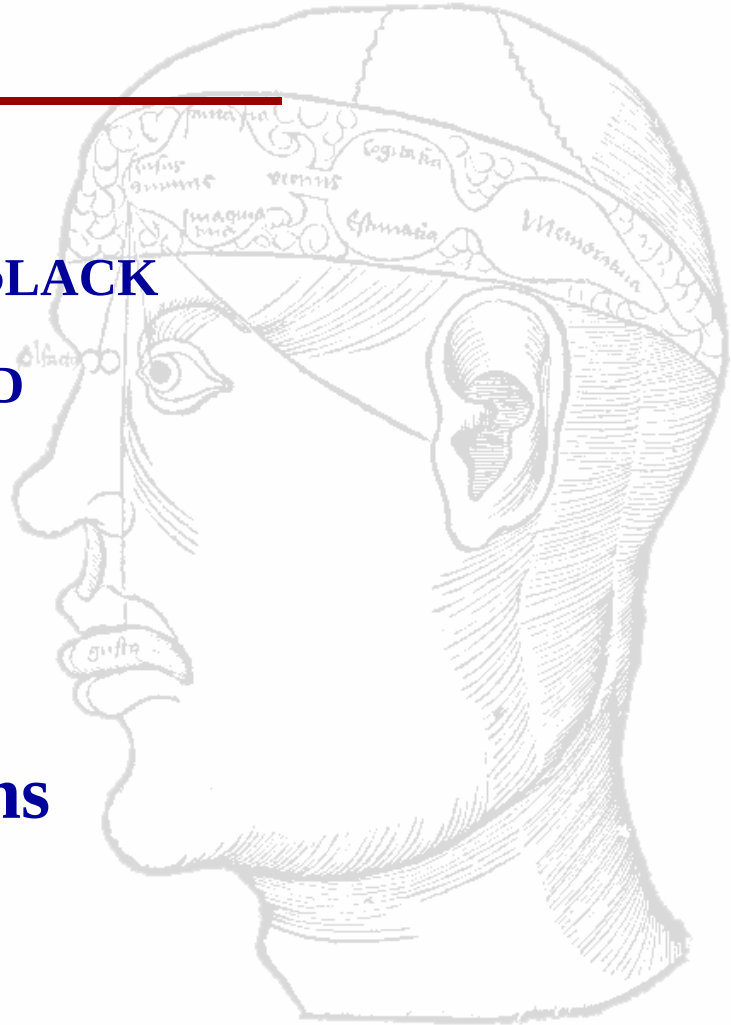
Topics in Brain Computer Interfaces
CS295-7



Professor: **MICHAEL BLACK**

TA: **FRANK WOOD**

Spring 2005

Repairing Humans

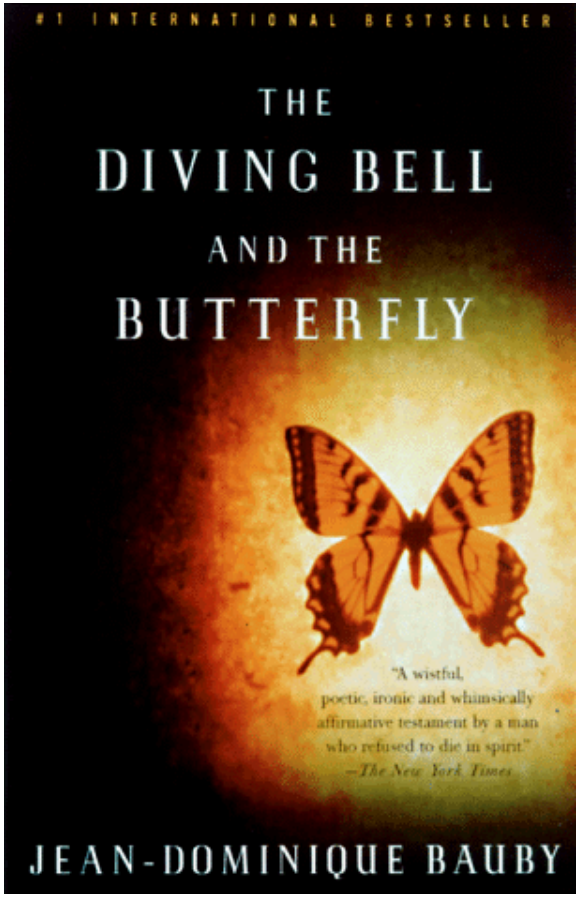
Plan for Today

- Come back to people and focus on real applications.
- Other recording technologies.
- How to build real prostheses.
- Plan for remaining classes.
- Project presentations.

Plan for Today

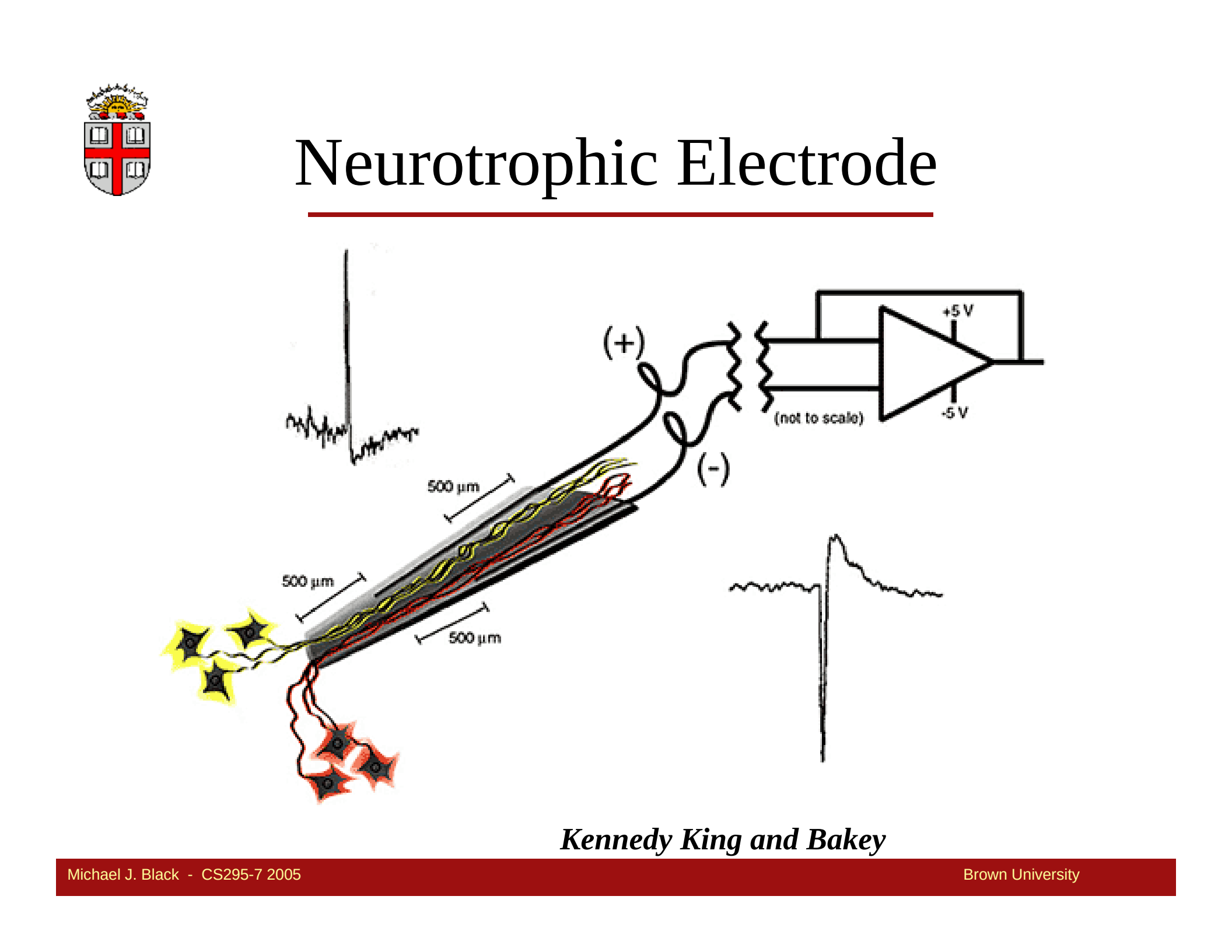
- Locked-in syndrome.
- Neurotrophic electrode.
- EEG and ECoG.
- Dasher??
- Peripheral nerves (cuffs and sieves).
- Robots and prostheses.
- Building a prosthetic limb.

Locked-in Syndrome



"Up until then, I had never heard of the brain stem. I've since learned that it is an essential component of our internal computer, the inseparable link between the brain and the spinal cord."

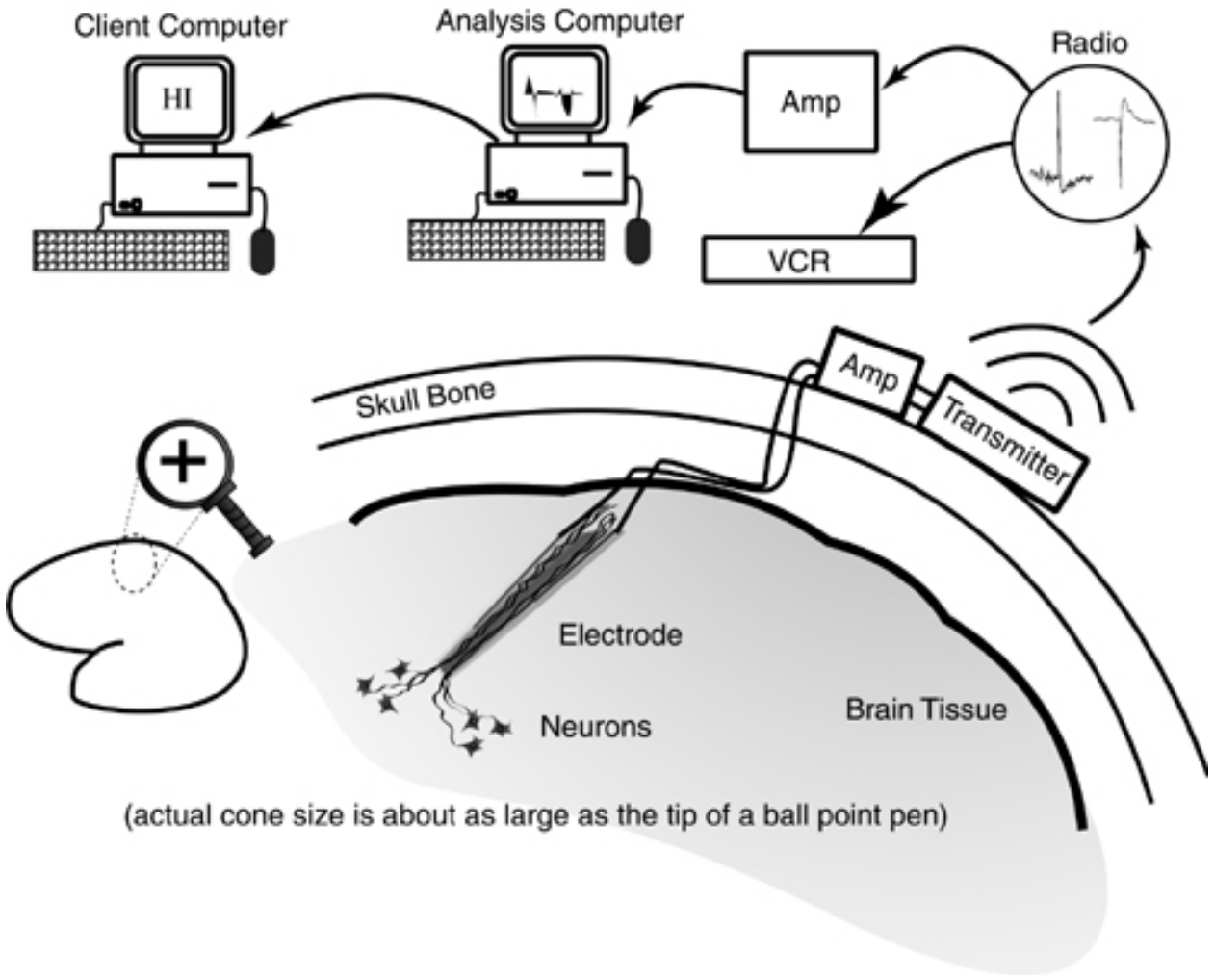
Jean-Dominique Bauby,
The Diving Bell and the Butterfly.



Neurotrophic Electrode

Kennedy King and Bakey

System


Client Computer
Analysis Computer
Radio
HI
Amp
VCR
Skull Bone
Amp
Transmitter
Electrode
Neurons
Brain Tissue
(actual cone size is about as large as the tip of a ball point pen)

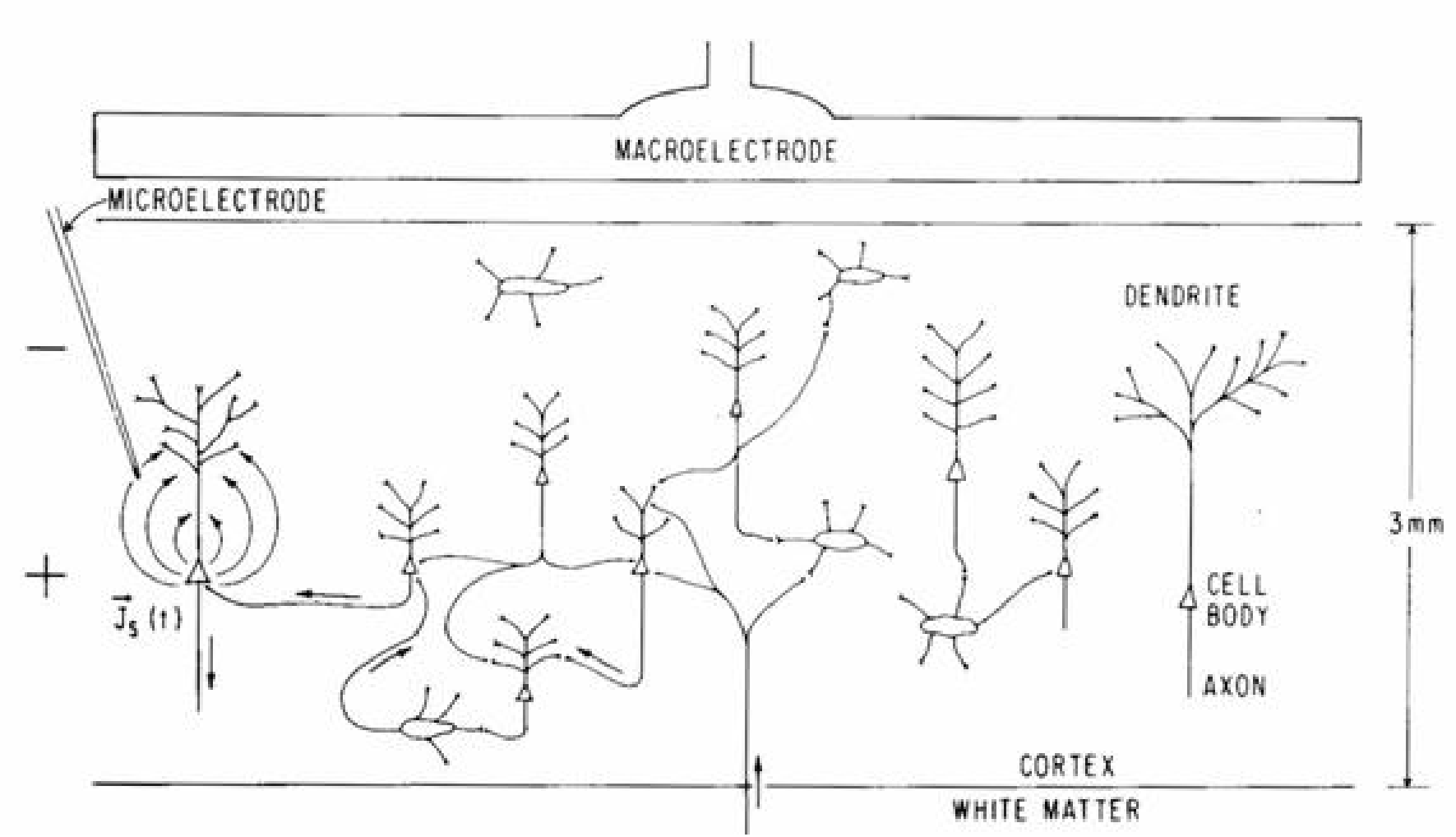
Non-invasive recoding

Electroencephalography (EEG)

Can’t measure activity of a single cells from outside the skull.

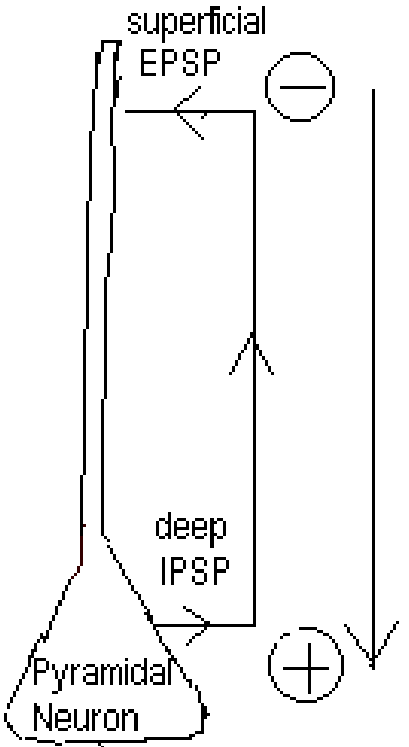
Instead record synchronized activity of large populations of cells.

EEG


MACROELECTRODE
MICROELECTRODE
DENDRITE
CELL BODY
AXON
3mm
CORTEX
WHITE MATTER

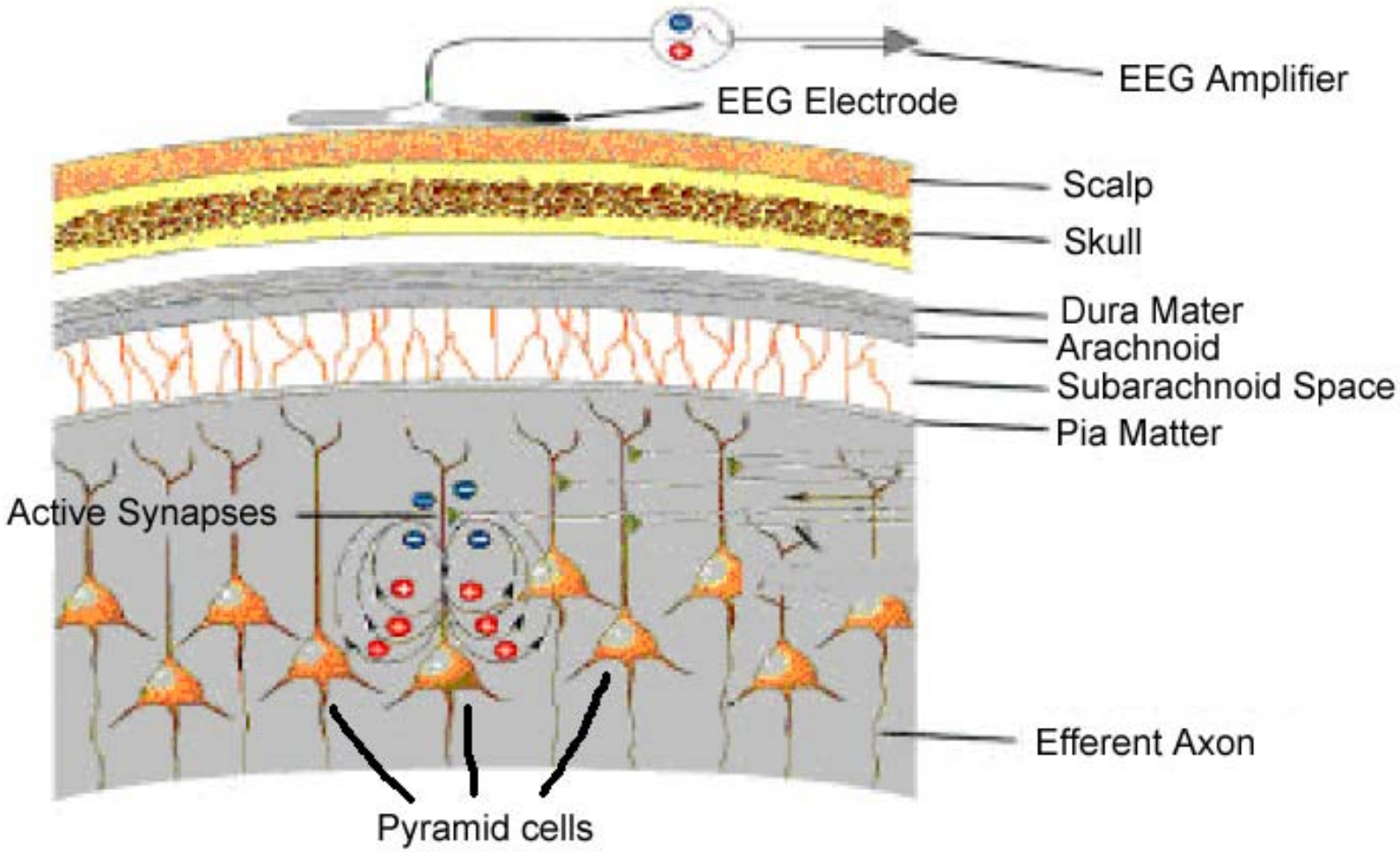
Dipoles

- A dipole source occurs when equal amounts of negative and positive charge are separated over a short distance.
- Assume synaptic currents occur in a vertically oriented neuron with a deep cell soma and superficial apical dendrite.



This diagram shows the current flow associated with a deep IPSP (positive outward) or superficial EPSP (negative inward) and the vertical downward equivalent dipole source .

EEG


EEG Amplifier
EEG Electrode
Scalp
Skull
Dura Mater
Arachnoid
Subarachnoid Space
Pia Matter
Active Synapses
Efferent Axon
Pyramid cells

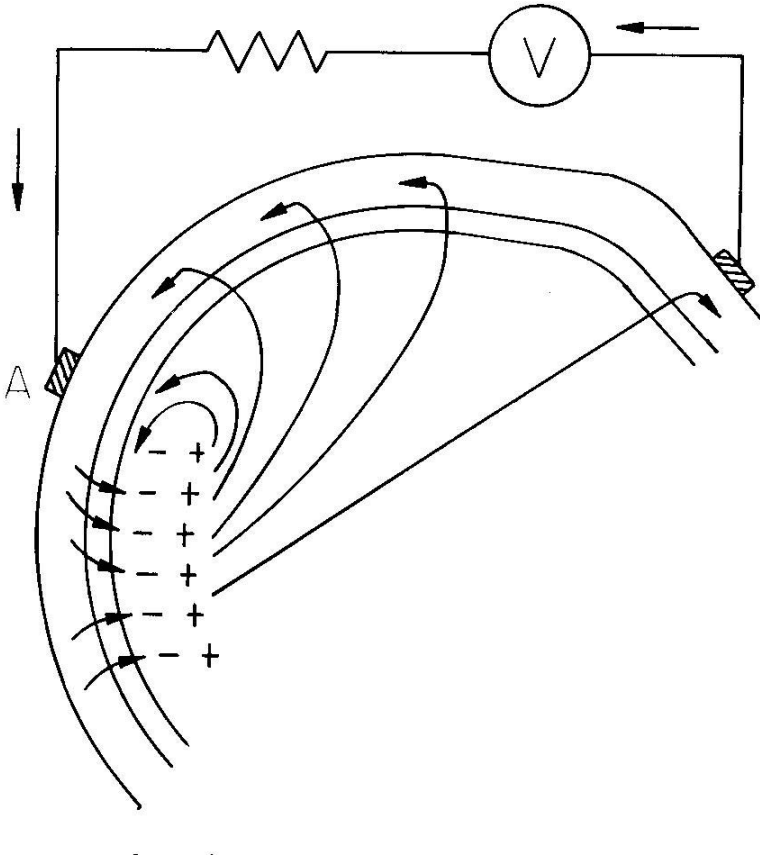
EEG

Oriented pyramidal cells in cortex.

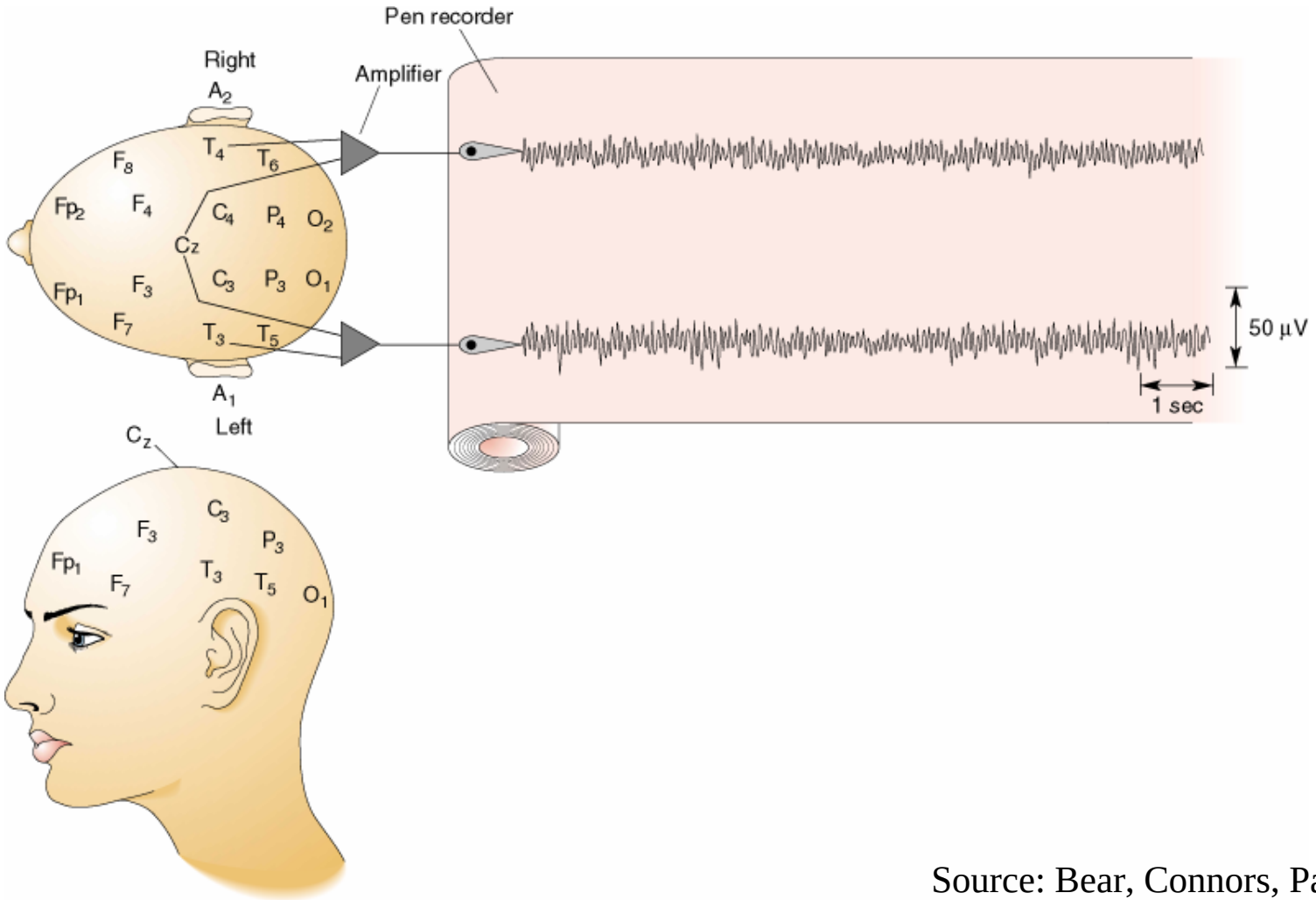
If activity is synchronized then many small dipoles combed to produce a current wrt a reference electrode.

Currents due to

- 1) **The parallel array of pyramidal cells**
- 2) not action potentials, which are fast, but rather **synaptic currents**, lasting 10-100's of milliseconds.



THE EEG

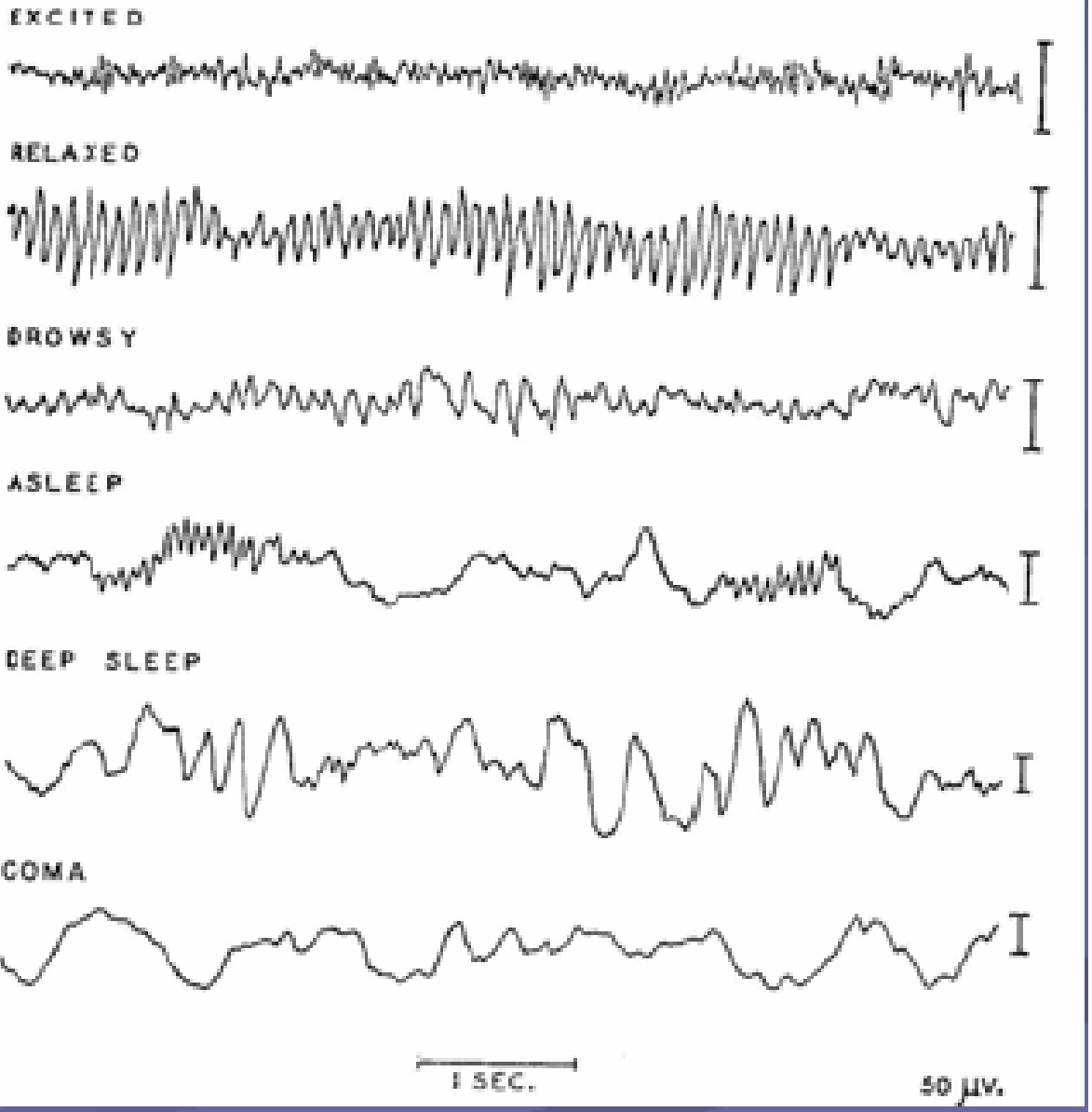


Source: Bear, Connors, Paradiso

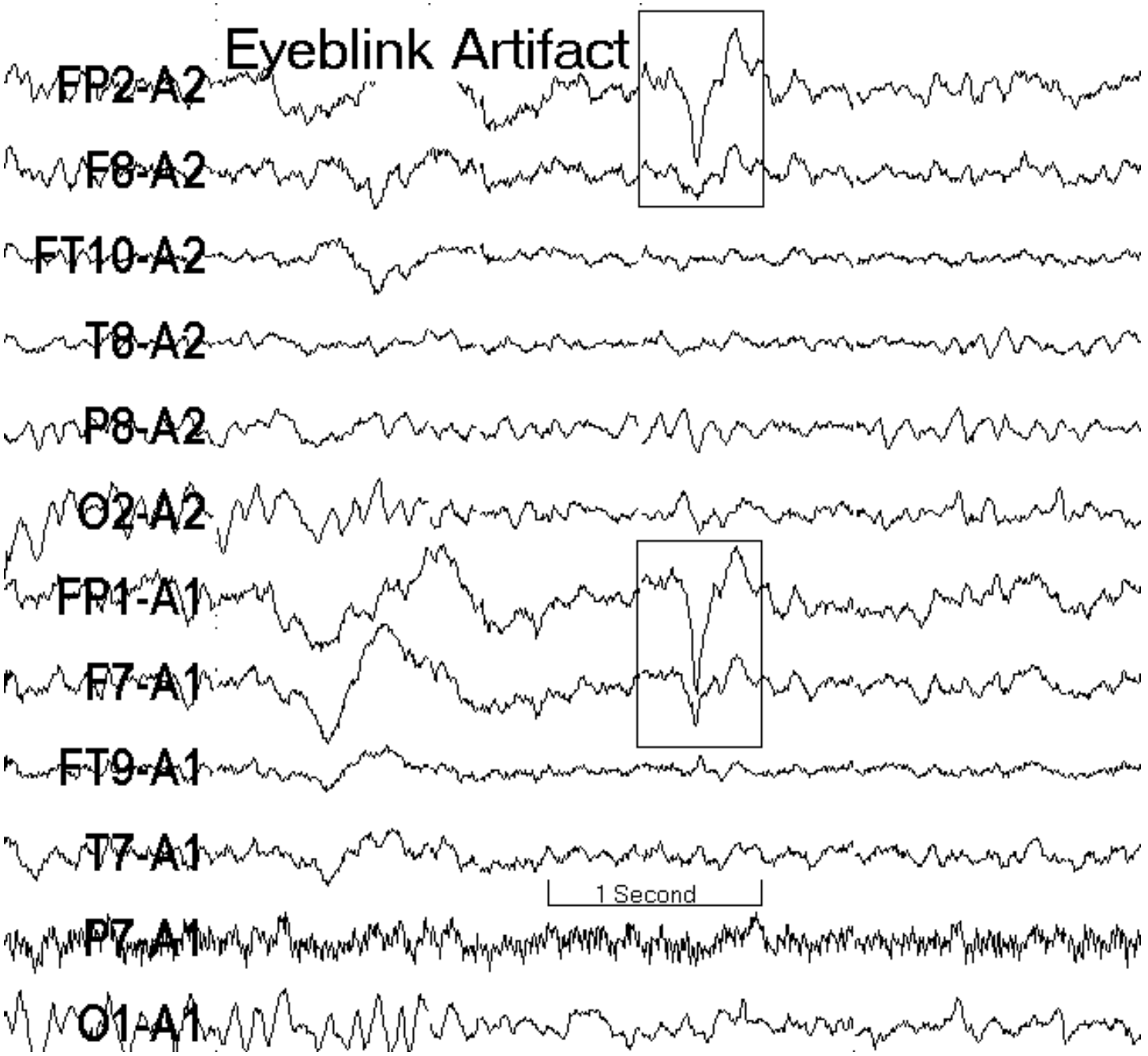
EEG

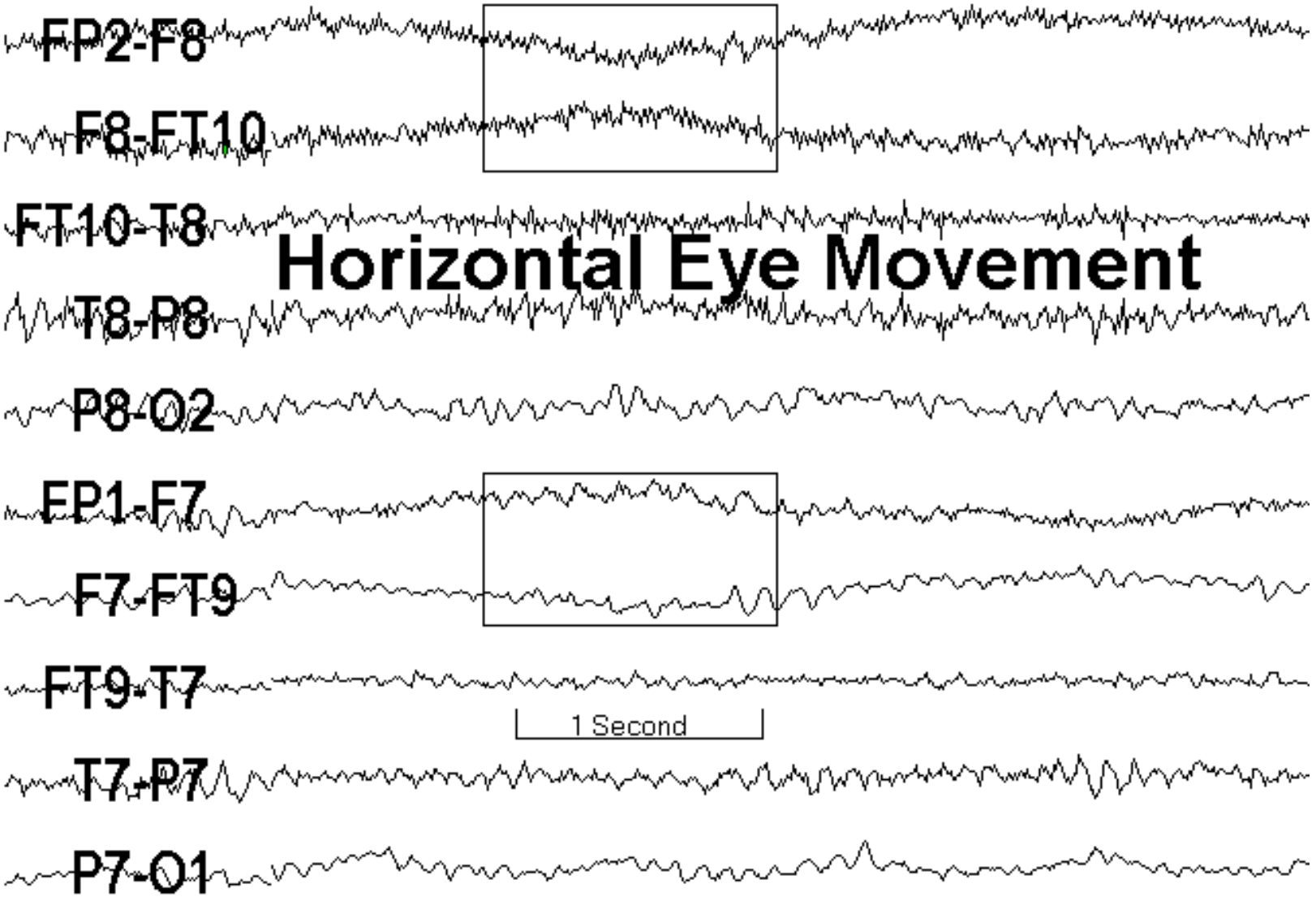
Frequency of EEG activity is denoted by

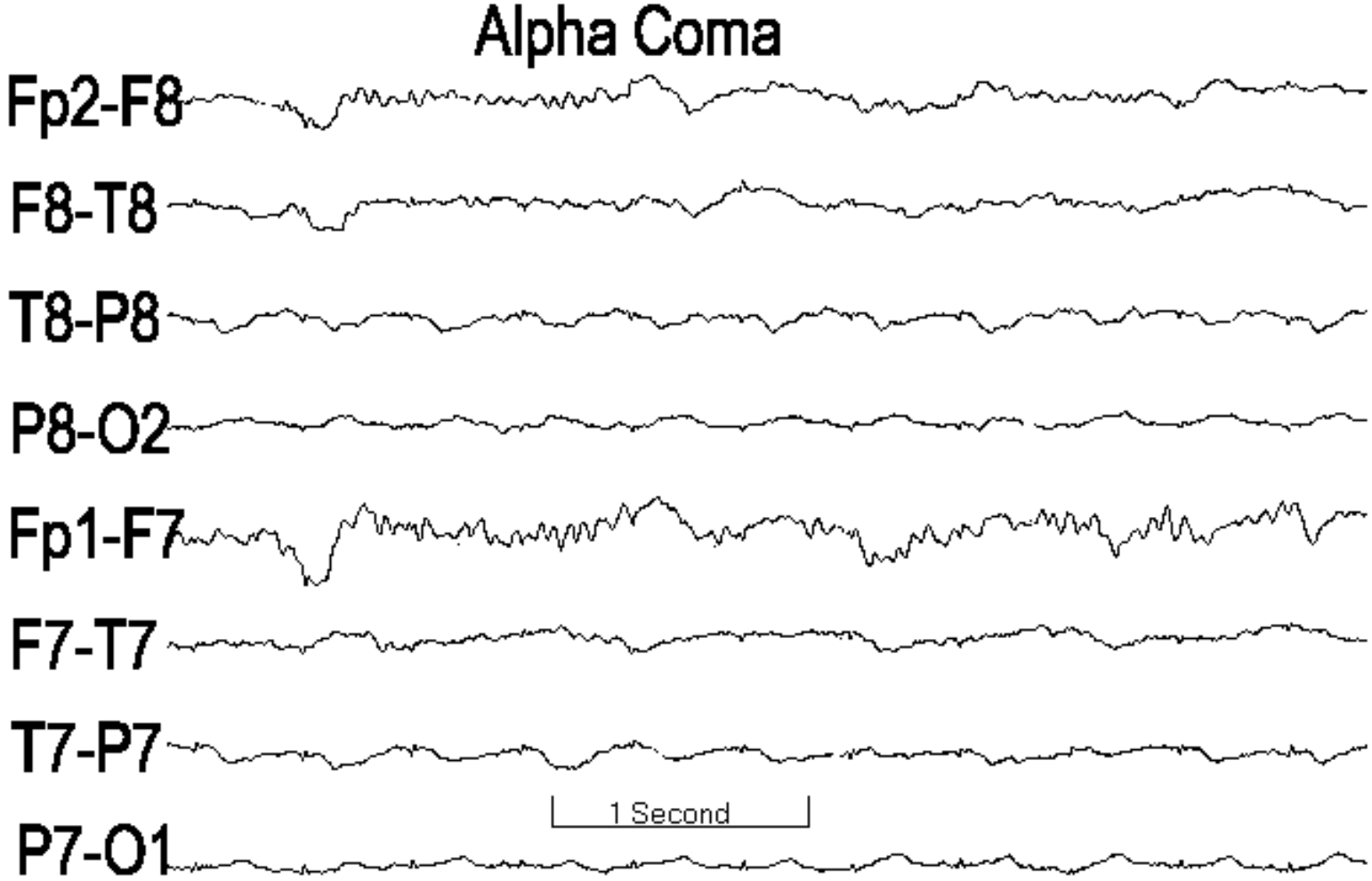
* delta (0-4 Hz),
* theta (4-8 Hz),
* alpha (8-12 Hz)
* beta (>12 Hz).



Niedermeyer & da Silva 1994


Eyeblink Artifact
FP2-A2
F8-A2
FT10-A2
T8-A2
P8-A2
O2-A2
FP1-A1
F7-A1
FT9-A1
T7-A1
1 Second
P7-A1
O1-A1

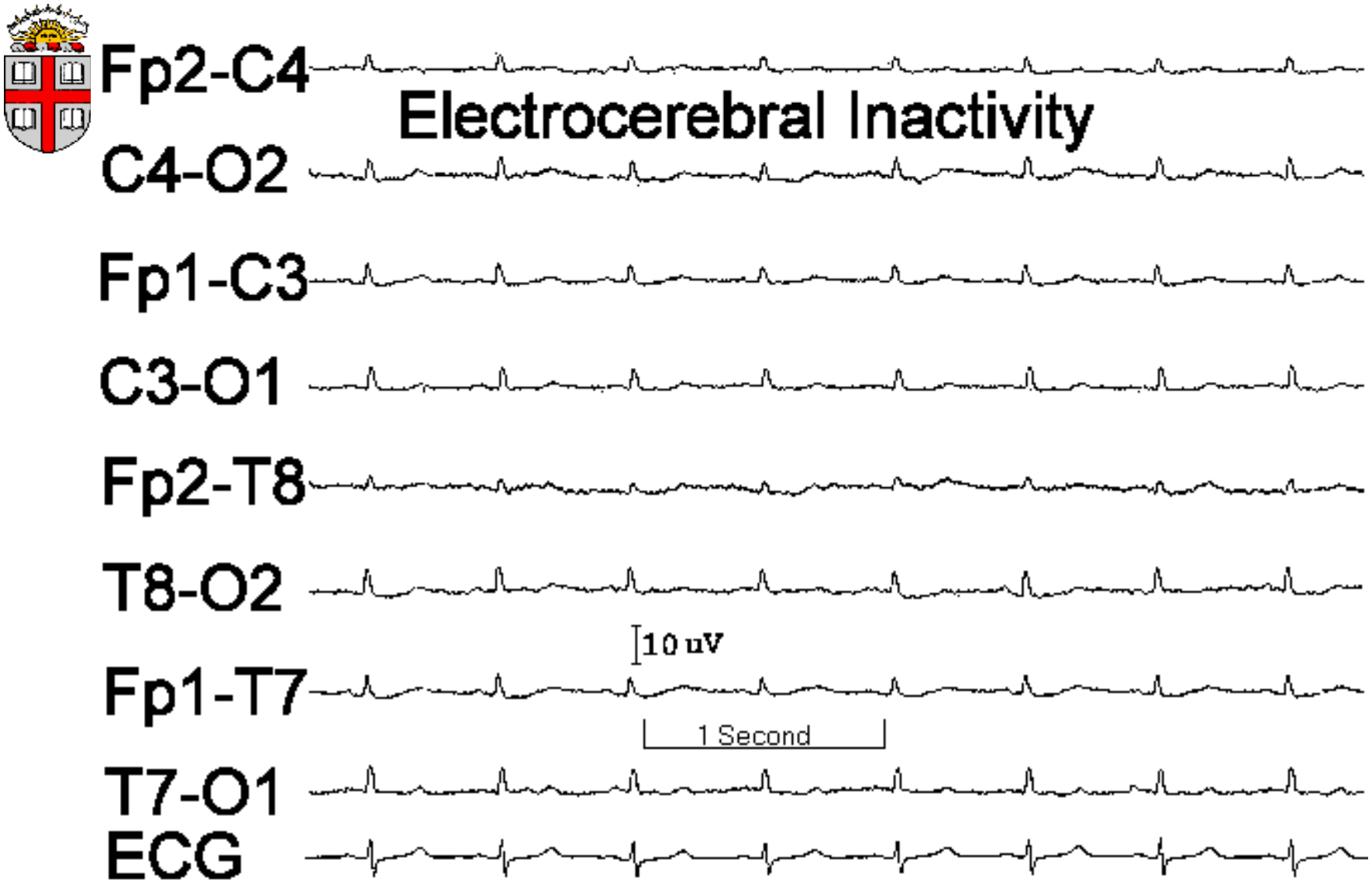

FP2-F8
F8-FT10
FT10-T8
Horizontal Eye Movement
T8-P8
P8-O2
FP1-F7
F7-FT9
FT9-T7
1 Second
T7-P7
P7-O1

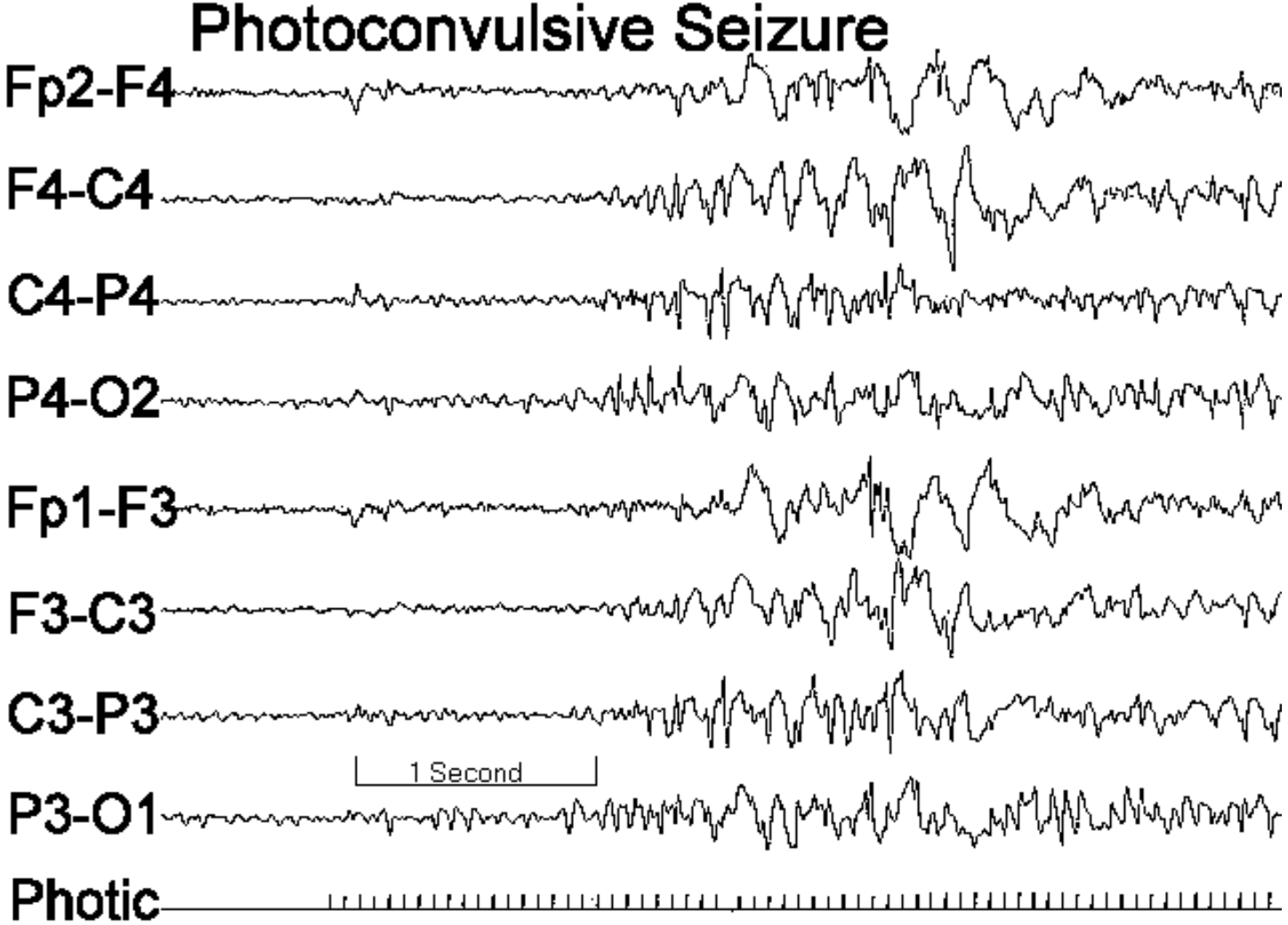


- Alpha Coma. This EEG pattern consists of anterior 8-12 Hz activity that does not change with stimulation. This pattern has a poor prognosis.

Brain death

- Electrocerebral inactivity is a pattern without any cerebral electrical activity. Specific requirements are: minimum of 8 channels, recording sensitivity at 2 uV/mm, long interelectrode distances (> 10 cm), electrode impedance 100 - 10,000 ohms, minimum of 30 minutes recording and time constant 0.3 - 0.4 seconds. In addition, the technician will touch each electrode to verify the integrity of the recording system and stimulate the patient to see if EEG activity occurs. Electrical activity of non-cerebral origin such as pulse and ECG artifacts may occur and should be distinguished from cerebral electrical activity. This pattern occurs in brain death but may also occur in drug overdose and hypothermia.


Electrocerebral Inactivity
Fp2-C4
C4-O2
Fp1-C3
C3-O1
Fp2-T8
T8-O2
10 uV
Fp1-T7
1 Second
T7-O1
ECG



http://www.neuro.mcg.edu/amurro/cnphys/index.html#Dipole%20Sources

EEG Interfaces

So how do you build an interface to control devices?

Two main paradigms

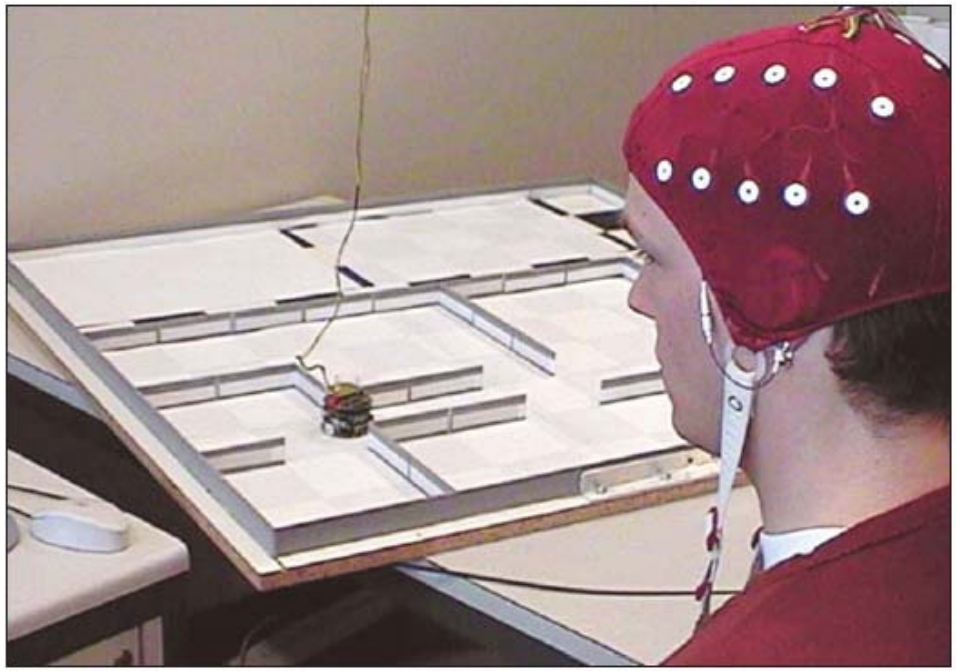
1) train the user

2) train the computer

Robot Control

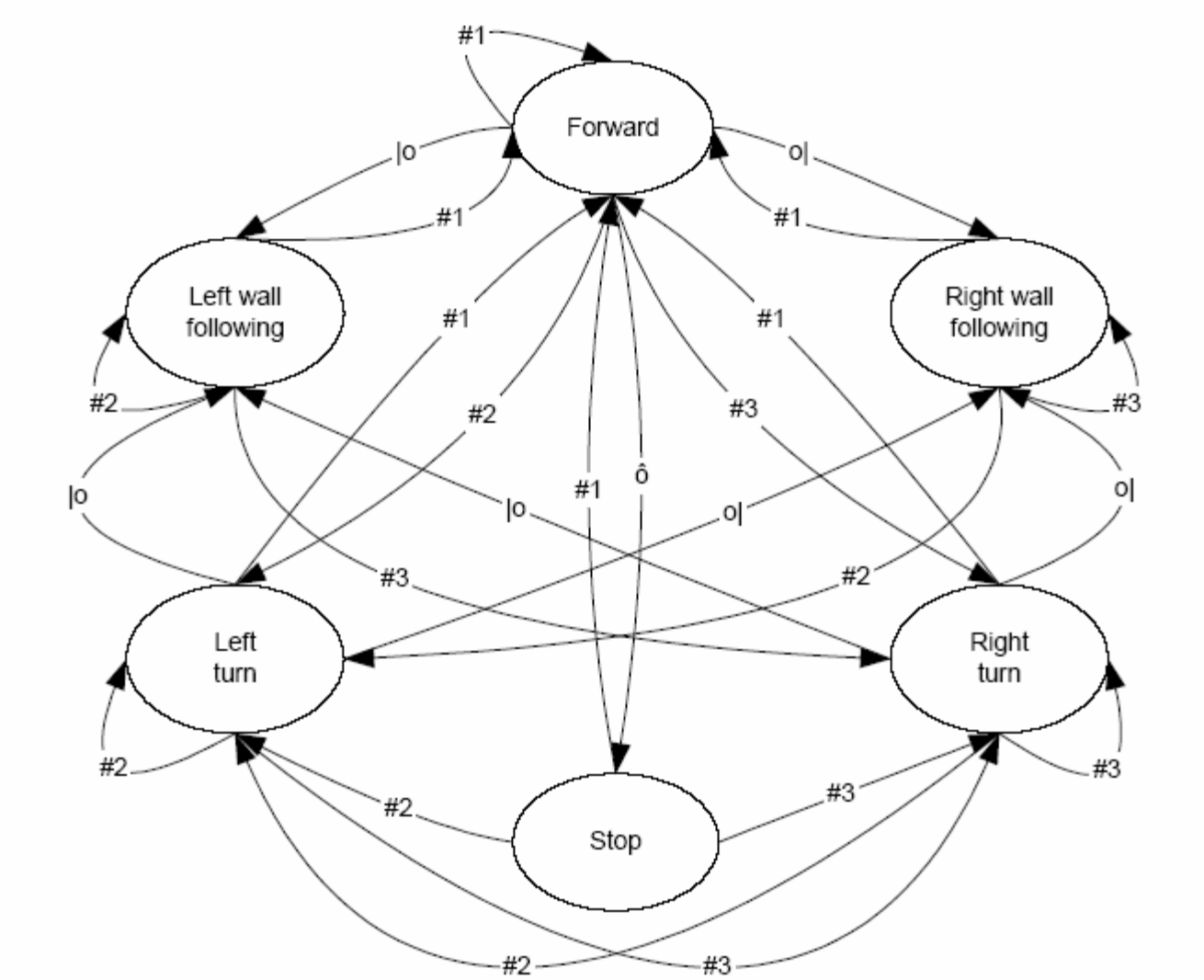
Tasks:

- relax
- imagine repetitive self-paced movements of a limb,
- visualize a spinning cube,
- subtractions by a fixed number (e.g., 64–3=61, 61–3=58, etc.),
- generating words that begin with the same letter.



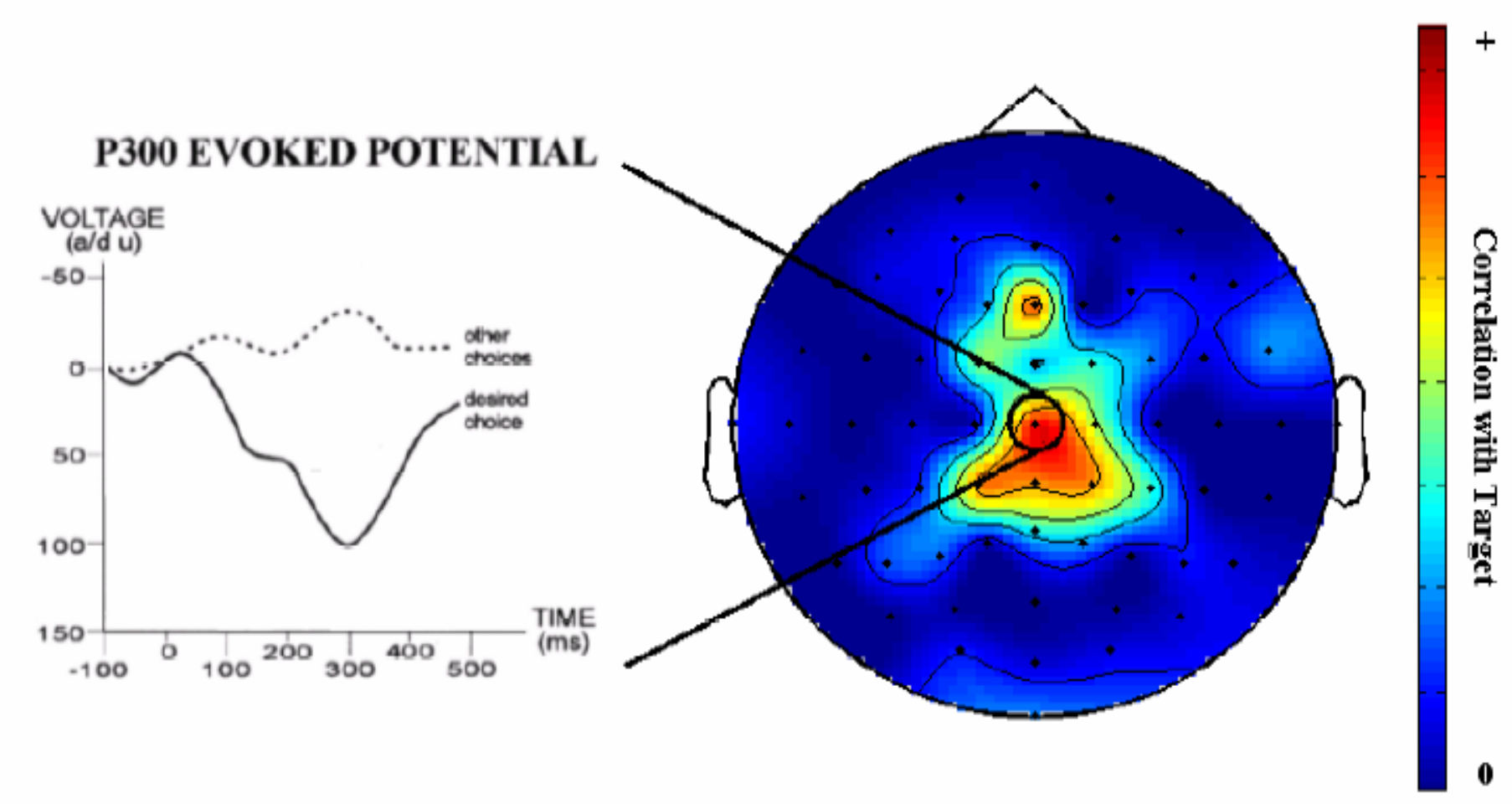
Classification task

http://diwww.epfl.ch/~gerstner/PUBLICATIONS/Millan04b.pdf



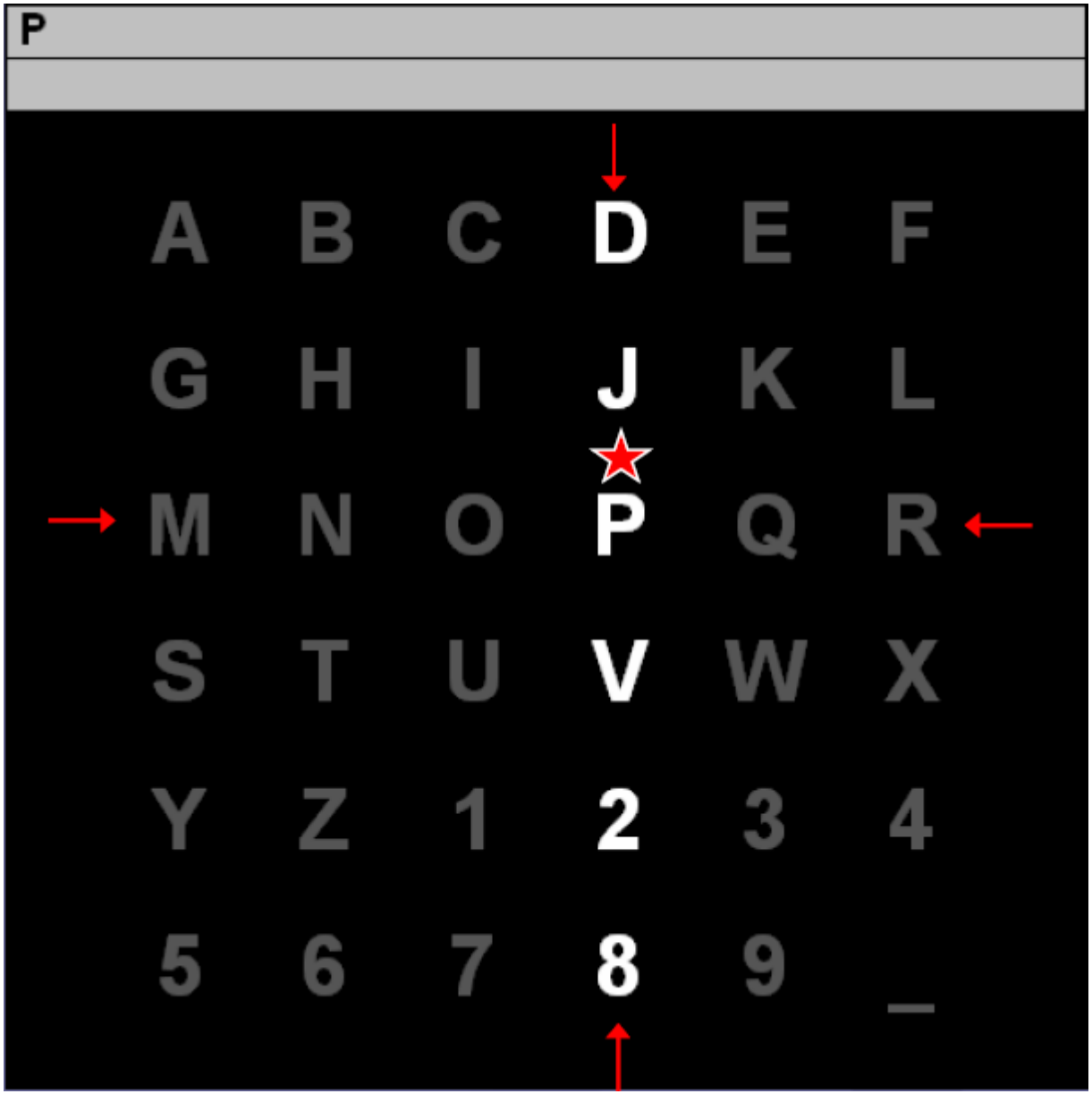
Transitions between the 6 behaviors were determined by 3 mental states (#1, #2, #3), 6 perceptual states (|o: left wall, o|: right wall, ô: wall or obstacle in front), and some memory variables.

Evoked potentials



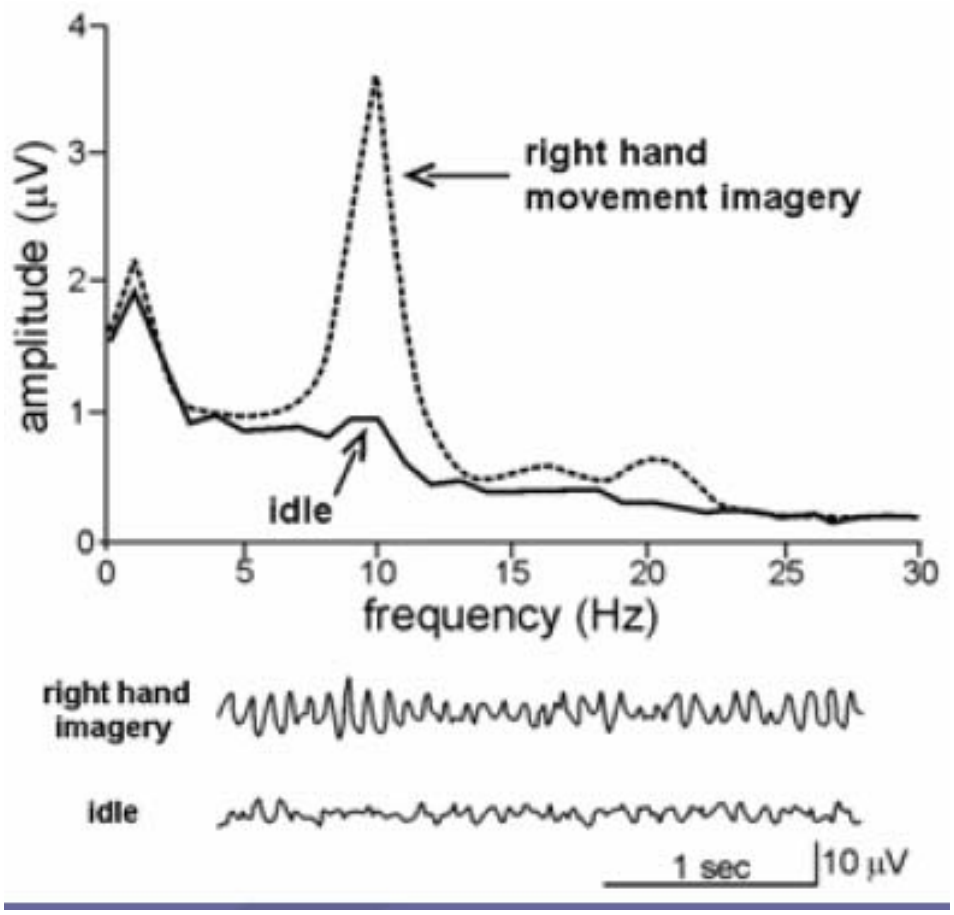
Evoked Potentials

- Oddball paradigm elicits a P300 evoked potential (ie 300ms after the event)
- Random sequence of events.
- Classification rule to separate events into categories.
- Task that requires the rule.
- At least one category presented infrequently.

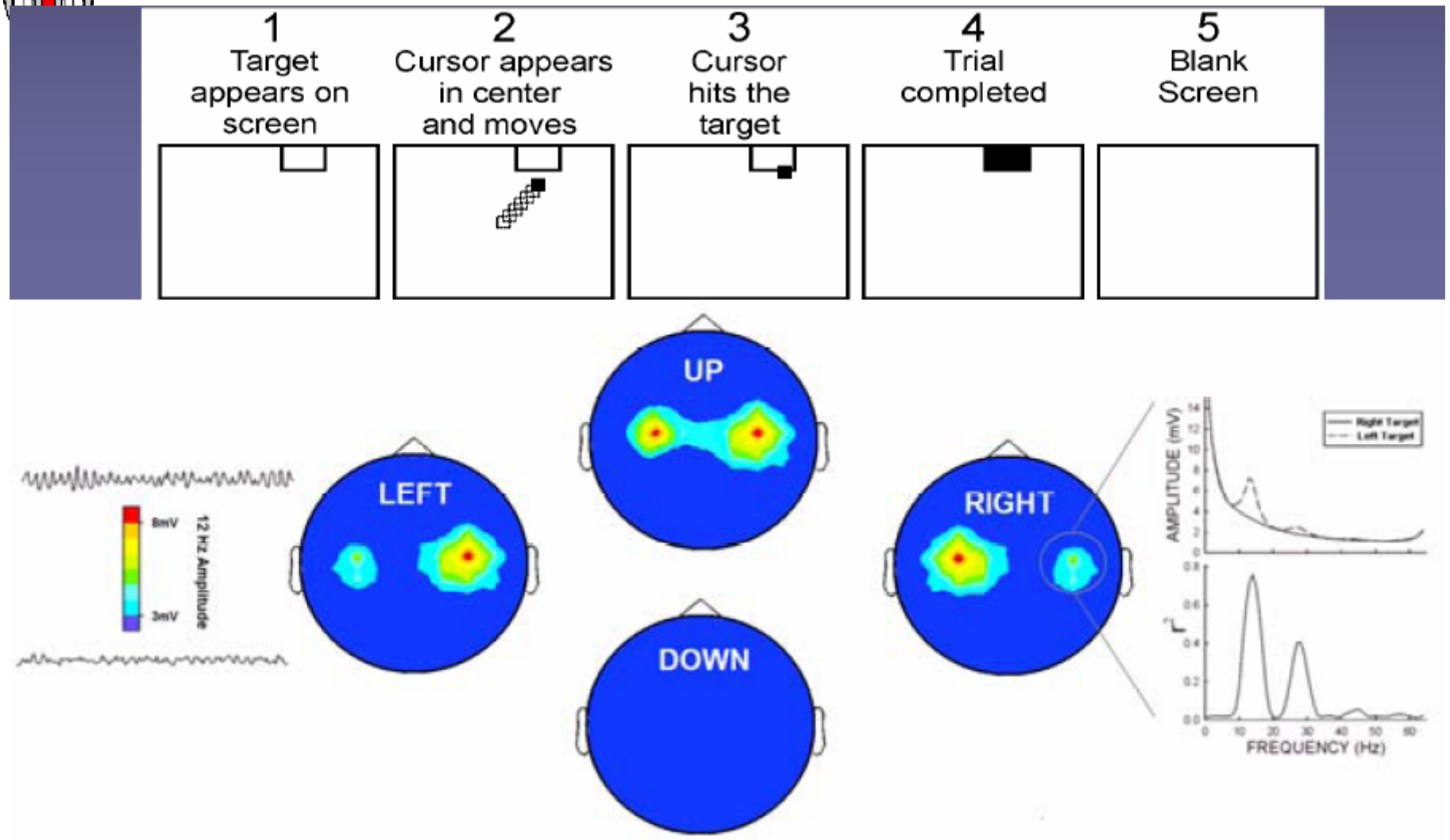

P
A B C D E F
G H I J K L
M N O P Q R
S T U V W X
Y Z 1 2 3 4
5 6 7 8 9 _

Imagined motion

- Sensorimotor Rhythms: localized, narrowband amplitude.
- modulations corresponding to movement, simulation, mental imagery



Dean Krusienski, Wadsworth Center


1
Target appears on screen
2
Cursor appears in center and moves
3
Cursor hits the target
4
Trial completed
5
Blank Screen
UP
LEFT
RIGHT
DOWN
8mV
3mV
12 Hz Amplitude
AMPLITUDE (mV)
FREQUENCY (Hz)

Dahser

"Dasher is a zooming interface. You point where you want to go, and the display zooms in wherever you point. The world into which you are zooming is painted with letters, so that any point you zoom in on corresponds to a piece of text. The more you zoom in, the longer the piece of text you have written. You choose what you write by choosing where to zoom."

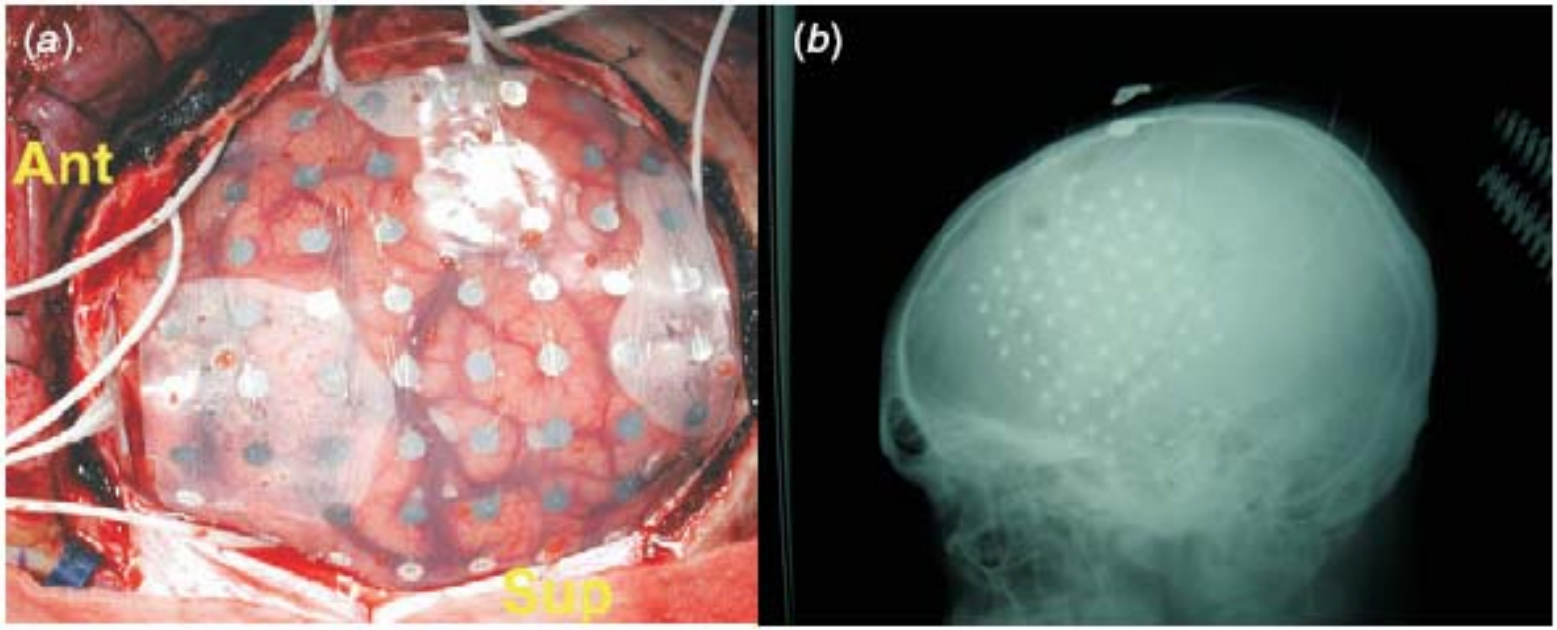
http://www.inference.phy.cam.ac.uk/dasher/

Interactive Institute, Stockholm.

Interactive Institute, Stockholm.

ECoG

Electrocorticography. Temporary implanted grid of surface electrodes for monitoring epileptic seizures.

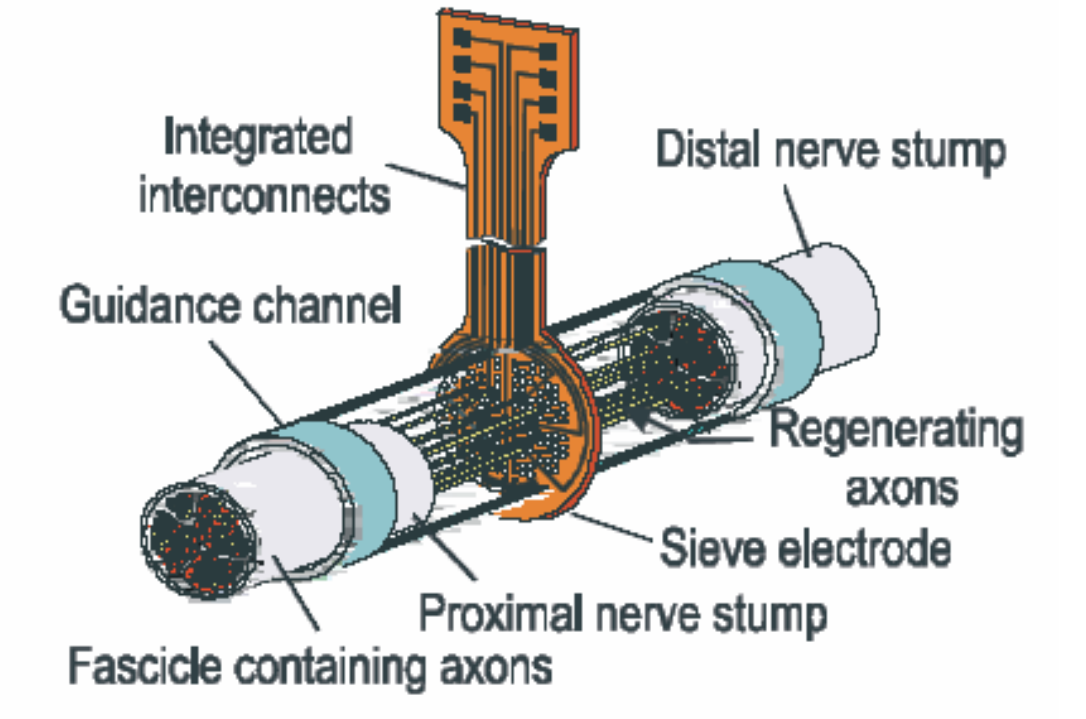


Leuthardt, **Schalk, Wolpaw**, **Ojemann and Moran**
A brain–computer interface using electrocorticographic signals in humans, J. Neural Engineering

ECoG

Leuthardt, **Schalk, Wolpaw**, **Ojemann and Moran**
A brain–computer interface using electrocorticographic signals in humans, J. Neural Engineering

Sieve Electrode



Record from and stimulate *peripheral* nerves.

P. Dario

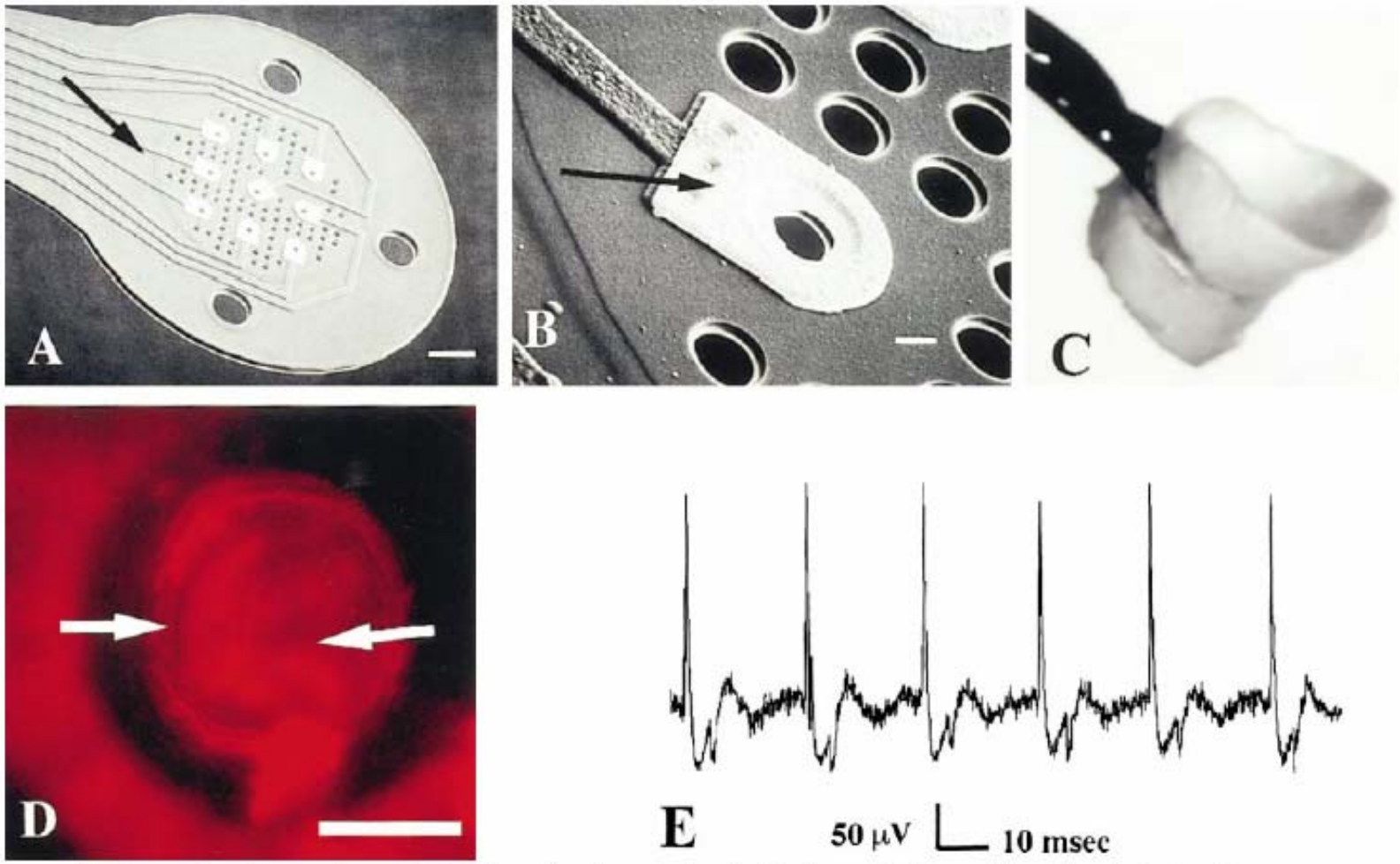


FIG. 1. *A*: scanning electron micrograph of a sieve microelectrode showing the nine active sites and the silicon leads (arrow). The iridium-lined active sites and unlined support pores for this probe design were 5–8 μm in diameter. *B*: scanning electron micrograph of the 8 μm iridium-lined active site. *C*: light micrograph of the sieve electrode with nerve guide tube. *D*: confocal micrograph of multiple regenerating axons growing through an active site of an entubulated silk-like protein with laminin functionality (SLPL) probe 60 days after implantation. Neural tissue has been reacted with a secondary tetramethylrhodamine antibody to neuron specific enolase. Arrows bracket the labeled tissue, which filled >50% of the pore. *E*: neural activity from the active site in *D* 45 days after transection. Scale bars (μm): *A* = 100; *B* = 8; *C* = 200; *D* = 20.

Mesenger et al, Chronic Recording of Regenerating VIIIth Nerve Axons With a Sieve Electrode

Sieve Electrode

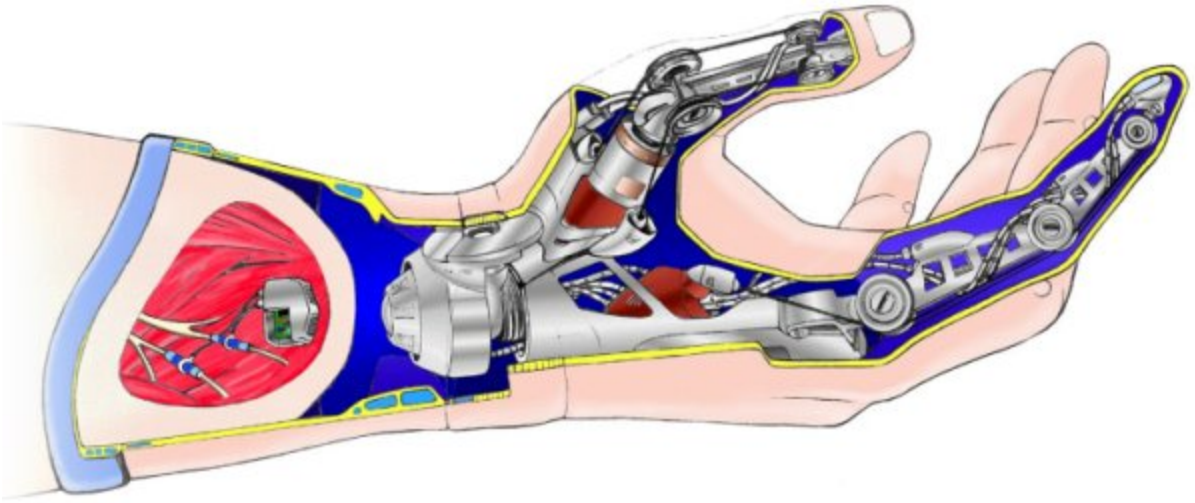
by courtesy of Xavier Navarro
Universidad Autonoma de Barcelona

Prostheses

Cosmetic

Functional and under electrical control using implanted electrodes in muscles

Cyberhand

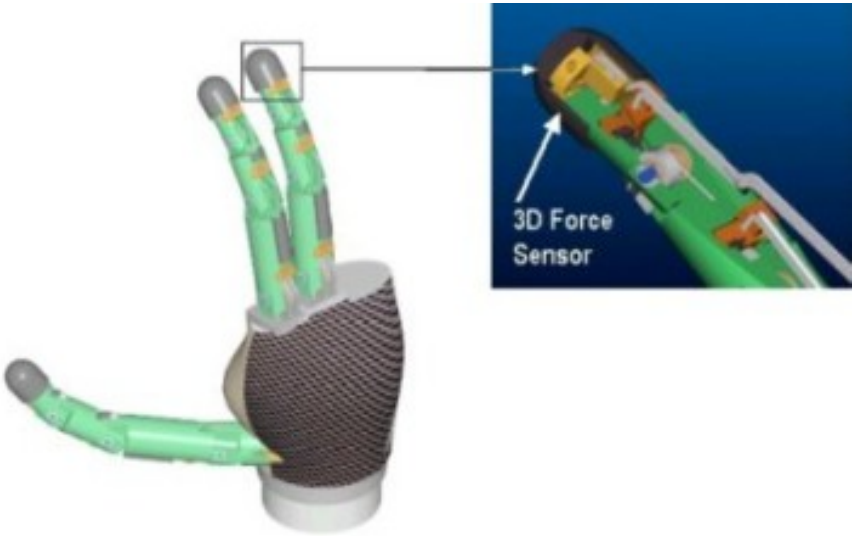


ADL

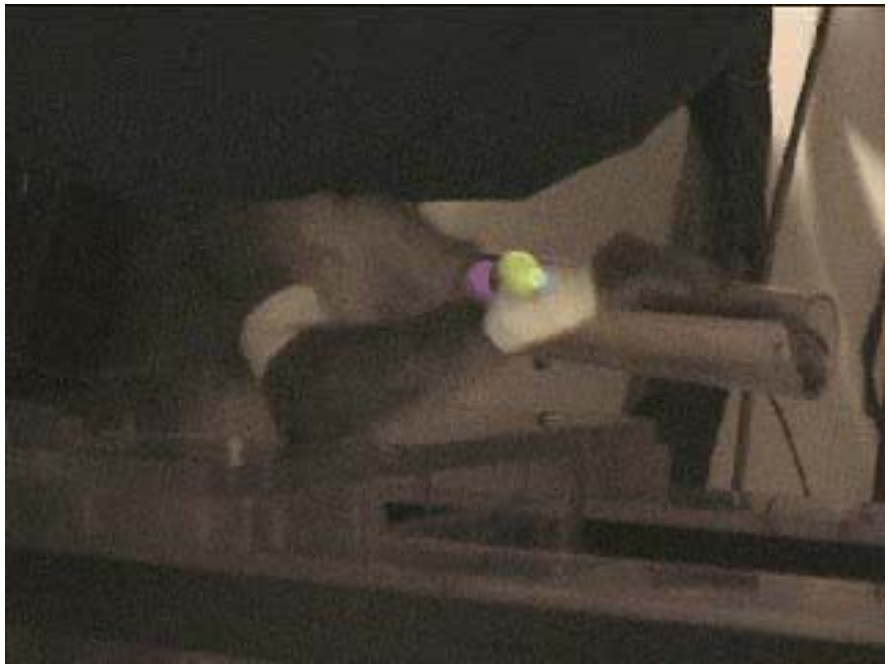
Activities of daily living


PEJO
FONTE ALPINA
NATURALE

Various sensors and actuators

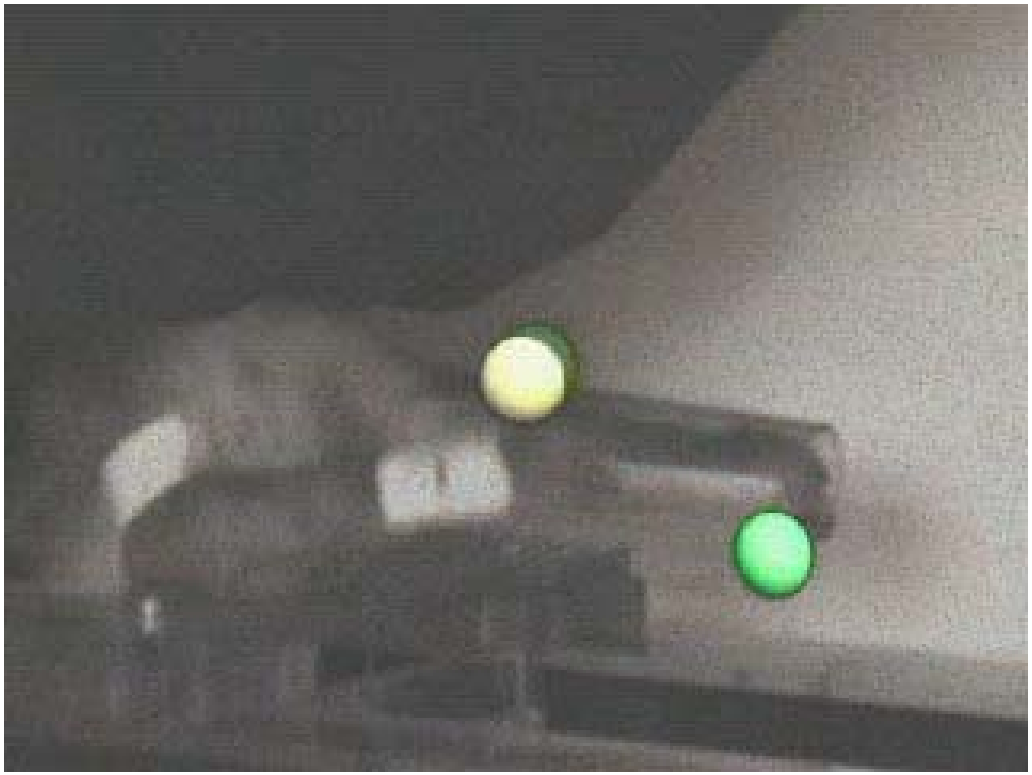


3D cursor control

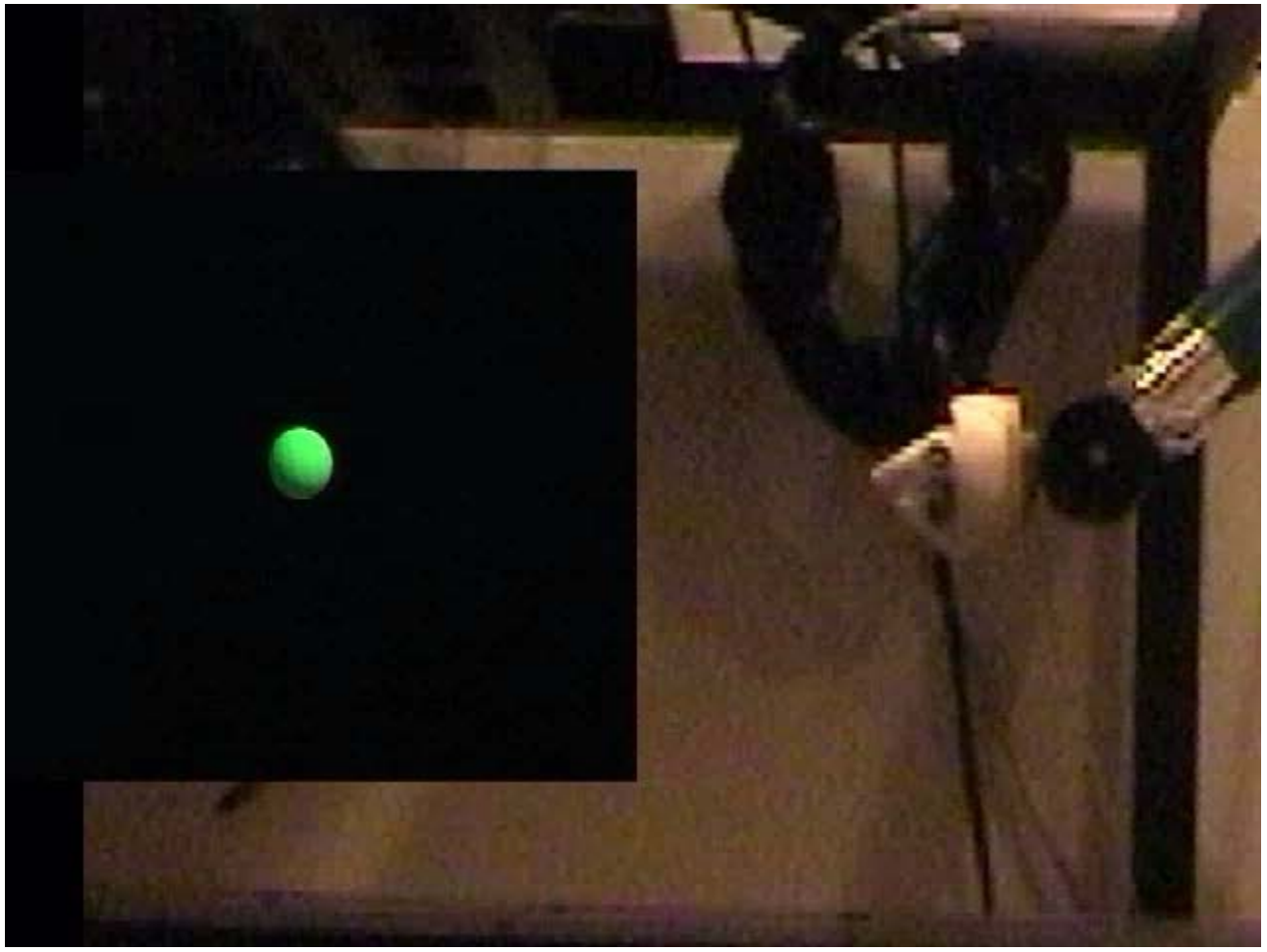


In **Movie 1, the cursor is initially controlled by the hand position, but later in the movie it is controlled** only by the brain-derived signal ("brain powered"). This was within the first few days that the monkey had been exposed to this task and we were using 24 simultaneously recorded units in motor cortex processed with the population vector algorithm.
http://motorlab.neurobio.pitt.edu/Motorlab/download_movies/download_movies.html

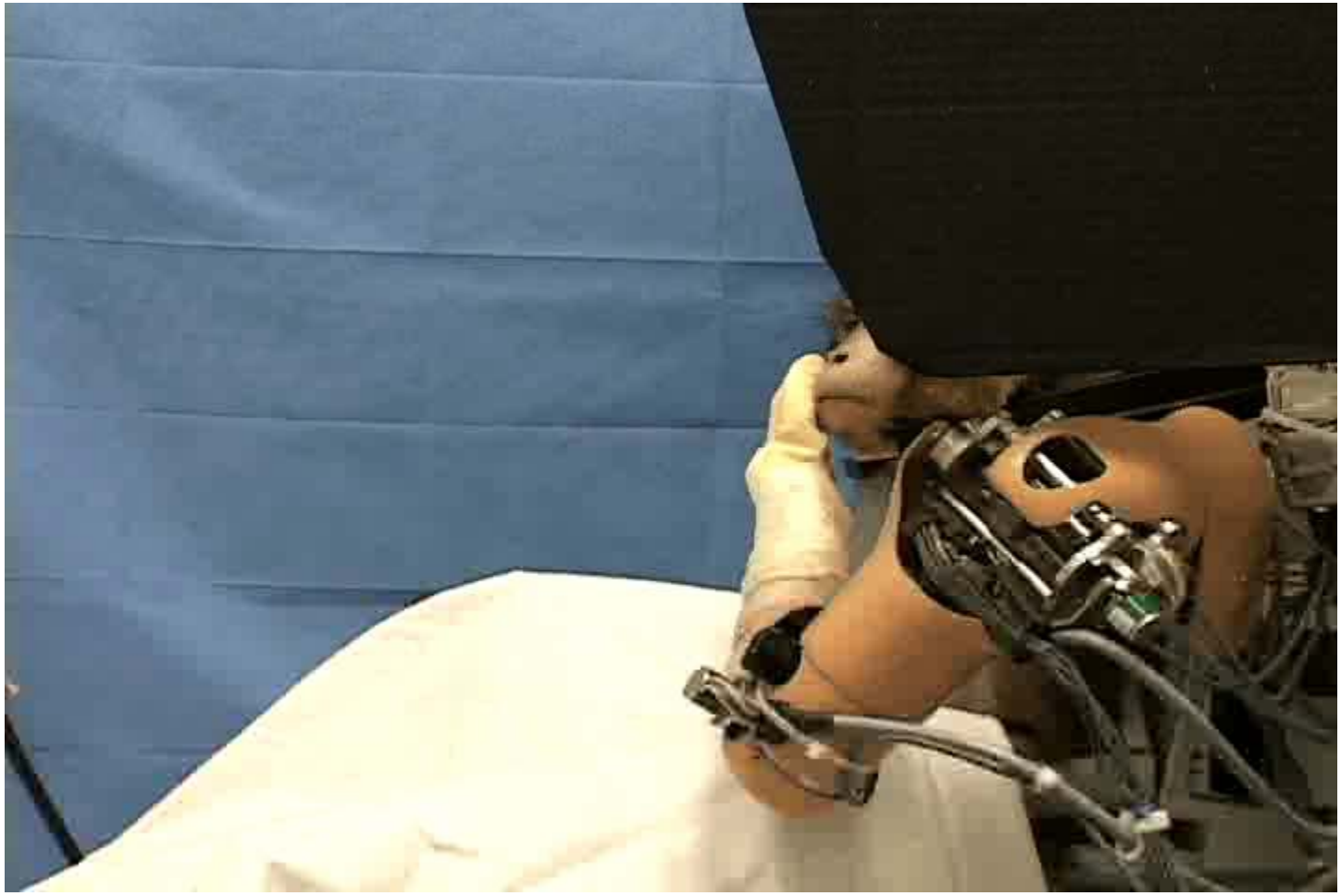
3D cursor control



<u>Movie 2</u> was recorded the day after movie 1.



Movie 3 was recorded several weeks later. Notice that in movie 1, the animal is moving its arm during the brain controlled portion, but in the subsequent movies it puts its arm down.



Monkey is directly controlling a 3-dimensionally moving prosthetic robot arm to feed itself.

Next class

- Last regular class.
- What do you want to cover that we haven't covered?

The Challenge

- Soldiers return from Iraq without arms (eg above elbow).
- Can we build a prosthetic arm that lets them
  - Comb their hair?
  - Eat with a knife and fork?
  - Drink a glass of water?
- DARPA wants this built in four years.

The Challenge

- What are the problems involved in building the arm?
- What technologies must be developed to build it?
- How would the subject control it?
  - What control issues can you think of?
- What signals would you use and how would you get them?
- What level of control could be achieved in 4 years?
- Think about the ADLs.

Project Presentations

- 10-12 minute presentation over 2 days
  - April 20 and 27 (WEB IS WRONG)
  - Need volunteers for April 20.
- Motivation, introduction, problem you are solving.
- Your method.
- Results (comparison with other methods). Plots, movies, etc.
- Where does it fail? What future work does it suggest?