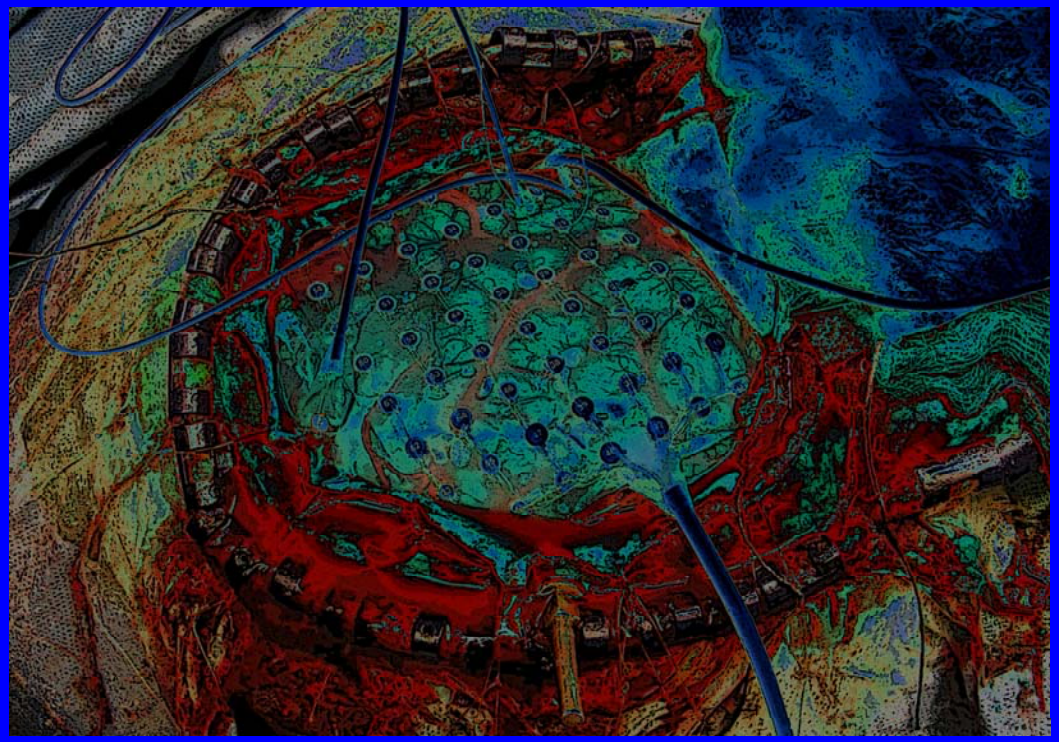
HIGH GAMMA in the HUMAN CORTEX

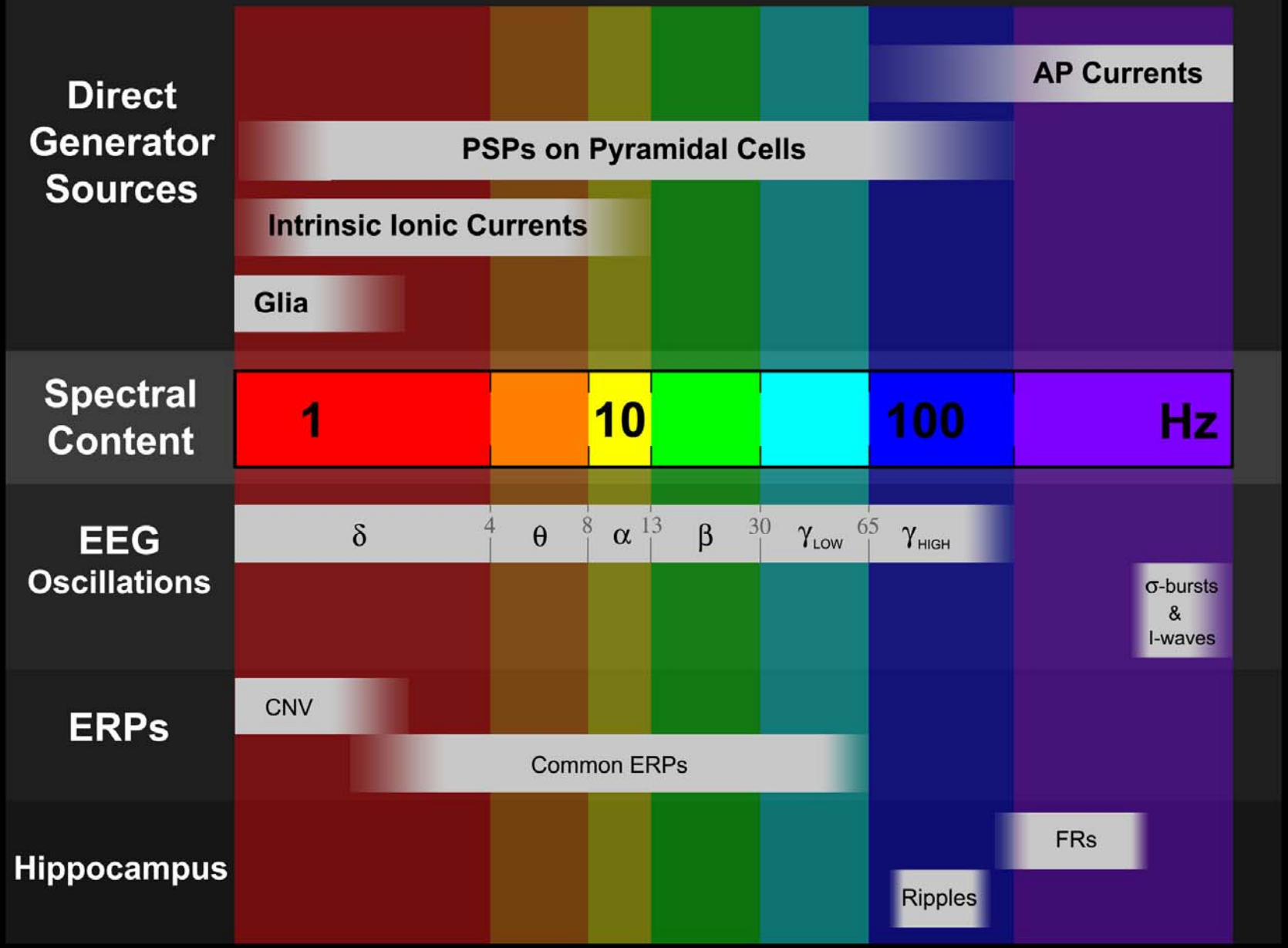
SWARTZ COMPUTATIONAL MEETING

RANCHO SANTE FE, 2006

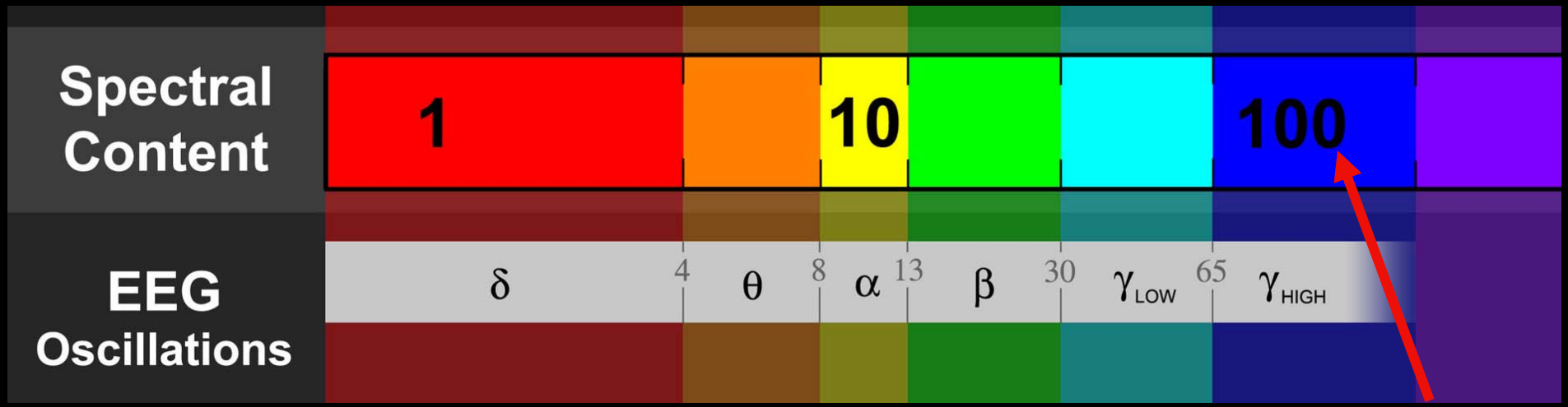
Robert T. Knight, M.D.
Department of Psychology
Helen Wills Neuroscience Institute
UC Berkeley

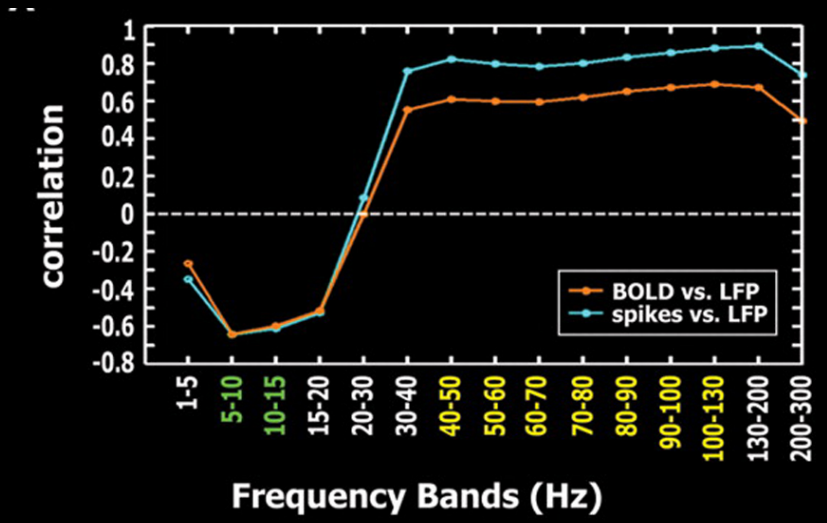


The Electroencephalographic Spectrum

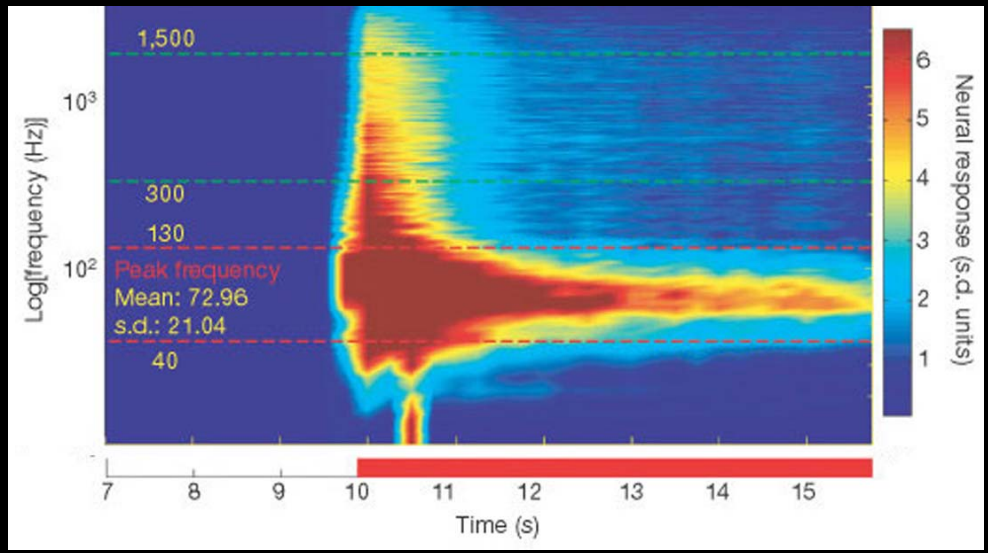


High Gamma and Cognition in Humans





Mukamel et al 2005



Logothetis 2001

History of Stimulation Mapping

1850 1875 1900 1925 1950 1975

1870

Fritsch: Motor Studies In Dogs

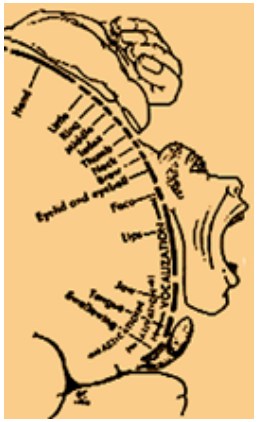
1875

Ferrier: Motor Studies In Primates

1917

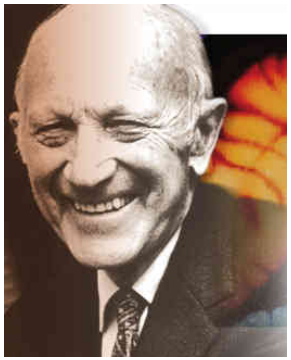
Sherrington: Motor Mapping In Primates

1938



Penfield: Motor Homunculus In Humans

1959



Penfield: Language Studies

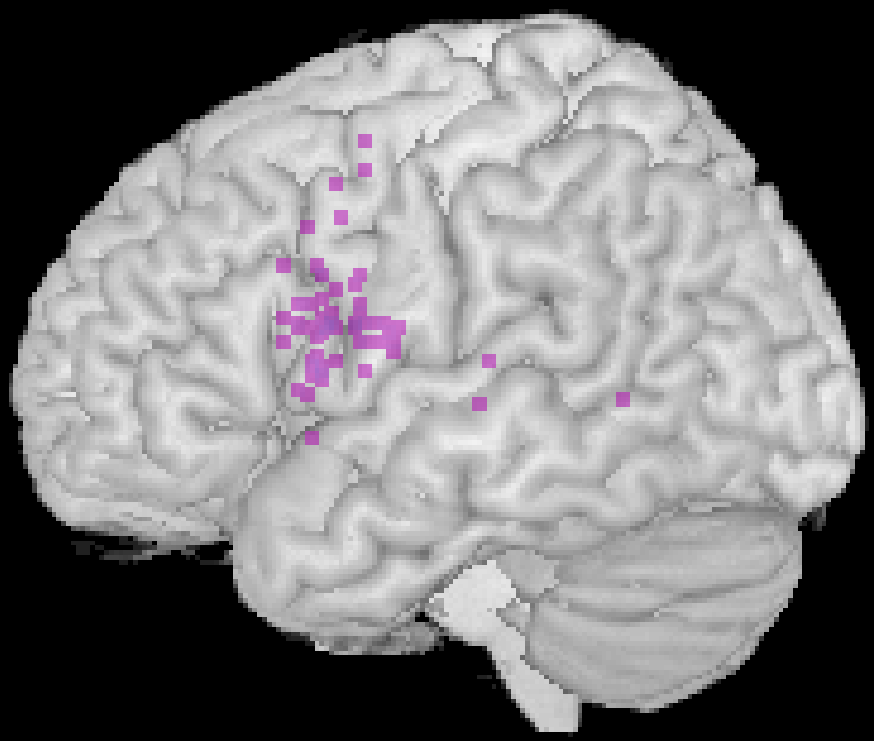
1970s

Ojemann: Language Studies

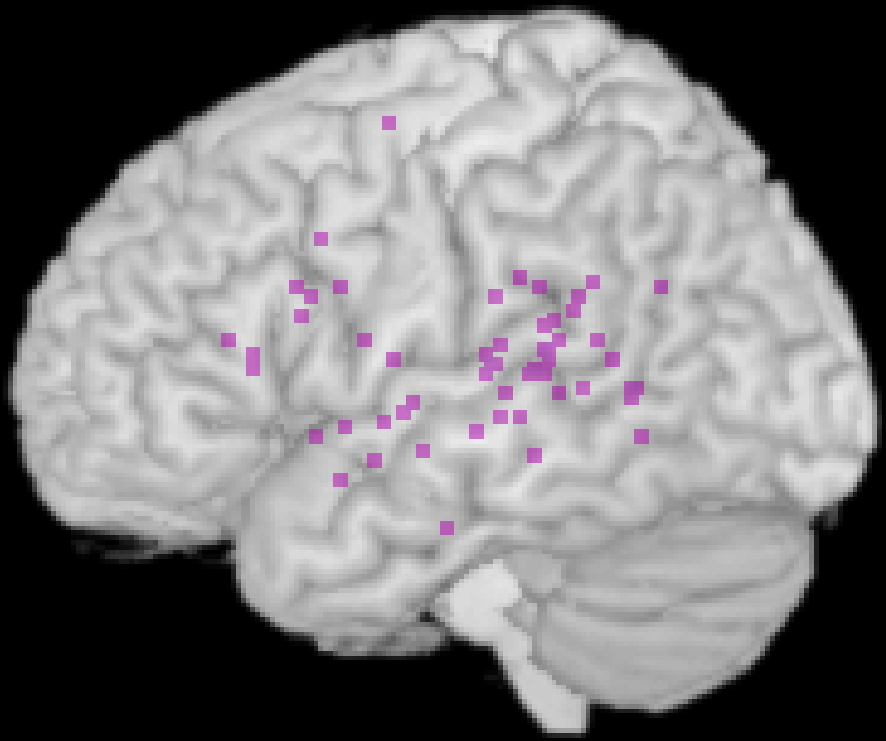
ACUTE CORTICAL MAPPING

UCB-UCSF INTRACRANIAL PROJECT

LANGUAGE DISRUPTION SITES

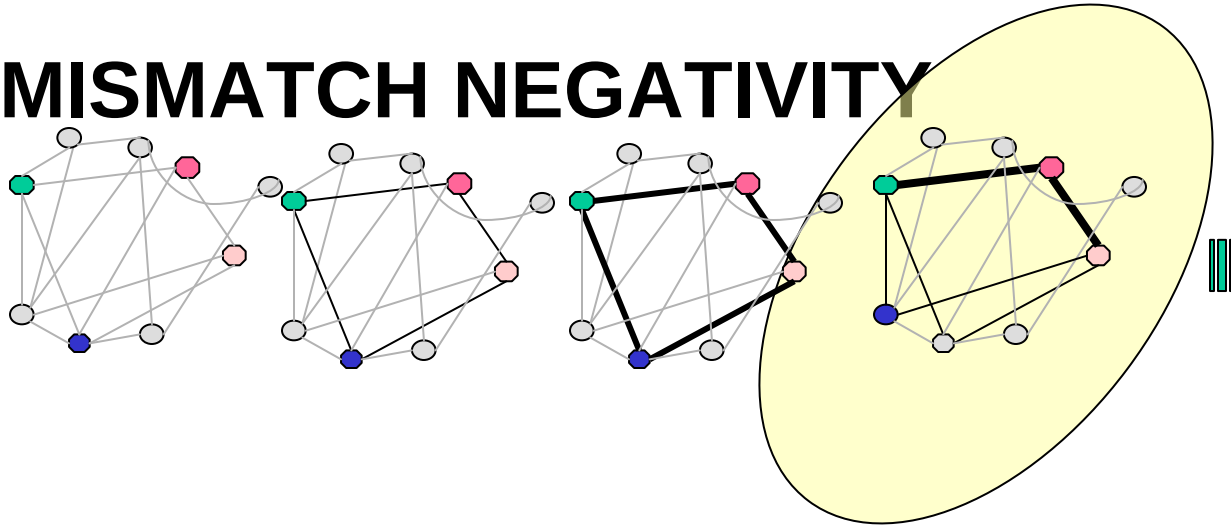


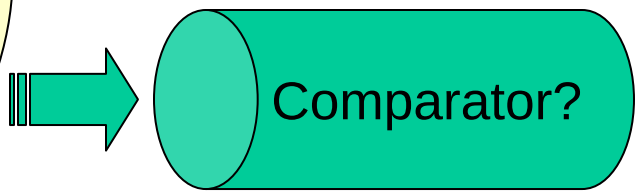
SPEECH ARREST

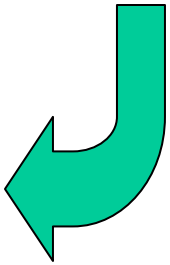


ANOMIA

MISMATCH NEGATIVITY

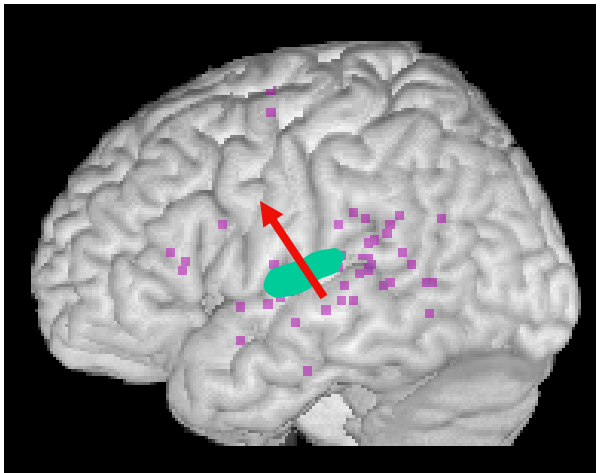






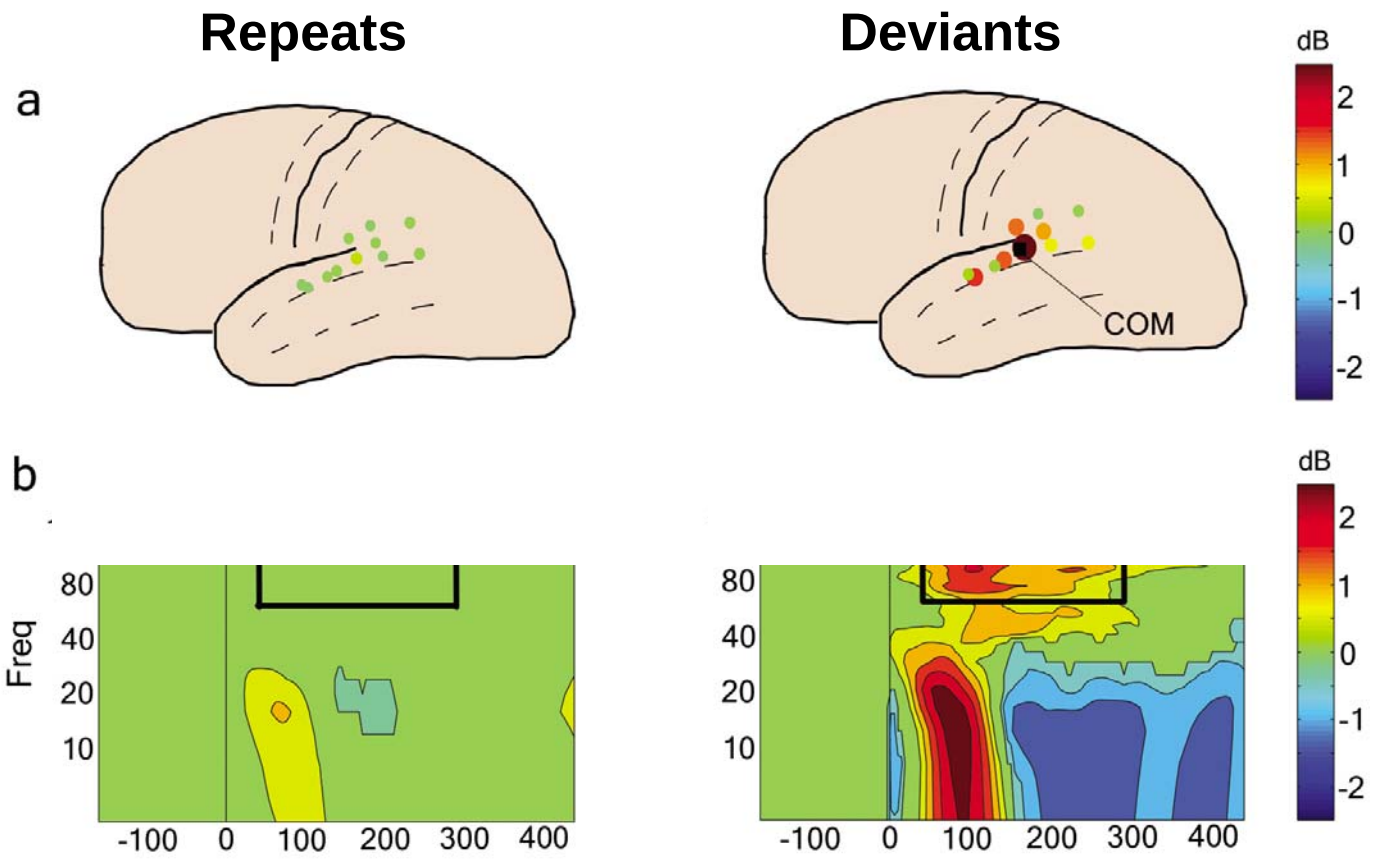
QuickTime™ and a
decompressor
are needed to see this picture.

- Sensory memory trace
- NMDA dependent
- Deviance detected in 100 – 250ms
- Automatic & pre-attentive



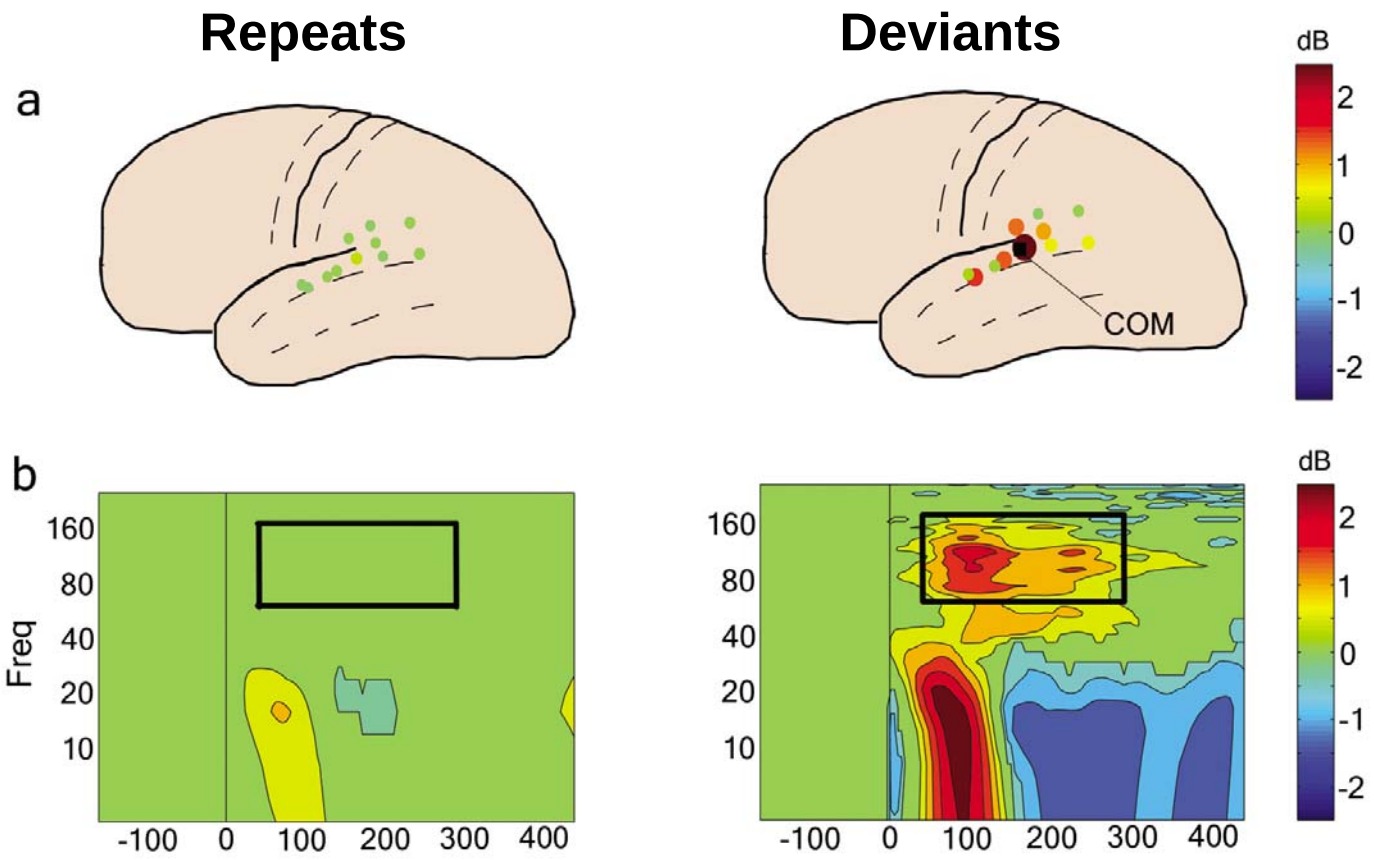
Attention Switch

HIGH GAMMA and AUDITORY DEVIANTS



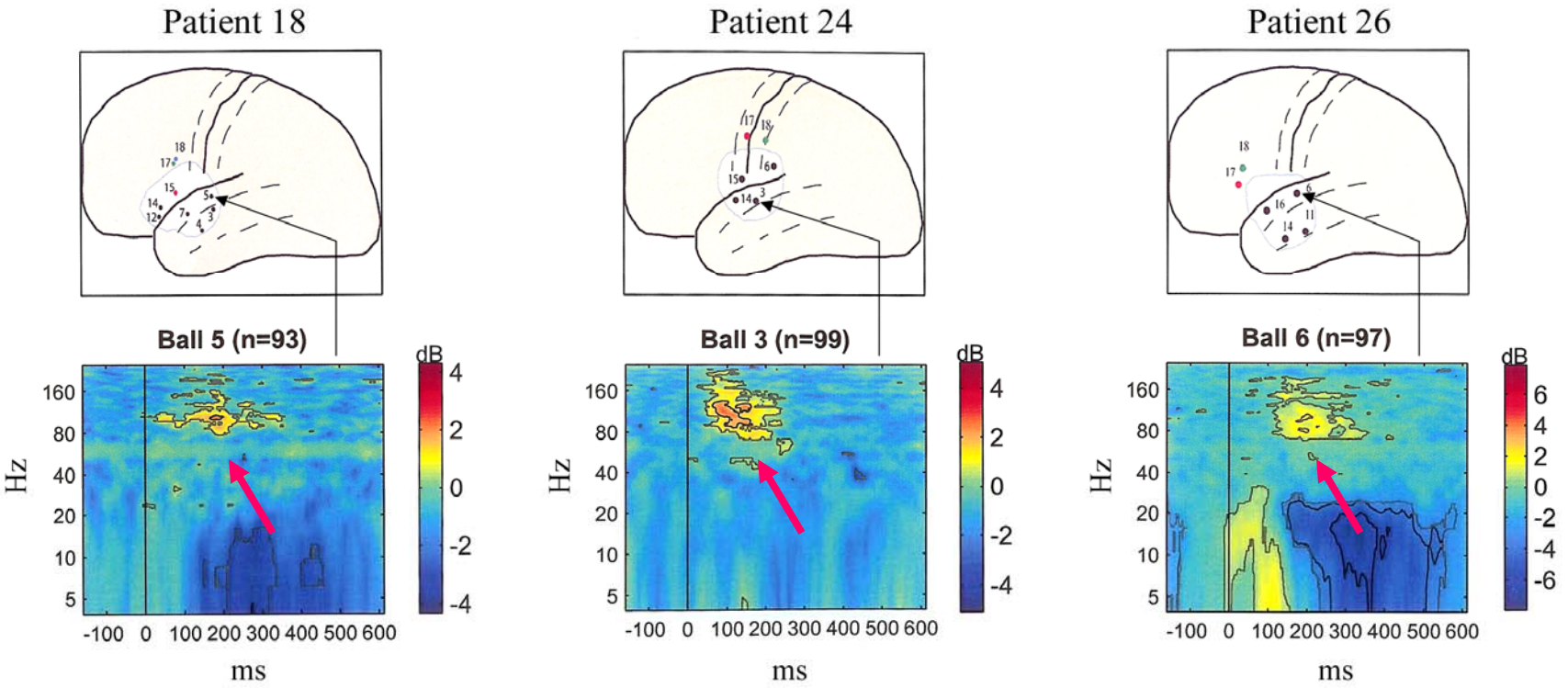
Edwards, Soltani et al, J. Neurophysiology, 2005

HIGH GAMMA and AUDITORY DEVIANTS

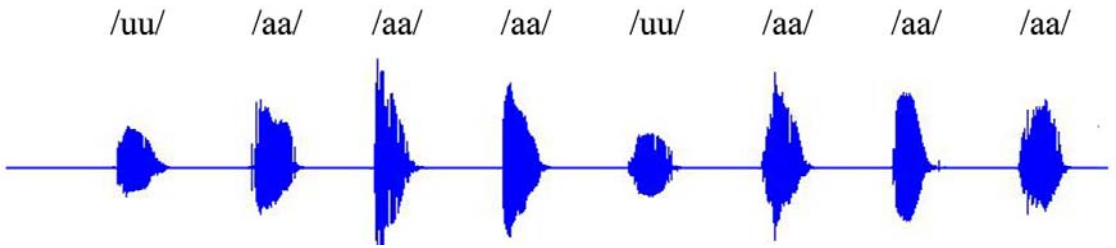


Edwards, Soltani et al, J. Neurophysiol., 2005

HIGH GAMMA PHONEME DEVIANTS



2. MMN Block: 20% /uu/, 80% /aa/



EEG Activation: The forgotton discovery of gamma (and high-gamma)?

Léon Ectors (1936): Étude de l'activité électrique du cortex cérébral chez le lapin non narcotisé ni curarisé

Recordings through skull trepinations in unanesthetized rabbits.
Bipolar electrode pairs were 4-5 mm apart on the cortical surface.

FIG. 1. — Lapin ayant subi deux heures auparavant (sous narcose à l'éther) une trépanation découvrant l'hémisphère gauche et portant le support à électrodes fixé sur le crâne.

EEG Activation: The forgotton discovery of gamma (and high-gamma)?

Léon Ectors (1936): Étude de l'activité électrique du cortex cérébral chez le lapin non narcotisé ni curarisé

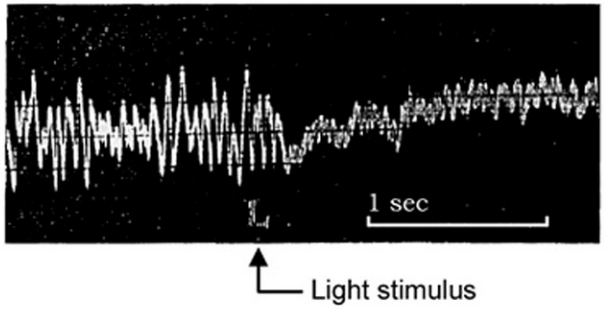
Recordings through skull trepinations in unanesthetized rabbits. Bipolar electrode pairs were 4-5 mm apart on the cortical surface.

FIG. 1. — Lapin ayant subi deux heures auparavant (sous narcose à l'éther) une trépanation découvrant l'hémisphère gauche et portant le support à électrodes fixé sur le crâne.

Sensory stimulation resulted in a suppression of the α waves and an augmentation of the amplitude and frequency of the β waves (30-50 Hz) in the appropriate sensory projection area.

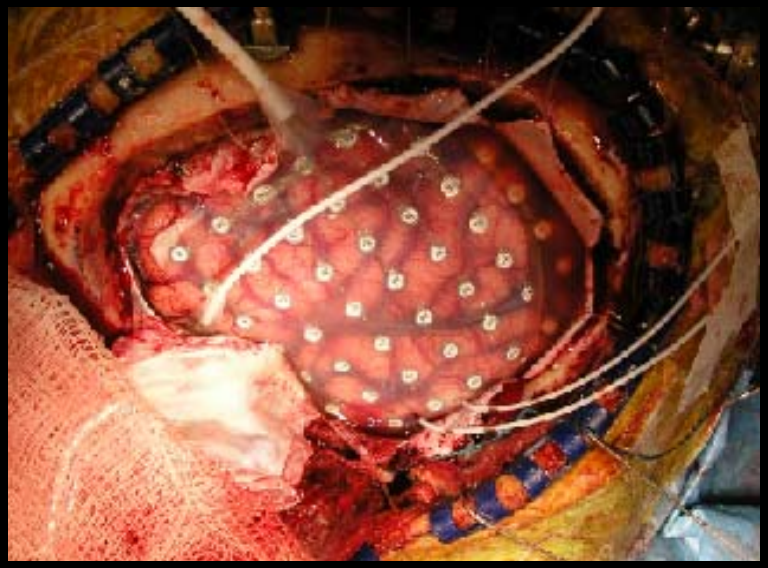
This was demonstrated for olfactory, optic, acoustic, gustatory, and tactile stimuli.

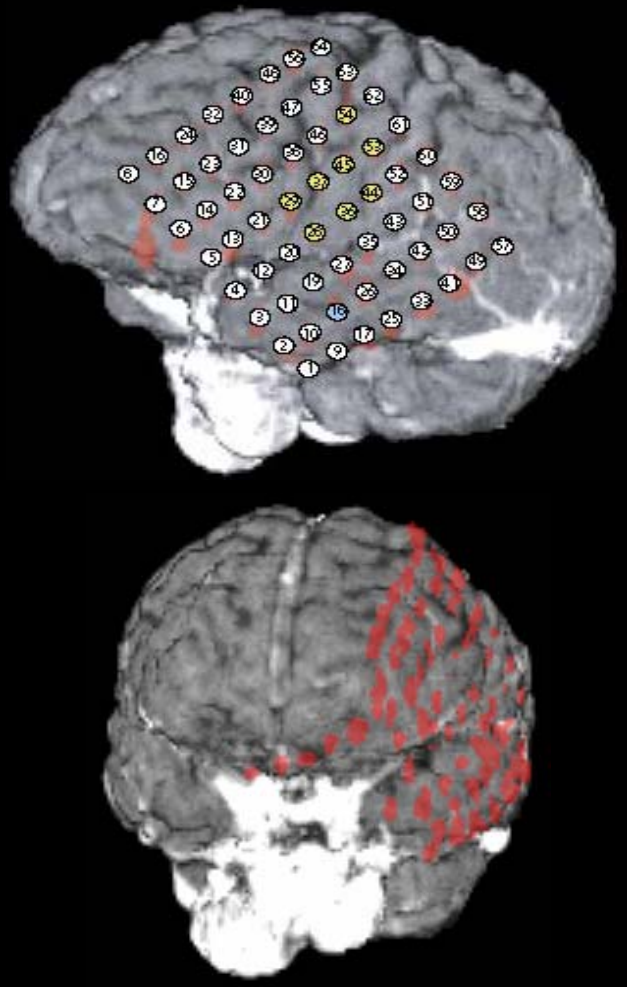
Example from visual cortex.



In cases of stimuli that were intense or particularly effective (for emotional/attentional reasons), the β waves reached frequencies of 80-100 Hz.

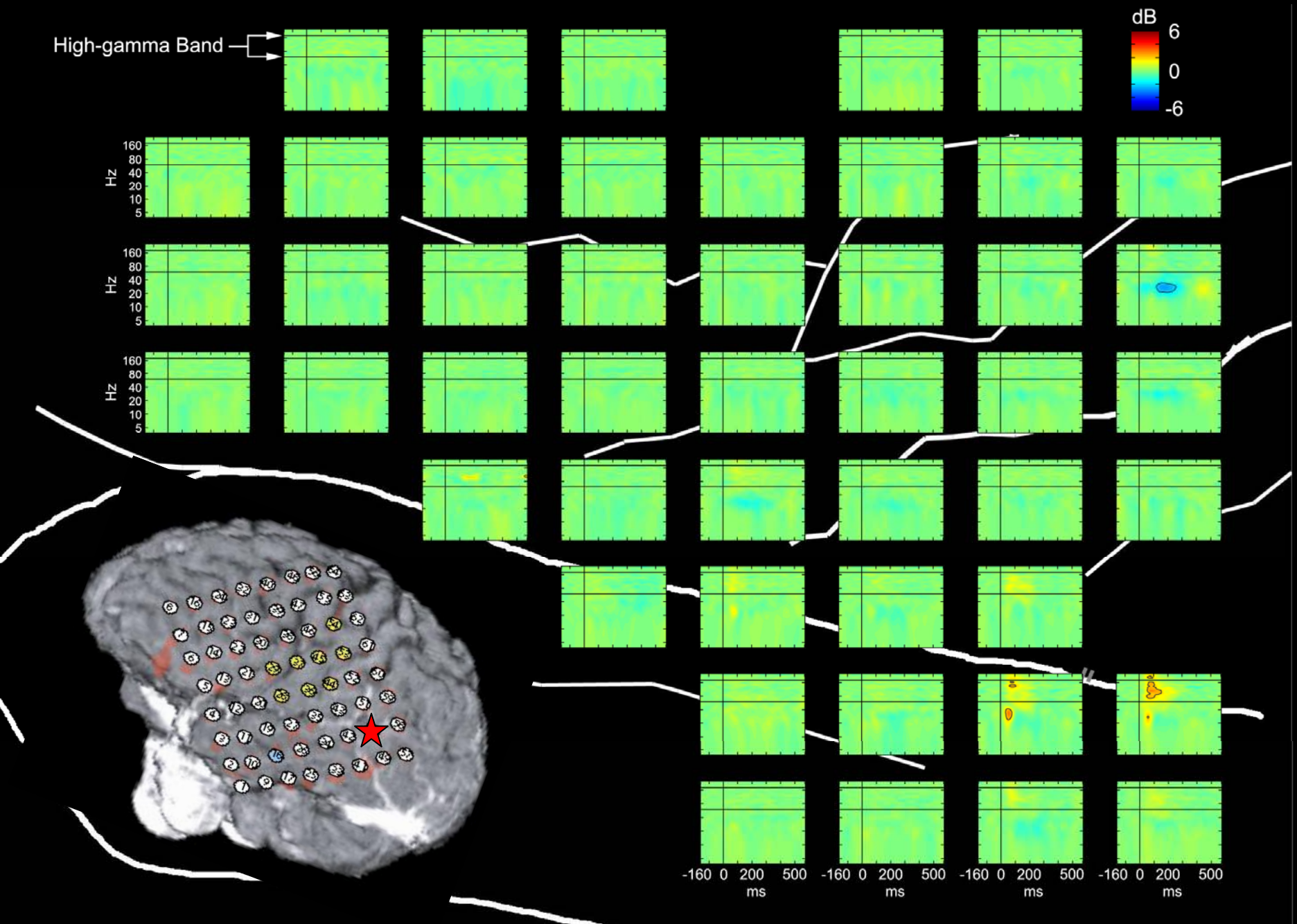
SUBDURAL GRIDS



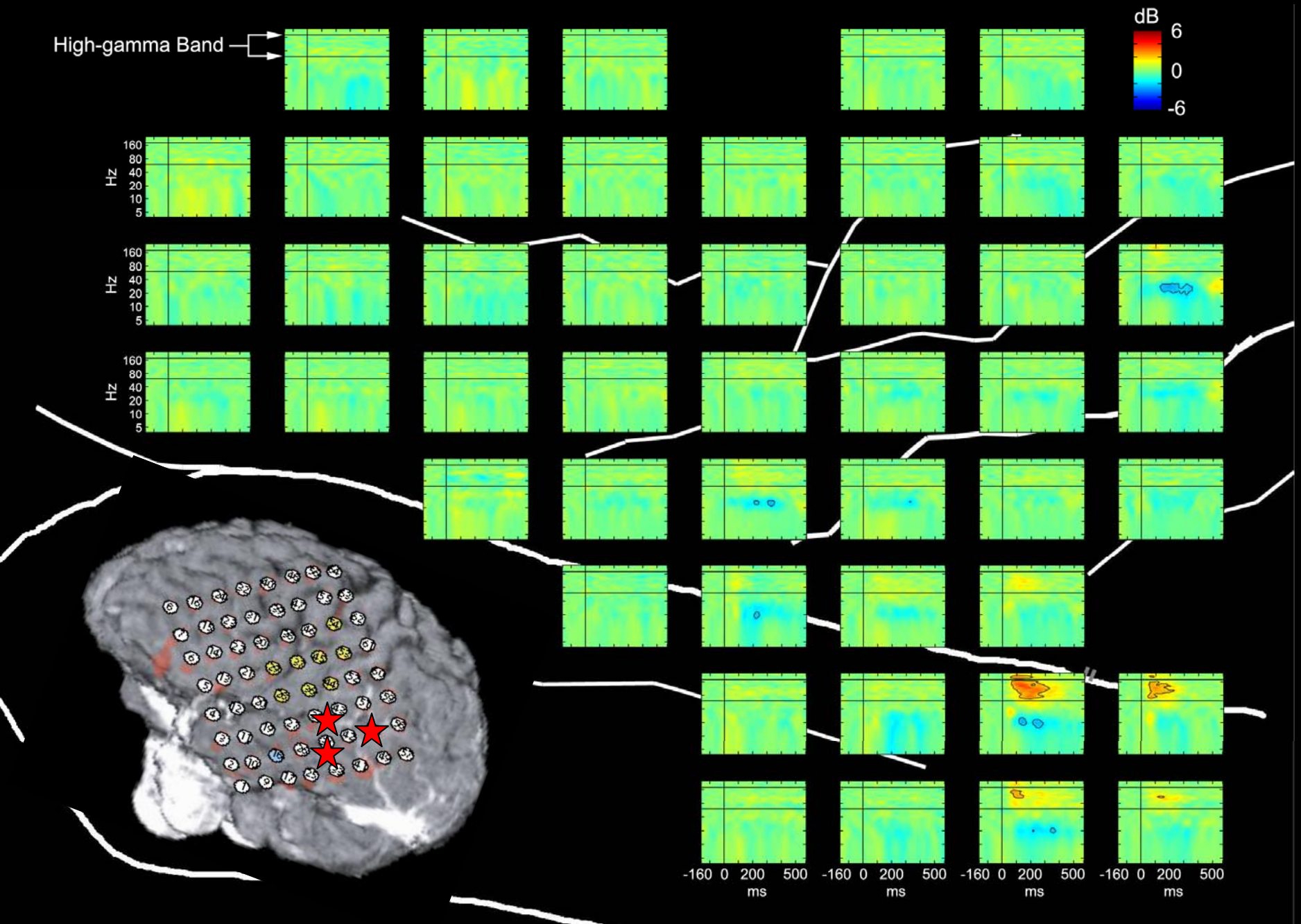


Intractable Epileptics
Electrodes Implanted for 4-7 days

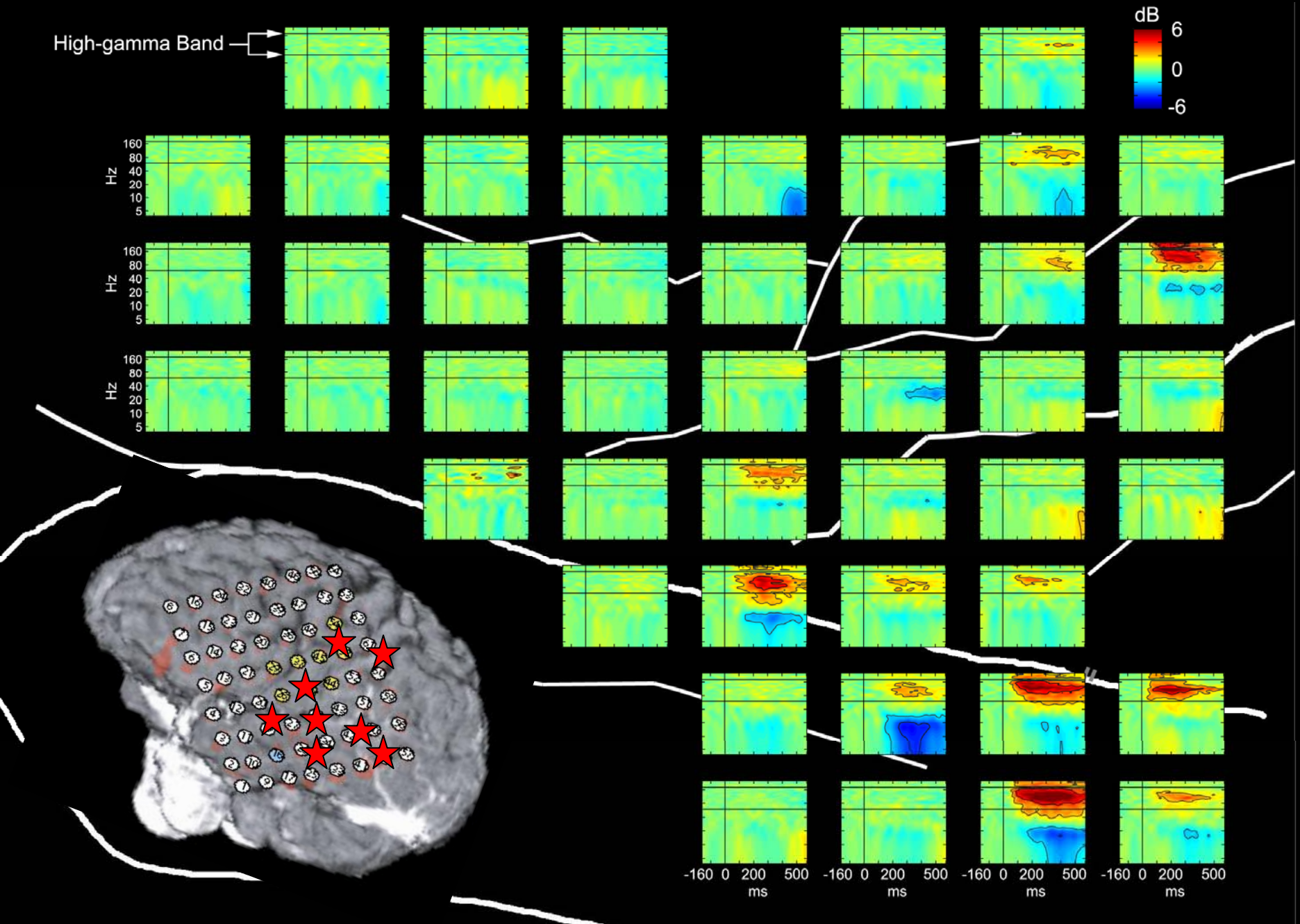
PASSIVE TONES



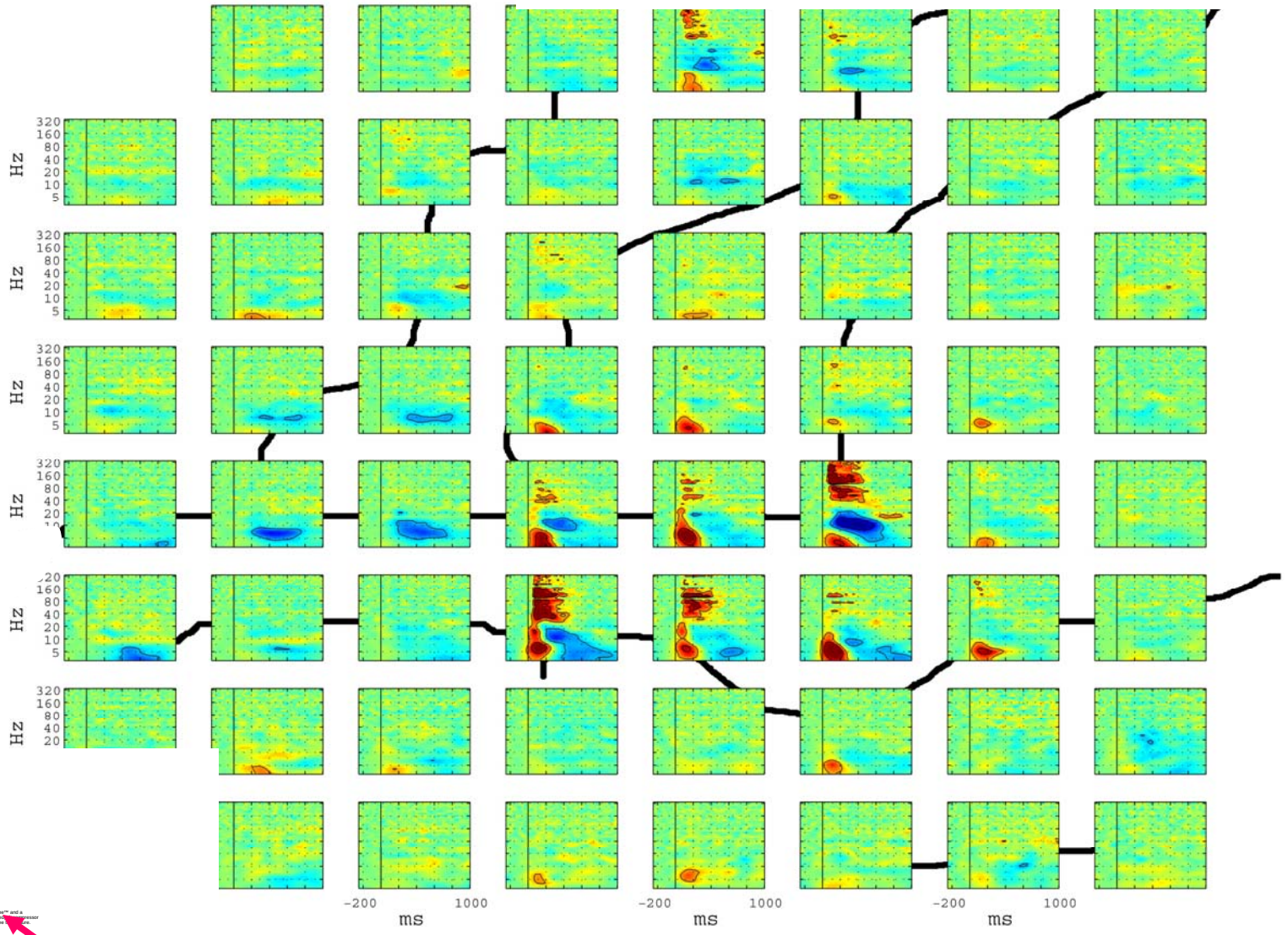
PASSIVE PHONEMES



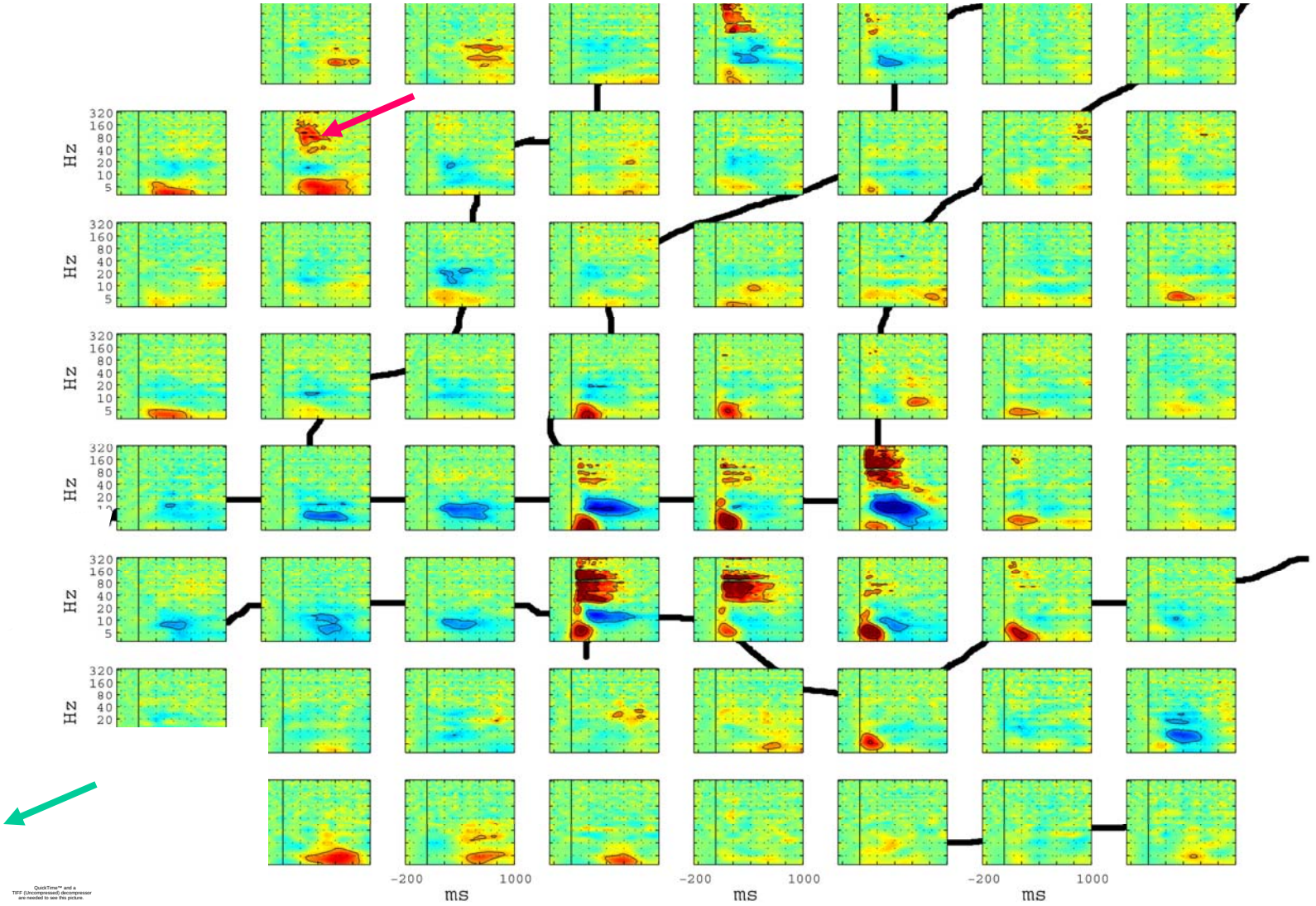
PASSIVE WORDS



PASSIVE PHONEME

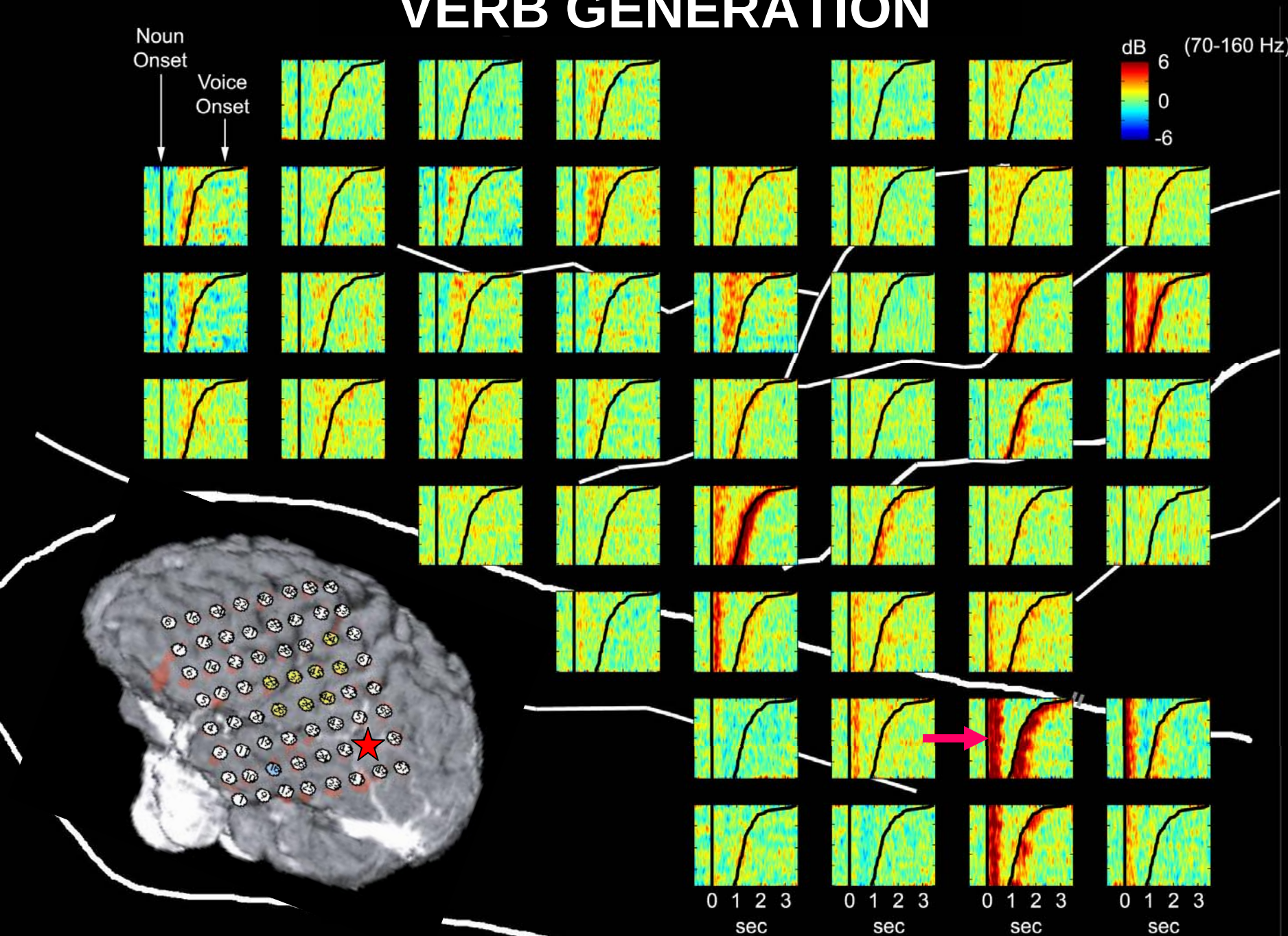


DETECT PHONEME

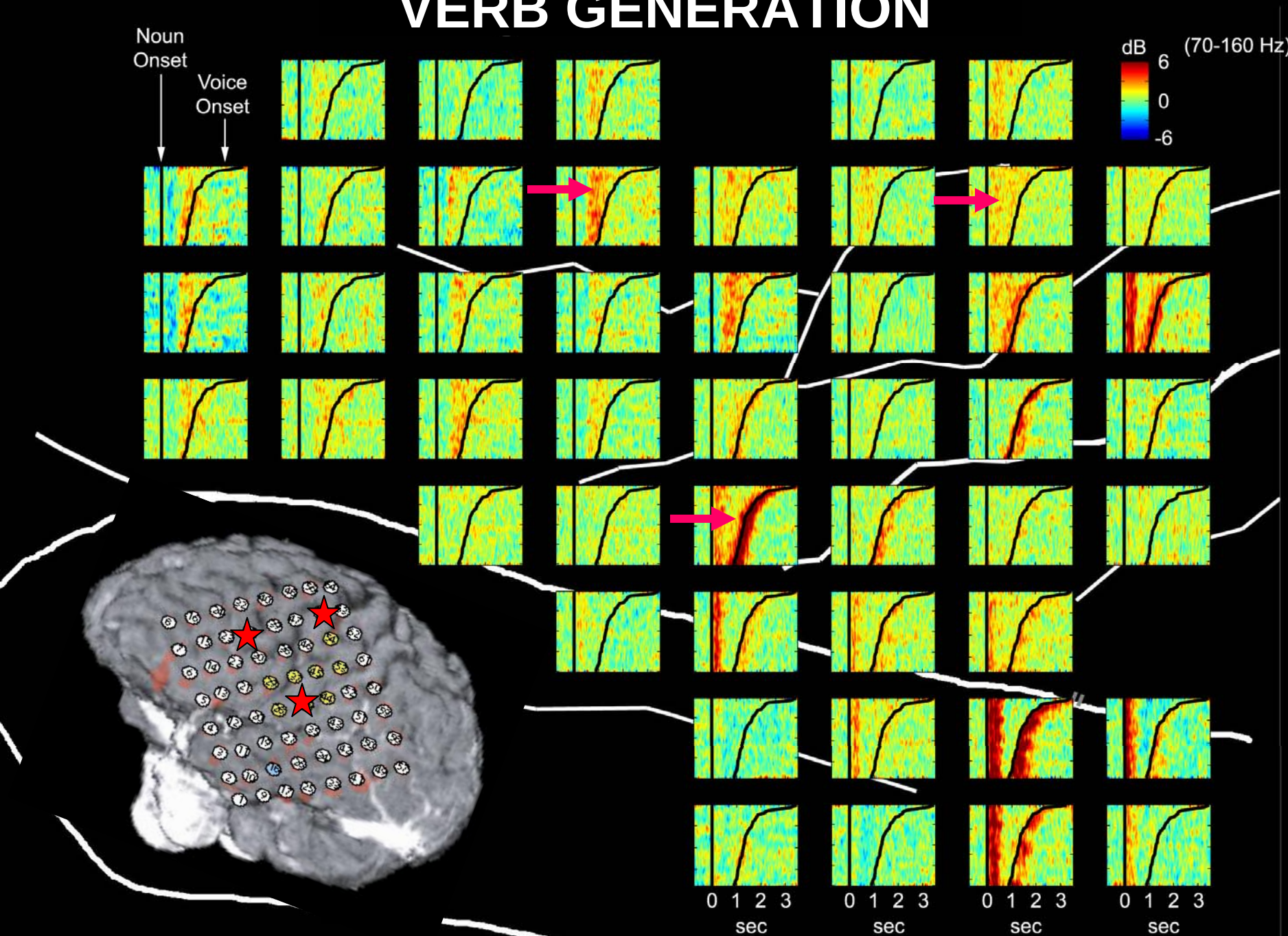


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

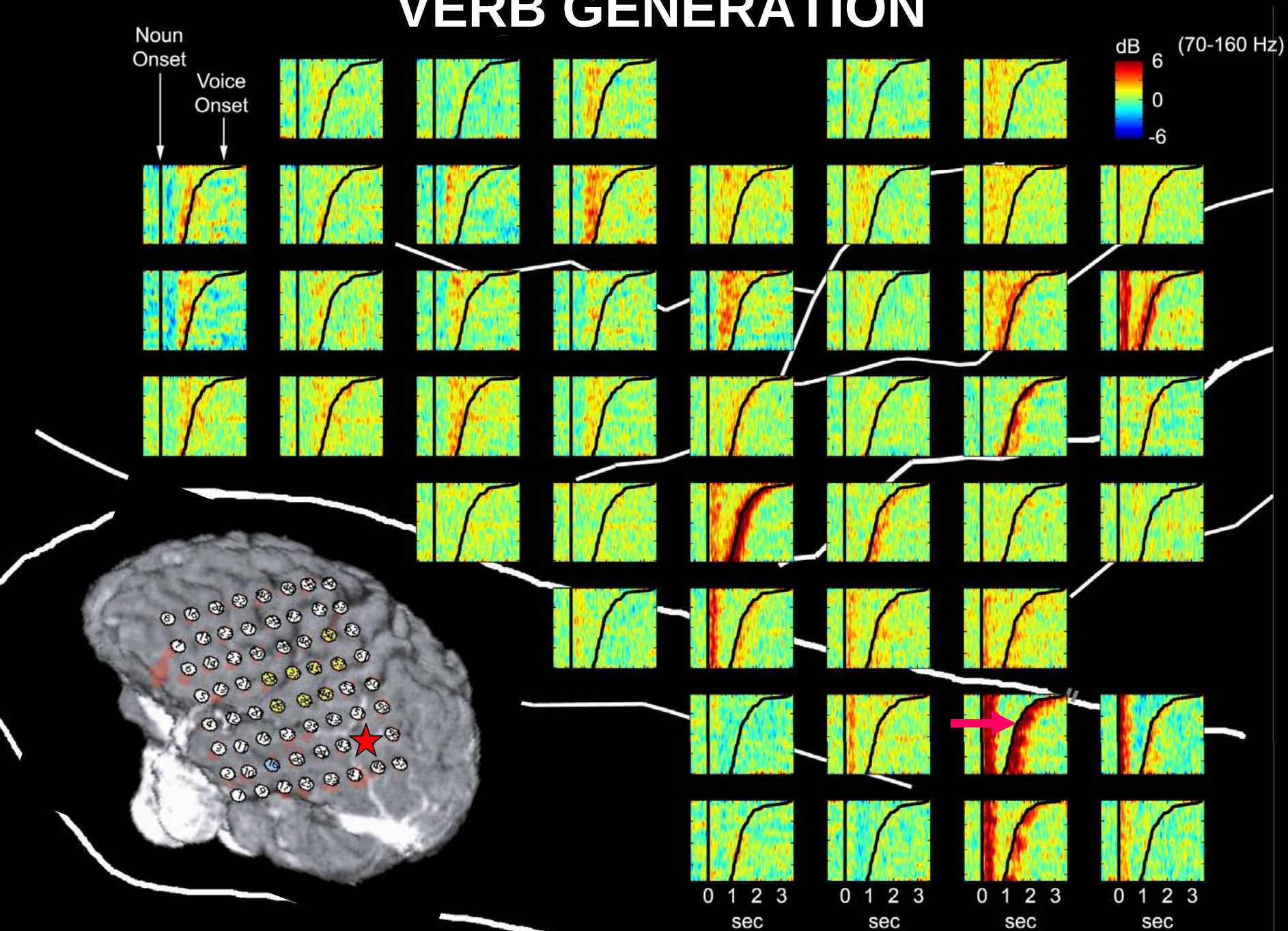
VERB GENERATION



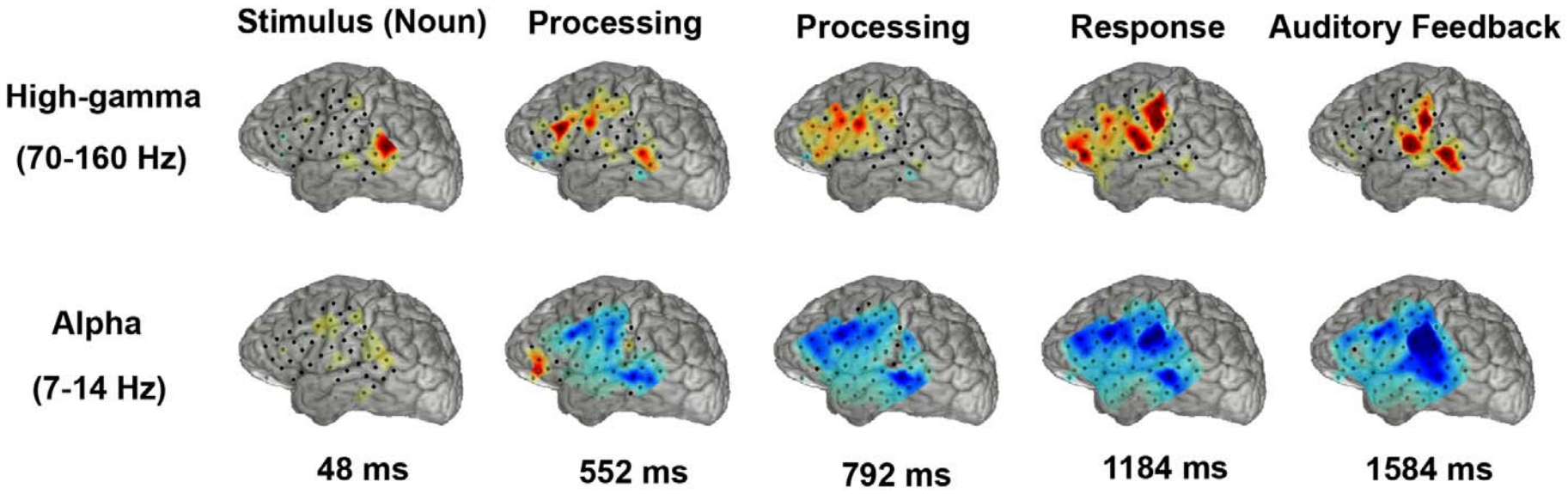
VERB GENERATION



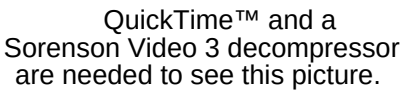
VERB GENERATION

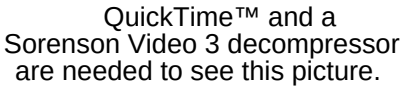


VERB GENERATION



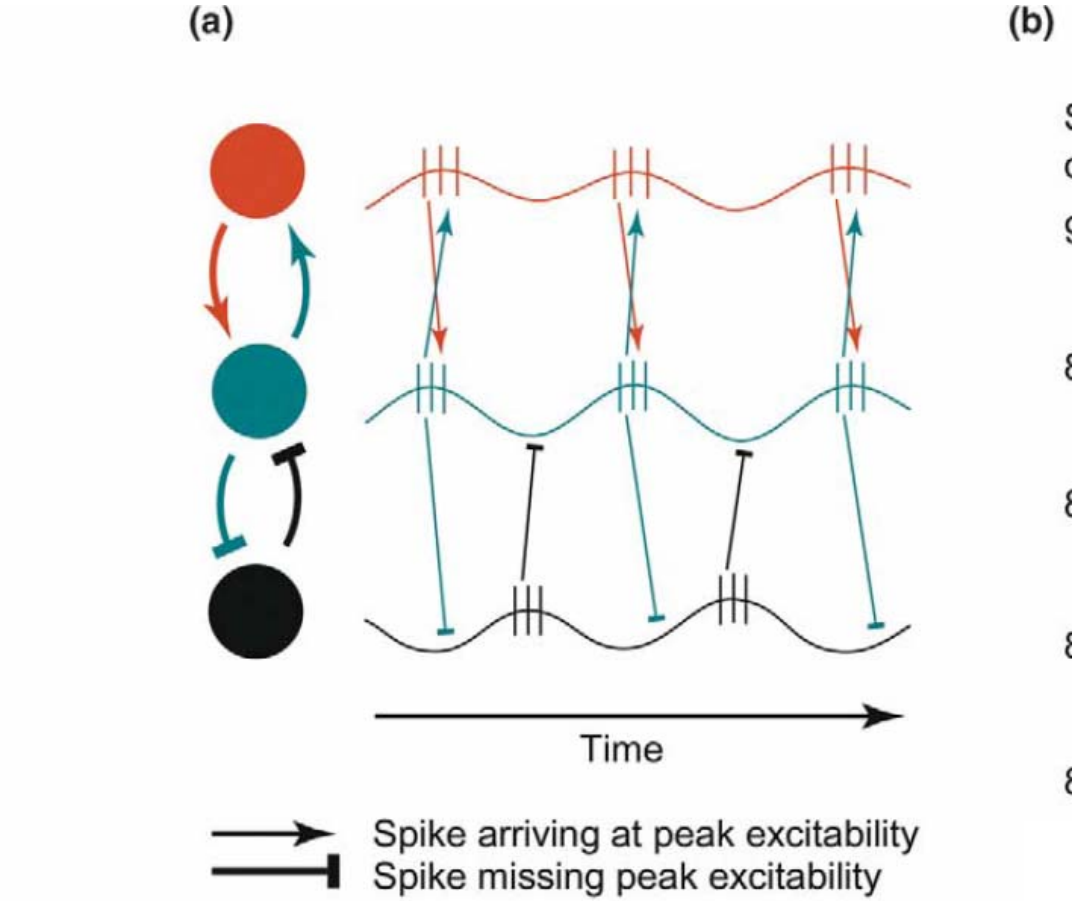
Edwards et al, Submitted


QuickTime™ and a
Sorenson Video 3 decompressor
are needed to see this picture.


QuickTime™ and a
Sorenson Video 3 decompressor
are needed to see this picture.

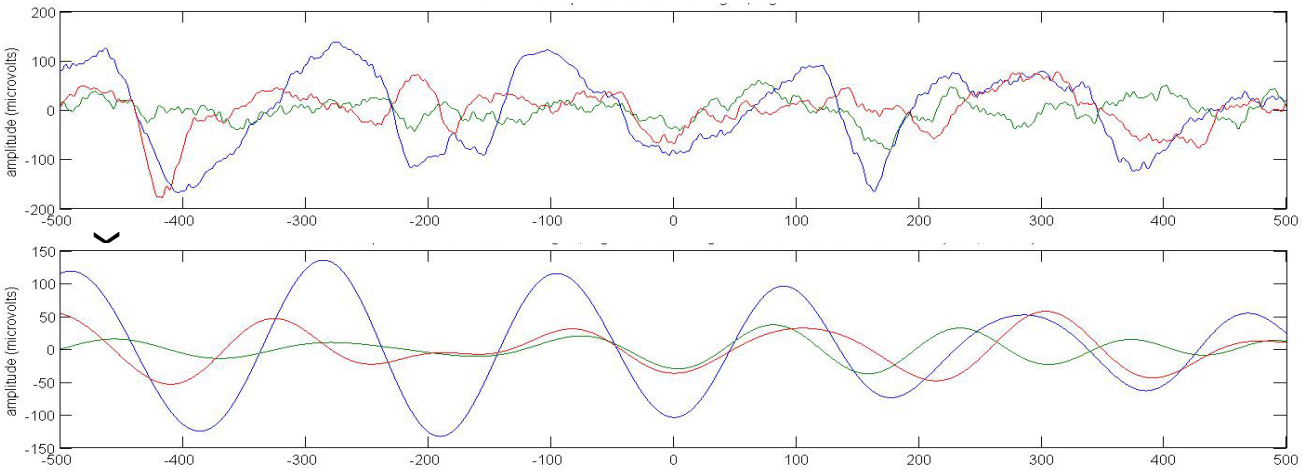
Effective communication between areas depends on:

1) oscillatory carrier frequency in each area
2) relative phase, and
3) axonal conduction delay



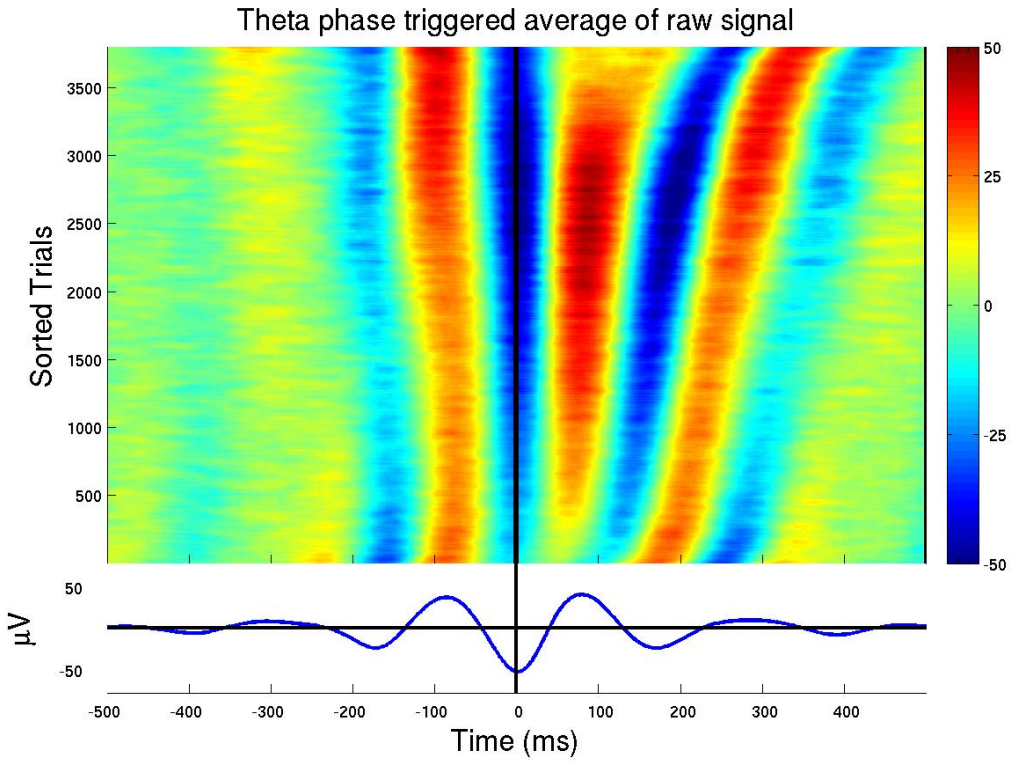
Fries, P., Trends Cogn. Sci., 2005

IDENTIFY THETA TROUGHS

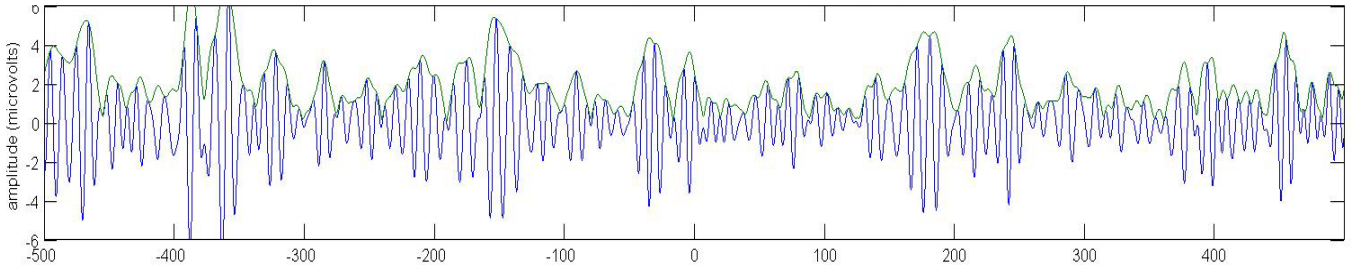


4-8 Hz

X 10

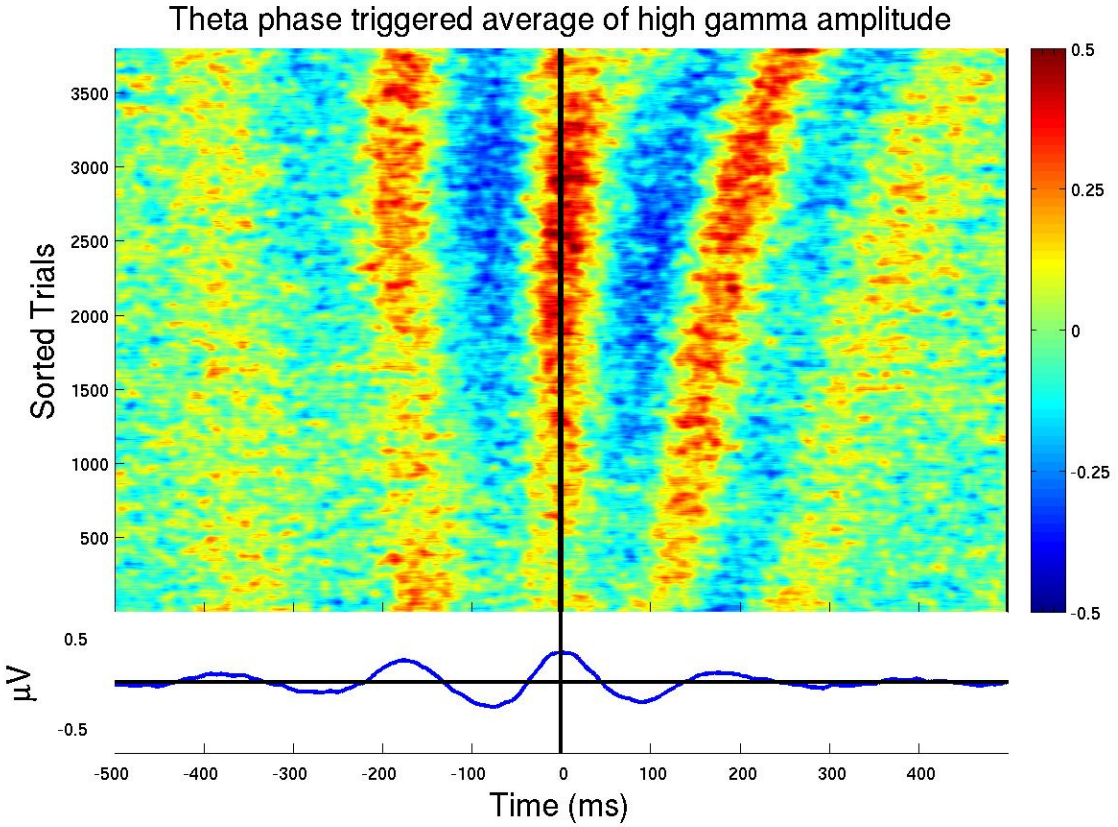


EXTRACT HIGH GAMMA AMPLITUDE



80-150 Hz

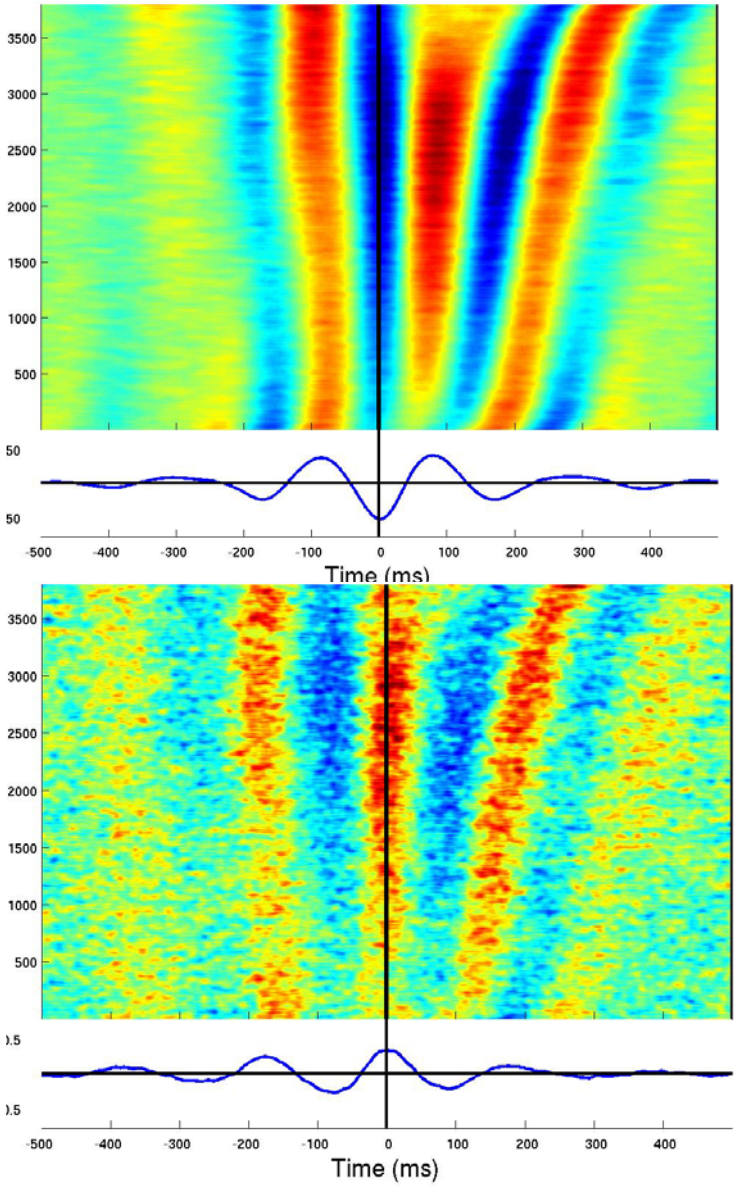
X 10

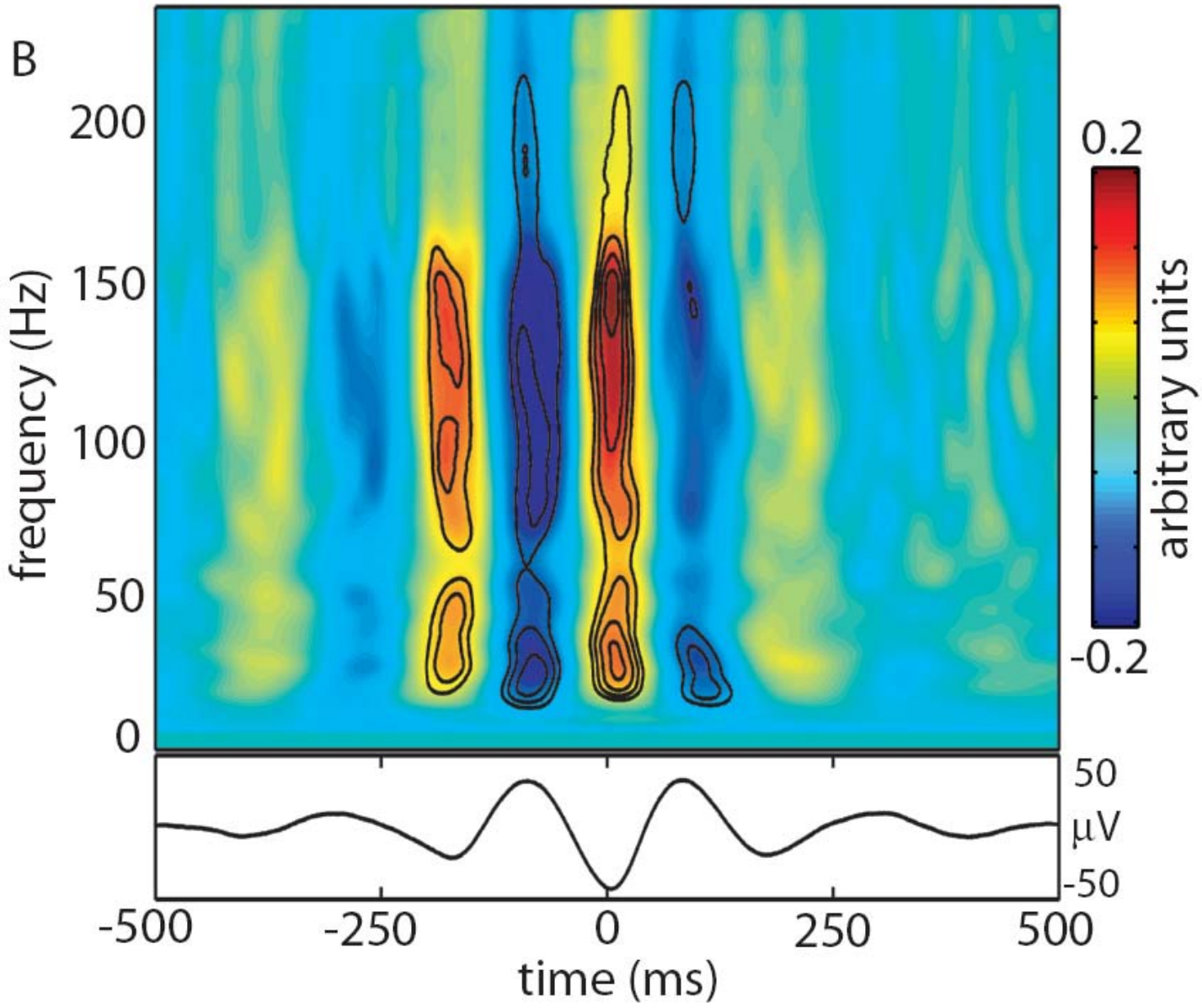


THETA-HIGH GAMMA COUPLING

THETA PHASE

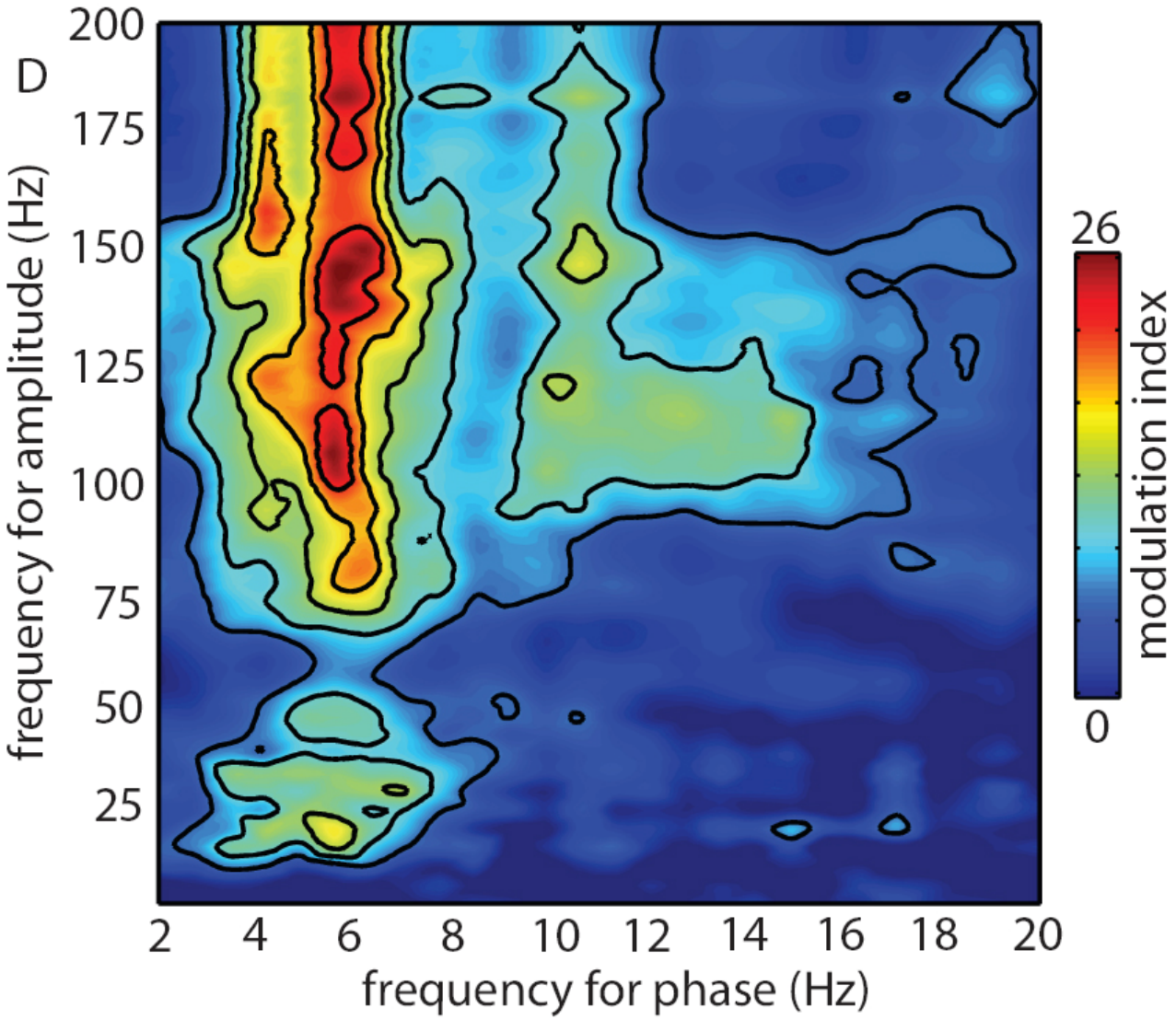
HIGH GAMMA AMPLITUDE



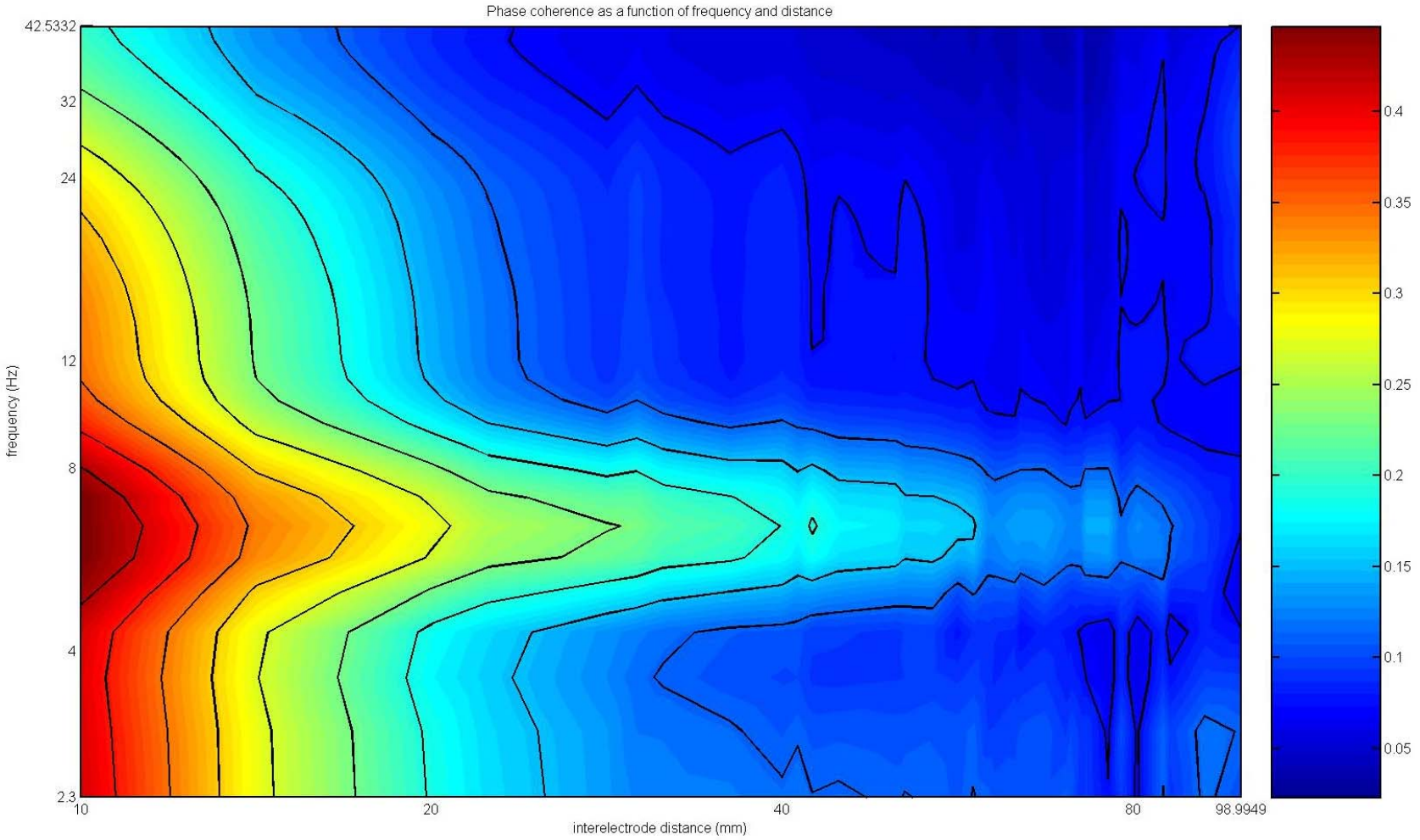


Canolty et al, Science 2006

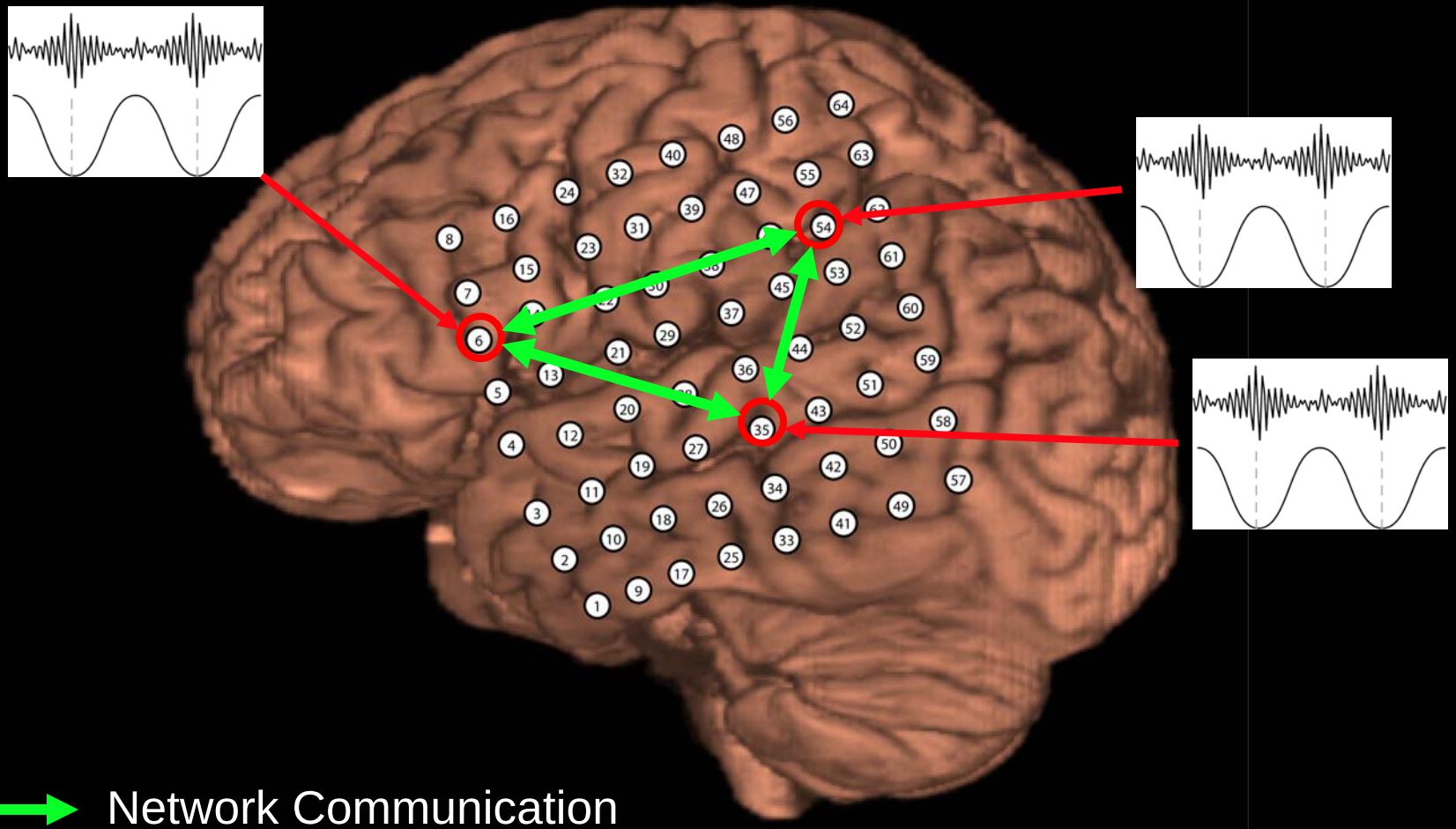
FREQUENCY SPECIFICITY



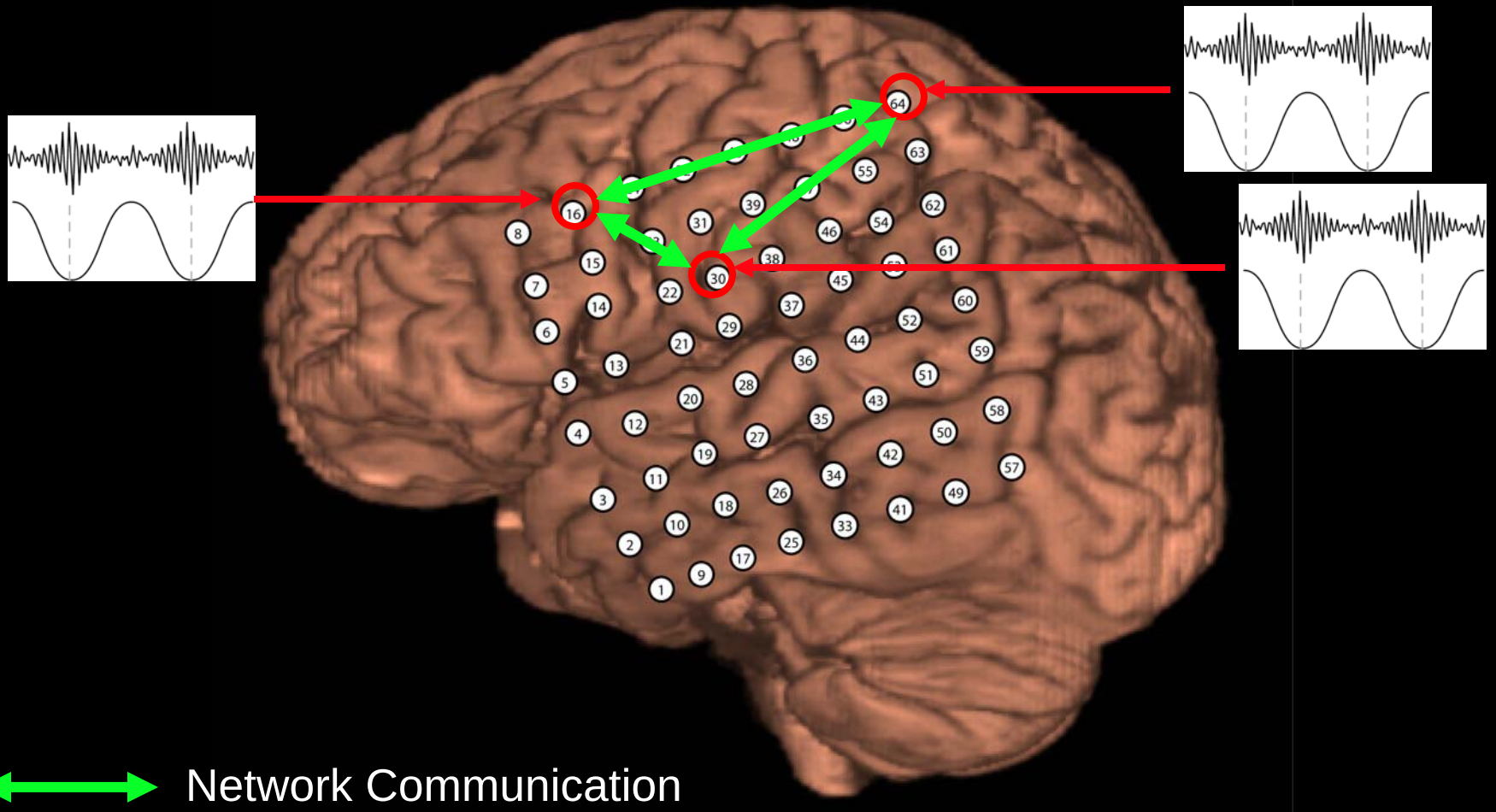
SPATIAL COHERENCE



THETA-GAMMA COUPLING LANGUAGE

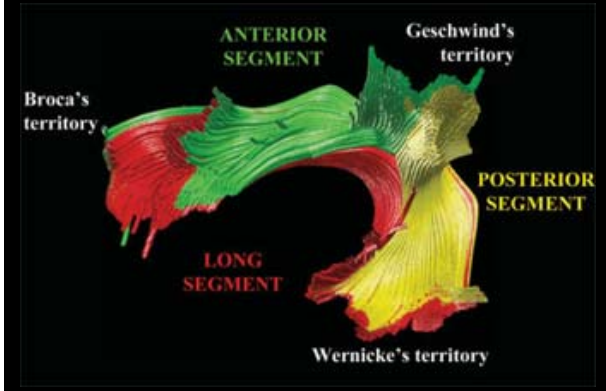


THETA-GAMMA COUPLING MOTOR



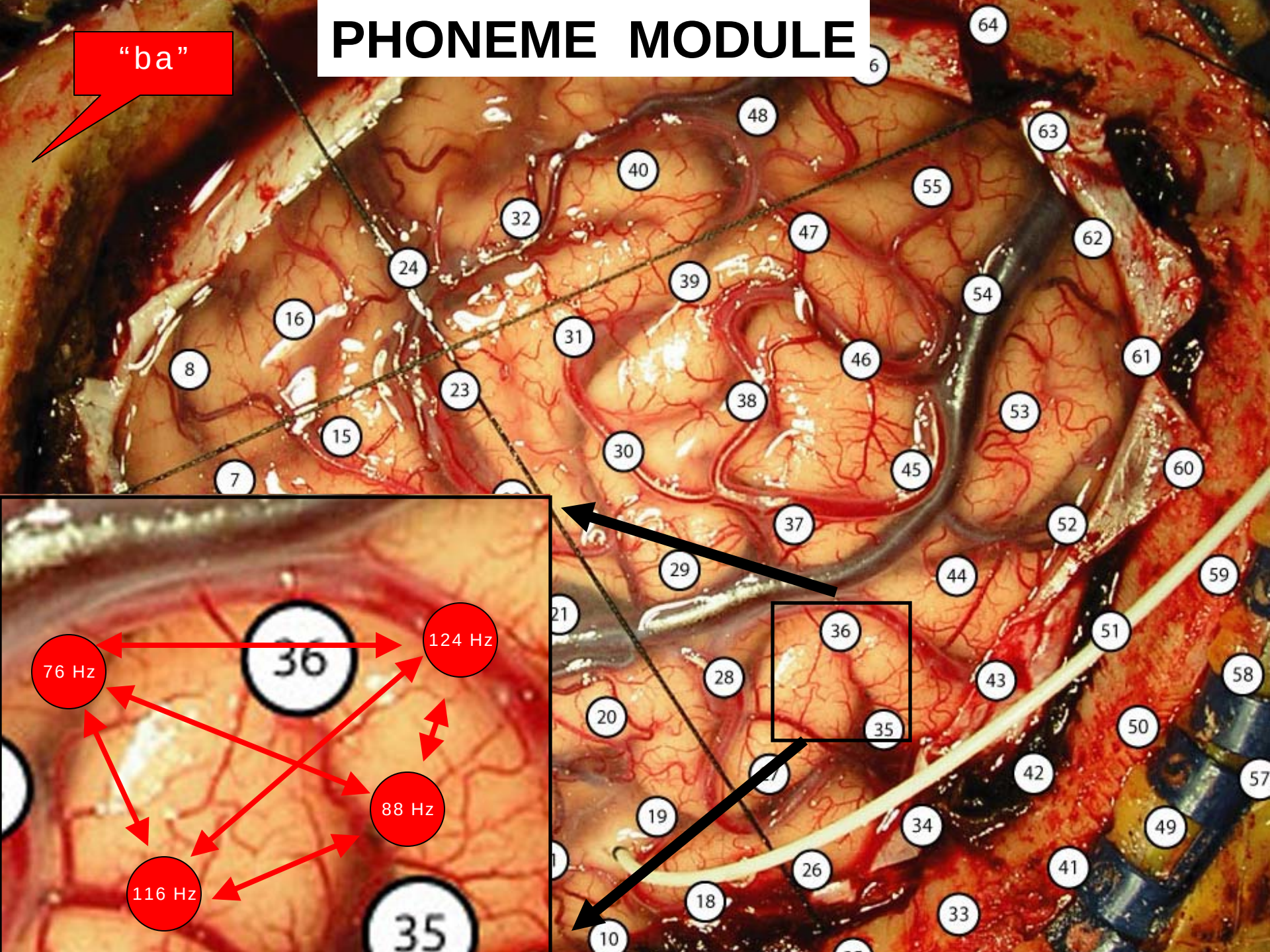
ARCUATE FASCICULUS

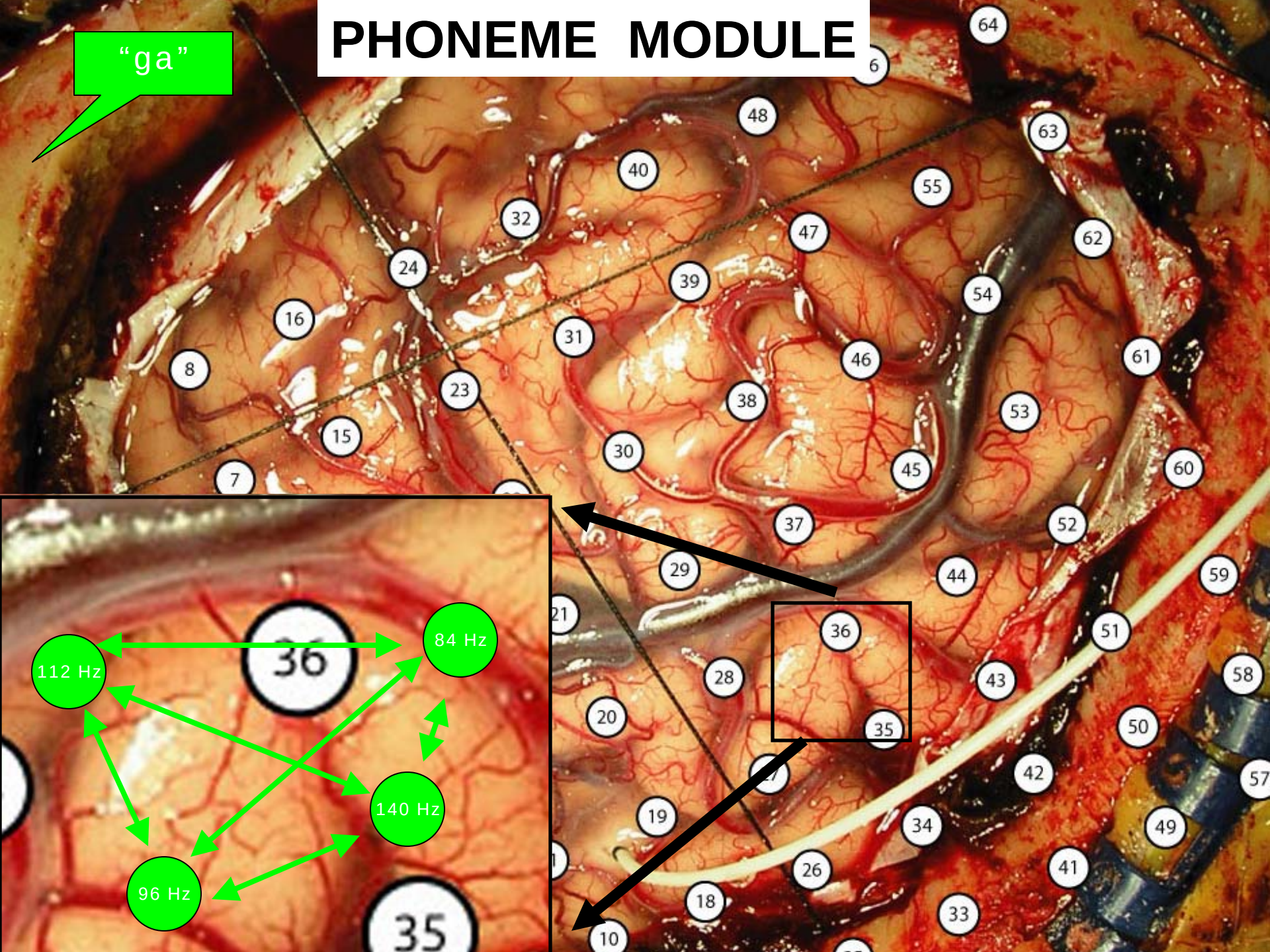
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.



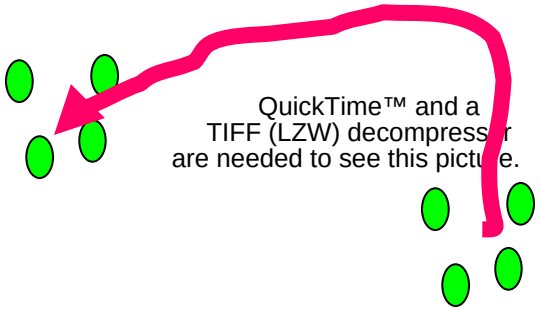
26 msec

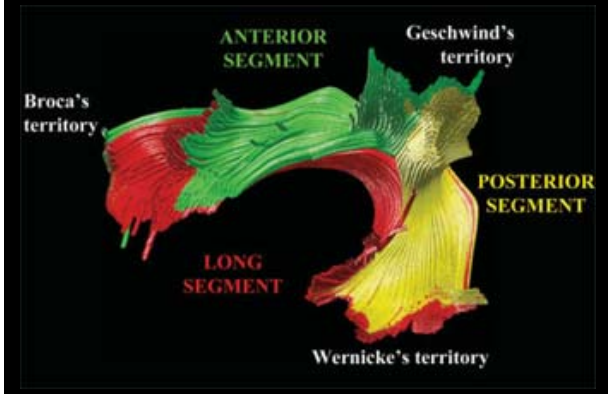
Connects Speech Input and Output Areas


PHONEME MODULE
“ba”
76 Hz
124 Hz
88 Hz
116 Hz
36
35


PHONEME MODULE
"ga"
112 Hz
84 Hz
140 Hz
96 Hz
36
35

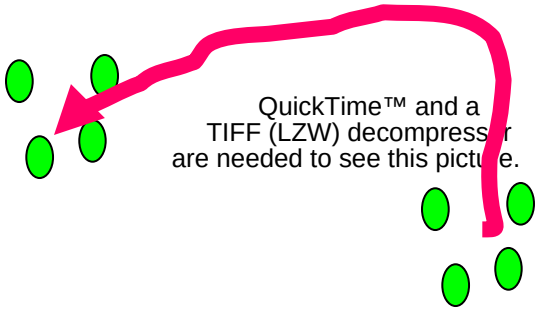
PARALLEL LINE COMMUNICATION

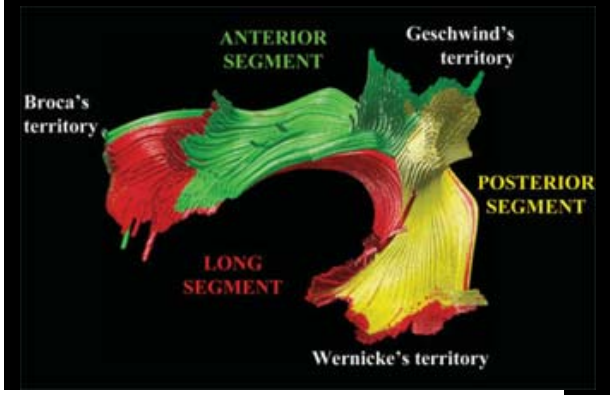




26 msec

PARALLEL LINE COMMUNICATION

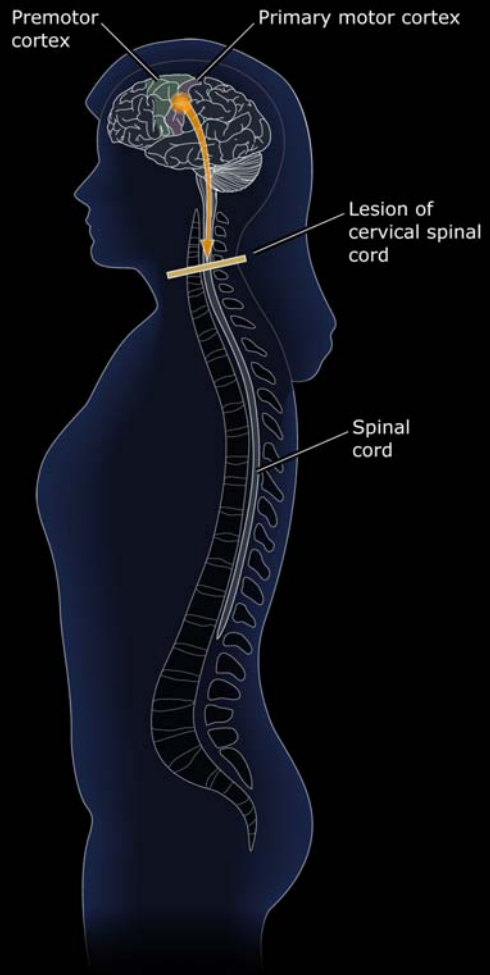


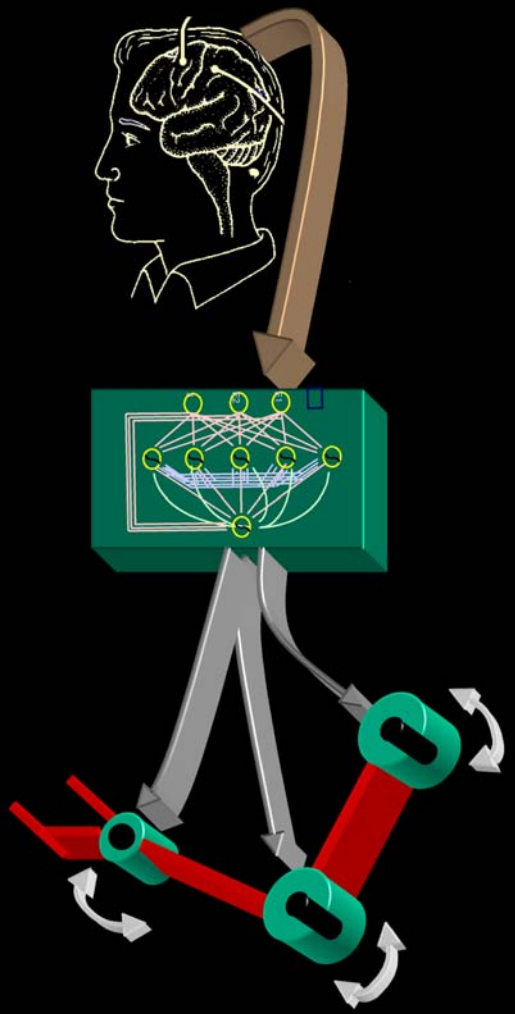


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

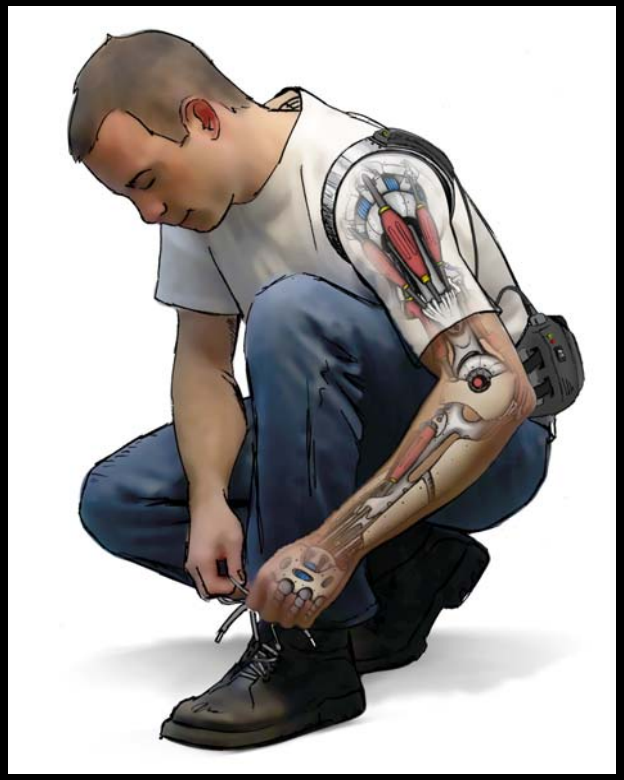
NEURAL PROSTHETICS FOR RESTORING FUNCTION

THE CONCEPT



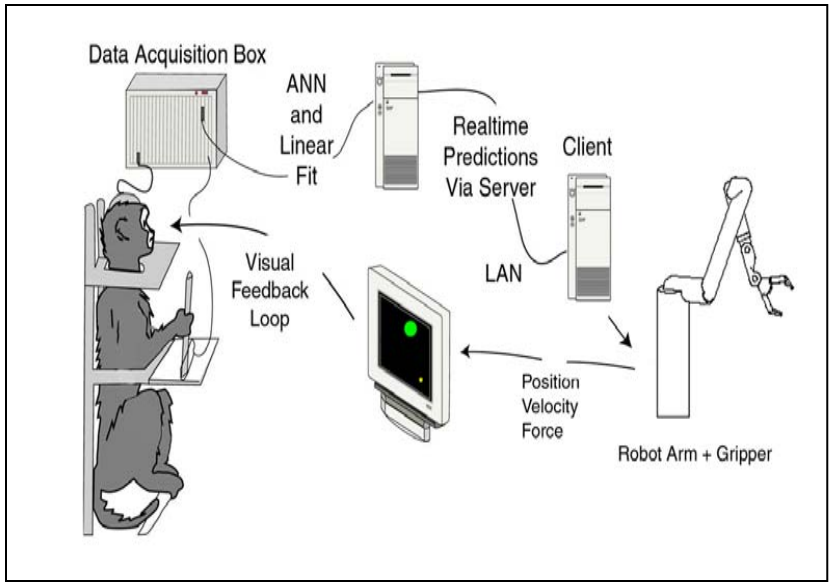


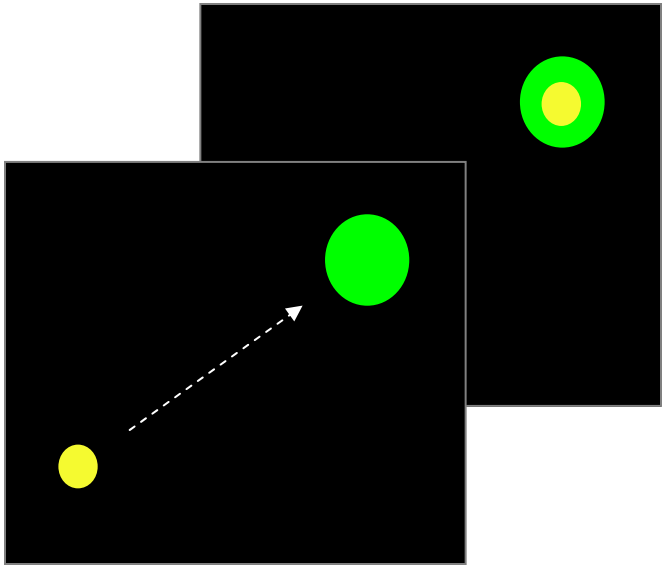
THE DREAM



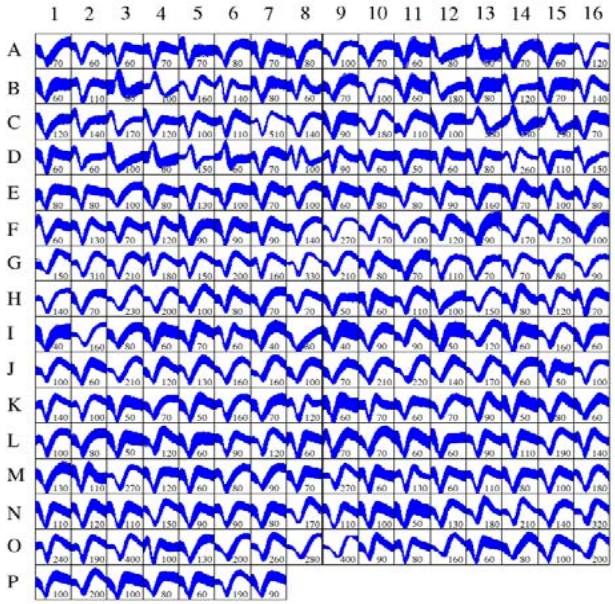
Nicollelis 2002

MOVE THE YELLOW DOT INTO THE GREEN CIRCLE



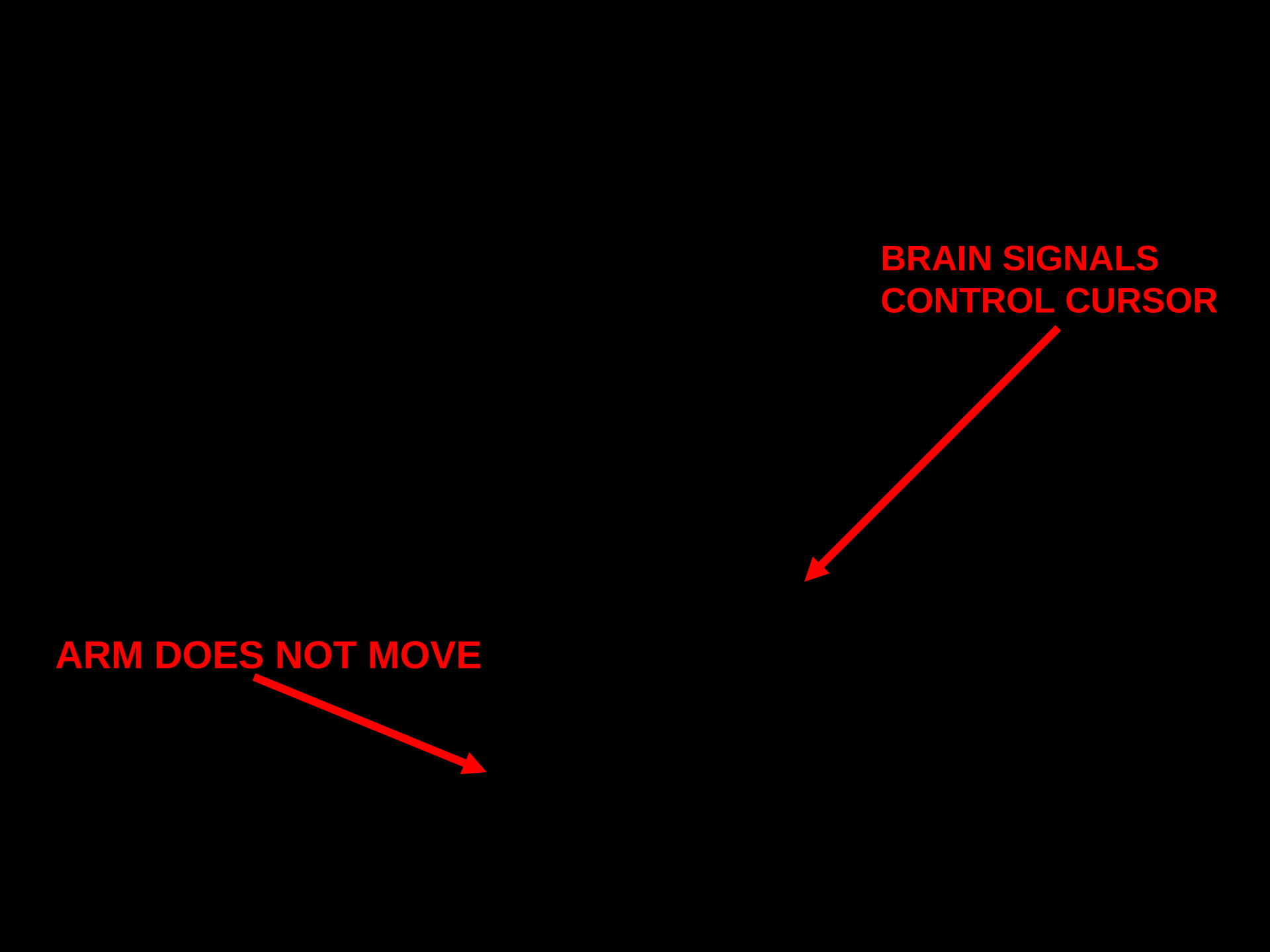


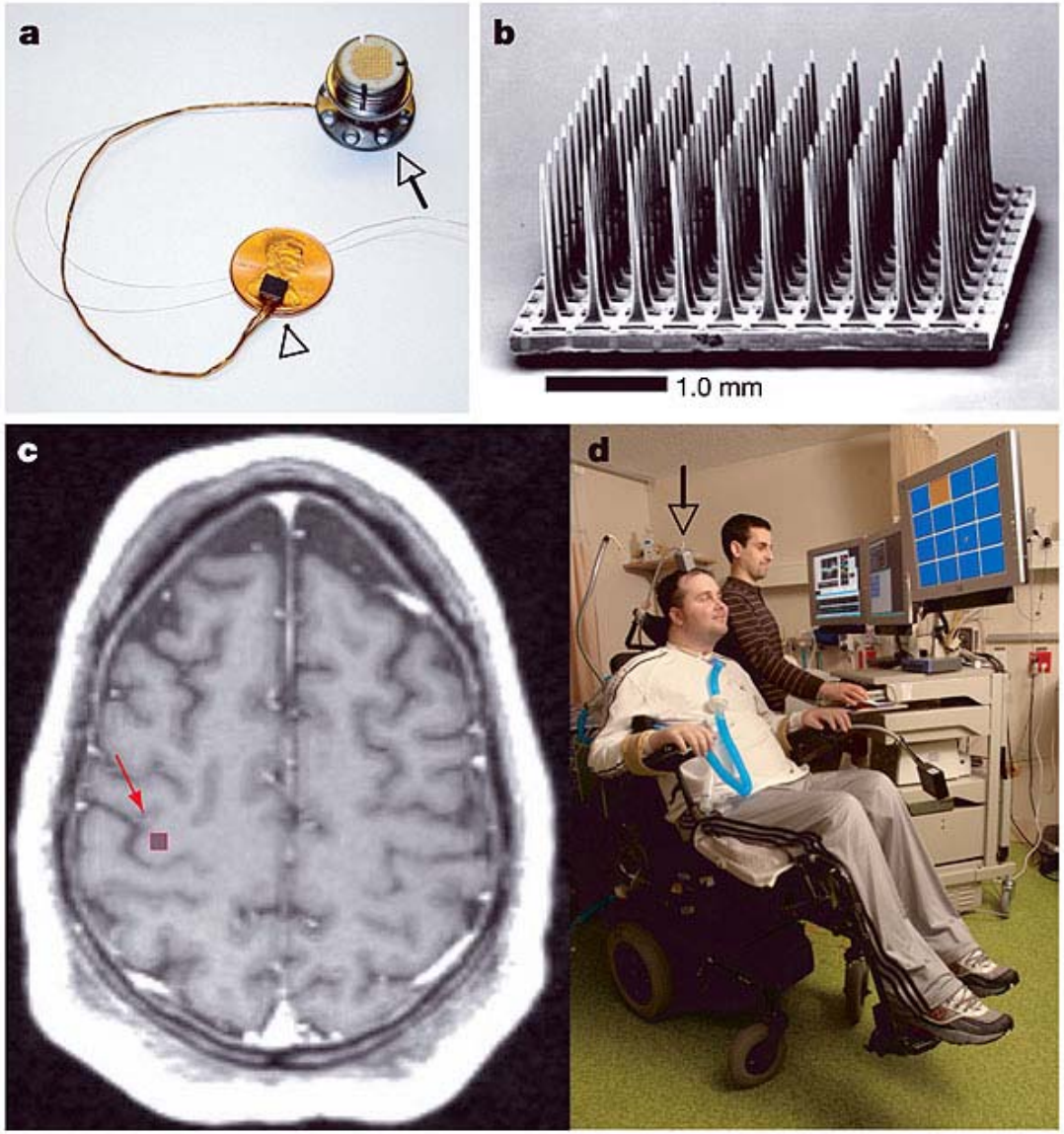
NEURONS



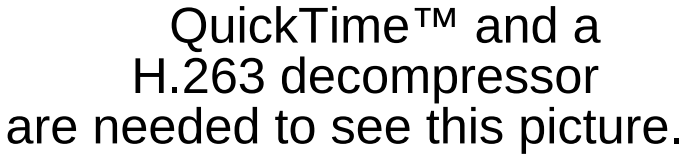
Carmena et al. 2003, PLoS Biology 1(2).

ARM CONTROL


BRAIN SIGNALS
CONTROL CURSOR
ARM DOES NOT MOVE



Serruya et al, Nature 2006


QuickTime™ and a
H.263 decompressor
are needed to see this picture.

THE INTRACRANIAL TEAM

PhD Students

Maryam

Erik

Sarang

Ryan

Post-docs

Galit

Noa

Faculty

Mitch

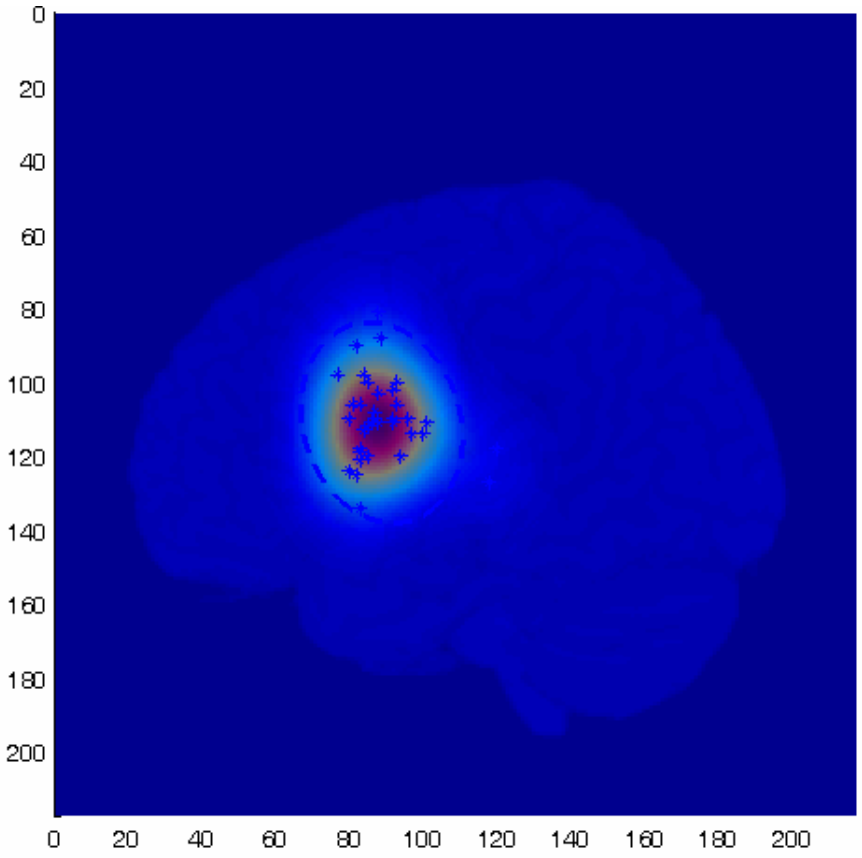
Nick

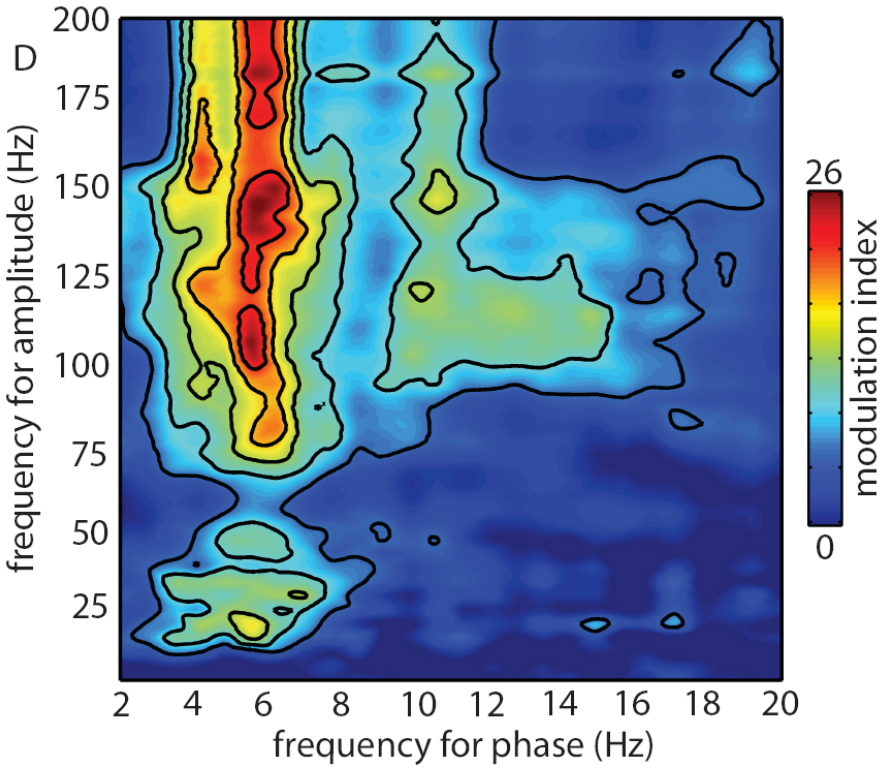
Heidi

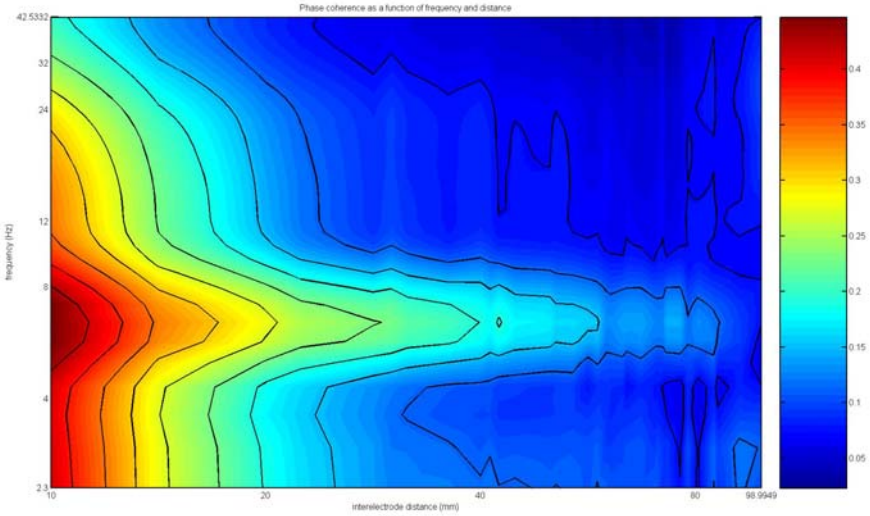
Sri

Leon

95% CONFIDENCE for SPEECH ARREST




D
200
175
150
125
100
75
50
25
frequency for amplitude (Hz)
2
4
6
8
10
12
14
16
18
20
frequency for phase (Hz)
26
0
modulation index


Phase coherence as a function of frequency and distance
42.5332
32
24
12
8
4
2.3
frequency (Hz)
10
20
40
80
98.9949
interelectrode distance (mm)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05