視覺短期記憶搜尋的神經機制 - 以EEG、MEG、fMRI實驗為例

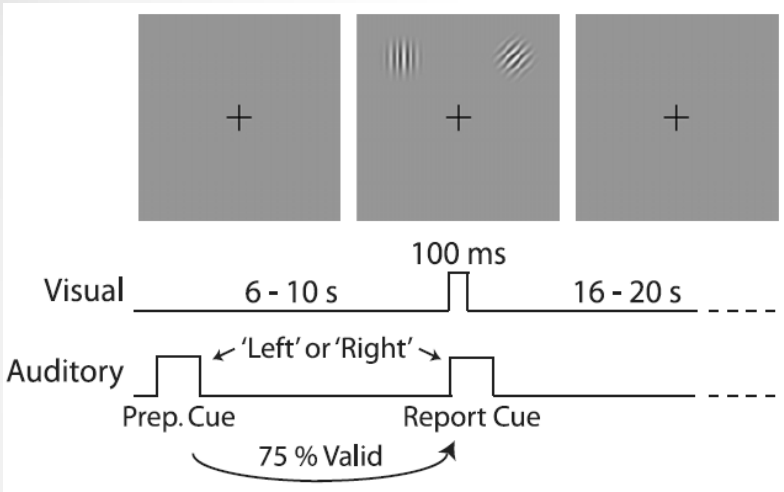
台灣大學心理系
郭柏呈

Background

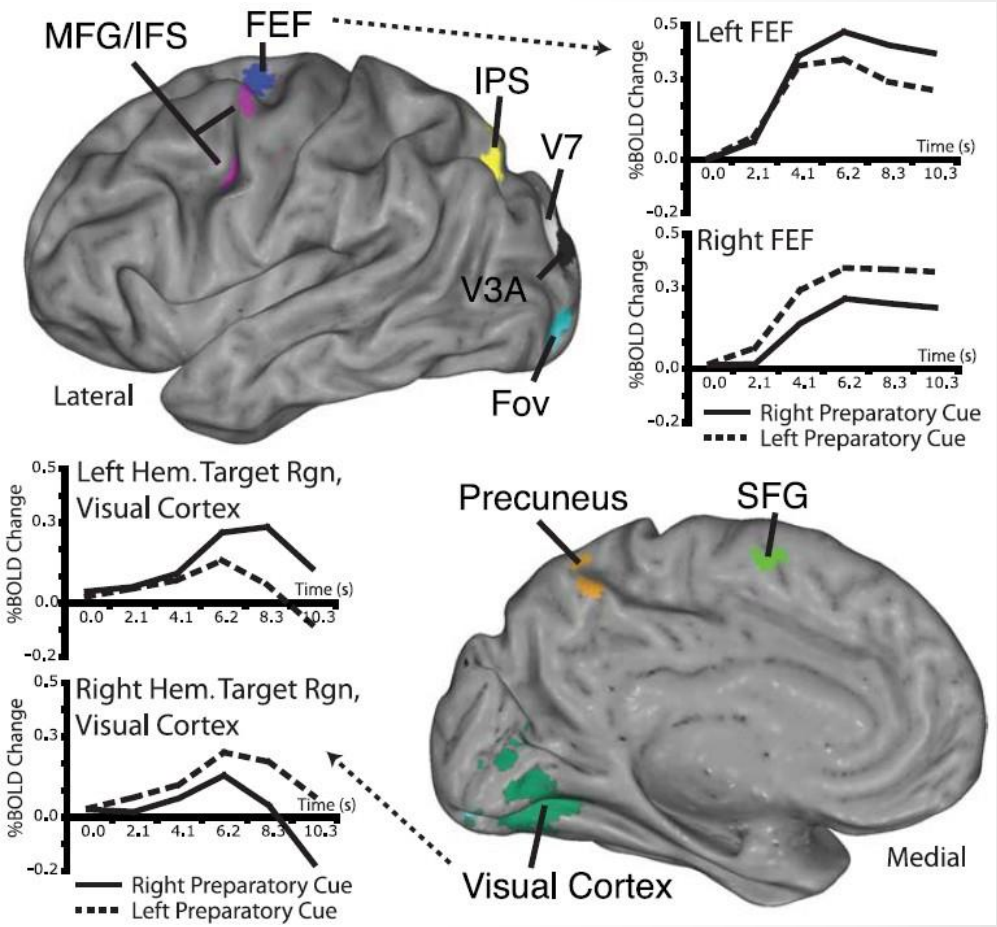
- **Top-down mechanisms** enable us to direct attention toward **a subset of relevant** information according to **our task goals or behavioural expectation**.
  - **External** – perceptual information
  - **Internal** – Mnemonic information

Top-down modulation of perceptual processing

Anticipatory signal for spatial attention modulated frontoparietal and visual areas

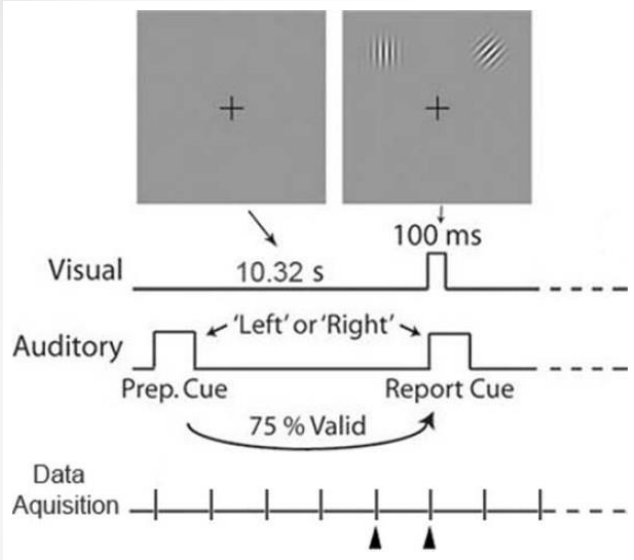


BOLD signals showed stronger effect for cue directing attention to contralateral visual field locations



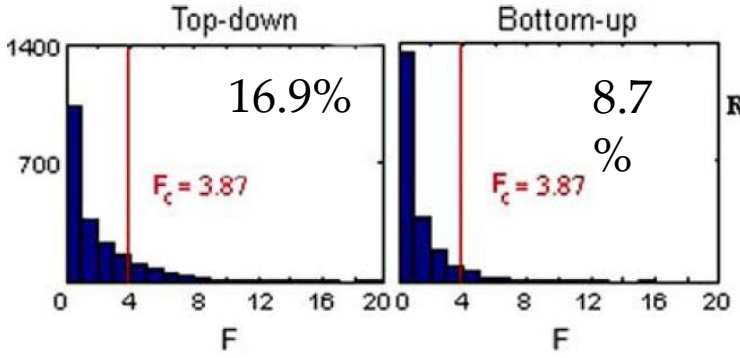
Sylvester et al., 2007, Journal of Neuroscience

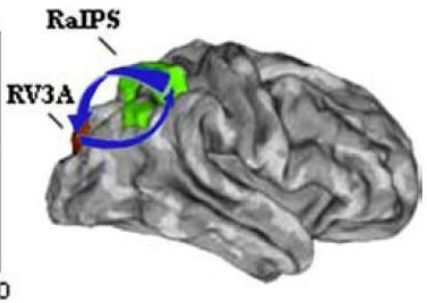
Causality of top-down biases from dorsal attention network onto visual vortex

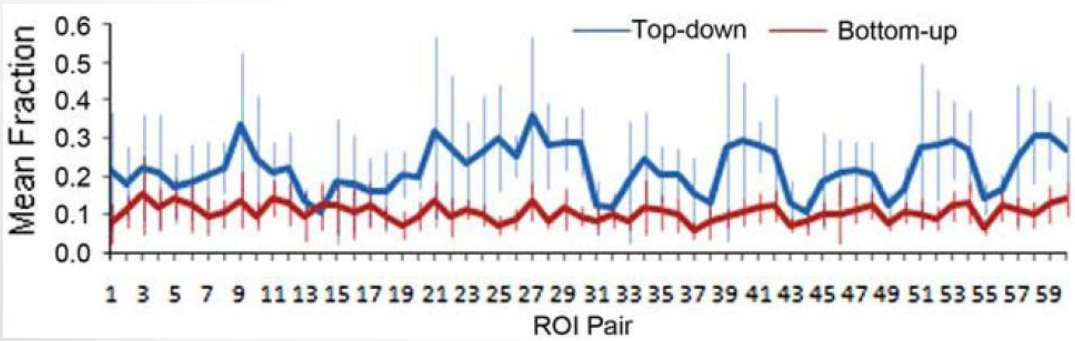


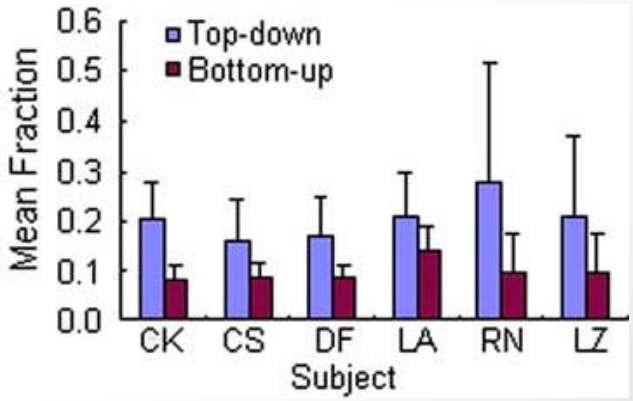
From FEF or IPS to visual occipital

From visual occipital To FEF or IPS



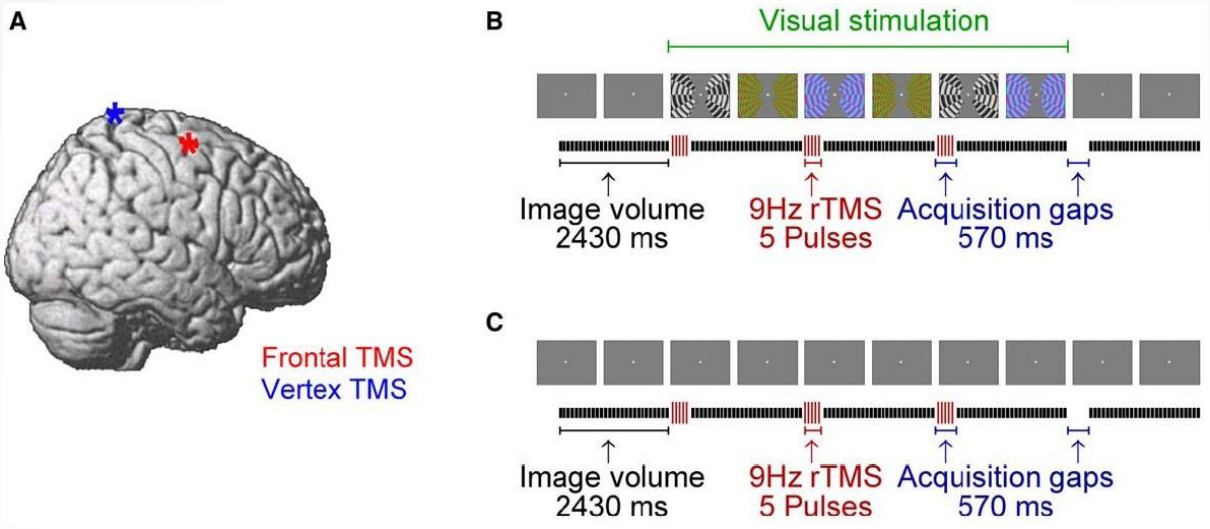




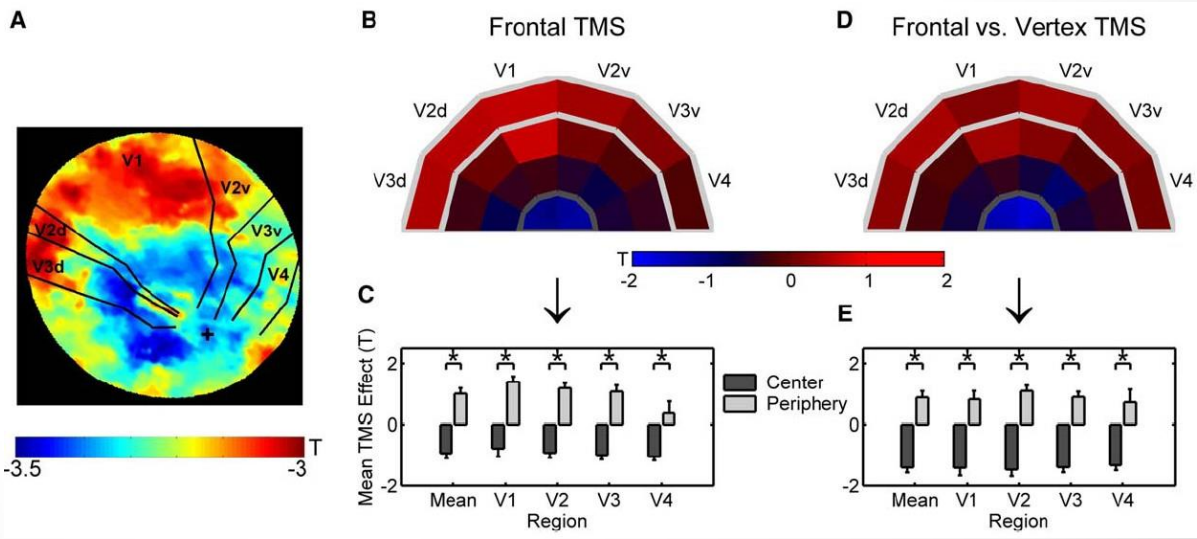


Bressler et al., 2008, Journal of Neuroscience

Frontal influences on retinotopic visual cortex: A concurrent TMS-fMRI study



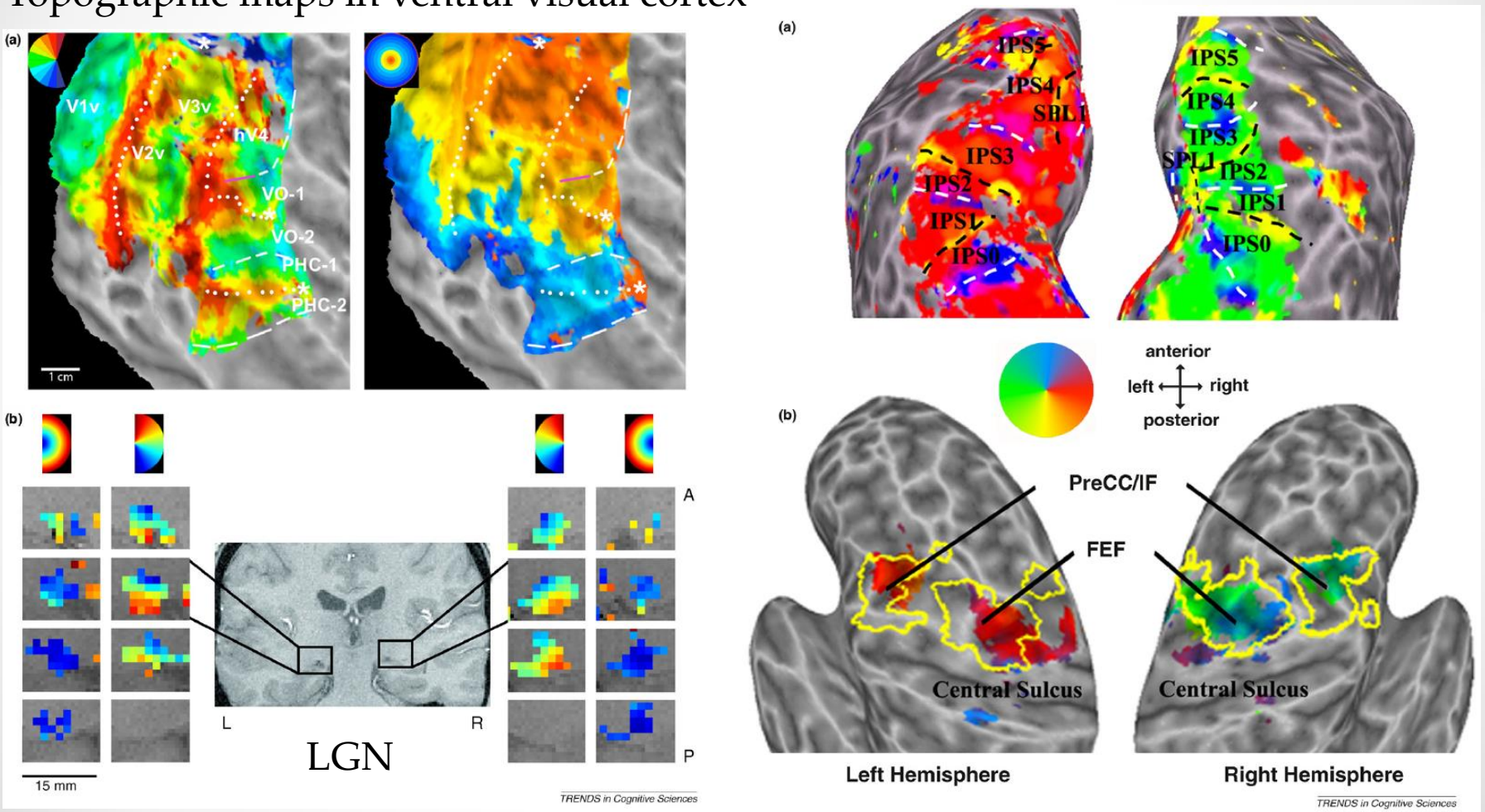
FEF TMS led to activity increases for retinotopic representations of the peripheral visual field, but to activity decreases for the central field



Ruff et al., 2006, Current Biology

Topographic organisation in dorsal attention network

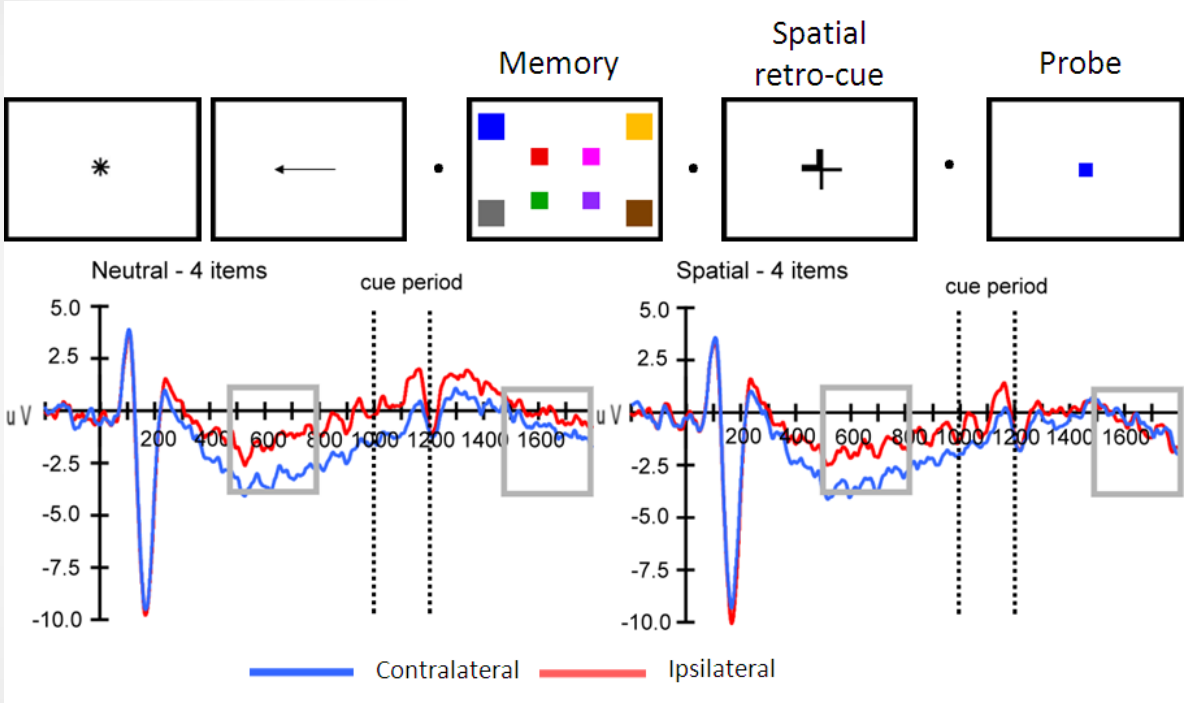
Topographic maps in ventral visual cortex



Silver & Kastner, 2009, TICS

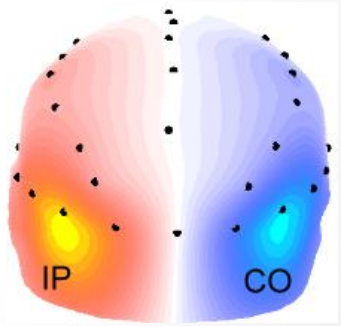
Top-down modulation of visual short-term memory (VSTM)

Top-down modulation of VSTM maintenance



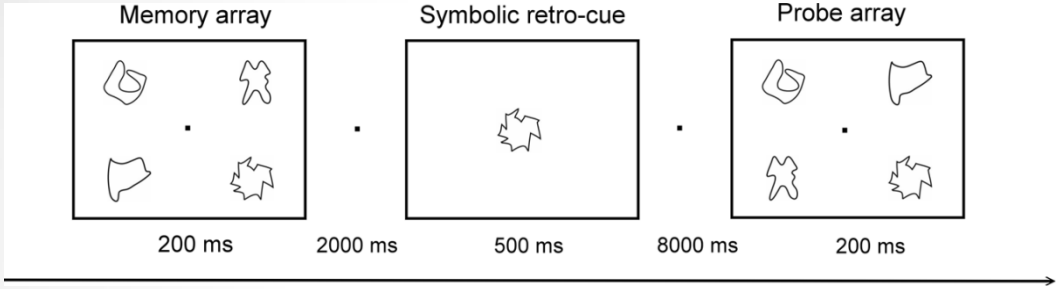
CDA:
A sustained lateralised negativity over posterior electrodes

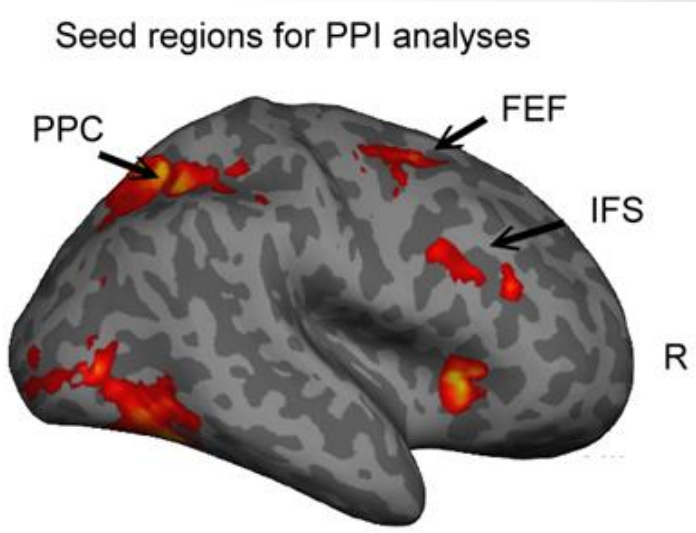
Correlates with the number of items being maintained

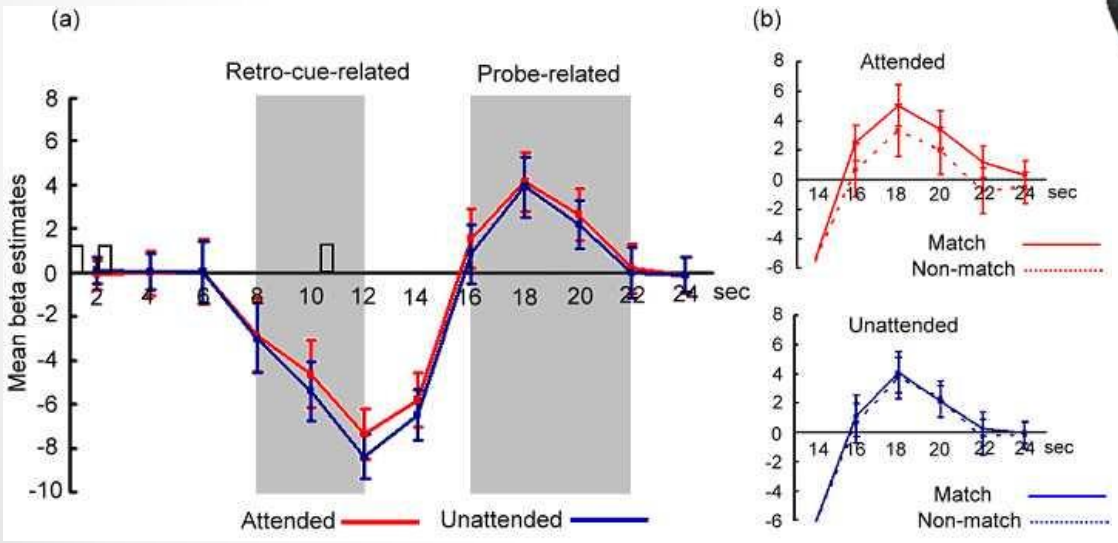


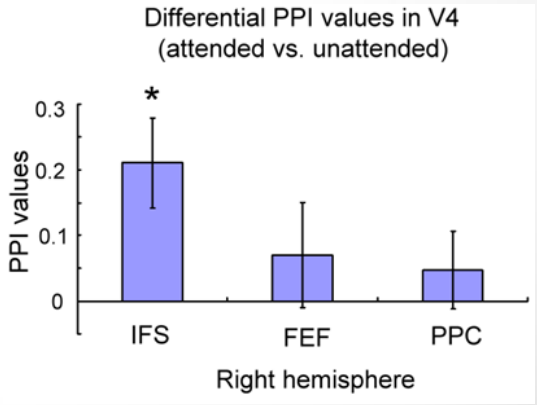
Kuo, Stokes, & Nobre, 2012, Journal of Cognitive Neuroscience

Top-down attention modulates visual activity in VSTM









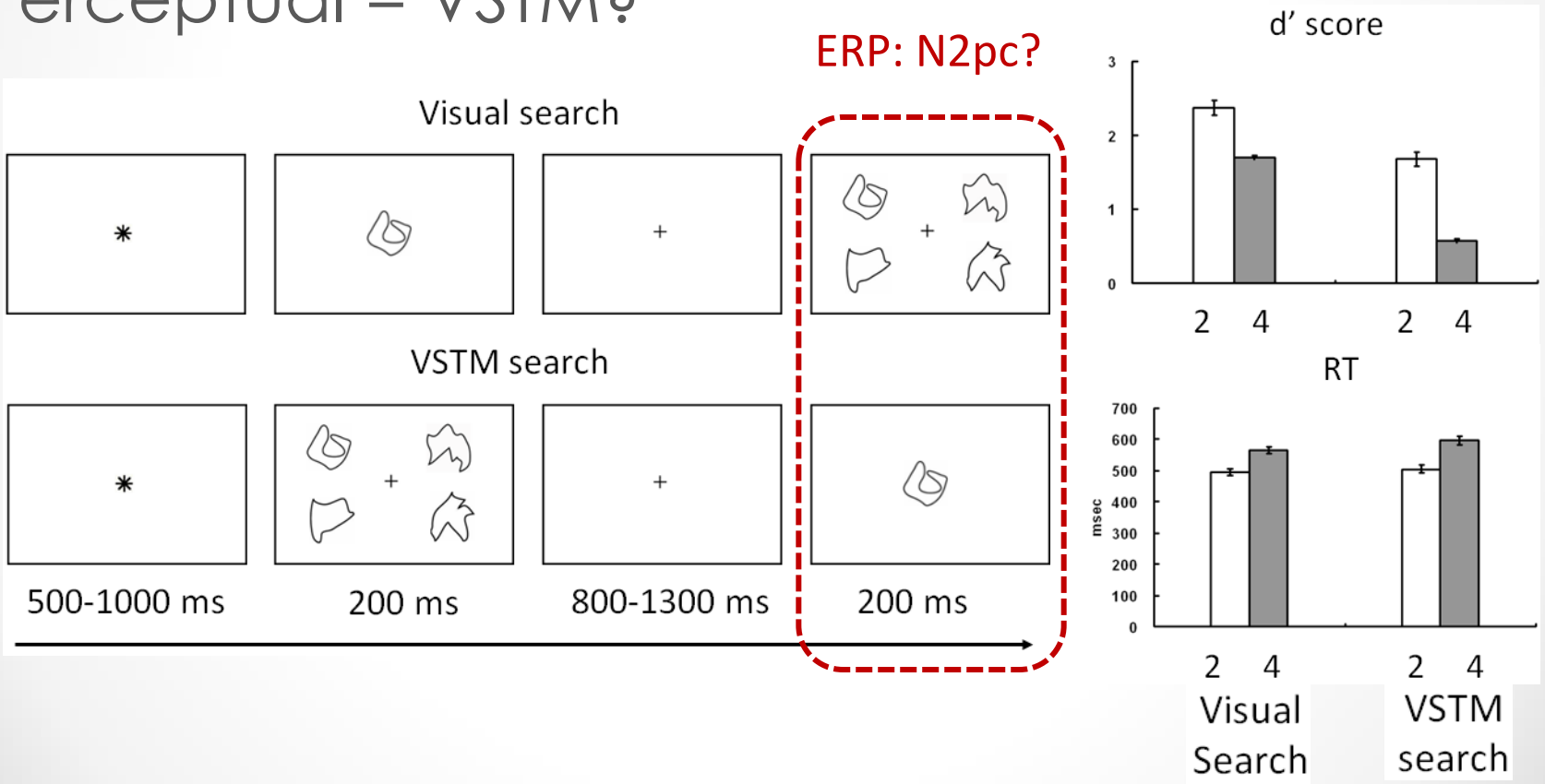
- Kuo, Stokes, Murray & Nobre, 2014, Journal of Cognitive Neuroscience

Research question?

- Whether top-down modulation serve as a common framework for selective attention processes in the service of both perceptual goals and those that underlie the different stages of VSTM?
  - Event-related potentials (**ERPs**)
  - Functional magnetic resonance imaging (**fMRI**)
  - Magnetoencephalography (**MEG**)

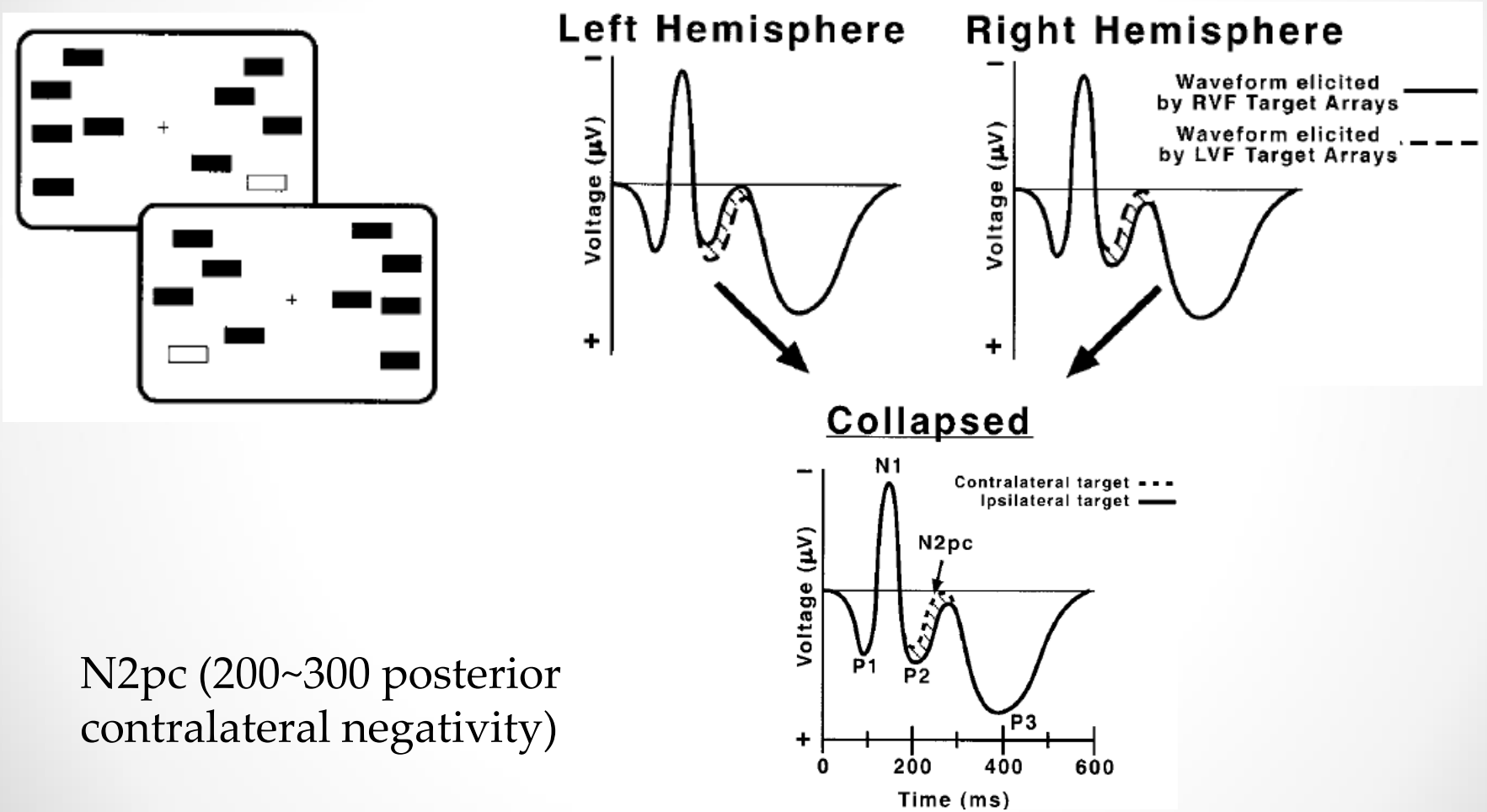
An ERP study: Searching for targets within spatial layout of VSTM

Spatially specific biasing of neural activity: Perceptual = VSTM?



Kuo, Rao, Lepsien, Nobre, 2009, Journal of Neuroscience

The role of spatial selection in visual search: target selection

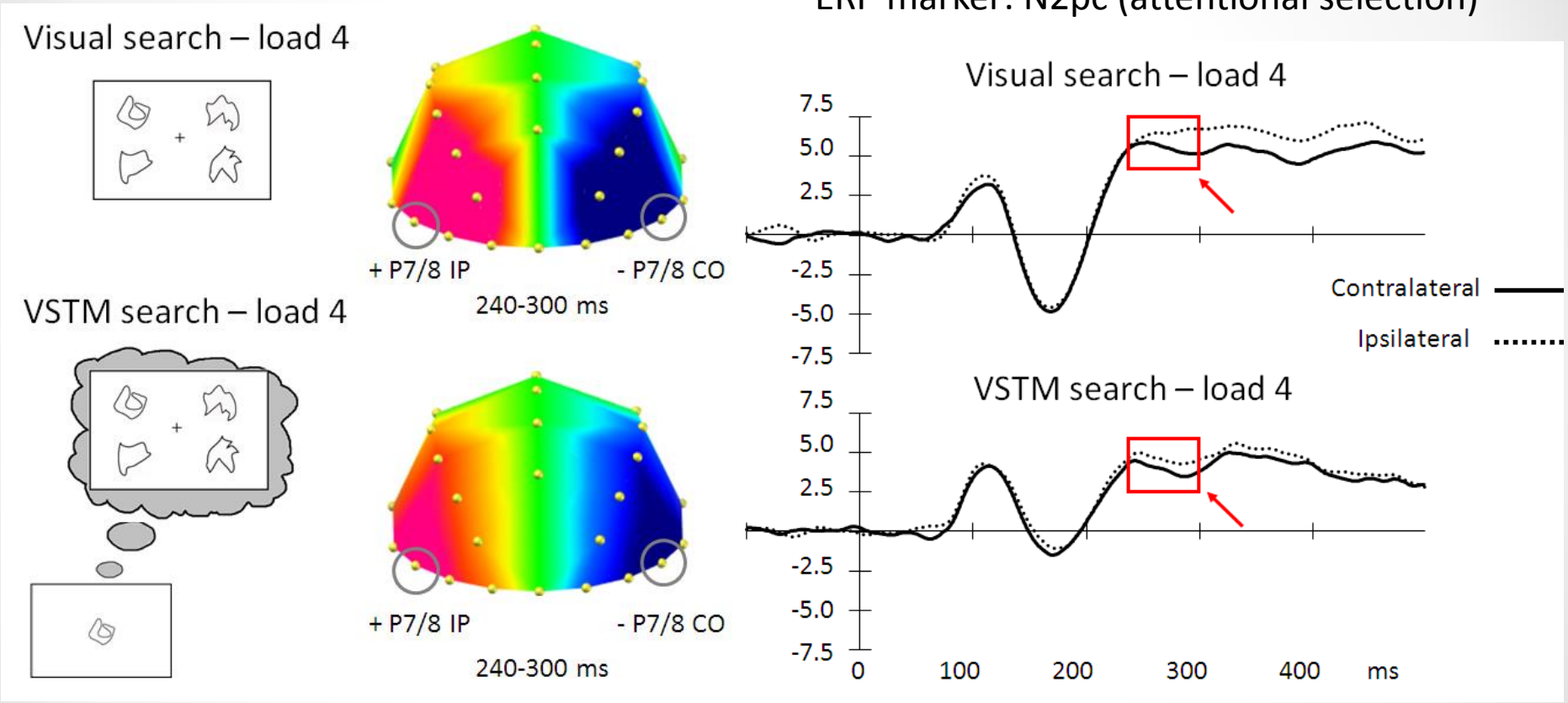


N2pc (200~300 posterior contralateral negativity)

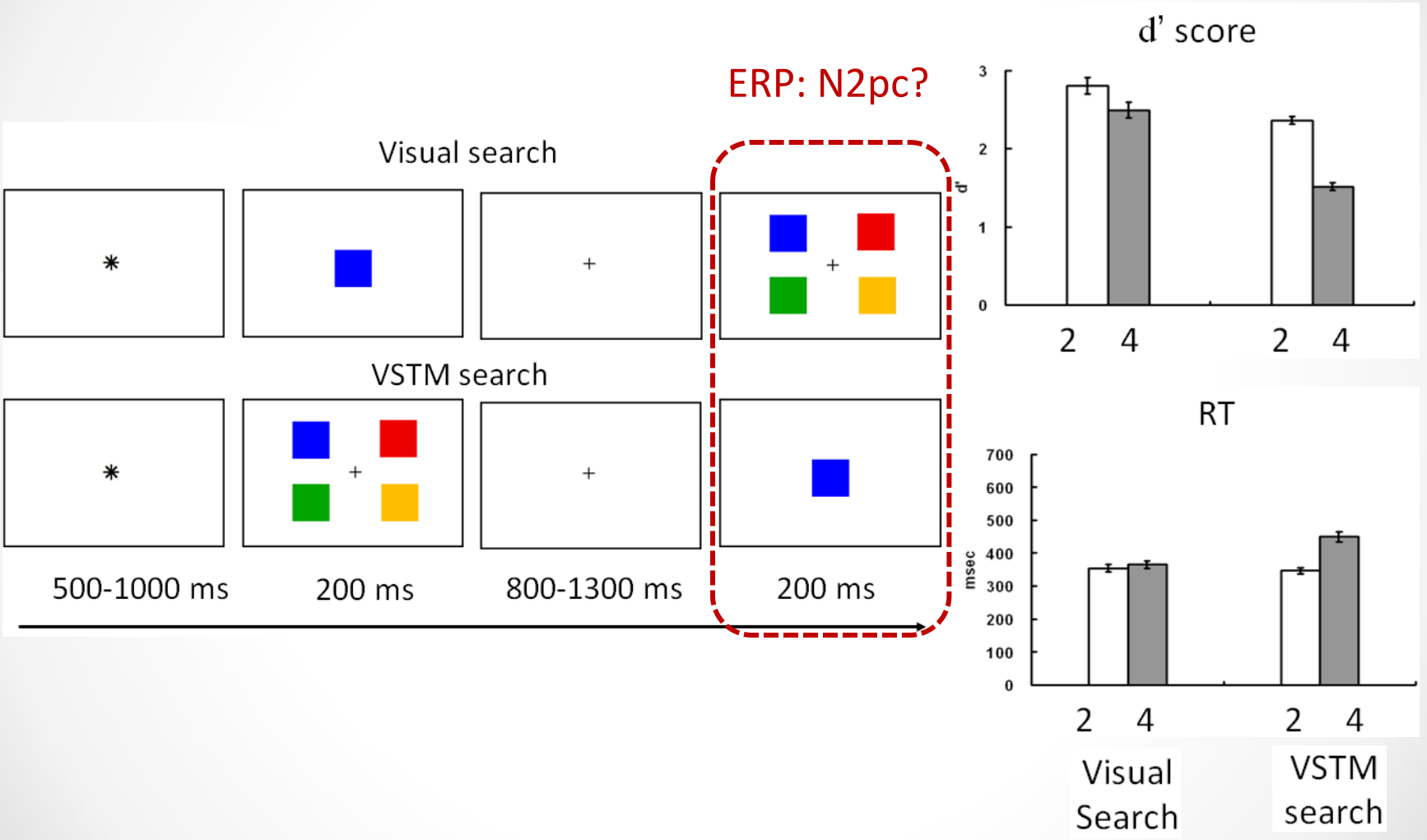
Woodman & Luck, 2003, JEP: HPP

Similar top-down biasing mechanisms in both VSTM and perceptual domains

ERP marker: N2pc (attentional selection)

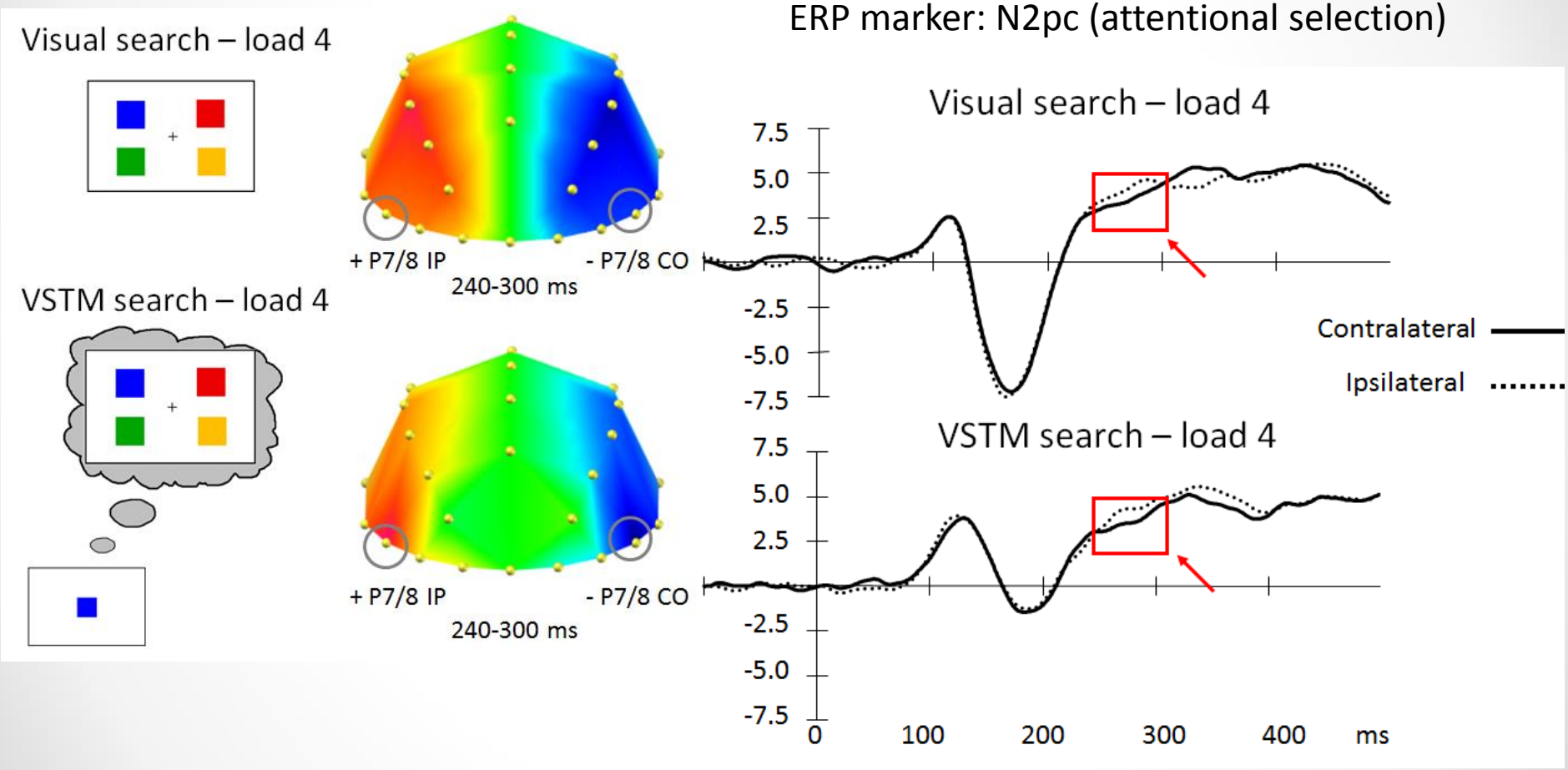


Kuo, Rao, Lepsien, Nobre, 2009, Journal of Neuroscience



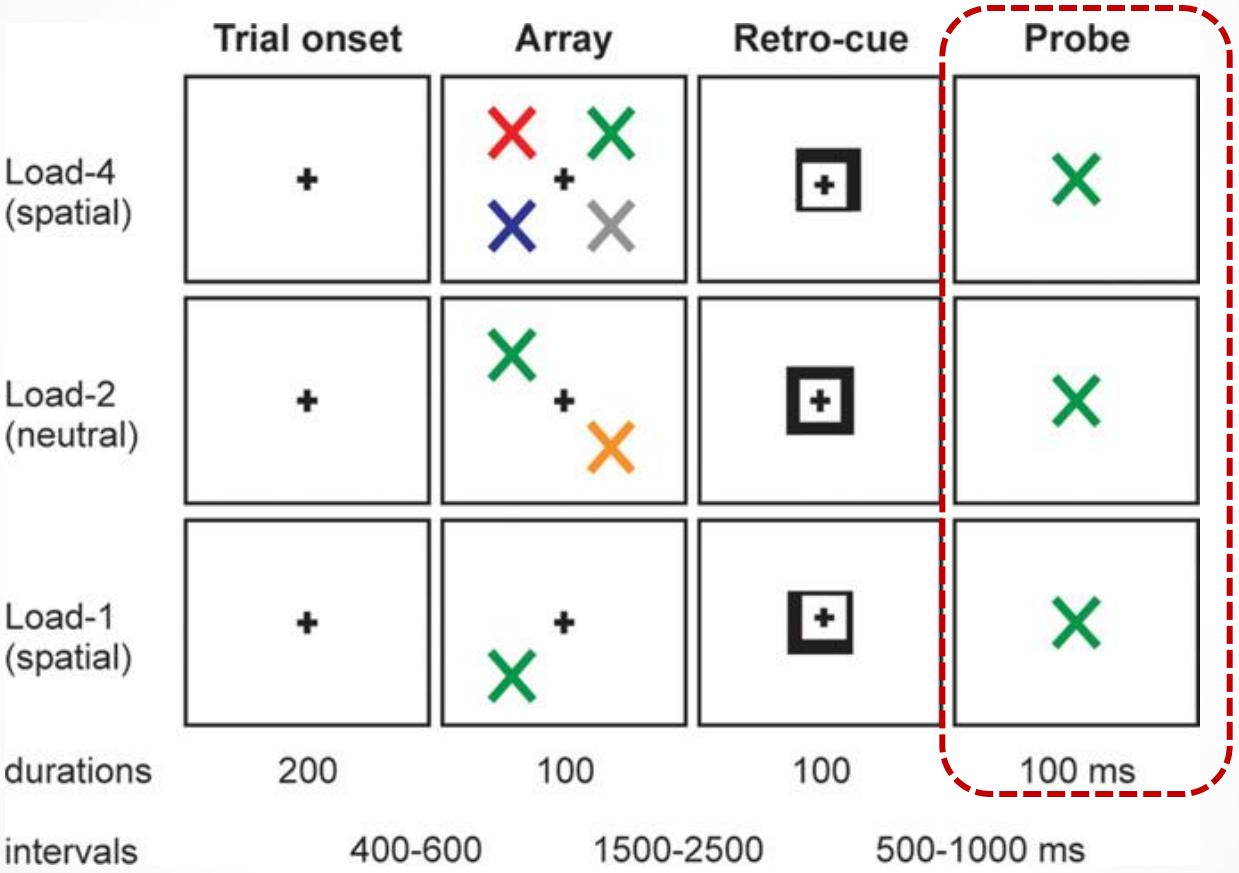
Kuo, Rao, Lepsien, Nobre, 2009, Journal of Neuroscience

ERP marker: N2pc (attentional selection)

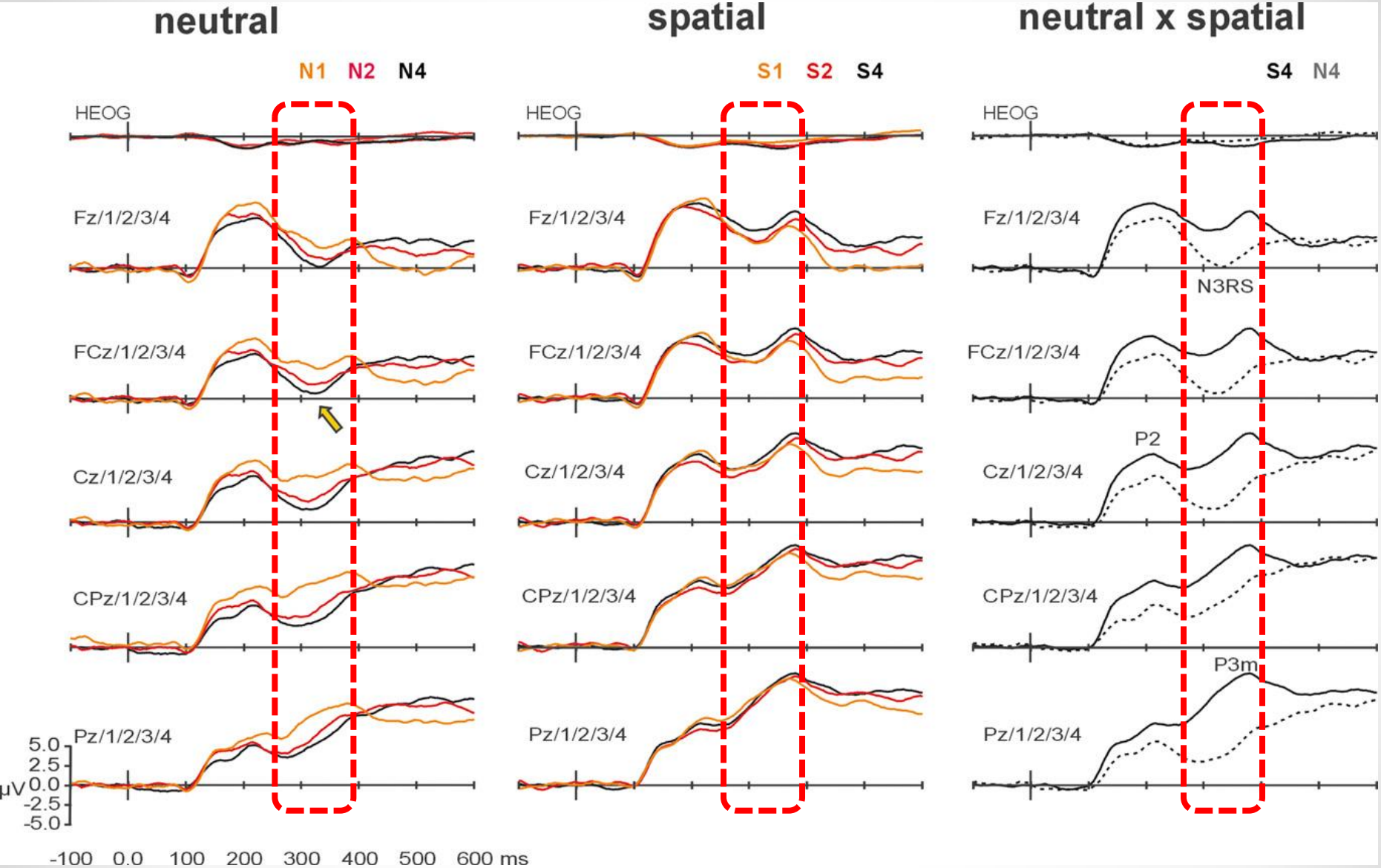


Kuo, Rao, Lepsien, Nobre, 2009, Journal of Neuroscience

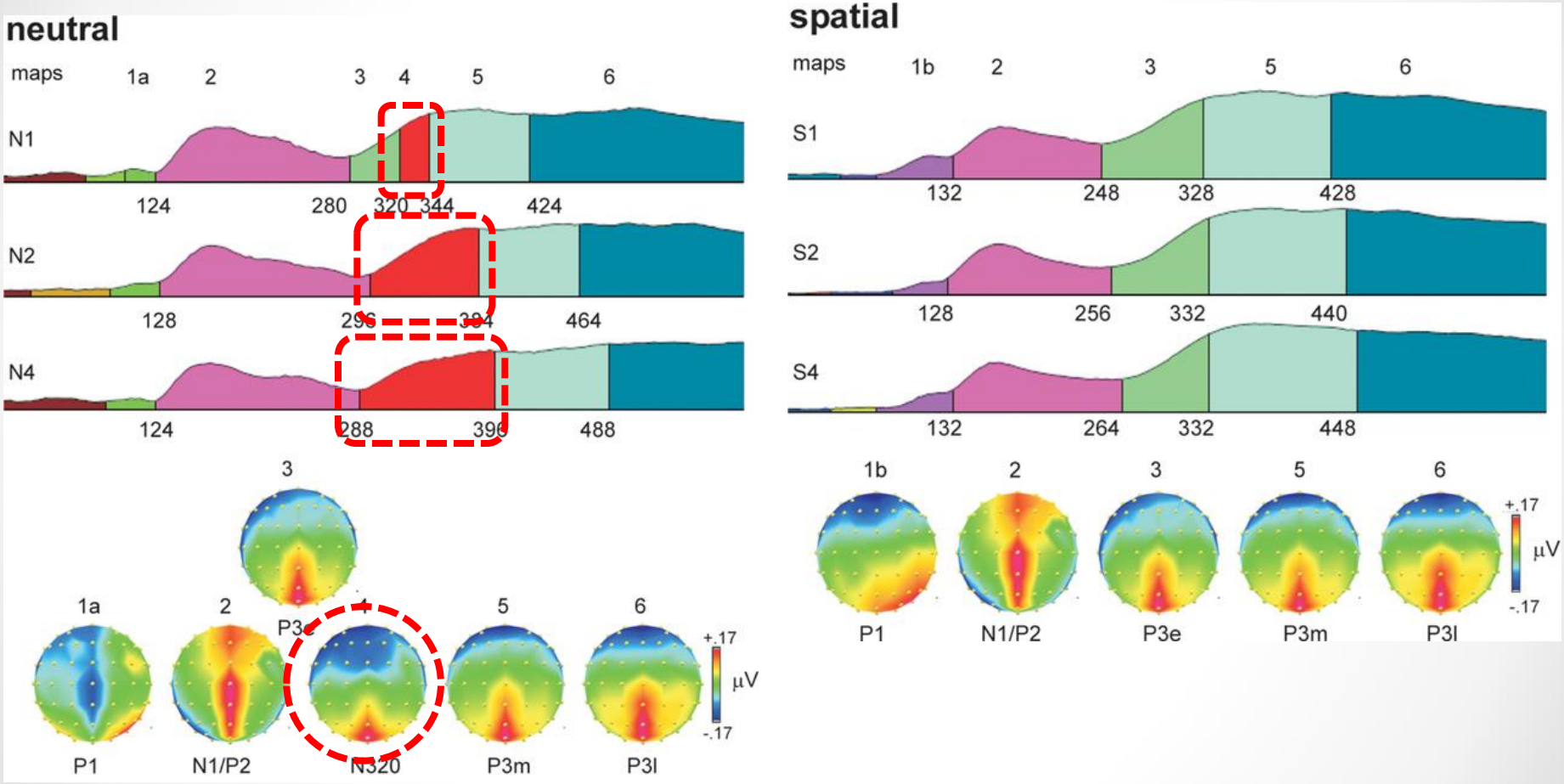
Retrospective search?



Nobre, Griffin, Rao, 2008, Frontiers in Human Neuroscience

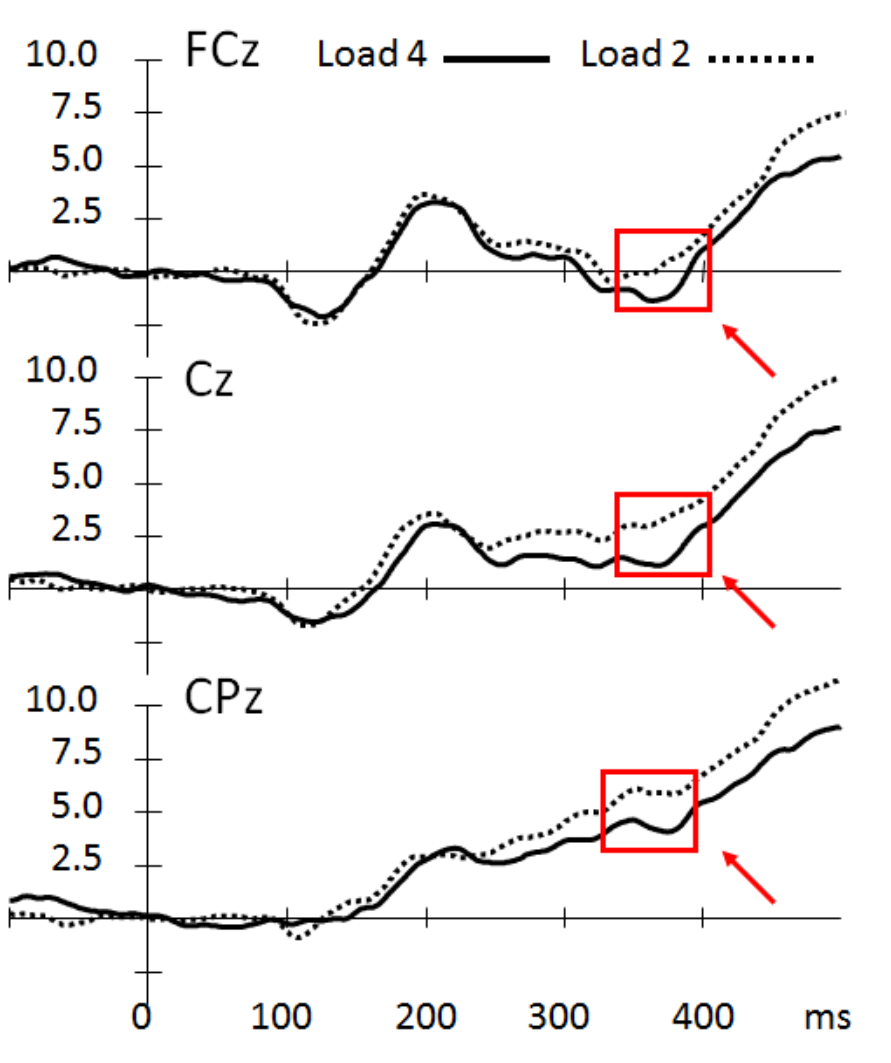


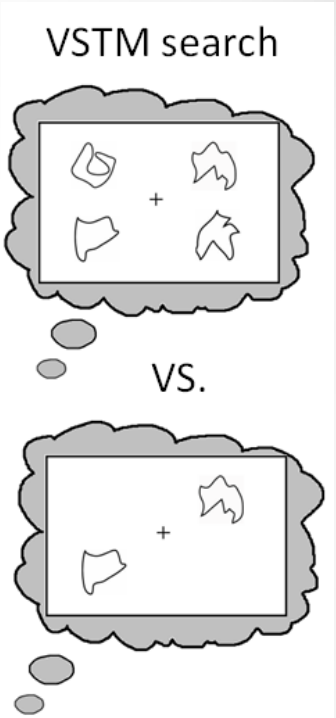
Nobre, Griffin, Rao, 2008, Frontiers in Human Neuroscience



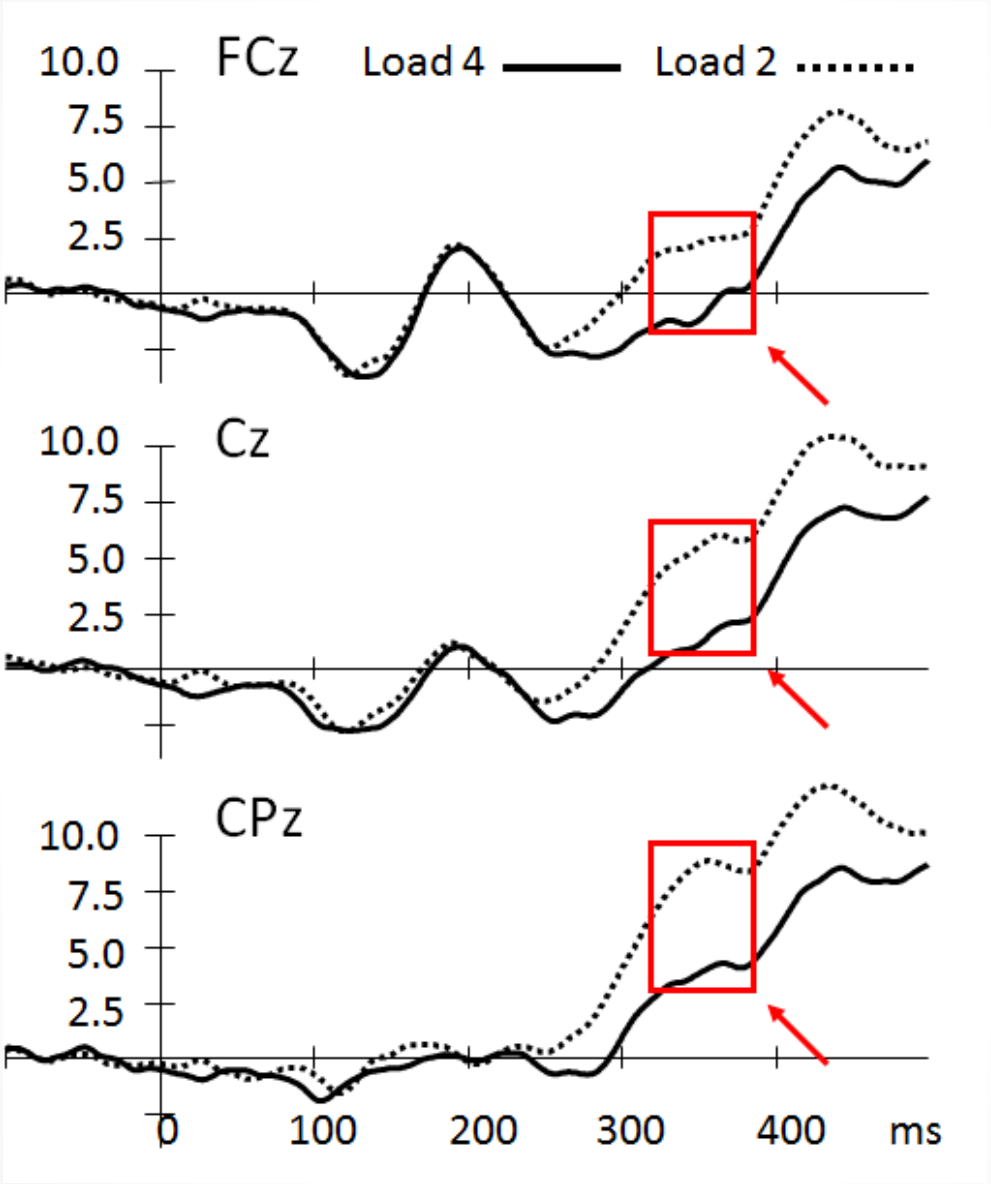
Nobre, Griffin, Rao, 2008, Frontiers in Human Neuroscience

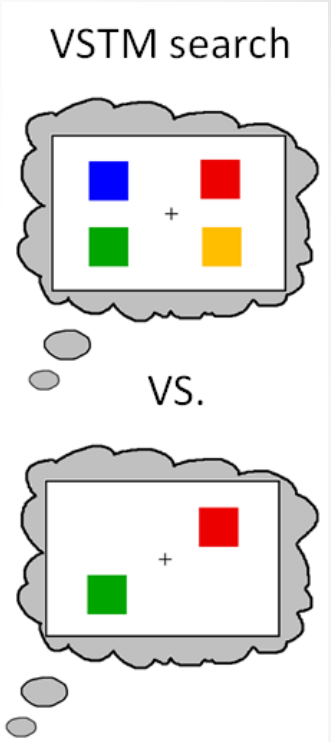
N3RetroSearch





Kuo, Rao, Lepsien, Nobre, 2009, Journal of Neuroscience



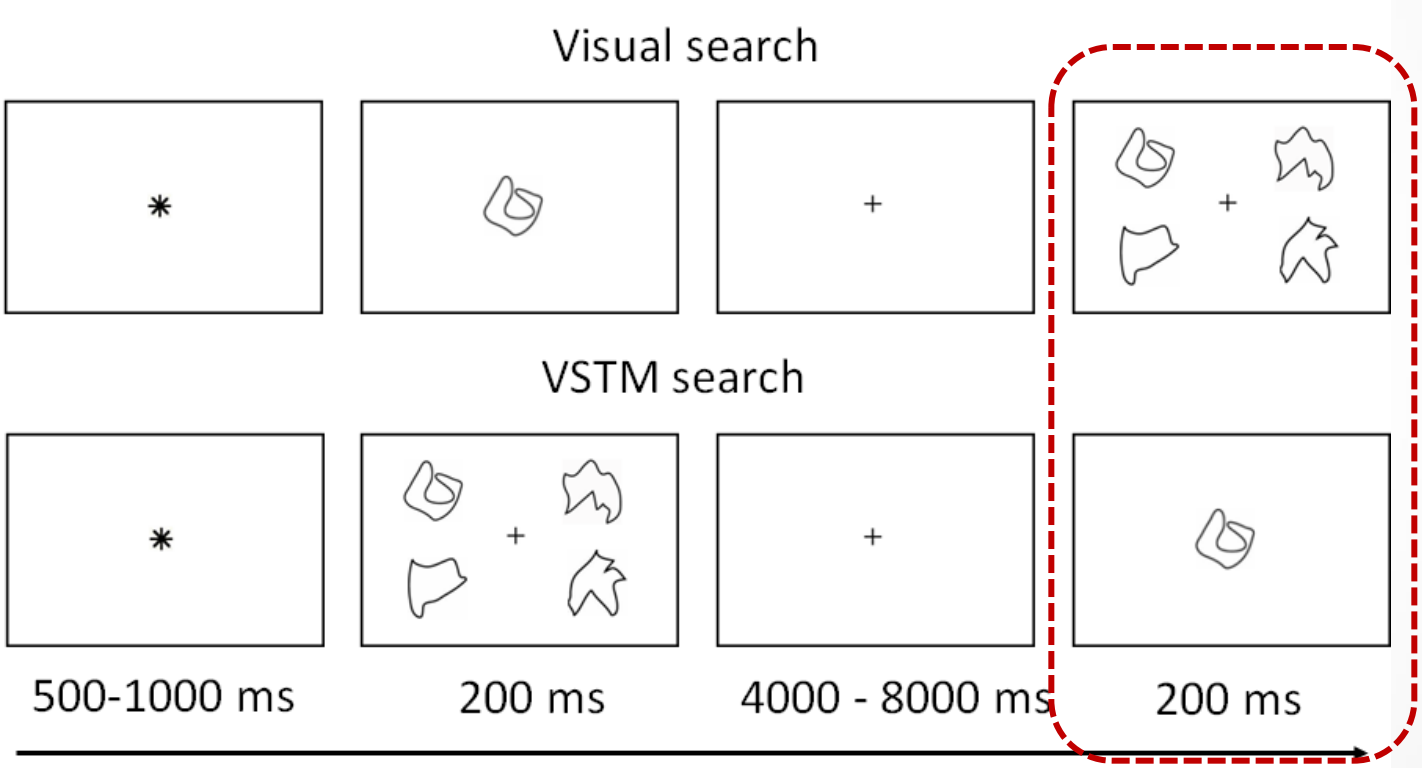


Kuo, Rao, Lepsien, Nobre, 2009, Journal of Neuroscience

Interim conclusions

- A similar (top-down) mechanism in both VSTM and perceptual domains
- N2pc is most likely to reflect the spatial layout of a putative target map
- N3RS reflects retrospective search

An fMRI study: Common and distinct neural sources for visual and VSTM search



ITI: 4000 - 8000 ms

Kuo & Nobre, in preparation

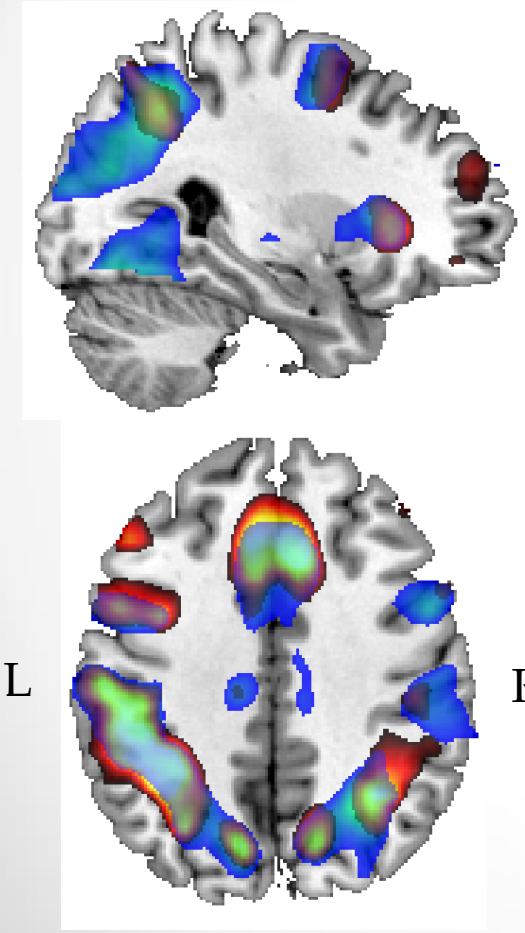
fMRI data analyses

- Standard group-level analysis
  - Normalised space
- Regions of interest (ROIs) analysis in early visual areas for each individual subject
- Functional connectivity analysis
  - Psychophysiological interaction (PPI)

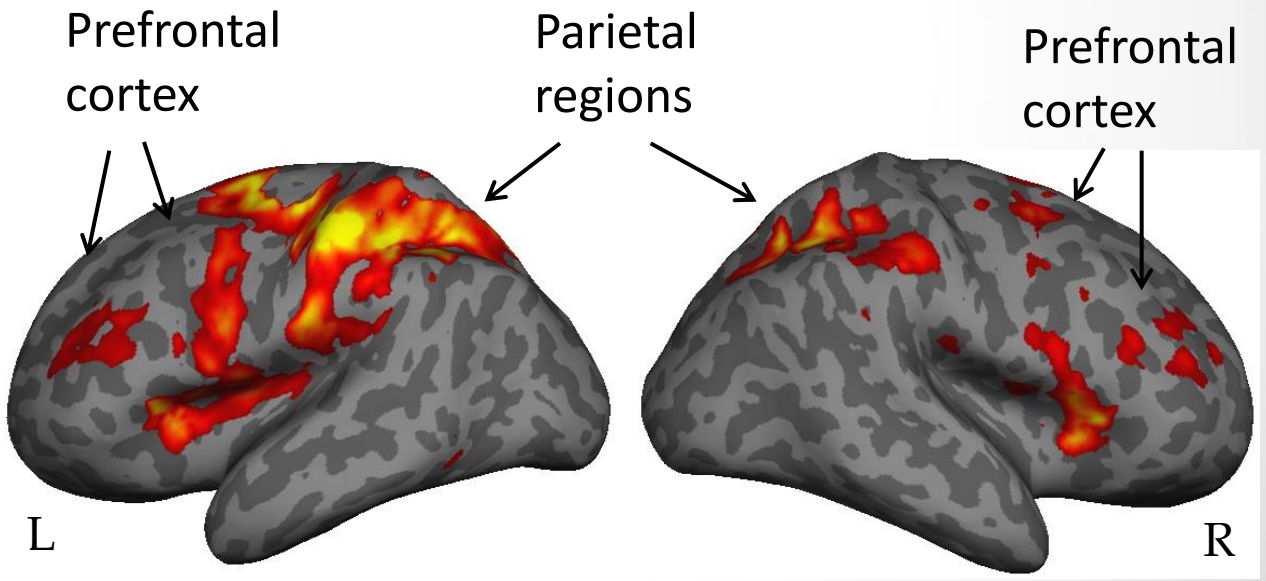
Common neural resources shared by selective attention for perceptual and VSTM goals

Visual search

VSTM search



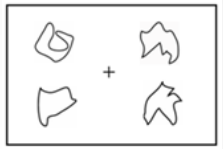
Conjunction analysis
(visual and VSTM search)

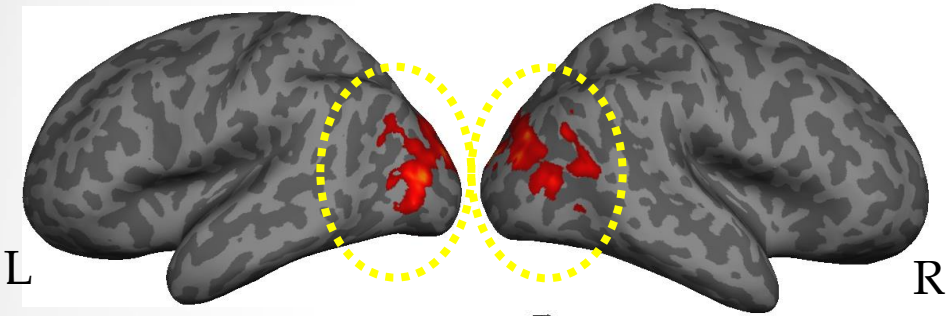


Visual search vs. VSTM search

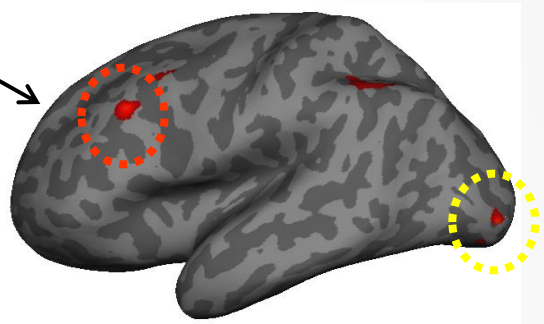
VS.

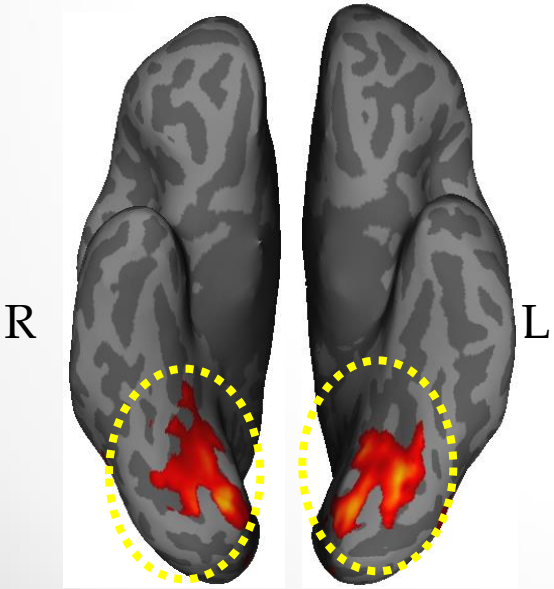
VS.

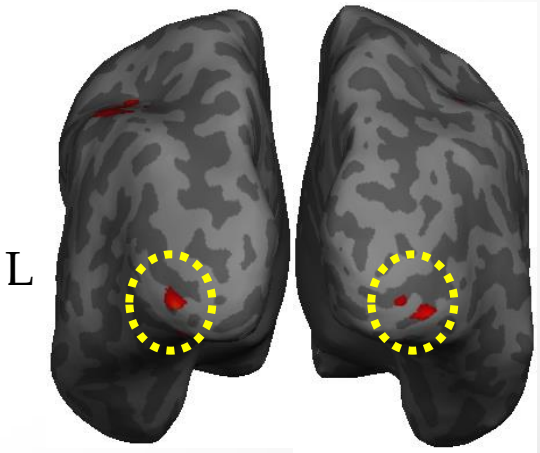




Prefrontal cortex

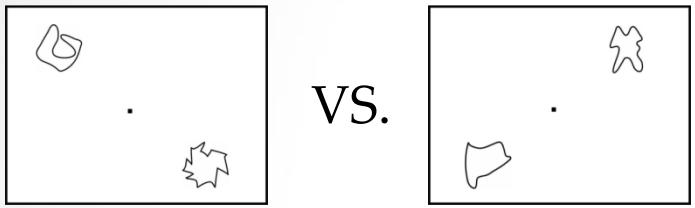


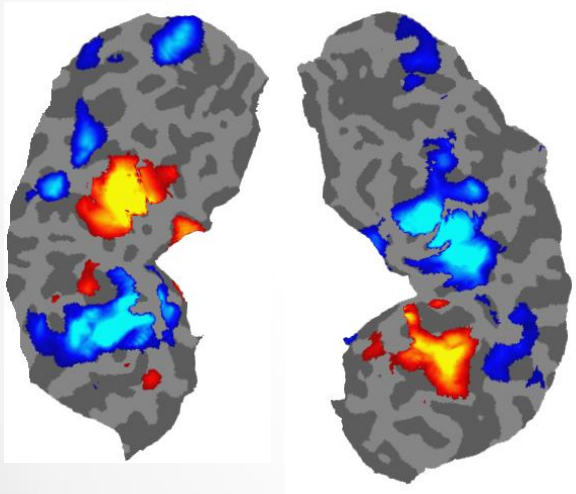


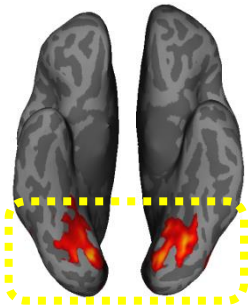


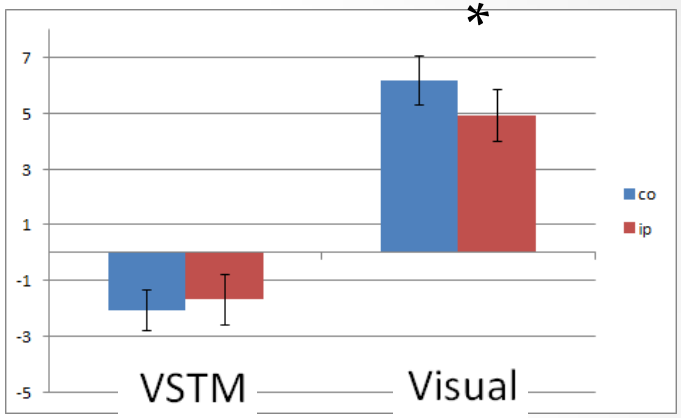
ROI analyses

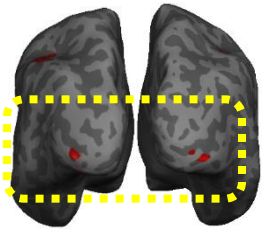
Visual localiser

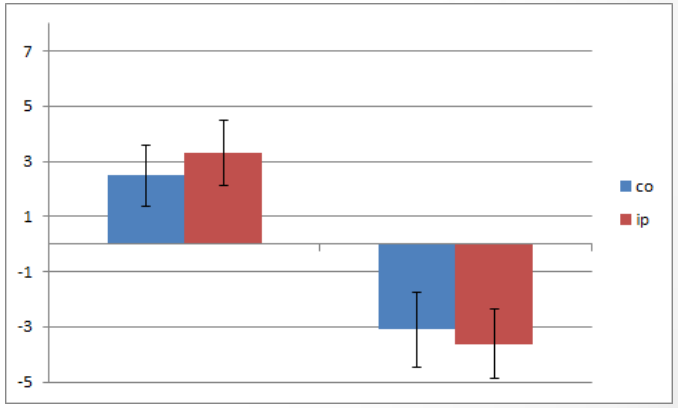




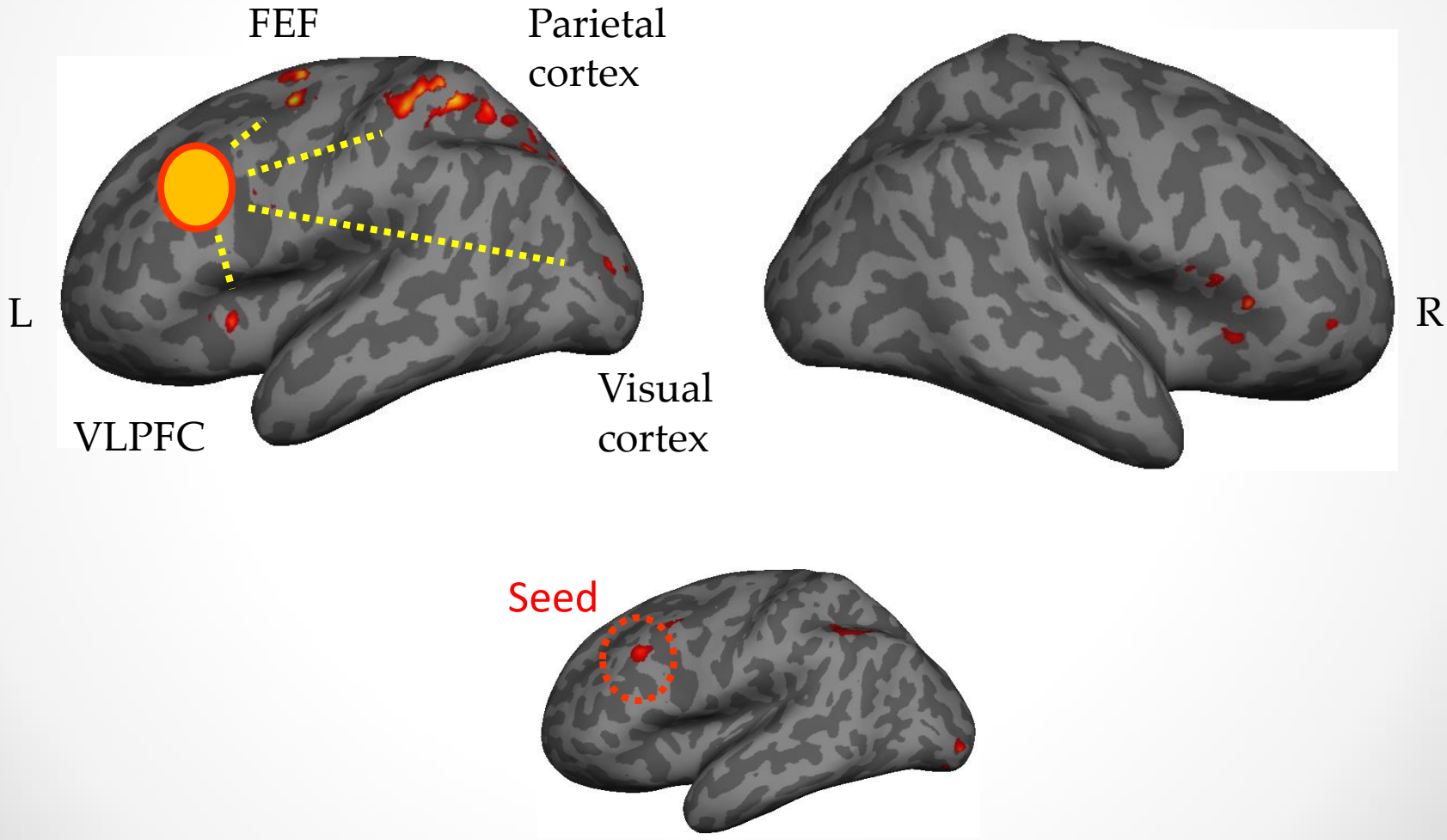








Functional connectivity of VSTM search vs. visual search

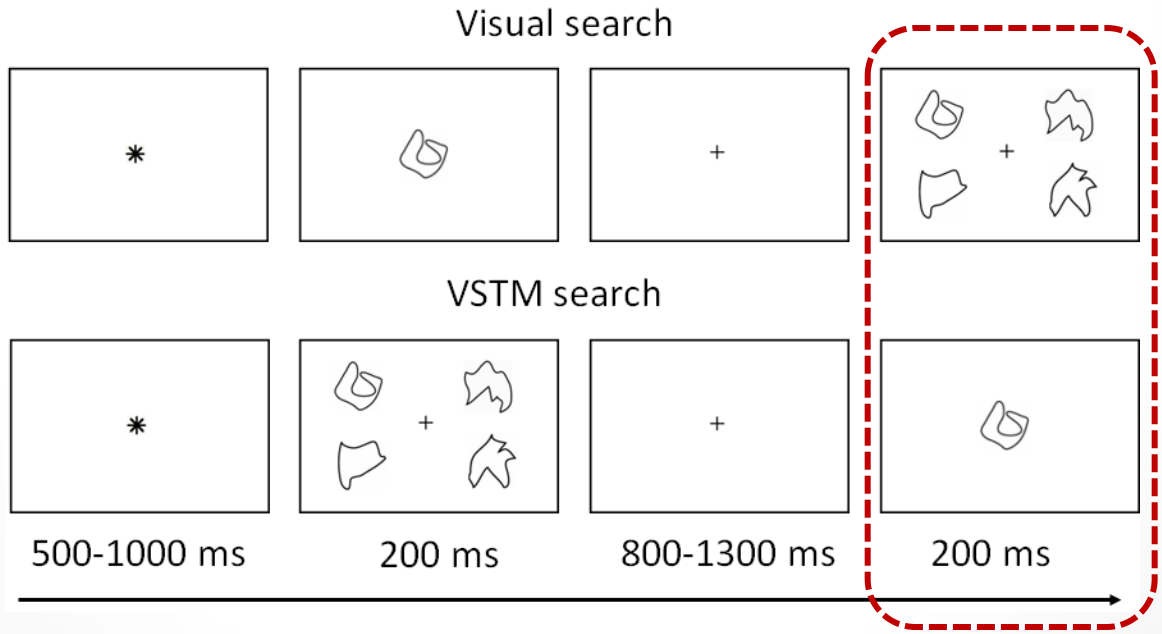


Interim conclusions

- Common top-down mechanisms for both VSTM and visual search
  - Prefrontal and parietal cortices
- Distinct neural sources
  - **Visual search**: top-down modulation of visual activity in a topographical fashion
  - **VSTM search**: stronger prefrontal-parietal inter-regional correlation

A MEG study: Neural sources of visual and VSTM search

Using MEG to test brain activity (ERMF and oscillation) associated with spatiotopic selection of targets in visual and VSTM representations



Kuo, Astle, Scerif, Woolrich, Nobre, in preparation

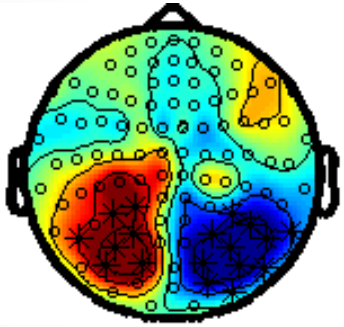
MEG data analyses

- Sensory space
  - Event-related magnetic fields (ERFs or ERMFs data)
  - Brain oscillations (time-frequency data)

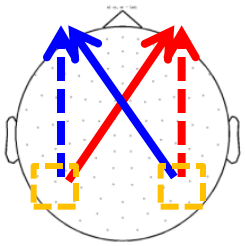
Sensor-space analysis: ERMF results

We found the mN2pc for both visual and VSTM search from ERMF recording.

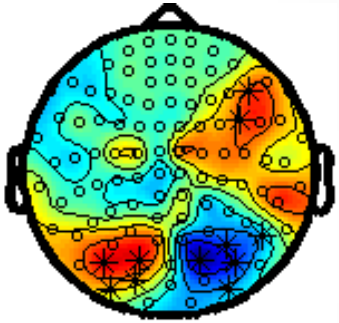
Visual search (left vs. right)



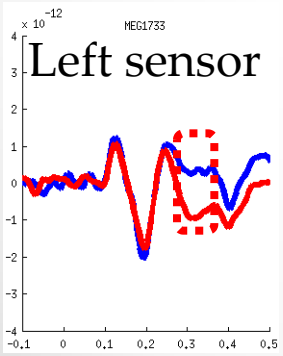
200 – 360 ms

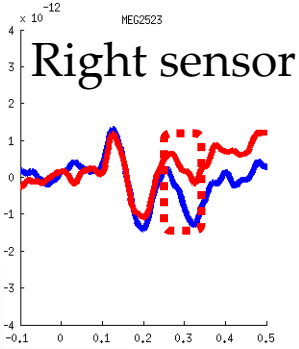


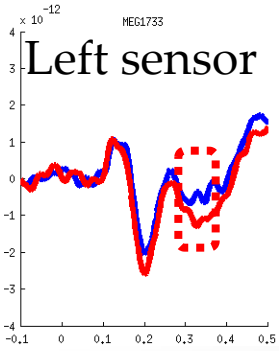
VSTM search (left vs. right)

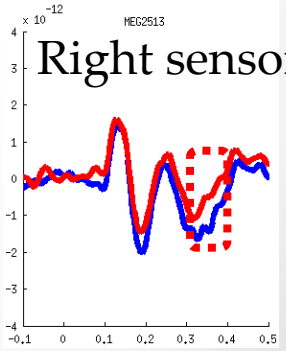


280 – 360 ms









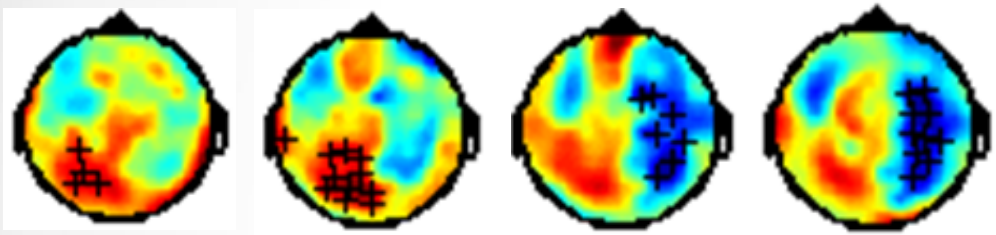
Search from left hemifield

Search from right hemifield

Sensor-space analysis: TF results

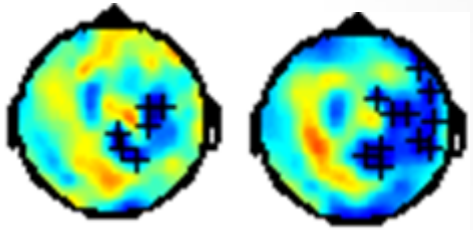
We found significant oscillatory modulation for both visual and VSTM search during alpha band (8 – 12 Hz).

Visual search (left vs. right)

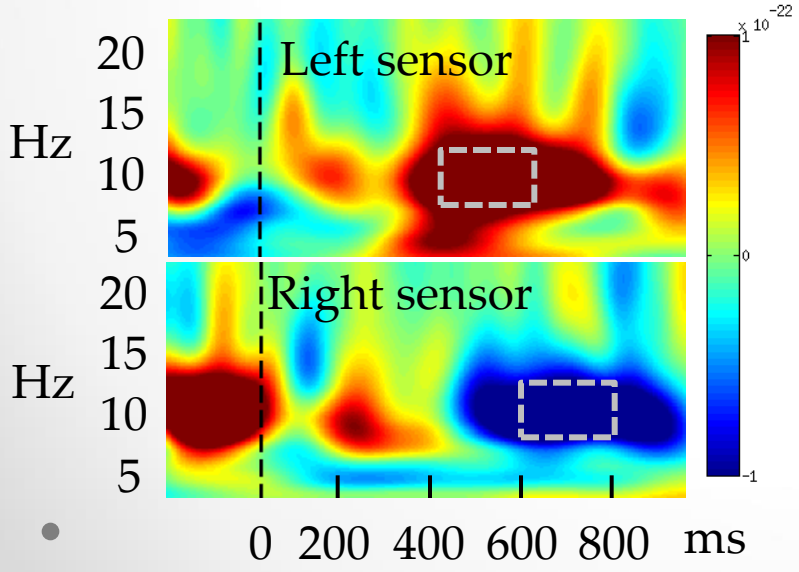


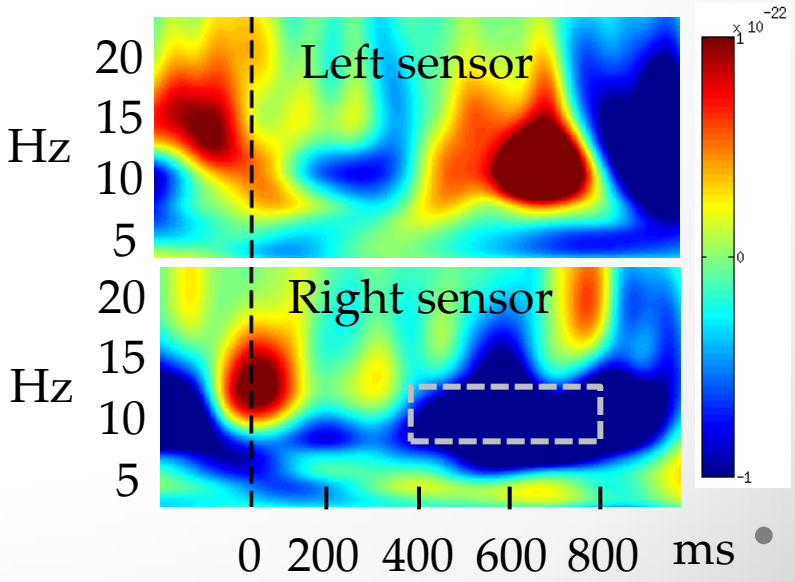
400- 500 500- 600 600- 700 700- 800

VSTM search (left vs. right)



400- 500 500- 600



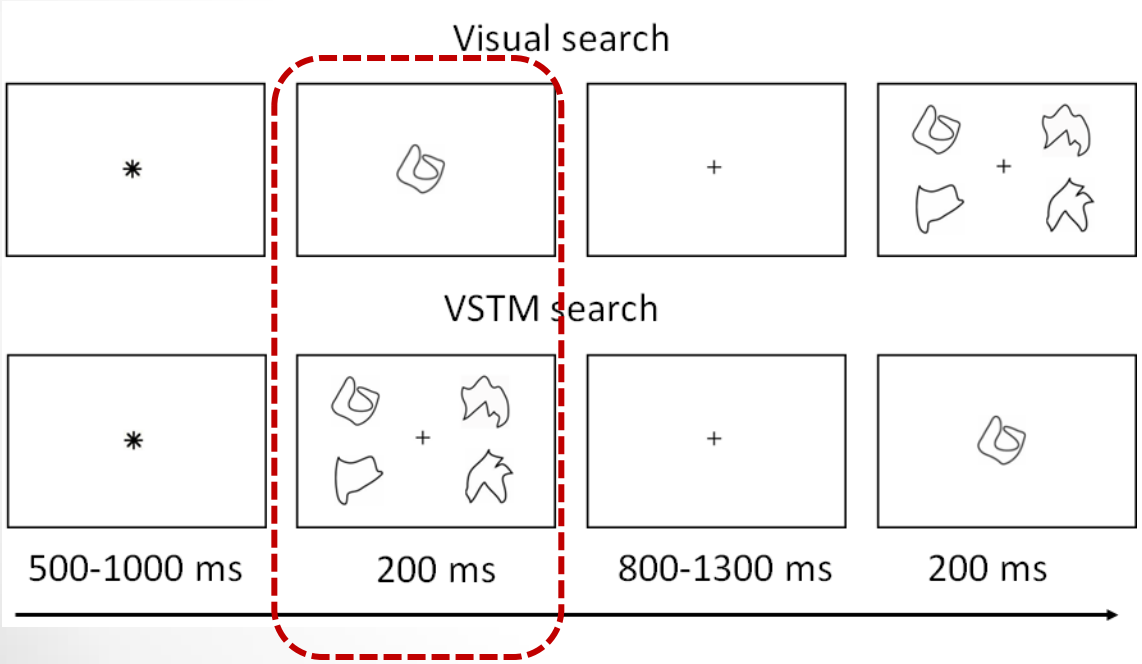


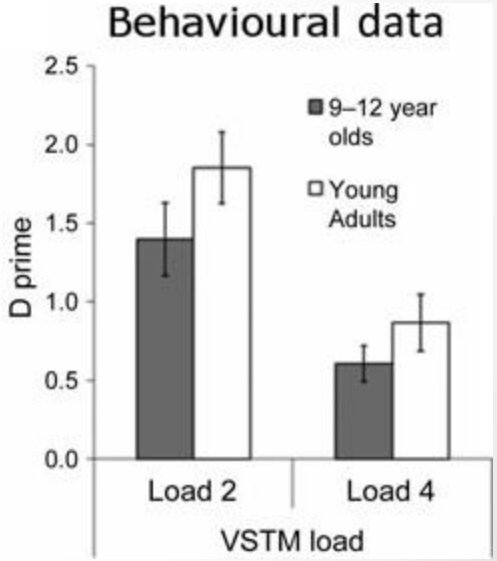
Interim conclusions

- Top-down biasing in VSTM may share properties with spatially specific attentional mechanisms that bias perceptual processing
  - ERMF (mN2pc)
  - Oscillation (alpha power)

A MEG study: Neural correlates of VSTM for children's variability

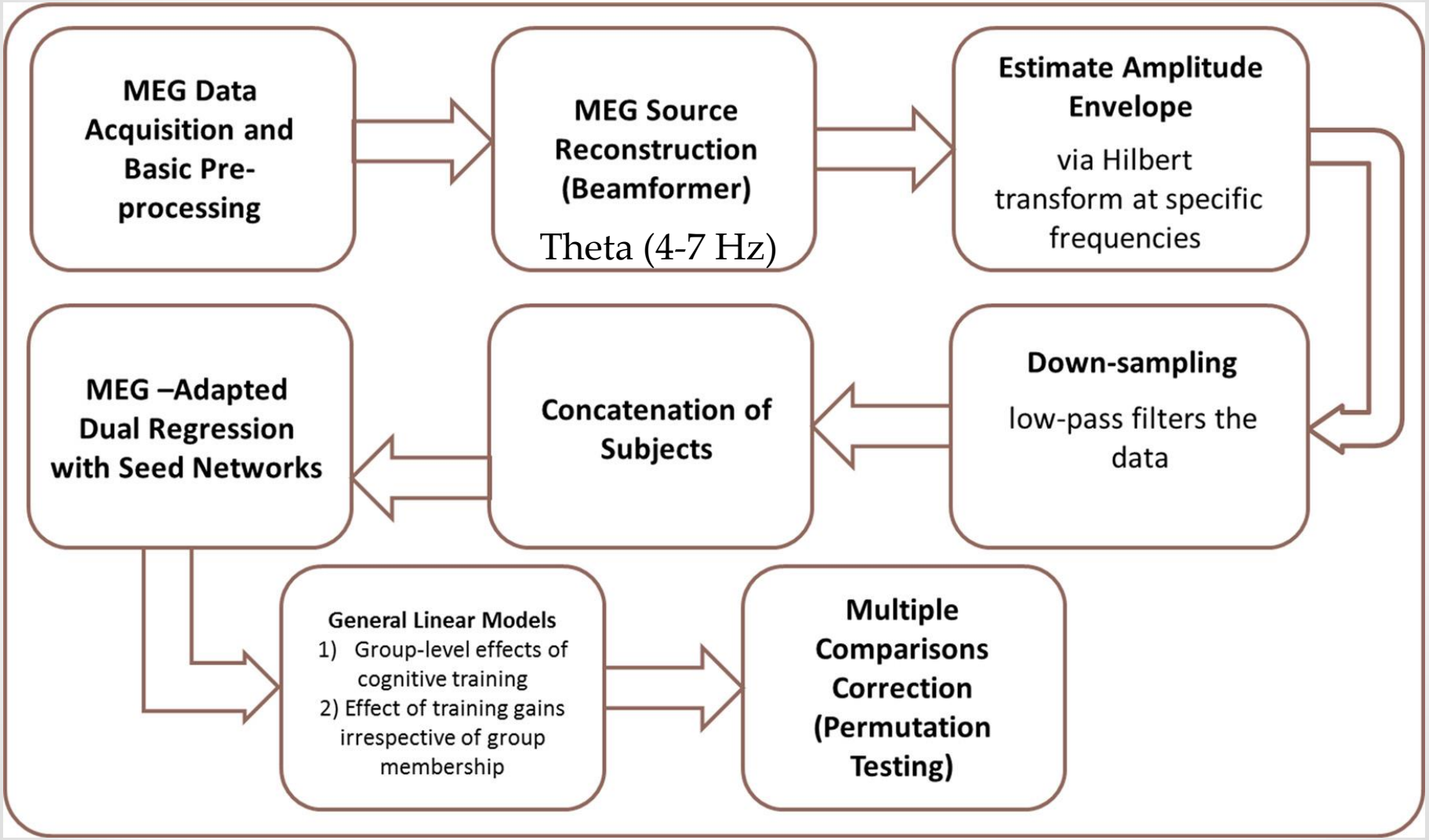
To test whether dynamic changes in fronto-parietal activity could account for children's variability in tests of VSTM using MEG



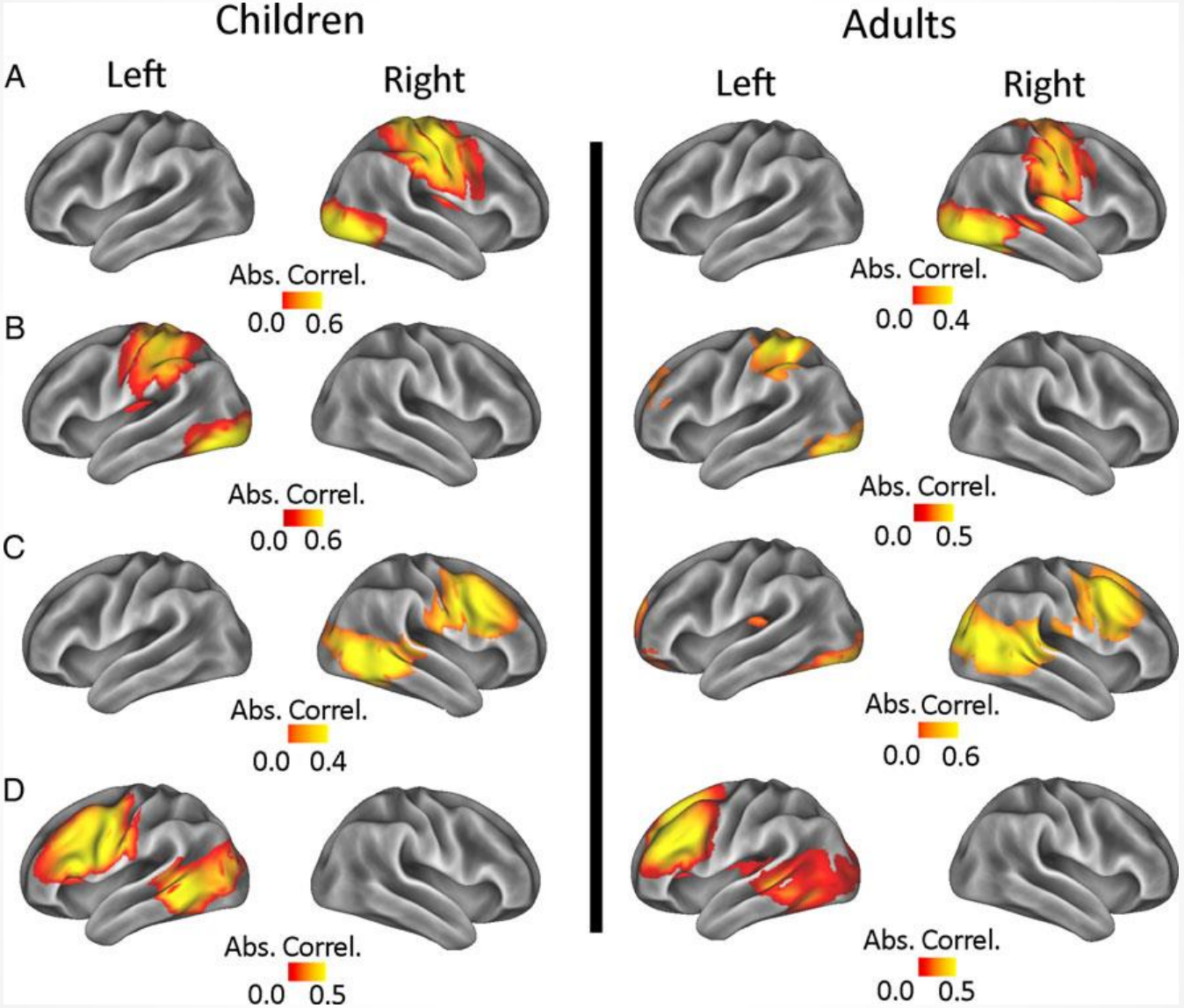


Astle, Luckhoo, Woolrich, Kuo, Nobre, Scerif, in press (Cerebral Cortex)

MEG data analyses

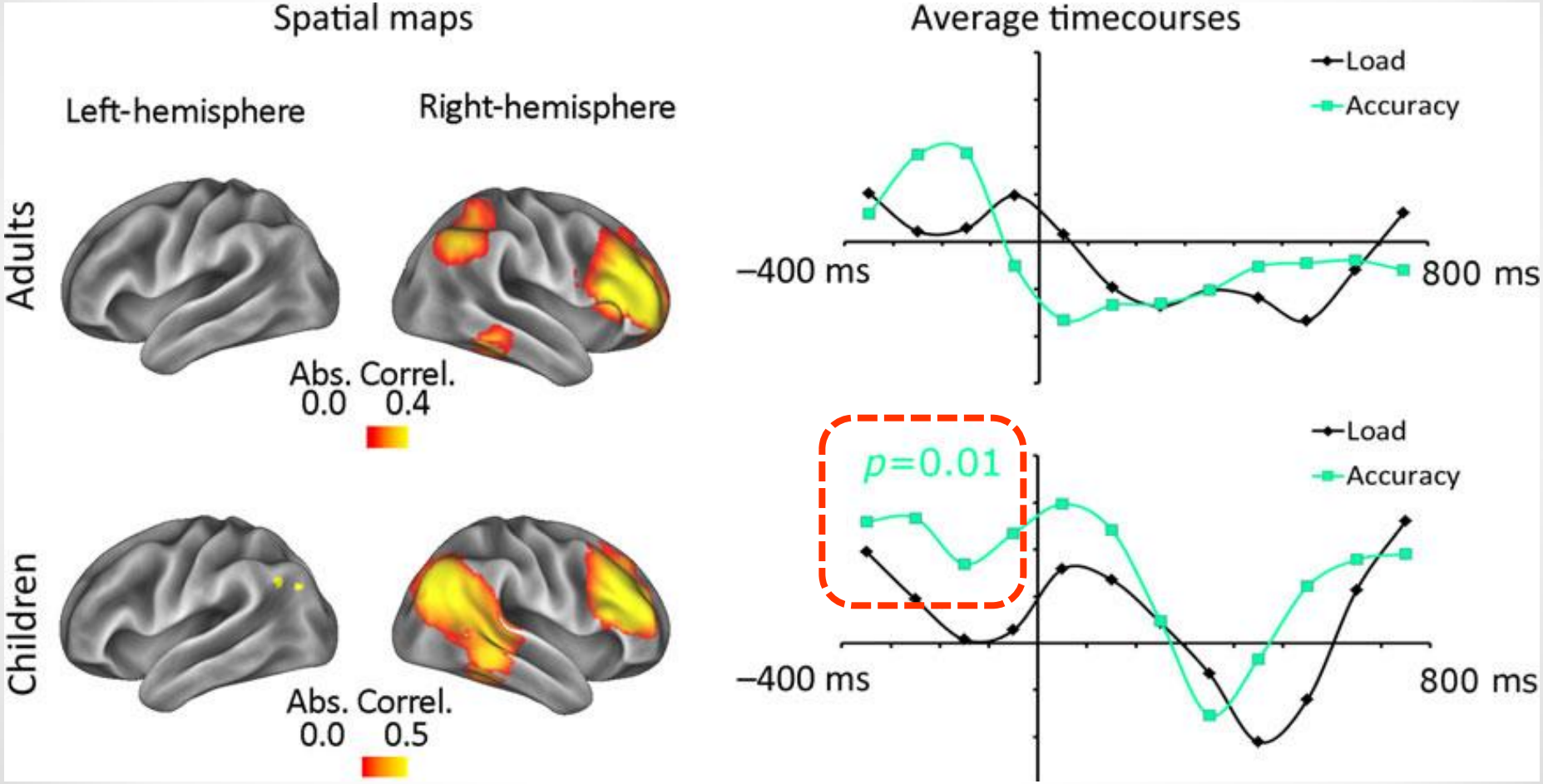


Independent Component Analysis (ICA)



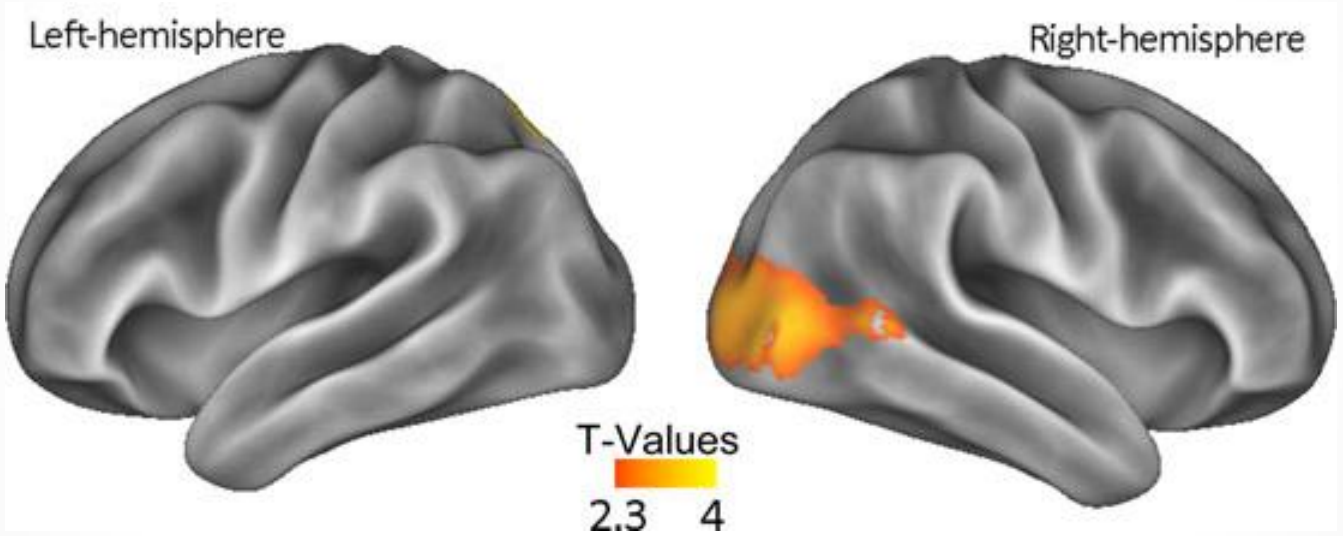
Astle, Luckhoo, Woolrich, Kuo, Nobre, Scerif, in press (Cerebral Cortex)

A close link between fronto-parietal network and VSTM performance



Astle, Luckhoo, Woolrich, Kuo, Nobre, Scerif, in press (Cerebral Cortex)

The post-stimulus consequences of pre-stimulus fronto-parietal network activity on the children's data



Astle, Luckhoo, Woolrich, Kuo, Nobre, Scerif, in press (Cerebral Cortex)

Interim conclusions

- The dynamic fluctuations of activity in the top-down fronto-parietal network regulate the state of visual excitability
  - In preparation for memory encoding
  - In support of VSTM performance

Summary of findings

- Whether top-down modulation serve as a common framework for selective attention processes in the service of both perception and VSTM?
  - **YES ☑**
    - **EEG ERP**: N2pc
    - **fMRI**: common frontal and parietal activation
    - **MEG EMRF**: mN2pc
    - **MEG TF**: alpha oscillation
  - **HOW:**
    - **Via top-down biasing** in favour of the relevant information