Spatial Attention Tunes Temporal Processing in Early Visual Cortex by Speeding and Slowing Alpha Oscillations

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Presented by: Sai Zhang

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Outline

Introduction

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

How spatial attention impacts the neural processing of dynamic visual stimuli

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See Nobre and Van Ede, 2018 for a review

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2 **opposing** functions in the perception of dynamic visual stimuli

- **integration:** to form unitary percepts and identify consistencies
- **segragation:** to parse separate objects and identify changes

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Integration	**Separation**

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- Sharp, Melcher, et al. (2018)

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How can spatial attention achieve this?

Hypothesis

Hypothesis: The impact of **spatial attention on temporal processing** is instantiated in part through effects on α **frequency** in **retinotopic visual cortex**.

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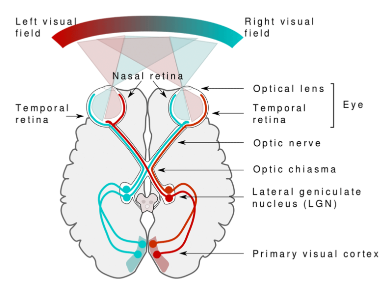

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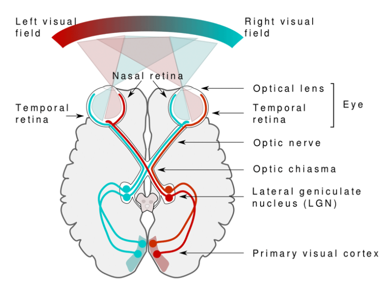

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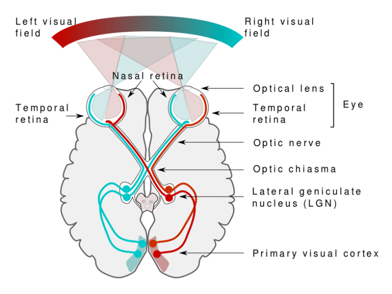

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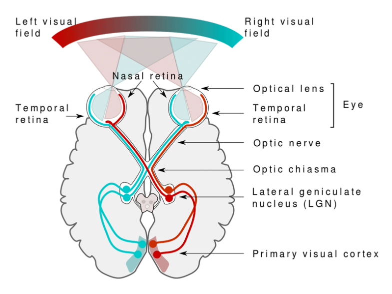

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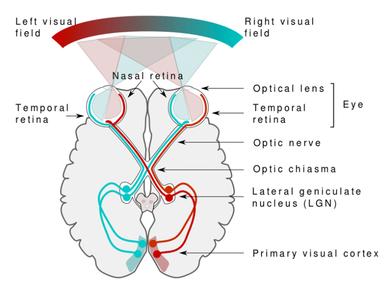

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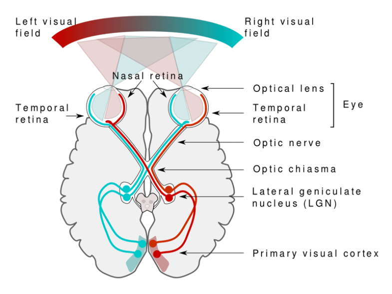

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- α rate reflects **temporal** expectation

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- manipulation of average α rate has an impact on **stretching/shrinking** of the perceptual window

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  See Cecere et al. (2015), Minami and Amano (2017), Mioni et al. (2020), and Ronconi et al. (2018)
- average α rate (immediately before stimuli) becomes **faster** for segregation; **slower** for integration

  See Wutz et al. (2018)

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- **spatial**: cue location $\Rightarrow$ *corresponding* location in retinotopic visual cortex
- **temporal**: segragation/integration $\Rightarrow$ $\alpha-$frequency faster or slower

Prediction

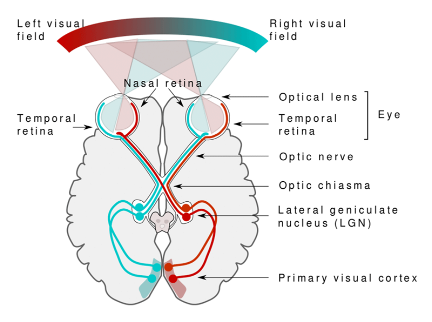

Figure 1: Retinotopic structure

	contralateral	ipsilateral
segragation	faster	*slower*
Integration	slower	*faster*

Use magnetoencephalogram (MEG) recording for analysis

Materials and Methods

Trial Structure

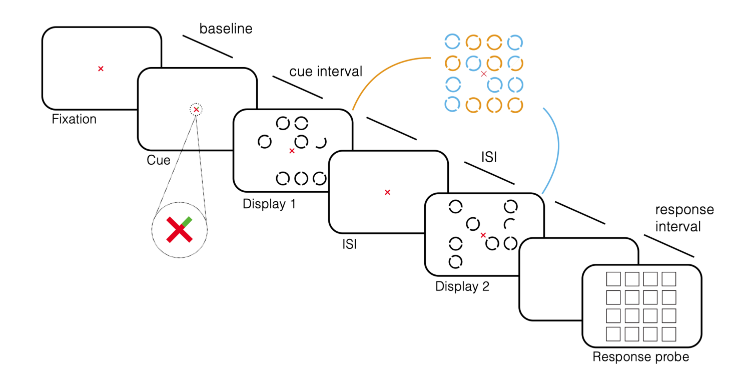

Figure 2: Trial Structure

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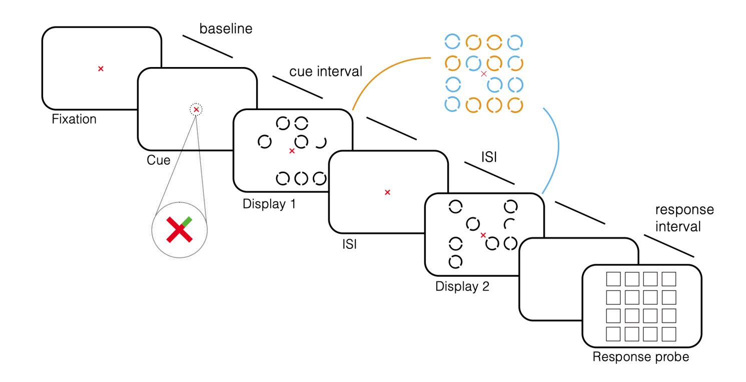

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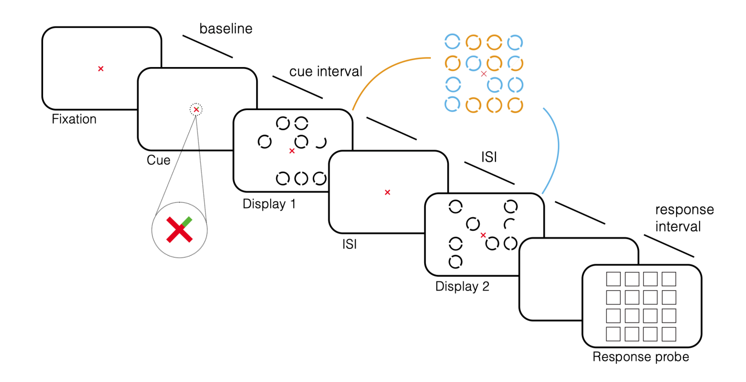
Timeline:

- pre-cue: 1000-1500ms
- cue interval: 850-1350ms (randomized)
- display: 16.67ms
- ISI: 48.3ms
- response delay: 400ms

Trial Structure



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visual cue: **red** cross

- 75% (T): one of the arms turn **green** (75% valid)
- 25% (C): neutral cue

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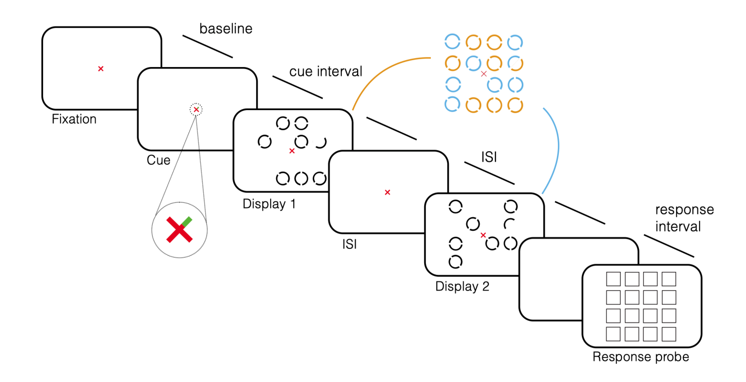

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2 displays: complementary, non-overlapping

- half-circle: the 2 displays **complete** each other
- empty: one left **empty** in both

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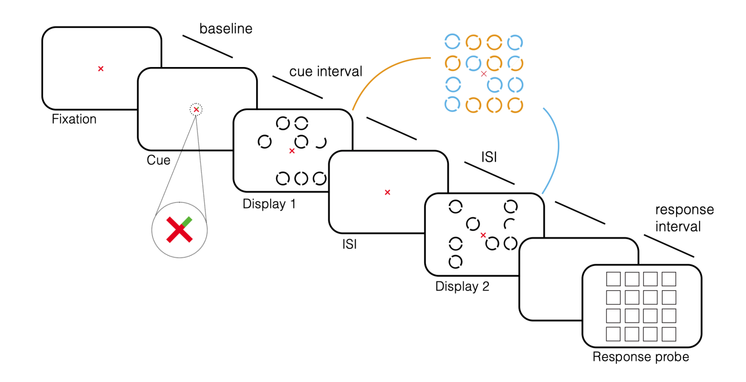

Figure 2: Trial Structure

task: moving a highlighted square

- **segregation**: targeting the half circle
- **integration**: targeting the empty spot

Measures

Eye tracking

MEG recording

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- sampling rate: 1kHz
- rejection:
  - saccades: 7±7% trials
  - blinks: 3±4% trials

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MEG recording

- estimate instantaneous $\alpha-$frequency: 7- to 14-Hz frequency band
- rejection
  - nonbiological noise: 10±1 channels

Analysis

Source analysis

Numerical analysis

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- combine head digitization data with anatomic MRI data
- regions of interest:
  - parietal cortex
  - occipital cortex

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Numerical analysis

- method: 2-way repeated ANOVA
- noise of raw estimates of α frequency: center on results following a **neutral-cue**
  - within each of the integration/segragation conditions separately

Other technical details

- Participants: 29 (**normal/corrected-to-normal** vision; age 24±2.7 years; 11 male, 18 female)

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- Base for numerical analysis: a shift in the **neutral-cue** baseline emerges equally in **ipsilateral** and **contralateral** signals

Results

Summary of 3 dimensions

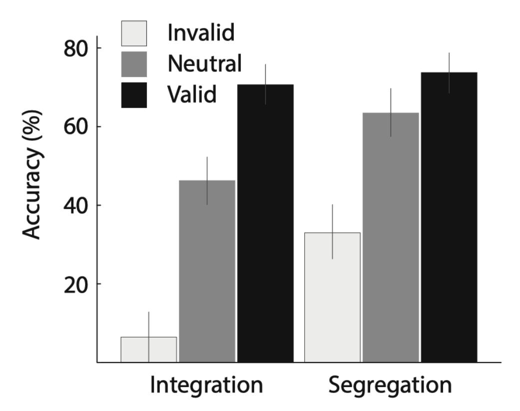
contralateral

	segregation	integration
valid		
neutral		
invalid		

ipsilateral

	segregation	integration
valid		
neutral		
invalid		

Result 1: Accuracy of Cues



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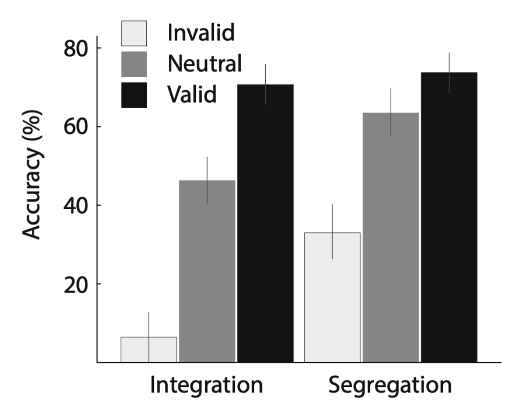

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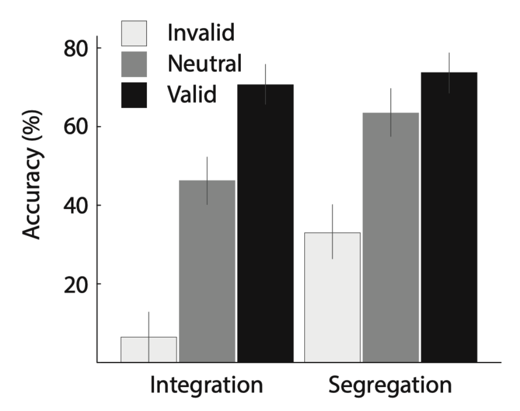

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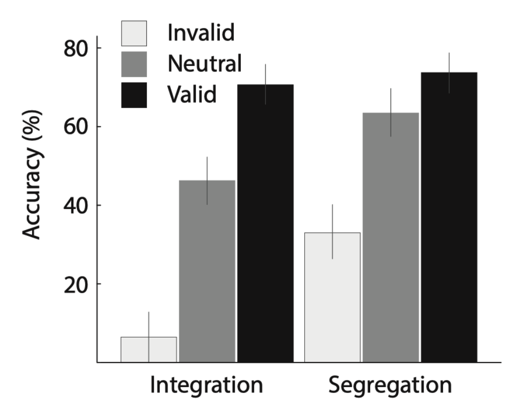
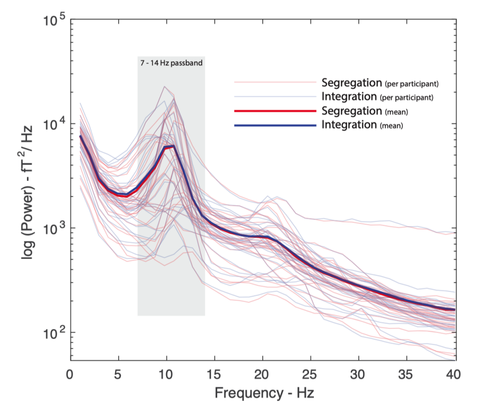


- valid cues $(+)$, invalid cues $(-)$
- greater effect of cues in the segregation task
- supported by eye-tracking:
  - visual angle shifts towards the cue direction
  - no significant differences between integration and segragation

Result 2: Suitability of the Data to Measure α Frequency



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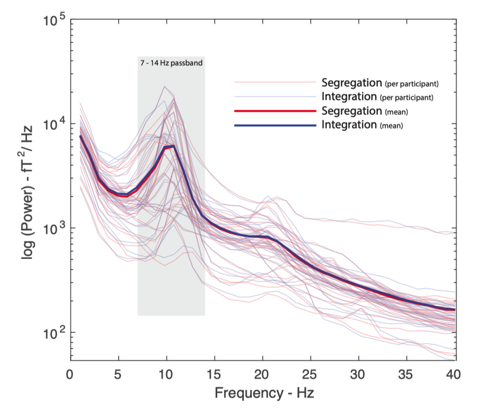

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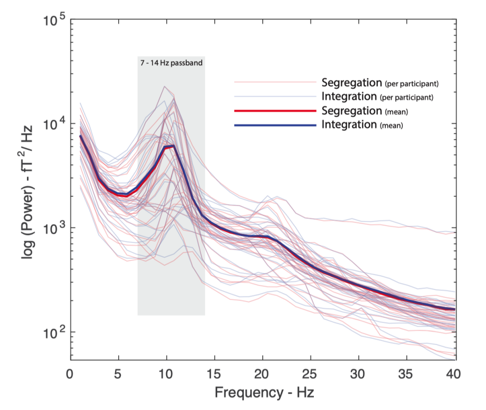
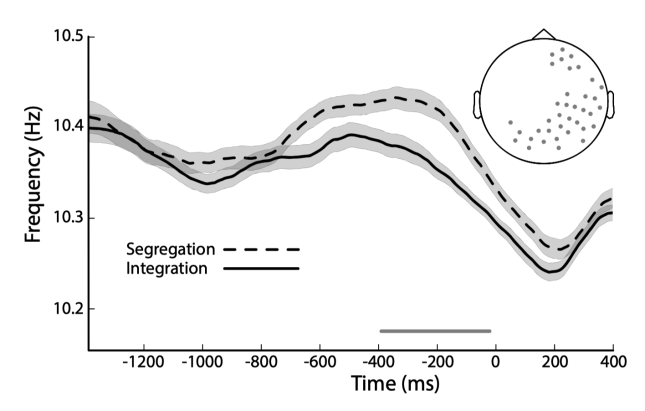


- the analytic passband (7-14Hz) contains **the peak** (In fact, the entire α bump for all participants)
- No significant difference in **power** or slope of the **1/f structure** between segregation and integration

Result 3: α Rate Is Higher for Segregation Tasks



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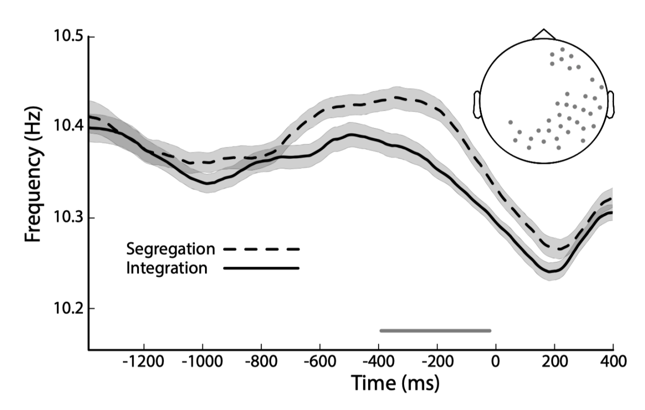

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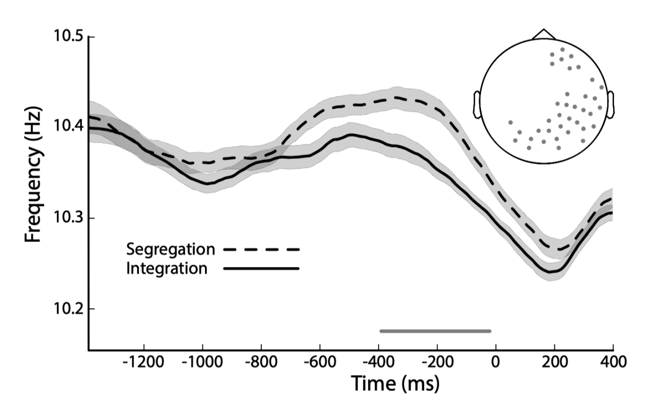
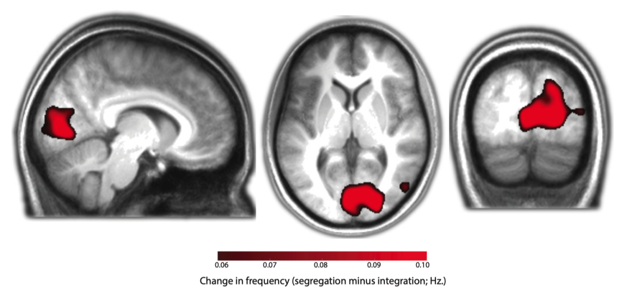


- significantly higher α rate for **segregation** before 1st display (t=0: the 1st display)
- results are from instantaneous frequency analysis of **neutral-cue** trails

Result 3: α Rate Is Higher for Segregation Tasks, Source Analysis



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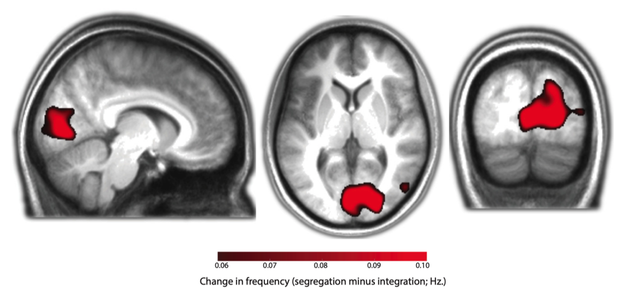

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- right lateralized frontal cortex

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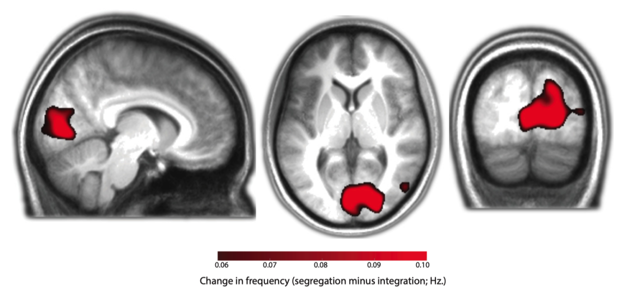

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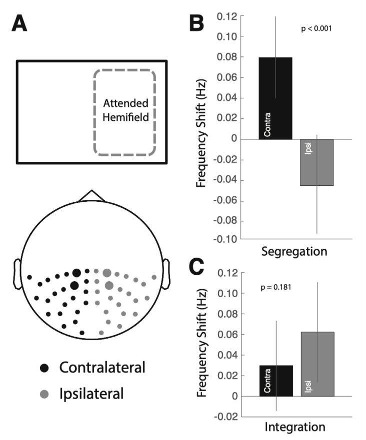
replicate the observations of Wutz et al. (2018)

Main Result: Lateral Analysis of α Frequency



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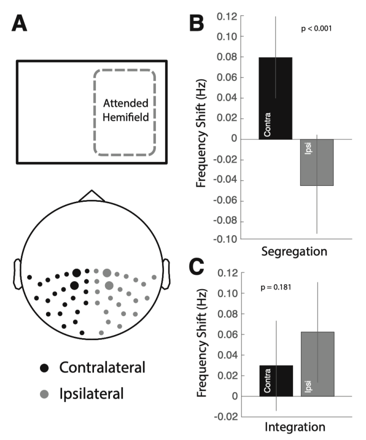

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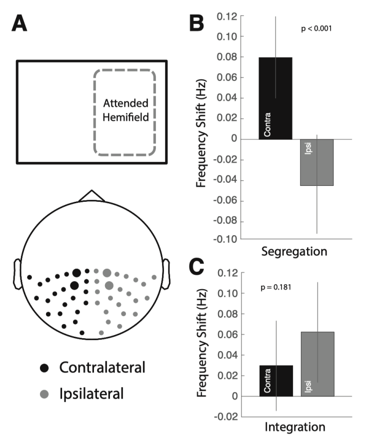

- base: any retinotopic effect **must** emerge over **posterior cortex**
- results:
  - segregation (faster α rate): contralateral **faster** than ipsilateral
  - integration (slower α rate): contralateral **slower** than ipsilateral

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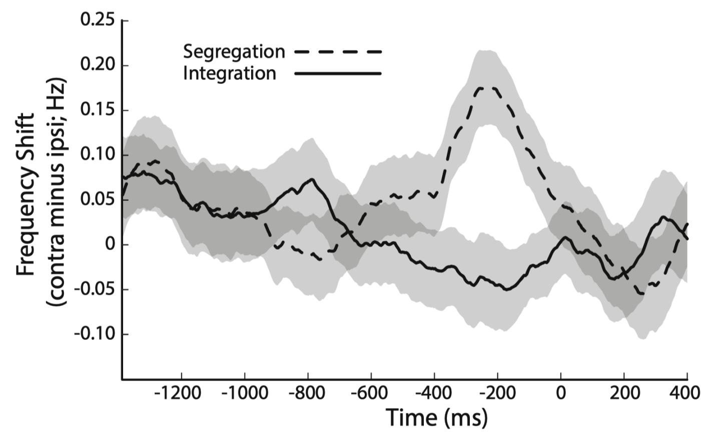

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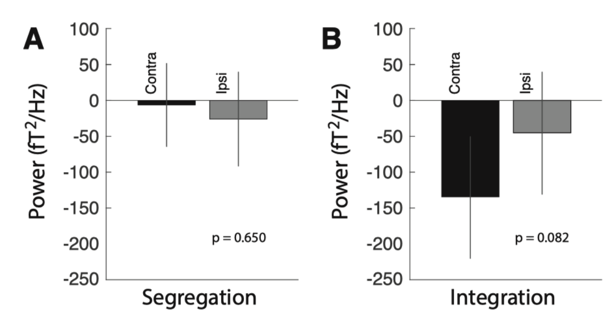

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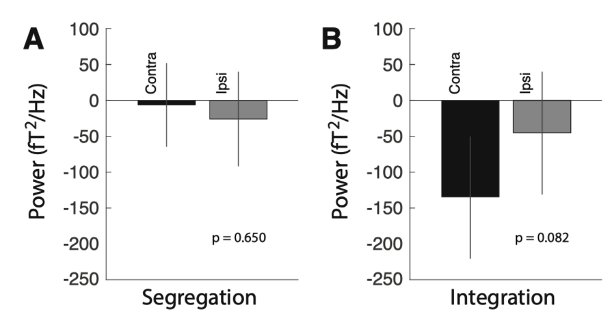

- no significant differences in the lateral effect between segregation and integration
- no significant decrease in α power in contralateral hemisphere

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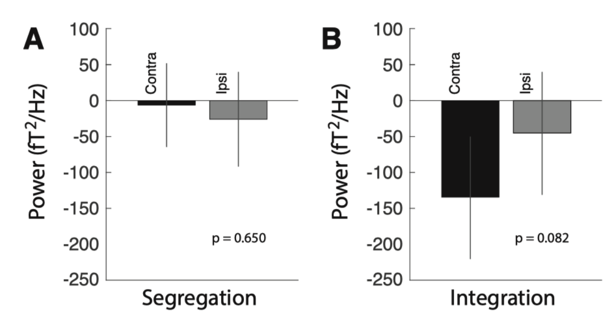

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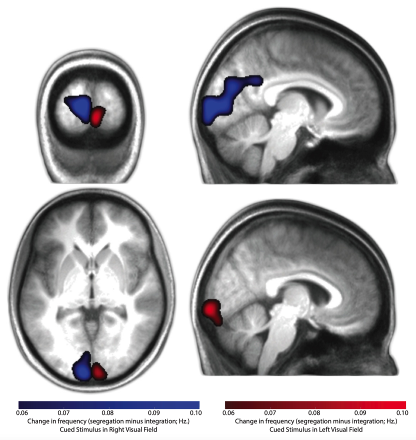
replicate the observations of Capilla et al. (2014) that the decrease in α power is sourced to **ventrolateral visual cortex**

Main Result: Lateral Analysis of α Frequency, Source Analysis



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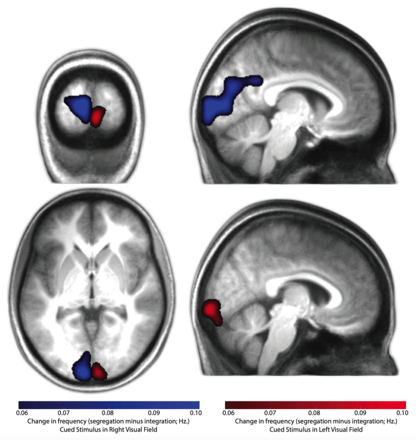

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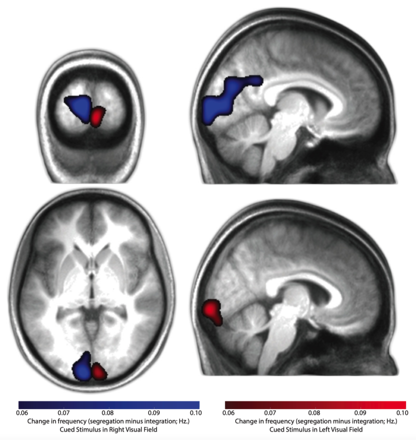

- both clusters are located in **early visual areas** at the **occipital** pole
- note:
  - **blue**: stimuli in **right** visual field
  - **red**: stimuli in **left** visual field

Discussion

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  - **increases** in speed to **segregate** sequential visual stimuli
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- integration **in a location** $\Rightarrow$ relatively slower **contralateral** α

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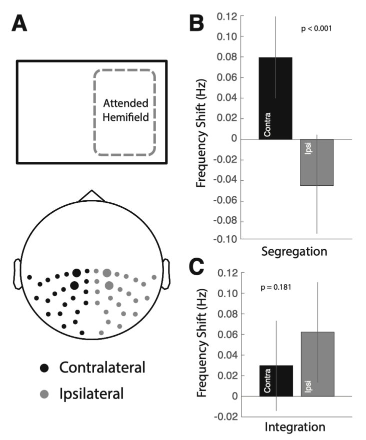

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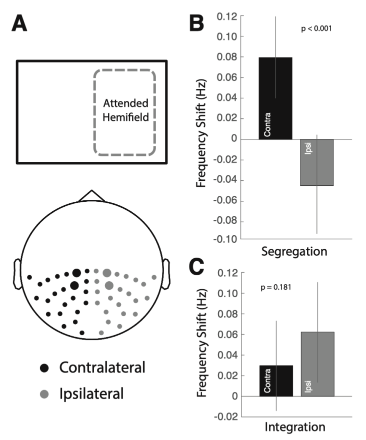
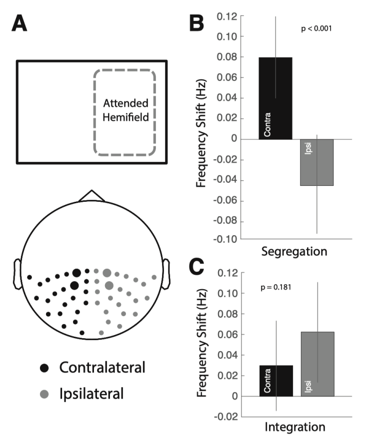


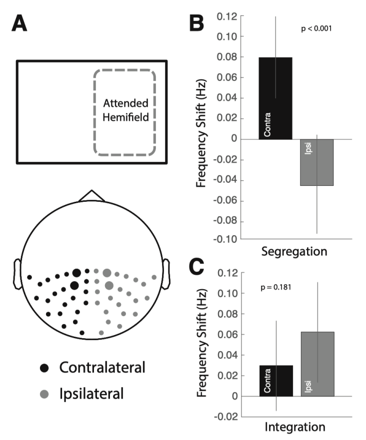
neutral-cue as baseline

Interpretation: Estimation



neutral-cue as baseline: like adding **task FE**

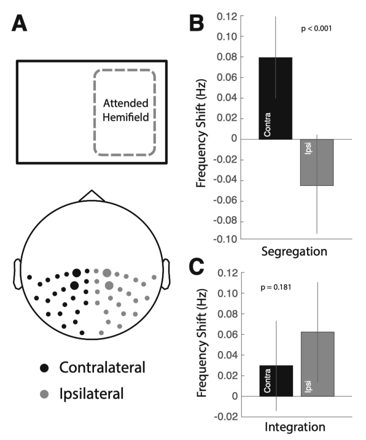
Interpretation: Estimation



neutral-cue as baseline: like adding **task FE**

- driven by contralateral cortex itself

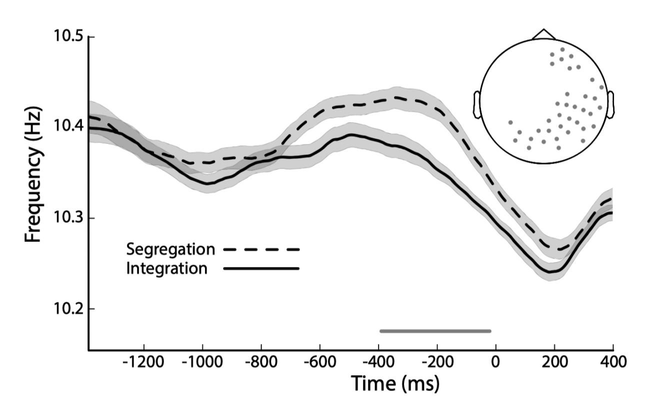
Interpretation: Estimation



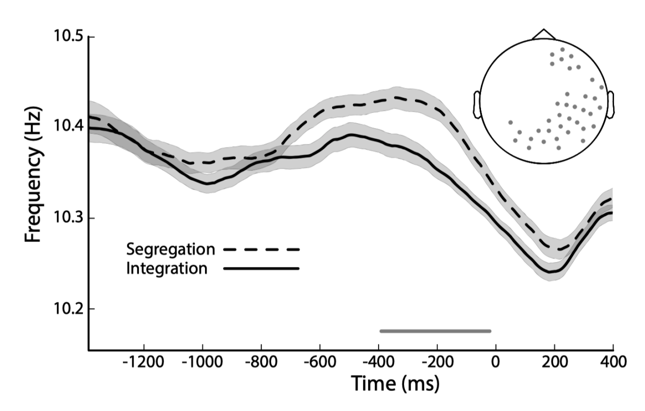
neutral-cue as baseline: like adding **task FE**

- driven by contralateral cortex itself
- opposite effects on contralateral and ipsilateral cortex

Interpretation: the Role of Spatial Attention



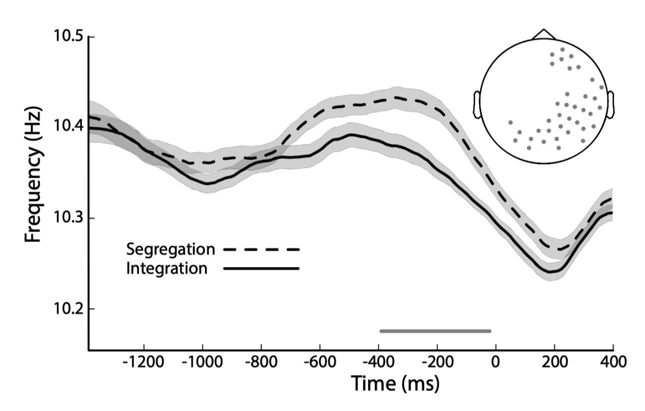
Interpretation: the Role of Spatial Attention



There is a difference under neutral cues:

- temporal visual processing is **itself** sentitive to strategic preparation

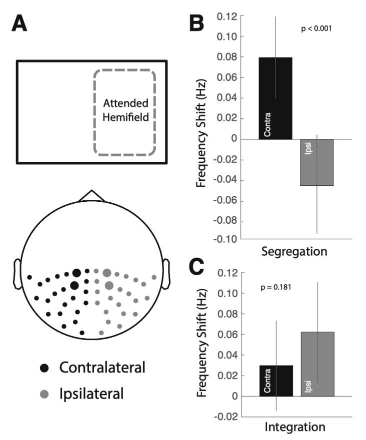
Interpretation: the Role of Spatial Attention



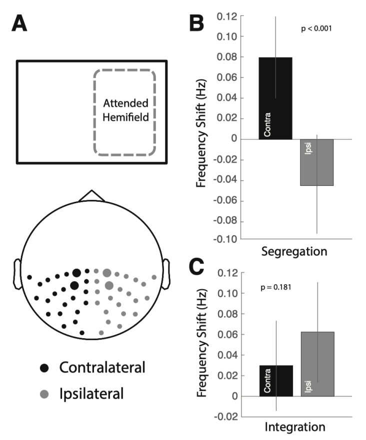
There is a difference under neutral cues:

- temporal visual processing is **itself** sentitive to strategic preparation
- spatial attention does **accentuate** this broader influence

Interpretation: Understanding α

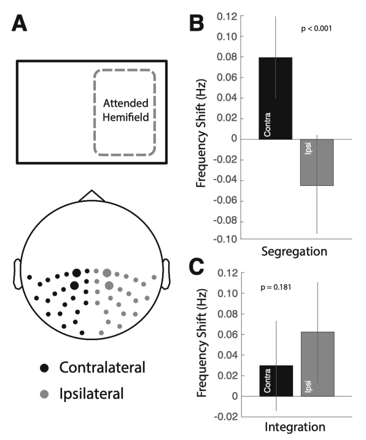


Interpretation: Understanding α



- more salient effects for **segragation**: increase in contralateral α is **associated** with perceptual sensitivity in the detection of fleeting visual stimuli (See Di Gregorio et al. (2022))

Interpretation: Understanding α



- more salient effects for **segragation**:
  increase in contralateral α is **associated** with perceptual sensitivity in the detection of fleeting visual stimuli (See Di Gregorio et al. (2022))
- α relects **rhythmic inhibition**:
  spatial attention (or the deployment of attention in general) can flexibly **adapt** oscillatory activity to strategically **optimize** the time duration that fits in the *open* portion of an α cycle

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Thank you!