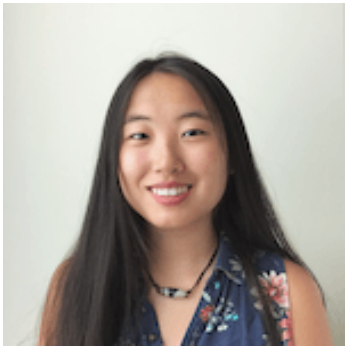
The processing of 3D motion in the human visual cortex

Michael S. Landy

New York University

Puti Wen, Rania Ezzo, Bas Rokers, NYU Abu Dhabi
Ari Rosenberg, University of Wisconsin
Lowell Thompson, University of Pennsylvania

Outline



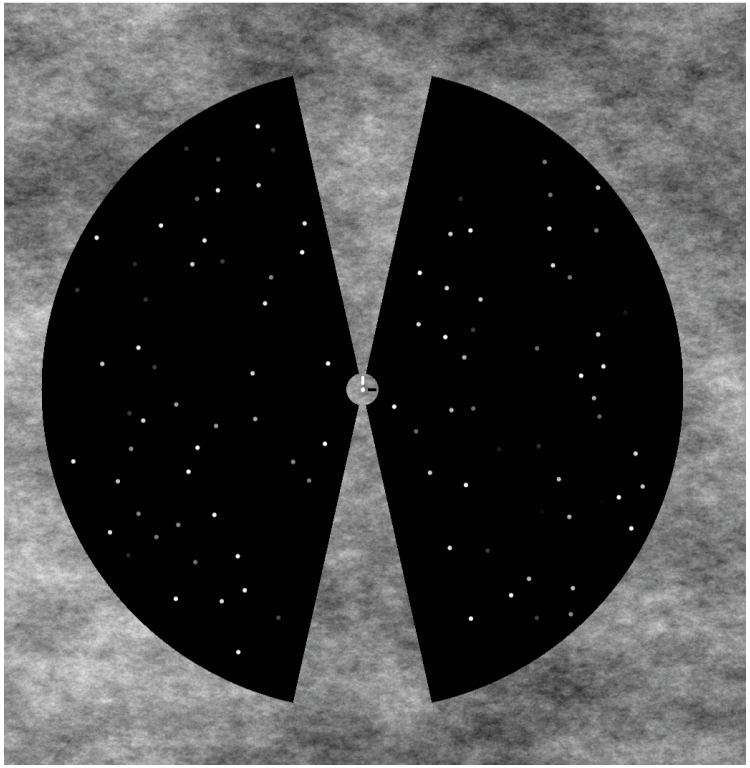
Puti Wen

- Cortical processing of 3-D motion
- Localizing the human homolog of Area FST
- Relating cortical responses in MT and FST to cues and behavior

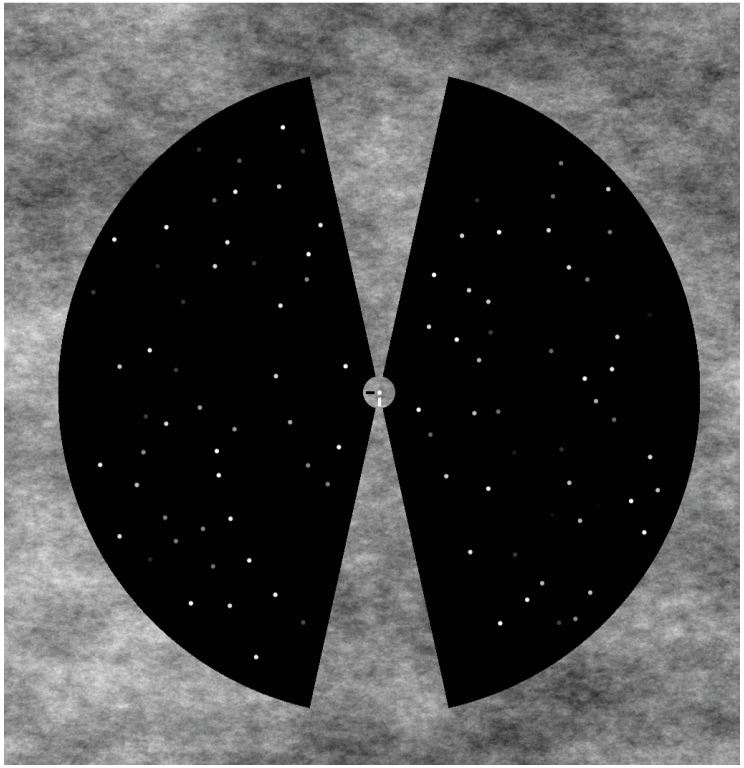
Outline

- Cortical processing of 3-D motion
- Localizing the human homolog of Area FST
- Relating cortical responses in MT and FST to cues and behavior

Visual stimulus

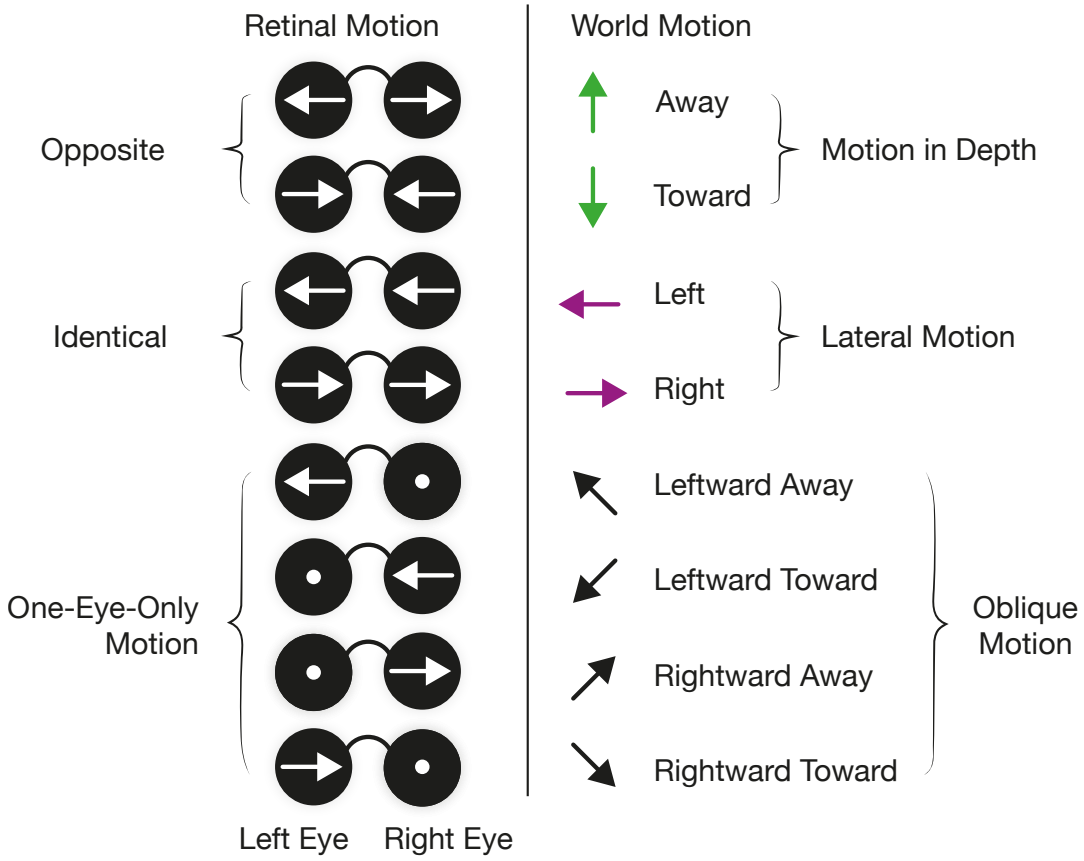


Left Eye

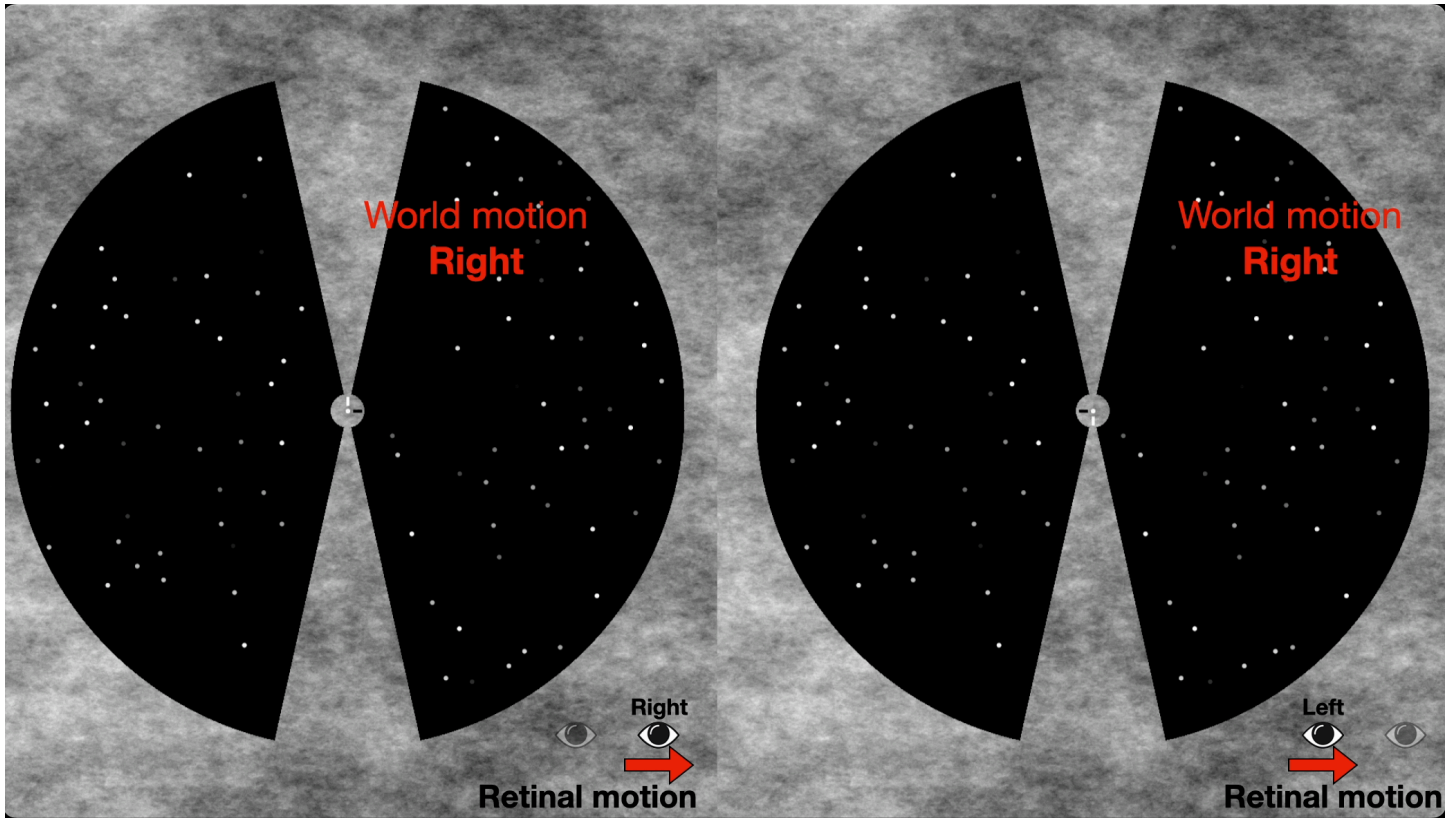


Right Eye

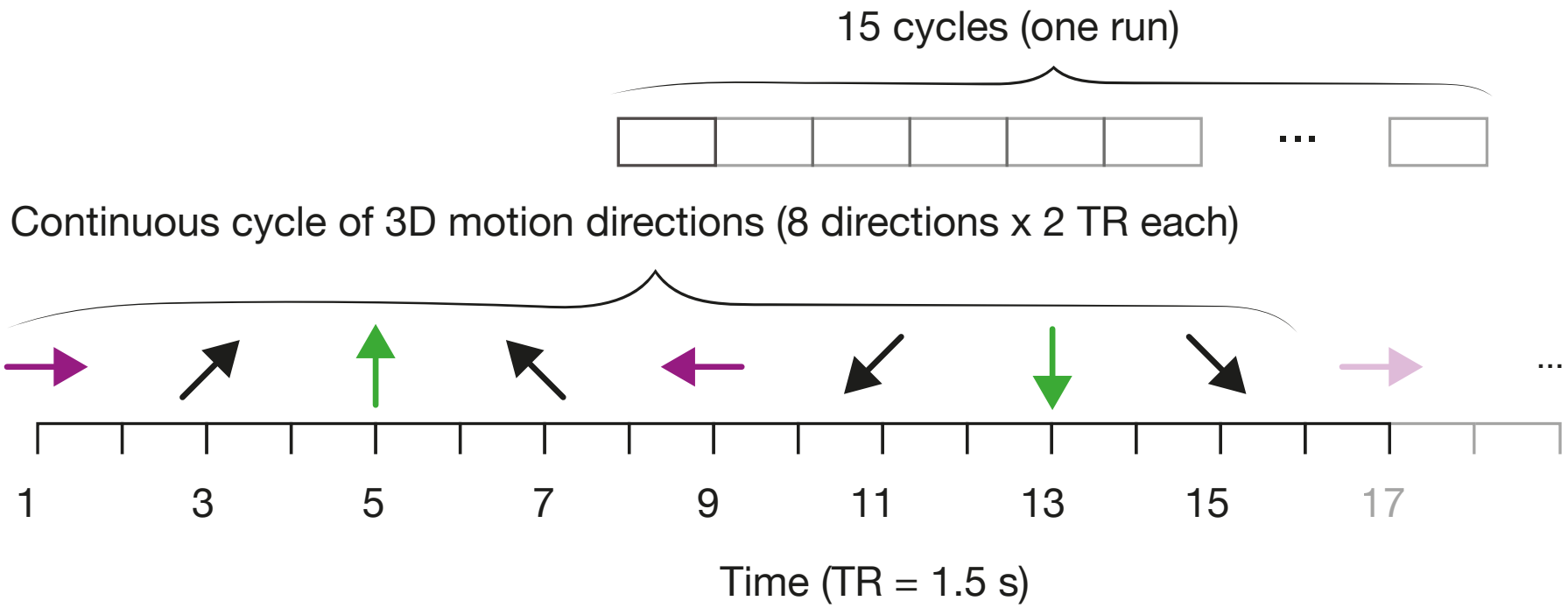
Conditions


Retinal Motion
World Motion
Opposite
Identical
One-Eye-Only Motion
Away
Toward
Motion in Depth
Left
Right
Lateral Motion
Leftward Away
Leftward Toward
Rightward Away
Rightward Toward
Oblique Motion
Left Eye
Right Eye

Visual stimulus

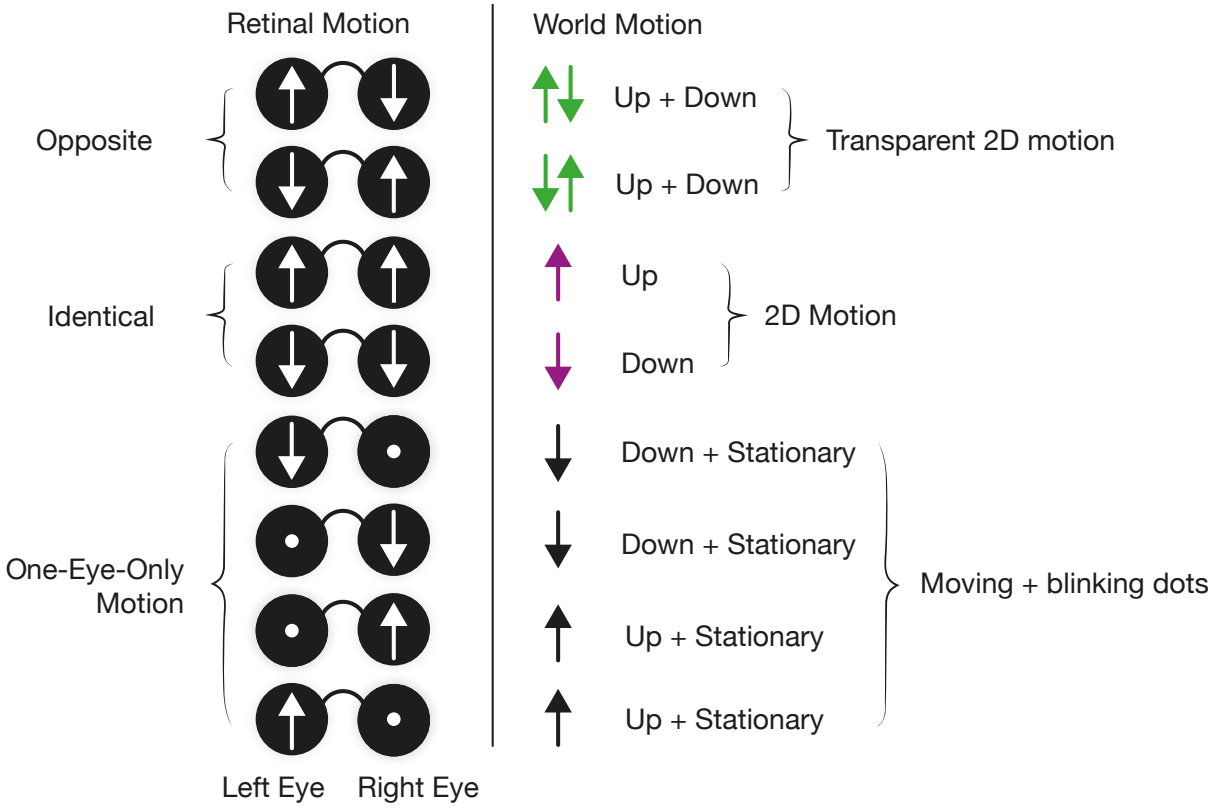


Timing

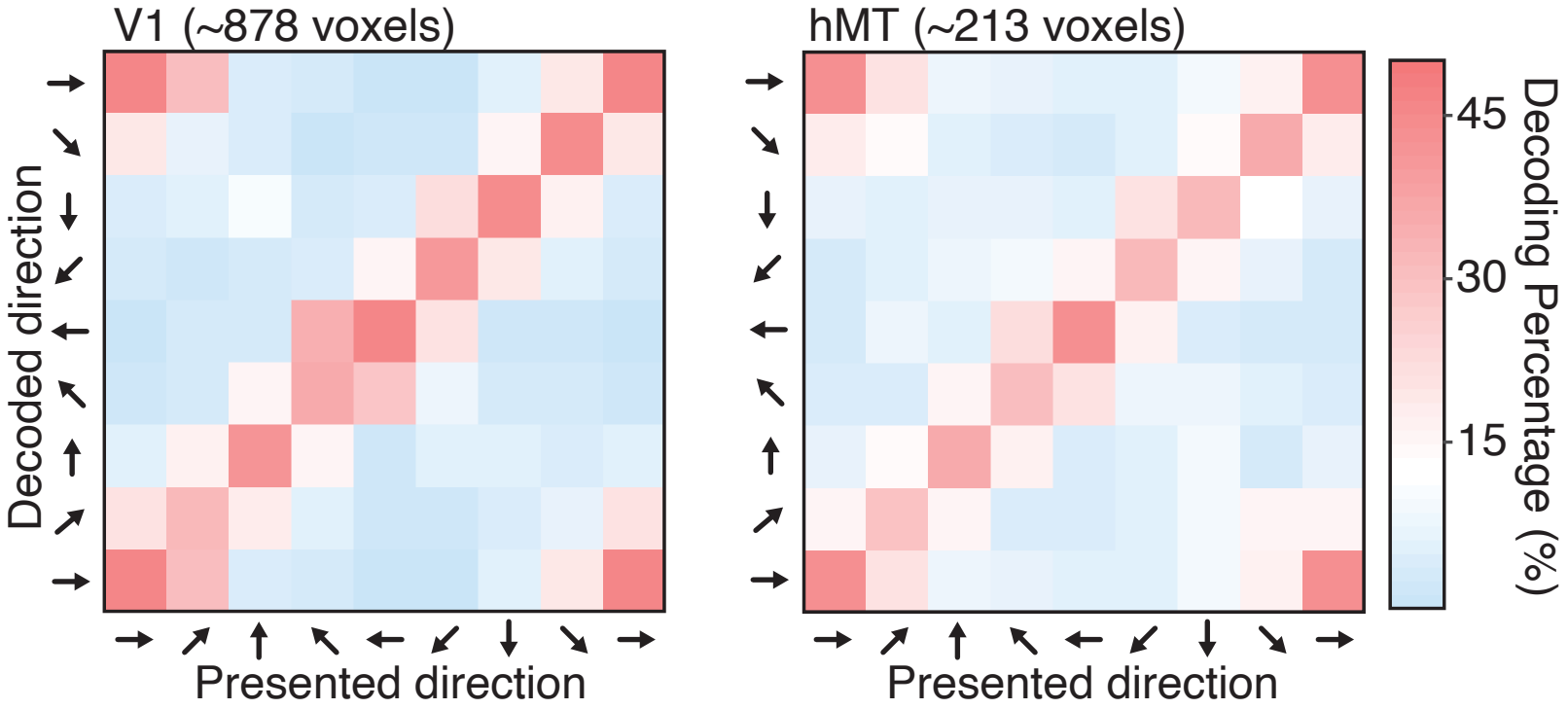


20 runs per participant (2 hours), 9 participants

Vertical condition

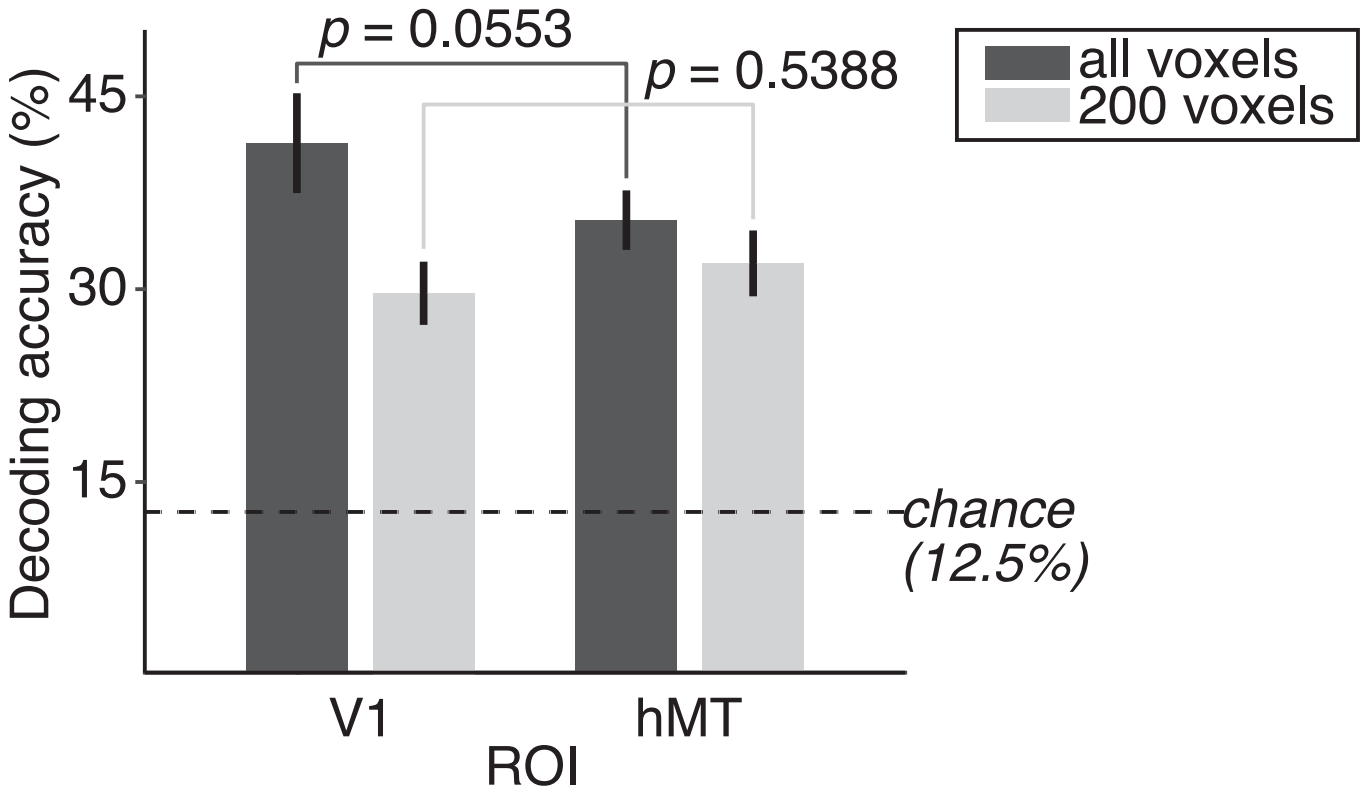


Decoding results

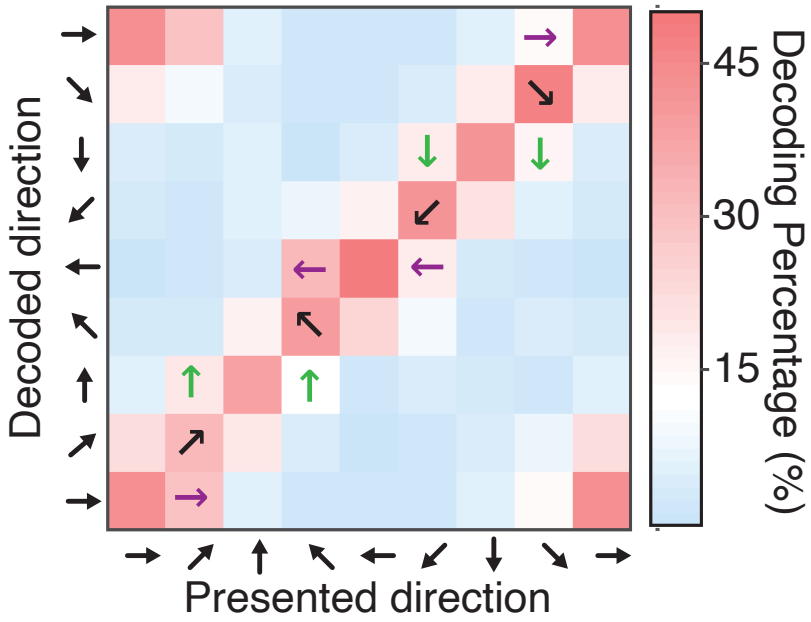


Decoder: TAFKAP (van Bergen & Jehee, 2021)

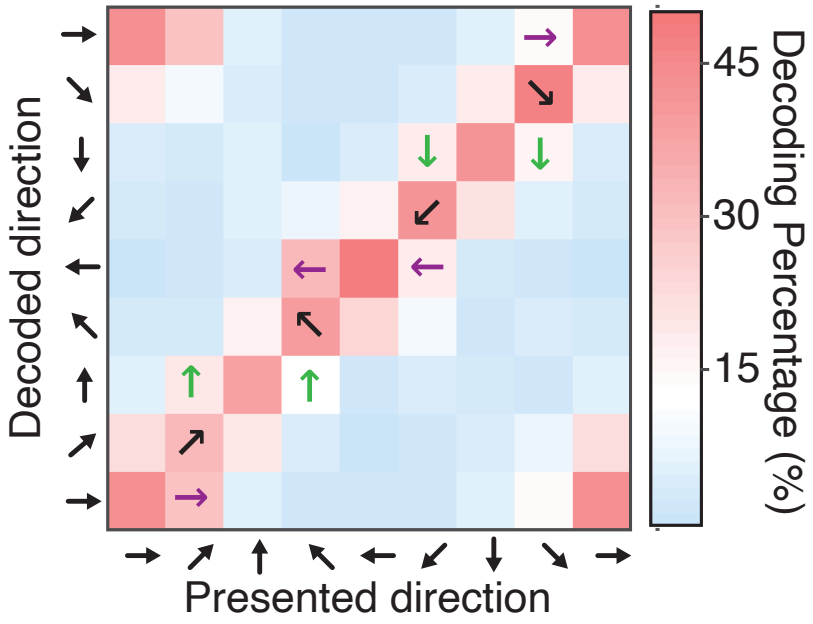
Decoding results

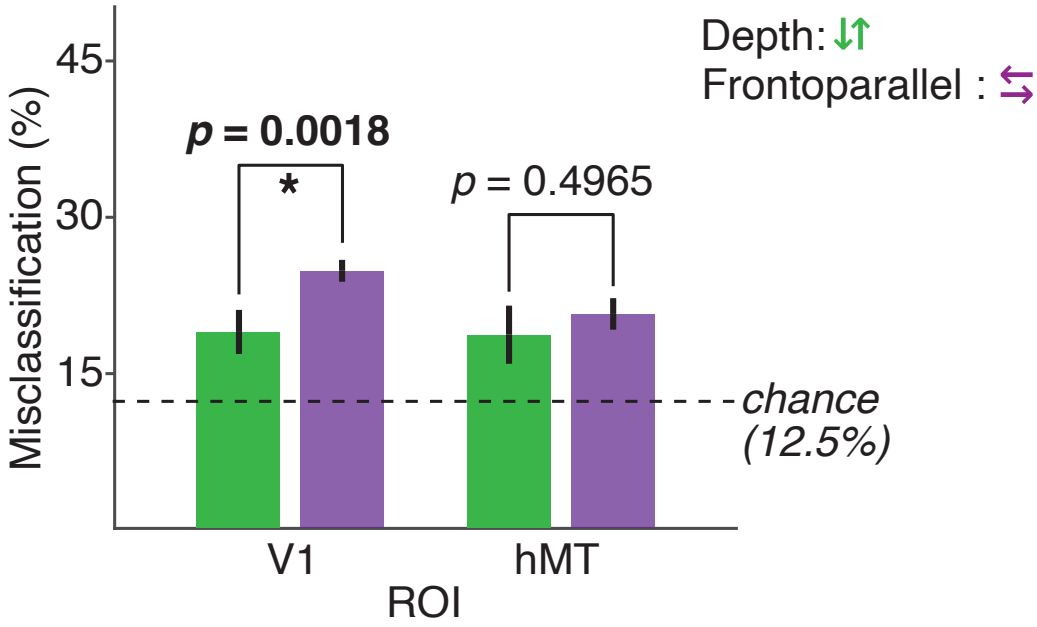


Confusions support MT as coding 3-D

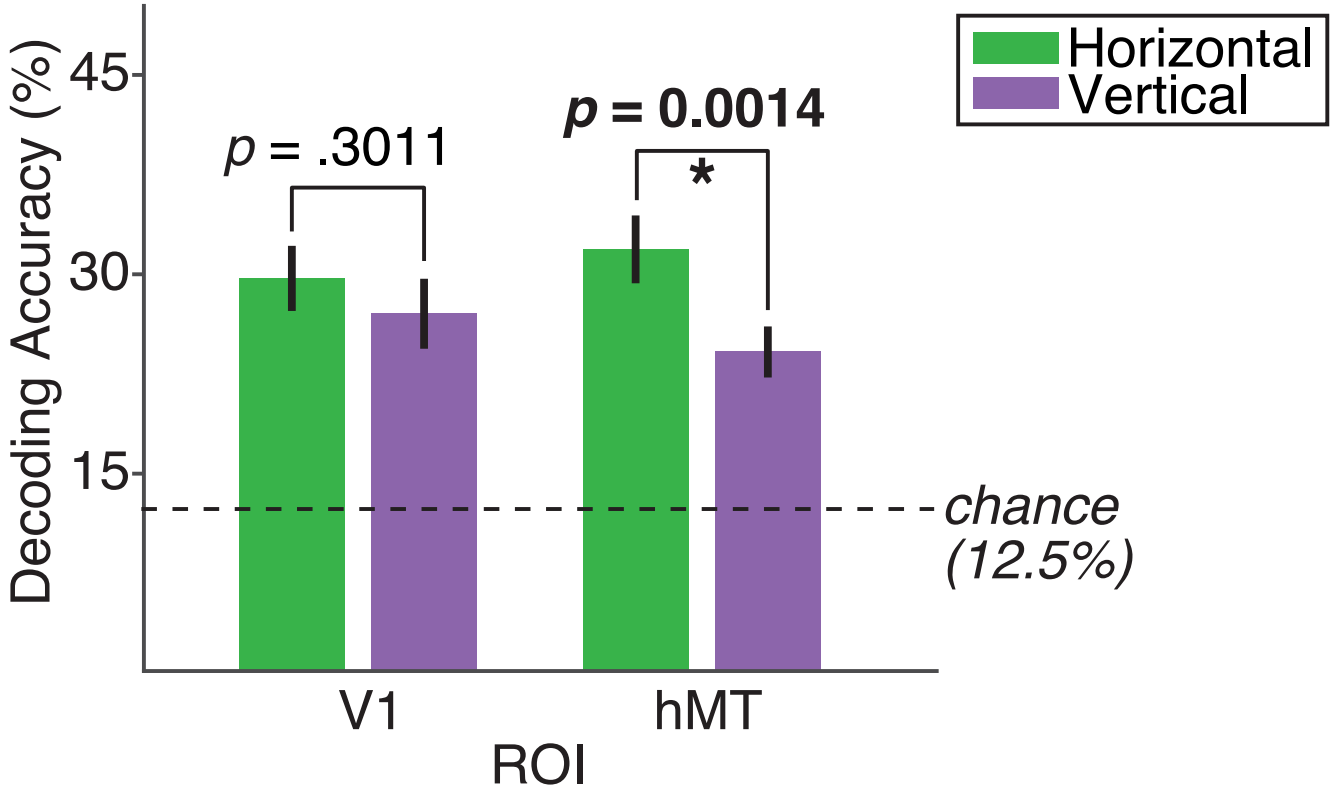


Confusions support MT as coding 3-D

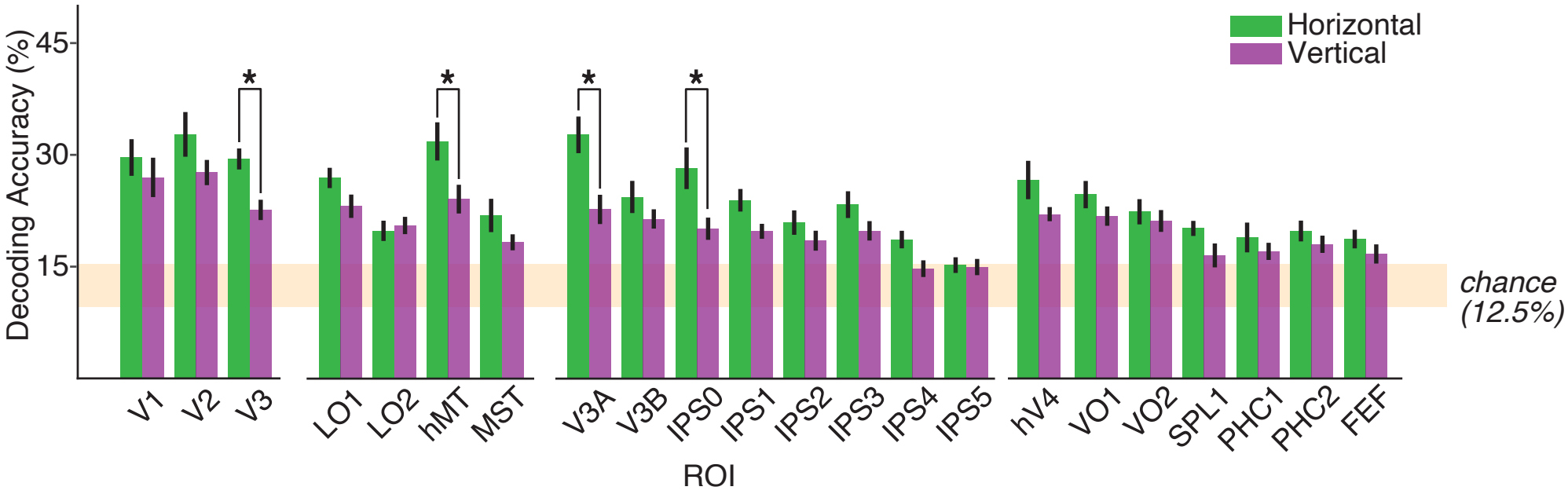




Vertical control supports MT as coding 3-D



Only 4 ROIs show this distinction



Part I: Discussion

- 3D-motion direction can be decoded from V1, MT and several other cortical regions.
- However, the confusion matrix for oblique motion directions differs across areas, with some emphasizing 2-D (retinal) motion errors and others with increased 3-D-motion confusions.
- In addition, the vertical-motion control indicated that V1 coded retinal motion, not 3-D per se, whereas MT coded 3-D motion.
- The areas that appear to encode 3-D motion by this criterion include MT, V3, V3A and IPS0.

Wen, Landy & Rokers, *Neuroimage*, 2023

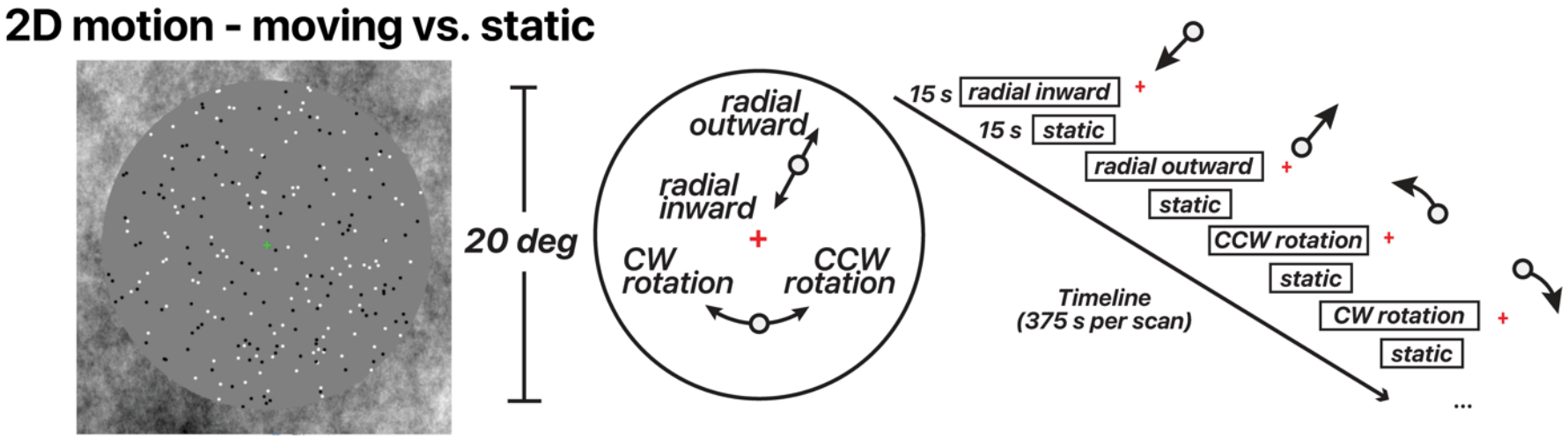
Outline

- Cortical processing of 3-D motion
- Localizing the human homolog of Area FST
- Relating cortical responses in MT and FST to cues and behavior

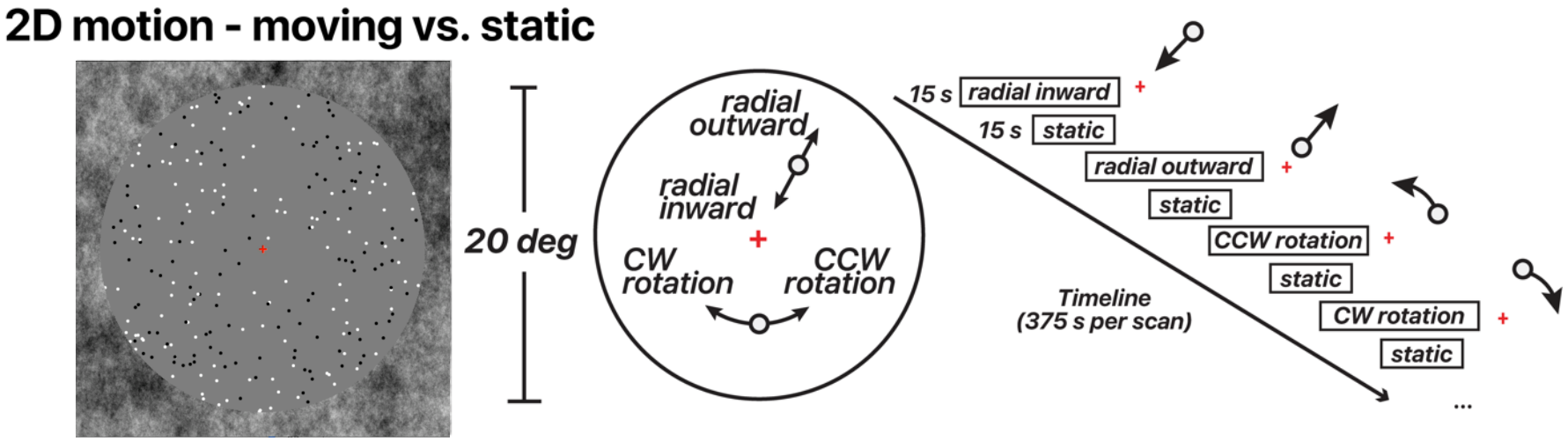
Area FST

- Area FST in macaque is a motion-selective area that has also been identified in several other primate species
- In macaque, FST has been implicated in processing structure-from-motion, 3-D motion, looming, and having distinct responses to opponent motion compared to, e.g., Area MT. 3-D-motion responses have also been found for putative FST in humans.
- The literature is mixed concerning the location of a possible human homolog to FST
- We sought a way to delineate human FST and used several techniques to validate our findings

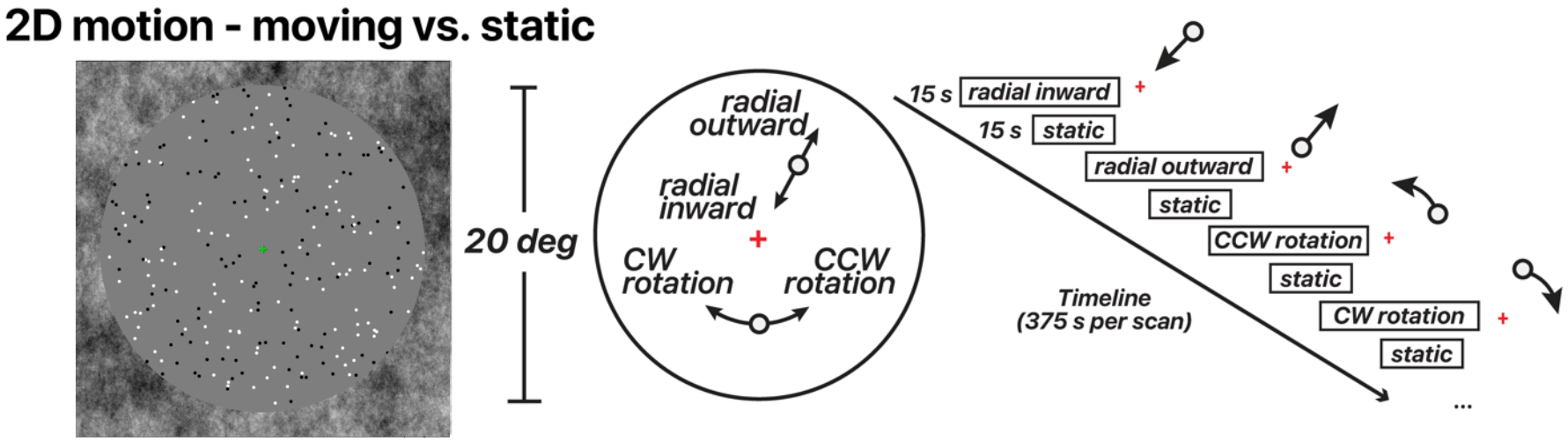
Visual conditions



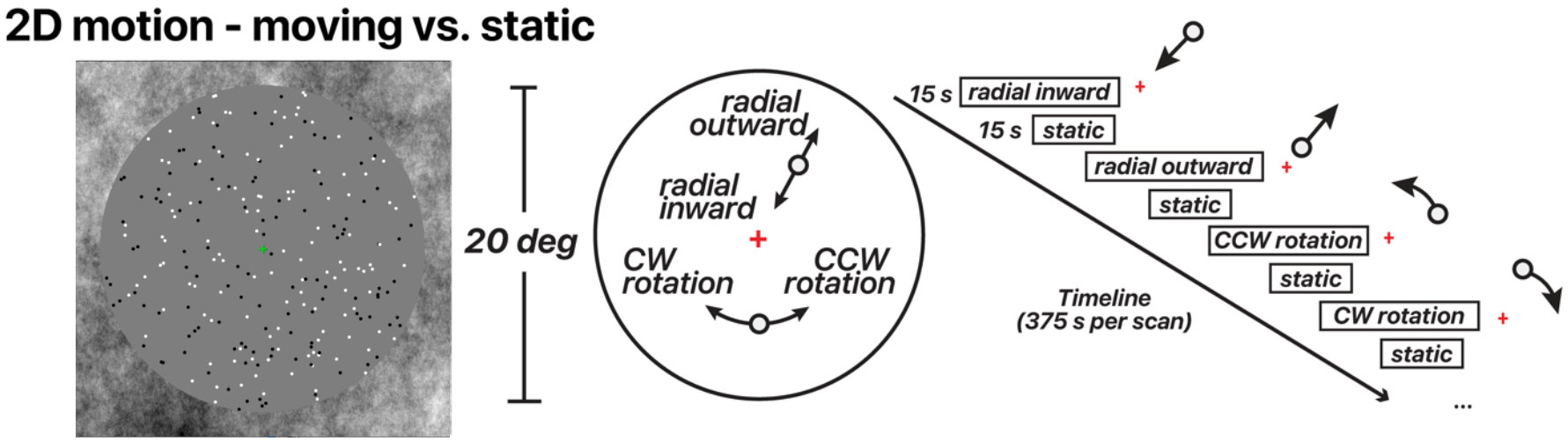
Visual conditions



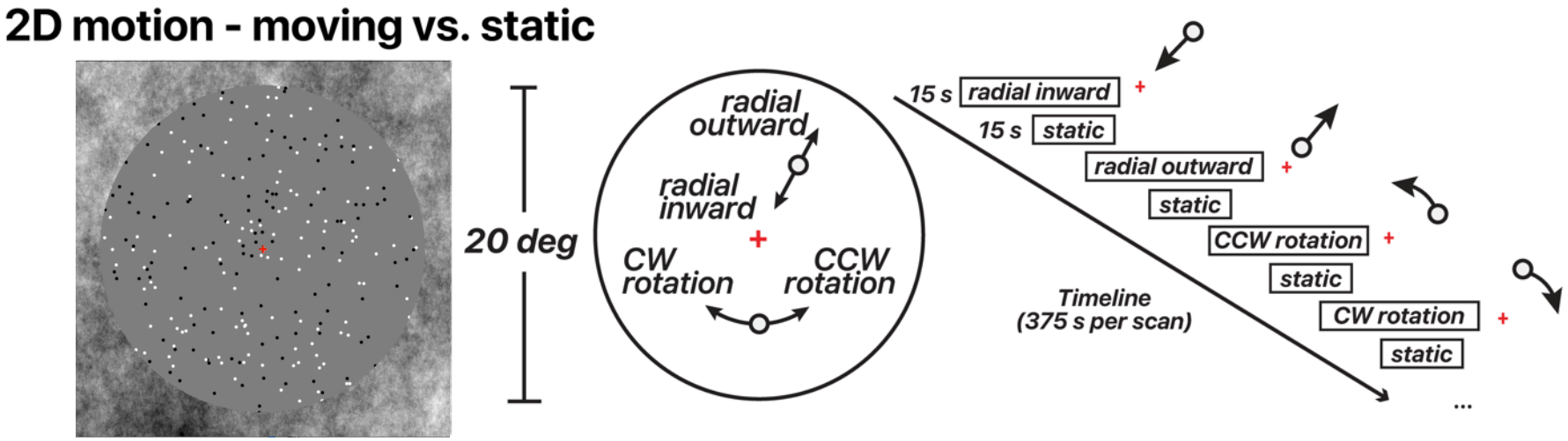
Visual conditions



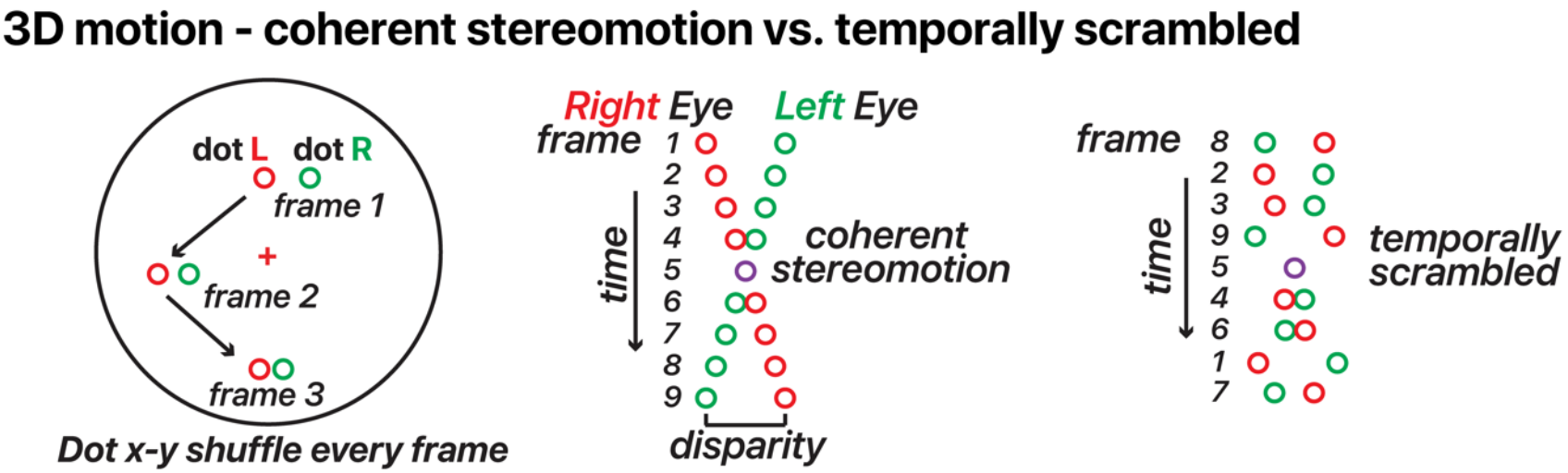
Visual conditions



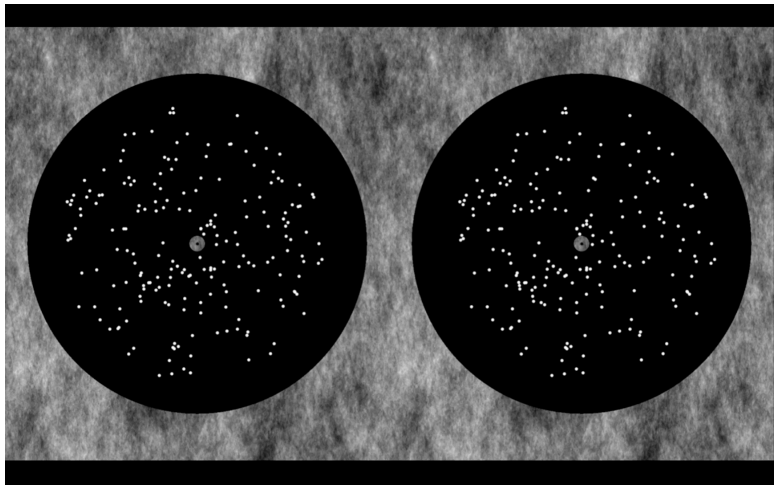
Visual conditions



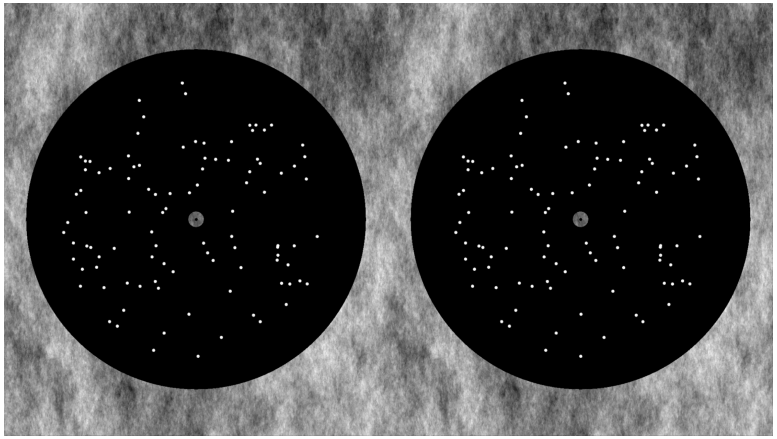
Visual conditions



Visual conditions

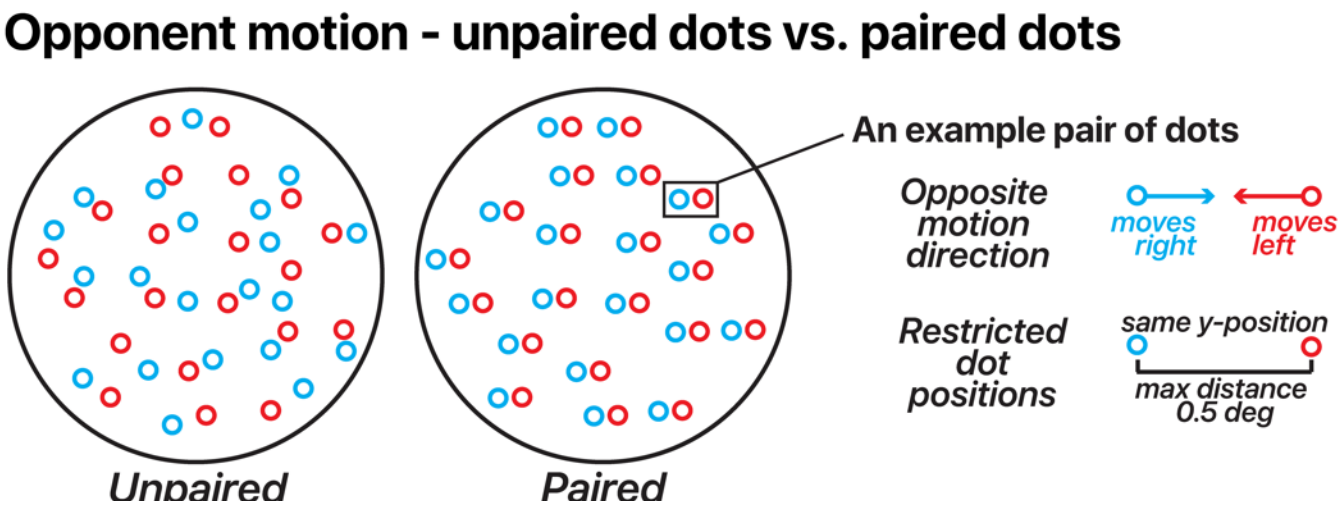


Coherent stereomotion

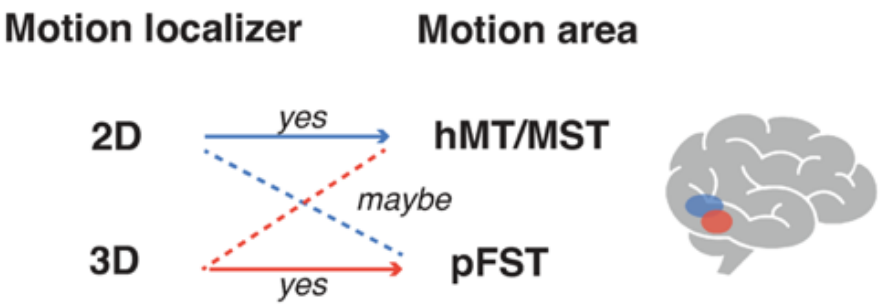


Temporally scrambled

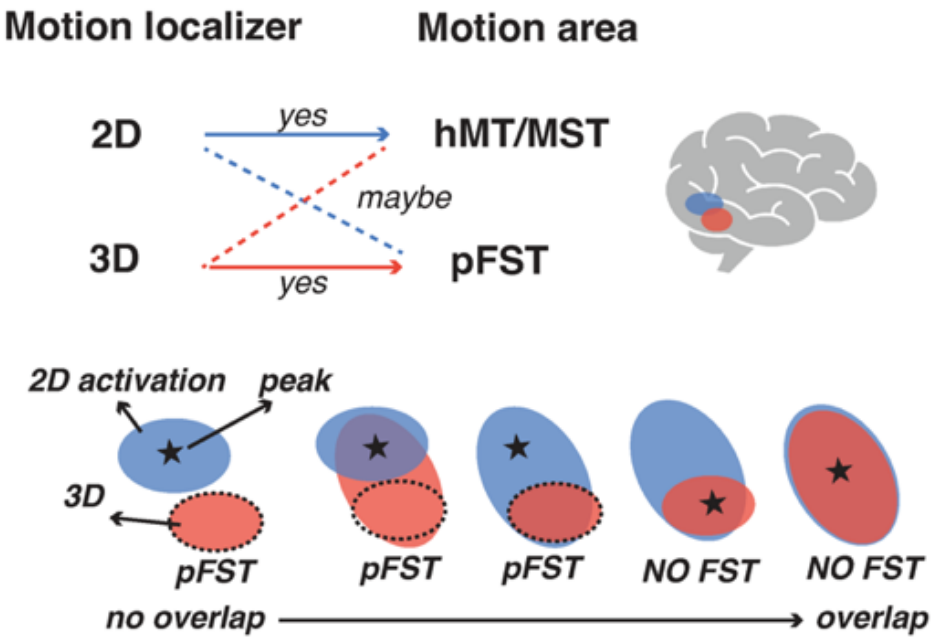
Visual conditions



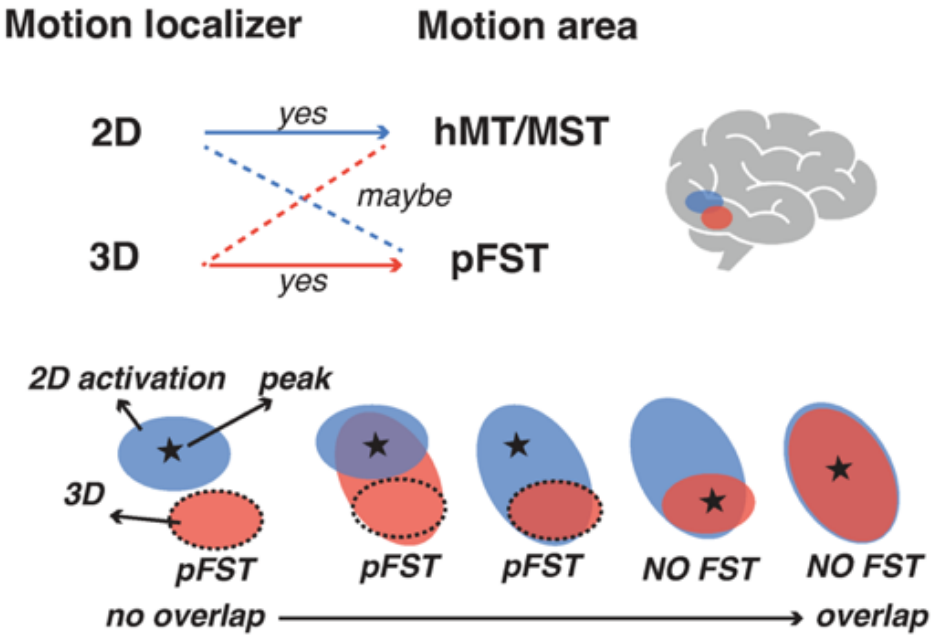
Logic to defining FST ROI

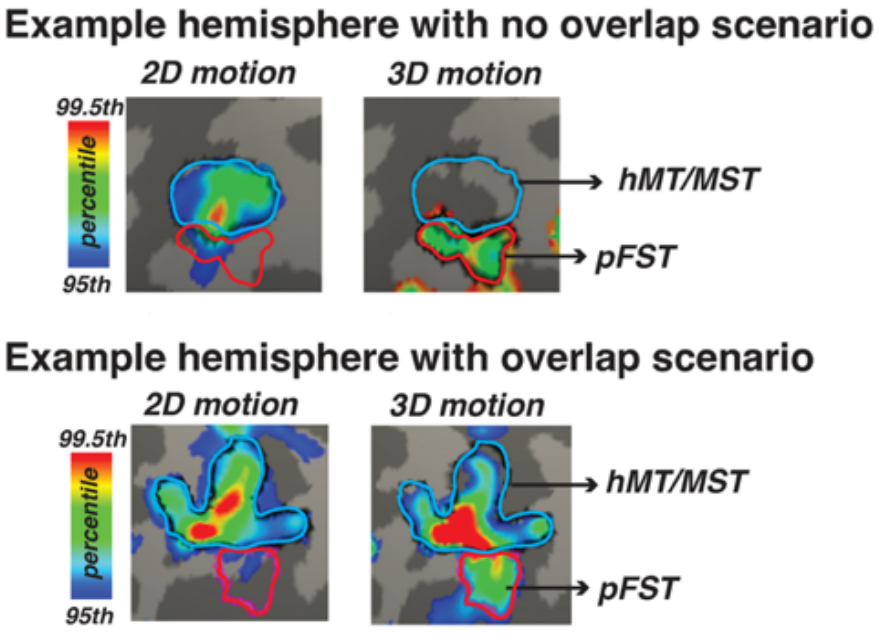


Logic to defining FST ROI

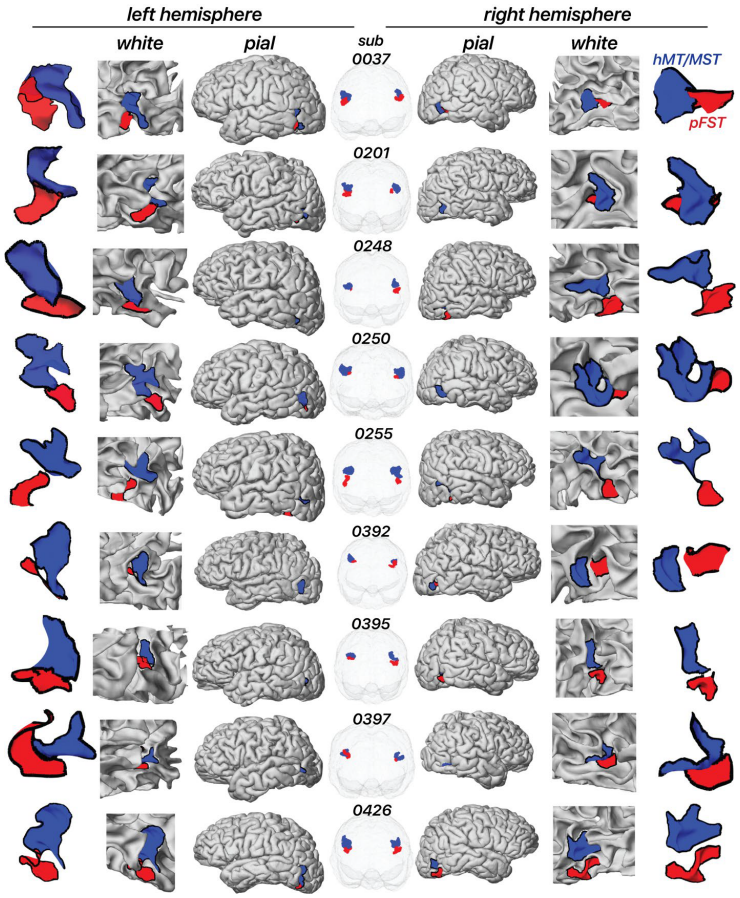


Logic to defining FST ROI

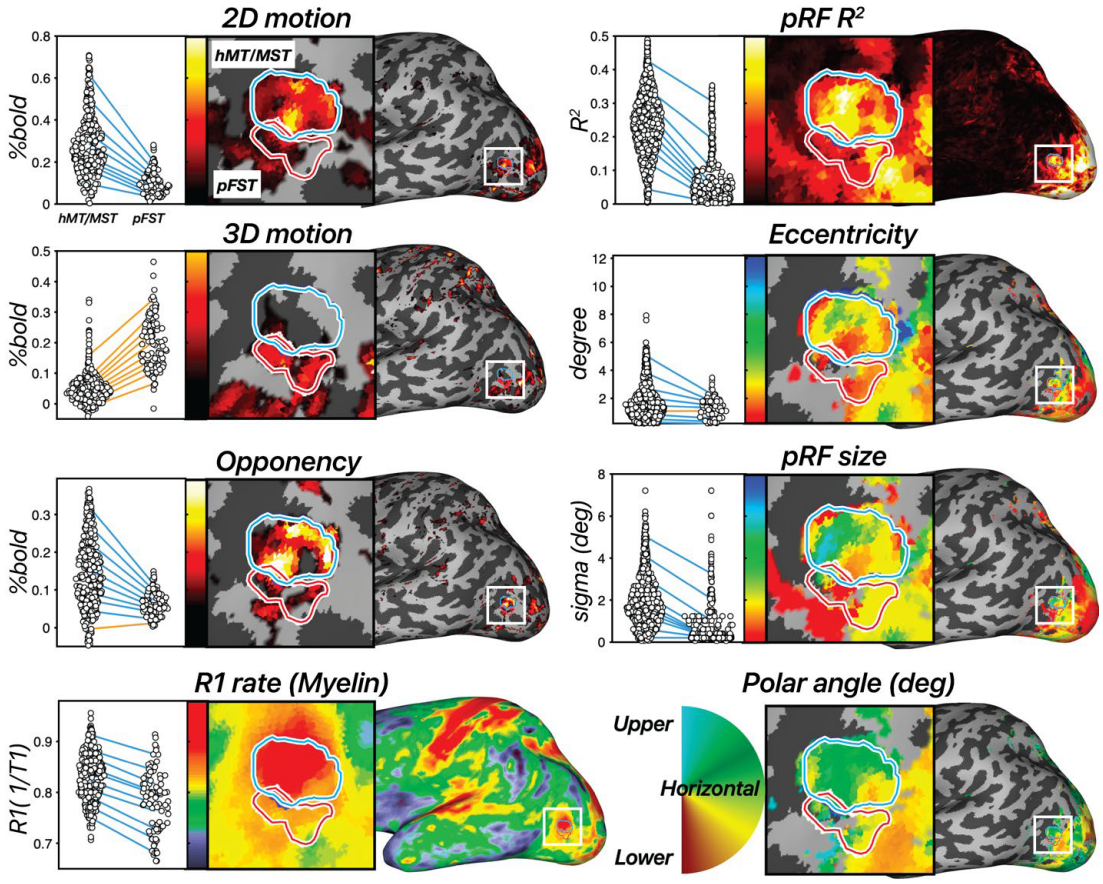




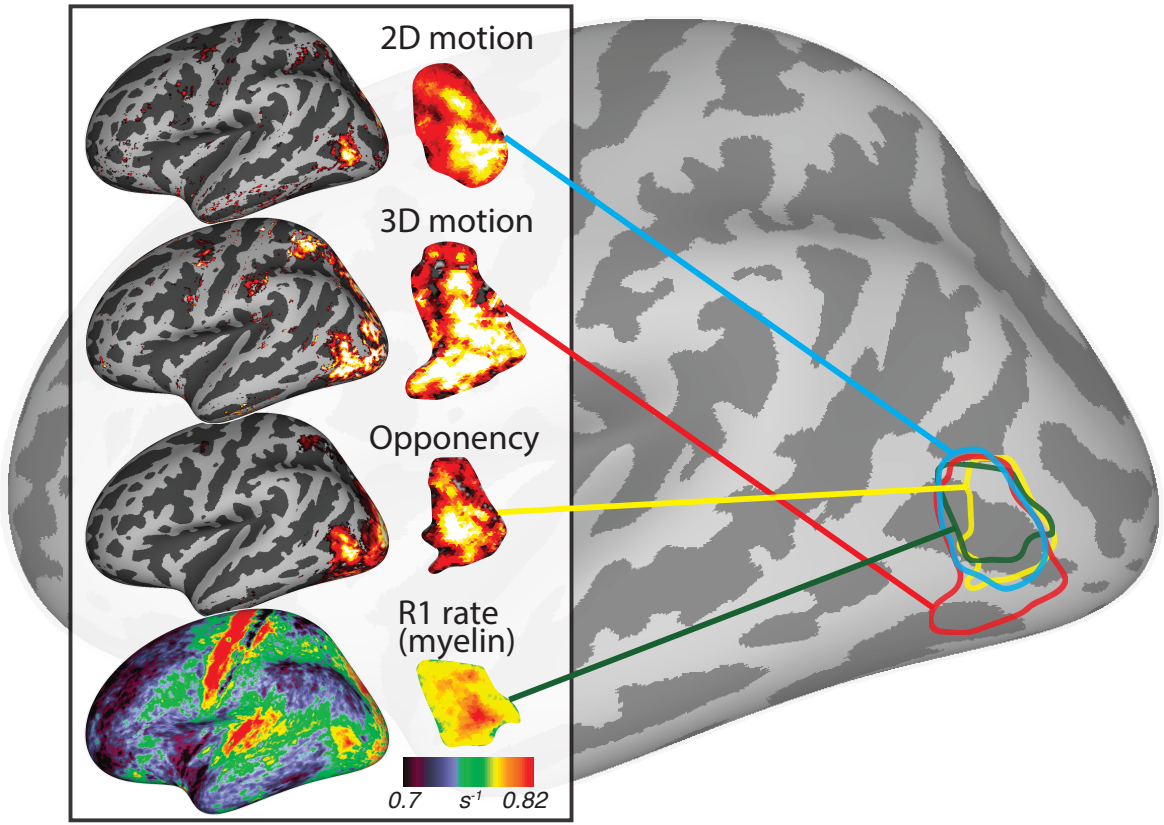
9 participants, 18 hemispheres



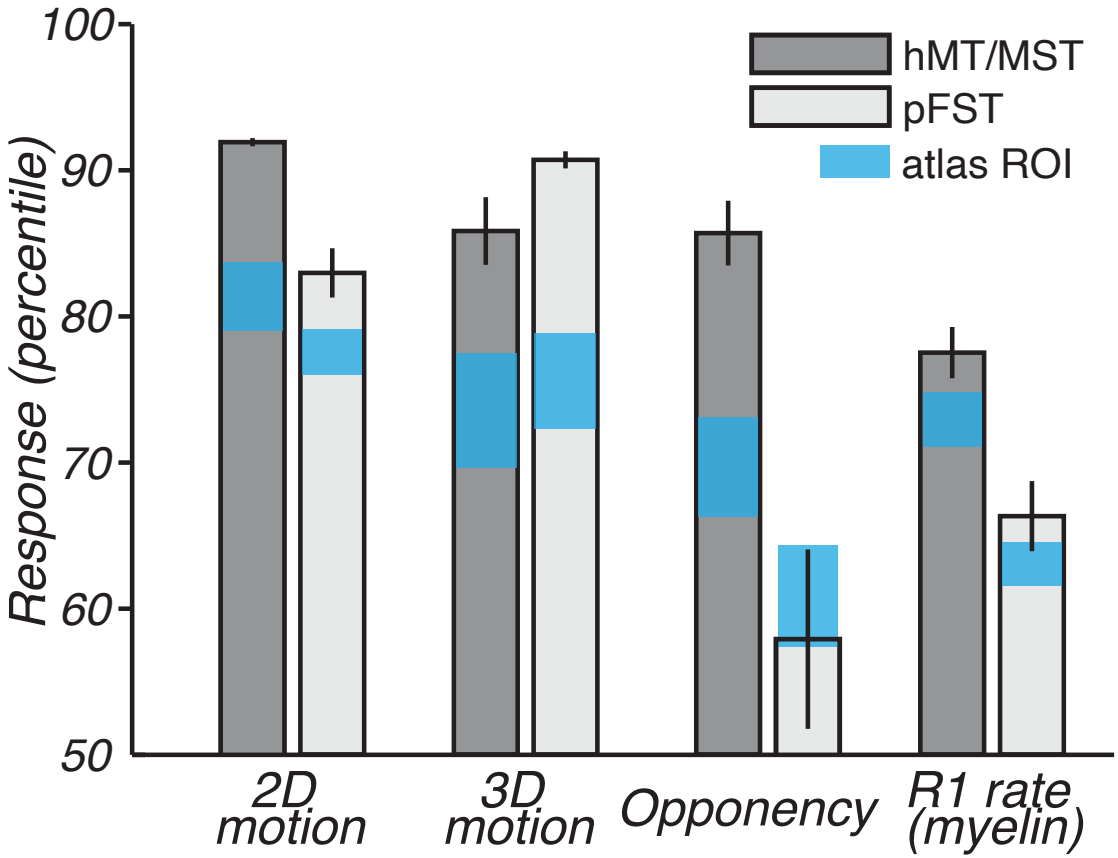
Confirmation by complementary methods



Group summary



Group summary



Part II: Discussion

- By comparing responses to a 2-D-motion and a coherent 3-D motion localizer, we can delineate putative human FST.
- This area is typically just ventral to MT/MST, but variation across participants is substantial.
- This segmentation is confirmed using an opponent-motion, paired-dot localizer as well as R1 rate (as an estimate of myelination), but not with atlas-defined ROIs.
- Note that segmentation using retinotopy is not effective, given the large population receptive fields and limited display size.

Wen, Ezzo, Thompson, Rosenberg, Landy & Rokers, under review

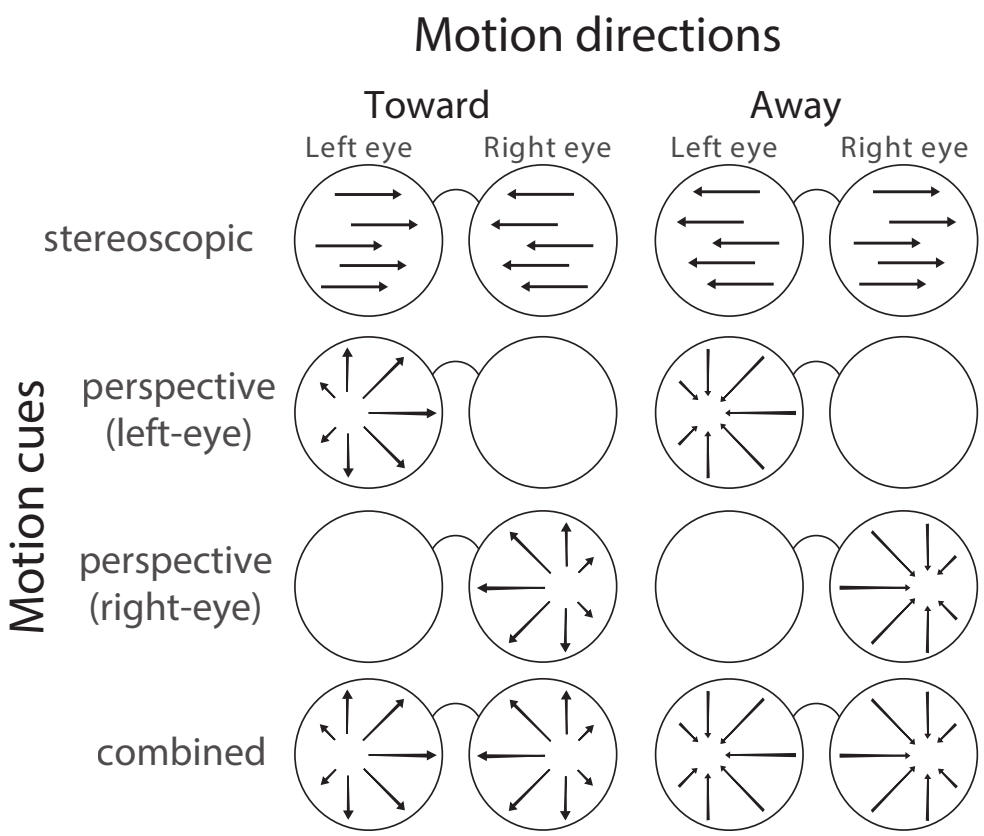
Outline

- Cortical processing of 3-D motion
- Localizing the human homolog of Area FST
- Relating cortical responses in MT and FST to cues and behavior

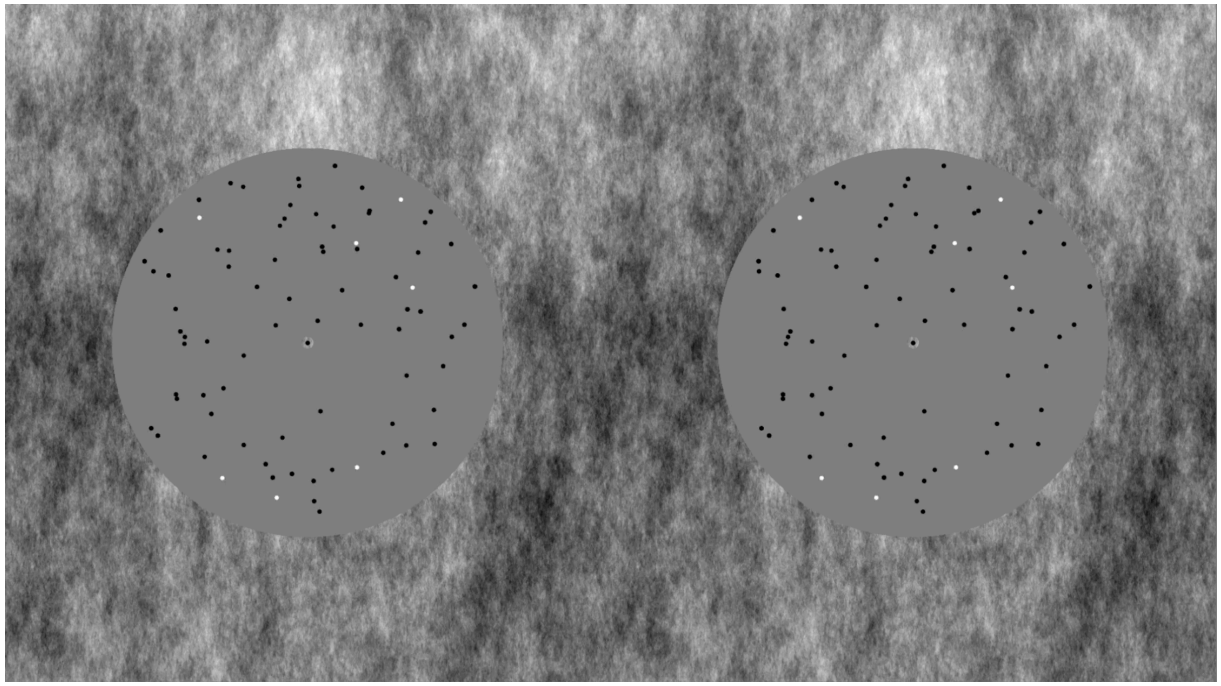
3-D motion cues

- There are a variety of visual cues to 3-D motion including the pattern of motion across the two retinae (disparity-change or interocular velocity difference) and monocular perspective cues (looming, density change, size change, etc.).
- Here, we vary the availability of these cues to determine which cortical areas (especially MT and FST) are specialized for each.
- In addition, we relate these findings across participants to their behavioral performance.

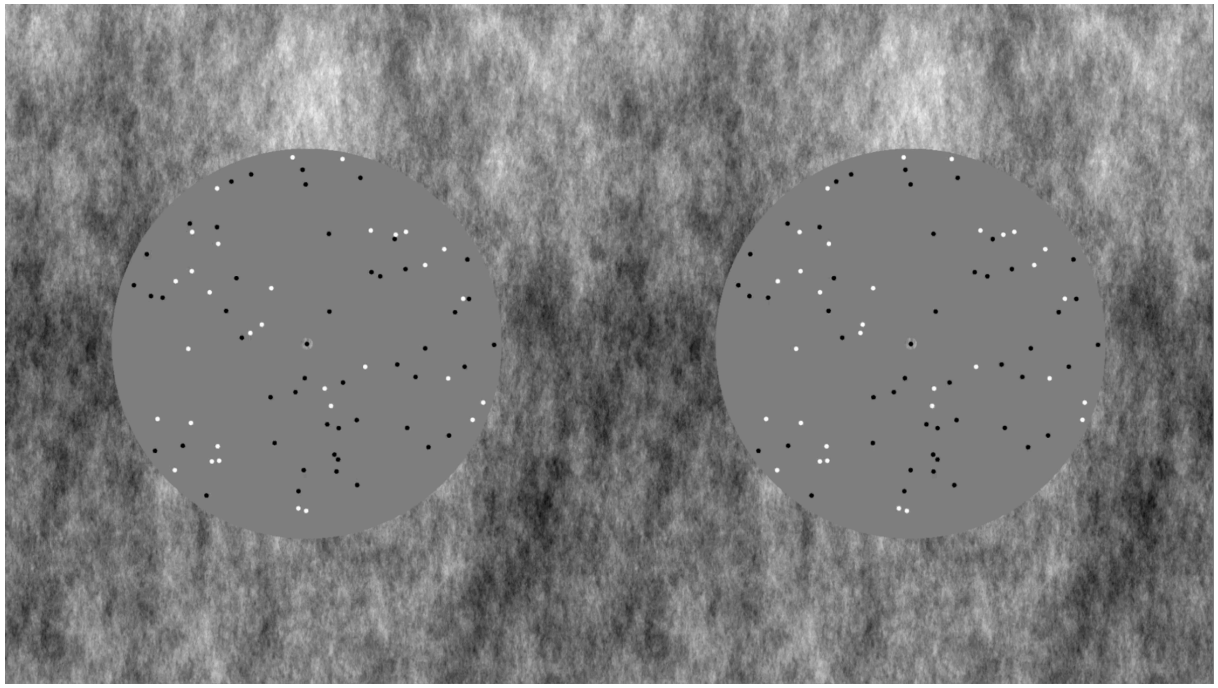
Stimulus conditions



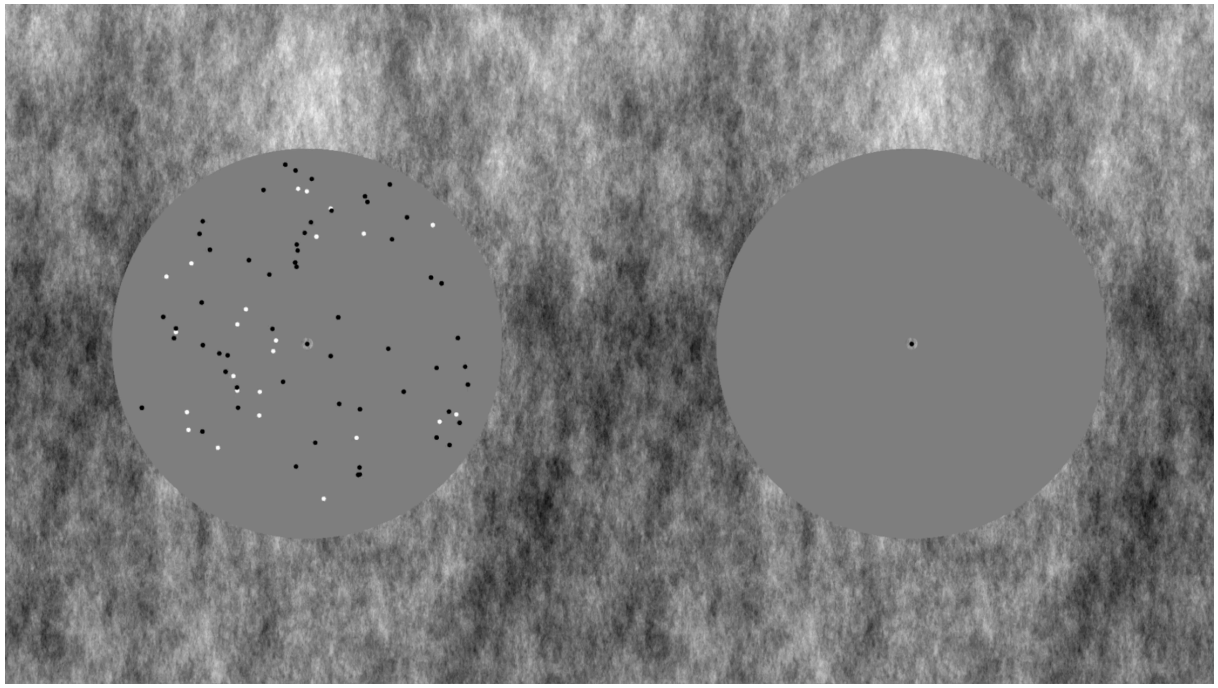
Example “combined” stimulus



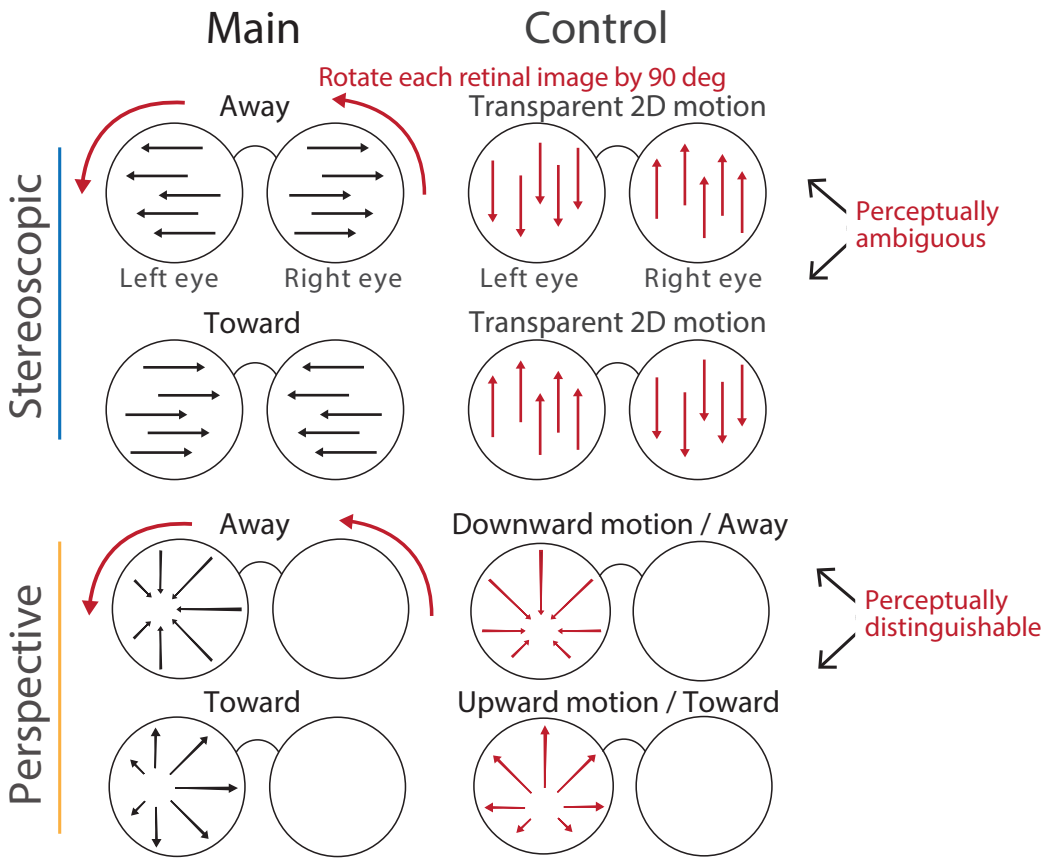
Example “binocular-only” stimulus



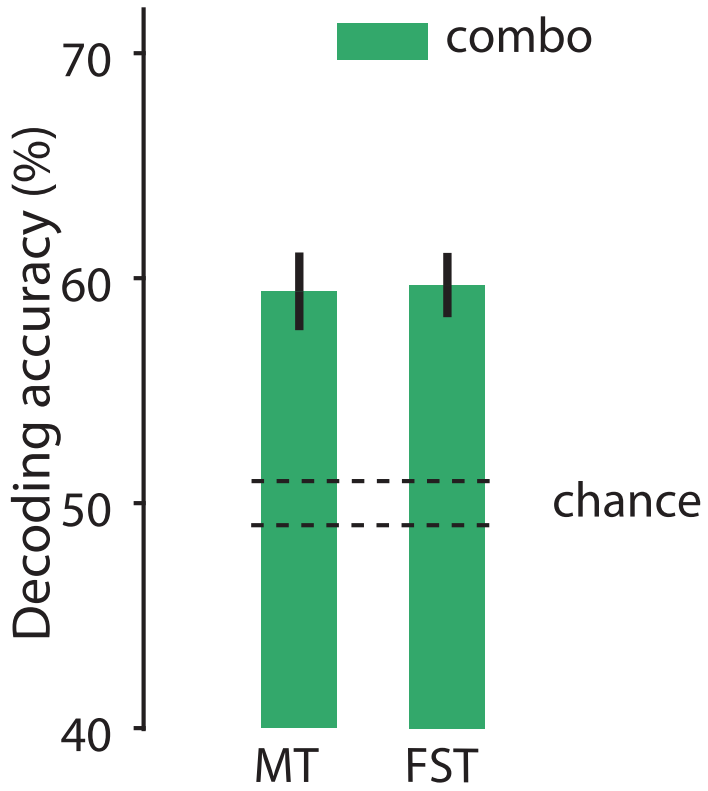
Example “monocular” stimulus



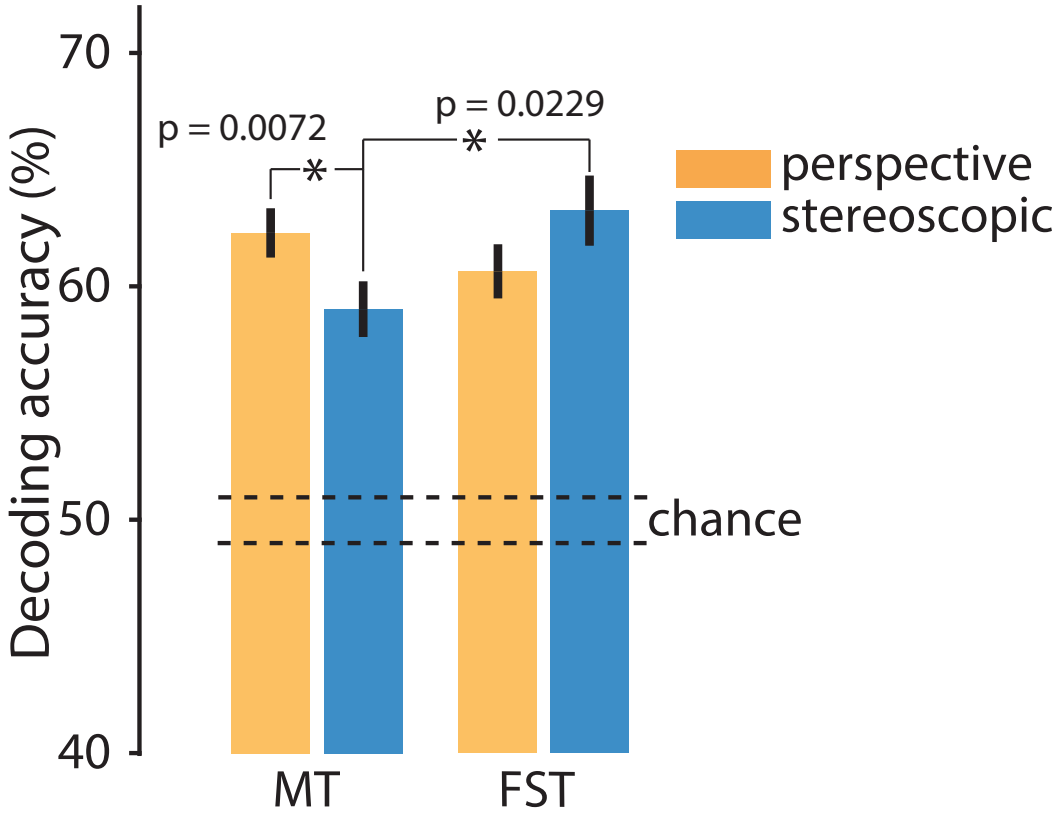
2-D control condition (rotated)



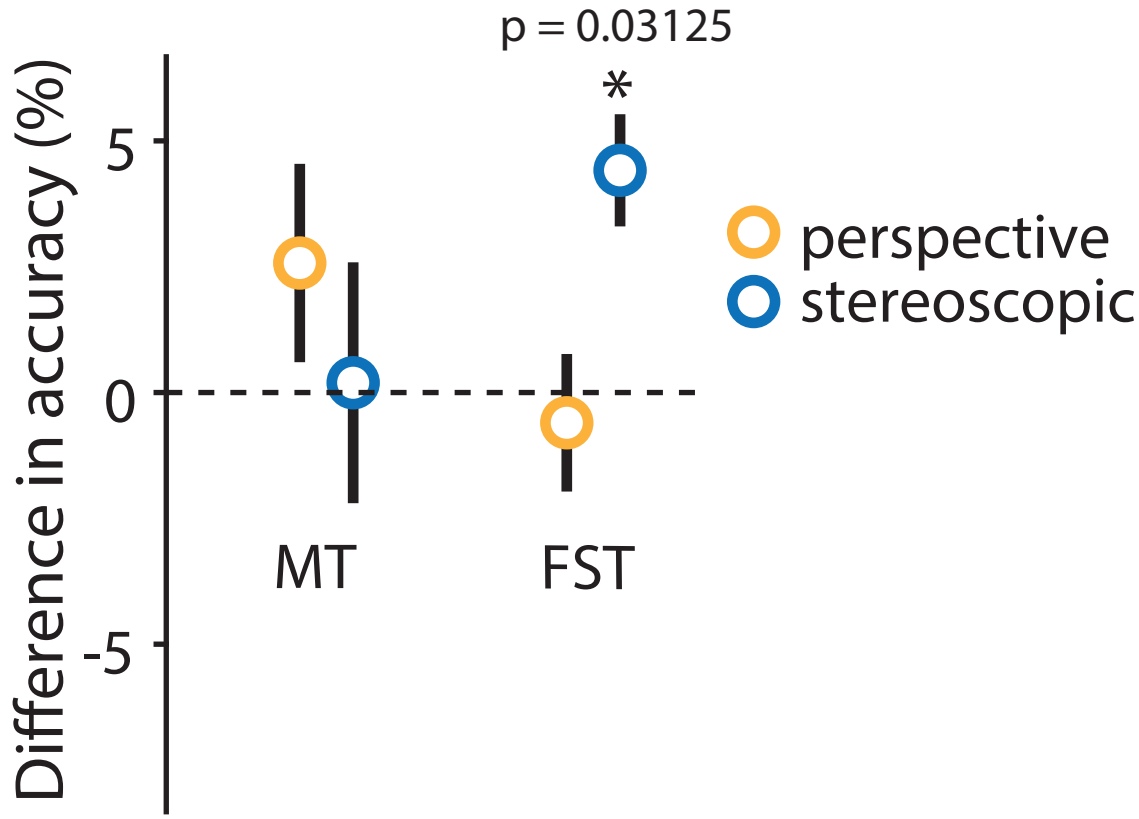
No MT/FST difference for combined cues



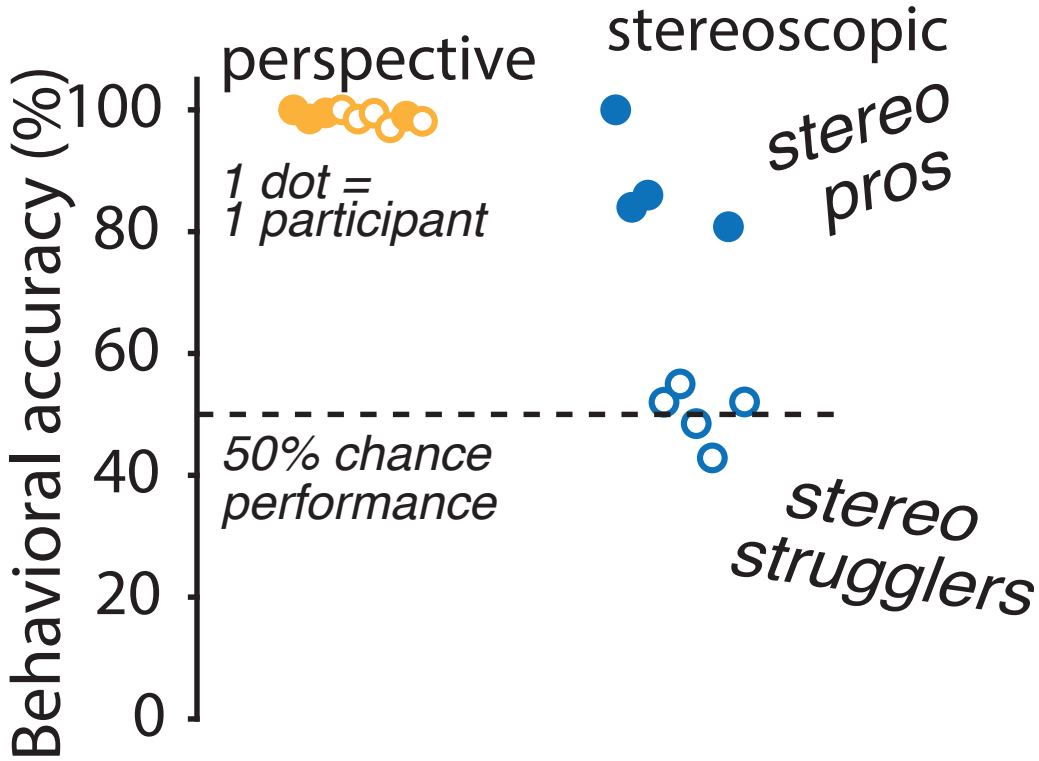
Striking MT/FST difference based on cue



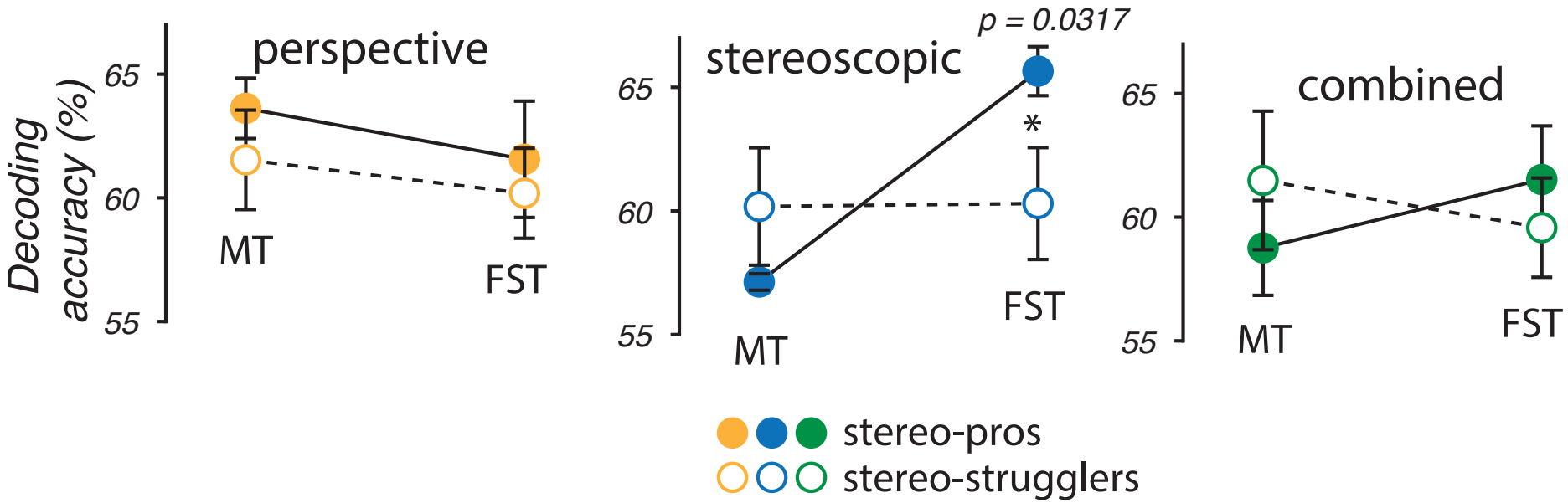
Striking MT/FST difference between regular and rotated control stimuli



Participants fell into two groups: Binocular pros and strugglers



MT vs. FST decoding discriminates binocular pros from strugglers



Part III: Discussion

- We compared decoding (toward vs. away motion) in areas MT and FST for stimuli with perspective, binocular motion and combined cues.
- Area FST showed evidence of specialization for coding stereomotion, not found in MT.
- This superiority of FST for coding stereomotion was not present in participants who failed at toward/away discrimination, suggesting that the code in FST for 3-D motion is used to guide behavior for 3-D motion discrimination.

Wen, Thompson, Rosenberg, Landy & Rokers, under review