Modelling Perceptual Decision Making: the Drift Diffusion Model (part D)

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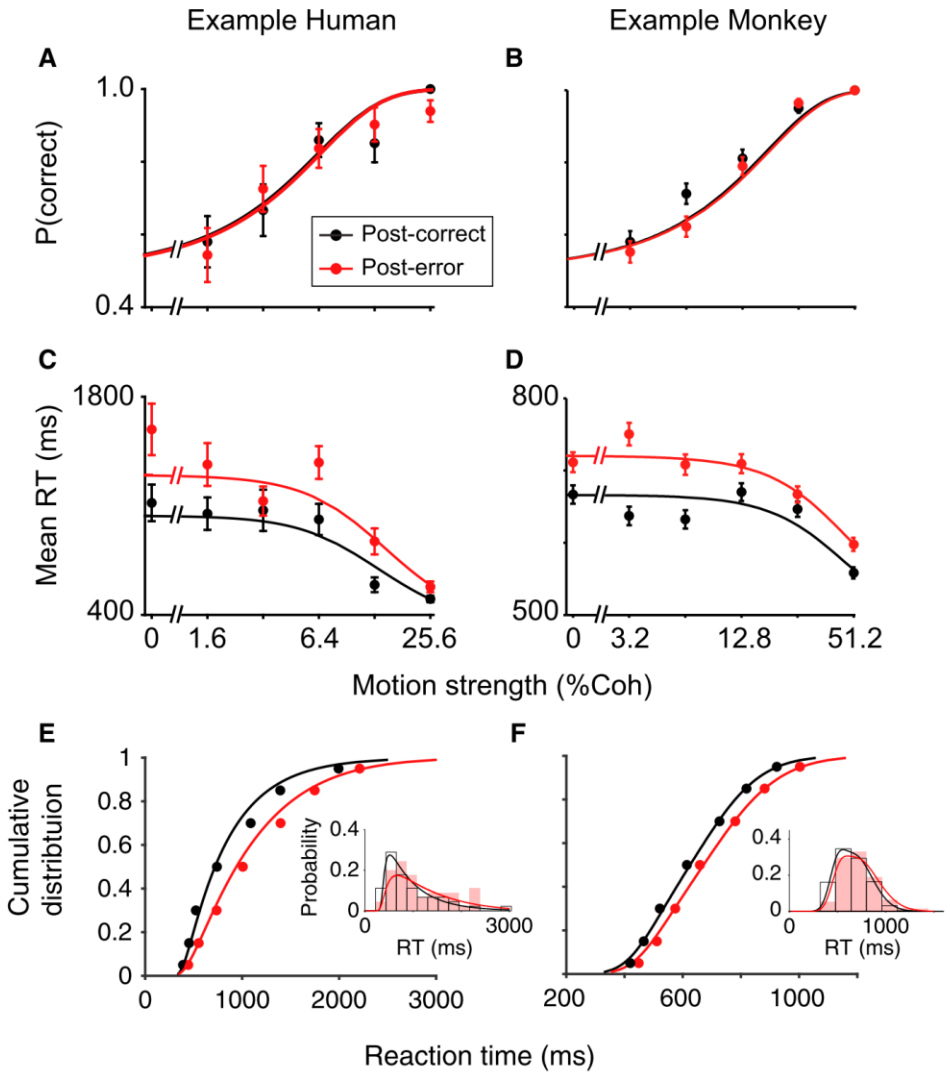
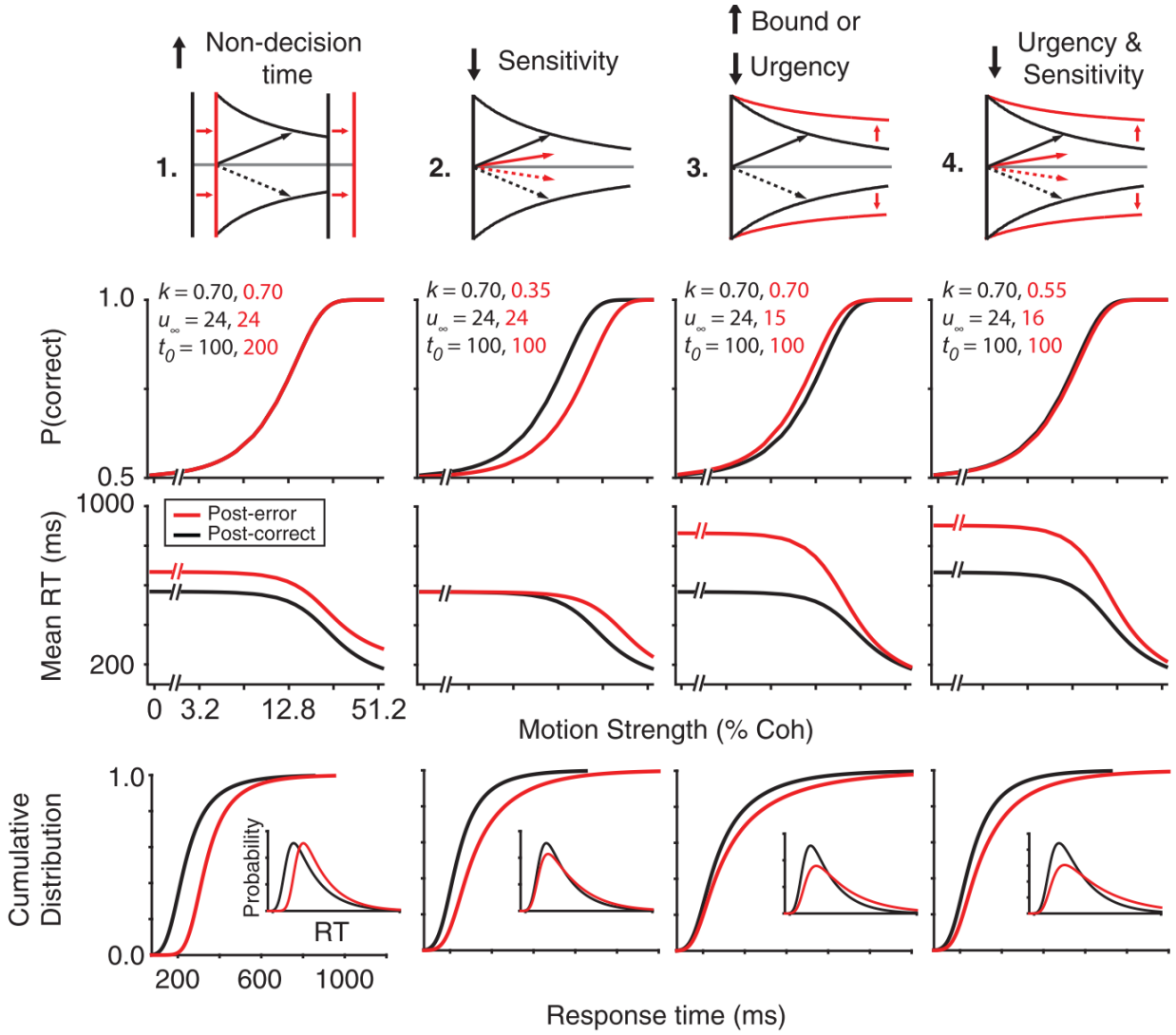
Slides are based on previous lectures by Alfonso Renart and Anne Urai

Outline

- Signal Detection Theory
- Sequential Probability Ratio Test (SPRT)
- Drift Diffusion Model (DDM)
- Applications and extensions of the DDM.

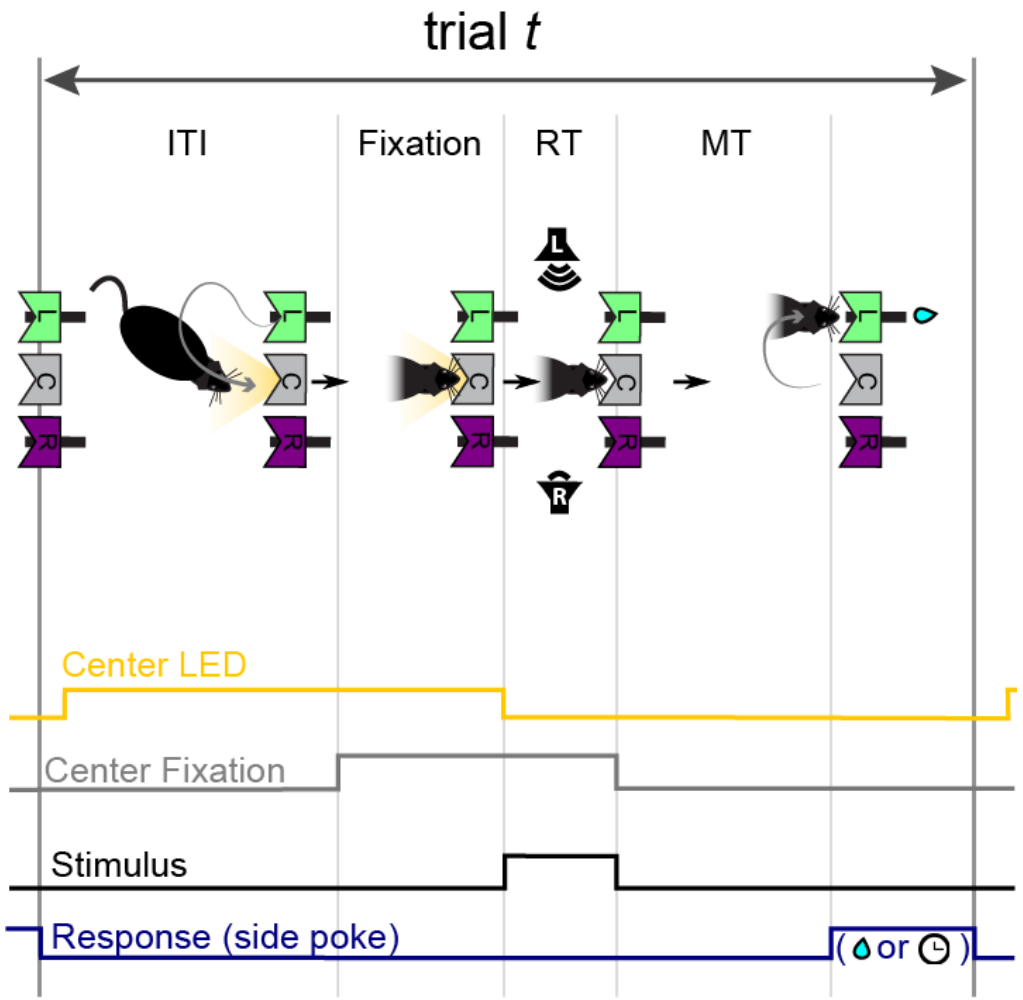
Post error slowing





Purcell and Kiani 2016

Two-alternative auditory discrimination task in rats

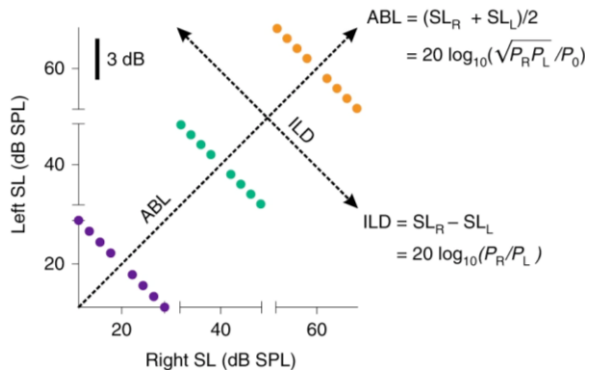


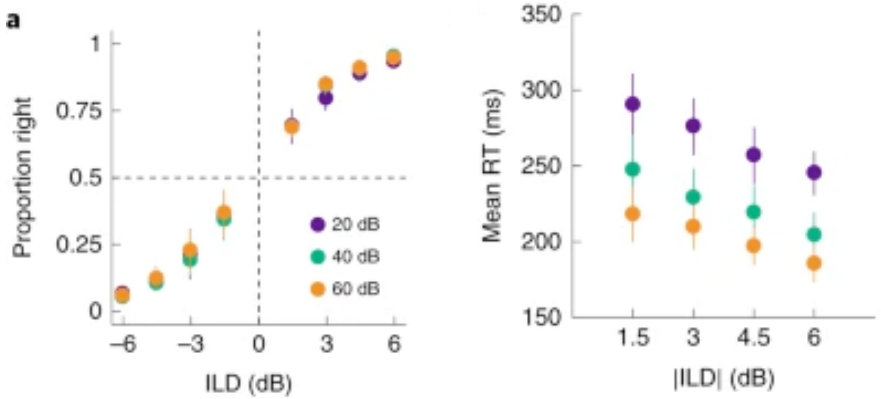
- Trial history effects (*Hermoso-Mendizabal, Hyafil et al., 2020)*
- Modeling Reaction Times *(Hernández-Navarro et al 2021)*
  Network modeling of task suboptimal behavior (*Molano-Mazón et al 2024; Shao, Molano-Mazón et al in prep)*
- Modeling of response trajectories (*Molano-Mazón, Castilla-Durán, Pastor, et al 2024)*
- Network modeling of task suboptimal behavior (*Molano-Mazón et al 2024)*
- Study of brain areas involved in task behavior (*Sindreu et al in preparation)*

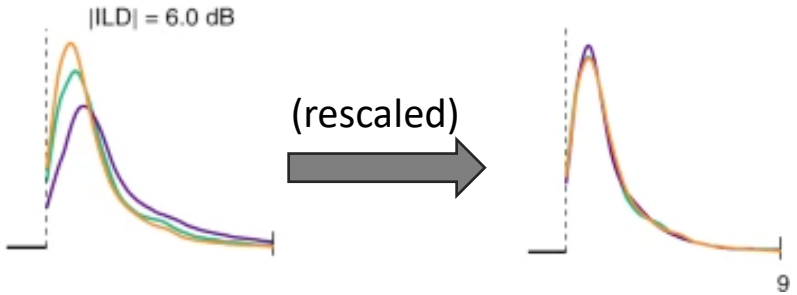
Weber's law and accumulation to bound

Pardo-Vázquez et al 2019

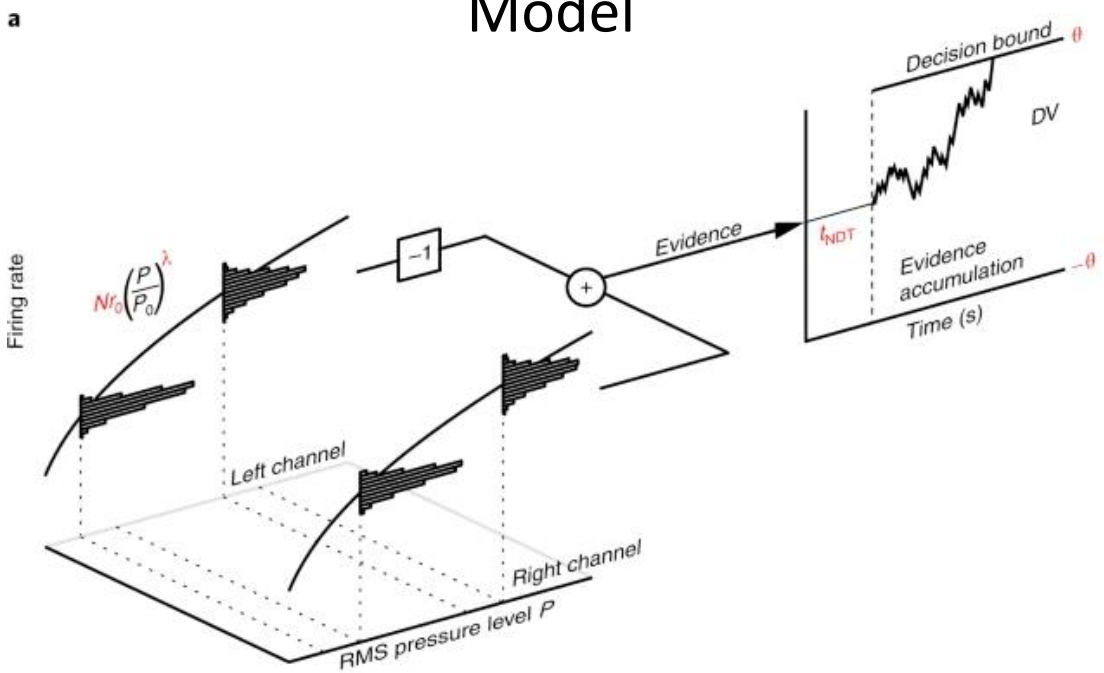
Data

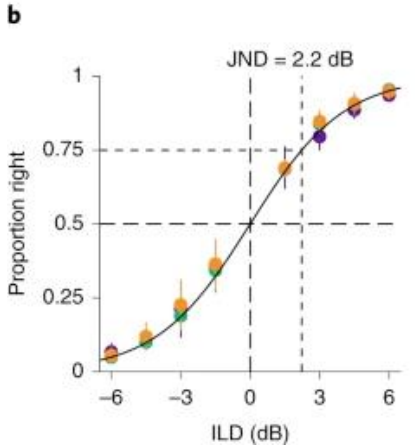


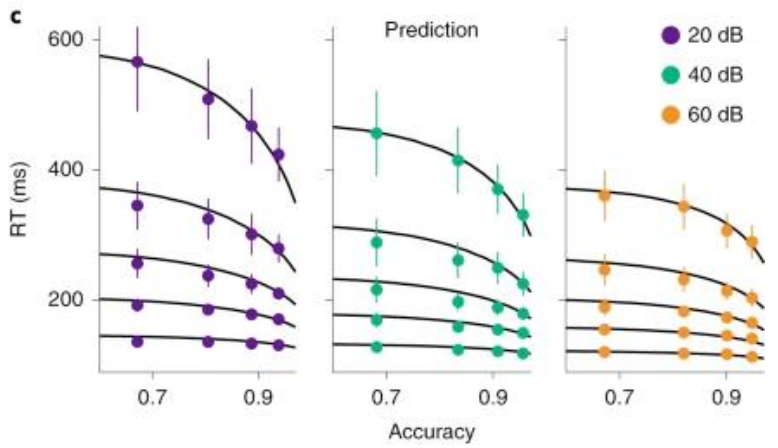




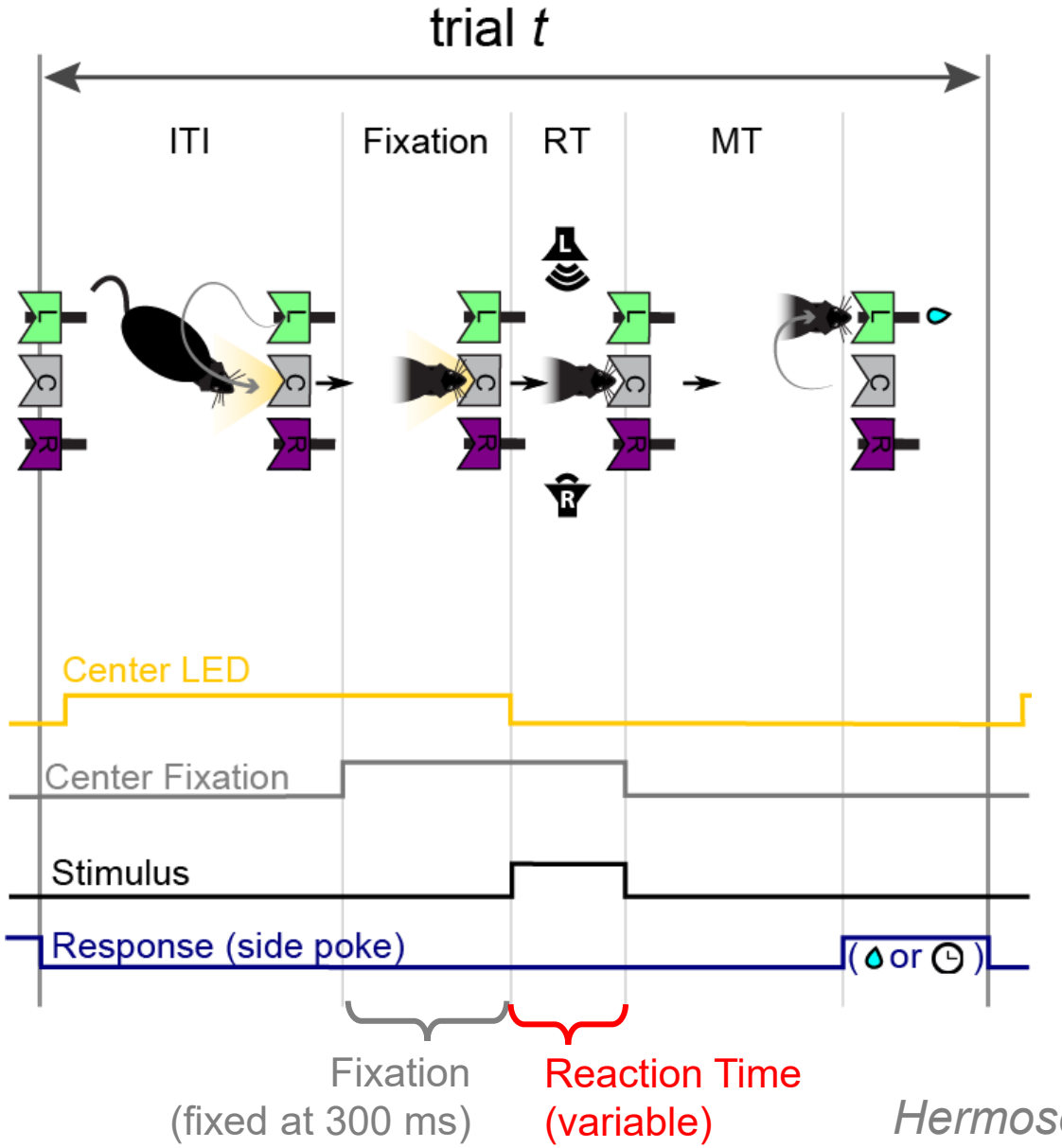
Model

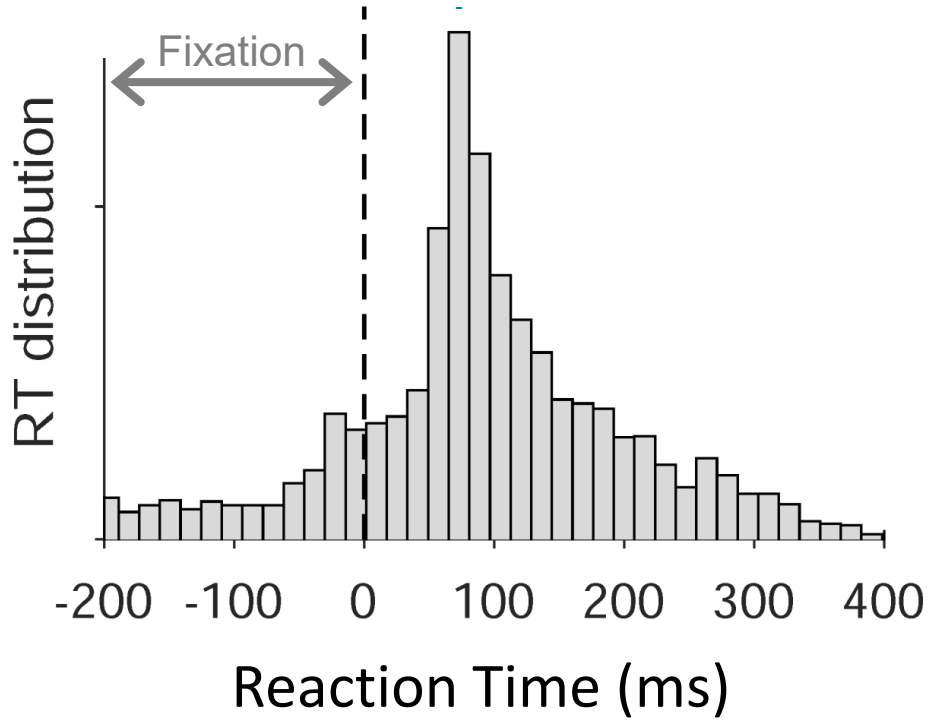






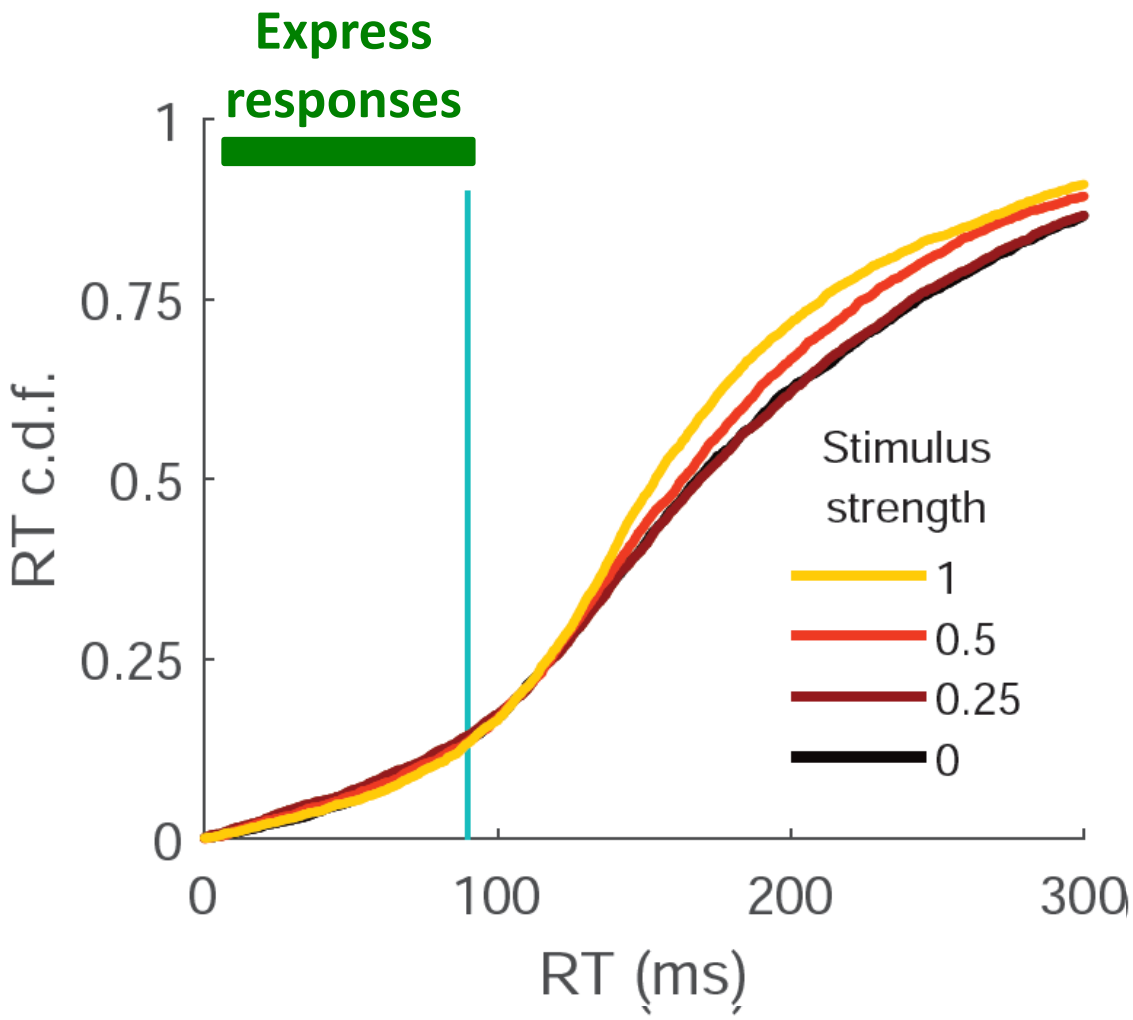
Two-alternative auditory discrimination task in rats

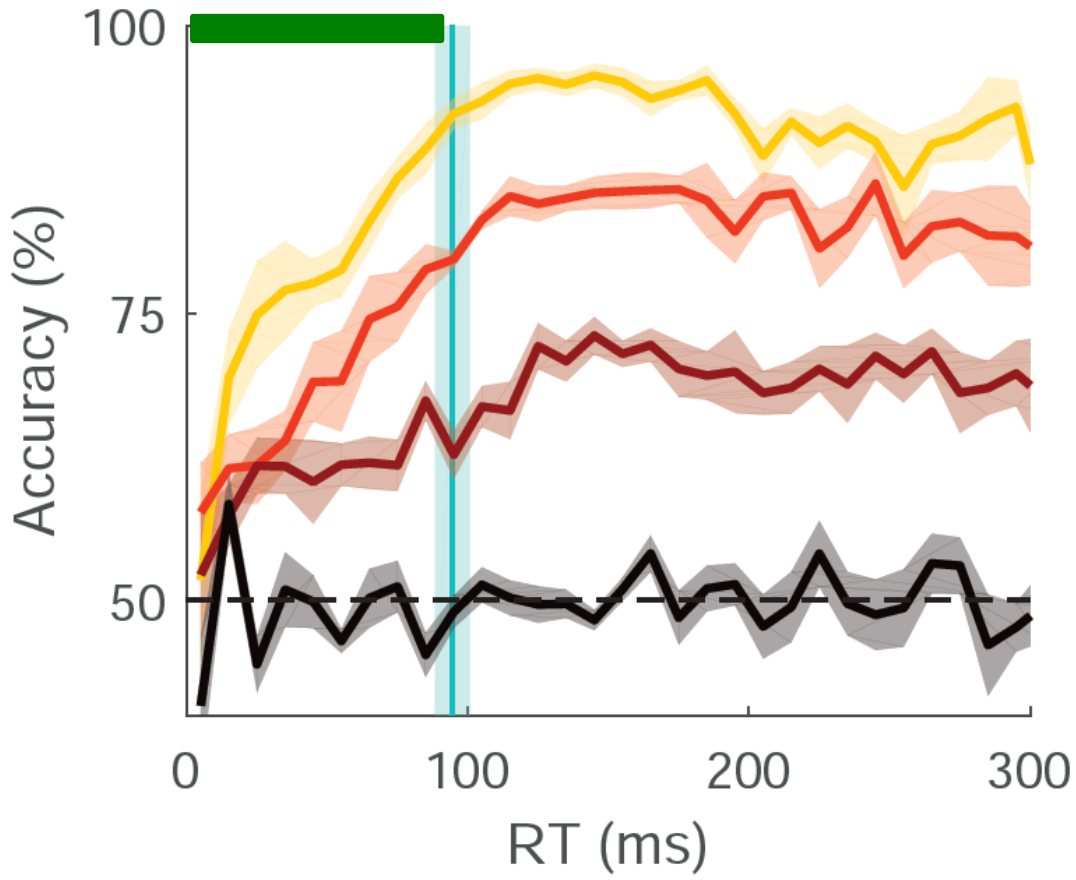




Hermoso-Mendizabal et al., 2020; Hernández-Navarro et al 2021;

Stimulus integration only modulates slow Reaction Times (RTs)





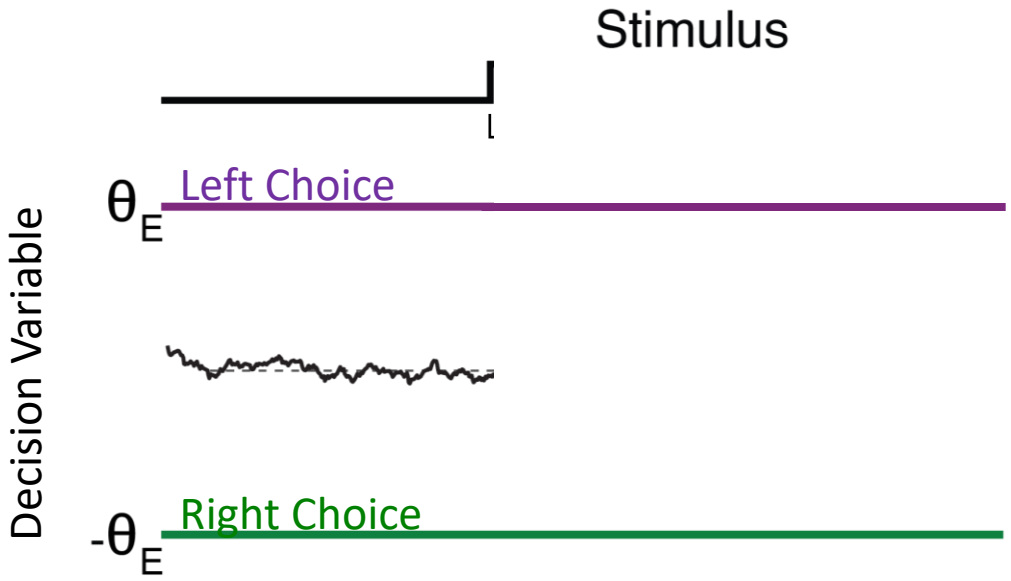
The RTs of express responses were stimulus-independent, but choices did depend on the stimuli.

Hernández-Navarro et al., 2021

Modeling Proactive and Reactive responses

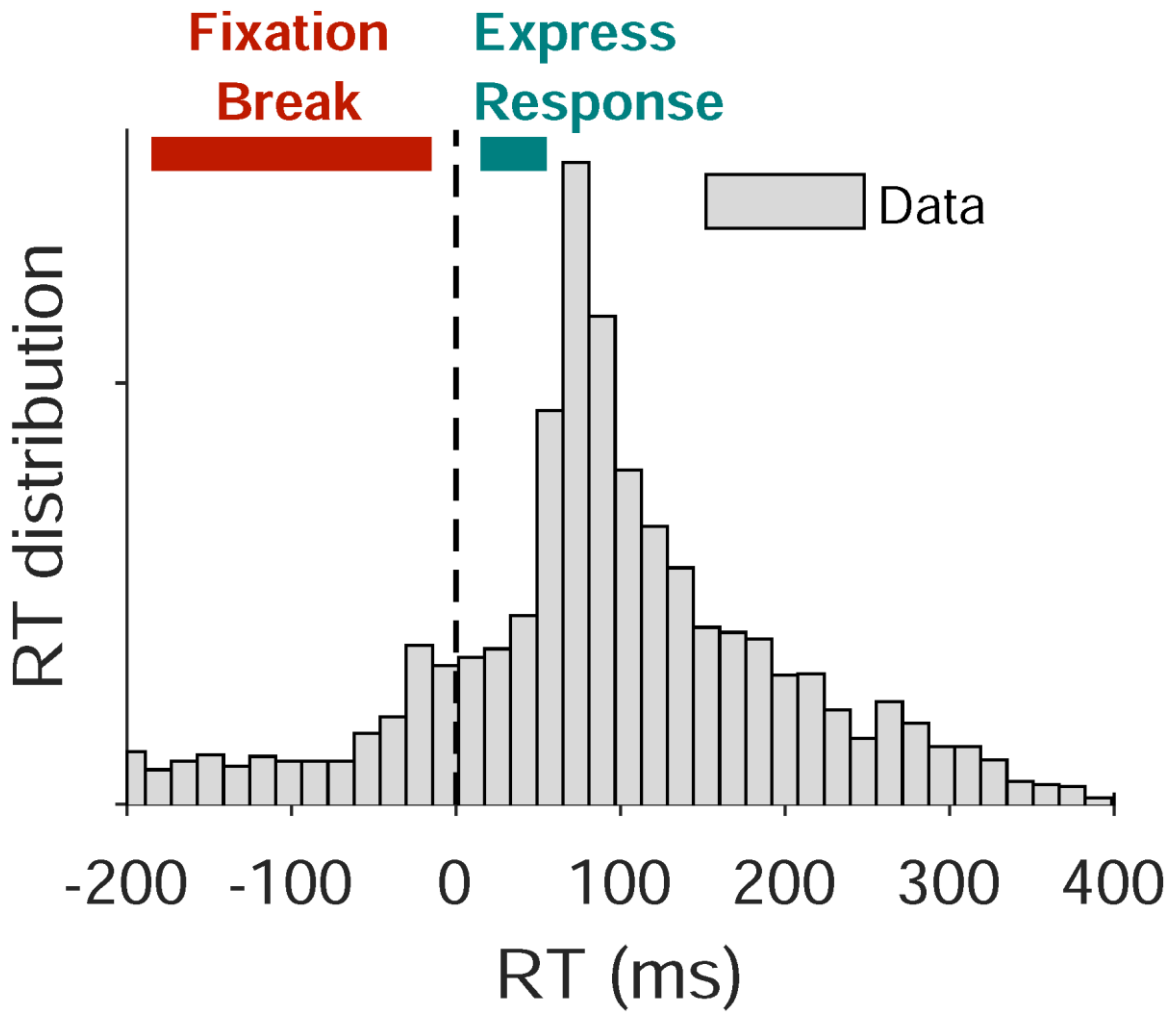
Reactive Response

Proactive Response

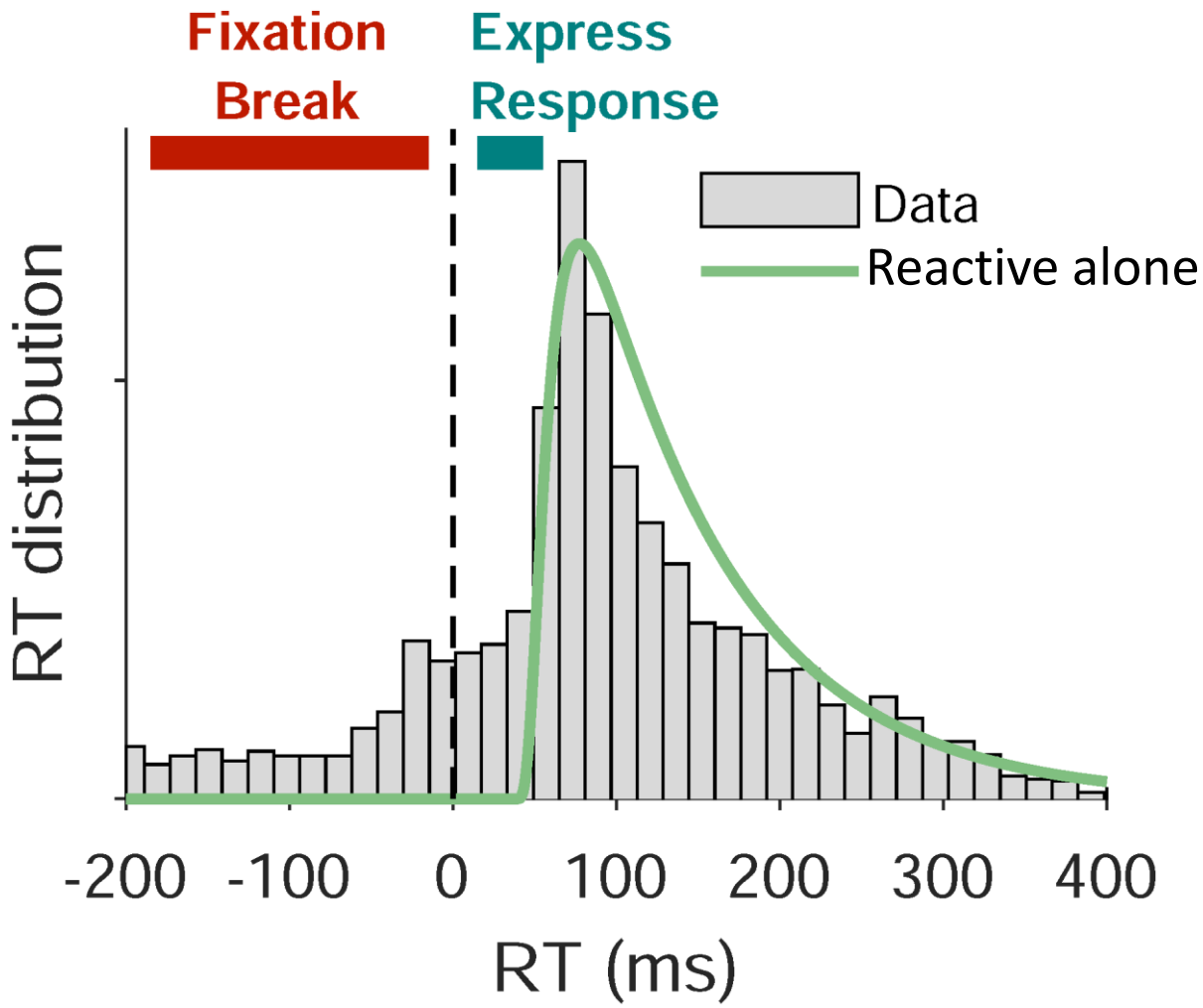


Hernandez-Navarro et al., 2021

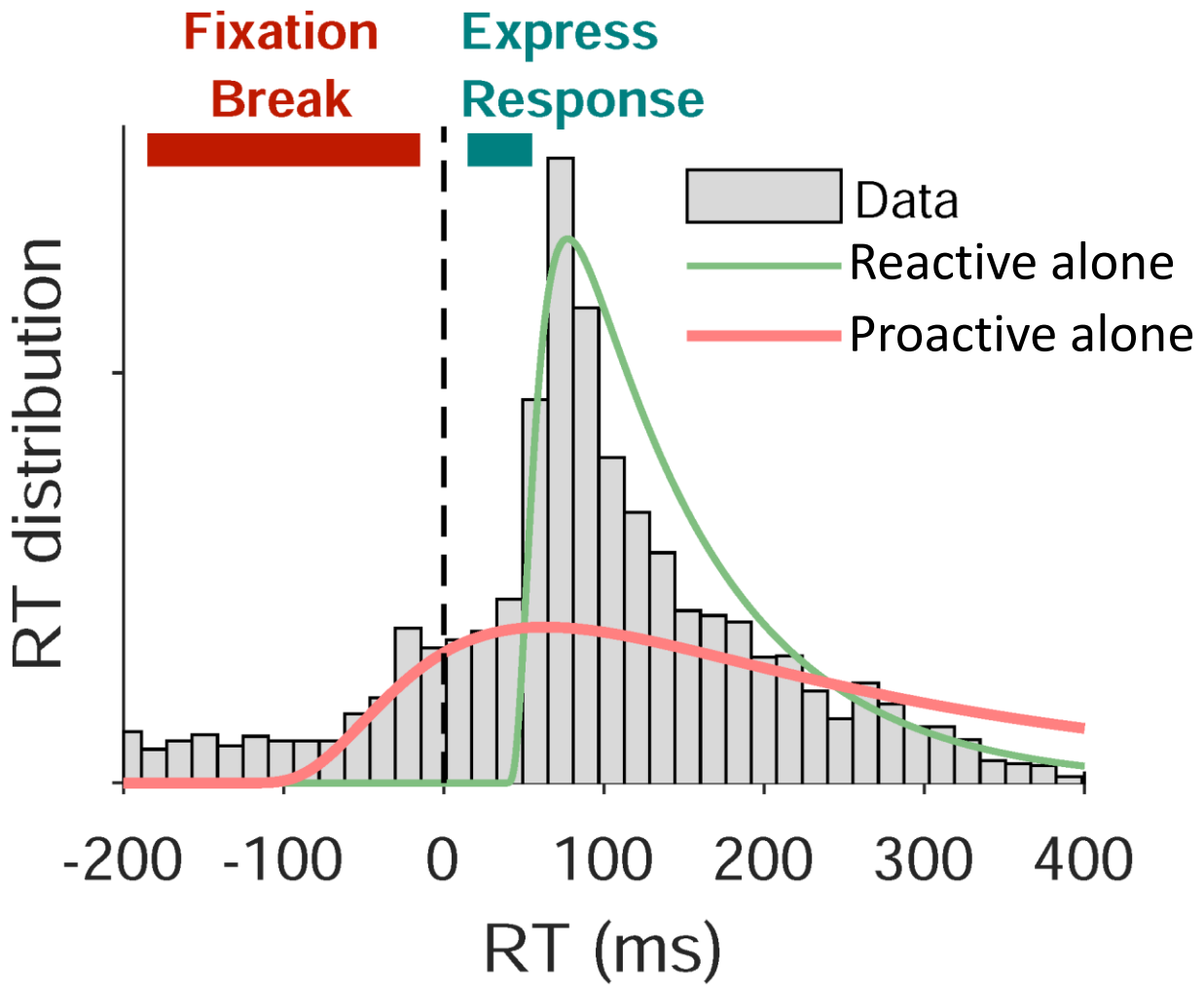
Parallel action initiation and evidence accumulation shape RTs



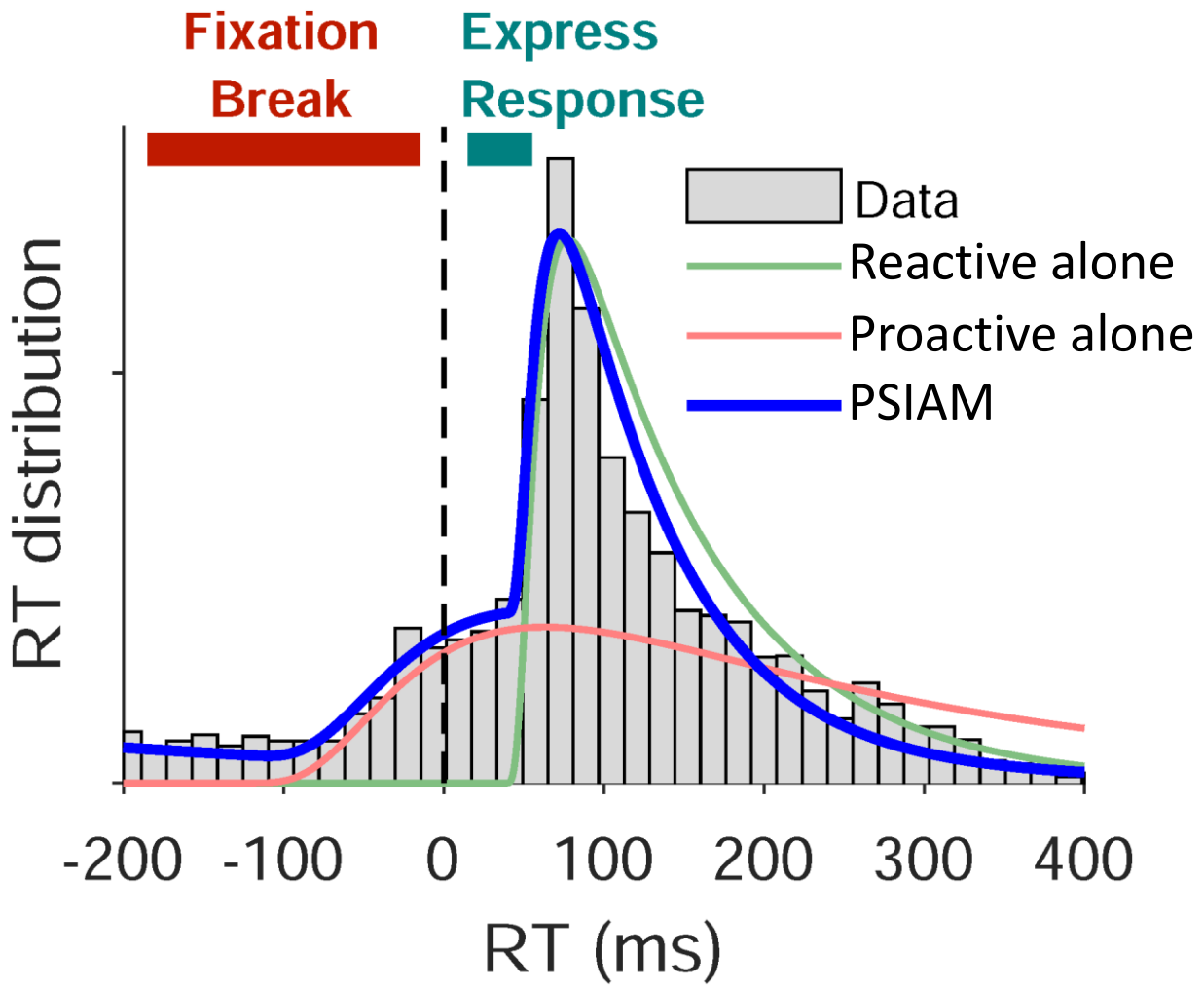
Parallel action initiation and evidence accumulation shape RTs



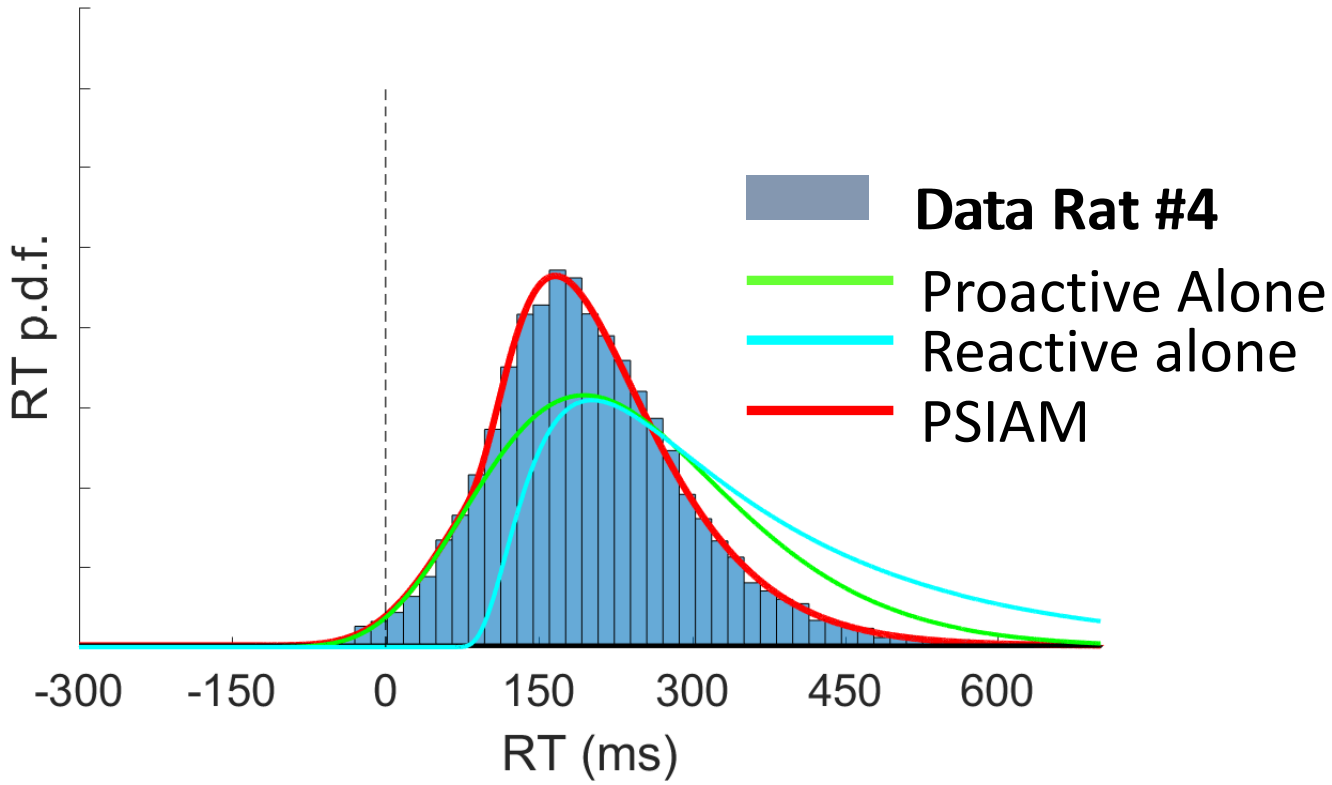
Parallel action initiation and evidence accumulation shape RTs

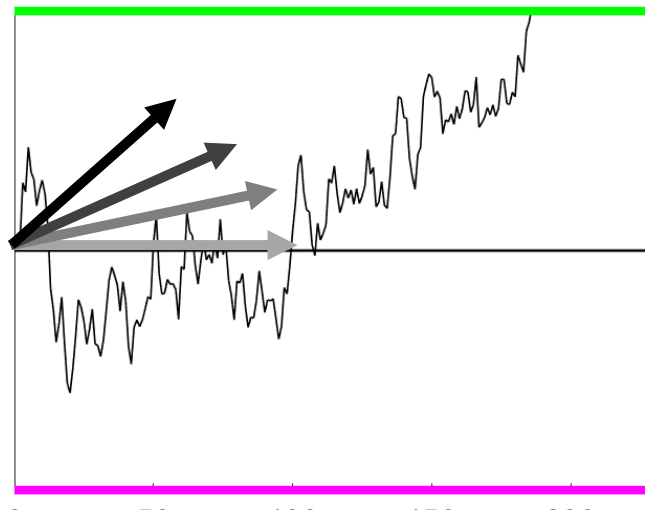


Parallel action initiation and evidence accumulation shape RTs

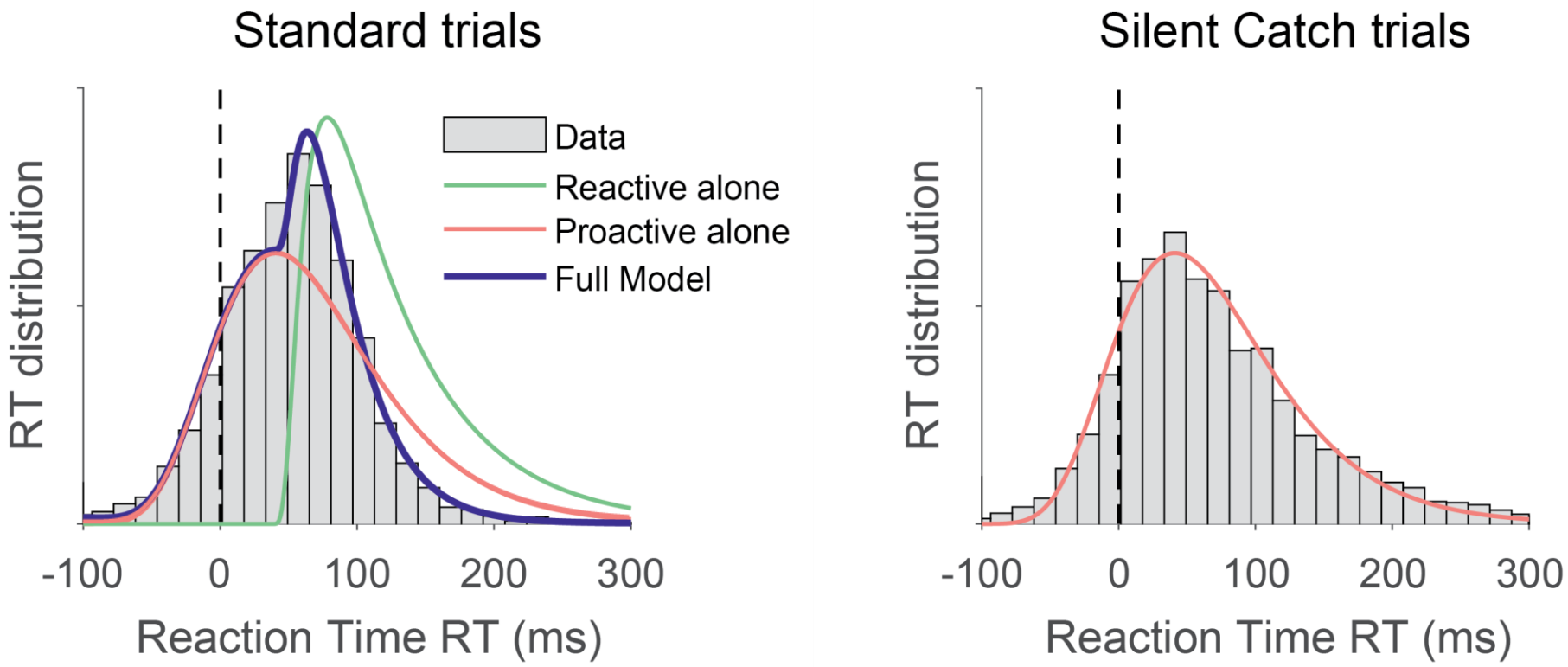


PSIAM captures the stimulus-independent RTs of express responses



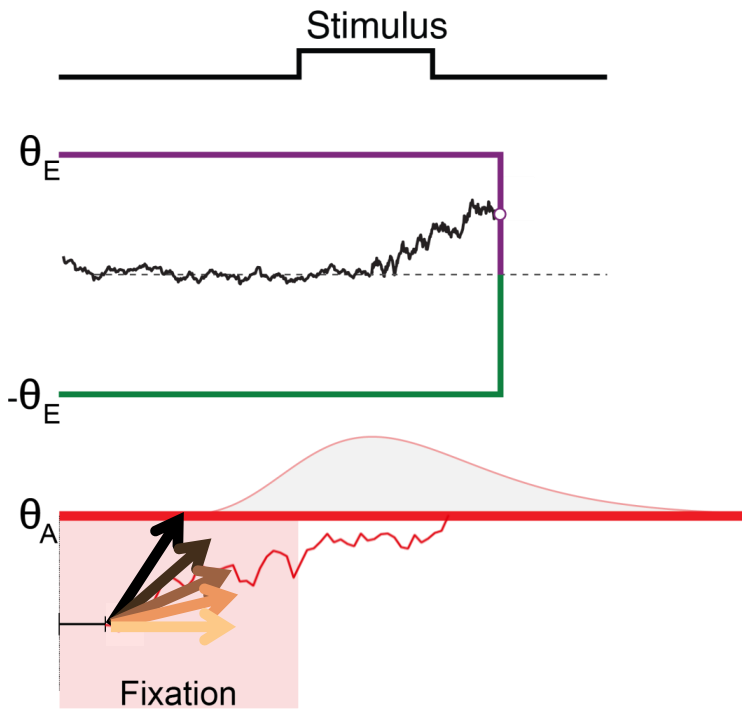


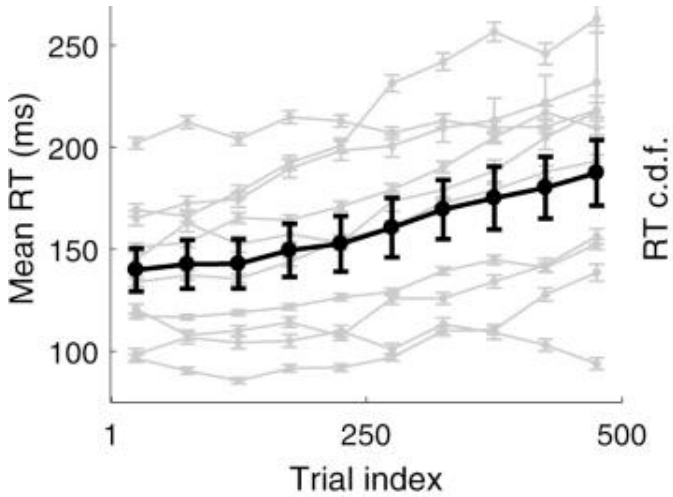
PSIAM predicts the RT distribution in silent trials

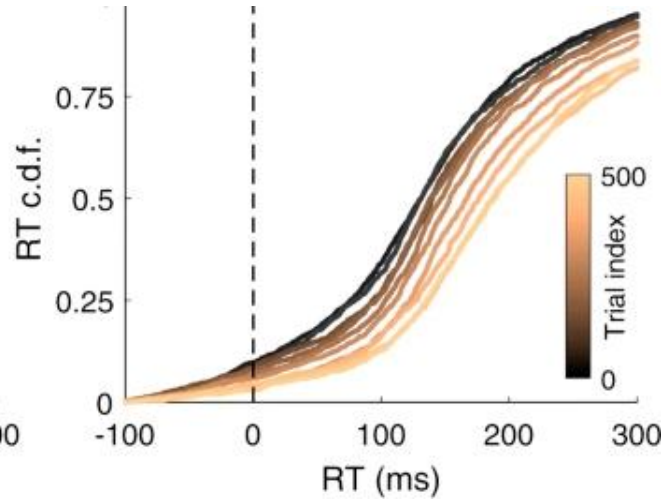


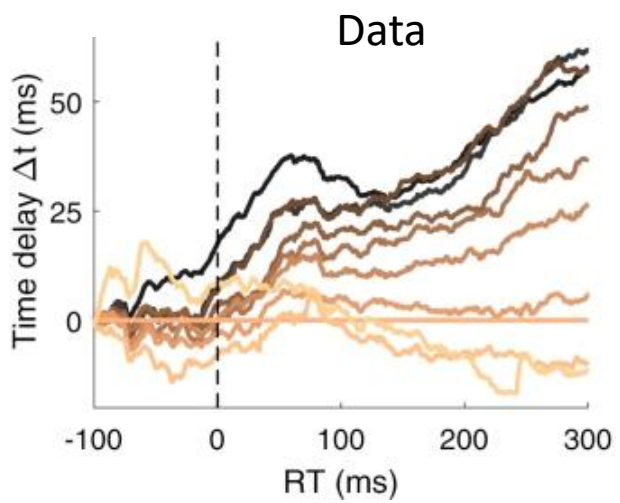
Hernández-Navarro et al., 2021

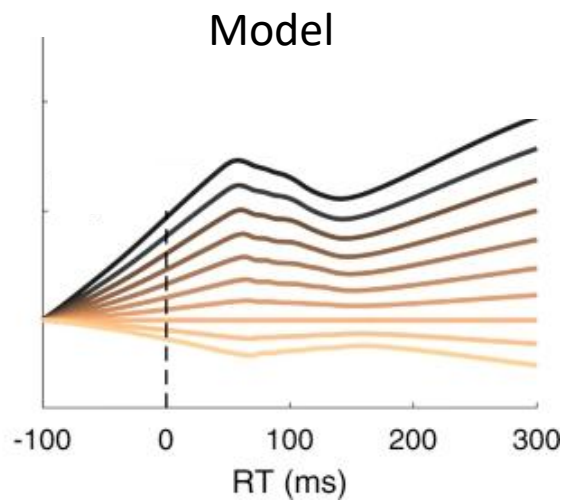
Within session slowing of RTs



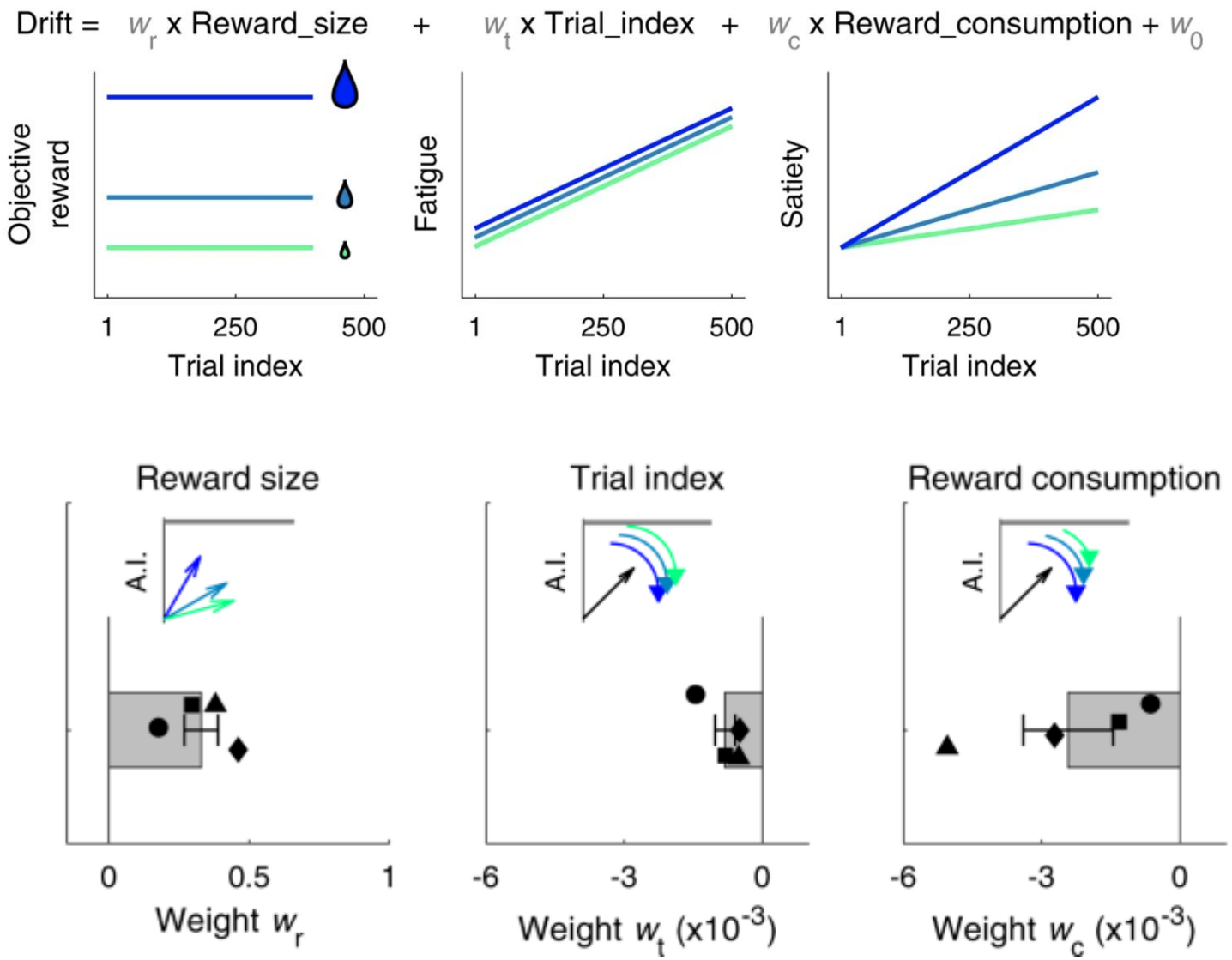








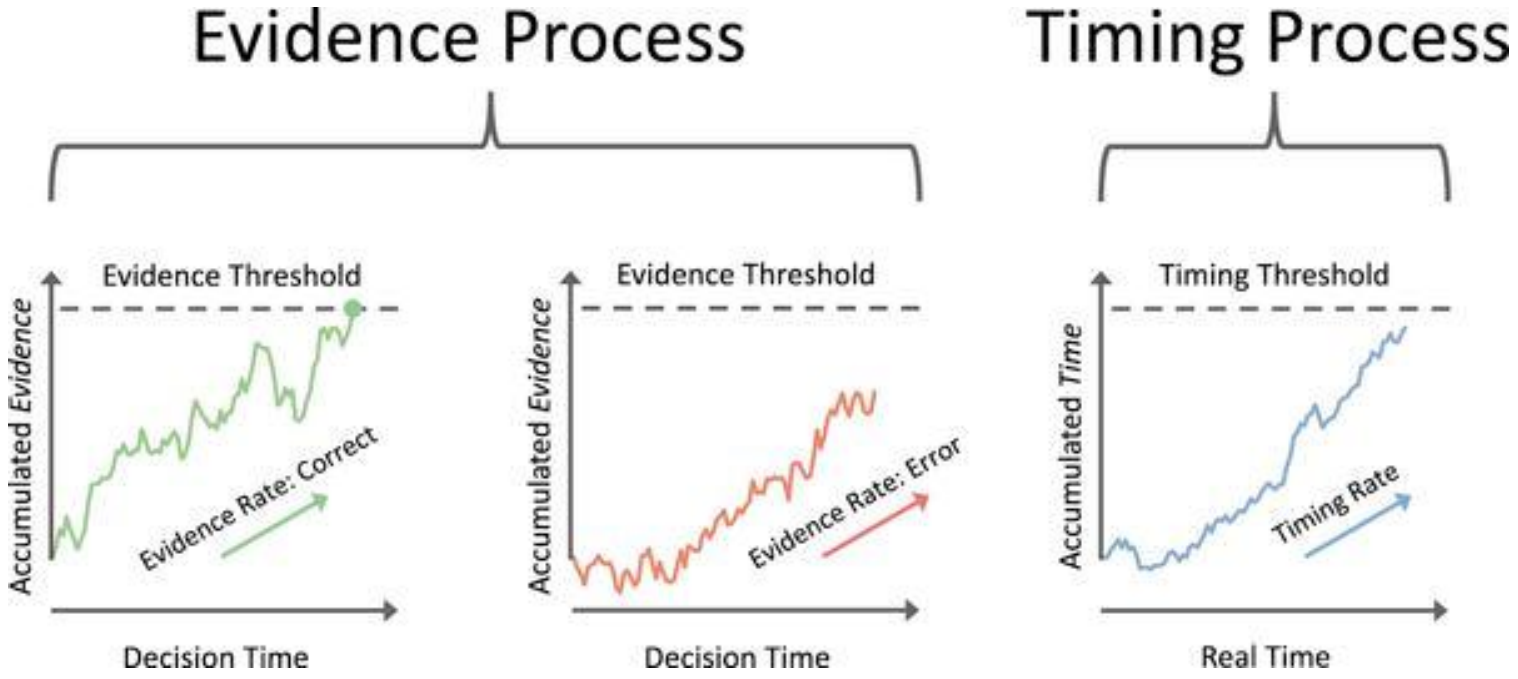
AI drift depends on reward size, trial index and reward consumed



Hernández-Navarro et al (2021).

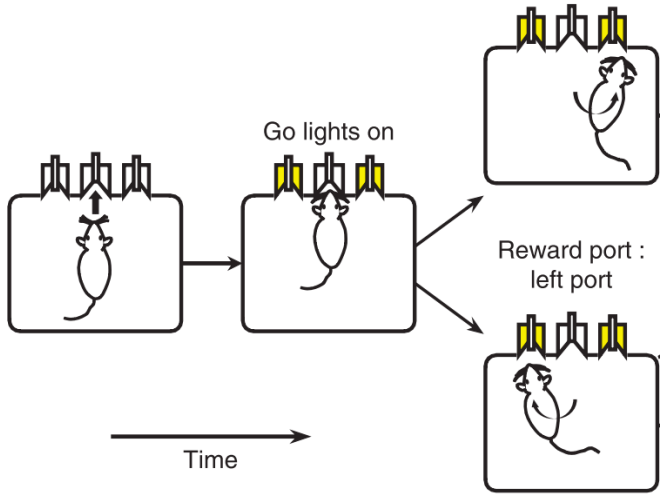
Is there any evidence that this race AI and EA takes occurs in humans?

- Yes!



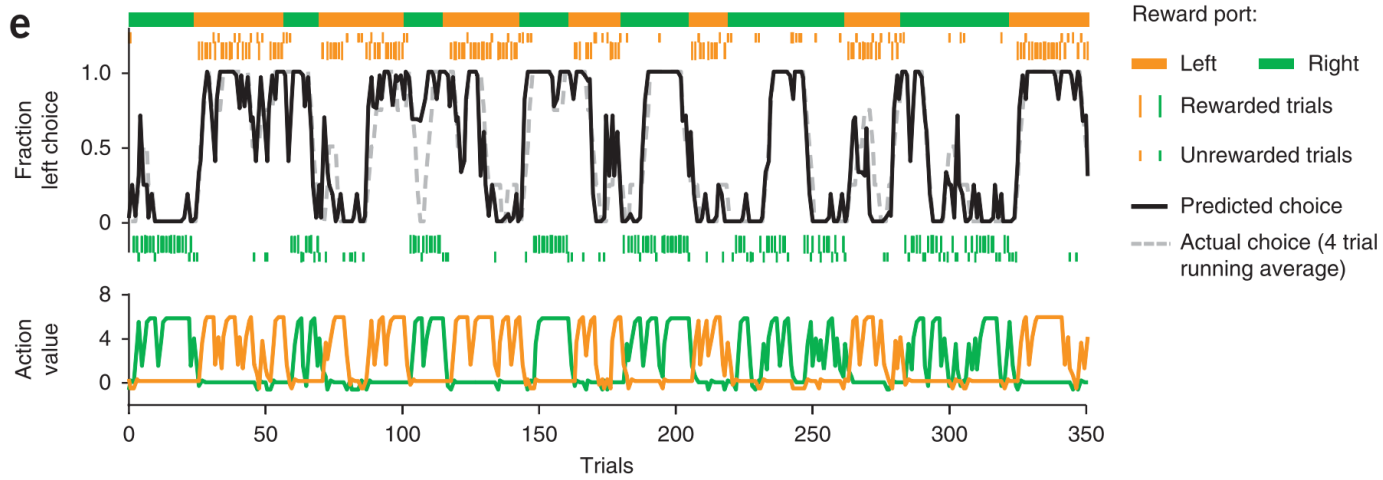
Hawkins, G. E., & Heathcote, A. (2021). Racing against the clock: Evidence-based versus time-based decisions. *Psychological Review,*

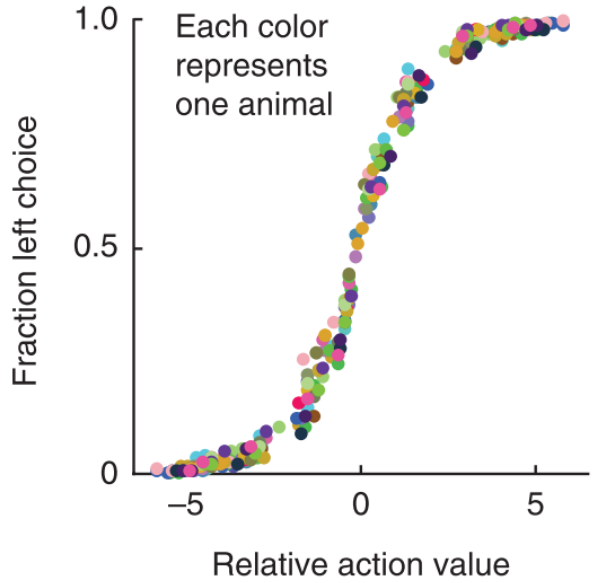
Value-based decision making



Prob. reward = p_{low}

Prob. reward = p_{high}

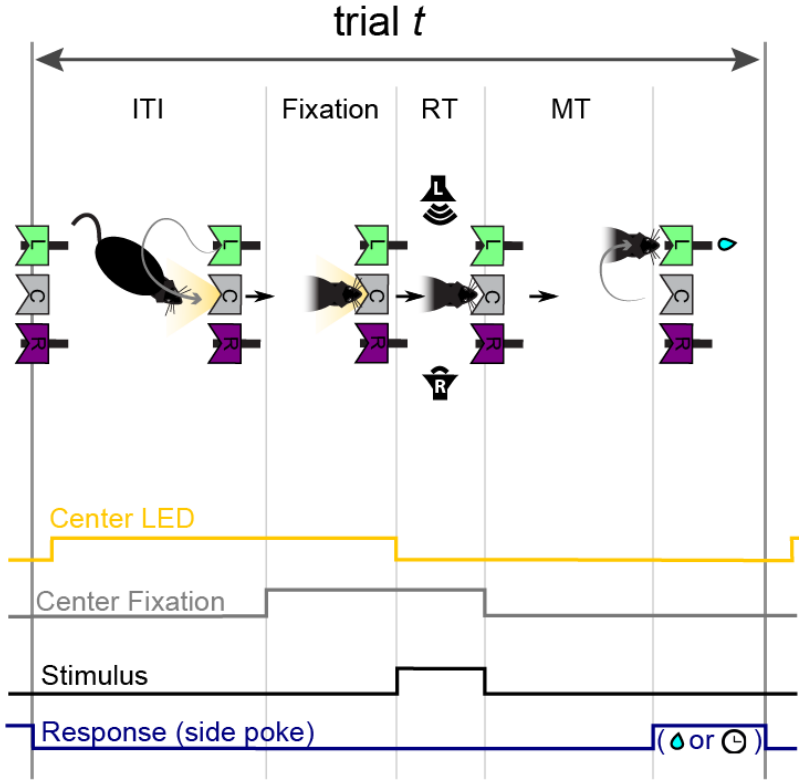




Tai *et al* . 2012

(Sugrue et al., 2004; Samejima et al., 2005; Daw et al., 2006; Lau and Glimcher, 2008; Tai et al., 2012; Donahue et al., 2013; Kim et al., 2013; Hattori et al 2019; Bari et al 2019).

Two-alternative auditory discrimination task in rats

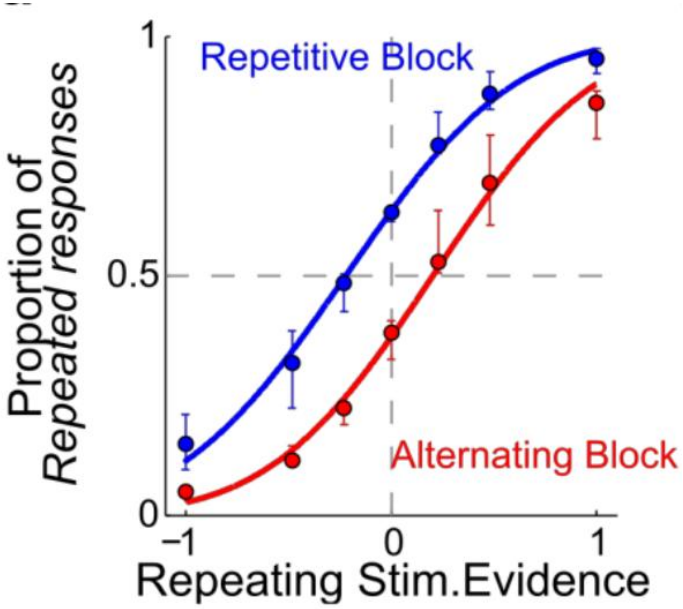


Repetitive block (P_{rep}=0.8)

trials

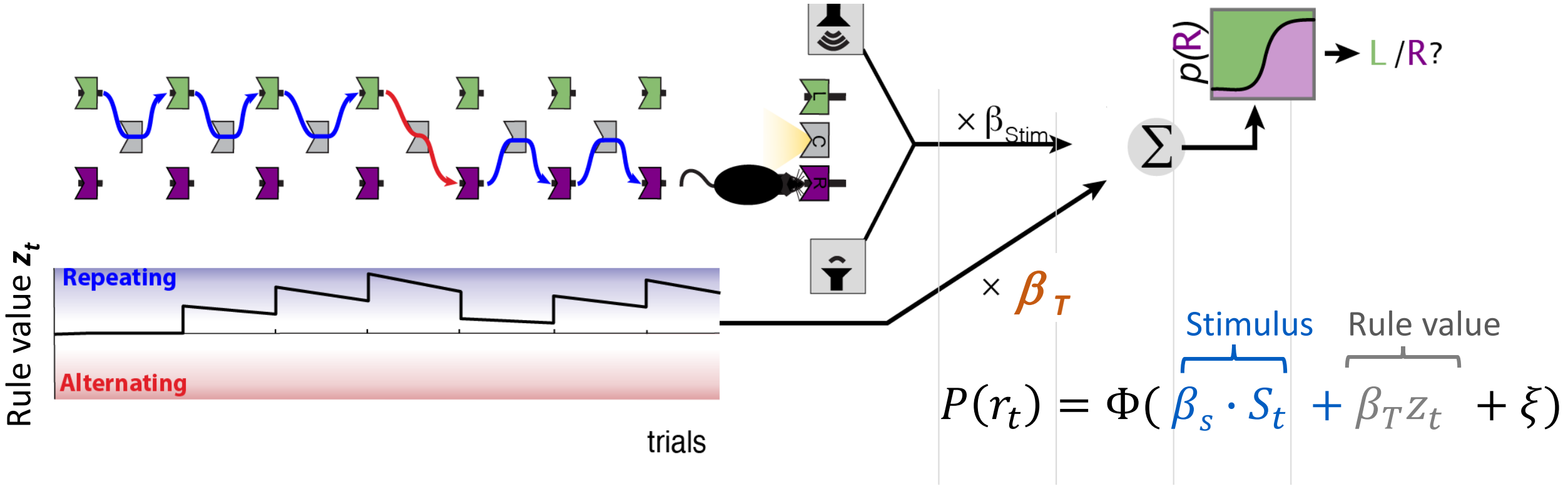
Alternating block (P_{rep}=0.2)

trials



Hermoso-Mendizabal, Hyafil et al., 2020

RL + Stimulus evidence Accumulation Model



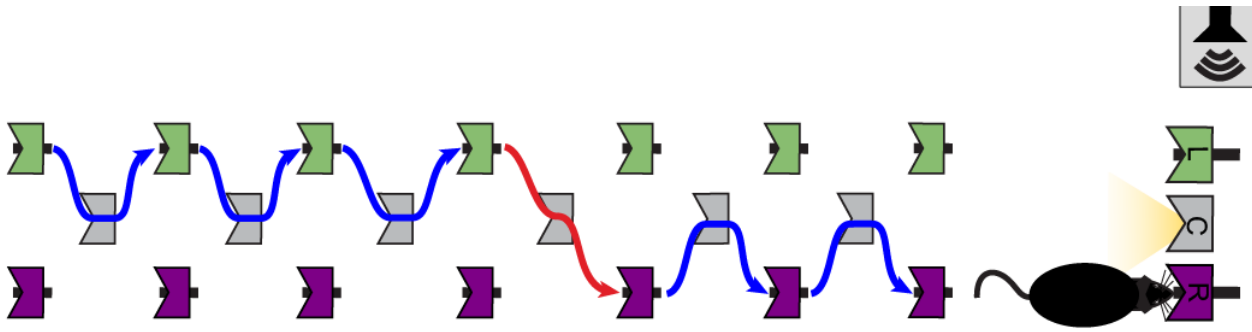
Rule value updating:

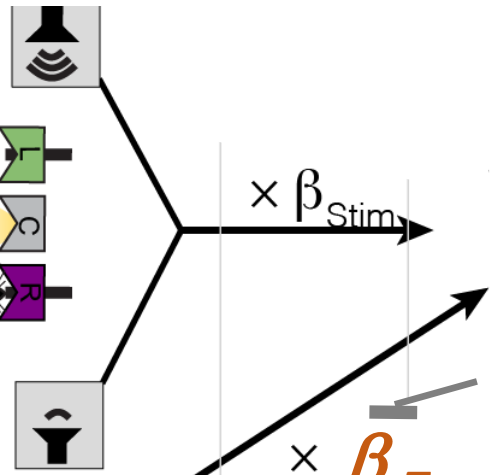
$$z_{t+1} = z_t(1 - \lambda) + \Gamma \; T_t^{++}$$

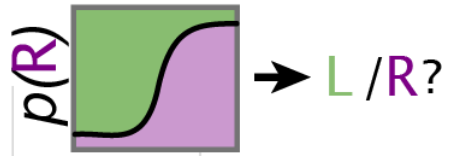
$$T_t^{++} = \begin{cases} +1 \;, \text{ Repetition} \\ -1 \;, \text{Alternation} \end{cases}$$

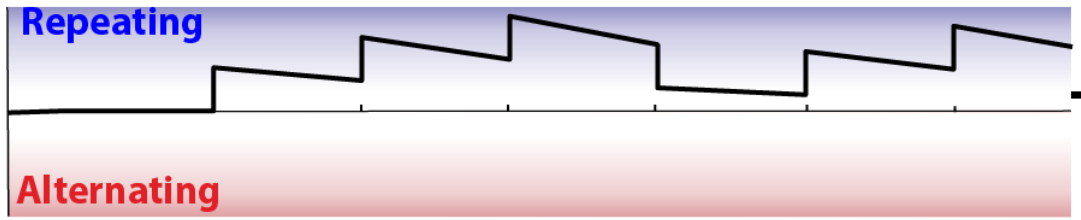
Sindreu et al., (in preparation)

RL + Stimulus evidence Accumulation Model

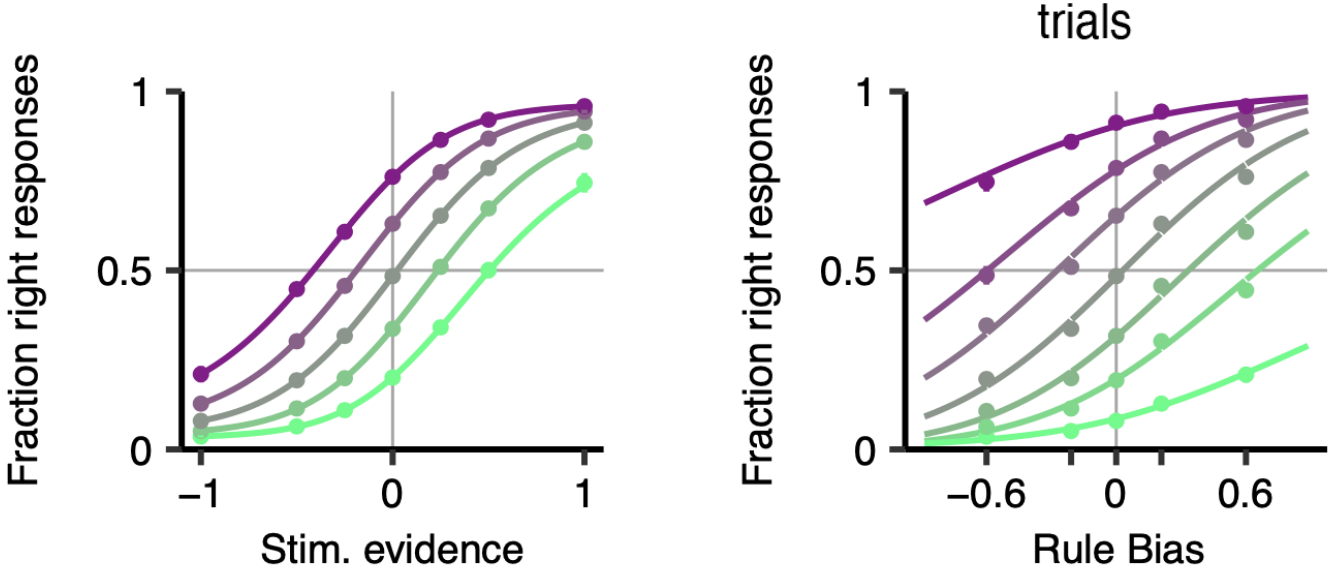






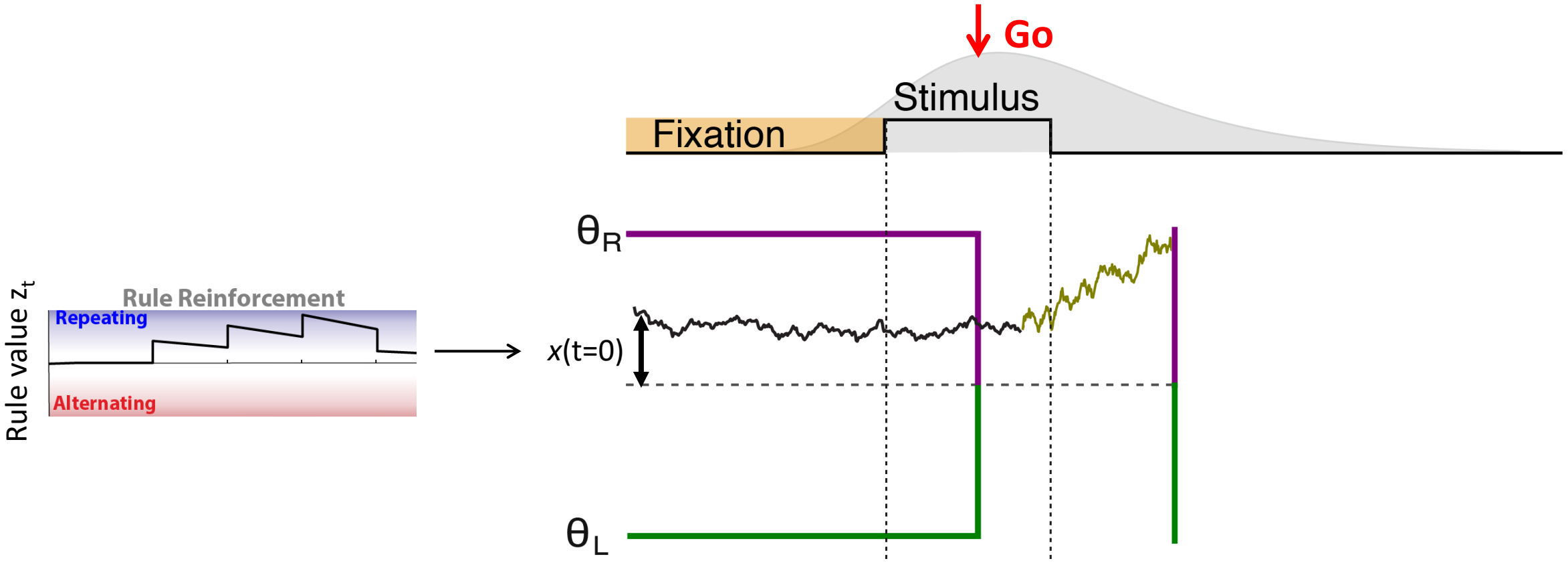


$$P(r_t) = \Phi(\underbrace{\beta_s \cdot S_t}_{\text{Stimulus}} + \underbrace{\beta_T z_t}_{\text{Rule value}} + \xi)$$



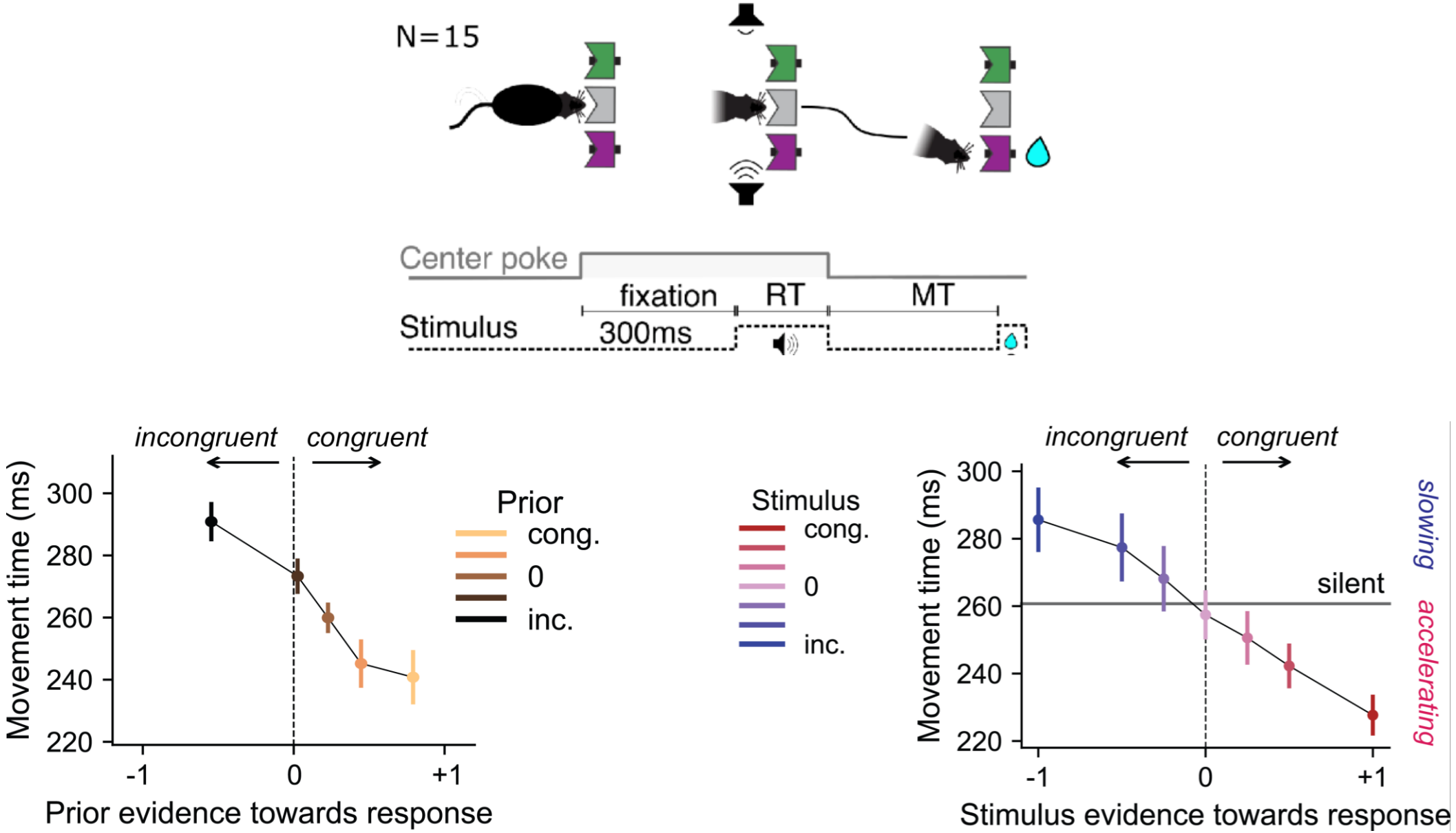
Sindreu et al., (in preparation)

RL + Stimulus evidence Accumulation Model

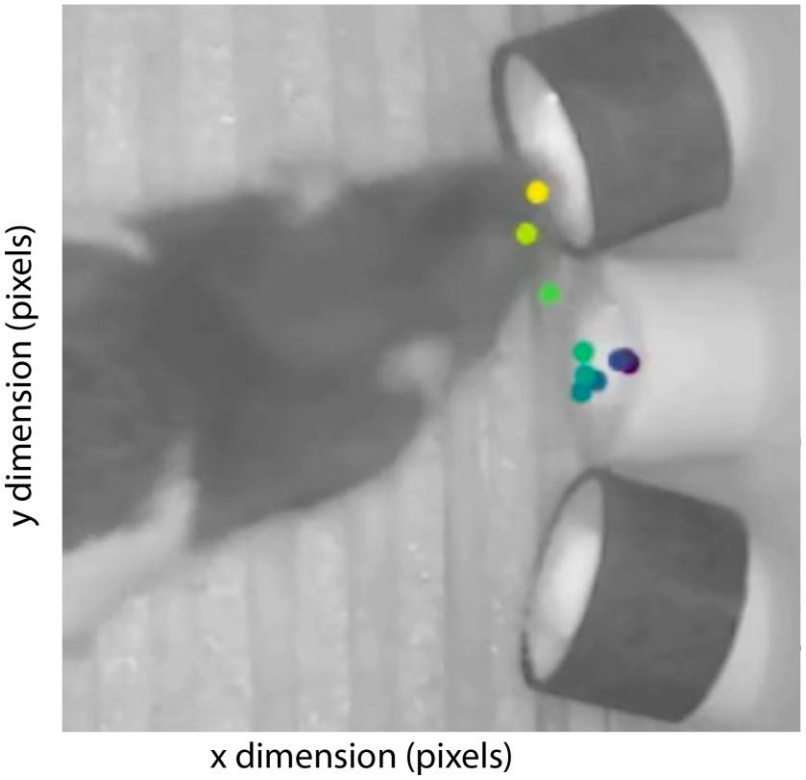


H0. Rats leave the port but wait to have all the information (prior + stimulus) to initiate their response.

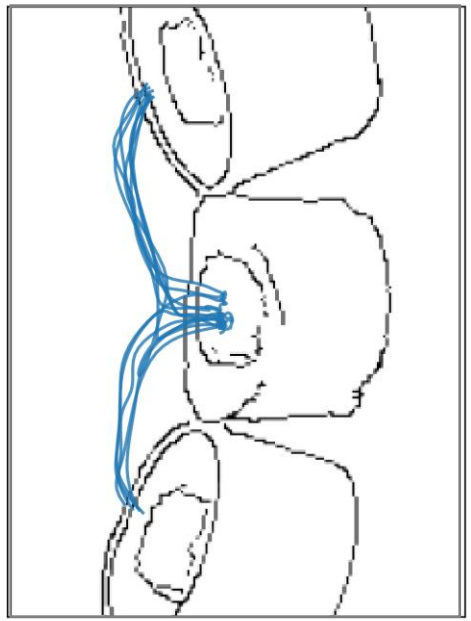
H1. Rats initiate their response with the available information at that moment and then incorporate the stimulus.


N=15
Center poke
fixation
RT
MT
Stimulus
300ms
incongruent
congruent
Movement time (ms)
300
280
260
240
220
-1
0
+1
Prior evidence towards response
Prior
cong.
0
inc.
Stimulus
cong.
0
inc.
incongruent
congruent
Movement time (ms)
300
280
260
240
220
silent
slowing
accelerating
-1
0
+1
Stimulus evidence towards response

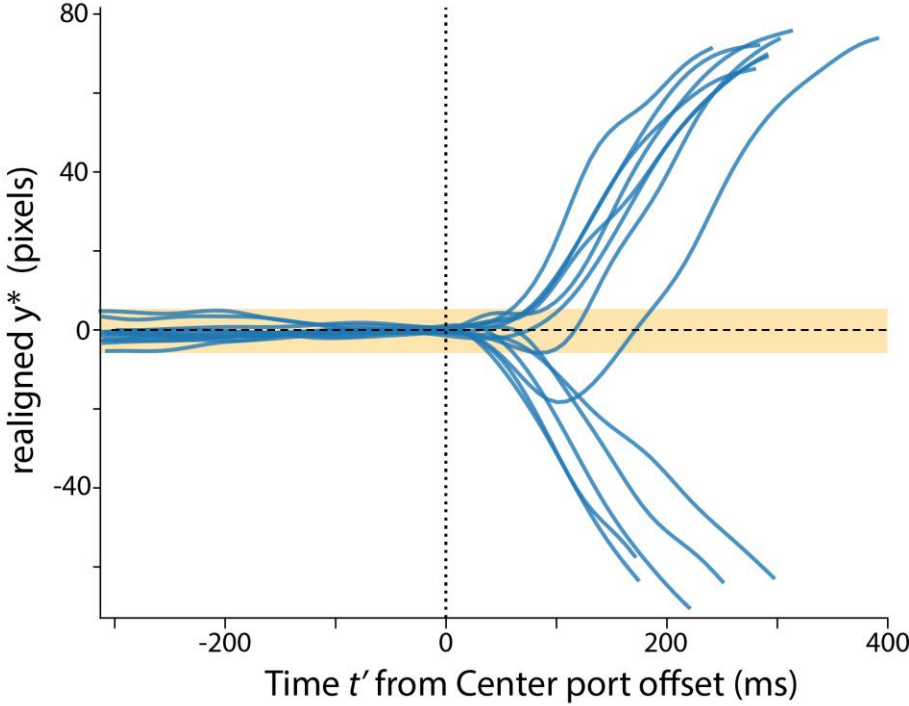
Analysis of orienting response trajectories



[x(t), y(t)]

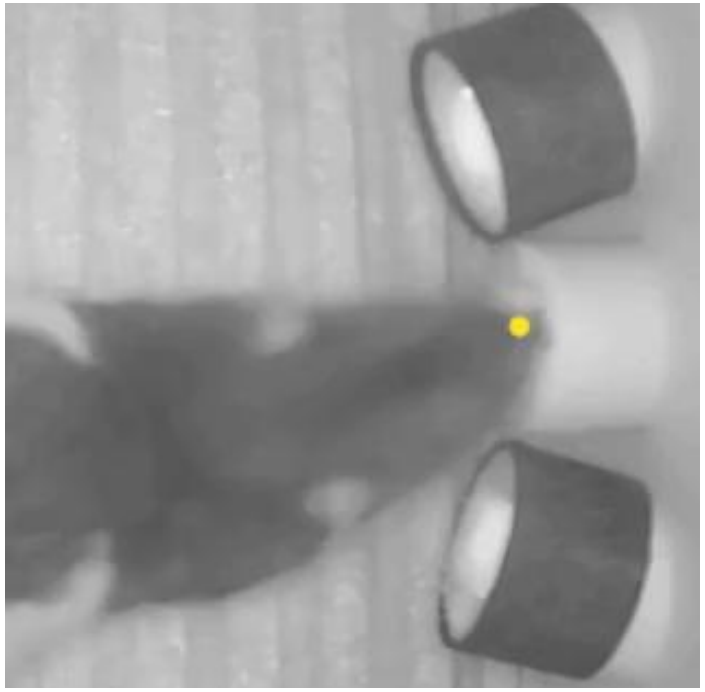


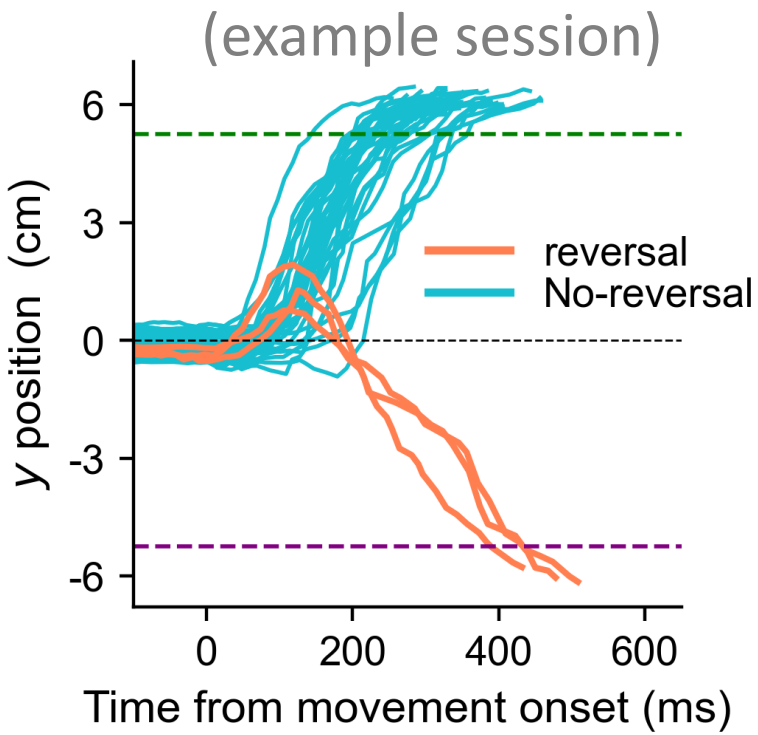
Y*(t')

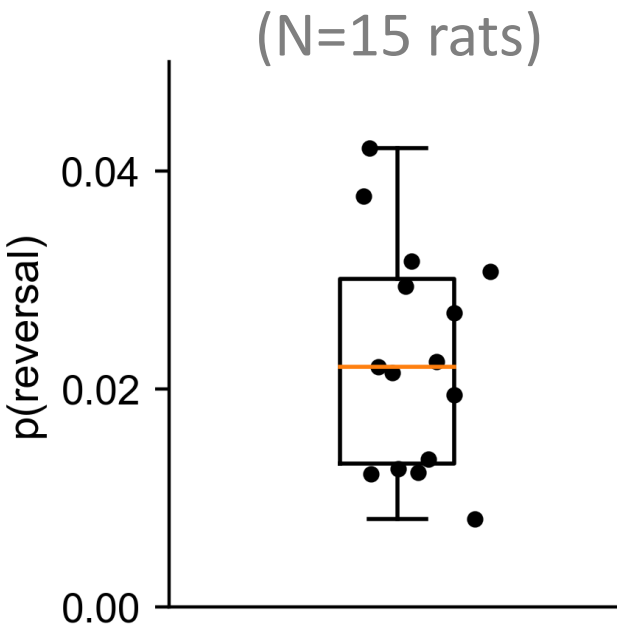


Molano-Mazón, García-Durán, Pastor et al., Nature Comms 2024

CoMs result from an incongruency of the prior and the stimulus evidence.

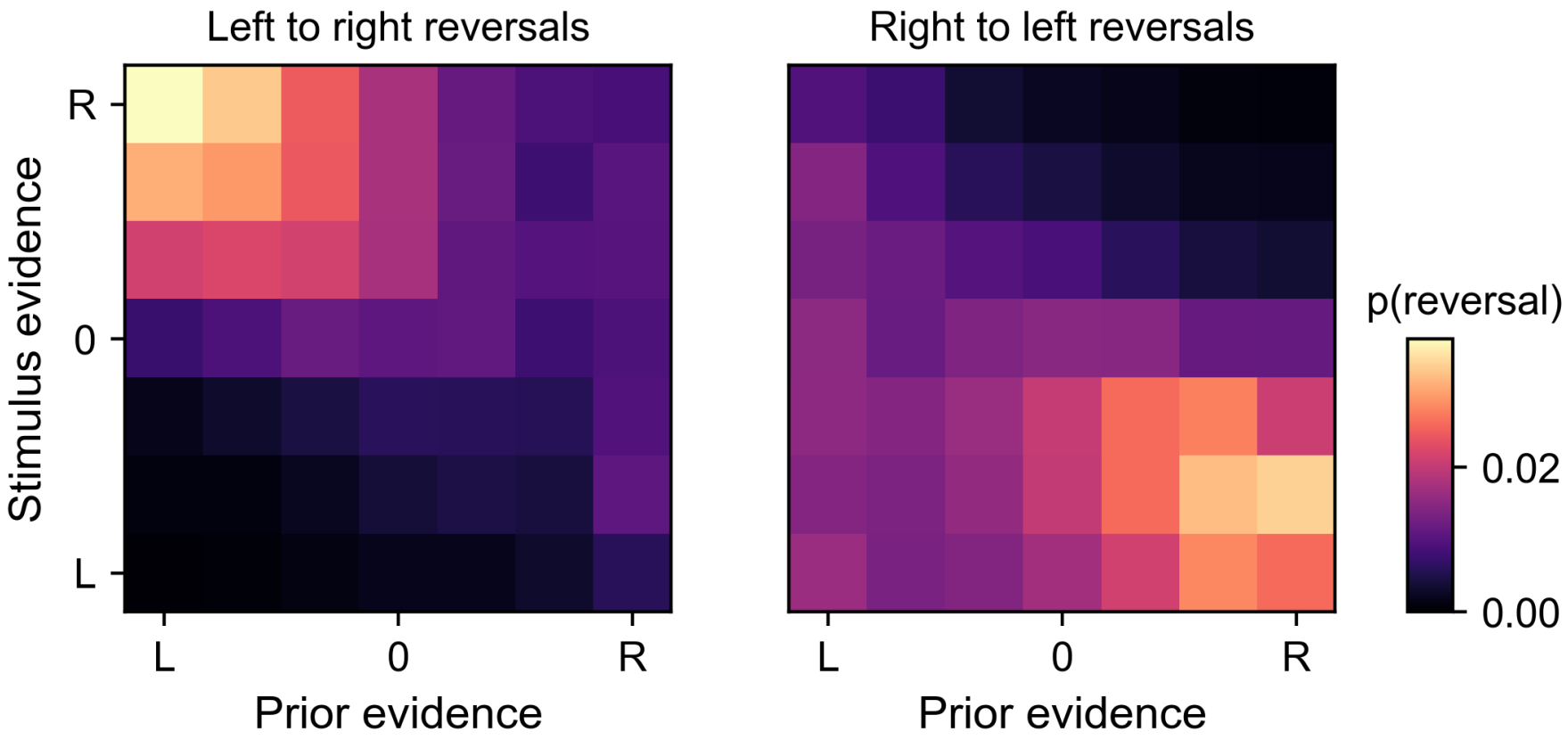






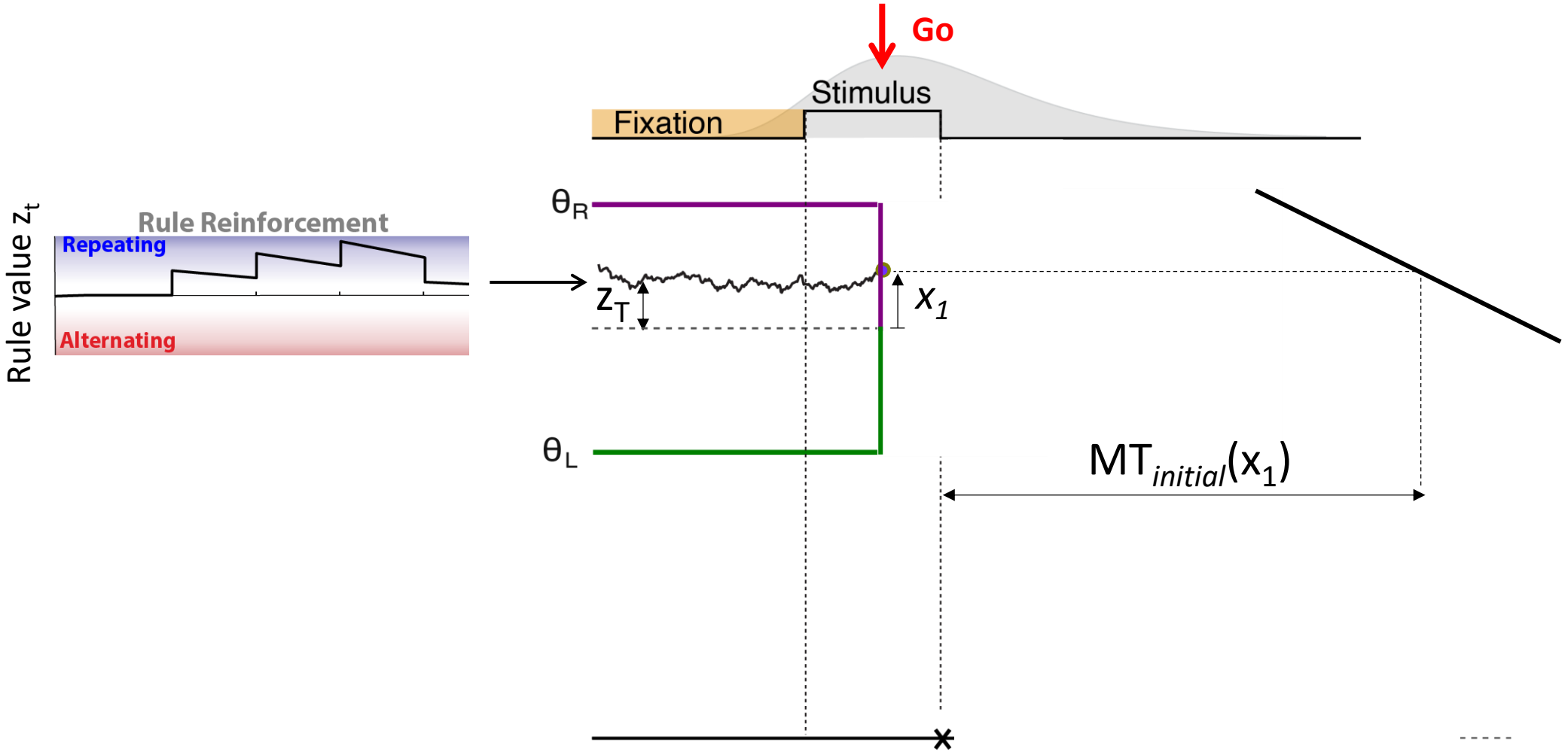
Molano-Mazón, García-Durán, Pastor et al., Nature Comms 2024

Do trajectory reversals reflect Changes of Mind?

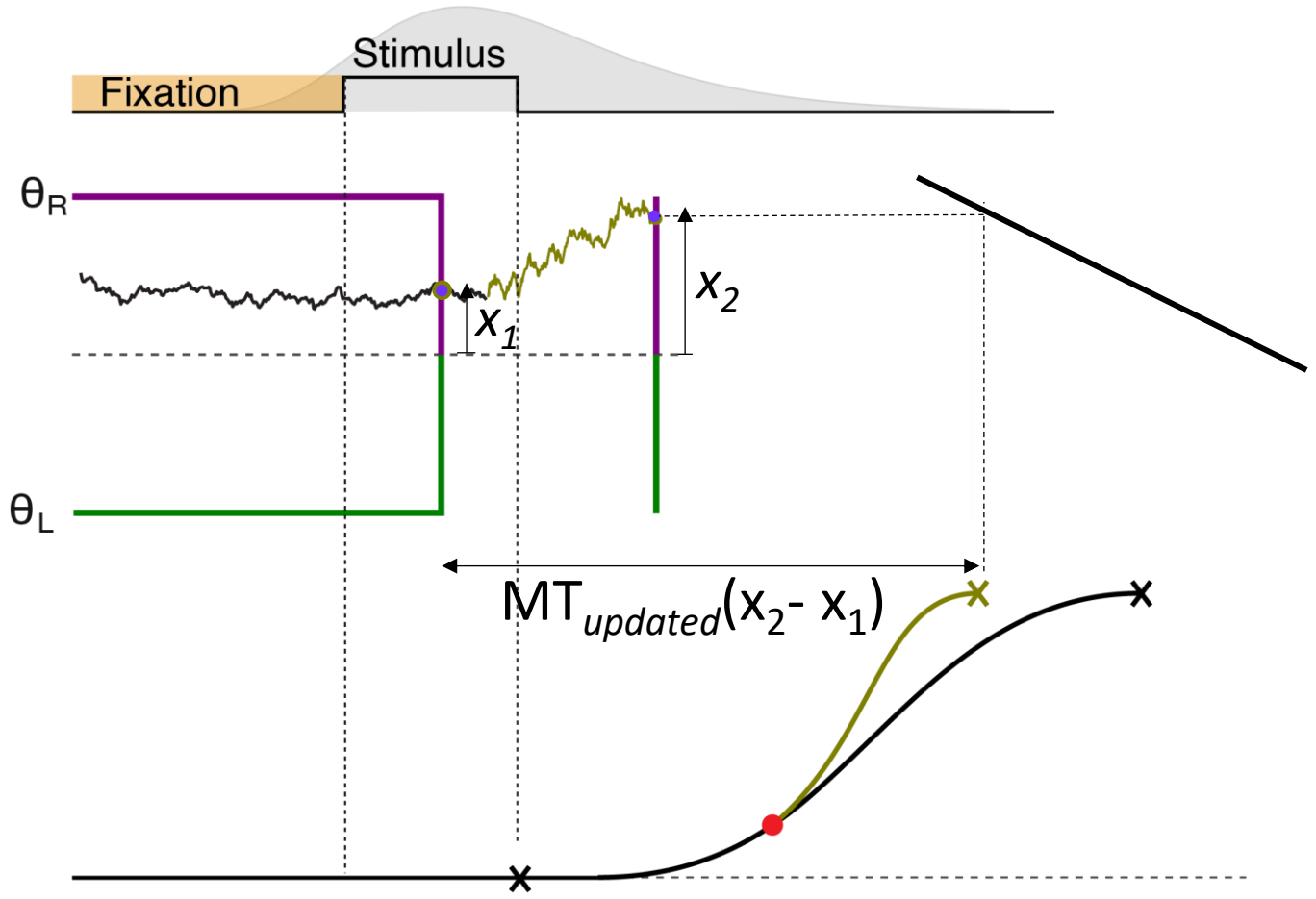


CoMs result from an incongruency of the prior and the stimulus evidence

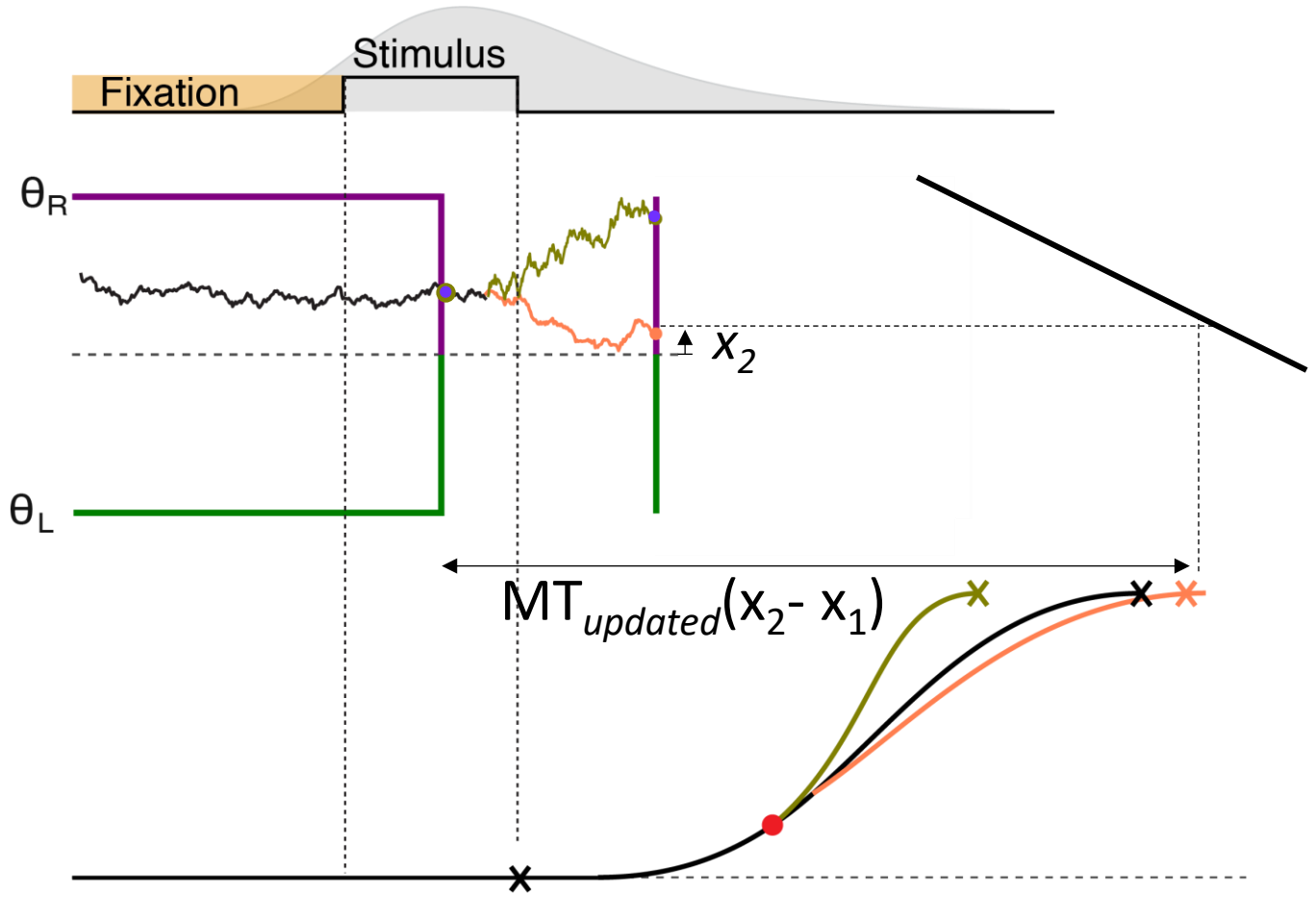
A model for response trajectories: plan, intiate and update



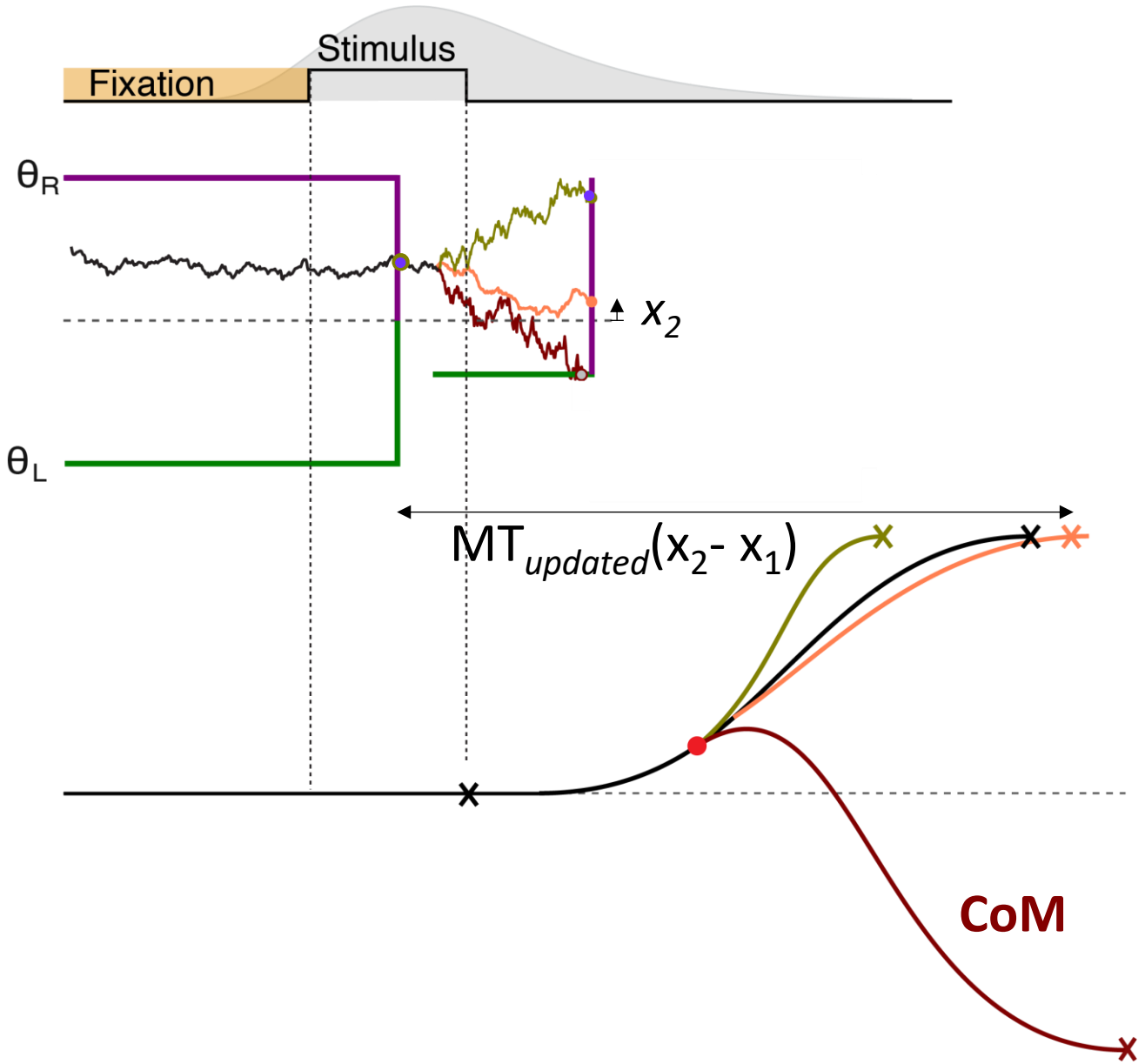
A model for response trajectories: plan, intiate and update



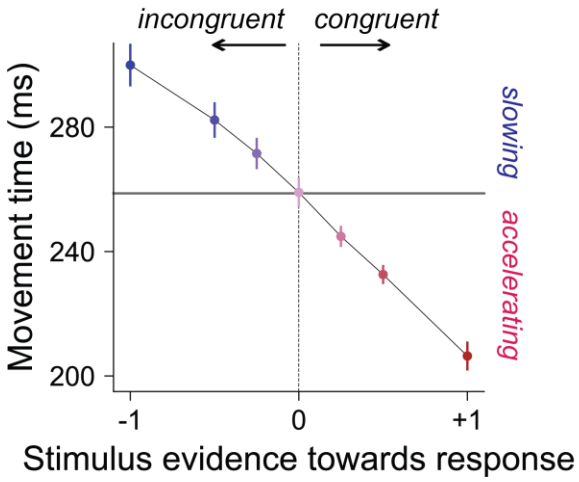
A model for response trajectories: plan, intiate and update

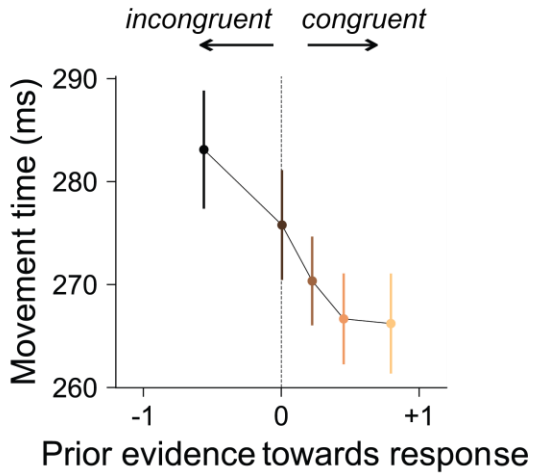


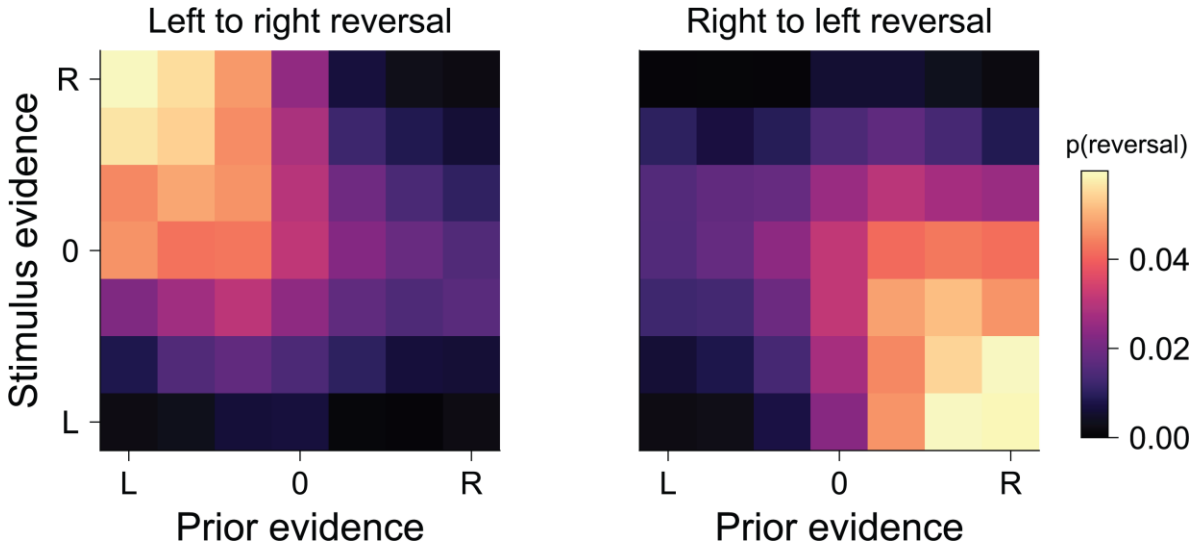
A model for response trajectories: plan, intiate and update



Model reproduces MT and CoM dependencies







Molano-Mazón, García-Durán, Pastor et al., Nature Comms 2024

Gracias