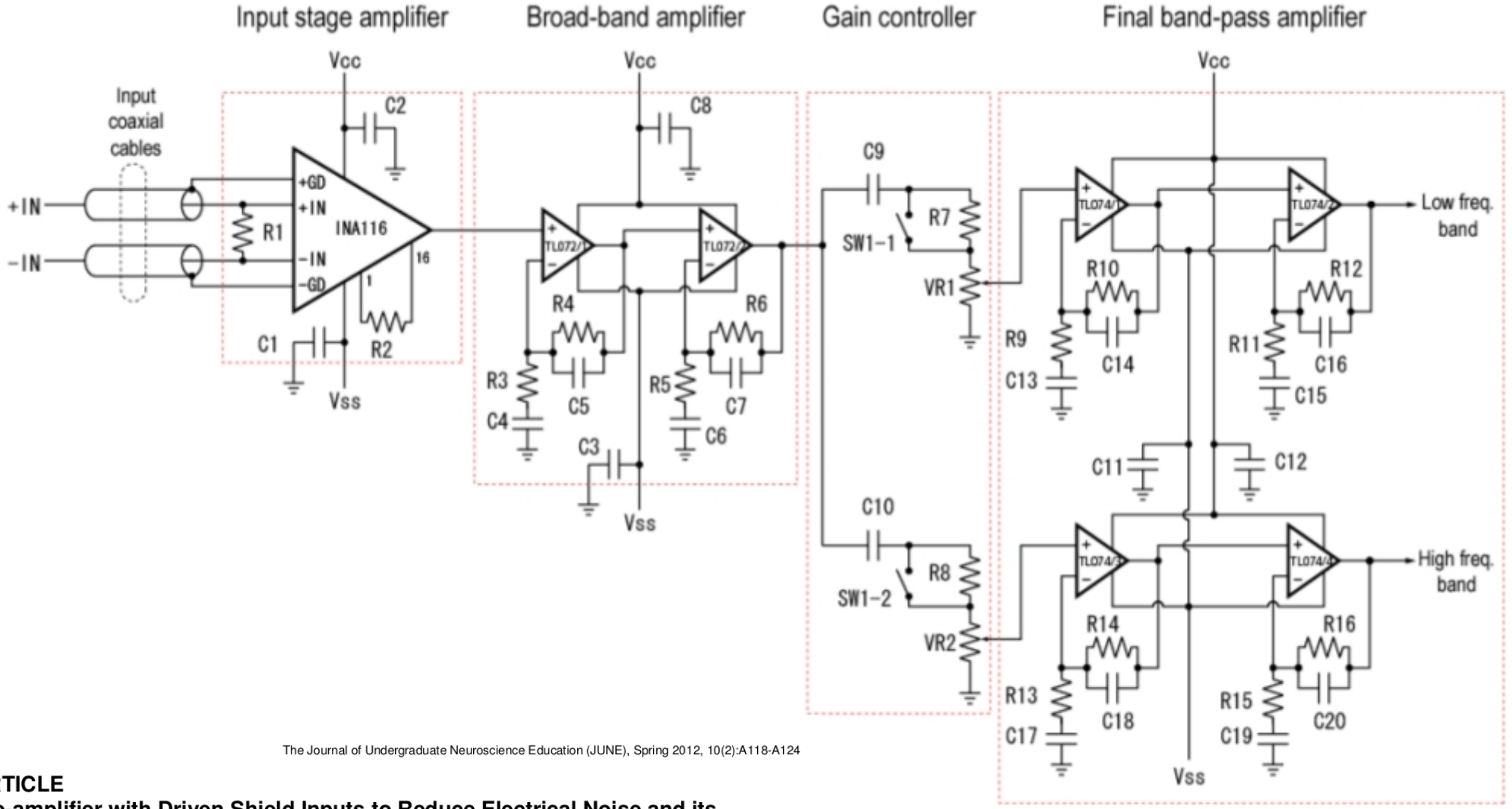
Clinical Instrumentation

Clinical Grade Systems:

1. Nicolet
2. Nihon-Koden

Not very useful for research

DIY Bio-Amplifiers for Electro-physiological recording



The Journal of Undergraduate Neuroscience Education (JUNE), Spring 2012, 10(2):A118-A124

ARTICLE

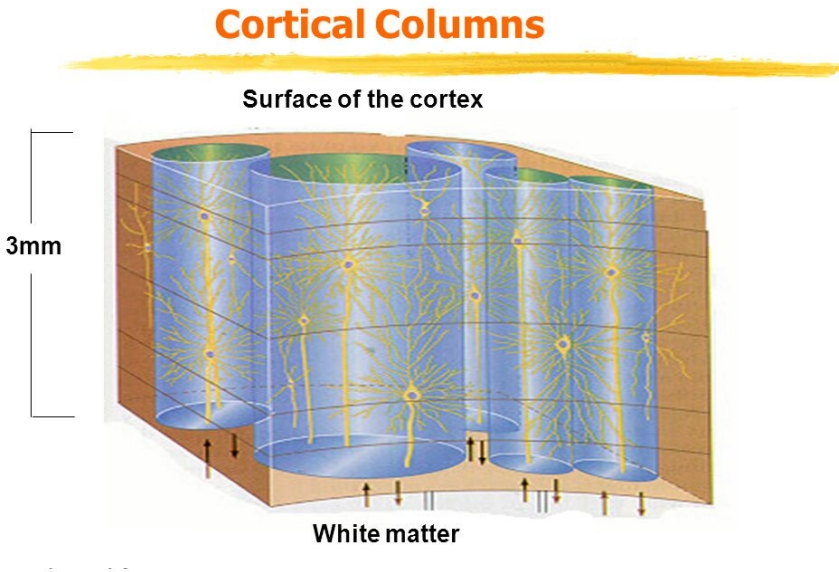
Bio-amplifier with Driven Shield Inputs to Reduce Electrical Noise and its Application to Laboratory Teaching of Electrophysiology

Yoshiya Matsuzaka[1], Toshiaki Ichihara[2], Toshihiko Abe[2], & Hajime Mushiake[1]

[1]Department of Physiology, Graduate School of Medicine, Tohoku University, Sendai 980-8575, JAPAN; [2]Institute of Field Generation Corp., Sendai 982-0261, JAPAN.

Neuroscience Primer

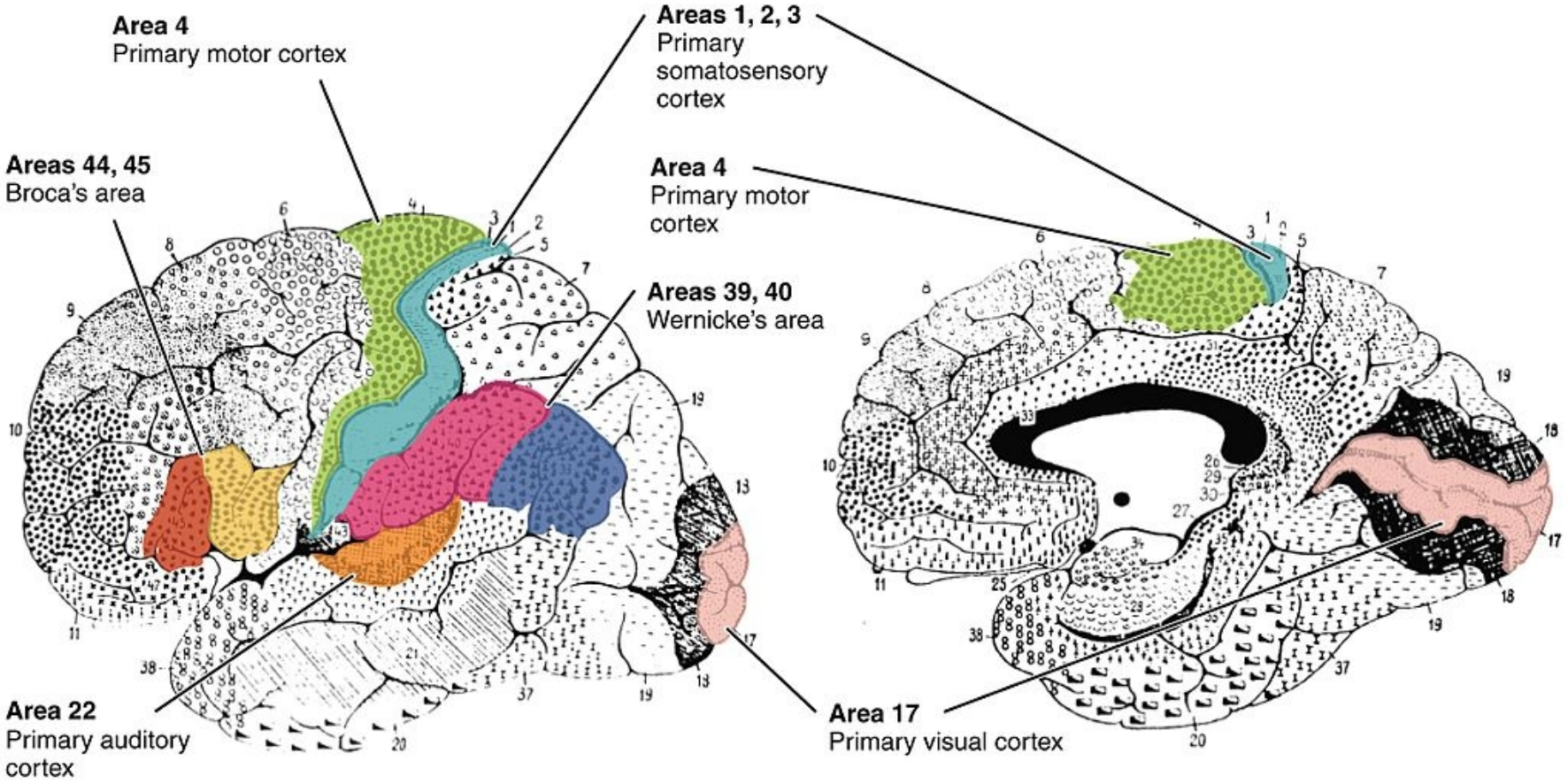
The Human Brain – Outer Grey matter, Inner White matter



Grey matter contains most of the brain's neuronal cell bodies. EEG originates here – from post-synaptic potentials not action potentials.

White matter is composed of bundles of nerve cell projections (or axons), which connect various gray matter areas and carry nerve impulses between neurons.

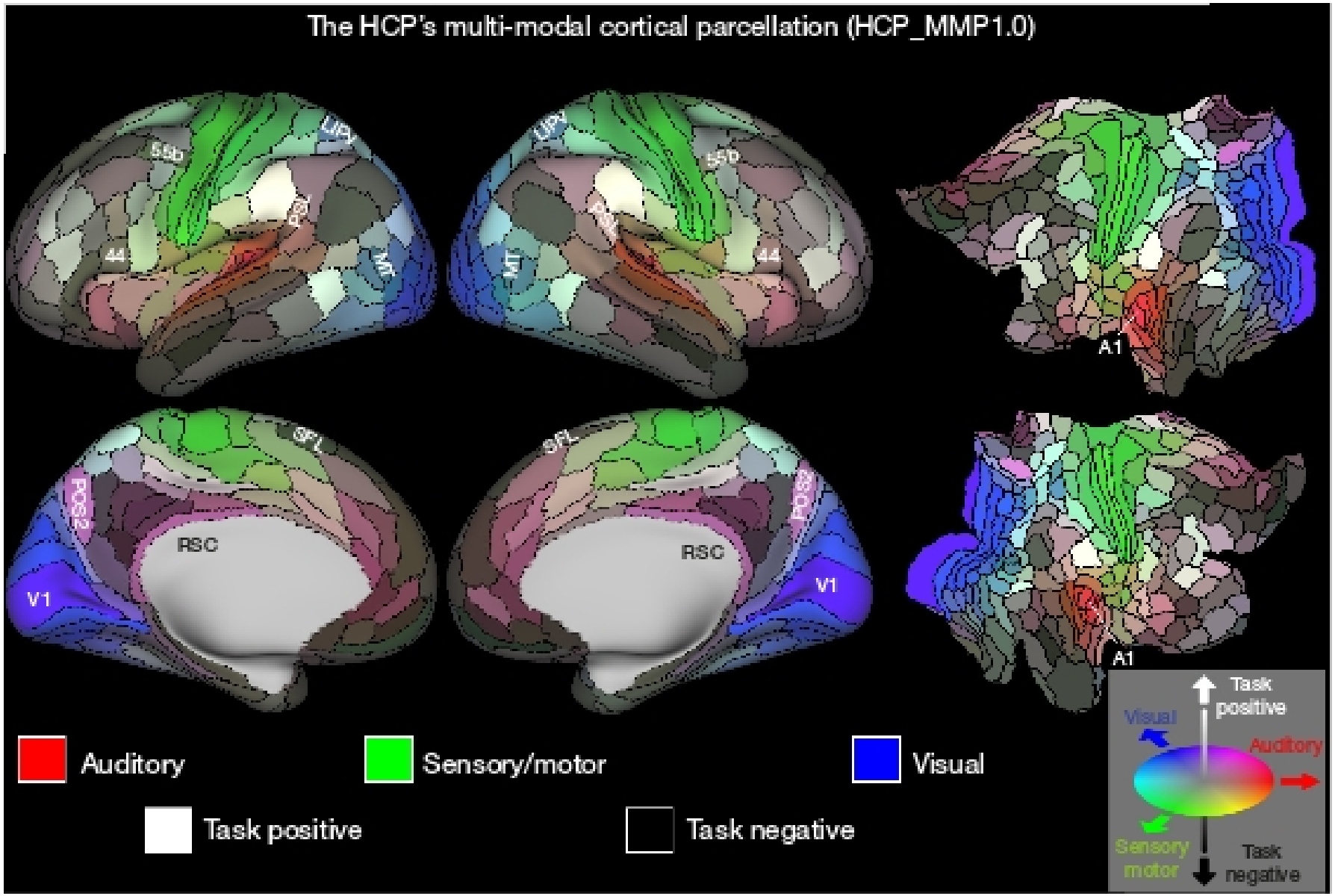
52 Different Cortical Grey matter areas (Brodmann, 1909)



Brodmann's cytotechtonic map (1909):
Lateral surface

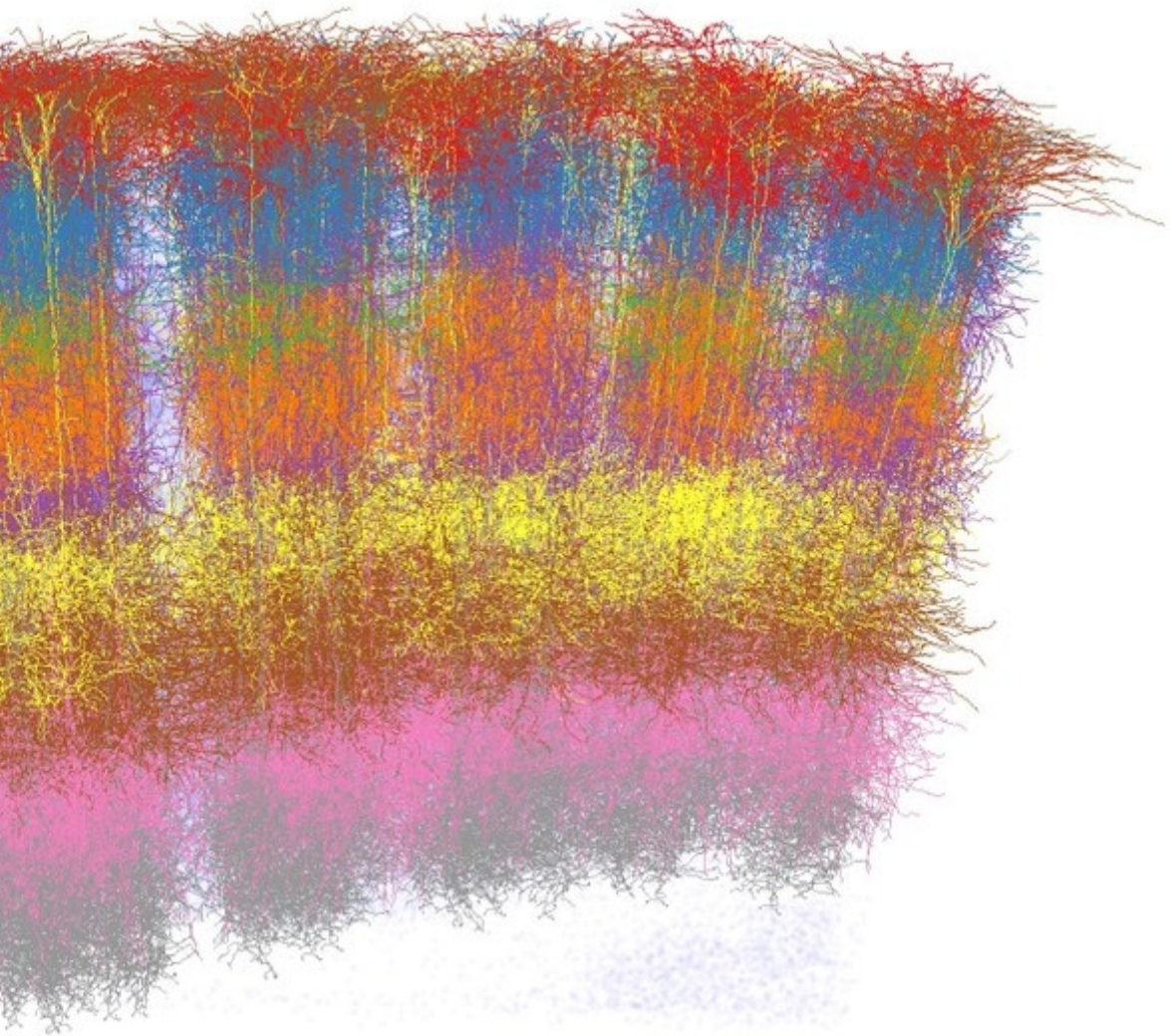
Brodmann's cytotechtonic map (1909):
Medial surface

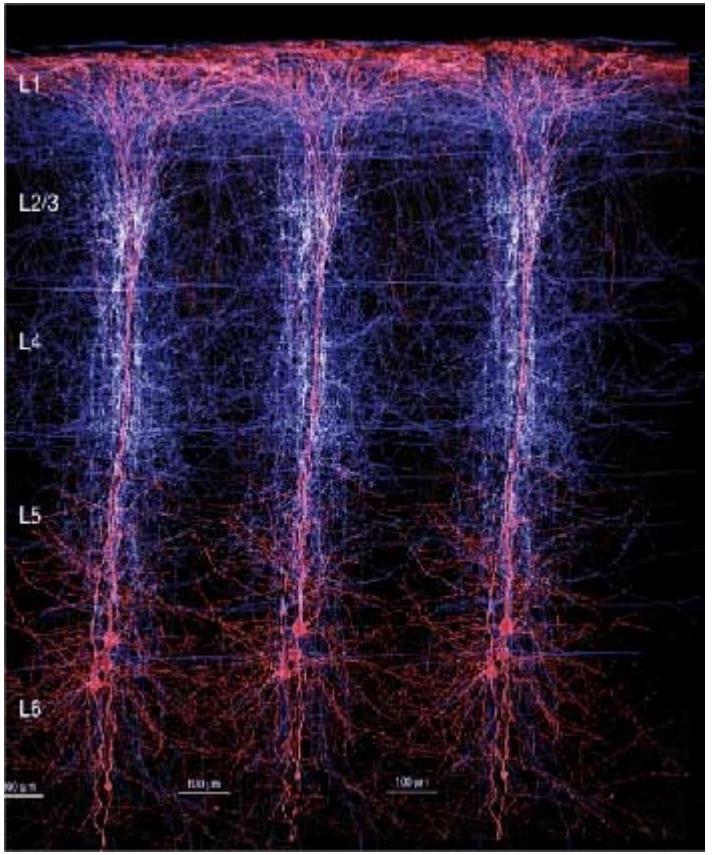
180 Areas – Human Connectome Project (Glaser, 2016)



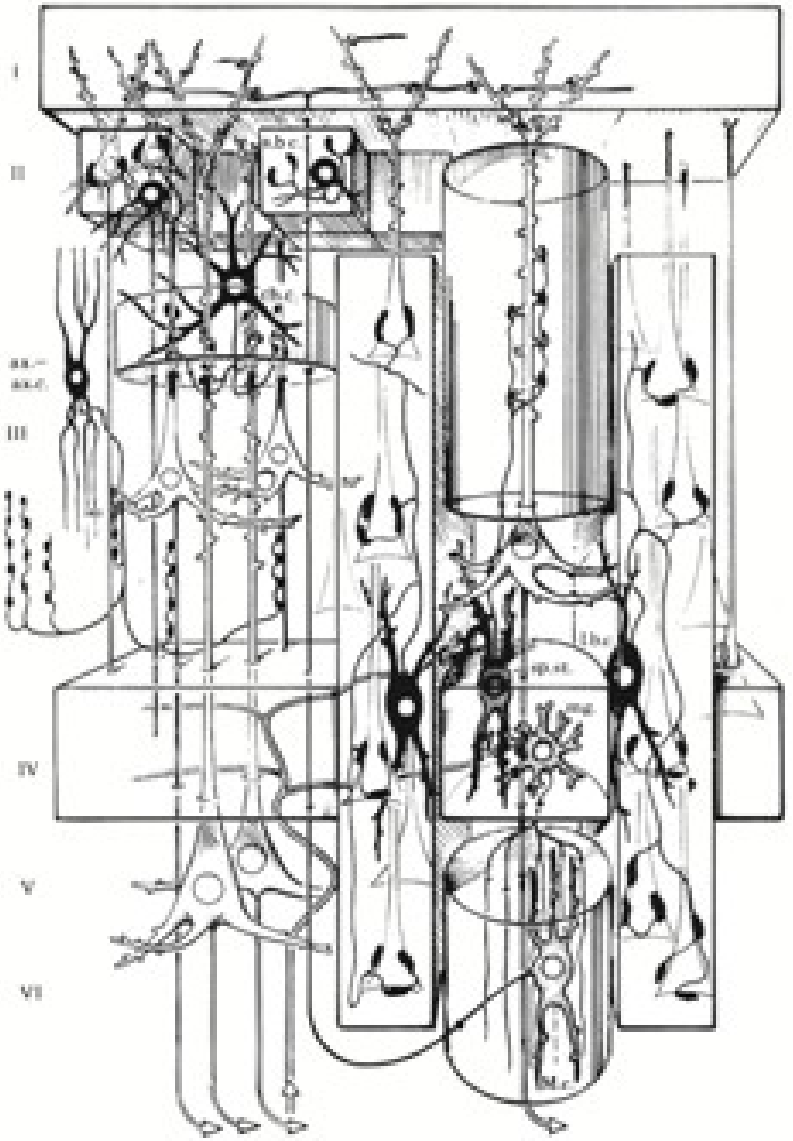
Glasser, M. F. et al. A multi-modal parcellation of human cerebral cortex.Nature 536, 171–178 (11 August 2016).

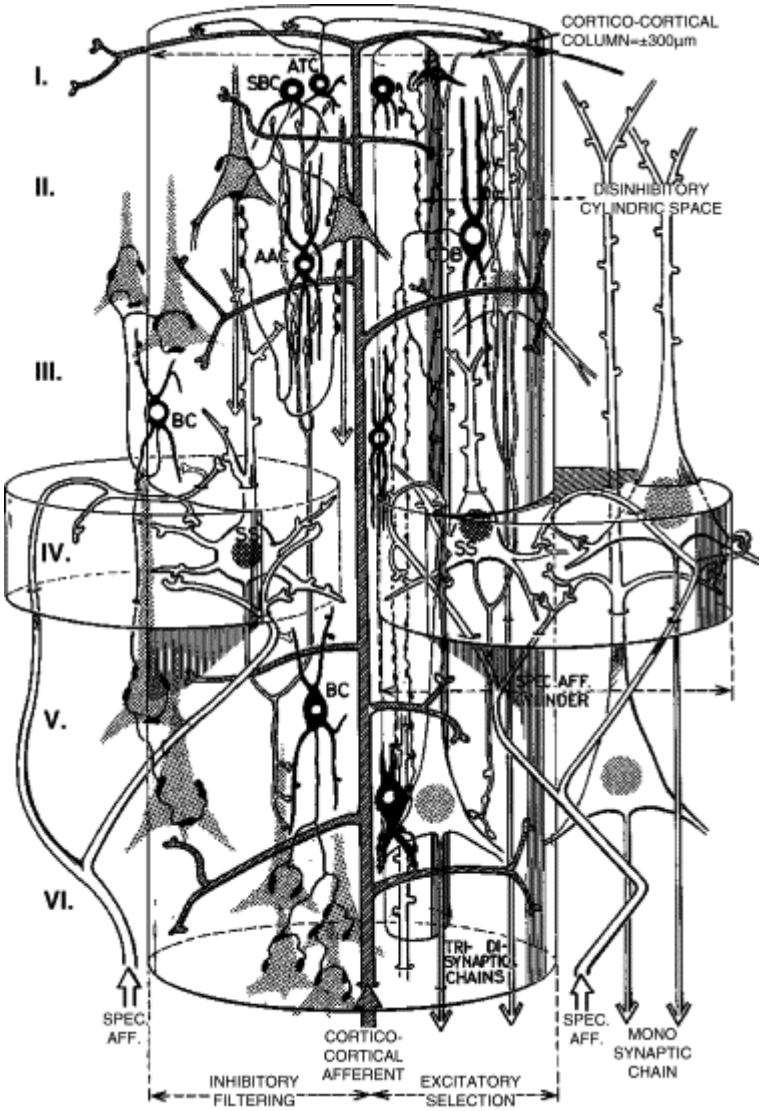
Layers & Columns are Highly Conserved in Mammals



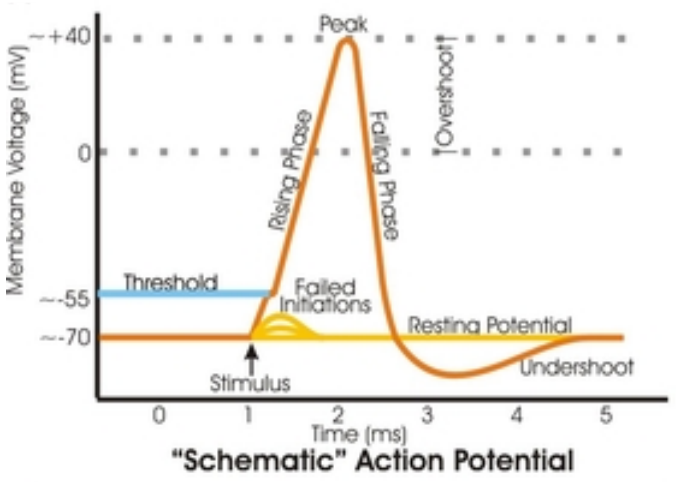


Cortical Circuits visulaized by the Golgi Stain

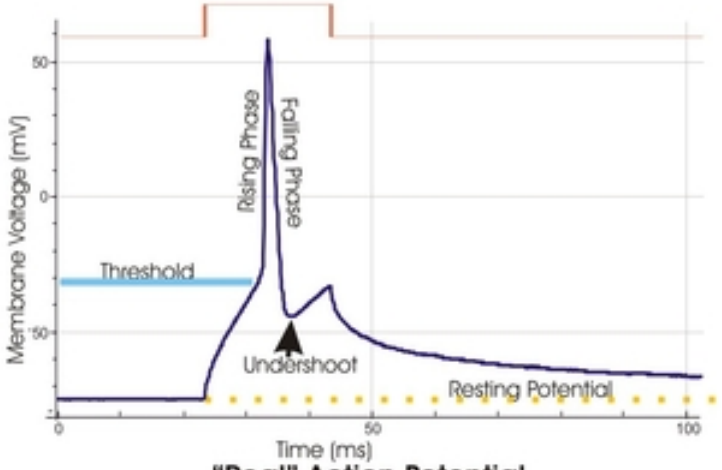




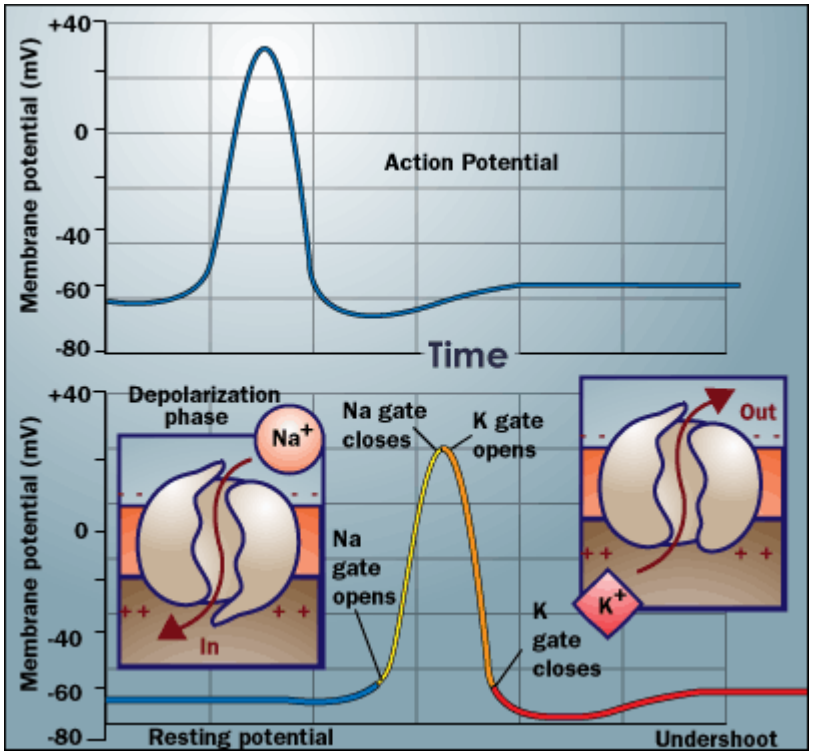
Ionic Basis of the Action Potential



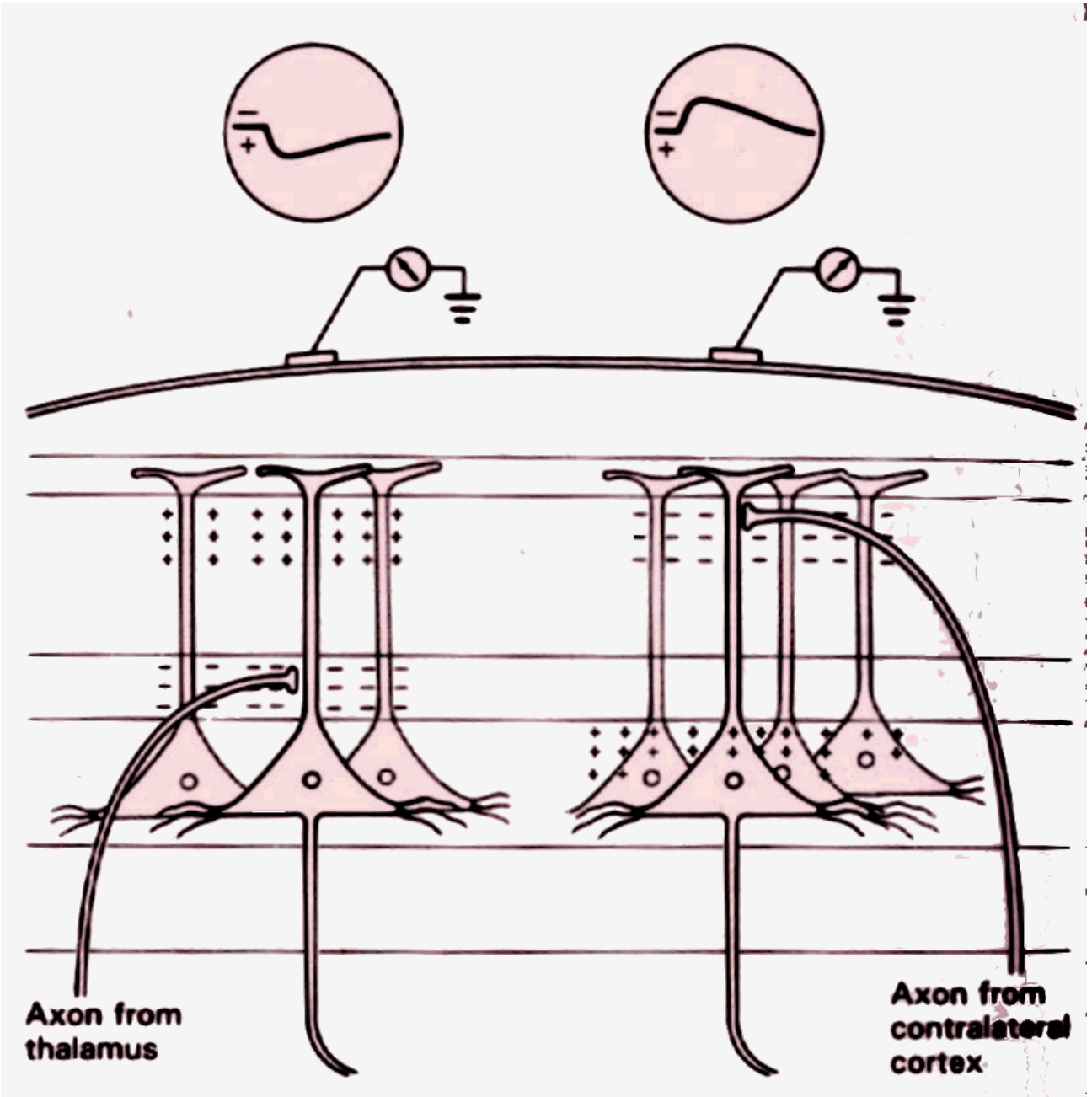
"Schematic" Action Potential



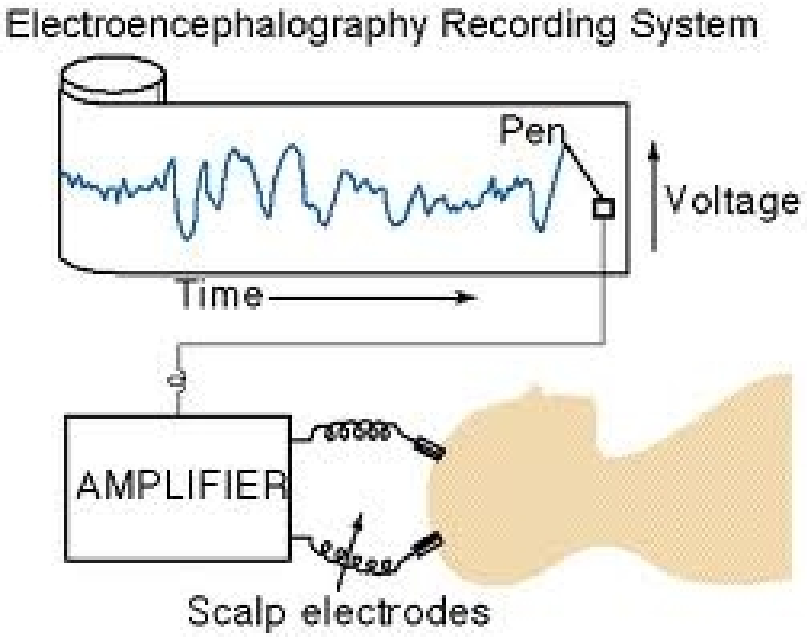
"Real" Action Potential

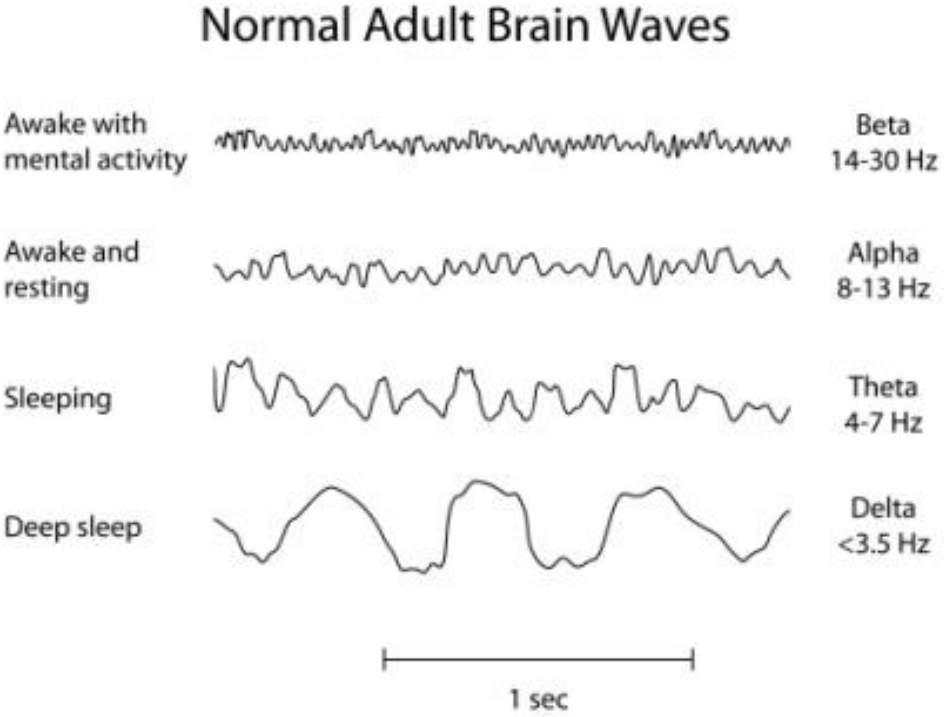


EEG – What are we recording? Inverse Problem



Free Running Brain Waves: Electroencephalogram (EEG)

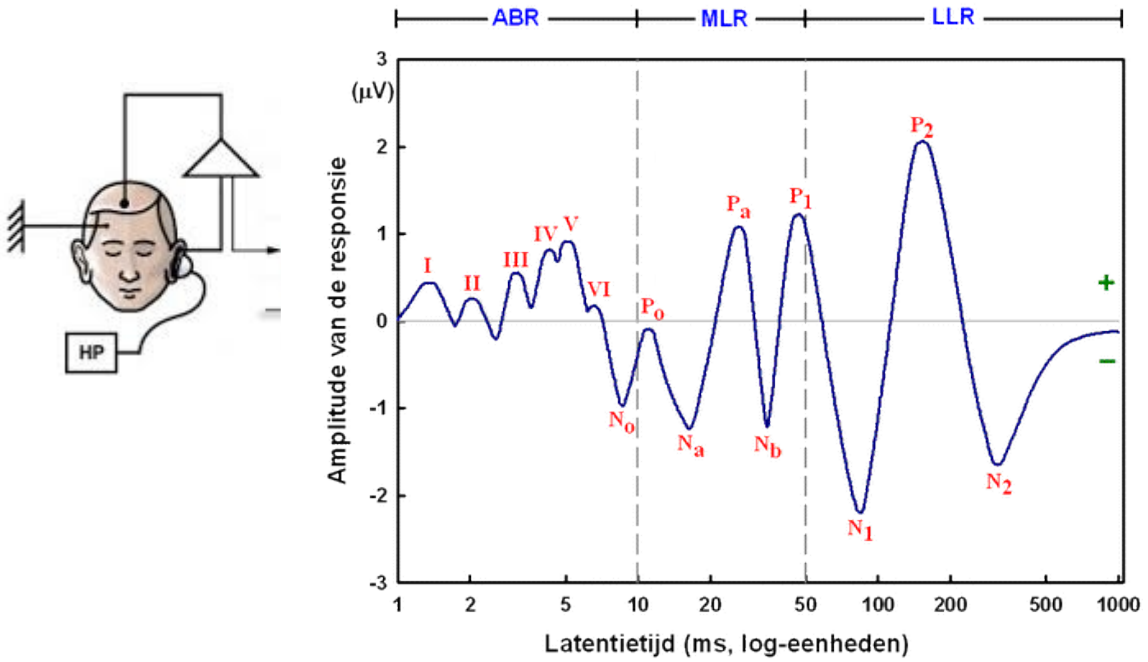




Evoked Potentials (EPs) are tools for Clinical Neurophysiology: Auditory, Visual & Somato-sensory

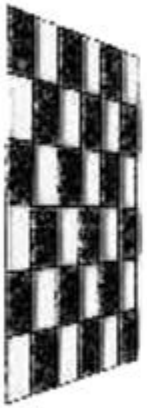
Clinical Auditory Evoked Potentials – ABR and AEP

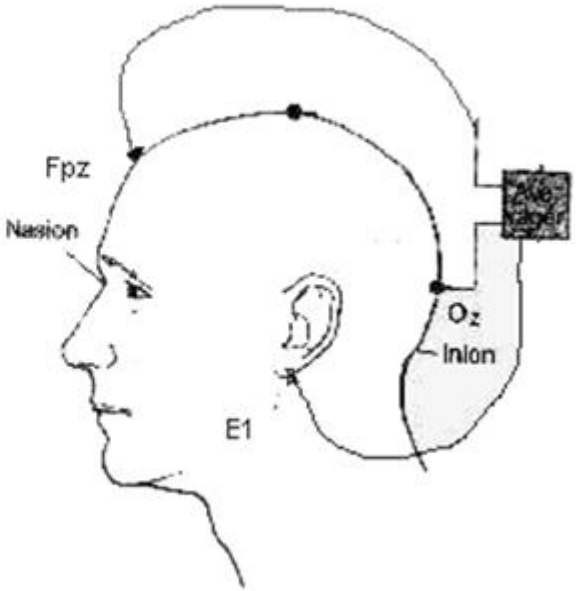
- Information about the inner ear and brain hearing pathways, cortical activity.
- Stimuli – 0.1-1ms clicks or tones; 60-70dB; ABR 100Hz; AEP 1-2Hz

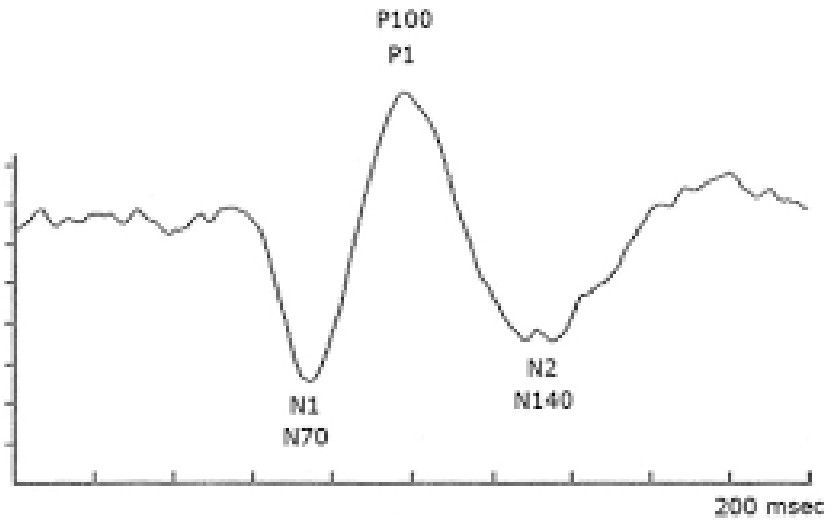


Clinical Visual Evoked Potentials (VEPs)

- VEP tests the function of the visual pathway from the retina to the visual cortex
- Delayed in disorders e.g., compressive tumors, MS
- Stimuli used are Visual Flash or a reversing Checker-Board (1Hz)





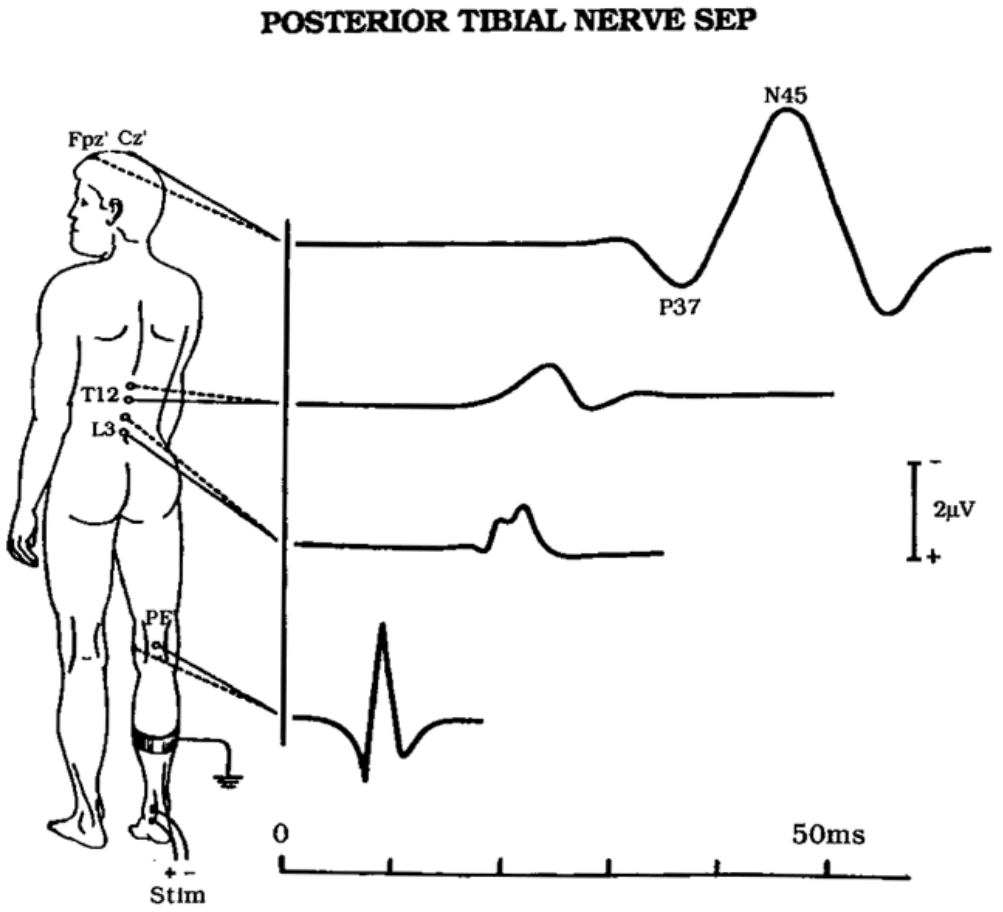


Clinical Somatosensory Evoked Potentials (SEPs)

- Identification of impaired conduction caused by axonal loss or demyelination, e.g., Multiple Sclerosis (MS)
- Localization of the anatomic site of lesions – **Intra-operative monitoring during spinal surgery**

<u>Stimulation</u>:

- Square waves:
- 0.2-2ms duration
- 1-8 mA



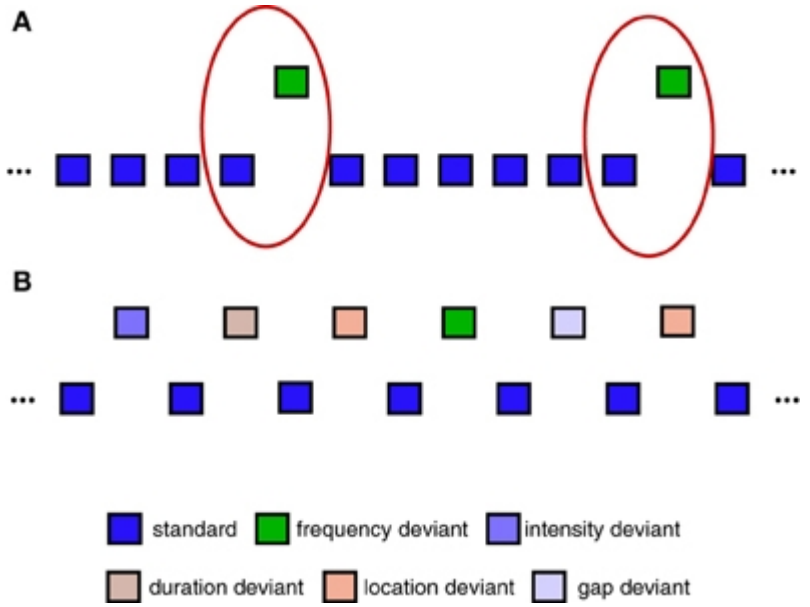
Event-Related Potentials (ERPs): A powerful tool for Cognitive Neurophysiology

Why are ERPs Important?

- Monitor cognitive function in Brain disorders – Stroke, AD, LDs, etc.
- Monitor effects of therapeutic interventions e.g., in Malnutrition
- Stringently evaluate interventions that augment Cognition
- This objective approach is superior to subjective evaluations by Psychologists and Psychiatrists

A. AEP & VEP Cognitive Applications: Diagnosing At-Risk Subjects for Mental disorders using P300/MMN

Mismatch Negativity (MMN) - paradigm



1. The MMN is elicited when there is a change in auditory expectation.

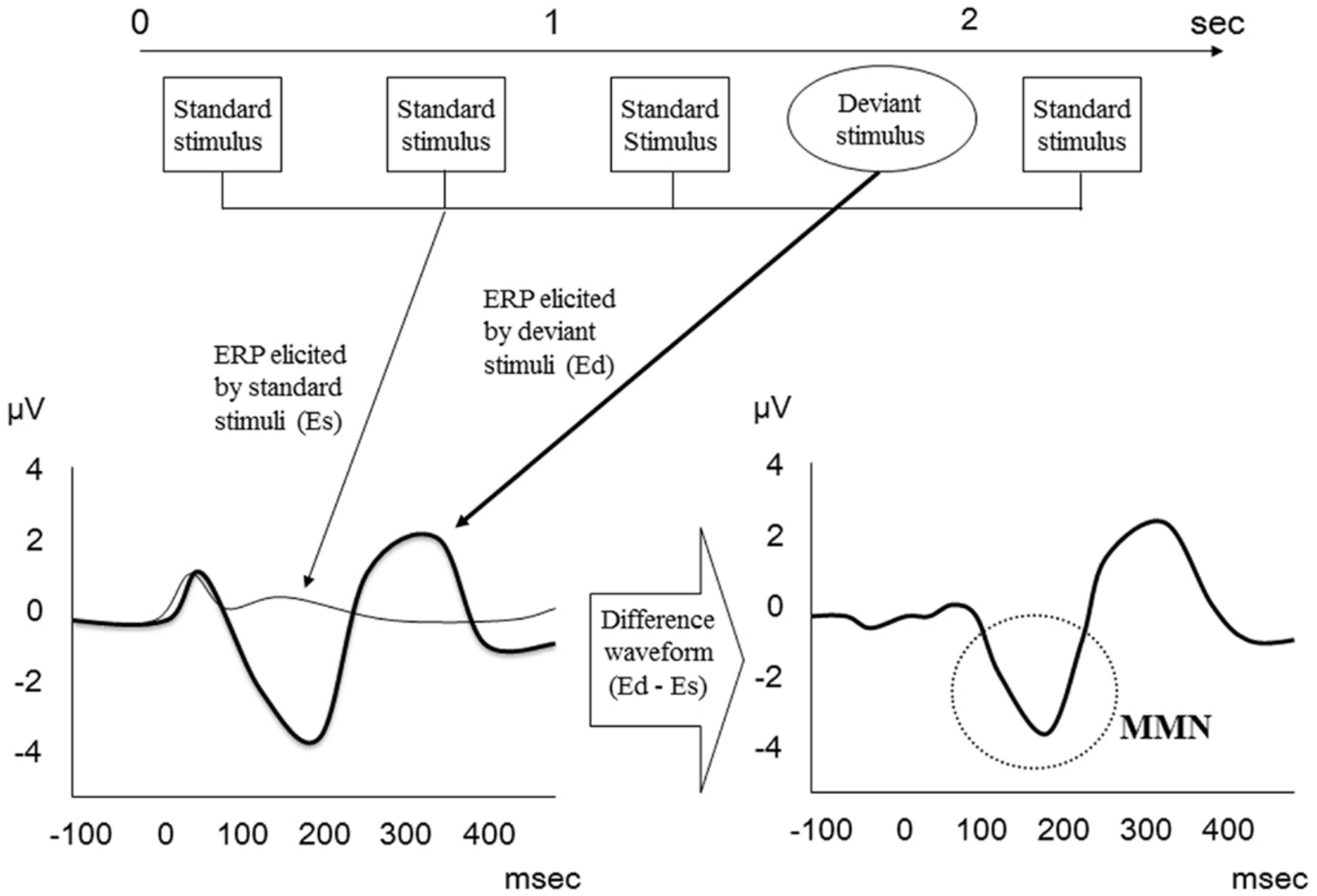
2. Any change in any auditory dimension evokes it, frequency, duration, timbre, etc.

3. Involuntary index of central auditory processing.

4. The 1st cognitive ERP – present at birth. Evolutionarily significant.

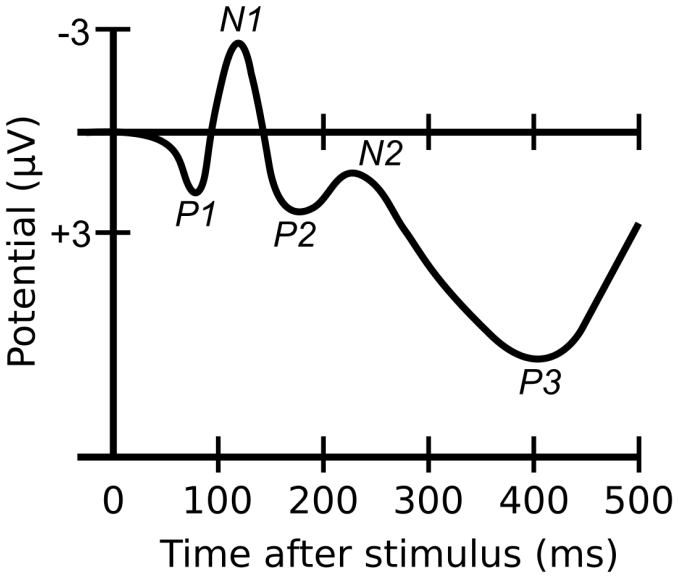
5. Diminished in diseases of Higher Mental Function, e.g., Schizophrenia, Bi-polar Disorders, Learning Disabilities, etc. Sensitive but not selective.

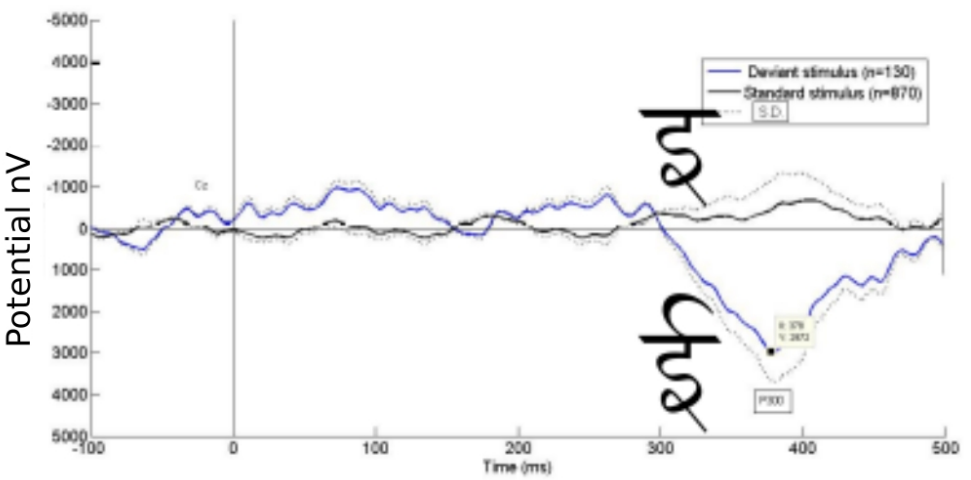
MMN epoch – 150-250ms after stimulus



MMN fMRI: Bilateral A1 and Right DLPF Cortex

P300 indexes Novelty



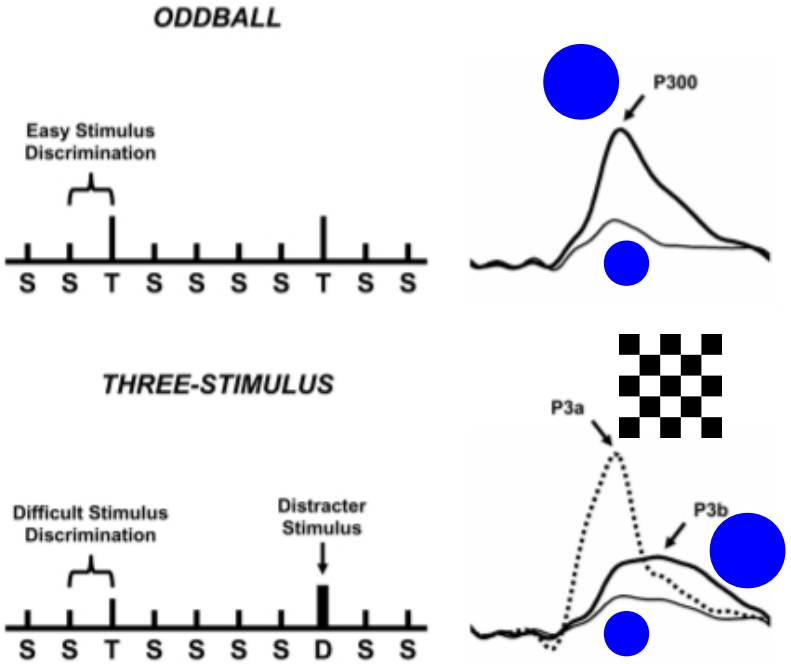


1. P300 occurs with an <u>oddball</u> or unexpected stimulus occurring at 300-400ms

2. Subjects are presented with stimuli belonging to one of two categories (rare, common). Rare stimuli at ~10-20% probability, elicit a P300.

3. Small variation in Linguistic stimuli give robust P300 responses

Attention and Working Memory P3a/P3b: (Polich, 2007)

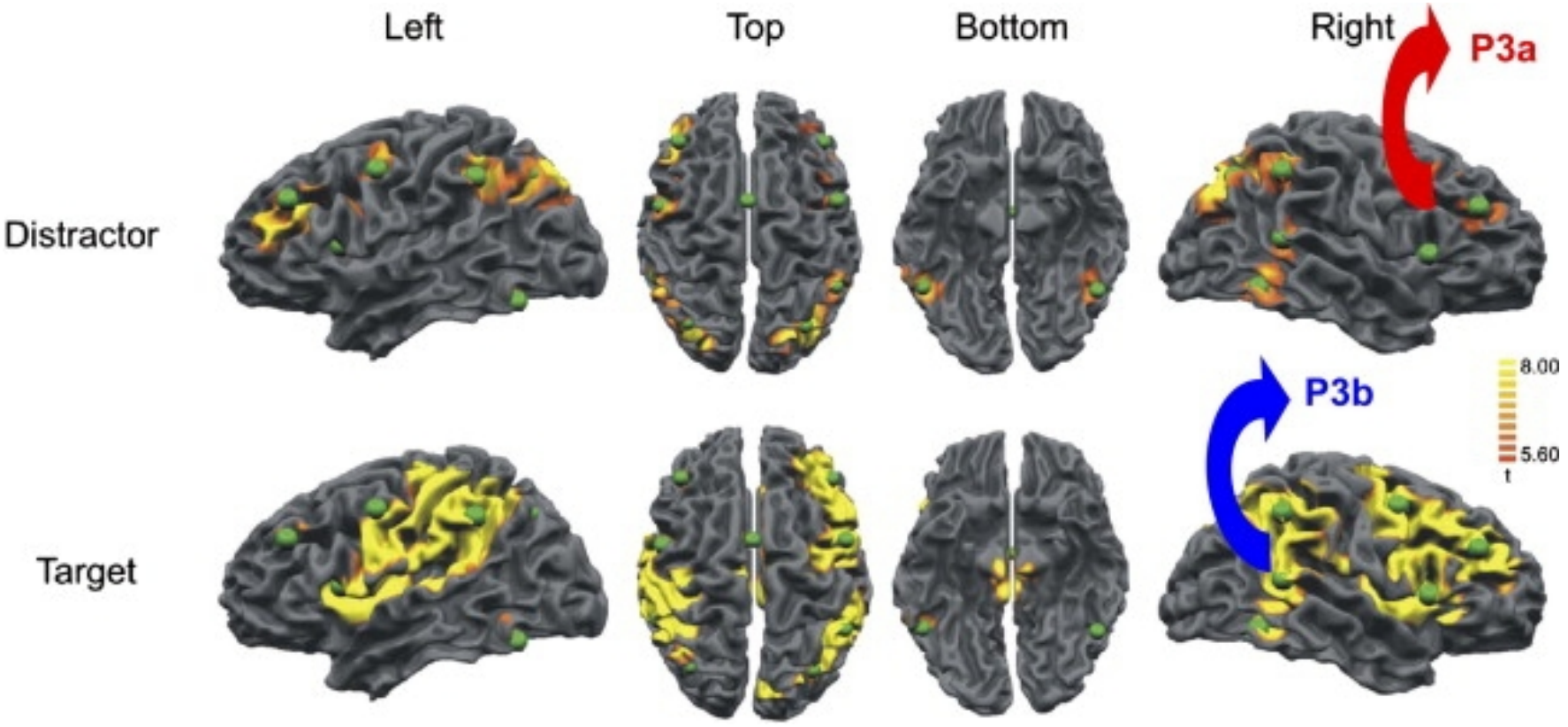


Grand Averages *(n = 120)*

1. 2-stimulus (P300) task
2. 3-stimulus (P3a and P3b) task

- Infrequent target (big circle) 10%
- Standard stimuli (small circle) 80%
- Infrequent distracter checkerboard 10%
- P3a – Attention
- P3b – Working Memory

Localising the P300 with fMRI



Brain activation from a visual three-stimulus oddball task used with fMRI (Bledowski et al., 2004).

The green spheres reflect calculated dipole generator sources.

P3a and dMMN predict At-Risk Mental States

frontiers in
BEHAVIORAL NEUROSCIENCE

HYPOTHESIS AND THEORY ARTICLE
published: 21 October 2013
doi: 10.3389/fnbeh.2013.00148

Electrophysiological and neuropsychological predictors of conversion to schizophrenia in at-risk subjects

***Tomiki Sumiyoshi*[1]*, *Tomohiro Miyanishi*[2], *Tomonori Seo*[2] and *Yuko Higuchi*[2]**

[1] *National Center of Neurology and Psychiatry, Kodaira, Tokyo, Japan*
[2] *Department of Neuropsychiatry, University of Toyama Graduate School of Medicine and Pharmaceutical Sciences, Toyama, Japan*

- Recently confirmed by independent groups
- A dedicated device can be designed to record and evaluate P3a and dMMN

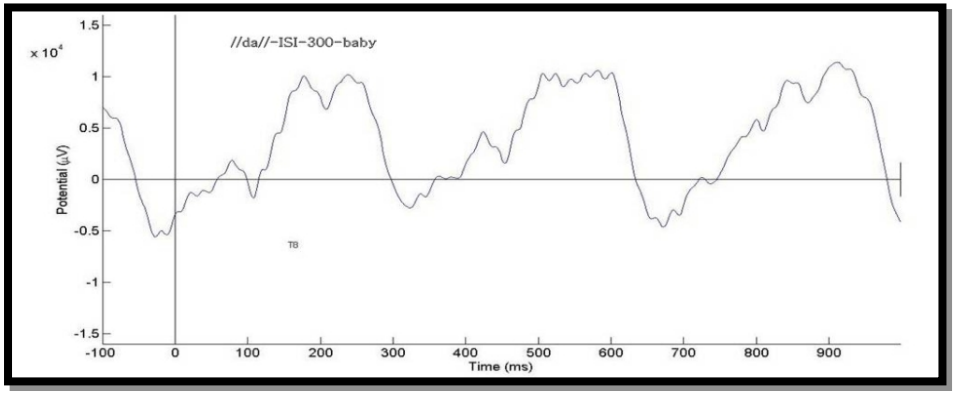
B. ERPs can be used to study Infant Cognition

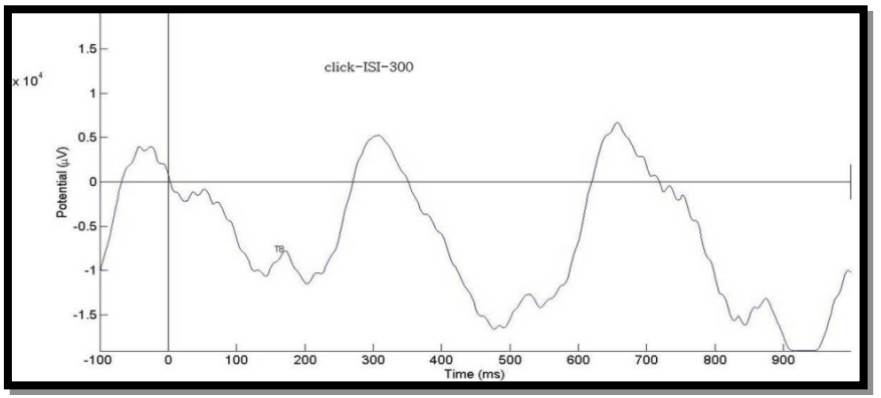
Challenges in Studying Infant Cognition

1. Technically difficult; noisy data
2. Inter-individual variability; Lack of Indian normative data
3. Infants cannot follow instructions; speech undeveloped
4. Difficult to get overt behavioral responses that satisfy statistical criteria

Recording AEPs and MMN from New-borns at SJMCH

Newborn Data from SJMCH NICU – BBWN vs "Da"





Newborns have a strikingly different response to vocalization //da// **(left)** compared to a Broad-Band White Noise (BBWN) burst **(right)**, as early as <u>36 hours</u> after birth

ISI=300ms; Polarity: positive-up; each ERP is an average of ~100 responses.

C. Diagnosing Learning Disabilities, e.g., Dyslexia, Dyscalculia

The Problem – 10% of children have Learning Disabilities

Specific learning Disabilities (SLDs) comprise of:

1. Reading deficits (Dyslexia),

2. Number blindness (Dyscalculia) and,

3. Specific Language Impairments e.g., grammar deficits

4. Autism (ASD)

5. ADHD

4 & 5 are clinically obvious and get more funding even though 1, 2,3 are twice as common

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4 & 5 are clinically obvious and get more funding even though 1, 2,3 are twice as common

Existing diagnosis occurs too late

Currently, there are no objective methods to quickly and accurately diagnose SLDs.

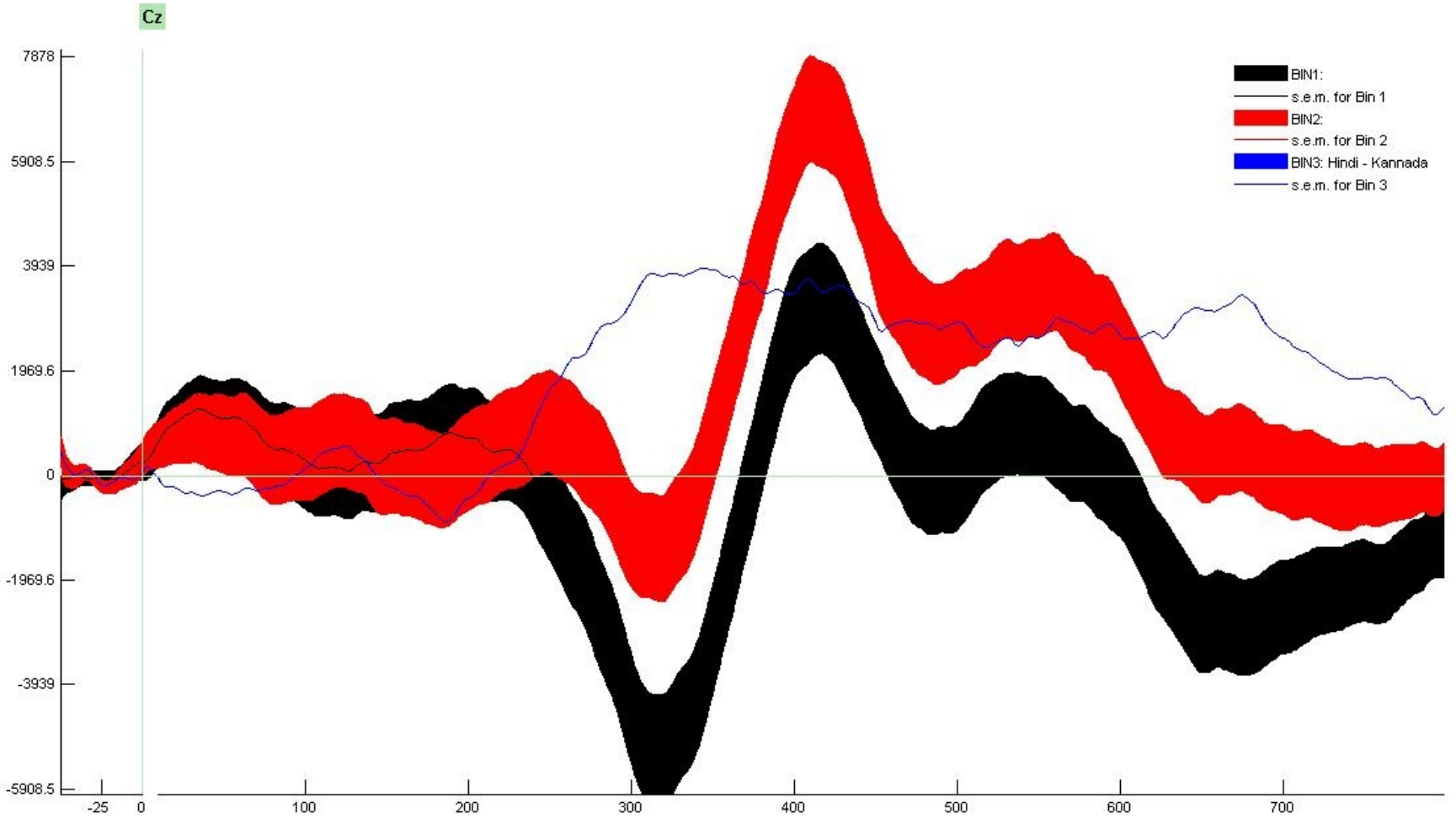
In the US, typically the child is noticed to lag behind by parents, teachers or school psychologists usually during late primary-school or middle-school.

Diagnosis is expensive.

In India, this occurs later, during preparation for the first major competitive school-leaving examination in high school (9th-10th Standard).

Social stigma.

The Recognition Potential in Indian Vowels
Rudell, 1990



RP = Average of Hindi vowels (black) – Kannada Vowels (red)

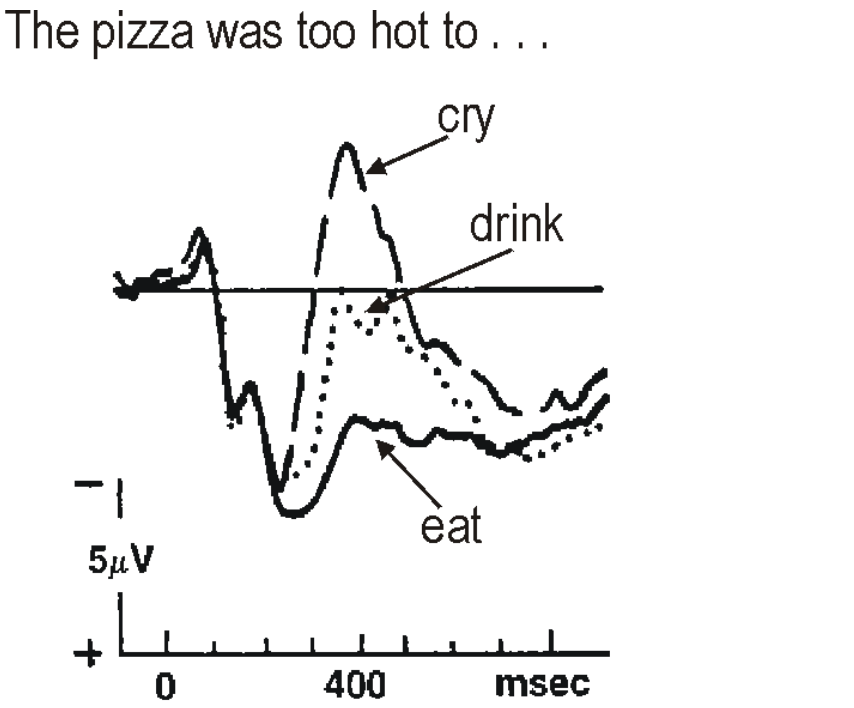
Rudell AP. The recognition potential: a visual response evoked by recognizable images. Neuroscience Abstracts. 1990;16:106.

Alphabet Recognition – Field data from Chhattisgarh

- Hypothesis: Linguistic visual stimuli can increase the analytical power of ERPs in Indian children.
- Indian alphabets are learned in an order of increasing complexity, i.e., Vowels (अ), Consonants (क), Consonants+*Matras* (चा) and Conjuncts (क्ष).

ERPs being recorded in the field in Chhattisgarh in a 1st Standard child in a Govt School, Ramanujganj Block, Balrampur District, Chhattisgarh.

Specific Learning Impairments – Semantic Incongruity N400 Kutas and Hillyard, 1980

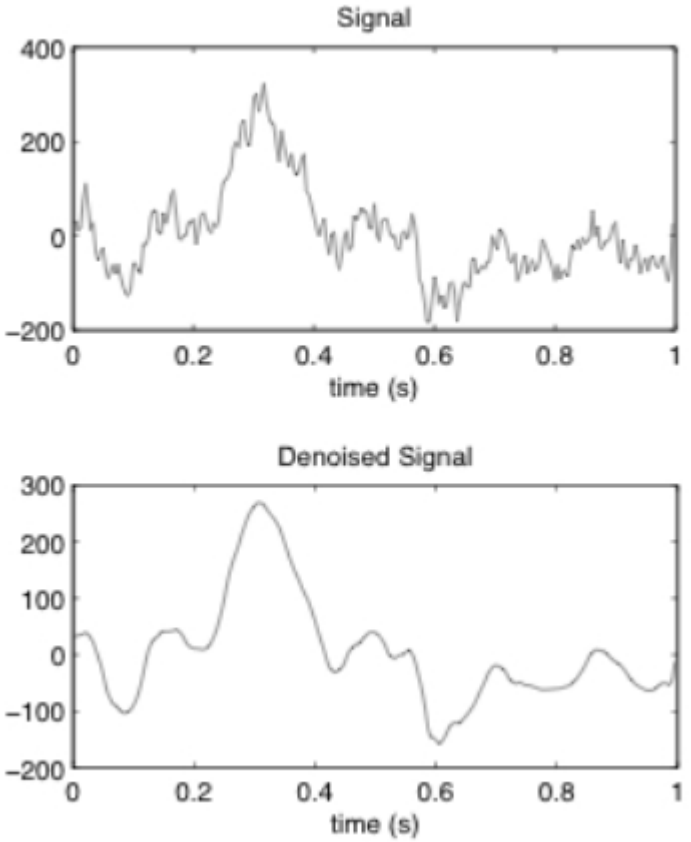


Churchland & Sejnowski (1993)

Kutas M, Hillyard SA. Reading senseless sentences: Brain potentials reflect semantic incongruity. Science. 1980;207:203–5.

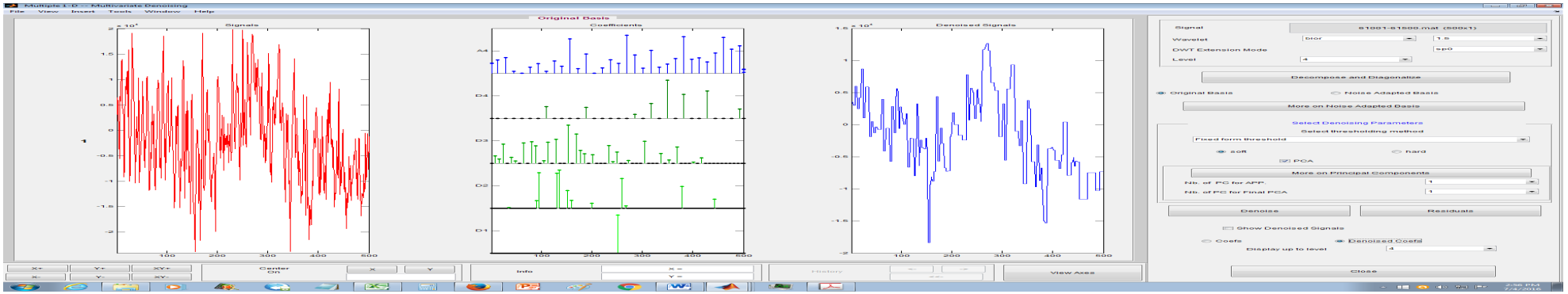
D. Advances in Math: Wavelet De-noising

De-noising the P300 with Quadratic B-Spline Wavelets*



*Rodrigo Quian Quiroga and H.Garcia. Single-trial event-related potentials with wavelet denoising. *Clinical Neurophysiology* 114 (2003) 376–390.

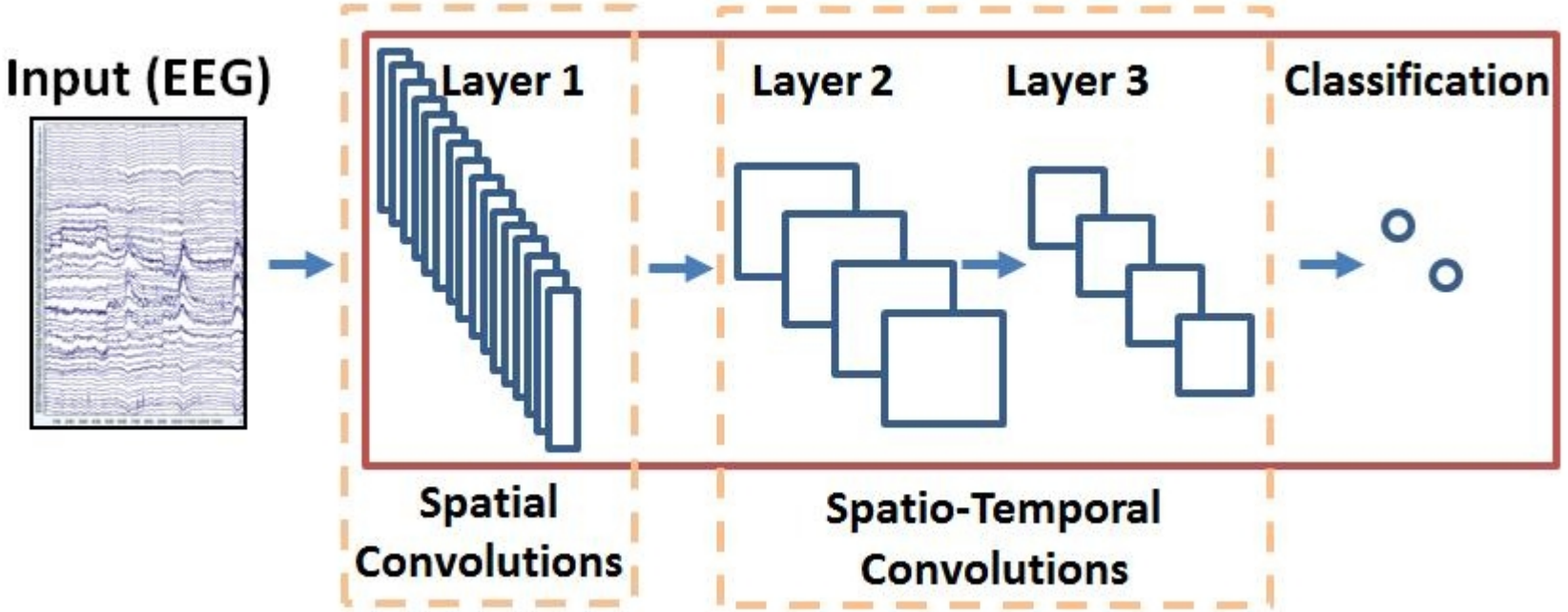
Single Event P300 can be identified with Wavelet Analysis



Can reduce recording time significantly:

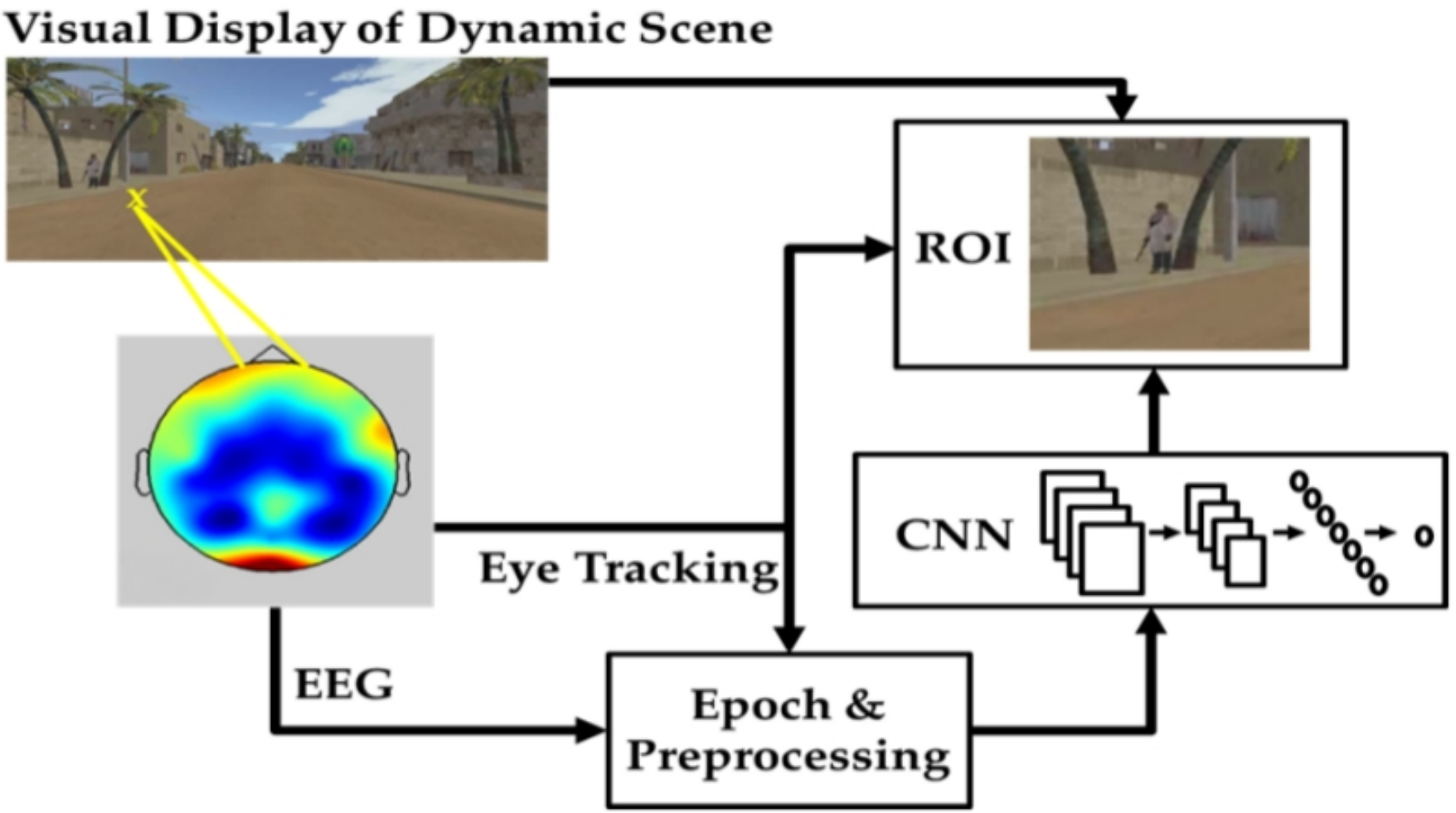
1. Pattern recognition in large datasets
2. Quicker clinical tests

Artificial Neural Network can recognize the P300



Human data used to train the Deep Learning network

Human Centric Scene Analysis (Gordon et al., 2017)



Thank you!

Contact

Mahesh Jayachandra MD, PhD
Bio-Engineering Group, NDRF

m.jayachandra@ndrf.res.in

Director, Laboratory of Neurophysiology,
St. John's Research Institute
Sarjapur Road,
Bangalore 560 034

Mahesh.j@sjri.res.in

(91) 984 598 0534