

# Confidence in Global Motion Direction Discrimination

Can Oluk<sup>1,3</sup>, Martin Szinte<sup>2</sup>, Guillaume S. Masson<sup>2</sup>, Pascal Mamassian<sup>1</sup>

- Behavioral Study (in Paris):

Psychophysics

Modeling



- fMRI Study (in Marseille):

Methods

Analysis Plans



<sup>1</sup> Laboratoire des Systèmes Perceptifs, École Normale Supérieure, Université PSL, CNRS, Paris, France

<sup>2</sup> Institut de Neurosciences de la Timone (UMR 7289), Centre National de la Recherche Scientifique and Aix-Marseille Université, Marseille, France

<sup>3</sup> Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

# Confidence in Global Motion Direction Discrimination



- Visual Motion Direction
- Confidence about the estimated direction

Understand the computational and neural mechanisms of confidence judgements

# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):

Psychophysics

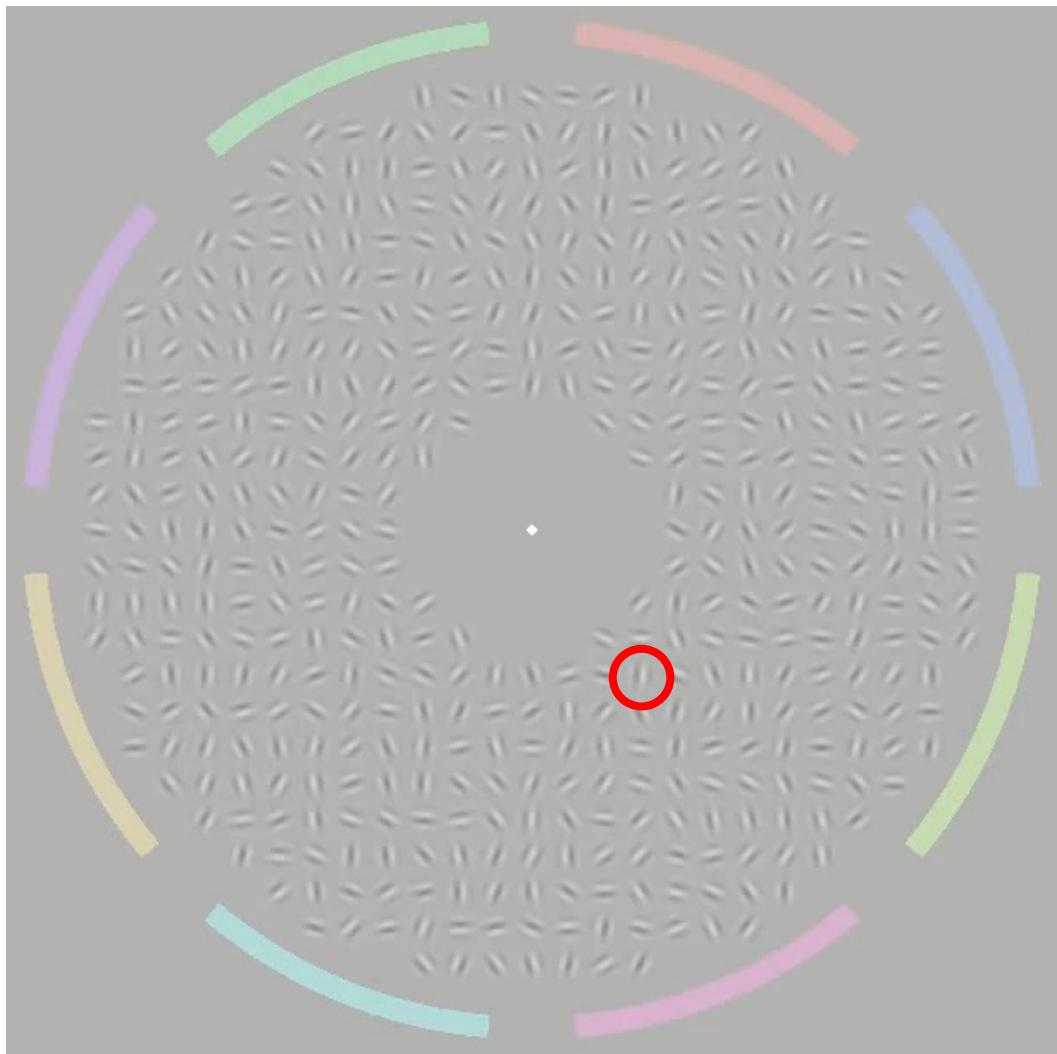
Modeling

- fMRI Study (in Marseille):

Methods

Analysis Plans

# Confidence in Global Motion Direction Discrimination: Behavioral Study



Drifting Gabor Stimuli (Amano et al., 2009, JoV)

16° diameter stimuli (4° diameter blank)

468 drifting Gabors

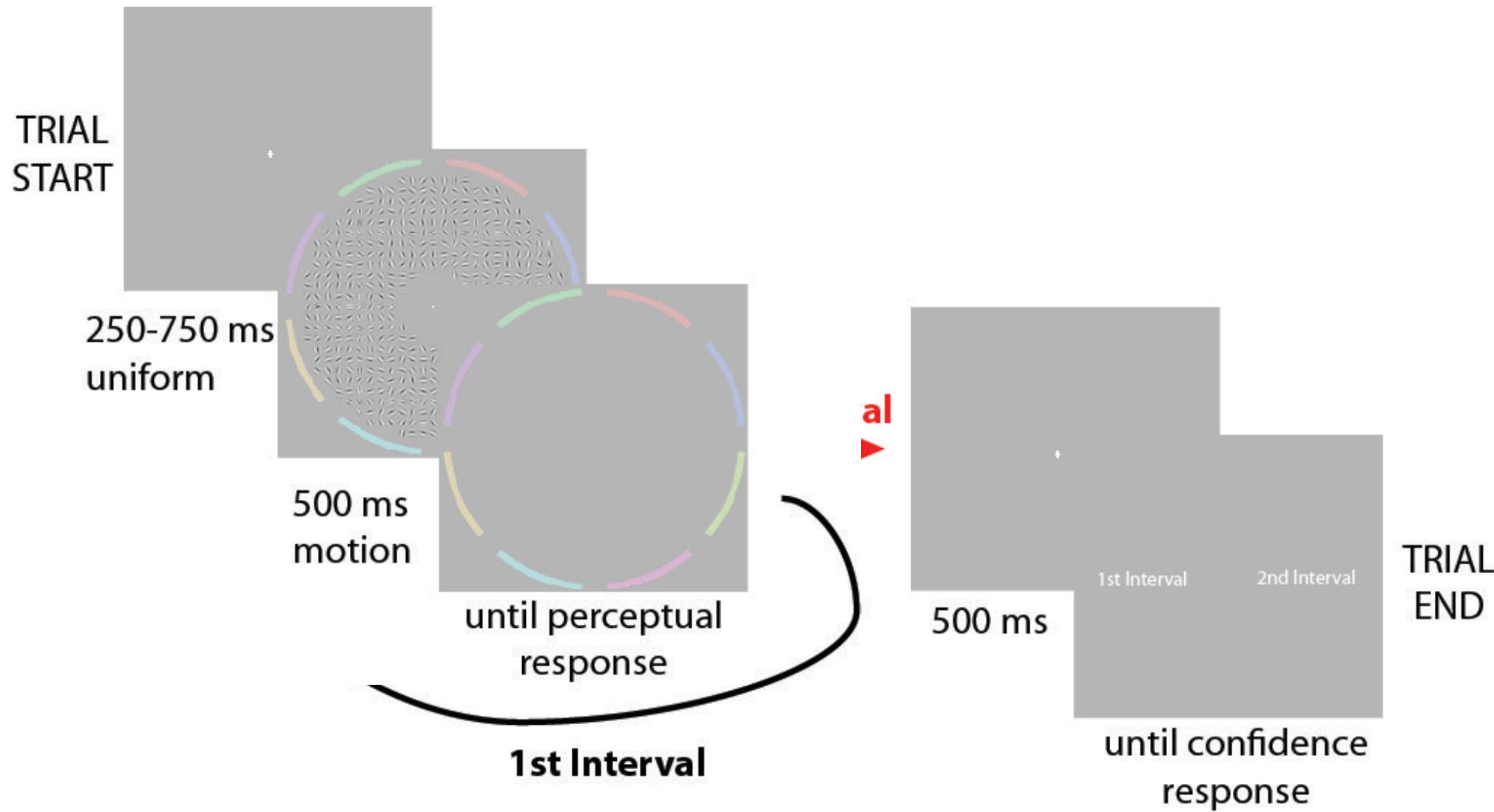
8 possible directions of global motion (2D)

Global motion speed: 0.5° per second

4 Coherence levels: 0.3, 0.5, 0.7 and 0.9  
(fraction of Gabor patches consistent with global motion)

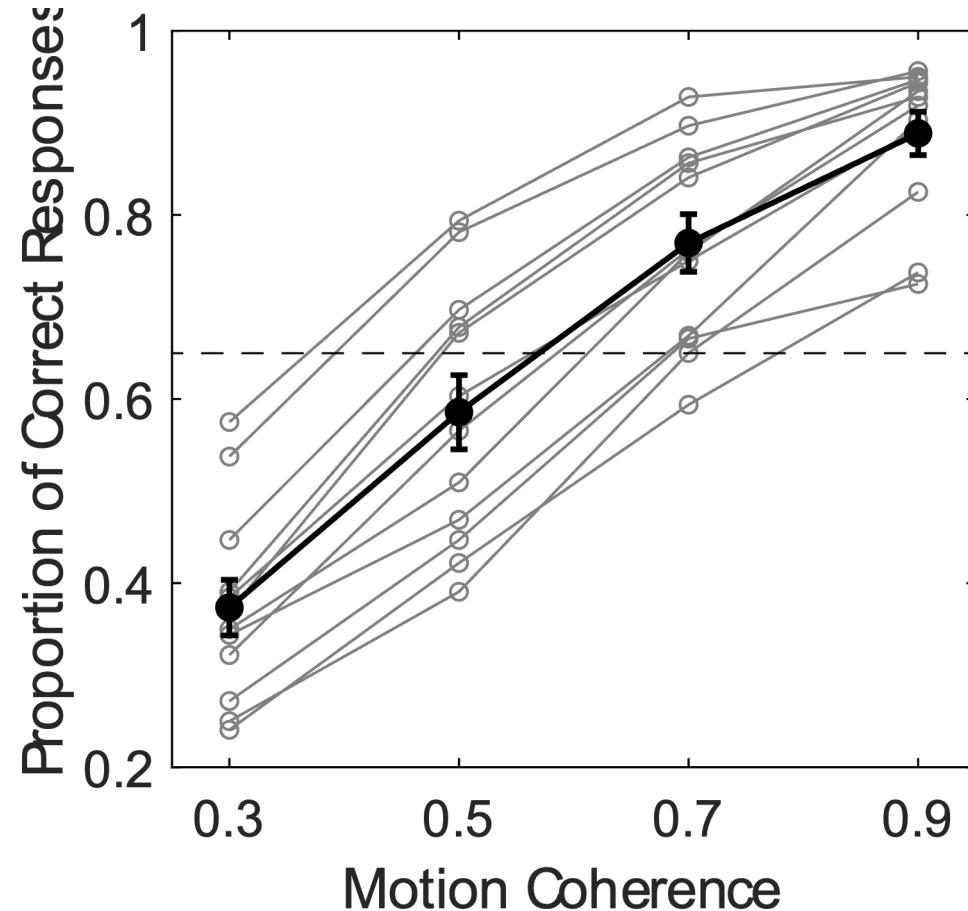
Perceived local motion in isolation is most of the time different than global motion.

# Confidence in Global Motion Direction Discrimination: Behavioral Study

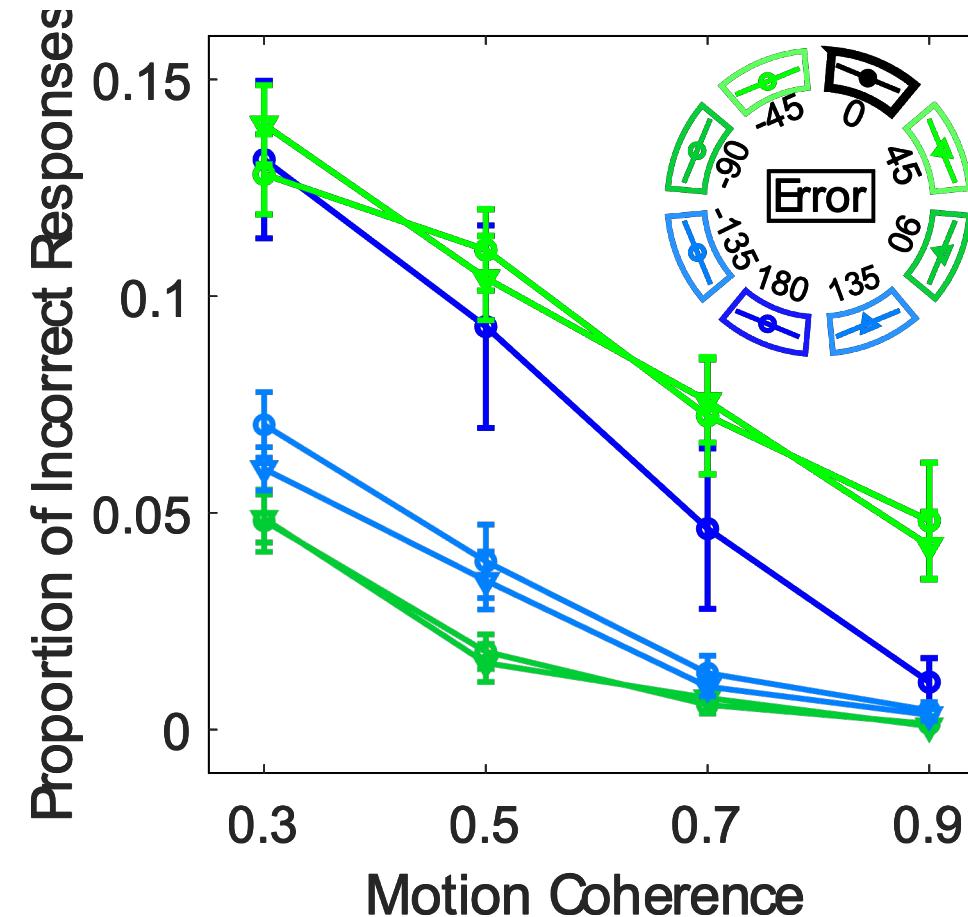


# Confidence in Global Motion Direction Discrimination: Behavioral Study

## Perceptual Responses



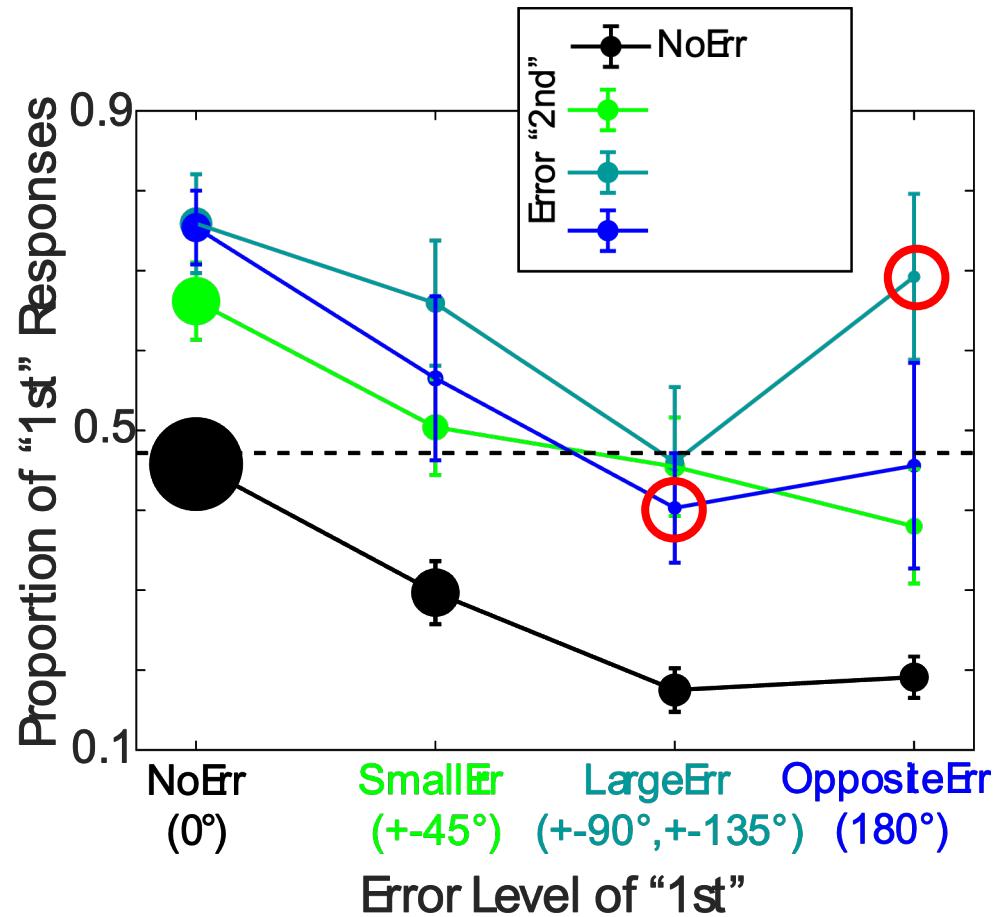
- Performance increases with motion coherence



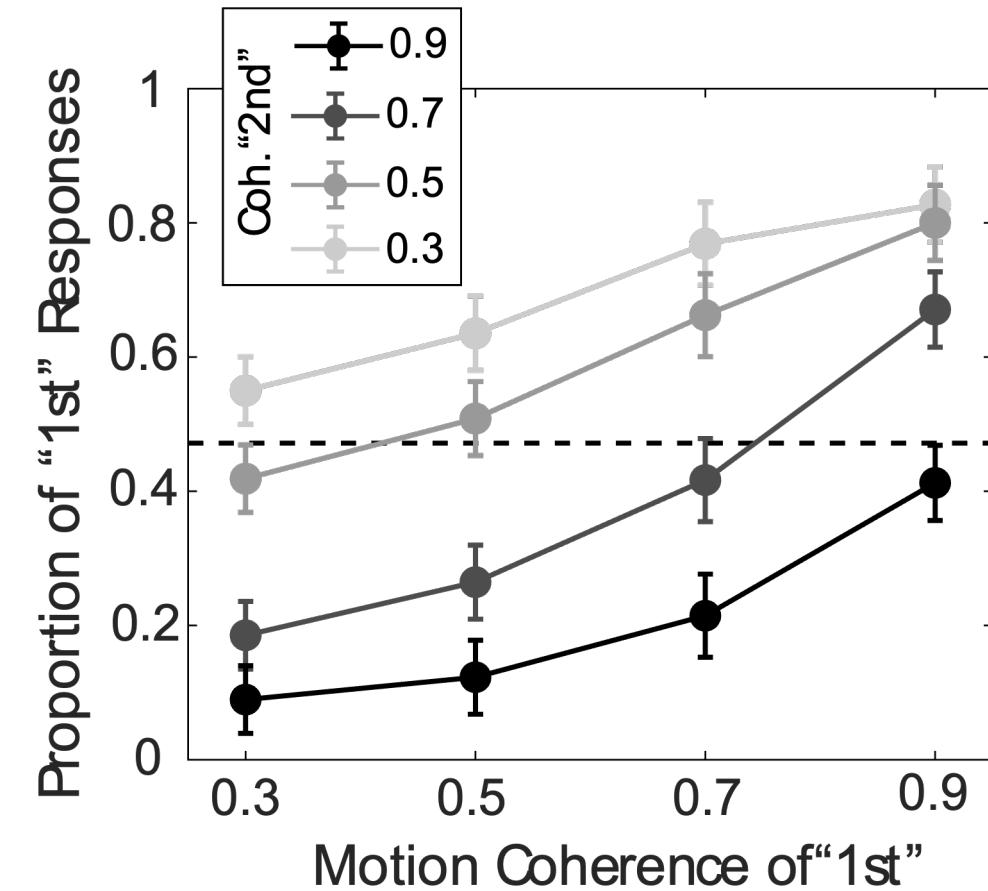
- Opposite-direction effect

# Confidence in Global Motion Direction Discrimination: Behavioral Study

## Confidence Responses



- Successful confidence judgments tied to perceptual performance
- Opposite-direction effect in confidence



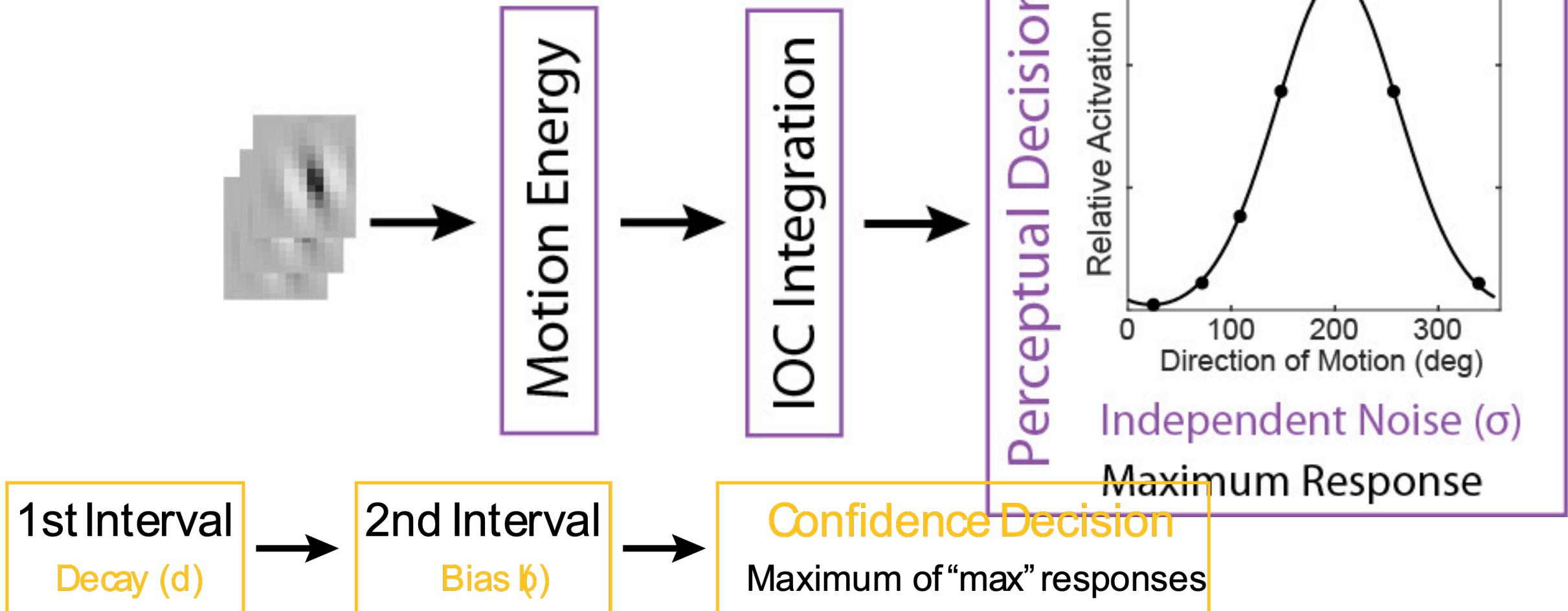
- Successful confidence judgments tied to motion coherence

# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):
    - Psychophysics
    - Modeling
  - fMRI Study (in Marseille):
    - Methods
    - Analysis Plans
- Opposite-direction effect in perceptual and confidence responses
  - Good and sensible perceptual and confidence performance

# Confidence in Global Motion Direction Discrimination: Behavioral Study

## The Standard Motion Energy Model with IOC Integration



Simoncelli & Heeger, 1998; Rust et al., 2006; Kane et al., 2011

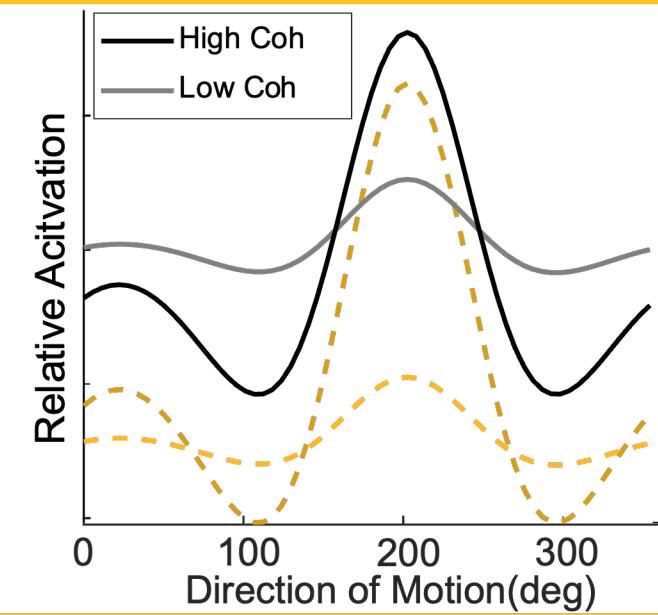
# Confidence in Global Motion Direction Discrimination: Behavioral Study

Addition of two plausible mechanisms

Dependency between motion coherence and total response

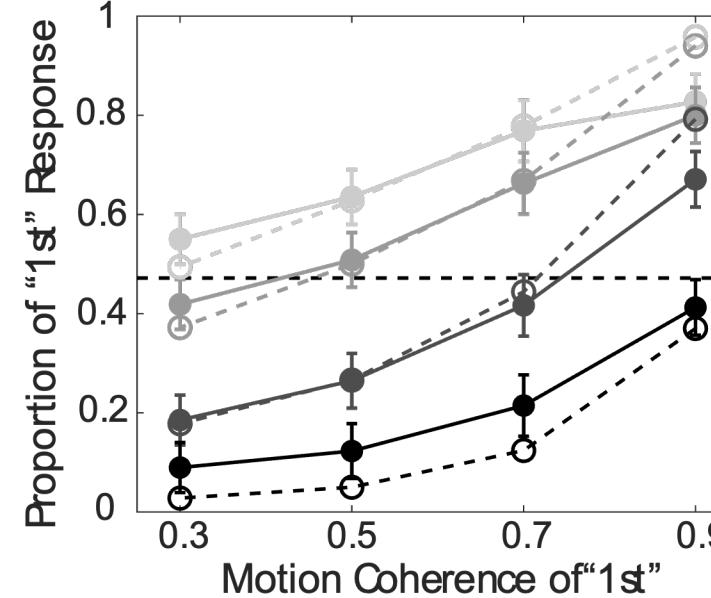
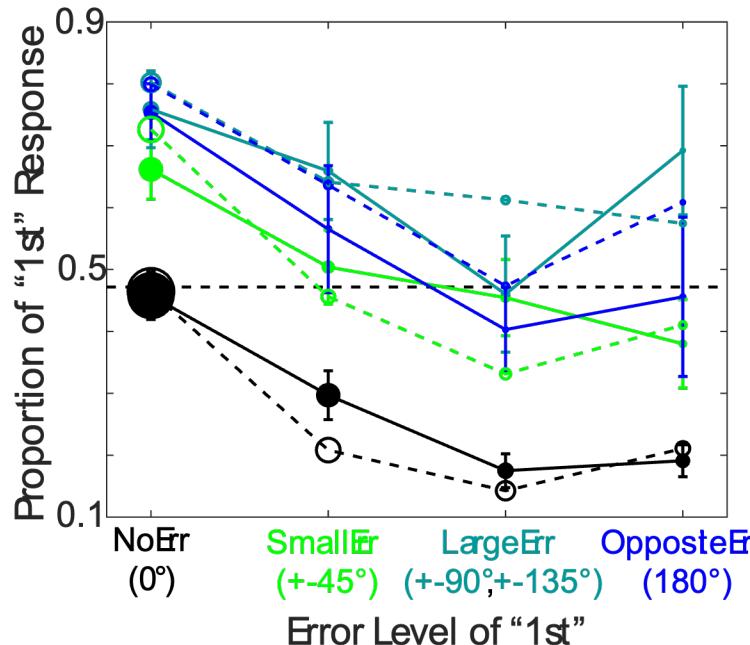
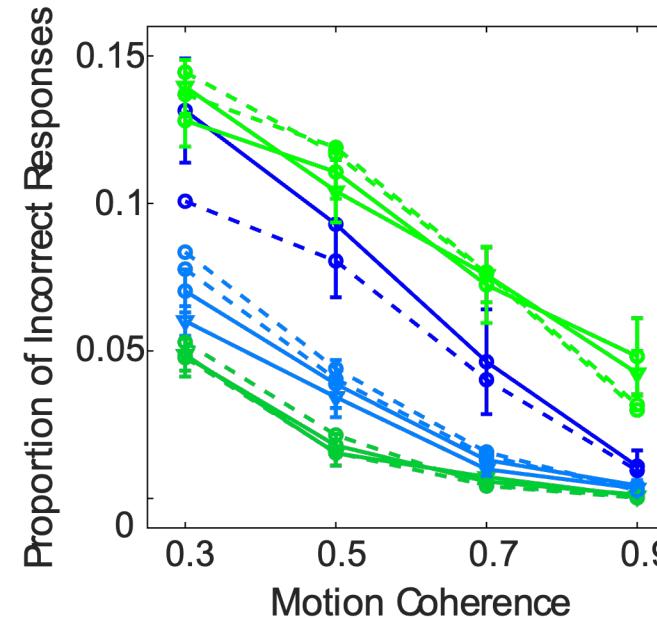
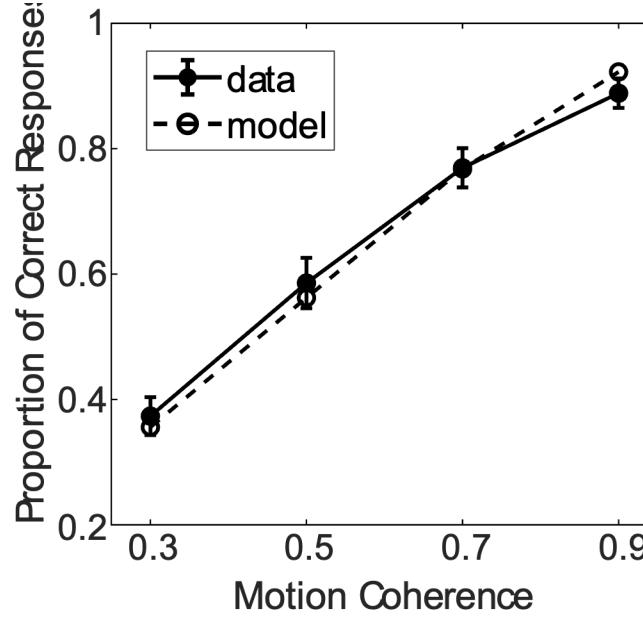
Gain-like Untuned Inhibition

gain factor ( $g$ )



Parameters:  $\sigma, w, i$  (Perceptual responses),  $d, b, g$  (Confidence responses)

# Confidence in Global Motion Direction Discrimination: Behavioral Study



- Six free parameters explain most of the variance in perceptual and confidence responses.

# Confidence in Global Motion Direction Discrimination

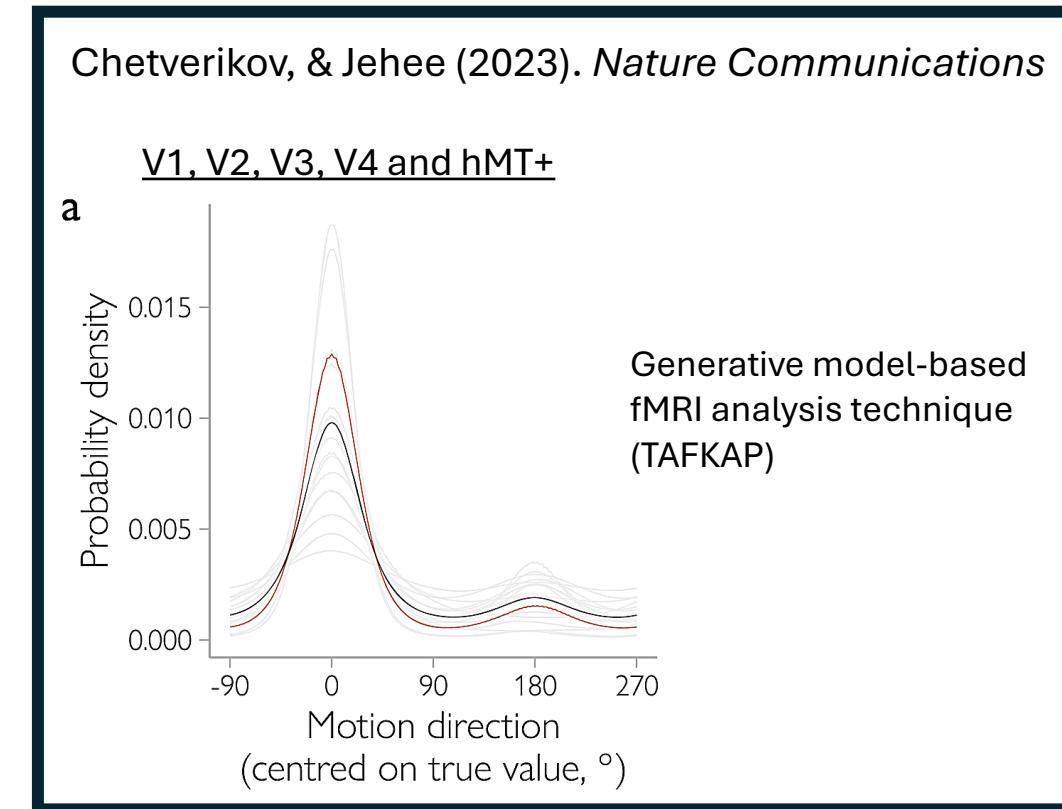
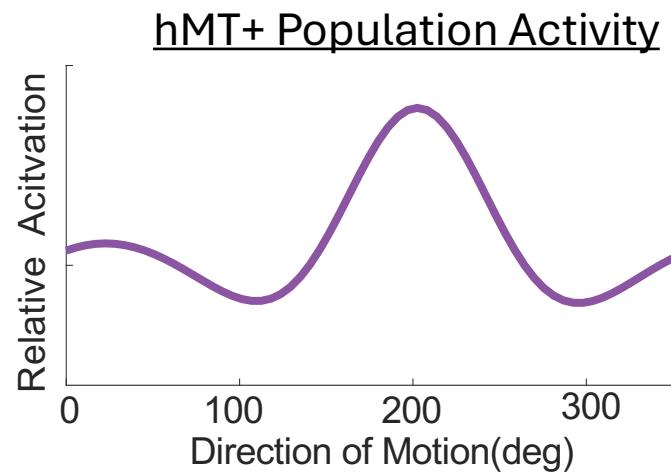
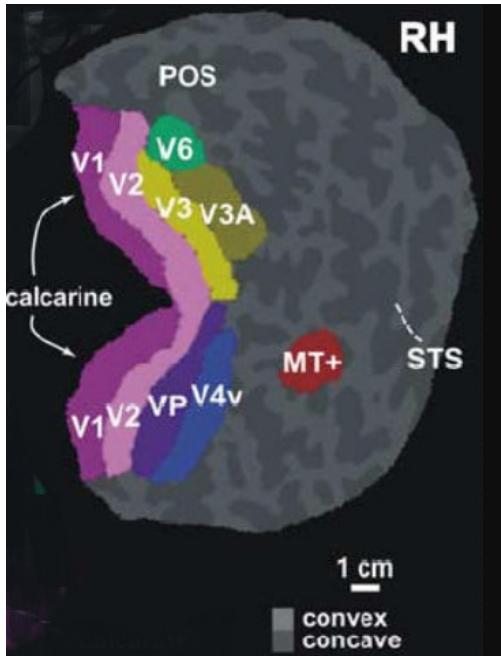
- Behavioral Study (in Paris):  
Psychophysics  
Modeling
  - Opposite-direction effect in perceptual and confidence responses
  - Good and sensible perceptual and confidence performance
  - Standard model of motion processing with plausible mechanisms explain both perceptual and confidence responses
- fMRI Study (in Marseille):  
Methods  
Analysis Plans

Confidence responses are strongly tied to perceptual reliability and predominantly inherit characteristics from the associated visual mechanisms.

# Confidence in Global Motion Direction Discrimination: fMRI Study

## Motivation

1. The opposite direction effect is a perceptual effect.



# Confidence in Global Motion Direction Discrimination: fMRI Study

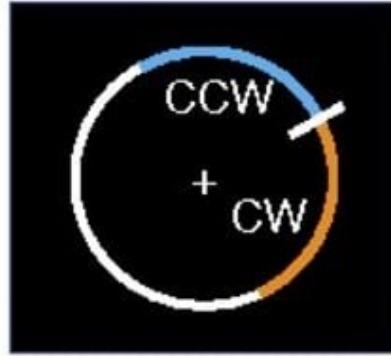
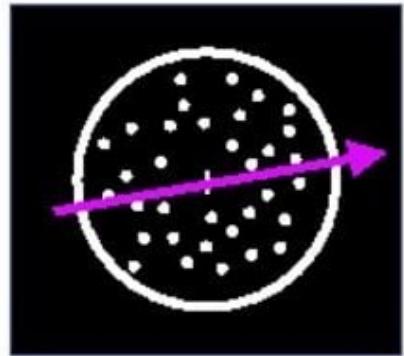
## Motivation

2. C

1s

unlimited

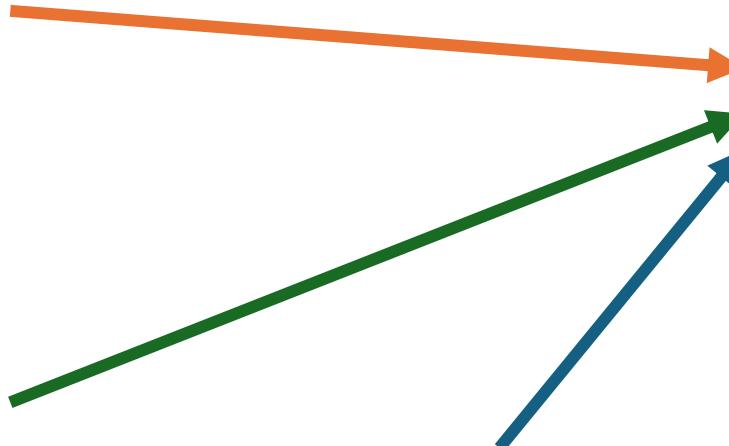
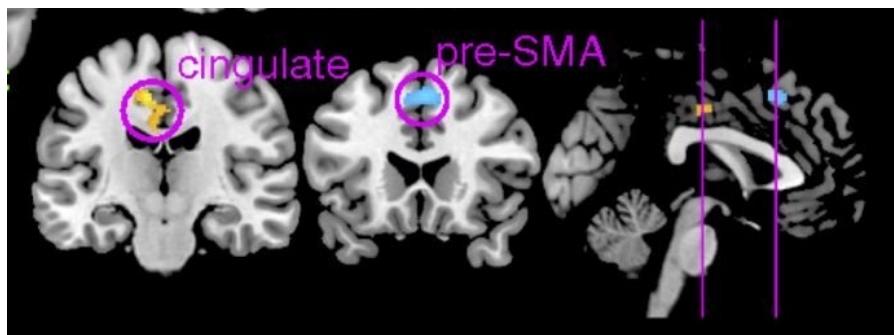
ability.



dot motion  
1 to 360°

reference  
-45° to 45°

### Cognitive factors

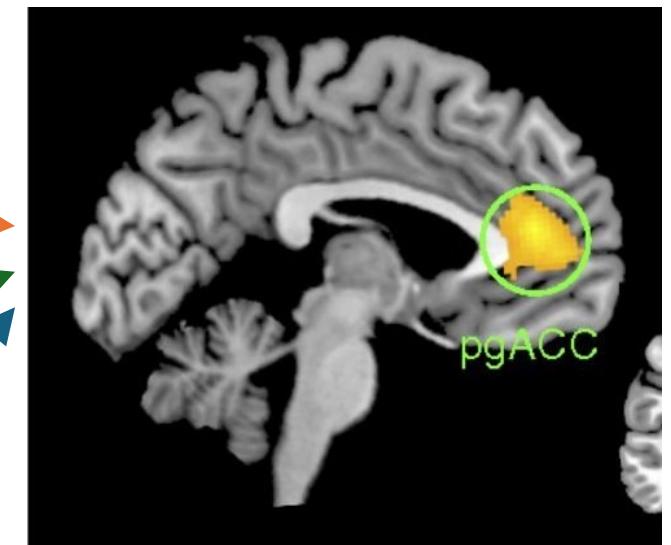


### Other visual factors

Range of Directions (Spence et al., 2016)

Local Contrast (Lee et al., 2023)

Total Positive evidence (Koizumi et al., 2015)



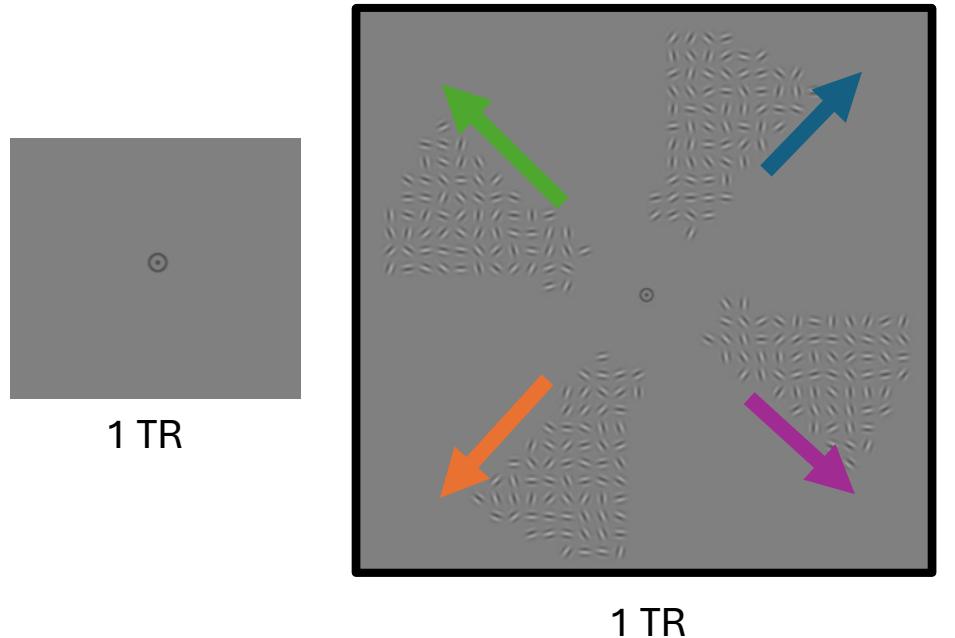
# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):  
Psychophysics  
Modeling
  - Neural mechanisms of opposite-direction effect
  - Neural mechanisms of confidence formation in a global motion direction discrimination task with complex stimuli
- fMRI Study (in Marseille):  
Methods  
Analysis Plans

# Confidence in Global Motion Direction Discrimination: fMRI Study

## Perceptual Part

### Interval 2



TR: 1.2 s

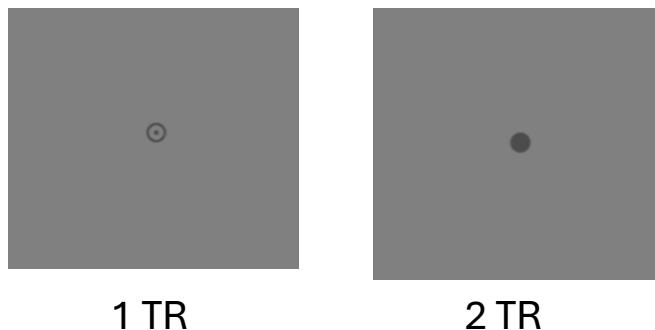
19° diameter stimuli (5° diameter blank)

Fixed Windmill configuration (268 Gabor)

4 possible directions (no color wheels)

3 coherence levels (0.3, 0.6, 0.9)

## Confidence Part



A single trial is 11 TR (13.2 seconds)

# Confidence in Global Motion Direction Discrimination: fMRI Study

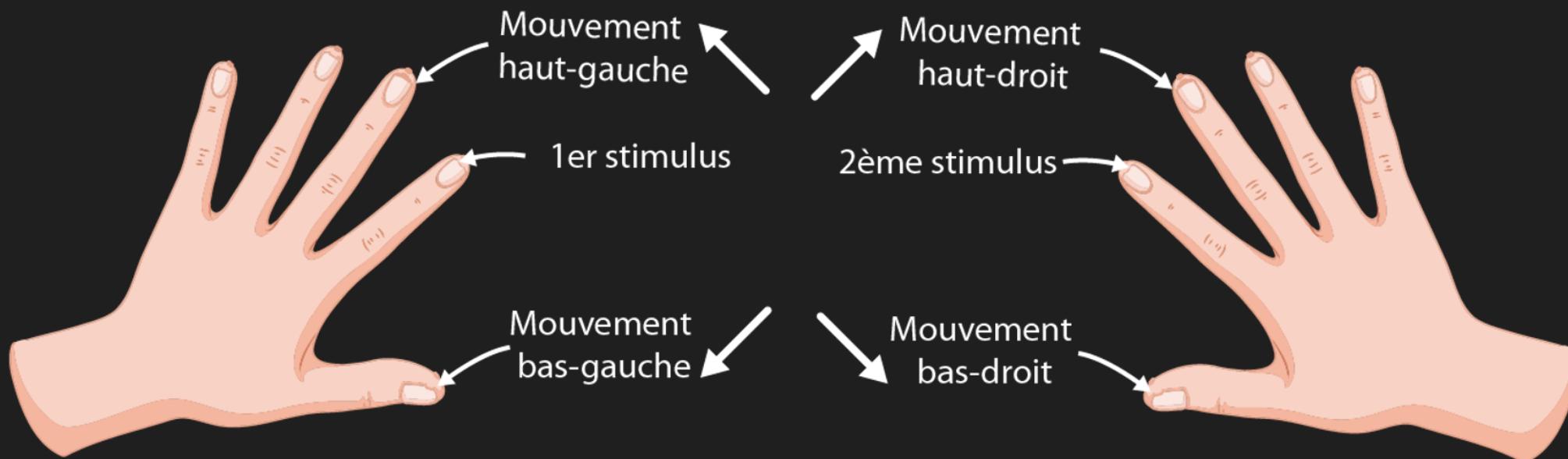
## Tâches

Gardez à tout instant le regard fixé sur le point de fixation.

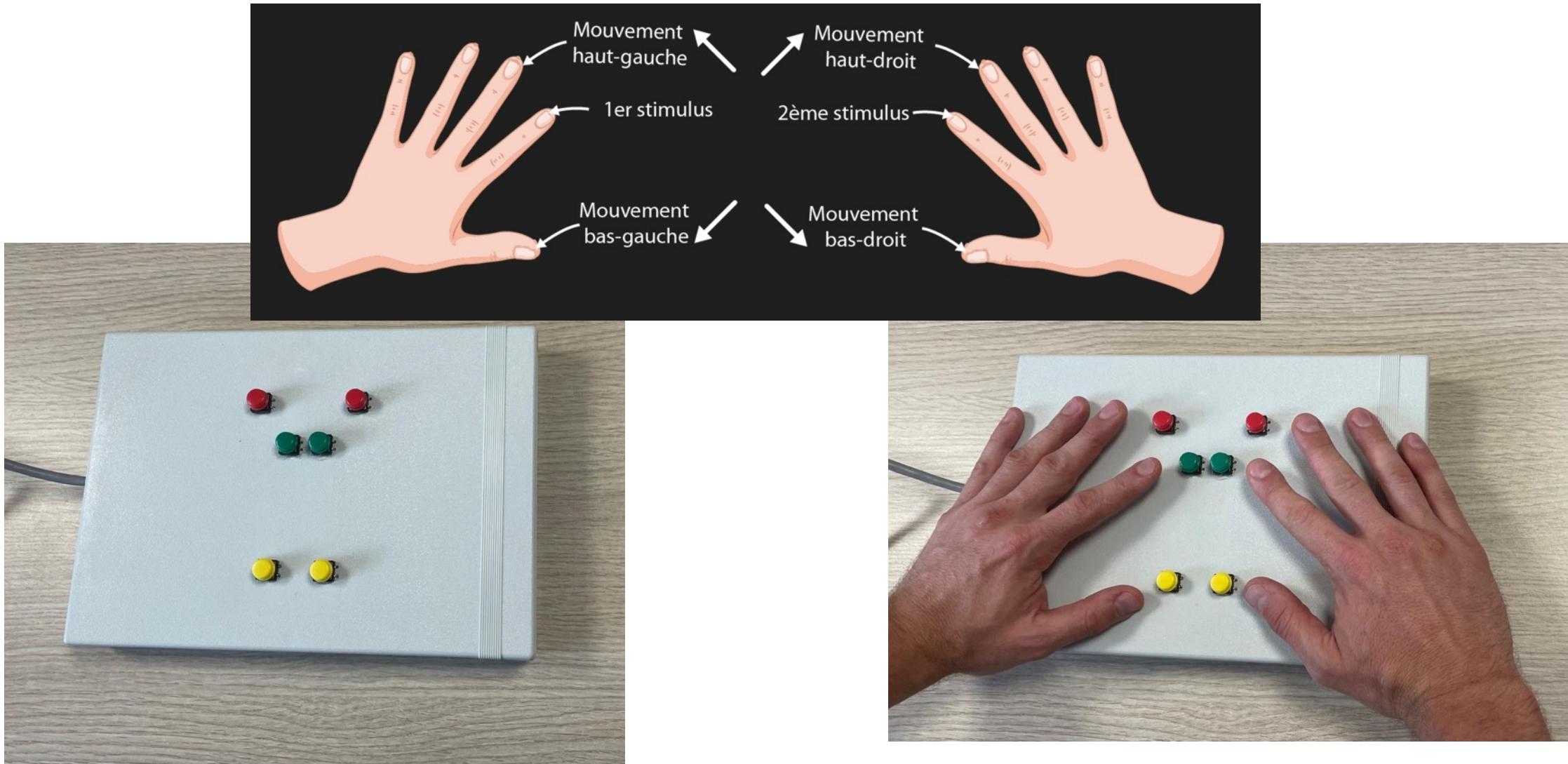
Deux stimuli en mouvement vont vous être présentés séquentiellement.

Après chaque stimulus, reportez sa direction.

Reportez ensuite le stimulus (1er ou 2ème) pour lequel votre décision a le plus de chance d'être correcte.



# Confidence in Global Motion Direction Discrimination: fMRI Study



Response box



# Confidence in Global Motion Direction Discrimination: fMRI Study

(Fast) Event related design – A single run: 3x3 coherence, 4 trials each, 36 trials (8 minutes)

Session 1: Behavioral Psychophysics – Training with the audio feedback

Session 2: fMRI (one-and-a-half hour session)

- Anatomy Scans (T1, T2)
- 5 runs of Retinotopy (4 minute per run) – 2 runs of Retinotopy
- 5 runs of MotConf (8 minutes per run)

Session 3: fMRI (one hour session)

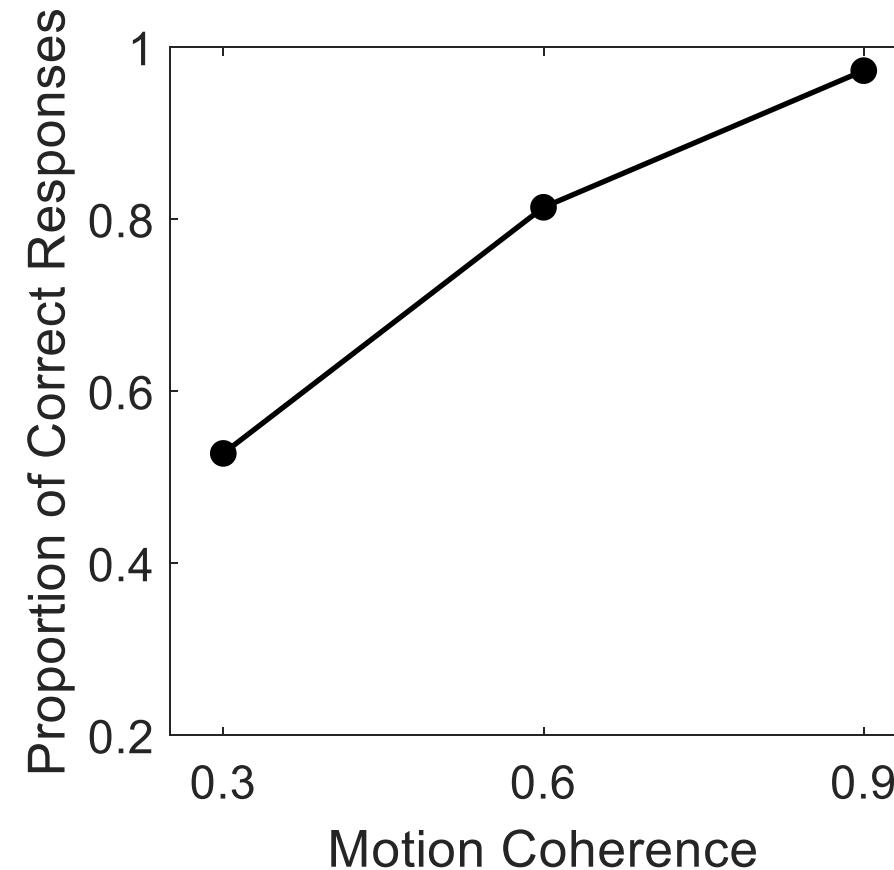
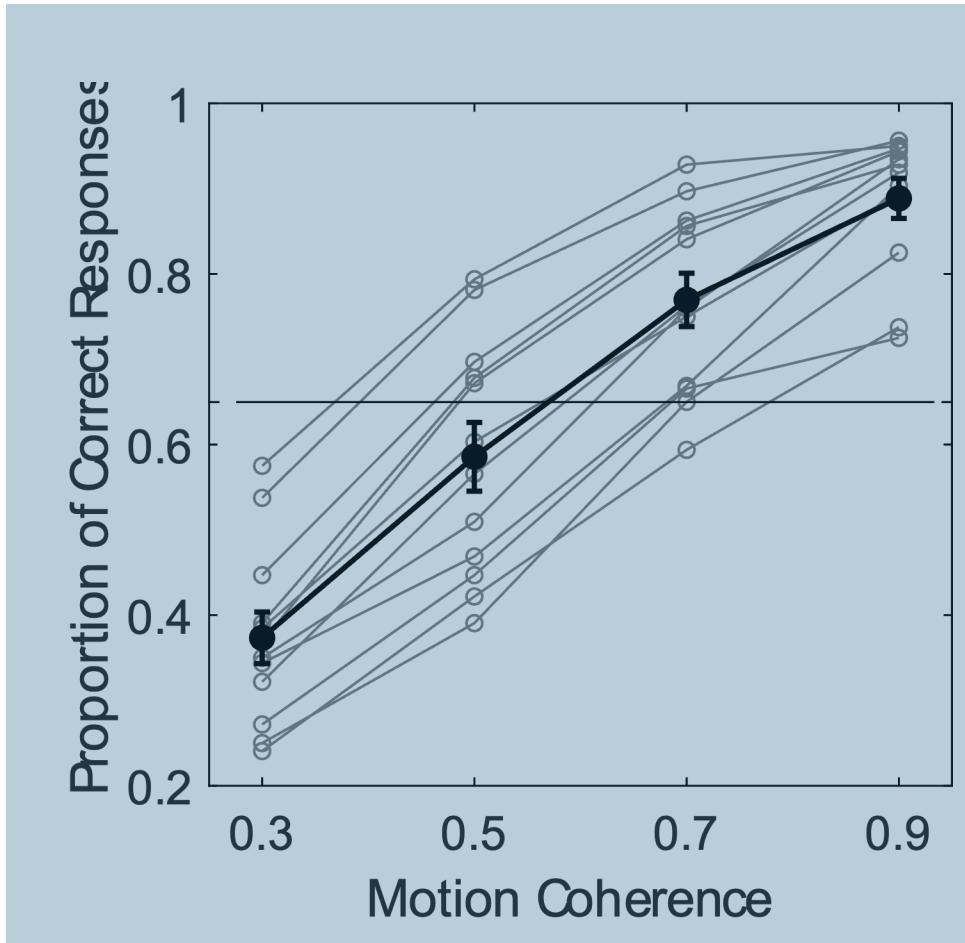
- 2 runs of Retinotopy (4 minute per run)
- 5 runs of MotConf (8 minutes per run)

# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):
  - Psychophysics
  - Modeling
- fMRI Study (in Marseille):
  - Methods
  - Analysis Plans
    - I. Behavioral Results (Pilot)
    - II. Retinotopy – Population Receptive Fields
    - III. Generative model-based fMRI analysis technique (TAFKAP)
- Neural mechanisms of opposite-direction effect
- Neural mechanisms of confidence formation in a global motion direction discrimination task with complex stimuli
- Simplified the task for the fMRI experiment

# Confidence in Global Motion Direction Discrimination: fMRI Study

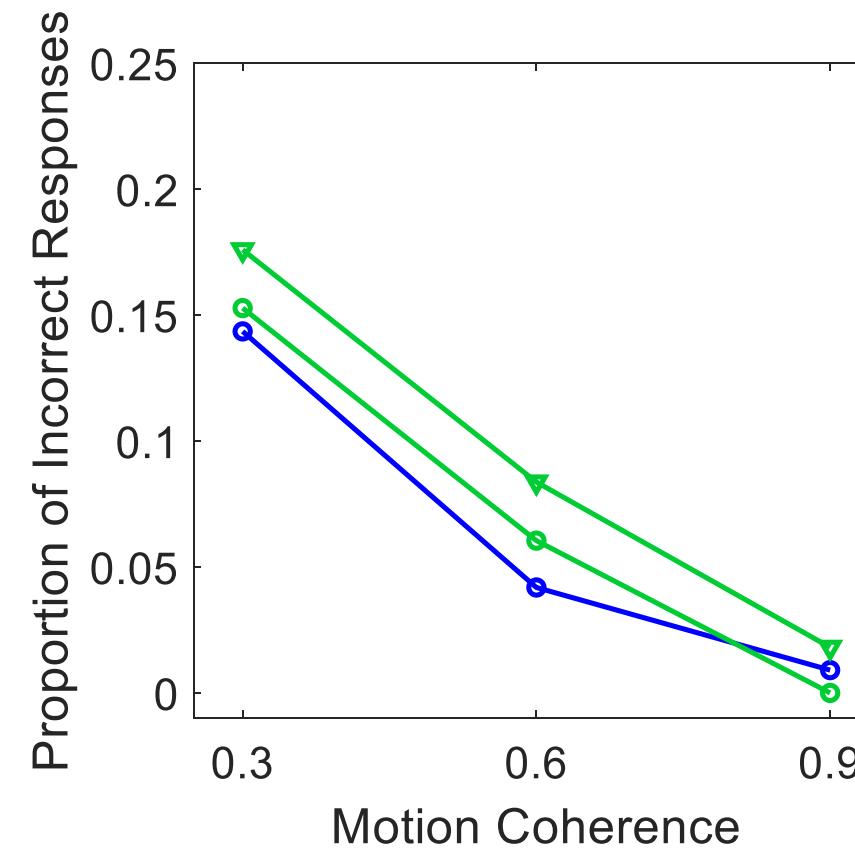
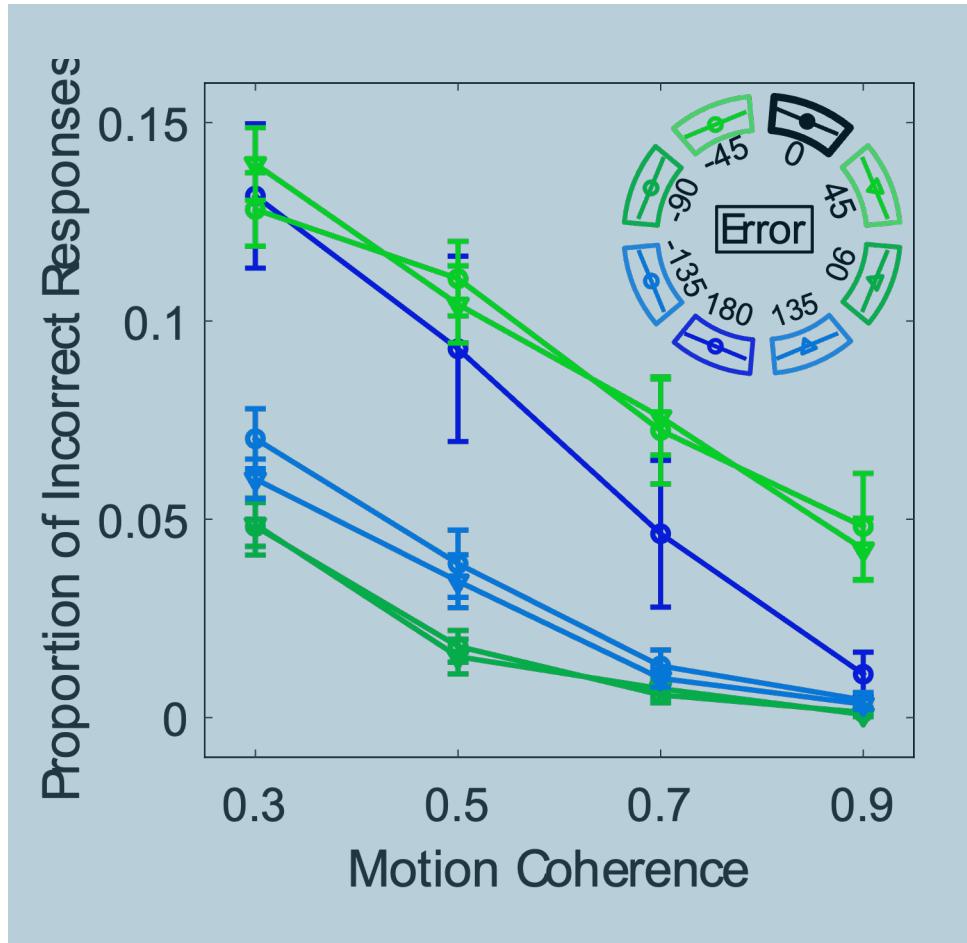
## Behavioral Analysis of Pilot Experiments (n=2)



- Performance increases with motion coherence

# Confidence in Global Motion Direction Discrimination: fMRI Study

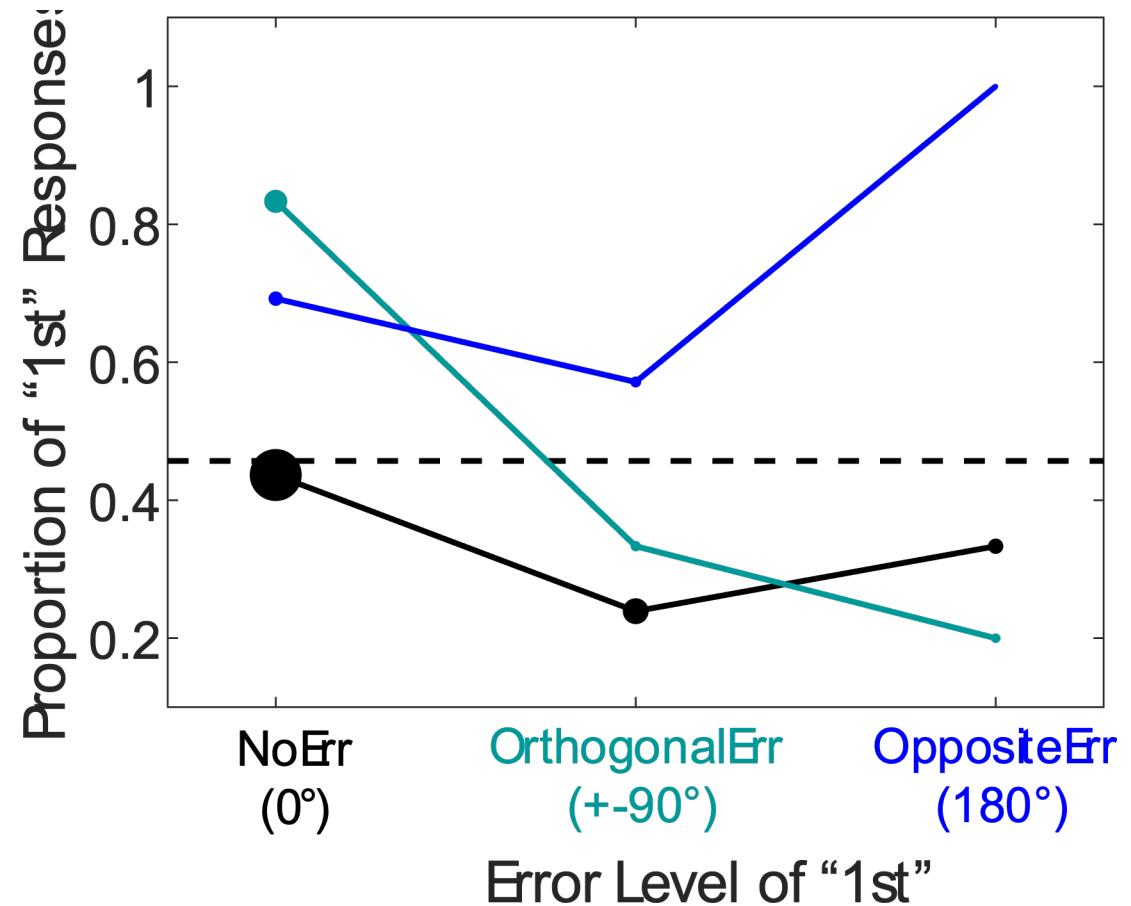
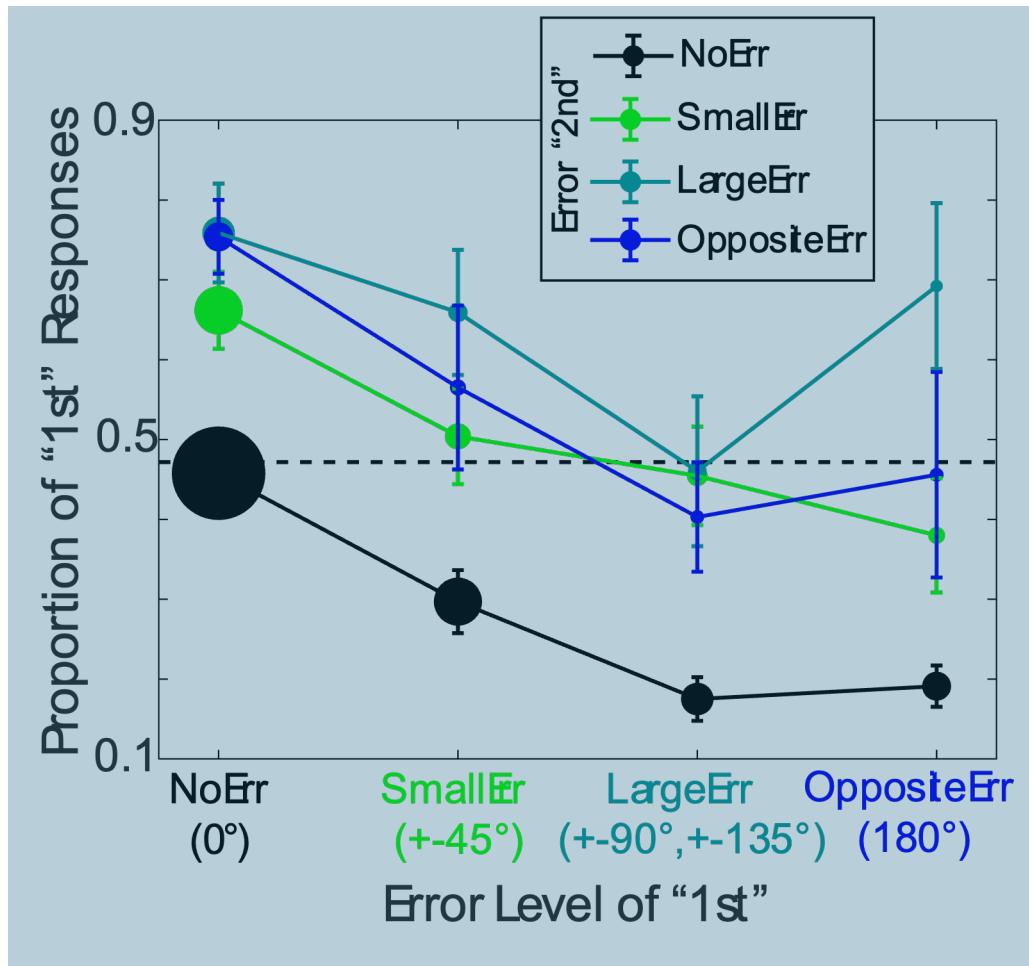
## Behavioral Analysis of Pilot Experiments (n=2)



- Weak Opposite-direction effect

# Confidence in Global Motion Direction Discrimination: fMRI Study

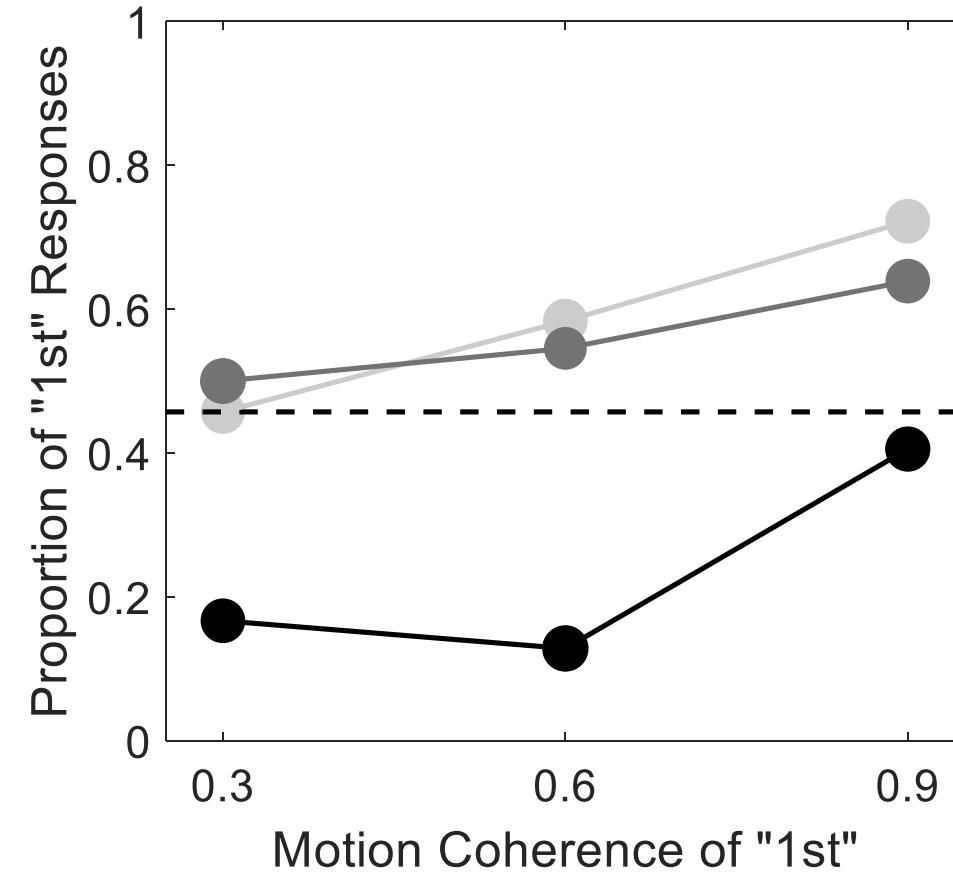
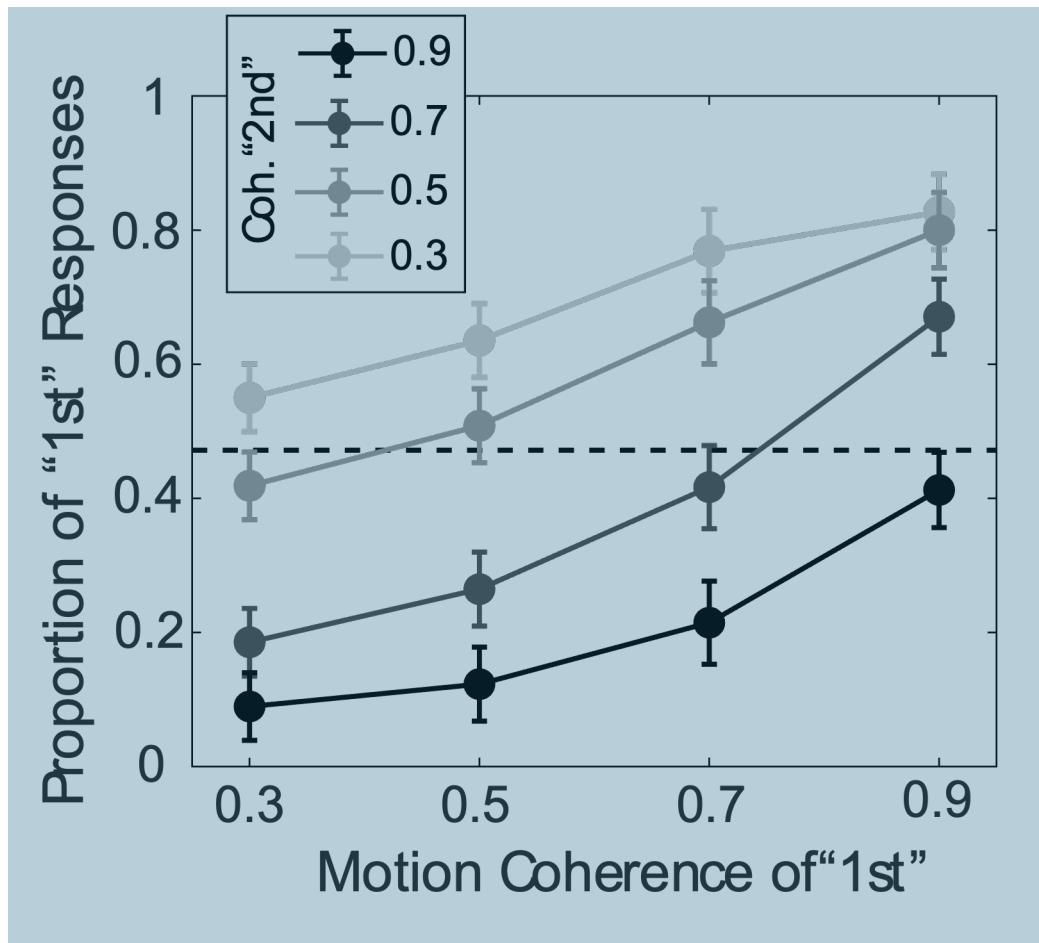
## Behavioral Analysis of Pilot Experiments (n=2)



- Successful confidence judgments tied to perceptual performance
- Weak Opposite-direction effect in confidence

# Confidence in Global Motion Direction Discrimination: fMRI Study

## Behavioral Analysis of Pilot Experiments (n=2)



- Successful confidence judgments tied to motion coherence

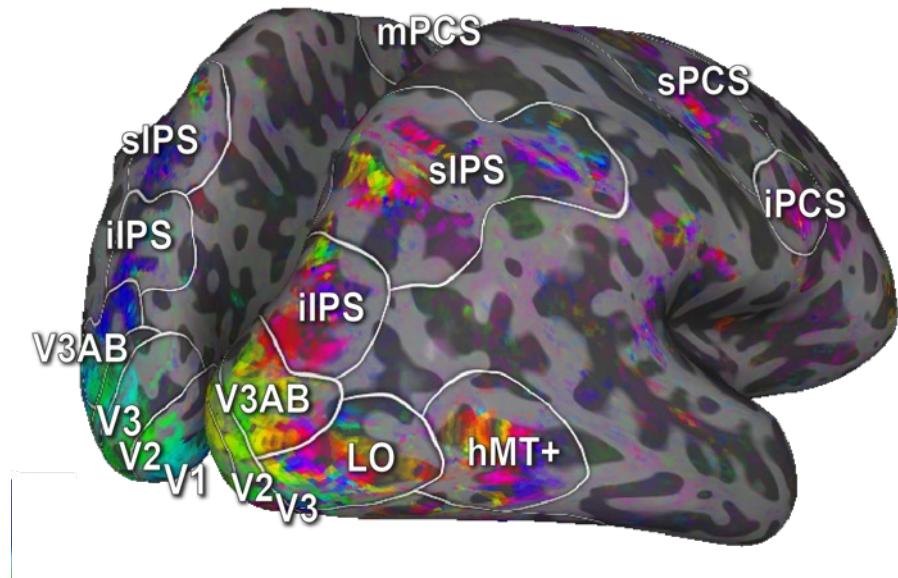
# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):
  - Psychophysics
  - Modeling
- fMRI Study (in Marseille):
  - Methods
  - Analysis Plans
    - I. Behavioral Results (Pilot)
    - II. Retinotopy – Population Receptive Fields
    - III. Generative model-based fMRI analysis technique (TAFKAP)
- Neural mechanisms of opposite-direction effect
- Neural mechanisms of confidence formation in a global motion direction discrimination task with complex stimuli
- Simplified the task for the fMRI experiment

# Confidence in Global Motion Direction Discrimination: fMRI Study

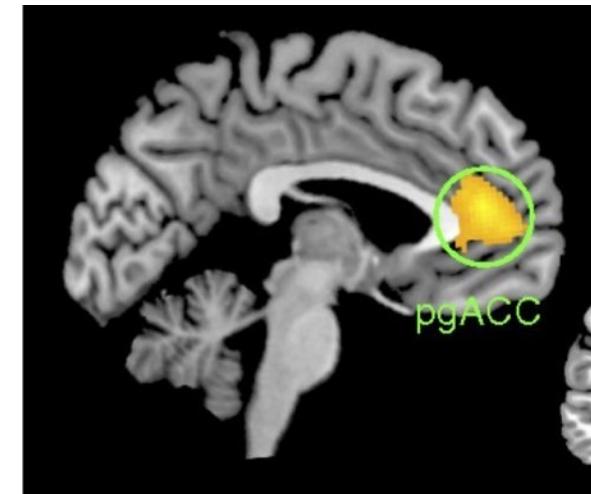
## fMRI Analysis of Pilot Experiments (n=2)

V1, V2, V3, V4, and hMT+ and intraparietal sulcus (IPS)



Retinotopy (Population Receptive Fields)

Anterior Cingulate and Medial Prefrontal

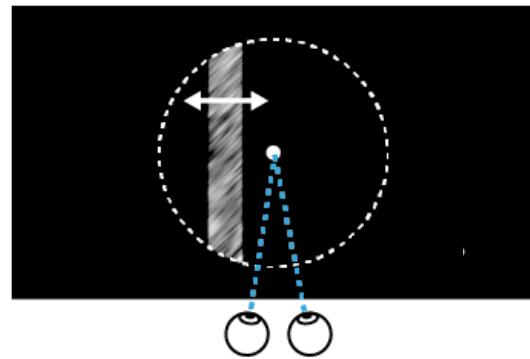


Anatomy (HCP-MMP1)

(the perigenual) anterior cingulate cortex  
(the dorsal) anterior cingulate cortex

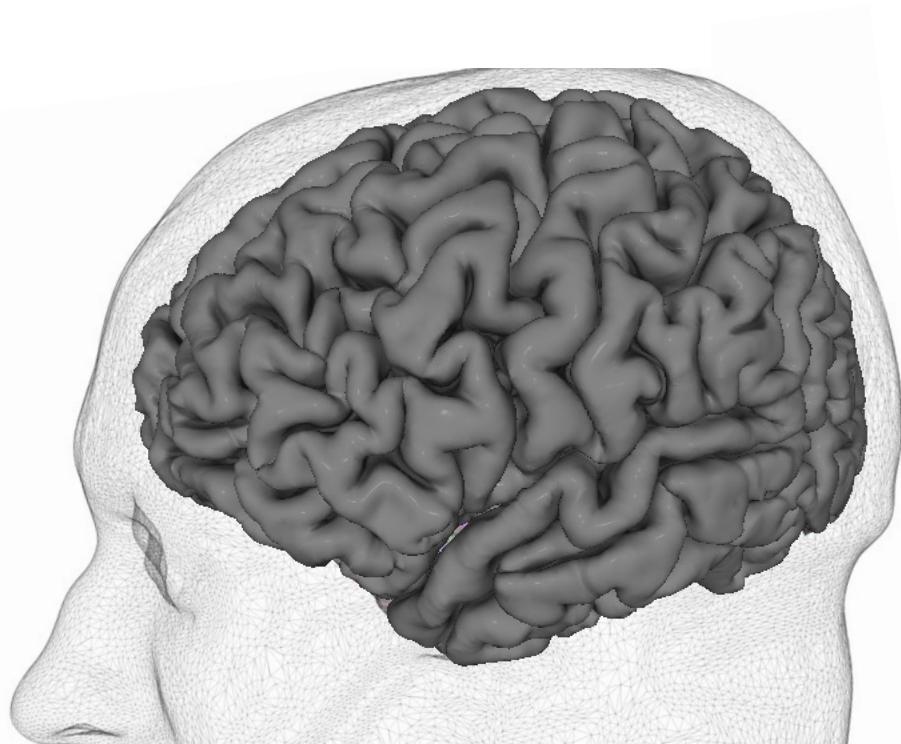
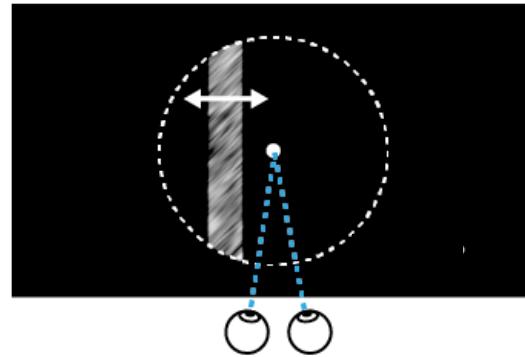
# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



# Confidence in Global Motion Direction Discrimination: fMRI Study

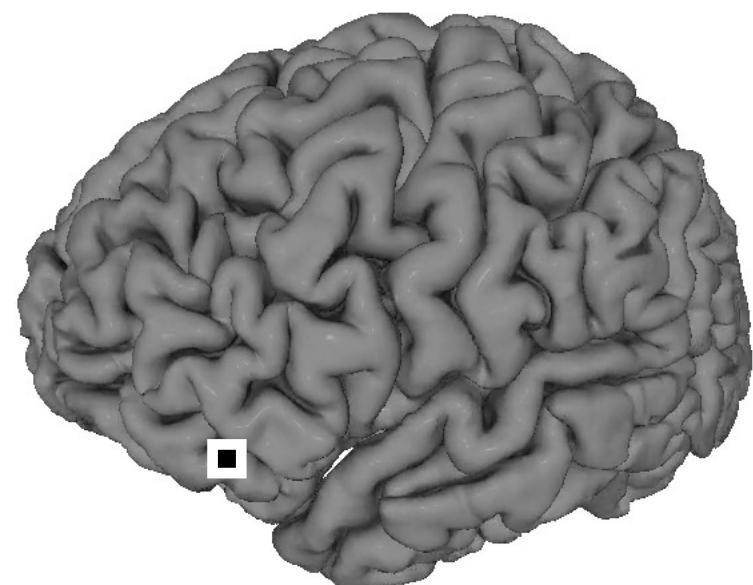
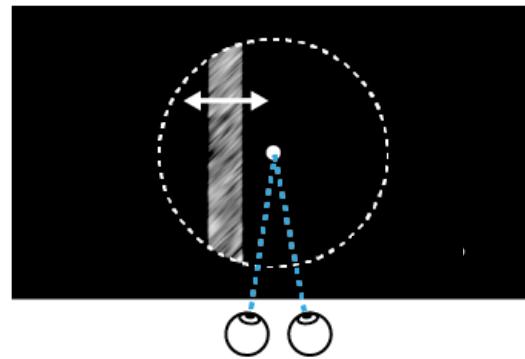
## Retinotopy: Population Receptive Fields



Szinte & Knapen (2020) *Cerebral Cortex*  
Dumoulin & Knapen (2018) *Annual Review of Visual Sciences*  
Dumoulin & Wandell (2004) *NeuroImage*

# Confidence in Global Motion Direction Discrimination: fMRI Study

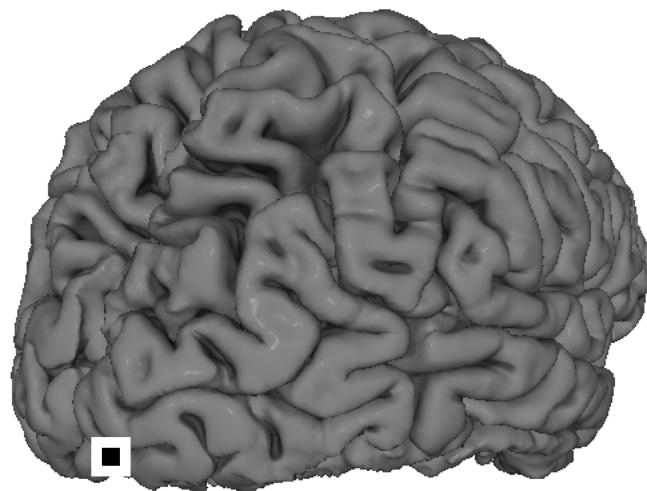
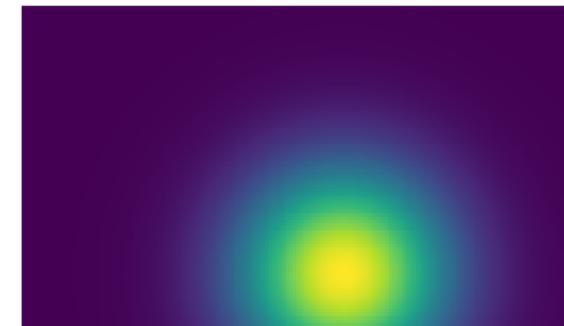
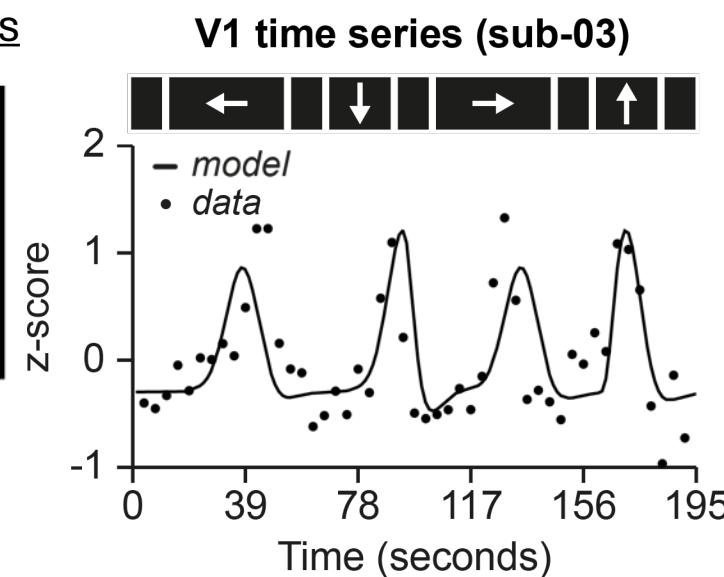
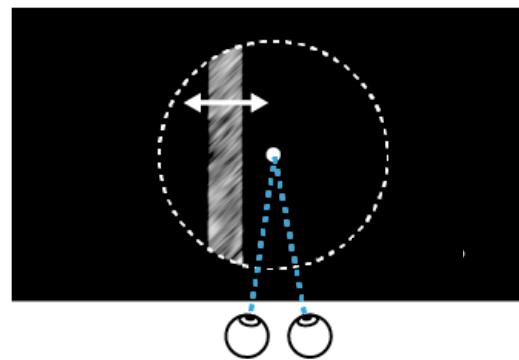
## Retinotopy: Population Receptive Fields



Szinte & Knapen (2020) *Cerebral Cortex*  
Dumoulin & Knapen (2018) *Annual Review of Visual Sciences*  
Dumoulin & Wandell (2004) *NeuroImage*

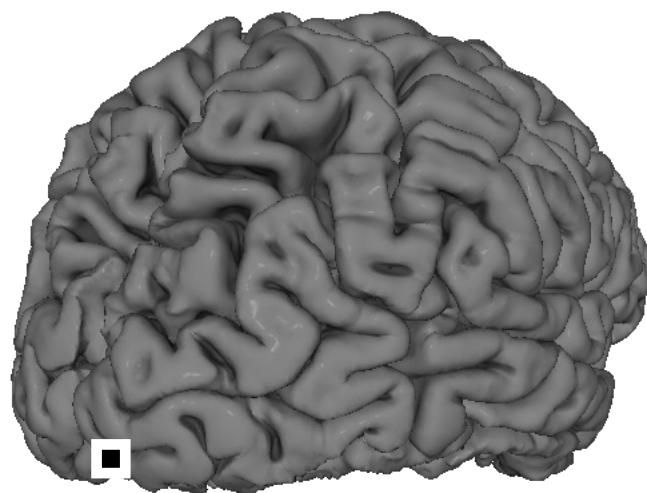
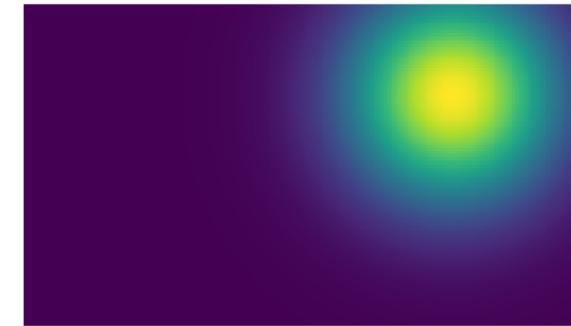
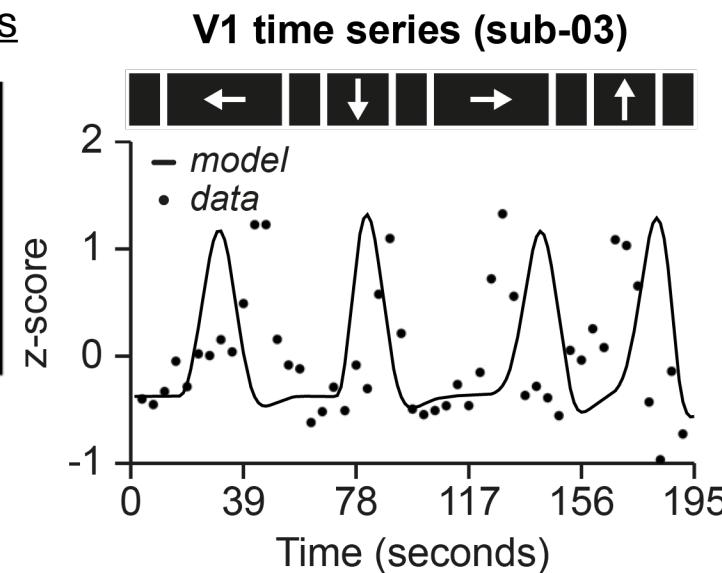
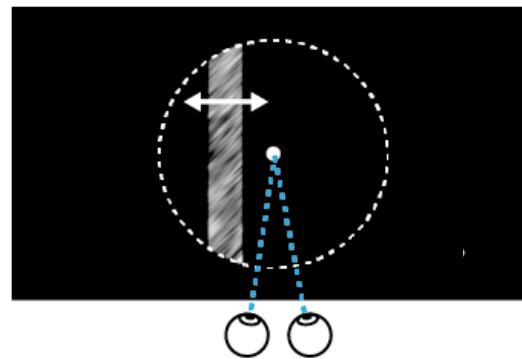
# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



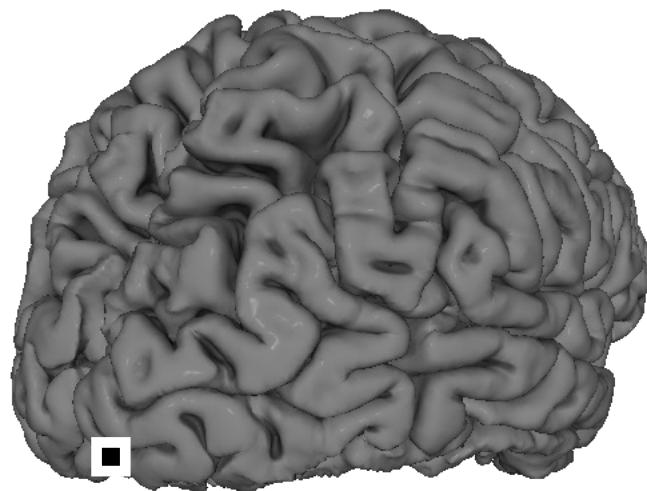
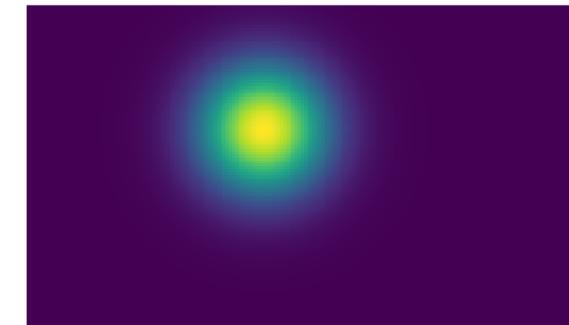
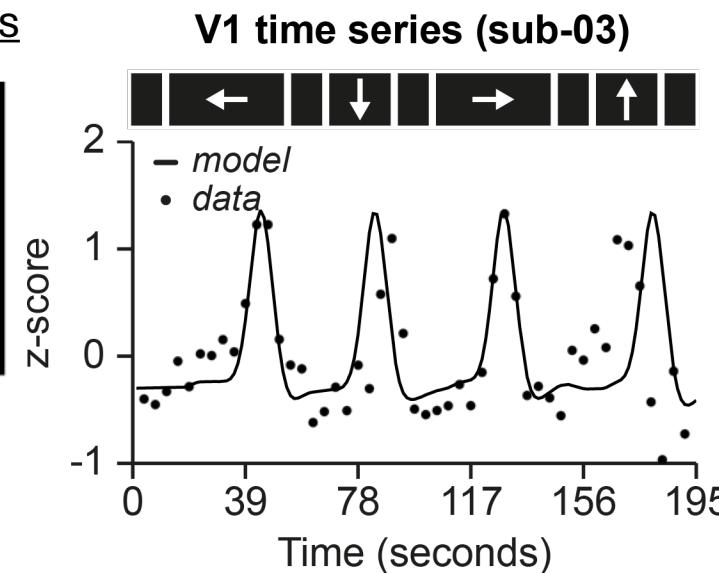
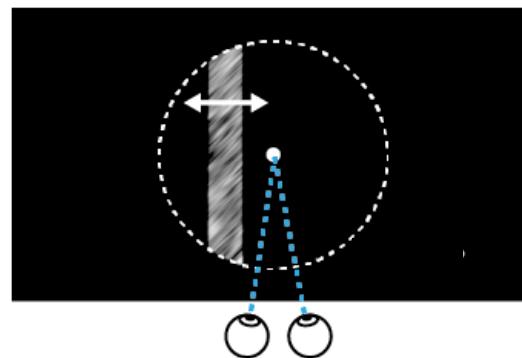
# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



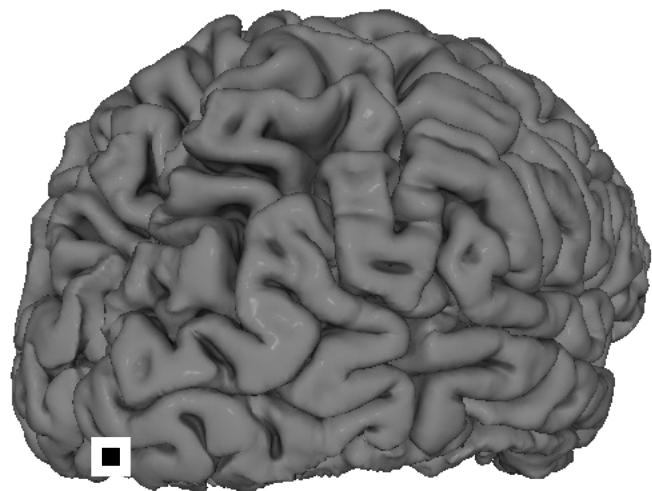
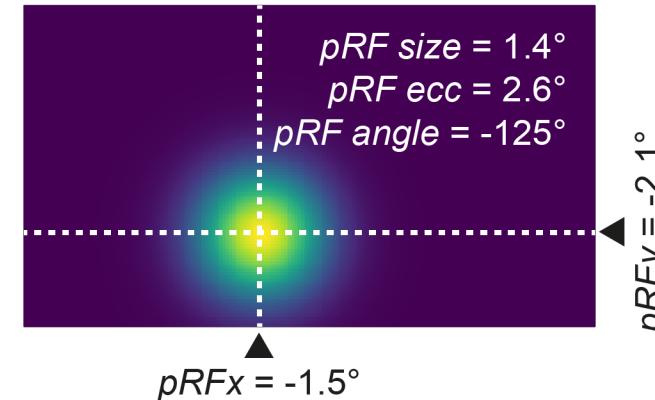
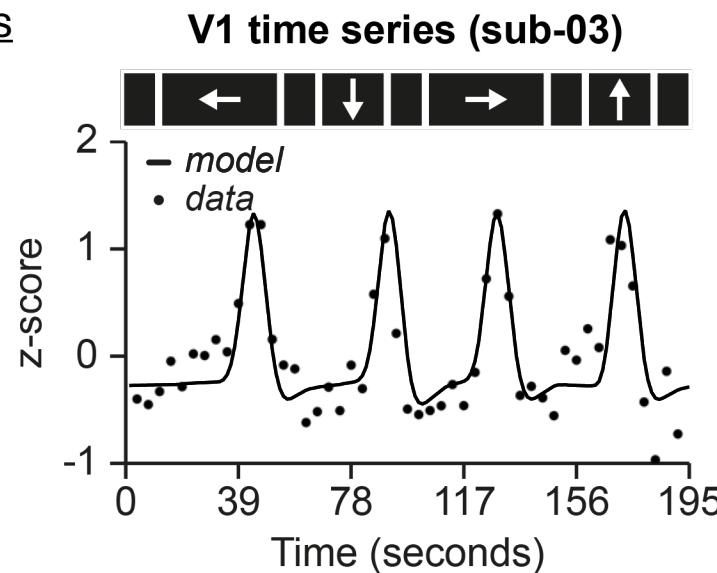
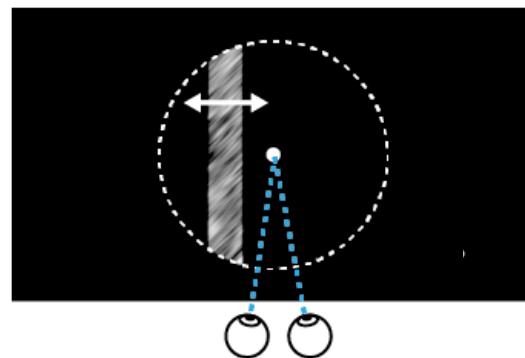
# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



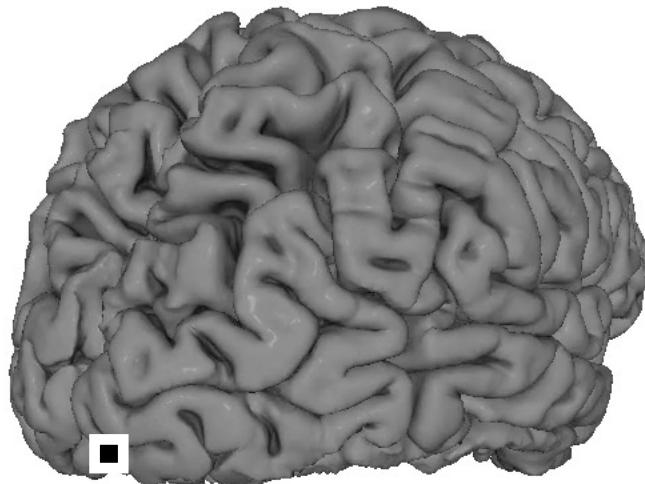
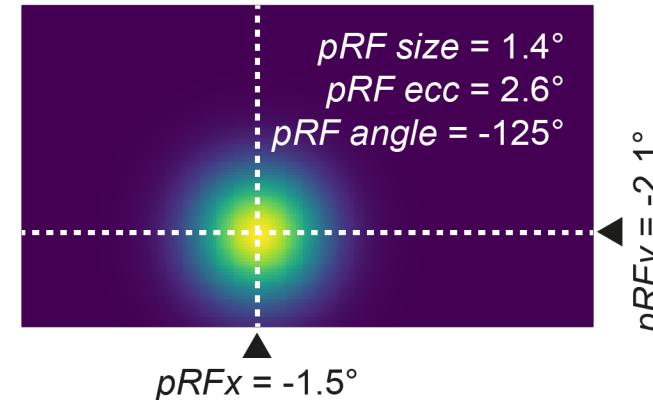
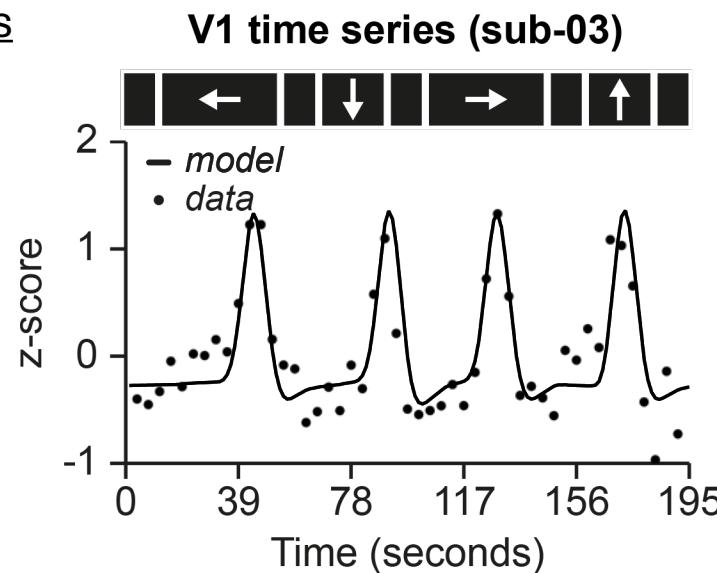
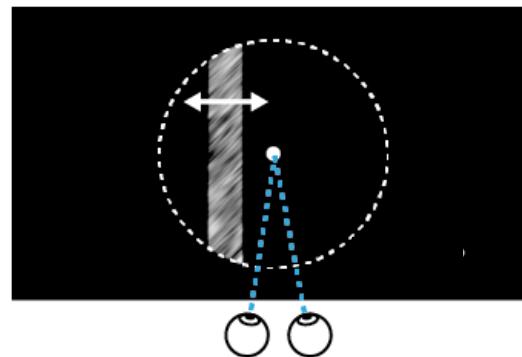
# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields

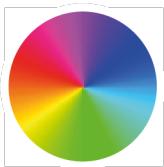
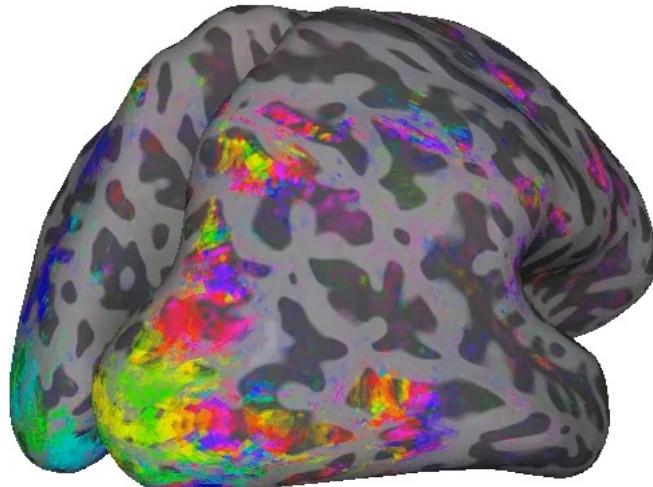
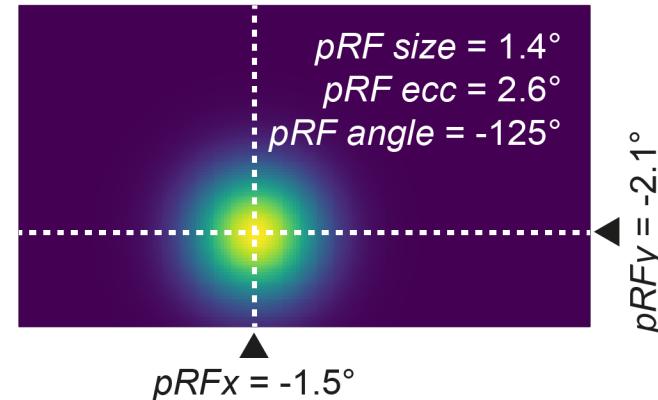
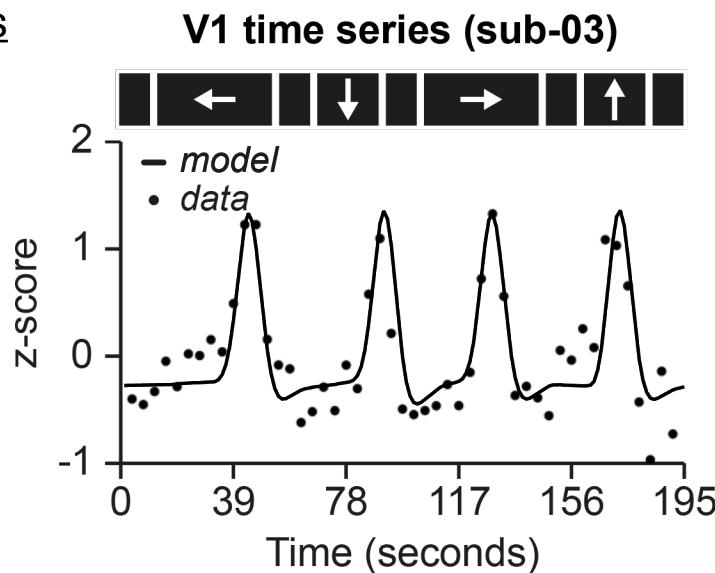
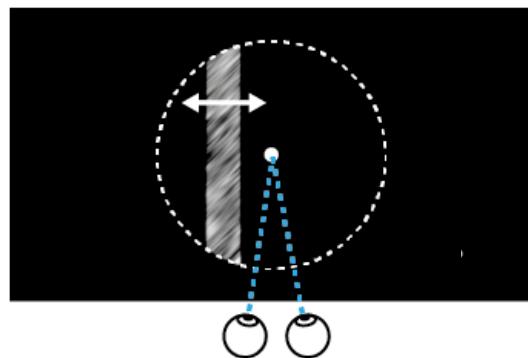


PRF angle map (sub-03)

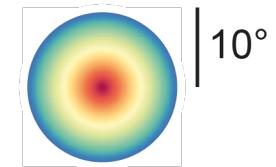
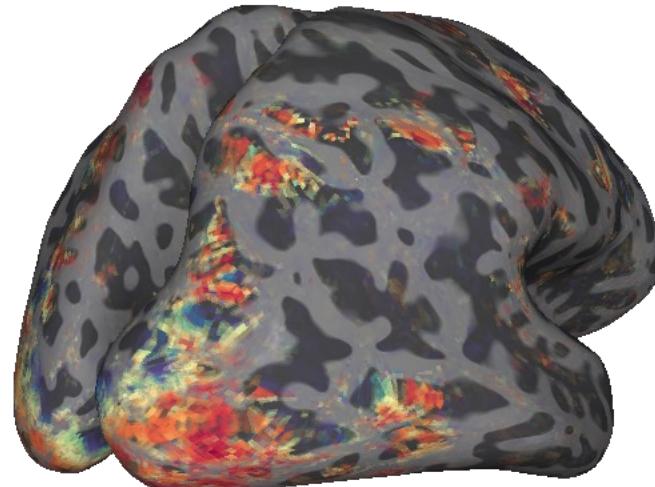
Szinte & Knapen (2020) *Cerebral Cortex*  
Dumoulin & Knapen (2018) *Annual Review of Visual Sciences*  
Dumoulin & Wandell (2004) *NeuroImage*

# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



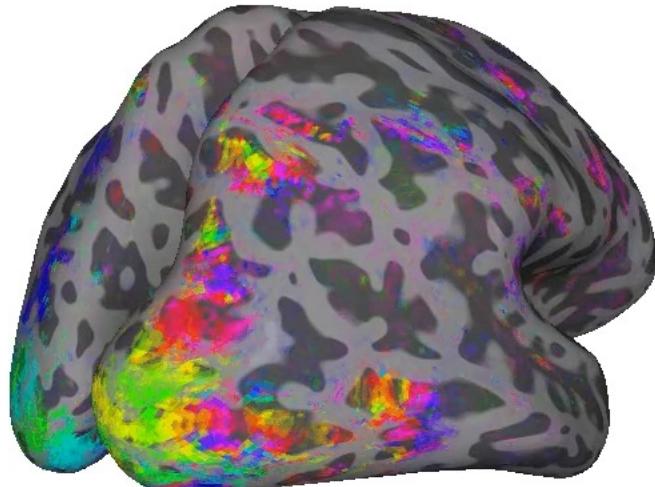
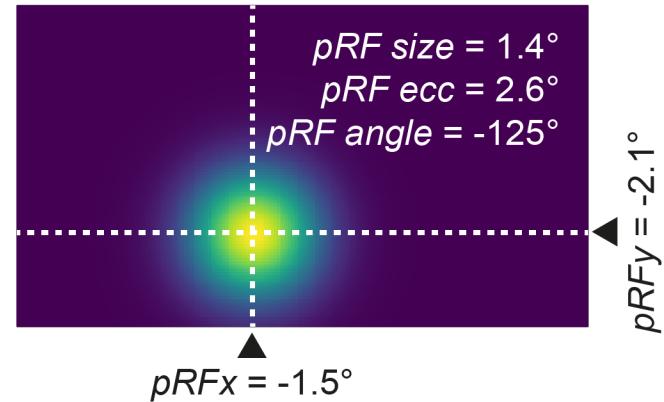
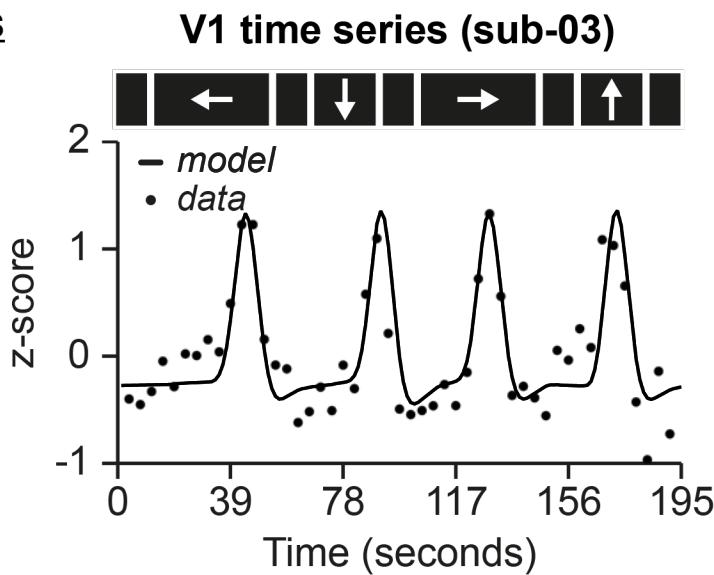
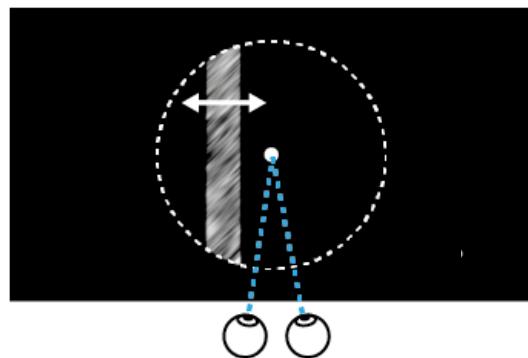
PRF angle map (sub-03)



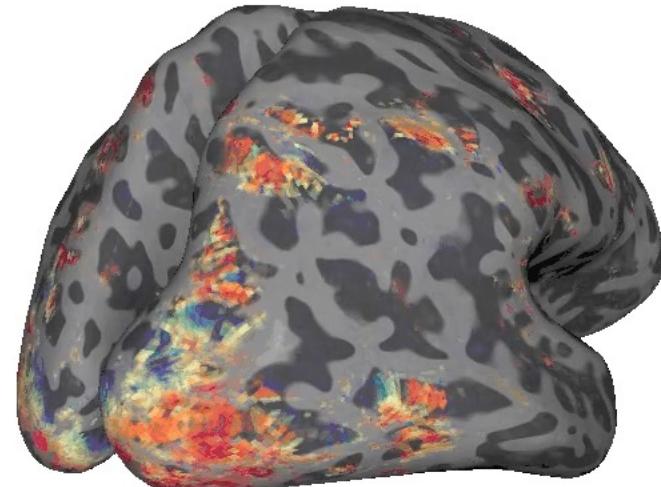
PRF eccentricity (sub-03)

# Confidence in Global Motion Direction Discrimination: fMRI Study

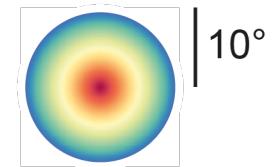
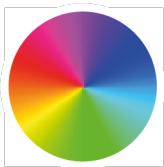
## Retinotopy: Population Receptive Fields



PRF angle map (sub-03)

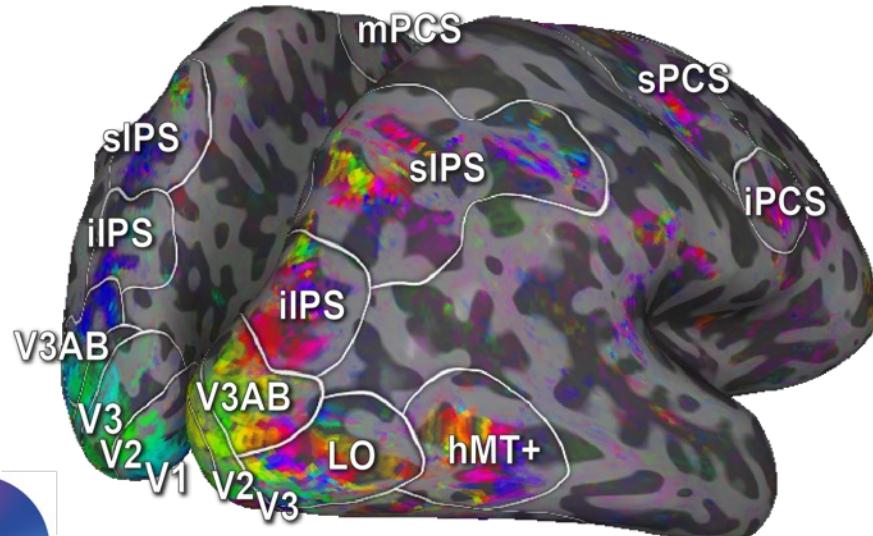
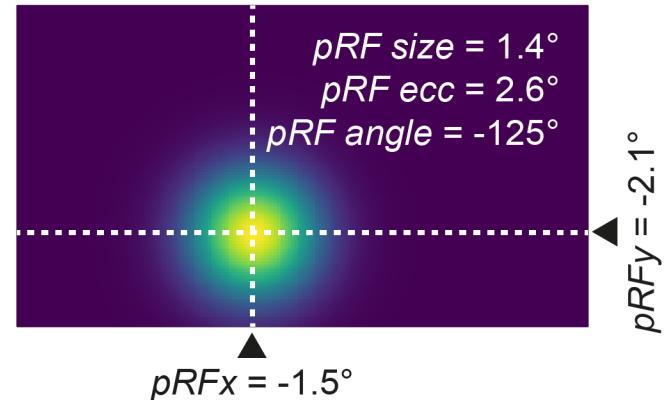
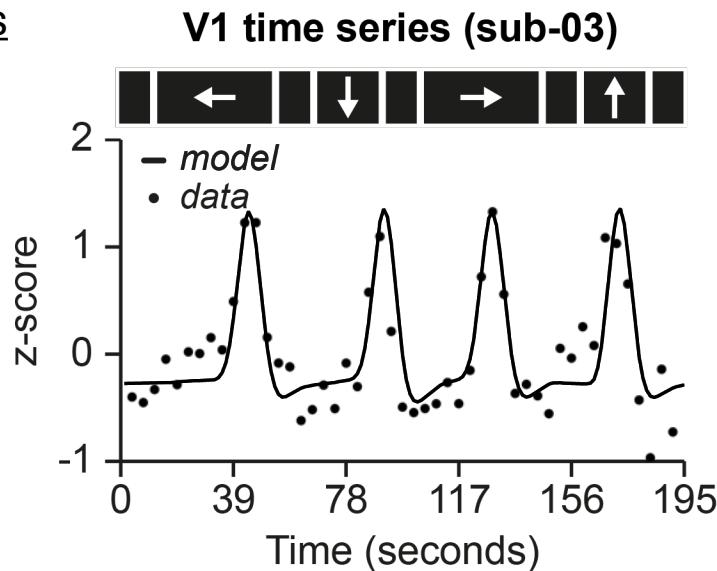
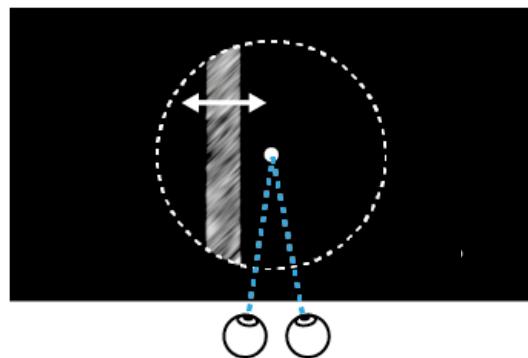


PRF eccentricity (sub-03)

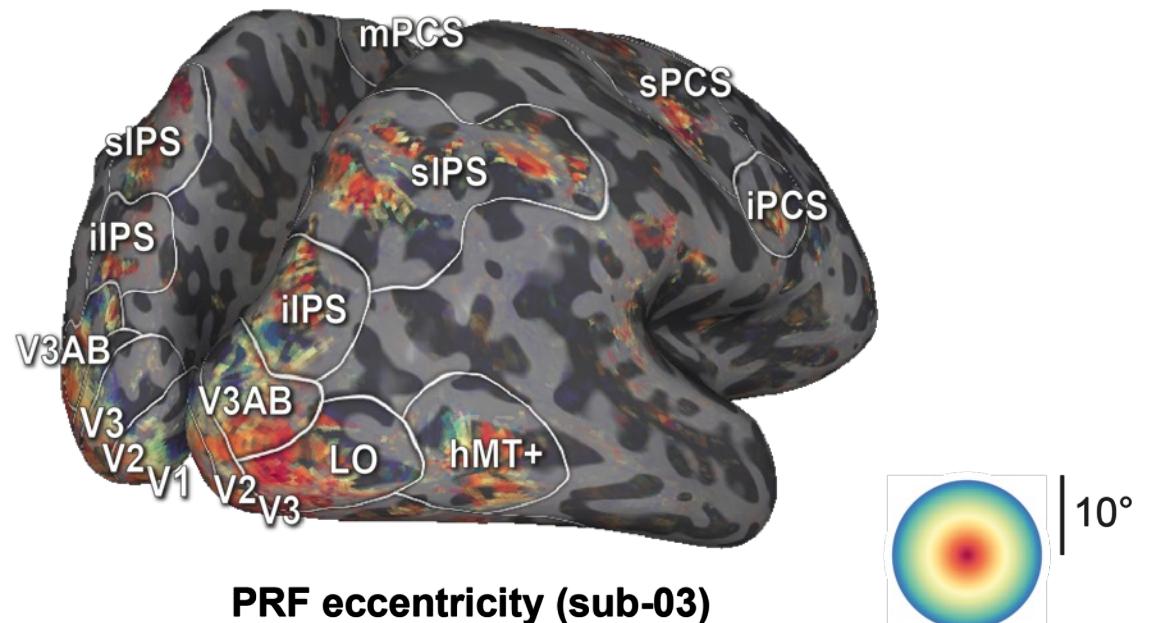


# Confidence in Global Motion Direction Discrimination: fMRI Study

## Retinotopy: Population Receptive Fields



PRF angle map (sub-03)



PRF eccentricity (sub-03)

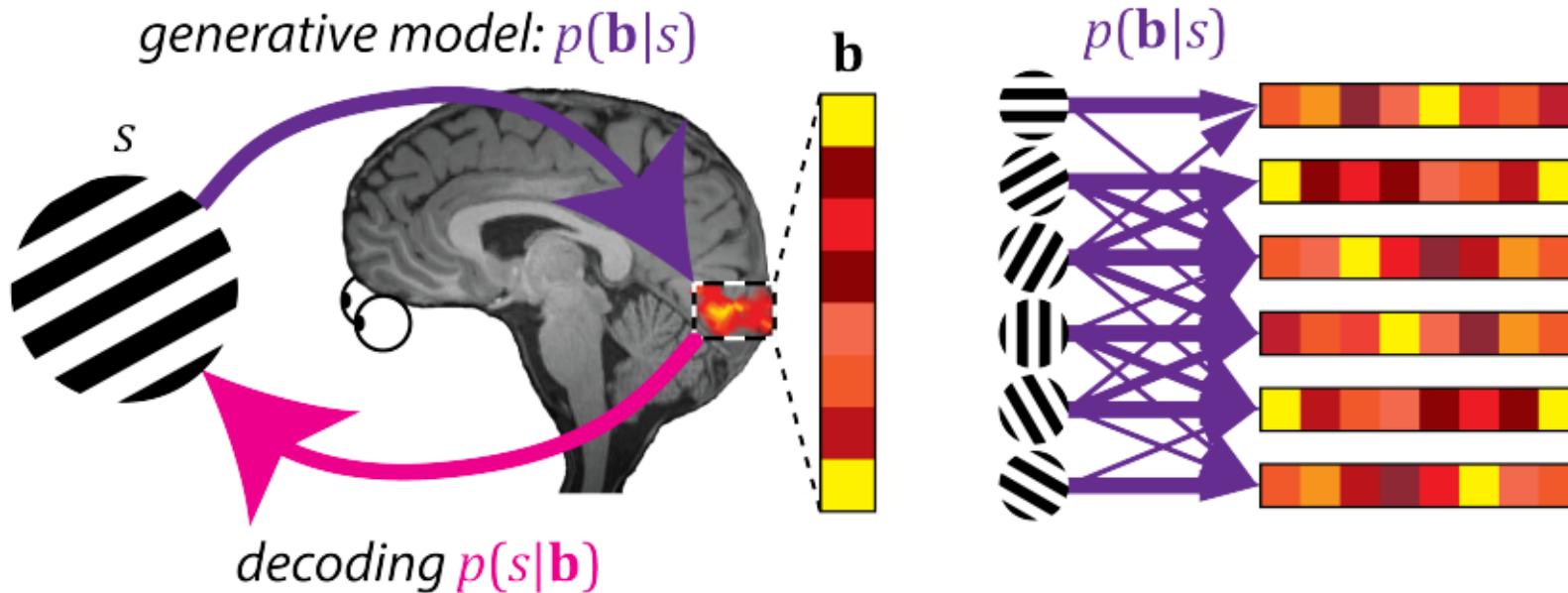
# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):
  - Psychophysics
  - Modeling
- fMRI Study (in Marseille):
  - Methods
  - Analysis Plans
    - I. Behavioral Results (Pilot)
    - II. Retinotopy – Population Receptive Fields
    - III. Generative model-based fMRI analysis technique (TAFKAP)
- Neural mechanisms of opposite-direction effect
- Neural mechanisms of confidence formation in a global motion direction discrimination task with complex stimuli
- Simplified the task for the fMRI experiment

# Confidence in Global Motion Direction Discrimination: fMRI Study

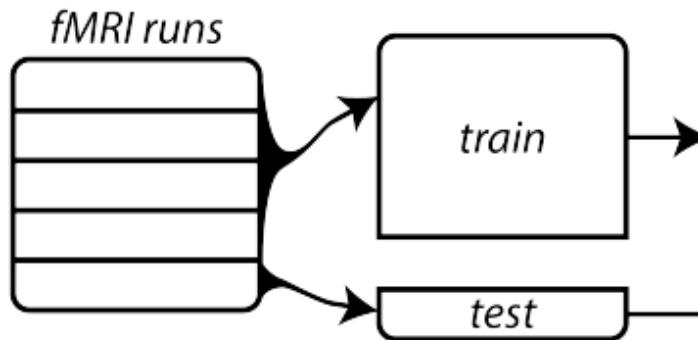
Generative model-based fMRI analysis technique (TAFKAP)

## (A) Decoding by inverting a generative model



# Confidence in Global Motion Direction Discrimination: fMRI Study

Generative model-based fMRI analysis technique (TAFKAP)



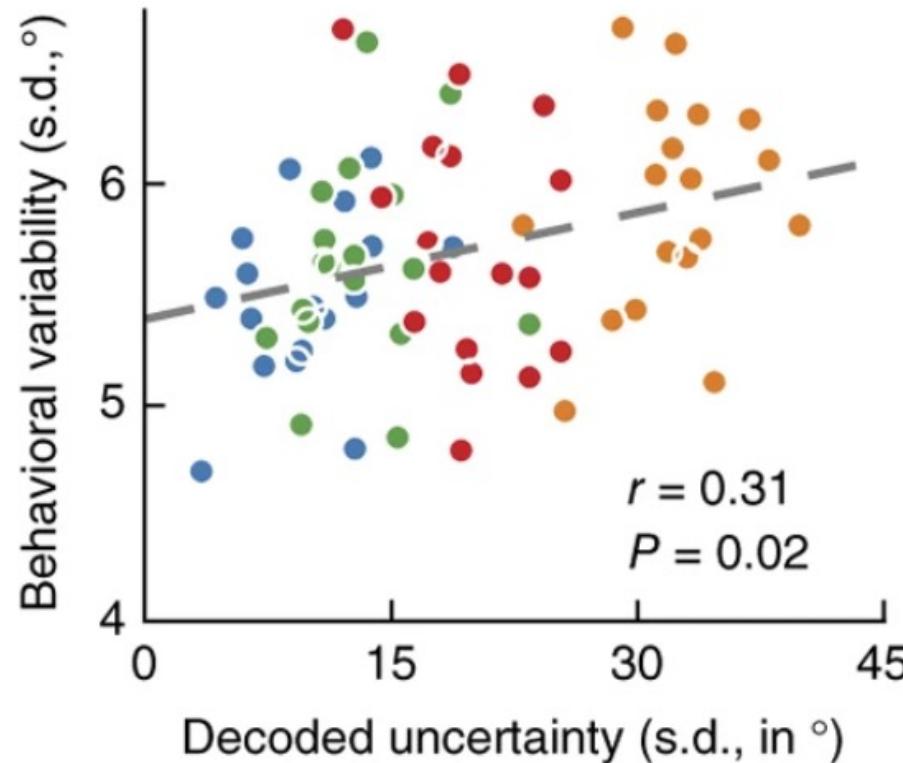
- Details? (If you are interested, let me know)
- Does it work? (uncertainty)

# Confidence in Global Motion Direction Discrimination: fMRI Study

Generative model-based fMRI analysis technique (TAFKAP)

Van Bergen et al., (2015). *Nature neuroscience*

Orientation Discrimination: Decoded perceptual uncertainty correlated with behavioral variability.

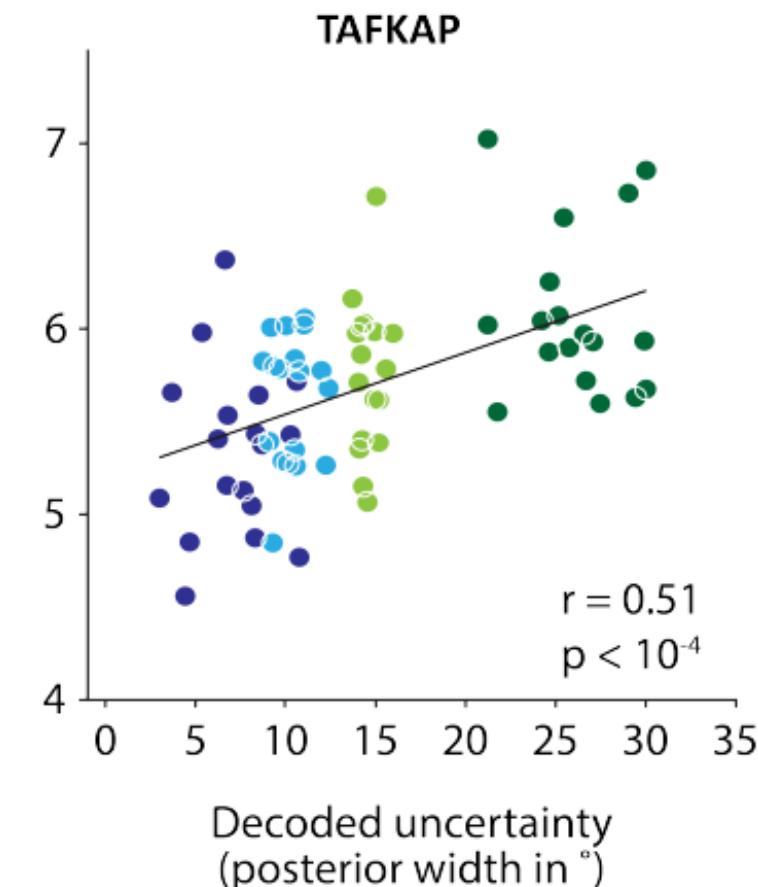
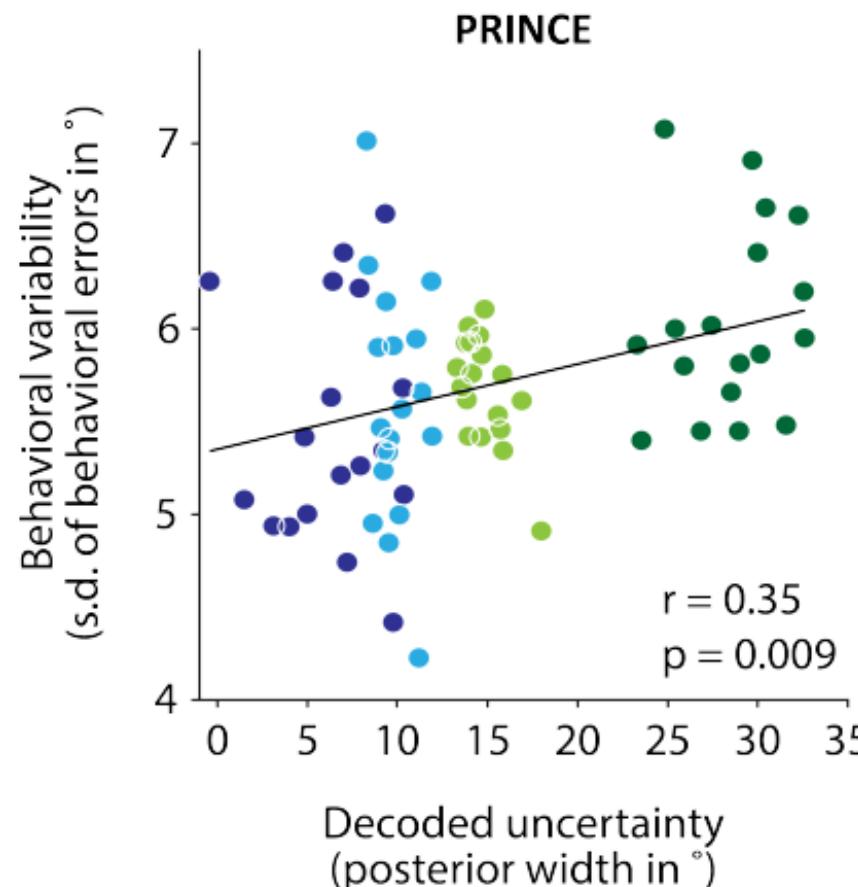


# Confidence in Global Motion Direction Discrimination: fMRI Study

Generative model-based fMRI analysis technique (TAFKAP)

Van Bergen, & Jehee. (2021). *BioRxiv*

Orientation Discrimination: Decoded perceptual uncertainty **better** correlated with behavioral variability.

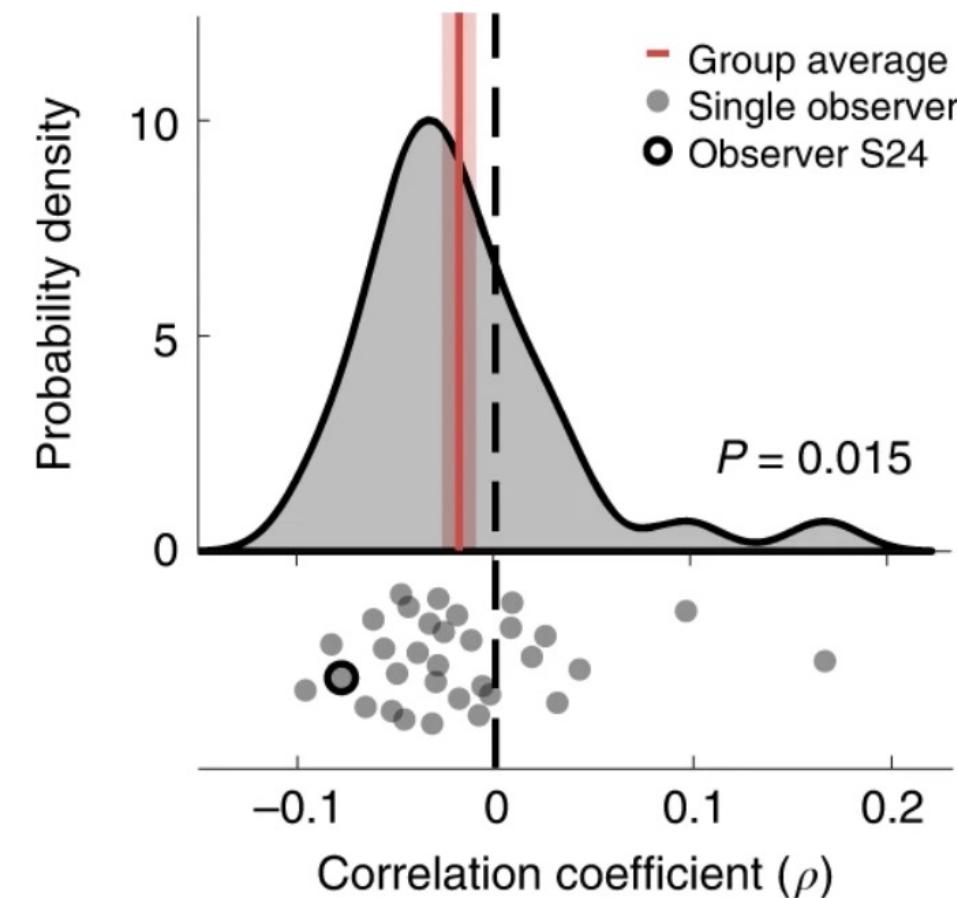
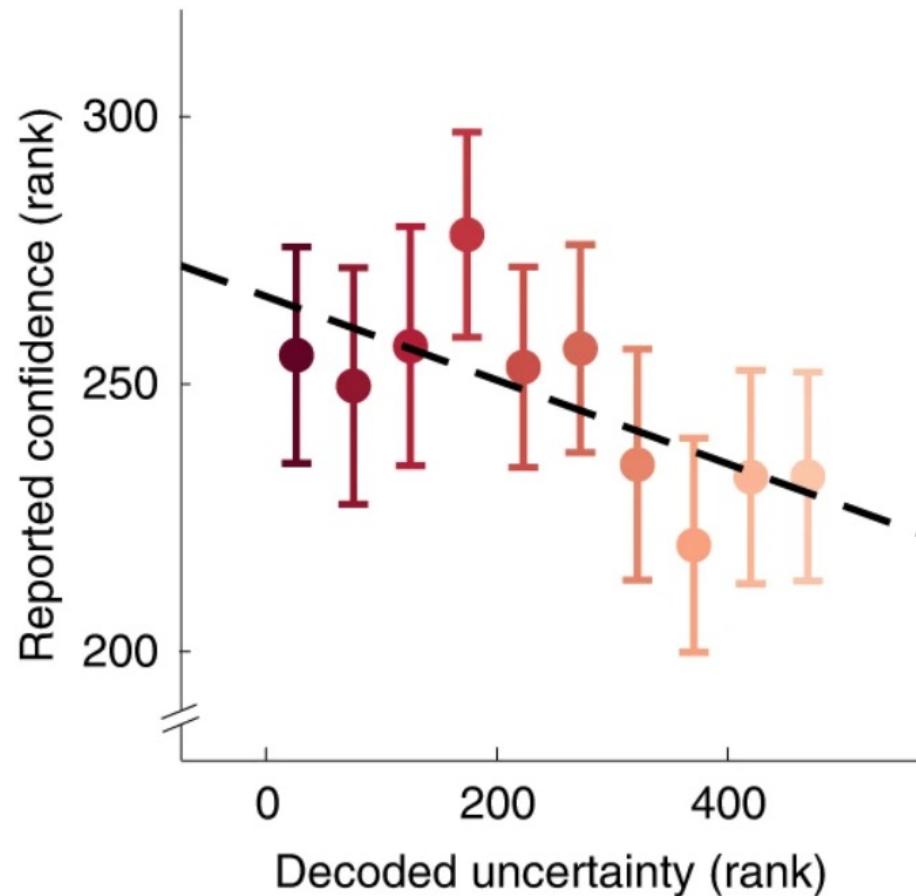


# Confidence in Global Motion Direction Discrimination: fMRI Study

Generative model-based fMRI analysis technique (TAFKAP)

Geurts et al., (2022). *Nature human behaviour*

Orientation Discrimination: Decoded perceptual uncertainty correlated with **confidence responses**.

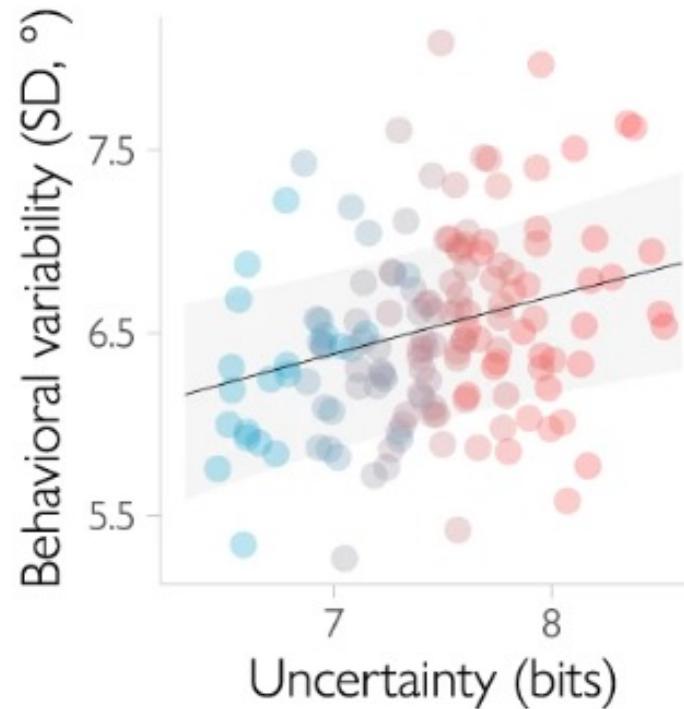


# Confidence in Global Motion Direction Discrimination: fMRI Study

Generative model-based fMRI analysis technique (TAFKAP)

Chetverikov, & Jehee (2023). *Nature Communications*

Motion Direction Discrimination: Decoded perceptual uncertainty correlated with behavioral variability.



# Confidence in Global Motion Direction Discrimination

- Behavioral Study (in Paris):
  - Psychophysics
  - Modeling
- fMRI Study (in Marseille):
  - Methods
  - Analysis Plans
    - I. Behavioral Results (Pilot)
    - II. Retinotopy – Population Receptive Fields
    - III. Generative model-based fMRI analysis technique (TAFKAP)
- Neural mechanisms of opposite-direction effect
- Neural mechanisms of confidence formation in a global motion direction discrimination task with complex stimuli
- Simplified the task for the fMRI experiment

# Confidence in Global Motion Direction Discrimination



The study will help us to learn more about how confidence estimation is associated with perceptual judgments in the brain!

# Confidence in Global Motion Direction Discrimination

Can Oluk<sup>1,3</sup>, Martin Szinte<sup>2</sup>, Guillaume S. Masson<sup>2</sup>, Pascal Mamassian<sup>1</sup>

- Behavioral Study (in Paris):

Psychophysics

Modeling



- fMRI Study (in Marseille):

Methods

Analysis Plans



Thanks for your attention.  
Questions?