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Human neurophysiology of slow cortical transients

Simone Sarasso, PhD

*Department of Biomedical and Clinical Sciences
Università degli Studi di Milano*



XXXI CONGRESSO NAZIONALE SIPF
Past, Present and Future Brains
Siena 9-11 novembre 2023
Museo Santa Maria della Scala





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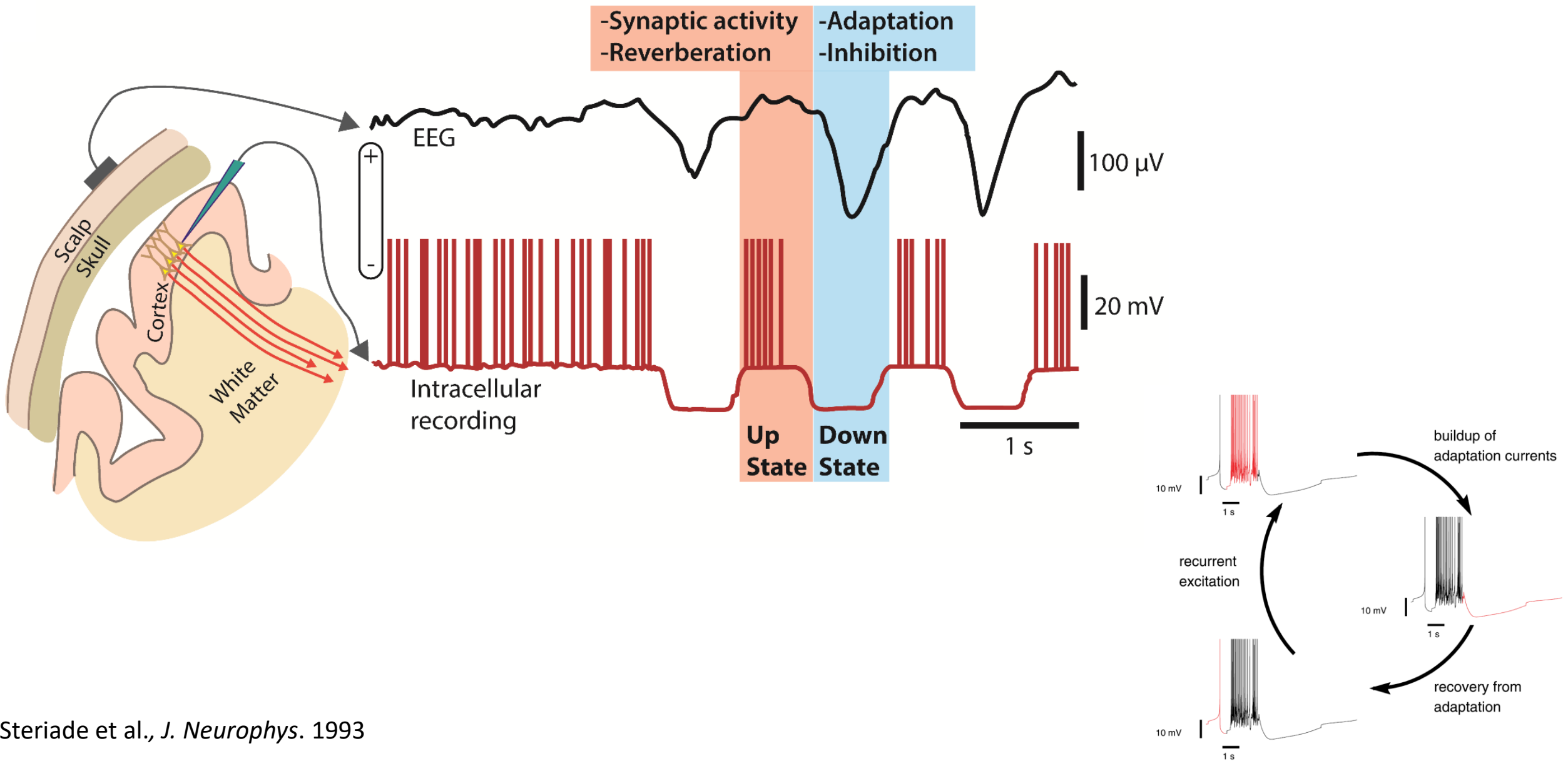


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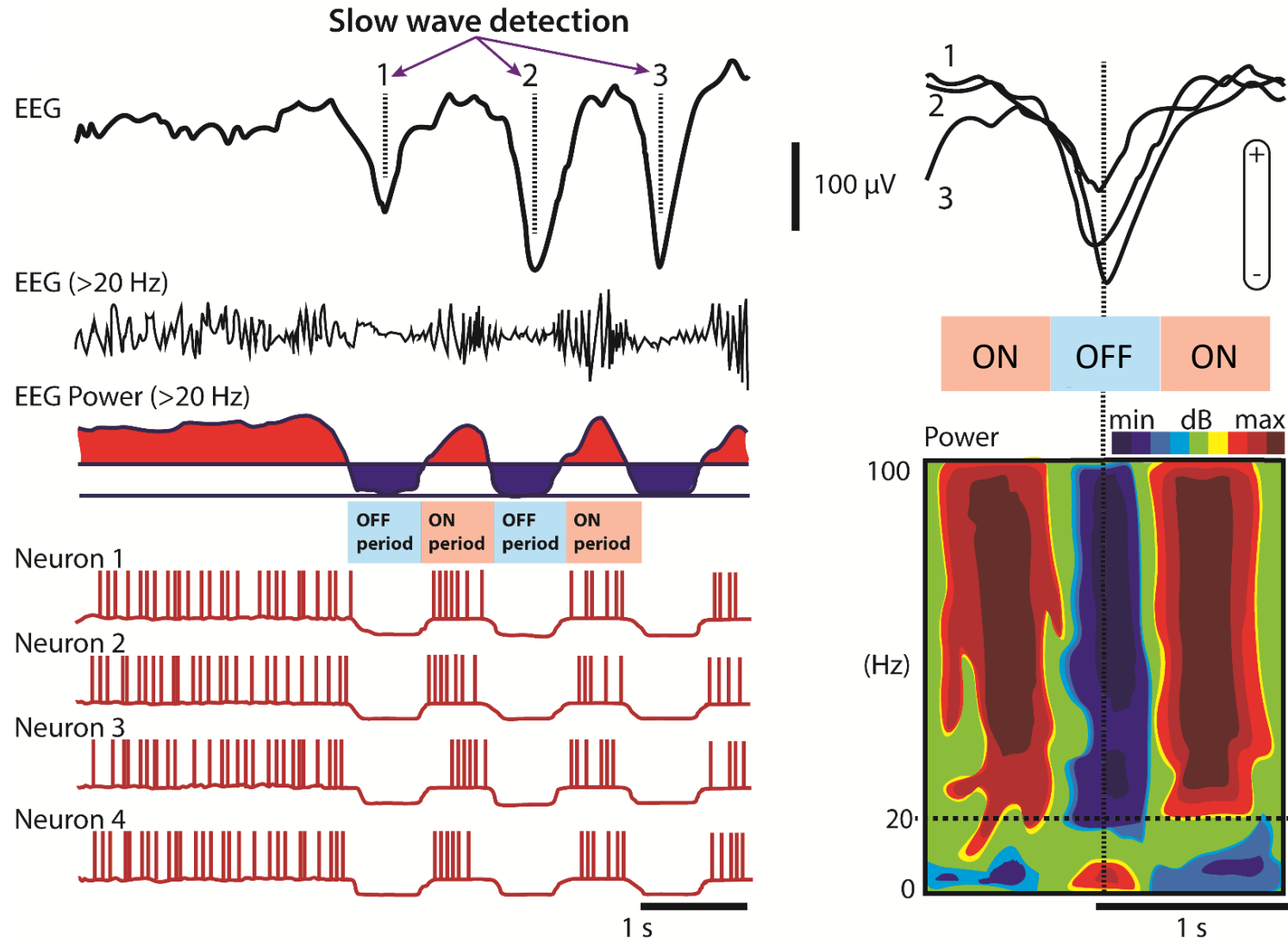
Disclosure:
I am shareholder and consultant
of Intrinsic Powers, Inc.



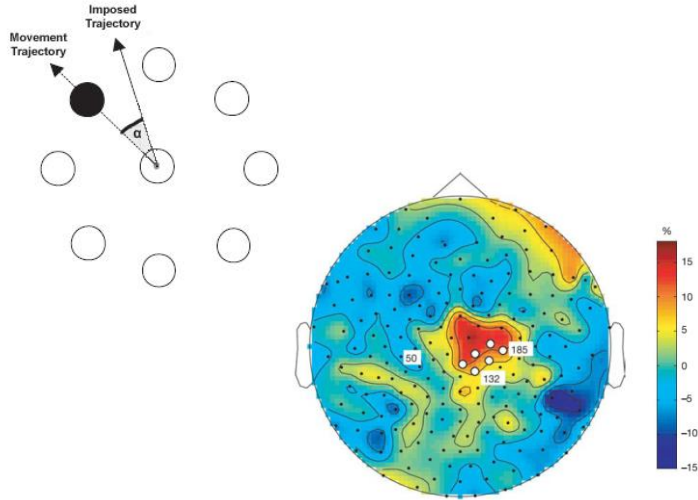
Physiological EEG sleep slow waves



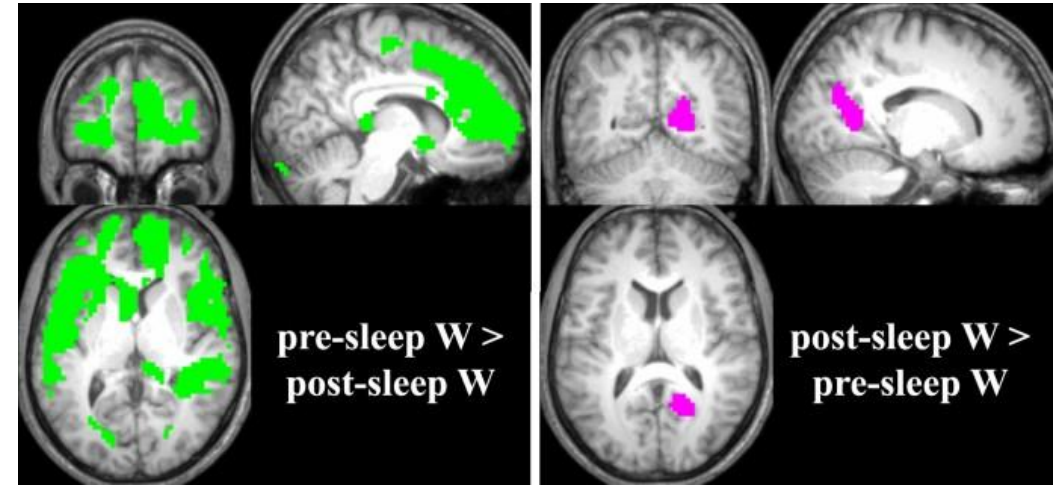
Physiological EEG sleep slow waves



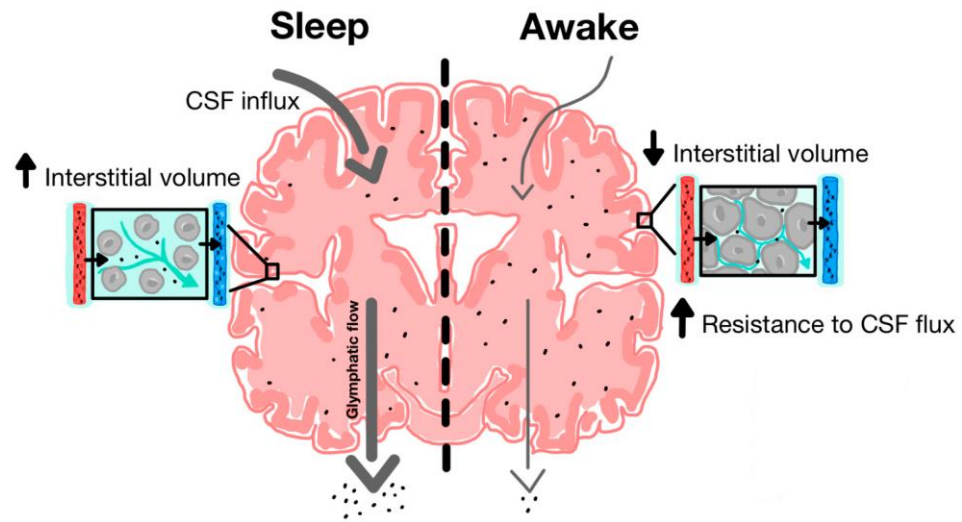
Sleep slow waves can be beneficial



Huber et al., *Nature* 2004



Tüshaus et al., *Sci Rep* 2017

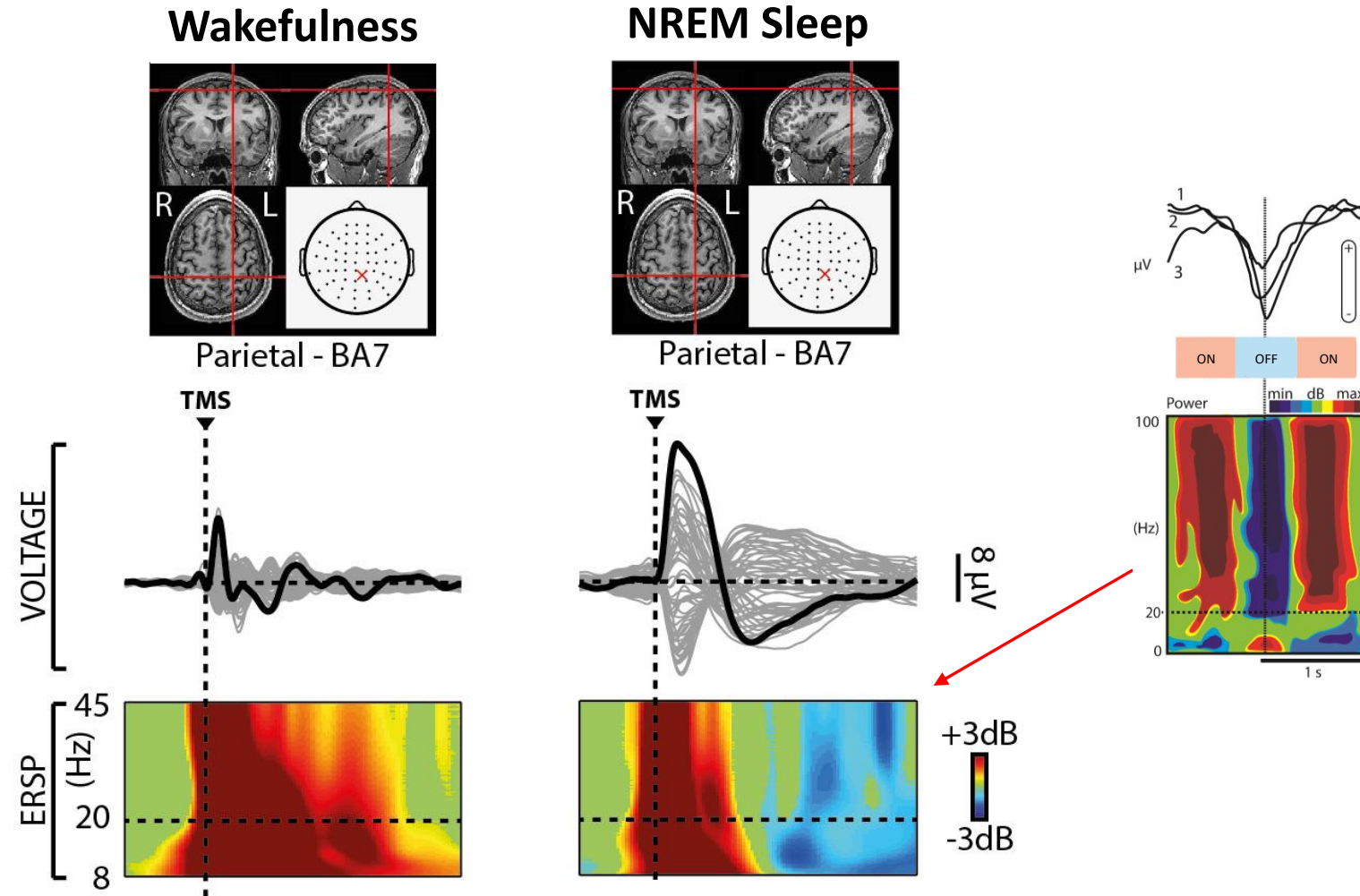


Xie et al., *Science* 2013

Sleep slow waves can be best revealed by perturbations



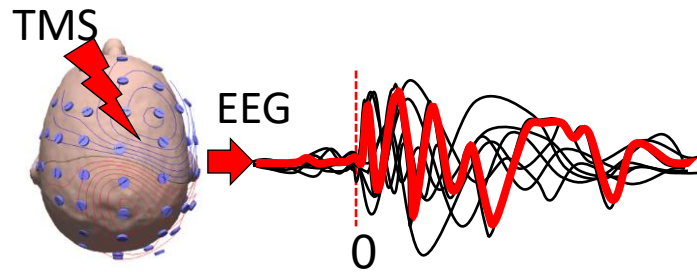
Sleep slow waves can be best revealed by perturbations



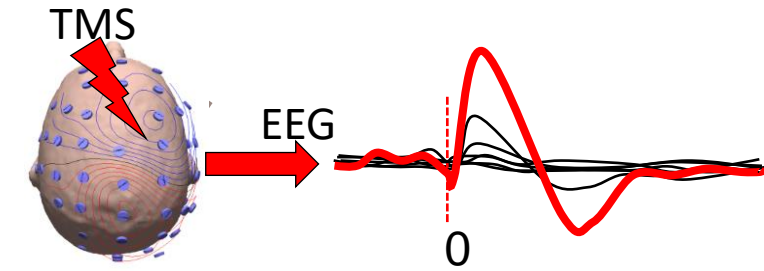
Massimini et al., *Science* 2005; Massimini et al., *PNAS* 2007; Rosanova et al., *J Neuroscience* 2009; Massimini et al., *Prog Brain Res* 2009; Massimini et al., *Eur J Neurosci* 2009; Ferrarelli et al., *PNAS* 2010; Massimini et al., *Arch Ital Biol* 2012; Massimini et al., *Cogn Neurosci* 2010; Rosanova et al., *Brain* 2012; Sarasso, Boly et al., *Curr Biol* 2015

The network consequence of sleep slow waves

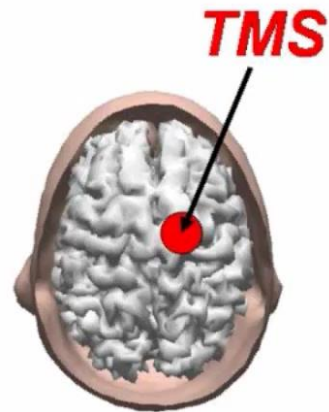
Wakefulness



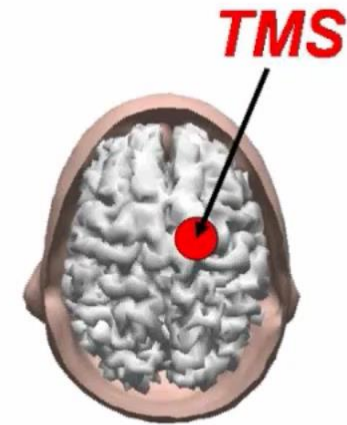
NREM Sleep



0 ms



0 ms



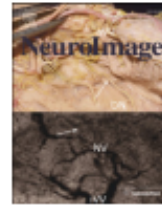
The network consequence of sleep slow waves



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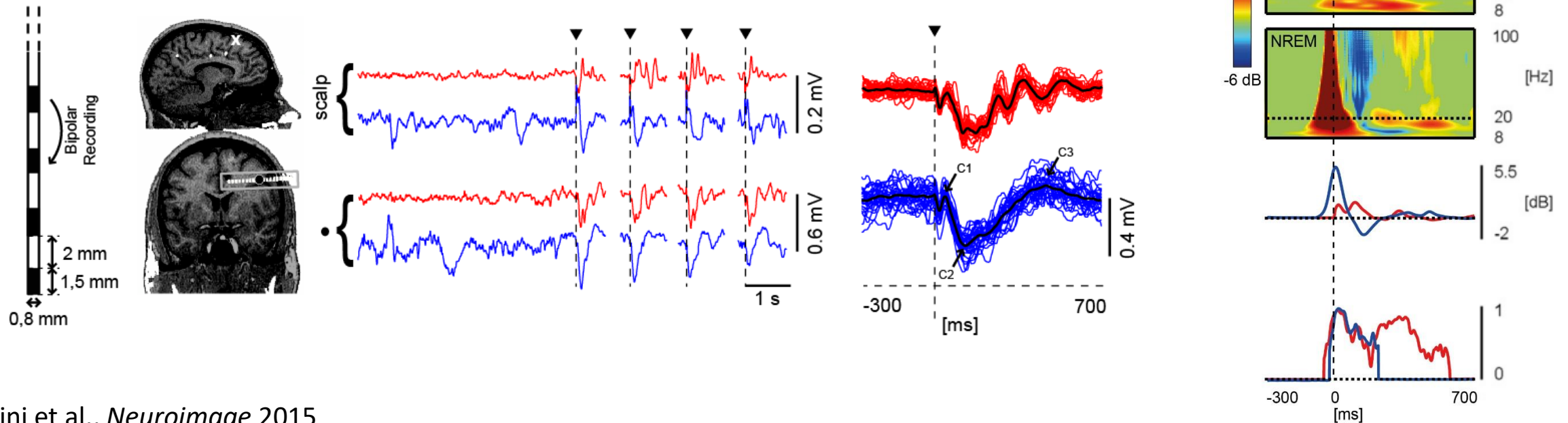


Full Length Articles

Bistability breaks-off deterministic responses to intracortical stimulation during non-REM sleep



Andrea Pigorini^a, Simone Sarasso^a, Paola Proserpio^b, Caroline Szymanski^c, Gabriele Arnulfo^d, Silvia Casarotto^a, Matteo Fecchio^a, Mario Rosanova^a, Maurizio Mariotti^a, Giorgio Lo Russo^b, J. Matias Palva^d, Lino Nobili^b, Marcello Massimini^{a,e,*}



The network consequence of slow waves

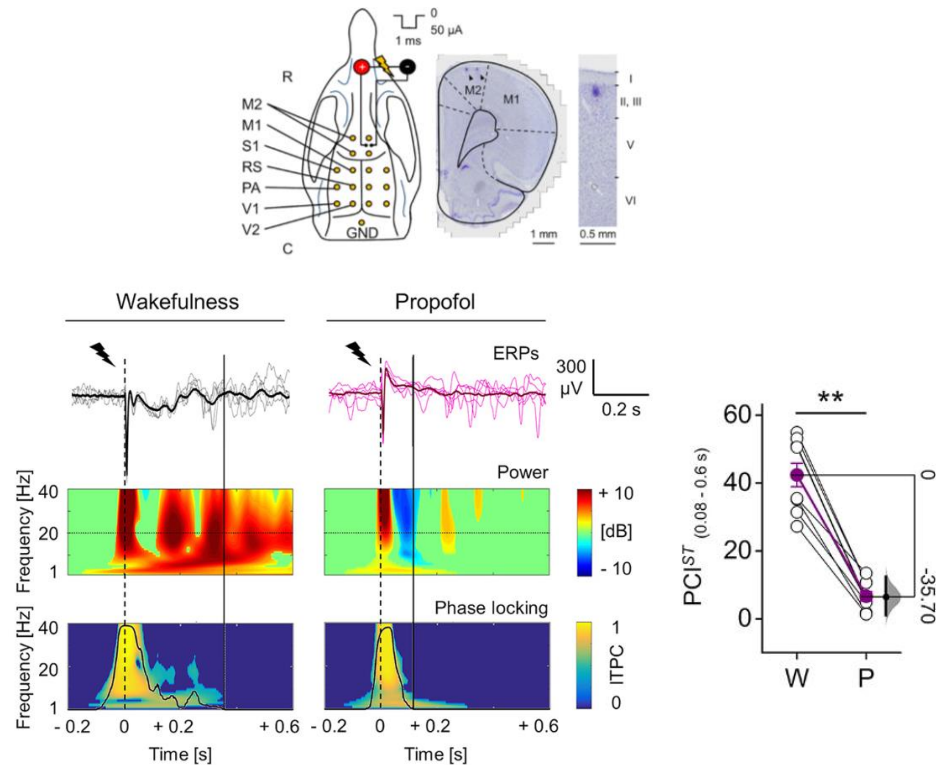
eNeuro

Research Article: New Research

Novel Tools and Methods

General Anesthesia Disrupts Complex Cortical Dynamics in Response to Intracranial Electrical Stimulation in Rats

A. Arena,¹ R. Comolatti,² S. Thon,¹ A. G. Casali,² and J. F. Storm¹



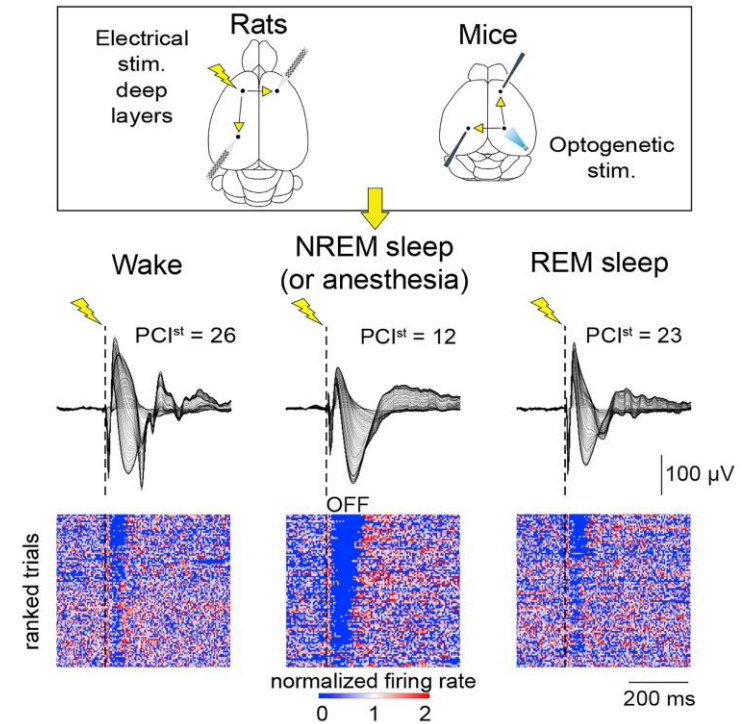
iScience

CellPress
OPEN ACCESS

Article

Sleep/wake changes in perturbational complexity in rats and mice

Matias Lorenzo Cavelli,^{1,3,4} Rong Mao,^{1,2,4} Graham Findlay,^{1,2} Kort Driessen,^{1,2} Tom Bugnon,¹ Giulio Tononi,^{1,*} and Chiara Cirelli^{1,5,*}



Slow waves can intrude into wakefulness

Slow waves during wakefulness affect behavior

ARTICLE

nature


doi:10.1038/nature10009

Local sleep in awake rats

Vladyslav V. Vyazovskiy¹, Umberto Olcese^{1,2}, Erin C. Hanlon¹, Yuval Nir¹, Chiara Cirelli¹ & Giulio Tononi¹


nature
medicine

Selective neuronal lapses precede human cognitive lapses following sleep deprivation

Yuval Nir¹, Thomas Andrillon²⁻⁴ , Amit Marmelshtein¹, Nanthia Suthana⁵, Chiara Cirelli⁴, Giulio Tononi^{4,7} & Itzhak Fried⁵⁻⁷








ARTICLE

 Check for updates

<https://doi.org/10.1038/s41467-021-23890-7>

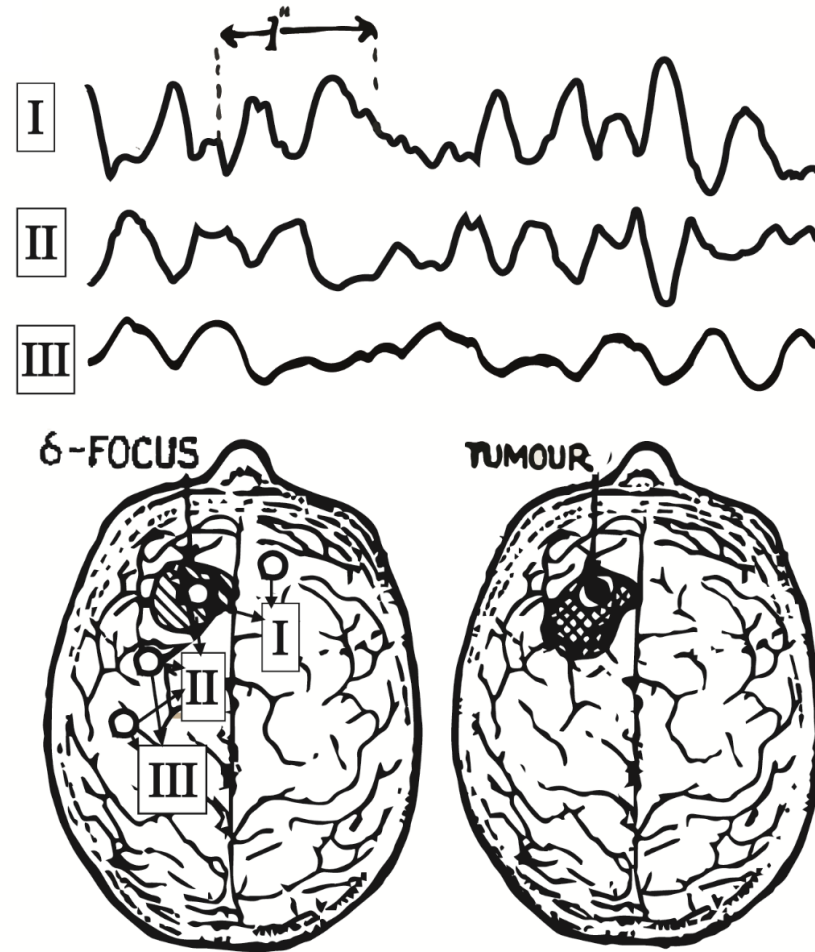
OPEN

Predicting lapses of attention with sleep-like slow waves

Thomas Andrillon ^{1,2} ^{2,3}, Angus Burns ¹, Teigane Mackay ¹, Jennifer Windt³ & Naotsugu Tsuchiya ^{1,4,5}

Slow waves can occur after brain injury

Slow waves: a consistent aftermath of brain injury









ARTICLE

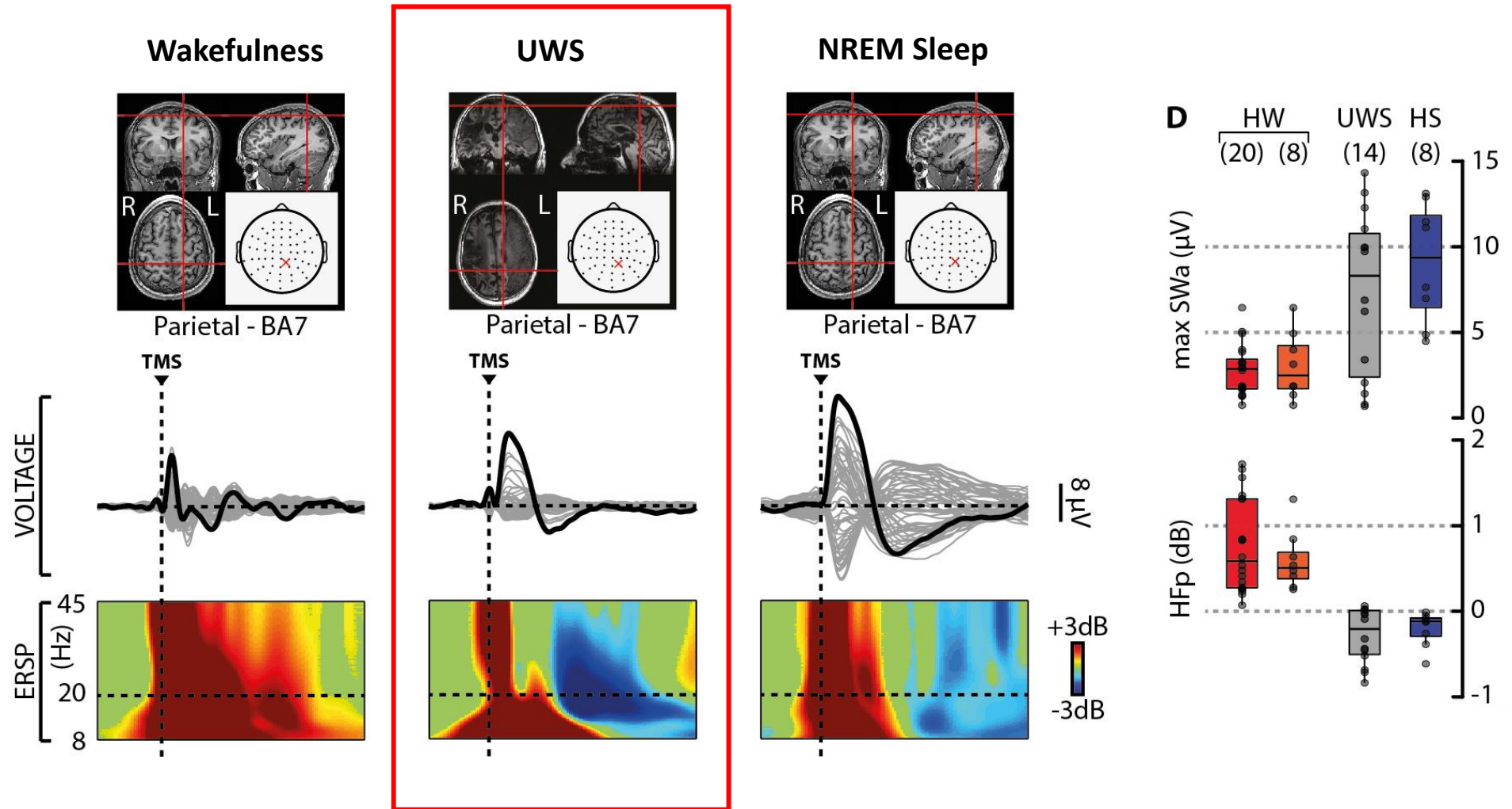
DOI: 10.1038/s41467-018-06871-1

OPEN

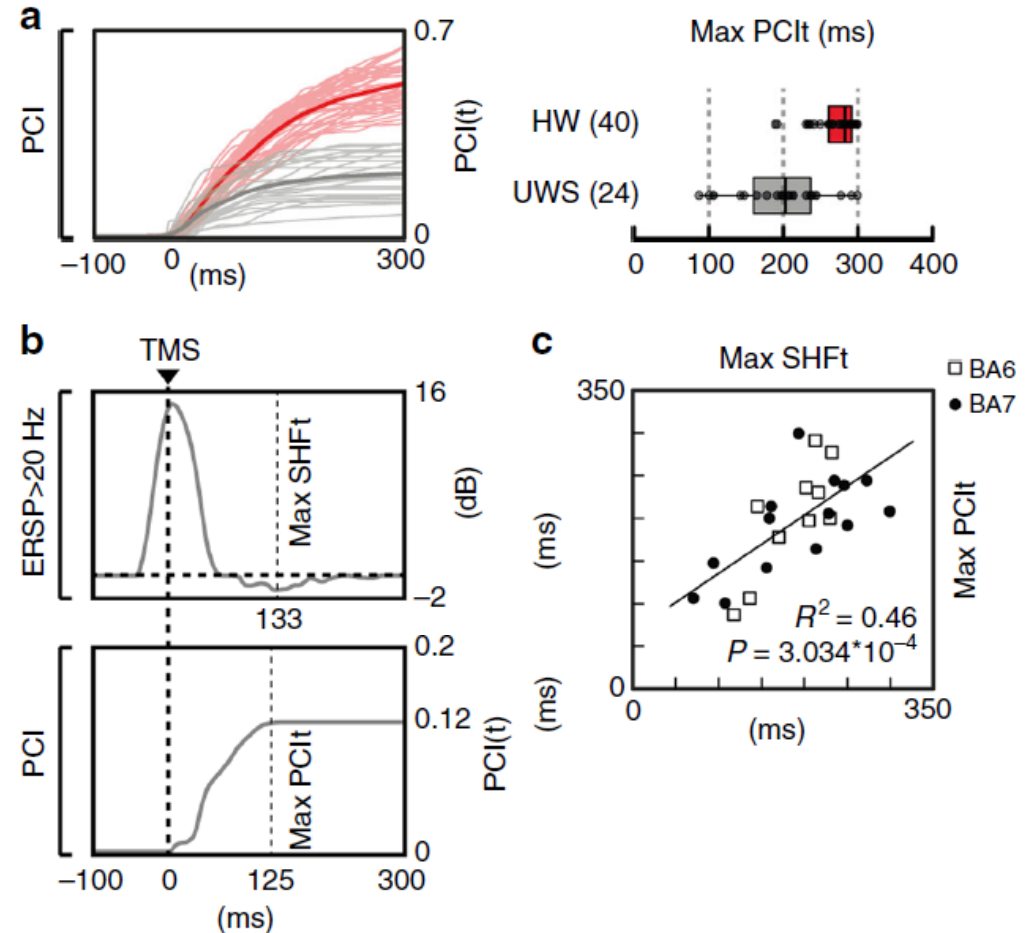
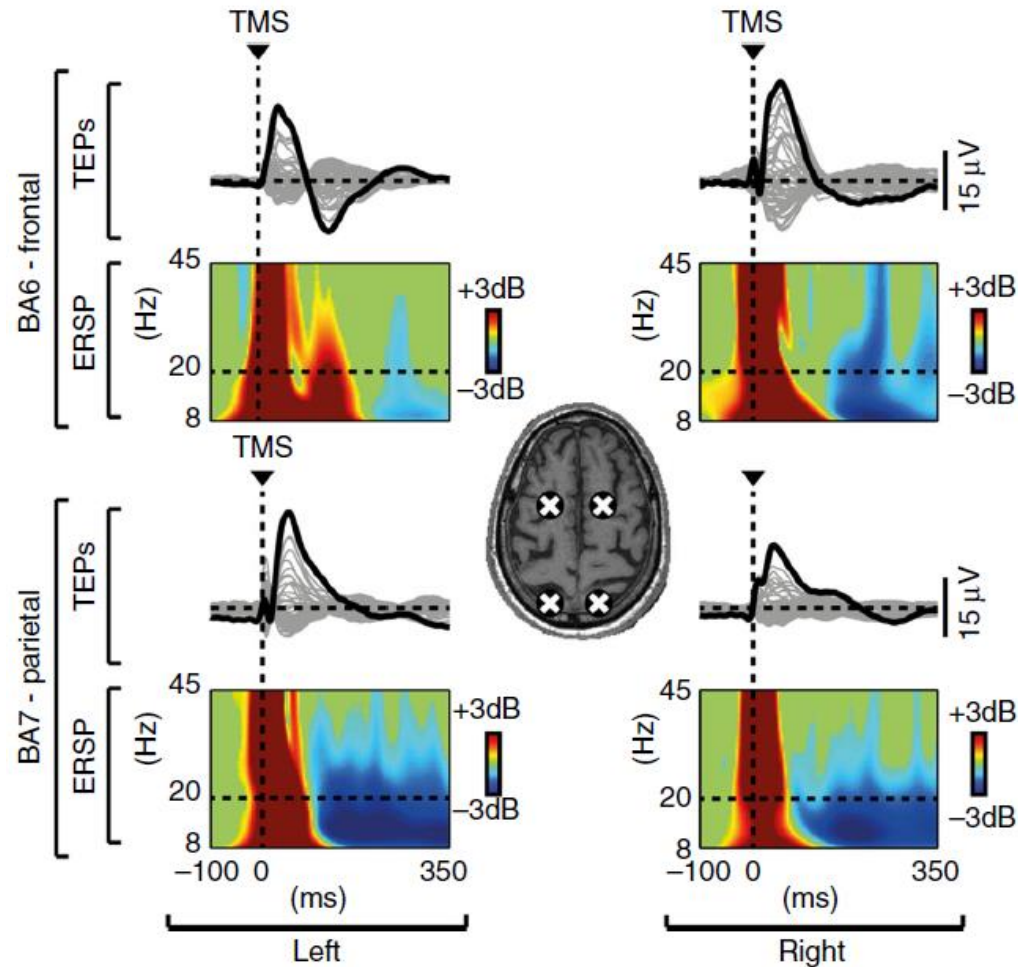
Sleep-like cortical OFF-periods disrupt causality and complexity in the brain of unresponsive wakefulness syndrome patients

M. Rosanova ^{1,2,3}, M. Fecchio ¹, S. Casarotto ^{1,4}, S. Sarasso ¹, A.G. Casali⁵, A. Pigorini¹, A. Comanducci¹, F. Seregni⁶, G. Devalle⁴, G. Citerio ⁷, O. Bodart ⁸, M. Boly^{9,10}, O. Gosseries⁸, S. Laureys⁸ & M. Massimini^{1,4}

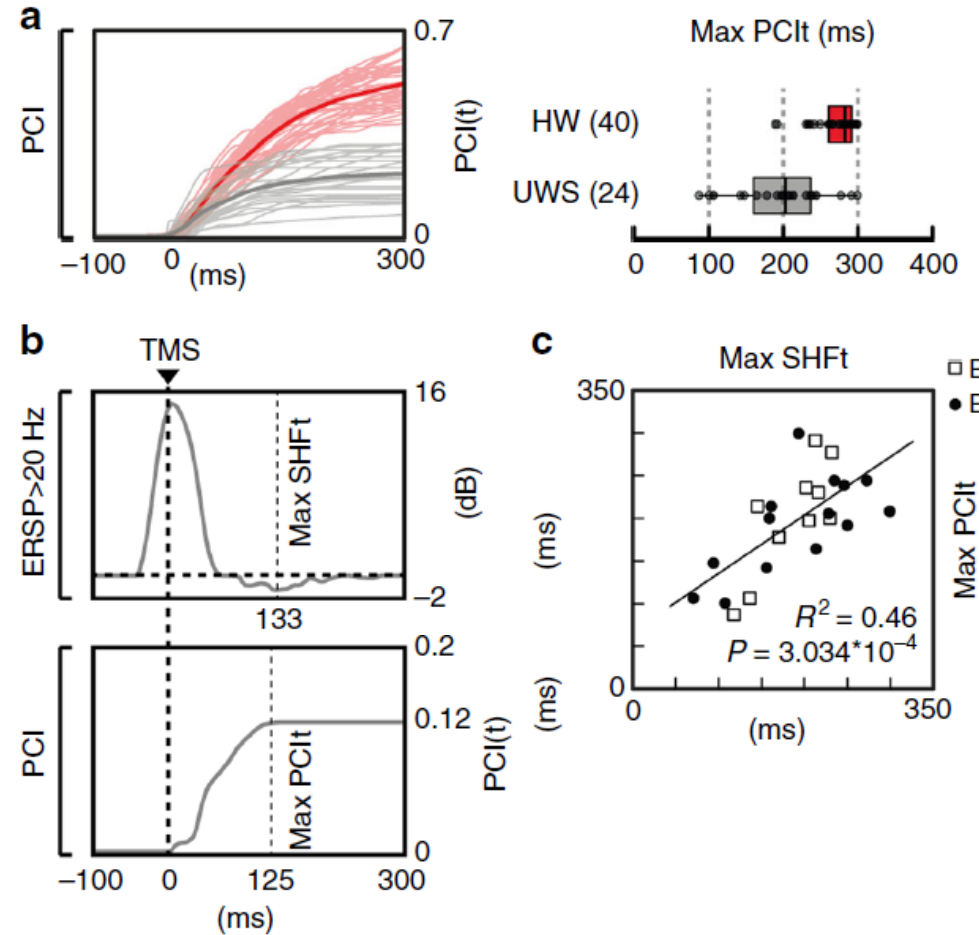
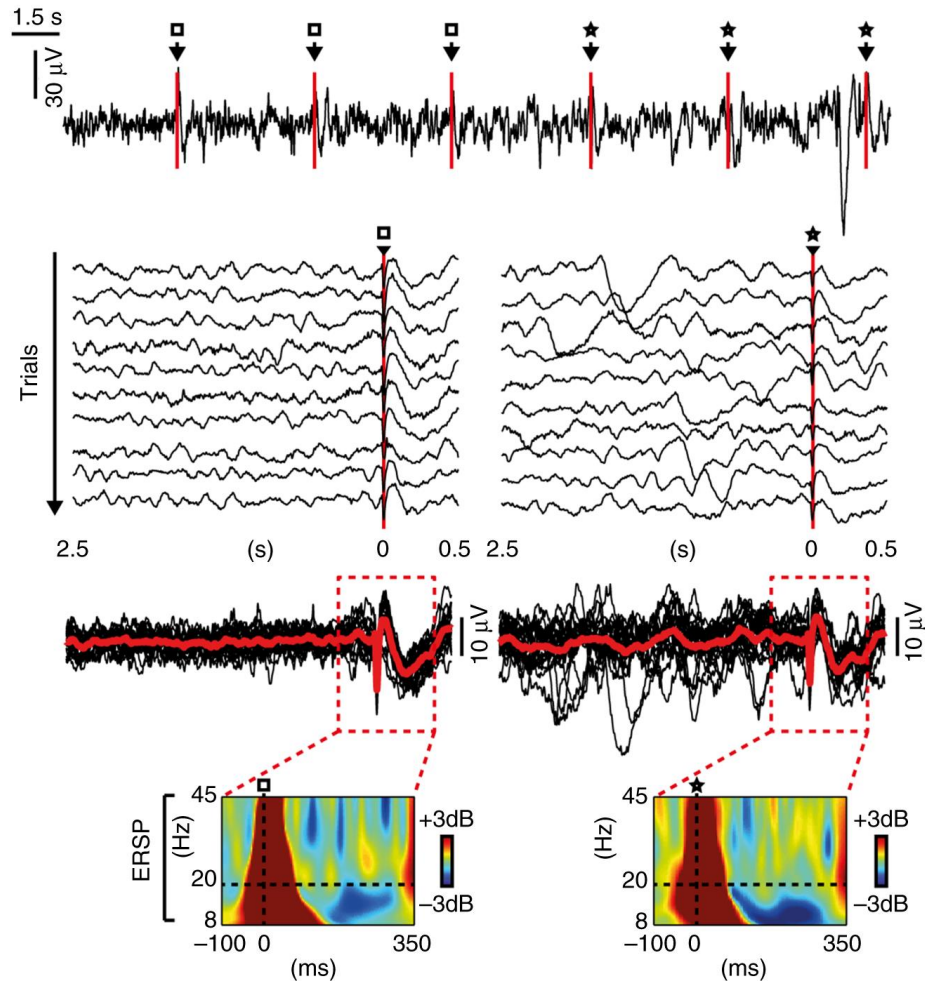
Slow waves in UWS/VS patients



Slow waves in UWS/VS are ubiquitous and affect global spatiotemporal complexity



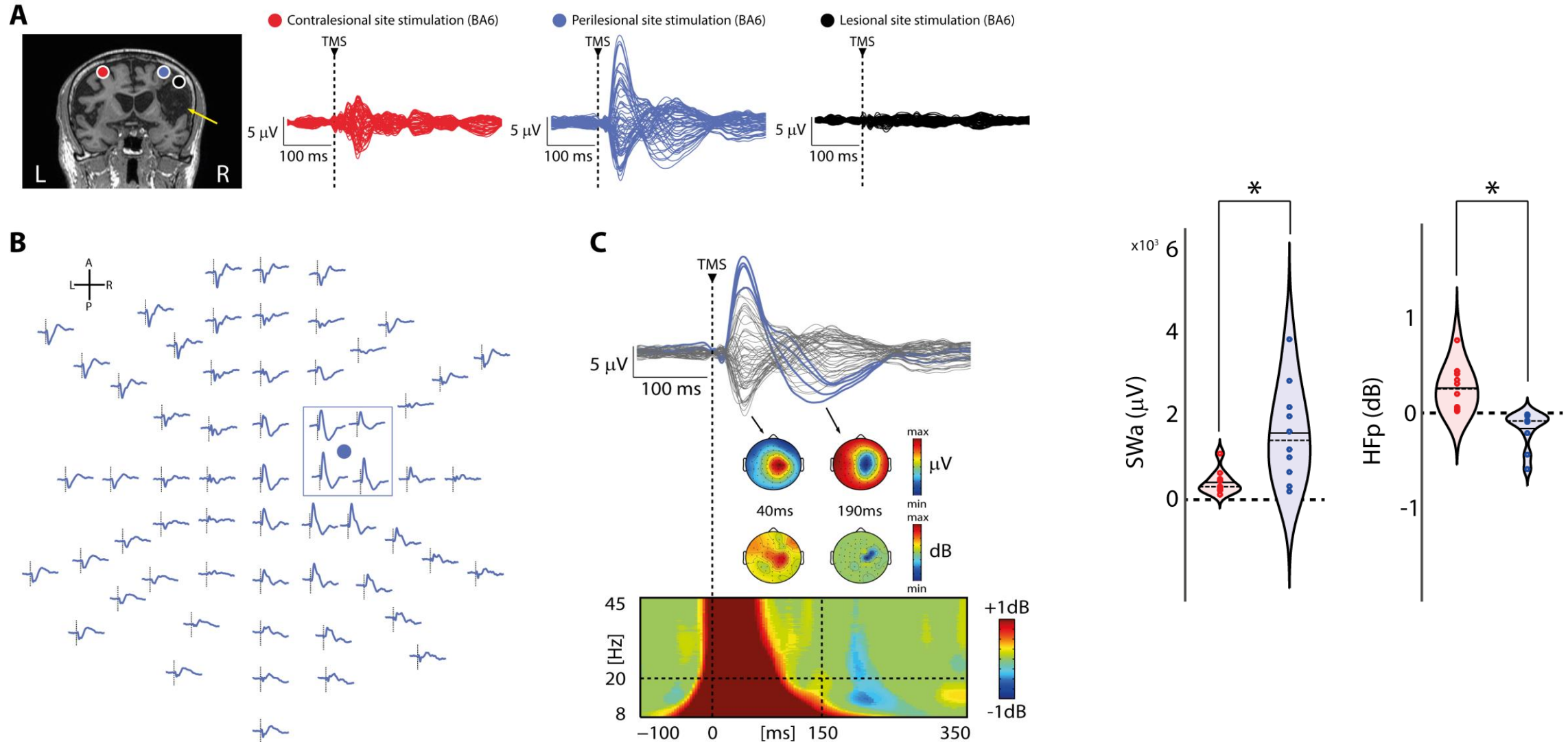
Slow waves in UWS/Vs are ubiquitous and affect global spatiotemporal complexity



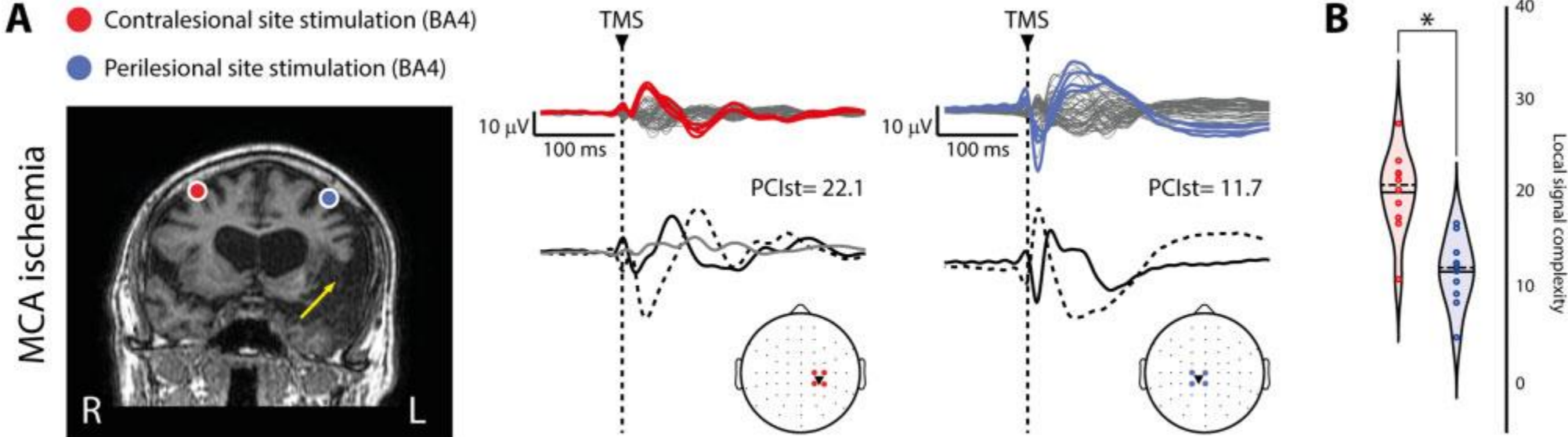
Local sleep-like cortical reactivity in the awake brain after focal injury

 **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}

Perilesional slow waves in awake stroke patients

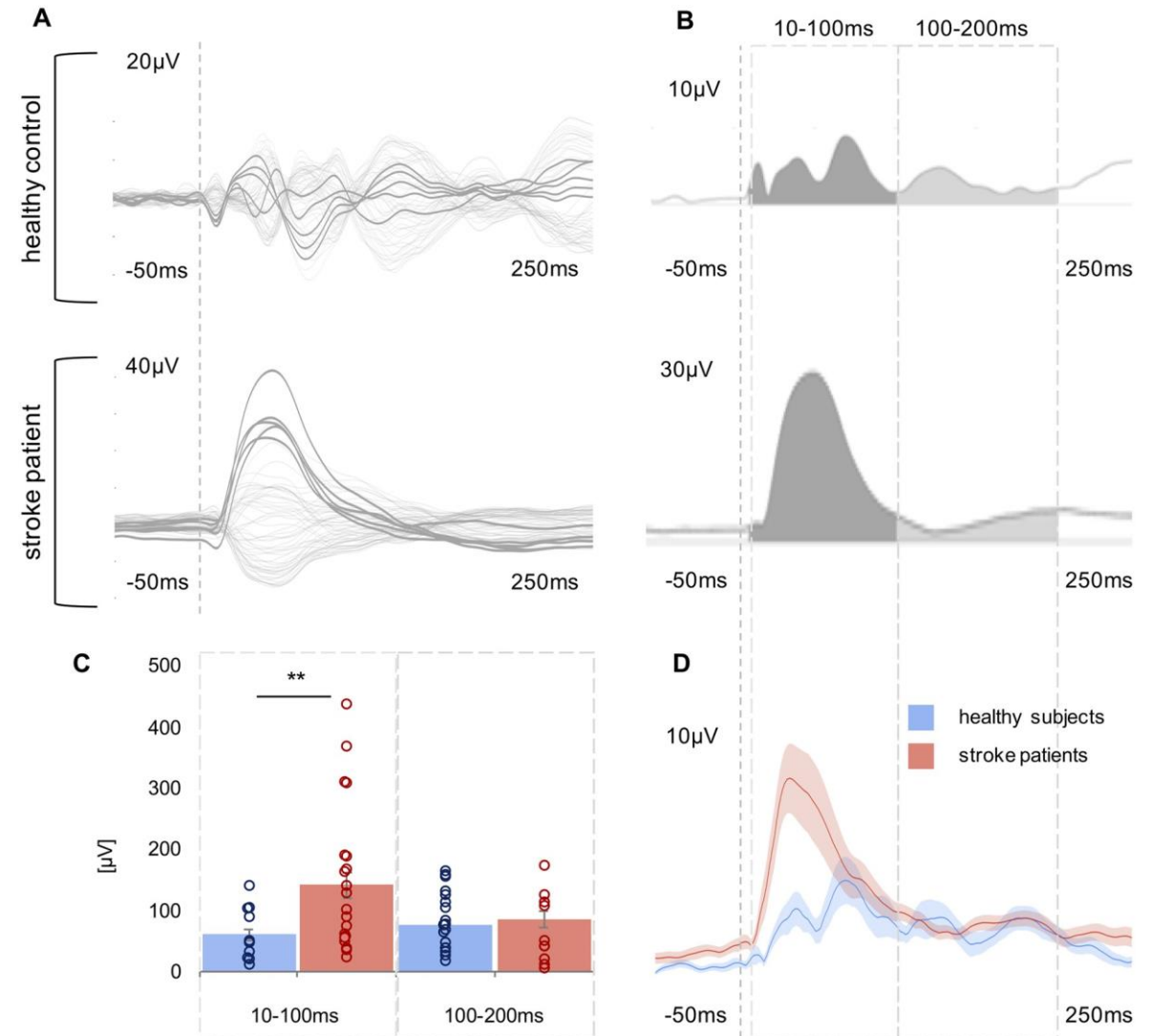
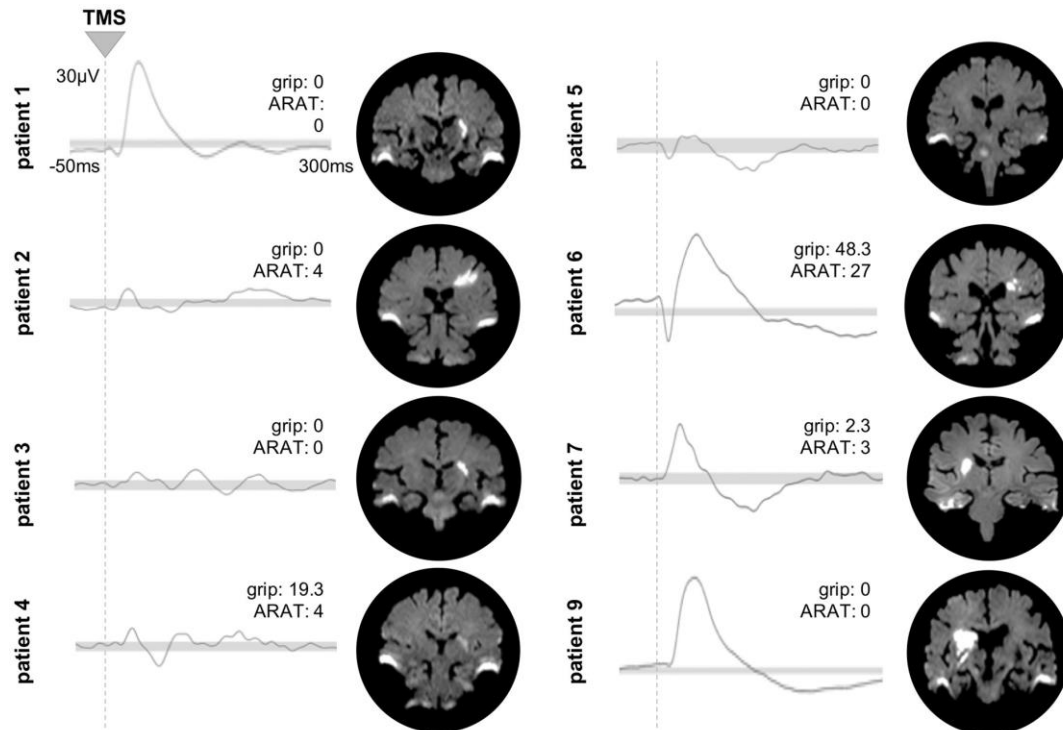


Perilesional slow waves affect local spatiotemporal complexity



Brain responsivity provides an individual readout for motor recovery after stroke

Caroline Tschempel,^{1,2} Sebastian Dern,¹ Lukas Hensel,¹ Ulf Ziemann,³
Gereon R. Fink^{1,2} and Christian Grefkes^{1,2}





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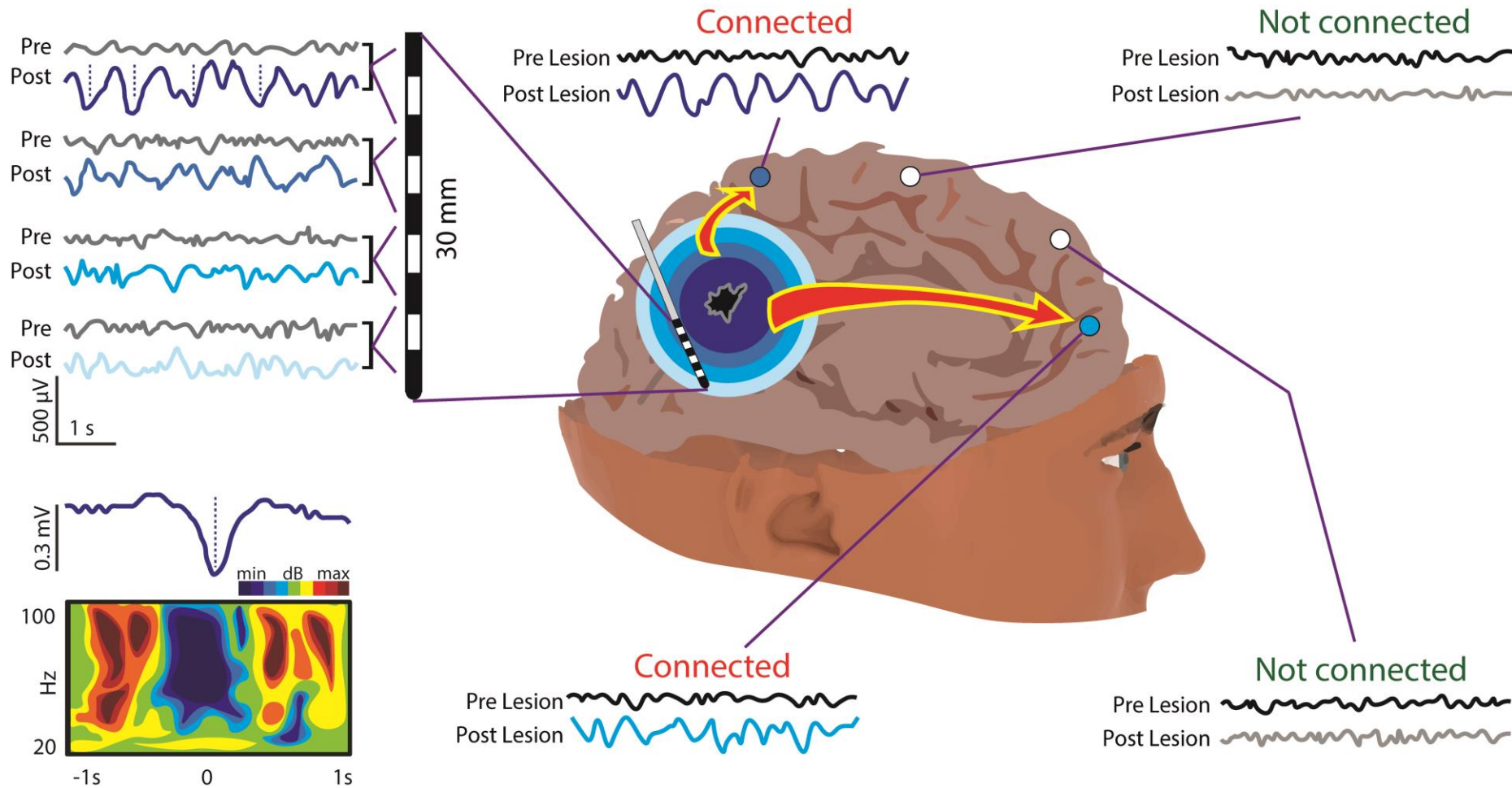


Focal lesions induce large-scale percolation of sleep-like intracerebral activity in awake humans

S. Russo^{a,1}, A. Pigorini^{a,1}, E. Mikulan^a, S. Sarasso^a, A. Rubino^b, F.M. Zauli^a, S. Parmigiani^a, P. d'Orto^{b,c}, A. Cattani^{a,d}, S. Francione^b, L. Tassi^b, C.L.A. Bassetti^f, G. Lo Russo^b, L. Nobili^{e,i}, I. Sartori^b, M. Massimini^{a,g,h,*}



Propagation of perilesional slow waves





The Sleep Slow Oscillation as a Traveling Wave

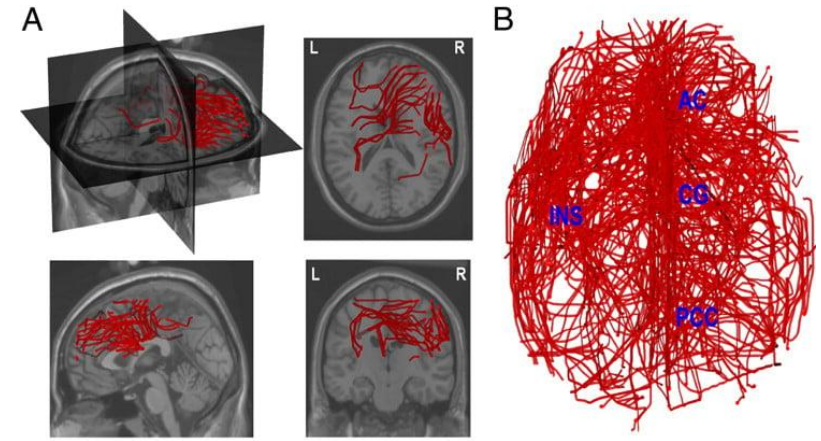
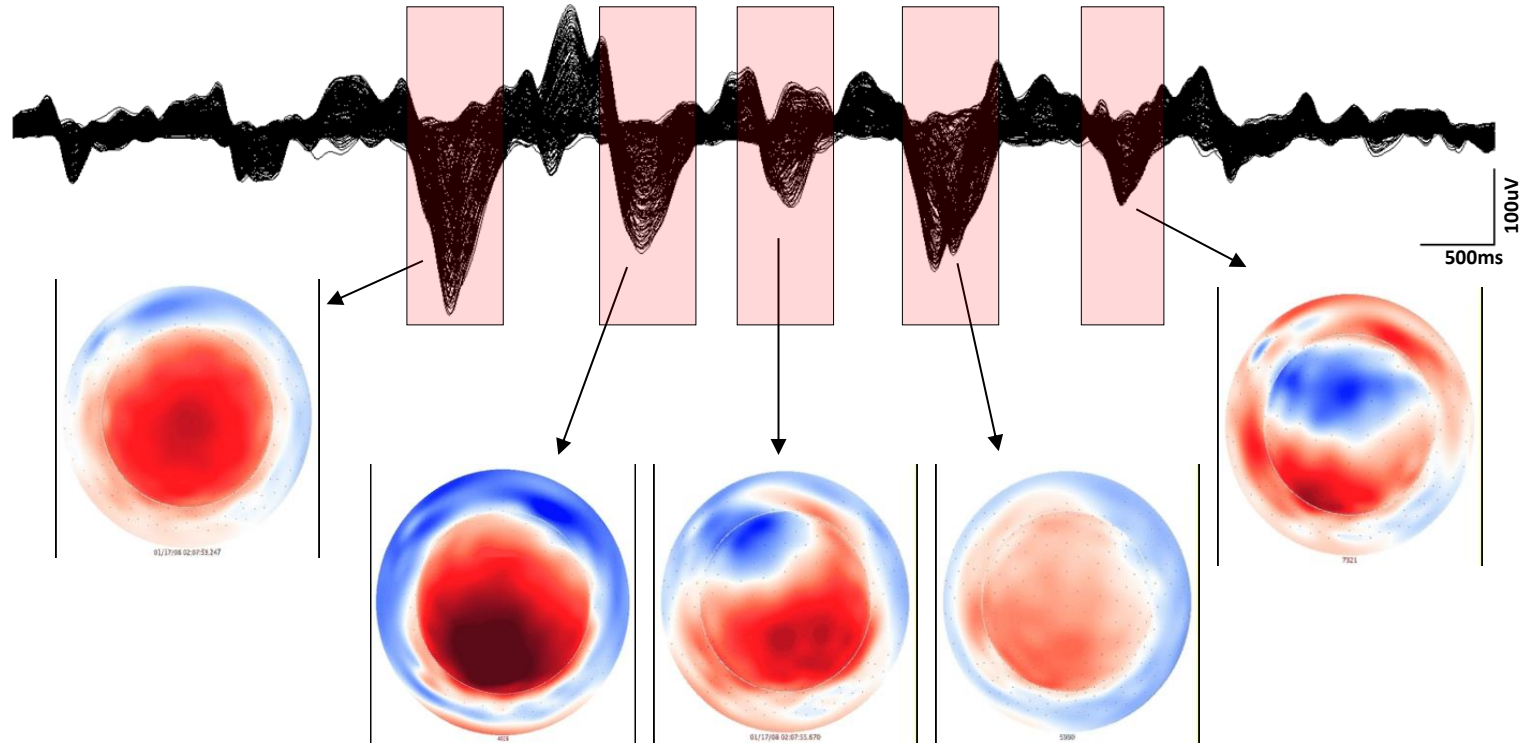
Source modeling sleep slow waves

Michael Murphy^{a,b,1}, Brady A. Riedner^{a,b,c,1}, Reto Huber^a, Marcello Massimini^a, Fabio Ferrarelli^a, and Giulio Tononi^{a,2}

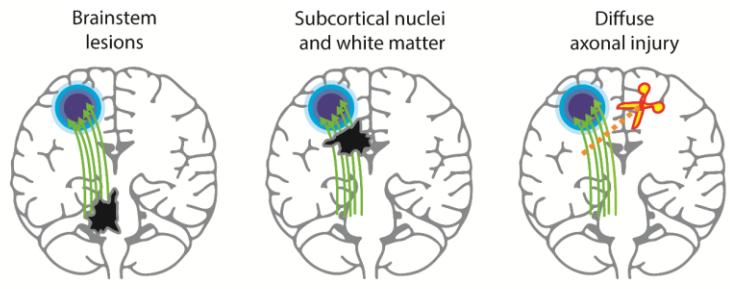
^aDepartment of Psychiatry, University of Wisconsin, Madison, WI 53719; and ^bNeuroscience Training Program and ^cClinical Neuroengineering Training Program, University of Wisconsin, Madison, WI 53706

Marcello Massimini, Reto Huber, Fabio Ferrarelli, Sean Hill, and Giulio Tononi

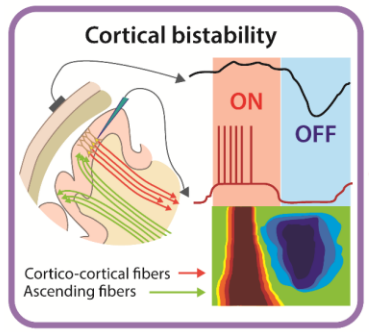
Department of Psychiatry, University of Wisconsin–Madison, Madison, Wisconsin 53719

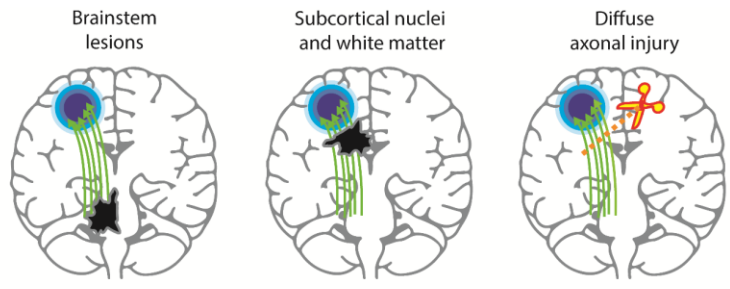


Mechanisms of postlesional slow waves

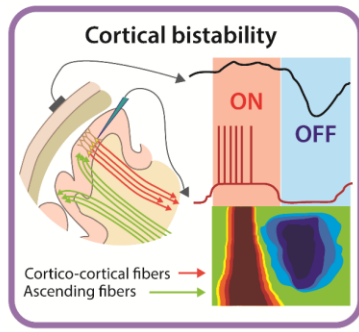


↑Adaptation

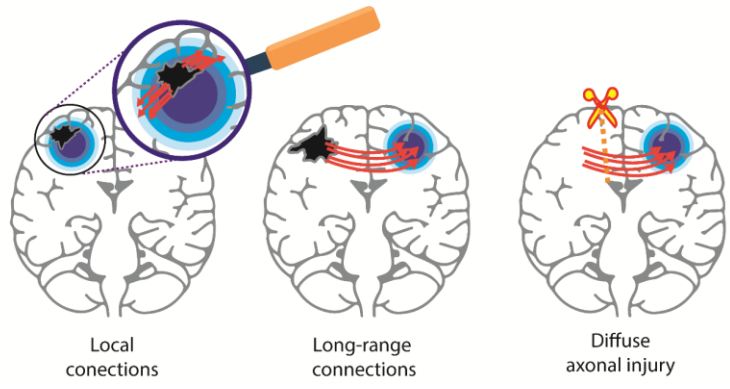


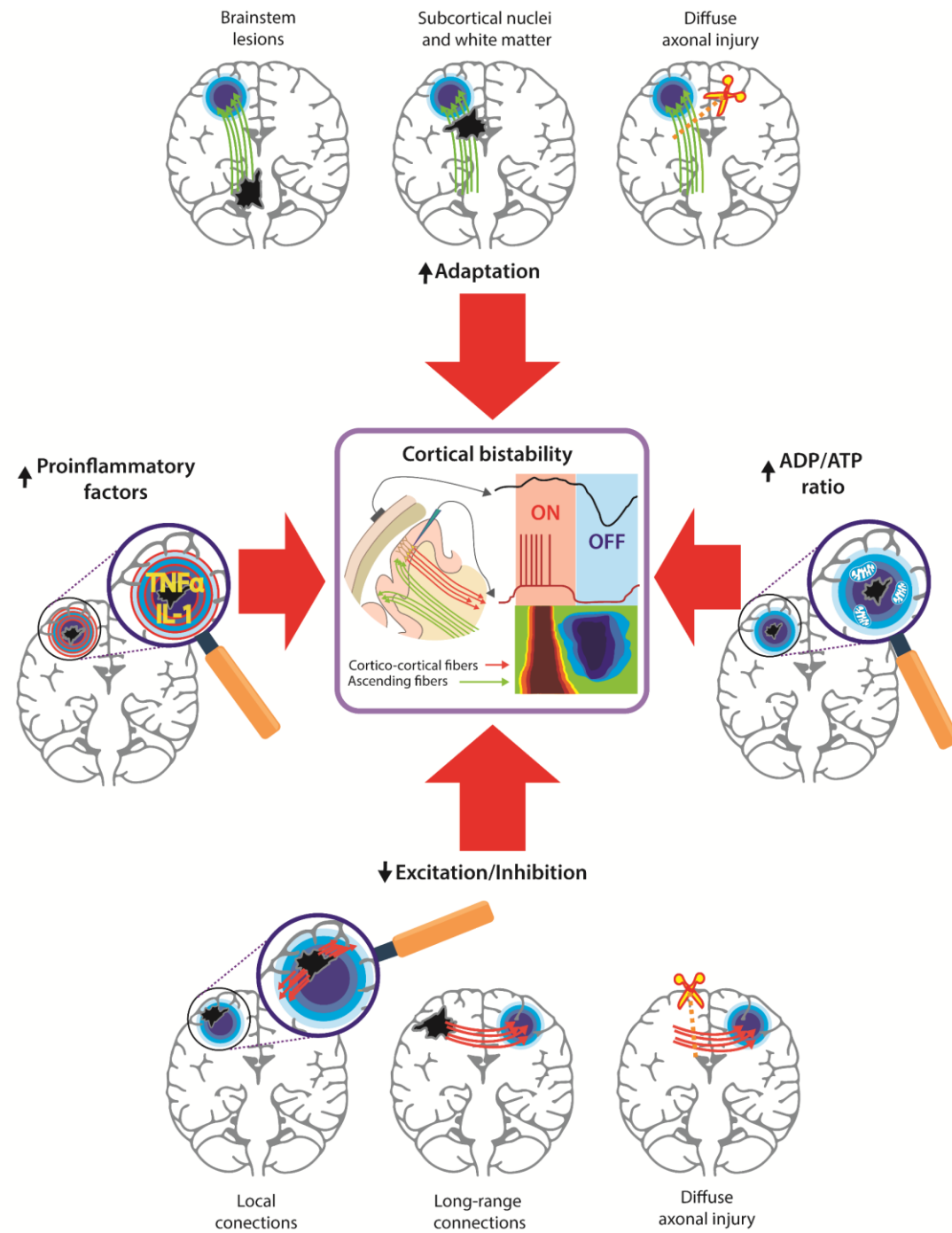


↑Adaptation

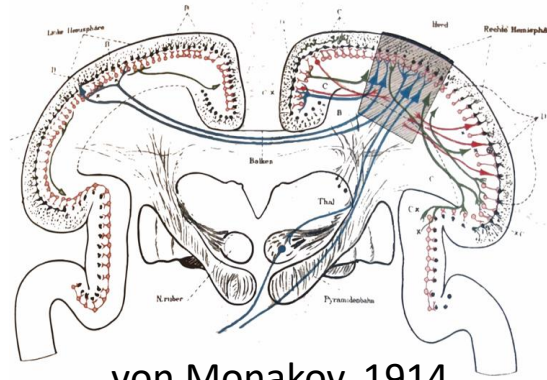


↓Excitation/Inhibition



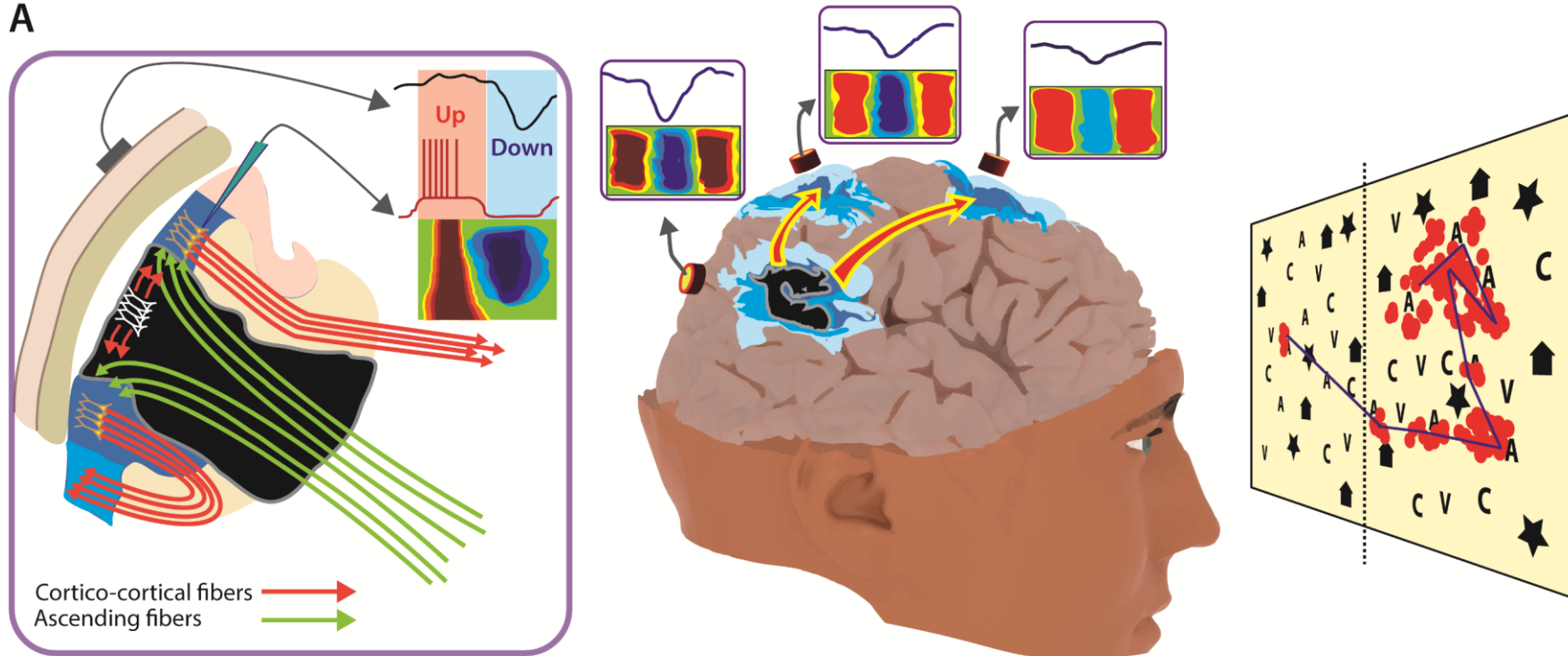


Reviving the classic notion of diaschisis



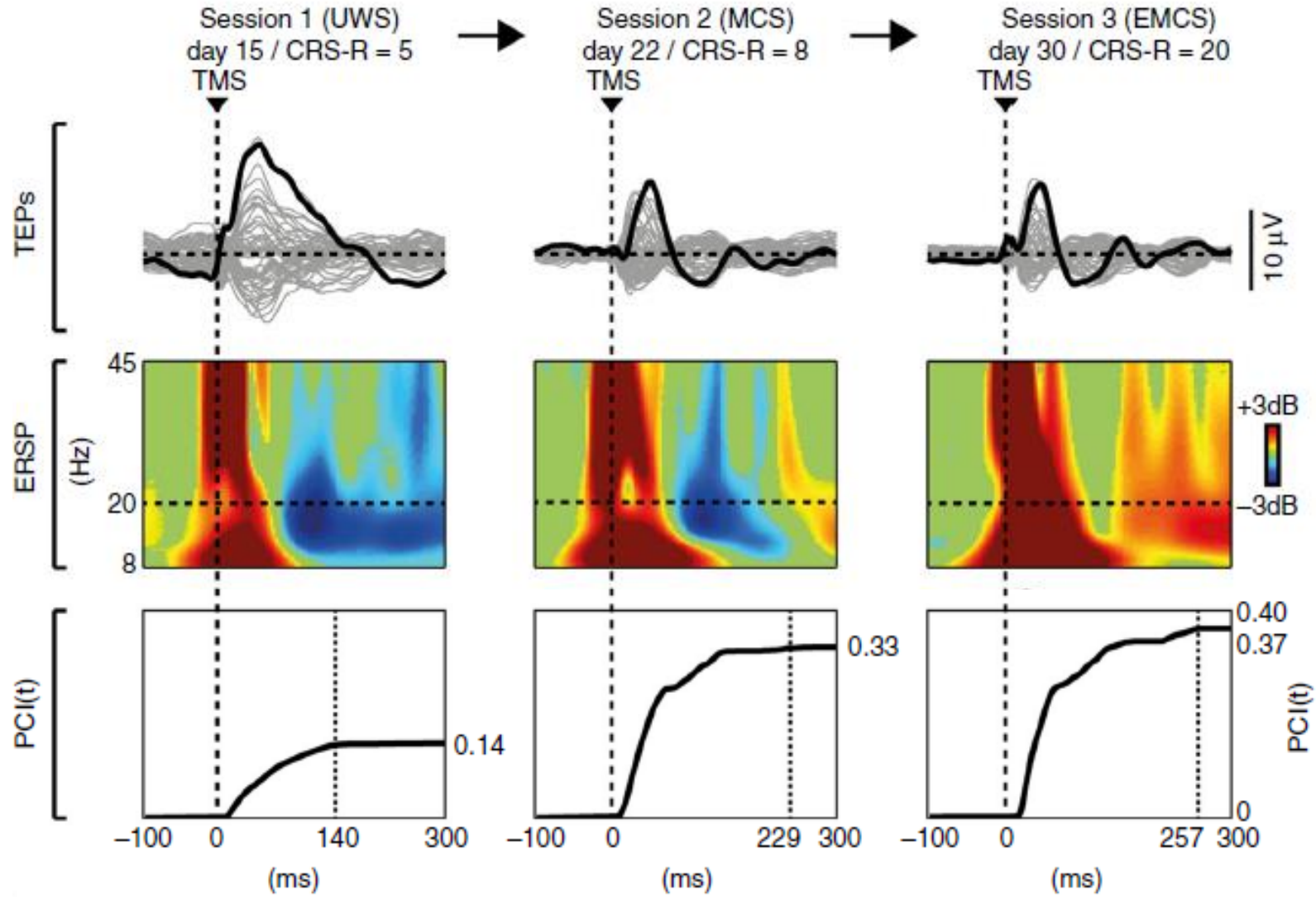
von Monakov, 1914

A

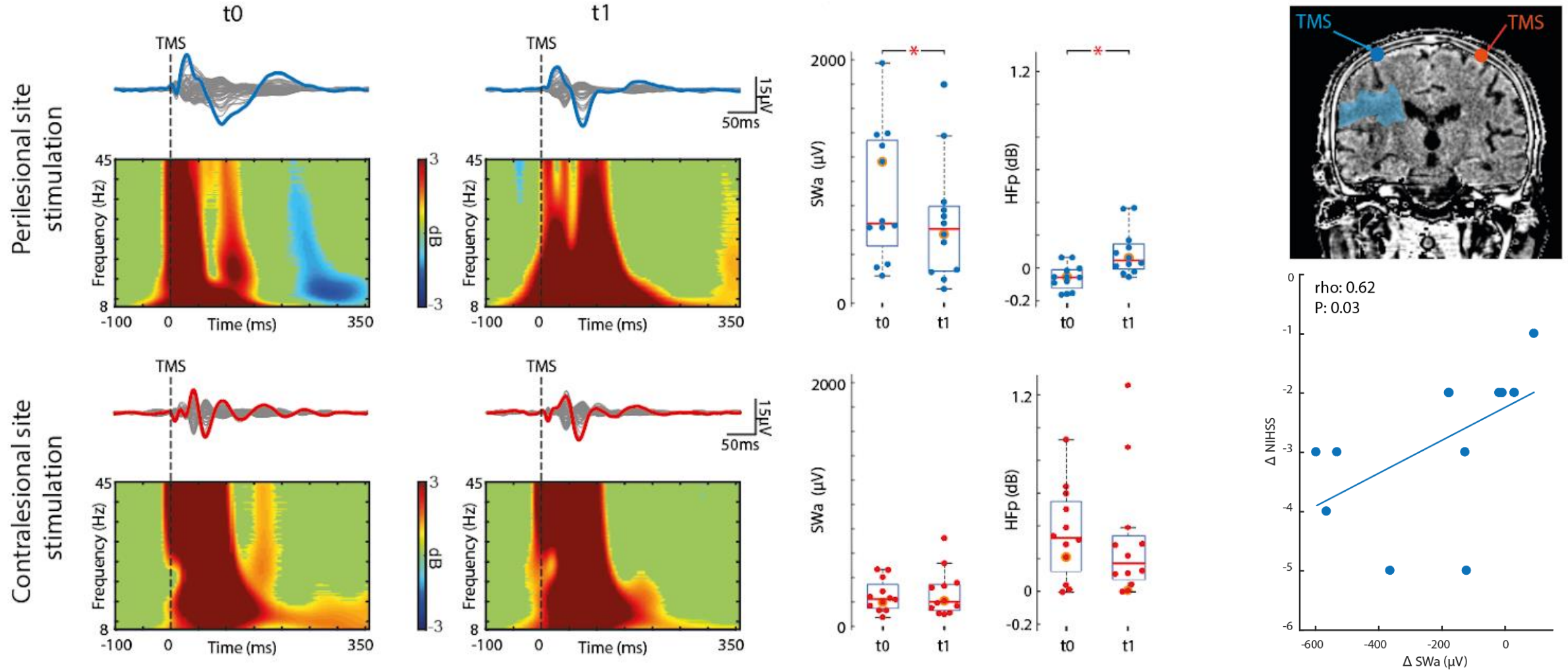


Implications for treatment and rehabilitation

Slow waves are reversible



Slow waves are reversible



Slow waves can be manipulated



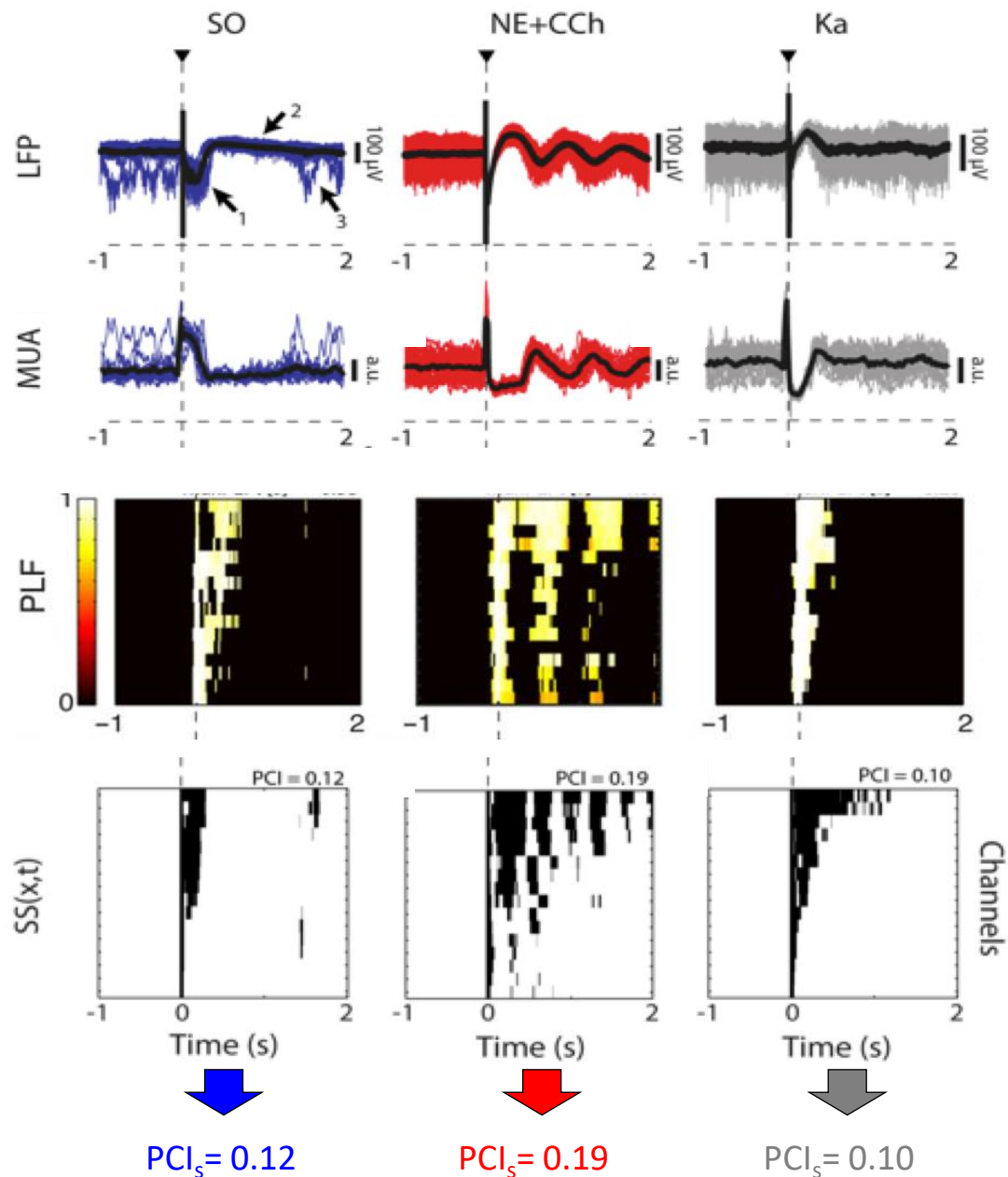
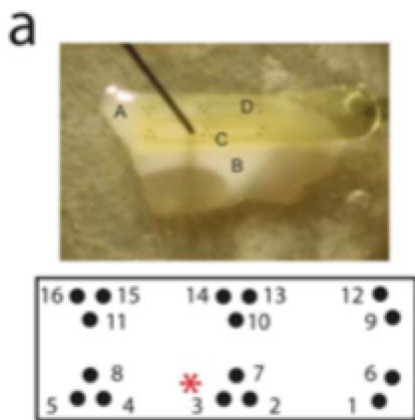
Cerebral Cortex, 2017; 1–10

doi: 10.1093/cercor/bhx122
Original Article

ORIGINAL ARTICLE

Bistability, Causality, and Complexity in Cortical Networks: An In Vitro Perturbational Study

Mattia D'Andola¹, Beatriz Rebollo¹, Adenauer G. Casali², Julia F. Weinert¹,
Andrea Pigorini³, Rosa Villa^{4,5}, Marcello Massimini^{3,6}
and Maria V. Sanchez-Vives^{1,7}



Thank you!



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CARLO GNOCCHI**
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FRANCESCA BAGLIO

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