Neural Mechanism for Visual Stability

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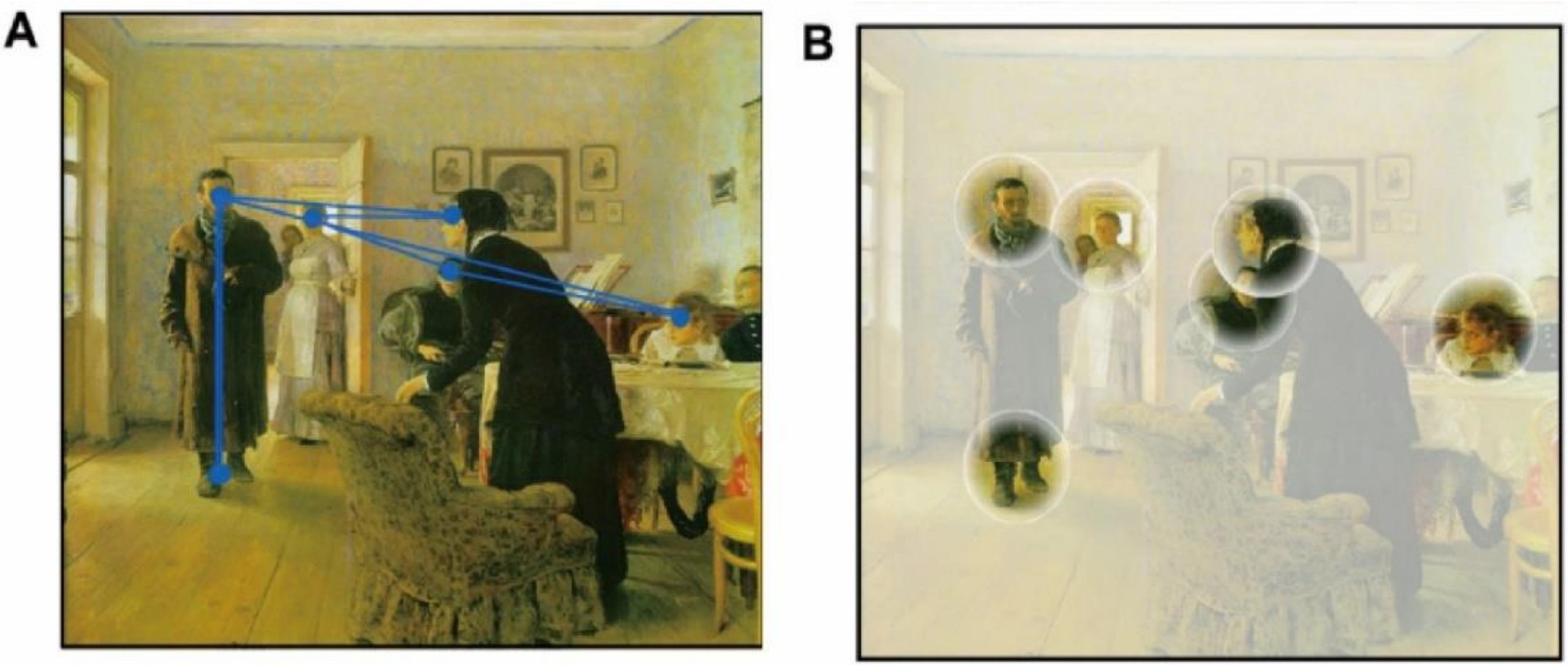
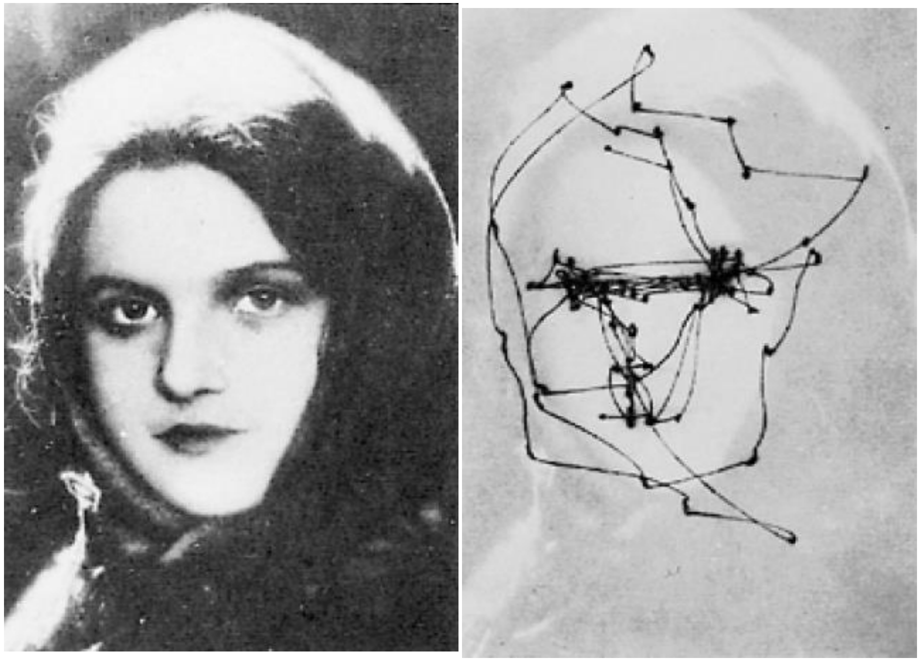
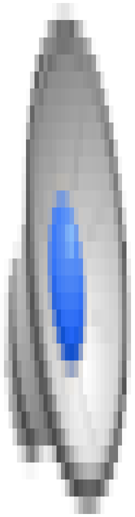
Eye： the window of the mind



Saccade disturbs visual stability



Saccade 3-4/s

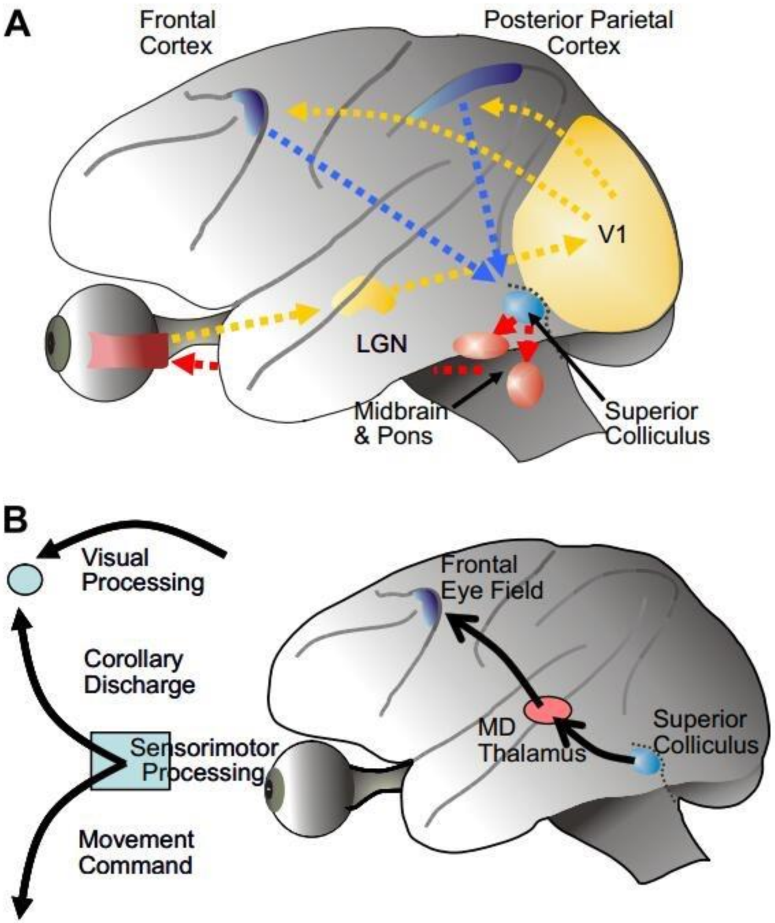


亥姆霍兹之问

亥姆霍兹

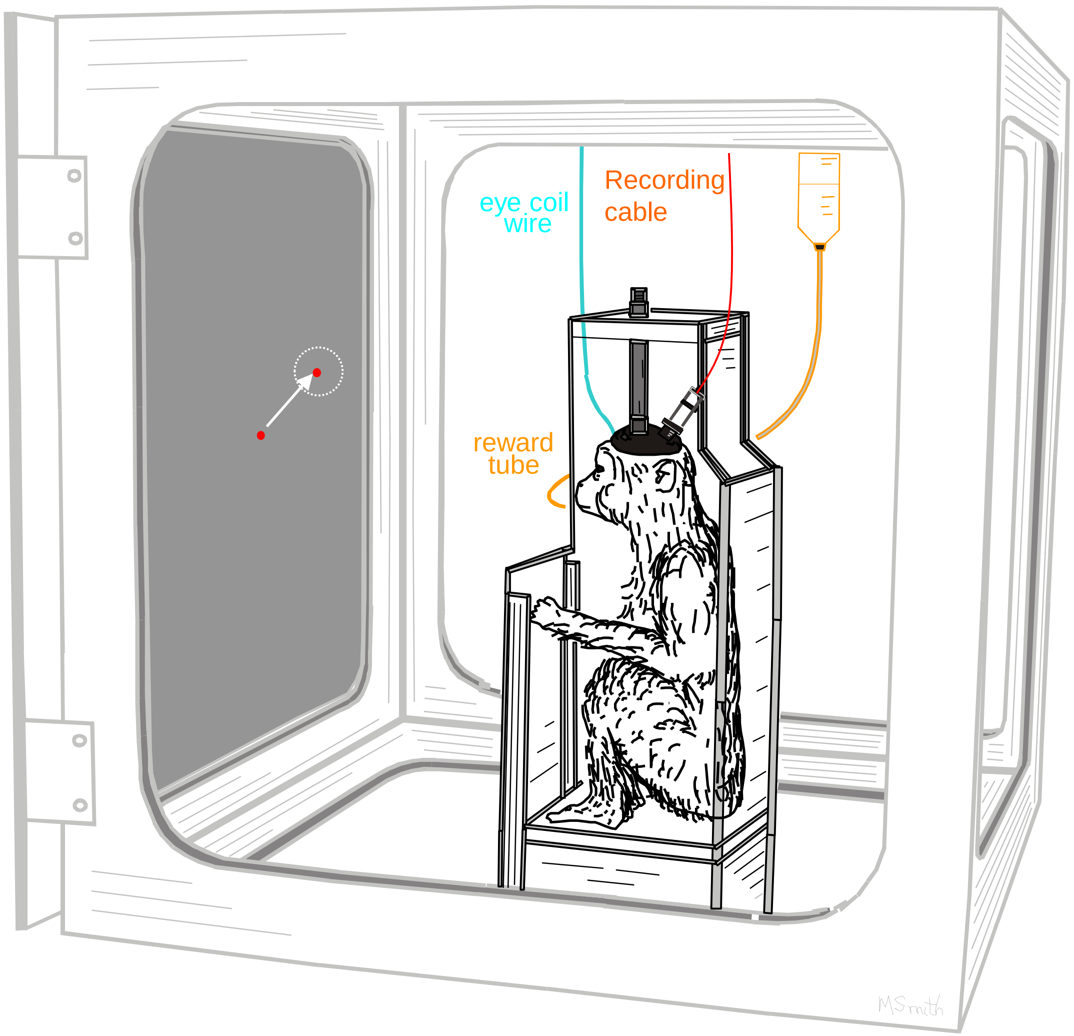
1821-1894年

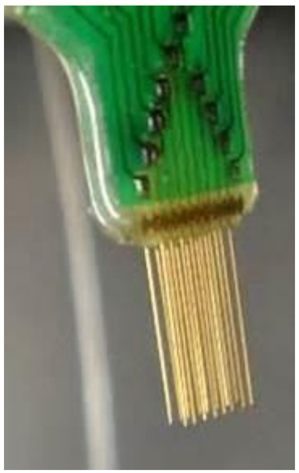
德国生物物理学家、数学家。“能量守恒定律”的创立者。在生理学、光学、电动力学、数学、热力学等领域中均有重大贡献。研究了眼的光学结构，发展了梯·扬格韵色觉理论，即扬格—亥姆霍兹理论；对肌肉活动的研究使他丰富了早些时候朱利叶斯·迈耶和詹姆斯·焦尔的理论，创立了能量守恒学说。

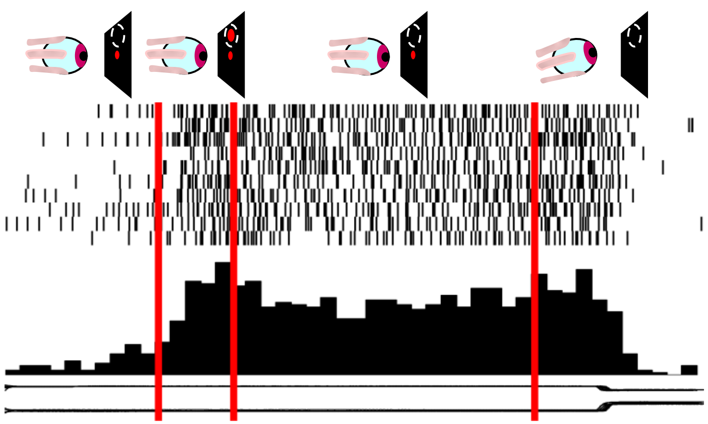


Good science starts from asking a good question!

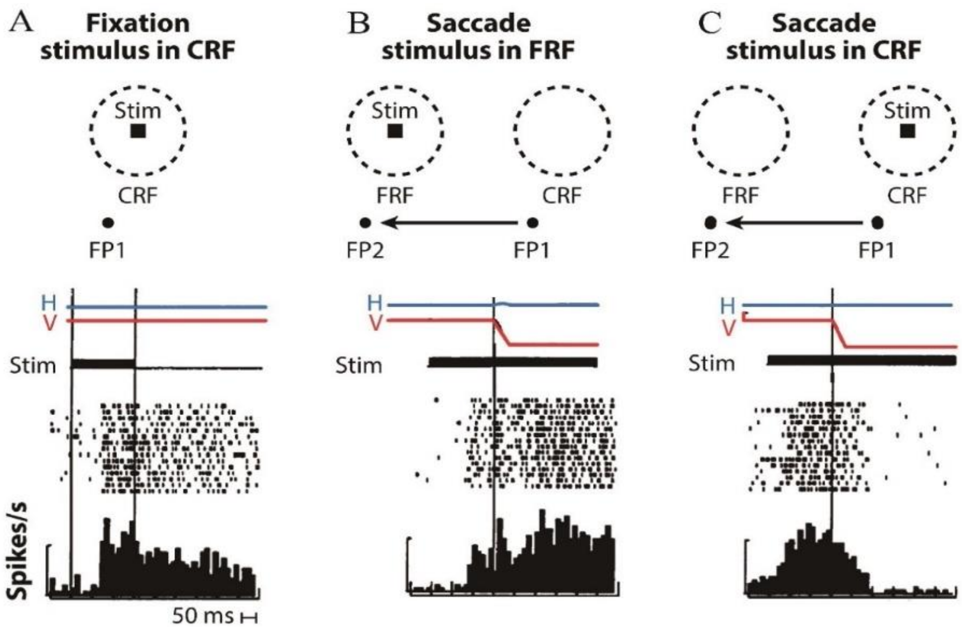
Monkey experiment



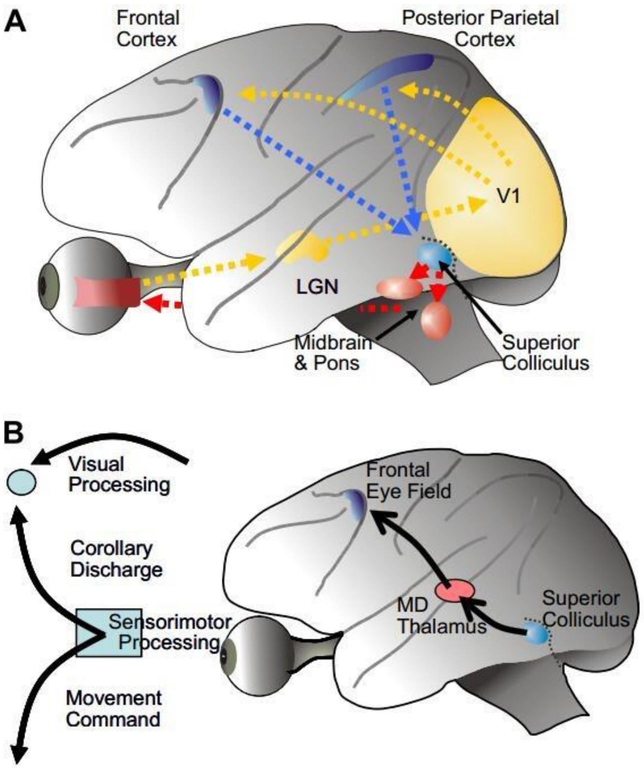




Predicting Remapping of Receptive Field

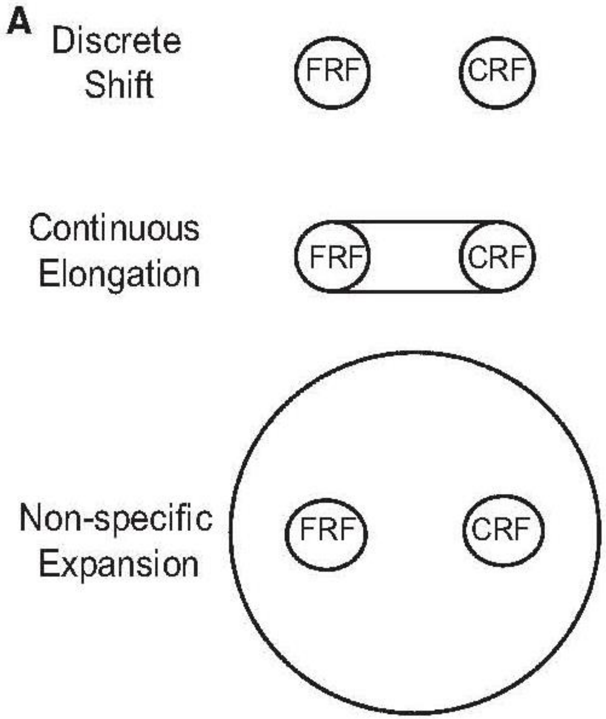


Linus D. Sun & Michael E. Goldberg, 2016

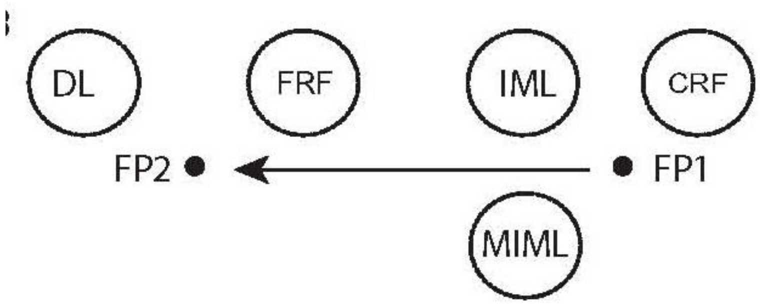


The time course of predictive remapping?

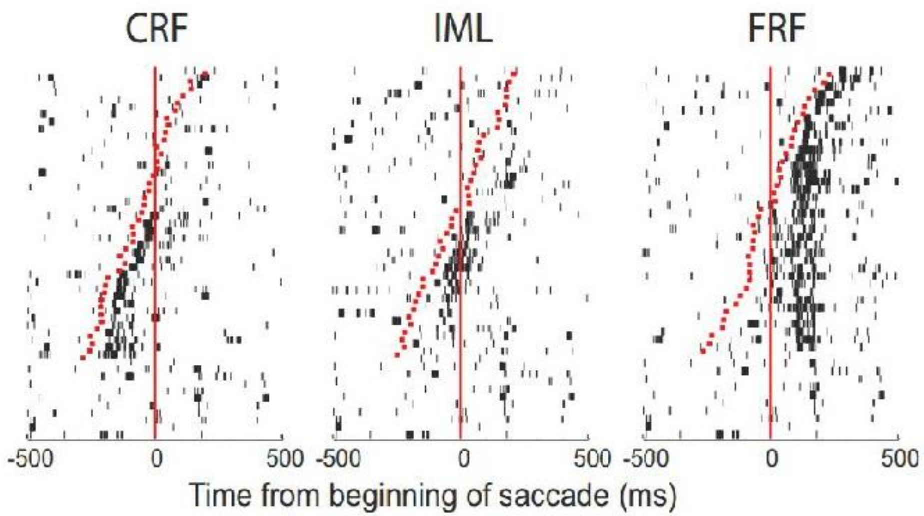
Three hypotheses

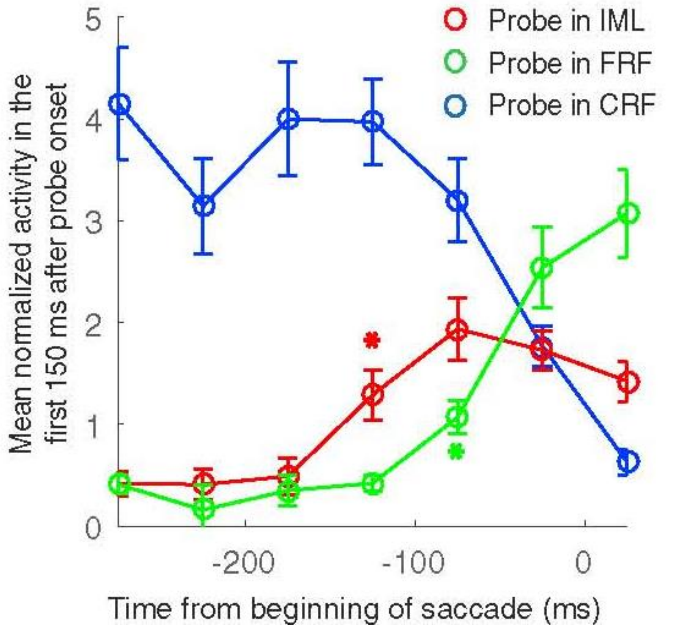


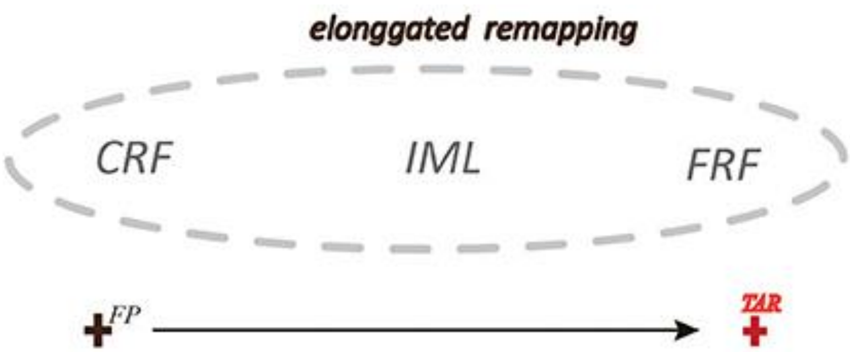
Experimental protocol



Elongation of neuronal receptive field

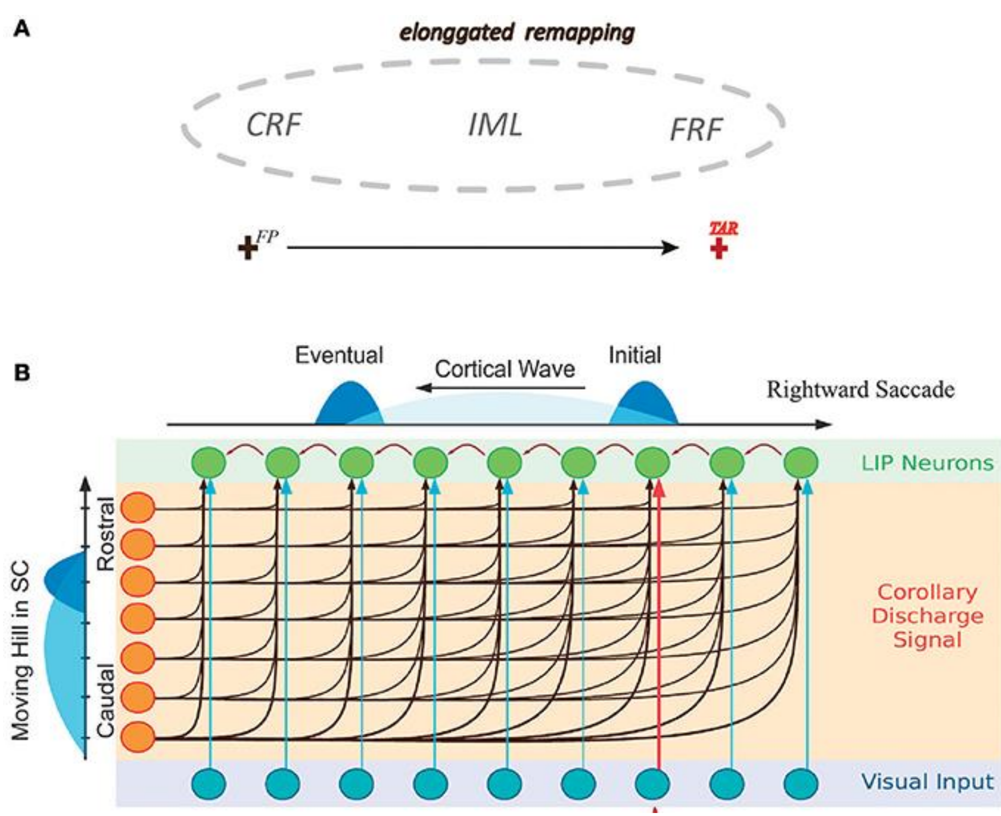


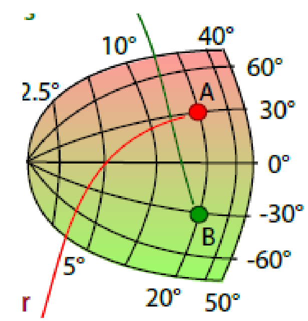




Wang et al.,2016

A Cortical Wave Model for RF Remapping

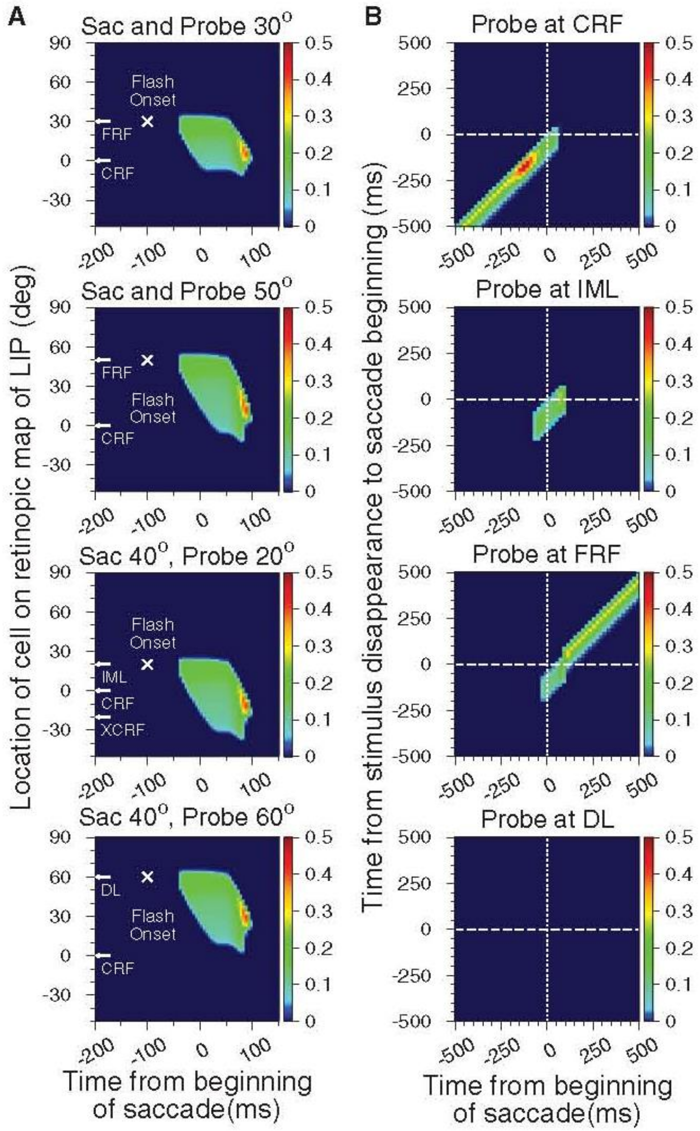


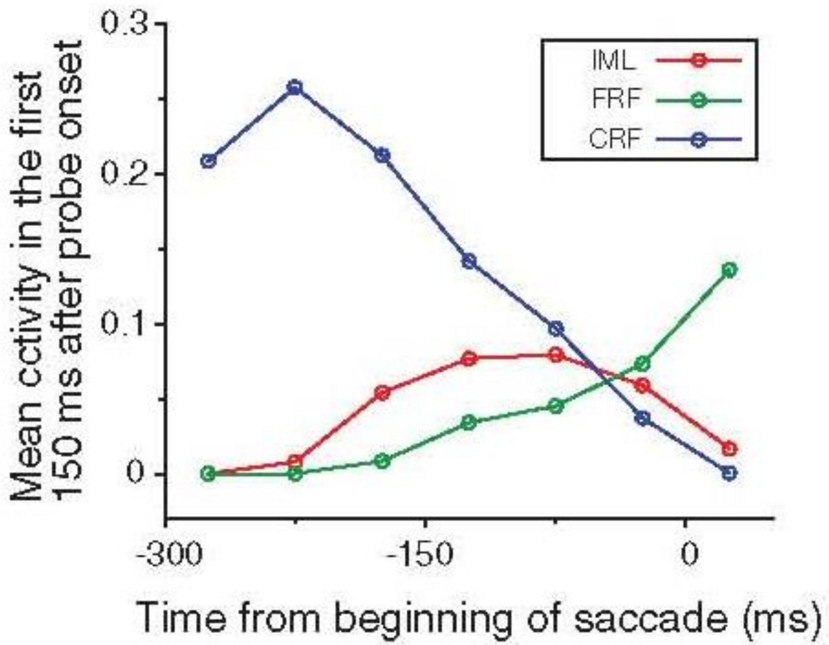


- ➢ Corollary discharge (CD) from SC contains the saccade information (direction & amplitude)
- ➢ CD warms up the paths along the saccade direction
- ➢ A visual stimulation activates neurons at future RF
- ➢ Asymmetric connections along the trajectory propagate neural activity
- ➢ The duration of CD decides the propagation distance

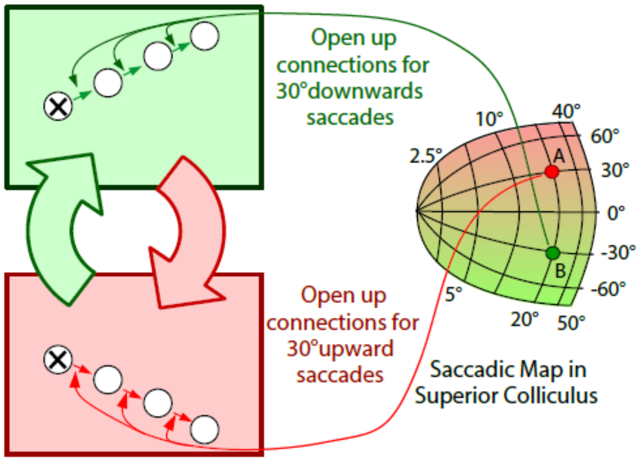
Wang et al.,2016

The model results





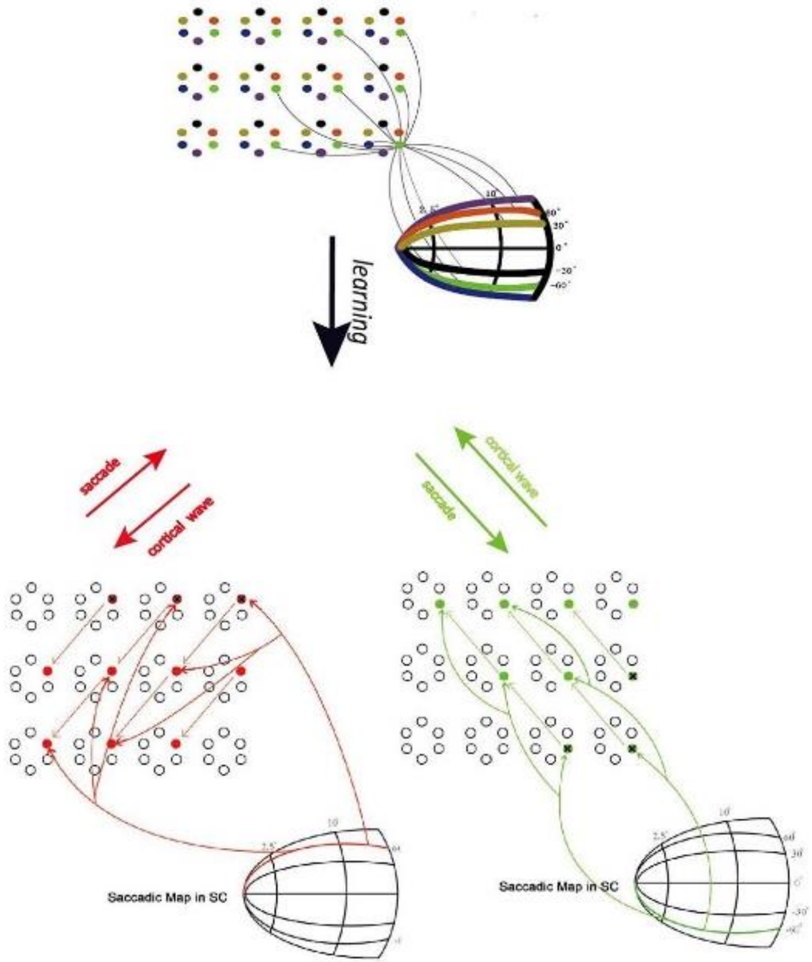
A 2D Model



Three key points:

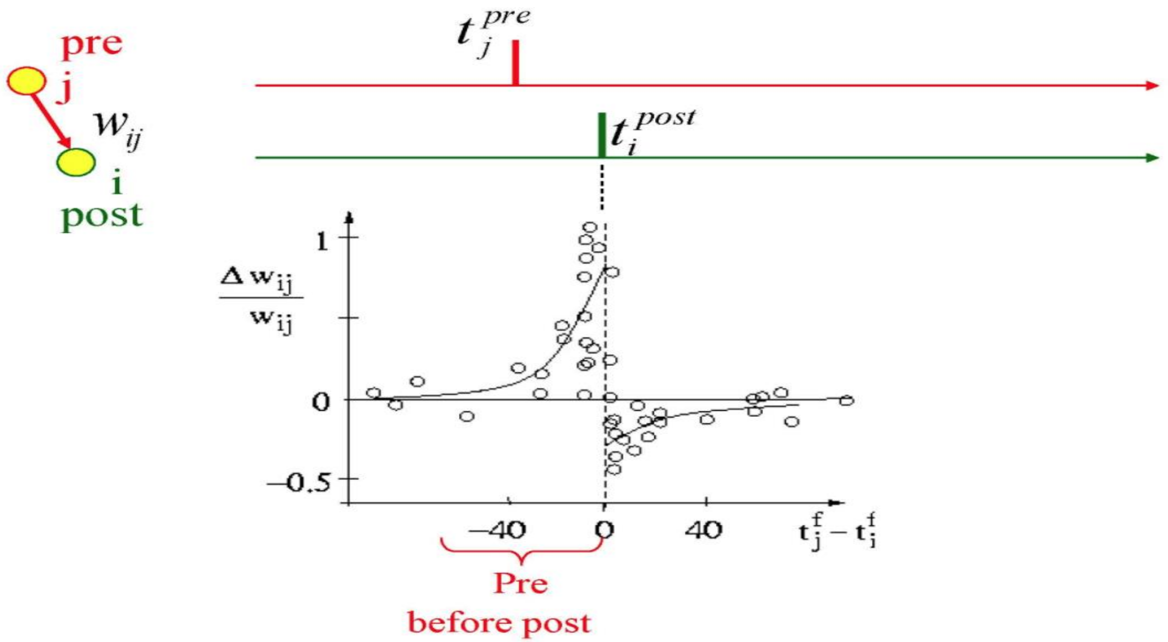
1. In the 2D space, there exist many groups of LIP neurons connected uni-directionally, and each of them is responsible for remapping in a specific saccadic direction.
2. The CD signal from SC, which conveys the saccadic direction information, "warms up" the neurons in the 2D space on that direction.
3. A visual stimulus combined with the CD signal triggers the cortical wave along the opposite direction of the saccade.

Learning the model from experiences



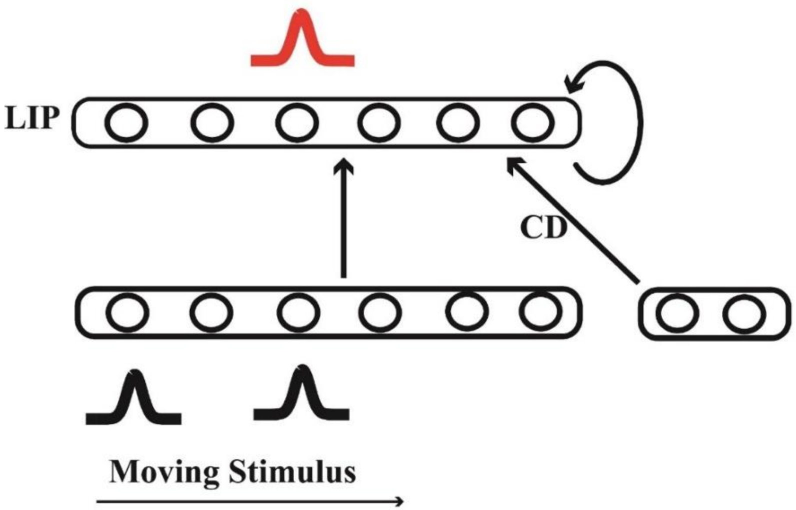
- At the early stage of development, no connections between LIP neurons exist, and hence no remapping. The CD signal from SC is homogenously sent to all LIP neurons without specification.
- With eye movement, a static visual stimulus sweeps through retina as if a stimulus is moving in the opposite saccadic direction. This passive movement serves as the cue to learn the remapping structure in LIP.
- Suppose that the eye makes the same movement repetitively, due to STDP, the uni-direction connections between LIP neurons will be learned, and the coupling between LIP and SC is strengthened. Thus, the remapping model is developed.

Spike-time-dependent-plasticity (STDP)



Bi & Poo, J. Neurosci. 1998

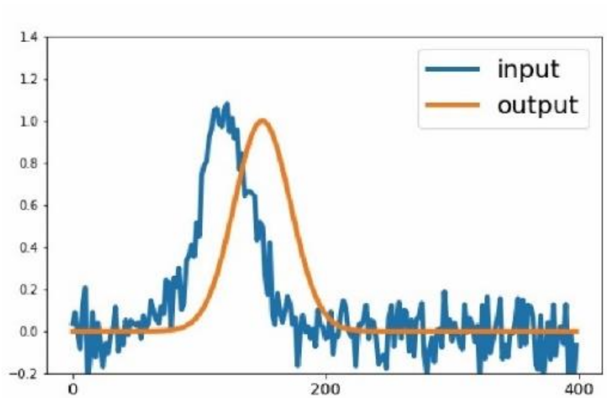
Learning the model for prediction



$$\tau \frac{dV_i^{LIP}}{dt} = -V_i^{LIP} + \sum_{i \neq j} W_{ij}^{rec} U_j^{LIP} + W_{ij}^{in} I_j + W^{cd} I_{CD},$$

$$U_j^{LIP} = \frac{1}{1+e^{-V_j^{LIP}}}.$$

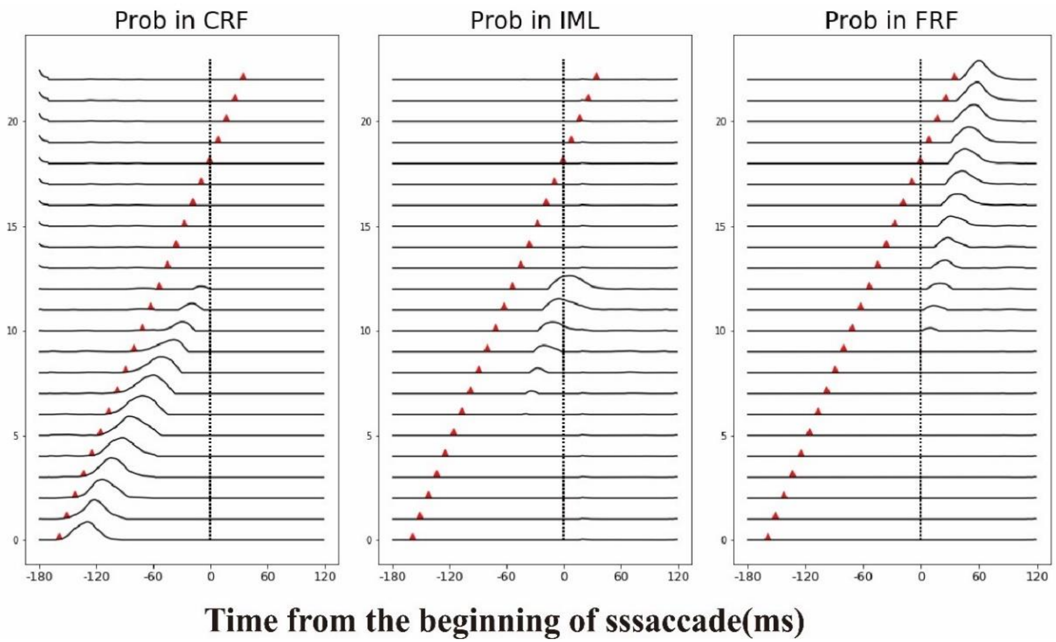
$$I_i(t) = A \exp\left\{ -\frac{[x(t)-x_i]^2}{\sigma^2} \right\},$$



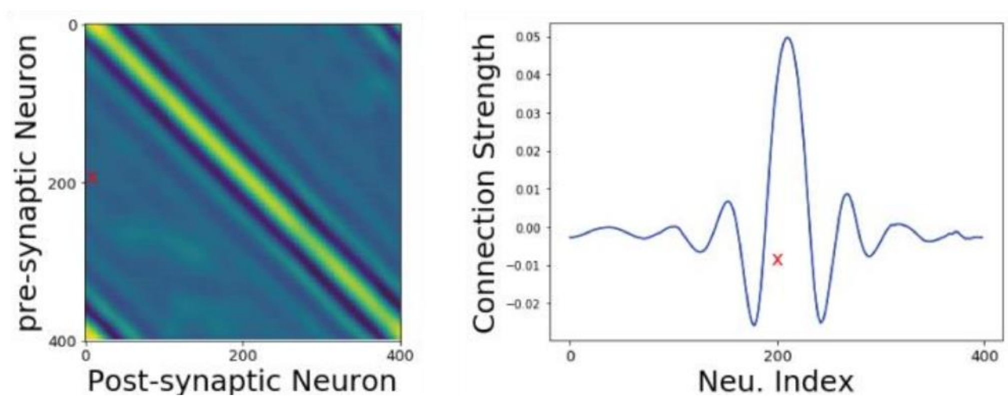
$$\boxed{L = \int_0^T \sum_i \frac{1}{2} (\hat{I}_i(t+\Delta t) - I_i(t+\Delta t))^2 \, dt,}$$

Minimize the loss via BPTT

Results: reproduce the experimental phenomenon



Learned asymmetric weights



References

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2. Xiao Wang, Yan Wu, Mingsha Zhang, Si Wu* (2017). Learning Peri-saccadic remapping of receptive field from experience in Lateral Intraparietal Area. Frontiers in Computational Neuroscience.
3. Xiao Wang, Mingsha Zhang, Si Wu* (2018). Perisaccadic Remapping Accounts for Visual Stability. Proceedings of The 17th IEEE International Conference on Cognitive Informatics & Cognitive Computing.