ICON XII, Brisbane, Australia, 7/30/2014

BRAIN PROCESSES ASSOCIATED WITH COGNITIVE CONTROL

Speakers

- Diane Beck (U. of Illinois)
  - The role of feedback in visual processing
- Paul Corballis (U. of Auckland)
  - Lateralisation o the ERP reveals neural correlates of attention, distractor suppression, and visual short term memory
- Gabriele Gratton (U. of Illinois)
  - Investigating brain networks in task preparation
- Pauline Baniqued (U. of Illinois)
  - A functional and structural view of task-switching dynamics in ageing

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INVESTIGATING BRAIN NETWORKS IN TASK PREPARATION

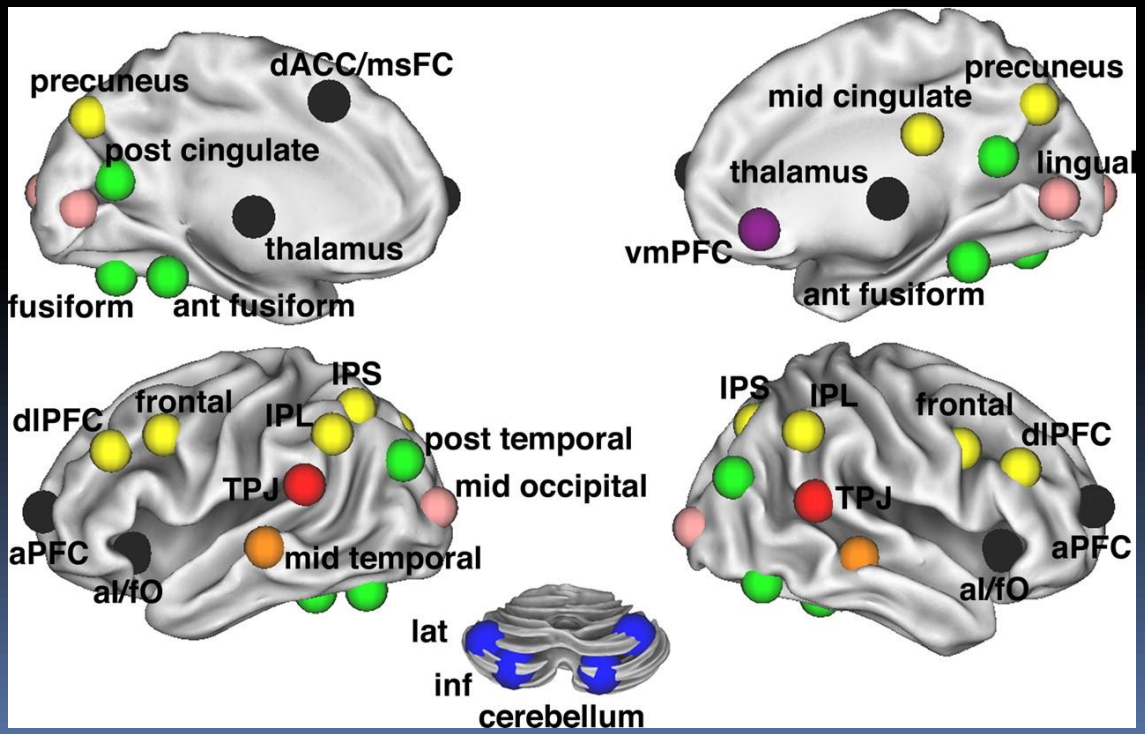
Gabriele Gratton & Monica Fabiani
Psychology Department & Beckman Institute
University of Illinois

Cognitive control

- Set of operations that prepares the brain to perform a particular cognitive task
  - The same stimulus information can be processed in different ways
- It involves setting up the information processing system so as to weigh information appropriately for the particular task context at hand
  - Notion of "prepared reflexes" (Allport, A&P, 1980)
  - Interaction between top-down and bottom-up processes

Brain areas involved in cognitive control

- From fMRI work
  - Cingulo-opercular network (black): Long-term goal setting
  - Dorsal attention network (yellow): Trial-to-trial adaptation
  - How are these areas related to each other?



From Dosenbach et al.
PNAS 2007;104:11073-11078

Preparation paradigm

- Indicates the "rule" or task for that trial

- Prompts when and how to perform the task
- Some level of <u>conflict</u>

- Use the default or old rule

Little activity

OR

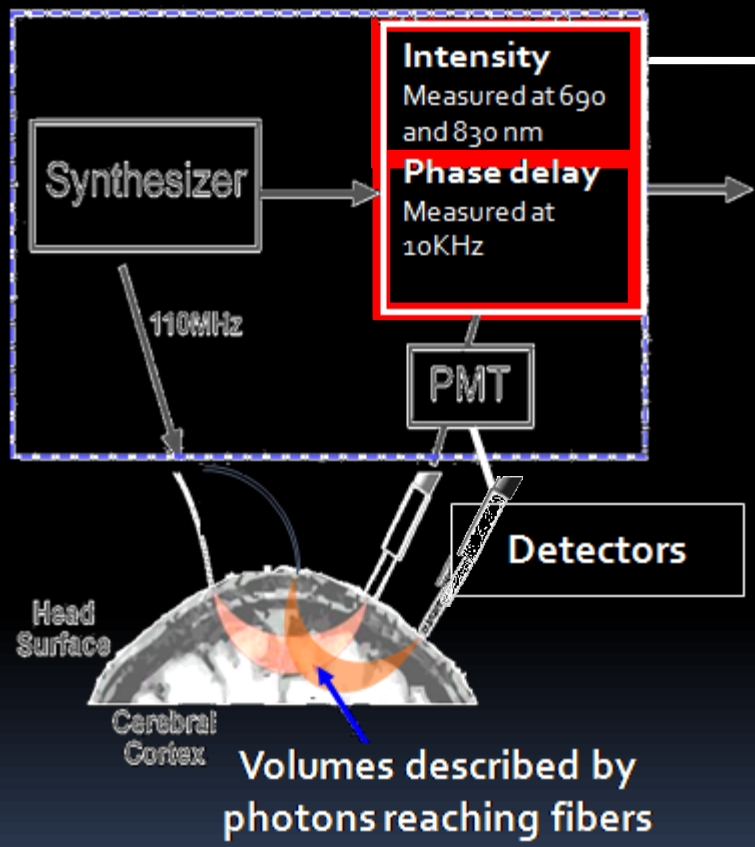
- Use a different rule

More activity

Gratton et al., 2009; Baniqued et al., 2013; Leaver et al., submitted; Low et al., in preparation

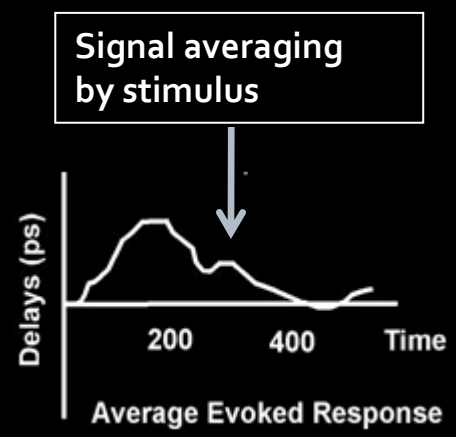
EROS: A tool for studying the time course of preparatory activity

Optical Recording



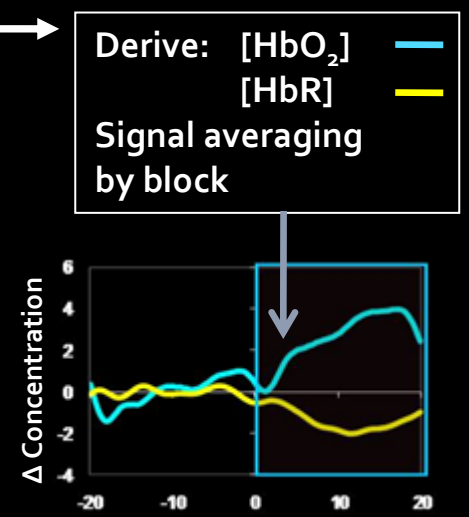
EROS

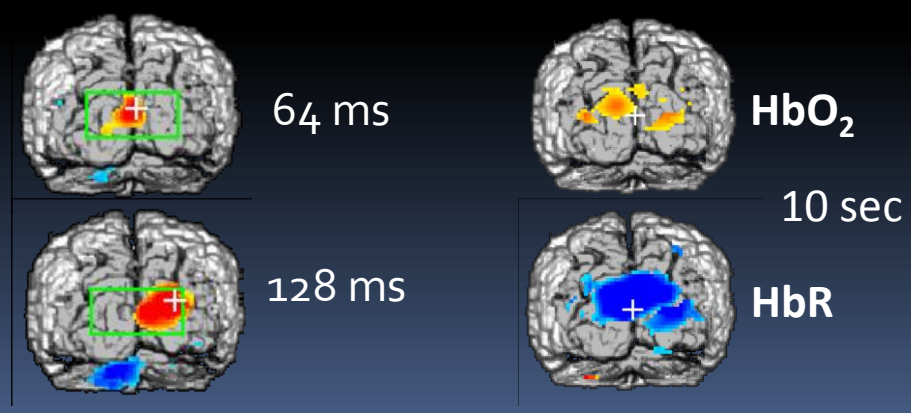
(Fast, neuronal)



NIRS

(Slow, hemodynamic)





Reviews:

Gratton & Fabiani, *TICS*, 2001

Gratton & Fabiani, *Frontiers in Human Neuroscience*, 2010

EROS: N=16/study

Study 1

Auditory/Visual

Precue:

Auditory	Visual
A	V

RS:

Lft Hand	Rt Hand
I	O

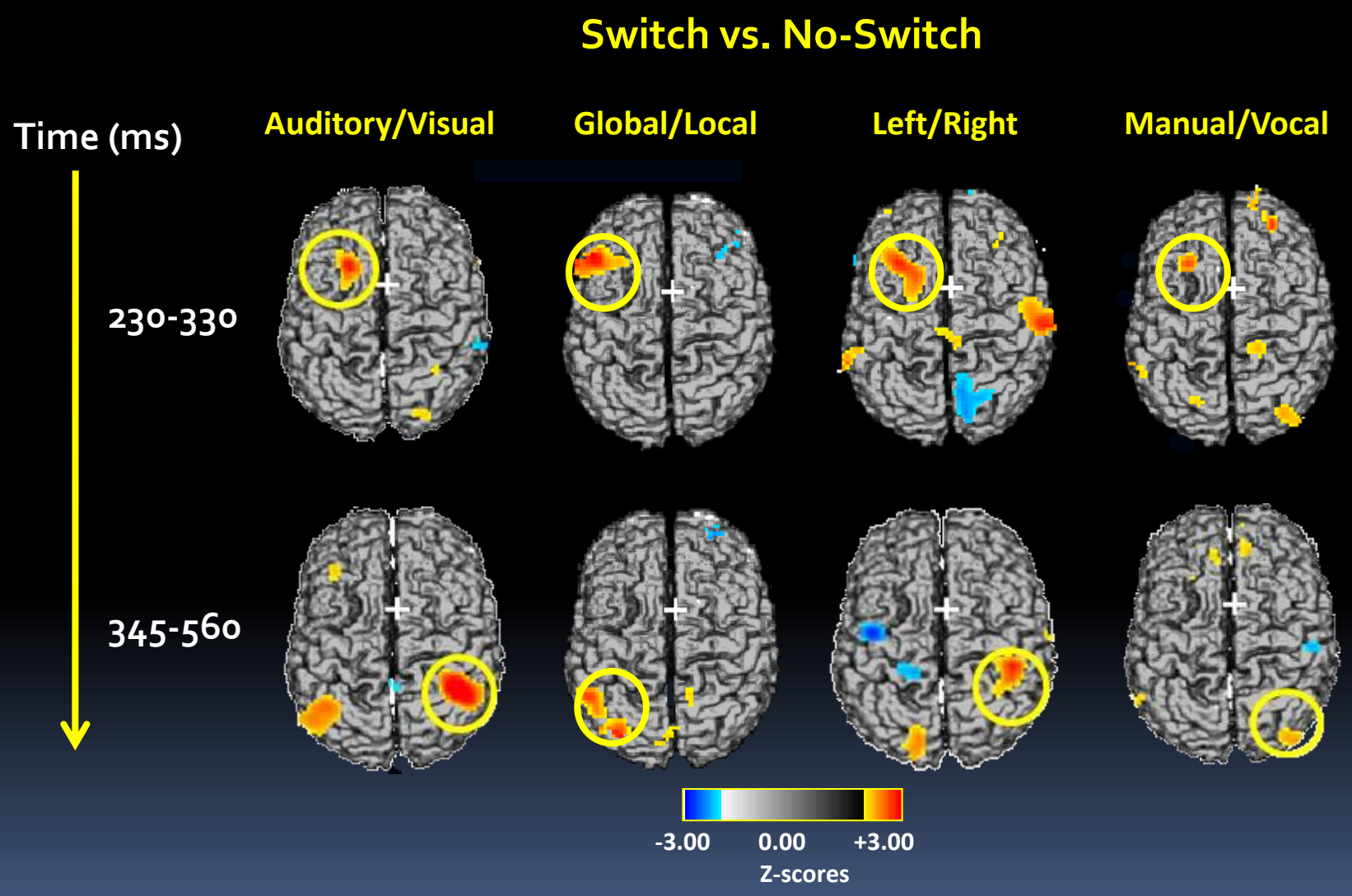
Conflict:

Hear “I” + See “O”

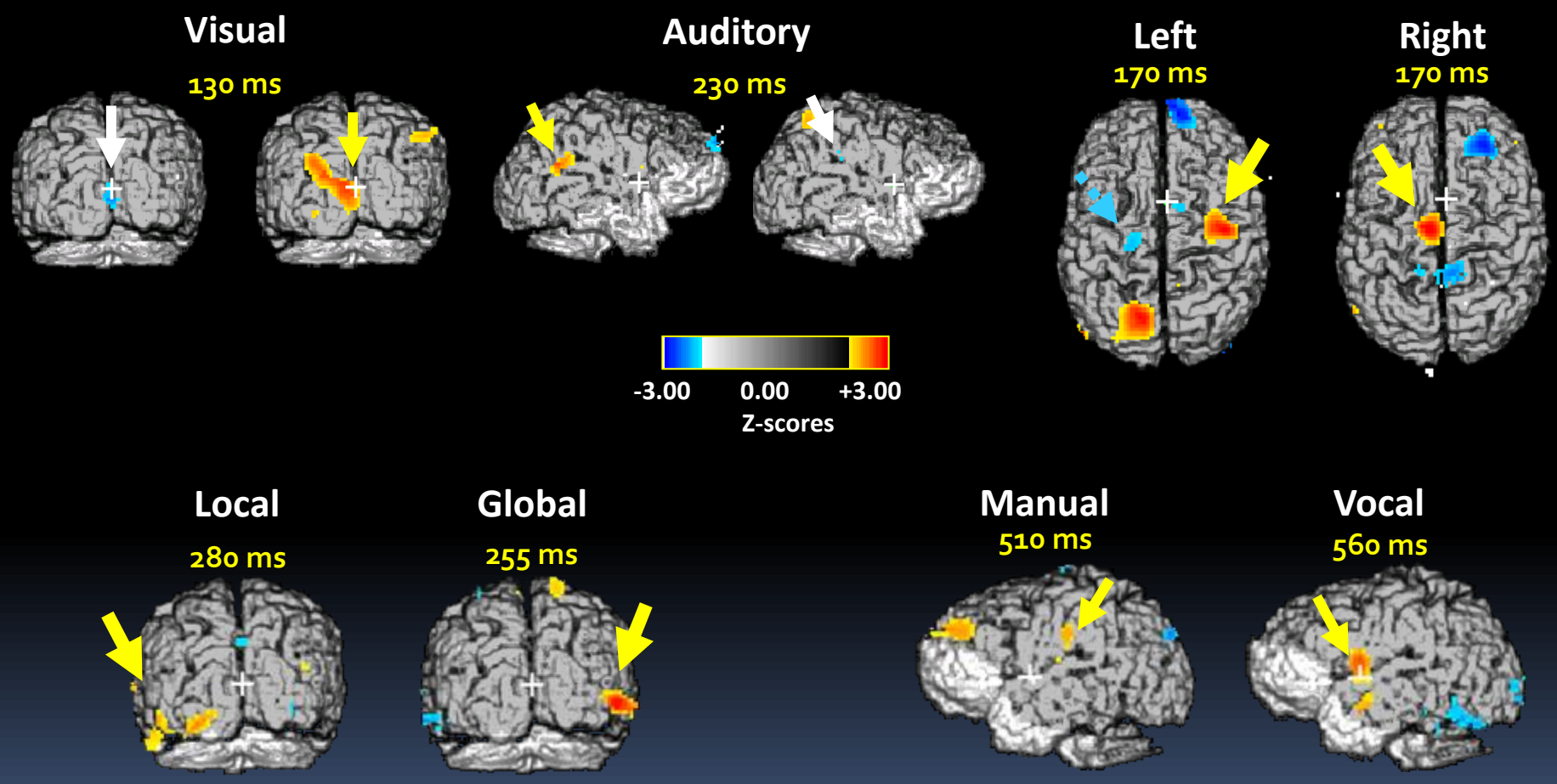
or

Hear “O” + See “I”

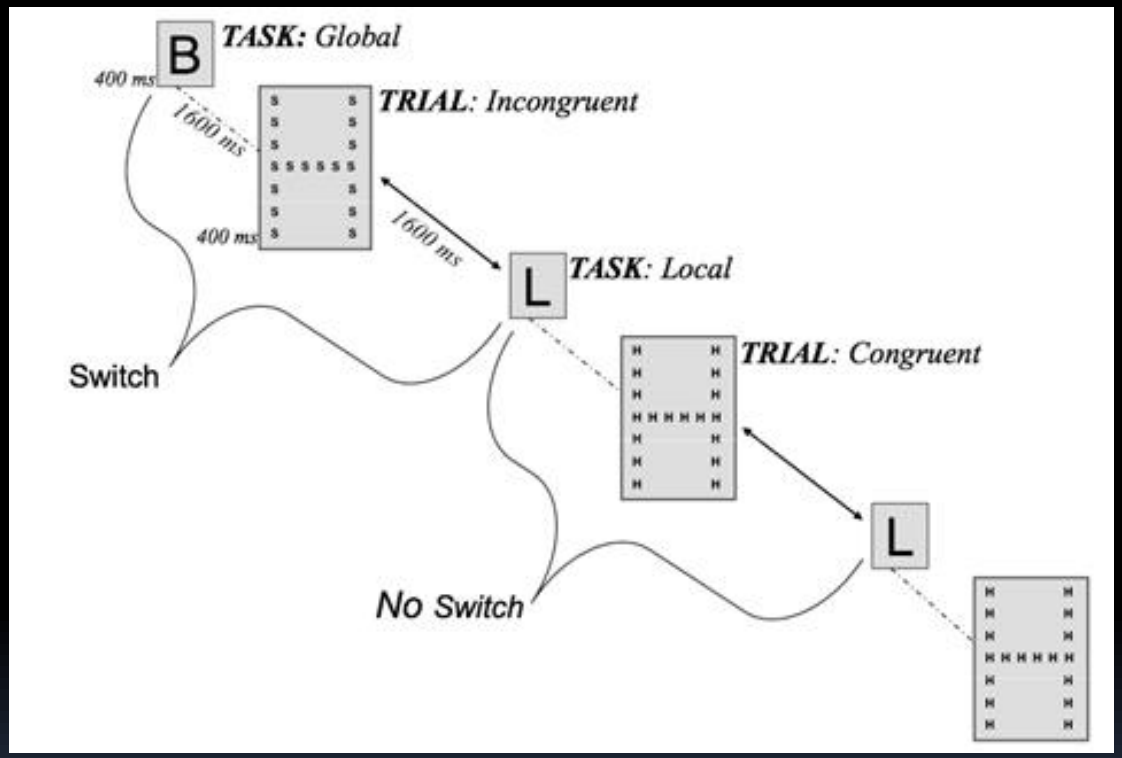
Task-general EROS activity



Task-specific EROS activity



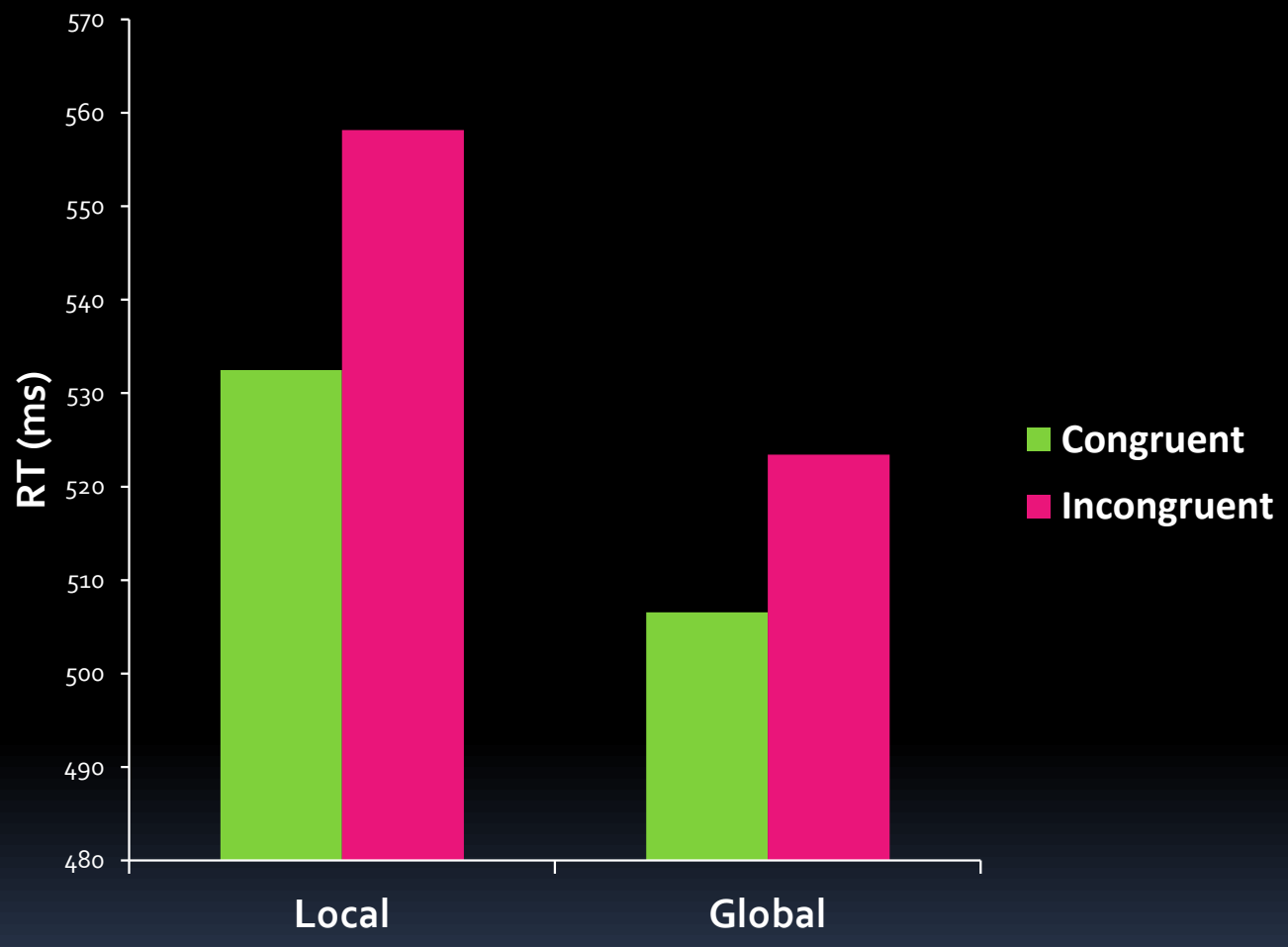
Preparation for Global/Local Processing



Congruent	Incongruent
H H H H H H H H H H H H H H H H H H	H H H H H H H H H H H H H H H H H H H H H H
S S S S S S S S S S S S S S S S S S S S S S	S S S S S S S S S S S S S S S S S S

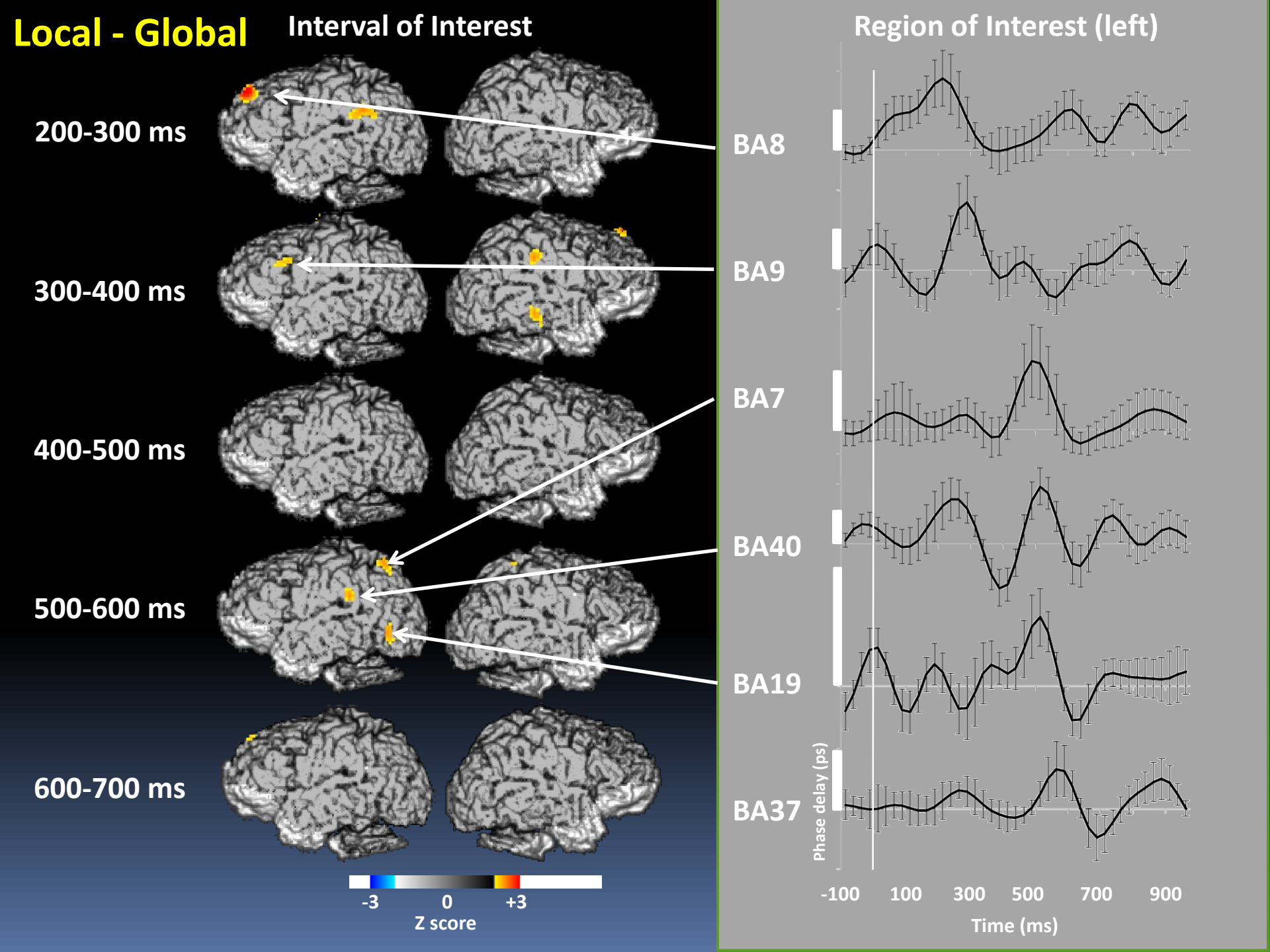
Leaver et al., submitted

Behavioral Results



Local task is harder than global task

More conflict in local than in global task


Local - Global
Interval of Interest
200-300 ms
300-400 ms
400-500 ms
500-600 ms
600-700 ms
-3
0
+3
Z score
Region of Interest (left)
BA8
BA9
BA7
BA40
BA19
BA37
Phase delay (ps)
-100
100
300
500
700
900
Time (ms)

Cross-correlation analysis

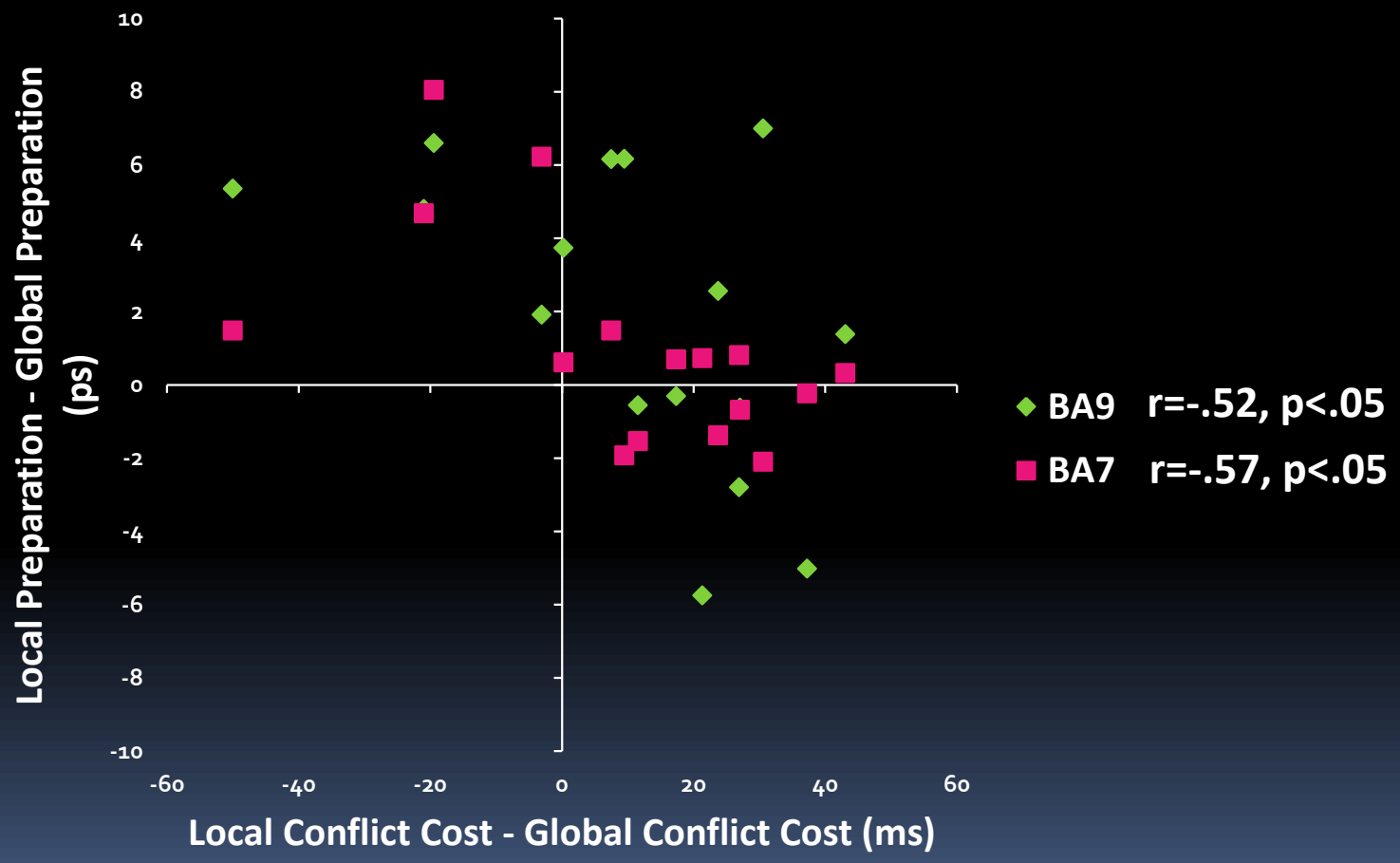
Left Hemisphere

0 ms	51 ms	128 ms	307 ms	358 ms
	Y=-11 Z=43 *z*=3.091	Y=-26 Z=21 *z*=3.809	Y=-68 Z=43 *z*=4.383	Y=-11 Z=43 *z*=2.785

Right Hemisphere

0 ms	26 ms	153 ms	256 ms	333 ms
	Y=12 Z=29 *z*=2.882	Y=-26 Z=33 *z*=3.812	Y=-11 Z=23 *z*=3.433	Y=-21 Z=-18 *z*=2.911

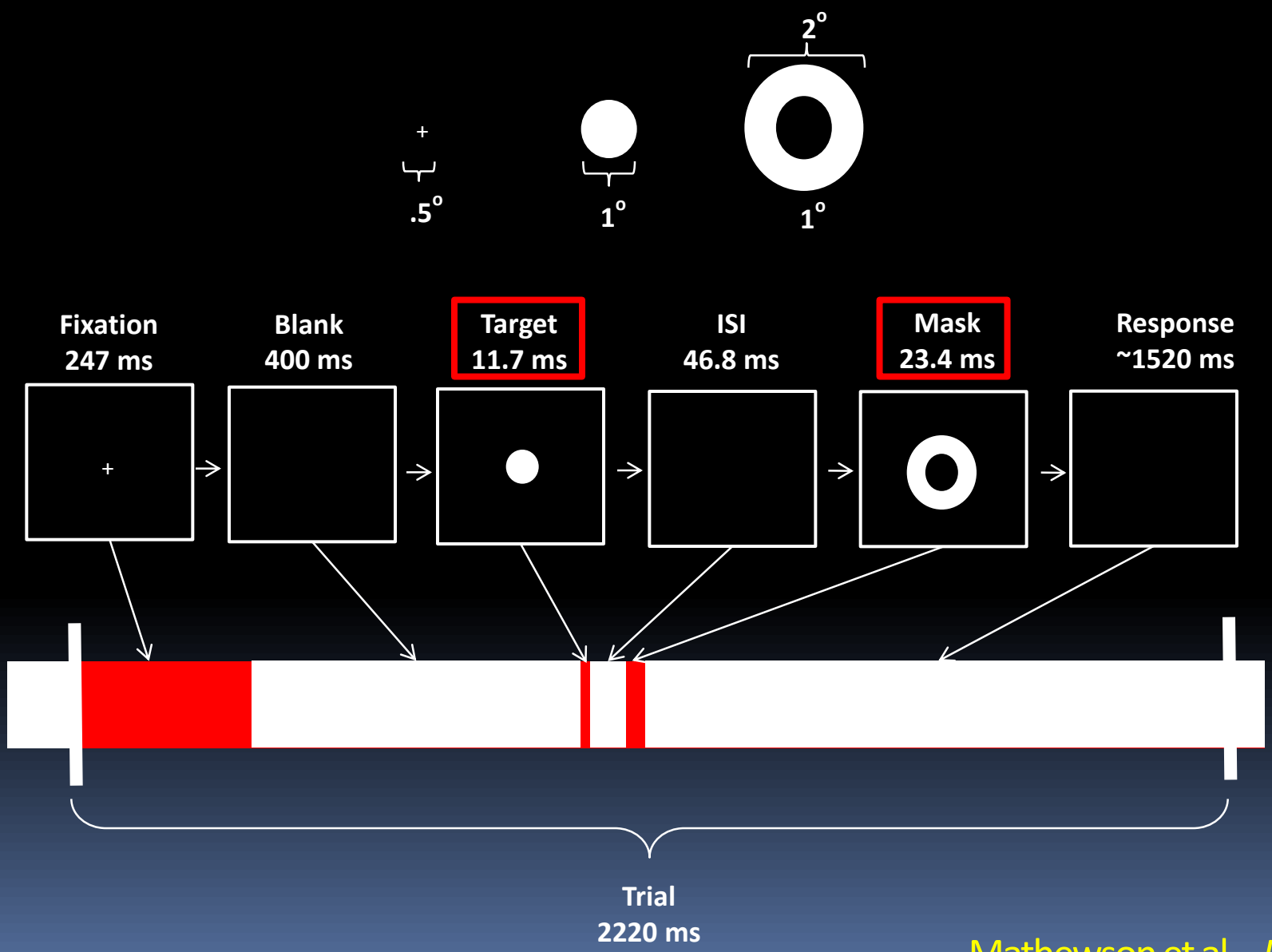
Preparation helps reduce conflict



How do top-down processes influence bottom-up processing?

- A flourishing of papers in the last five years indicate that processing of sensory stimuli is influenced by the amplitude and phase of oscillatory activity (alpha) in sensory cortex
  - E.g., Mathewson et al., JoN, 2009
- Do attentional networks influence these oscillatory activities?
  - E.g., Thut & Miniussi, TICS, 2009

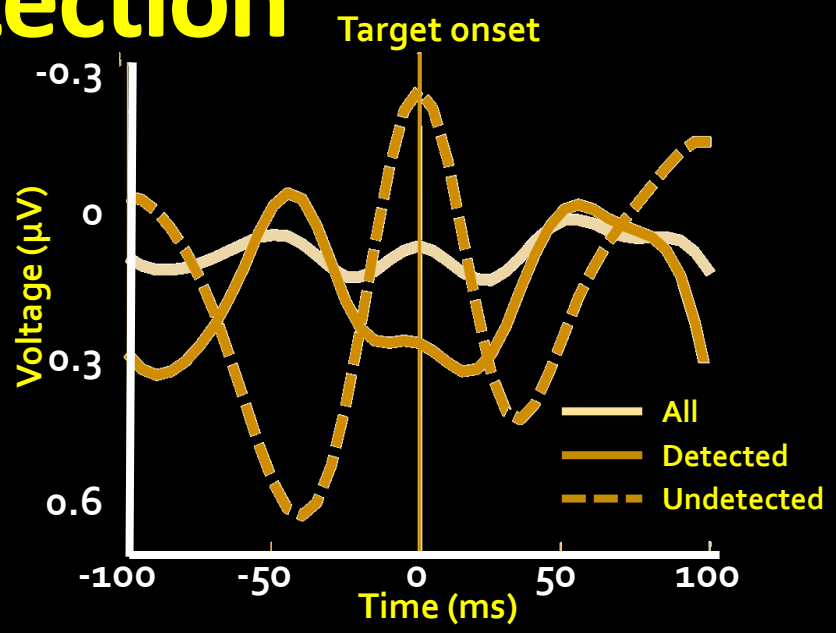
Meta-contrast masking

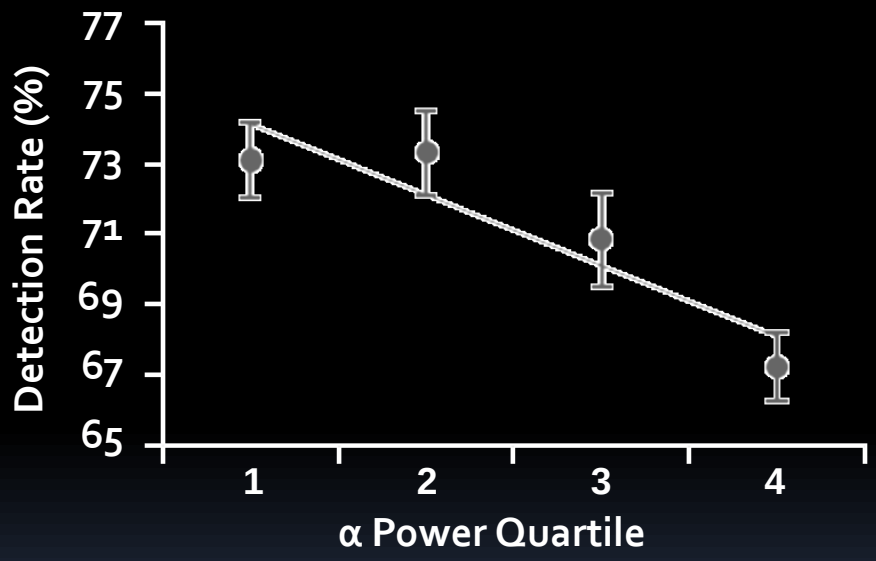


Mathewson et al., *JoN*, 2009

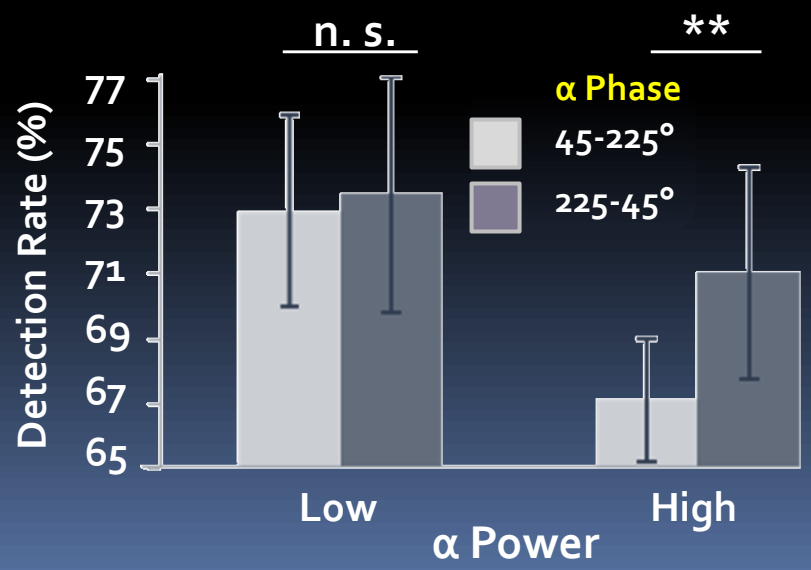
Brain states and detection

Averaged evoked potential
for detected and undetected targets





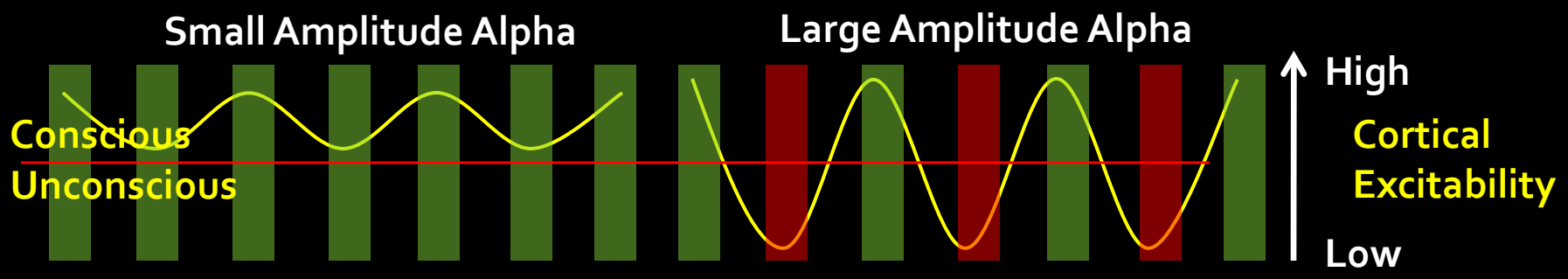
Probability of detection for trials
with large and small alpha power

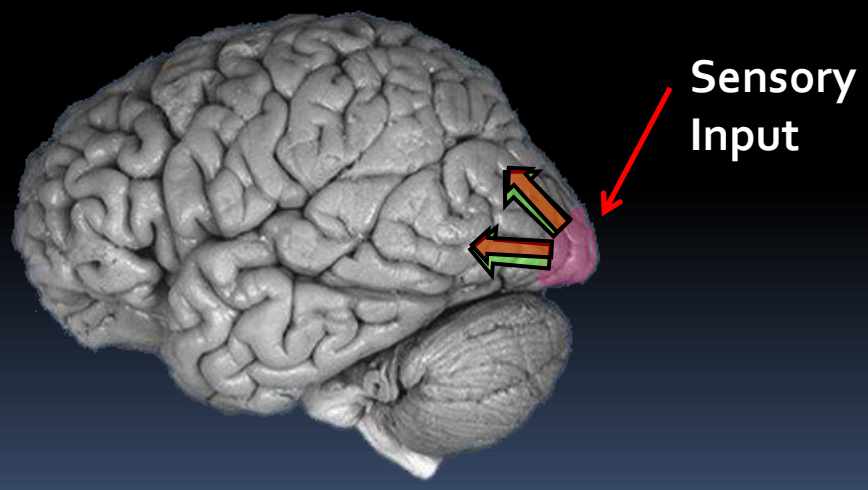


Probability of detection for trials with
alpha phase in "high" and "low" mode

Mathewson et al., *JoN*, 2009

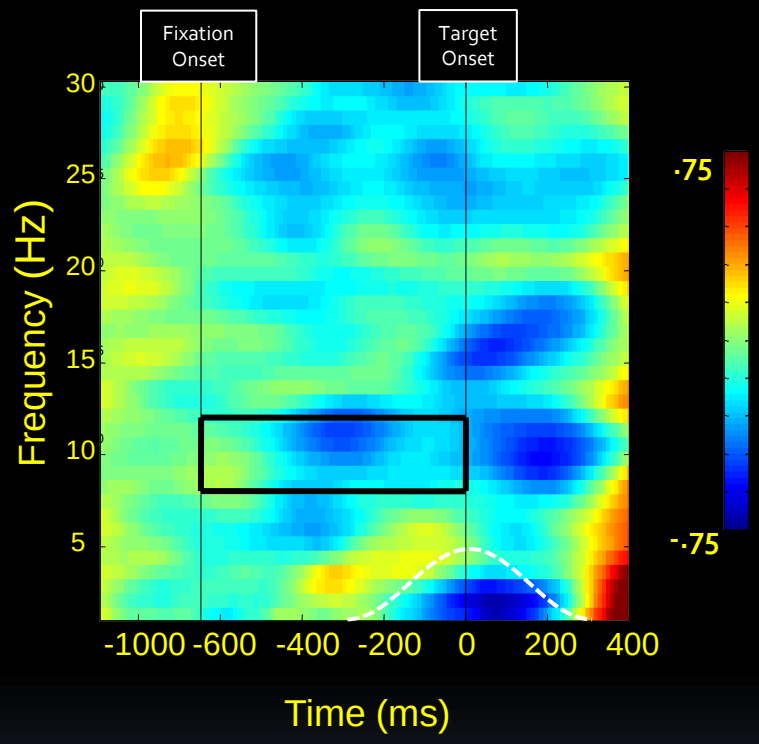
Cortical excitability and alpha oscillations



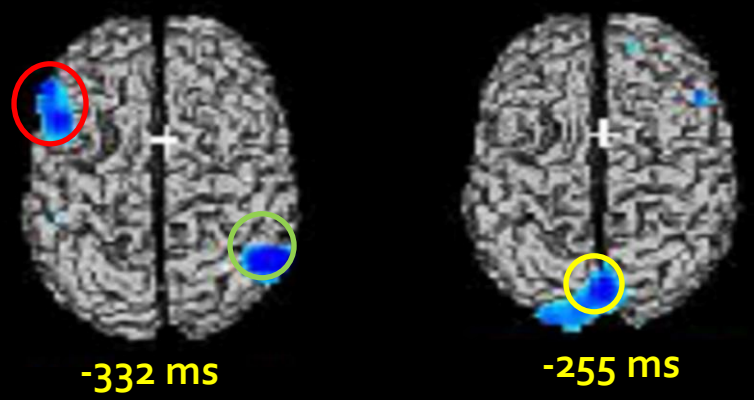


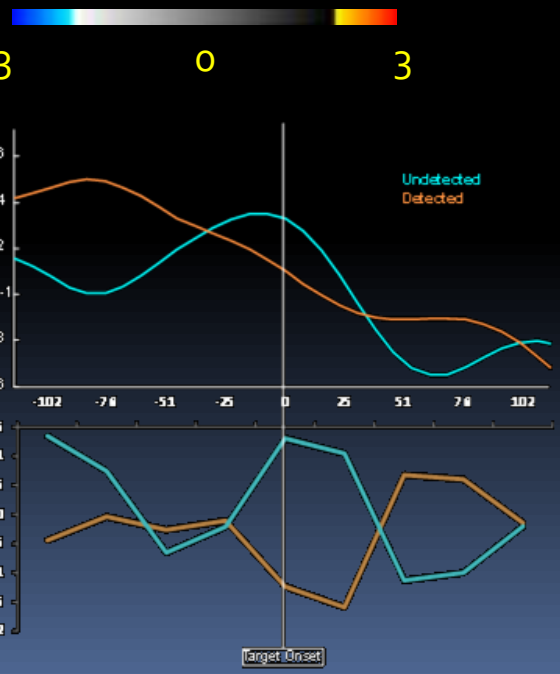
Brain activity prior to targets

EEG time frequency
Detected - Undetected



EROS alpha power map
Detected - Undetected

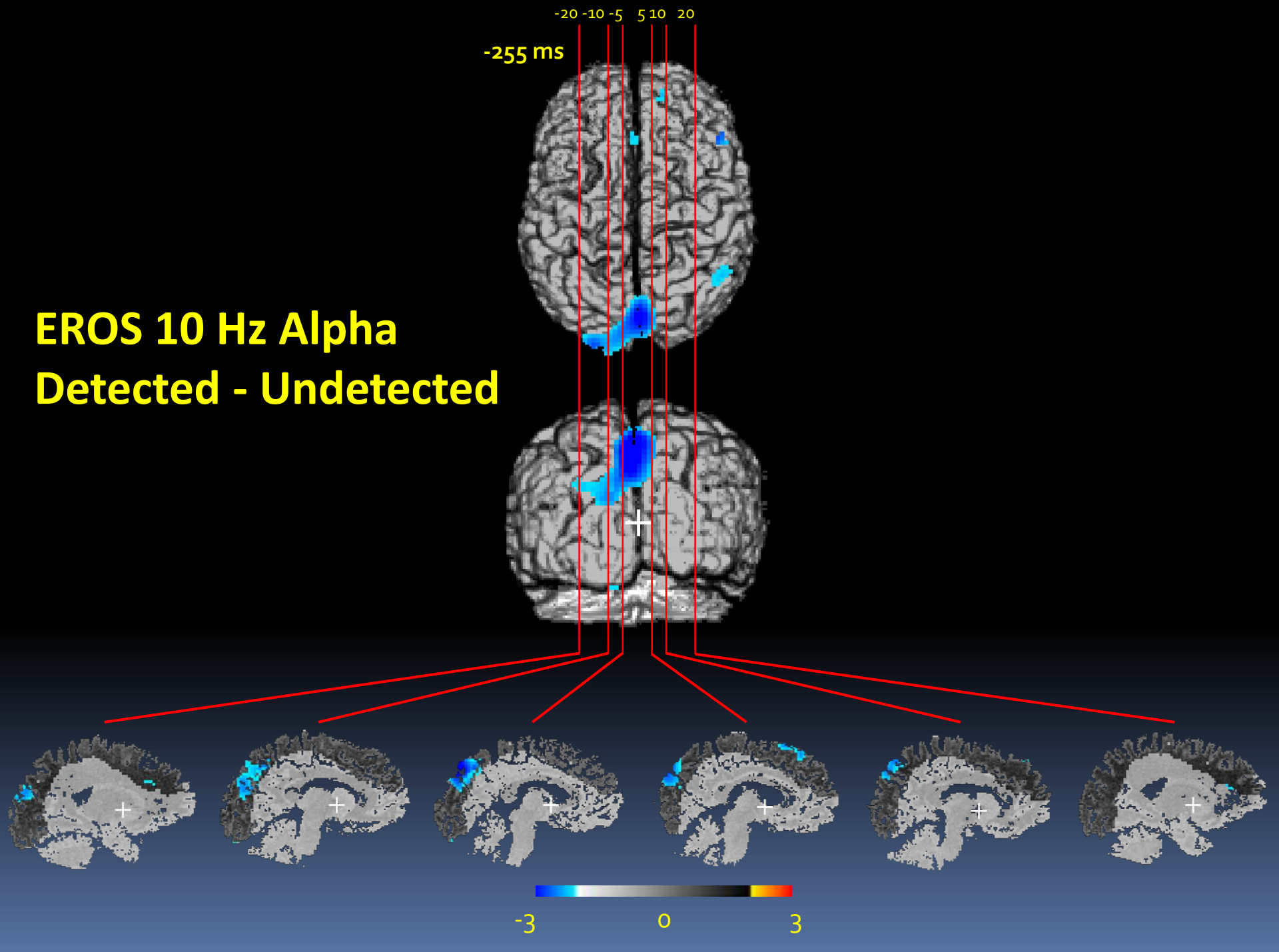




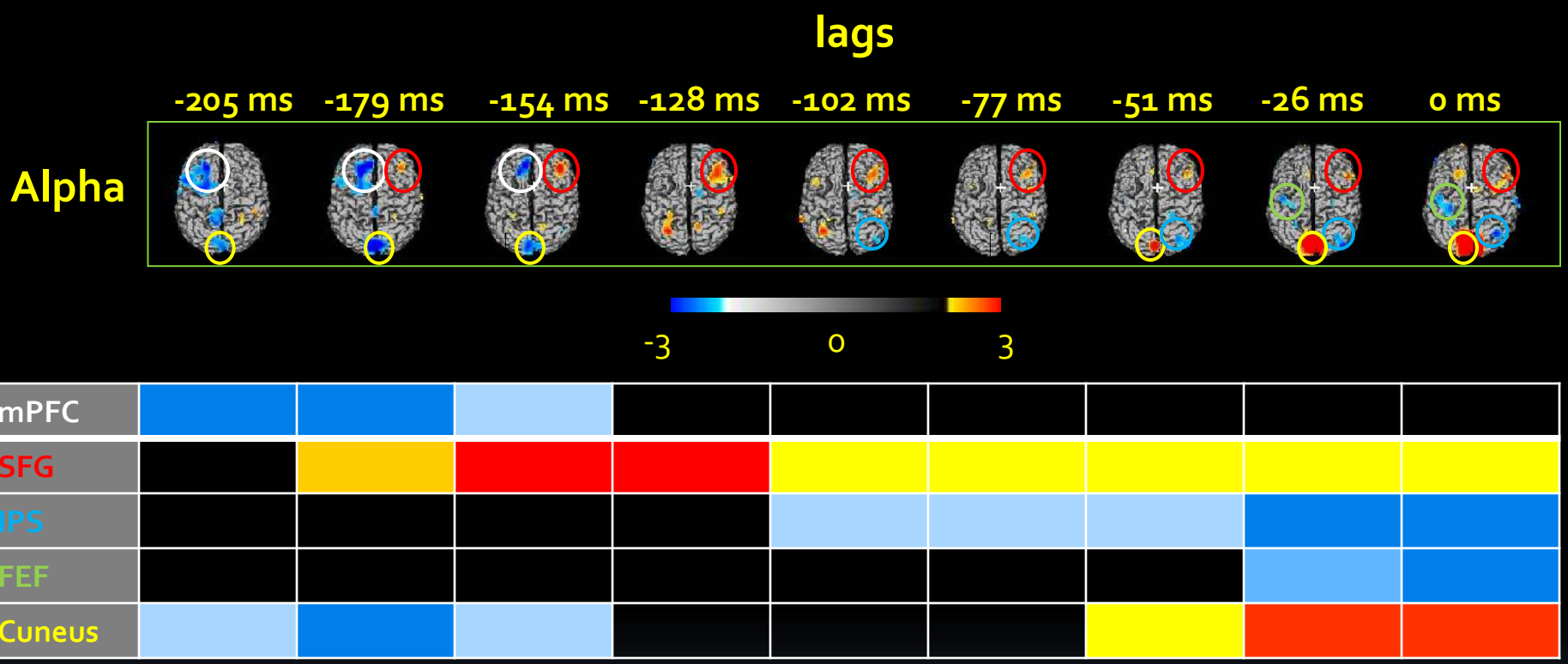
Time-locked activity
Detected vs. Undetected

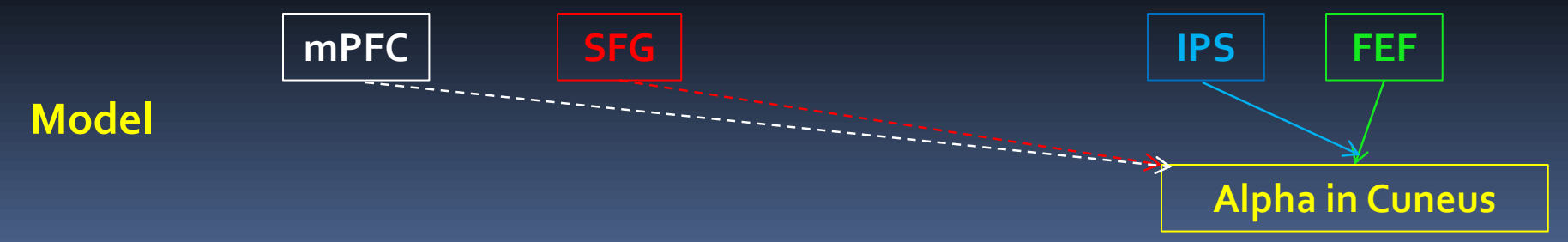
Mathewson, Beck, Ro, Fabiani, & Gratton, 2014

EROS 10 Hz Alpha
Detected - Undetected



Backward-Lagged Cross Correlation
Seed in cuneus (alpha)





Discussion

- Interaction between task-general areas (involved in top-down regulation) and task-specific areas (involved in bottom-up processing)
  - Task general areas include DAN and CON
    - Within DAN, frontal areas are activated before parietal ones
    - What is their respective role?
    - How are action plans represented here?
  - Task specific areas include visual, auditory, and motor networks
    - During preparation, they are activated during the foreperiod
    - Regulation of these areas may involve up- or down-regulation of rhythmic activity
      - The phase of the rhythmic activity may be involved in gating information processing
      - It may represent the excitability of particular cortical regions

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  - NIMH
  - NRCC
  - ONR

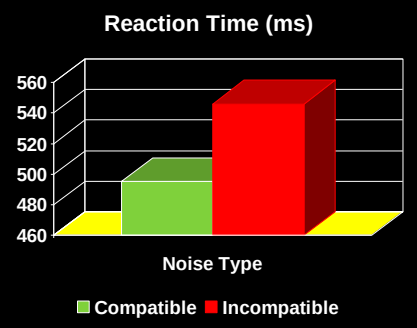
Thank you

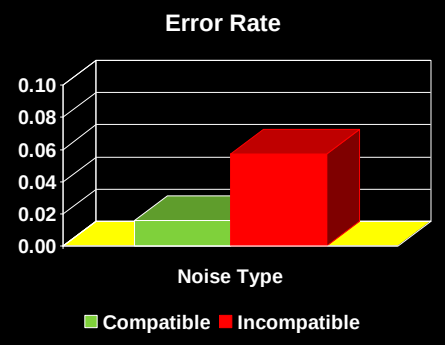
Dynamics of cognitive control

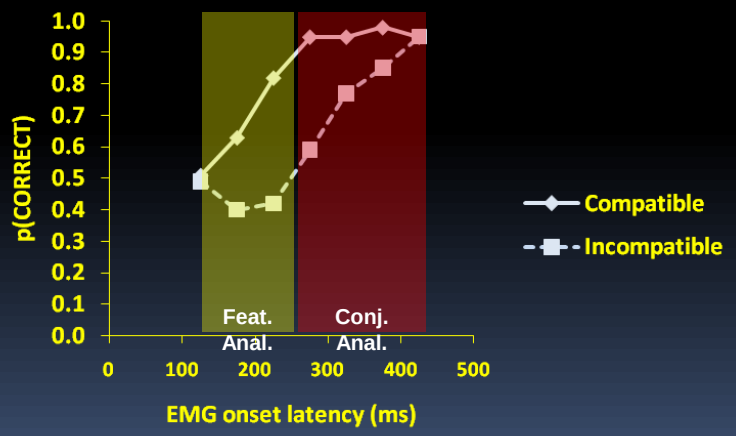
- How does cognitive control operate?
  - What are the relationships between different cognitive control regions?
  - How do they influence each other?
  - How do they influence perceptual (bottom-up) areas?
  - What happens in the perceptual areas that influences stimulus processing?

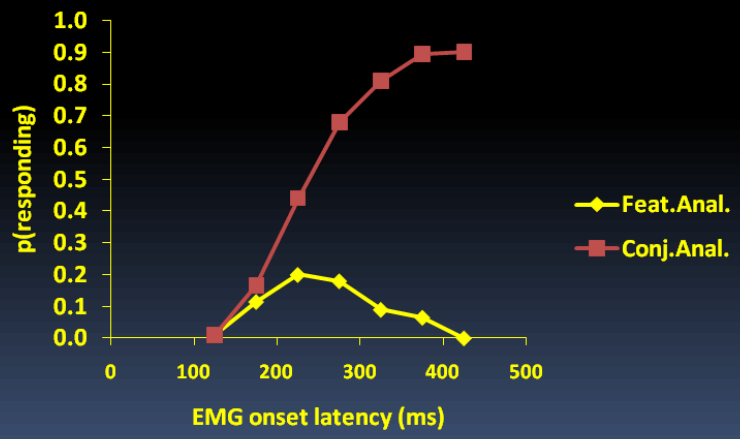
Example: Conflict effects

Compatible	Incompatible	
HHHHH	SSHSS	Respond Left/Right
SSSSS	HHSHH	Respond Right/Left







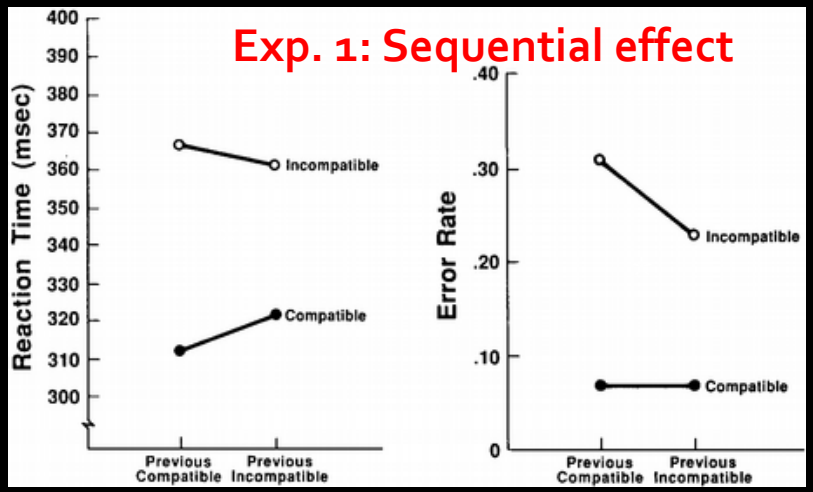


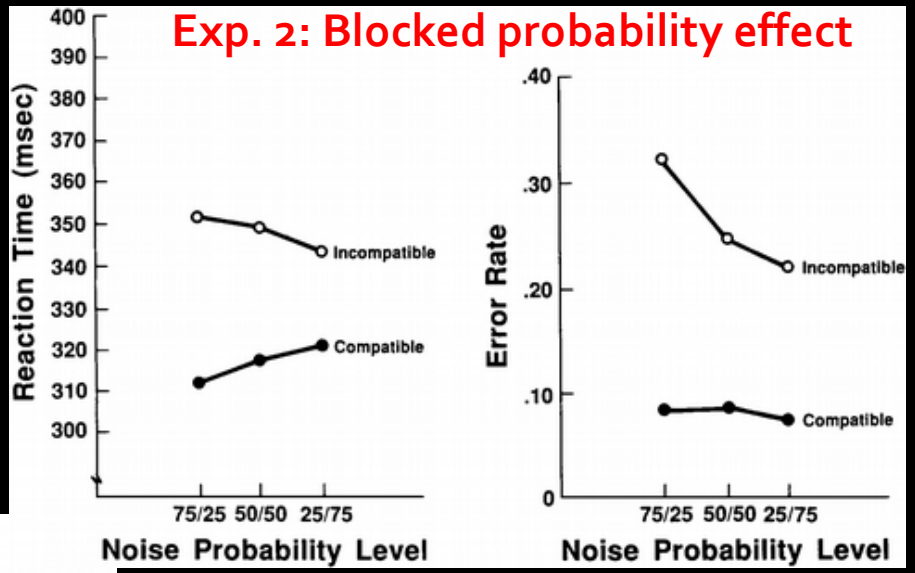
p(Feature Analysis) = acc(comp) – acc(incomp)

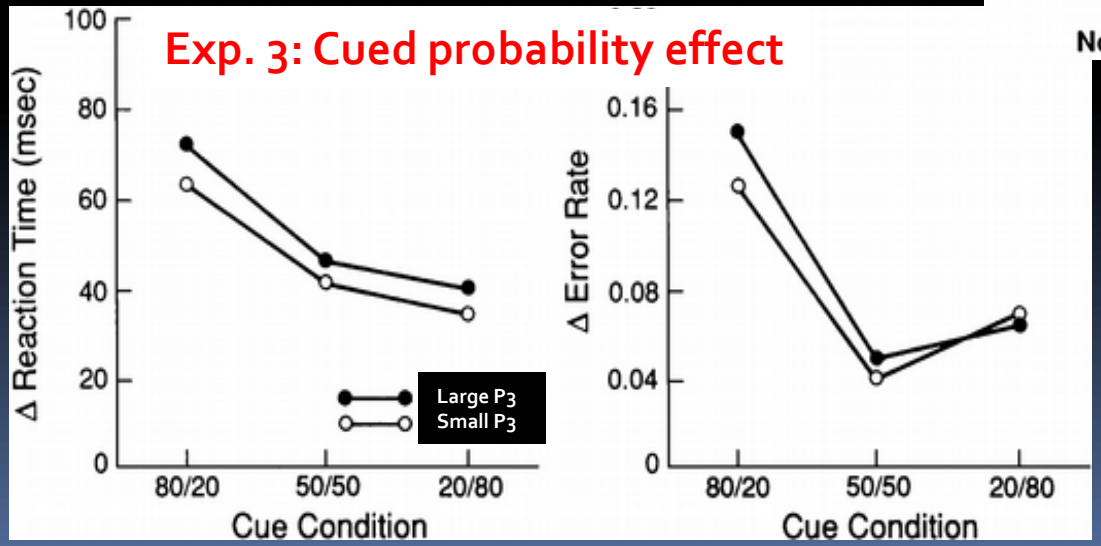
p(Conjunction Analysis) = 0.5*(acc(comp)+acc(incomp))

Gratton et al., *JEP: Gen., 1992*

Conflict adaptation: Effects of changes in expectation







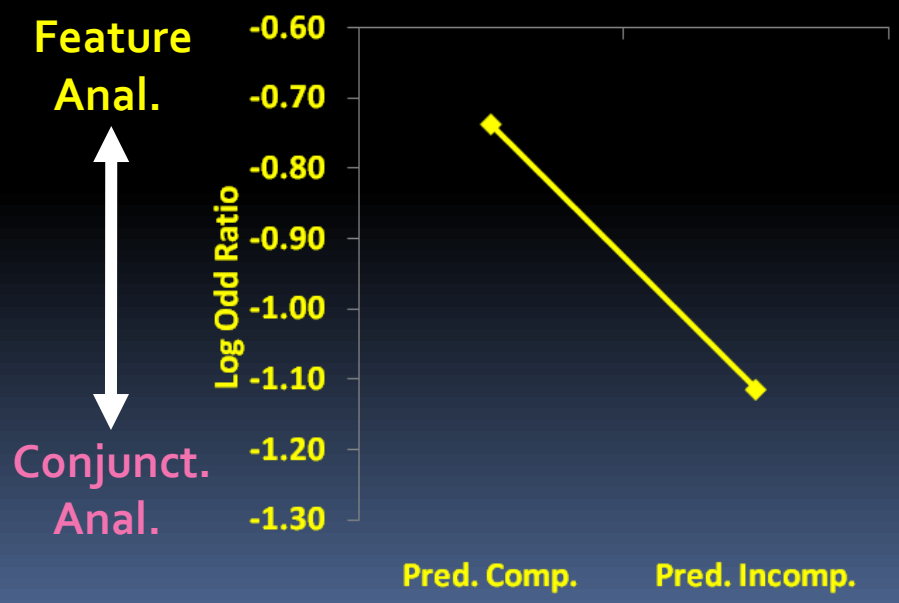
Gratton et al., JEP: General, 1992

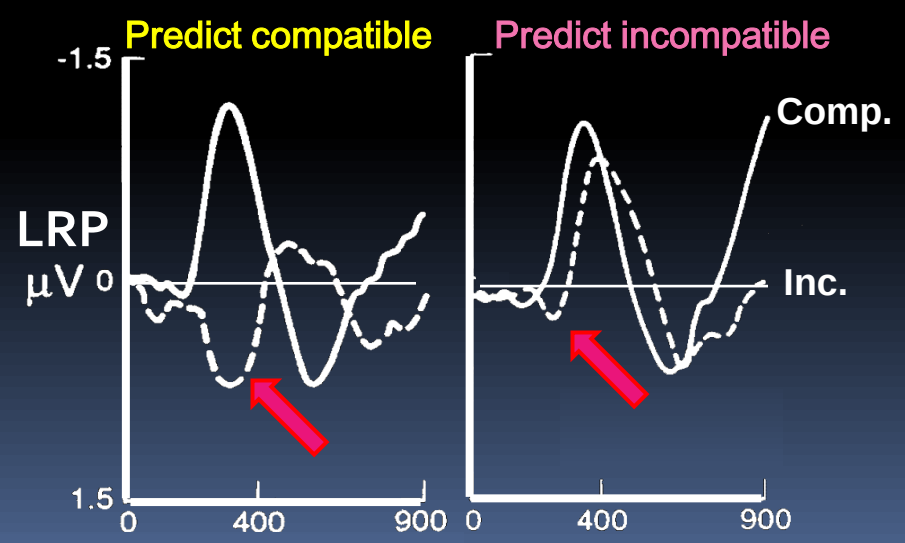
Interpreting conflict adaptation

- Strategy selection can be influenced by varying expectancy for compatible and incompatible noise

Precue A (predict compatible)
Precue B (predict incompatible)

Compatible	Incompatible
HHHHH	SSHSS
SSSSS	HHSHH





Gratton et al., *JEP: General*, 1992

Summary

- In RT tasks, subjects prepare for incoming stimuli by preparing appropriate stimulus-response plans
  - ideomotor function
- The fronto-parietal network (FPN) exerts an important role in preparation
  - Activation occurs first in frontal and then in parietal areas
  - Activation in FPN precedes that occurring in task-specific areas
  - The amount of preparatory activity is predictive of subsequent behavioral advantages
- EROS provides a tool for tracking the time course of preparatory activity