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

Poppy Sharp, Tjerk Gutteling, David Melcher, Clayton Hickey

Presented by: Sai Zhang

November 15, 2022

Outline

Introduction

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

How spatial attention impacts the neural processing of dynamic visual stimuli

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

How spatial attention impacts the neural processing of dynamic visual stimuli is **unclear**

See Nobre and Van Ede, 2018 for a review

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

How spatial attention impacts the neural processing of dynamic visual stimuli is **unclear**

See Nobre and Van Ede, 2018 for a review

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

- **integration:** to form unitary percepts and identify consistencies

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

How spatial attention impacts the neural processing of dynamic visual stimuli is **unclear**

See Nobre and Van Ede, 2018 for a review

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

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

Surprisingly, spatial attention can **flexibly** benefit both:

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

Surprisingly, spatial attention can **flexibly** benefit both:

Integration	Separation

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

Surprisingly, spatial attention can **flexibly** benefit both:

Integration

- Hein et al. (2006)
- Sharp, Melcher, et al. (2018)

Separation

- Akyürek et al. (2007)
- Hochmitz et al. (2021)

Inspiration: The Puzzle of Spatial Attention and Dynamic Stimuli

Surprisingly, spatial attention can **flexibly** benefit both:

Integration	Separation
- Hein et al. (2006) - Sharp, Melcher, et al. (2018)	- Akyürek et al. (2007) - Hochmitz et al. (2021)

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**.

Hypothesis

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

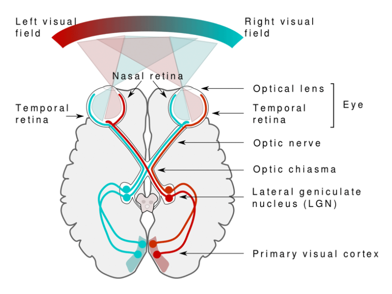


Figure 1: Retinotopic structure

Hypothesis

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

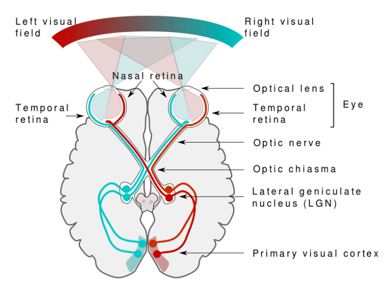


Figure 1: Retinotopic structure

- **striate** and **extrastriate** visual areas: spatially organized, corresponding to specific areas of the retina

Hypothesis

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

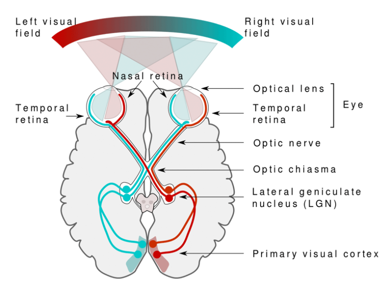


Figure 1: Retinotopic structure

- **striate** and **extrastriate** visual areas: spatially organized, corresponding to specific areas of the retina
- representing **static** stimuli: Yes!

Hypothesis

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

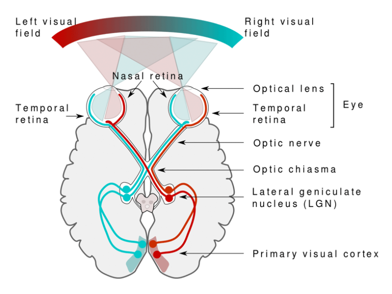


Figure 1: Retinotopic structure

- **striate** and **extrastriate** visual areas: spatially organized, corresponding to specific areas of the retina
- representing **static** stimuli: Yes!
- representing **temporal** stimuli?

Hypothesis

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

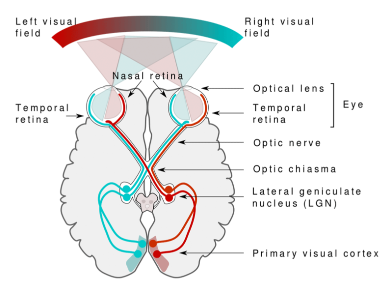


Figure 1: Retinotopic structure

- **striate** and **extrastriate** visual areas: spatially organized, corresponding to specific areas of the retina
- representing **static** stimuli: Yes!
- representing **temporal** stimuli: *shrinking/stretching the temporal scope of visual input summarizing*

Hypothesis

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

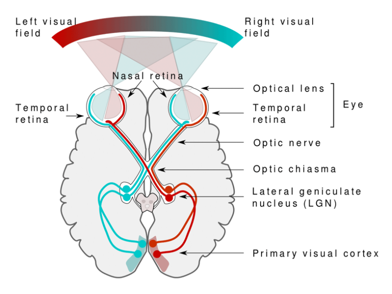


Figure 1: Retinotopic structure

- **striate** and **extrastriate** visual areas: spatially organized, corresponding to specific areas of the retina
- representing **static** stimuli: Yes!
- representing **temporal** stimuli: *shrinking/stretching the temporal scope of visual input summarizing*

Hypothesis

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

shrinking/stretching the temporal scope of visual input summarizing

Hypothesis

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

shrinking/stretching the temporal scope of visual input summarizing

Hypothesis

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

shrinking/stretching the temporal scope of visual input summarizing

- α rate reflects **temporal** expectation

  See Buergers and Noppeney (2022) and Samaha and Postle (2015)

Hypothesis

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

shrinking/stretching the temporal scope of visual input summarizing

- α rate reflects **temporal** expectation

  See Buergers and Noppeney (2022) and Samaha and Postle (2015)

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

  See Cecere et al. (2015), Minami and Amano (2017), Mioni et al. (2020), and Ronconi et al. (2018)

Hypothesis

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

shrinking/stretching the temporal scope of visual input summarizing

- α rate reflects **temporal** expectation

  See Buergers and Noppeney (2022) and Samaha and Postle (2015)
- manipulation of average α rate has an impact on **stretching/shrinking** of the perceptual window

  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)

Hypothesis

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

- **spatial**: cue location $\Rightarrow$ *corresponding* location in retinotopic visual cortex

Hypothesis

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

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

Prediction

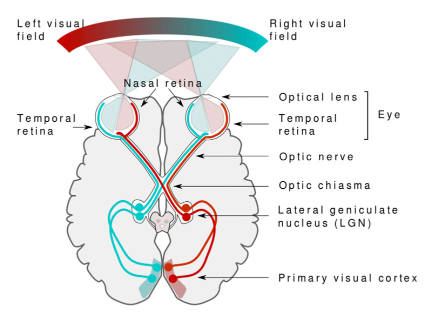


Figure 1: Retinotopic structure

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

Use magnetoencephalogram (MEG) recording for analysis

Materials and Methods

Trial Structure

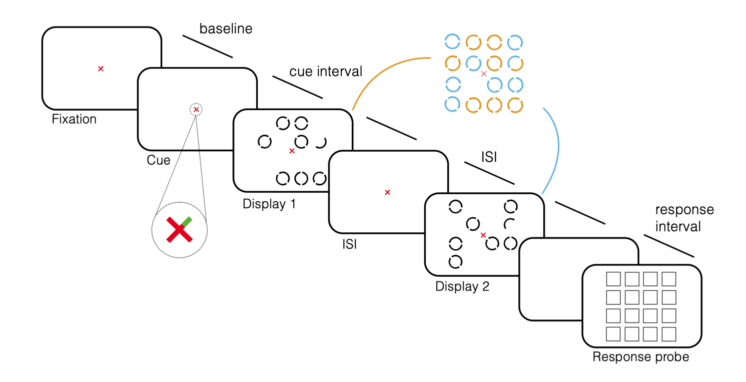


Figure 2: Trial Structure

Trial Structure

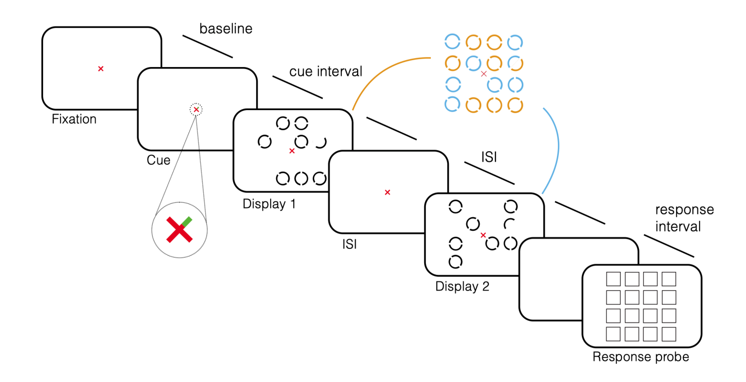


Figure 2: Trial Structure

Timeline:

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

Trial Structure

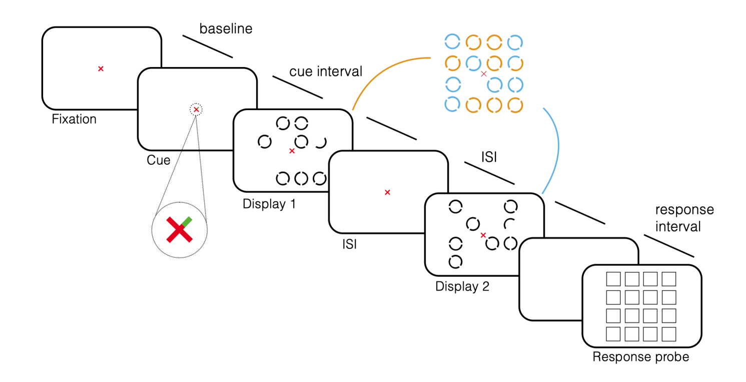


Figure 2: Trial Structure

visual cue: **red** cross

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

Trial Structure

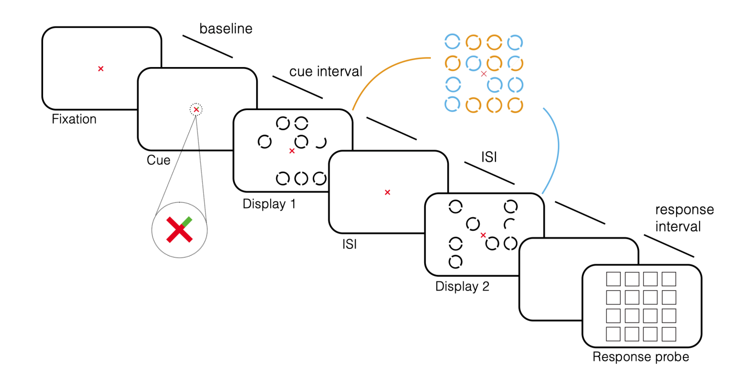


Figure 2: Trial Structure

2 displays: complementary, non-overlapping

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

Trial Structure

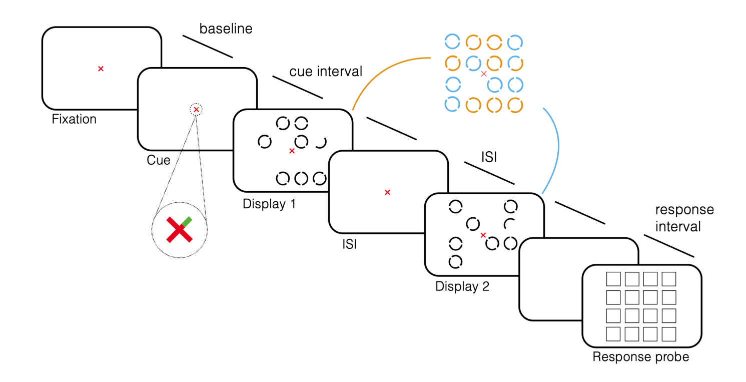


Figure 2: Trial Structure

task: moving a highlighted square

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

Measures

Eye tracking

MEG recording

Measures

Eye tracking

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

MEG recording

Measures

Eye tracking

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

MEG recording

- estimate instantaneous α−frequency: 7- to 14-Hz frequency band
- rejection
  - nonbiological noise: 10±1 channels

Analysis

Source analysis

Numerical analysis

Analysis

Source analysis

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

Numerical analysis

Analysis

Source analysis

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

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)

Other technical details

- Participants: 29 (**normal/corrected-to-normal** vision; age 24±2.7 years; 11 male, 18 female)
- Stimuli: projected at 120Hz onto a translucent screen, at a viewing distance of **1m**

Other technical details

- Participants: 29 (**normal/corrected-to-normal** vision; age 24±2.7 years; 11 male, 18 female)
- Stimuli: projected at 120Hz onto a translucent screen, at a viewing distance of **1m**
- Pre-MEG: 30 practice trials to achieve at least 25% accuracy

Other technical details

- Participants: 29 (**normal/corrected-to-normal** vision; age 24±2.7 years; 11 male, 18 female)
- Stimuli: projected at 120Hz onto a translucent screen, at a viewing distance of **1m**
- Pre-MEG: 30 practice trials to achieve at least 25% accuracy
- Number of trials: 10 blocks $\times$ 67 trials/block

Other technical details

- Participants: 29 (**normal/corrected-to-normal** vision; age 24±2.7 years; 11 male, 18 female)
- Stimuli: projected at 120Hz onto a translucent screen, at a viewing distance of **1m**
- Pre-MEG: 30 practice trials to achieve at least 25% accuracy
- Number of trials: 10 blocks $\times$ 67 trials/block
- Base for numerical analysis: a shift in the **neutral-cue** baseline emerges equally in **ipsilateral** and **contralateral** signals

Results

Summary of 3 dimensions

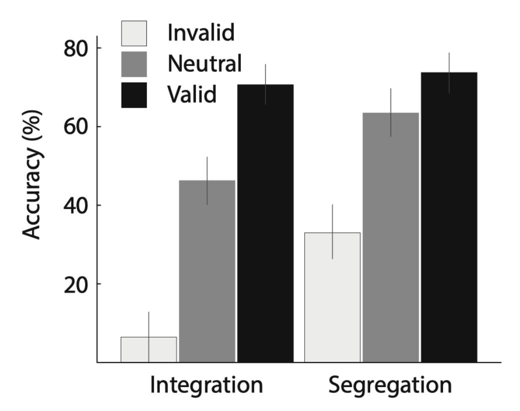
contralateral

	segregation	integration
valid		
neutral		
invalid		

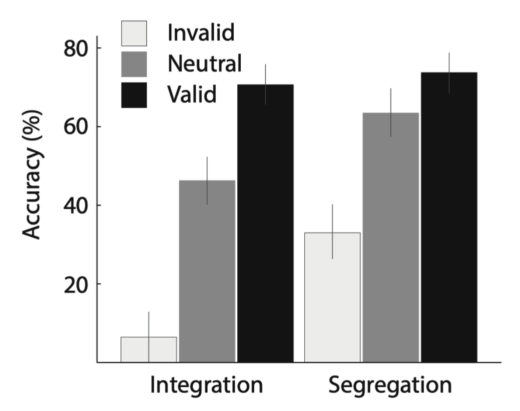
ipsilateral

	segregation	integration
valid		
neutral		
invalid		

Result 1: Accuracy of Cues

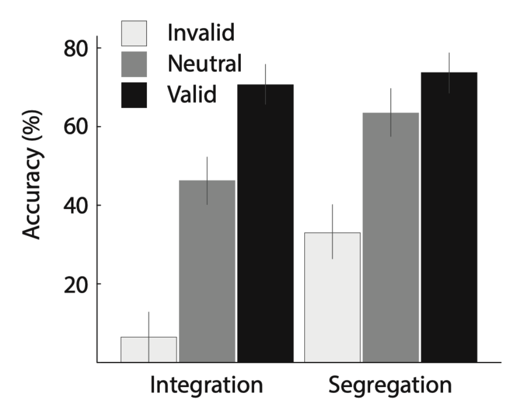


Result 1: Accuracy of Cues



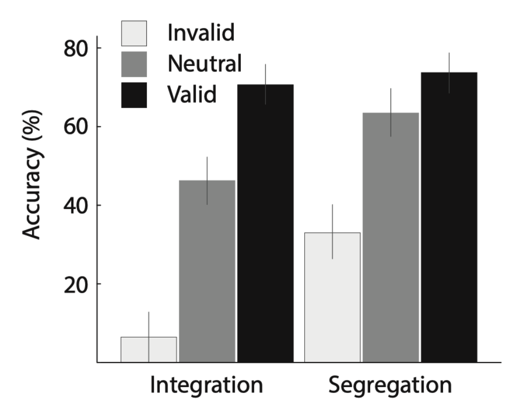
- valid cues $(+)$, invalid cues $(-)$

Result 1: Accuracy of Cues



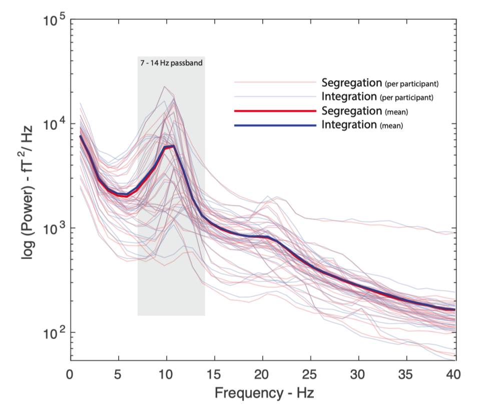
- valid cues $(+)$, invalid cues $(-)$
- greater effect of cues in the segregation task

Result 1: Accuracy of Cues

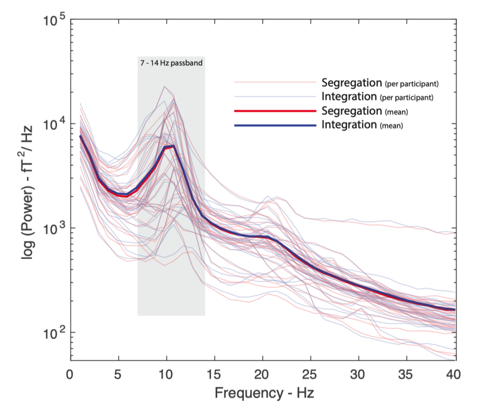


- valid cues $(+)$, invalid cues $(-)$
- greater effect of cues in the segregation task
- supported by eye-tracking:
  - visual angle shifts towards the cue direction
  - no significant differences between integration and segragation

Result 2: Suitability of the Data to Measure α Frequency

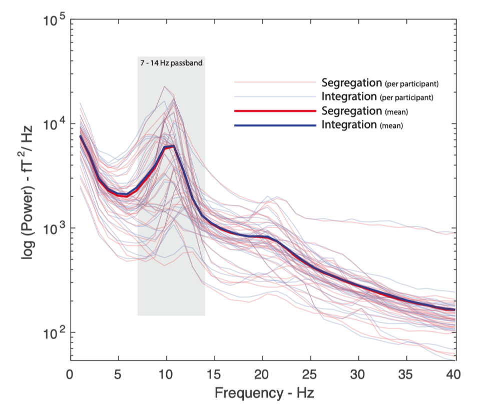


Result 2: Suitability of the Data to Measure α Frequency



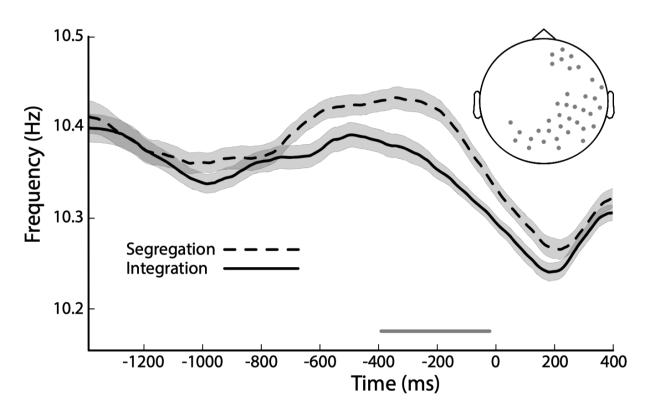
- the analytic passband (7-14Hz) contains **the peak** (In fact, the entire α bump for all participants)

Result 2: Suitability of the Data to Measure α Frequency

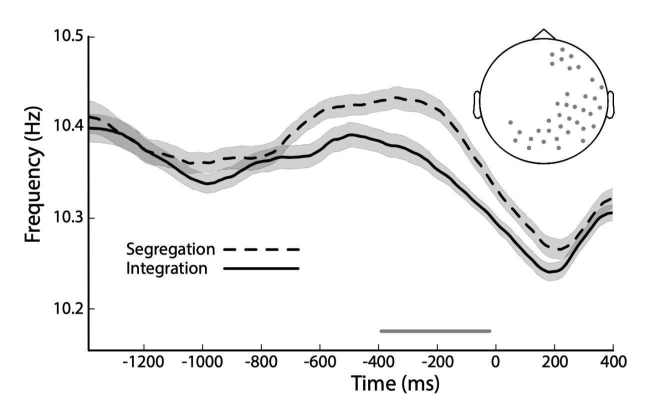


- the analytic passband (7-14Hz) contains **the peak** (In fact, the entire α bump for all participants)
- No significant difference in **power** or slope of the **1/f structure** between segregation and integration

Result 3: α Rate Is Higher for Segregation Tasks

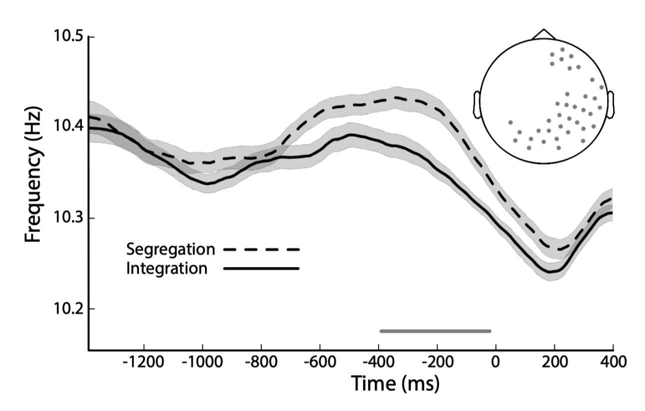


Result 3: α Rate Is Higher for Segregation Tasks



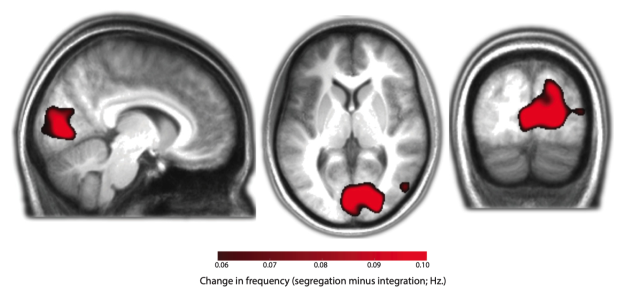
- significantly higher α rate for **segregation** before 1st display (t=0: the 1st display)

Result 3: α Rate Is Higher for Segregation Tasks

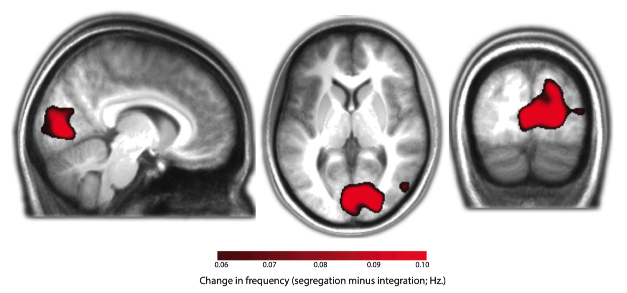


- significantly higher α rate for **segregation** before 1st display (t=0: the 1st display)
- results are from instantaneous frequency analysis of **neutral-cue** trails

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

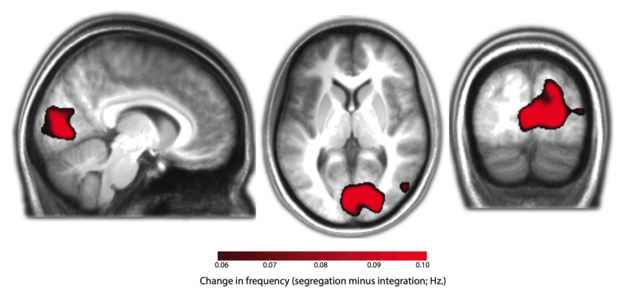


Result 3: α Rate Is Higher for Segregation Tasks, Source Analysis



- bilateral occipito-parietal cortex
- right lateralized frontal cortex

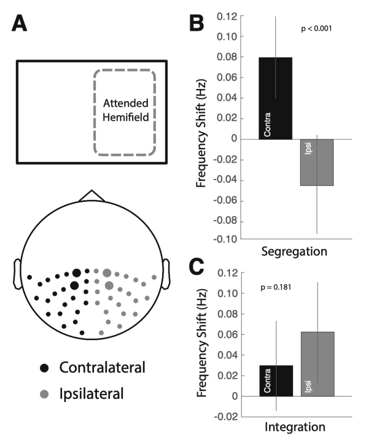
Result 3: α Rate Is Higher for Segregation Tasks, Source Analysis



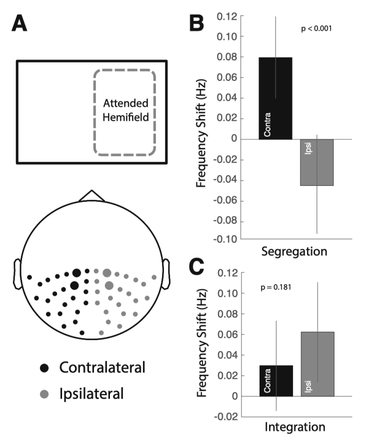
- bilateral occipito-parietal cortex
- right lateralized frontal cortex

replicate the observations of Wutz et al. (2018)

Main Result: Lateral Analysis of α Frequency

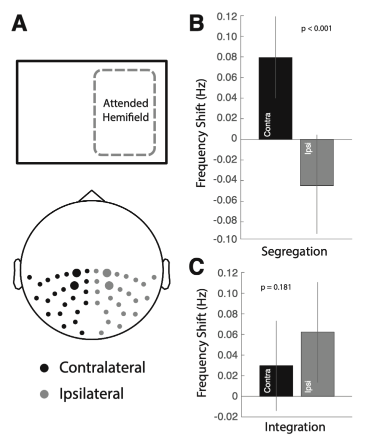


Main Result: Lateral Analysis of α Frequency



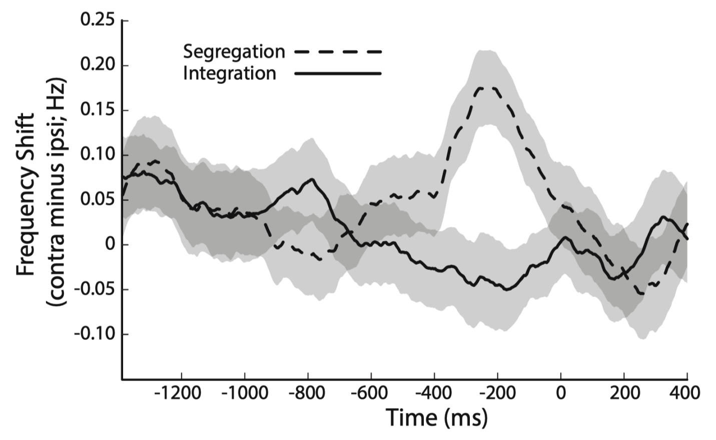
- base: any retinotopic effect **must** emerge over **posterior cortex**

Main Result: Lateral Analysis of α Frequency

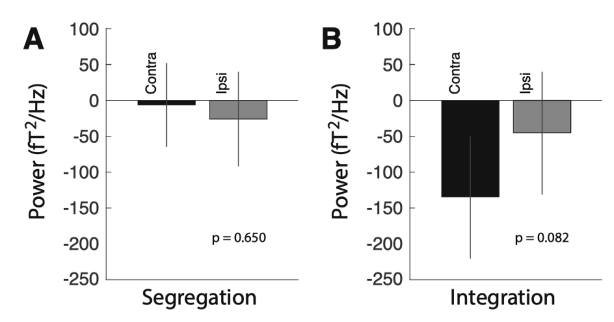


- base: any retinotopic effect **must** emerge over **posterior cortex**
- results:
  - segregation (faster α rate): contralateral **faster** than ipsilateral
  - integration (slower α rate): contralateral **slower** than ipsilateral

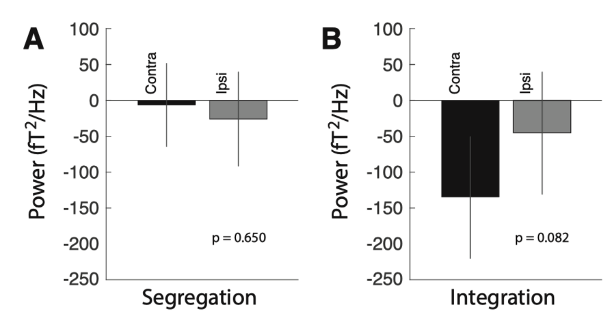
Main Result: Lateral Analysis of α Frequency



Main Result: Ruling out the Effect of Lateral Oscillatory α Power

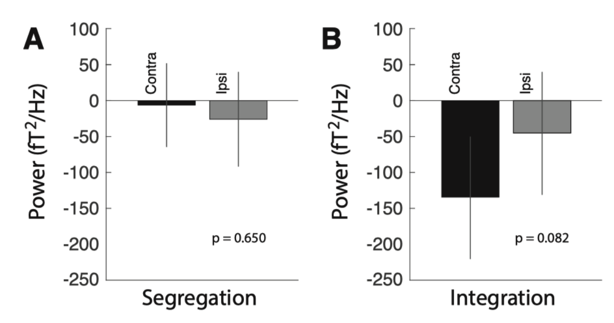


Main Result: Ruling out the Effect of Lateral Oscillatory α Power



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

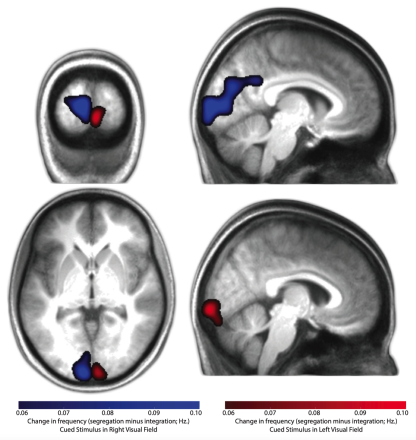
Main Result: Ruling out the Effect of Lateral Oscillatory α Power



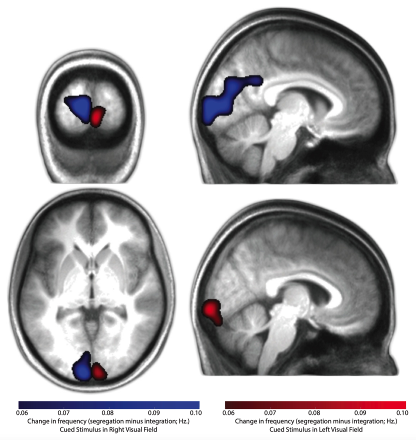
- no significant differences in the lateral effect between segregation and integration
- no significant decrease in α power in contralateral hemisphere

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

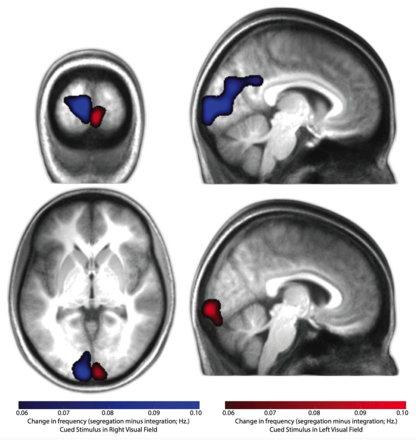


Main Result: Lateral Analysis of α Frequency, Source Analysis



- both clusters are located in **early visual areas** at the **occipital** pole

Main Result: Lateral Analysis of α Frequency, Source Analysis



- 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

Significance: Interaction between Temporal and Spatial Processing

Previously:

Significance: Interaction between Temporal and Spatial Processing

Previously:

- Spatial attention can benefit **both** segregation and integration of visual stimuli

Significance: Interaction between Temporal and Spatial Processing

Previously:

- Spatial attention can benefit **both** segregation and integration of visual stimuli
- α frequency in posterior cortex
  - **increases** in speed to **segregate** sequential visual stimuli
  - **decreases** in speed to **integrate** sequential visual stimuli

Significance: Interaction between Temporal and Spatial Processing

Previously:

- Spatial attention can benefit **both** segregation and integration of visual stimuli
- α frequency in posterior cortex
  - **increases** in speed to **segregate** sequential visual stimuli
  - **decreases** in speed to **integrate** sequential visual stimuli

This study **bridges** the two aspects:

Significance: Interaction between Temporal and Spatial Processing

Previously:

- Spatial attention can benefit **both** segregation and integration of visual stimuli
- α frequency in posterior cortex
  - **increases** in speed to **segregate** sequential visual stimuli
  - **decreases** in speed to **integrate** sequential visual stimuli

This study **bridges** the two aspects:

- segragation **in a location** $\Rightarrow$ relatively faster **contralateral** α

Significance: Interaction between Temporal and Spatial Processing

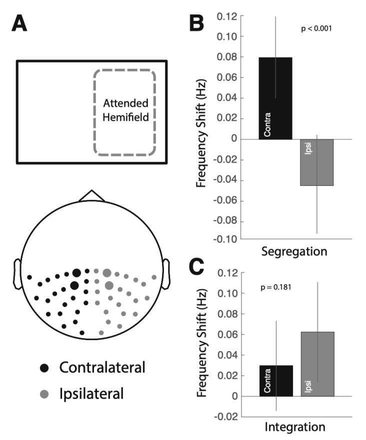
Previously:

- Spatial attention can benefit **both** segregation and integration of visual stimuli
- α frequency in posterior cortex
  - **increases** in speed to **segregate** sequential visual stimuli
  - **decreases** in speed to **integrate** sequential visual stimuli

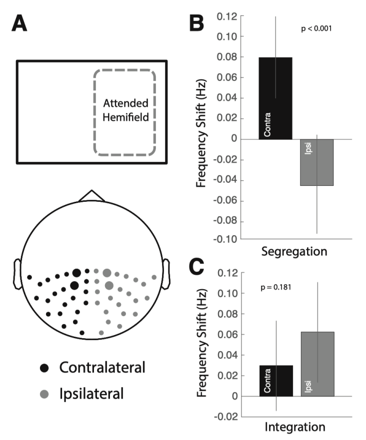
This study **bridges** the two aspects:

- segragation **in a location** $\Rightarrow$ relatively faster **contralateral** α
- integration **in a location** $\Rightarrow$ relatively slower **contralateral** α

Interpretation: Estimation

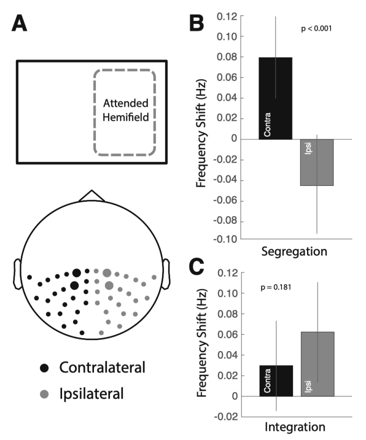


Interpretation: Estimation



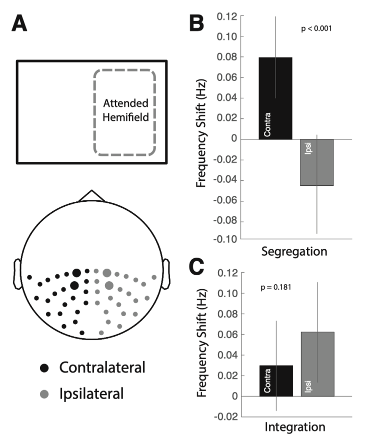
neutral-cue as baseline

Interpretation: Estimation



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

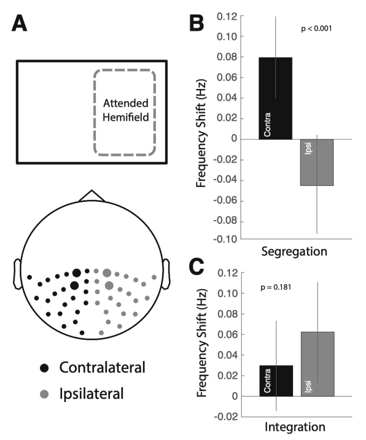
Interpretation: Estimation



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

- driven by contralateral cortex itself

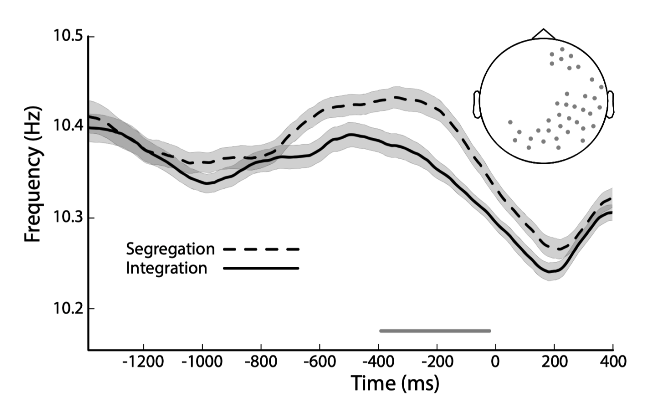
Interpretation: Estimation



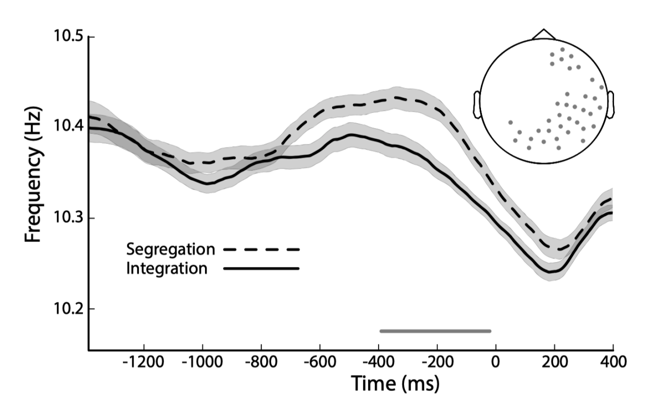
neutral-cue as baseline: like adding **task FE**

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

Interpretation: the Role of Spatial Attention



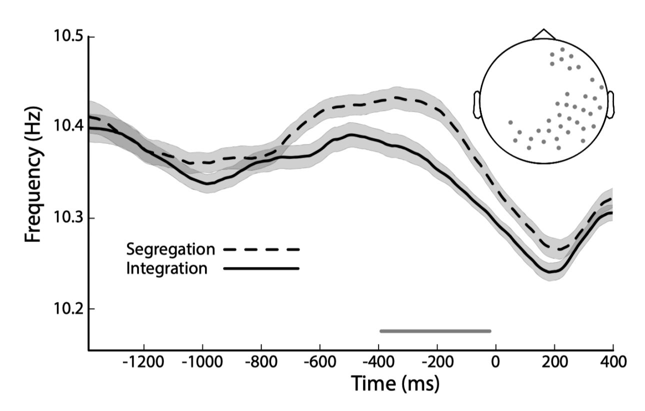
Interpretation: the Role of Spatial Attention



There is a difference under neutral cues:

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

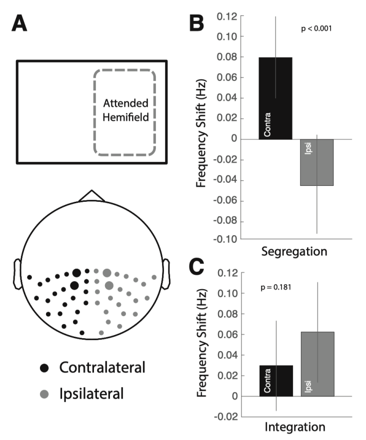
Interpretation: the Role of Spatial Attention



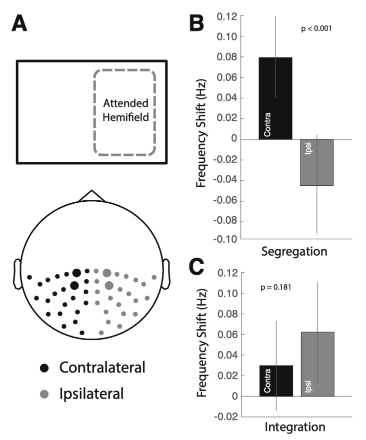
There is a difference under neutral cues:

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

Interpretation: Understanding α

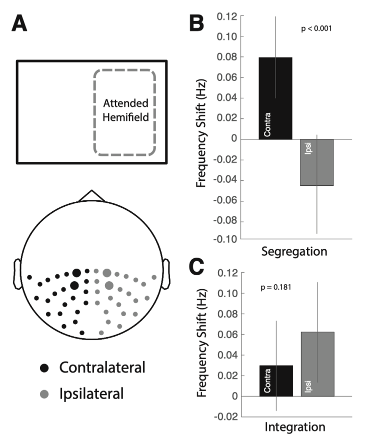


Interpretation: Understanding α



- 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

References I

Akyürek, E. G., Riddell, P. M., Toffanin, P., & Hommel, B. (2007). Adaptive control of event integration: Evidence from event-related potentials. *Psychophysiology*, *44*(3), 383–391.

Buergers, S., & Noppeney, U. (2022). The role of alpha oscillations in temporal binding within and across the senses. *Nature Human Behaviour*, *6*(5), 732–742.

Capilla, A., Schoffelen, J.-M., Paterson, G., Thut, G., & Gross, J. (2014). Dissociated alpha-band modulations in the dorsal and ventral visual pathways in visuospatial attention and perception. *Cerebral Cortex*, *24*(2), 550–561.

Cecere, R., Rees, G., & Romei, V. (2015). Individual differences in alpha frequency drive crossmodal illusory perception. *Current Biology*, *25*(2), 231–235.

Di Gregorio, F., Trajkovic, J., Roperti, C., Marcantoni, E., Di Luzio, P., Avenanti, A., . . . Romei, V. (2022). Tuning alpha rhythms to shape conscious visual perception. *Current Biology*, *32*(5), 988–998.

Hein, E., Rolke, B., & Ulrich, R. (2006). Visual attention and temporal discrimination: Differential effects of automatic and voluntary cueing. *Visual Cognition*, *13*(1), 29–50.

References II

Hochmitz, I., Hein, E., & Yeshurun, Y. (2021). The effects of spatial attention on temporal integration measured with the ternus display.. *Journal of Experimental Psychology: Human Perception and Performance.*

Minami, S., & Amano, K. (2017). Illusory jitter perceived at the frequency of alpha oscillations. *Current Biology, 27*(15), 2344–2351.

Mioni, G., Shelp, A., Stanfield-Wiswell, C. T., Gladhill, K. A., Bader, F., & Wiener, M. (2020). Modulation of individual alpha frequency with tacs shifts time perception. *Cerebral Cortex Communications, 1*(1), tgaa064.

Nobre, A. C., & Van Ede, F. (2018). Anticipated moments: Temporal structure in attention. *Nature Reviews Neuroscience, 19*(1), 34–48.

Ronconi, L., Busch, N. A., & Melcher, D. (2018). Alpha-band sensory entrainment alters the duration of temporal windows in visual perception. *Scientific reports, 8*(1), 1–10.

Samaha, J., & Postle, B. R. (2015). The speed of alpha-band oscillations predicts the temporal resolution of visual perception. *Current Biology, 25*(22), 2985–2990.

References III

Sharp, P., Gutteling, T., Melcher, D., & Hickey, C. (2022). Spatial attention tunes temporal processing in early visual cortex by speeding and slowing alpha oscillations. *Journal of Neuroscience, 42*(41), 7824–7832.

Sharp, P., Melcher, D., & Hickey, C. (2018). Endogenous attention modulates the temporal window of integration. *Attention, Perception, & Psychophysics, 80*(5), 1214–1228.

Wutz, A., Melcher, D., & Samaha, J. (2018). Frequency modulation of neural oscillations according to visual task demands. *Proceedings of the National Academy of Sciences, 115*(6), 1346–1351.

Thank you!