Functional architecture and mechanisms for 3D direction & distance in middle temporal visual area.

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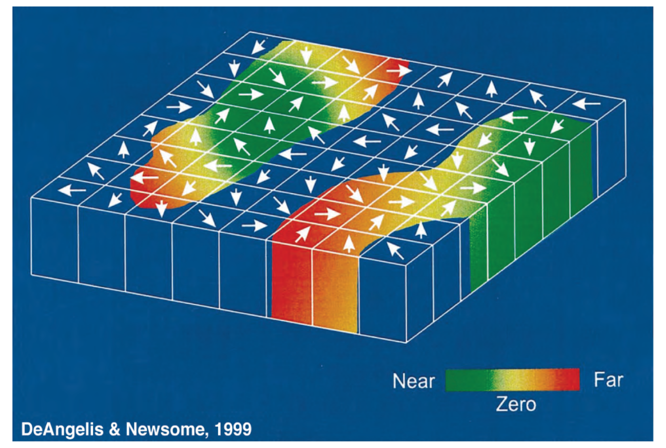
How are 3D motion & space represented in MT?

Recent evidence for 3D direction selectivity

- Most MT neurons exhibit selectivity for 3D motion direction (Czuba, Huk, Cormack, Kohn, 2014; Sanada & DeAngelis, 2014)
- Tuning for 3D motion along XZ-plane is non-gaussian
- Well predicted by Binocular 3D model based on monocular speed tuning & projective geometry (Bonnen, Czuba, Whritner, Kohn, Huk, Cormack, 2019 In Review)

Canonical model of MT functional topography

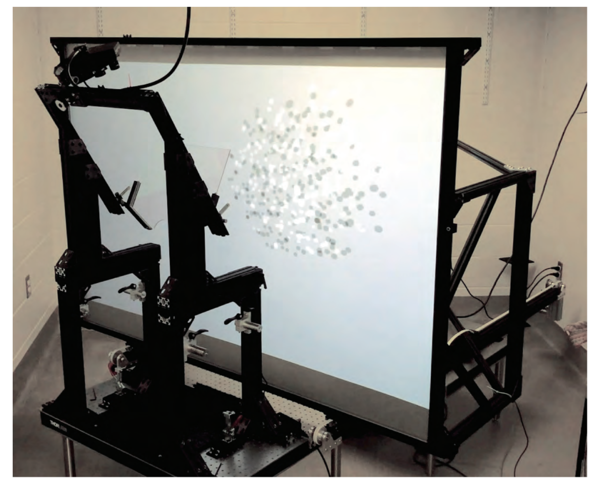
- Orderly progression of direction & disparity preference (DeAngelis & Newsome, 1999)



- 2D direction columns
- Interdigitated bands of strong/weak disparity tuning
- How is 3D selectivity organized?

Characterize MT responses to binocular 3D motion using stimulus geometry more similar to natural viewing

View-Dist 3D Display & Recording



Projective 3D stimulus geometry

- On-the-fly adjustable viewing distance (30–120 cm)
  - 1.8 m wide • 154–73° field-of-view • 120 Hz/eye, ≤1% crosstalk
- 3D rear-projection system w/ passive circular polarization

Extracellular recording in awake–fixating macaque

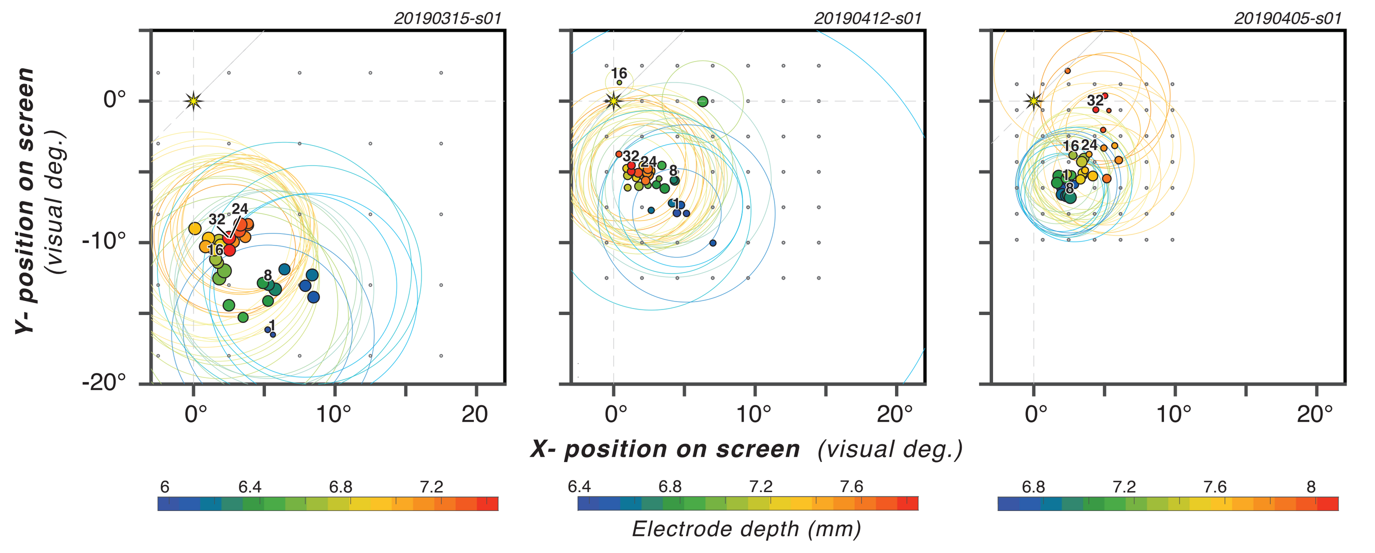
- Linear array penetrations tangential to cortical surface
- 32 channels arranged in 16 stereotrode sites (Plexon U-Probe)
- 50 μm within, 100 μm between stereo-pairs • 1.5 mm total span

Site selection & mapping in 3D space

- All stimuli presented in full projective geometry
  - Incl. binocular & monocular depth cues
- Spatial receptive fields mapped with 3D grid of moving dot spheres
  - 3–5° dia. • Uniform dot density
  - Standard 2D sampling grid presented across three planes of disparity (±1°)
  - Rapid sequential presentation during binocular tracking of stable fixation

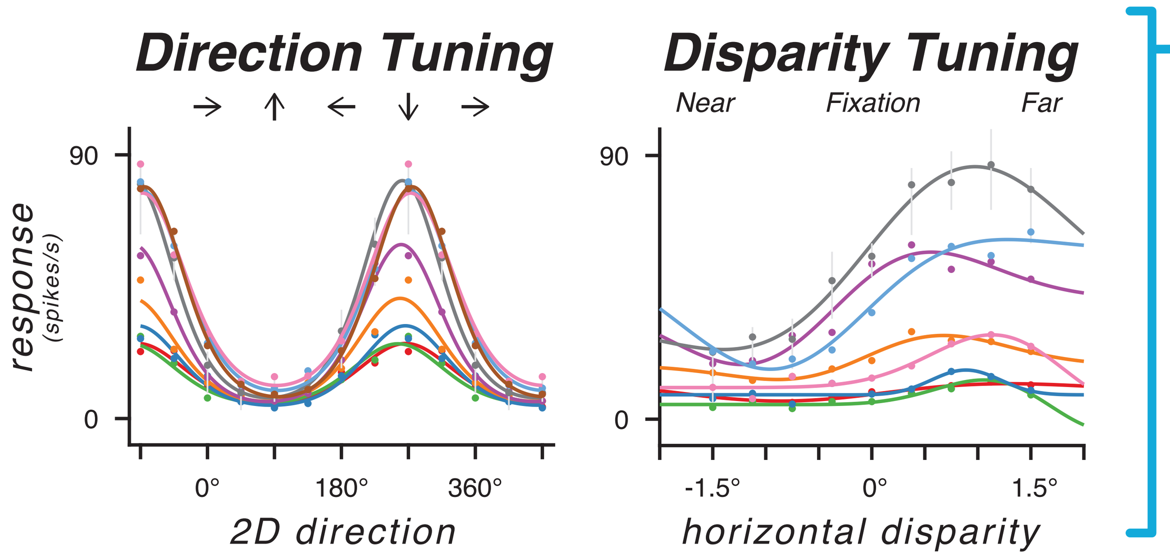
Stimulus Demos

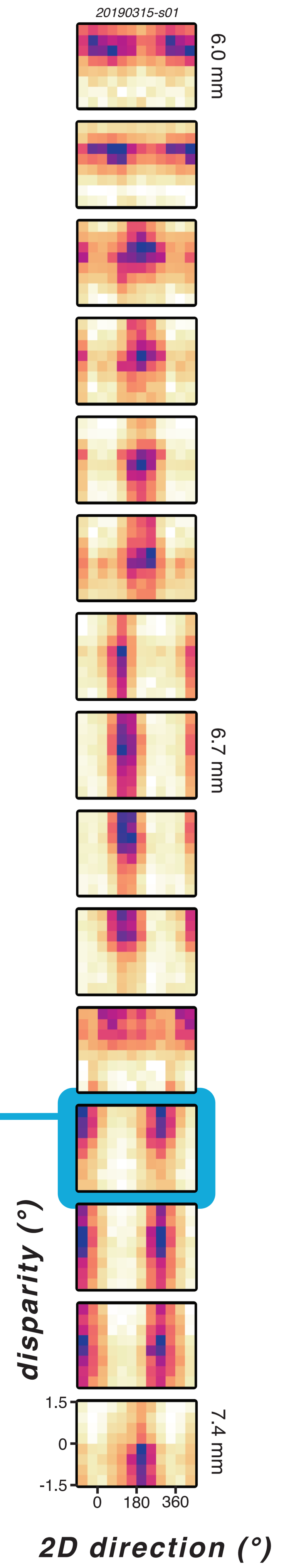
Tangential penetrations allow simultaneous sampling across cortical surface



Concurrent mapping of 2D direction & binocular disparity tuning

- Frontoparallel plane of moving dots: 0–360°, 45° inc, 10-12°/s
- Offset in depth: 9 steps, spanning ±1.5° horiz. disparity
- Retinal size, speed, & spatial extent matched across depth

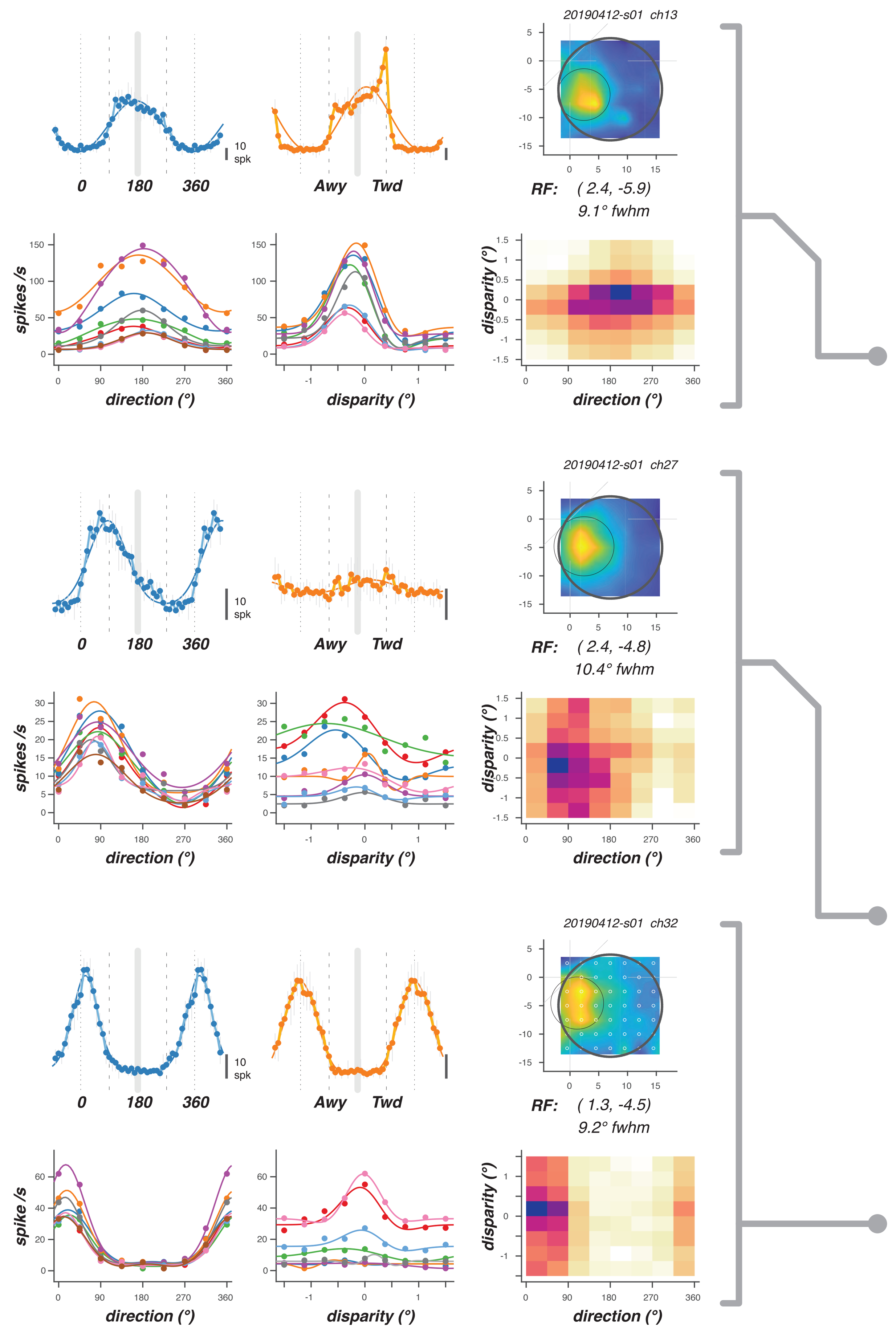


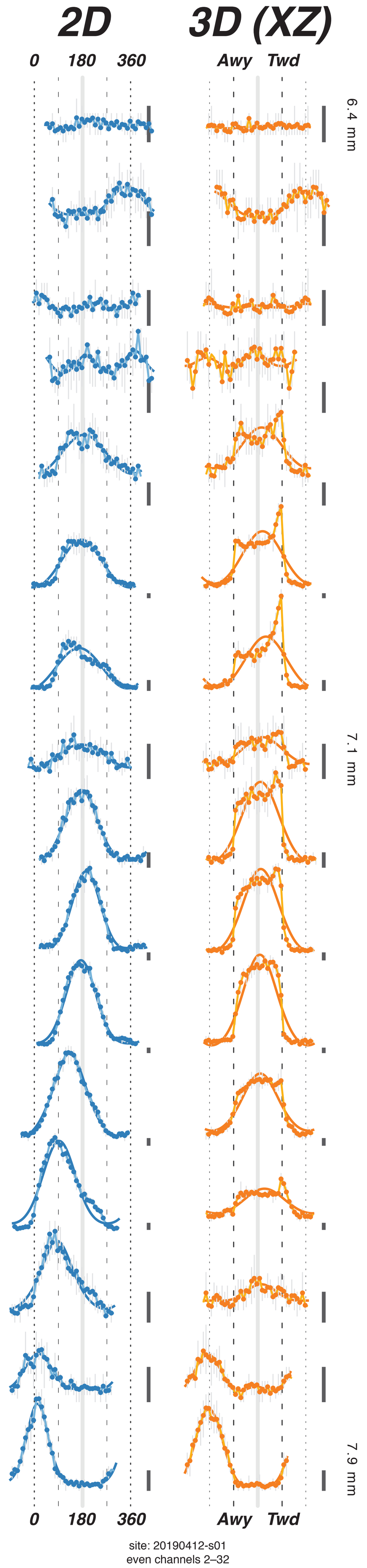


Tuning for 3D motion direction in the XZ plane

- Uniform sphere of moving dots
  - Diameter scaled to span aggregate RFs (~15-30°)
  - Rendered with full binocular, expansion, & size-chage depth cues
- Motion direction sampled in 10° inc. across:
  - 2D frontoparallel plane: Left/Right—Up/Down
  - 3D XZ plane: Left/Right—Toward/Away
- Egocentric frame of reference
  - XZ 90° & 270° always directly Away & Toward

Distinct tuning for motion in 3D space

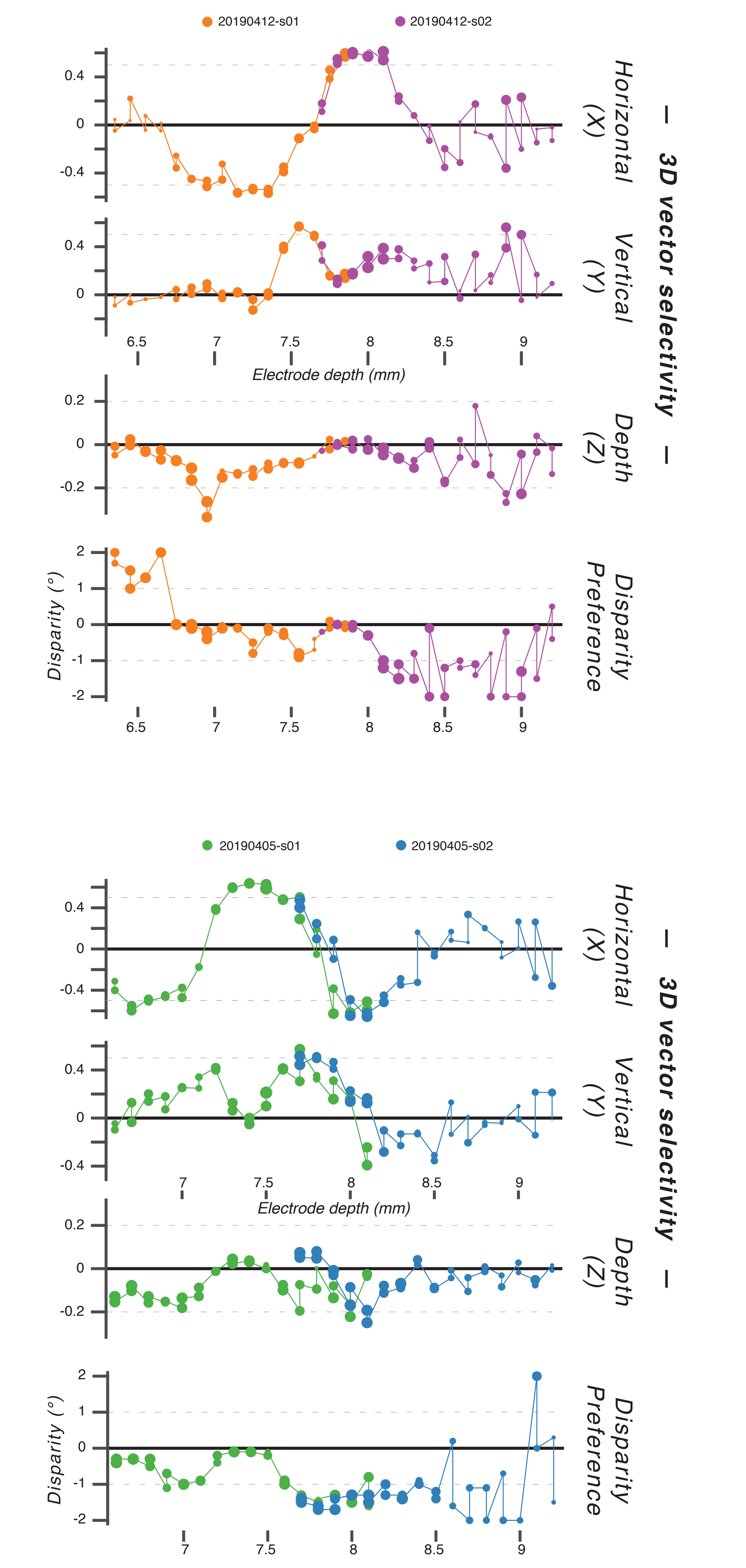




Functional topography of MT reveals orderly transitions of complex selectivity for 3D motion & space

- Decomposition of X, Y, & Z component response across recording penetrations

$$r_x = \frac{r_{xy}^{\top}\cos(\theta_{xy})}{\|r_{xy}\|\,\|\cos(\theta_{xy})\|} \quad r_y = \frac{r_{xy}^{\top}\sin(\theta_{xy})}{\|r_{xy}\|\,\|\sin(\theta_{xy})\|} \quad r_z = \frac{r_{xz}^{\top}\sin(\theta_{xz})}{\|r_{xz}\|\,\|\sin(\theta_{xz})\|}$$



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