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High-resolution imaging of skin deformation shows that afferents from human fingertips signal slip onset

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Presented by: James Goodman

Neurobiology Group Journal Club

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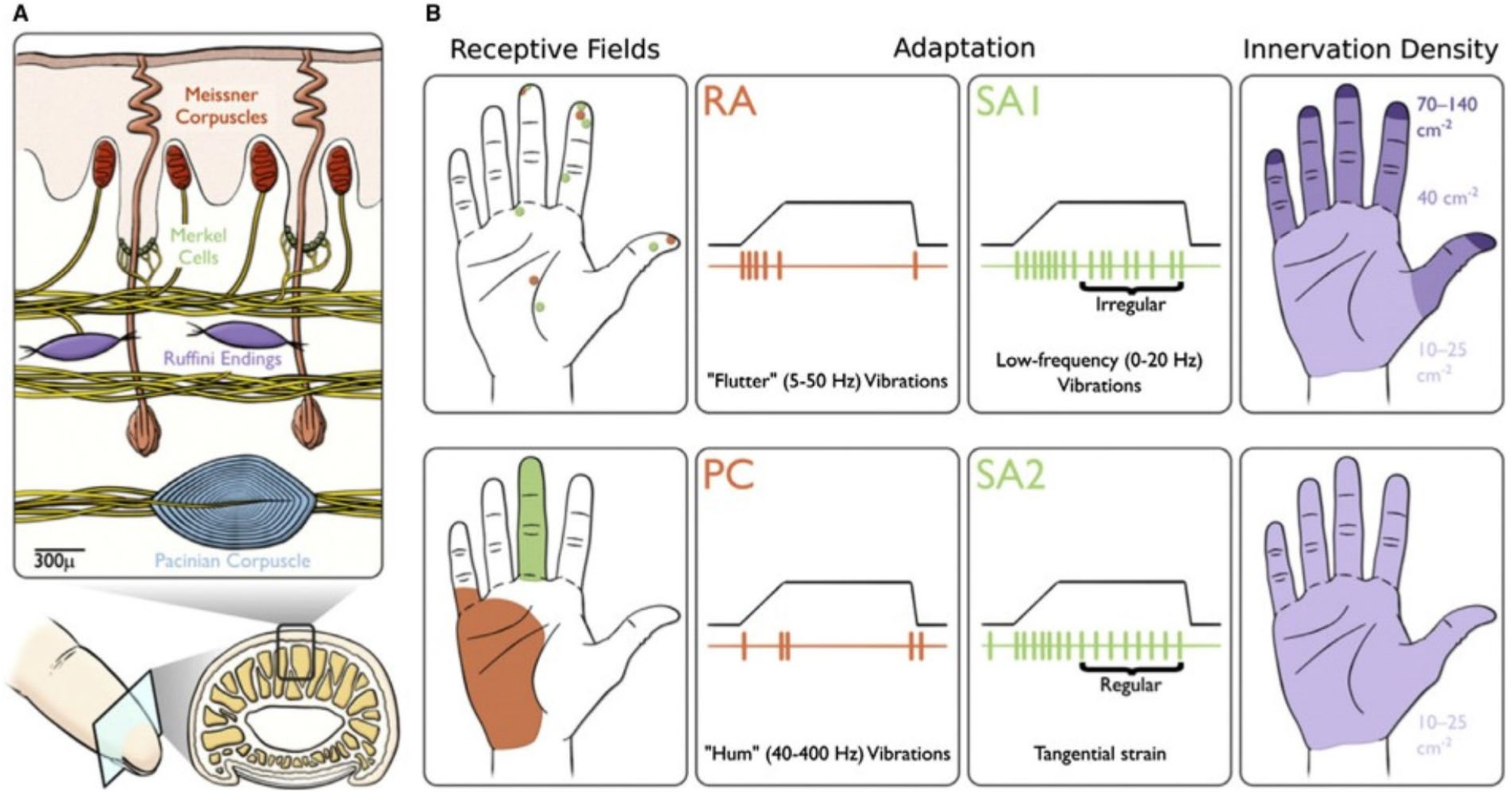
Mitglied der Leibniz-Gemeinschaft

Why this paper for this group?

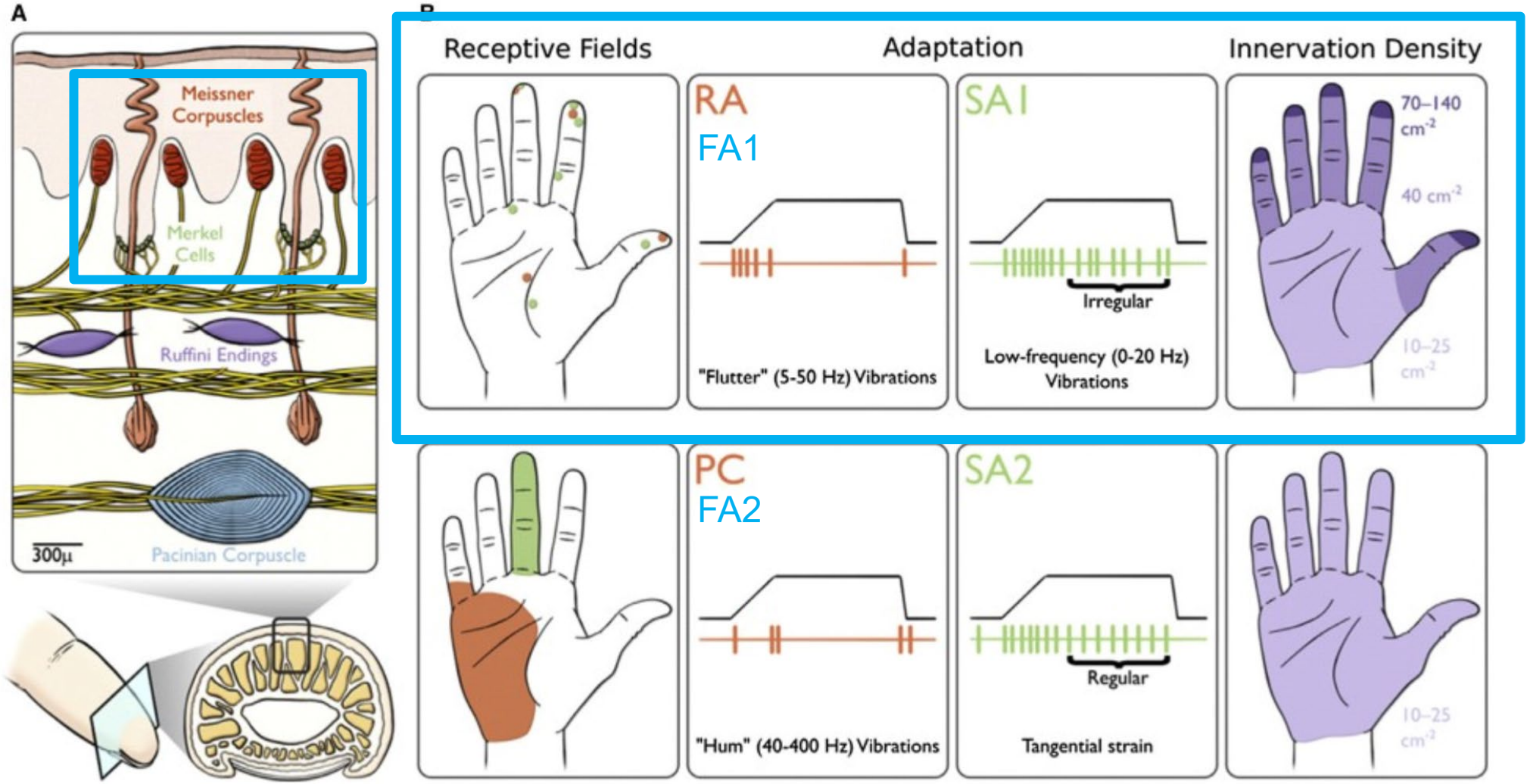
- There is a general, at least passing interest in touch research
- This paper studies a stimulus class often neglected, yet quite important, in touch research
- The methodology is impressive and likely of general interest

Tactile afferents: a review



Adapted from: Vallbo & Johansson 1984 *Hum. Neurobiol.*

Tactile afferents: a review



By Kenzie Green for Goodman & Bensmaia 2020 *The Senses*.

Adapted from: Vallbo & Johansson 1984 *Hum. Neurobiol.*

Normal perturbations are the typical context studied

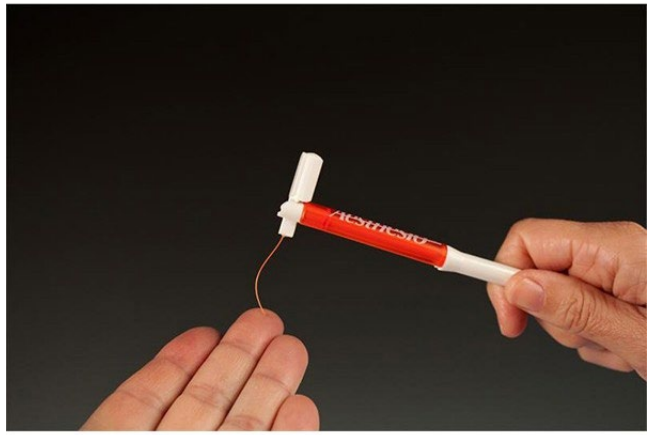


Image credit:

von Frey filament merchant:

Bioseb

bioseb.com

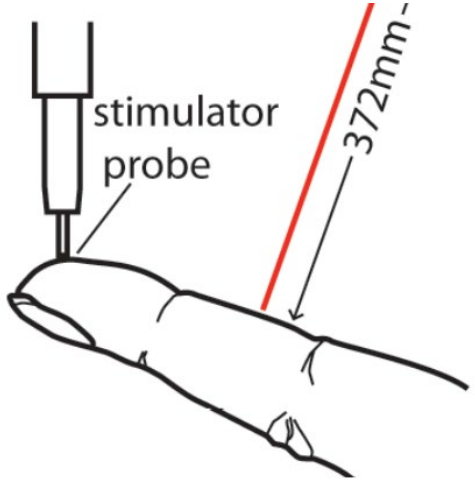


Image credit:

Manfredi et al. 2012 *PLoS One*

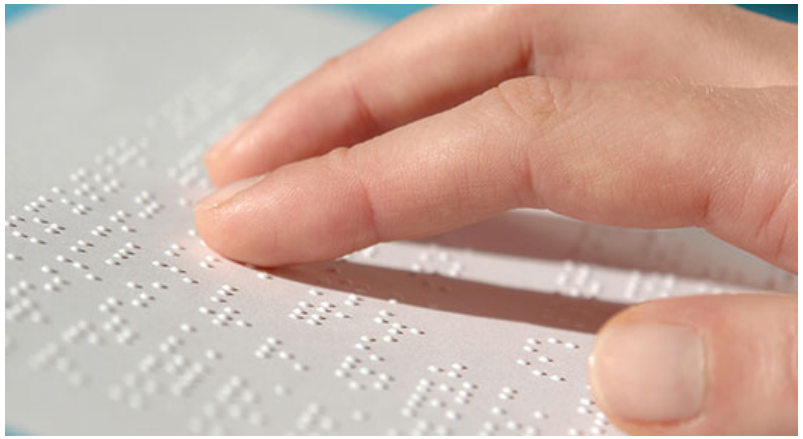
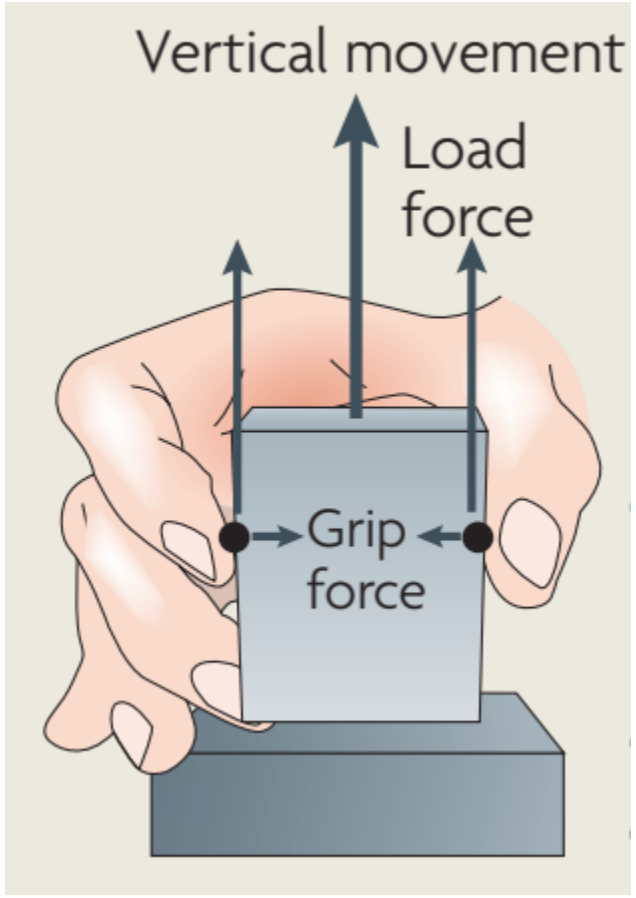


Image credit:

American Foundation for the Blind

afb.org

During movement, tangential perturbations are important



Johansson and Flanagan 2009 *Nat Rev Neurosci*

Setup at a glance

Stimulus: a smooth, tangentially-shifting plane with a camera imaging from underneath

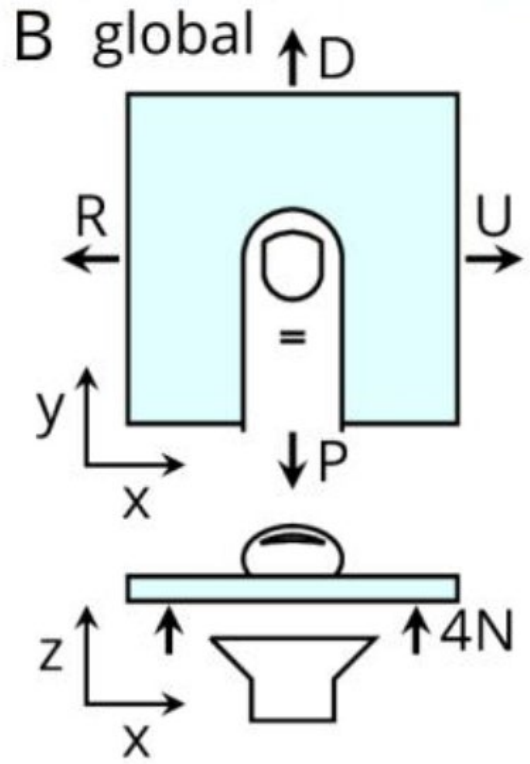
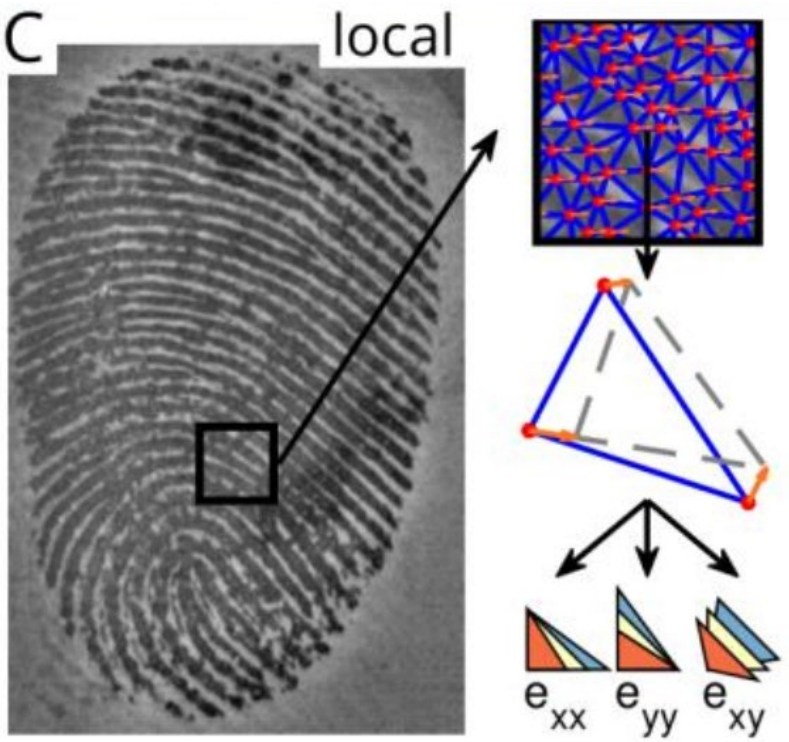


Image processing technique to compute tangential strains and contact area



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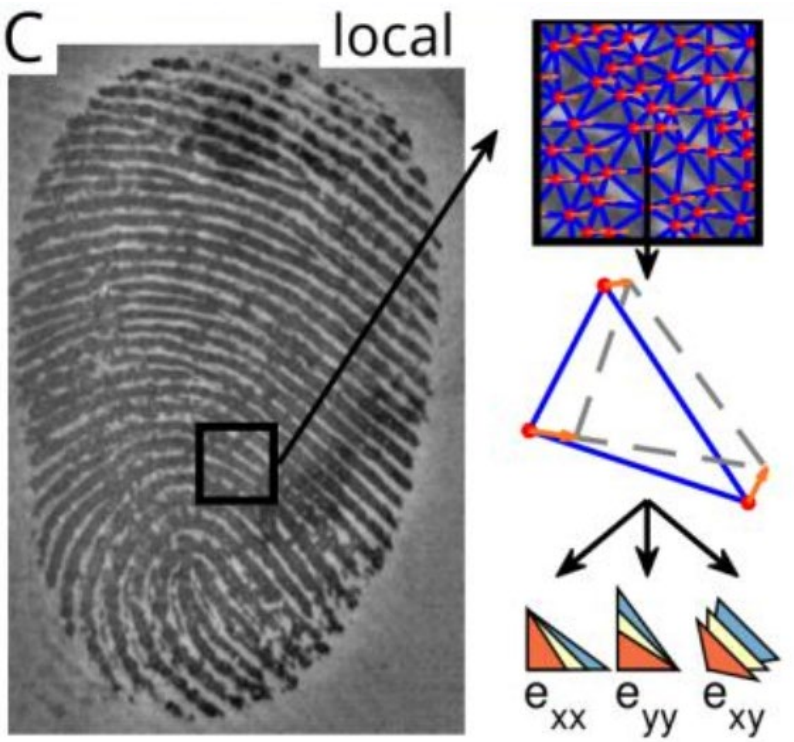
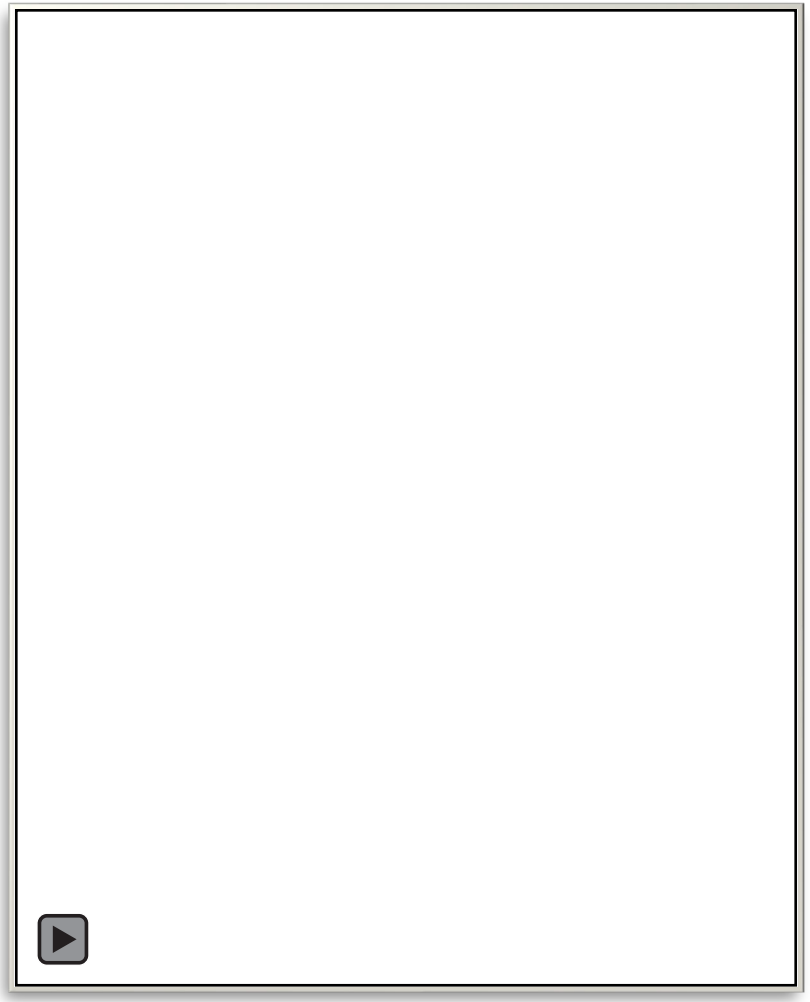
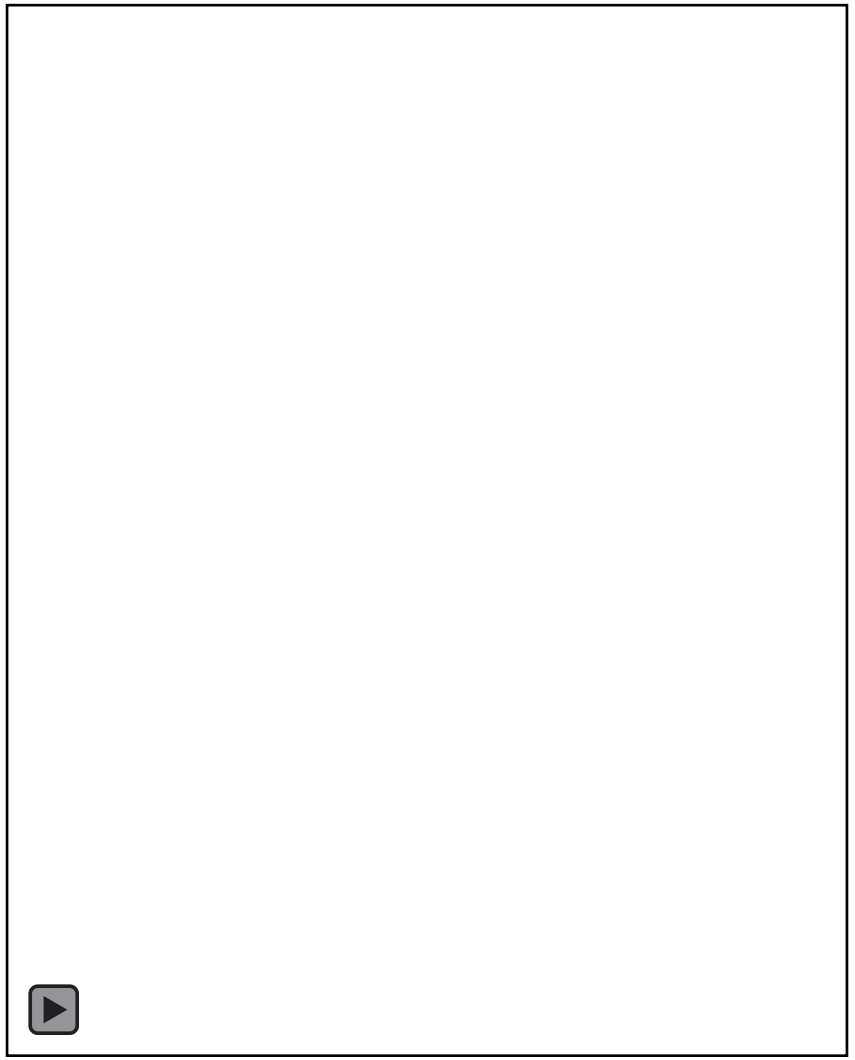


- Grid sampling of features on frame 1
- Optical flow algorithm to automatically track features
- Delaunay triangulation
- Green-Lagrange strains of those triangles

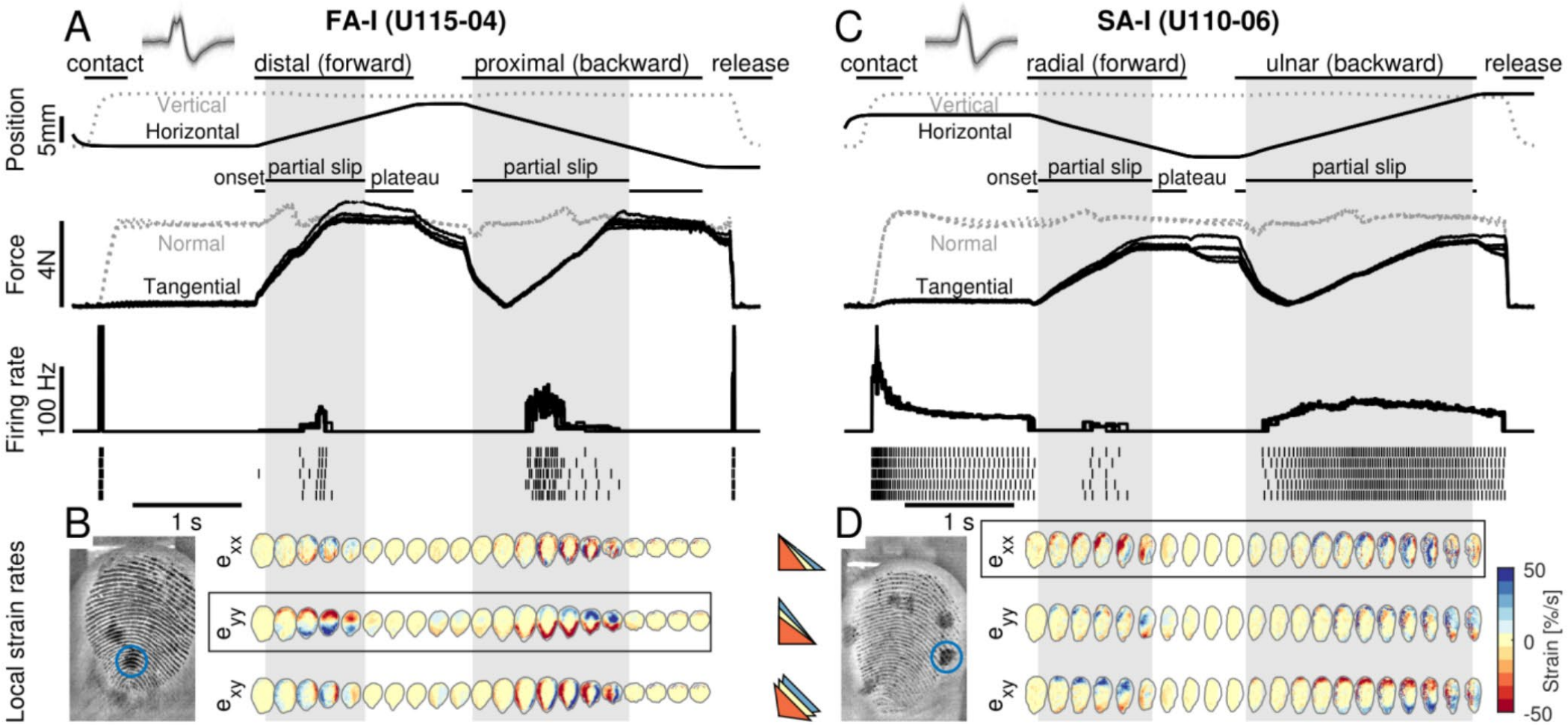
What the experiment looks like in motion: example FA-1 unit



What the experiment looks like in motion: example SA-1 unit



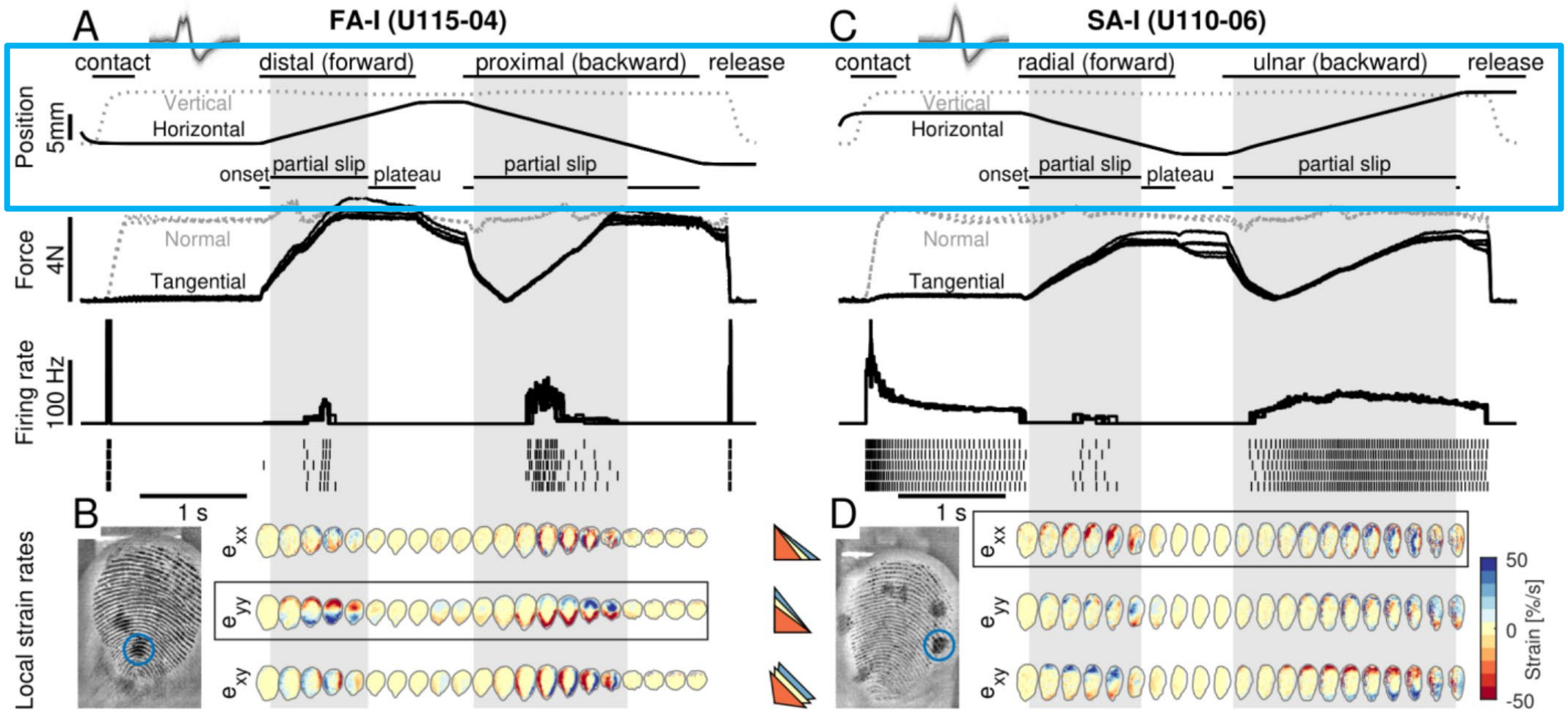
Example FA-1 and SA-1 unit data



Example FA-1 and SA-1 unit data

Stimulus

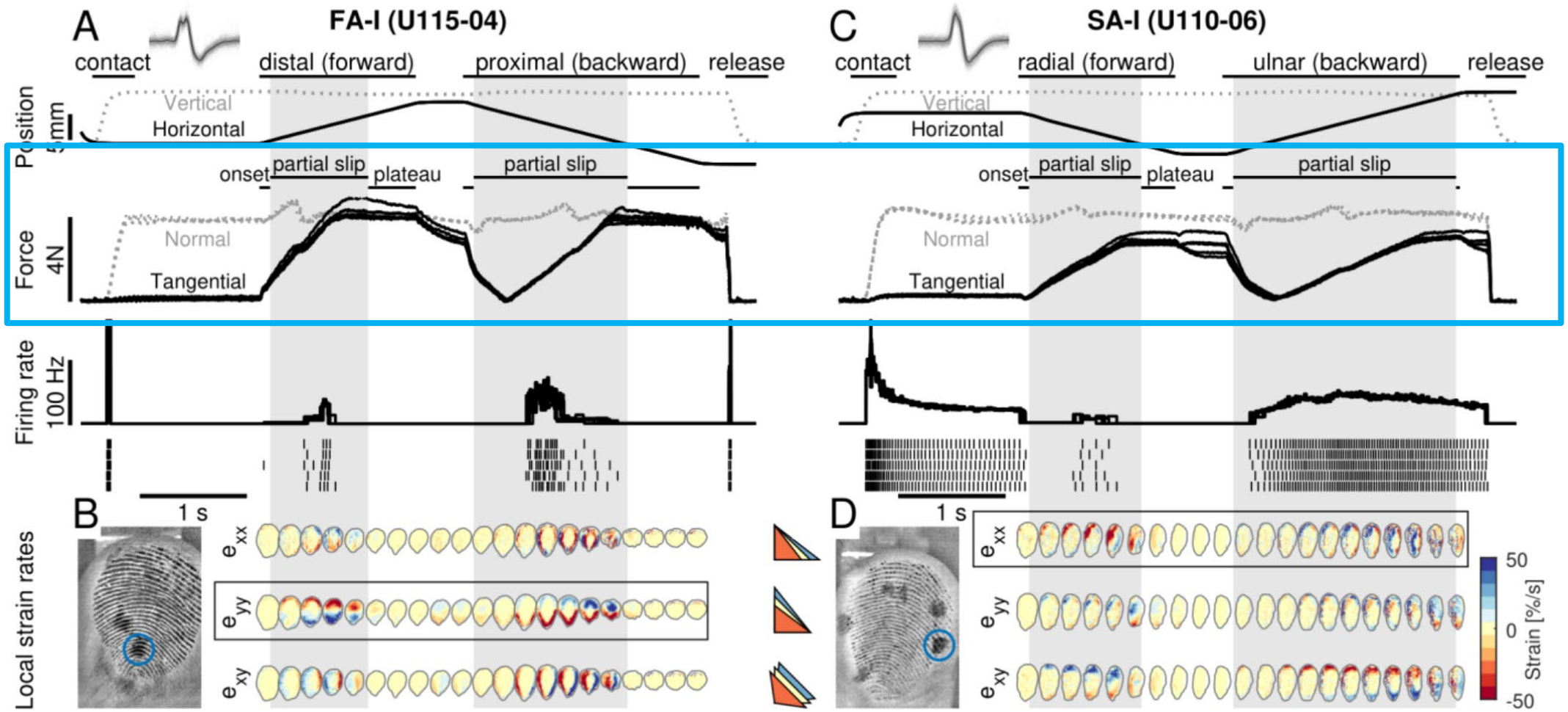
Kinematics



Example FA-1 and SA-1 unit data

Stimulus

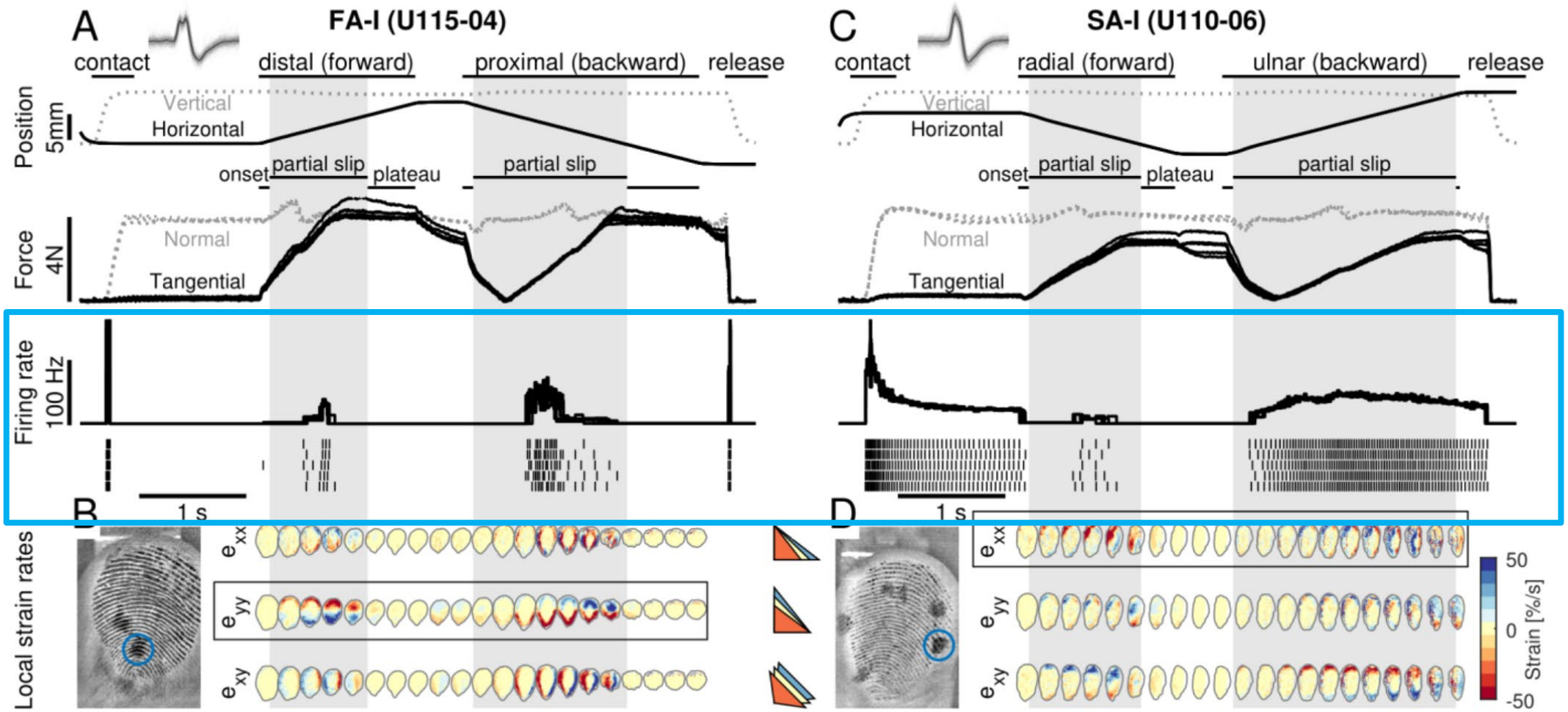
Kinetics



Example FA-1 and SA-1 unit data

Afferent

Spiking



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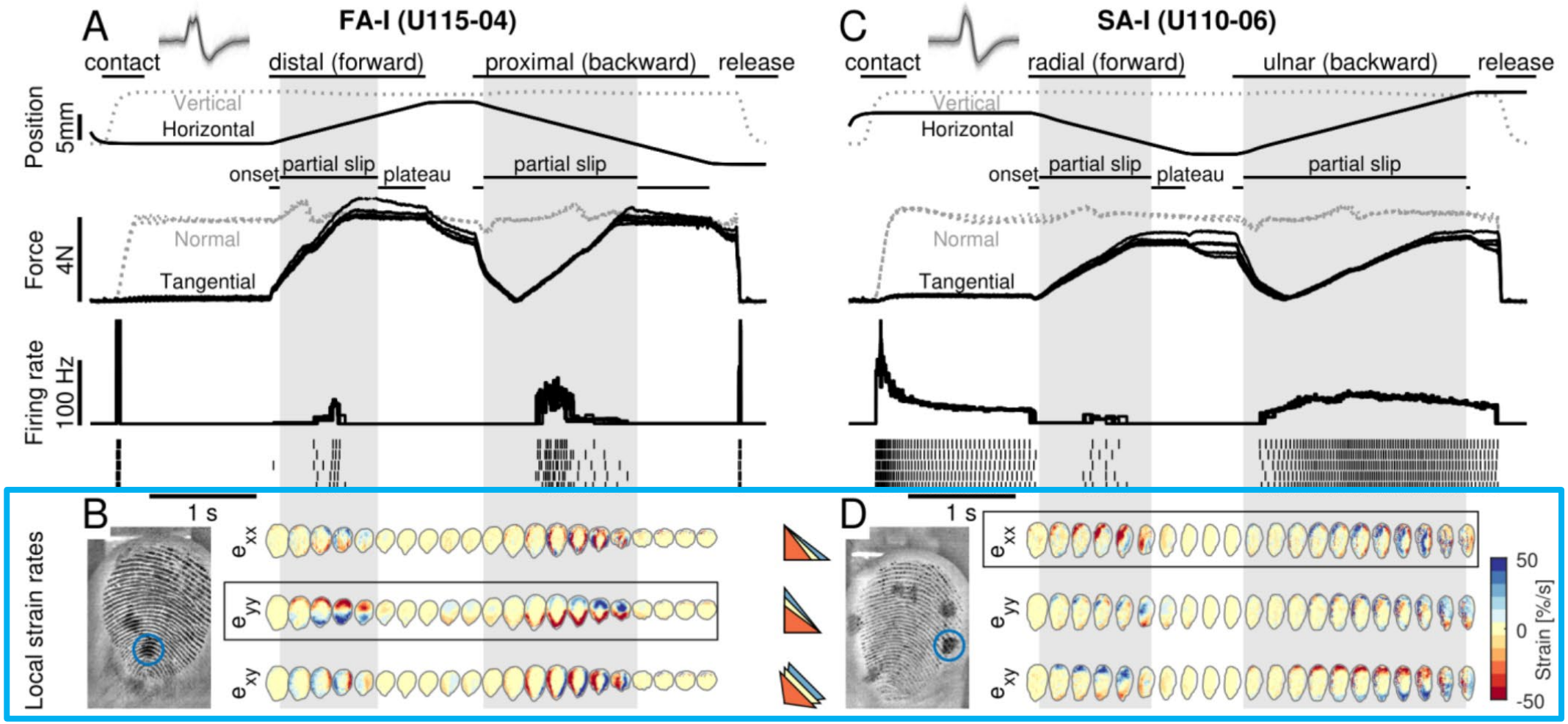
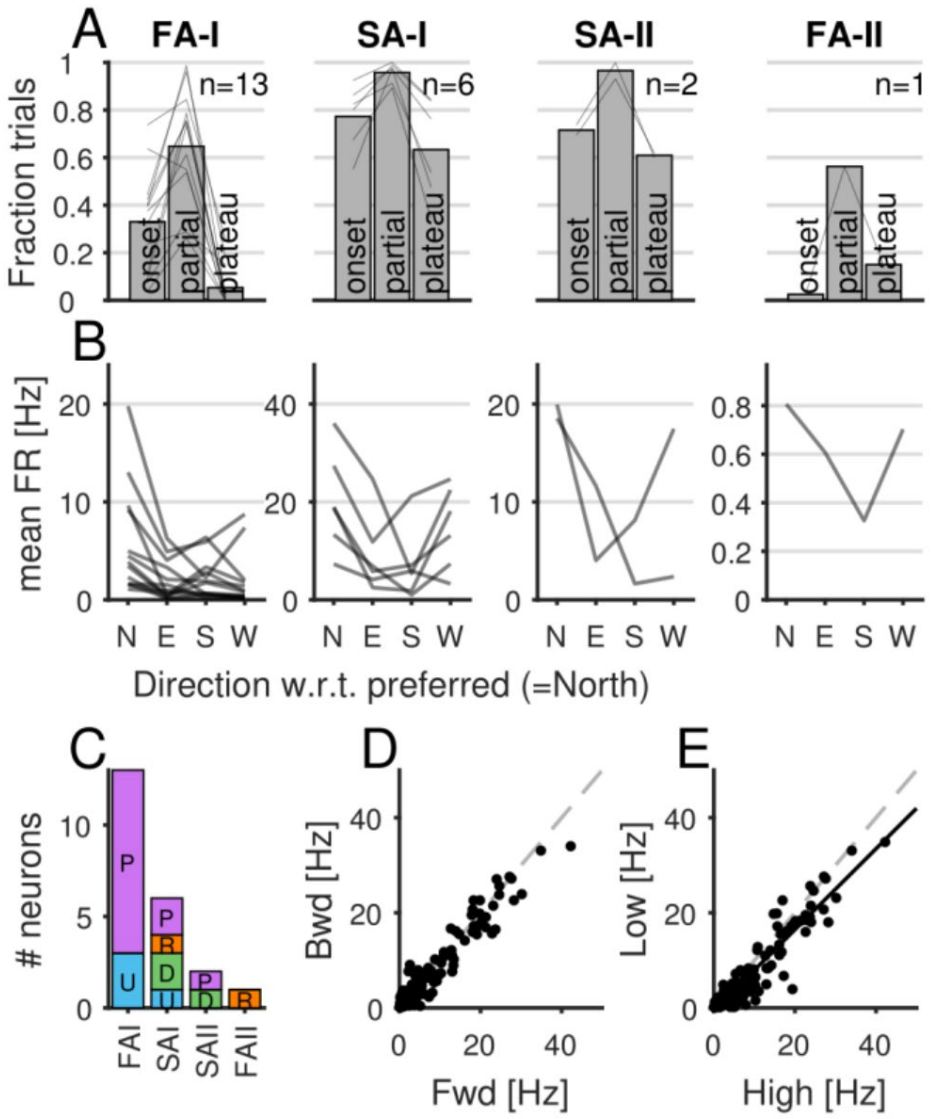


Local Strains

Global stimulus preferences

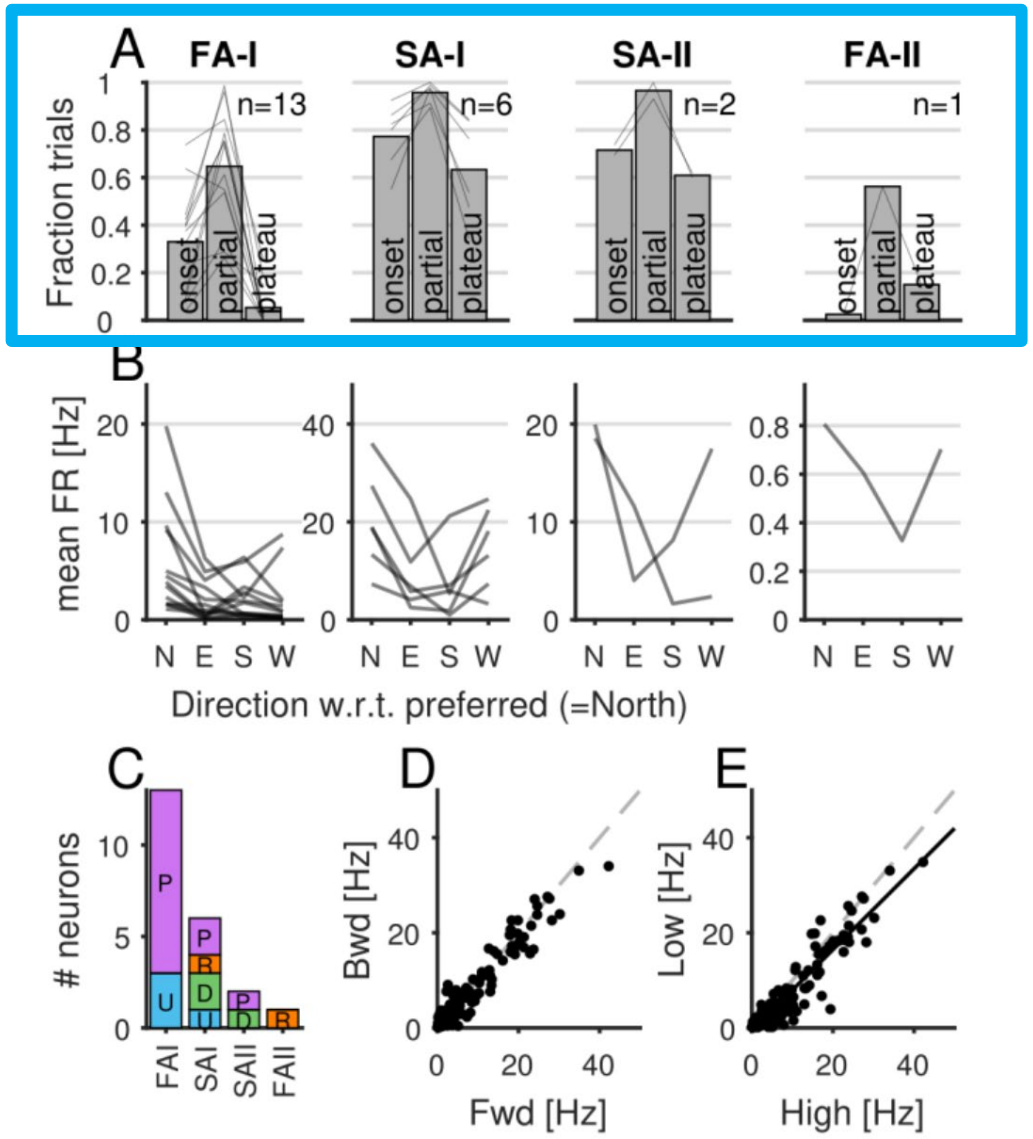


Global stimulus preferences

Fraction of trials

with significant response

(average across neurons)



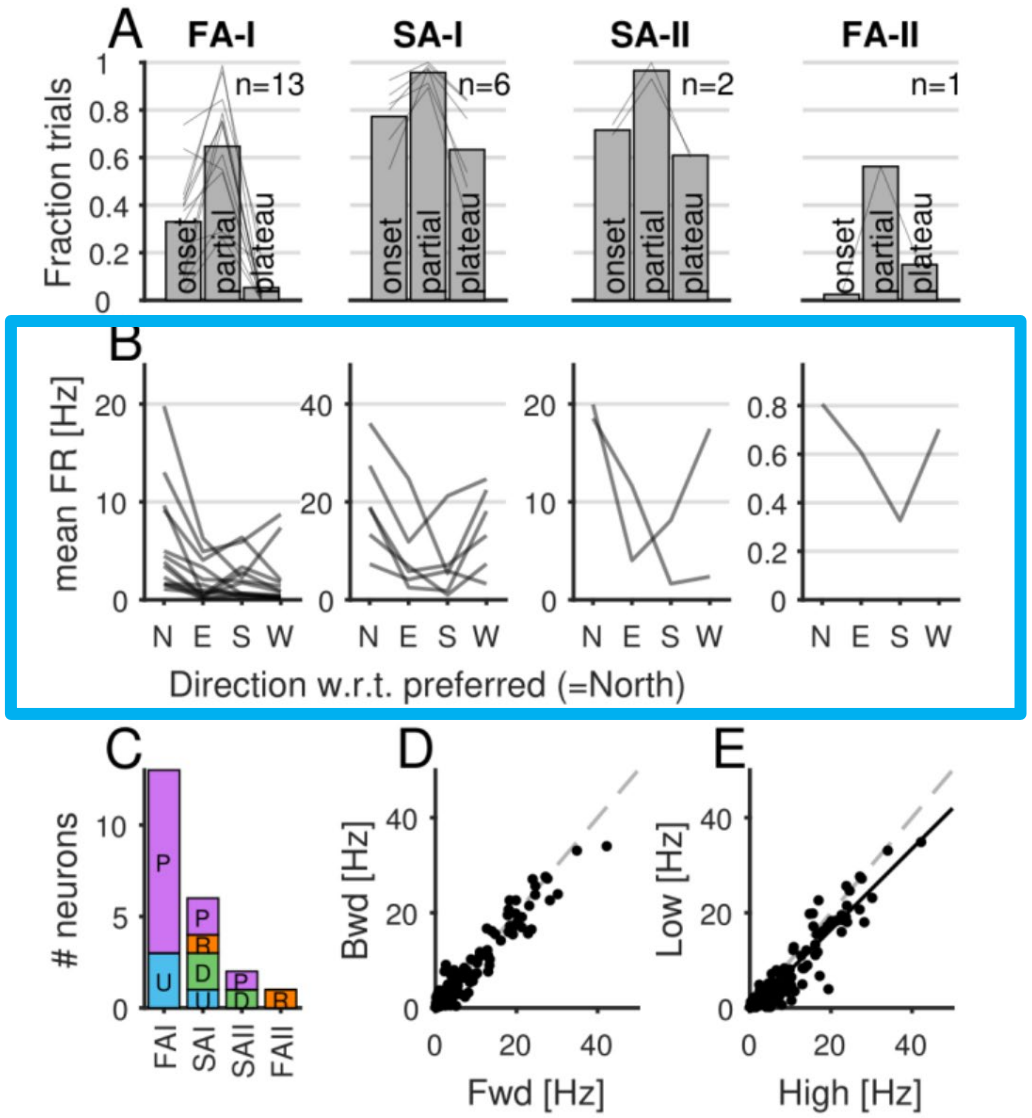
Global stimulus preferences

Average firing rate

during “Partial slip”

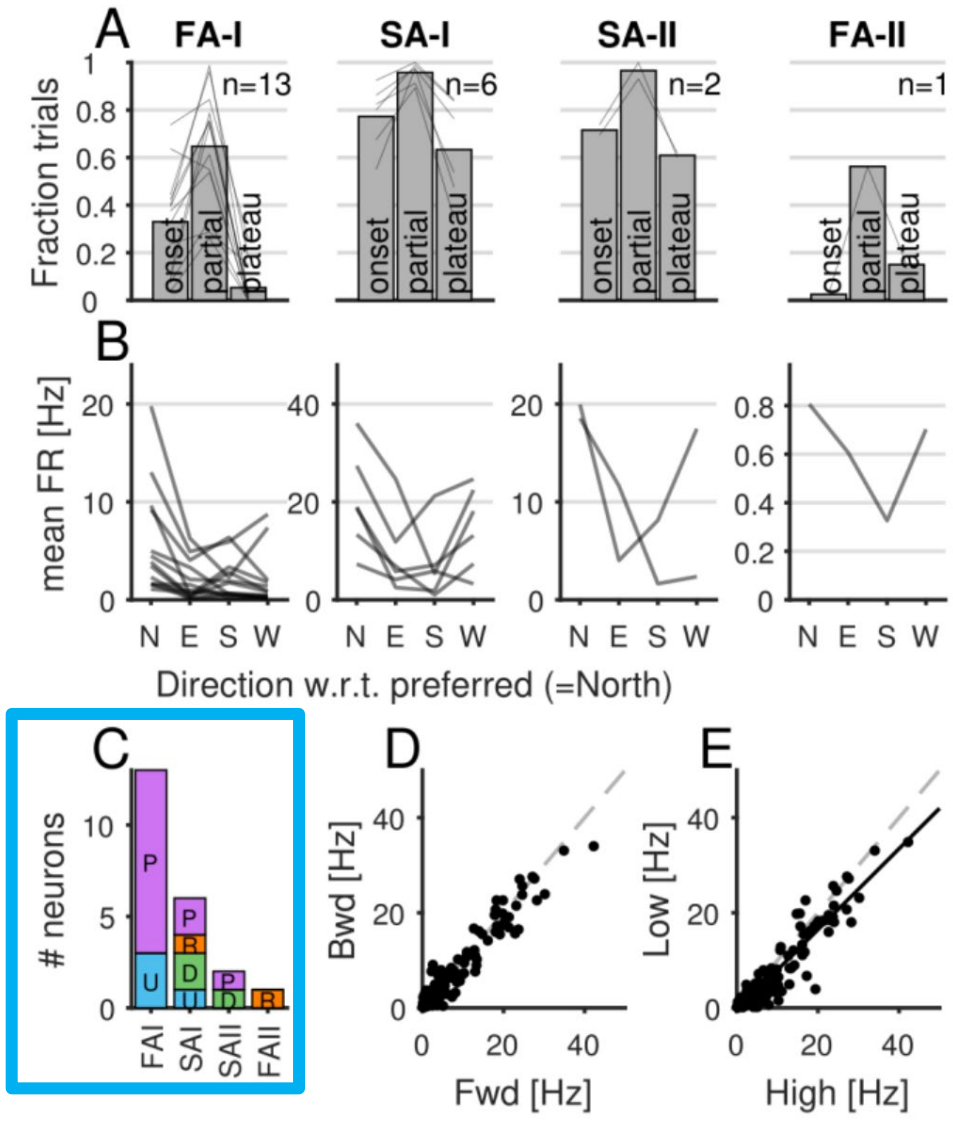
w.r.t. scanning direction

(N = preferred direction)

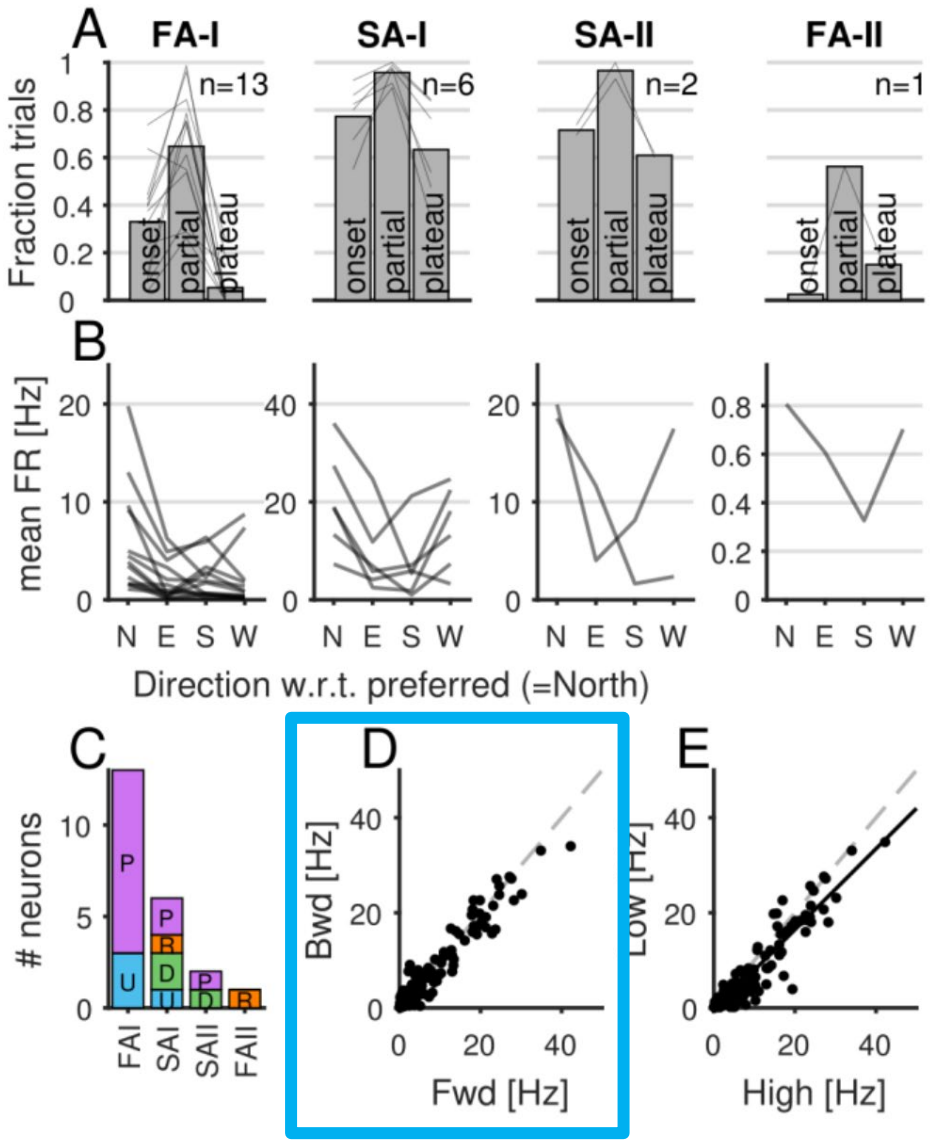


Global stimulus preferences

Distribution of scanning direction preferences

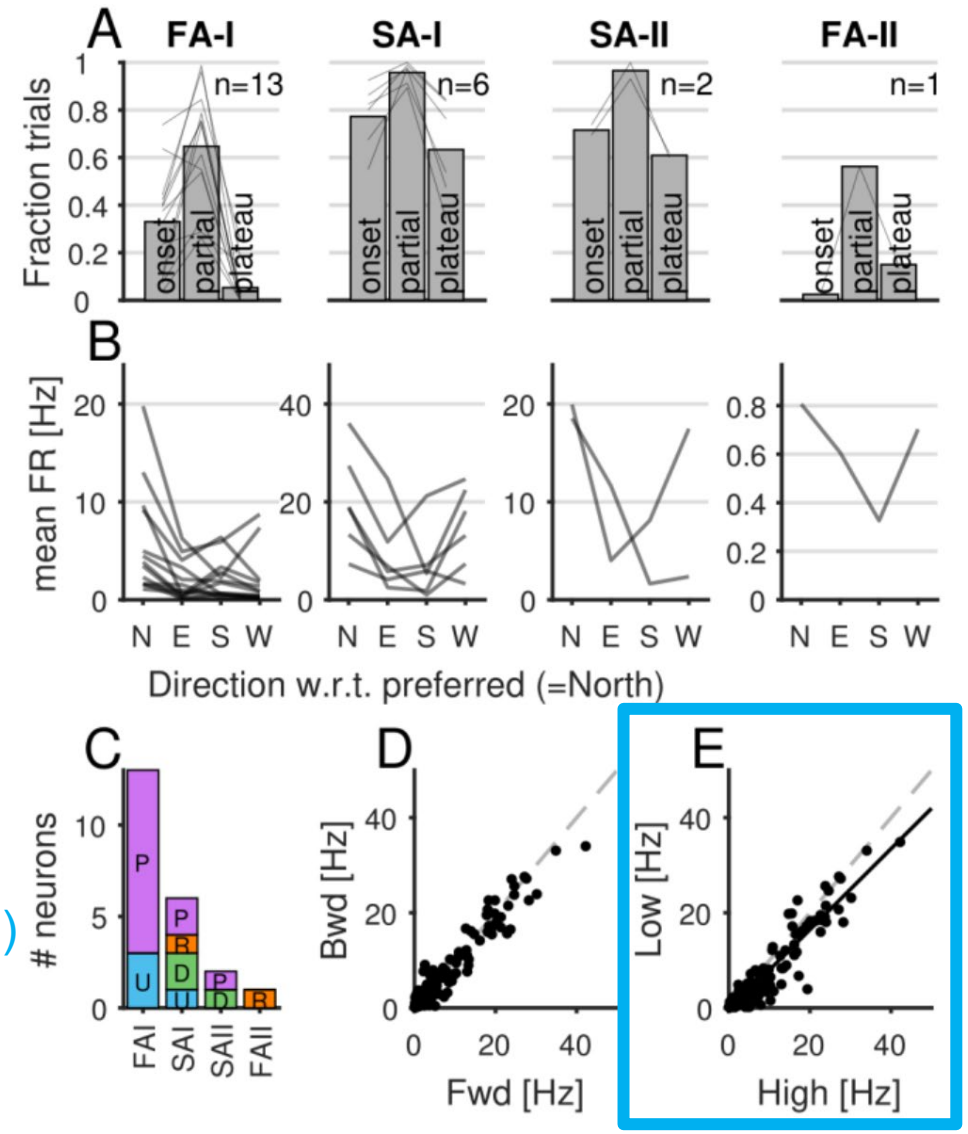


Global stimulus preferences



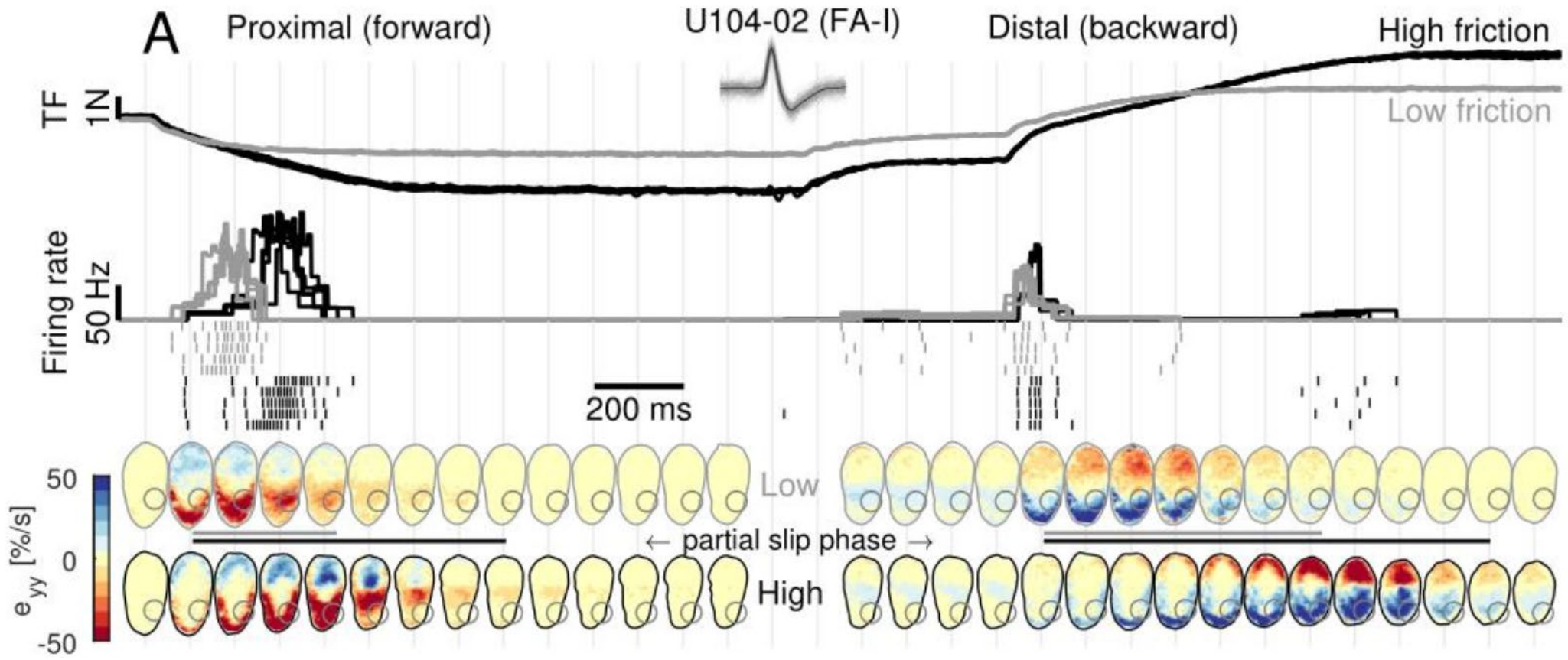
Firing rate when preferred direction came first (Fwd) or second (Bwd)

Global stimulus preferences

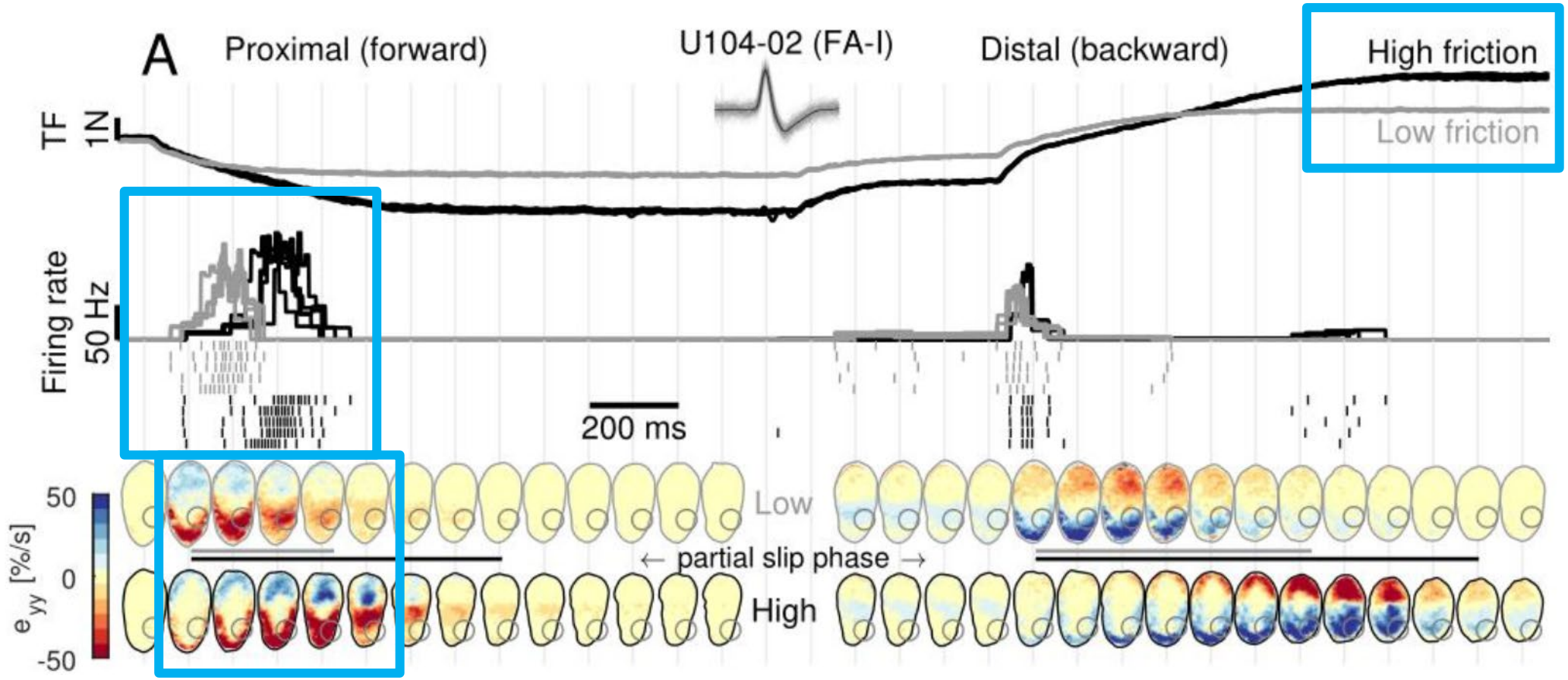


Firing rate when surface was untreated (High friction) or treated (Low friction)

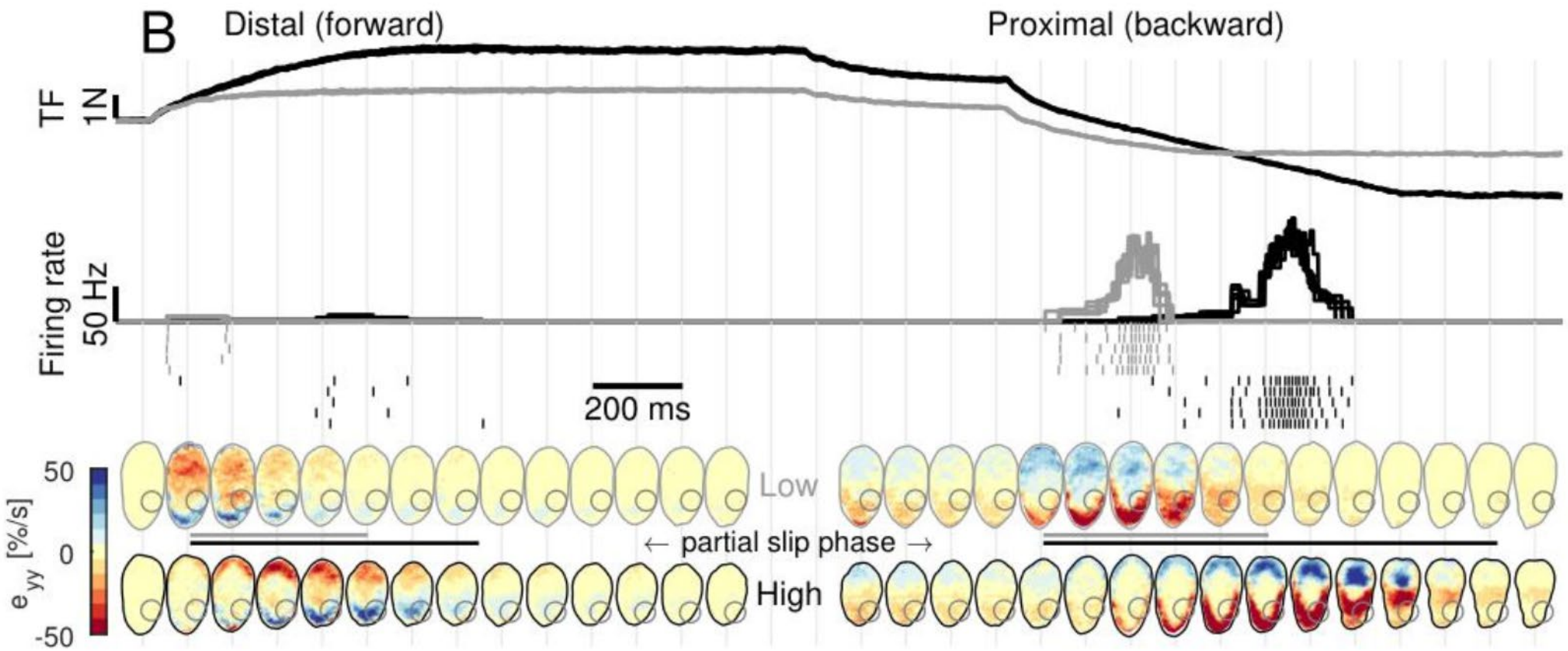
Local strains explain responses to different friction



Local strains explain responses to different friction



Local strains explain responses to different friction (reversed stimulus)



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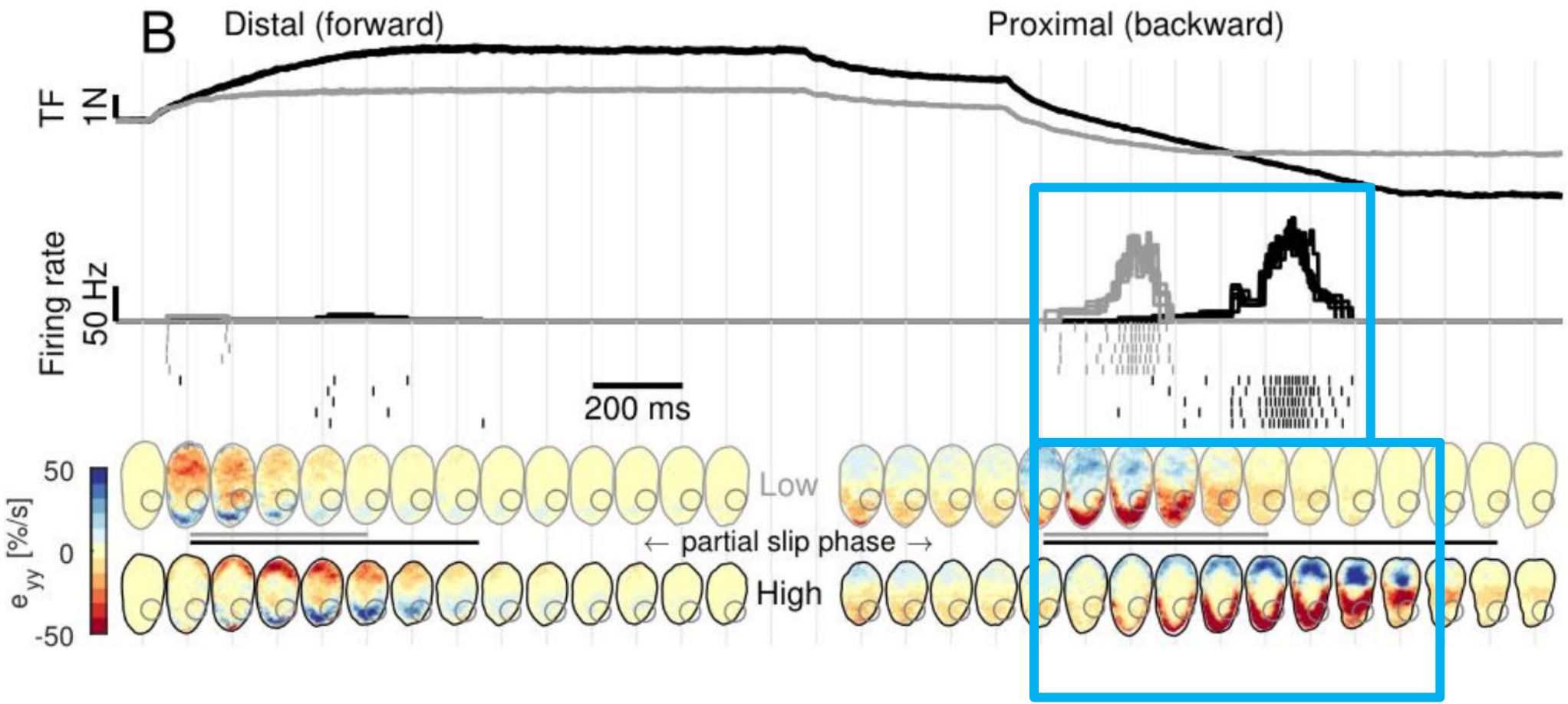
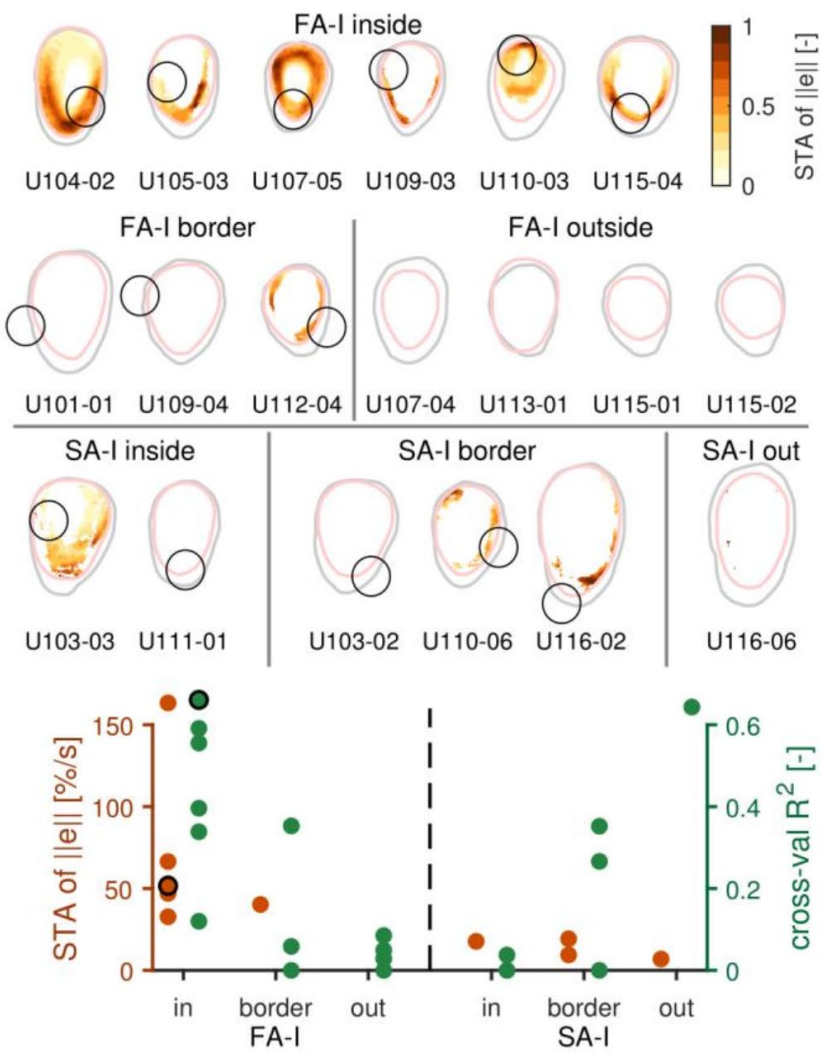
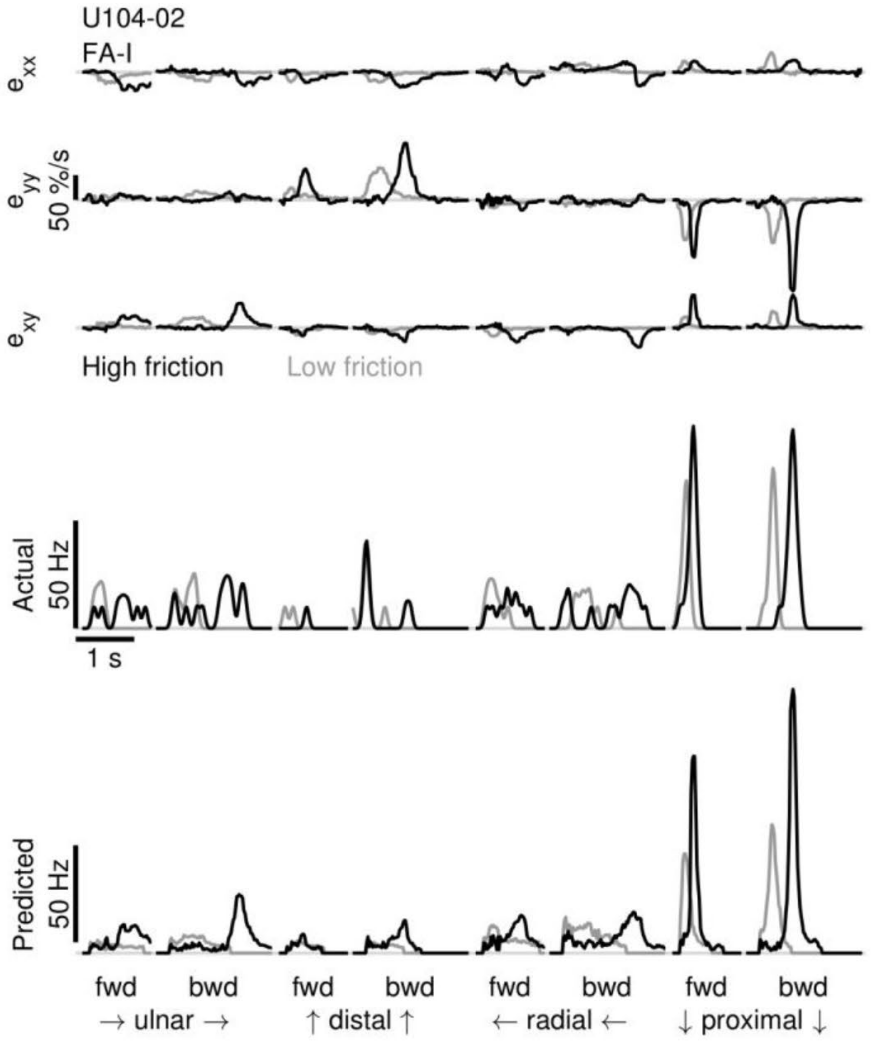


Spike-triggered averages suggest FA1 afferents are the most sensitive class





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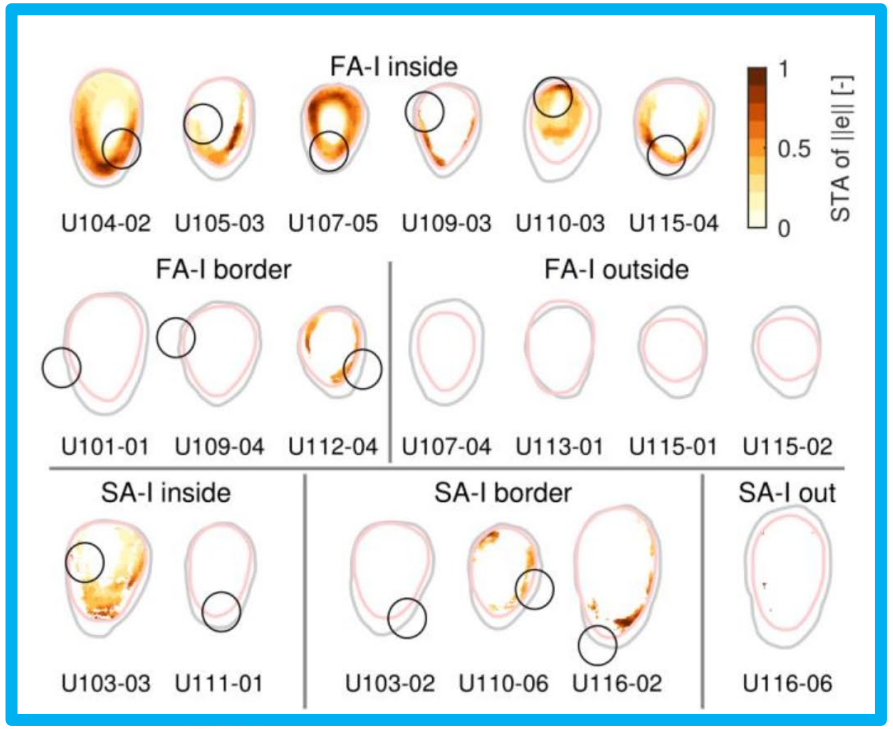

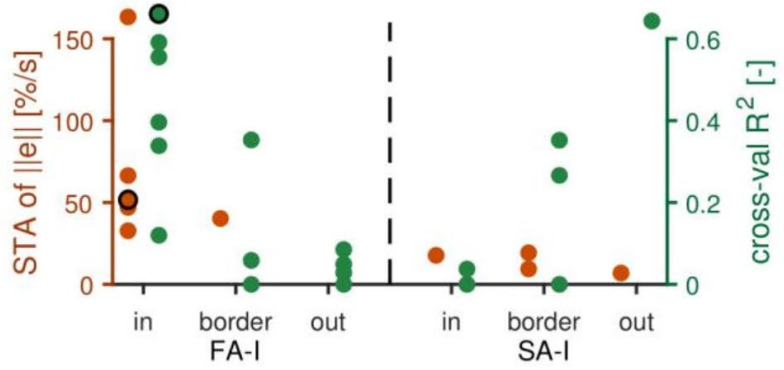

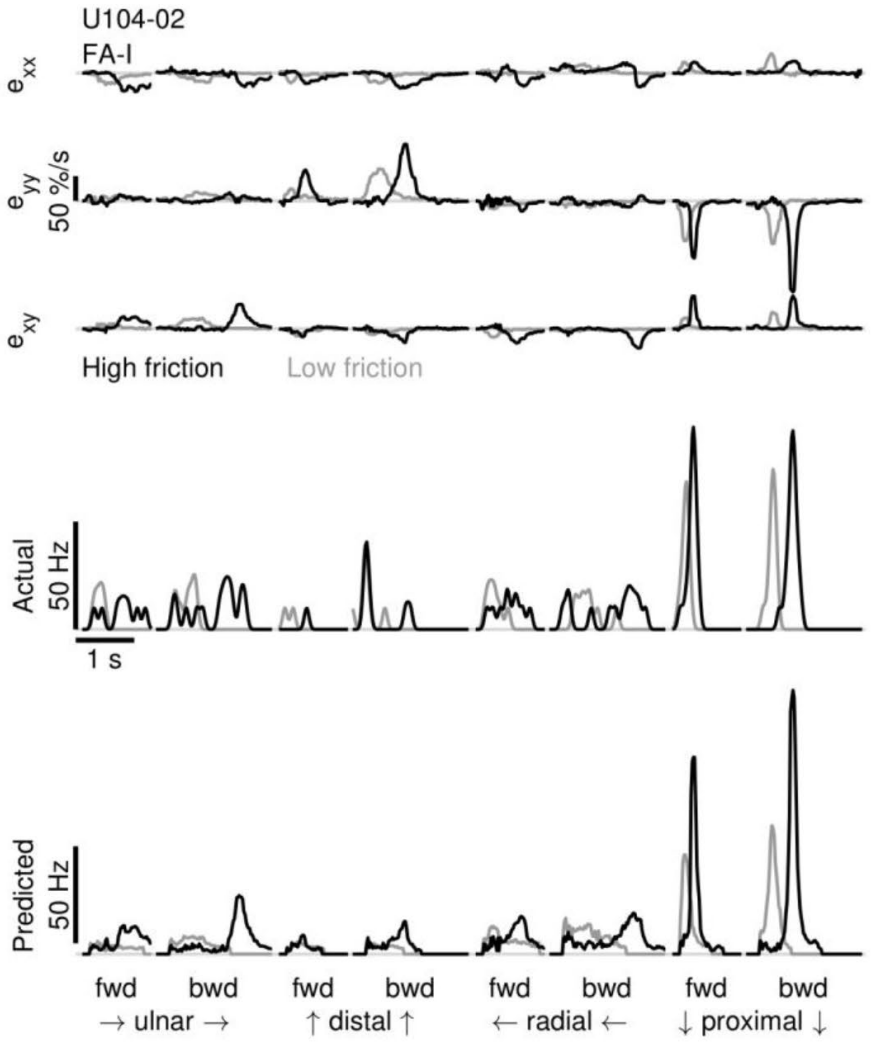

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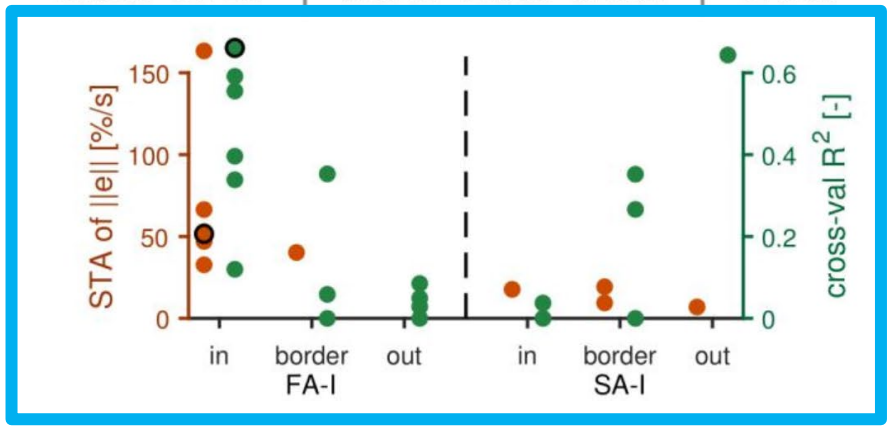

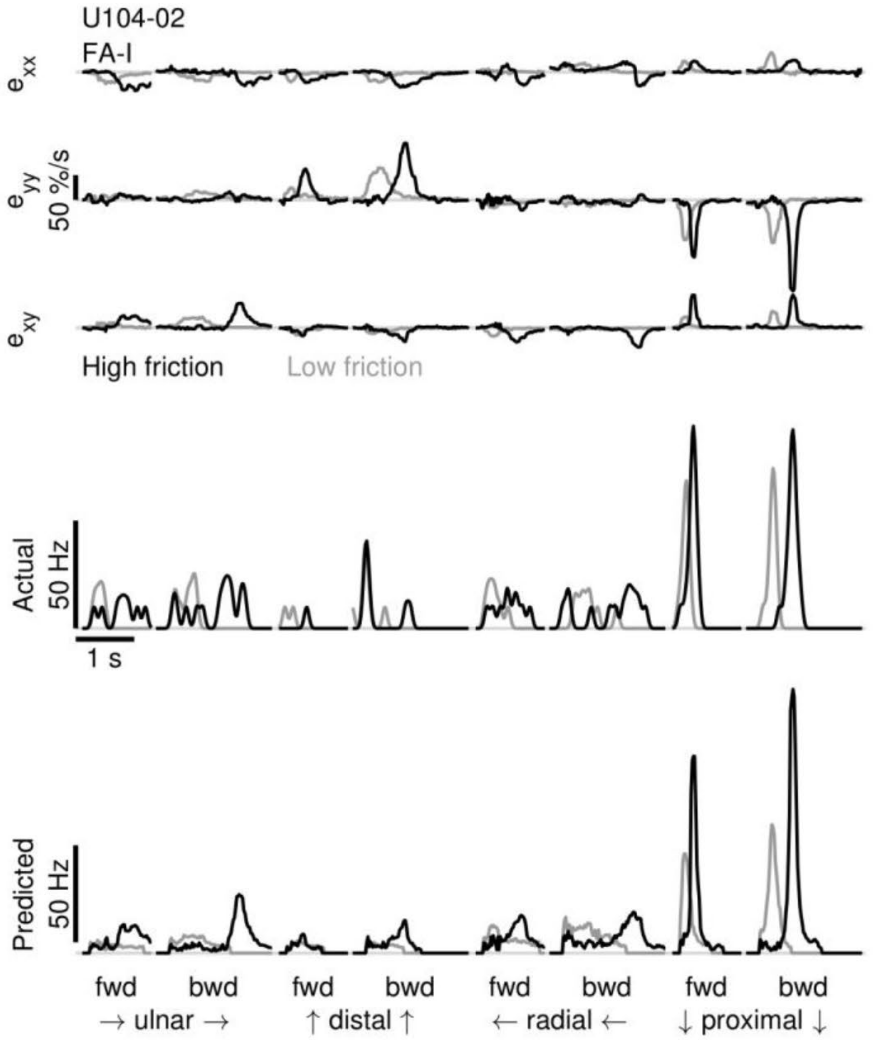

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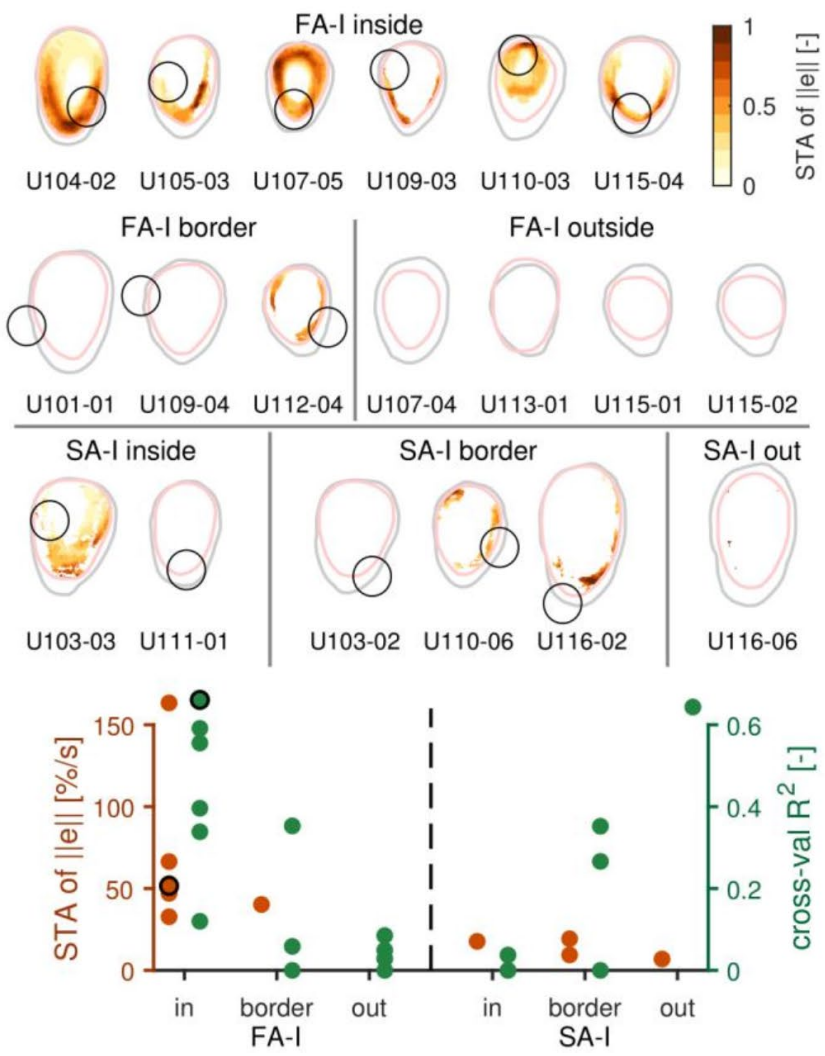
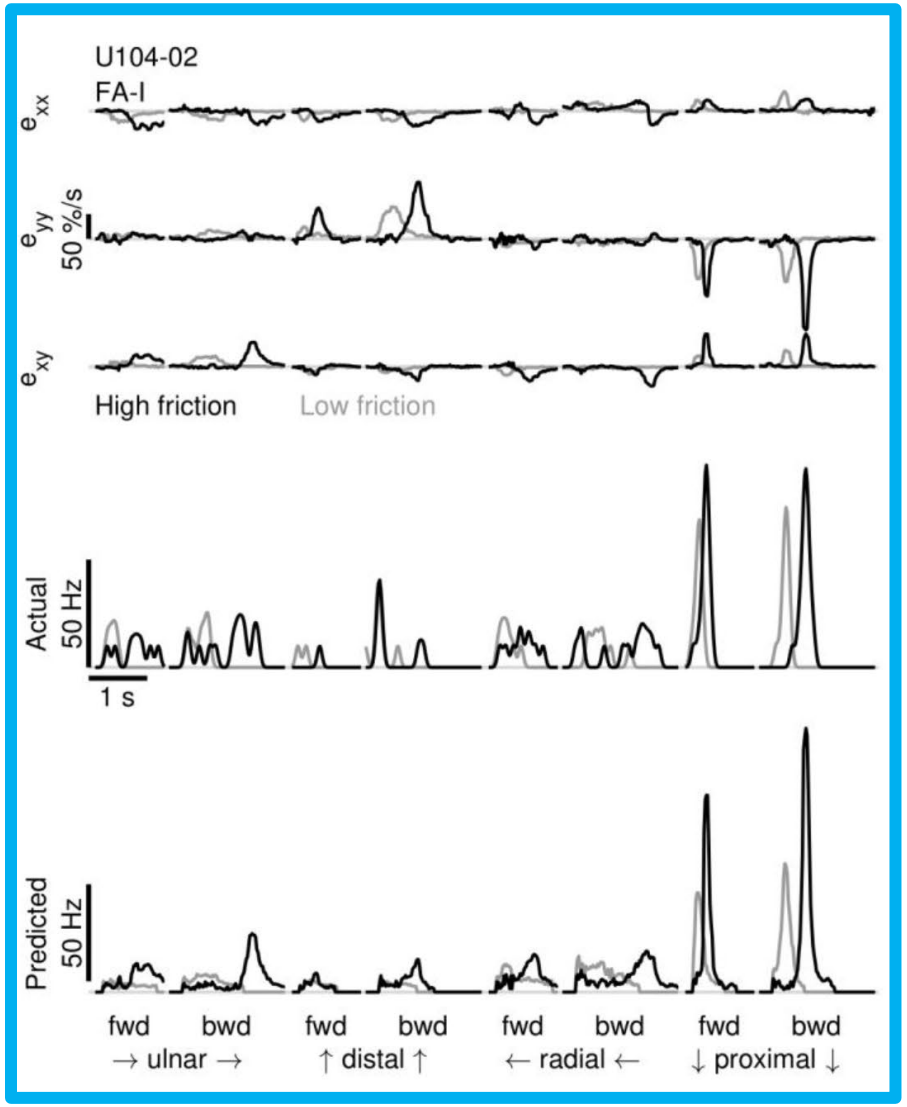


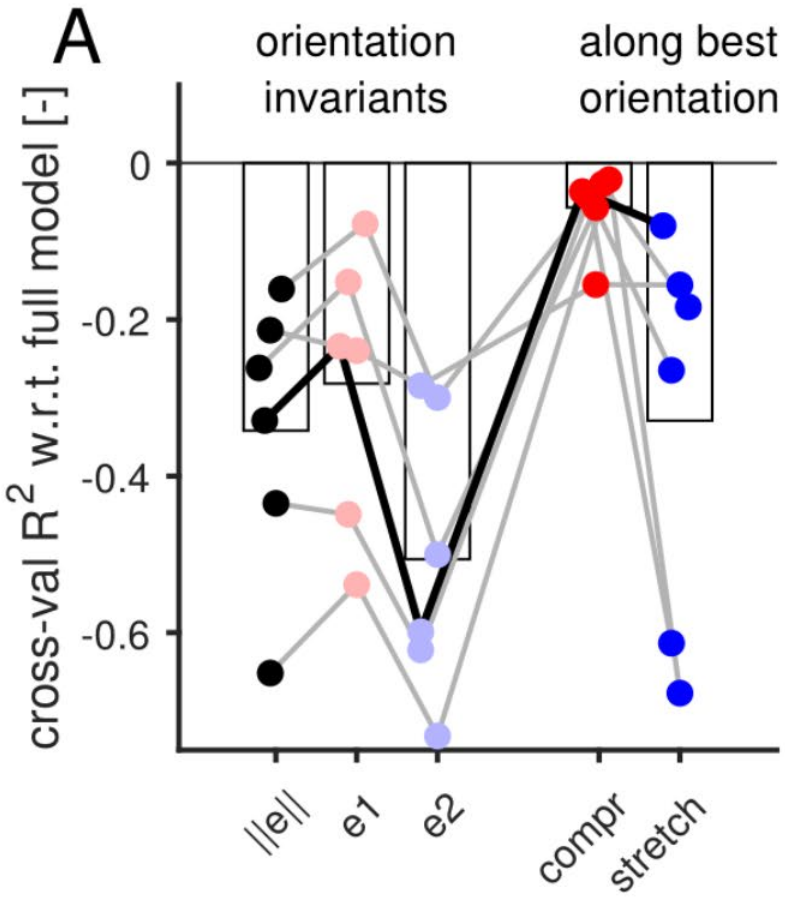


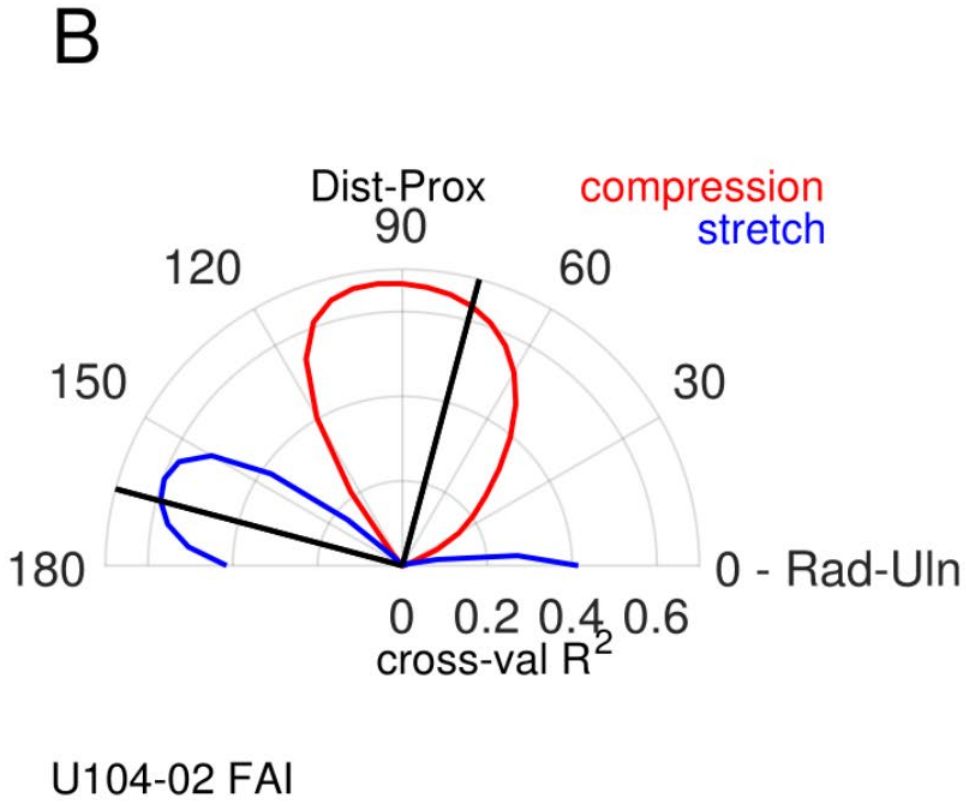
local strain components

recorded spiking

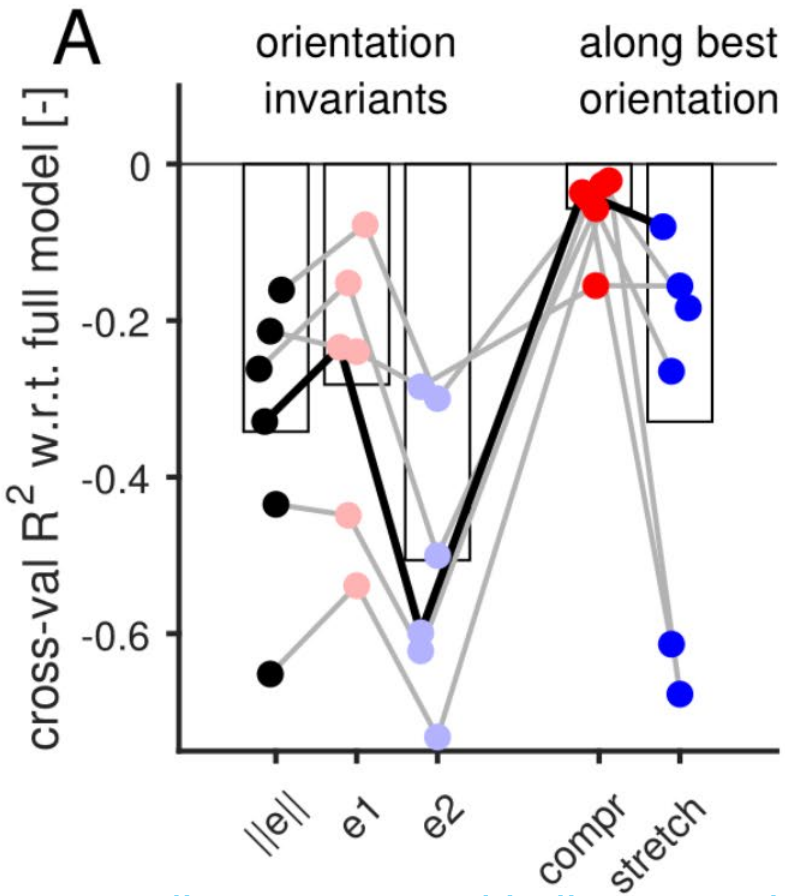
predicted spiking

FA1 afferents specifically prefer compressive strains

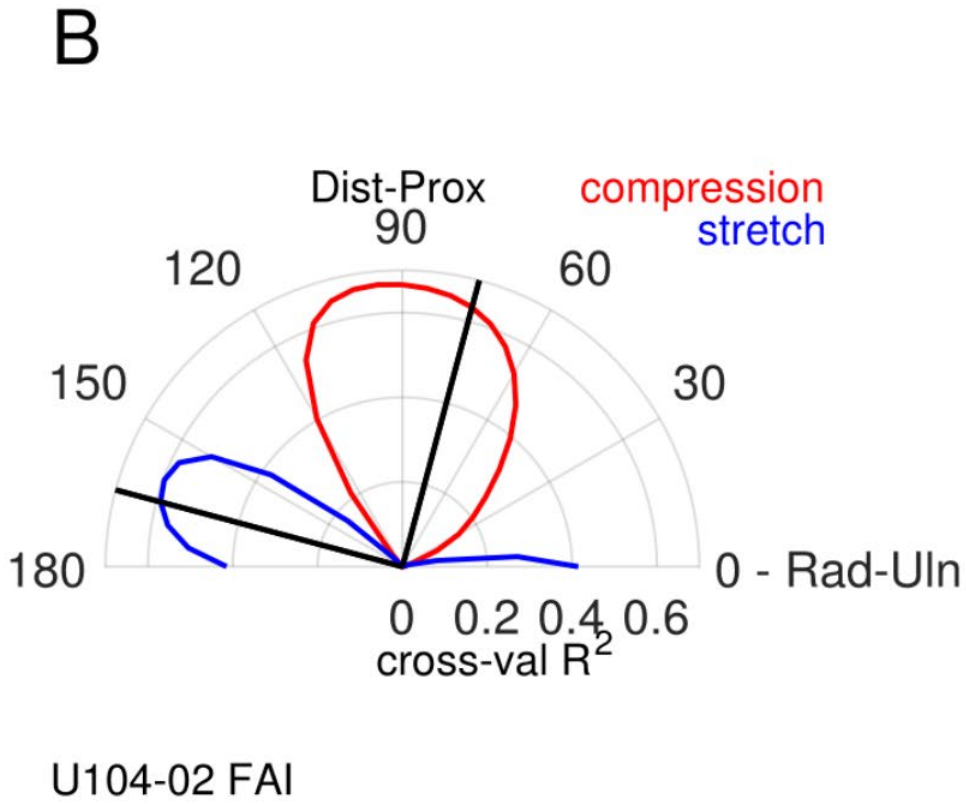




FA1 afferents preferentially respond to oriented, compressive strains



predictor sets used in linear models



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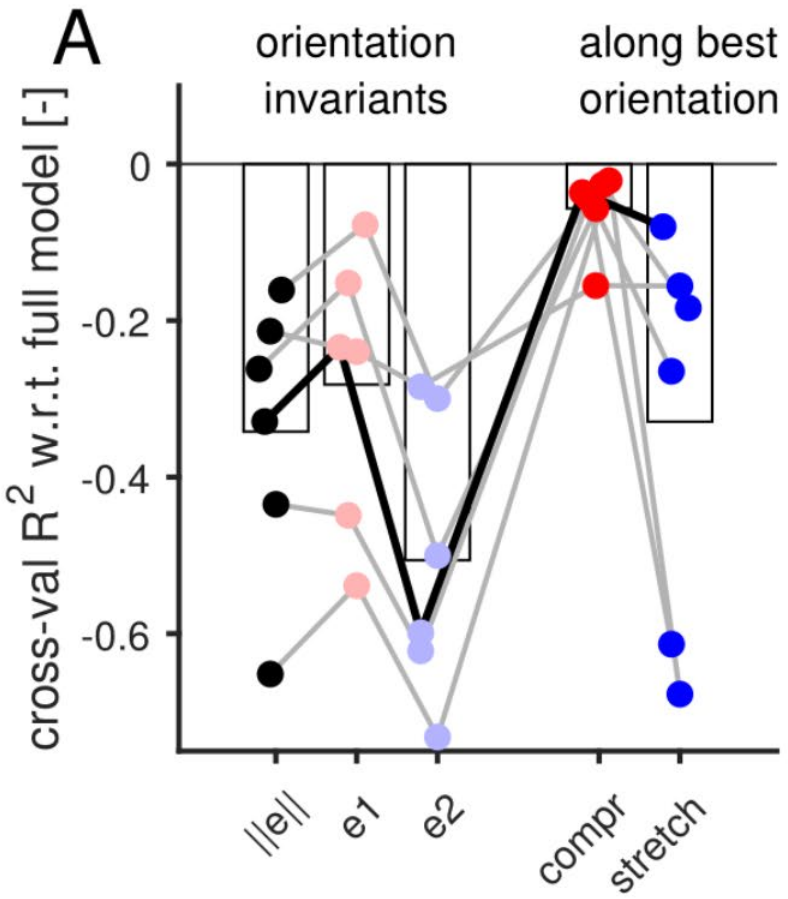
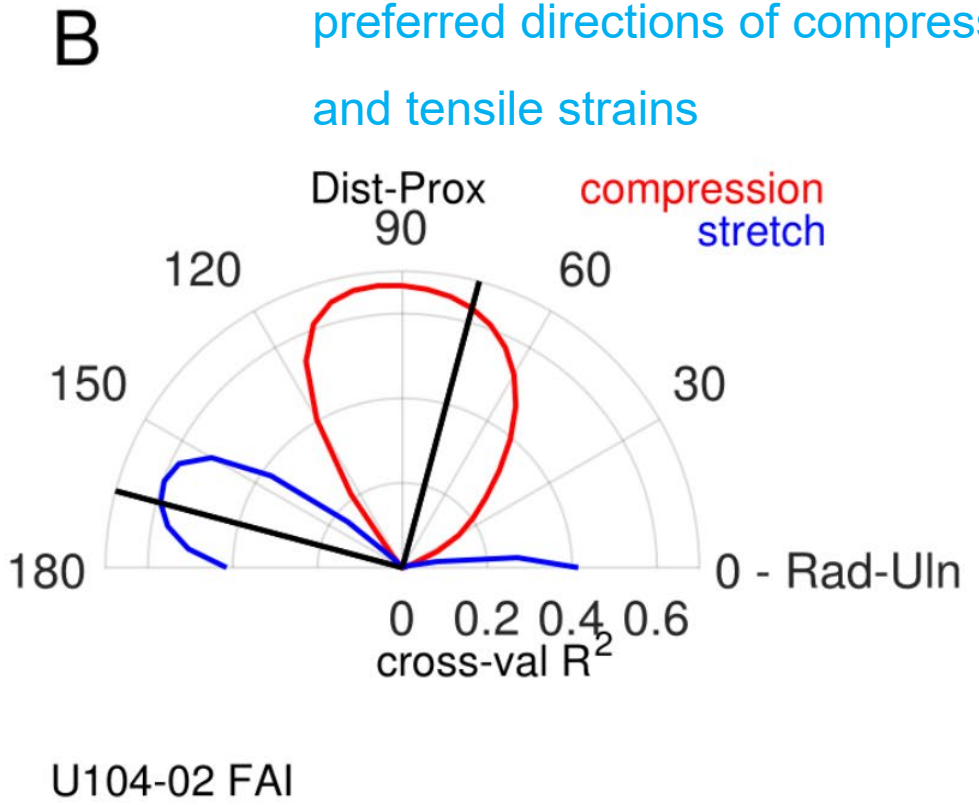
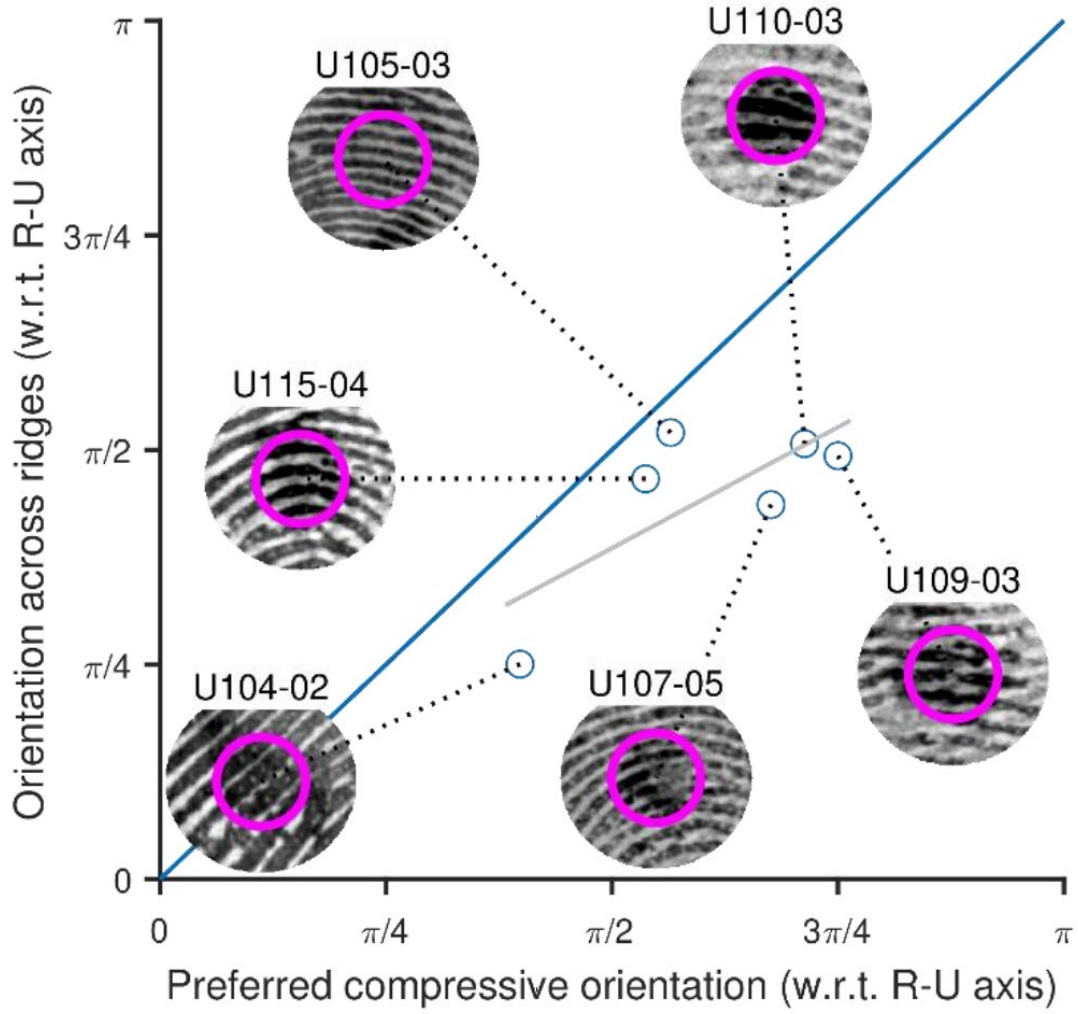




Possible (but not yet significant) relationship to fingerprint ridge orientation?



Conclusions

- Tangential strains are sufficient to excite SA1 and FA1 tactile afferents
- FA1 afferents seem to be most responsive to tangential strains
- They respond specifically to highly localized patches of tangential strain
- They tend to respond preferentially a specific orientation of compressive strain
- Simple strain sensitivity is sufficient for slip sensation!
  - Complicated computation of surface friction or texture is not required!
  - Suitable for rapid grip adjustments

Critiques

- Base result seems obvious: yes, afferents will respond to this
- Sustained, global normal force seems quite high (4N, or 400g)
- Pontificating about a tangential vs. normal force framework is a bit misguided
- (In any case, the compressive-strain preference could be explained by sensitivity to local normal pressure)
- Sustained strains could not be properly measured for SA1 afferents, so an FA1-centric interpretation seems extremely hasty (and misguided)

Credit where it’s due

- Impressive methodology
- Detailed data
- Tackle a seldom-studied, yet important tactile stimulus class