Neural basis of coordinate transformations of tactile motion stimuli on the hand

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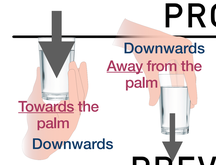
INTEGRATION OF TOUCH AND PROPRIOCEPTION

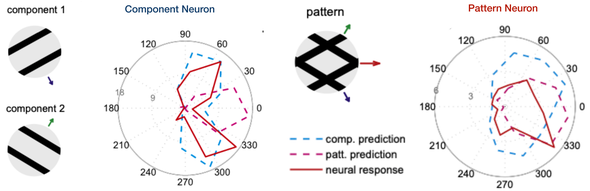


How are tactile inputs on the hand integrated with proprioceptive signals?

How is this integration controlled by the reference frame?

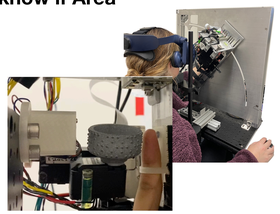
PREVIOUS RESEARCH

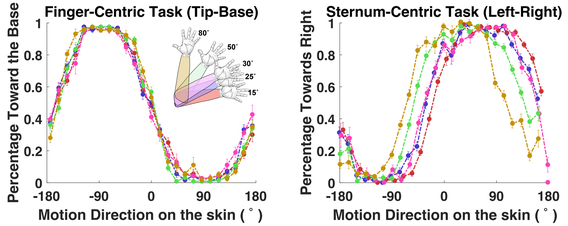
Area 1 of the Somatosensory Cortex has been shown to integrate local motion direction cues to compute a global motion percept (*Pei et. al, 2011*).



This results from these studies were derived with the **hand in only one posture, so we don't know if Area 1 neurons are modulated by proprioception.**

In our psychophysics work, we show that humans integrate posture and tactile motion direction in a reference-frame dependent manner (*Ahuja et. al 2024*)



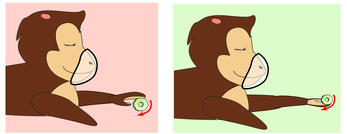


RESEARCH QUESTION

Are *tactile-motion direction sensitive* neurons in Area 1 modulated by proprioception?

Can these neurons generate readouts in non-skin-centric coordinates?

METHODOLOGY



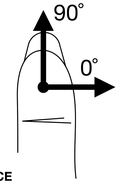
Anesthetized NHP preparation (N=1)

Two Postures — Supinated and Pronated roll around the elbow.

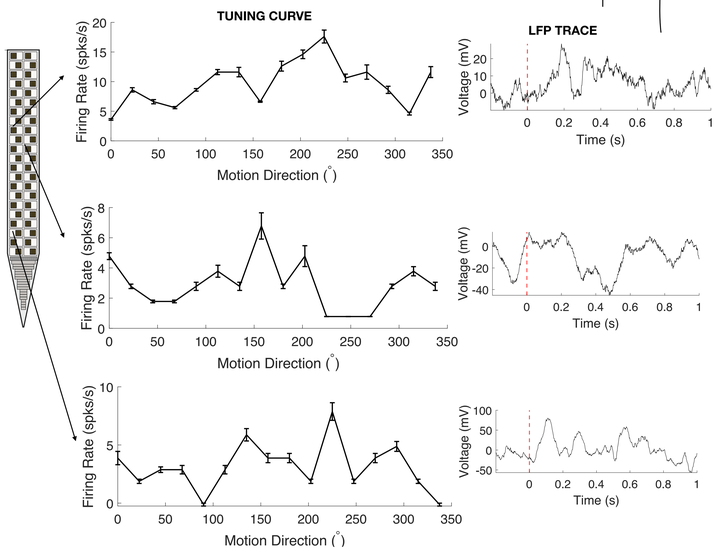
Recordings in the Somatosensory cortex using **NHP Neuropixels**.

Stimulator: Rotating wheel in 12 directions (0˚-360˚) steps of 22.5˚

RESULTS

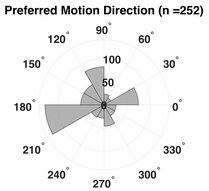


1 Typical motion-tuned neurons were observed in the anesthetized recordings.

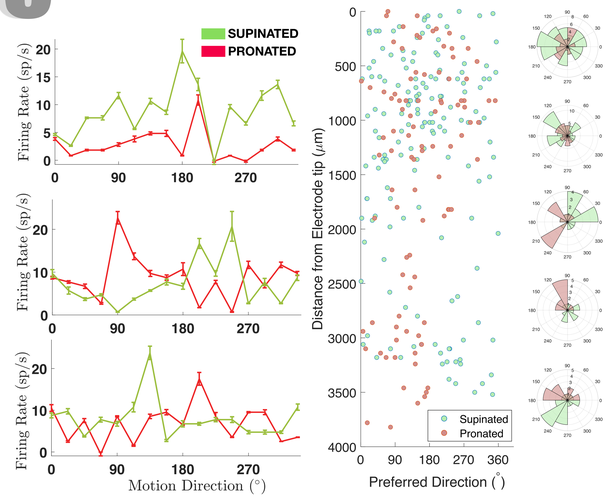


2 Population Statistics

Neuron Type	Number of Units
Isolated Single Unit	582
Responsive	355
Motion Selective	252
Traditional	92



3 Proprioception modulates the tuning properties of motion-sensitive neurons

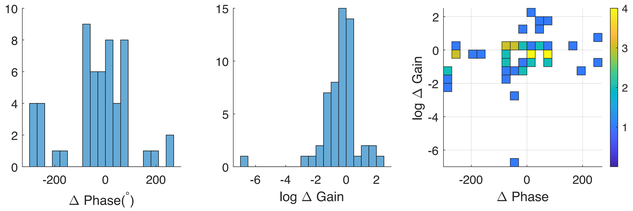


4 Traditional neurons have independent gain change and phase changes

$$FR(\theta; g, \mu, \sigma) = g \cdot exp\left(\frac{-2 \cdot (1 - cos(\theta - \mu))}{\sigma^2}\right)$$

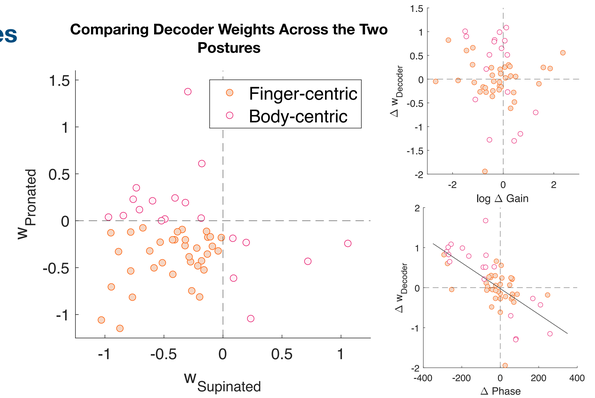
$$\Delta\text{Phase} = \mu_{\text{Pro}} - \mu_{\text{Sup}}$$

$$\log \Delta\text{Gain} = \log \frac{g_{\text{Pro}}}{g_{\text{Sup}}}$$

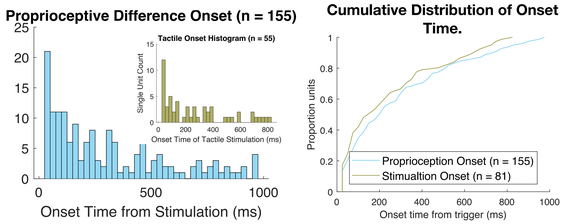


5 Neurons with larger phase and gain contribute more to a decoder that differentiates left stimulus from the right.

$$w = \Sigma^{-1}(\overline{fr}_{0^\circ} - \overline{fr}_{180^\circ}) \qquad \Sigma = diag\left(\frac{\overline{fr}_{0^\circ} + \overline{fr}_{180^\circ}}{2}\right)$$



6 Onset time for neurons with post-trigger proprioceptive differences has a bimodal distribution.



CONCLUSION

Proprioception modulates the preferred direction of tactile motion of neurons in the somatosensory cortex, with changes in tuning functions better explained by phase-shifting as opposed to gain-changing mechanisms.

Posture-dependent changes appear to be most prominent in deeper layers of area 3b (or potentially in area 1)

The effects of proprioception on tactile motion tuning functions are delayed, indicating that that proprioceptive-dependent changes on neurons' preferred direction emerge from feedback mechanisms.

In general, our experiment showcases a feasible paradigm to study neural interactions between proprioceptive and tactile signals in somatosensory cortical neurons of non-human primates.

ACKNOWLEDGEMENTS

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