Magnetoencephalographic signatures of human Perceptual Decision Making

Società Italiana di Psicologia e Neuroscienze Cognitive

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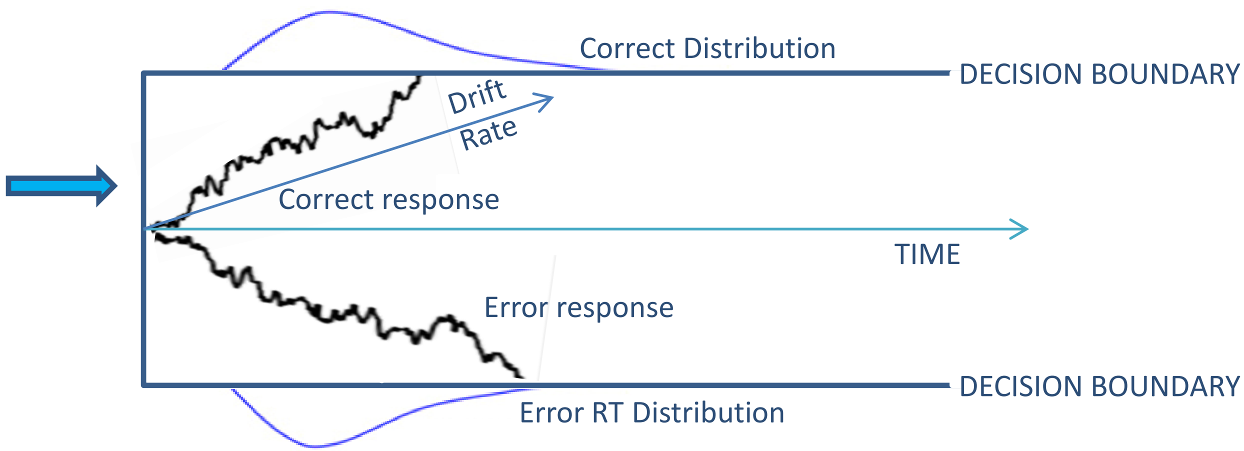
Perceptual decision models

Perceptual decision-making is classically defined as the ability to convert a sensorial input from the external environment into an appropriate course of action

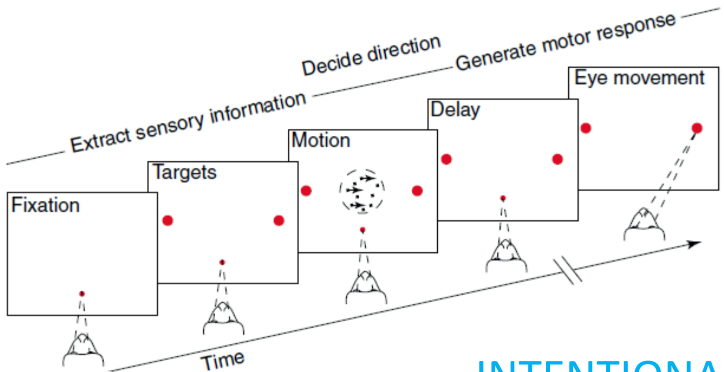
DRIFT DIFFUSION MODEL



Decisions are based on an integrative mechanism of accumulation of sensory information until a response boundary, with the rate of this evidence-accumulation process that increases as a function of the quality of information extracted from the stimulus

- Rilling & Sanfey, 2011
- Smith &Vickers, 1988
- Smith and Ratcliff 2004
- Ratcliff and McKoon, 2008

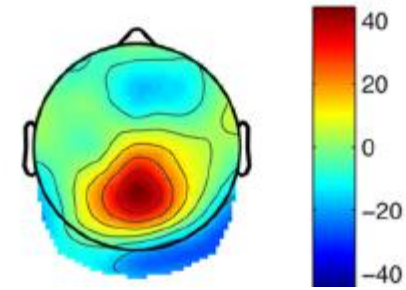
Previous studies



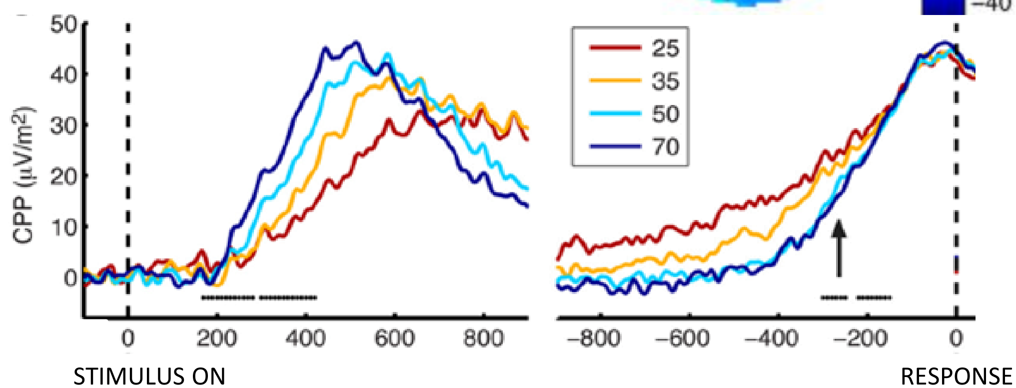
Boundary-crossing noisy accumulation process

The transformation of the motion information into a saccadic movement was directly represented within the saccadic-related LIP neurons

INTENTIONAL ACCOUNT OF DECISION MAKING



A freely evolving decision variable signal in humans that exhibited every aspect of the dynamics observed in the monkey LIP area during perceptual decision-making



Task related decrease in α power and increase in β power most prominently observed during active detection

- Shadlen et al., 2007 review
- Kelly et al., 2015

- Haegens et al., 2011; 2014

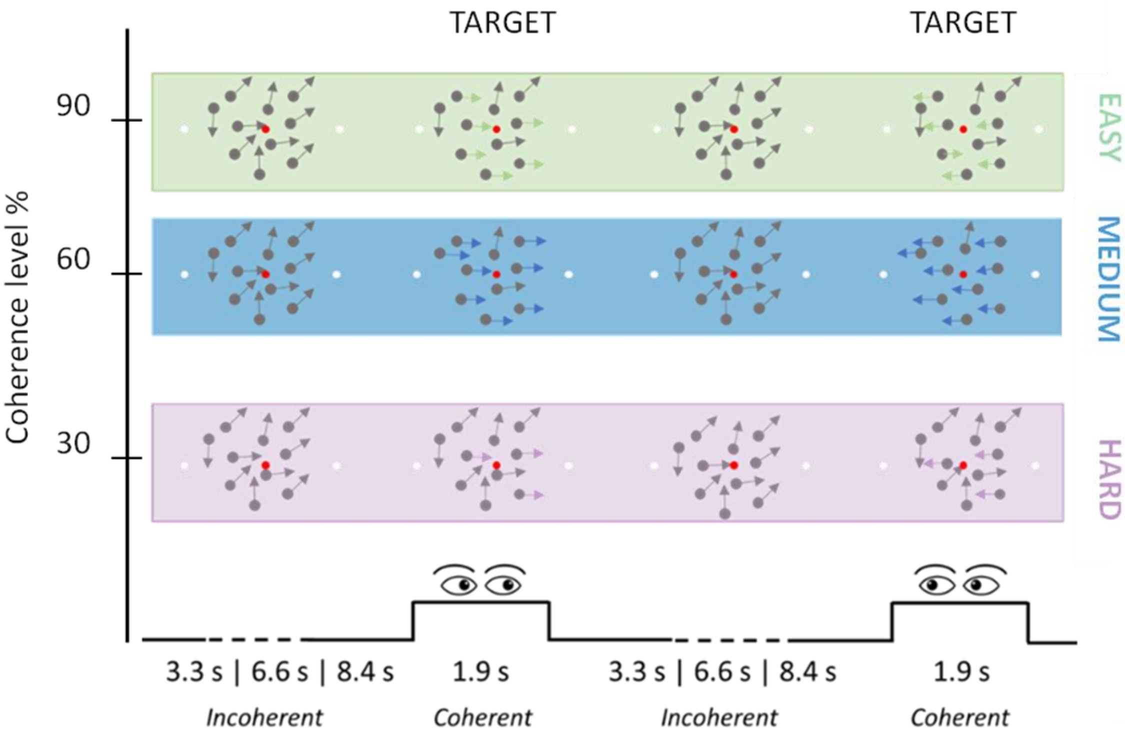
Aims

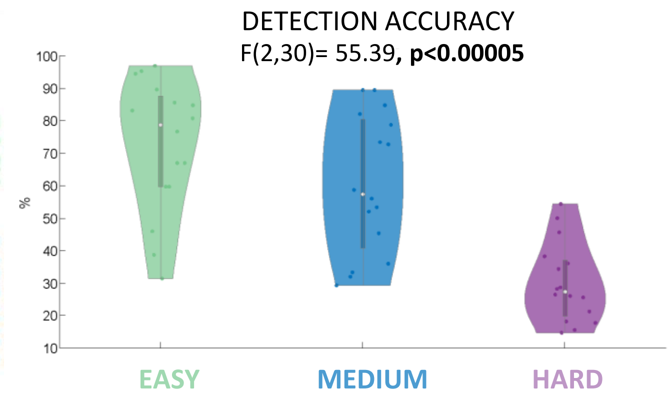
Q1: Is it possible to identify a human homologue of the decision variable described in the monkey that follows the principles intentional model of decision-making?

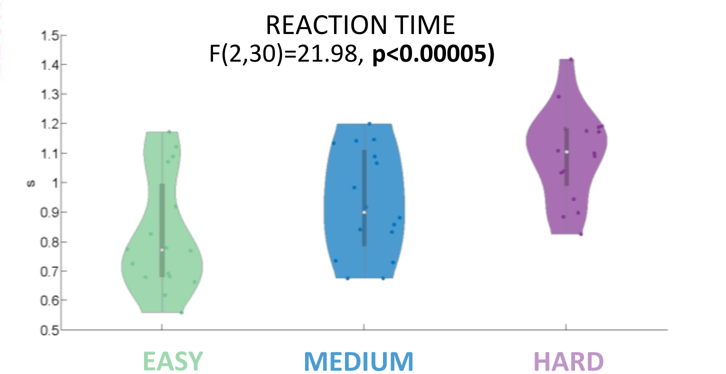
Q2: Is the decisional neural signal predictive of the behavior?

Q3: Does it have a specific frequency signature?

Paradigm and behavioral results







Repeated-measures ANOVA

MAIN EFFECT OF EVIDENCE ON BOTH INDICES OF PERFORMANCE

Significant difference between all the conditions Bonferroni post-hoc tests; hard vs. medium vs. easy; accuracy: all $p<0.02$; RTs: all $p<0.04$)

- Kelly et al., 2015

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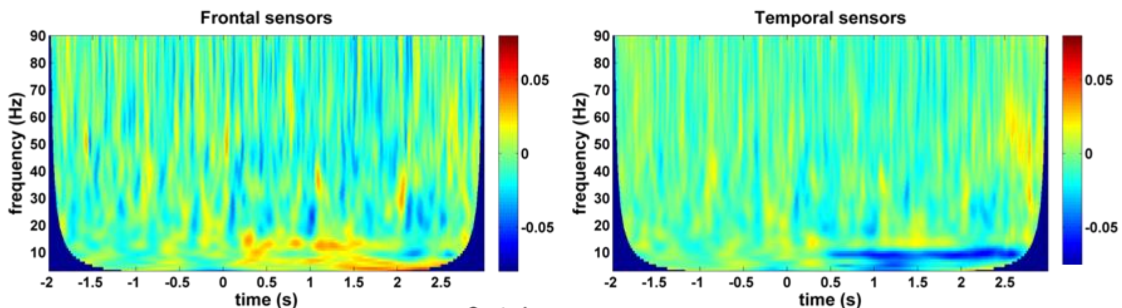
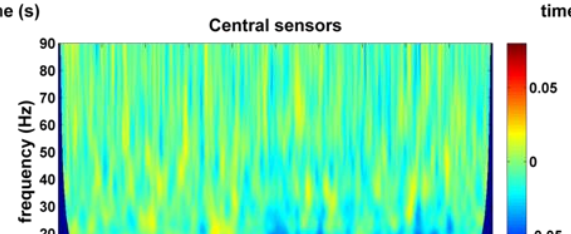
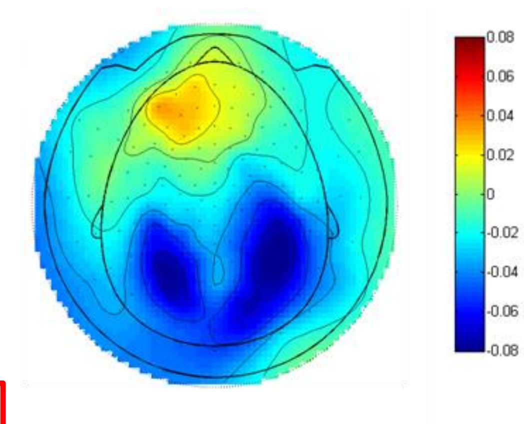
Frequency-specific power modulation: α band ERD

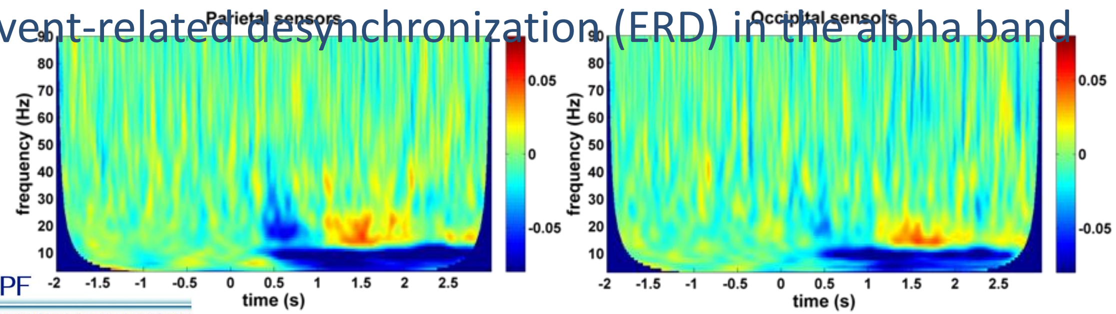
The TF analysis time-locked to the target stimulus onset and corrected to baseline was conducted for the medium condition







The results showed a significant alpha power modulation over the occipital and parietal sensor that qualifies as an event-related desynchronization (ERD) in the alpha band



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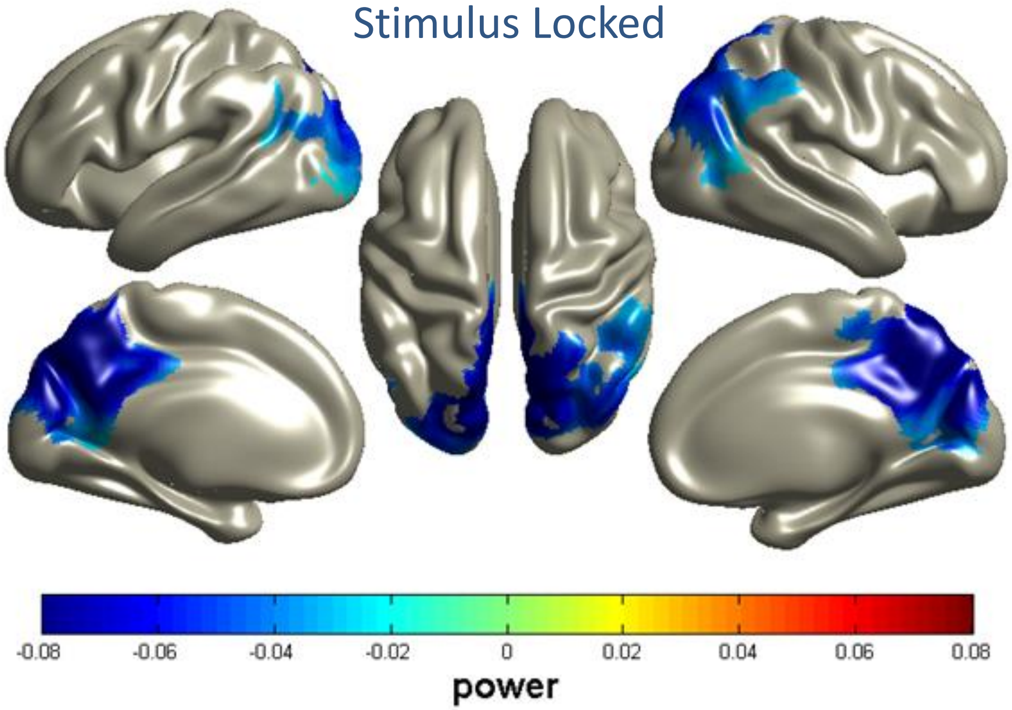
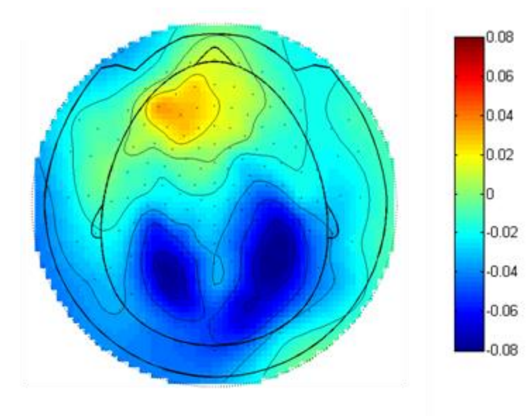
Frequency-specific power modulation: α band ERD

MEG-source level analysis
Stimulus Locked



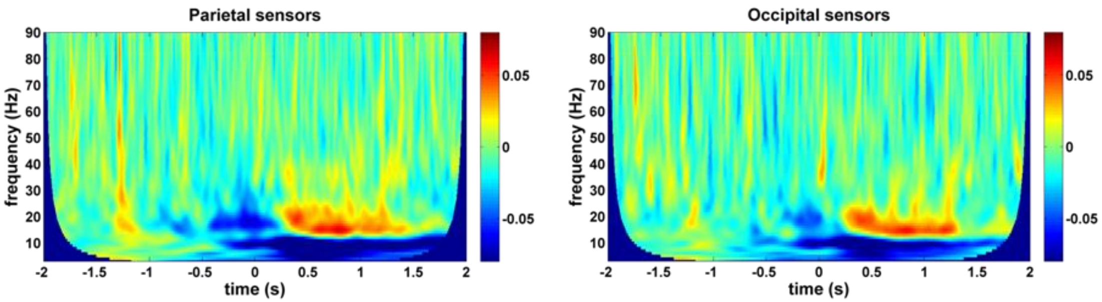
NO α MODULATION IN TRIALS IN WHICH NO DECISION WAS TAKEN

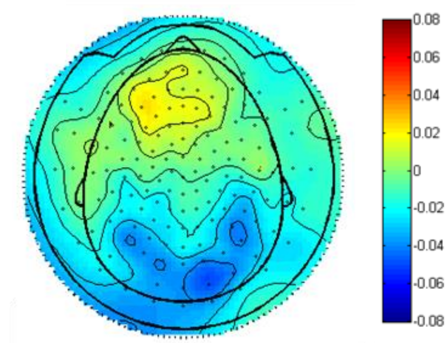


The alpha-band ERD localized in regions of the occipito-parietal cortex, particularly the activity modulation was more robustly observed in regions of the dorso-medial parietal cortex

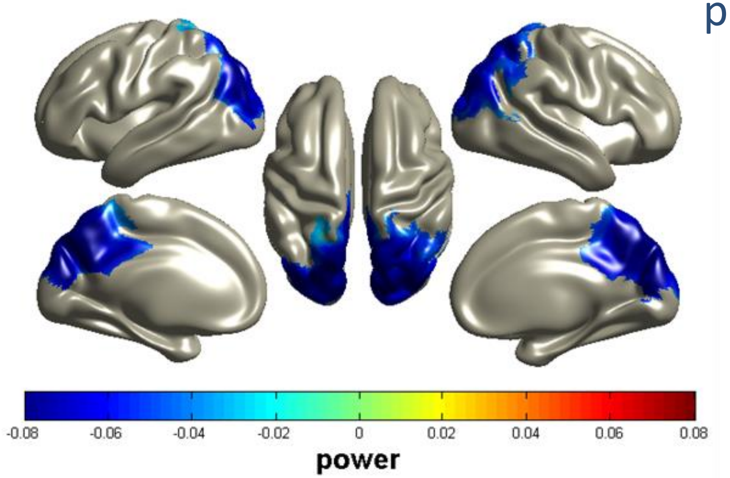
Frequency-specific power modulation: α band ERD

TF analysis time-locked to the response execution





Significant alpha power desynchronization was again observed over the occipital and parietal sensors



The alpha-band ERD localized in the same parieto-occipital regions emerged from the TF analysis conducted in the target stimulus interval

CONFIRMING THAT THE ALPHA BAND ERD OCCURS INDIPENDENTLY FROM THE SACCADE EXECUTION

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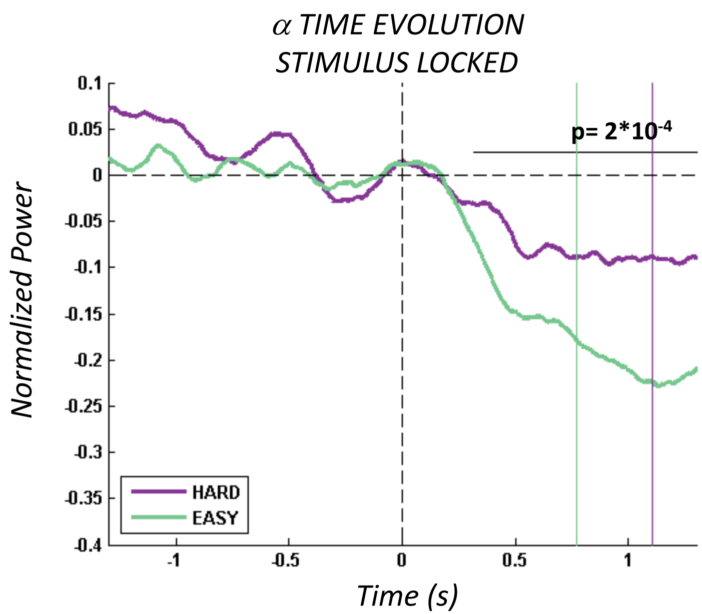
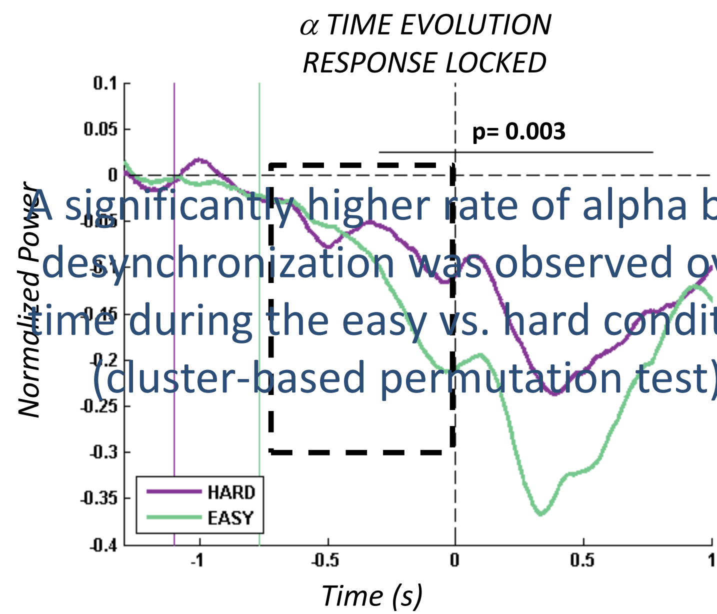
α power modulates for hard vs. easy perceptual decisions





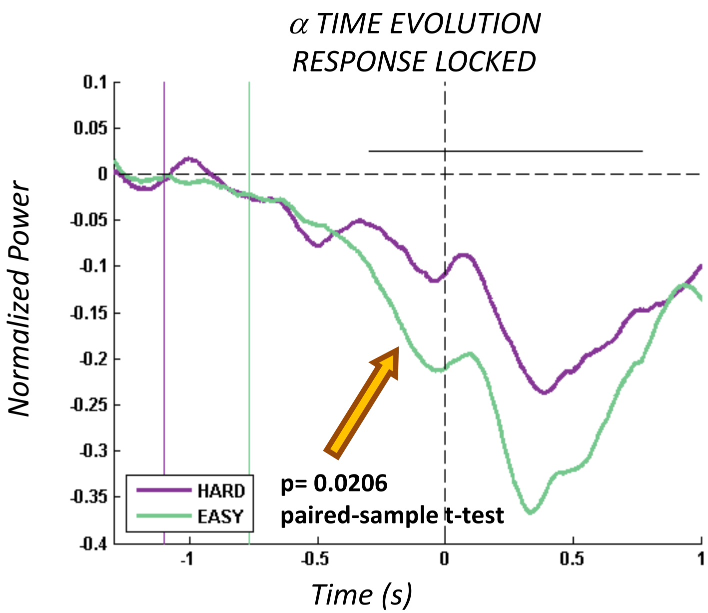
A significantly higher rate of alpha band desynchronization was observed over time during the easy vs. hard condition (cluster-based permutation test)

The time evolution of the alpha band ERD modulation locked to response execution indicated a larger alpha power decrease in the easy vs. the hard condition

✓ *ALPHA REFLECTS A DECISION RELATED PROCESS RATHER THAN AN EPIPHENOMENON CORRELATED WITH SACCADIC EXECUTION*

✓ *ALPHA DESYNCHRONIZATION LINKED TO EVIDENCE ACCUMULATION*

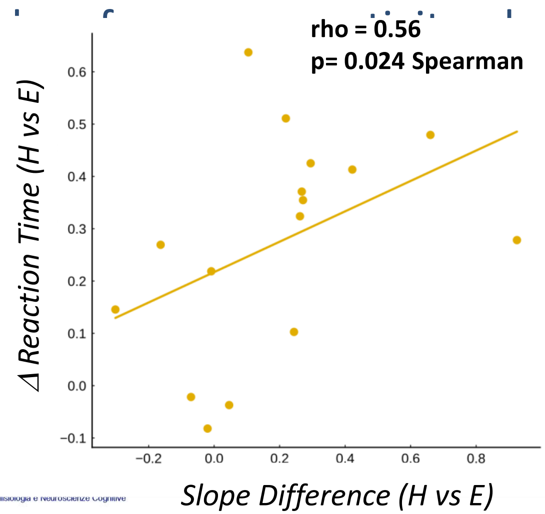
α power modulation predicts behavior

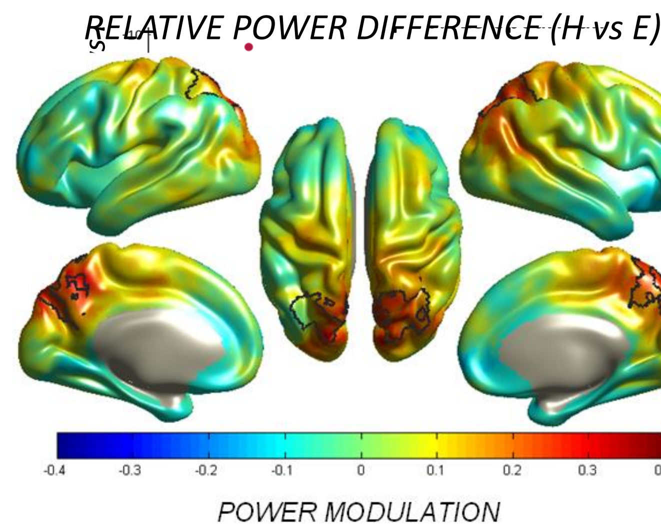


The slope of the time evolution of α power modulation is significantly steeper in the easy vs hard condition

✓α MODULATION REFLECTS AN EVIDENCE ACCUMULATION PROCESS WHOSE RATE DEPENDS ON THE QUALITY OF INFORMATION

The pe ... el was observe ... ng with saccadic ... omotor decision ... entified through





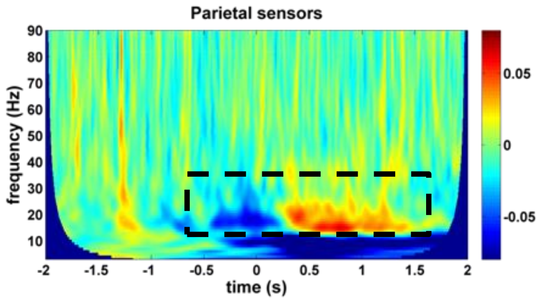
Significa ... rence and the difference performance in the two conditions

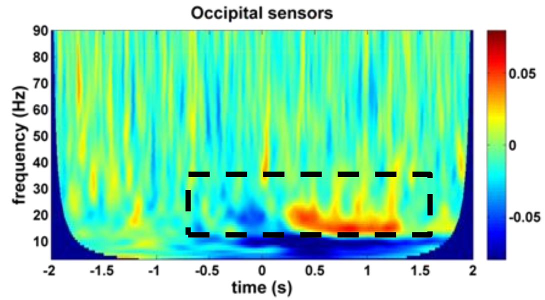
NT OF DECISION MAKING

•Tosoni et al., 2008

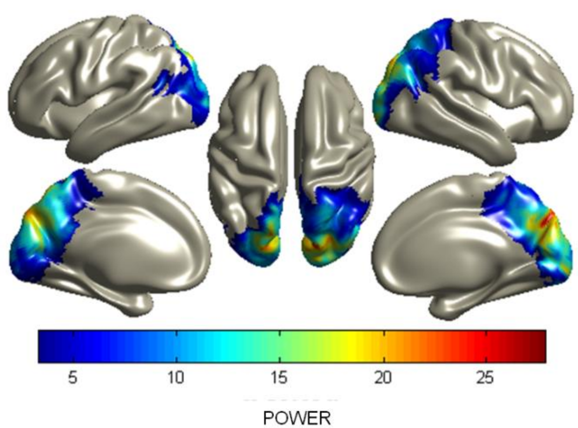
What about β band?

α band modulation paired to a β power modulation

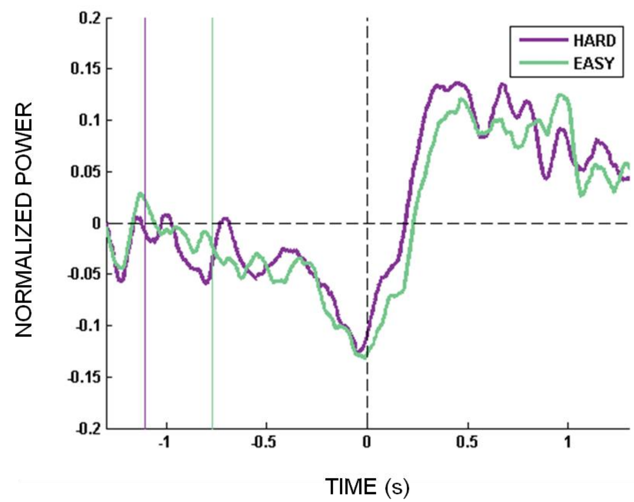




ANOVA β ERD/ERS



β TIME EVOLUTION RESPONSE LOCKED



✓β BAND MODULATION REFLECTS A FREQUENCY SPECIFIC MECHANISM OF MOTOR PREPARATION AND EXECUTION

Conclusion

Q1: Is it possible to identify a human homologue of the decision variable described in the monkey that follows the principles intentional model of decision-making?

A power modulation of the α band that scales with the amount of sensory evidence and occurs indipendently from the saccadic response was localized in regions of the dorso-medial parietal cortex

Q2: Is the decisional neural signal predictive of the behavior?

We found significant correlation between the α power modulation and the behavioral performance

Q3: Does it have a specific frequency signature?

Although the decision-making process and the planning of action execution occurs in the same areas it exploits two different frequency specific mechanisms with different functional roles

Thanks to

M. A. M. B. O.
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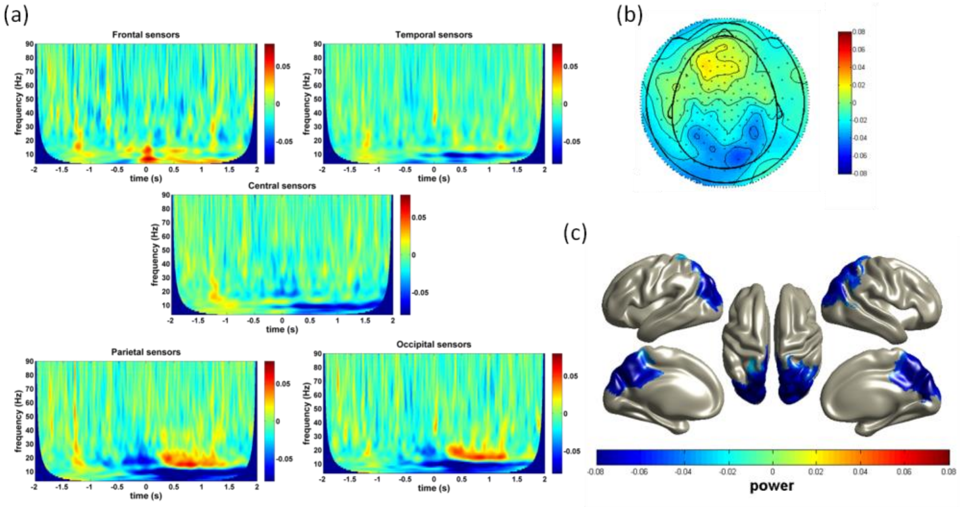
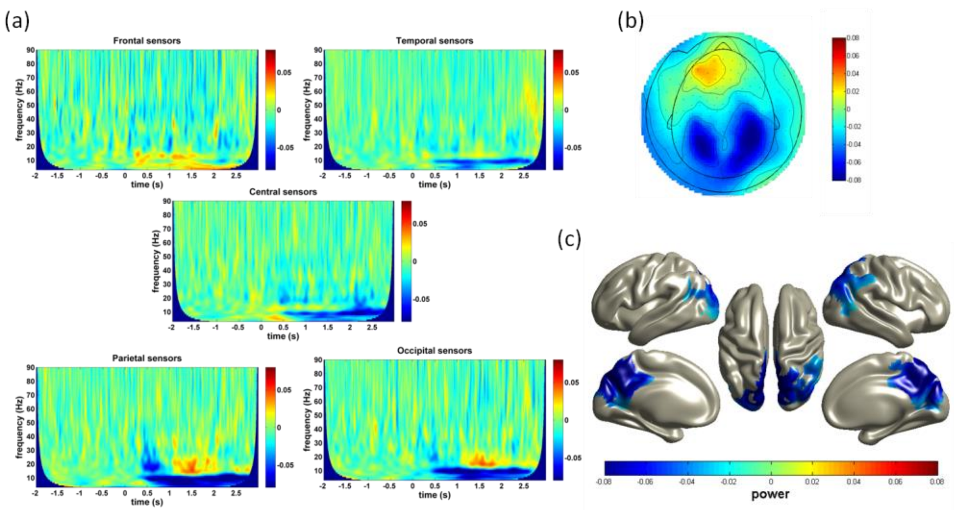
... and for your attention


(a)
Frontal sensors
Temporal sensors
Central sensors
Parietal sensors
Occipital sensors
frequency (Hz)
time (s)
(b)
(c)
power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