Neural prelude to a movement:
movement utility and the preparation to move

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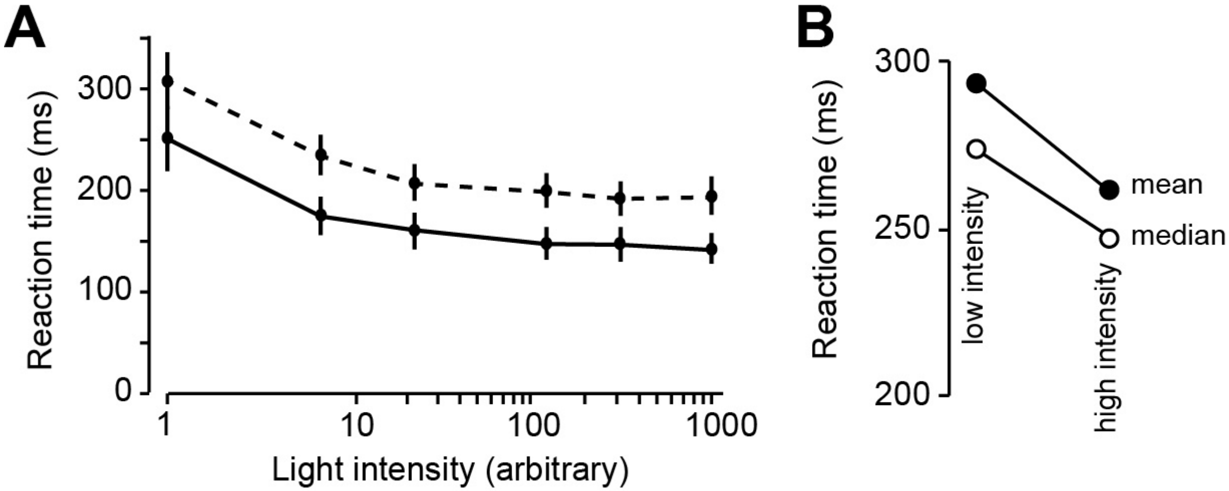
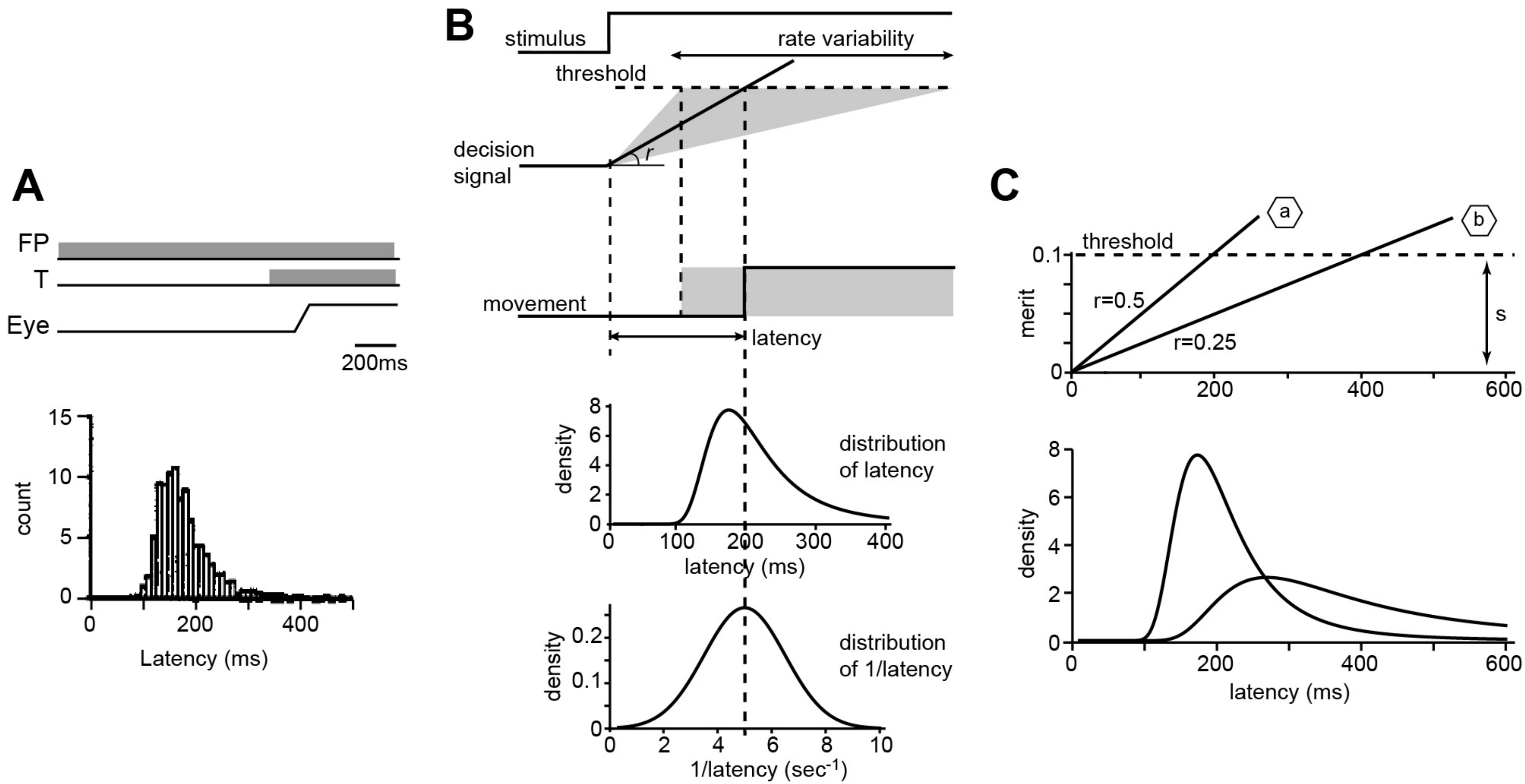
Movement latency is smaller for stimuli with greater intensity



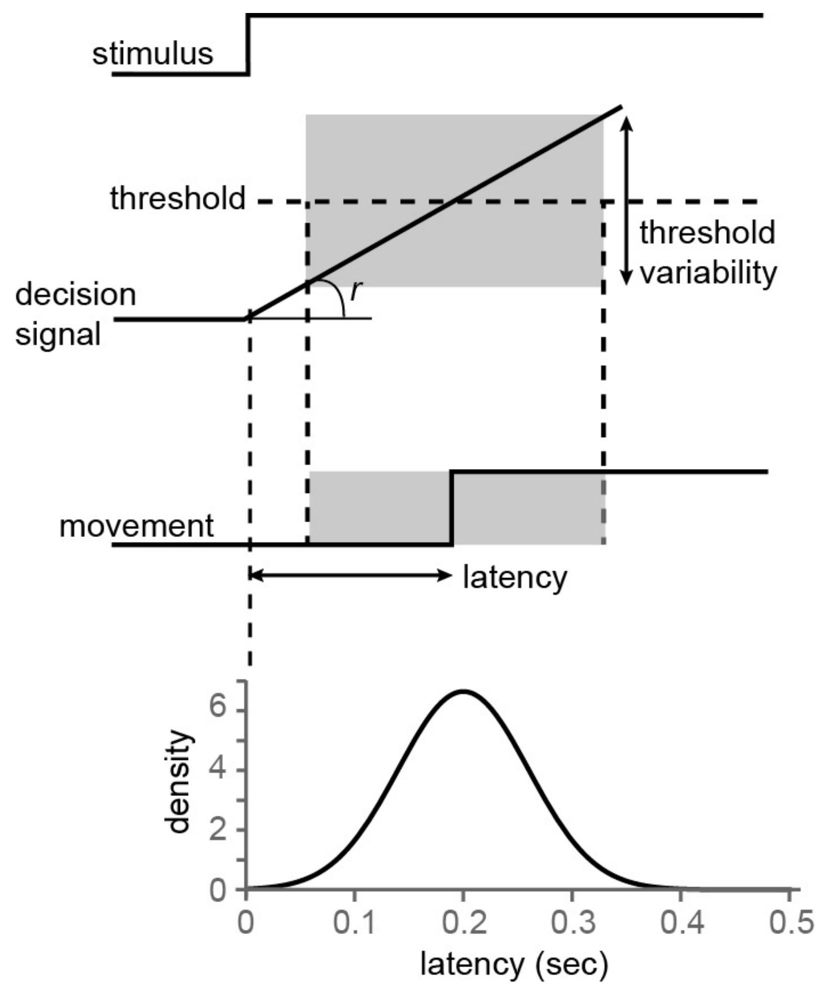
James Cattell (1886)

Development of a model: variable rise to a constant threshold

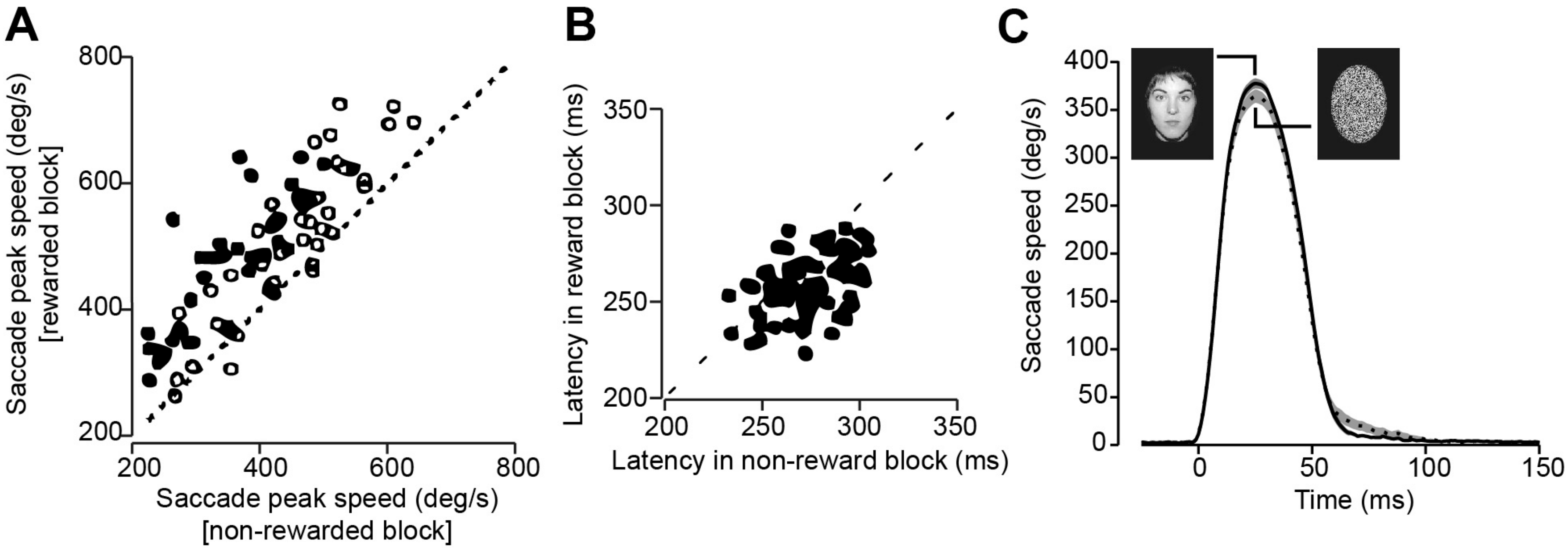


McGill (1961), Vickers (1970), Ratcliff (1978), Carpenter (1999)

Alternate model: constant rise to a variable threshold

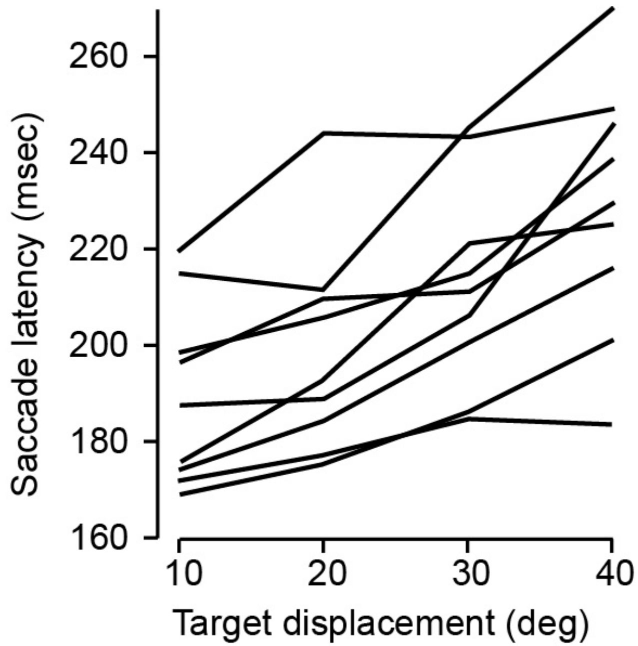


Increased reward reduces movement latency, and increases movement vigor



Takikawa et al. (2002) and Xu-Wilson et al. (2009)

Increased effort increases movement latency

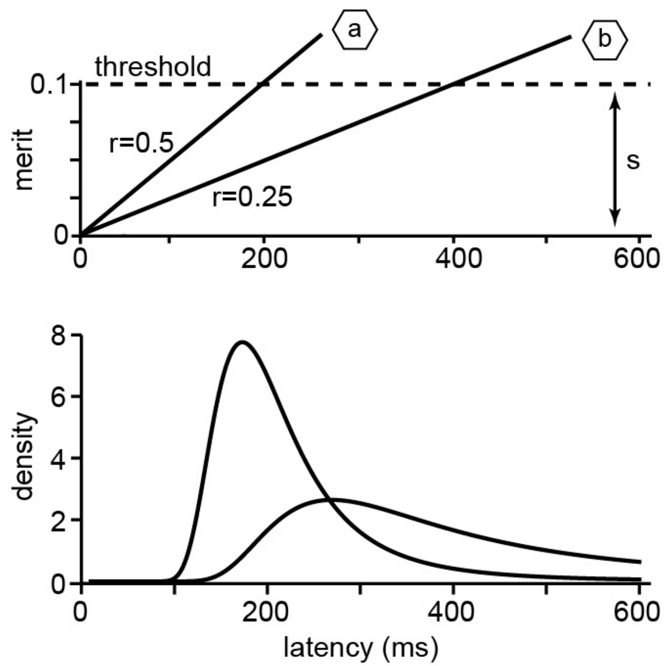


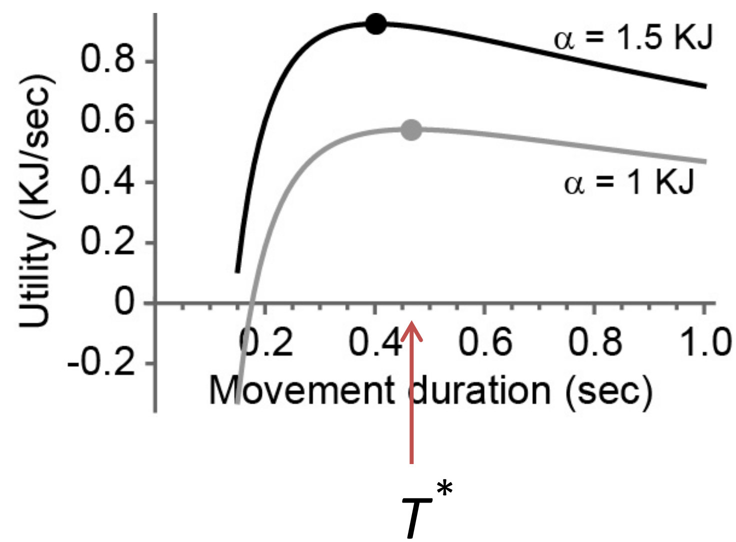
Fuller, 1996

Idea: perhaps latency is related to movement utility

utility, reward, effort, duration

$$J = \frac{\alpha - e(T)}{1 + \gamma T}$$

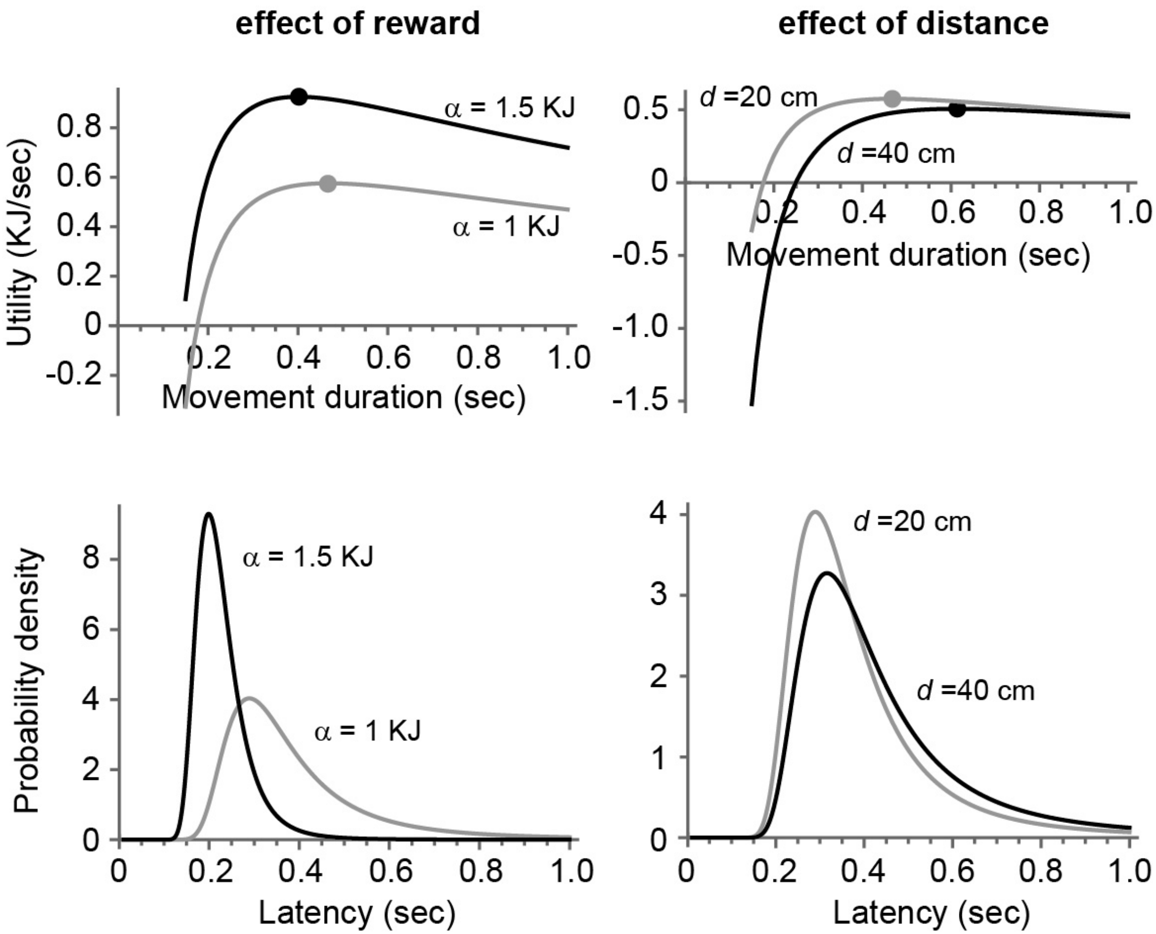




Let us assume that the rate of rise is proportional to the utility.

$$r \sim N\left(J\left(T^*\right), \sigma^2\right)$$

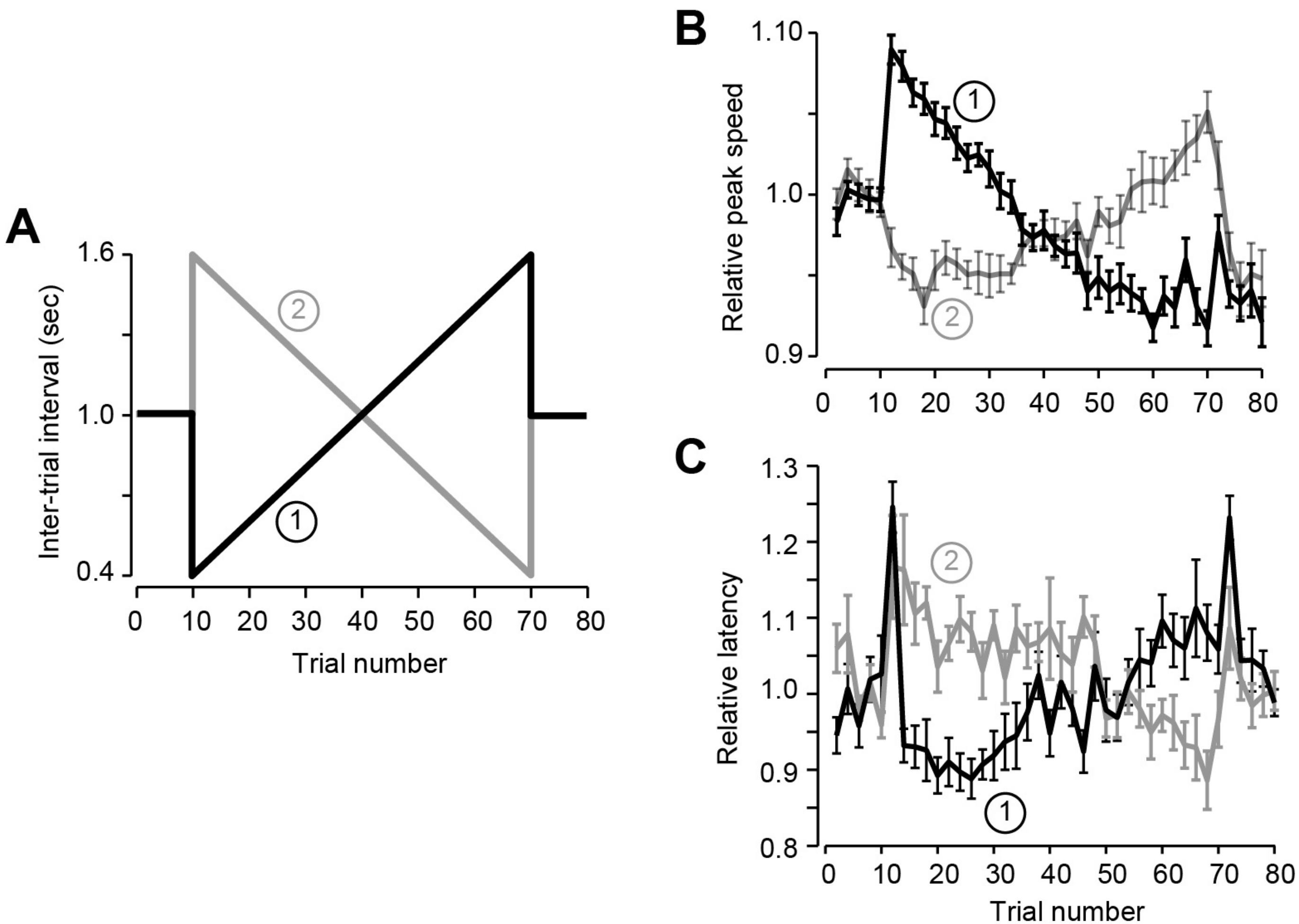
Model: rate of rise is proportional to utility



$$J = \frac{\alpha - e(T)}{1 + \gamma(T + q)}$$

Inter-trial interval

Increased inter-trial interval reduces vigor and increases latency of saccades

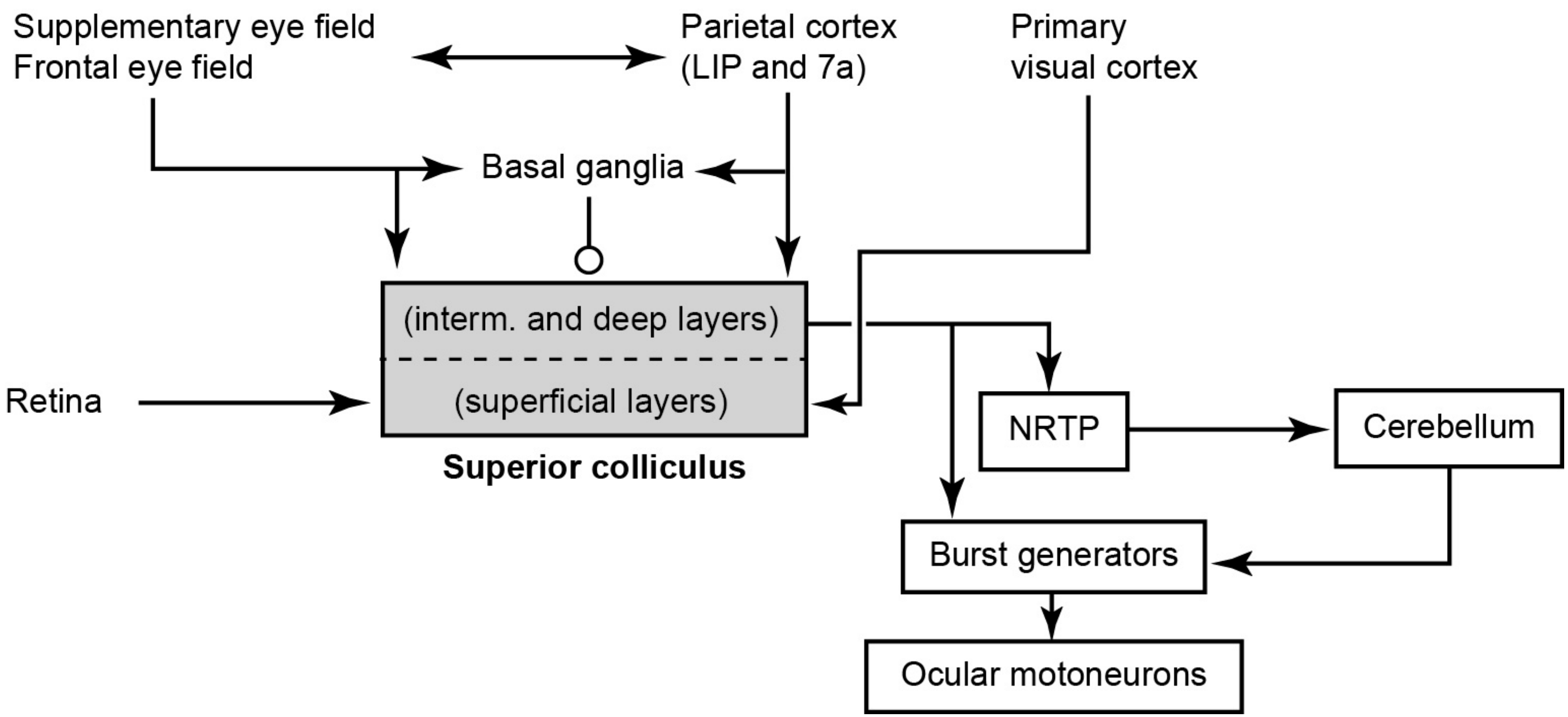


Haith et al., 2012

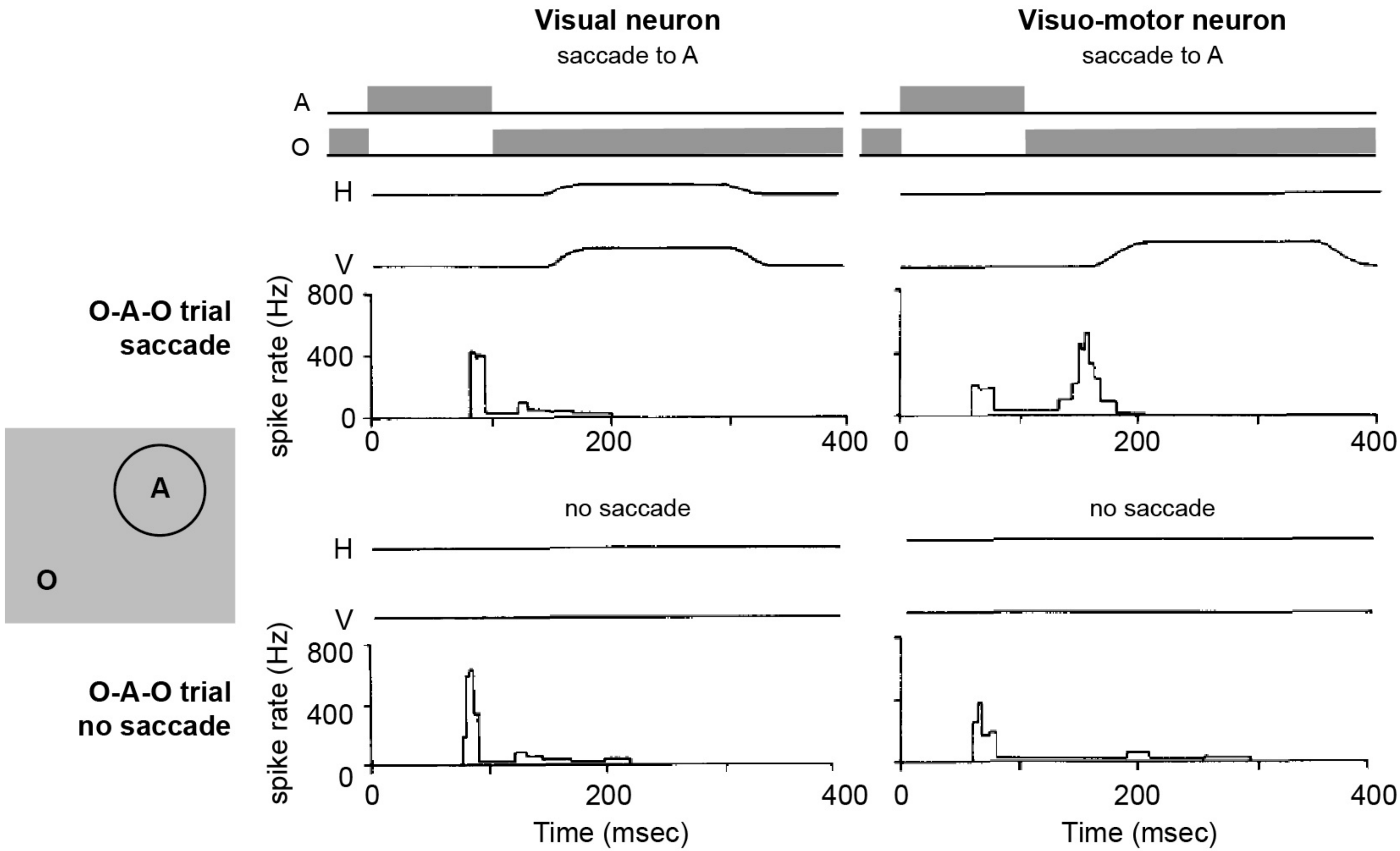
Summary

- It takes time to start a movement: latencies have a skewed distribution.
- It is thought that movement latency is related to a decision-making process in which merits of an action are accumulated, rising toward a threshold.
- A normally distributed rate of rise coincides with a skewed distribution of latencies.
- Here, we conjectured that the rate of rise may be proportional to utility of the movement.
- Increased reward increases utility. This coincides with reduced movement latency, and increased vigor.
- Increased effort decreases utility. This coincides with increased movement latency, and decreased vigor.
- Increased inter-trial interval decreases utility. This coincides with increased movement latency, and decreased vigor.

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

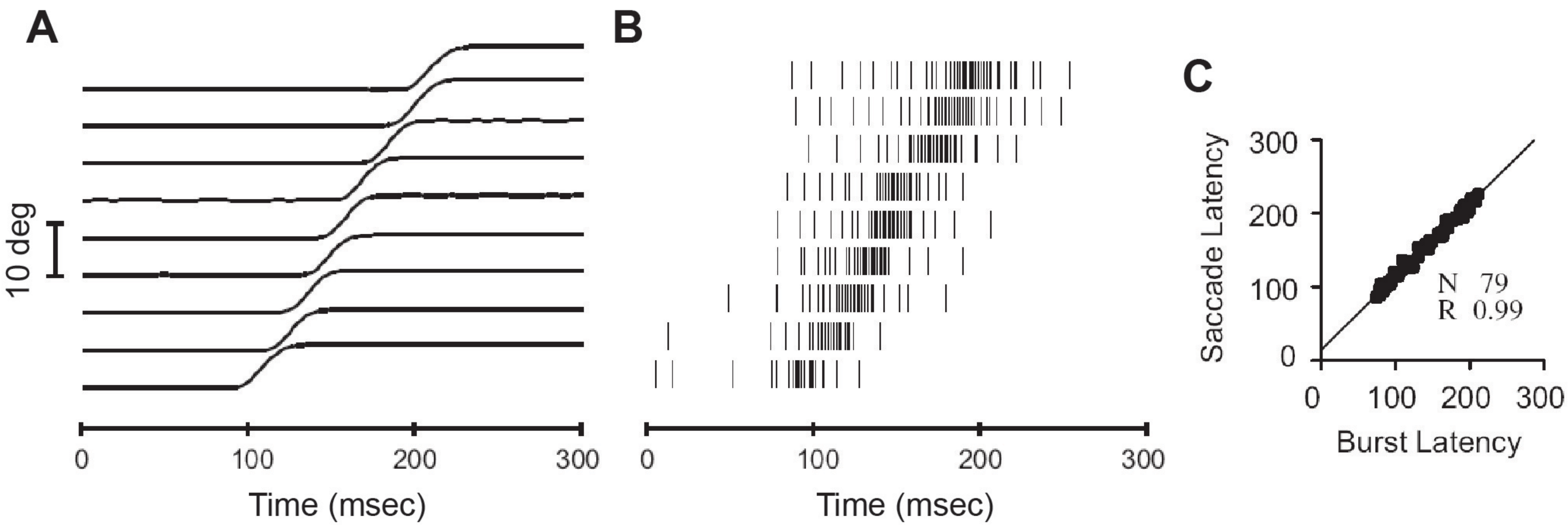


Visual and motor responses in the superior colliculus



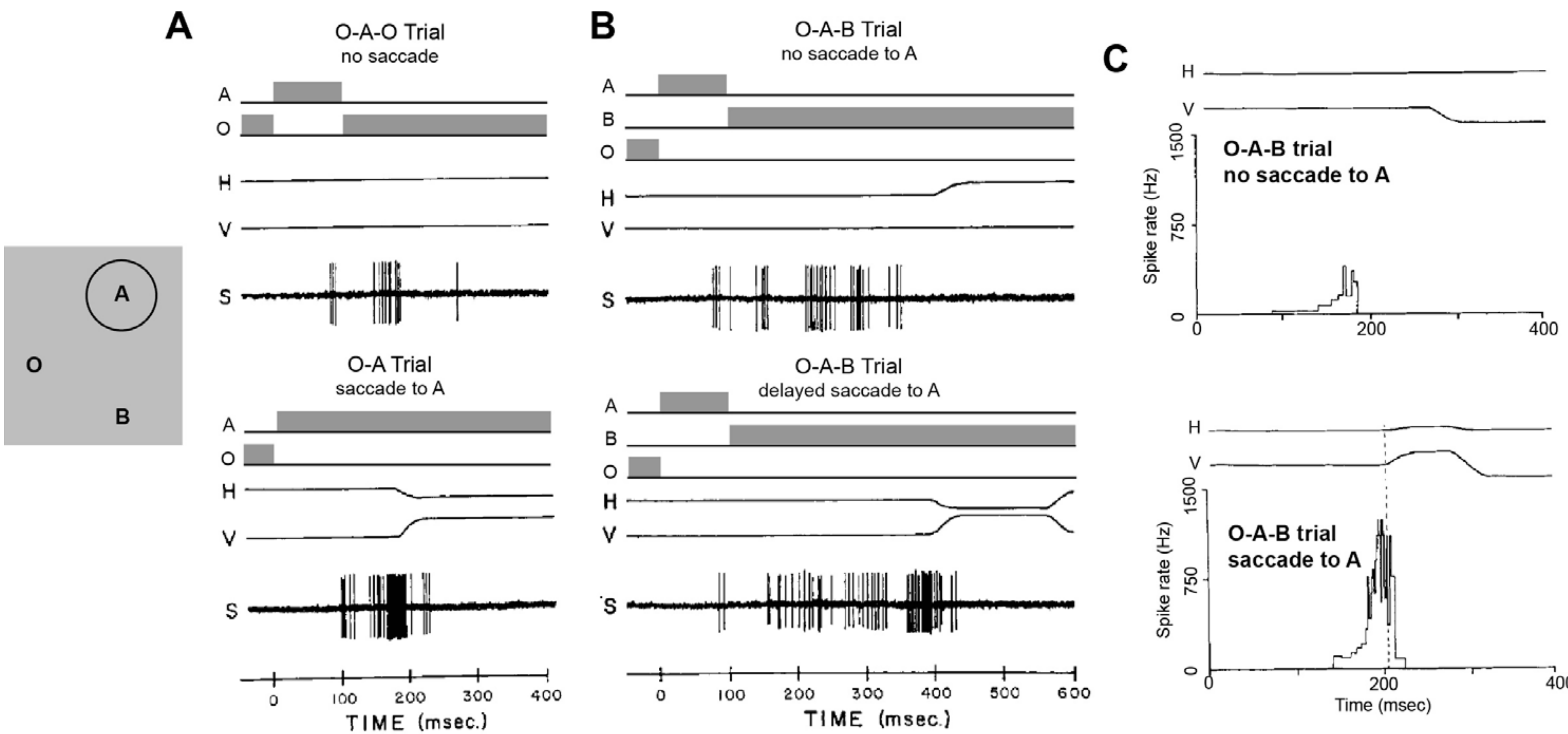
Sparks, 1978

A burst in the visuomotor neuron always coincides with a saccade



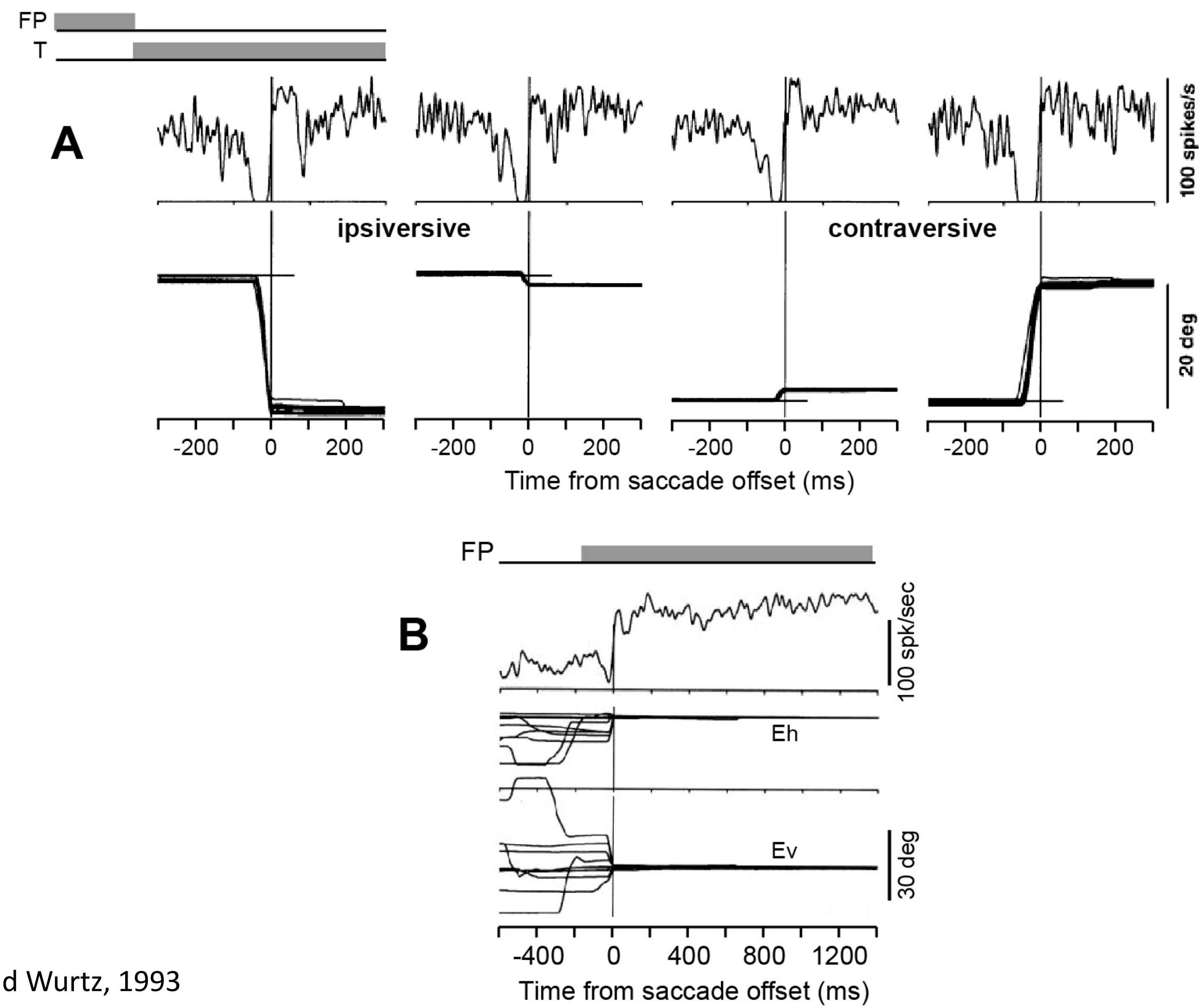
Sparks and Hu, 1999

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



Sparks, 1978

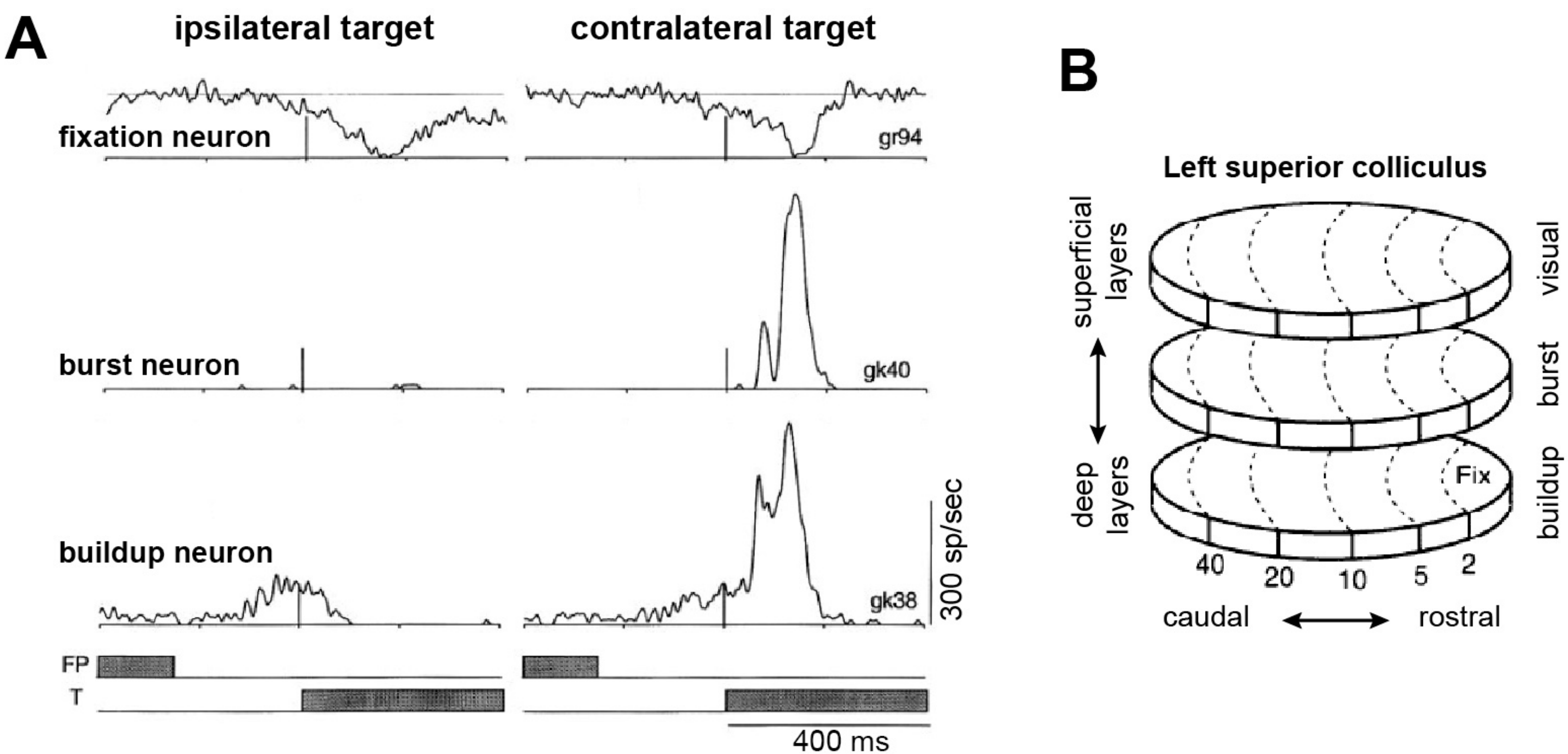
Fixation-related cells pause during saccades



Munoz and Wurtz, 1993

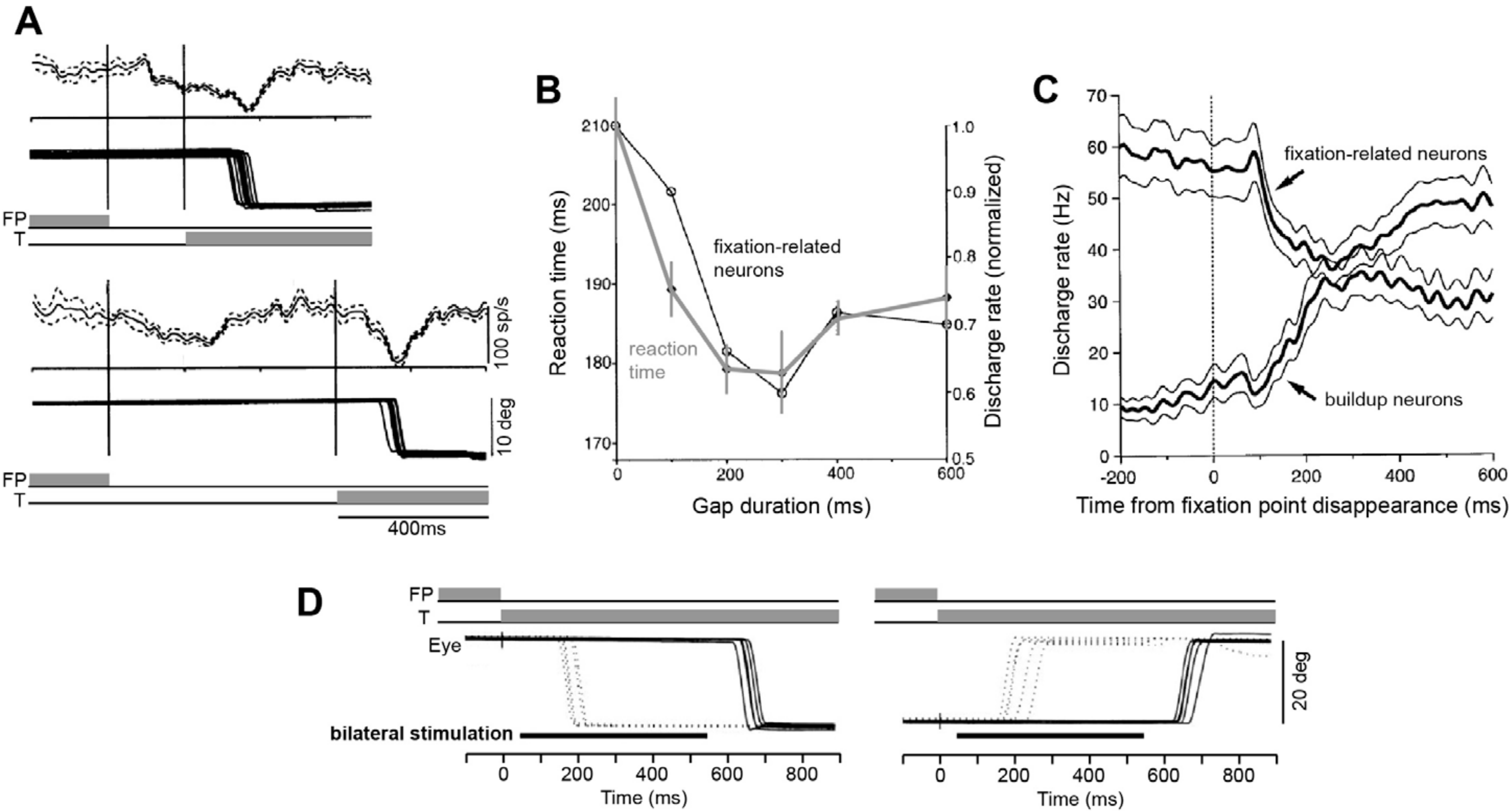
Two events occur during reaction time:

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



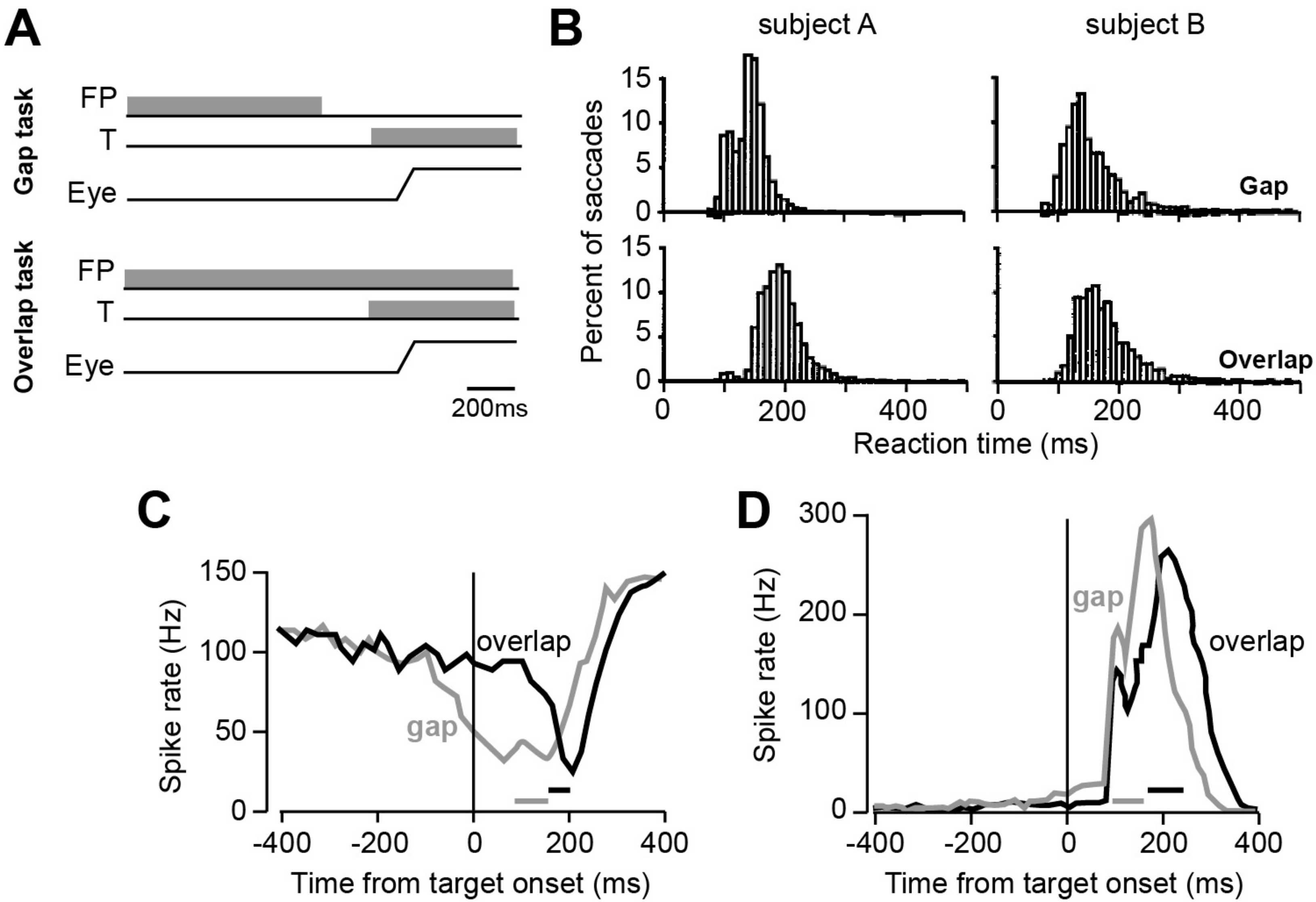
Munoz and Wurtz, 1993

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



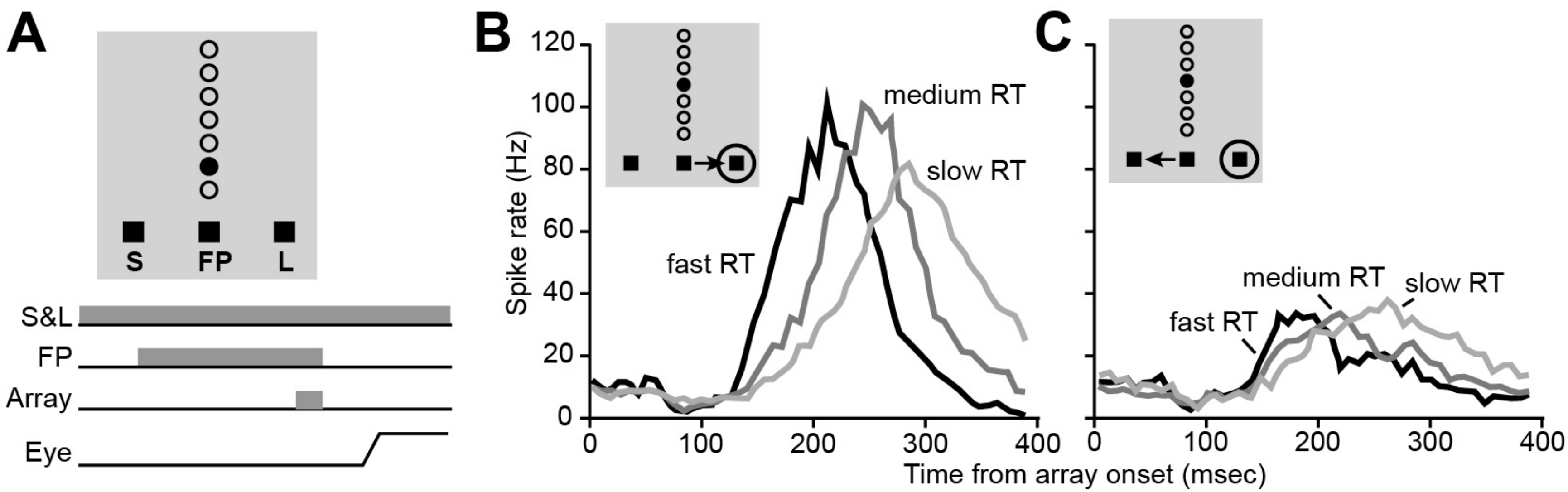
Dorris and Munoz, 1995

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



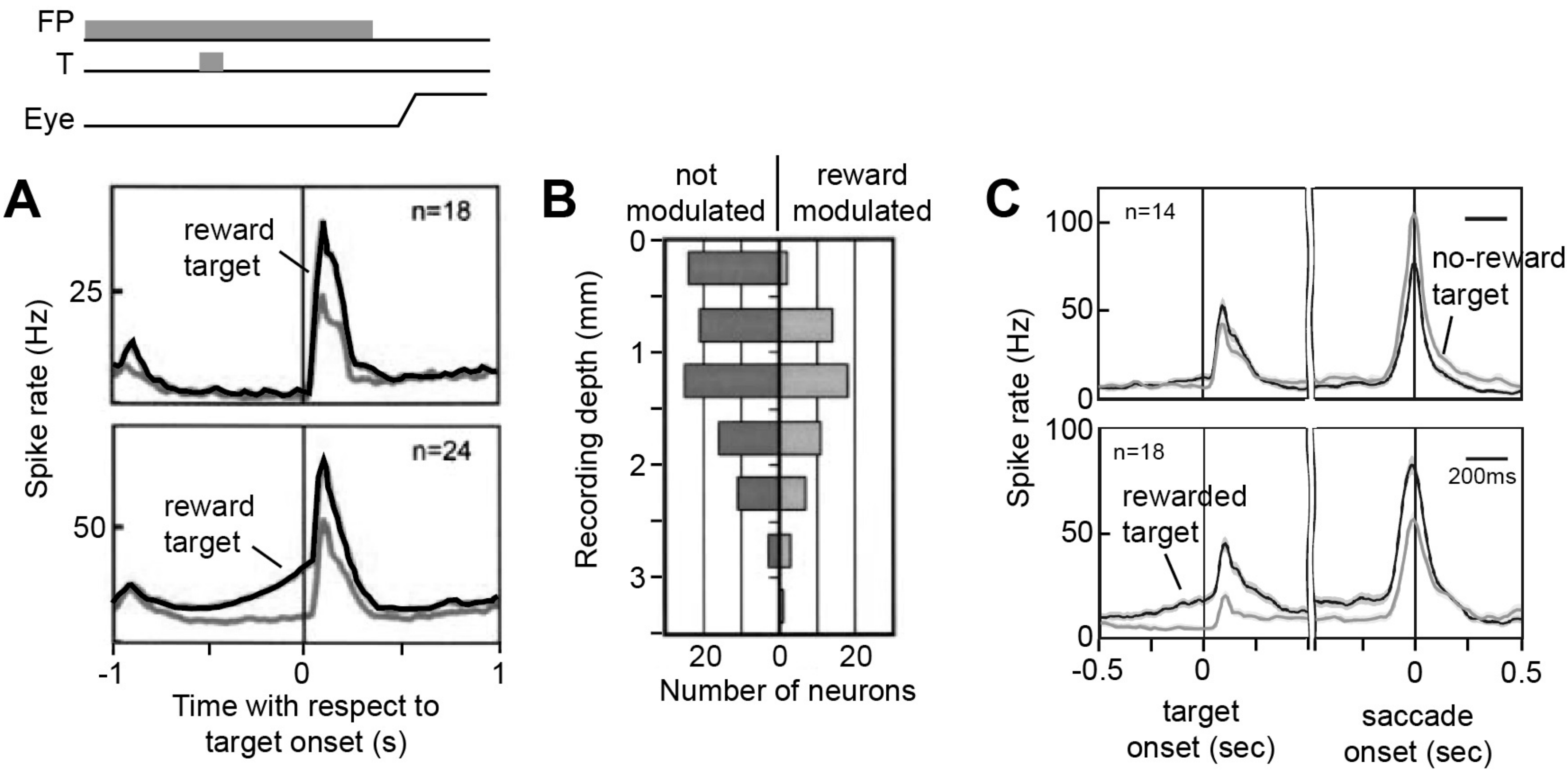
Everling et al., 1999

Latency is shorter when activity in buildup neurons rises faster



Ratcliff et al., 2007

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

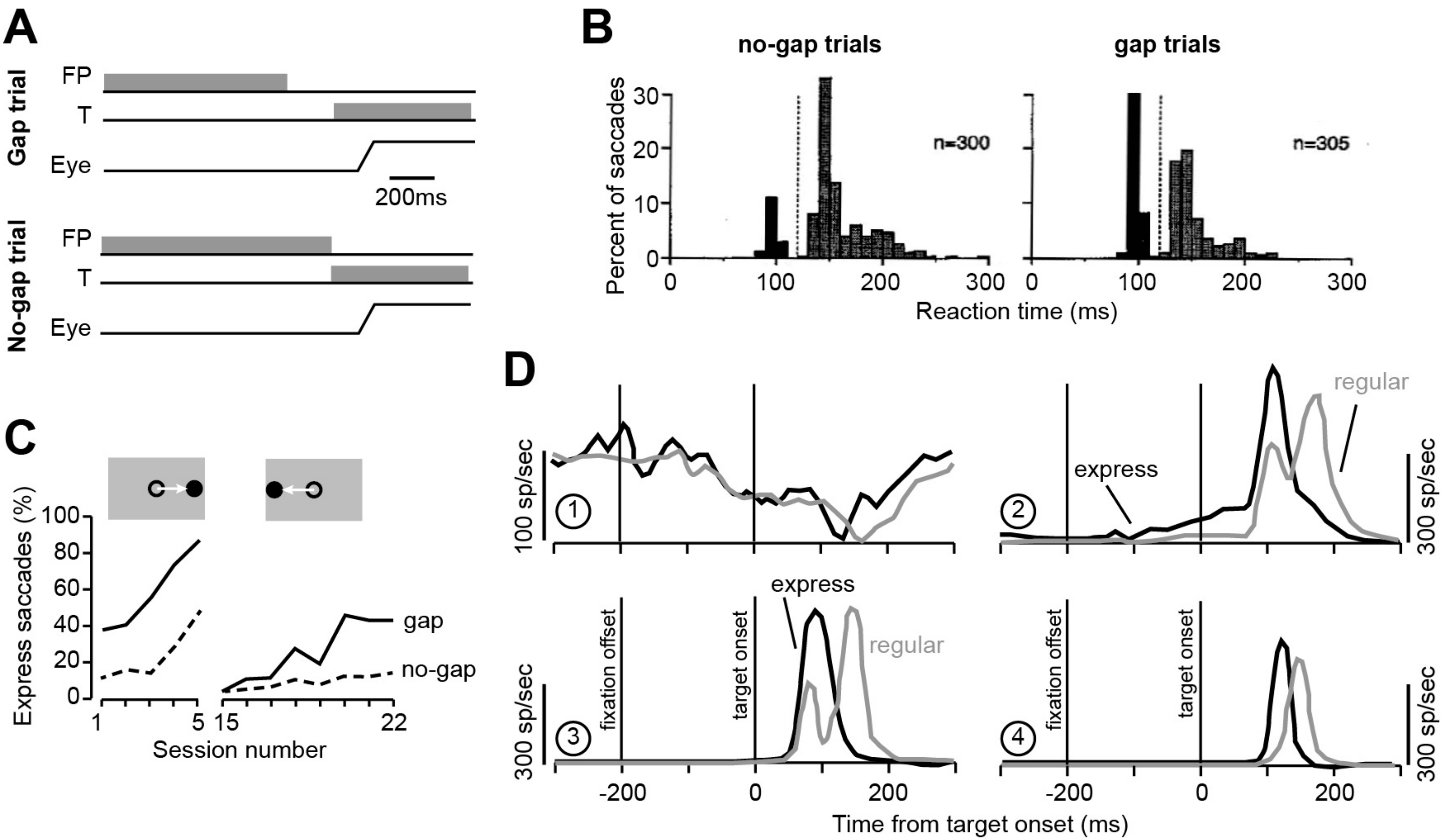


Ikeda and Hikosaka, 2007

Summary

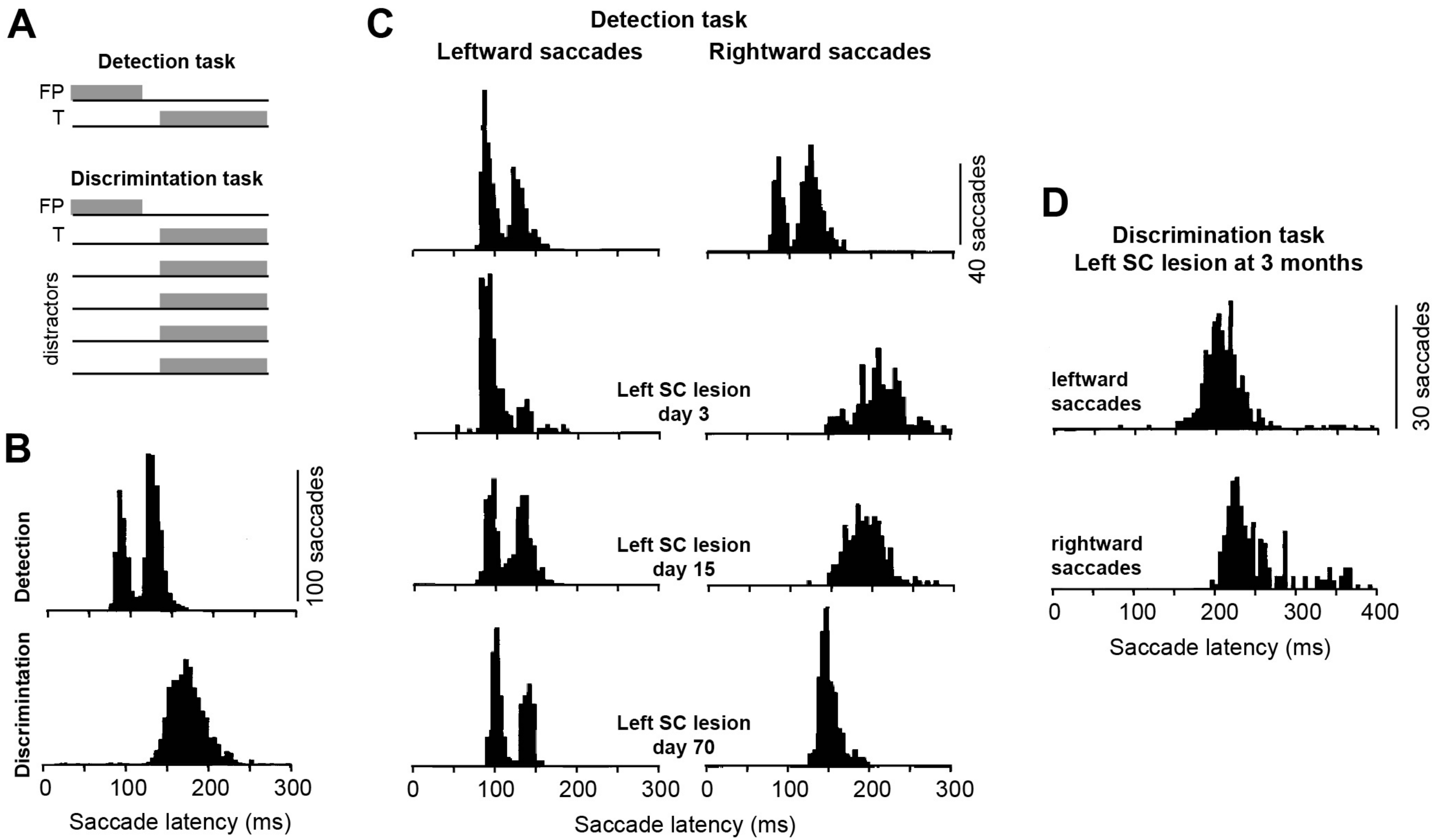
- In SC, cells respond to visual stimulus onset at 80ms, but it takes another 80ms or more to start a movement.
- During the reaction time, two events occur: activity of the fixation-related neurons decline, while activity in the movement-related neurons increase.
- Utility of the action during holding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



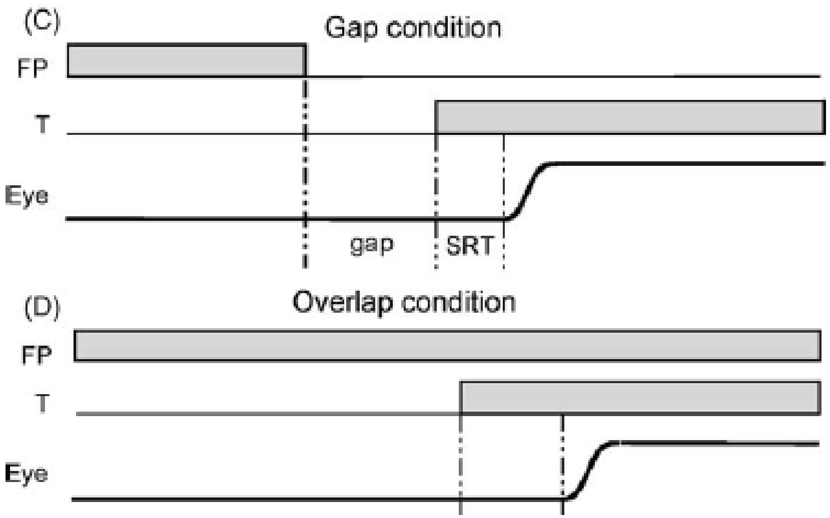
Pare and Munoz, 1996

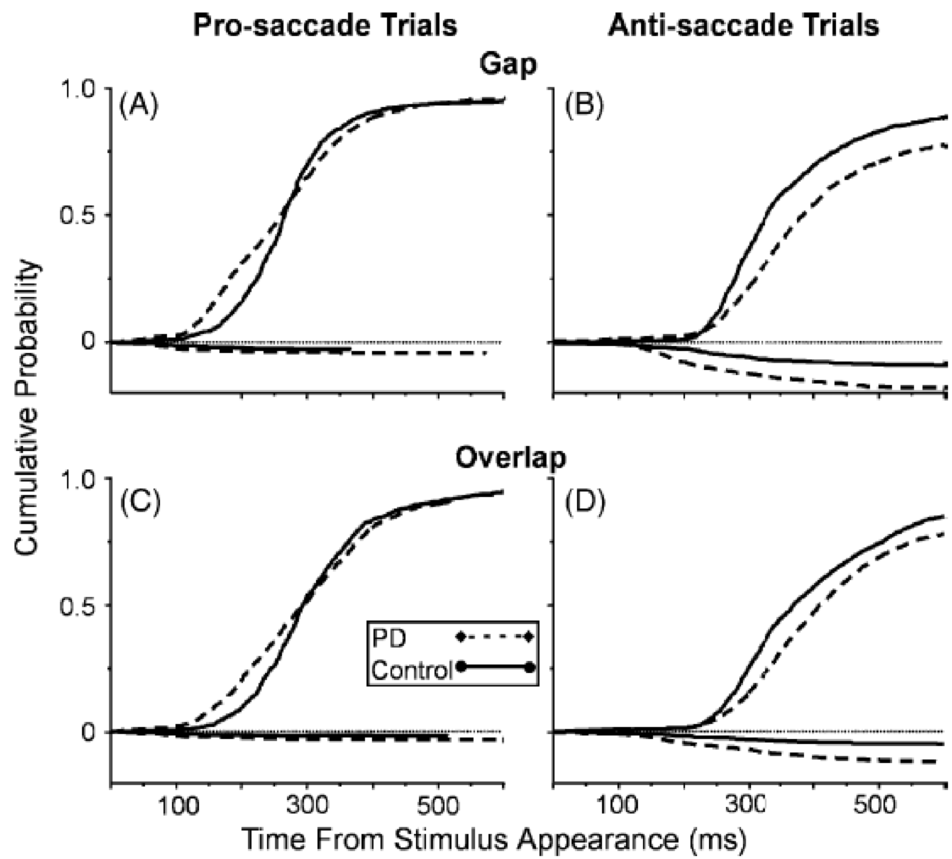
Superior colliculus is required for express saccades



Schiller et al., 1987

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

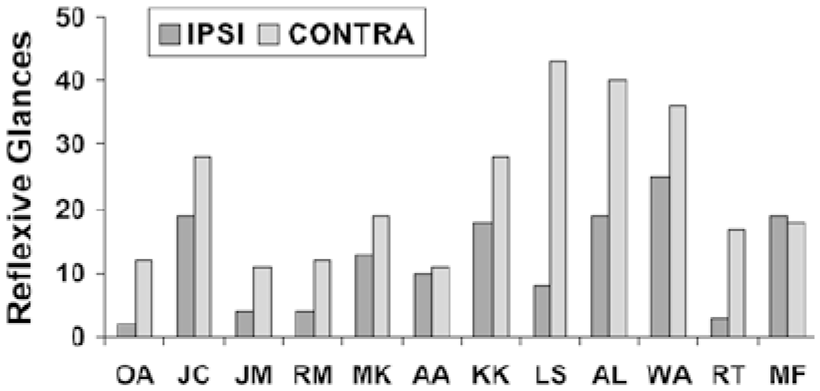




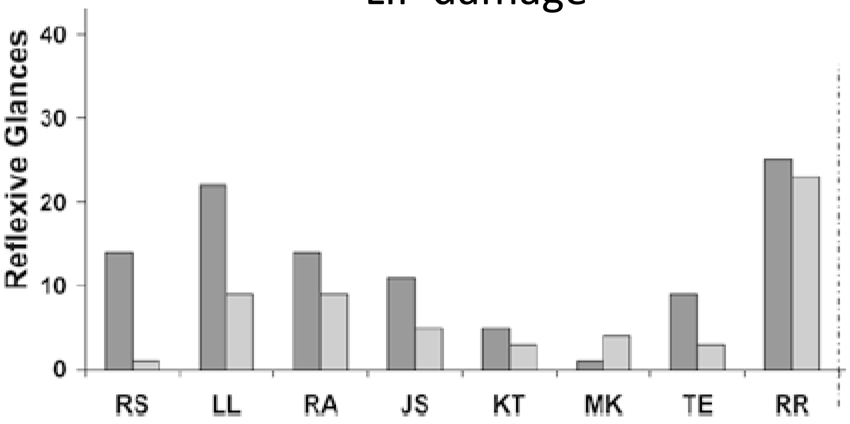
Chan et al. (2005)

Anti-saccade task

FEF damage



LIP damage



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

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.

Questions

- Is in fact reaction time related to utility?
- What neural structure sets the “threshold”?
- How is a utility optimized to produce a feedback control system that results in a movement?
- Does this view of reaction time in eye movements have parallels for skeletal movements?