Working memory and alpha oscillations

Mattia F. Pagnotta

Oscillatory Brain Waves symposium

December 11, 2024

Berkeley Neuroscience
HELEN WILLS NEUROSCIENCE INSTITUTE

FNSNF
SWISS NATIONAL SCIENCE FOUNDATION

Early Postdoc.Mobility P2FRP3_195083
Postdoc.Mobility P500PB_214404

Mark D'Esposito

Robert T. Knight

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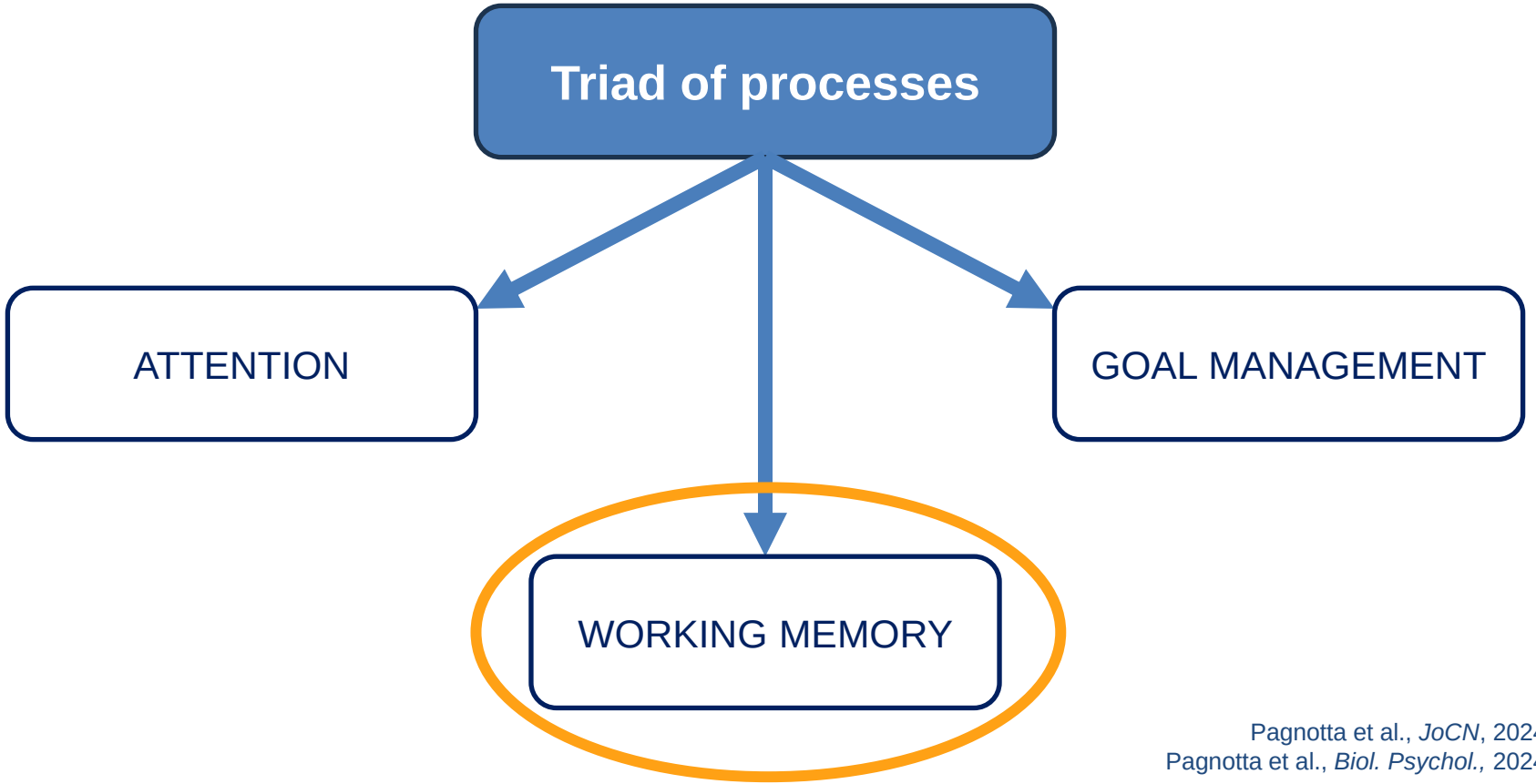
Early Postdoc.Mobility P2FRP3_195083
Postdoc.Mobility P500PB_214404

Cognitive control



Pagnotta et al., *JoCN*, 2024
Pagnotta et al., *Biol. Psychol.,* 2024

Working memory

“I know that Matt Walker said that sleep is our superpower. While we are awake, working memory is our superpower, because it allows us to translate our knowledge into action by holding this information in mind.”

“The Boss” Mark D'Esposito

The ‘two lives’ of alpha in working memory

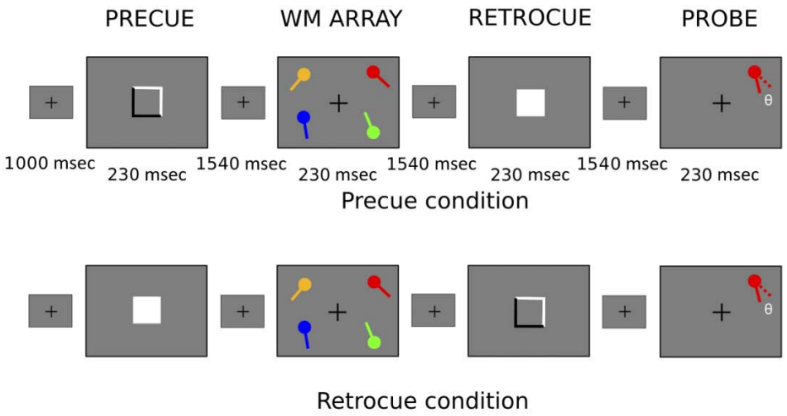
Alpha oscillations (8–12 Hz)

(1) **Gating**: suppression of irrelevant information

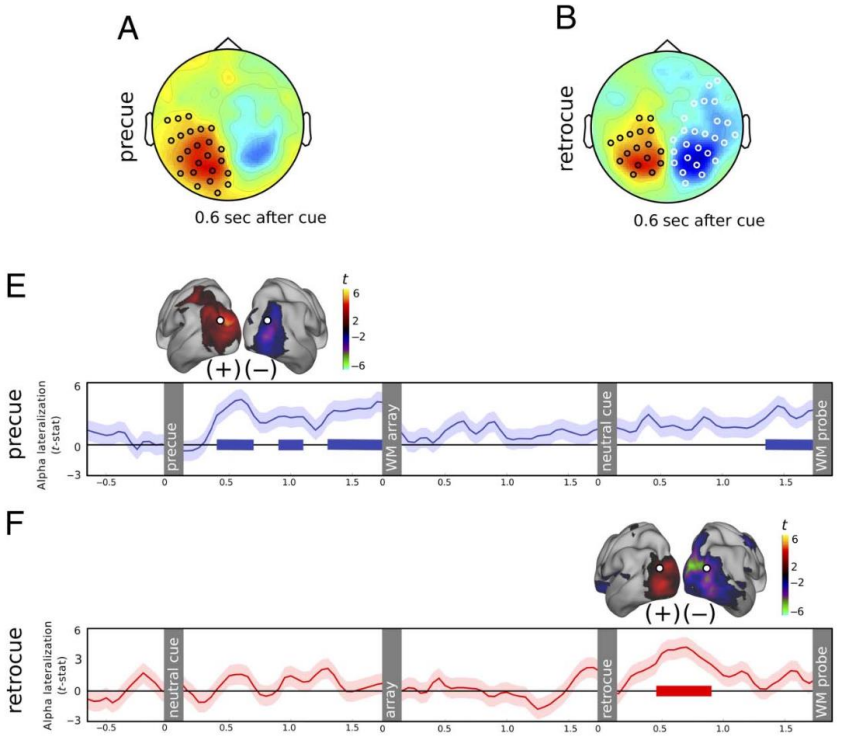
(2) **Maintenance**: holding relevant information in mind

Alpha power increases to suppress irrelevant visual stimuli

(1) **Gating**: suppression of irrelevant information



MEG data

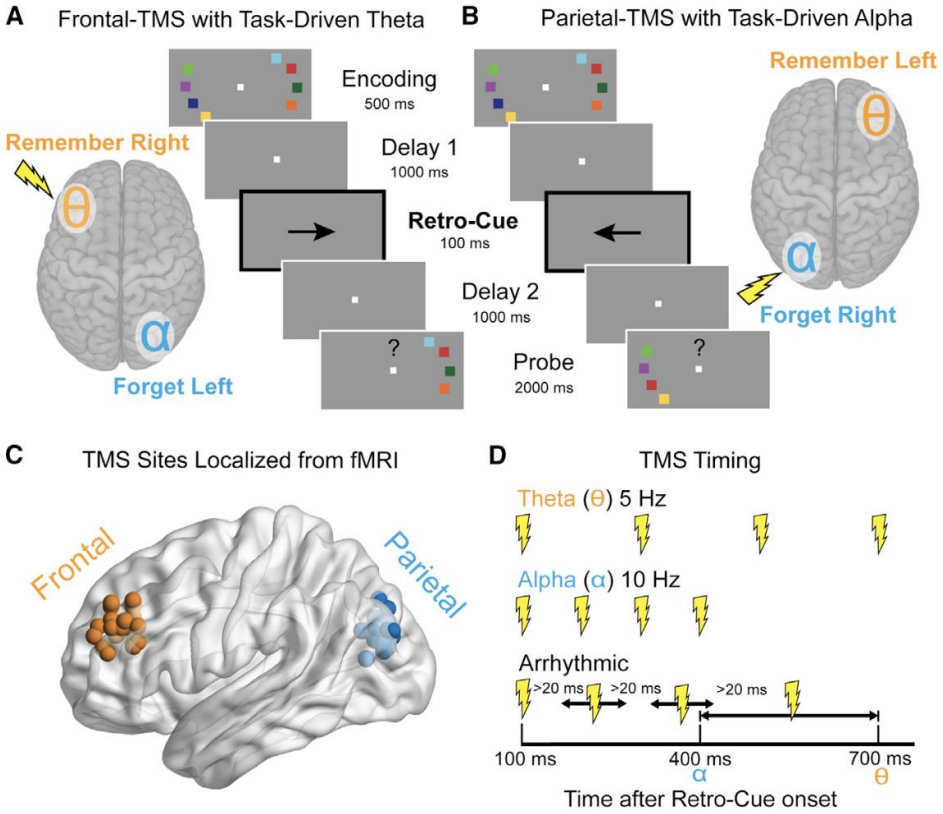


Wallis et al., *JoCN,* 2015

Alpha stimulation facilitates the suppression of irrelevant information

(1) **Gating**: suppression of irrelevant information

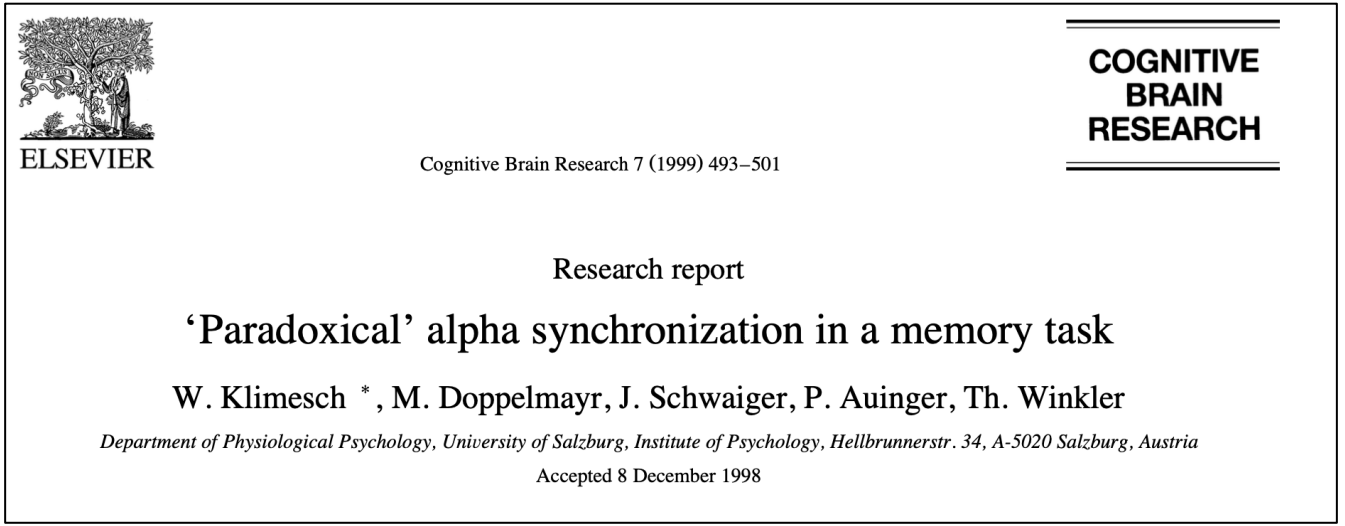
Justin Riddle



Riddle et al., *Curr. Biol.,* 2020

The second ‘life’ of alpha oscillations

(2) **Maintenance**: holding relevant information in mind



ELSEVIER

Cognitive Brain Research 7 (1999) 493–501

COGNITIVE BRAIN RESEARCH

Research report

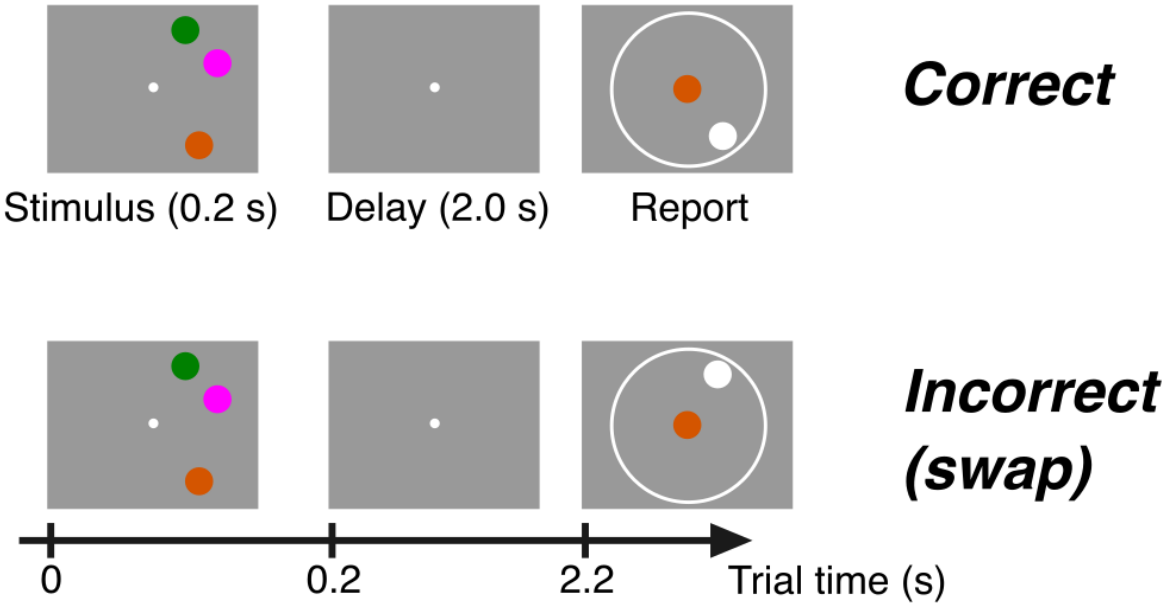
‘Paradoxical’ alpha synchronization in a memory task

W. Klimesch *, M. Doppelmayr, J. Schwaiger, P. Auinger, Th. Winkler

Department of Physiological Psychology, University of Salzburg, Institute of Psychology, Hellbrunnerstr. 34, A-5020 Salzburg, Austria

Accepted 8 December 1998

Alpha is important for correctly maintaining information



Pagnotta et al., *bioRxiv,* 2024

Binding color and location through synchronization

frontiers in Neural Circuits

BRIEF RESEARCH REPORT
published: 20 September 2021
doi: 10.3389/fncir.2021.716965

Across-Area Synchronization Supports Feature Integration in a Biophysical Network Model of Working Memory

*Joao Barbosa[1,2], Vahan Babushkin[3], Ainsley Temudo[3], Kartik K. Sreenivasan[3] and Albert Compte[1]**

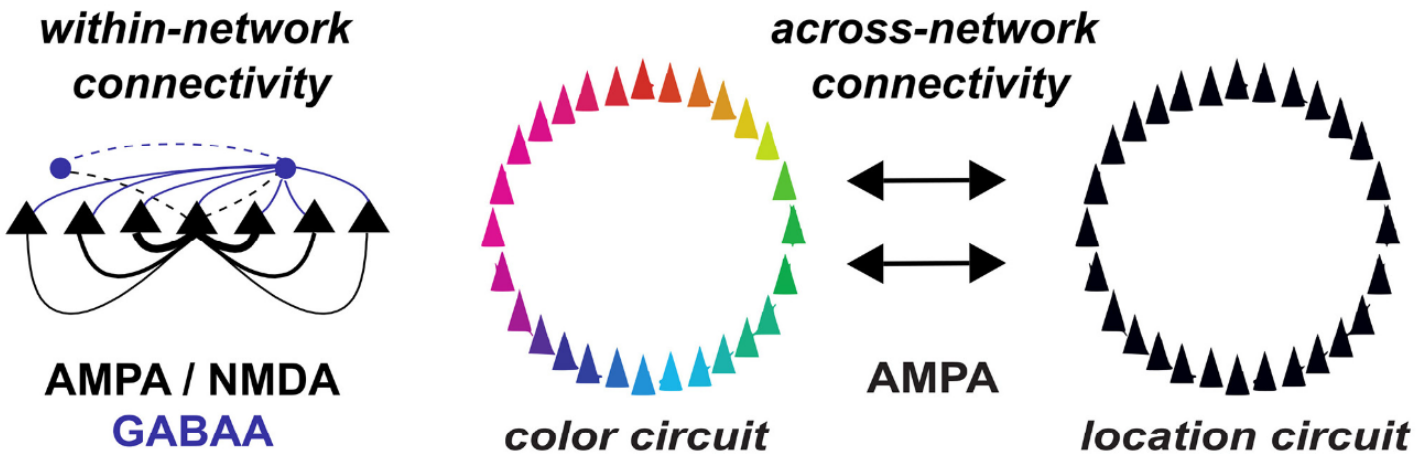
[1] Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain, [2] Laboratoire de Neurosciences Cognitives et Computationnelles, INSERM U960, Ecole Normale Supérieure – PSL Research University, Paris, France, [3] Division of Science and Mathematics, New York University Abu Dhabi, Abu Dhabi, United Arab Emirates

João Barbosa

Albert Compte

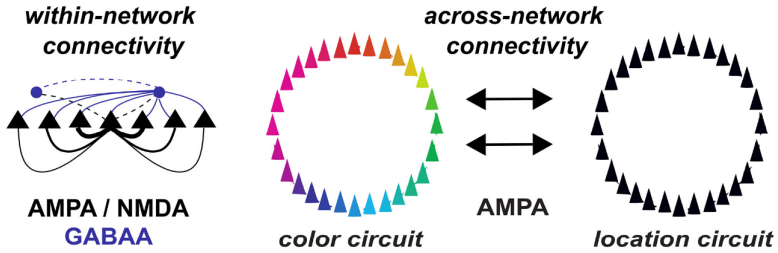
Barbosa et al., *Front. Neural Circuits,* 2021

Binding color and location through synchronization



Barbosa et al., *Front. Neural Circuits,* 2021

Binding color and location through synchronization

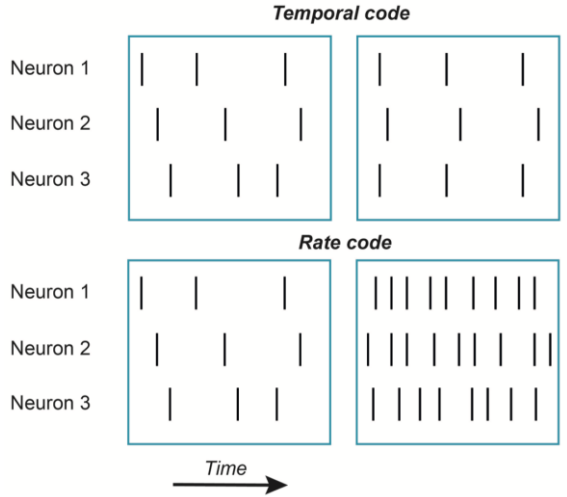


Maintenance: **temporal coding**

(*coding scheme in which the stimulus information is encoded in the temporal structure of spike trains, in terms of the relative timing of spikes in a population of neurons or with respect to an ongoing brain oscillation*)

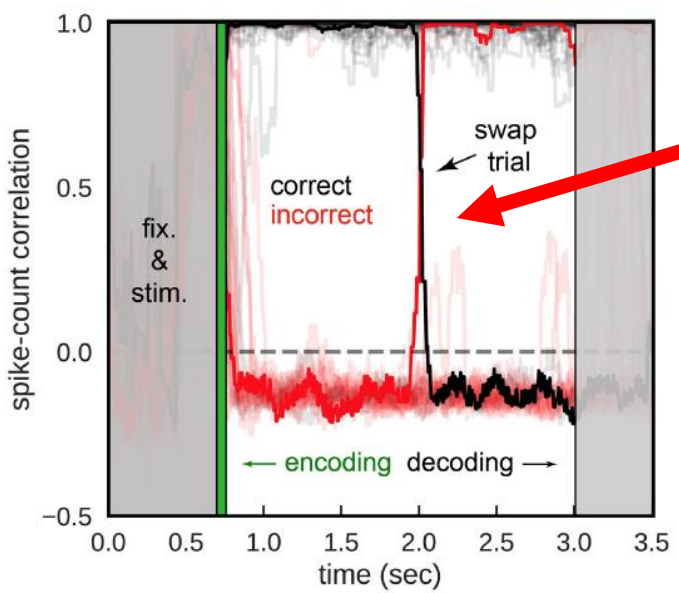
Encoding and decoding: **rate coding**

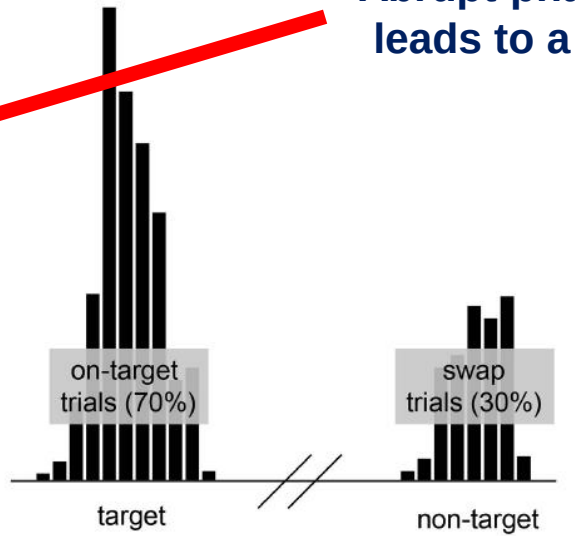
(*coding scheme in which the stimulus information is contained in the firing rate of the neuron—that is, the frequency of action potentials increases as the intensity of the stimulus increases*)



Barbosa et al., *Front. Neural Circuits,* 2021
Baranauskas, *Front. Syst. Neurosci.*, 2015

Binding color and location through synchronization

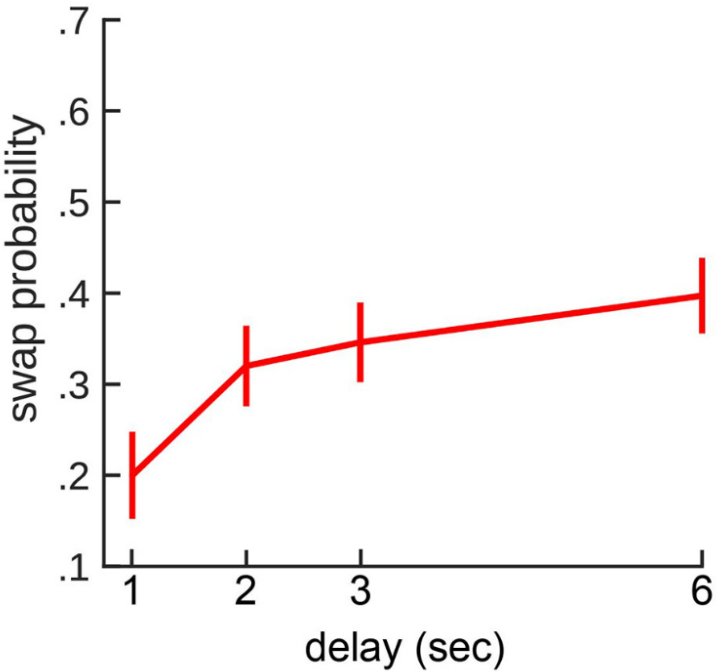


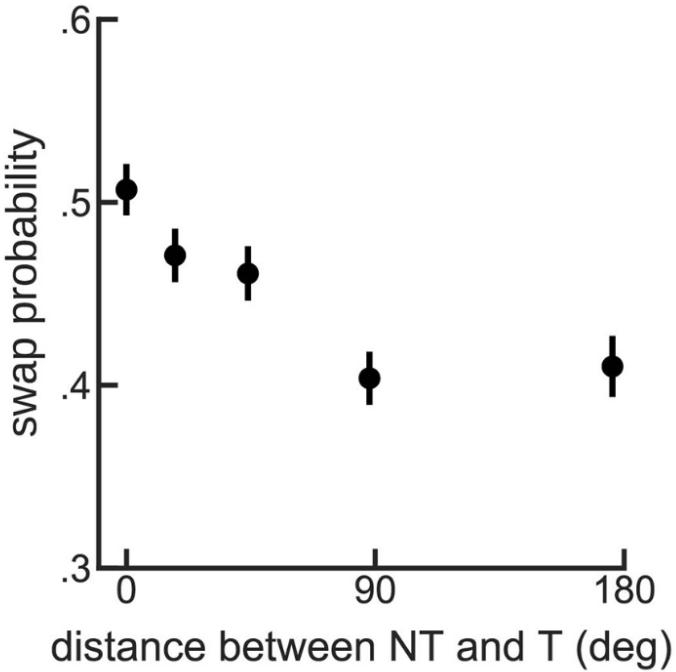


Abrupt phase change leads to a swap trial

Barbosa et al., *Front. Neural Circuits,* 2021

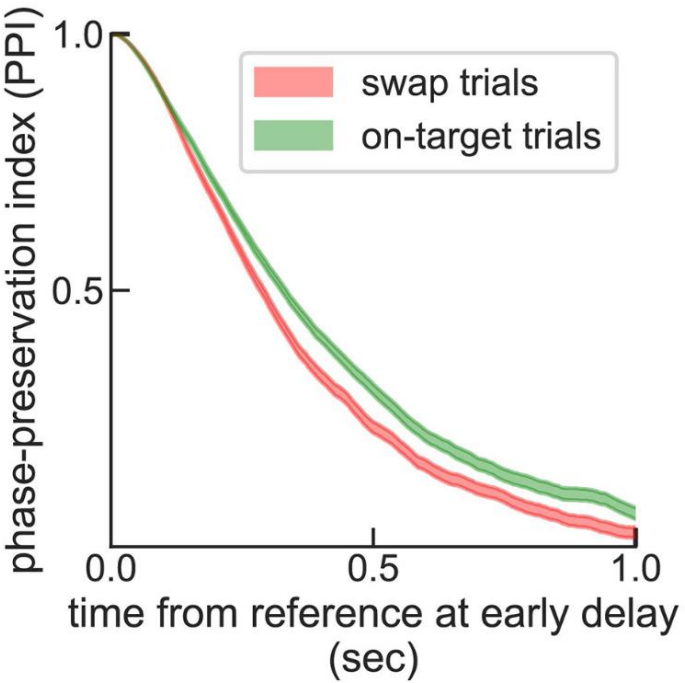
Behavioral predictions





Barbosa et al., *Front. Neural Circuits,* 2021

Neurophysiological predictions



Barbosa et al., *Front. Neural Circuits,* 2021

Neurophysiological predictions

Alpha phase-coding supports feature binding during working memory maintenance

Mattia F. Pagnotta, Aniol Santo-Angles, Ainsley Temudo, Joao Barbosa, Albert Compte, Mark D'Esposito, Kartik K. Sreenivasan

doi: https://doi.org/10.1101/2024.01.21.576561

Kartik Sreenivasan

Aniol Santo-Angles

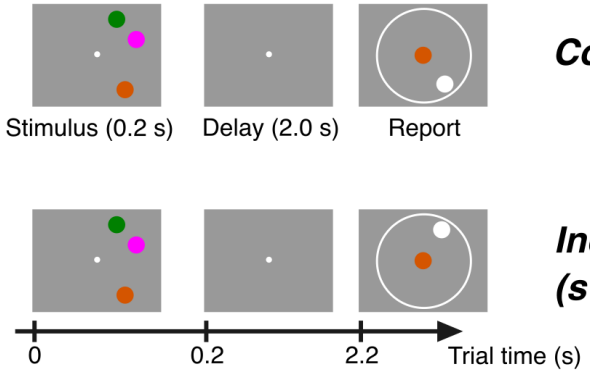
Ainsley Temudo

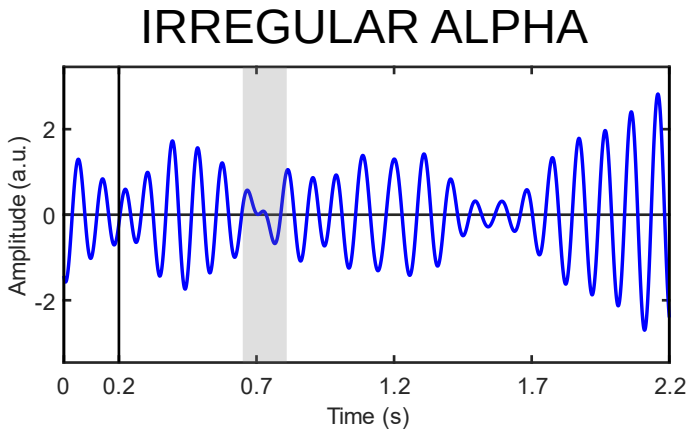
João Barbosa

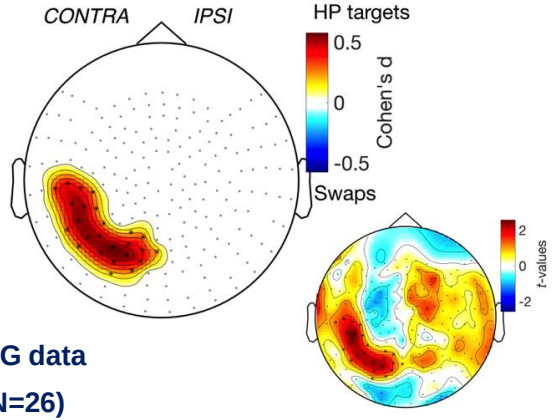
Albert Compte

Mark D'Esposito

Alpha phase is irregular in incorrect trials (swaps)





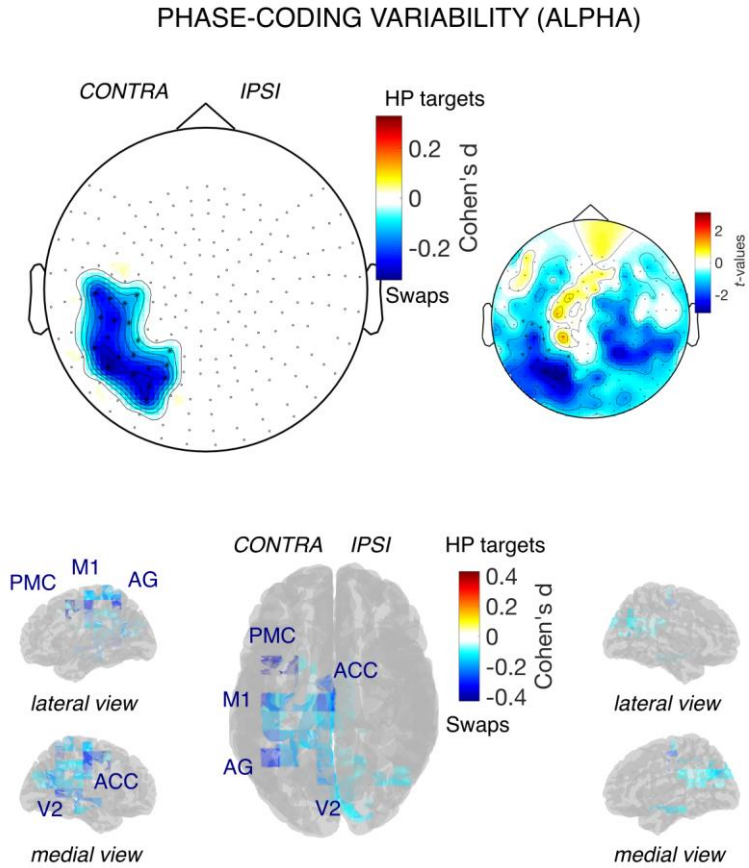


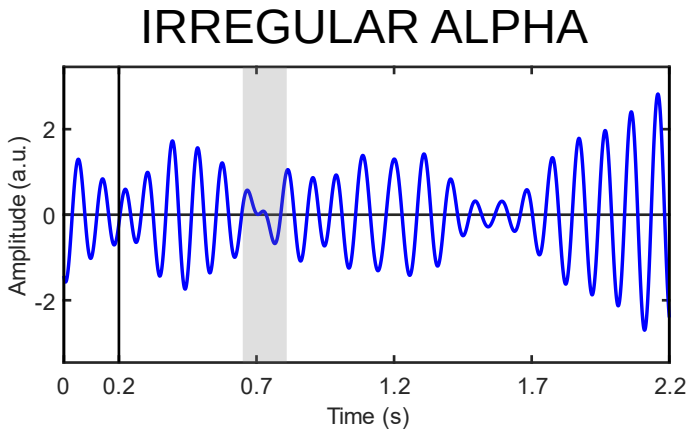
MEG data

(N=26)

Pagnotta et al., *bioRxiv,* 2024

Alpha phase is irregular in incorrect trials (swaps)



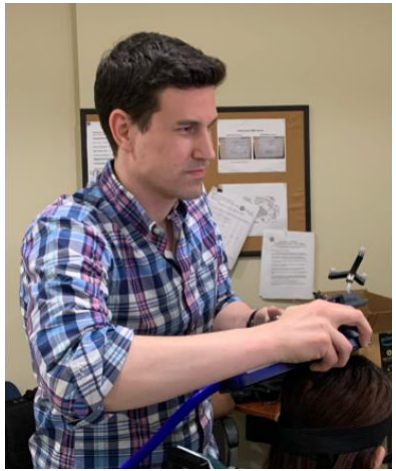


Pagnotta et al., *bioRxiv,* 2024

Can we provide causal evidence for the role of alpha oscillations during working memory maintenance?

TMS study: the people

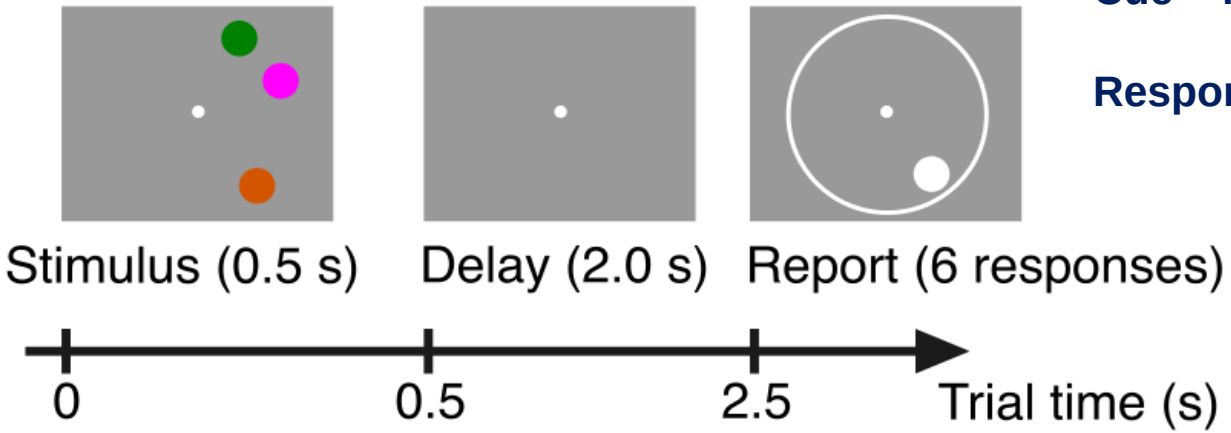
Jason Scimeca



Karena Balagula; Ethan Sheppy;
Isabella Ruiz; Kaitlin Canotal

And also…
Alex Martinez; Sarah Barton; Shree Parekh; Matthew Yoshida;
Gustavo Flores; Isabella Fruto Mariazeta; Hiya Ghosh; Eli Levy

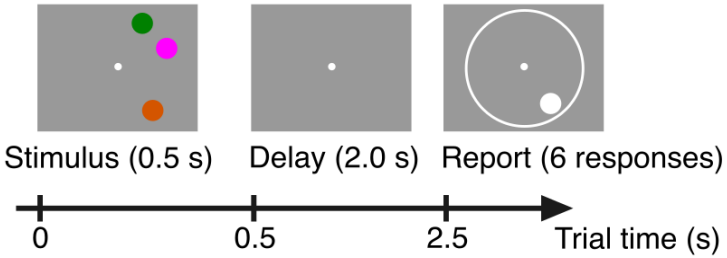
TMS study: the design



Cue = location

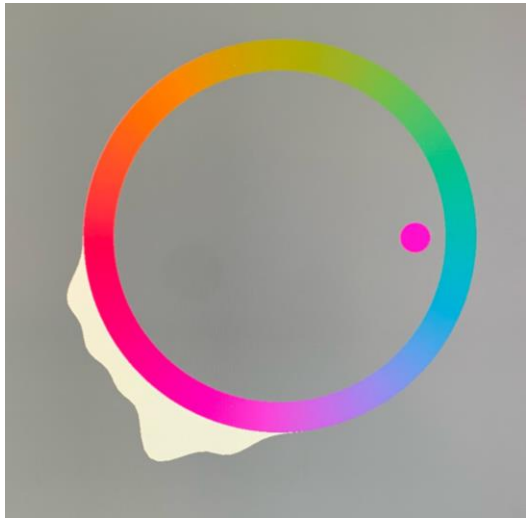
Response = color

TMS study: the *color wheel*



Cue = location

Response = color



Mixture model of participants' responses

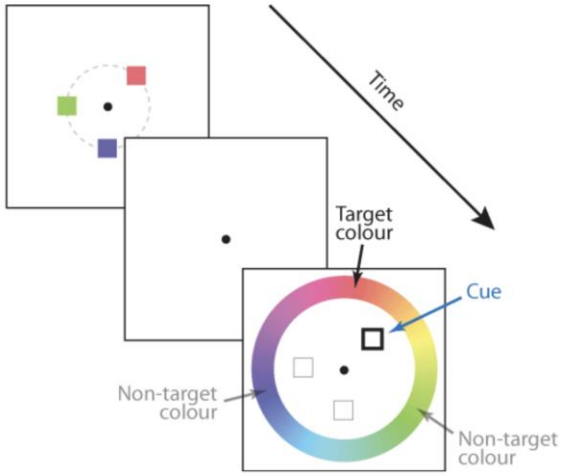


Figure 1 | The colour report task.

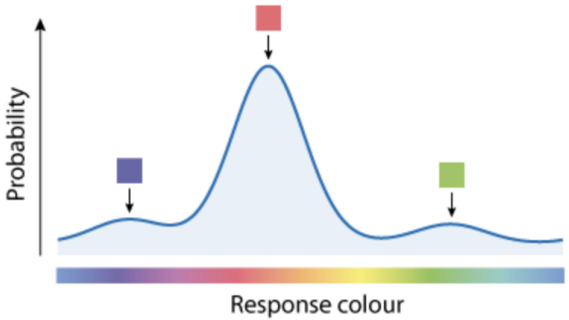


Figure 3 | Probability distribution of responses on a single trial.

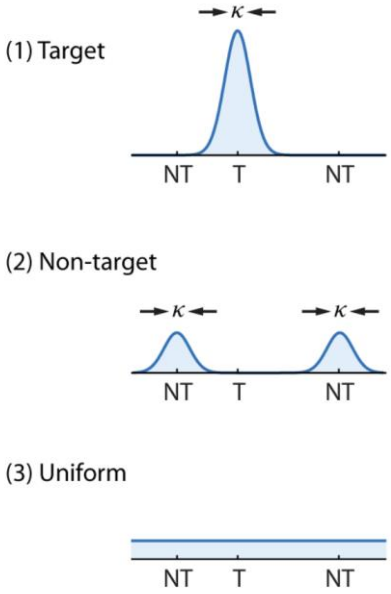


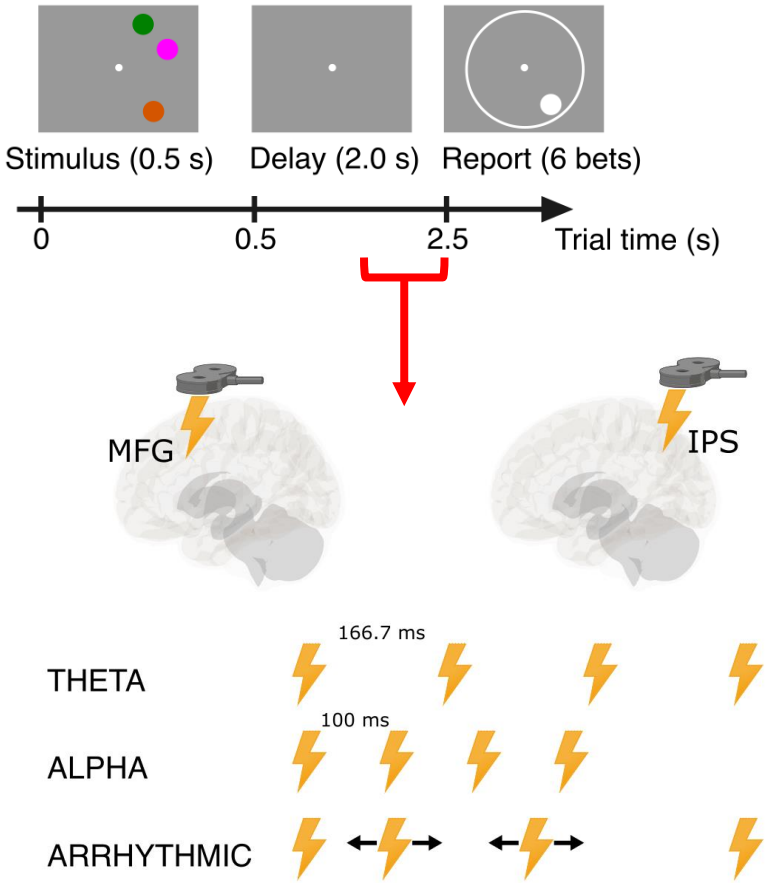
Figure 7 | Mixture model components

MEASURES:

- Number of swap trials
- Number of guess trials
- Error (accuracy)
- **Von Mises k (precision)**

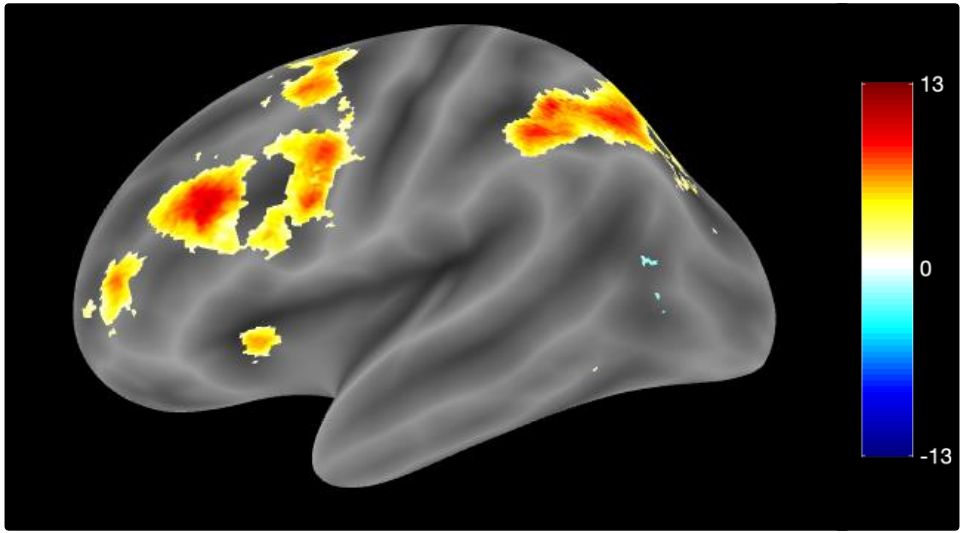
Analogue Report Toolbox (https://www.paulbays.com/toolbox/)
Bays et al., *J Vis*, 2009
Schneegans & Bays, *Cortex*, 2016

TMS study: the design



TMS study: the targets

Neurosynth.org: ***"working memory"*** (meta-analysis of 1091 studies)



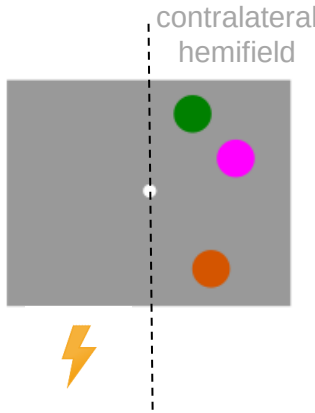
Created and maintained by Tal Yarkoni
Supported by NIH award R01MH096906

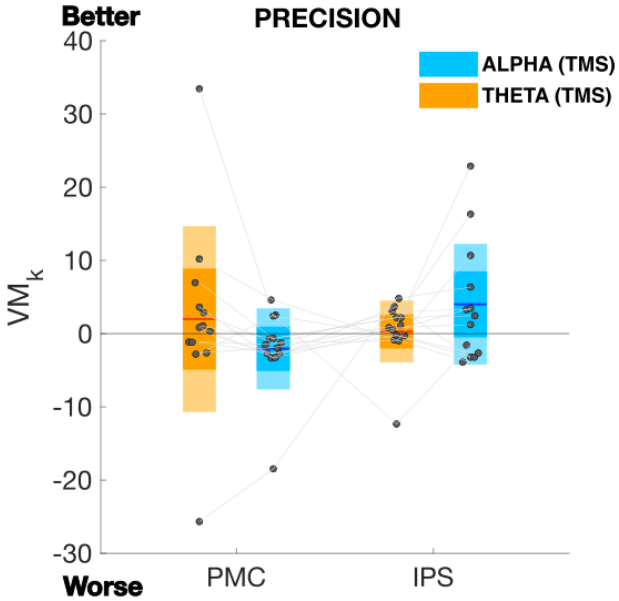
National Institute of Mental Health

Precision increased by:

Alpha stimulation in IPS

Theta stimulation in MFG





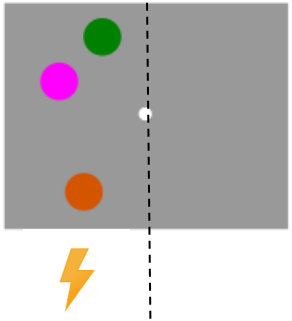
***Interaction**

Precision increased by:

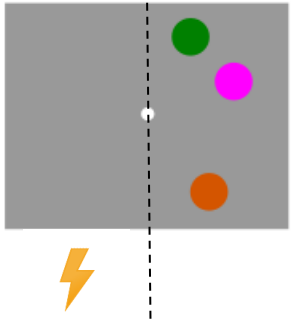
Alpha stimulation in IPS

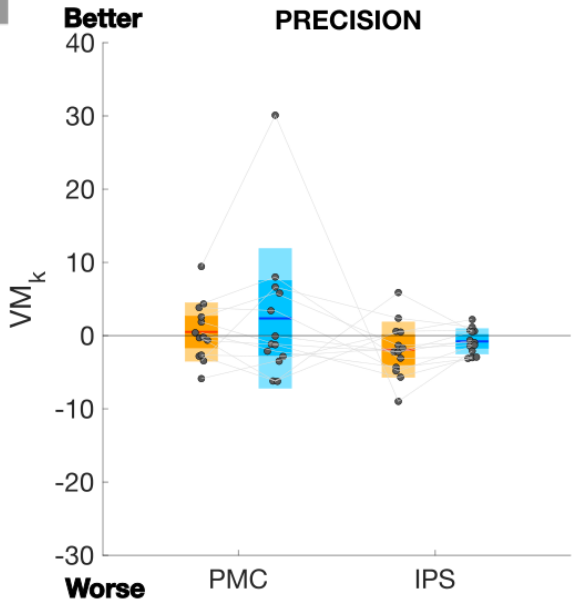
Theta stimulation in MFG

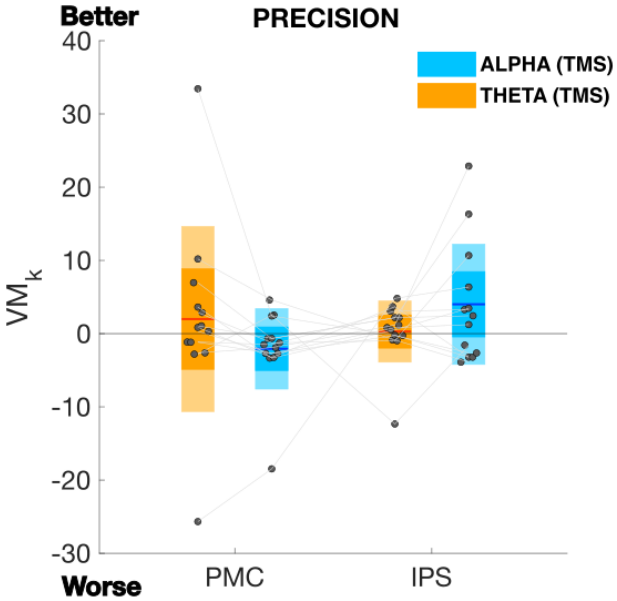
ipsilateral hemifield



contralateral hemifield







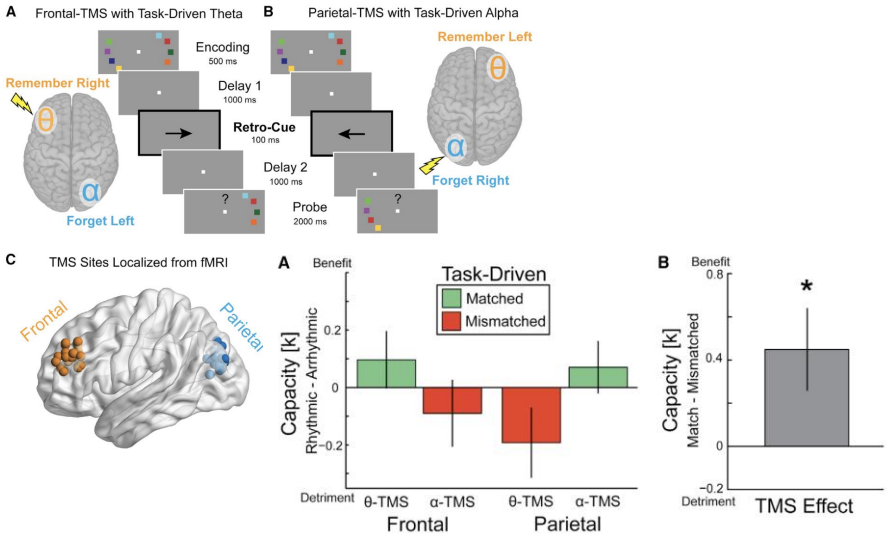
N.S.

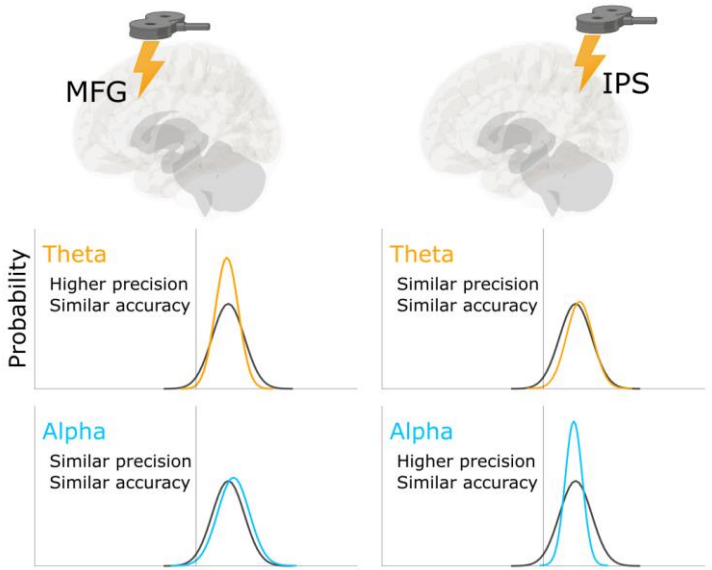
***Interaction**

Alpha stimulation facilitates:

(1) **Gating**: suppression of irrelevant information

(2) **Maintenance**: holding relevant information in mind

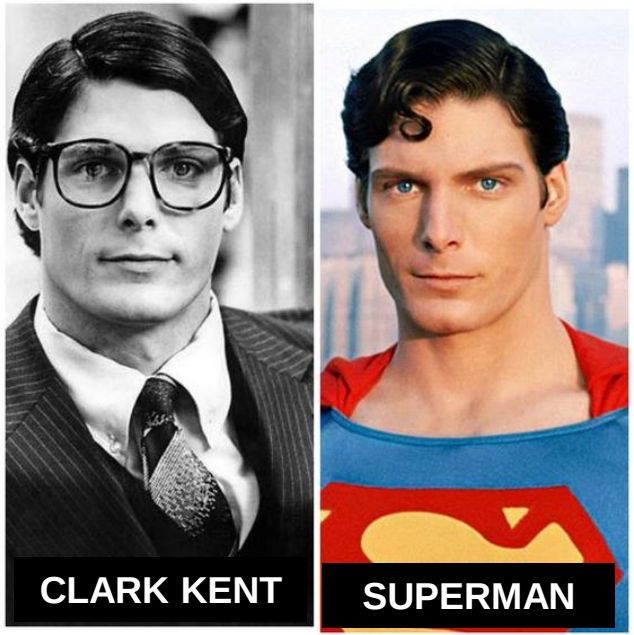




Riddle et al., *Curr. Biol.,* 2020

(Ongoing TMS study)

The ‘two lives’ of alpha in working memory



What exactly is the stimulation doing on this frontoparietal network?

Mark D'Esposito

Bob Knight

Berkeley Neuroscience
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João Barbosa

Inserm

LSU

Jason Scimeca

UAB

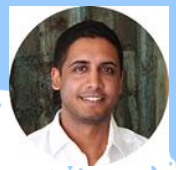
J. Nicole Bentley

Florida State University 1851

Justin Riddle

IDIBAPS

Albert Compte



جامعة نيويورك أبوظبي

NYU ABU DHABI

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Early Postdoc.Mobility P2FRP3_195083
Postdoc.Mobility P500PB_214404

Thank you for organizing!

Maria Rubega

David Pascucci *(summer 2017)*