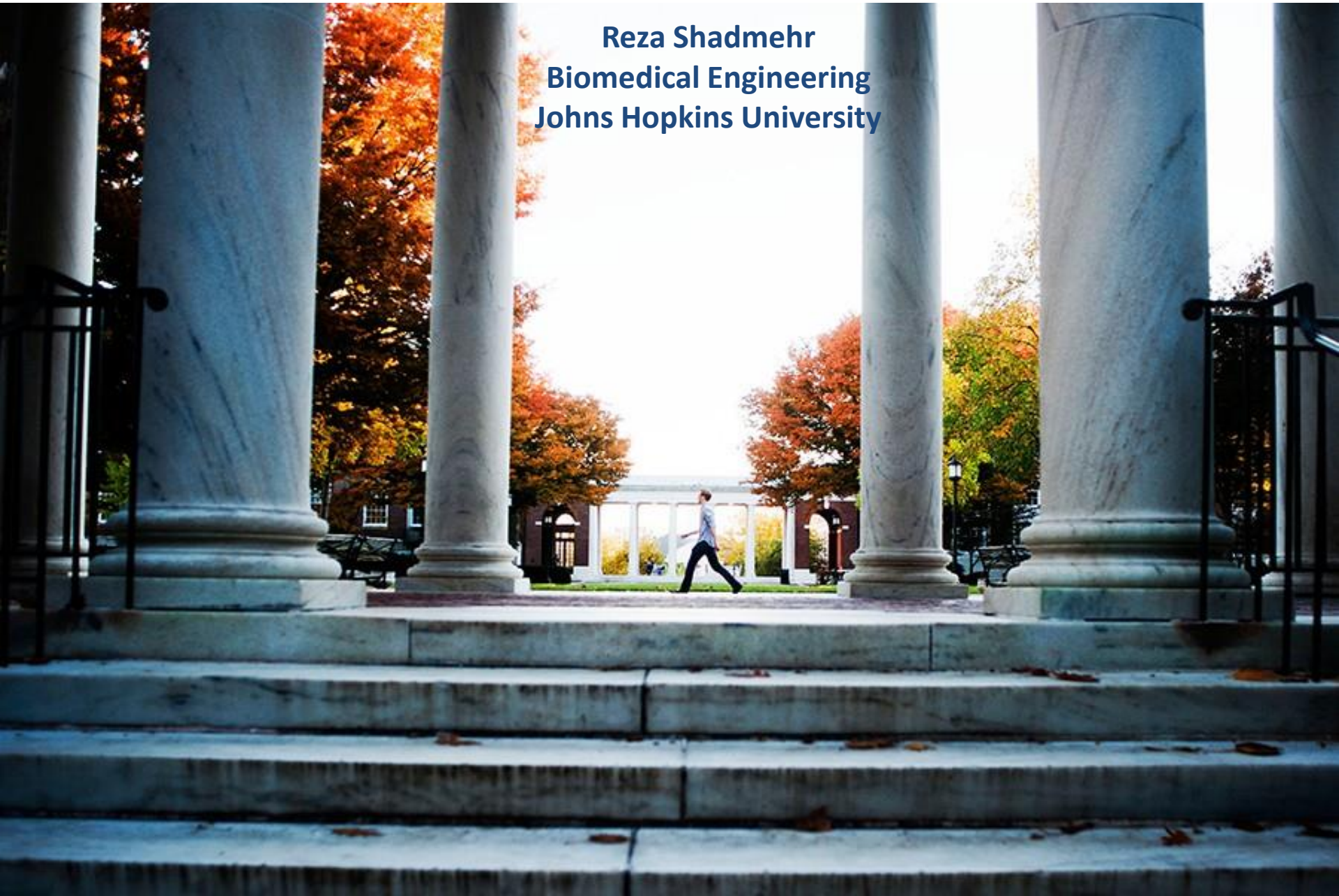
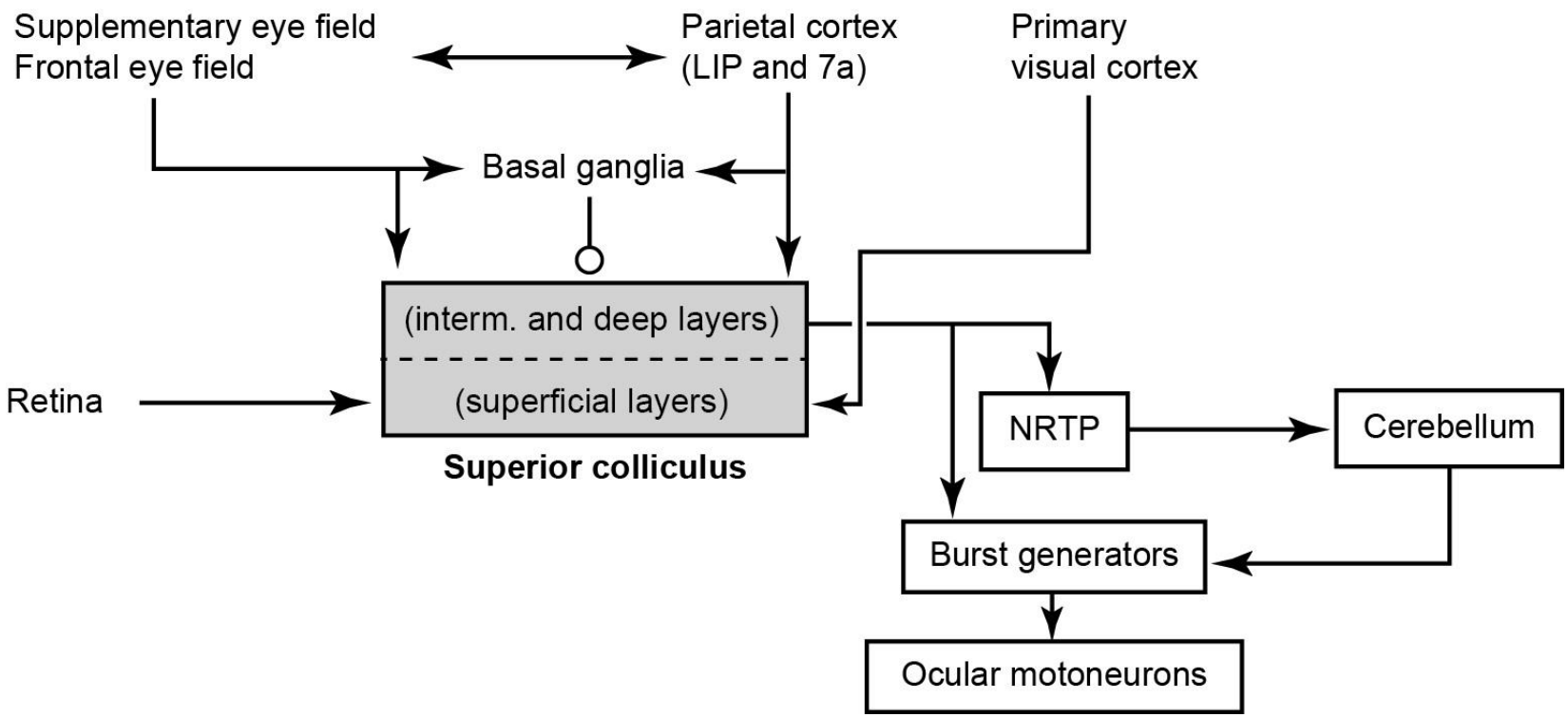
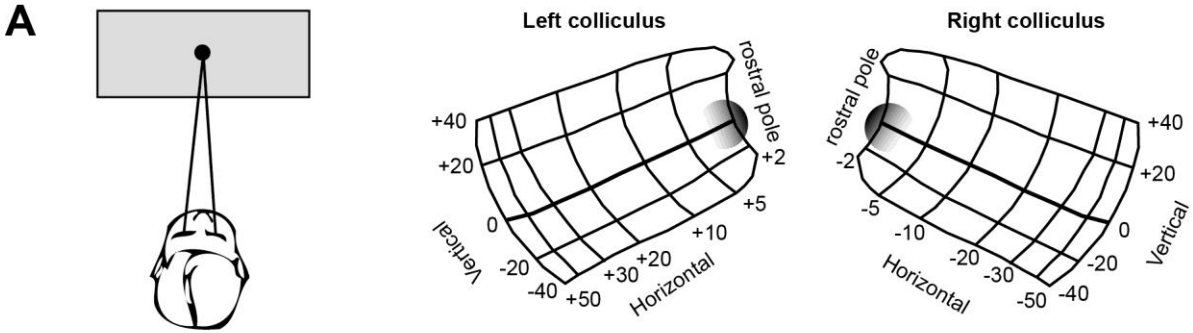
Neural prelude to a movement



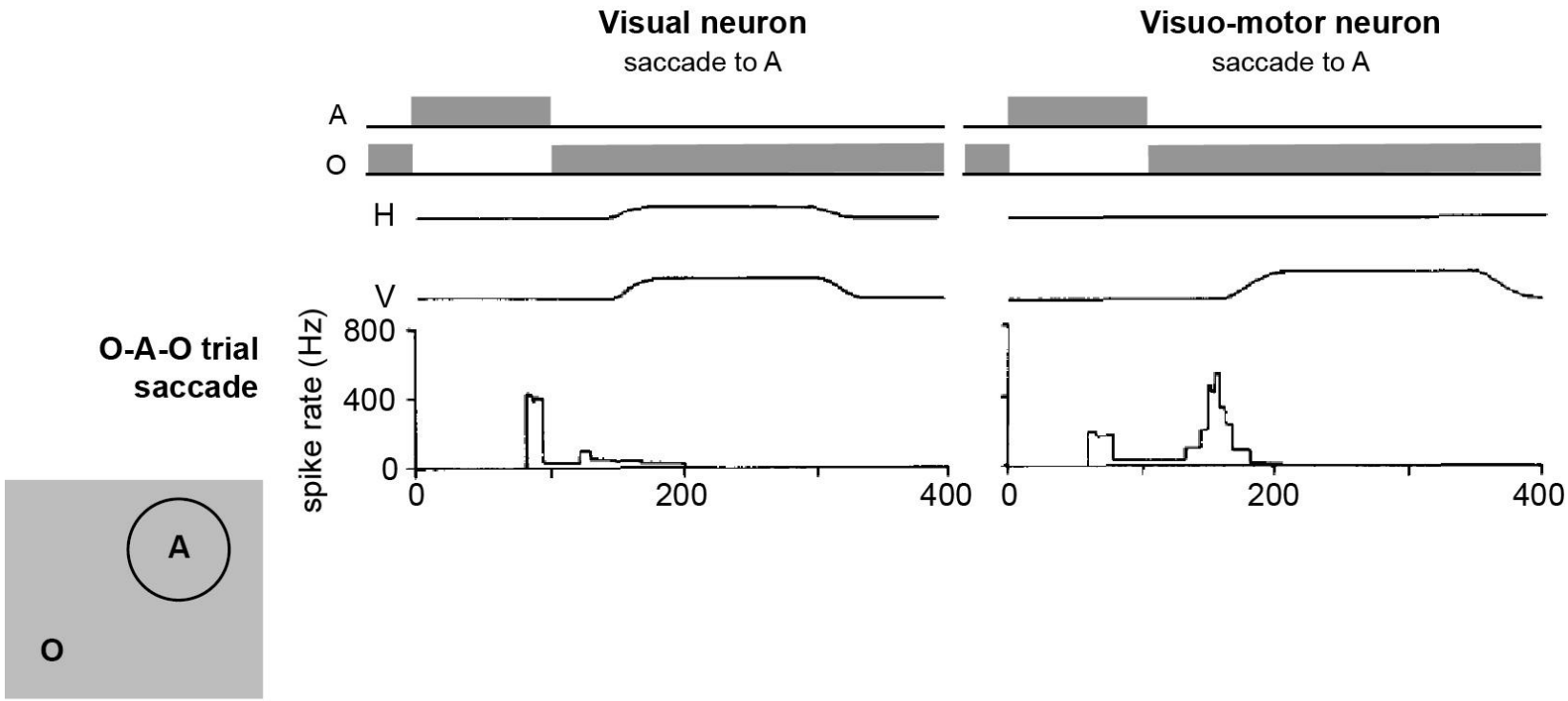
Reza Shadmehr
Biomedical Engineering
Johns Hopkins University

Why does it take so long to start a movement?
Neural basis of movement latency



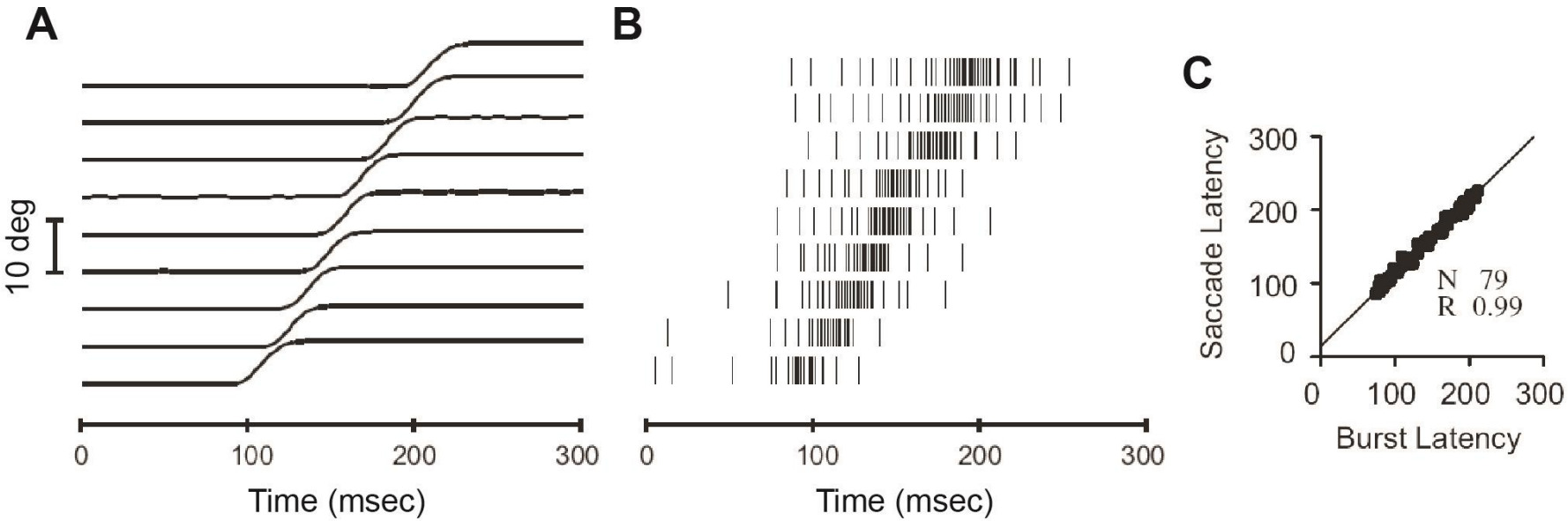

A
Left colliculus
Right colliculus
rostral pole
+40
+20
0
-20
-40
Vertical
+2
+5
+10
+20
+30
+50
Horizontal
rostral pole
-2
-5
-10
-20
-30
-50
Horizontal
+40
+20
0
-20
-40
Vertical

Visual and motor responses in the superior colliculus



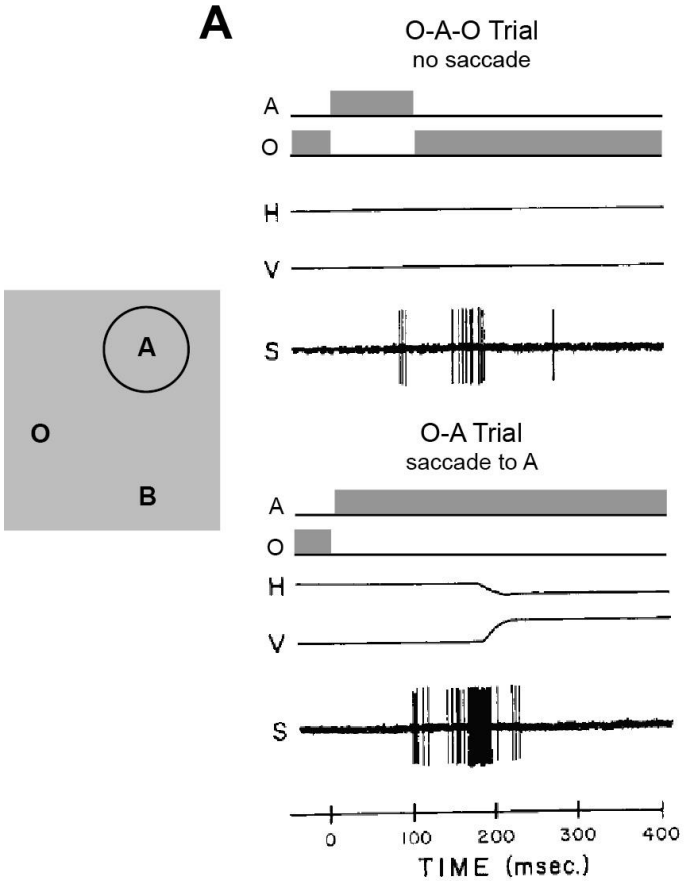
Sparks, 1978

A burst in the visuomotor neuron always coincides with a saccade



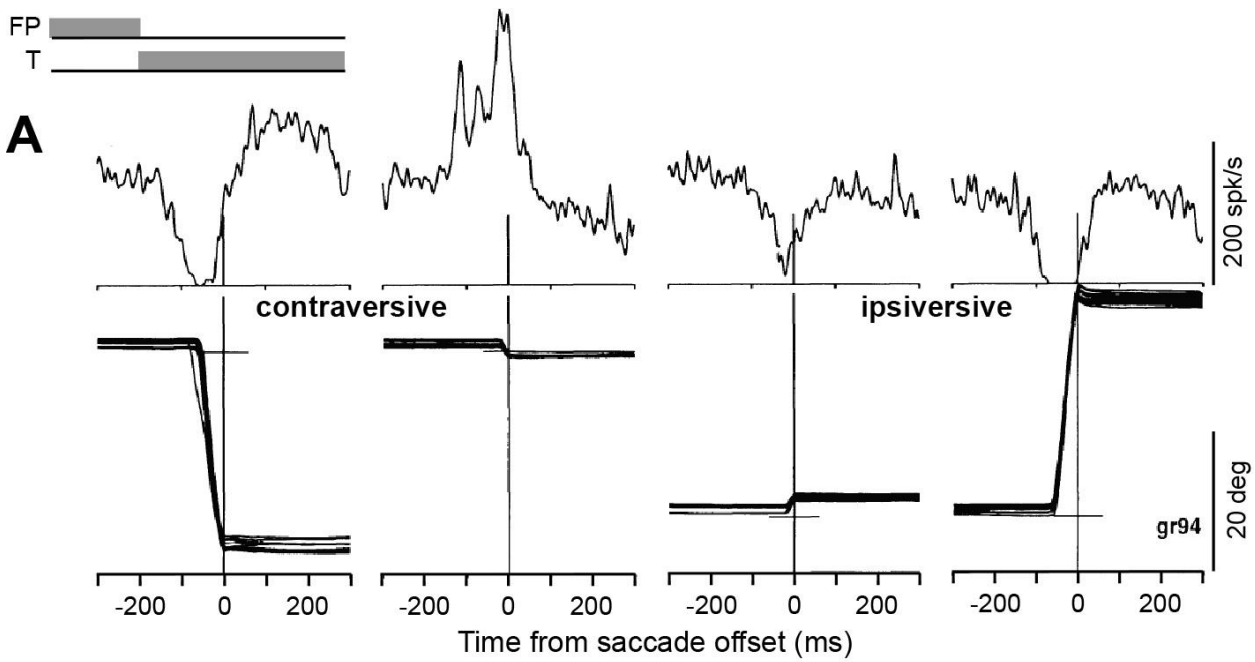
Sparks and Hu, 1999

There is buildup of activity in the visuomotor neurons, but only sometimes it becomes large enough to produce a burst



Sparks, 1978

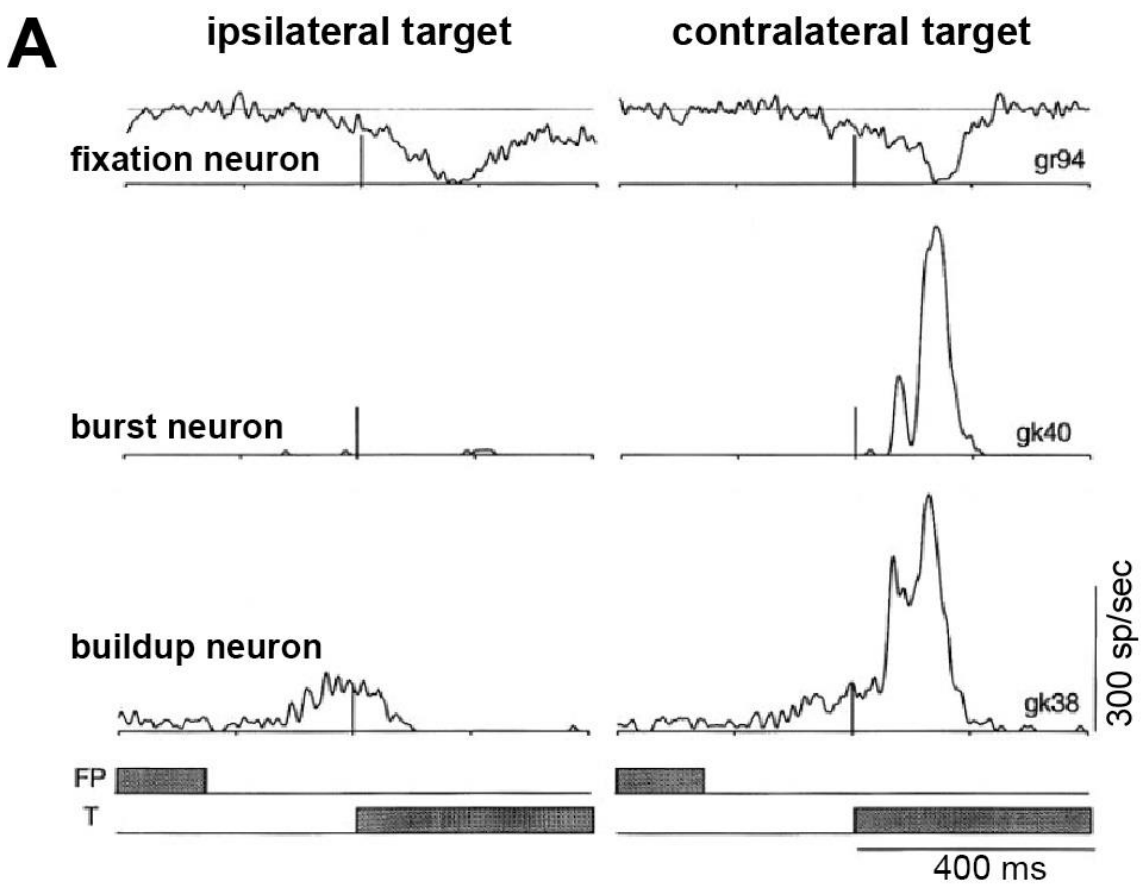
Fixation-related cells pause during saccades



Munoz and Wurtz, 1993

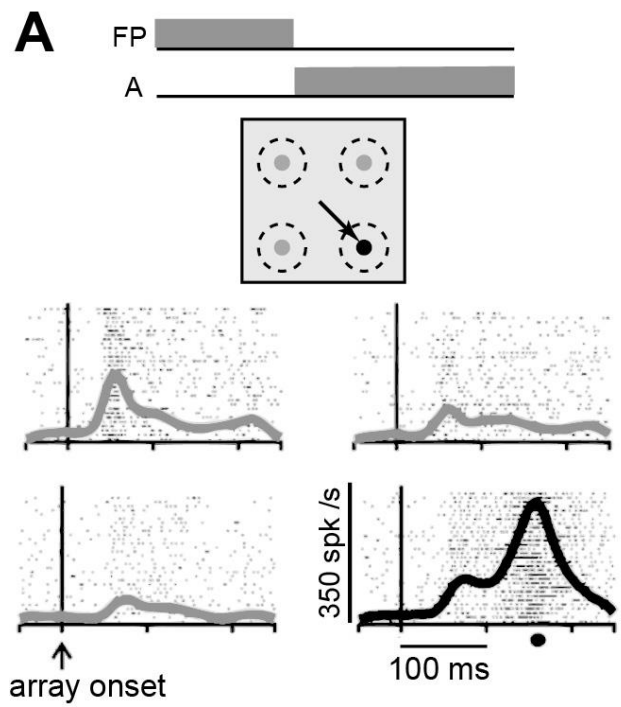
Two events occur during reaction time:

- **Activity falls in the fixation-related neurons**
- **Activity rises in the buildup and burst neurons**



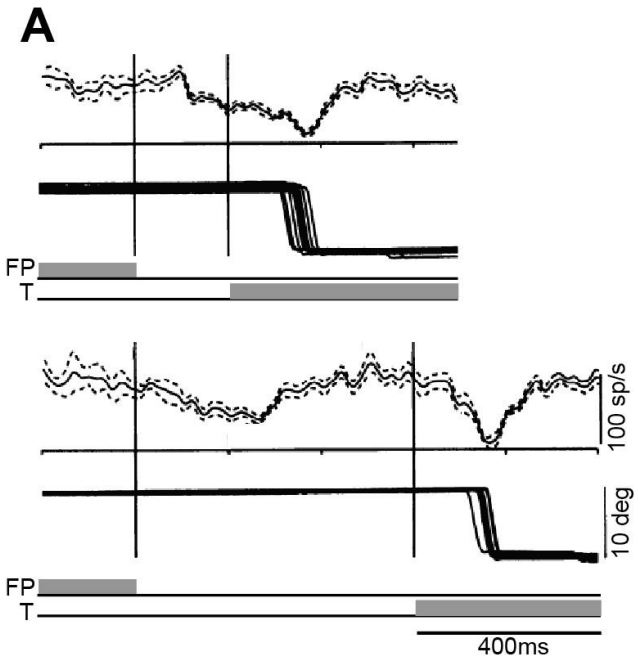
Munoz and Wurtz, 1993

Reaction time tracks changes in the activity of fixation-related and build-up neurons



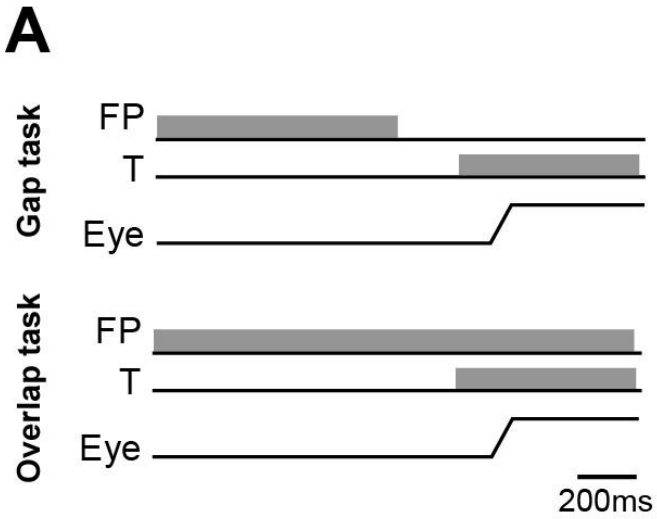
Kim and Basso (2010), McPeek and Keller (2002)

Reaction time tracks changes in the activity of fixation-related and build-up neurons



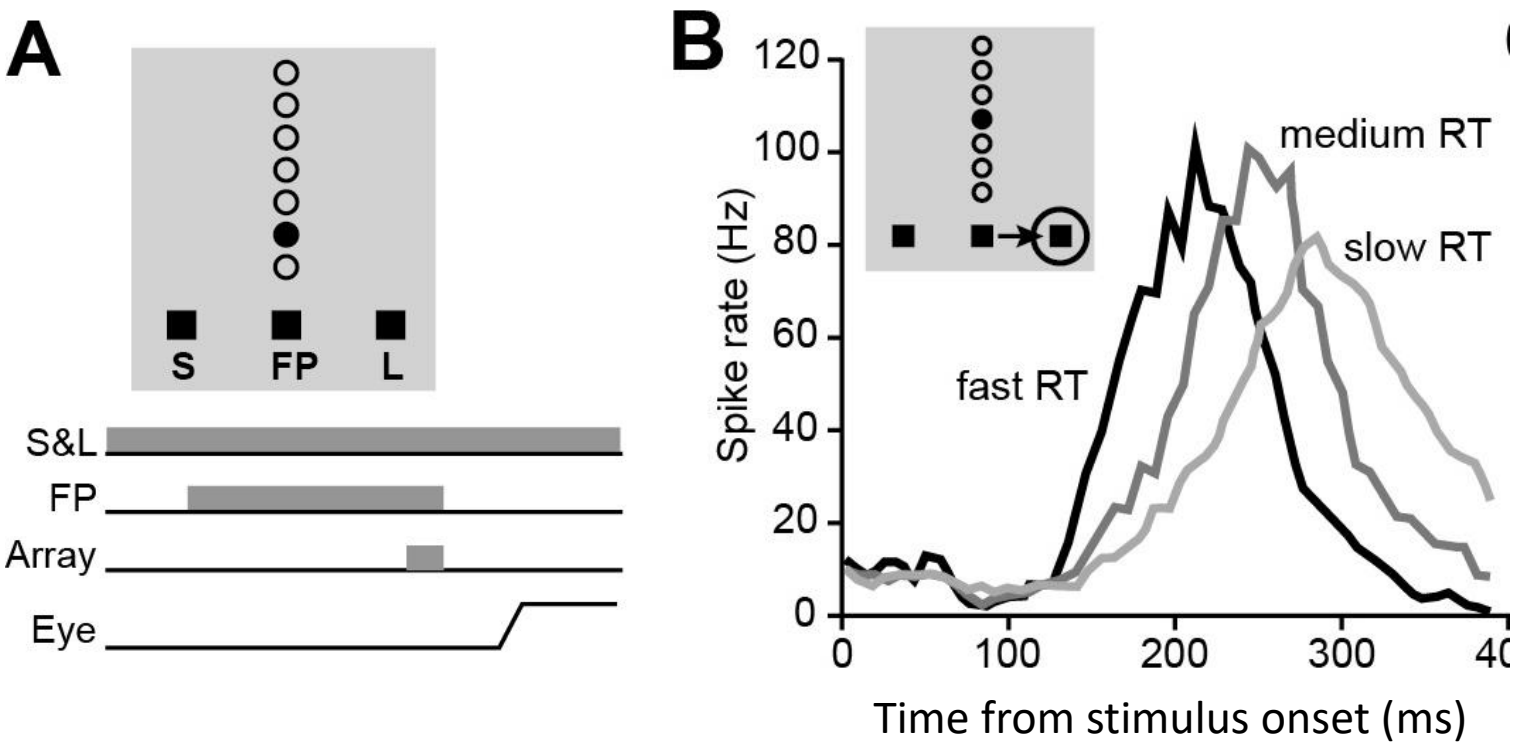
Dorris and Munoz, 1995

Latency is shorter when activity in fixation-related neurons declines earlier



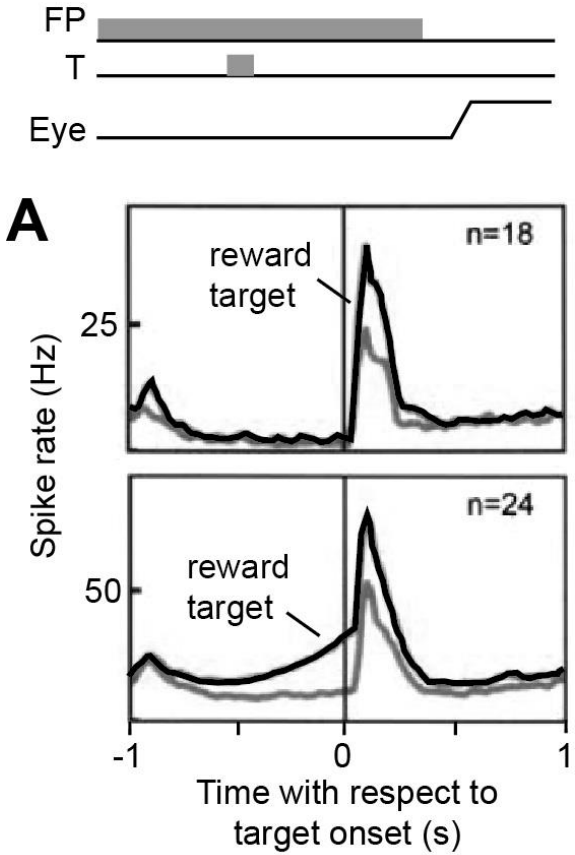
Everling et al., 1999

Latency is shorter when activity in buildup neurons rises faster



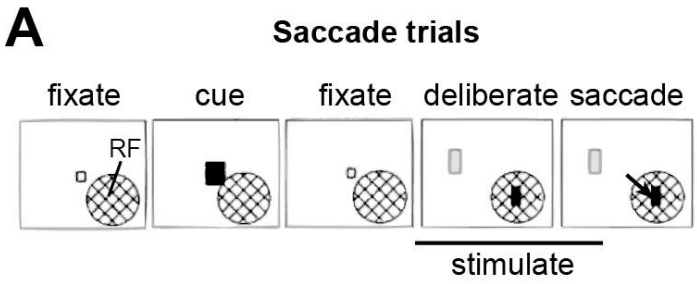
Ratcliff et al., 2007

Reward increases the background activity in the visuomotor neurons, making them respond more strongly to the visual stimulus



Ikeda and Hikosaka, 2007

Stimulating the colliculus influences the decision

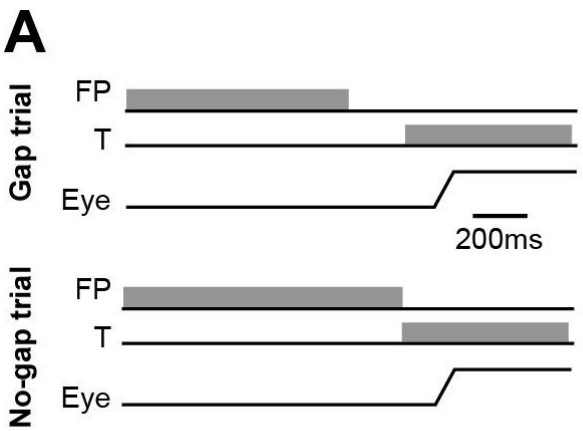


Carello and Krauzlis, 2004

Summary

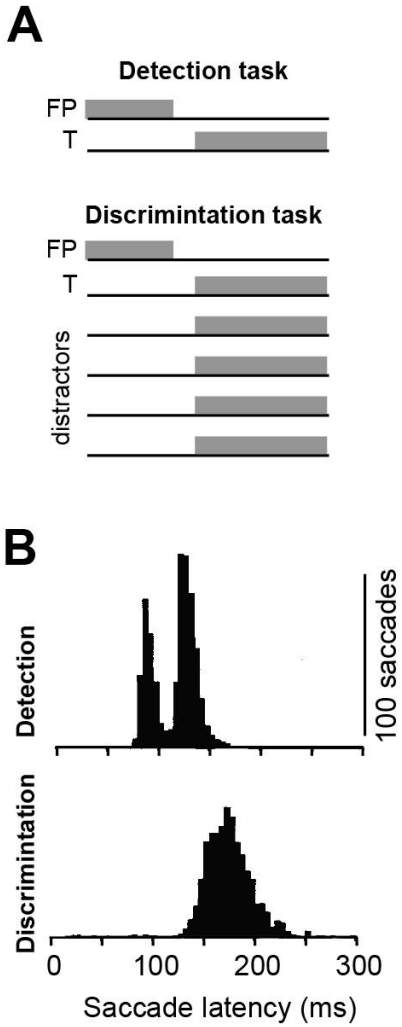
- In SC, cells respond to visual stimulus onset at 80ms, but it takes another 80ms or more to start a movement.
- During the reaction time, two events occur: activity of the fixation-related neurons decline, while activity in the movement-related neurons increase.
- Utility of the action during holding appears to influence the rate of decline in the fixation-related neurons.
- Utility of the action that evokes the saccade appears to influence the rate of increase in the movement-related neurons.

Reducing the reaction time by half: express saccades



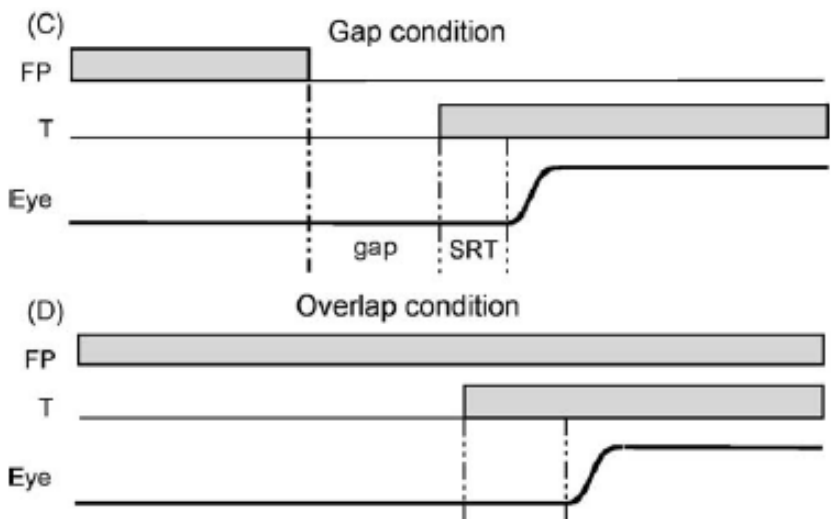
Pare and Munoz, 1996

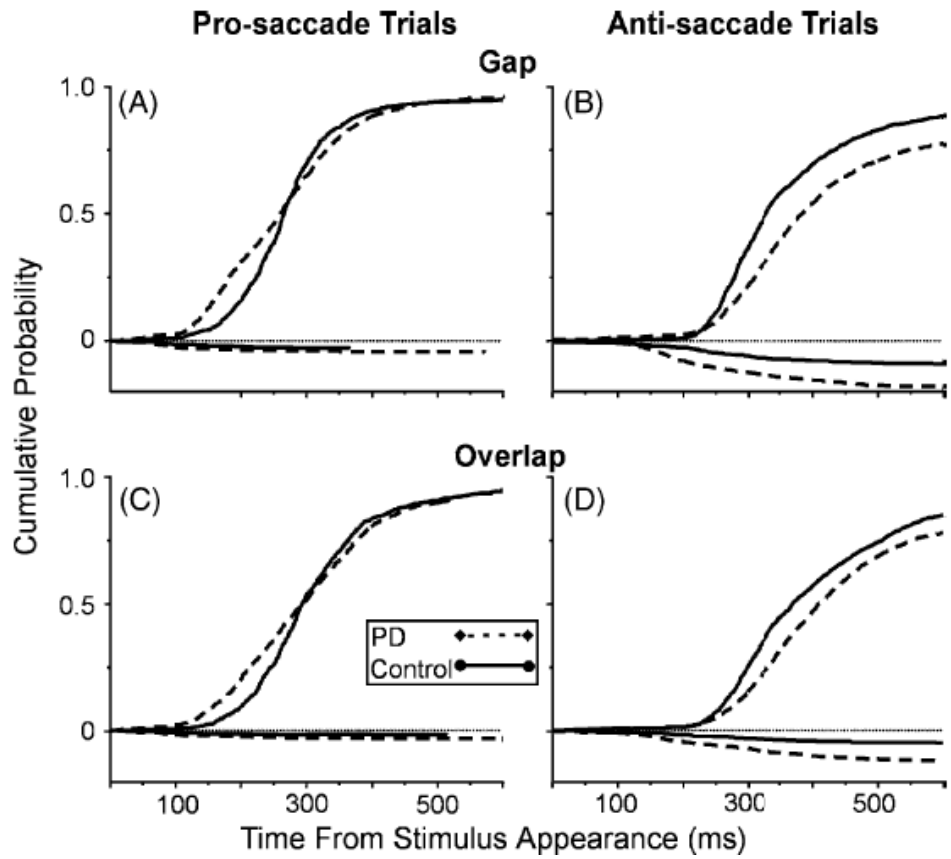
Superior colliculus is required for express saccades



Schiller et al., 1987

Pro- and Anti-saccade task
PD patients exhibit a reduced ability to inhibit reflexive saccades

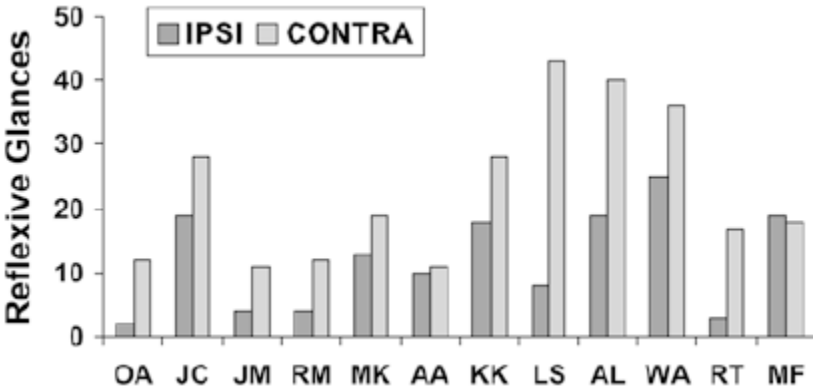




Chan et al. (2005)

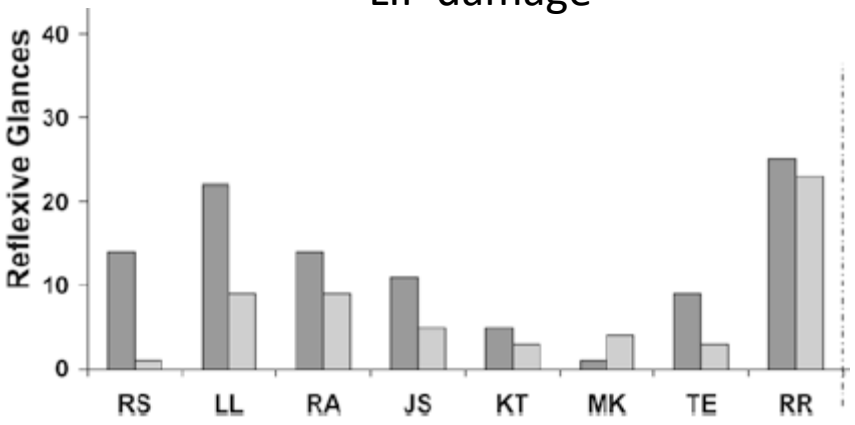
Anti-saccade task

FEF damage



FEF patients make more errors when the target is contralateral to the side of the lesion

LIP damage



Parietal patients make more errors when the target is ipsilateral to the side of the lesion

Machado and Rafal 2004

Summary

- In SC, cells respond to visual stimulus onset at 80ms, but normally it takes another 80ms or more to start a movement.
- During the reaction time, two events occur: activity of the fixation-related neurons decline, while activity in the movement-related neurons increase.
- Utility of the stimulus holding the eyes, and the stimulus beckoning it, affect the reaction time.
- It is possible to half the reaction time so that a saccade is made at 100ms or less following the stimulus.
- In this case, the colliculus is primed for the movement by two factors: removal of the stimulus at fixation prior to target onset, and presentation of the target at one of finite and predictable locations.
- Damage to the basal ganglia, FEF, and LIP suggest that the utility of the action may be computed elsewhere, and imposed on the SC.

Limitations and questions

- Rostral colliculus remains a mystery. Activity may be related to value of the stimulus on the fovea, but the cells also participate in making micro-saccades.
- What neural structure sets the “threshold”?
- How is a utility transformed to produce a feedback control system that makes a movement?
- Does this view of reaction time in eye movements have parallels for skeletal movements?