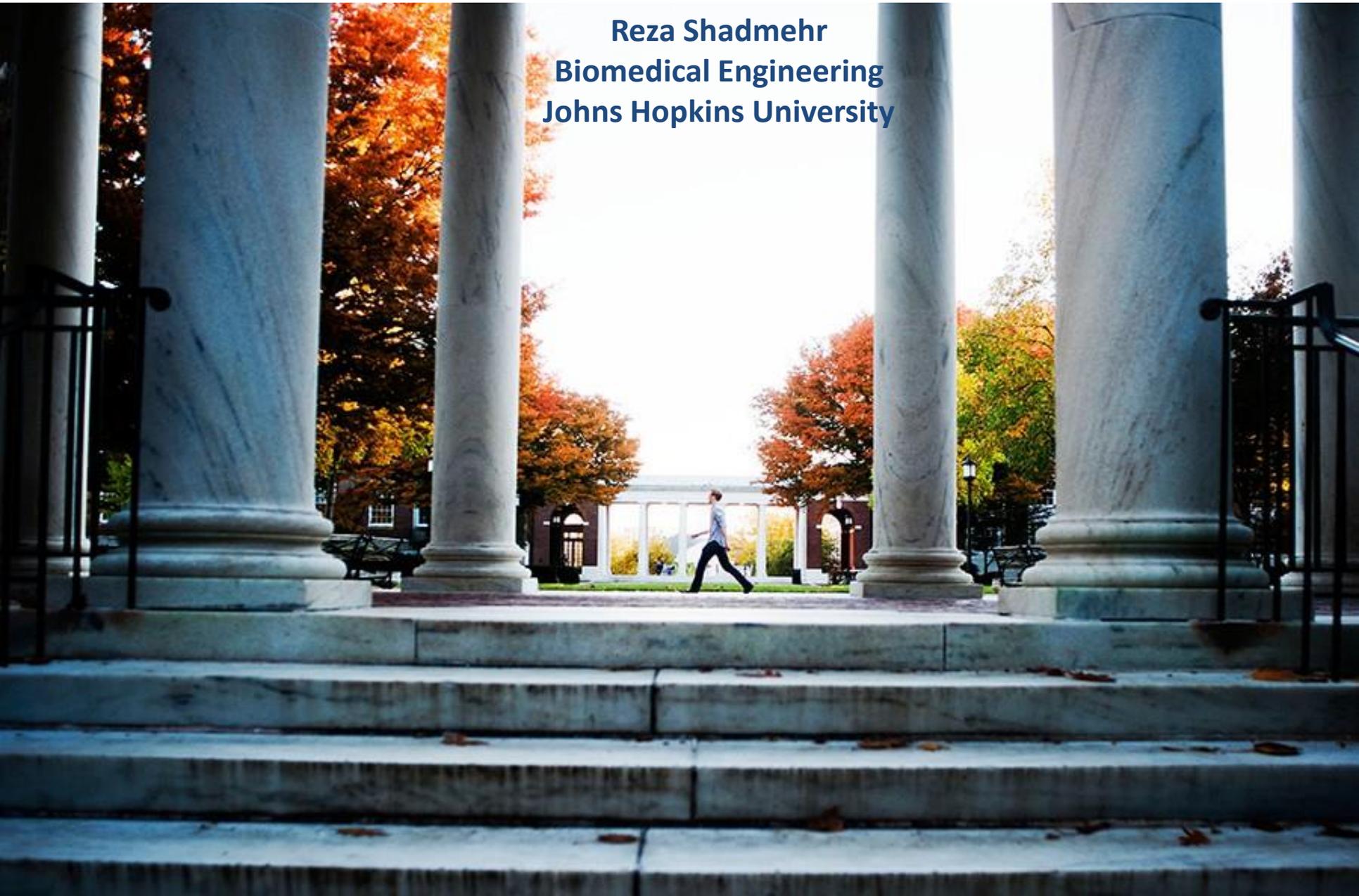
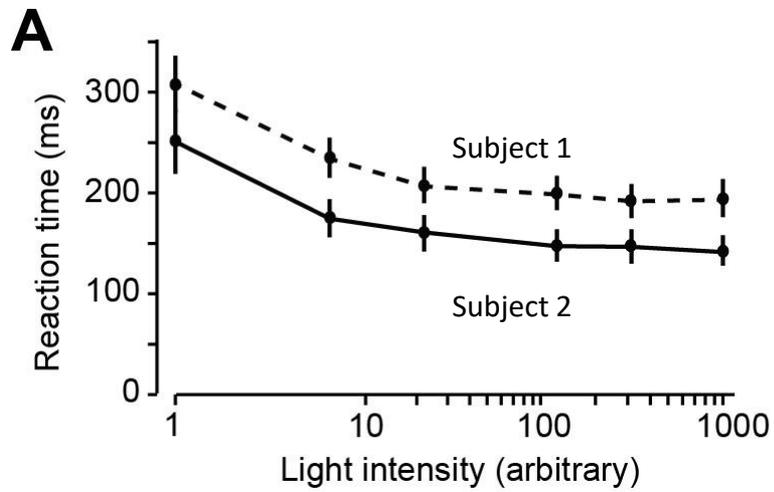


# Reaction time of movements

Reza Shadmehr  
Biomedical Engineering  
Johns Hopkins University

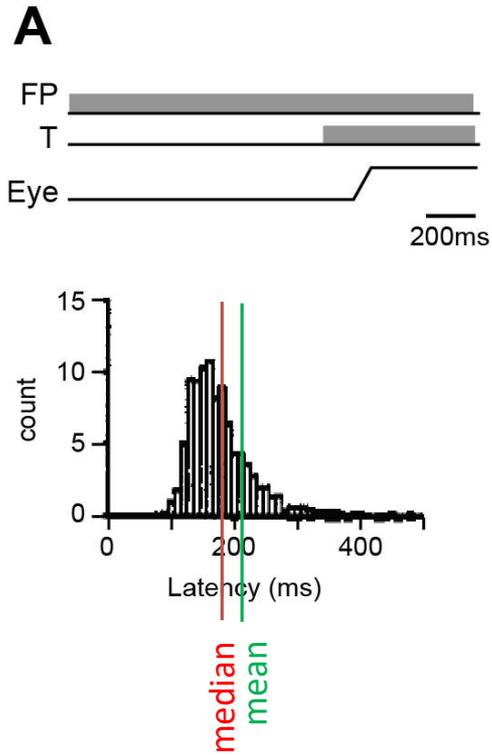


## Movement latency is smaller for stimuli with greater intensity

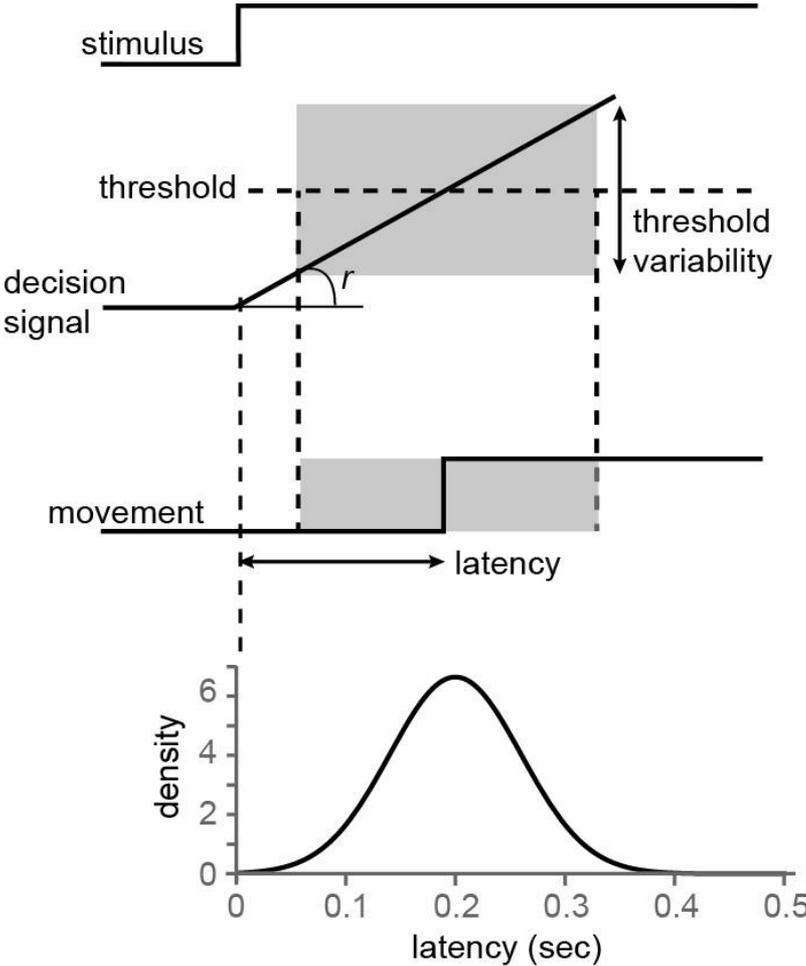


James Cattell (1886)

## Development of a model: variable rise to a constant threshold



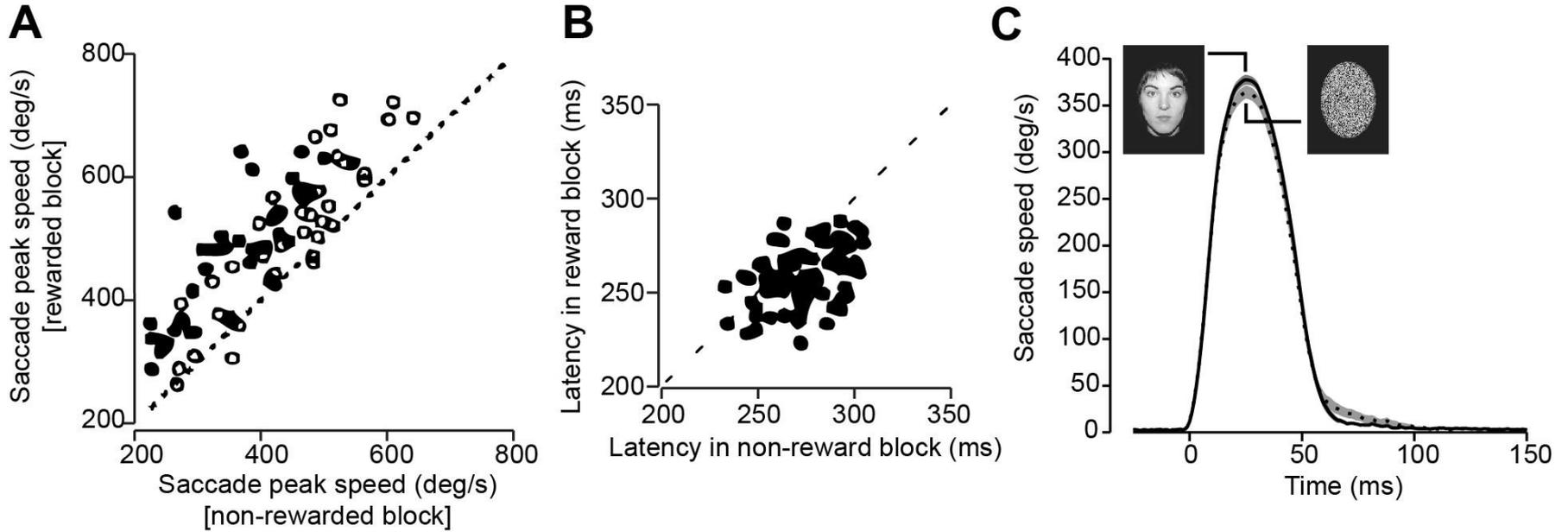
**Alternate model: constant rise to a variable threshold**  
**This model does not produce a skewed latency distribution**



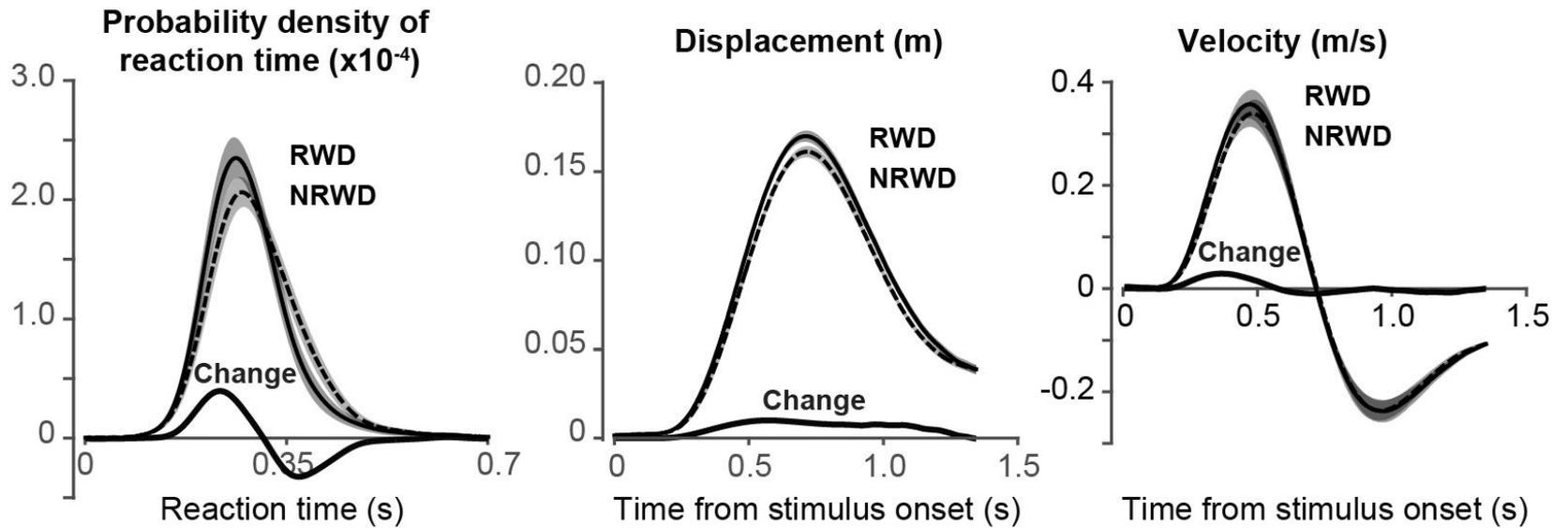
## Summary

- 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.
- A normally distributed threshold coincides with a normally distributed latency.
- Because movement latencies are skewed, this is consistent with a process where merit of an action is a random variable, integrated till it reaches a constant threshold.

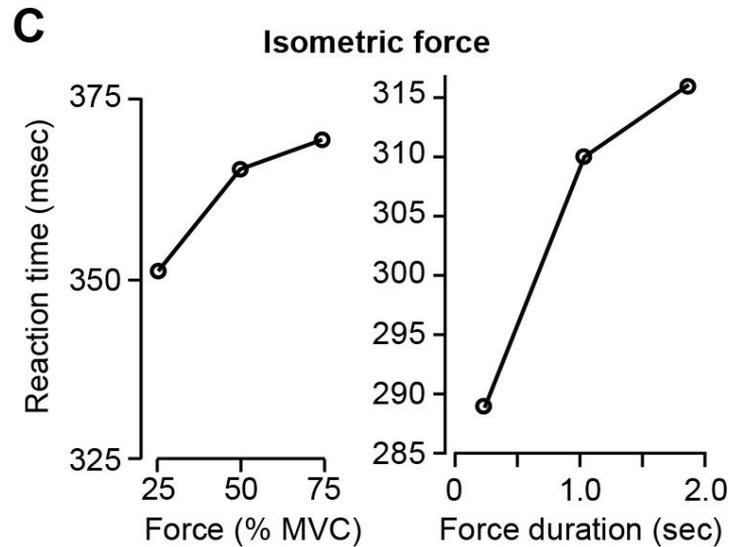
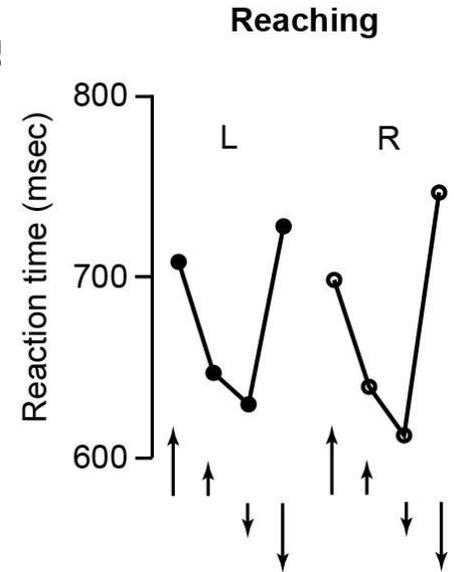
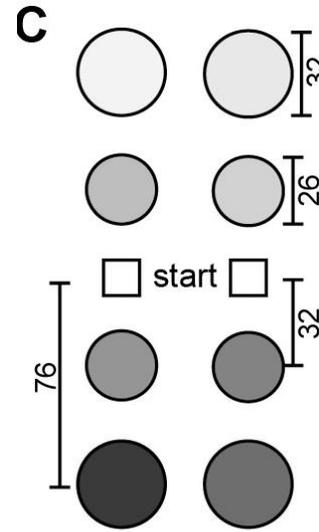
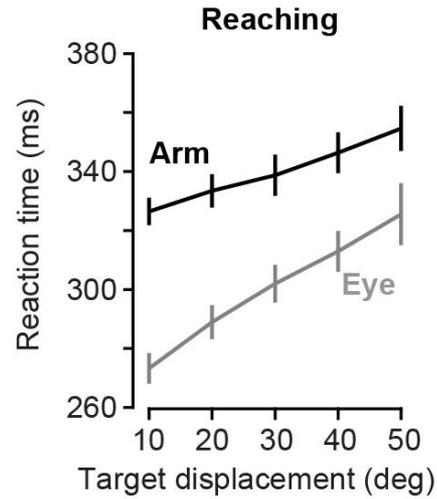
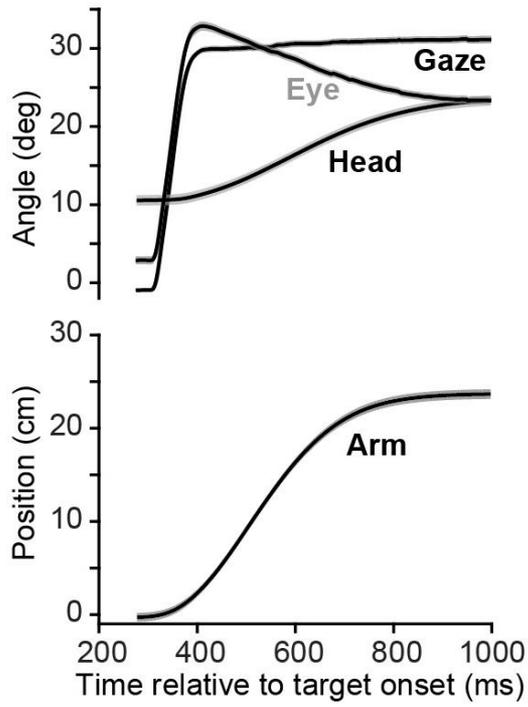
# Increased reward reduces movement latency, and increases movement vigor



# Increased reward reduces movement latency, and increases movement vigor



## Increased effort increases movement latency

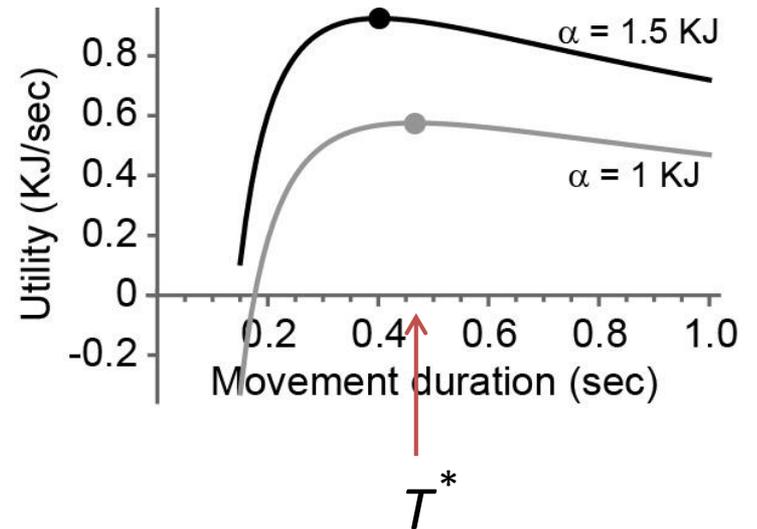
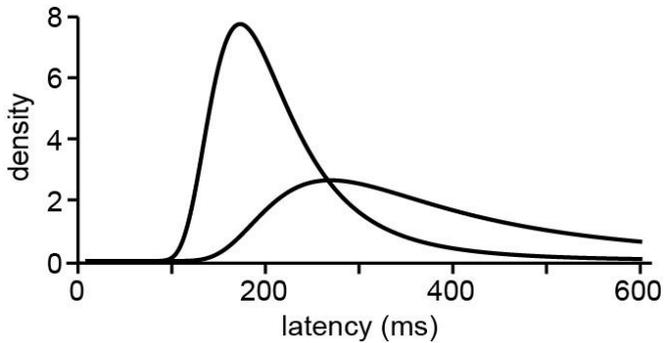
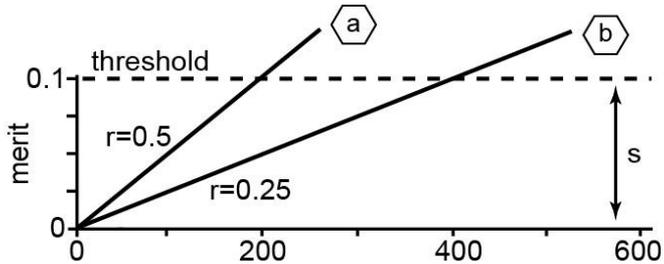


Reppert et al. (2018),  
Stelmach and Worringham (1988),  
Ivry (1986), Rosenbaum (1980)

## Idea: perhaps latency is related to movement utility

$$J = \frac{\text{reward} - \text{effort}(T)}{1 + \gamma T} \text{ duration}$$

utility

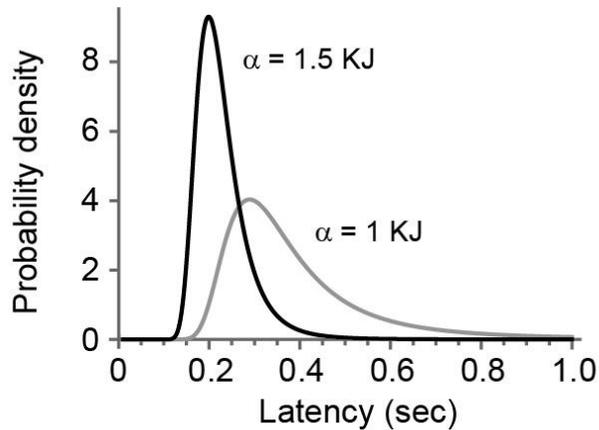
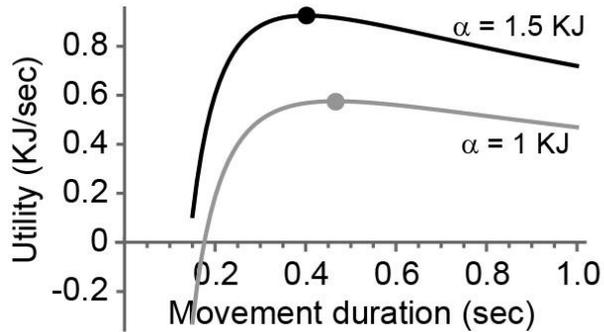


Let us assume that the rate of rise is proportional to the utility.

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

## Model: rate of rise is proportional to utility

effect of reward

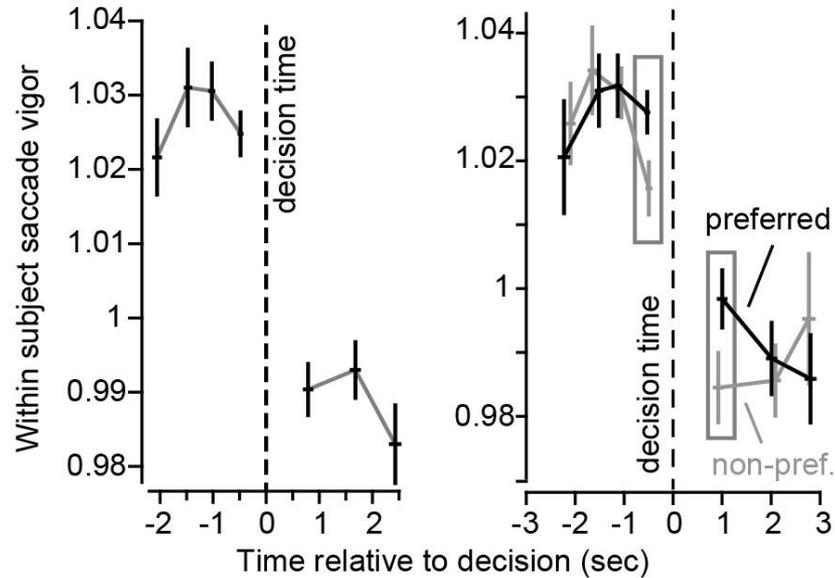
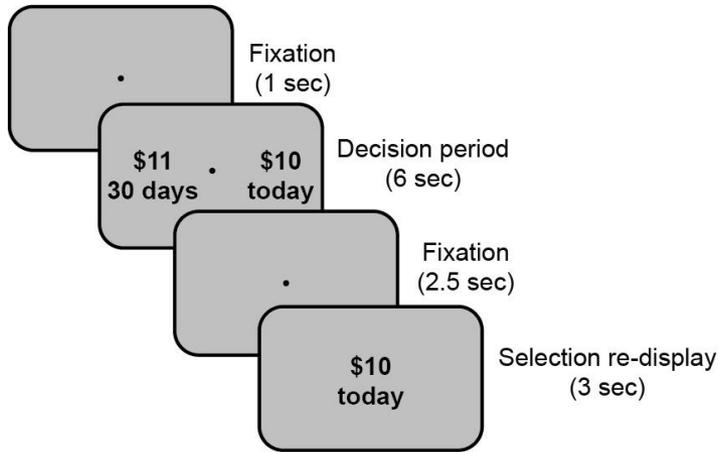


$$J = \frac{\alpha - e(T)}{1 + \gamma T}$$

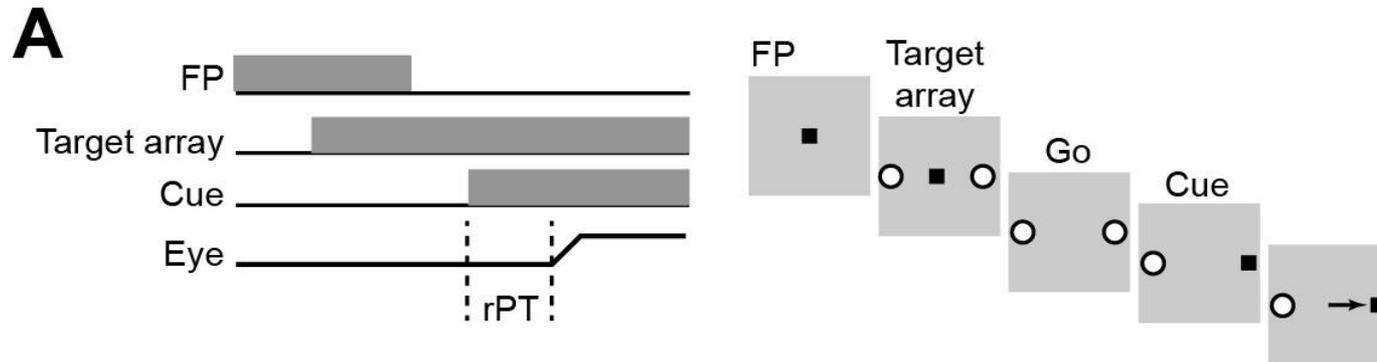
$$r \square N\left(J(T^*), \sigma^2\right)$$

# Vigor as a read-out of the decision variable during deliberation

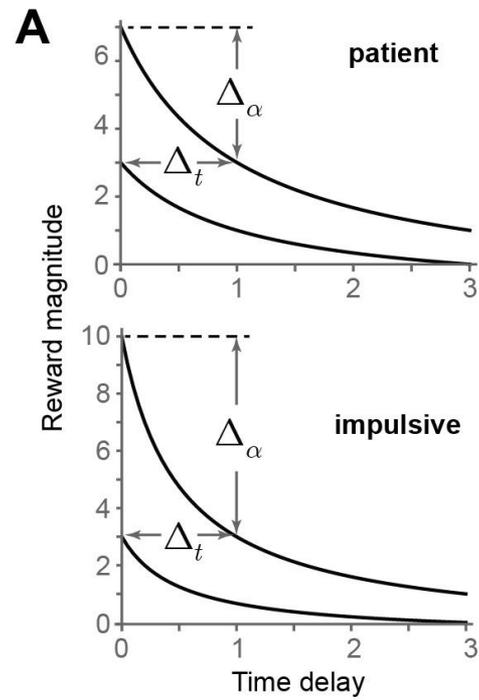
**A**



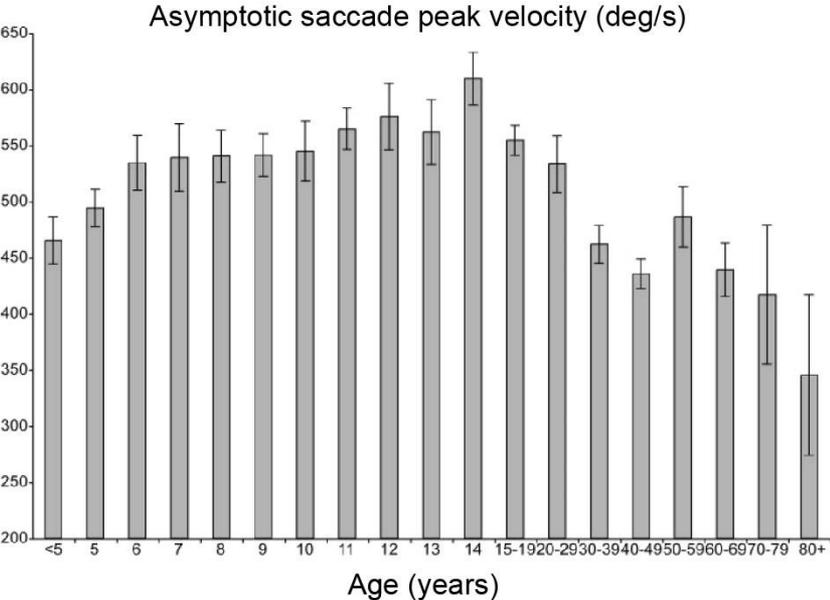
## Vigor as a read-out of the decision variable during deliberation



Between subject differences in decisions making and movement vigor



# Between subject differences in decisions making and movement vigor



## 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.

## Limitations and questions

- There is utility for moving, but also a utility associated with staying. Sometimes we have many things to do, and our time is valuable, implying that utility of any one action cannot be viewed in isolation, but likely depends on interactions of these variables and more.
- Is vigor and reaction time a trait-like characteristics of individuality?