Attention controls multisensory perception via two distinct mechanisms at different levels of the cortical hierarchy

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Fundamentals of Neuroscience II
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Ansley Kunnath

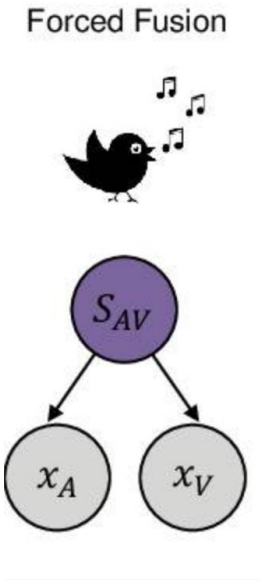
Outline

1. Multisensory perception & attention
2. Experimental paradigm
3. Results
4. Limitations
5. Conclusions
6. Questions

Ventriloquist effect

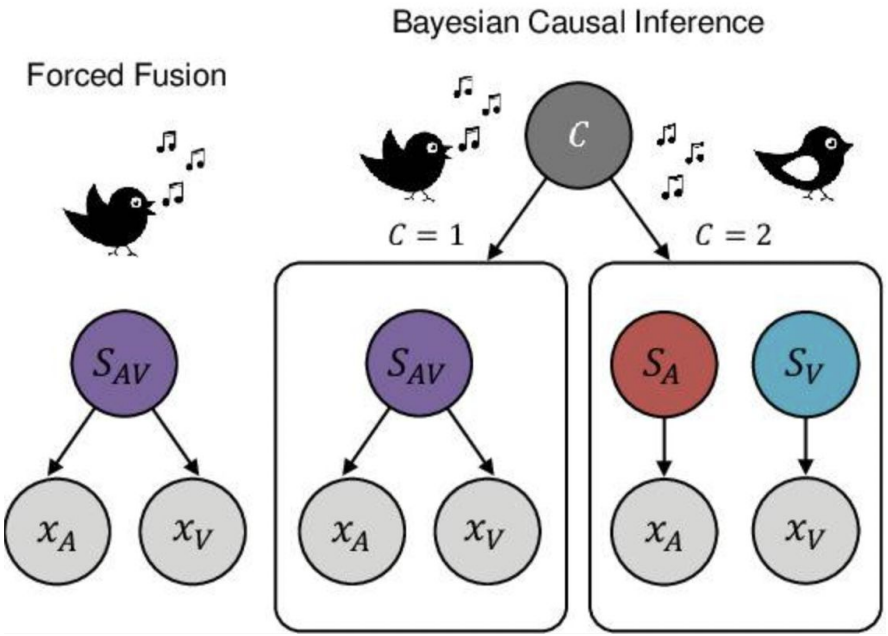
Mechanism of multisensory perception

- **Forced Fusion** (FF): Single source generates A and V signals



Mechanism of multisensory perception

- **Forced Fusion** (FF): Single source generates A and V signals
- **Bayesian Causal Inference** (BCI): Uncertainty about whether signals come from common or independent sources



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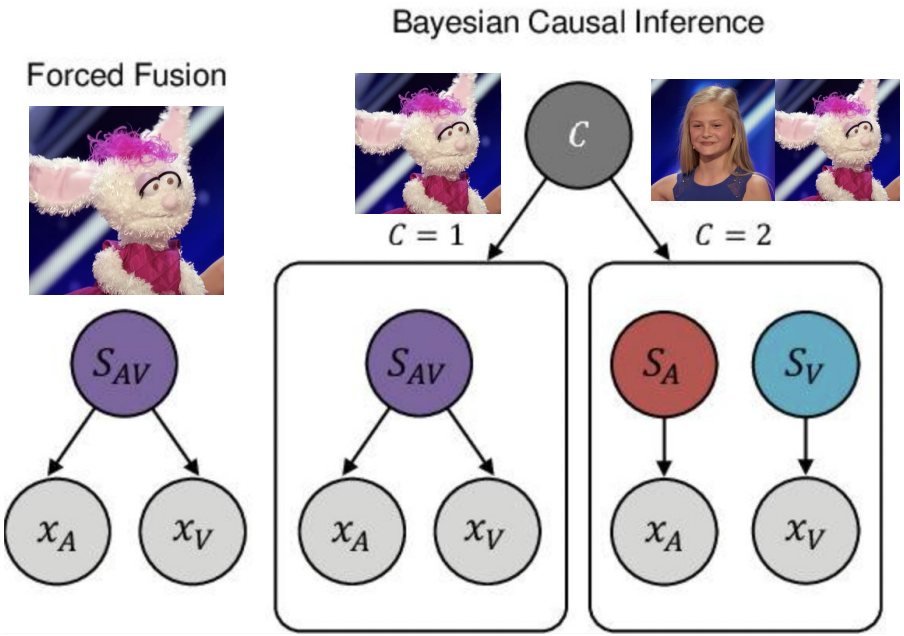
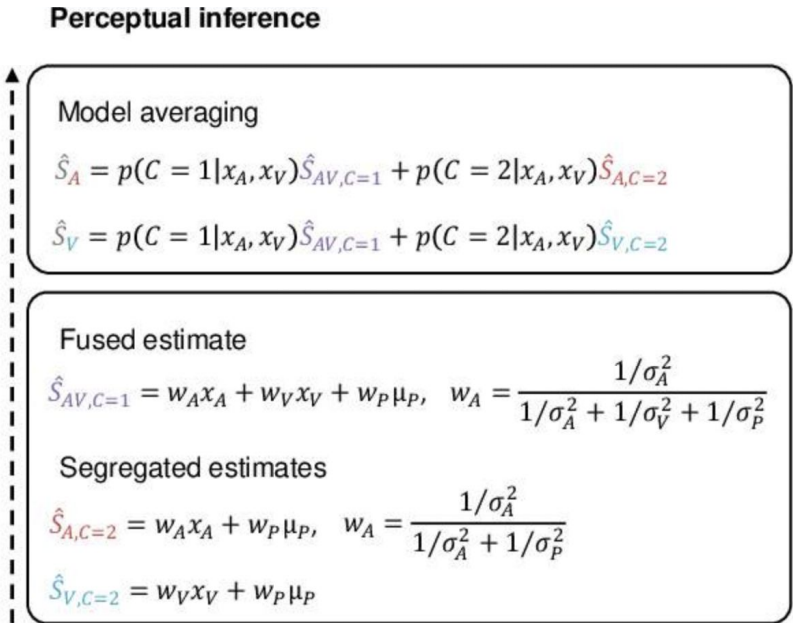
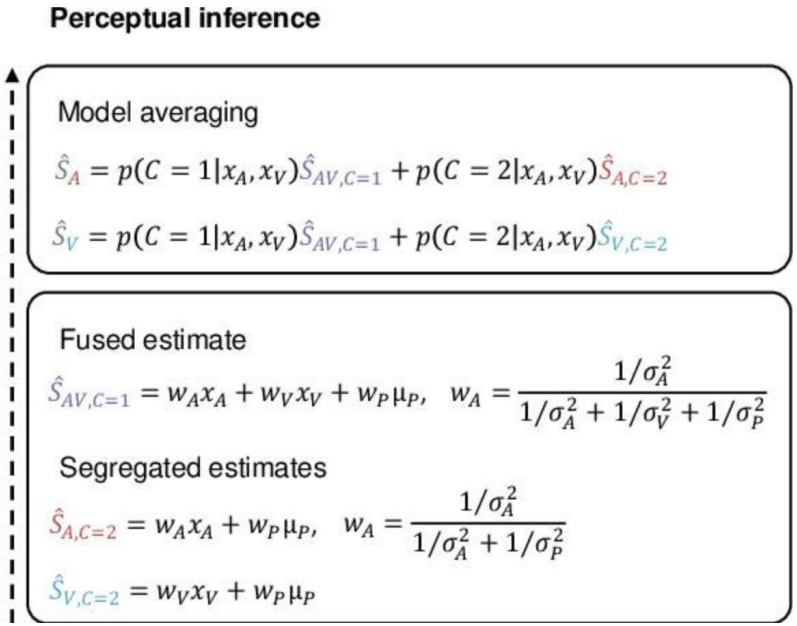


Effects of attention on perception



Effects of attention on perception

Make A/V location estimates for common vs. separate sources (**FF**)



Effects of attention on perception

Create average model based on probability of common vs. separate source **(BCI)**

Make A/V location estimates for common vs. separate sources (**FF**)

Perceptual inference

Model averaging

$$\hat{S}_A = p(C=1|x_A,x_V)\hat{S}_{AV,C=1} + p(C=2|x_A,x_V)\hat{S}_{A,C=2}$$

$$\hat{S}_V = p(C=1|x_A,x_V)\hat{S}_{AV,C=1} + p(C=2|x_A,x_V)\hat{S}_{V,C=2}$$

Fused estimate

$$\hat{S}_{AV,C=1} = w_A x_A + w_V x_V + w_P \mu_P, \quad w_A = \frac{1/\sigma_A^2}{1/\sigma_A^2 + 1/\sigma_V^2 + 1/\sigma_P^2}$$

Segregated estimates

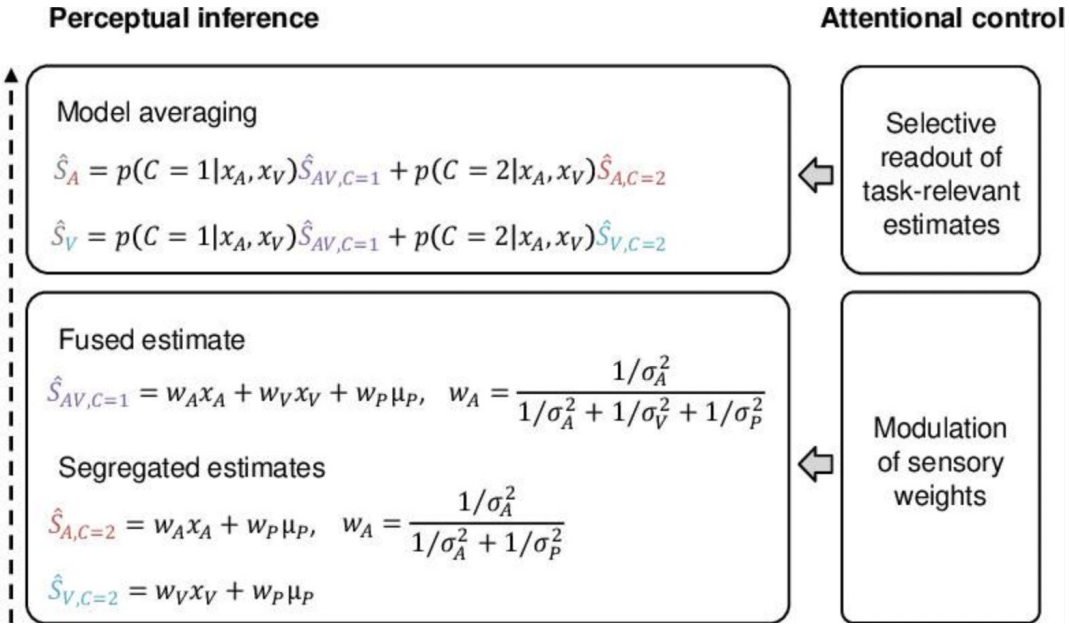
$$\hat{S}_{A,C=2} = w_A x_A + w_P \mu_P, \quad w_A = \frac{1/\sigma_A^2}{1/\sigma_A^2 + 1/\sigma_P^2}$$

$$\hat{S}_{V,C=2} = w_V x_V + w_P \mu_P$$

Effects of attention on perception

Create average model based on probability of common vs. separate source **(BCI)**

Make A/V location estimates for common vs. separate sources (**FF**)



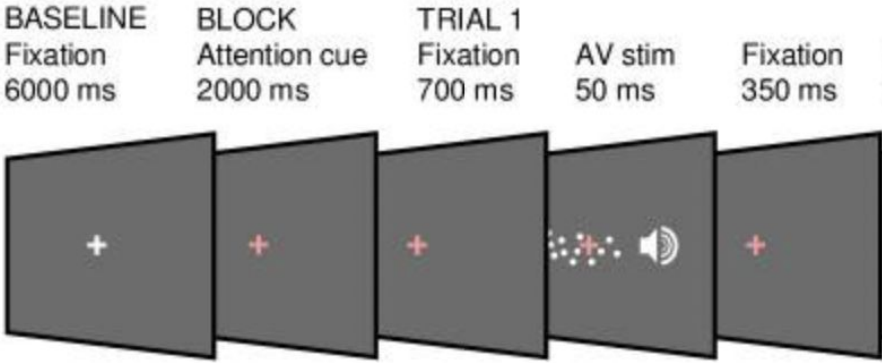
How does attention control multisensory perception?

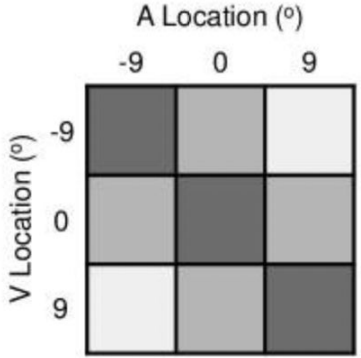
Experiment

BASELINE
Fixation
6000 ms

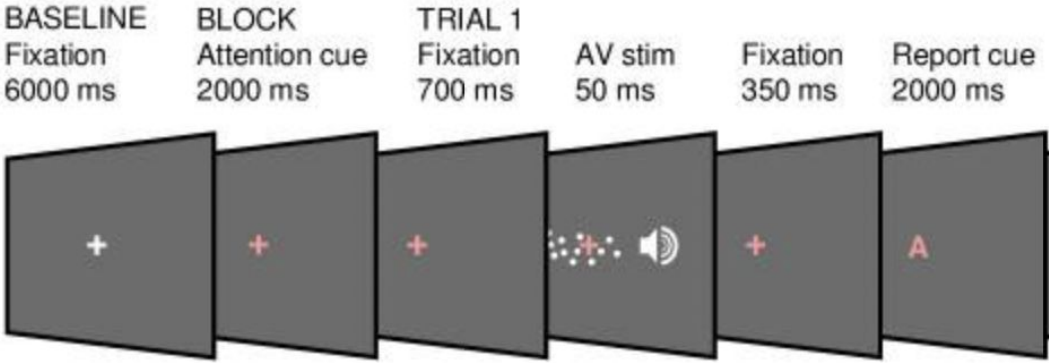
BLOCK
Attention cue
2000 ms

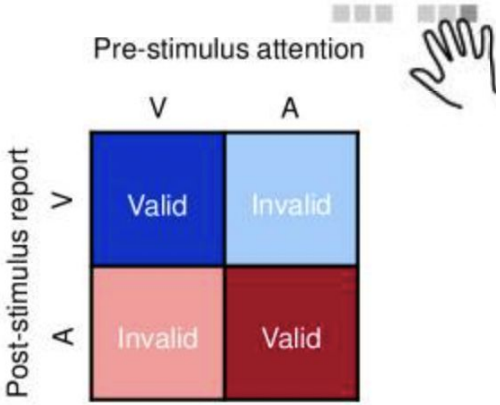
Experiment


BASELINE
Fixation
6000 ms
BLOCK
Attention cue
2000 ms
TRIAL 1
Fixation
700 ms
AV stim
50 ms
Fixation
350 ms

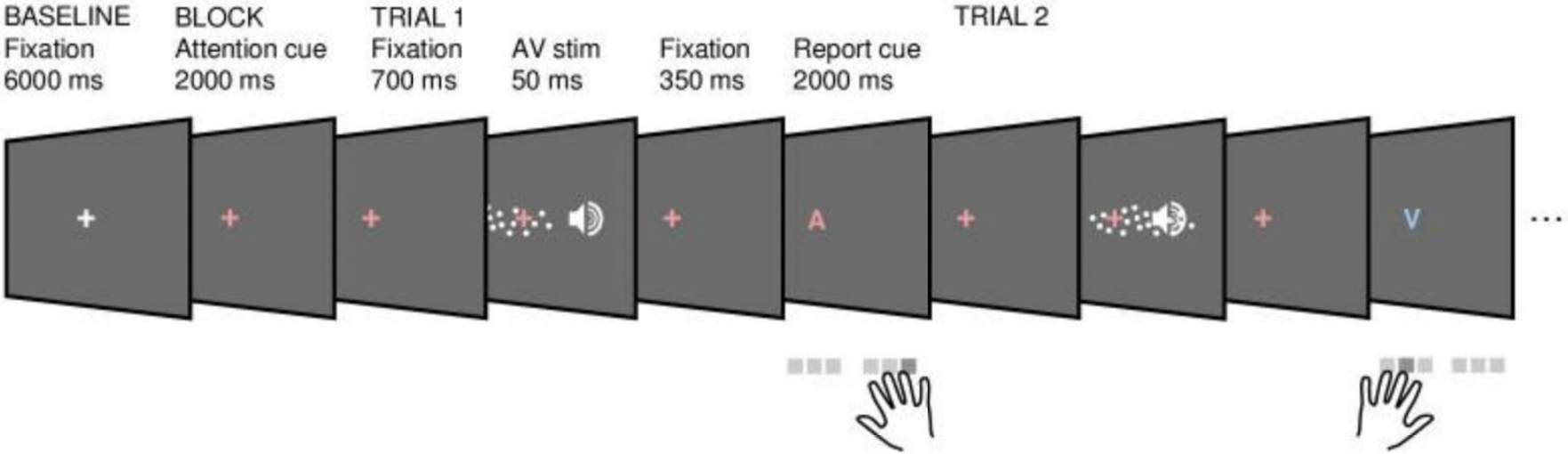

A Location (°)
-9
0
9
V Location (°)
-9
0
9

Experiment

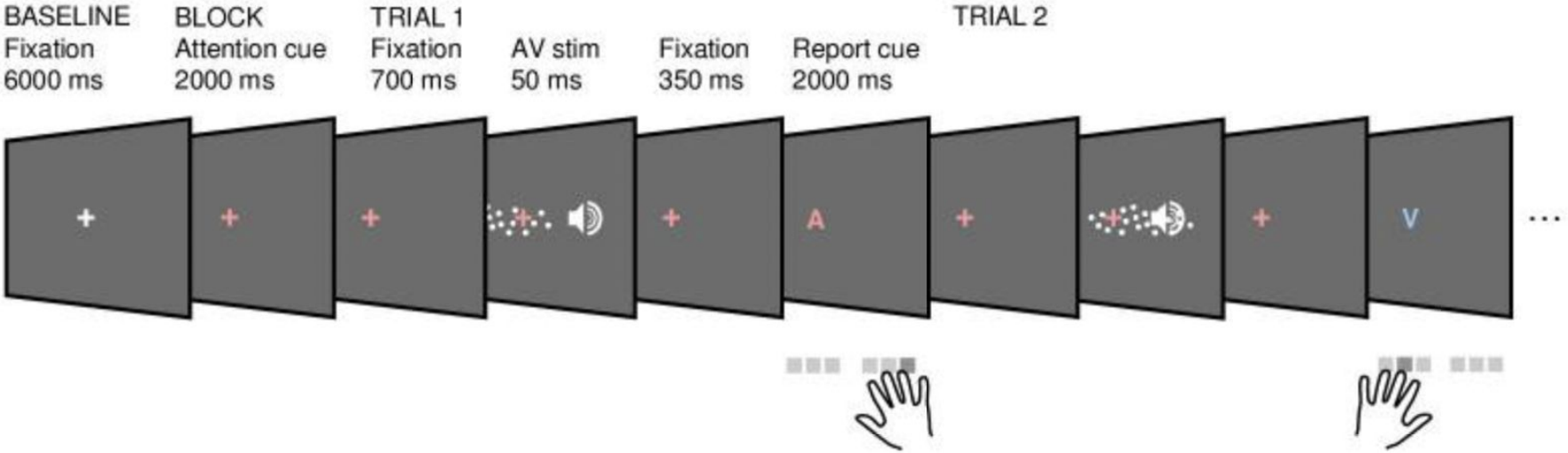

BASELINE
Fixation
6000 ms
BLOCK
Attention cue
2000 ms
TRIAL 1
Fixation
700 ms
AV stim
50 ms
Fixation
350 ms
Report cue
2000 ms
A


Pre-stimulus attention
V
A
Post-stimulus report
V
A
Valid
Invalid
Invalid
Valid

Experiment


BASELINE
Fixation
6000 ms
BLOCK
Attention cue
2000 ms
TRIAL 1
Fixation
700 ms
AV stim
50 ms
Fixation
350 ms
Report cue
2000 ms
TRIAL 2
A
V

Experiment

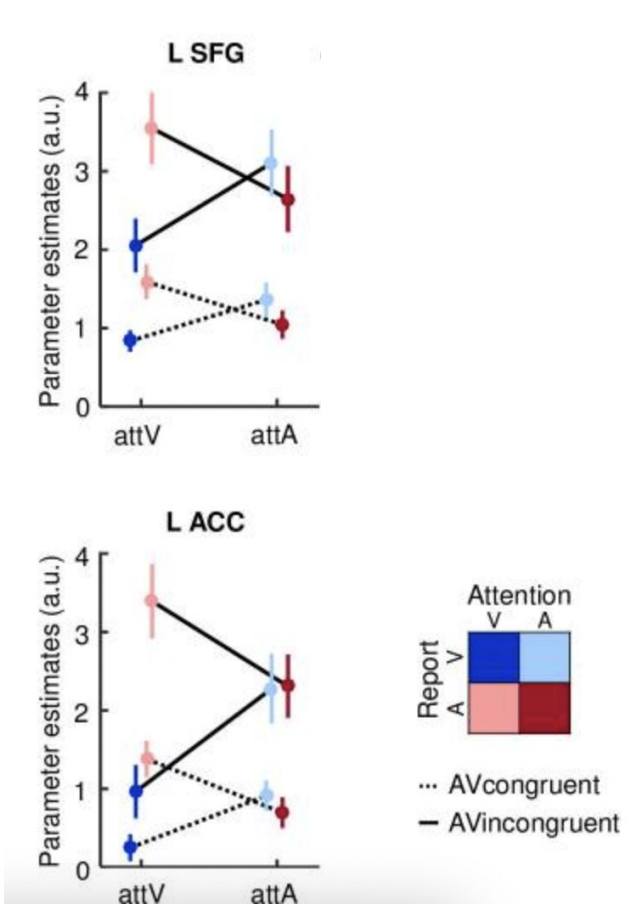


Attention cue modulates sensory representation at early sensory cortices (FF)

Report cue modulates task relevance at anterior parietal cortices (BCI)

Neuroimaging results

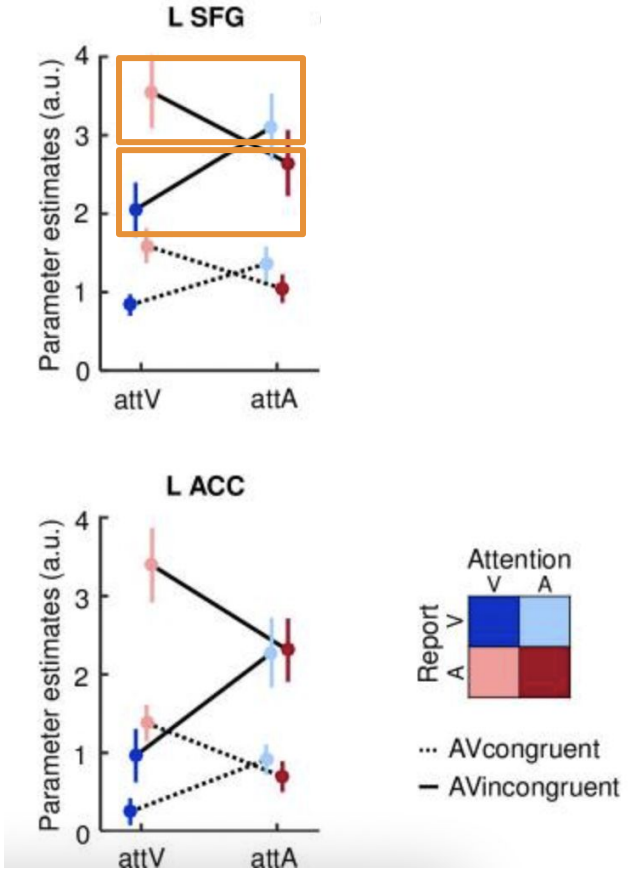
- Increased SFG/ACC activity with:



Neuroimaging results

- Increased SFG/ACC activity with:

  → **invalid cue** trials

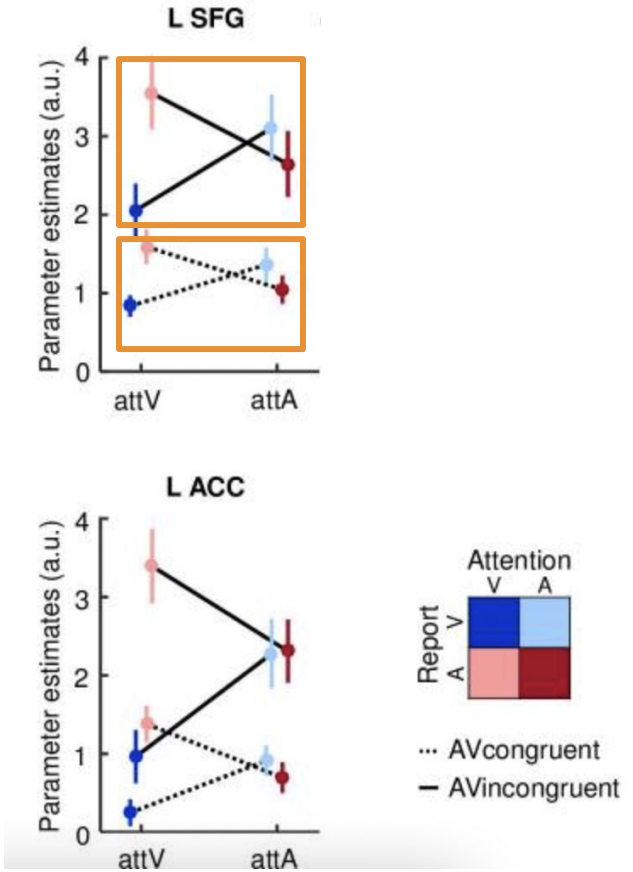


Neuroimaging results

- Increased SFG/ACC activity with:

  → **invalid cue** trials

  → **spatially incongruent** trials



Neuroimaging results

- Increased SFG/ACC activity with:

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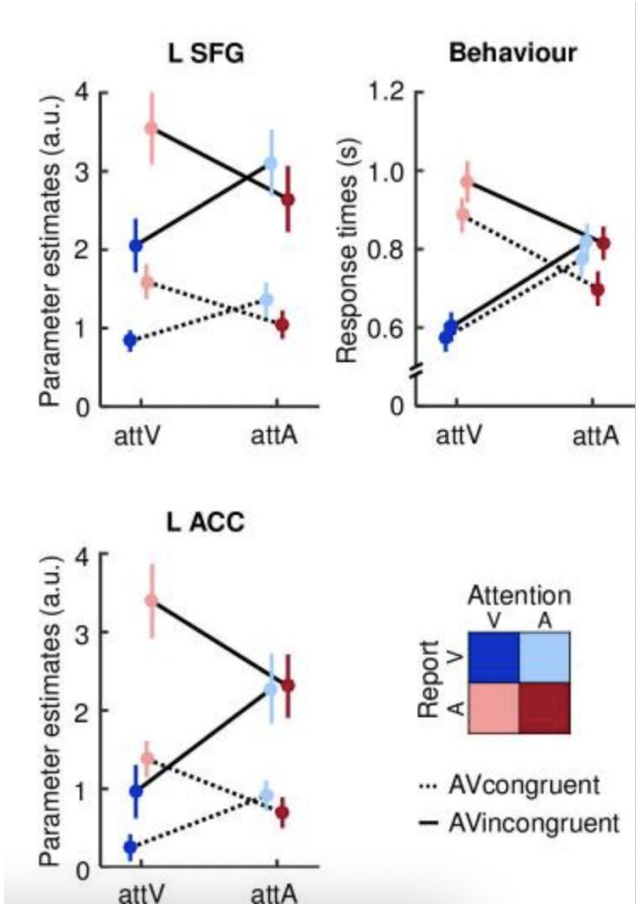
  → **spatially incongruent** trials

- Valid cues had faster response times



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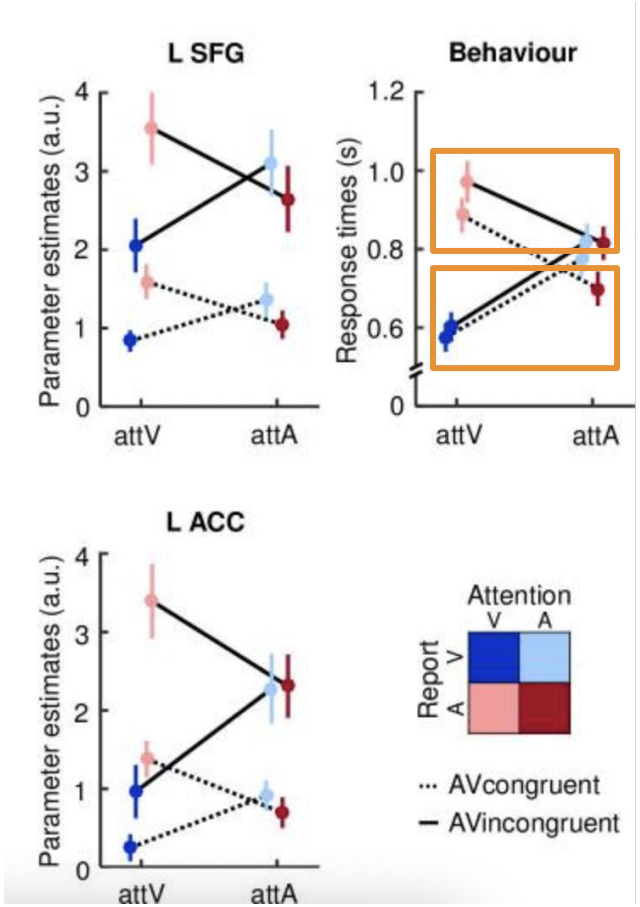


Audiovisual weight index

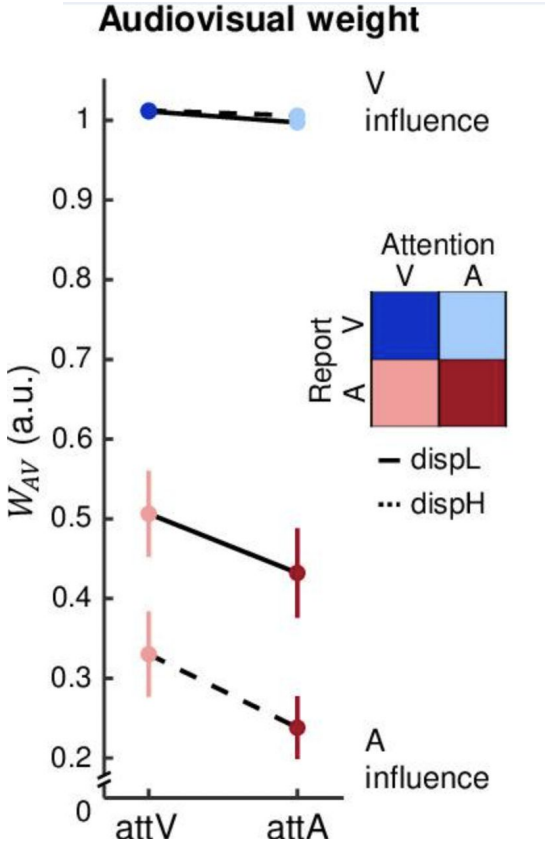
$$w_{AV,XY} = \frac{Reported\ location_{Incongruent,\ A=X,\ V=Y} - Reported\ location_{Congruent,\ AV=X}}{Reported\ location_{Congruent,\ AV=Y} - Reported\ location_{Congruent,\ AV=X}}$$

wAV = 1 $\longrightarrow$ completely relying on V location

wAV = 0 $\longrightarrow$ completely relying on A location

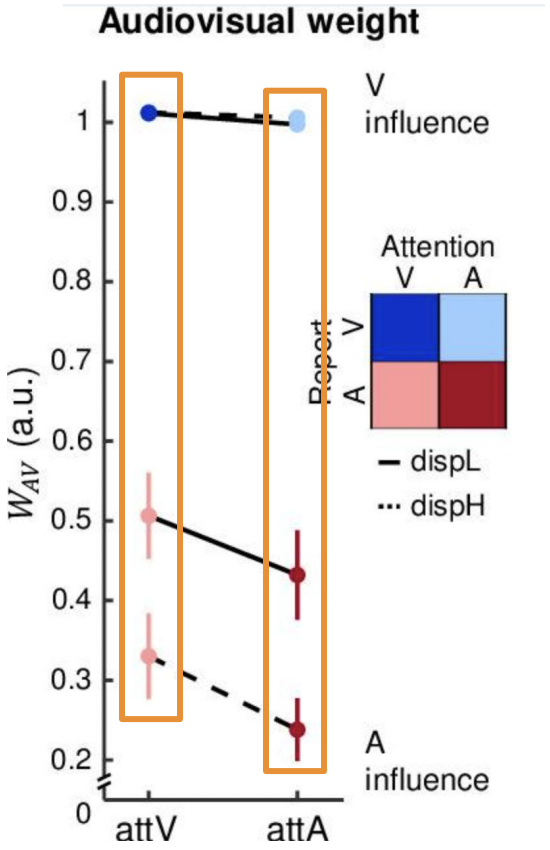
Behavioral results

- Cue effects
- Report effects
- Disparity effects



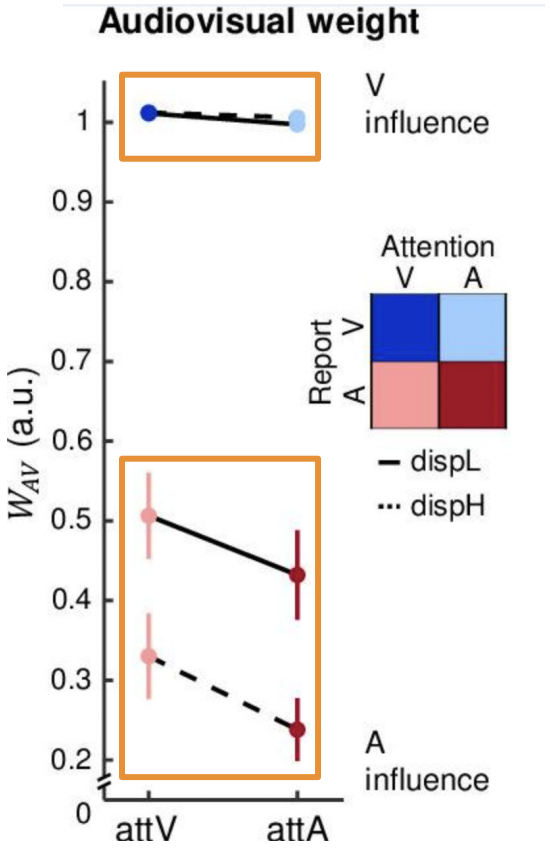
Behavioral results

- **Cue effects**
- Report effects
- Disparity effects



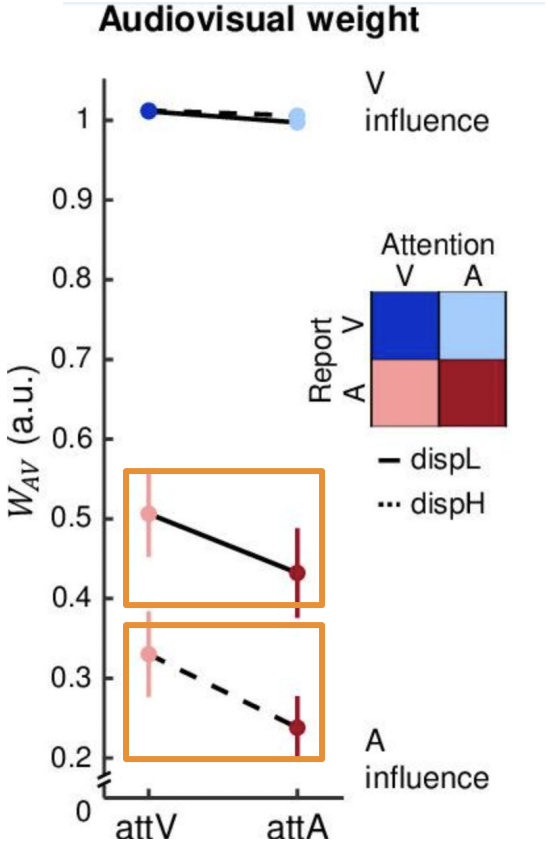
Behavioral results

- Cue effects
- **Report effects**
- Disparity effects



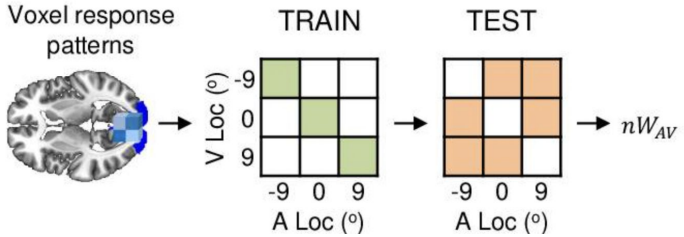
Behavioral results

- Cue effects
- Report effects
- **Disparity effects**



Multivariate decoding

- Computed neural AV weight index (nwAV) for incongruent trials using fMRI data from congruent trials



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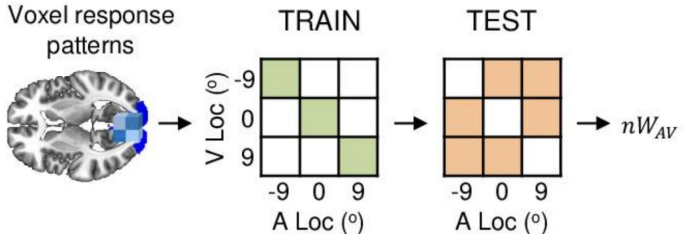

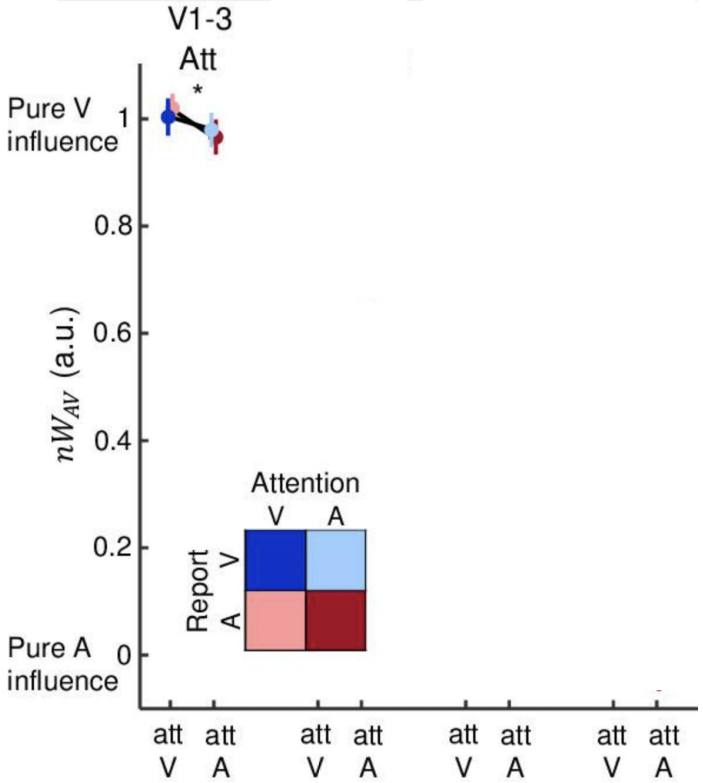

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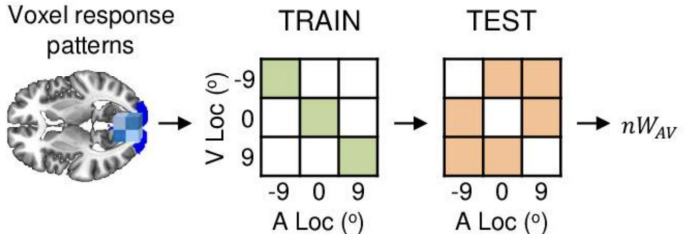

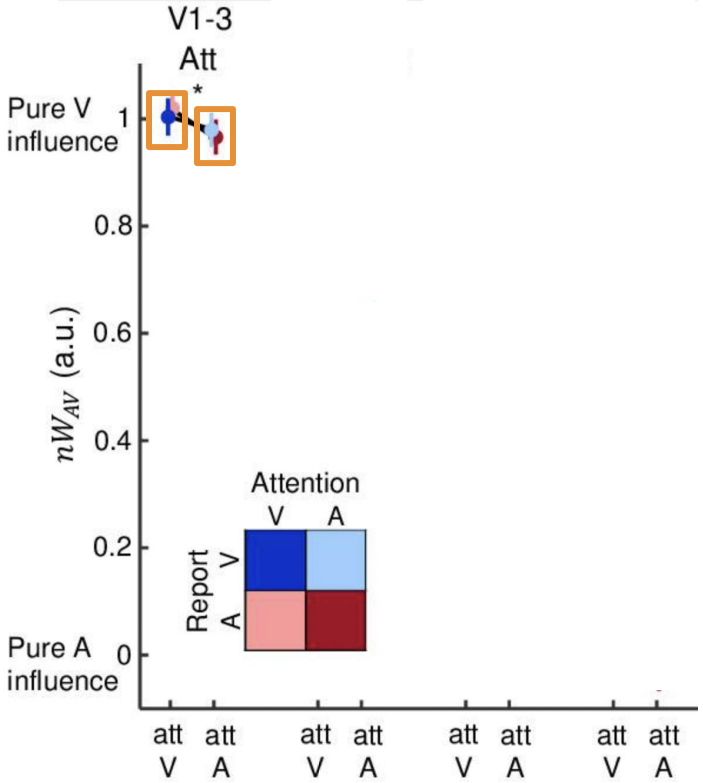

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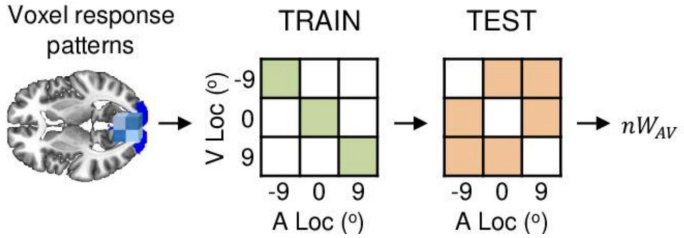

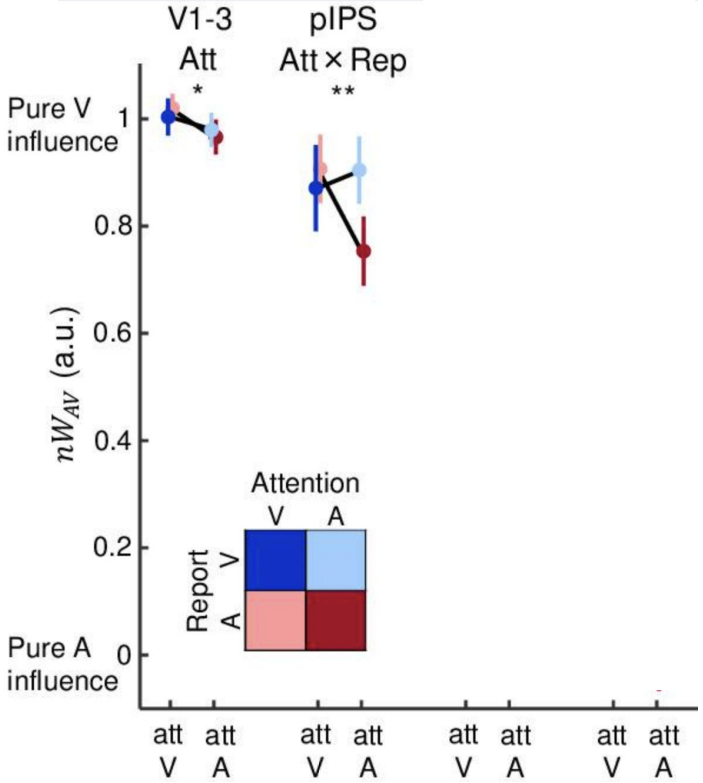

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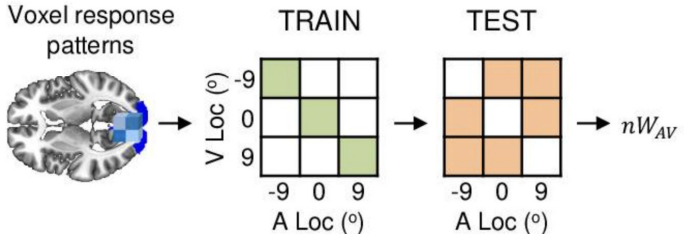

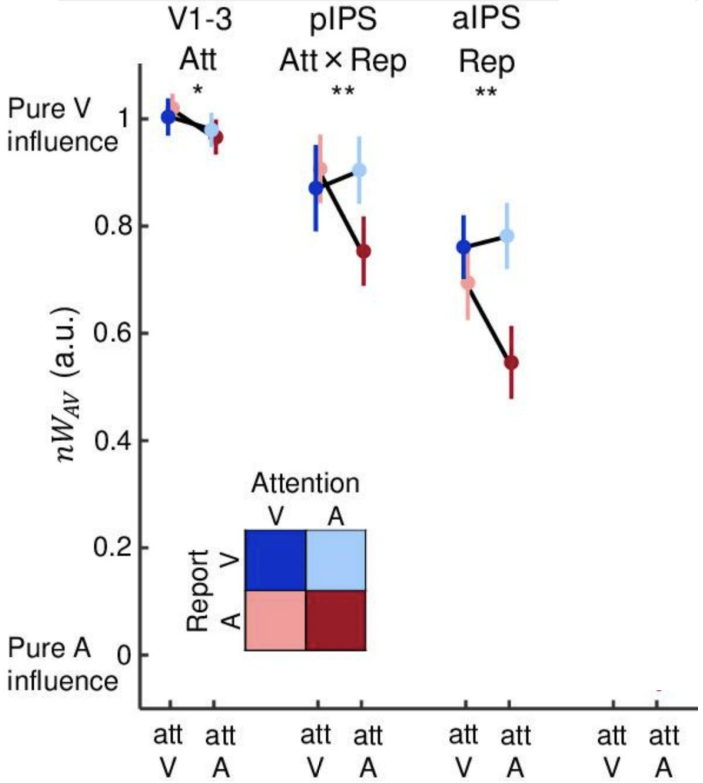

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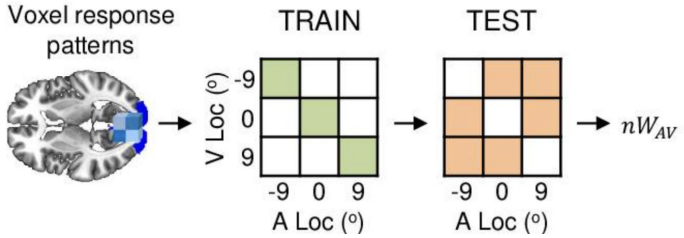

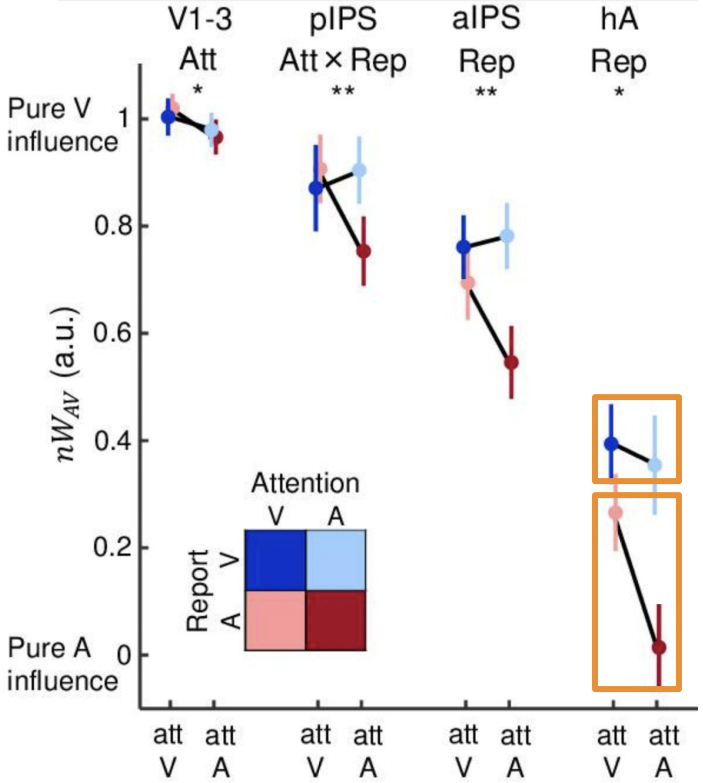

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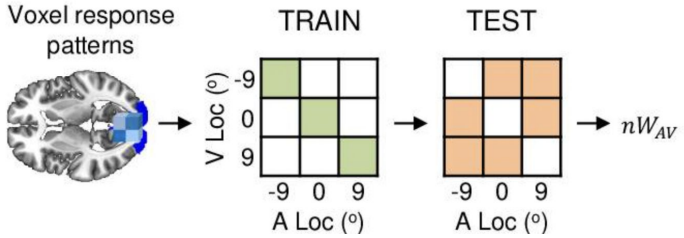
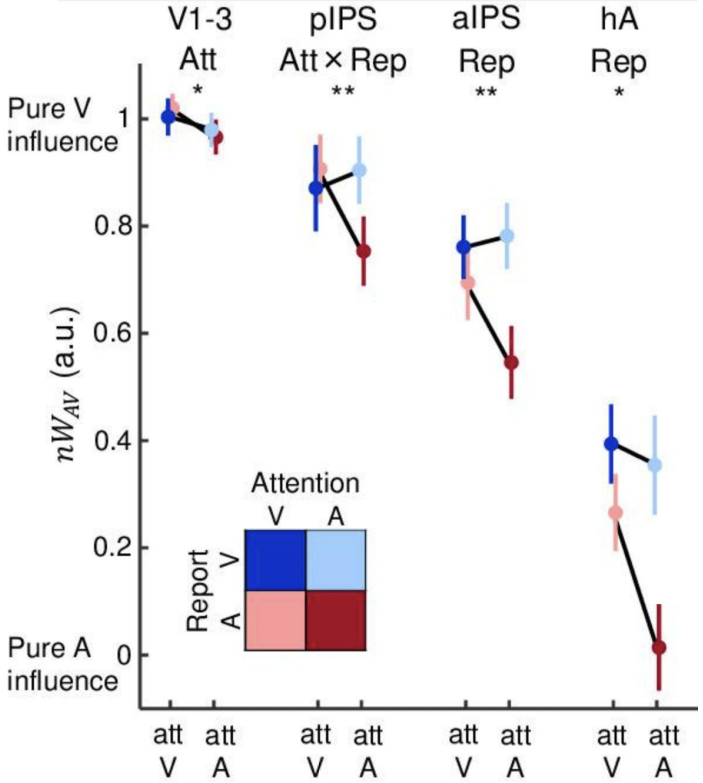


- Multisensory interactions increase progressively along the cortical hierarchy



Conclusions

1. Multisensory processing controlled by frontoparietal insular system
2. Prestimulus attention → precision of sensory input & weights for forced fusion
3. Poststimulus report → task-relevant estimate for Bayesian causal inference
4. Multisensory interactions increase across the cortical hierarchy

Limitations

1. Visual system bias for spatial localization
2. Use of visual-only cues
3. Use of highly reliable stimuli limits multisensory integration
4. Effect of button press on cortical responses
5. Temporal limitations of fMRI

Questions

1. How would the results be different for a temporal order judgement task?

2. What do you think would happen if they used an auditory or audiovisual cue?

3. Which level of the cortical hierarchy does the ventriloquist effect rely on?

Thank you for your attention!