

# Primary visual consciousness of qualia: the neural basis

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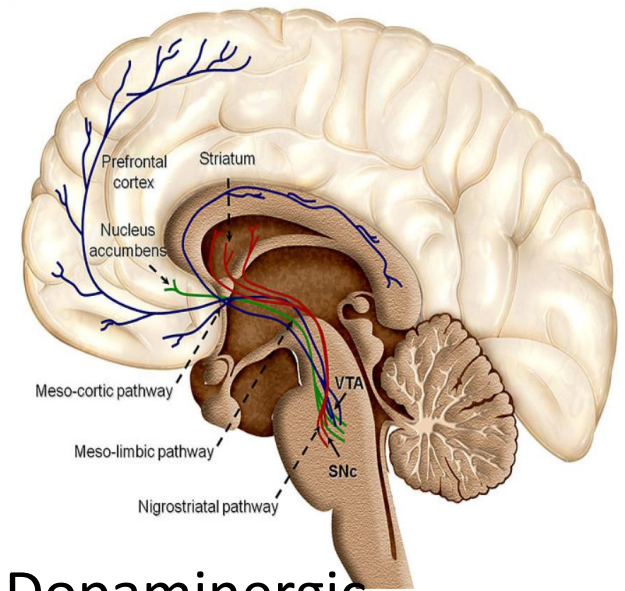
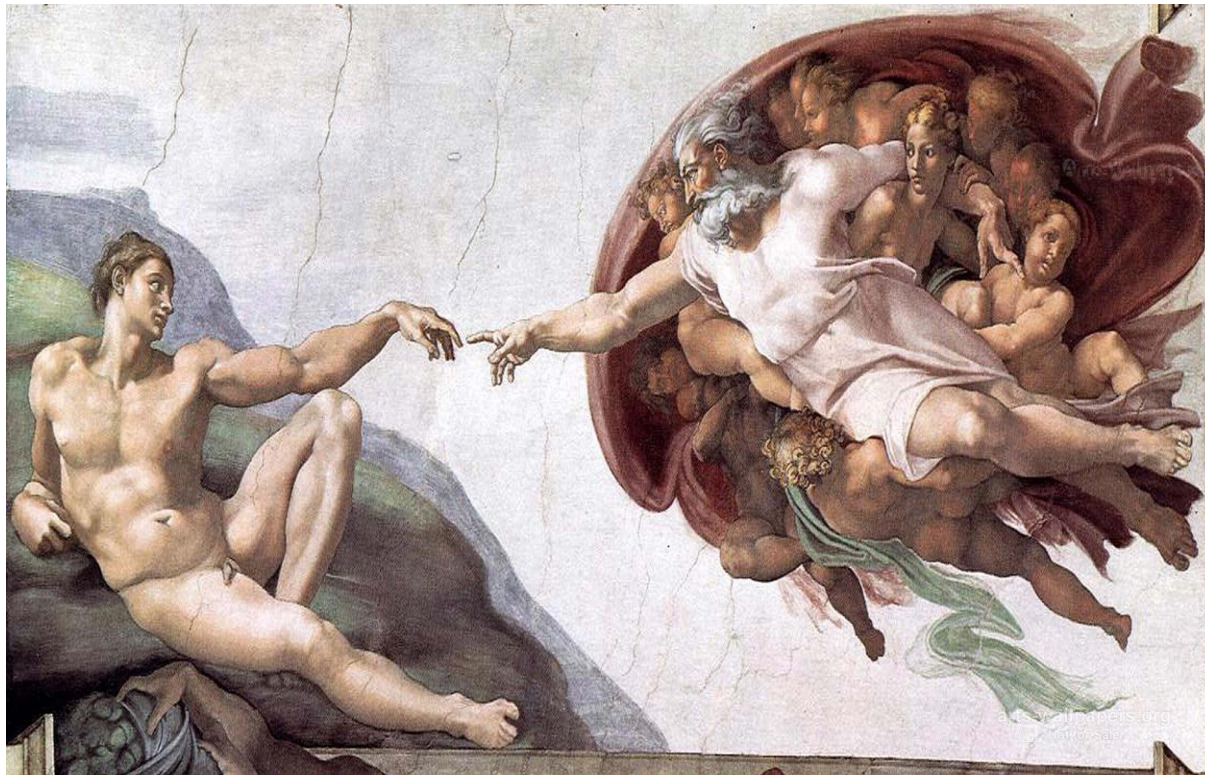
**SAPIENZA**  
UNIVERSITÀ DI ROMA

# Primary (phenomenal) consciousness vs. non conscious stimulus processing

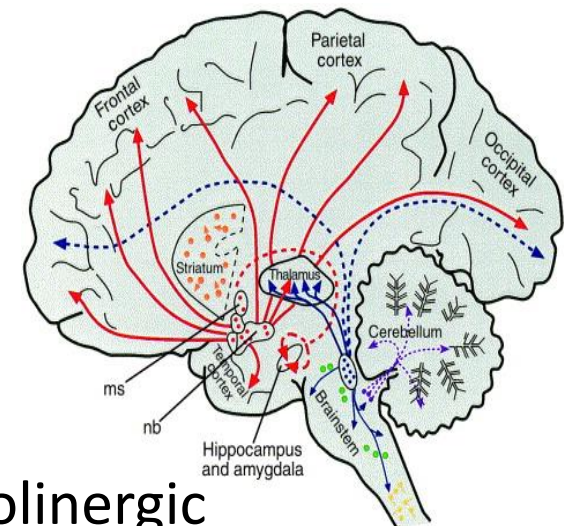


In the figure, **primary consciousness** is related to reading the newspaper article, while non conscious processes elaborate walking people stimulus. **Qualia** are defined as individual instances of subjective, conscious experience

# What markers of **ascending reticular activating** systems, vigilance, and consciousness?



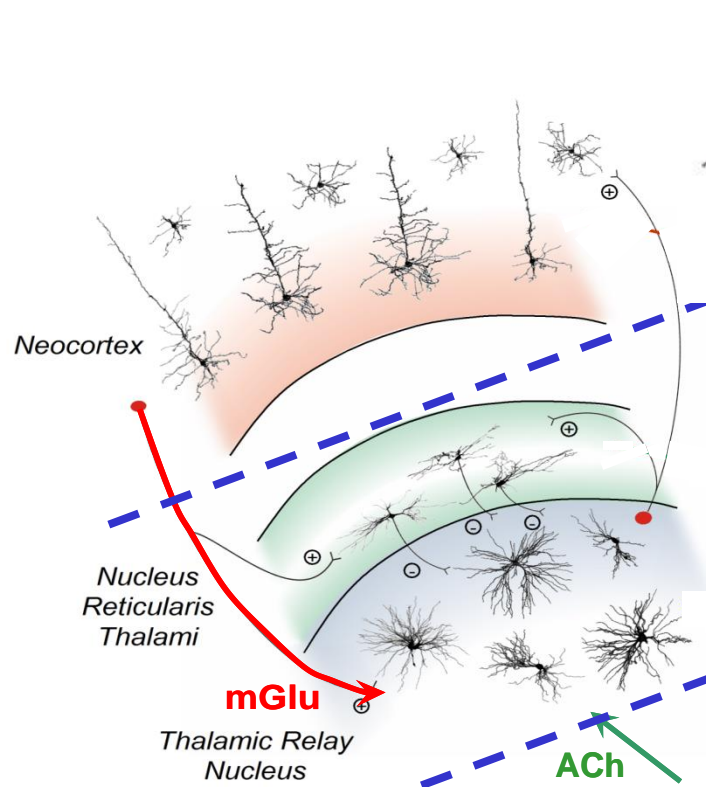
Dopaminergic



Cholinergic

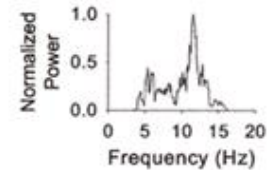
Sistine Chapel ceiling (1508 – 1512; Michelangelo); Meshberger, 1990 - JAMA

# On-going EEG alpha rhythms may reflect “thalamocortical synchronizing capacity” in humans and ... mice



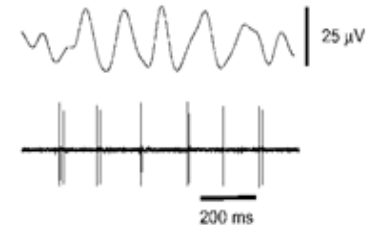
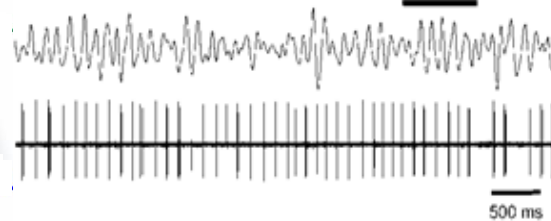
## Visual cortex

$\alpha$  Waves (relaxed wakefulness)



## Thalamus (lateral geniculate nucleus)

$\alpha$  Waves (150  $\mu$ M trans-ACPD)

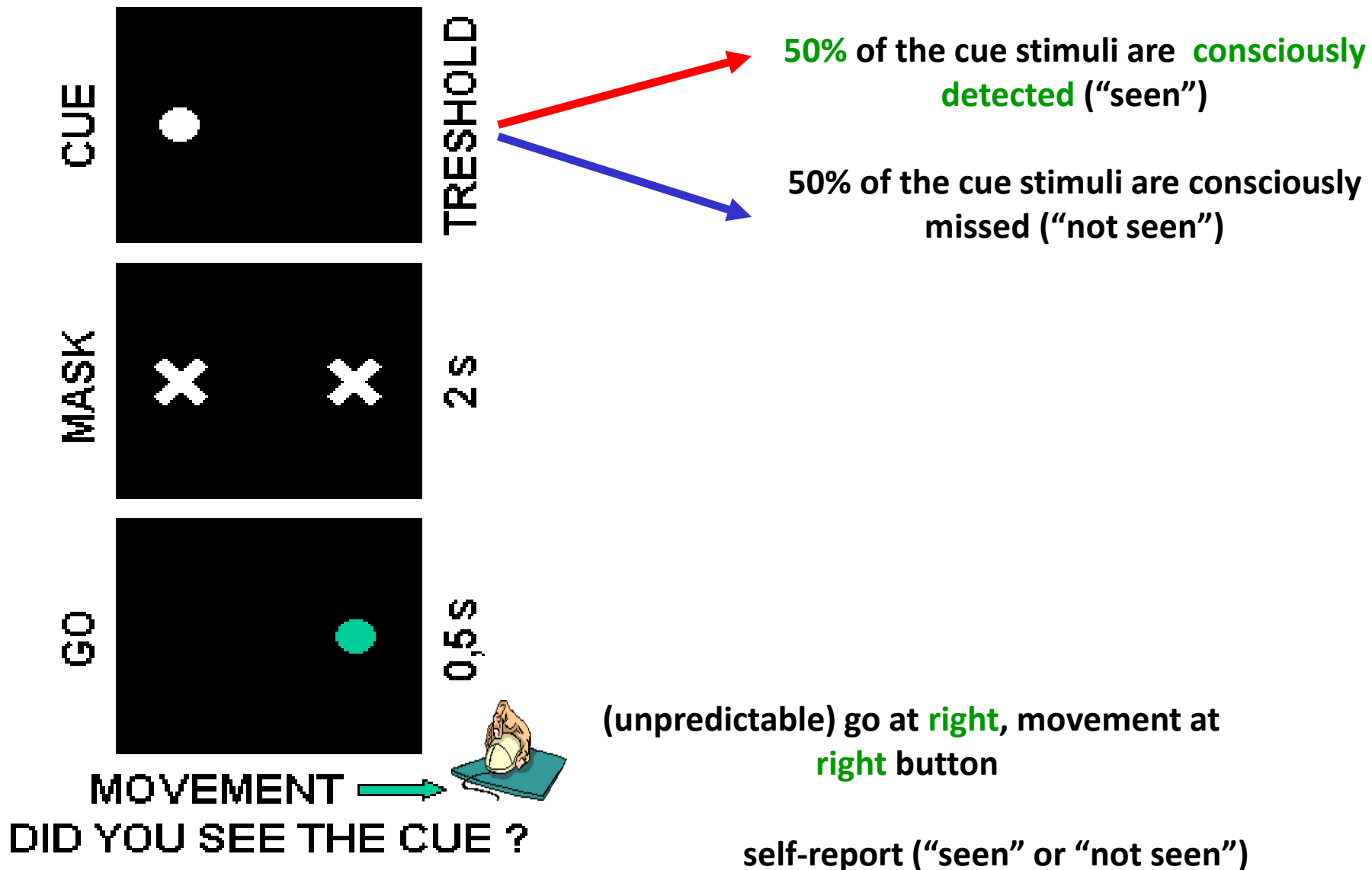


Alpha rhythms appear after the in-vitro stimulation of (1) glutamatergic metabotropic receptors with aminocyclopentane dicarboxylic acid, ACPD (**mGlu**) and (2) metabotropic receptors with Acetylcholine (**ACh**)

Lorincz ML, Kékesi KA, Juhász G, Crunelli V, Hughes SW. Temporal framing of thalamic relay-mode firing by phasic inhibition during the alpha rhythm. *Neuron*. 2009 Sep 10;63(5):683-96. doi: 10.1016/j.neuron.2009.08.012.

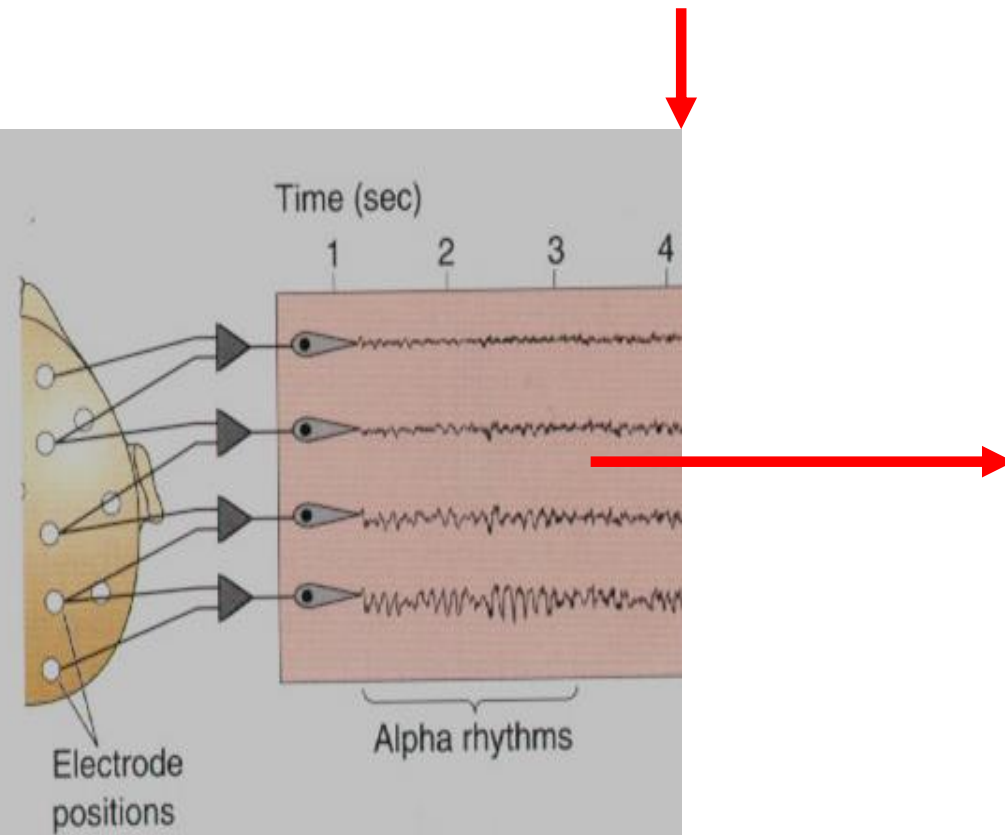


**Primary consciousness of visuo-spatial functions can be experimentally studied giving visual stimuli at **threshold** time (passive view)**

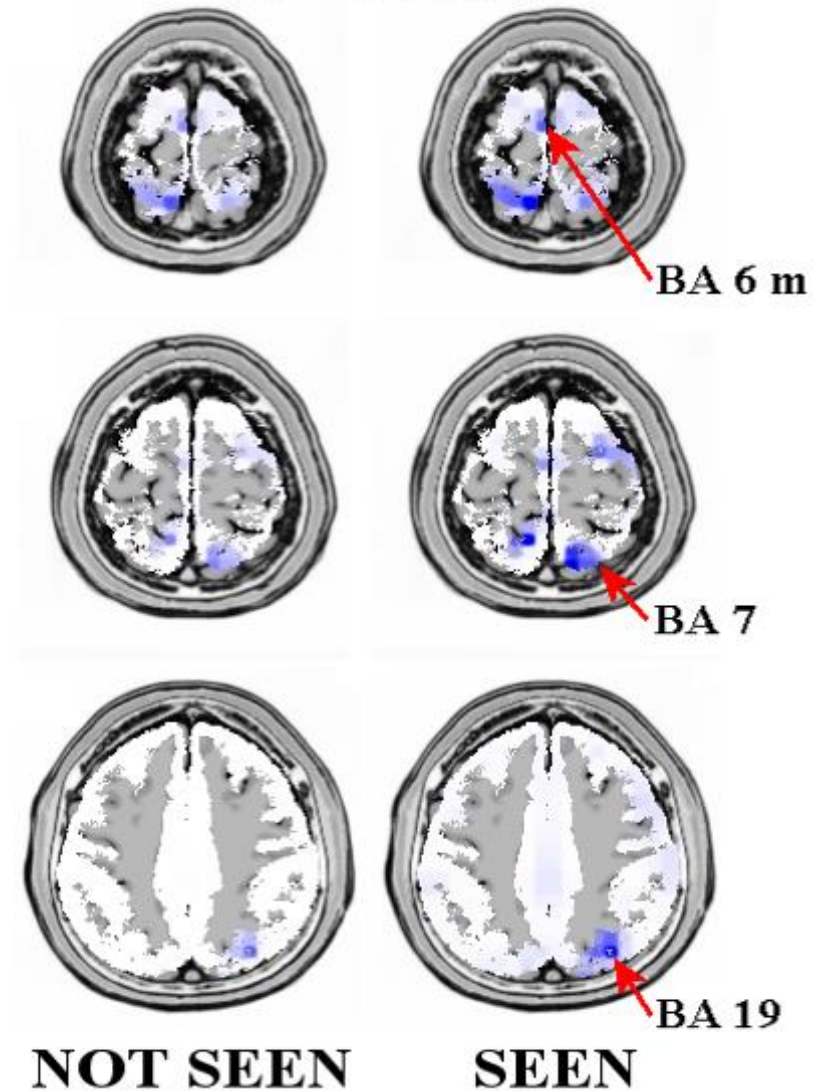


# Occipital and posterior parietal sources of pre-stimulus alpha rhythms are related to **consciousness of visuo-spatial stimuli**

Cue stimulus onset



LORETA sources  
**ALPHA 1**



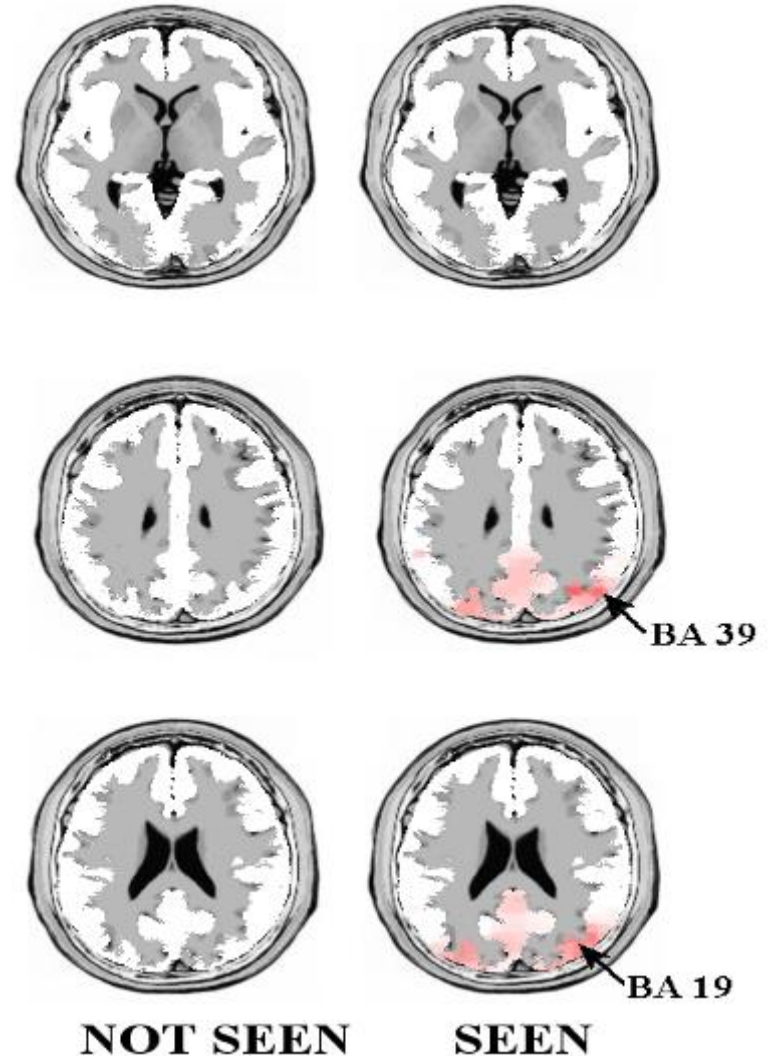
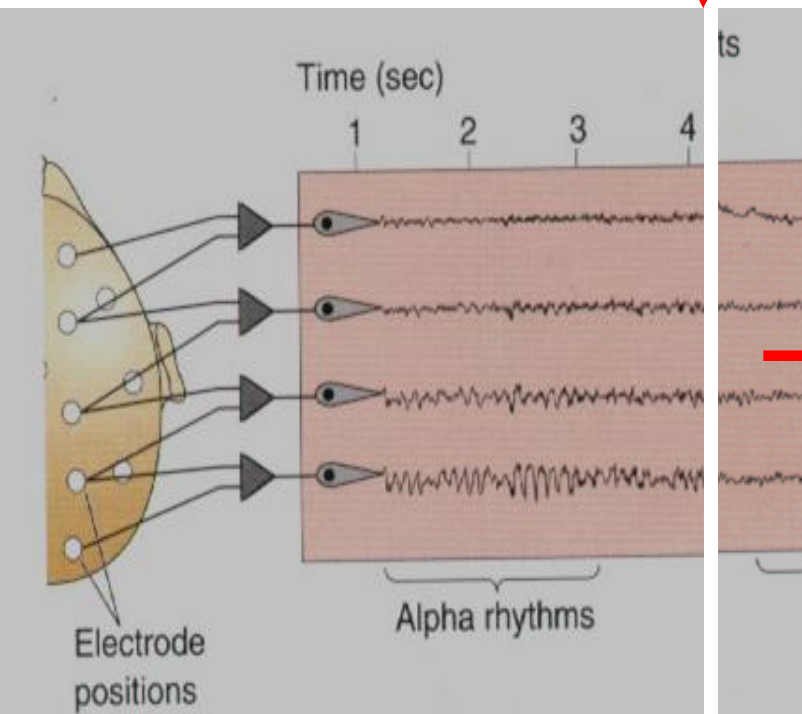
Babiloni C, Vecchio F, Bultrini A, Luca Romani G, Rossini PM. Pre- and poststimulus alpha rhythms are related to conscious visual perception: a high-resolution EEG study. *Cereb Cortex*. 2006a Dec;16(12):1690-700.

# Occipital and posterior parietal sources of alpha event-related desynchronization (ERD) are related to **consciousness** of visuo-spatial stimuli

Cue stimulus onset

LORETA sources

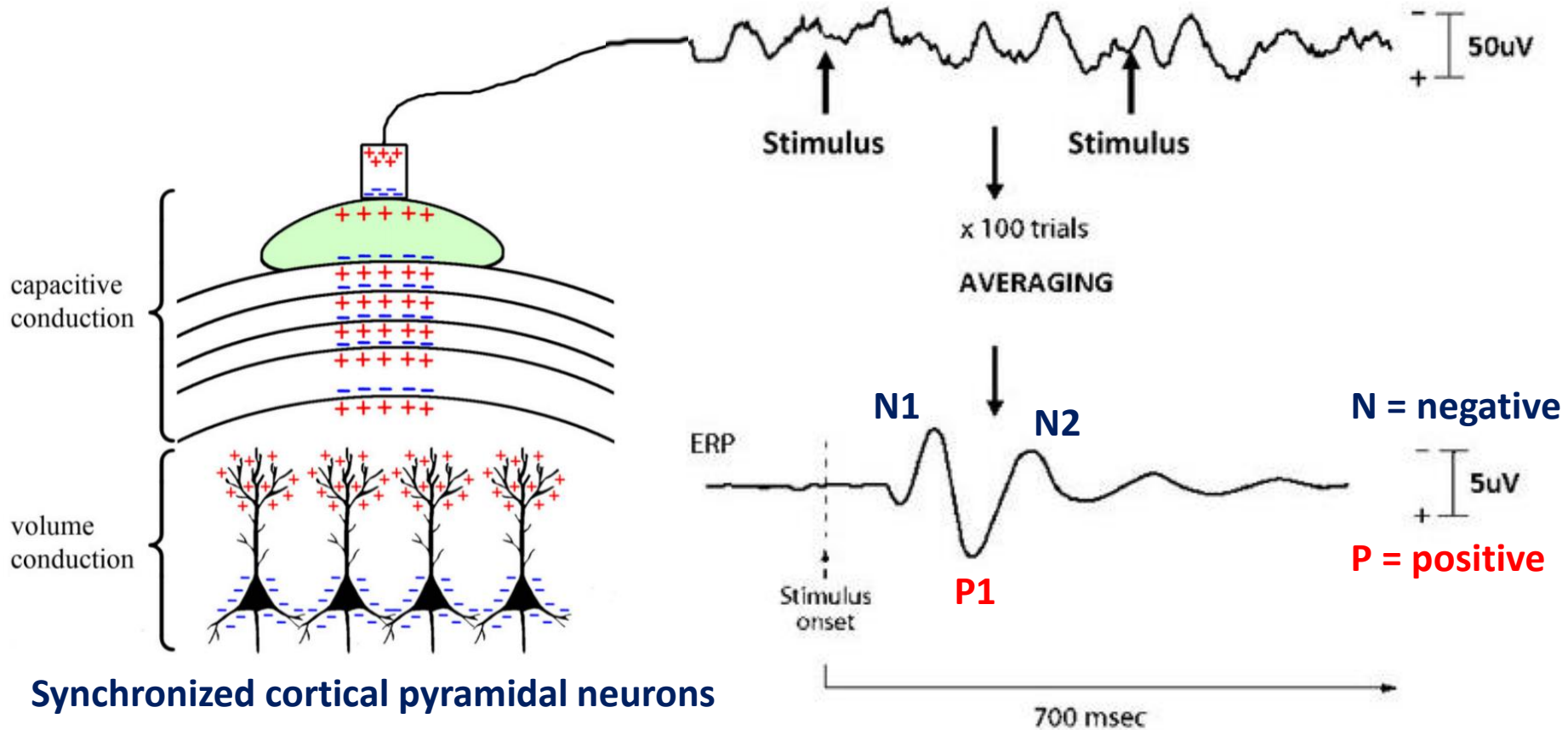
ALPHA 3



Babiloni C, Vecchio F, Bultrini A, Luca Romani G, Rossini PM. Pre- and poststimulus alpha rhythms are related to conscious visual perception: a high-resolution EEG study. *Cereb Cortex*. 2006a Dec;16(12):1690-700.

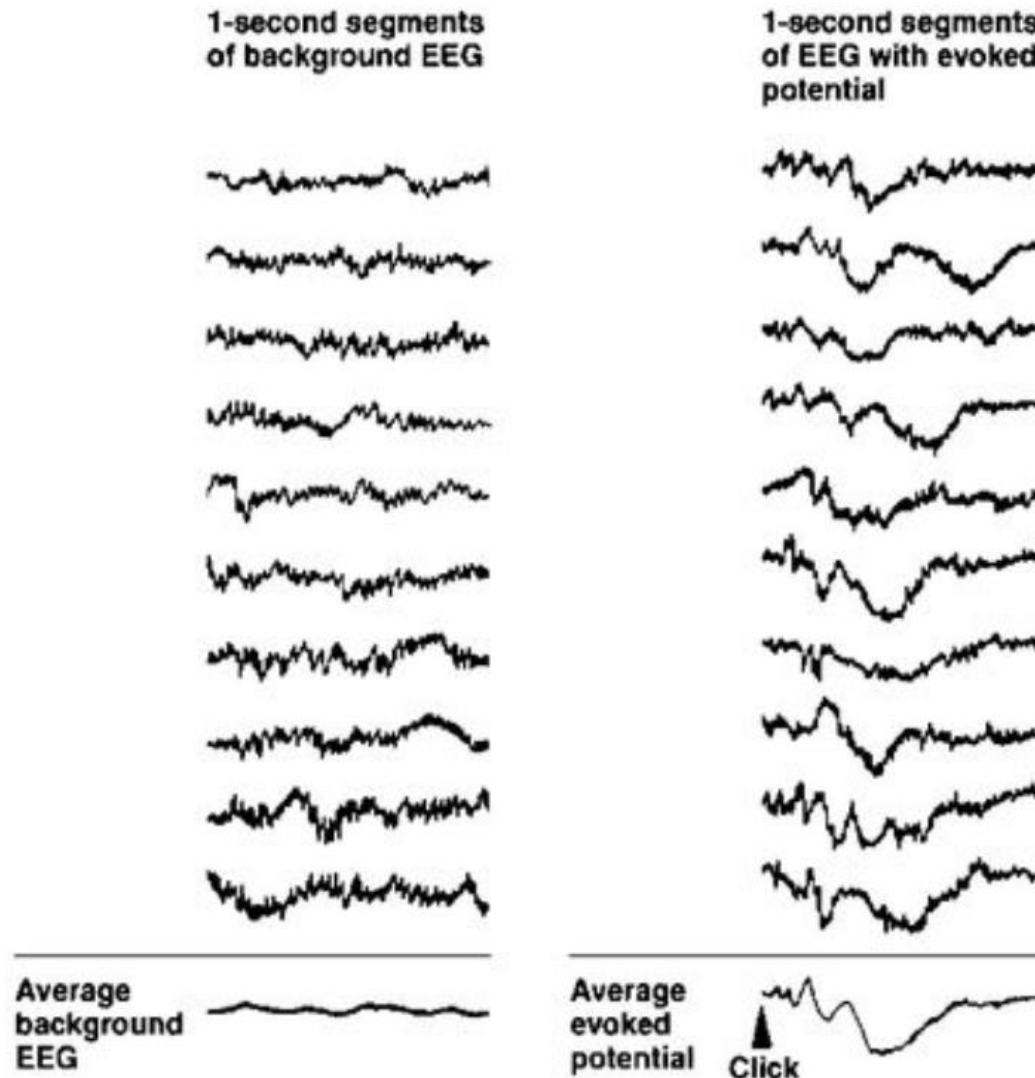
# Averaged event-related potentials (ERPs) may reflect the spatial and temporal summation across volume conduction of post-synaptic potentials of “synchronized” cortical pyramidal neurons

1 stimulus + ongoing EEG recording = 1 trial or epoch





# Event-related or evoked potentials (ERP/EPs): back-ground EEG rhythms are canceled in the averaging across trials

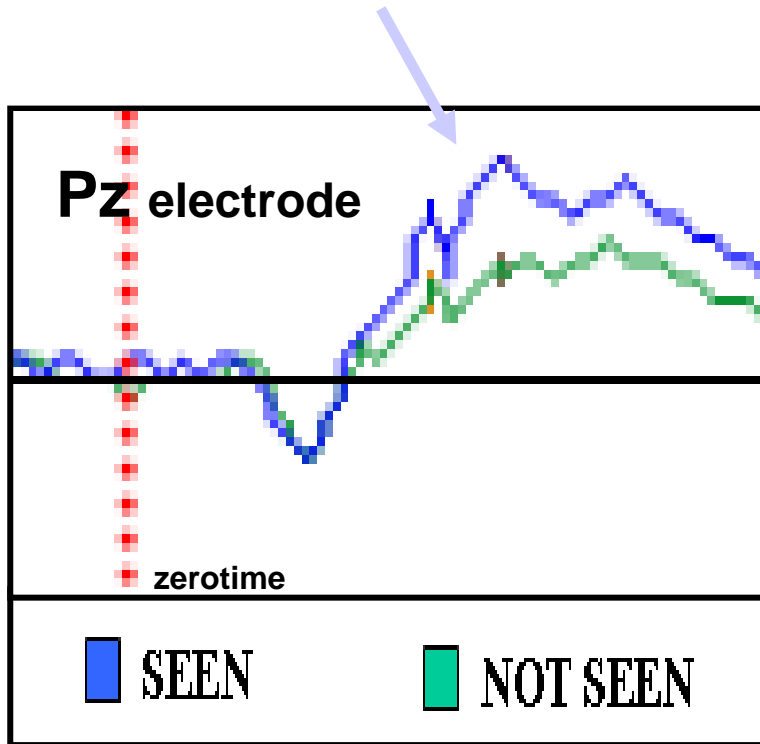


Source: [https://web.cs.dal.ca/~tt/CSCI690611/eeg\\_intro\\_lecture.pdf](https://web.cs.dal.ca/~tt/CSCI690611/eeg_intro_lecture.pdf)

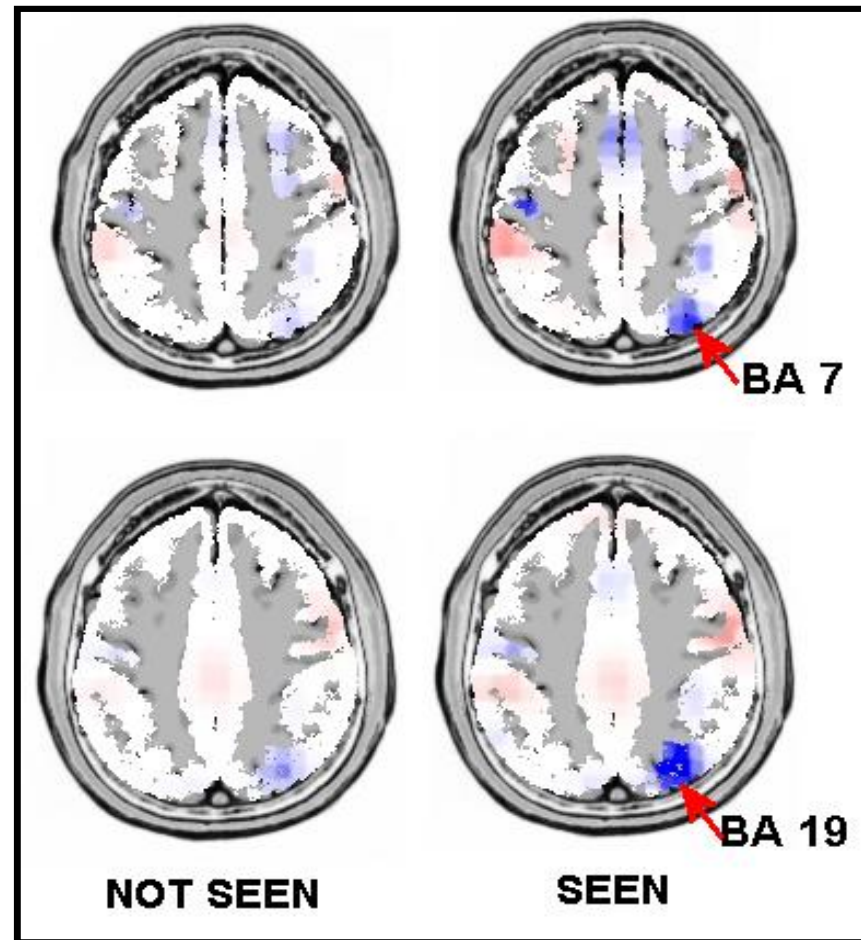
An Introduction to the Event-Related Potential Technique by Steven J. Luck

# Occipital and posterior parietal sources of P3 are related to **consciousness of visuo-spatial stimuli**

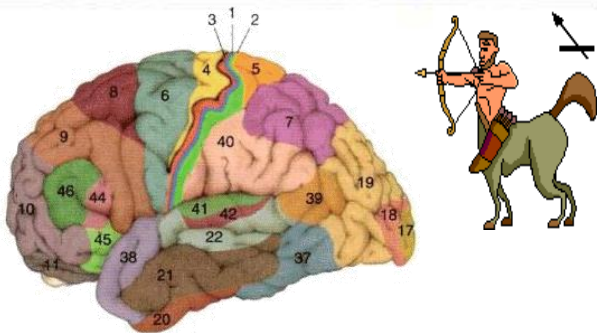
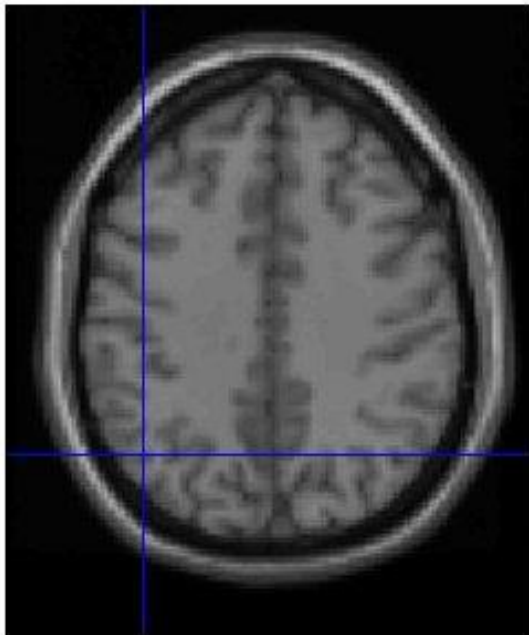
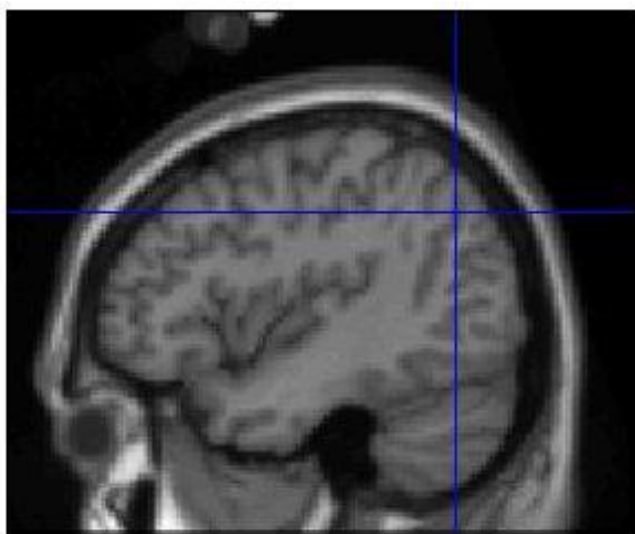
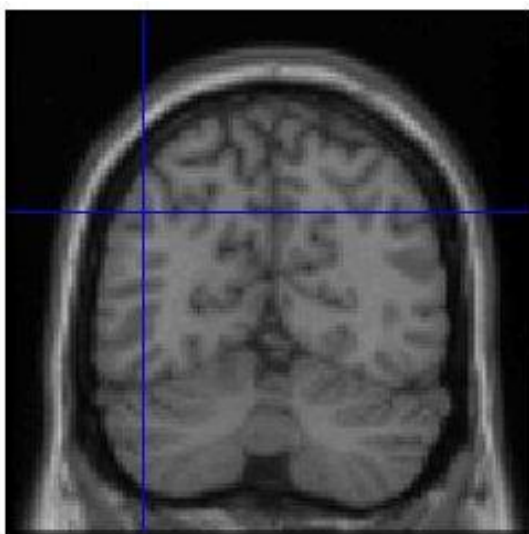
**P3 peak** (about +400 ms post-stimulus)



**LORETA sources**



# Are parietal alpha ERD epiphenomena for visuo-spatial consciousness?



Repetitive transcranial magnetic stimulation (rTMS) over

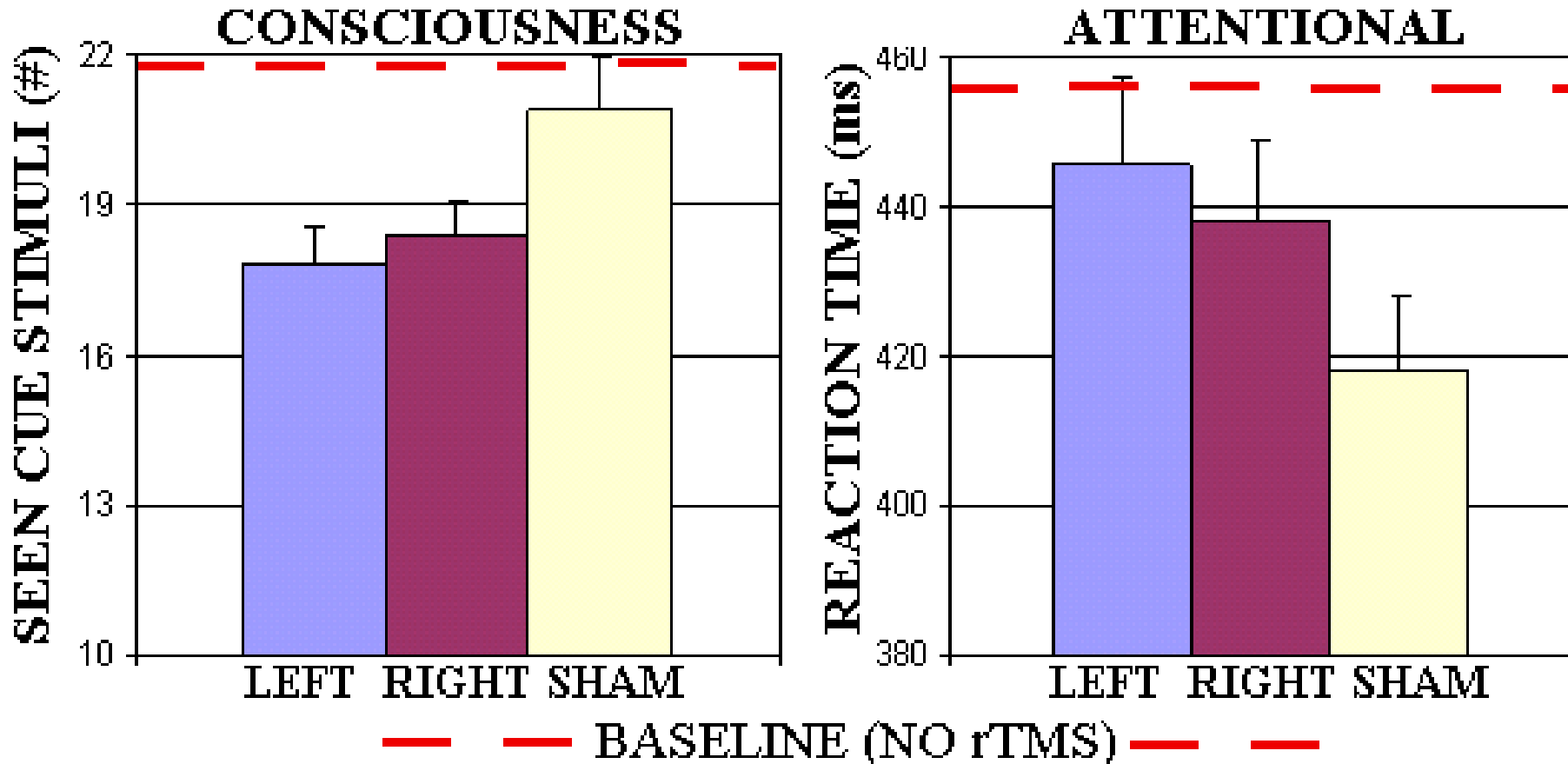
BA 7-39

BA 6 (sham)

Babiloni C, Vecchio F, Rossi S, De Capua A, Bartalini S, Olivelli M, Rossini PM. Human ventral parietal cortex plays a functional role on visuospatial attention and primary consciousness. A repetitive transcranial magnetic stimulation study. *Cereb Cortex*. 2007 Jun;17(6):1486-92.

# Visuo-spatial attention and consciousness are impaired by rTMS in parietal areas showing maximum alpha ERD

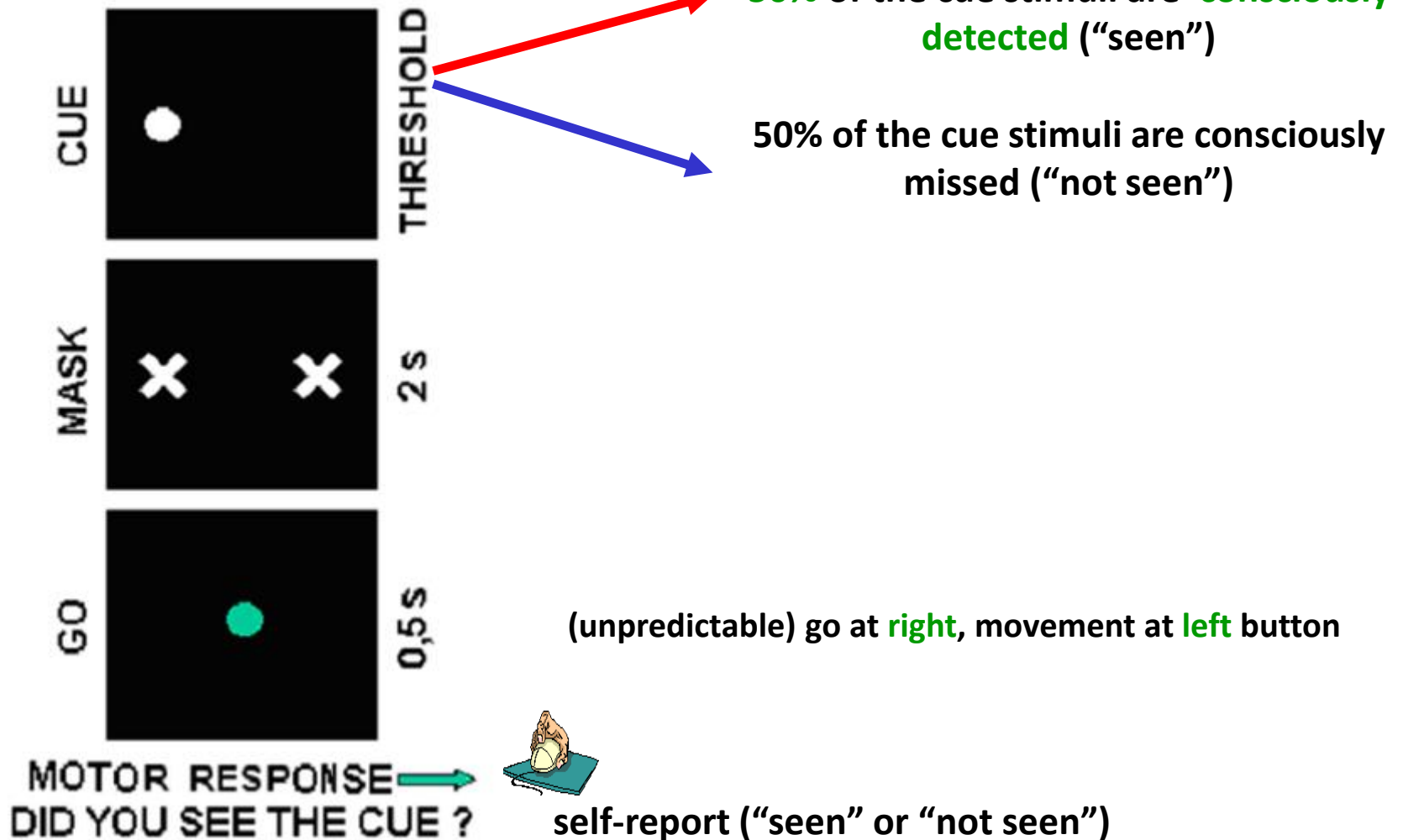
## EFFECT OF rTMS ON INFERIOR PARIETAL CORTEX



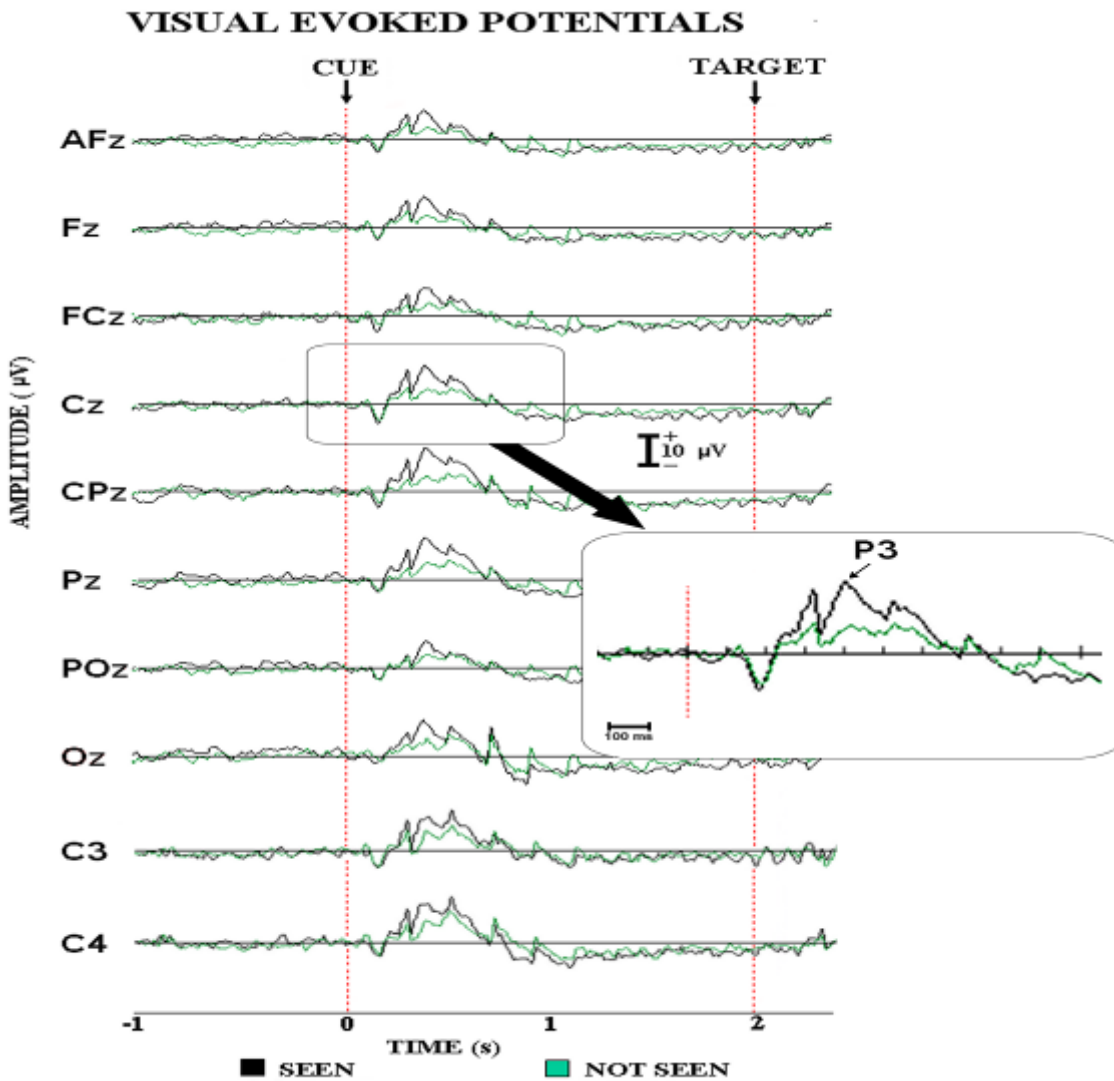


# Primary consciousness of frontal executive functions can be experimentally studied (paradigm of “inverted response”)

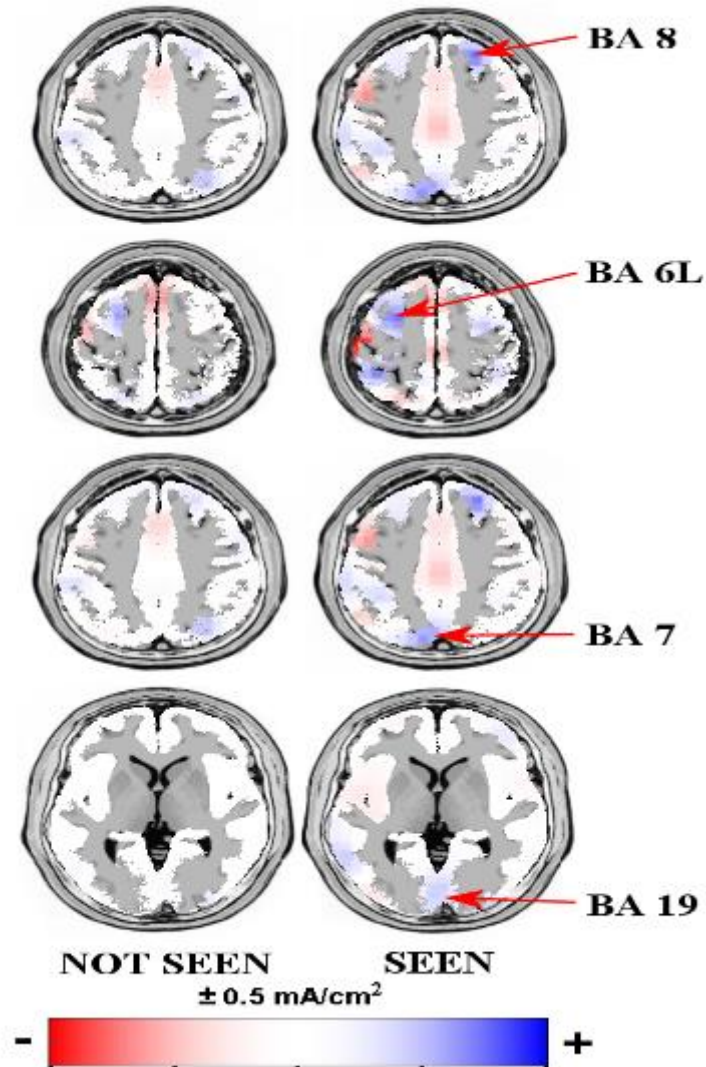
## PARADIGM



# Frontal and parieto-occipital sources of P3 are related to **consciousness** of **visuo-spatial** stimuli during **executive** functions

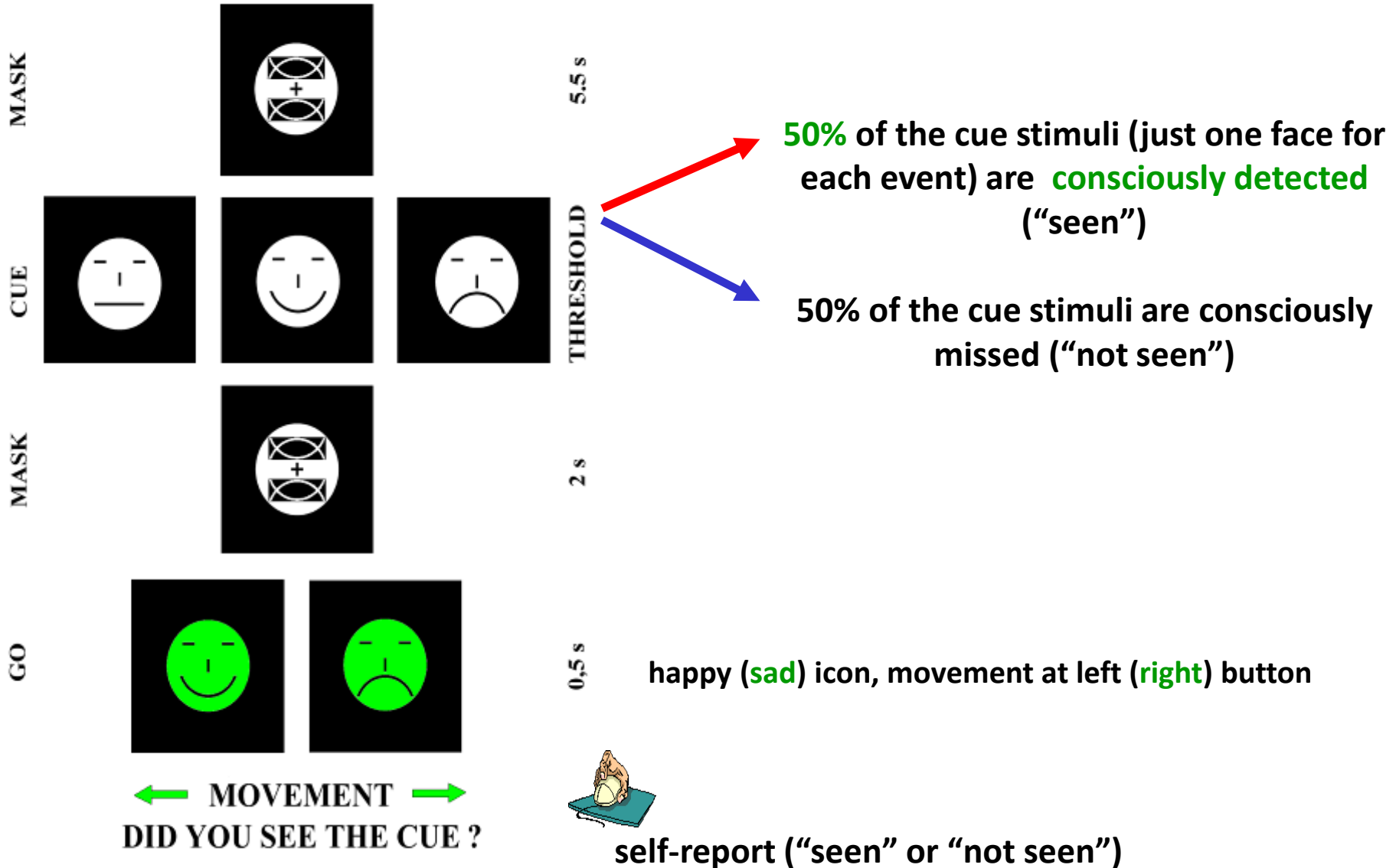


## P3-LORETA CURRENT DENSITY

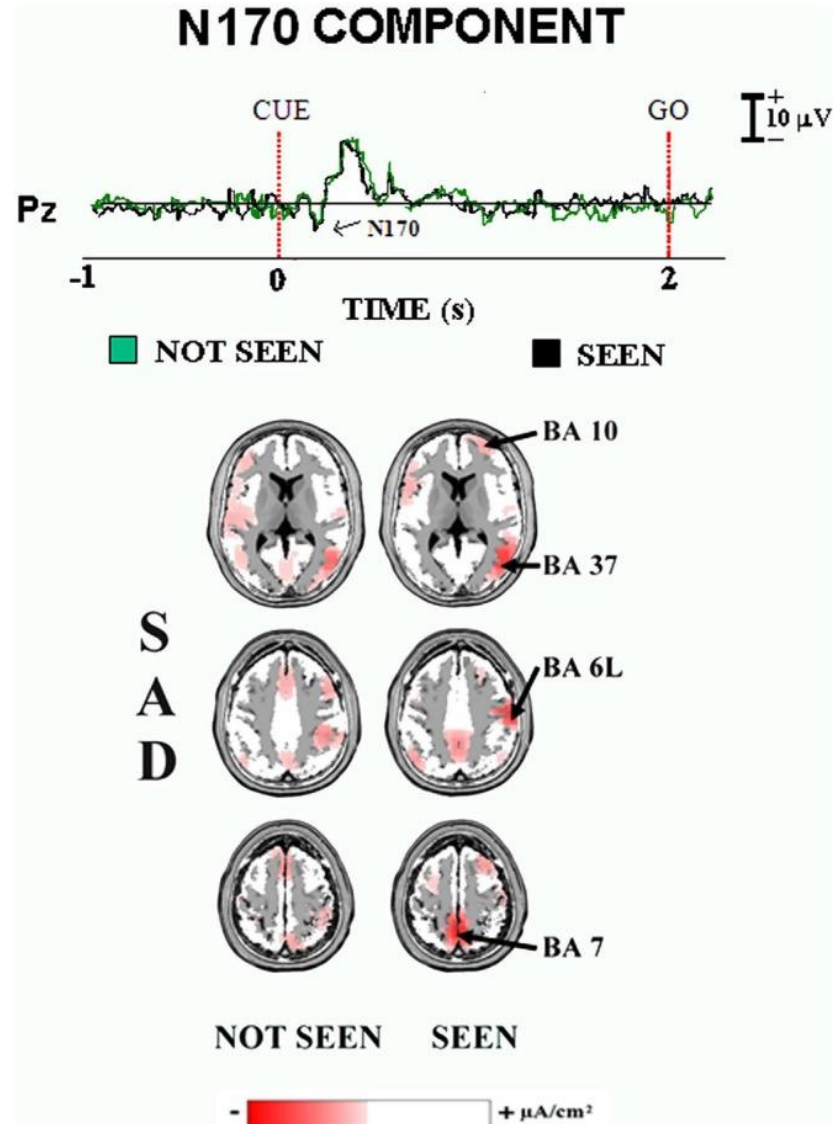


# Primary consciousness of emotional faces can be experimentally studied (passive view)

## PARADIGM



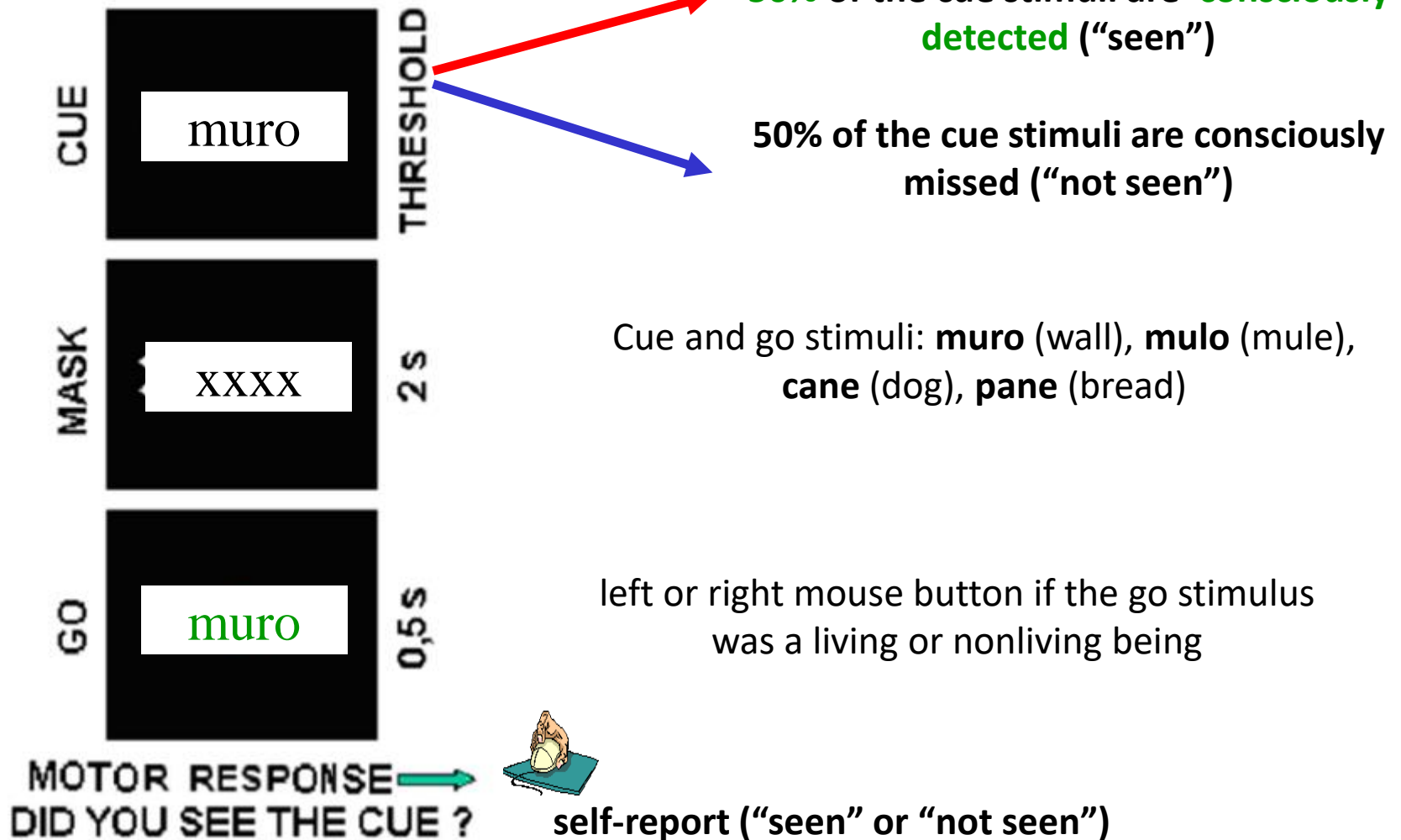
# Frontal and posterior parietal (LORETA) sources of N170 are related to consciousness of emotional sad faces



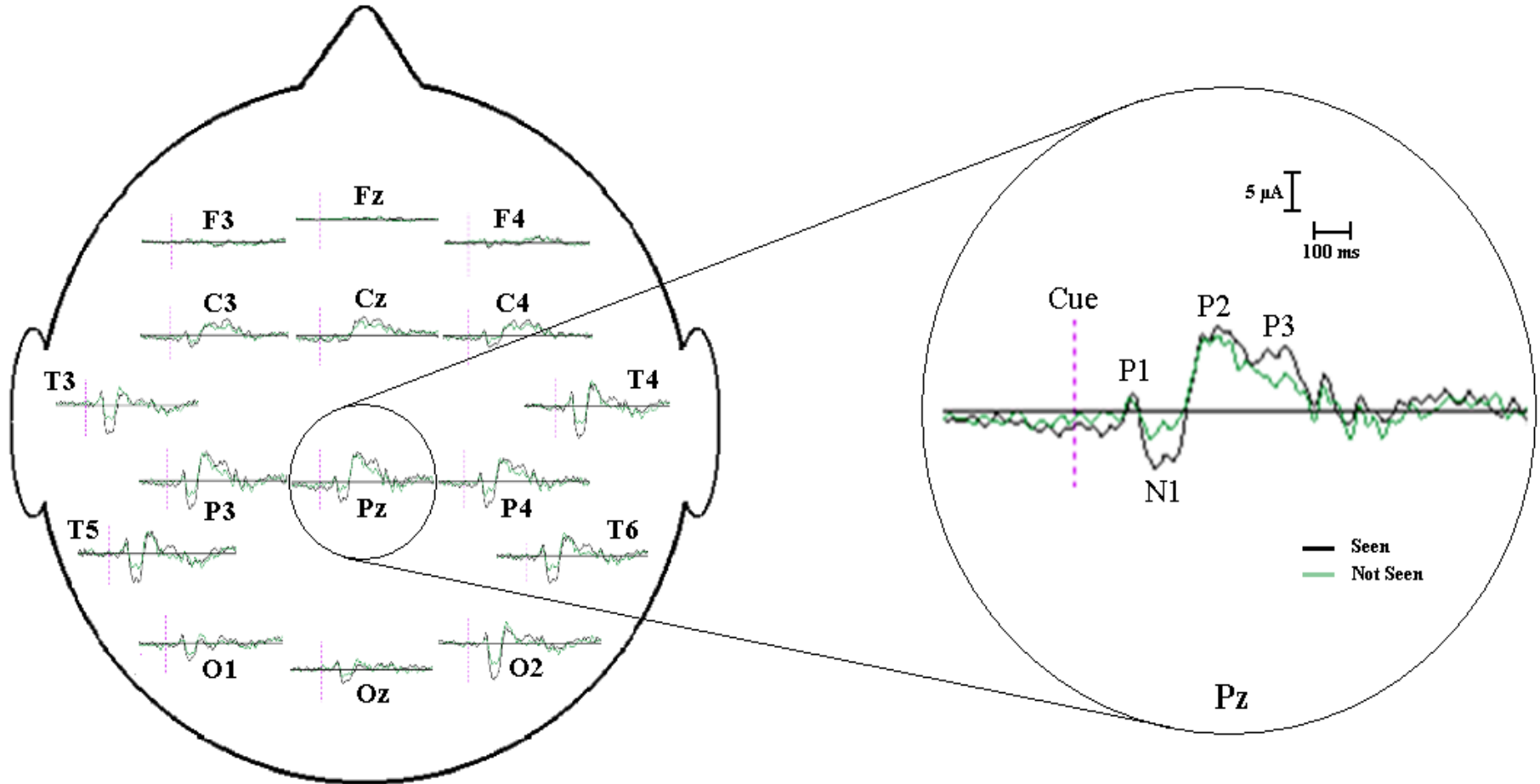


# Primary consciousness of words can be experimentally studied (passive view)

## PARADIGM

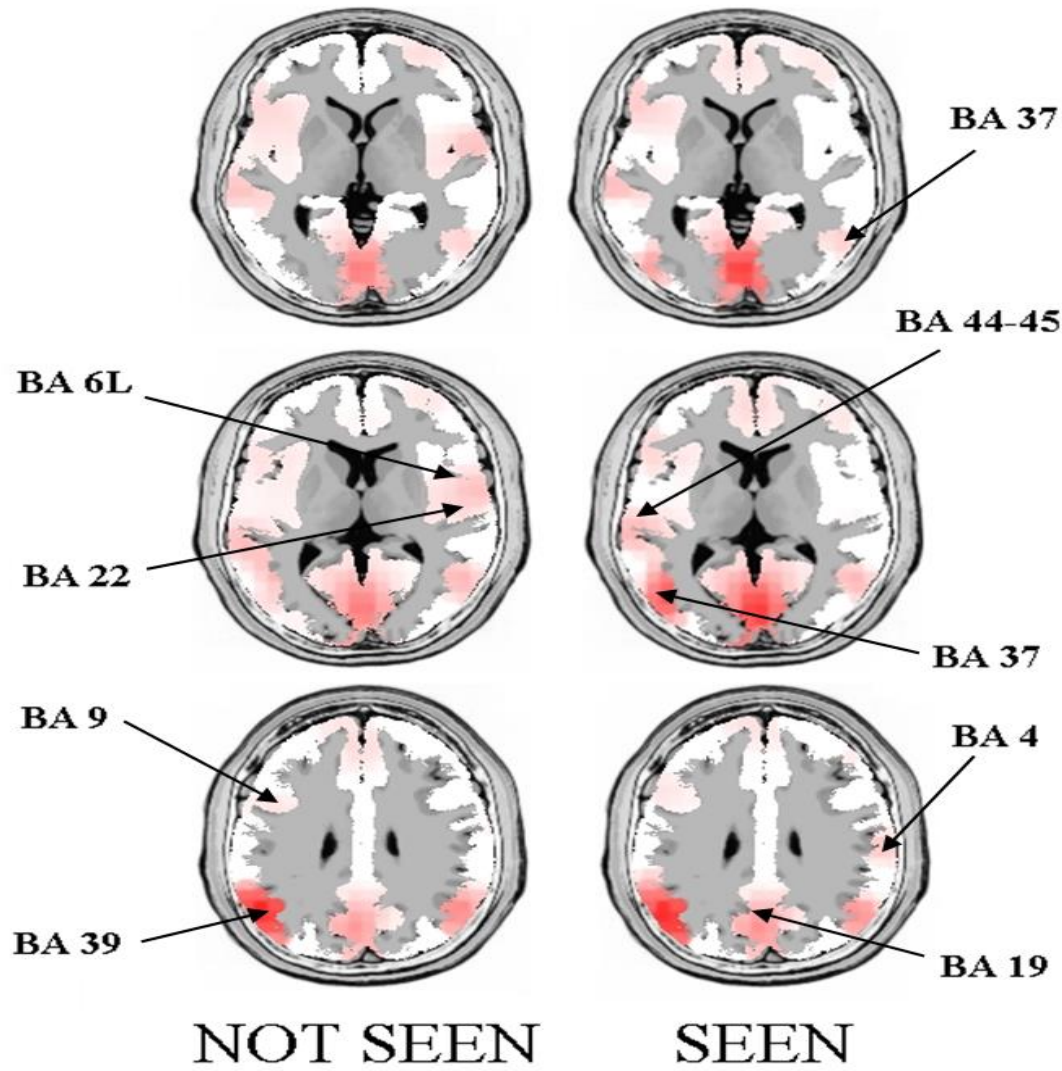


# ERPs to cue stimuli (words) are higher in amplitude at N1 and P3 peaks during primary consciousness



# N1 LORETA SOURCES

Occipito-temporal **N1** sources are related to primary **consciousness** of **words**



-  +  $\mu\text{A}/\text{cm}^2$

Babiloni C, Marzano N, Soricelli A, Cordone S, Millán-Calenti JC, Del Percio C, Buján A. Cortical Neural Synchronization Underlies Primary Visual Consciousness of Qualia: Evidence from Event-Related Potentials. *Front Hum Neurosci.* 2016 Jun 30;10:310.

# EEG provides the high temporal resolution necessary for the study of **secondary** (“extended”) **consciousness** including autobiographical, moral consciousness, and social interactions

## GLASGOW COMA SCALE

### EYE OPENING

Spontaneous	4
To loud voice	3
To pain	2
None	1

### VERBAL RESPONSE

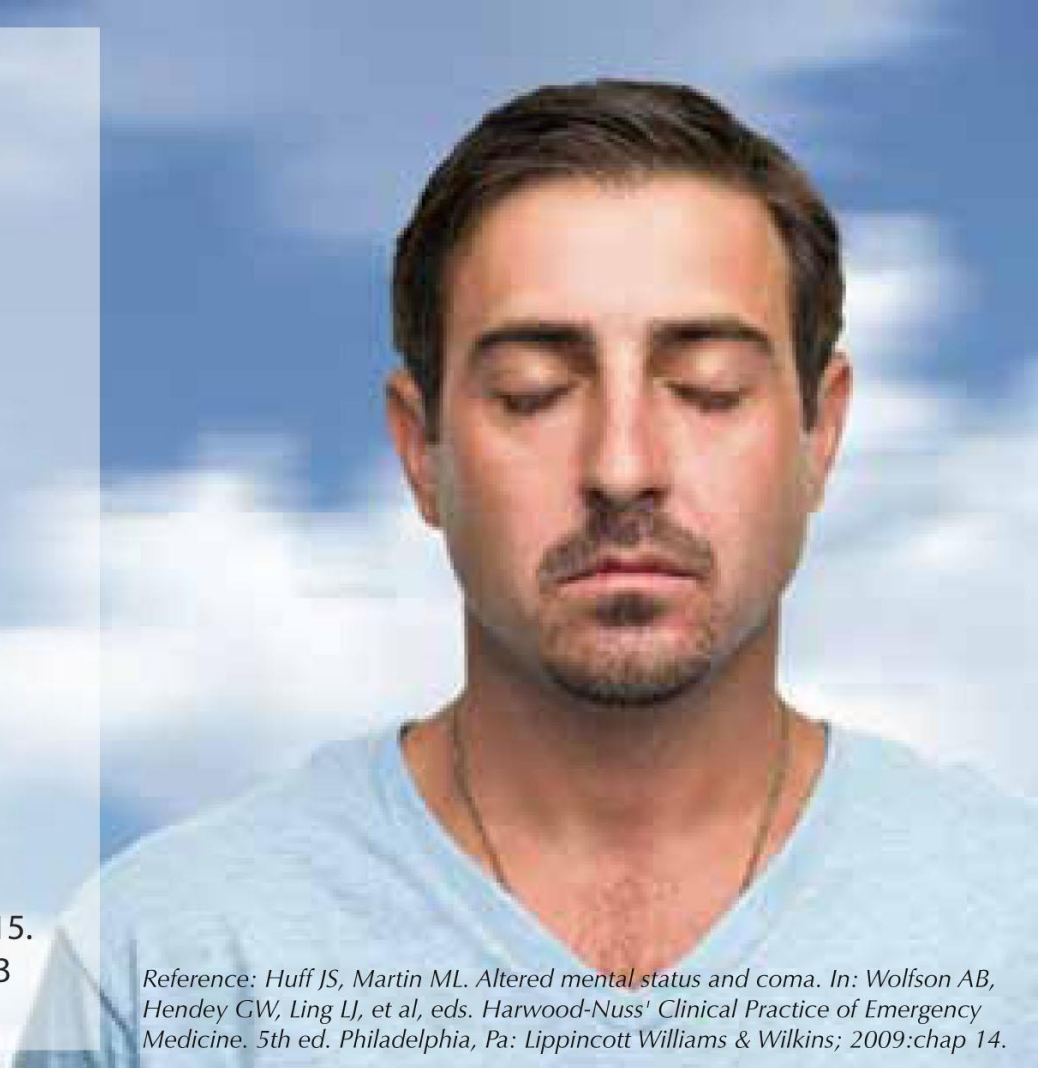
Oriented	5
Confused, disoriented	4
Inappropriate words	3
Incomprehensible words	2
None	1

### MOTOR RESPONSE

Obeys commands	6
Localizes pain	5
Withdraws from pain	4
Abnormal flexion posturing	3
Extensor posturing	2
None	1

A fully conscious patient has a Glasgow Coma Score of 15.

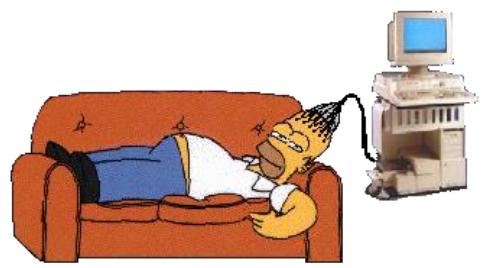
A person in a deep coma has a Glasgow Coma Score of 3 (there is no lower score).



*Reference: Huff JS, Martin ML. Altered mental status and coma. In: Wolfson AB, Hendey GW, Ling LJ, et al, eds. Harwood-Nuss' Clinical Practice of Emergency Medicine. 5th ed. Philadelphia, Pa: Lippincott Williams & Wilkins; 2009:chap 14.*



# Resting state alpha sources are especially depressed in persistent vegetative state (PVS) subjects (awake but not conscious) who will not recover consciousness at 3-months follow up

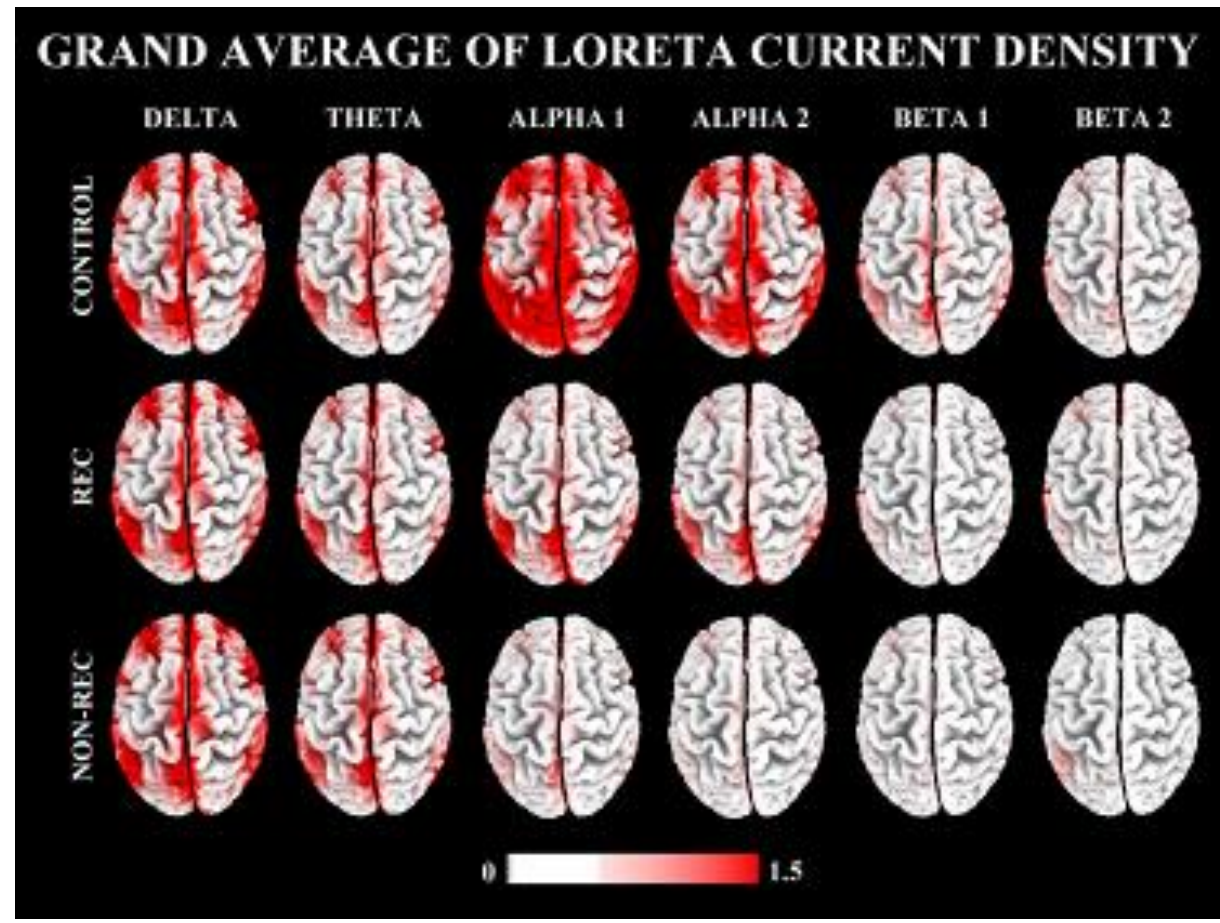


Resting EEG data

30 normal controls

12 PVS recovered

32 PVS not recovered



Babiloni C, Sarà M, Vecchio F, Pistoia F, Sebastiano F, Onorati P, Albertini G, Pasqualetti P, Cibelli G, Buffo P, Rossini PM. Cortical sources of resting-state alpha rhythms are abnormal in persistent vegetative state patients. Clin Neurophysiol. 2009 Apr;120(4):719-29.

# In PVS subjects, permanent deterioration of **secondary consciousness** may be related to abnormality of resting state **alpha** rhythms



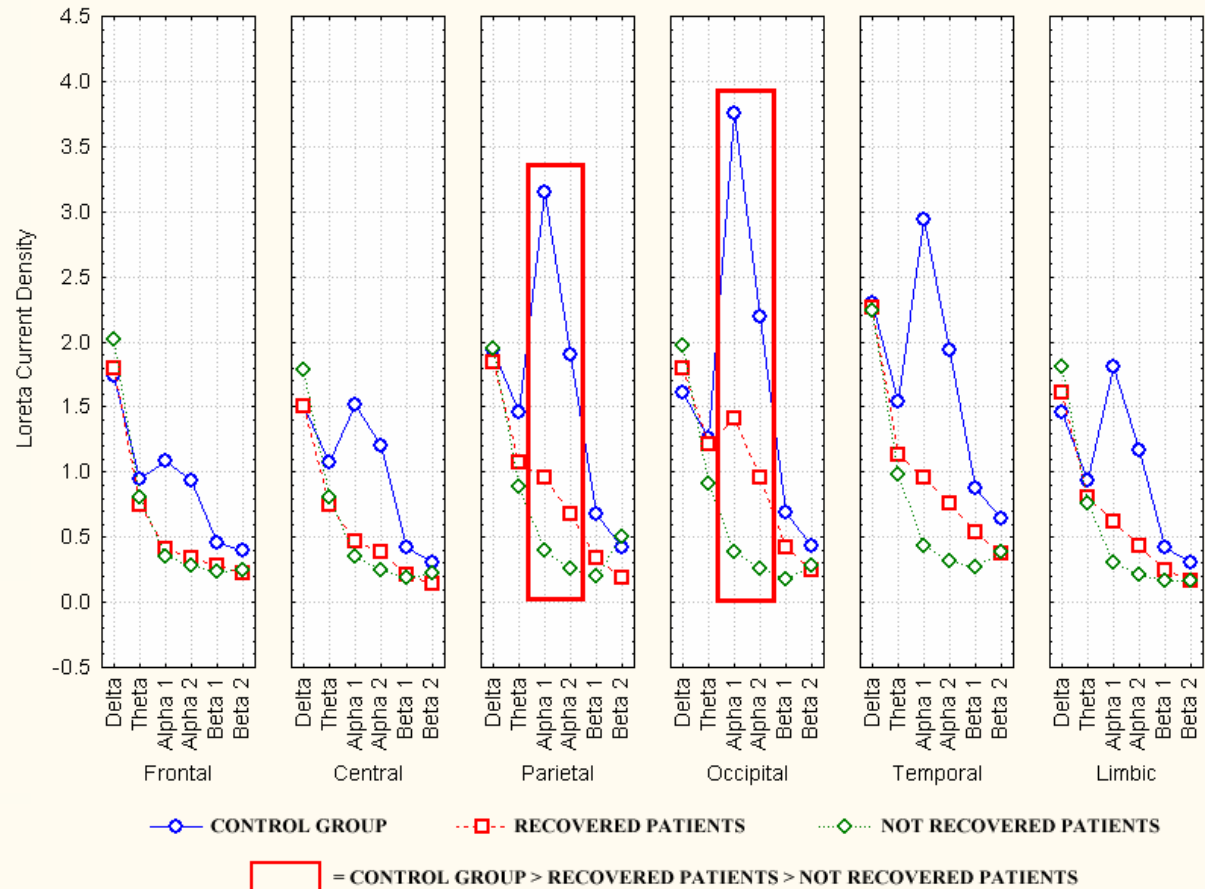
Resting EEG data

30 normal controls

32 PVS recovered

12 PVS not recovered

STATISTICAL ANOVA INTERACTION AMONG GROUP, BAND AND ROI



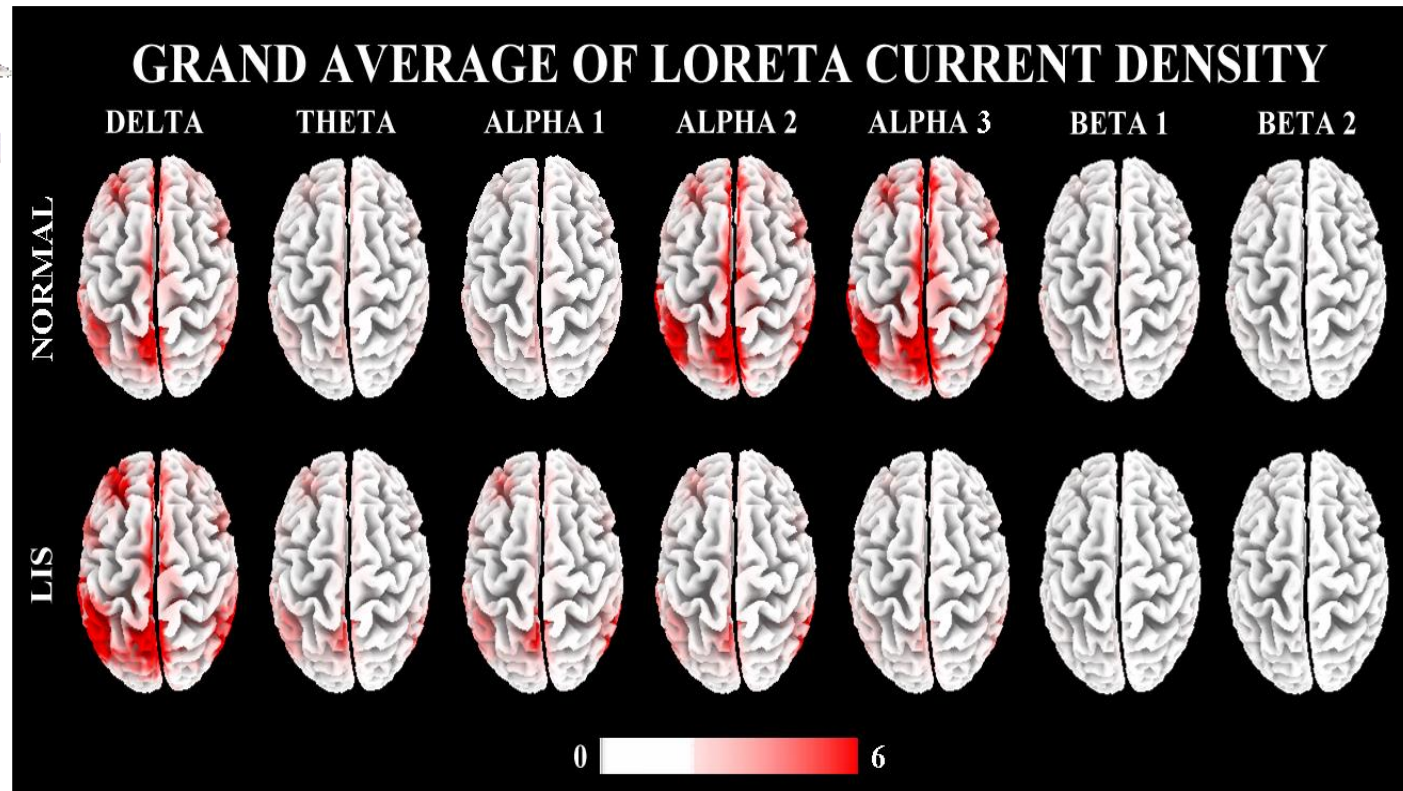
# Resting state alpha sources are depressed in locked in syndrome (LIS) subjects (conscious but with abnormalities in emotional experiences)



Resting EEG  
data

15 normal controls

13 LIS



# In LIS subjects, some abnormal **conscious experience** may be related to abnormality of resting state **alpha** rhythms

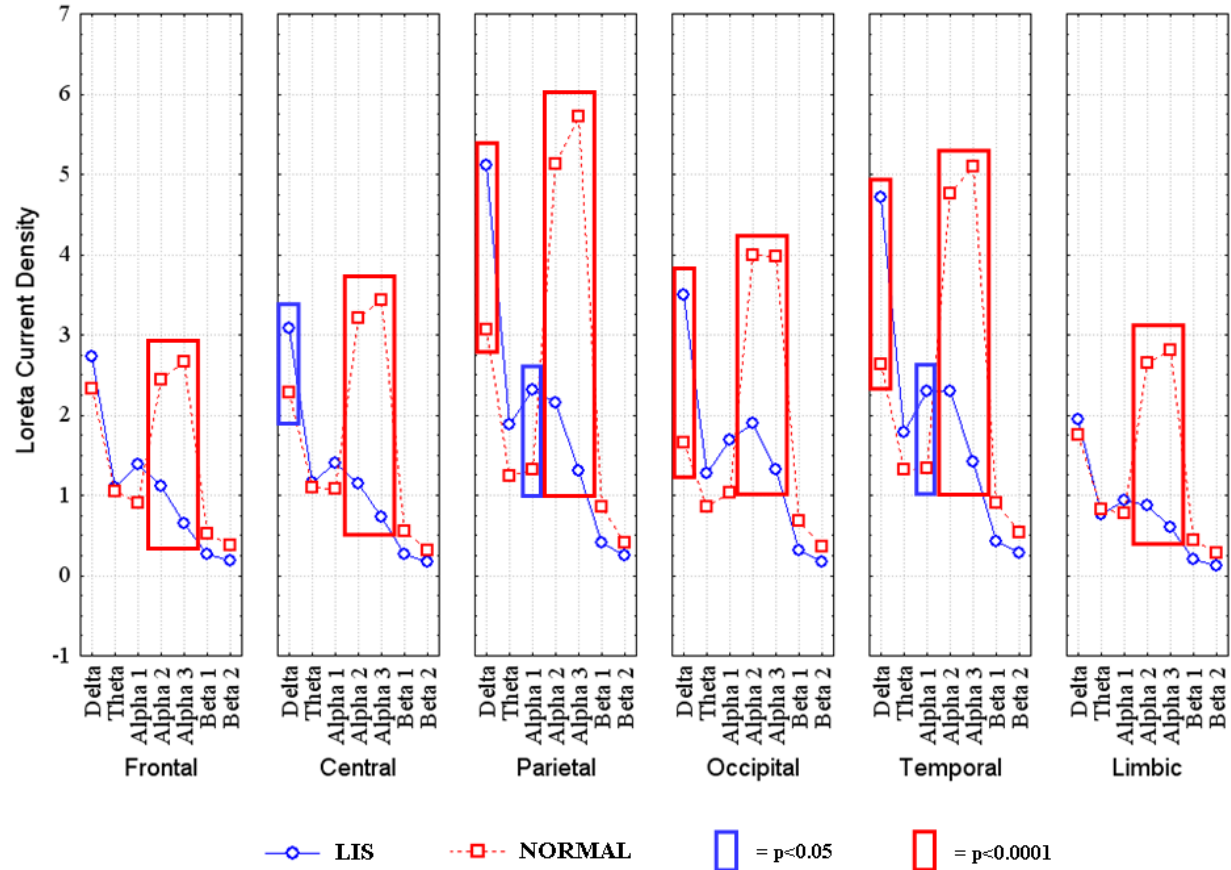


Resting EEG data

15 normal controls

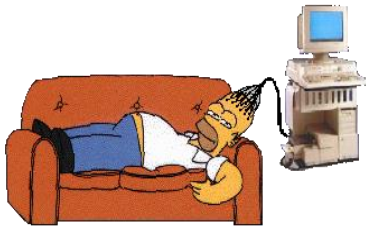
13 LIS

## ANOVA INTERACTION AMONG GROUP, BAND, AND ROI





**Widespread delta (2-4 Hz) and posterior alpha (8-10.5 Hz) source activities were abnormal in AD and aMCI subjects: abnormal cortical neural synchronization at delta and alpha rhythms in AD and MCI subjects**

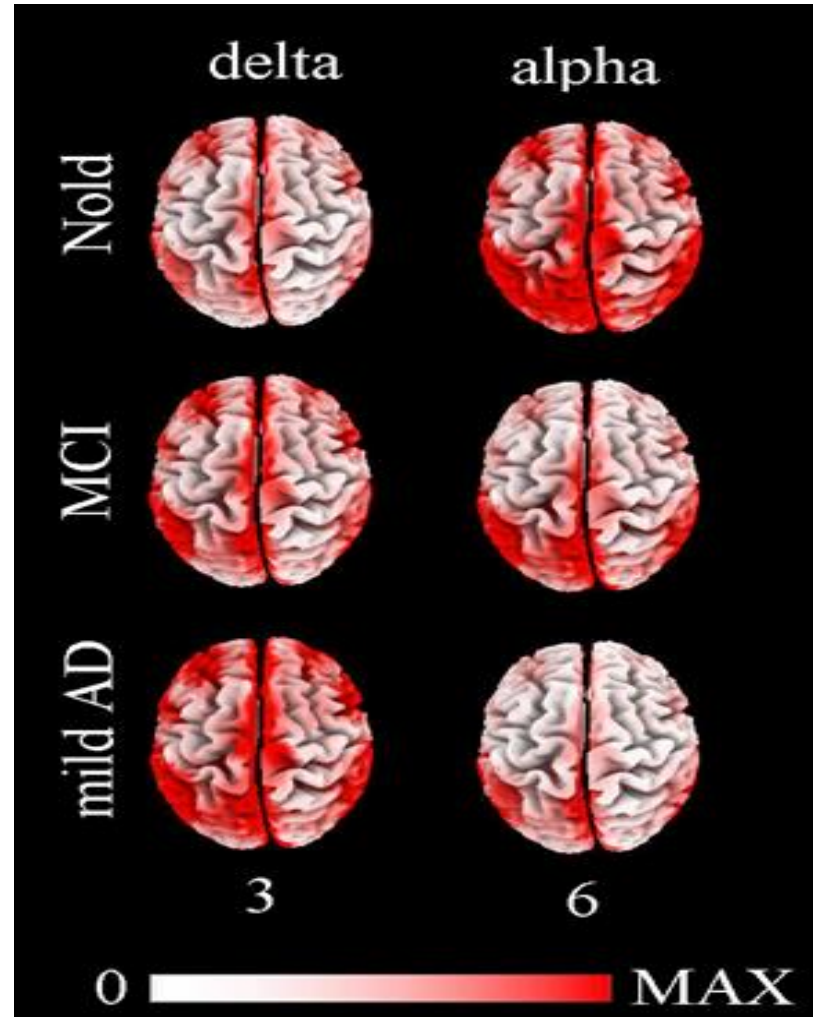


Resting EEG  
data

126 Nold

155 MCI (ADMCI)

193 mild AD (ADD)

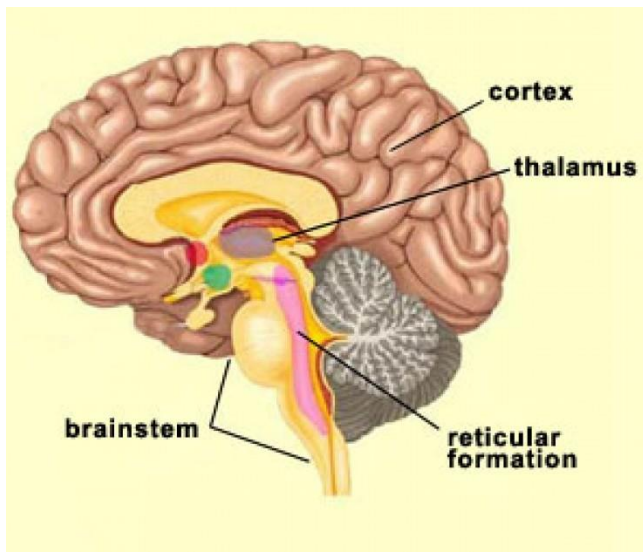


# Conclusions: mapping **alpha rhythms** or **ERPs** unveils cortical processes related to primary and secondary consciousness

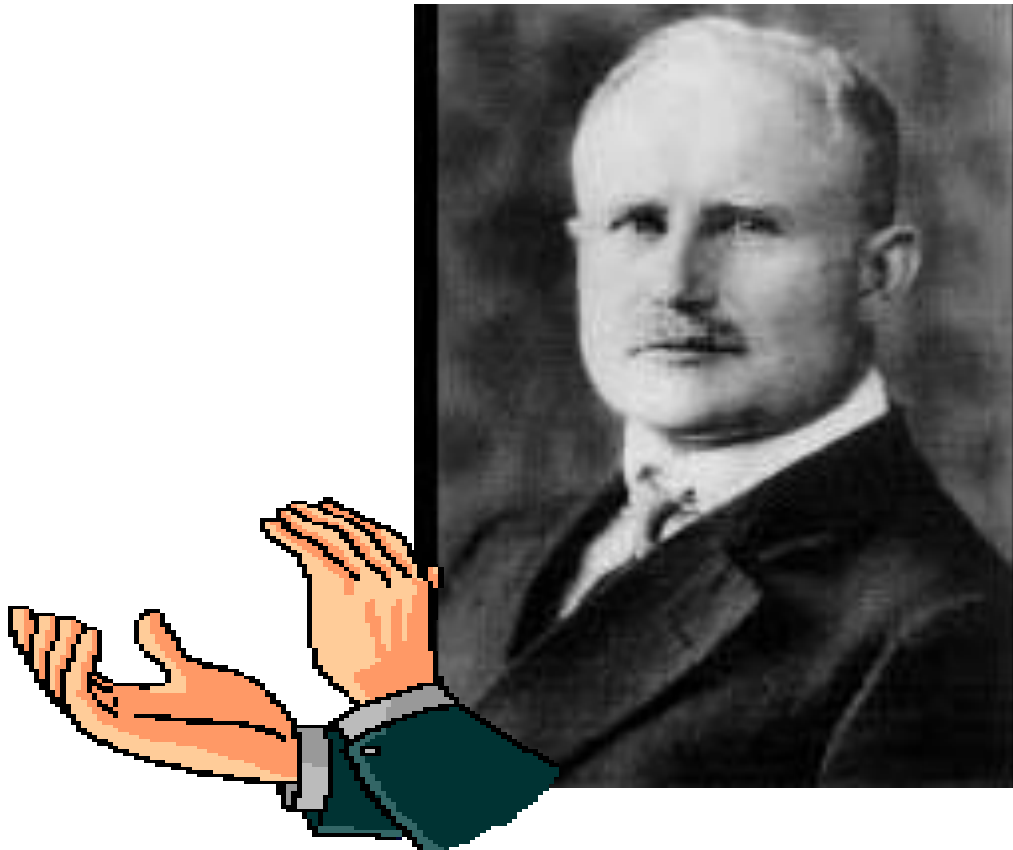
Cortical **alpha rhythms** before and during the stimulus are related to primary consciousness (“**neuromodulatory context of cortical neural synchronization/desynchronization**”)

Cortical resting state **alpha rhythms** are abnormal in subjects with persistent **abnormal consciousness**, in **subjects with locked in syndrome**, and Alzheimer’s disease

**ERPs** disclose the spatio-temporal evolution (100-400 ms post-stimulus) of cortical responses related to **primary consciousness** (“**re-phasing and synchronization of cortical neurons**”)



# Thanks for your consciousness



**The father of EEG:  
Hans Berger**