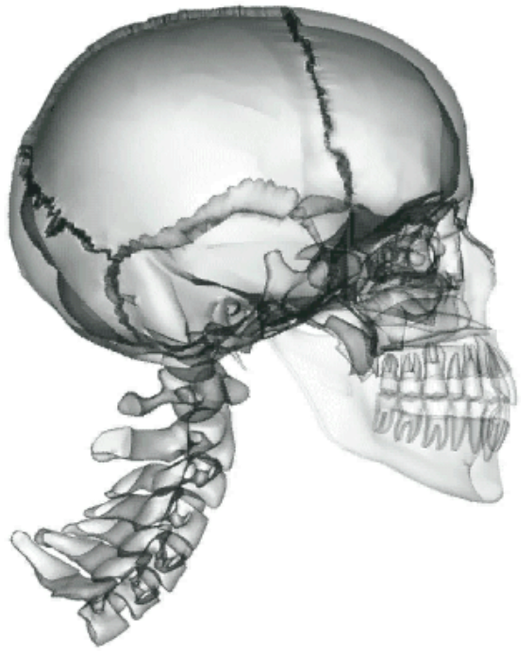
Cognition On The Run

Testing a New Mobile Brain Imaging Modality



Klaus Gramann

Swartz Center for Computational Neuroscience
University of California, San Diego

Why Imaging The Brain During 'Active Cognition'

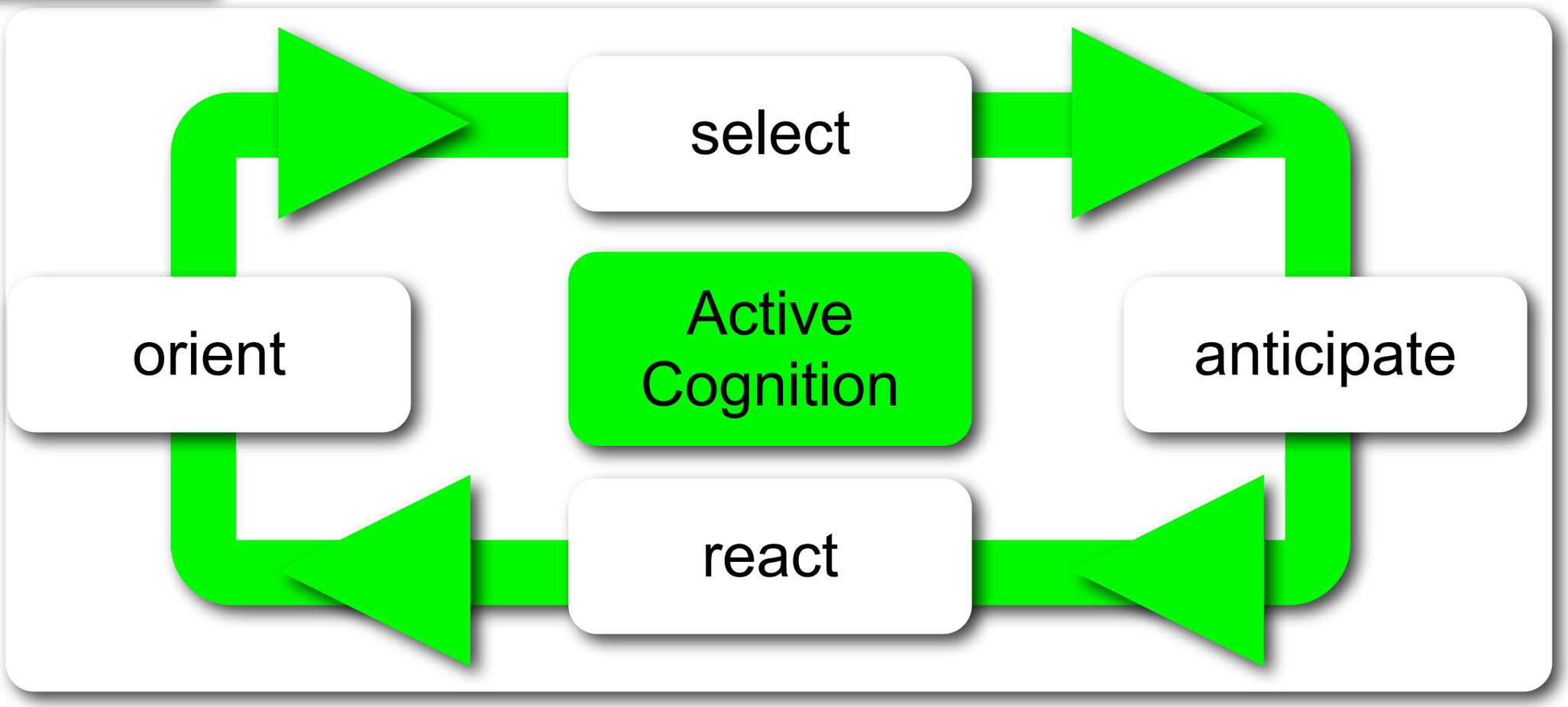
- Brains have evolved to control behavior in an ever changing 3-D environment.
  - Cognition evolved in organisms with specific physical attributes and is therefore shaped by and to take advantage of these features for cognitive ends.
  - Cognition developed in the context of reliable environmental features.
  - Cognition is for action and must be understood in its ultimate contribution to situation-appropriate behavior (Wilson, 2002),
- The development of mobile brain imaging is therefore essential for understanding natural human cognition.

The Traditional Approach to measure Active Cognition - Caveats (1)

- We record brain dynamics with millions of bits of information per second.
  - However, standard analysis of data reduces this information to single channels,
  - and further averages across trials, and
- finally compares the brain dynamics to ~1 bit of information from human behavior (usually button press).

- The ultimate goal is to analyze the full bandwidth of brain dynamics together with the full range of complex human behavior on single-trial level.

The Traditional Approach to measure Active Cognition - Caveats (2)



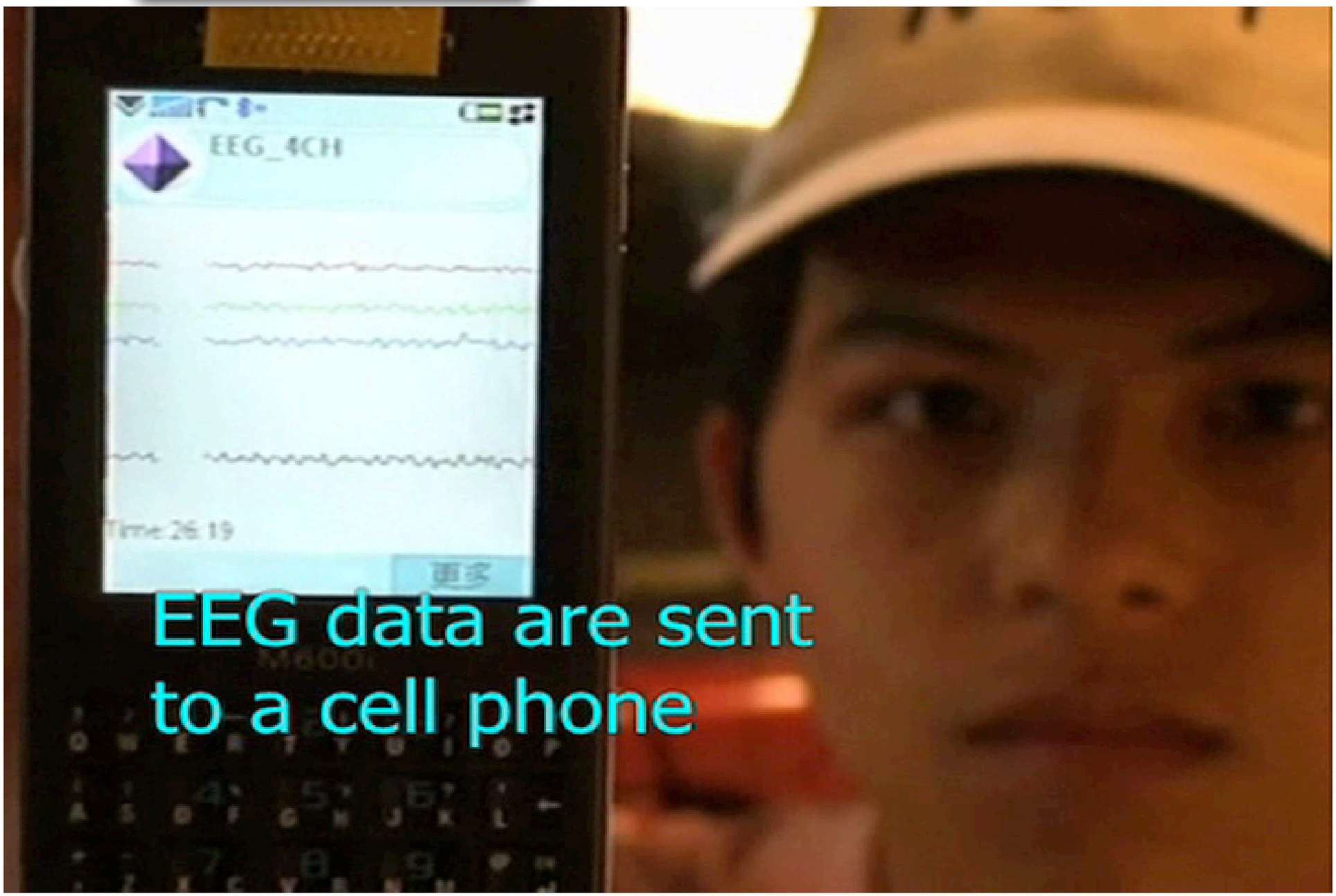
- The ultimate goal is to analyze active cognition and the accompanying distributed brain dynamics.

The Traditional Approach to Active Cognition - Caveats (3)

- Sensors are too heavy (MEG, PET, MRI) to follow movements of the subjects.
- Rigidly static positions (sitting or lying) are required to avoid movements.
  - Movement is not allowed and considered as source of artifacts.
  - Even eye-movement is considered as an artefact in EEG experiments.

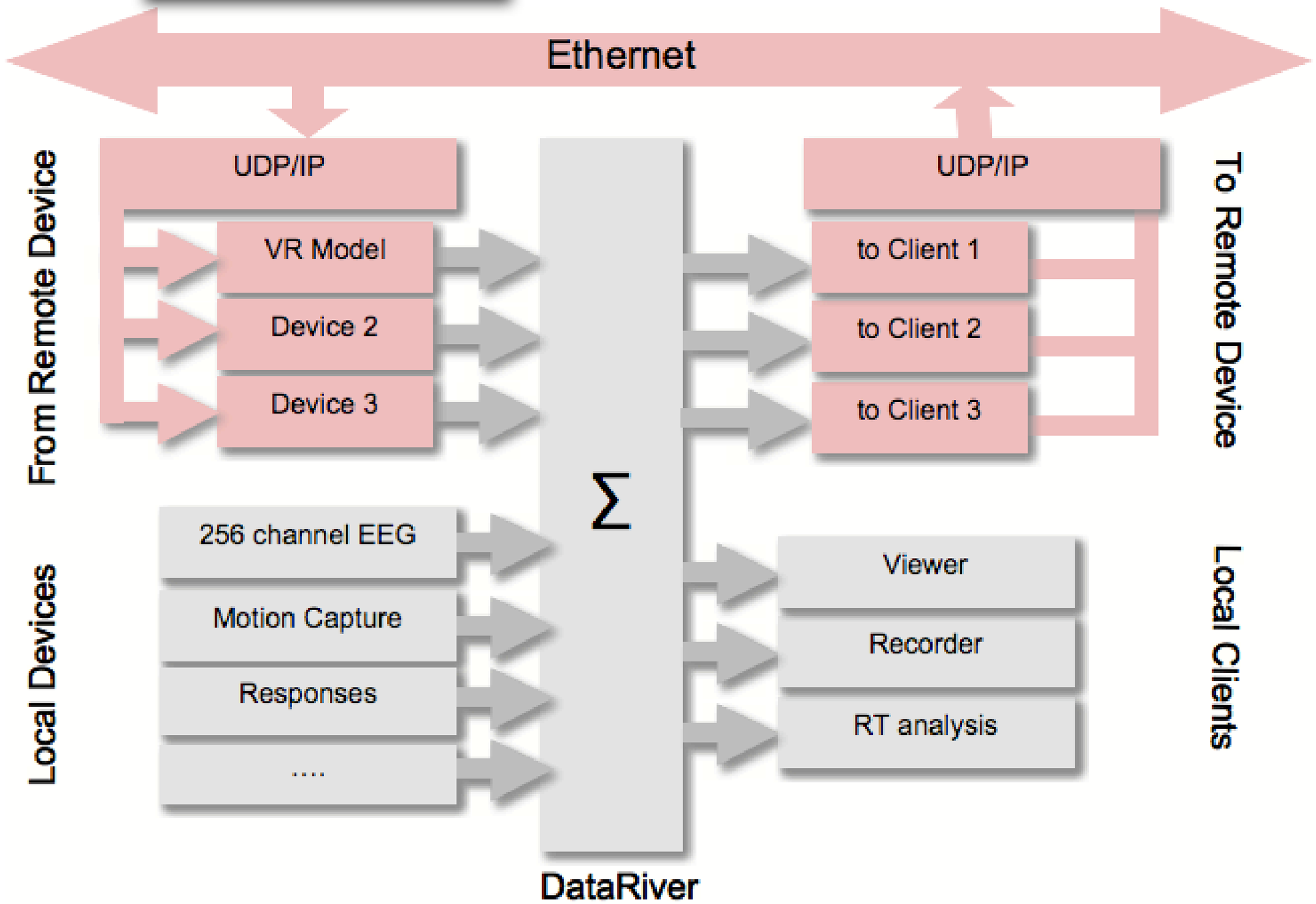
- New technologies have to be developed and integrated to allow for recordings of active cognition.

How to Image The Mobile Brain - Technology

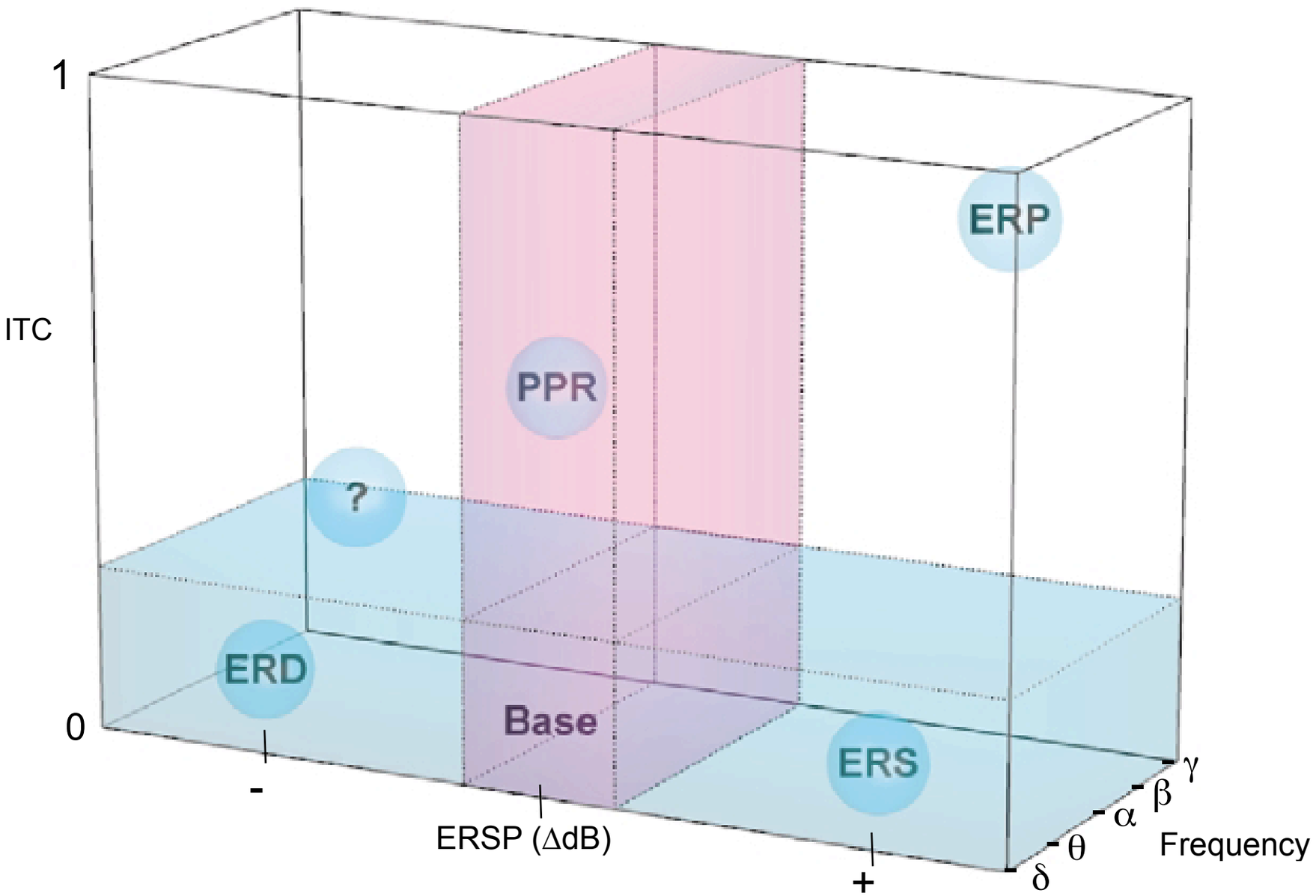


How to Image The Mobile Body - Technology

How to Image Mobile Cognition - Technology

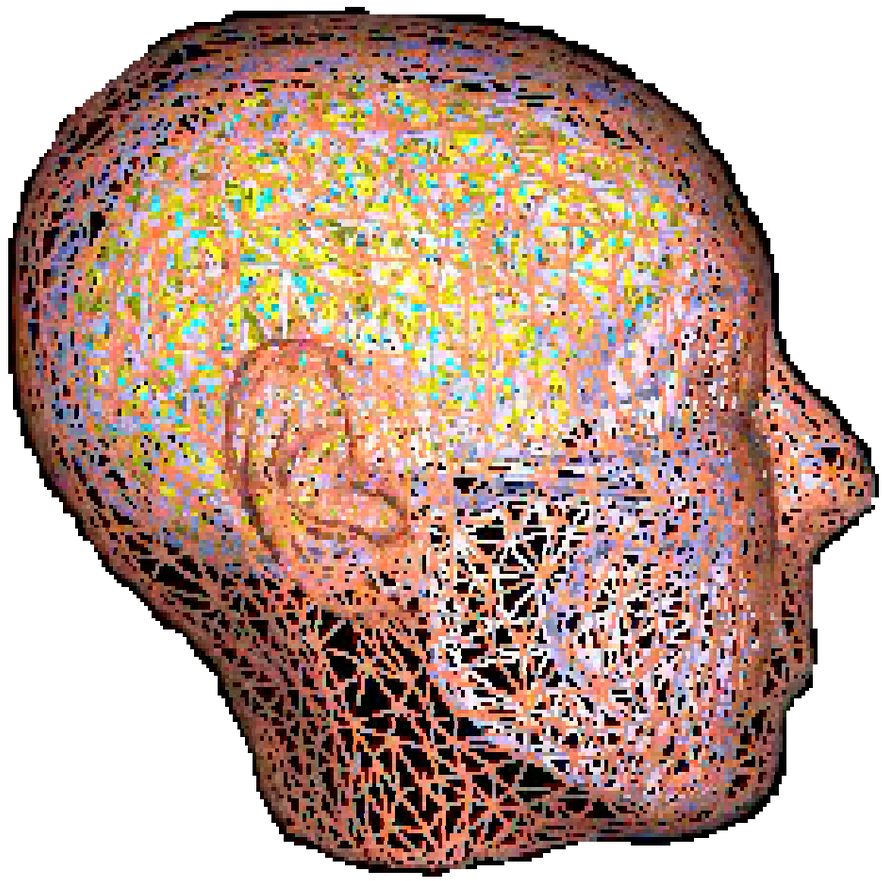


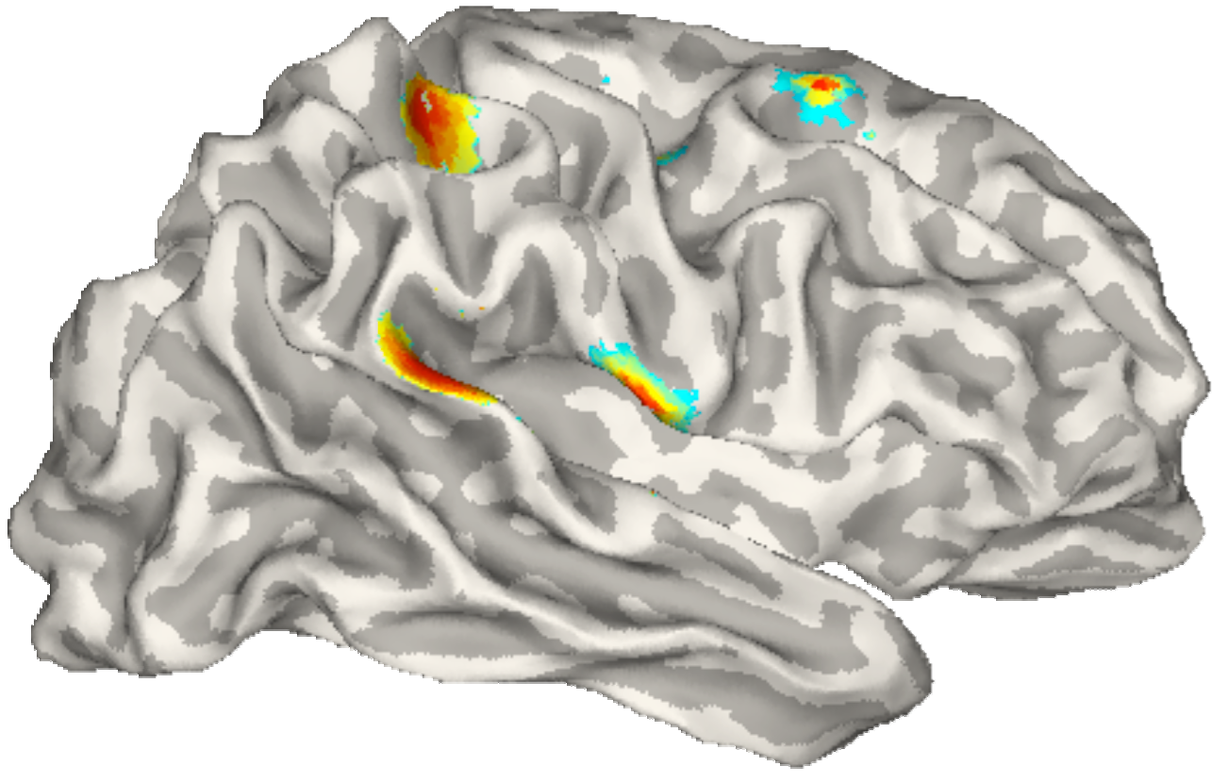
How to Image Mobile Cognition - Data Analyses



Makeig et al. (2004). *TICS*

How to Image Mobile Cognition - Data Analyses



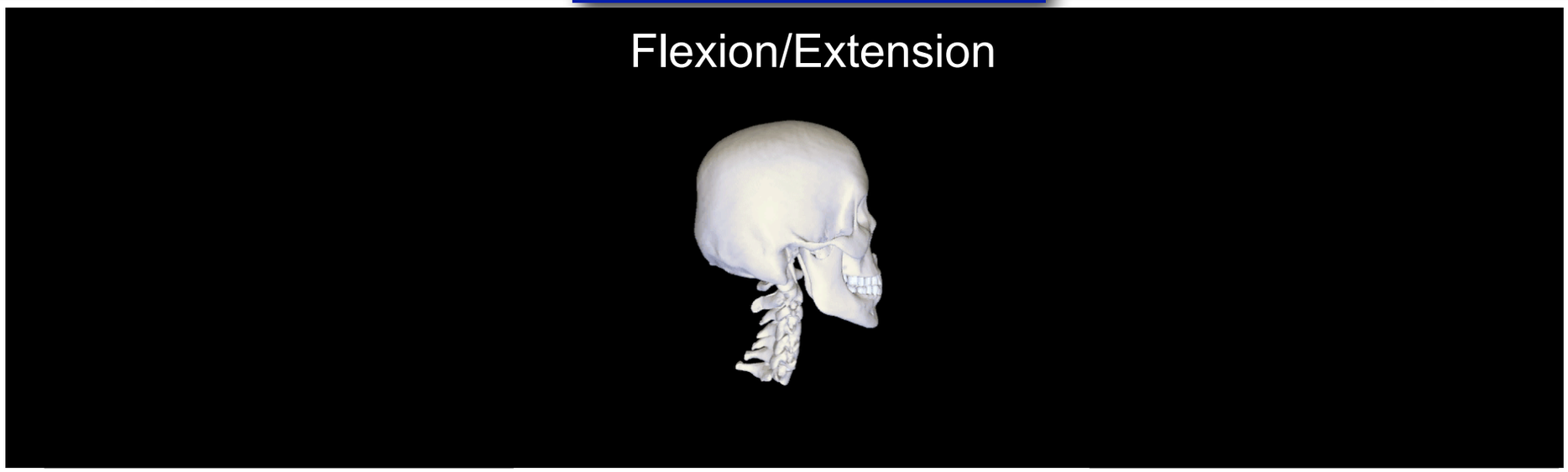


Akalın-Acar & Gencer, (2004) *Physics in Medicine and Biology*
Ataseven et al (2008) *Med. & Biol. Eng. & Comp.*

A First Experiment Using MoBI

A First Experiment Using MoBI

What Kind Of ‘Artifactual Activity’ is Measured With EEG?



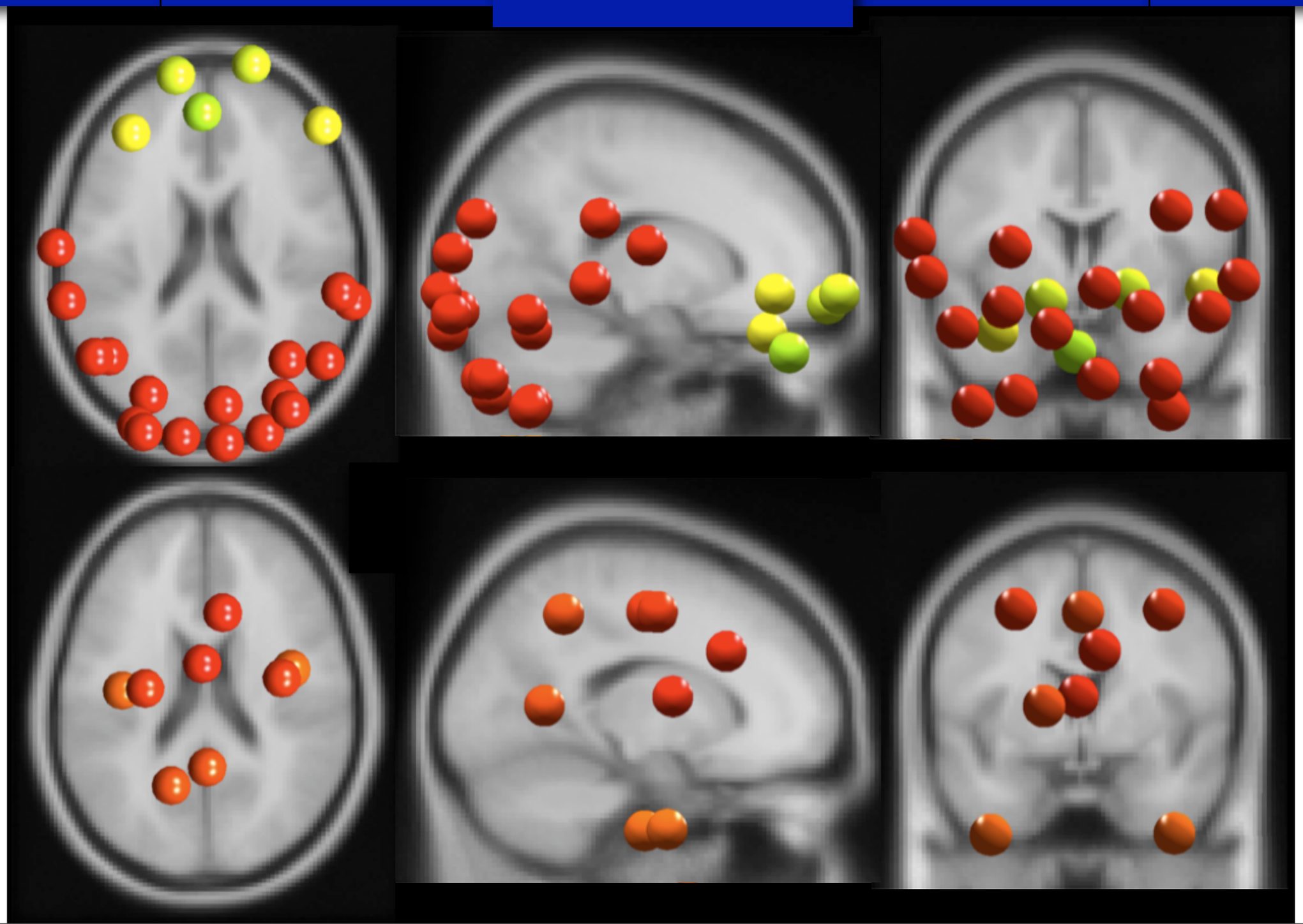
Neck Extension

- Trapezius
- Semispinalis Capitis (bilateral)
- Splenius Capitis (bilateral)
- Rectus Posterior (Minor & Major)
- Rectus Oblique Superior

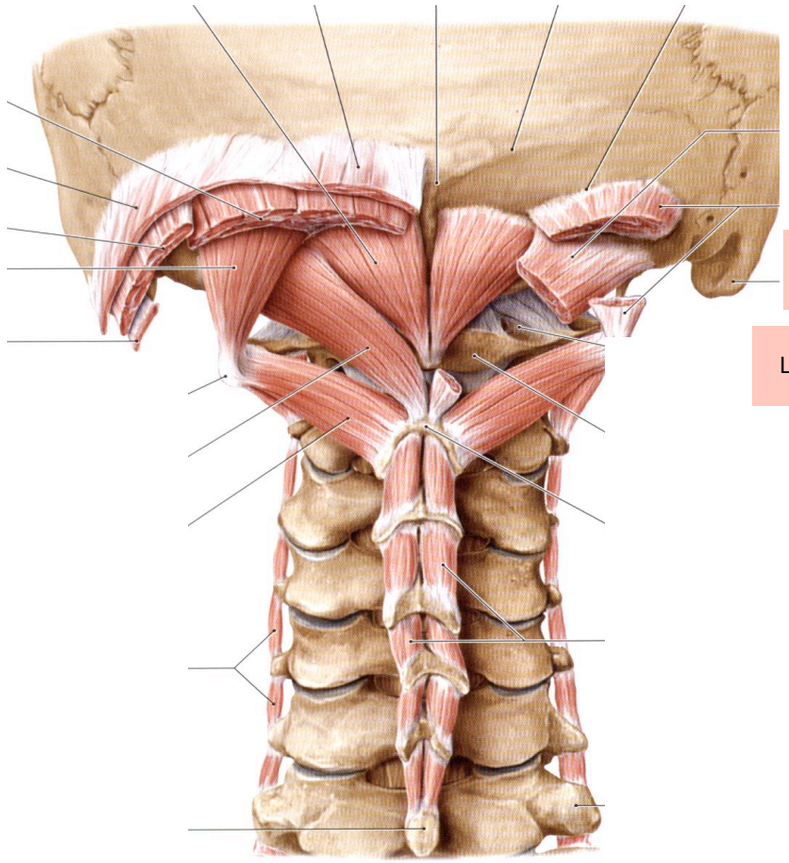
Neck Flexion

- Longus Capitis
- Longus Colli

‘Artefacts’ (?)
During Natural Movements

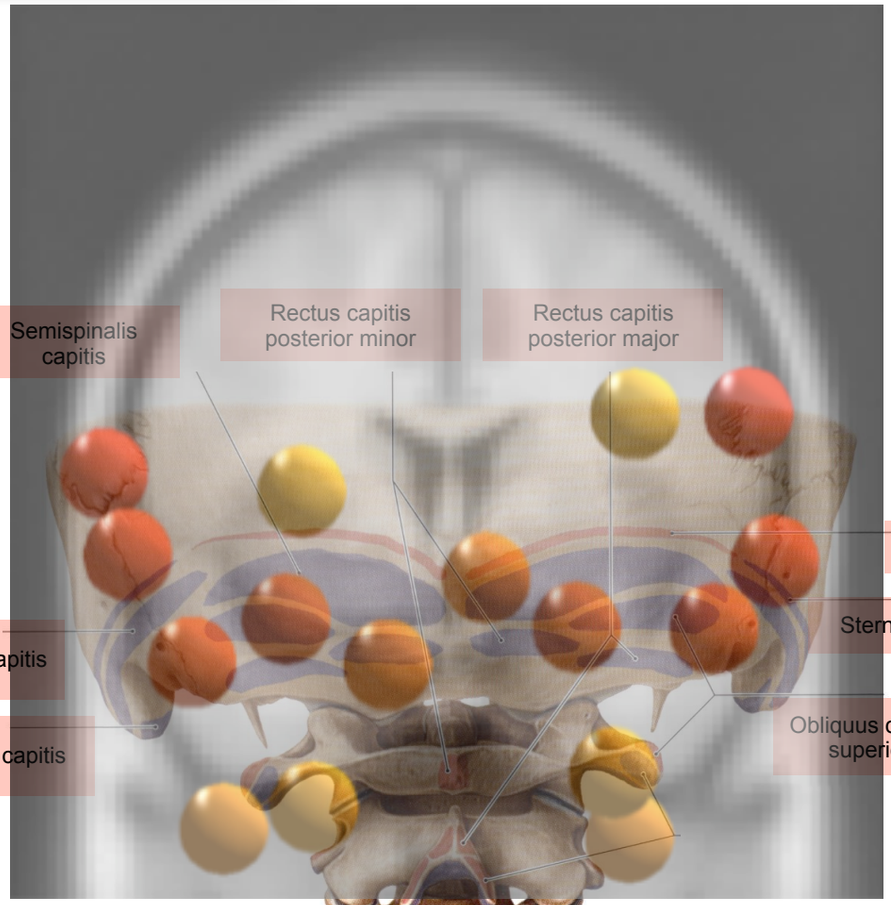


Muscles Attached To The Occipital Bone

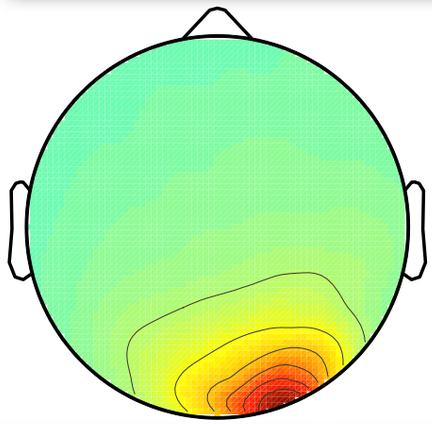


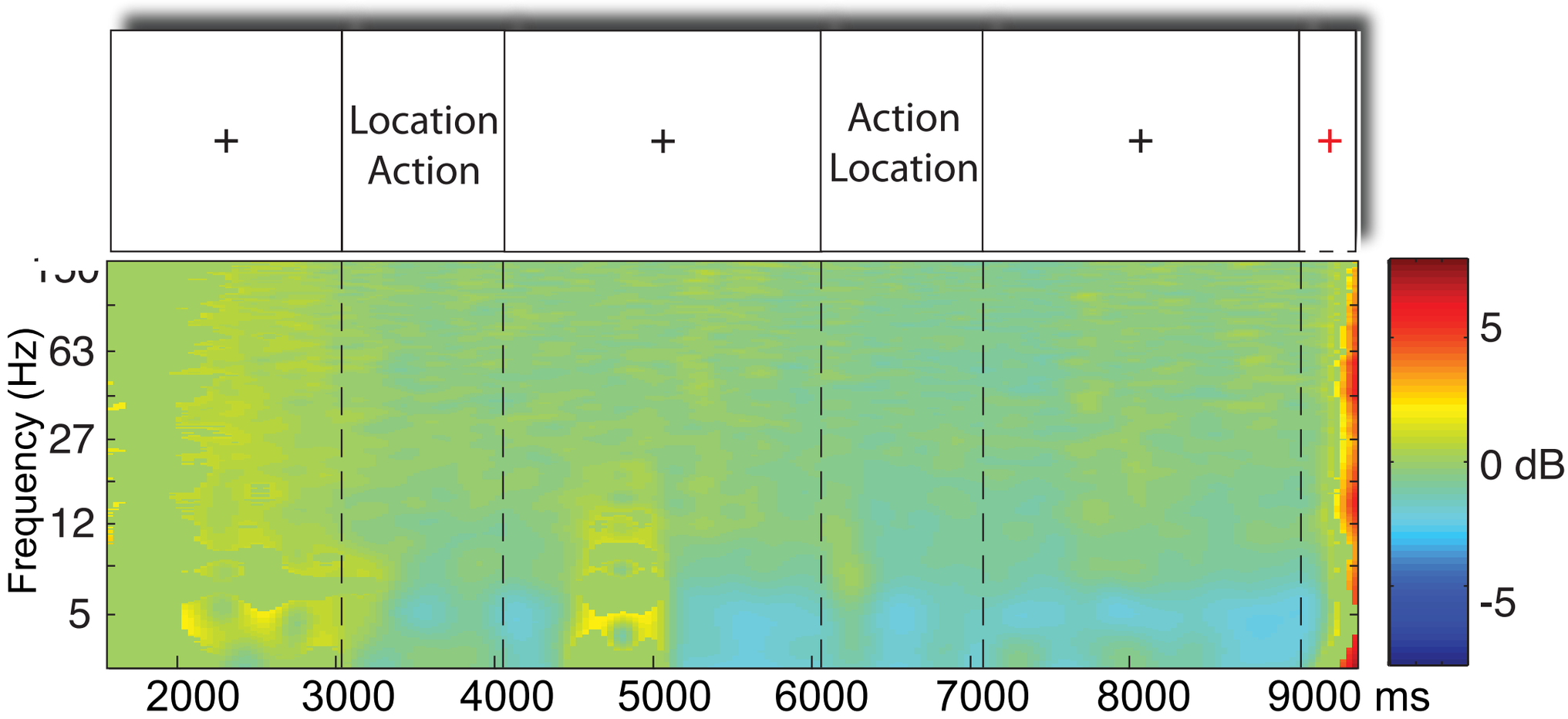
Splenius capitis

Longissimus capitis

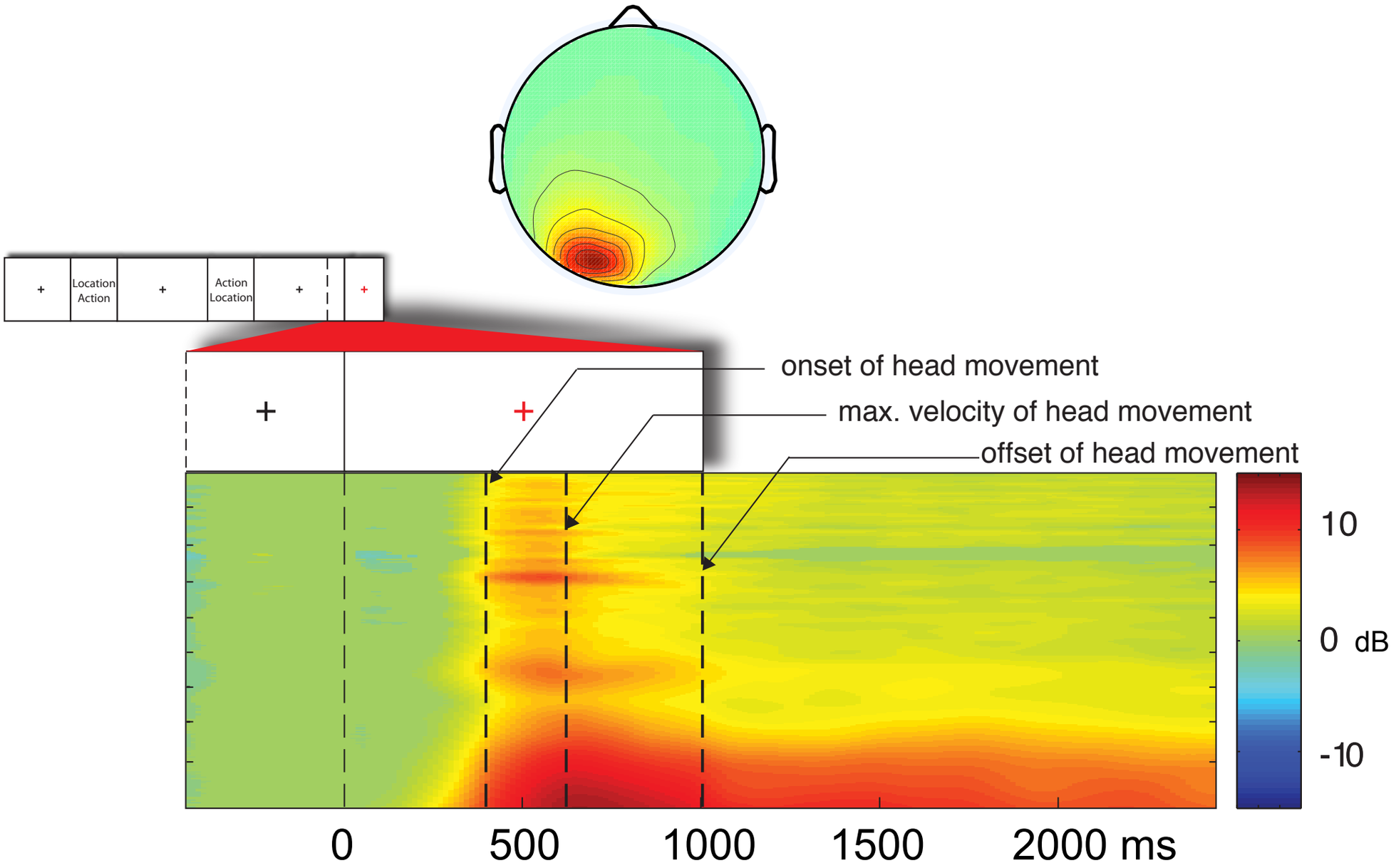


Neck Muscles Activity During Looking and Pointing Movements





Neck Muscles Activity During Looking and Pointing Movements

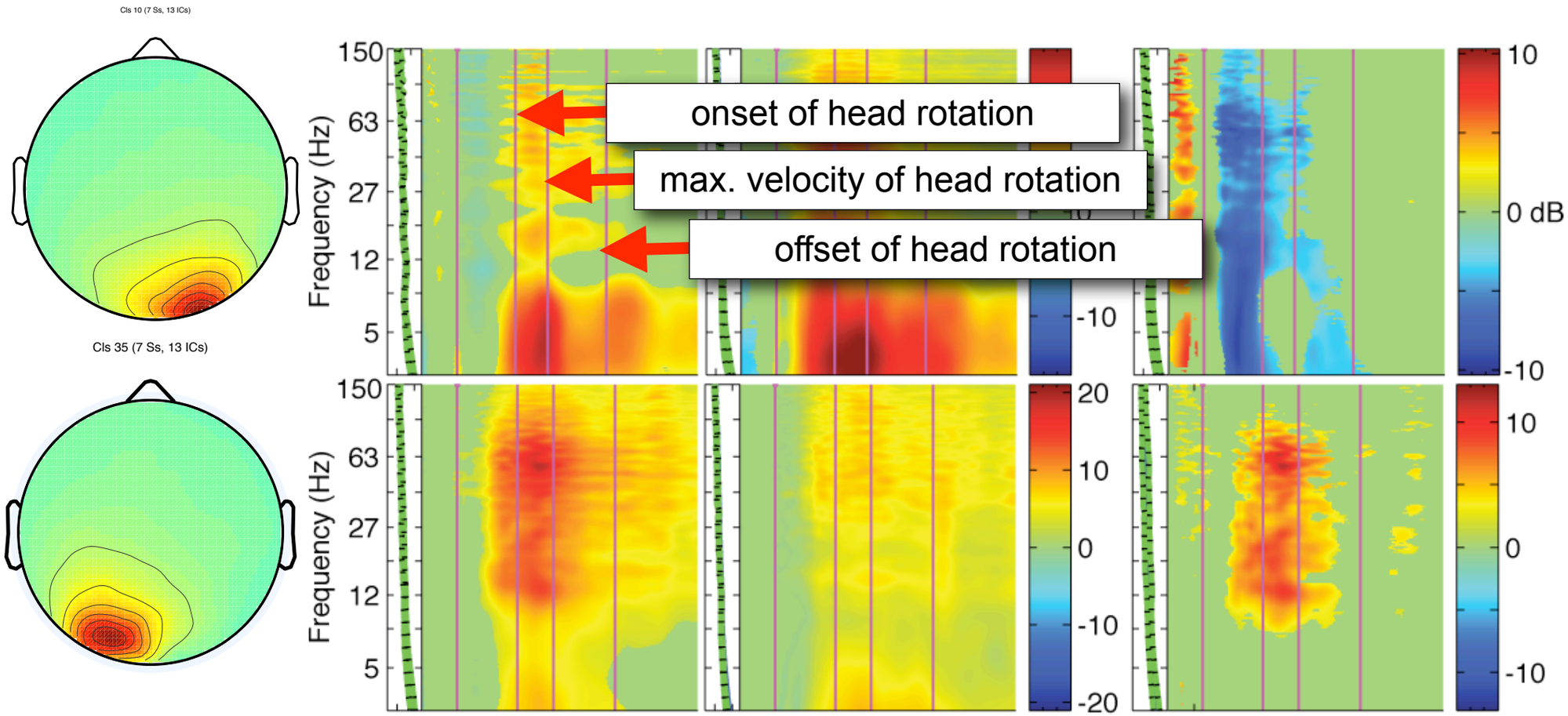


Neck Muscles Activity During Looking and Pointing Movements

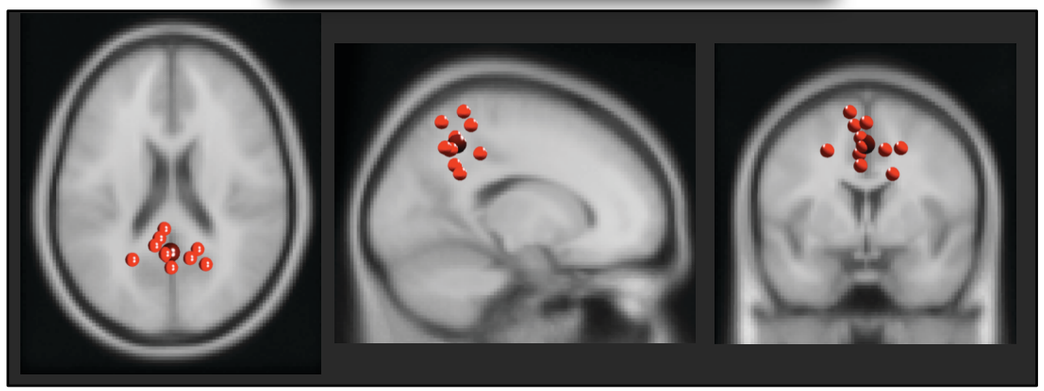
look / point to left

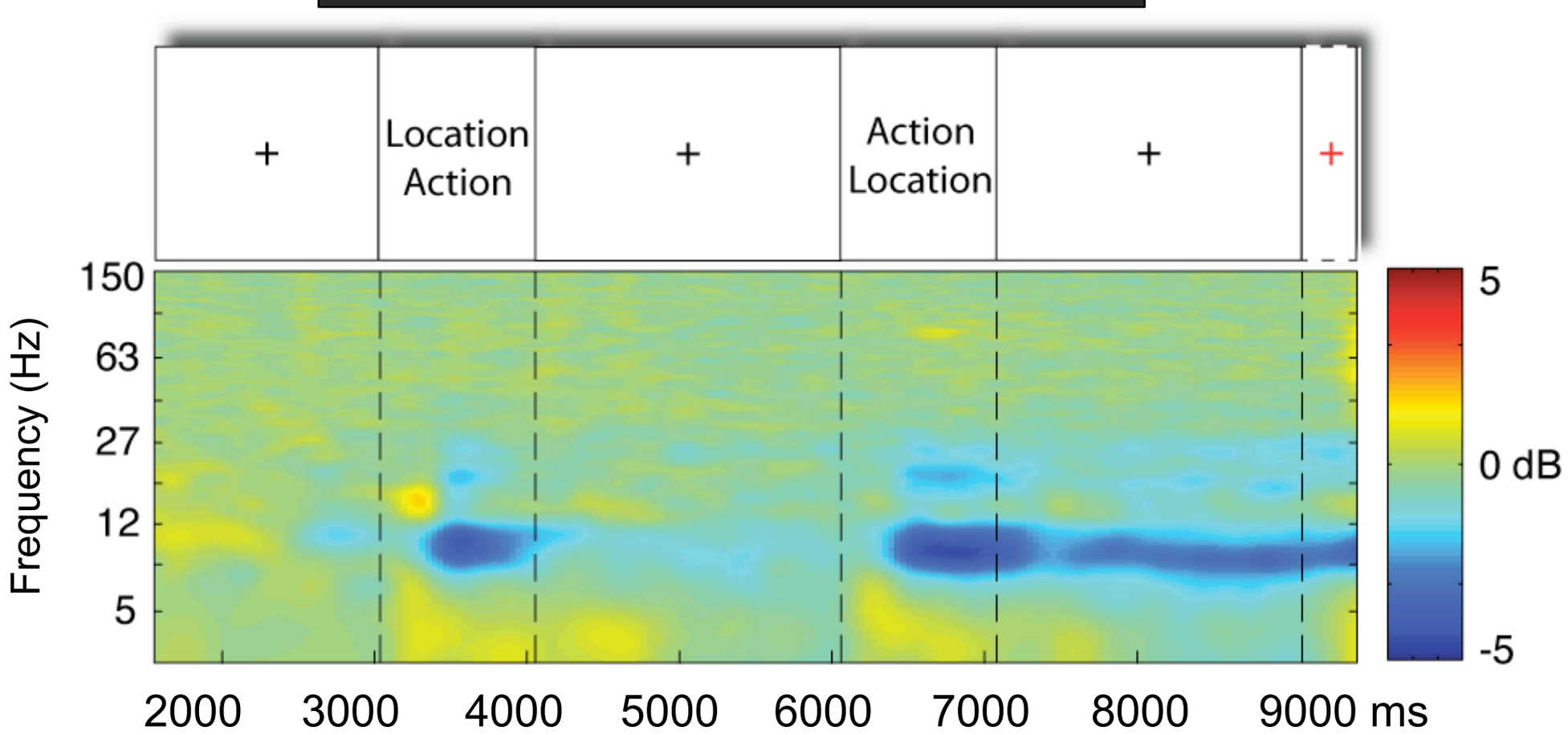
look / point to right

difference

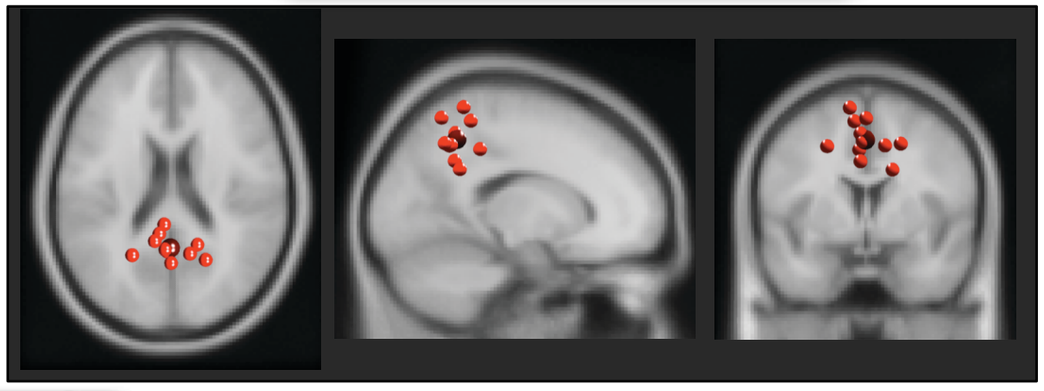


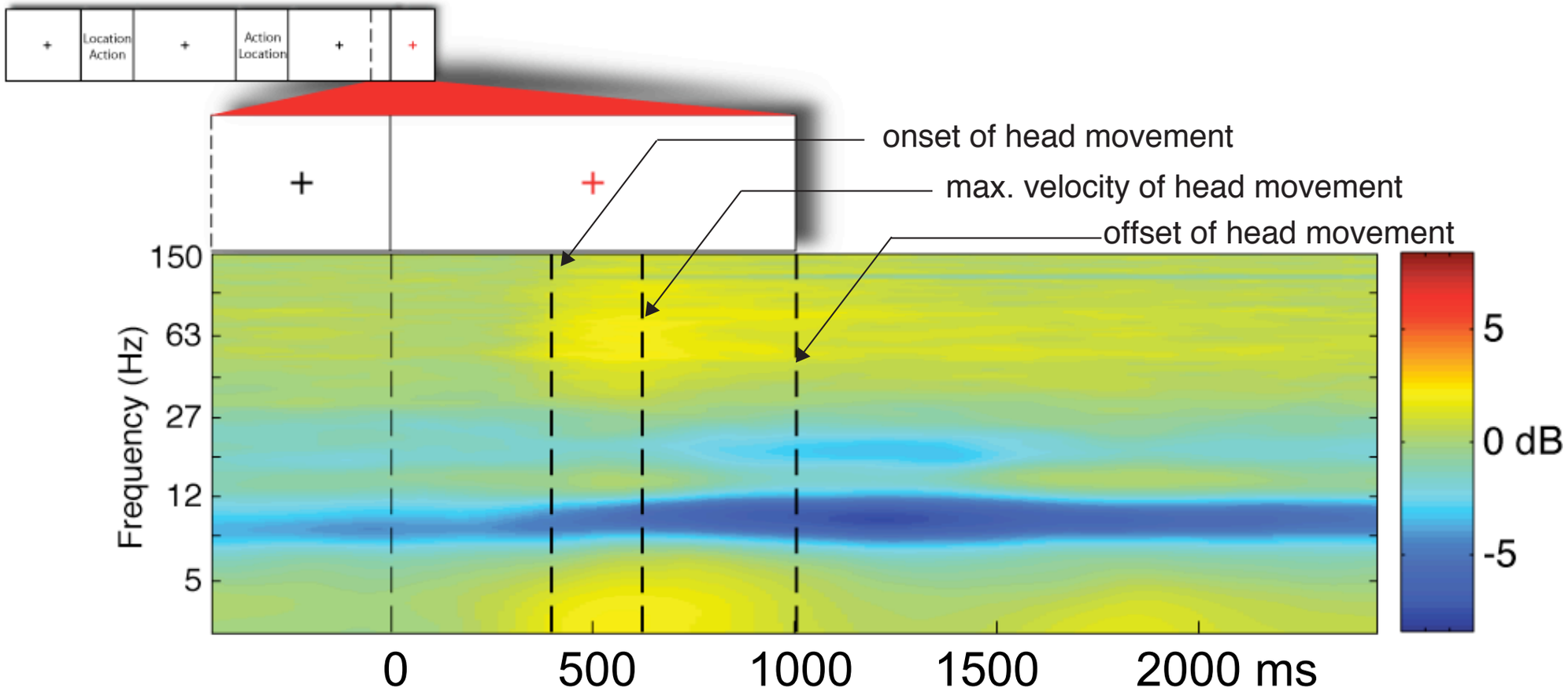
Brain Dynamics During Looking and Pointing Movements



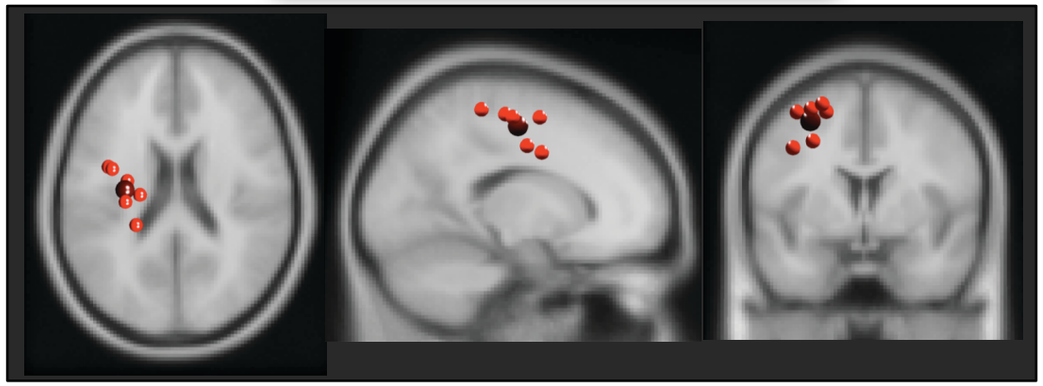


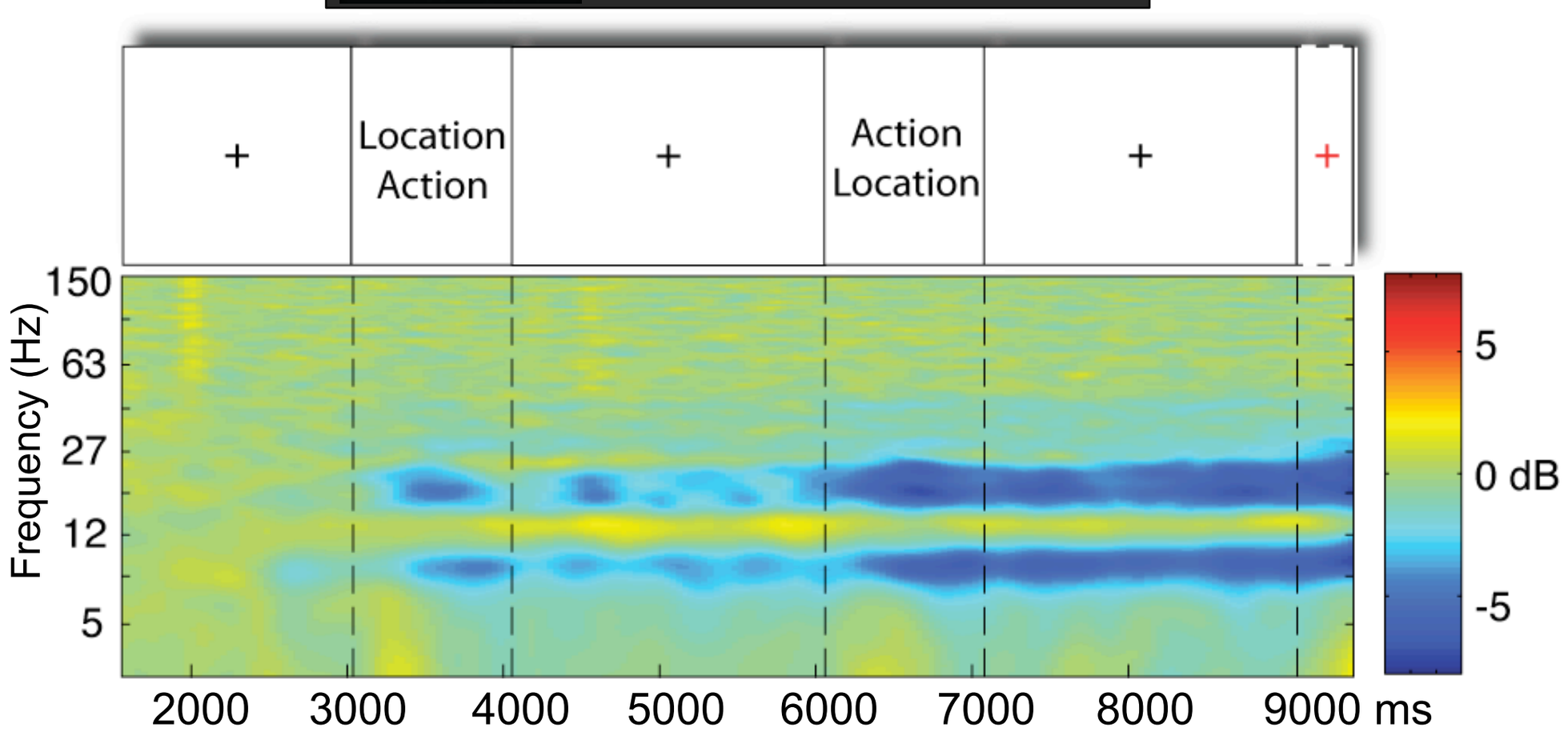
Brain Dynamics During Looking and Pointing Movements



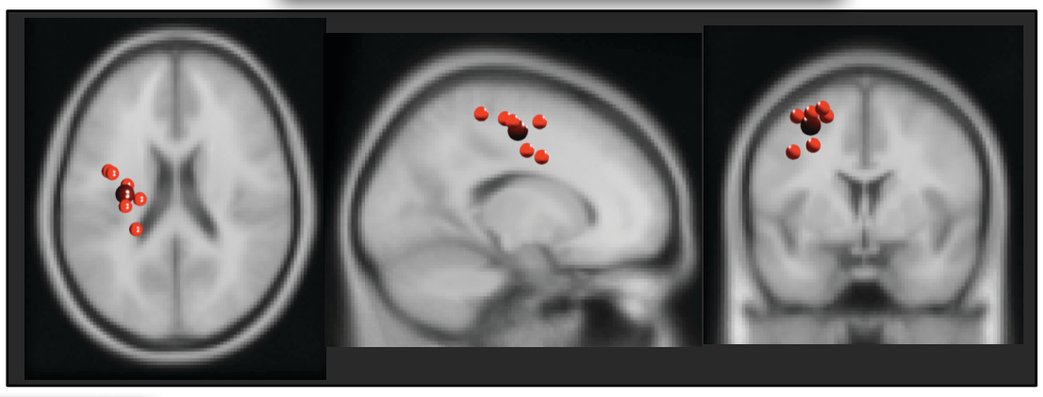


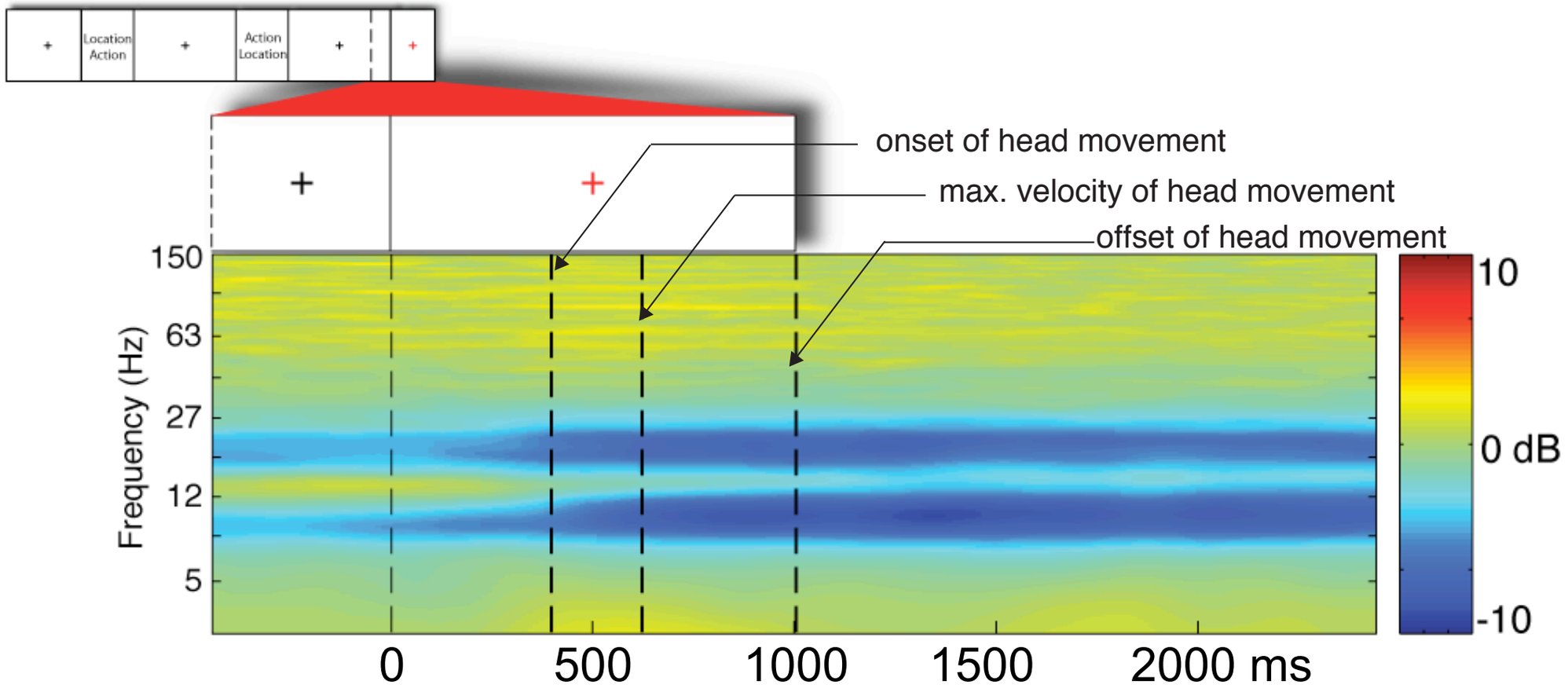
Brain Dynamics During Looking and Pointing Movements



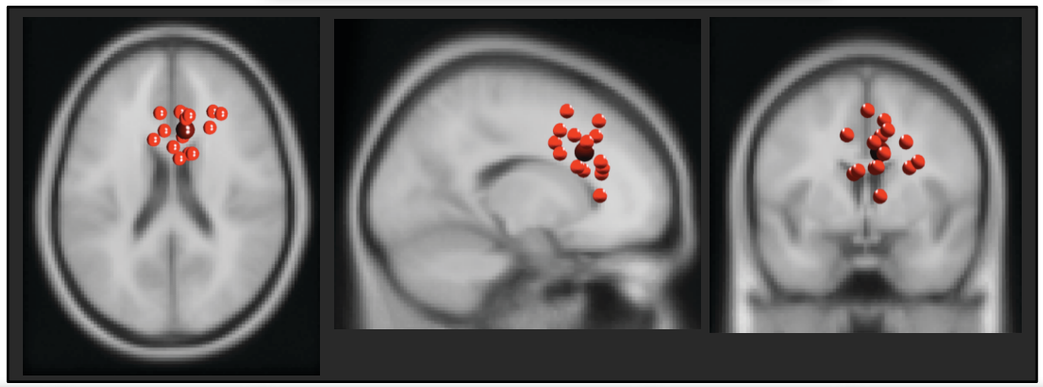


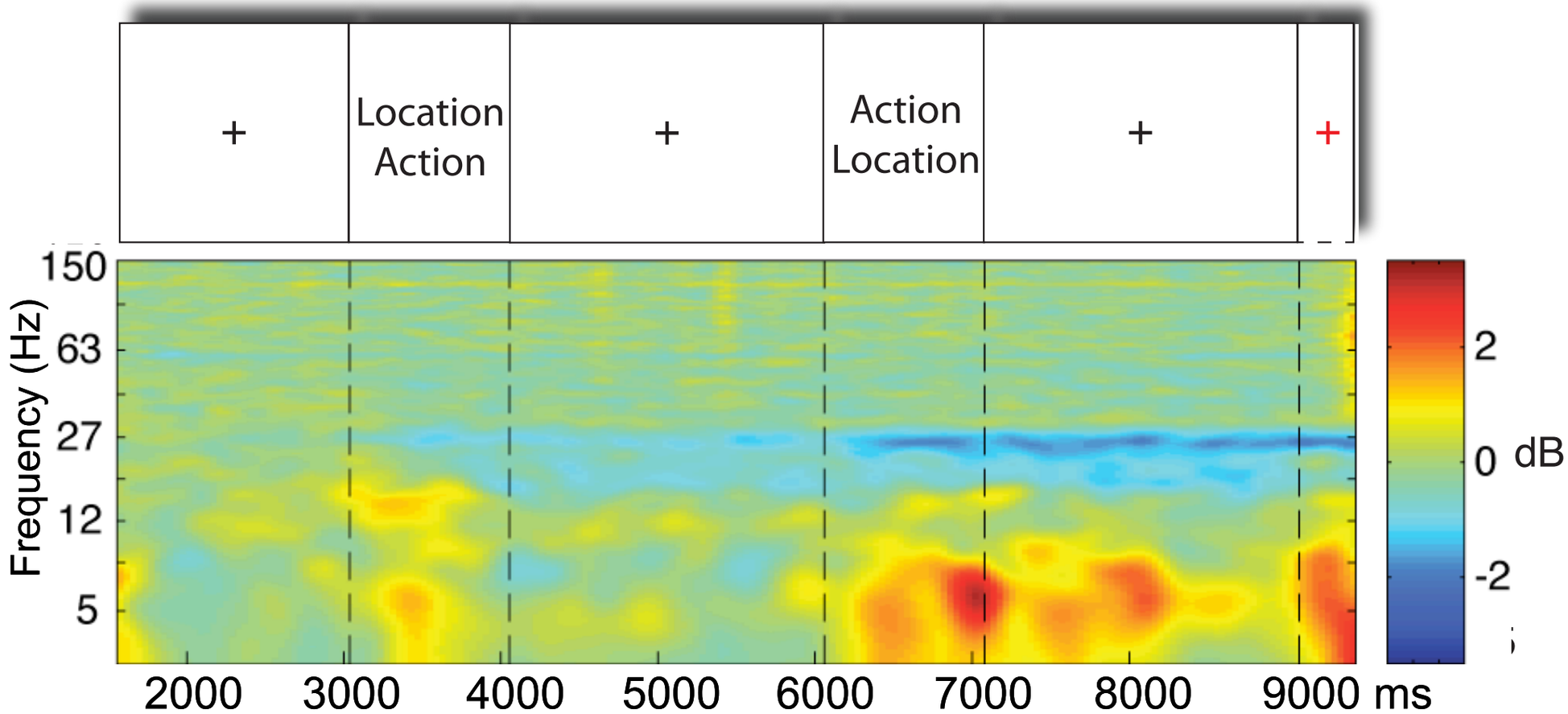
Brain Dynamics During Looking and Pointing Movements



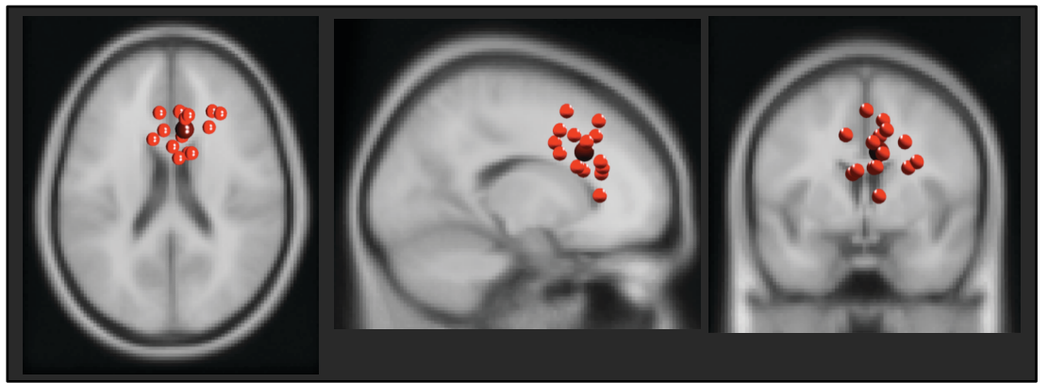


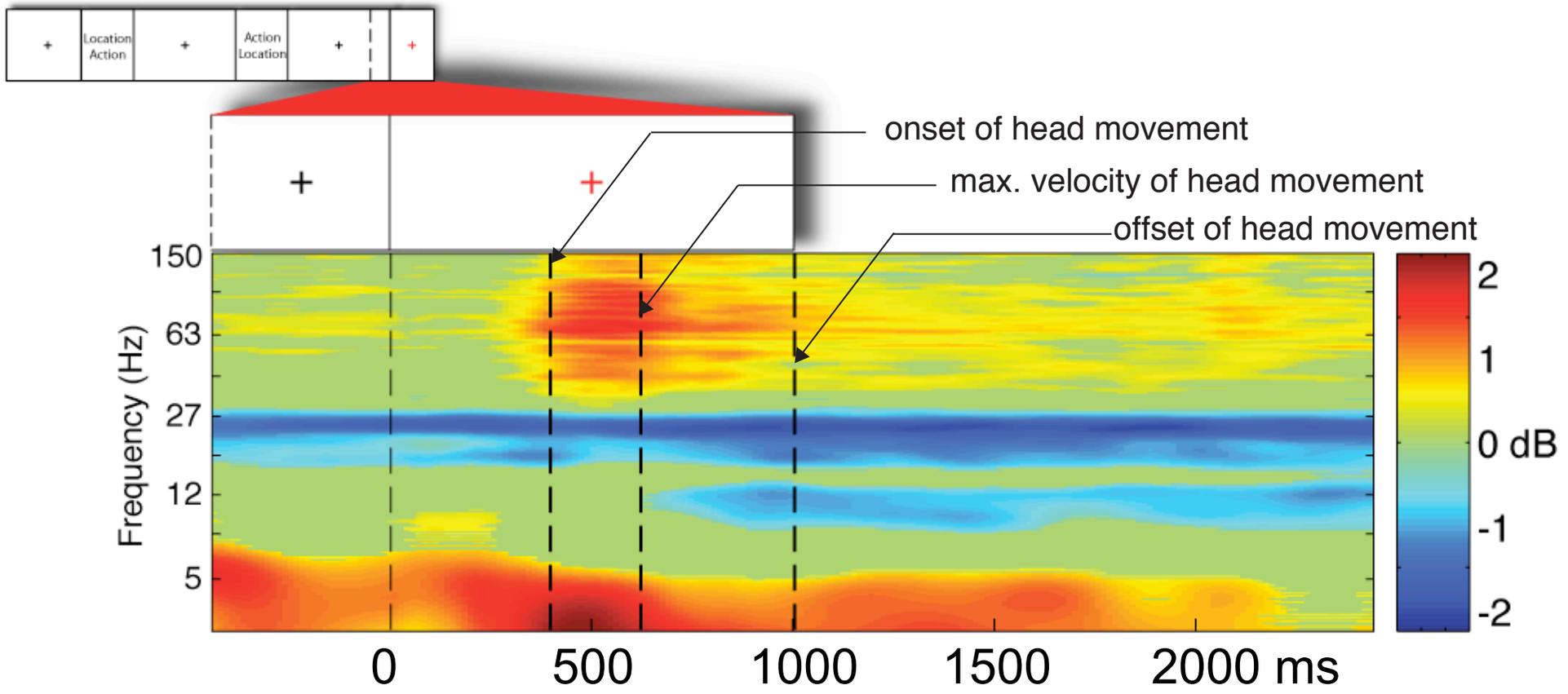
Brain Dynamics During Looking and Pointing Movements



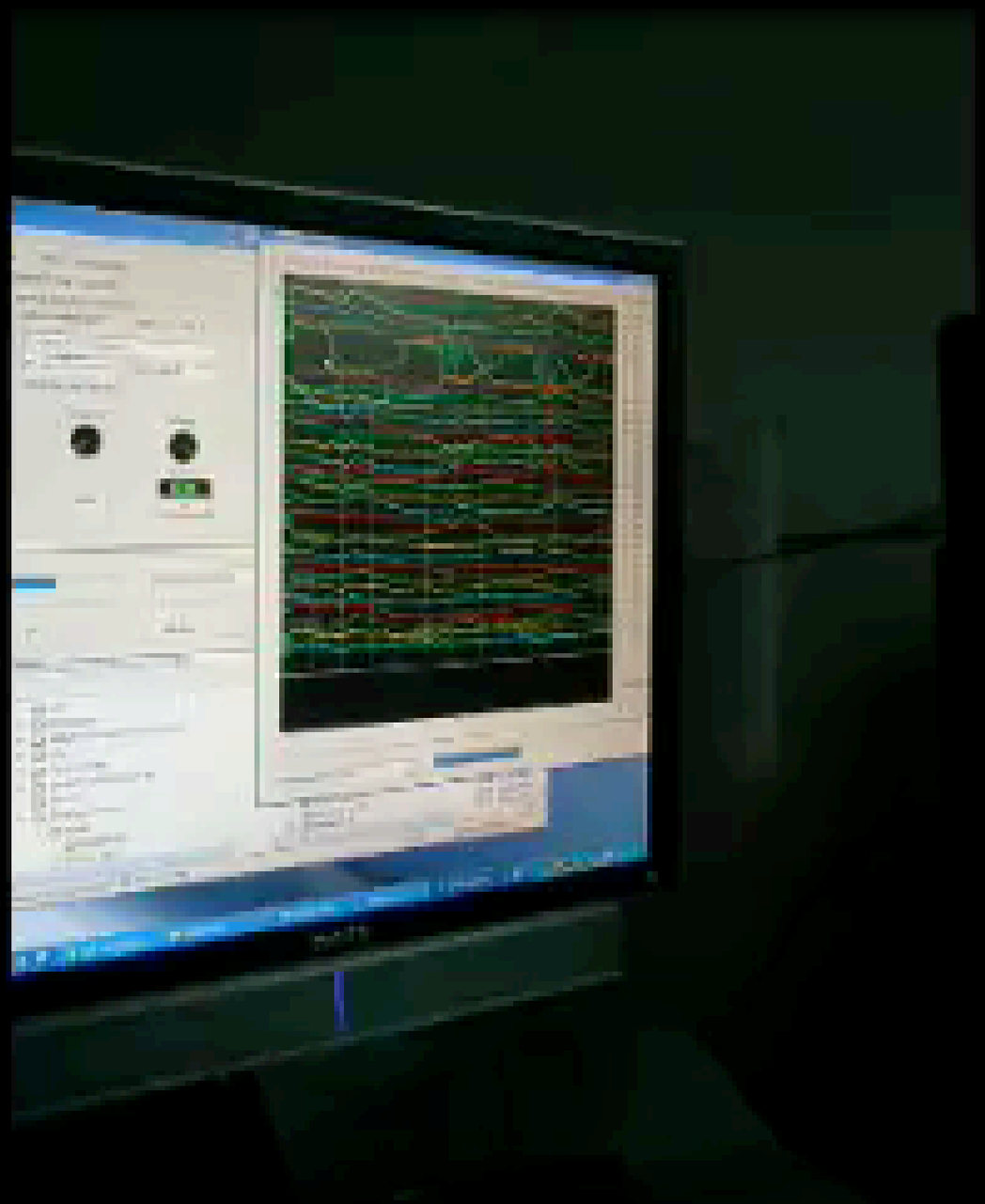


Brain Dynamics During Looking and Pointing Movements

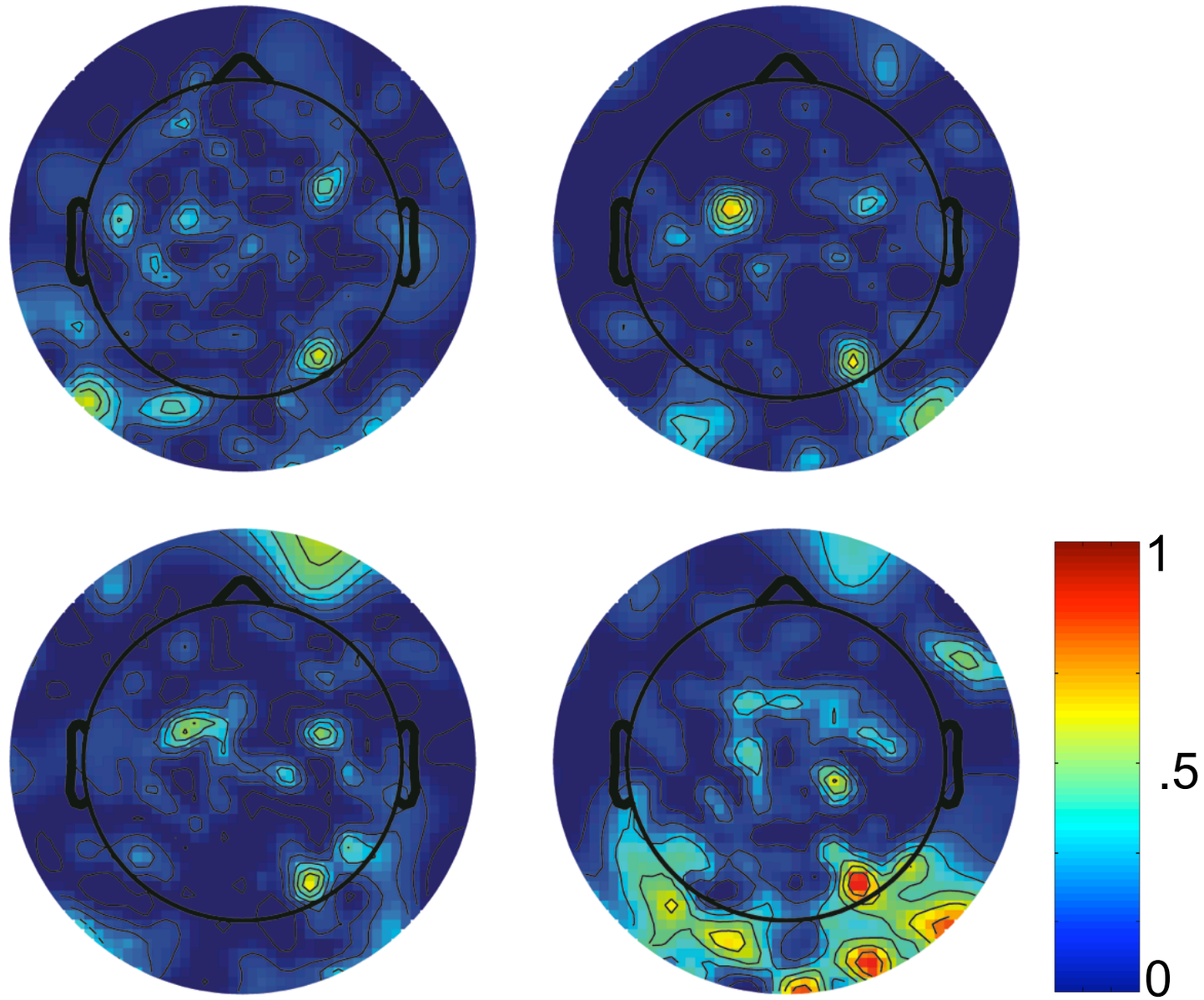




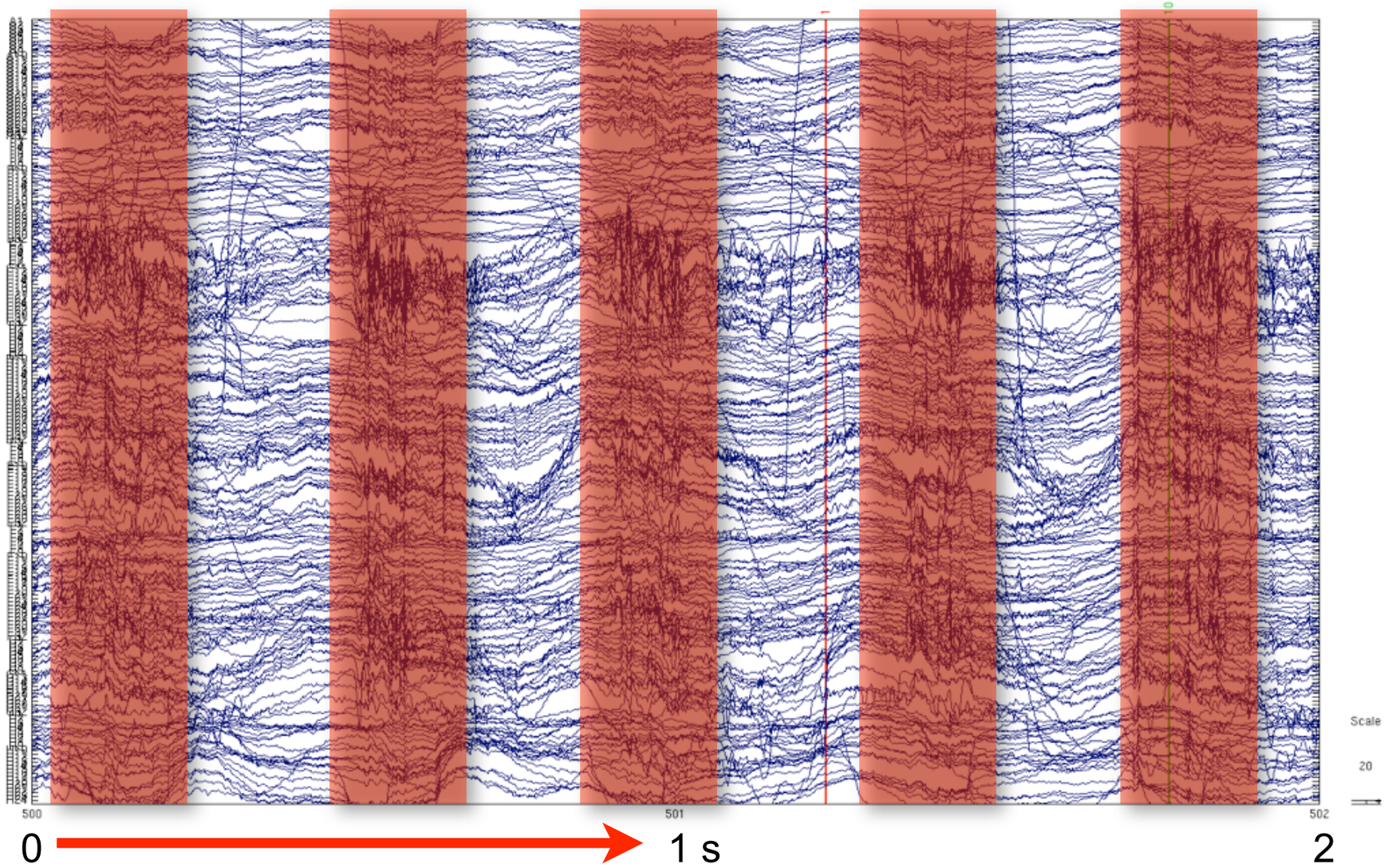
Cognition on the Run



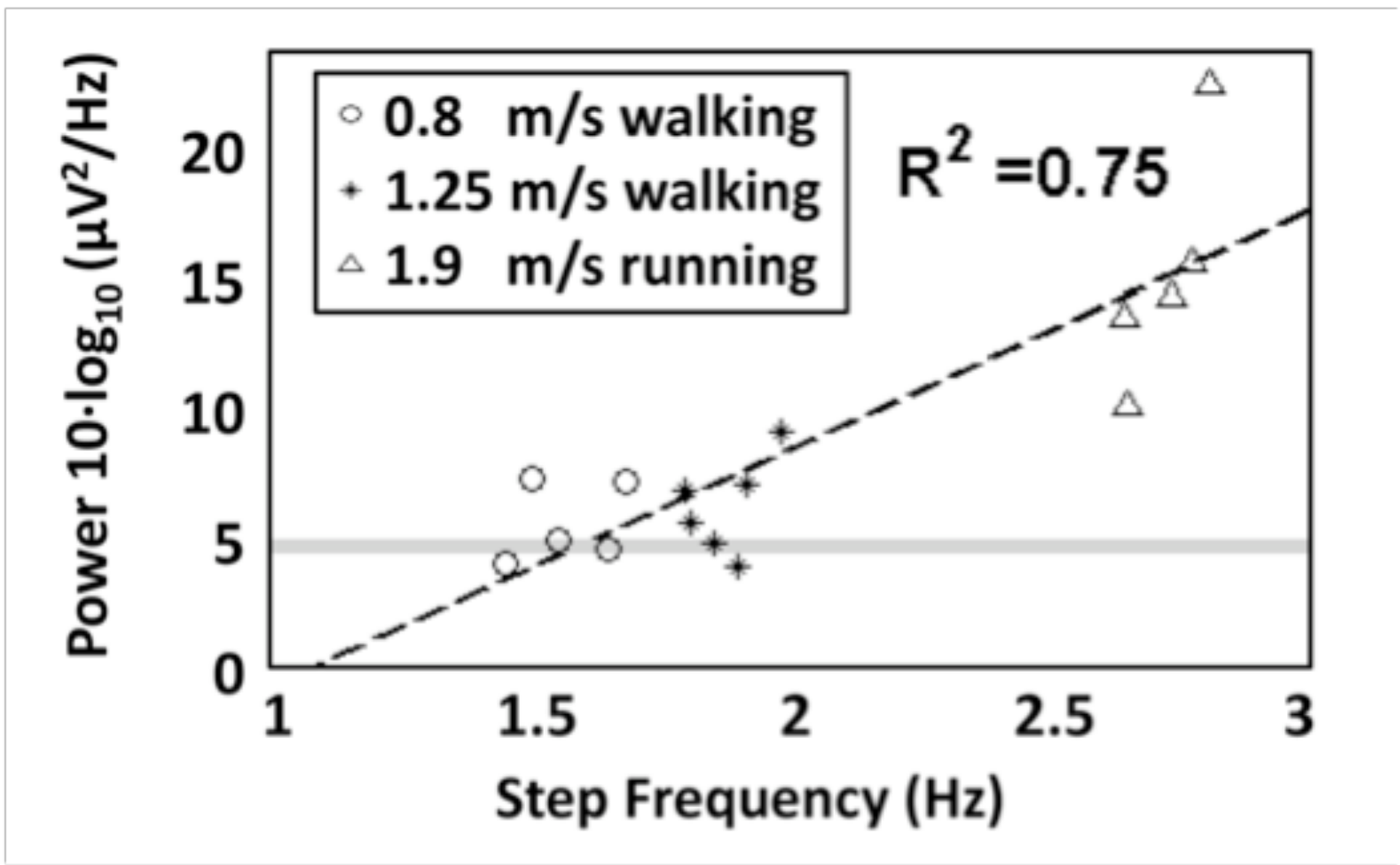
Which Electrodes are Likely to Make Trouble?



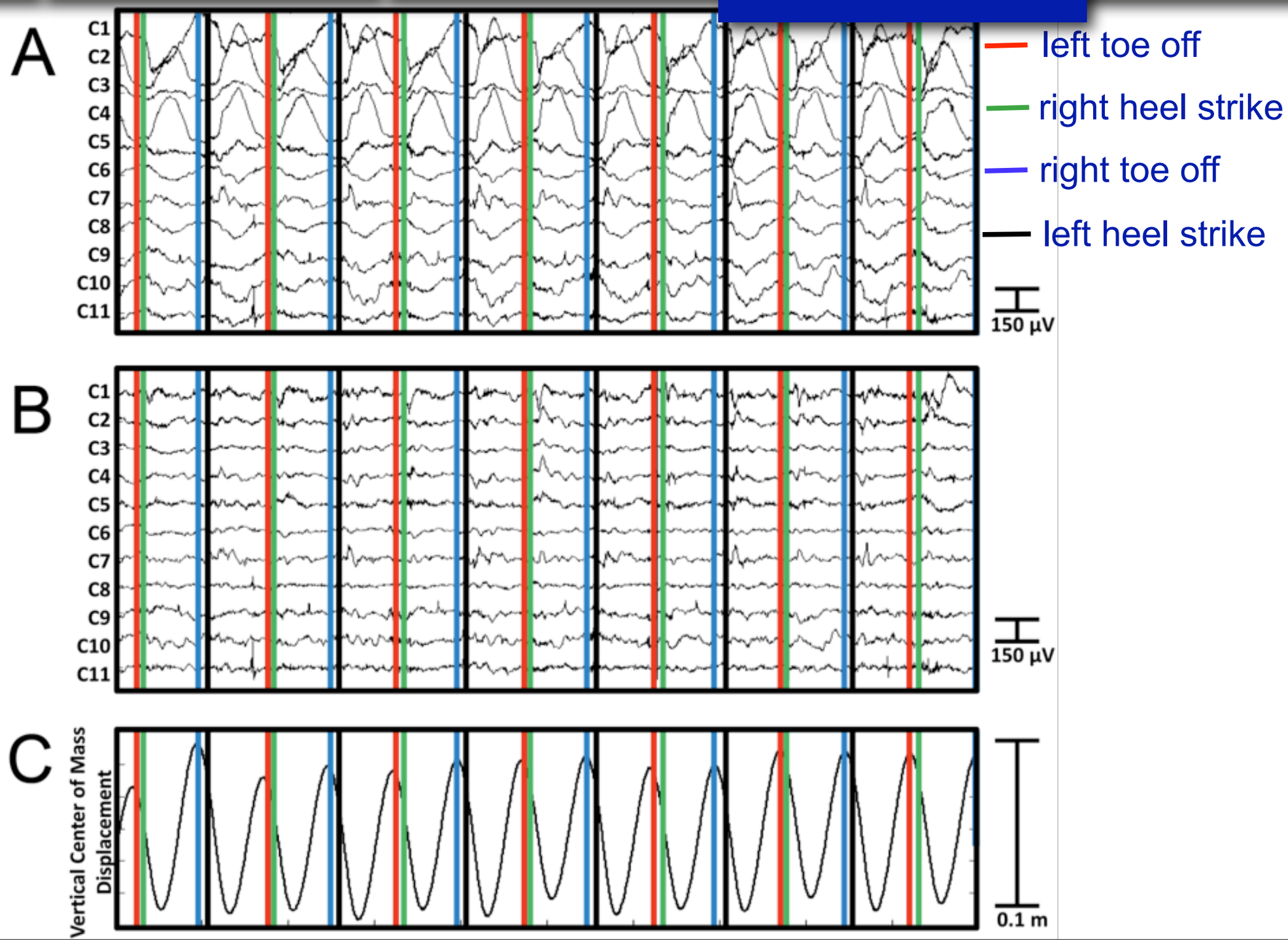
Which Electrodes are Likely to Make Trouble?



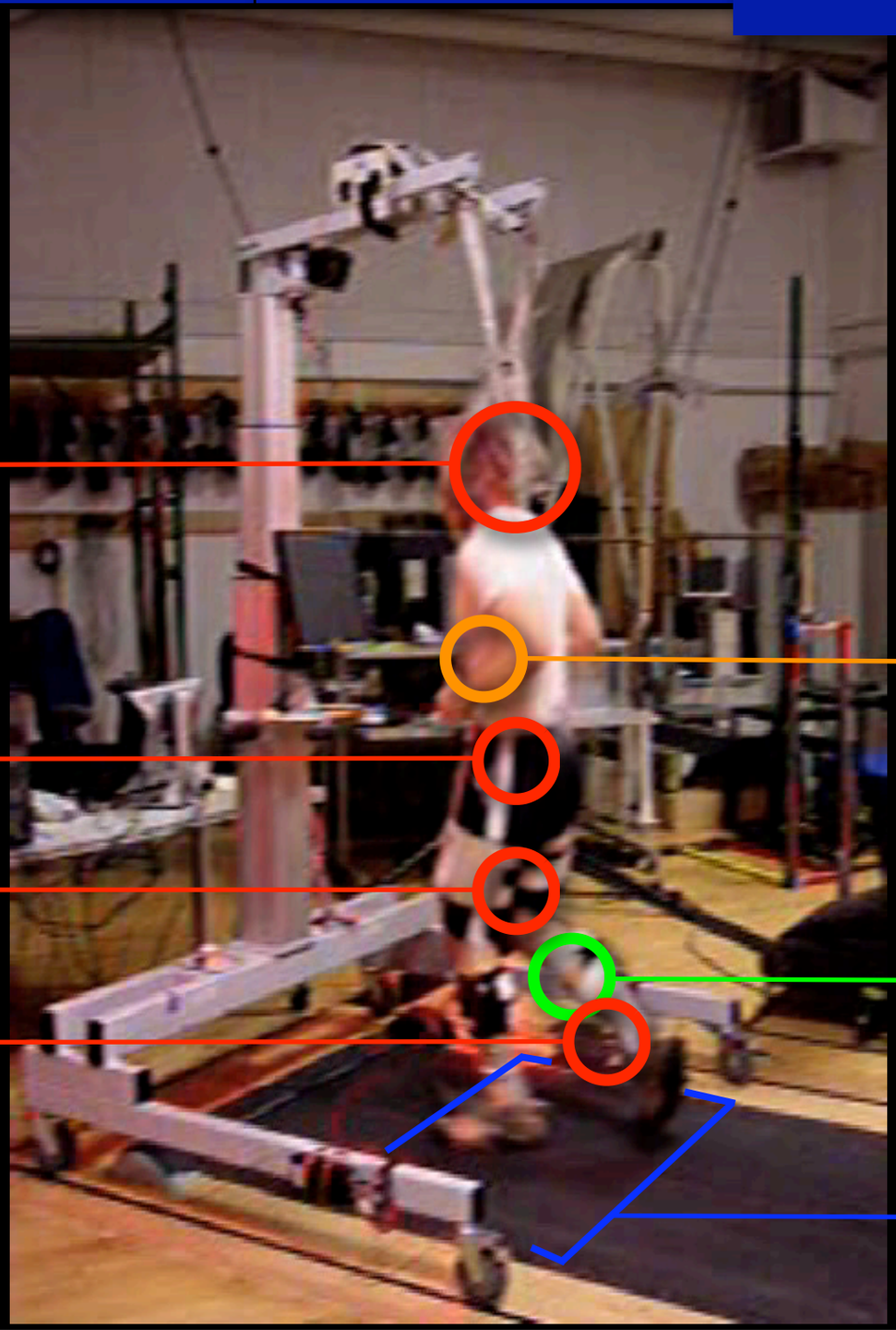
Power Increase of Step Frequency



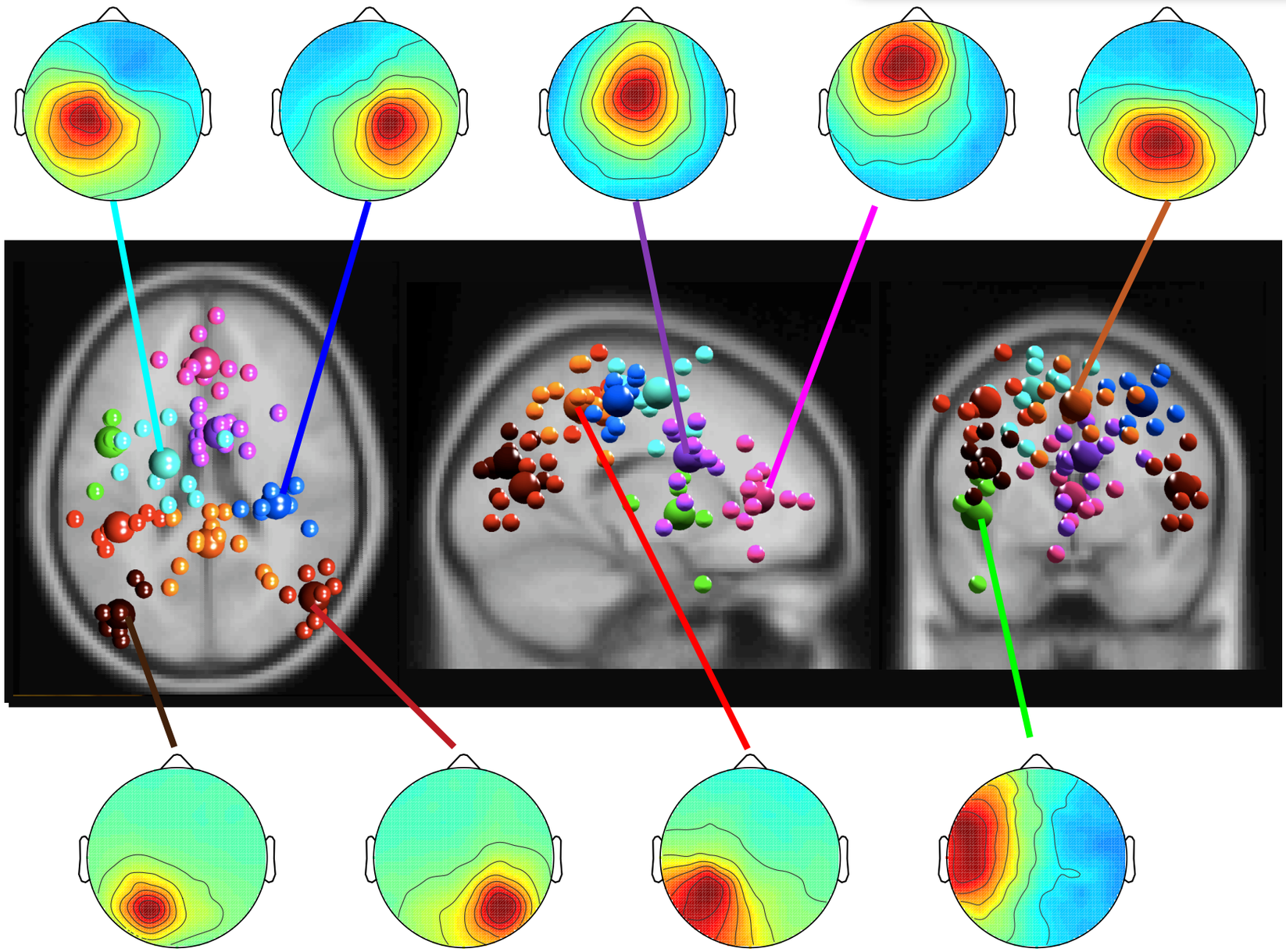
Cognition on the Run?



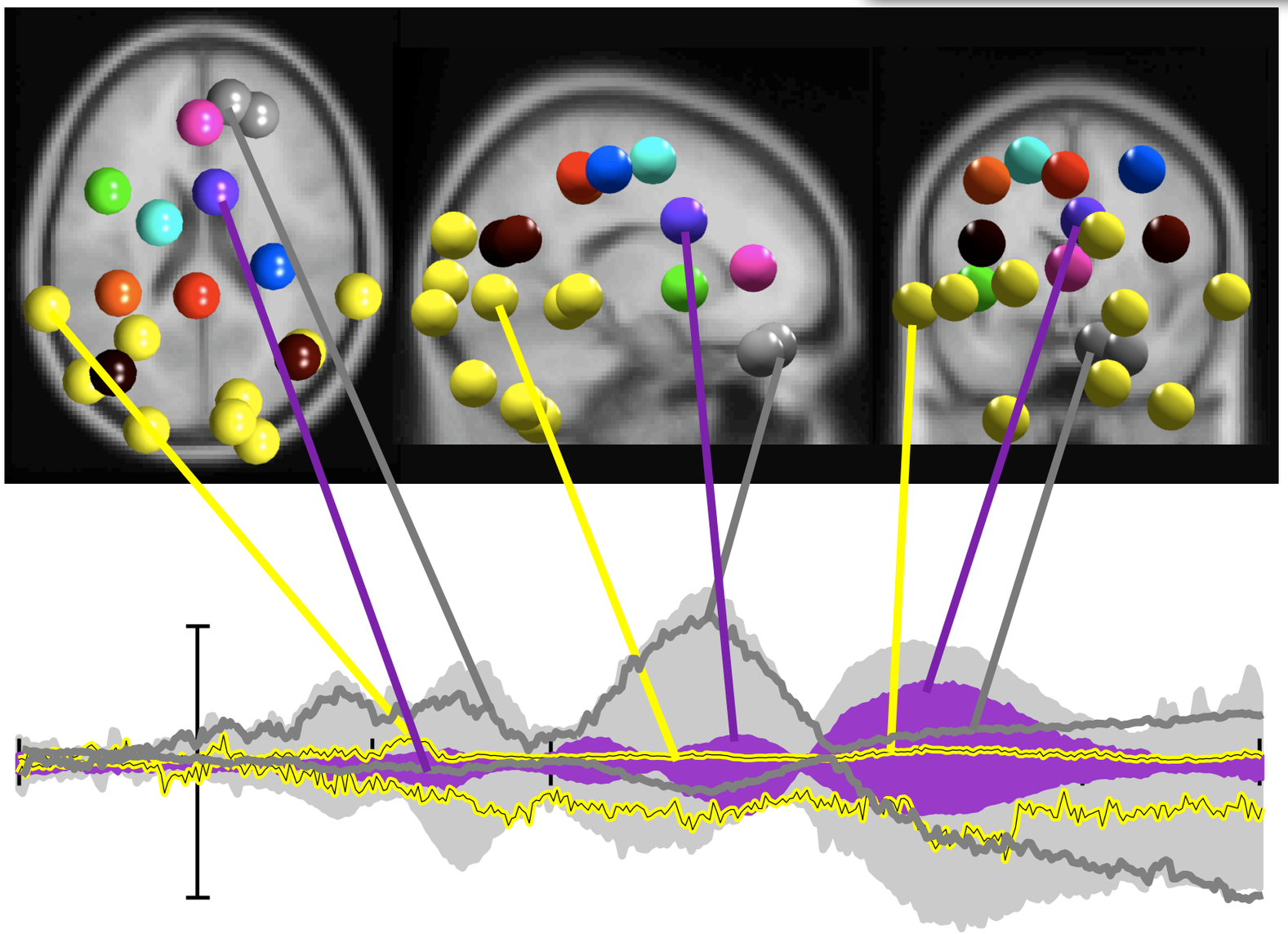
Cognition on the Run



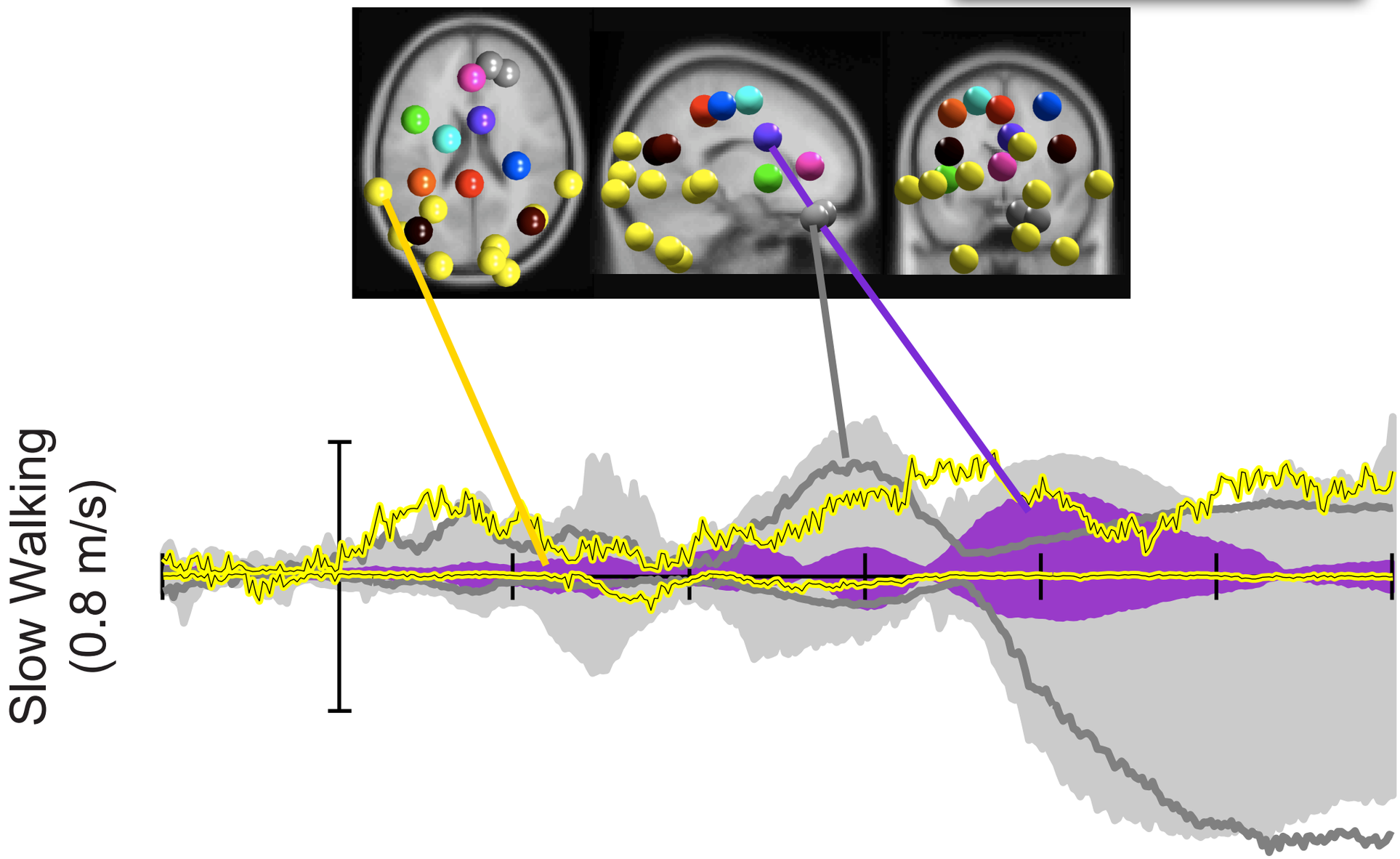
P300 while Standing, Walking and Running



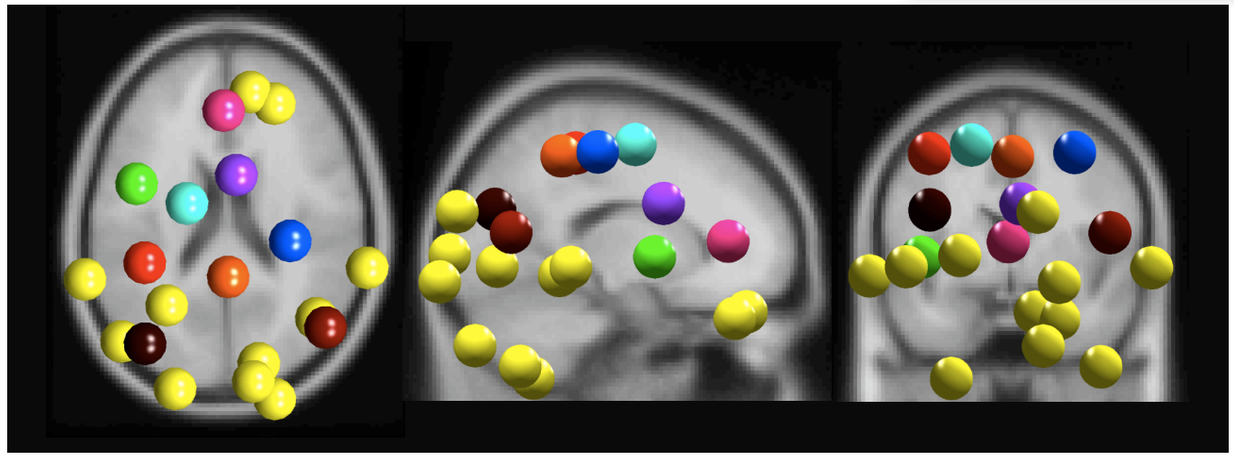
P300 Contribution of Non-Brain Activity to the Surface Potential

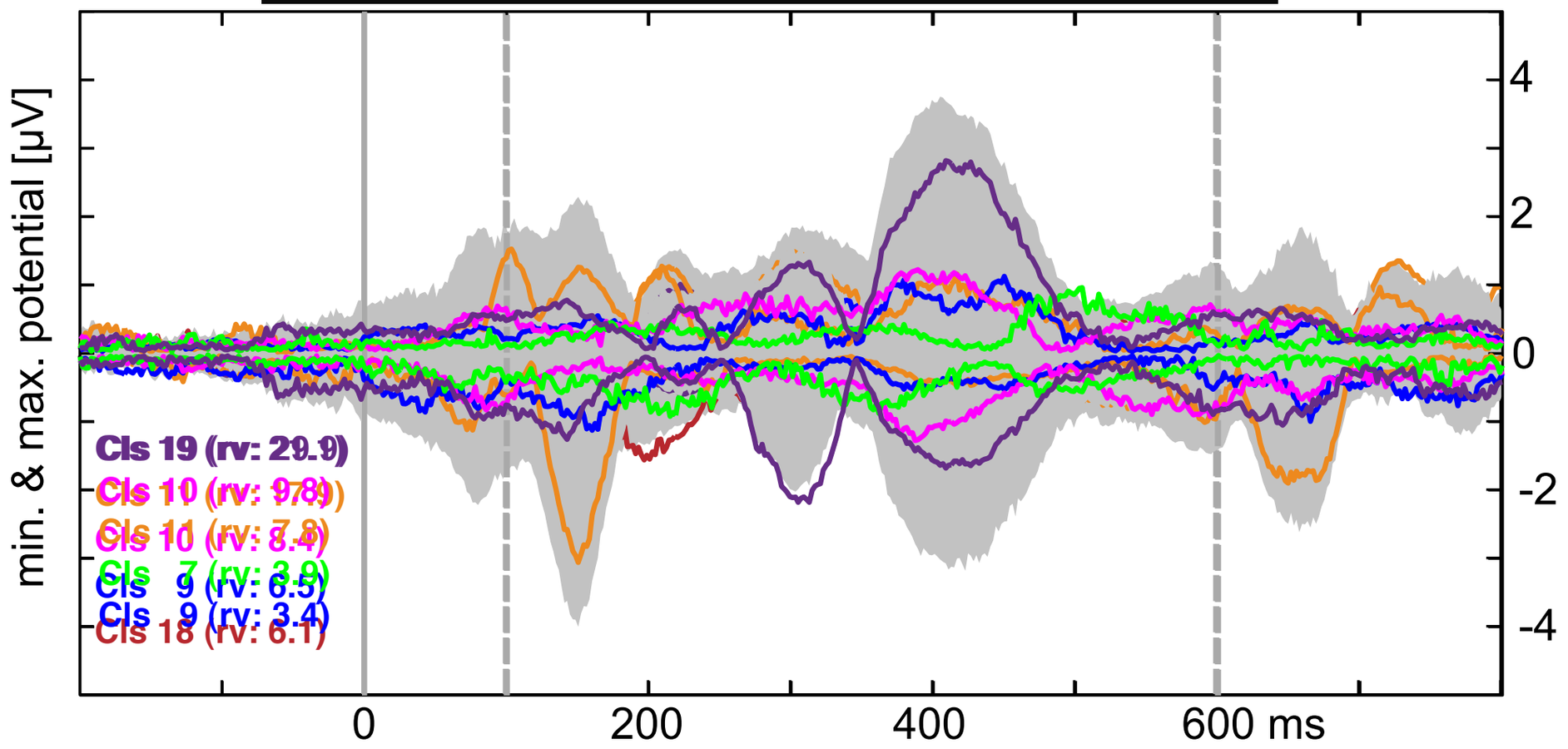


Contribution of Non-Brain Activity to the Surface Potential

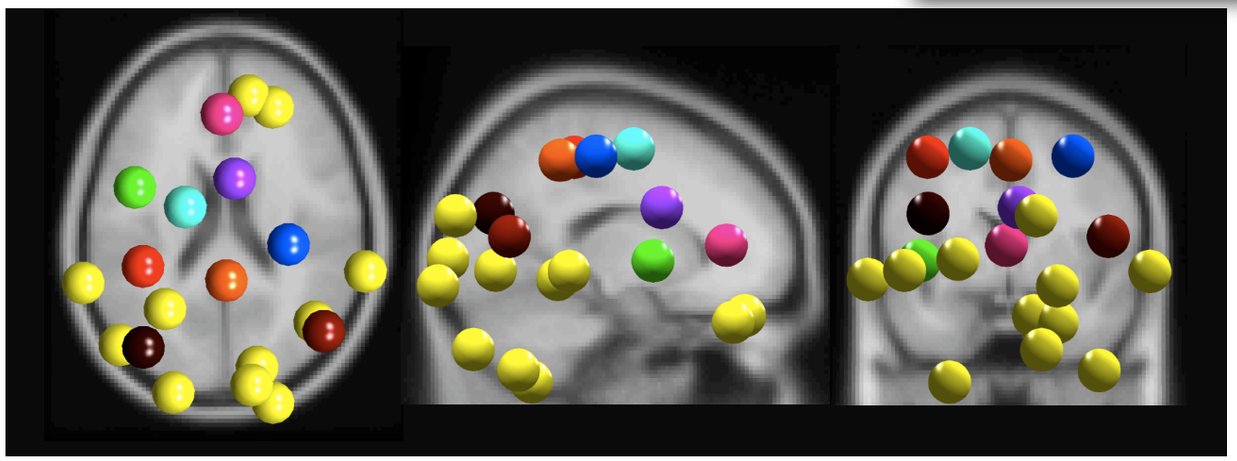


P300 while Standing

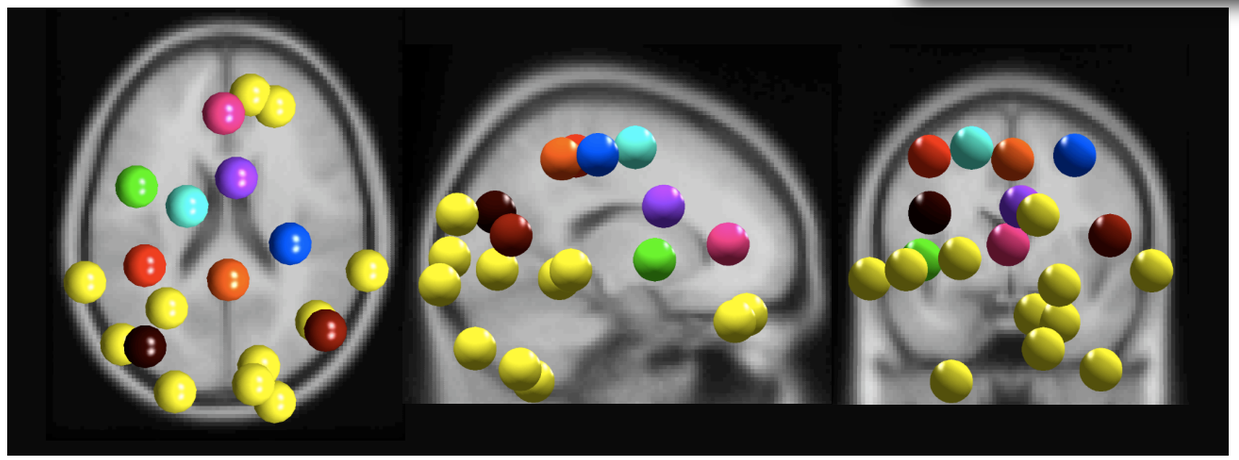


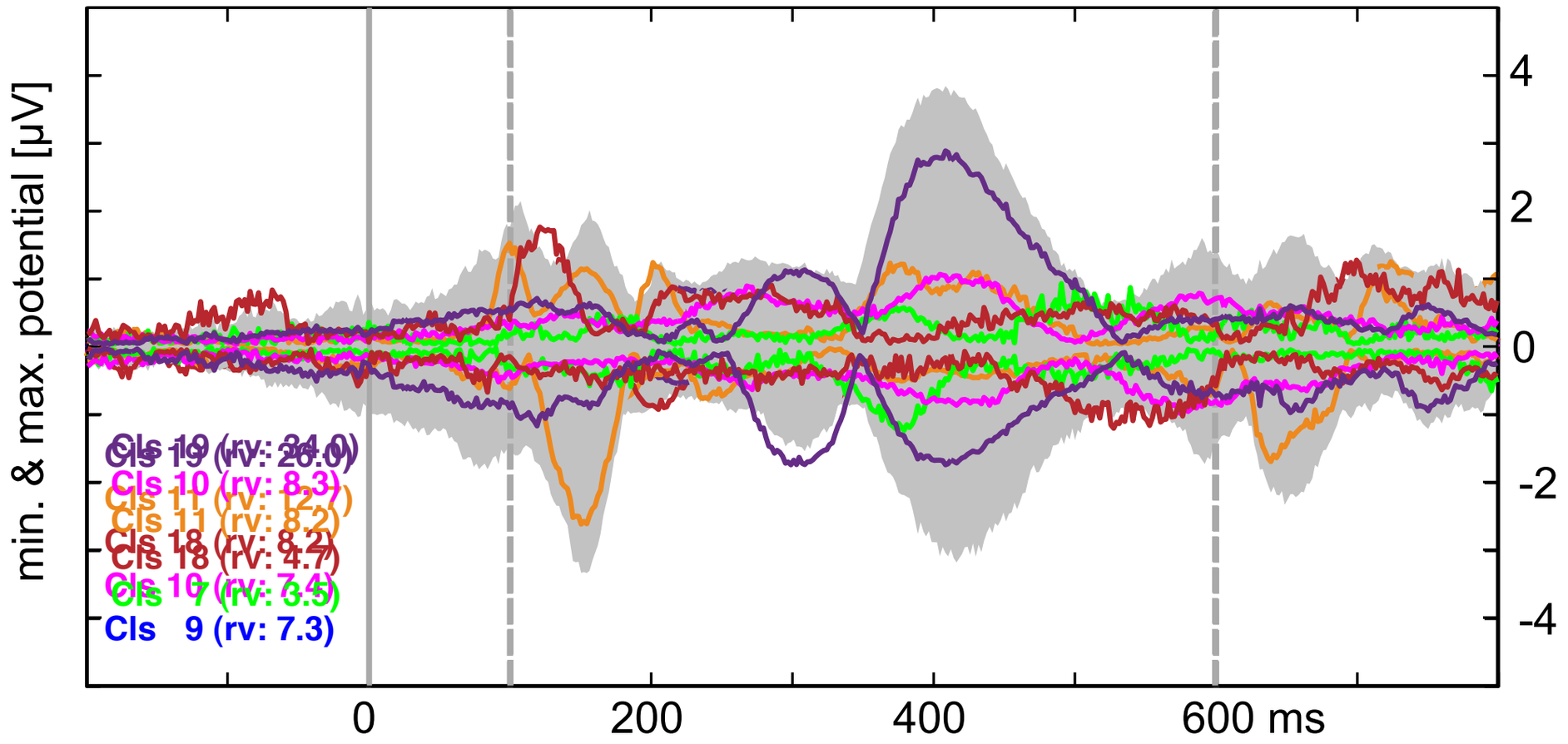


P300 while Slow Walking (0.8 m/s)

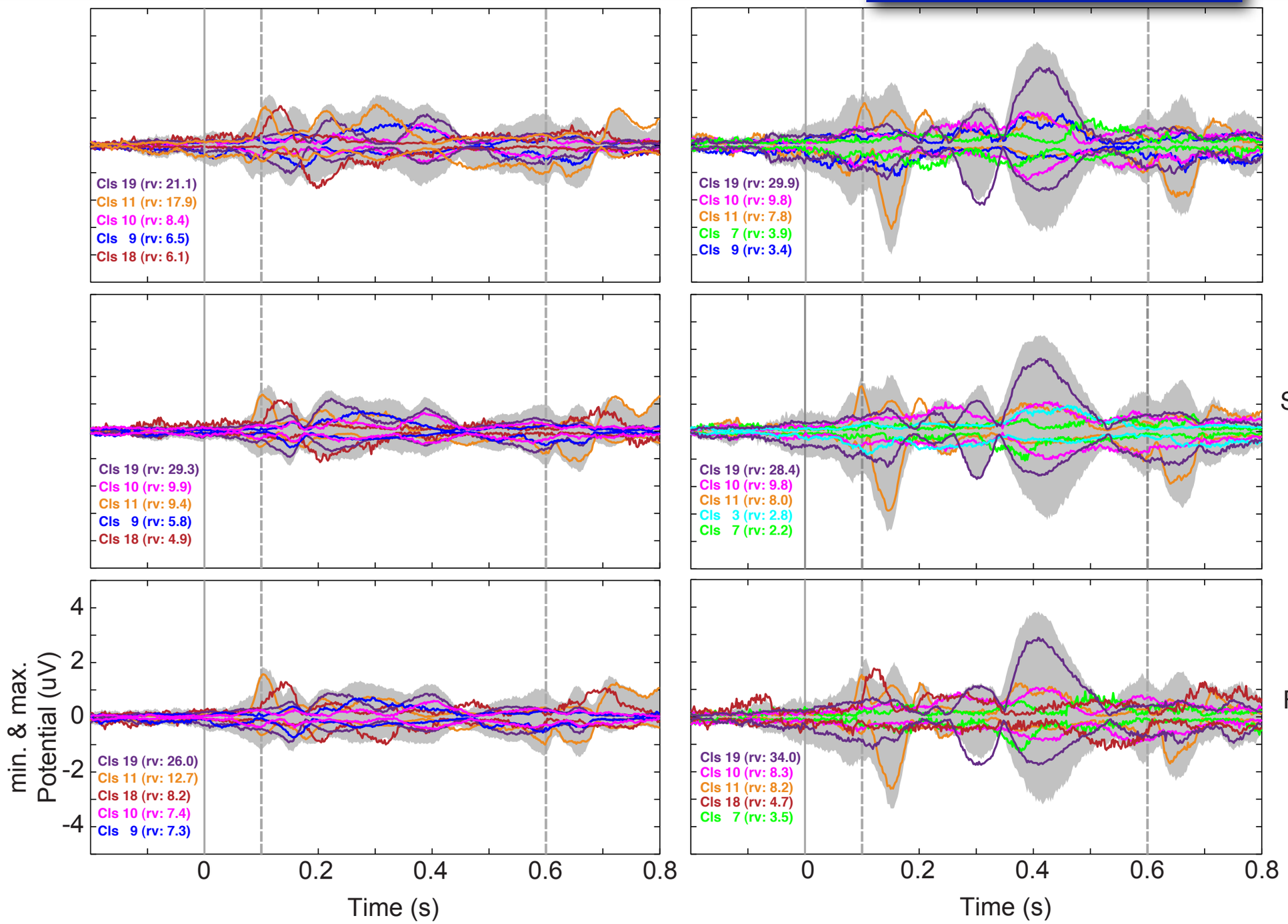


P300 while Fast Walking (1.2 m/s)

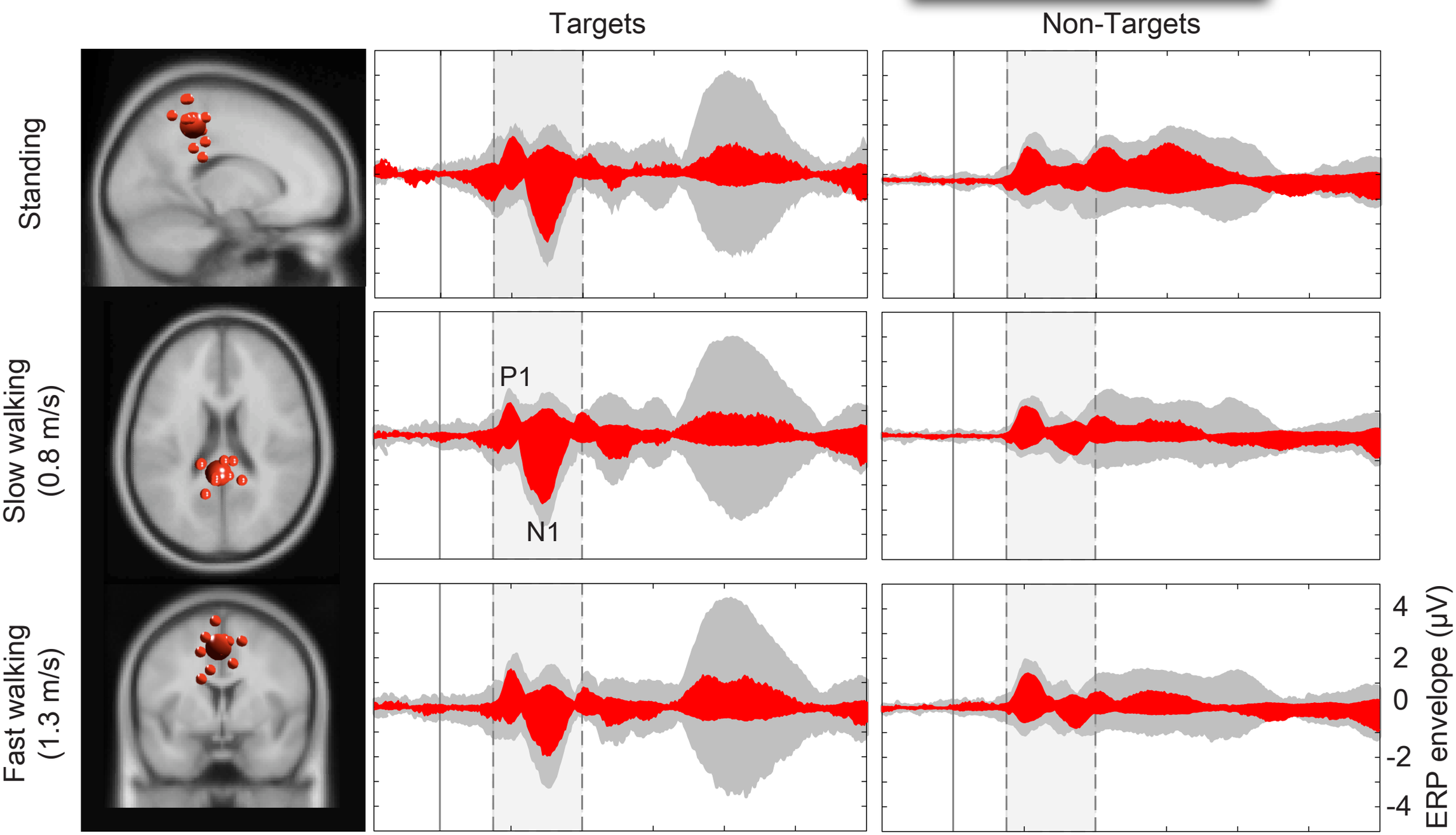




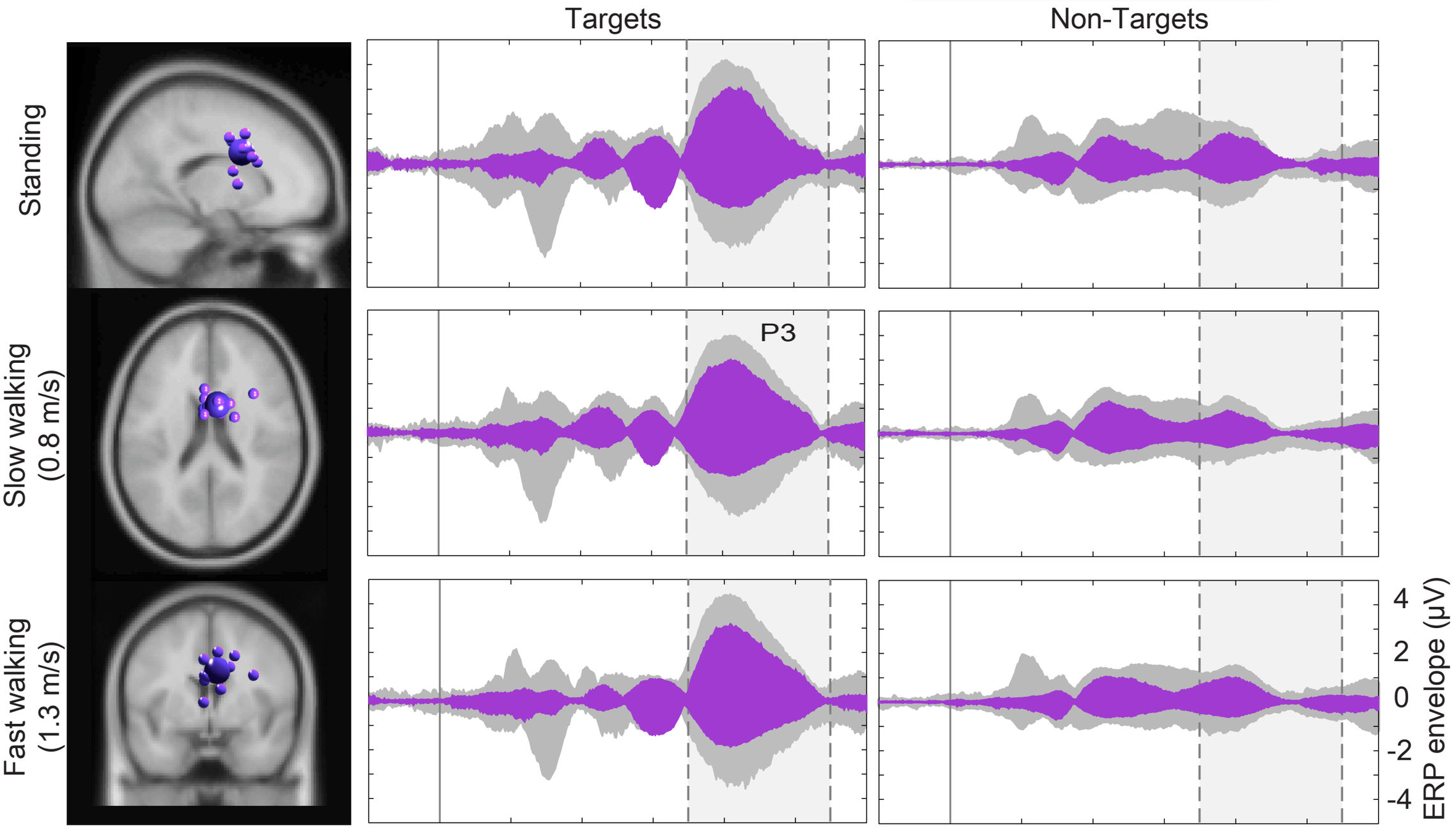
Reliable Reconstruction of a Late Positive Complex



Reliable Reconstruction of a Late Positive Complex



Reliable Reconstruction of a Late Positive Complex



Discussion

- First (pilot) studies clearly demonstrate that we are able to record and analyze cognitive processes during active motor behavior of subjects.
  - Restrictions apply to excessive movements that are associated with cable sway.
  - Future wireless technology is likely to overcome these restrictions.
- MoBI demonstrates that the timing of movements and/or different phases of spatially extended movement is essential and reflected in brain dynamics.

Discussion

- Future studies need to:
  - extend data analysis including head models that integrate muscles in source space,
  - add recordings of eye movements for integrated analysis,
  - make use of developments in data-driven signal analyses to gain insights into the relation of
    - active motor behavior and brain dynamics,
    - identify levels of comparison for different data models.

MOBILE B
IMAGING

Existing brain-imag
they work only when
still. Now University
tive neuroscientist S
system using electro
isolate and record br
the body while the w

The EEG cap bea
electrical activity pr
brain. Chips on the
bodysuit ❸ emit inf
movements. Infrare
these points of light

Software integrat
reveal which parts o
Until now, "no one h
dynamics underlying ordinary activities, because no one has had the technology and the analysis software," Makeig says. Early experiments have already shown that a surprisingly large portion of the cerebral cortex is engaged in even the simplest actions, such as reaching out to touch an object. **Eliza Strickland**