UNIVERSITÀ DEGLI STUDI DI MILANO

IMT SCUOLA ALTI STUDI LUCCA

Blindness affects occipital cortex reactivity: a TMS-EEG study

Gabriel Hassan – University of Milan

SIPF

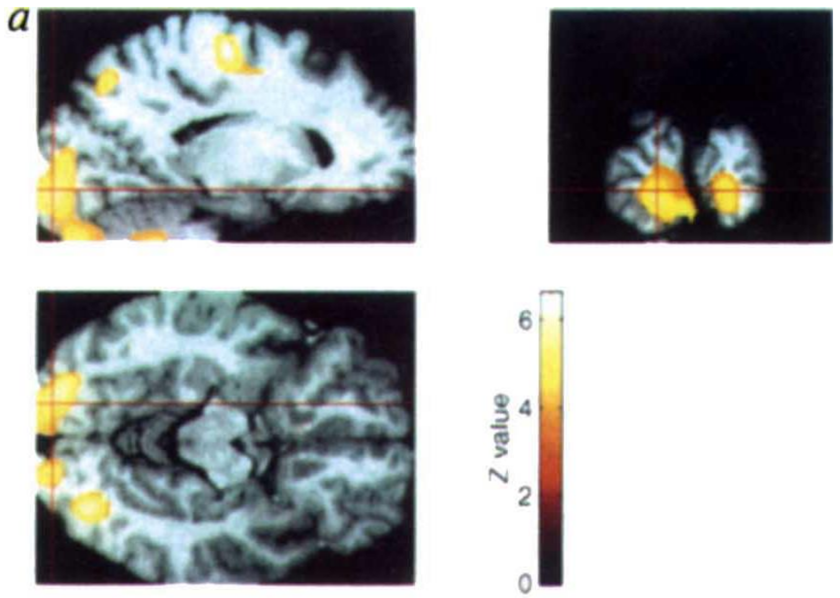
Società Italiana di Psicofisiologia e Neuroscienze Cognitive

Blindness as a model of functional brain plasticity

- Brain structure and function are adaptive to changes.
- An extreme model of brain plasticity is represented by the total and permanent deprivation of visual input occurring in blindness.
- In blind individuals, the visual cortex can be activated by various external inputs, spanning from different modalities and across cognitive tasks (i.e., crossmodal plasticity)

Activation of the primary visual cortex by Braille reading in blind subjects

Norihiro Sadato*†, Alvaro Pascual-Leone*, Jordan Grafman‡, Vicente Ibañez*, Marie-Pierre Deiber*, George Dold§ & Mark Hallett*



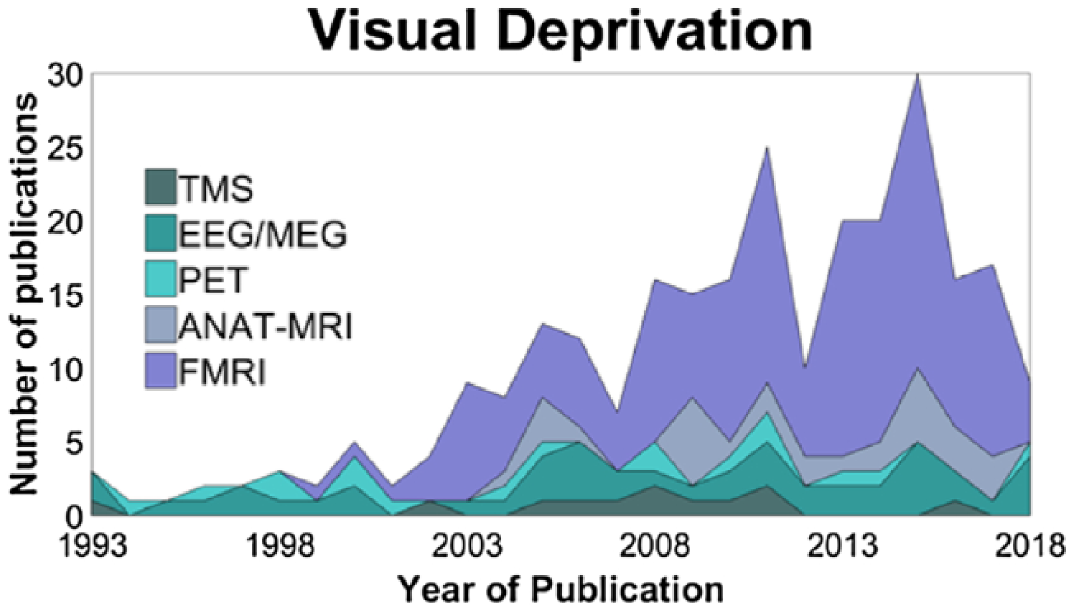
A relative lack of electrophysiological studies in blindness

- In the last two decades, we have seen a blossoming of studies in the field of cross-modal plasticity in blind subjects across different tasks, mainly employing neuroimaging techniques.

Editorial

The sensory-deprived brain as a unique tool to understand brain development and function

Emiliano Ricciardi, Davide Bottari, Maurice Ptito [a, b], Brigitte Röder, Pietro Pietrini



Limitations of the current state of the art

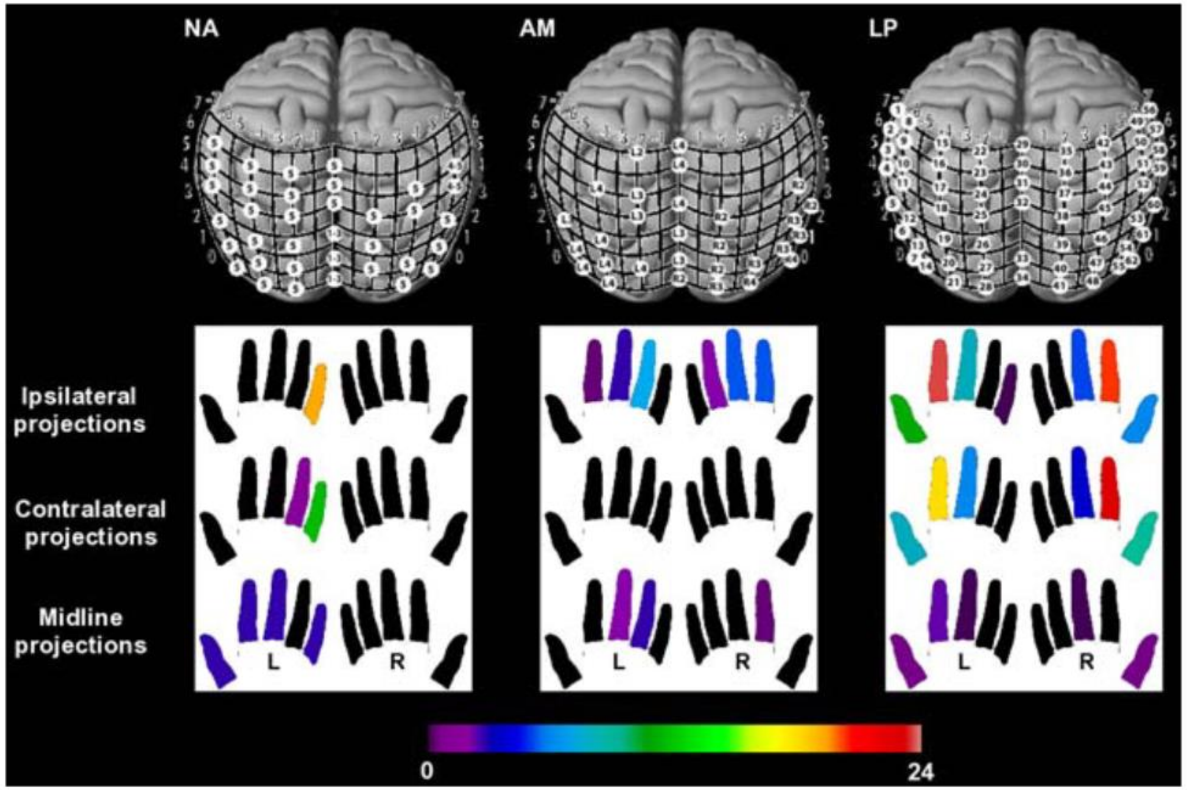
- Mostly correlational data
- Behavioral tasks do not always separate high-order and basic functions.
- Relative lack of electrophysiological studies
- Relative lack of multimodal studies

Insights from a TMS-only study in blind subjects

- During TMS stimulation of the occipital cortex, some blind subjects reported tactile sensations in the fingers that were somatotopically organized onto the visual cortex. The number of cortical sites inducing tactile sensations appeared to be related to the number of hours of Braille reading per day, Braille reading speed and dexterity.

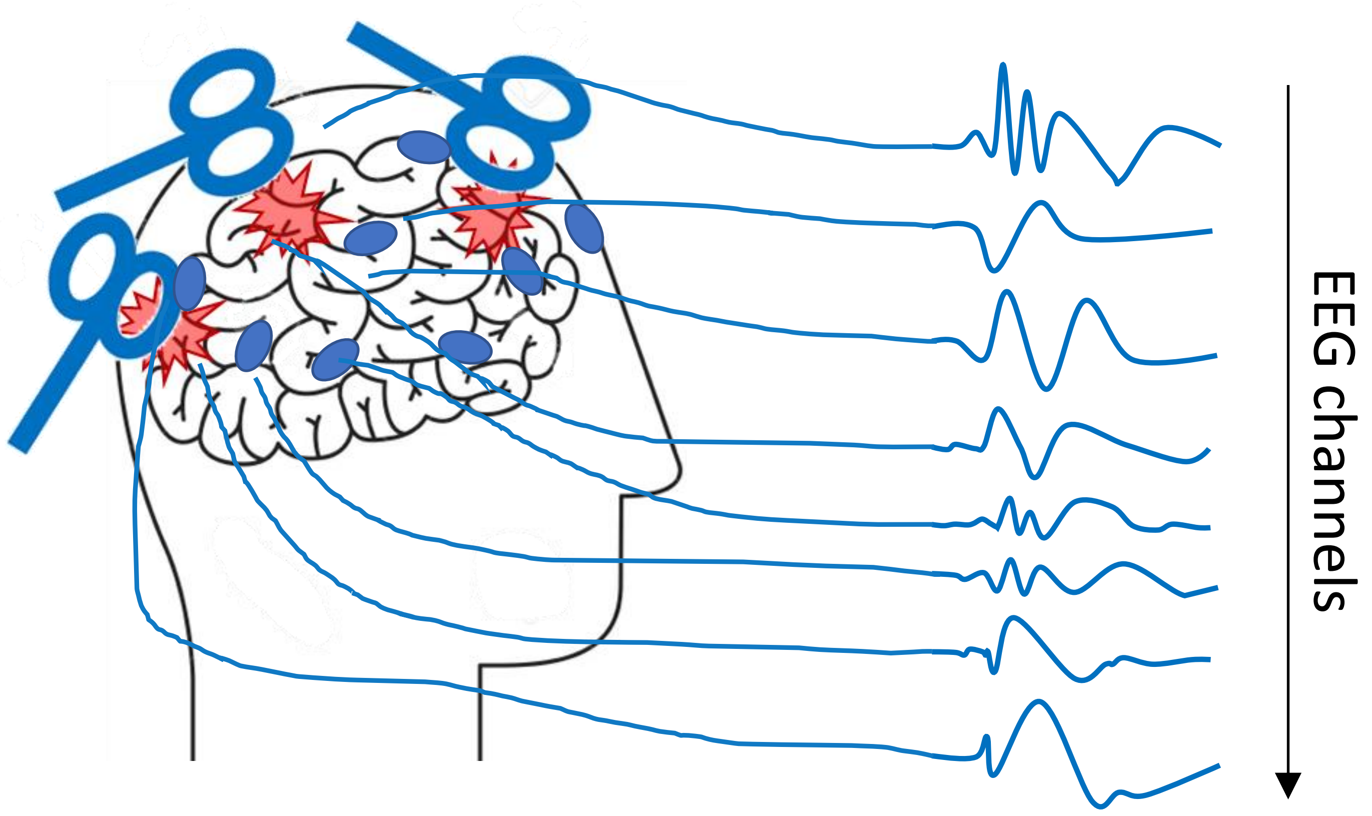
TMS of the occipital cortex induces tactile sensations in the fingers of blind Braille readers

M. Ptito · A. Fumal · A. Martens de Noordhout · J. Schoenen · A. Gjedde · R. Kupers



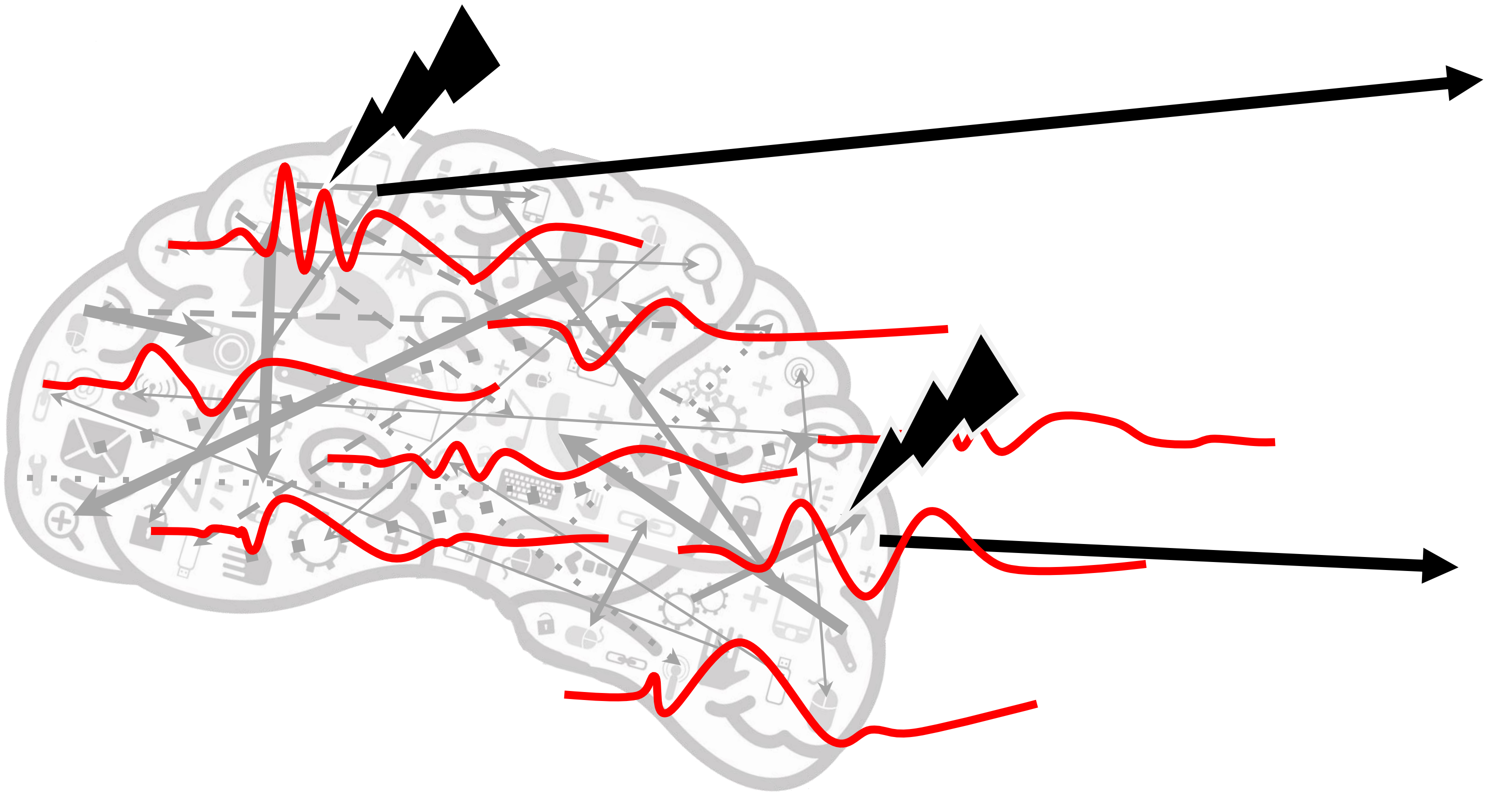
TMS-EEG to measure cortical reactivity

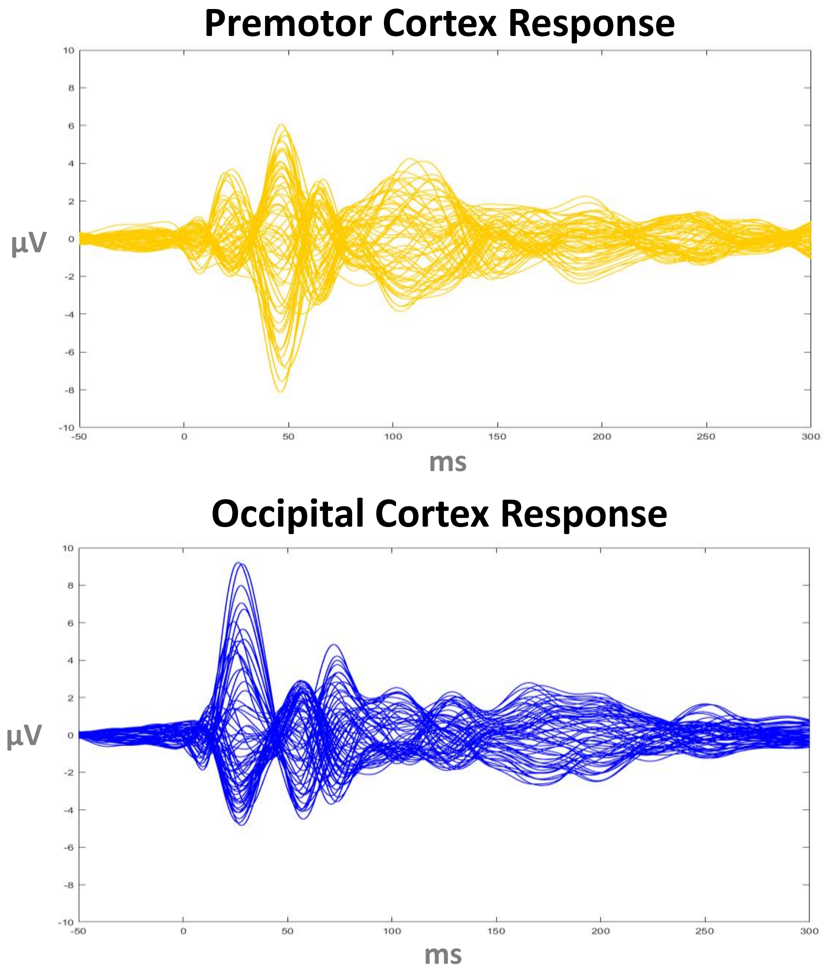
- Transcranial magnetic stimulation (TMS) can directly probe any cortical area.
- Recording EEG activity while perturbing the brain reveals some specific features of the targeted areas, like when we instinctively knock on the surface of an object to appreciate its internal structure.



TMS-evoked potentials (TEP)

SPECIFICITY OF THE TEPs ACROSS DIFFERENT CORTICAL AREAS





TMS-EEG has been used to investigate brain reactivity across different physiological states and different clinical conditions

Local sleep-like cortical reactivity in the awake brain after focal injury

Simone Sarasso,[1] Sasha D'Ambrosio,[1,2,3] Matteo Fecchio,[1] Silvia Casarotto,[1] Alessandro Viganò,[4] Cristina Landi,[5] Giulia Mattavelli,[6] Olivia Gosseries,[7] Matteo Quarenghi,[8] Steven Laureys,[7] Guya Devalle,[4] Mario Rosanova[1,5] and Marcello Massimini[1,4]

Quantifying Cortical EEG Responses to TMS in (Un)consciousness

Clinical EEG and Neuroscience
1–10

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Simone Sarasso[1], Mario Rosanova[1,2], Adenauer G. Casali[1,3], Silvia Casarotto[1], Matteo Fecchio[1], Melanie Boly[4,5], Olivia Gosseries[4,5], Giulio Tononi[5], Steven Laureys[4], and Marcello Massimini[1,6]

Breakdown in cortical effective connectivity during midazolam-induced loss of consciousness

Fabio Ferrarelli[a], Marcello Massimini[b], Simone Sarasso[a], Adenauer Casali[b], Brady A. Riedner[a], Giuditta Angelini[c], Giulio Tononi[a,1], and Robert A. Pearce[c,1]

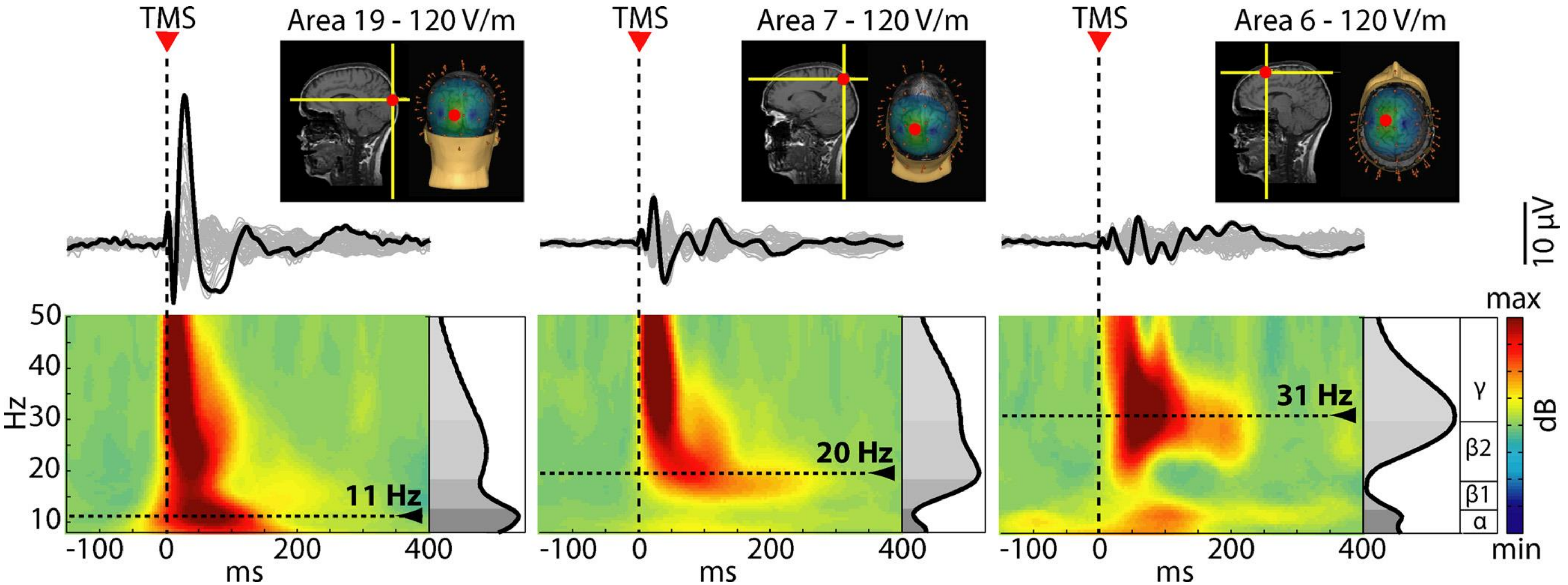
Breakdown of Cortical Effective Connectivity During Sleep

Marcello Massimini,[1,2] Fabio Ferrarelli,[1] Reto Huber,[1] Steve K. Esser,[1] Harpreet Singh,[1] Giulio Tononi[1]*

Natural Frequencies of Human Corticothalamic Circuits

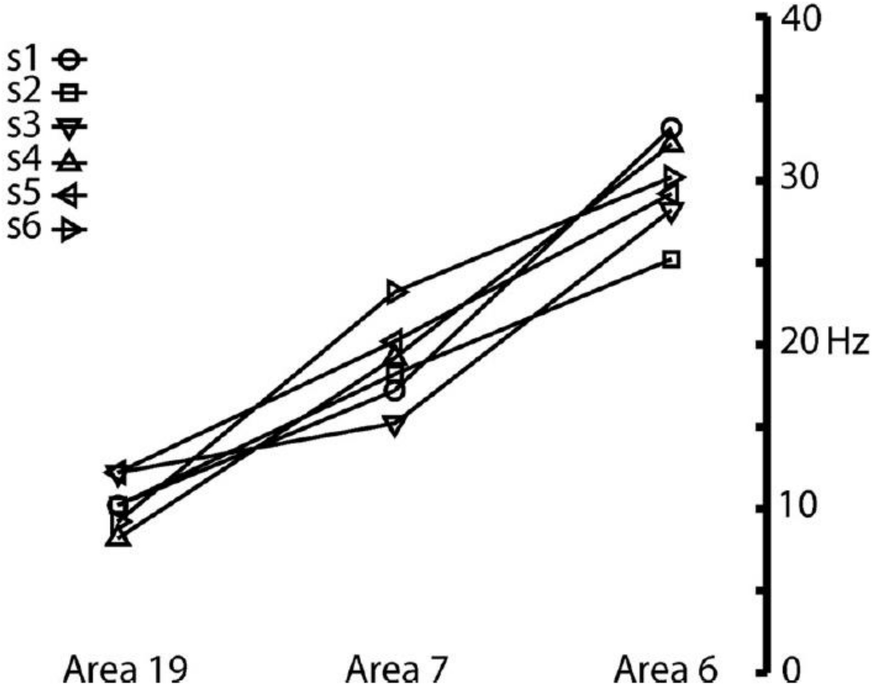
Mario Rosanova,[1] Adenauer Casali,[1] Valentina Bellina,[1] Federico Resta,[2] Maurizio Mariotti,[1] and Marcello Massimini[1]
[1]Department of Clinical Sciences, "Luigi Sacco," Università degli Studi di Milano, and [2]Division of Radiology, Ospedale Luigi Sacco, 20157 Milan, Italy

Different brain regions tend to engage in electrical oscillations at different frequencies.



The so-called *natural frequency* is the main rate of the EEG oscillations elicited by TMS.
The natural frequency **increases from posterior to anterior** brain regions,
e.g., α-range for occipital, β-range for parietal and high- β/low-γ range for frontal stimulation.

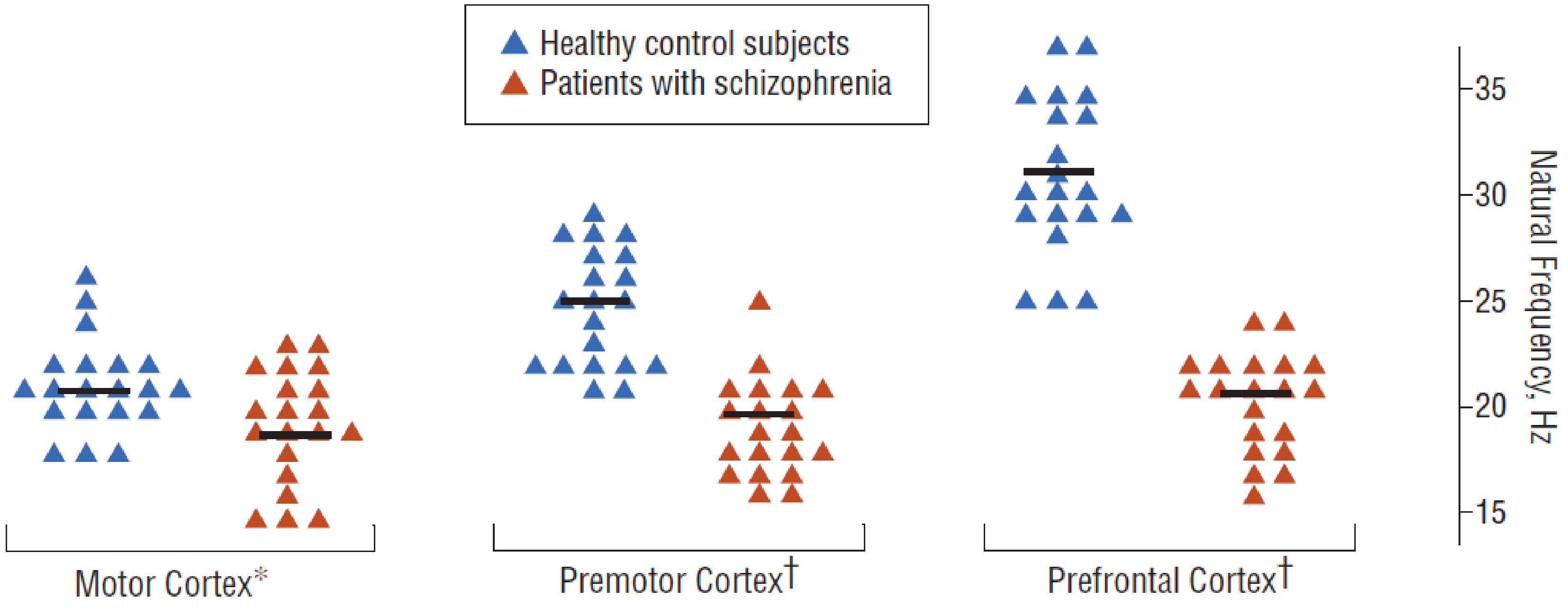
Rosanova et al., J Neurosci 2009



The natural frequency of occipital, parietal and frontal cortex is **consistent across healthy subjects**

Rosanova et al., J Neurosci 2009

The natural frequency of frontal cortex is significantly **slower in schizophrenic** patients than healthy subjects



Ferrarelli et al., Arch Gen Psychiatry 2012

AIM

Measuring the electrophysiological features of the occipital cortex in blind subjects employing a non-invasive and direct “perturb and measure” approach with TMS-EEG

MATERIALS & METHODS

SUBJECTS

- 12 Blind Subjects (3 congenital)
- 12 Sighted Controls

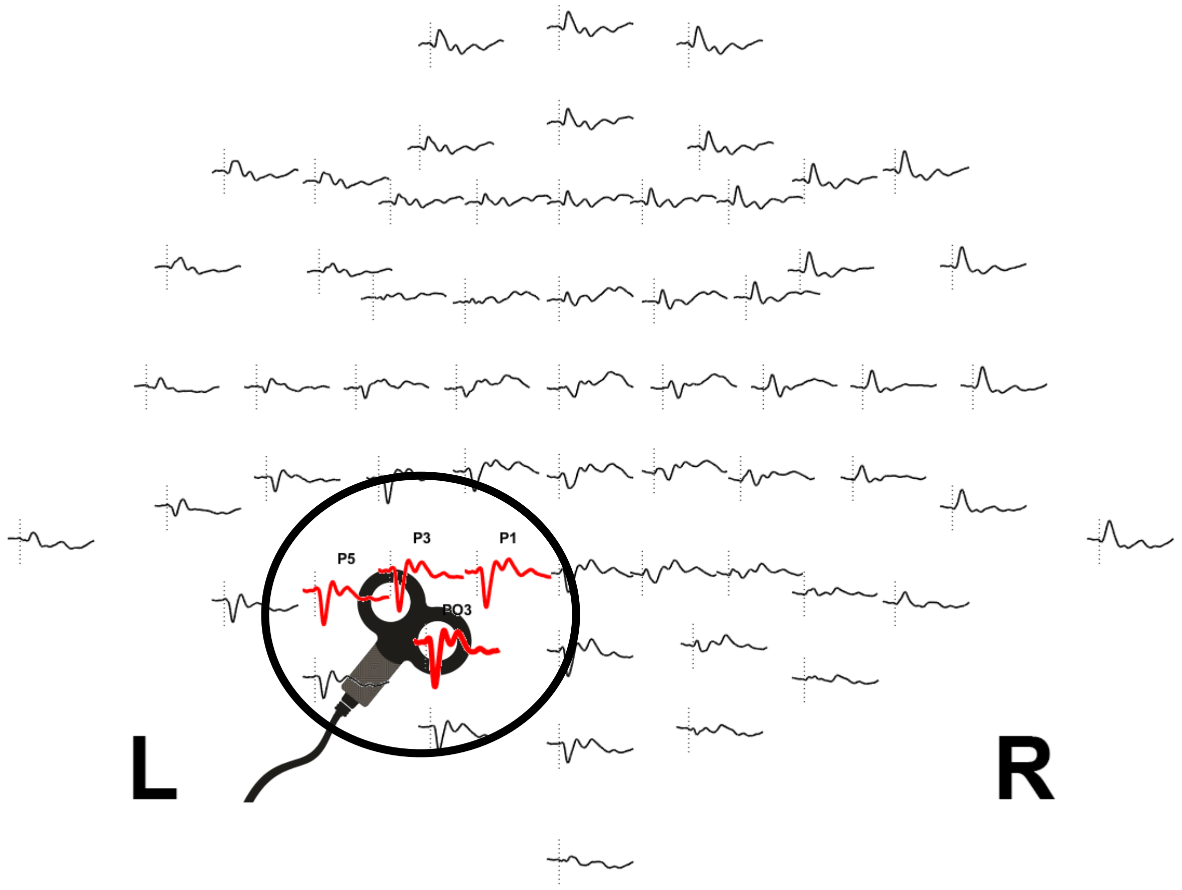
TMS TARGETS

- Bilateral Occipital Cortex (BA 18/19 – Target Sites)
- Left Premotor Cortex (BA 06 – Control Site)

EQUIPMENT

- TMS-Compatible 64ch EEG system.
- Neuronavigated TMS system based on individual subject structural MRI

LATENCY MEASUREMENTS



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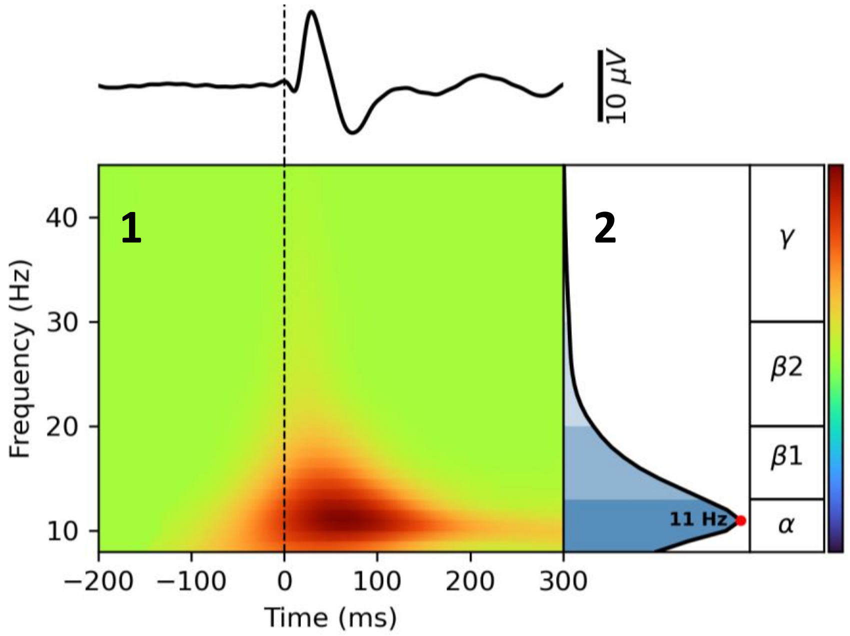
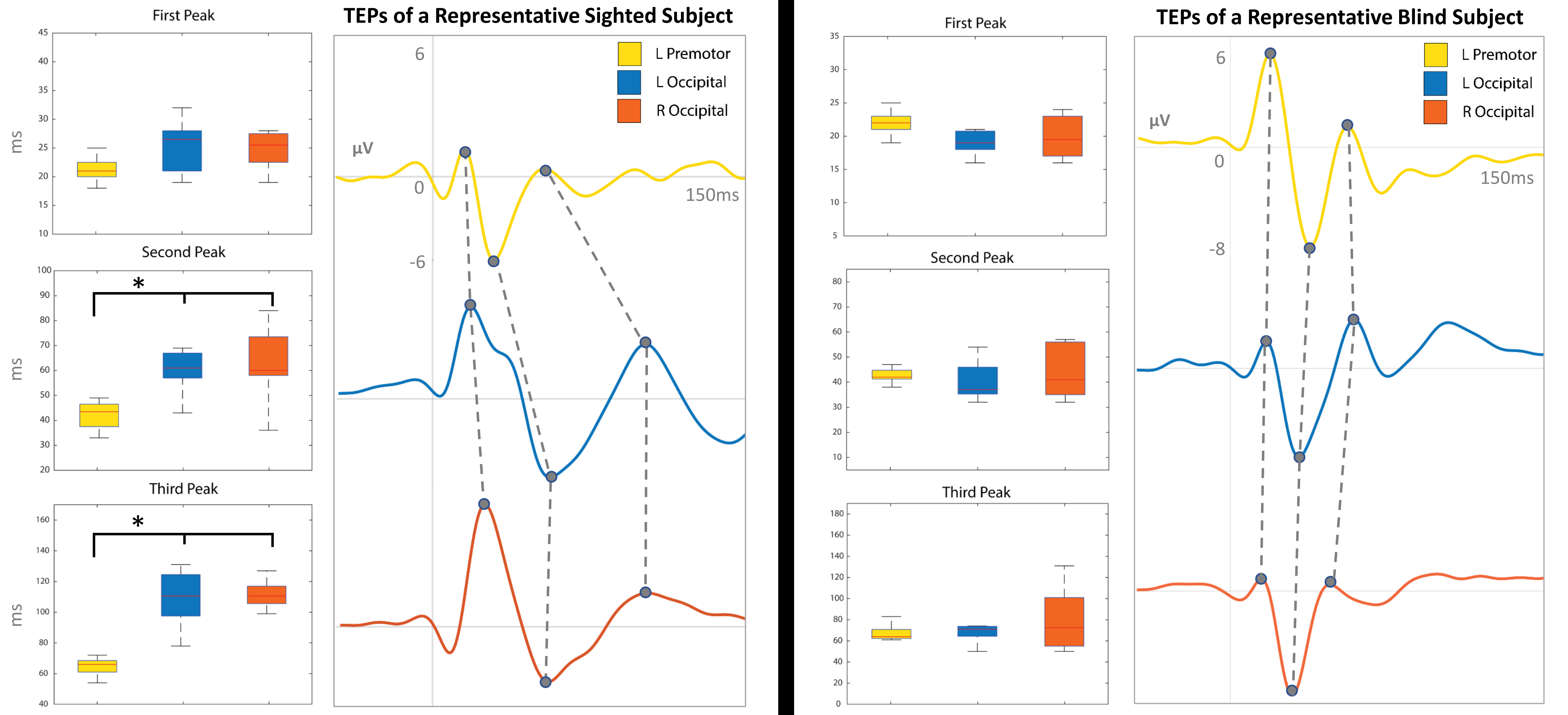
FREQUENCY MEASURE

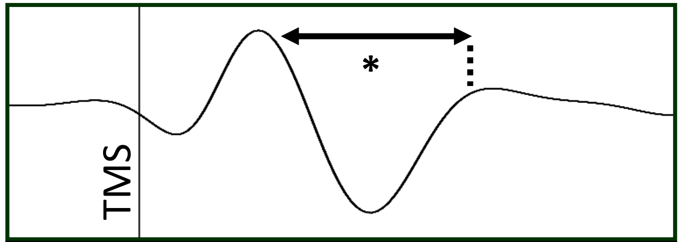


1. Time-frequency decomposition of the average of 4 channels with the largest response under the coil.
2. Spectral power cumulated between 20 and 120 ms post-stimulus

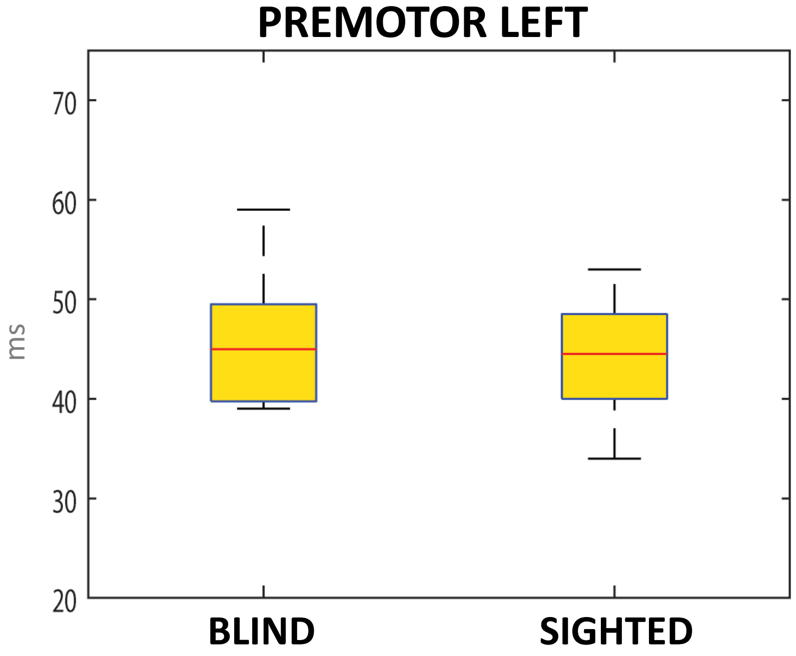
RESULTS: Peaks Latencies



RESULTS: Comparison of the InterPeak times between BLIND and SIGHTED

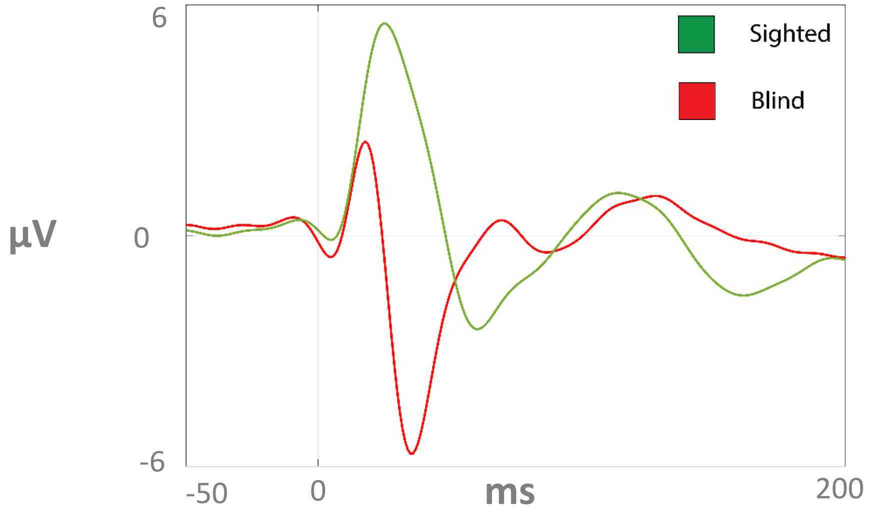


*InterPeak time: the time lag between the first two positive peaks evoked by TMS.

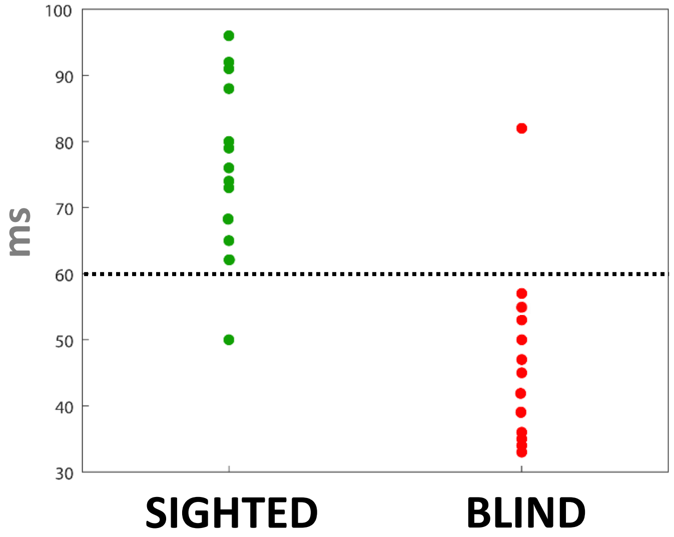


Comparison of the InterPeak times between BLIND and SIGHTED subjects. TEPs grand average and individual results

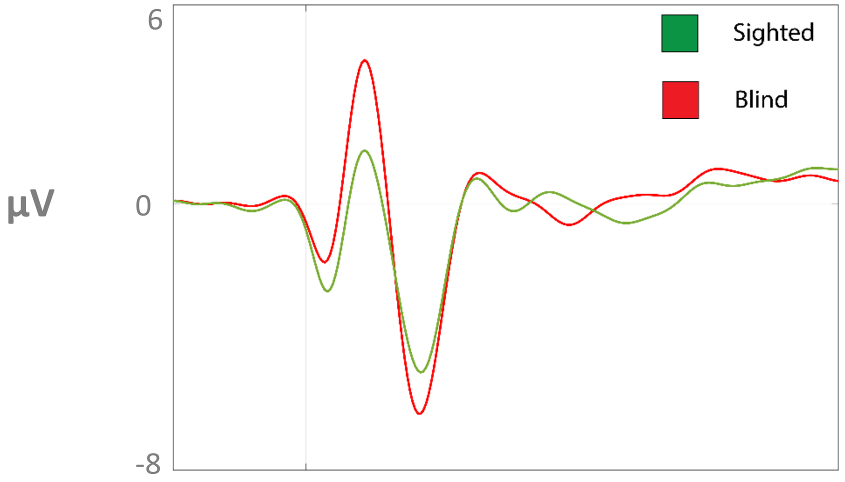
Faster Occipital TEPs Grand Average



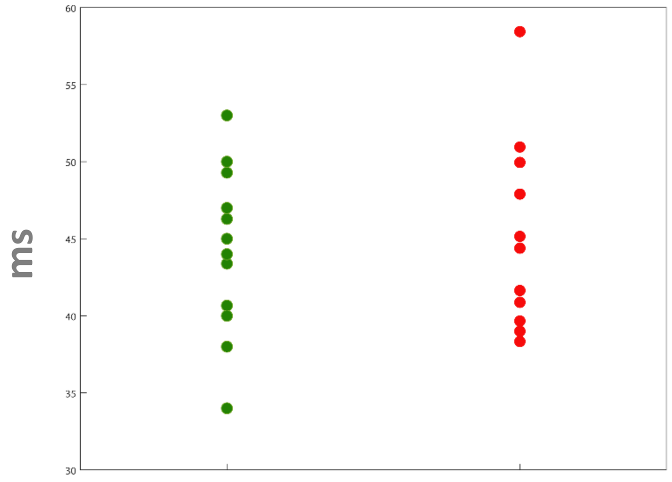
Individual Occipital Faster InterPeak Time



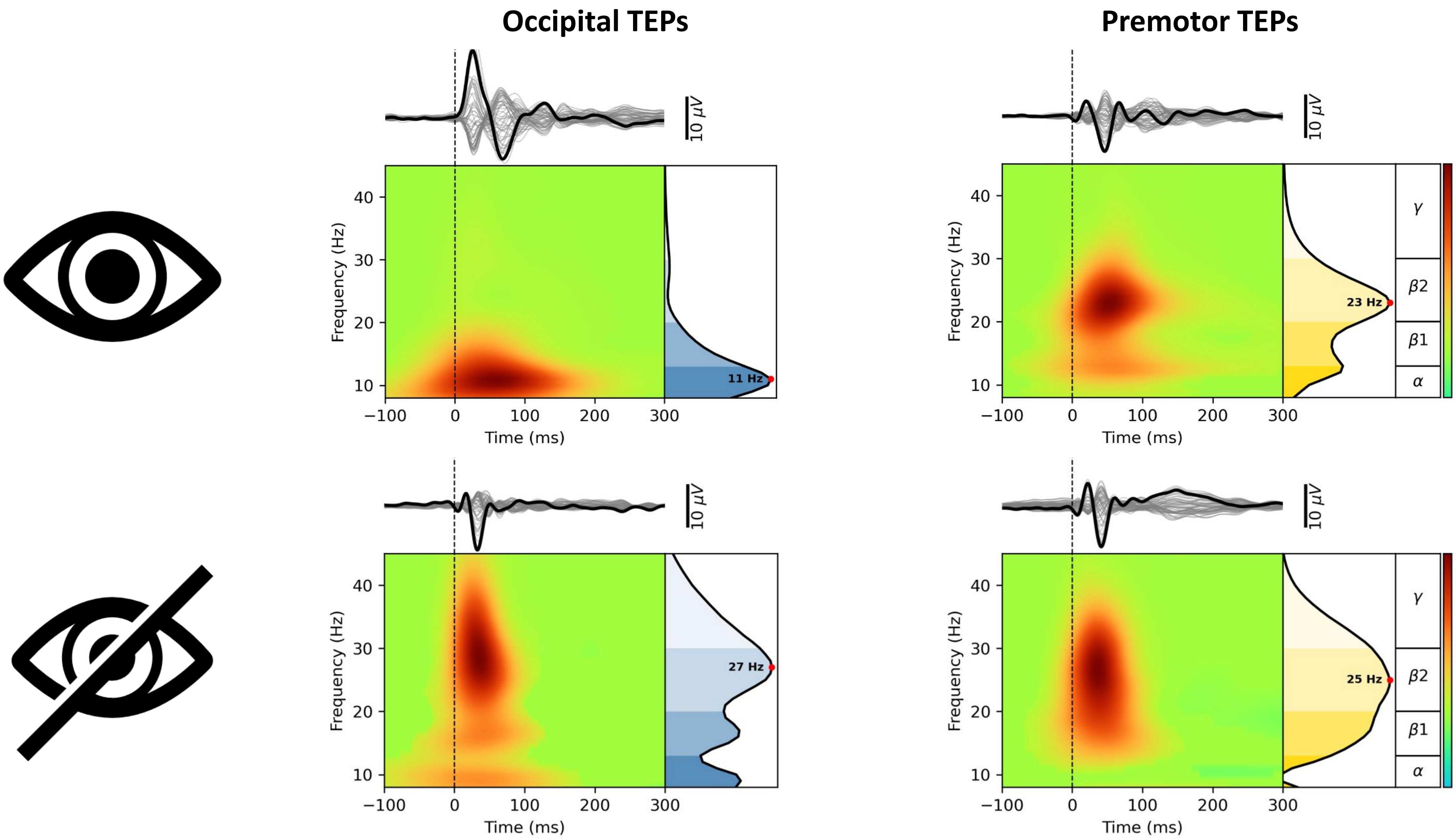
Left Premotor TEPs Grand Average



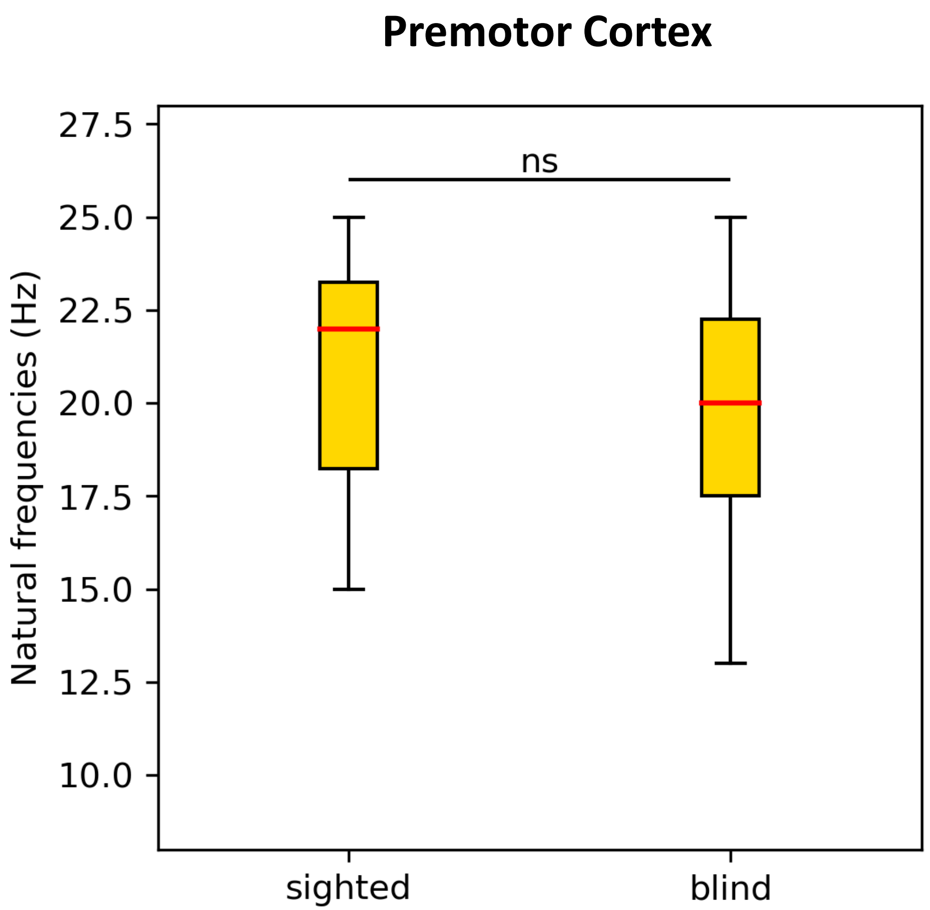
Individual L Premotor InterPeak Time

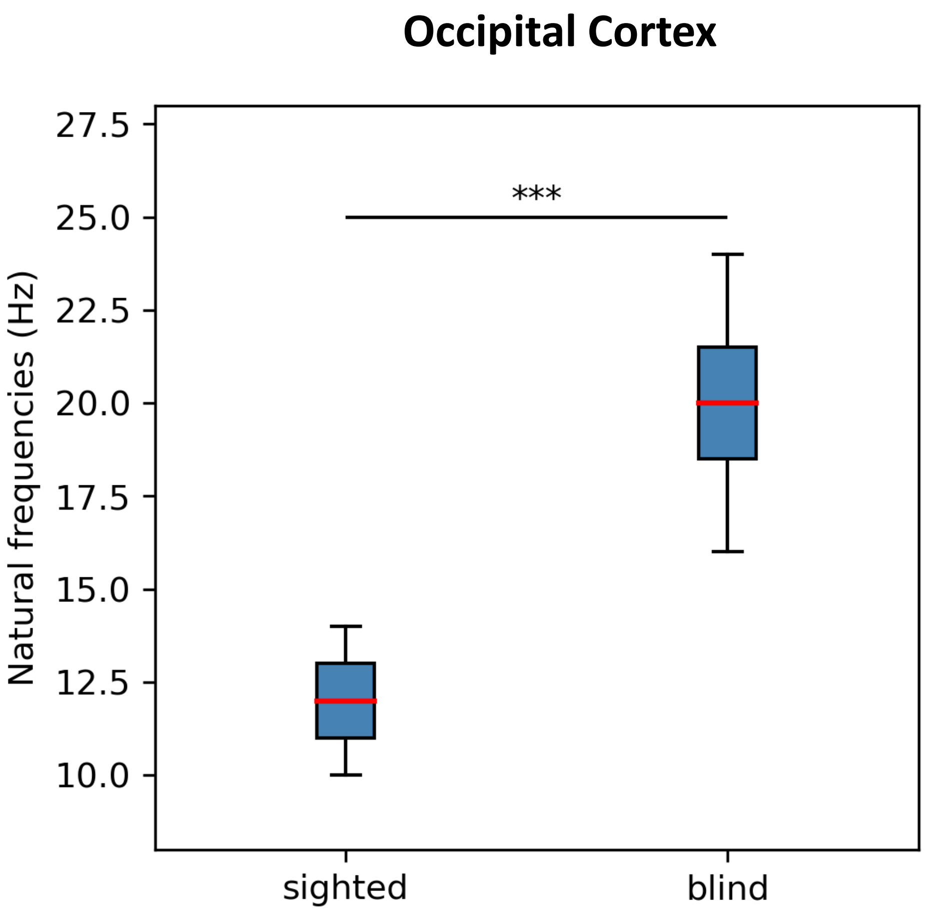


RESULTS: Time-Frequency



RESULTS: Comparison of the Natural Frequencies between BLIND and SIGHTED





TAKE HOME MESSAGES

Main Findings:

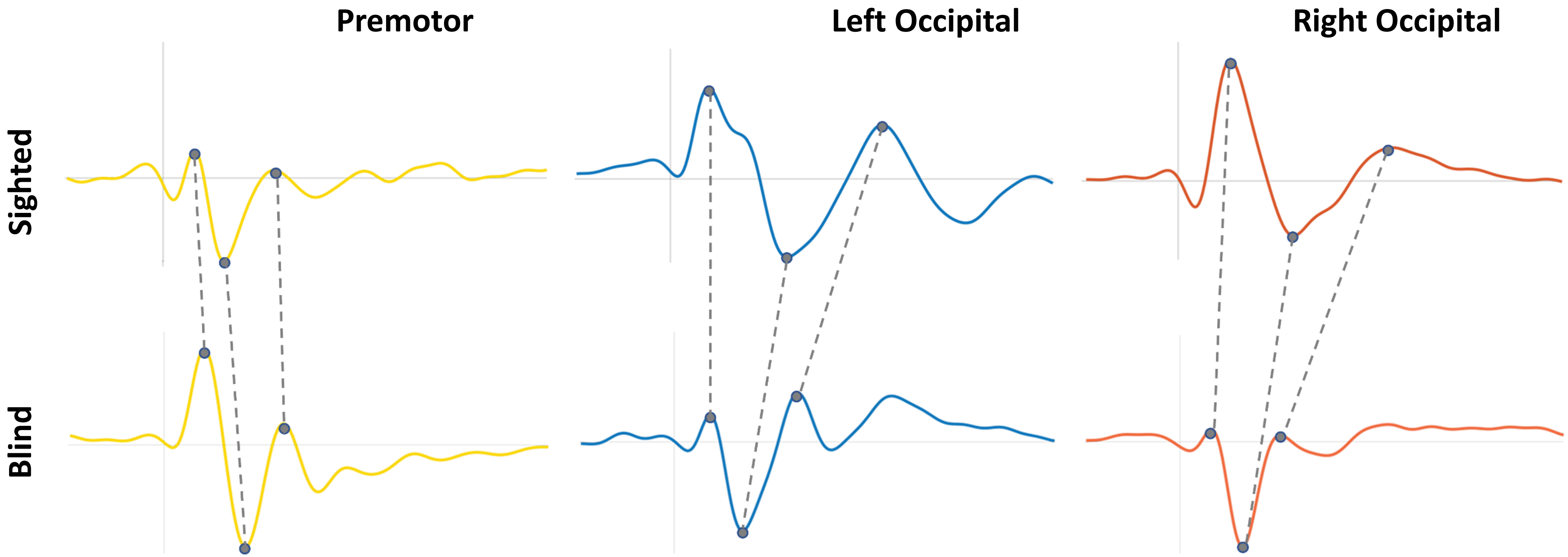
- TMS-EEG uniquely allows for a direct investigation of the electrophysiological features of the occipital cortex in blind subjects.

- The observed changes:
  - Are specific to occipital TEPs, while premotor responses were similar between Blind and Sighted subjects.
  - Also occurred in not congenitally blind subjects

- Blind Occipital TEPs are almost as fast as premotor responses. Is this a sign of cross-modal plasticity?

A sign of cross-modal plasticity?

Different sensory modalities carry information at different frequencies. Faster occipital TEPs in blind subjects may reflect a specific adaptation of cortical areas usually involved in visual processing to deal with non-visual sensory information.



THANK YOU!

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- Marta Porro
- Letizia Bernardelli
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- Gianluca Gaglioti

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- Giulio Bernardi
- Pietro Pietrini