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Attentional Amplification in Losses: an aDDM Puzzle

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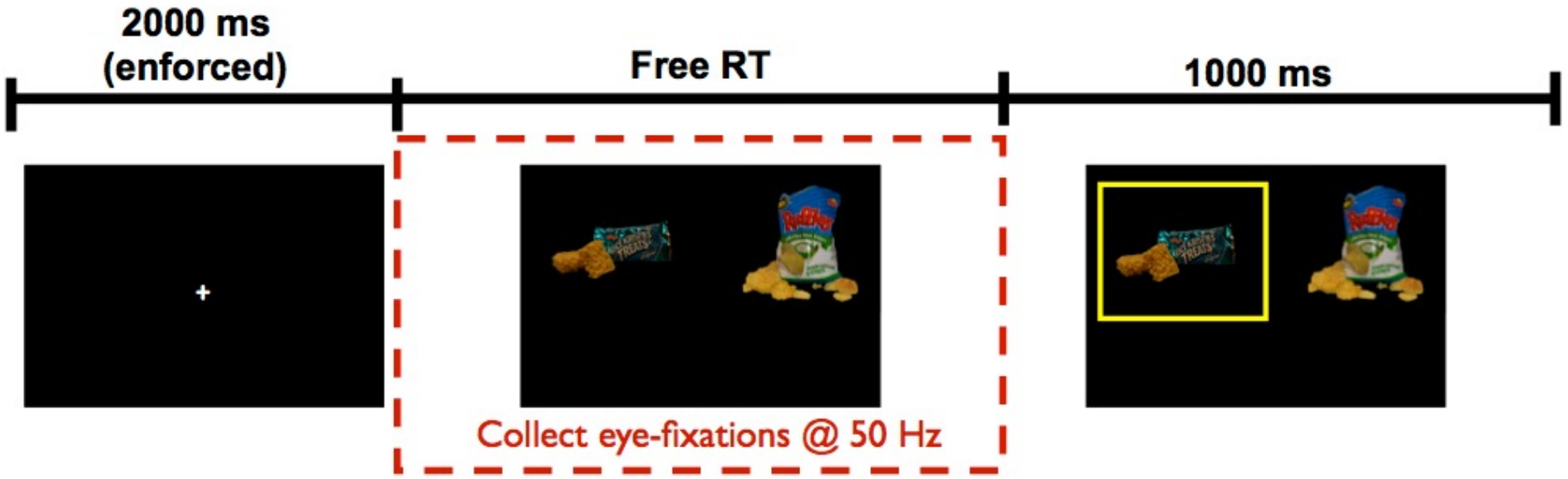
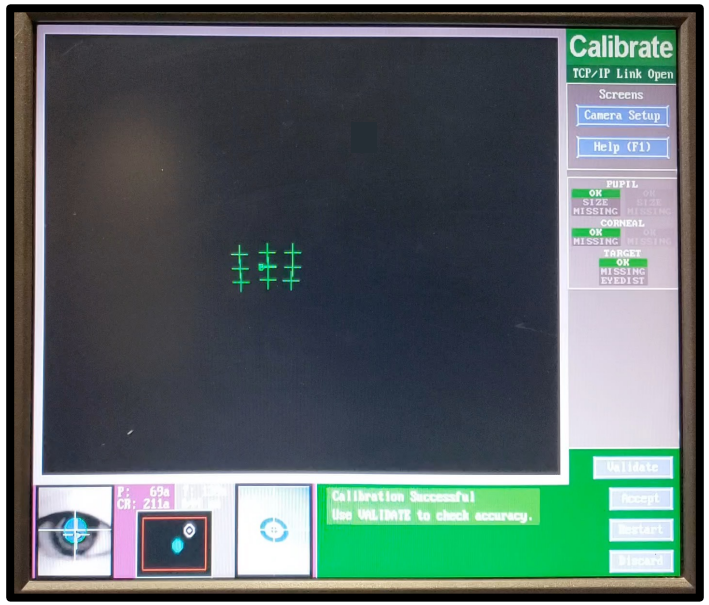
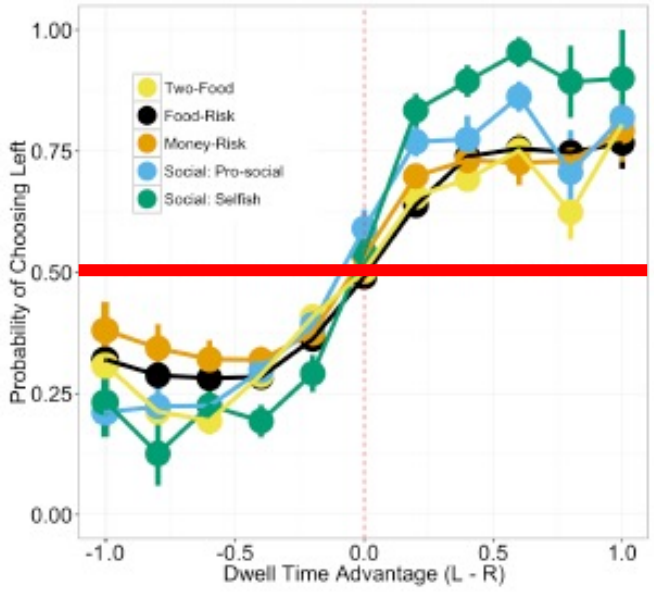
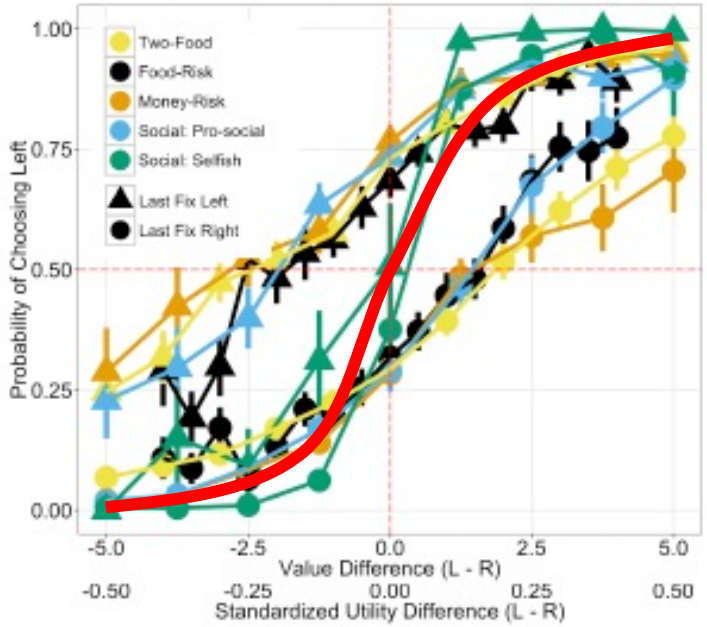




Krajbich, Armel, Rangel (2010, Nat Neuro)



Net Fixation Bias



Last Fixation Bias

Smith, Krajbich (2018, J Exp Psychol Gen)

Attentional Drift-Diffusion-Model (aDDM)

$$evidence_t = evidence_{t-1} + \mu_t + e_t$$

Noisy process:

$$e_t \sim N(0, \sigma^2)$$

$$evidence_0 = b$$

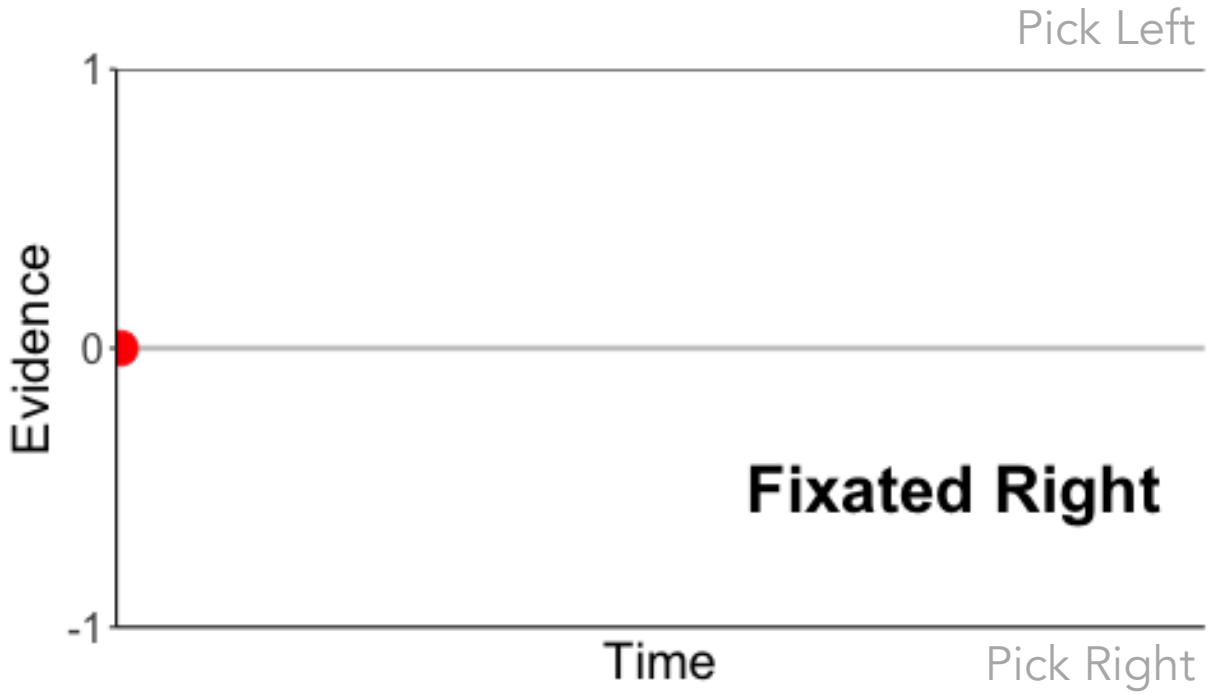
If looking left:

$$\mu_t = d(V_L - \theta V_R)$$

If looking right:

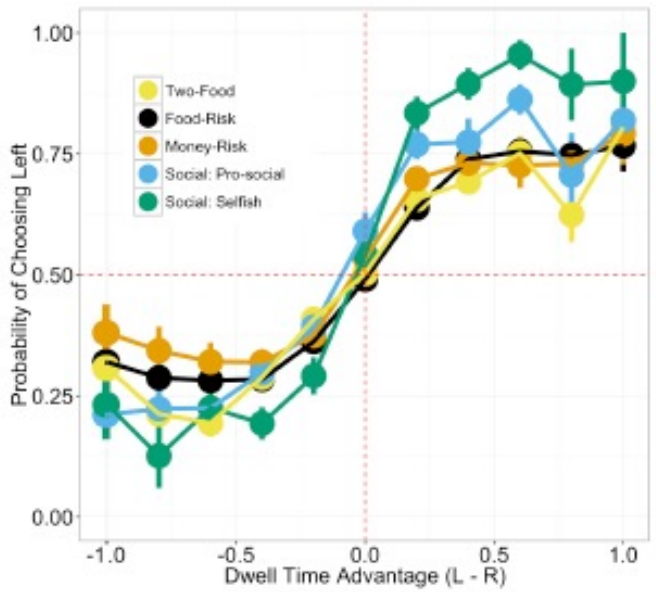
$$\mu_t = d(\theta V_L - V_R)$$

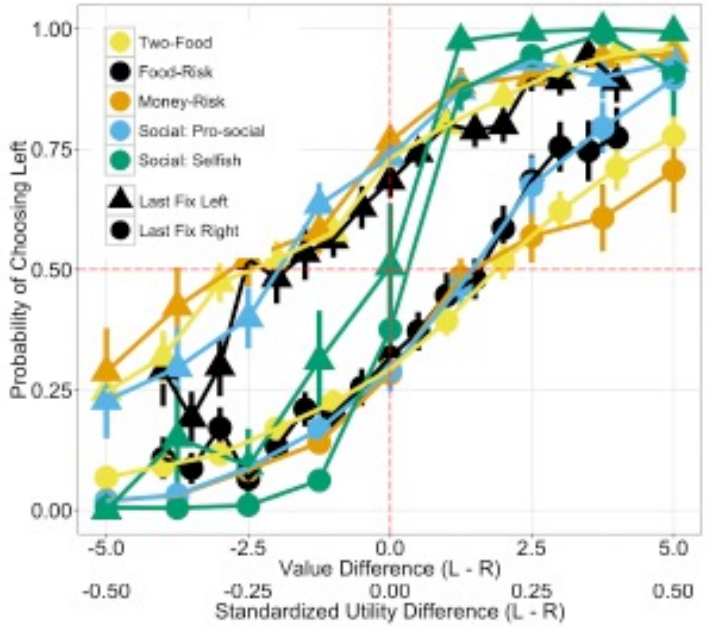
The model is agnostic to modeling the fixation process.



aDDM Predictions

average $\hat{\theta} \approx 0.53$ (.005)





1. Attentional Discounting

2. Net Fixation Bias

3. Last Fixation Bias

Bhatnagar, Orquin (2022, J Exp Psychol Gen)

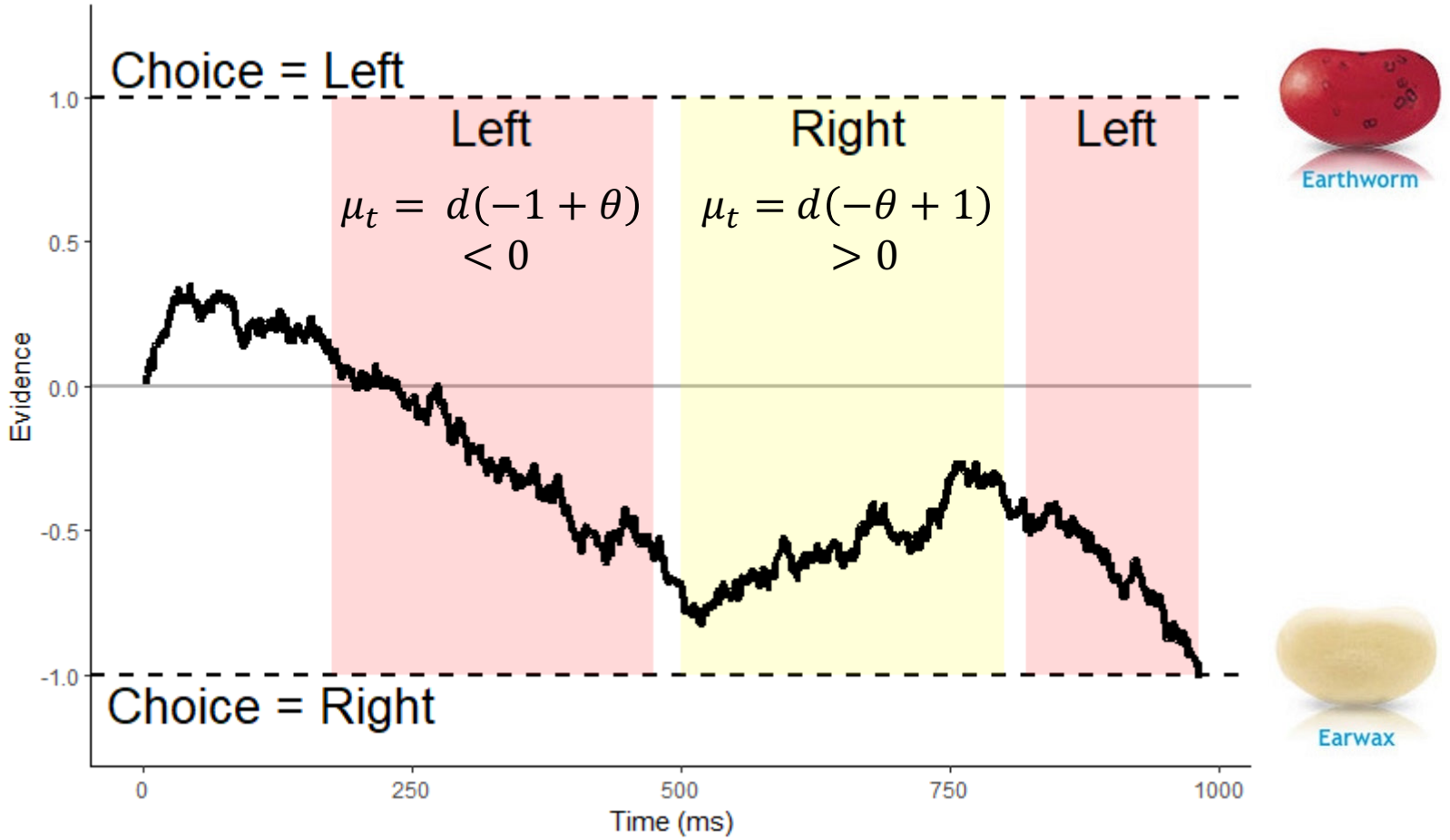
Smith, Krajbich (2018, J Exp Psychol Gen)

See Smith, Krajbich (2018, J Exp Psychol Gen); Bhatnagar, Orquin (2022, J Exp Psychol Gen); Fiedler, Glöckner (2012, Front Psychol)


Harry Potter
Banana
Black Pepper
Blueberry
Booger
Candyfloss
Cherry
Cinnamon
Dirt
Earthworm
Earwax
Grass
Green Apple
Marshmallow
Rotten Egg
Sausage
Lemon
Soap
Tutti-Fruitti
Vomit
Watermelon

Suppose $V_L = -1,\ V_R = -1$, and $\theta \in (0,1)$.

$$evidence_t = evidence_{t-1} + \mu_t + e_t$$



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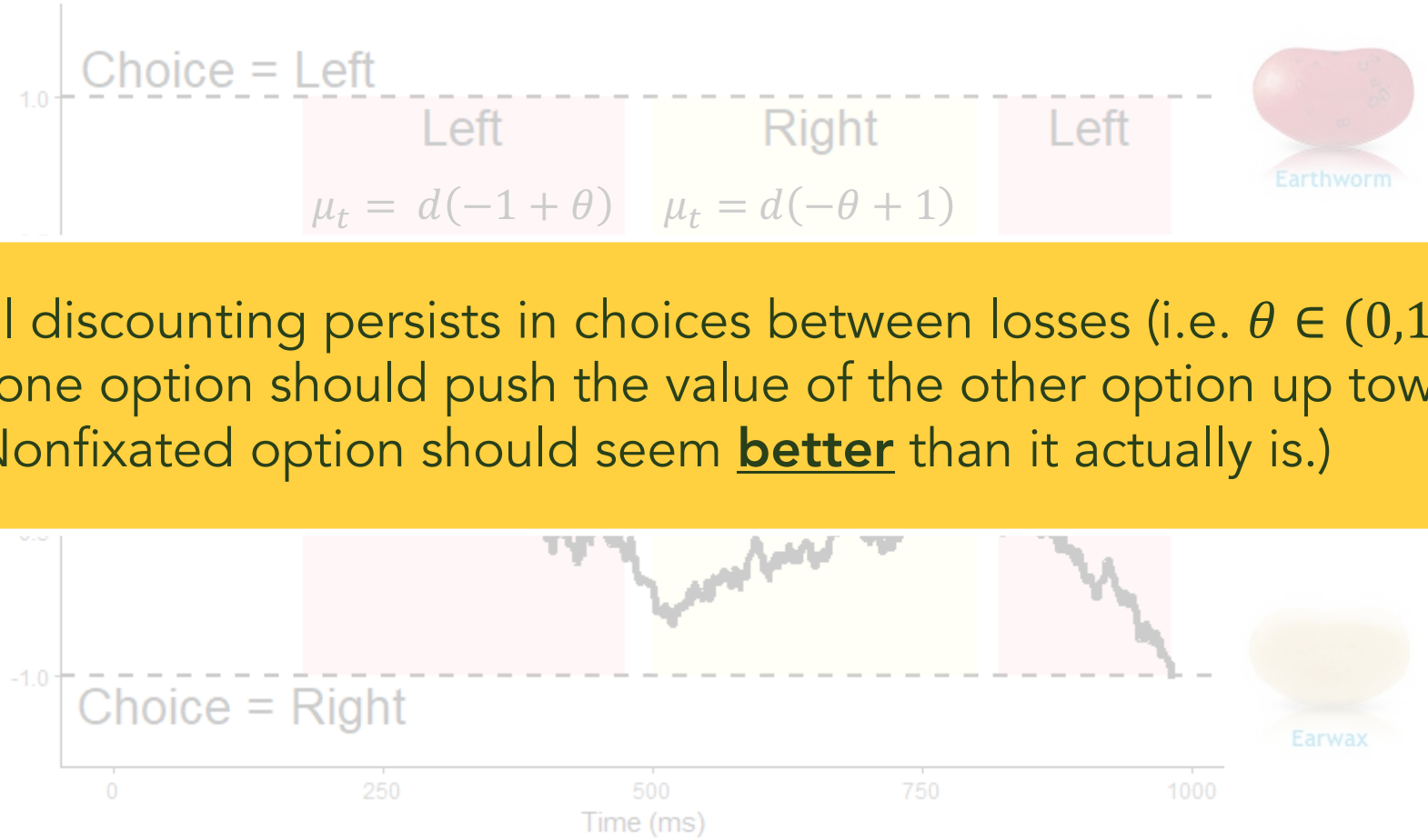
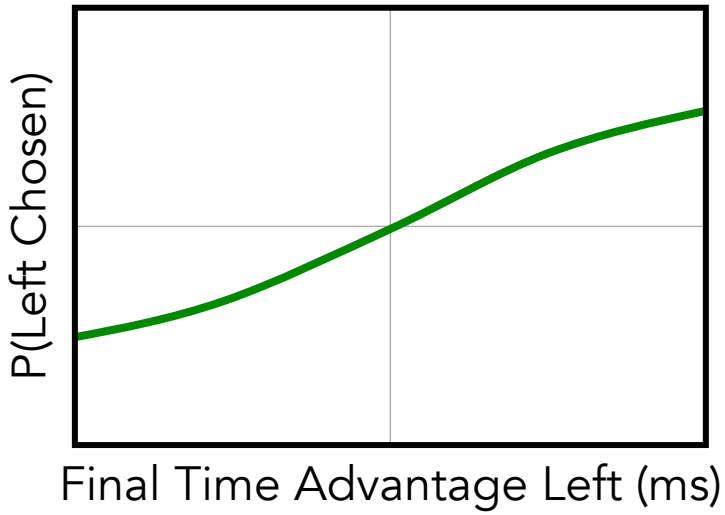


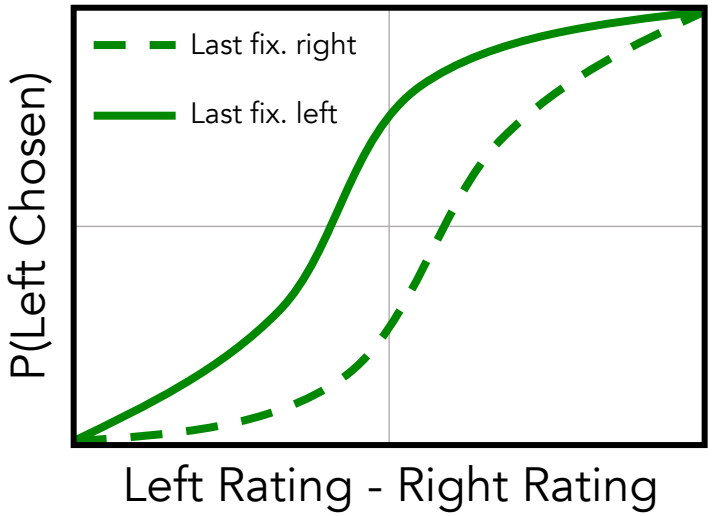
If attentional discounting persists in choices between losses (i.e. $\theta \in (0,1)$), then fixating on one option should push the value of the other option up towards 0. (i.e. Nonfixated option should seem **better** than it actually is.)

Attentional Choice Biases

Net Fixation Bias

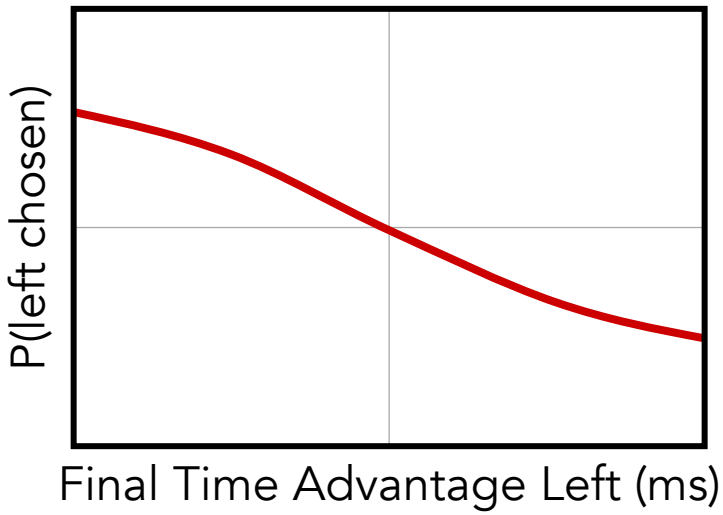


Last Fixation Bias

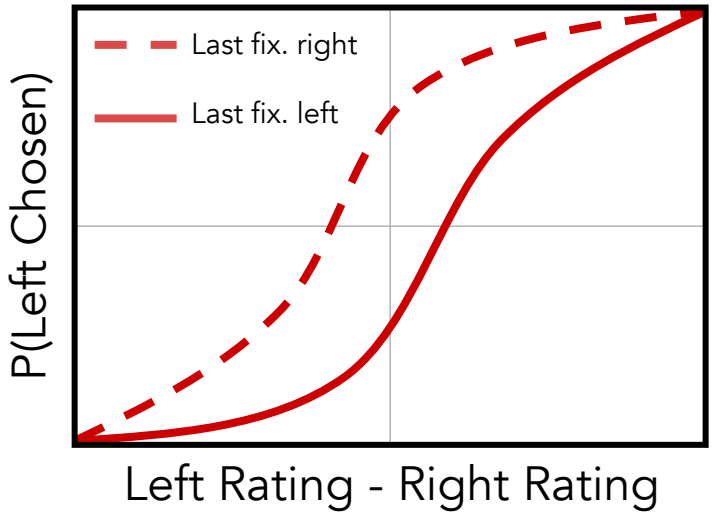


Attentional Choice Biases Should Flip!

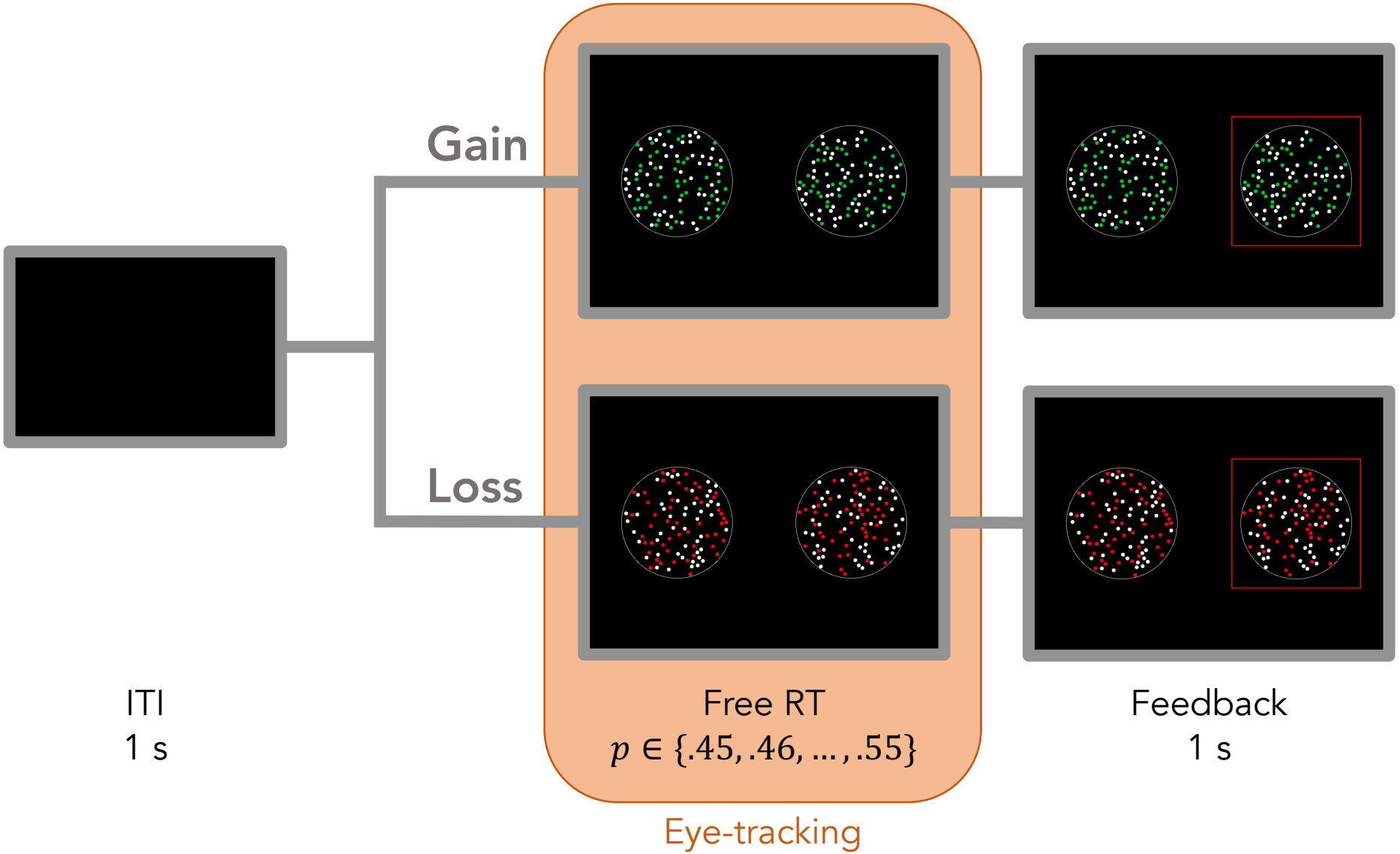
Net Fixation Bias



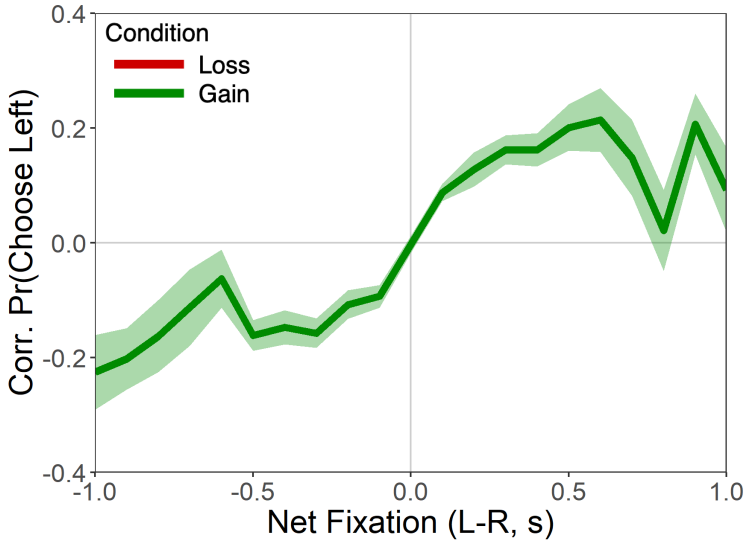
Last Fixation Bias

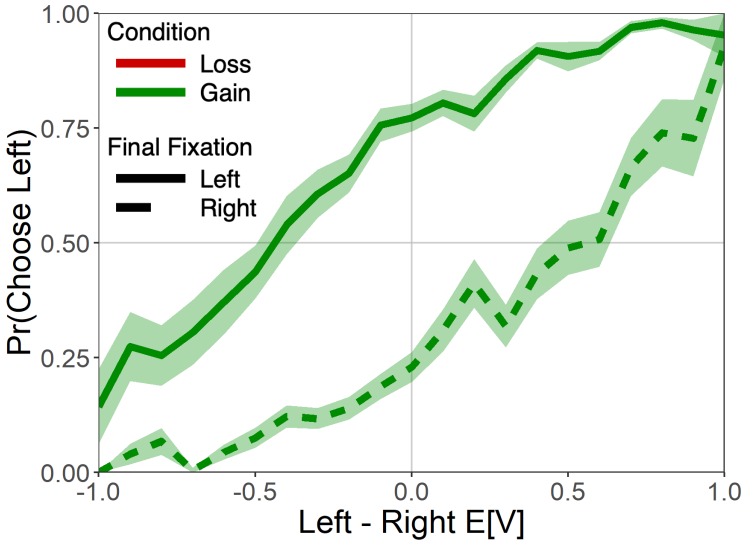


Study #1: "Dots"
N=35
400 trials

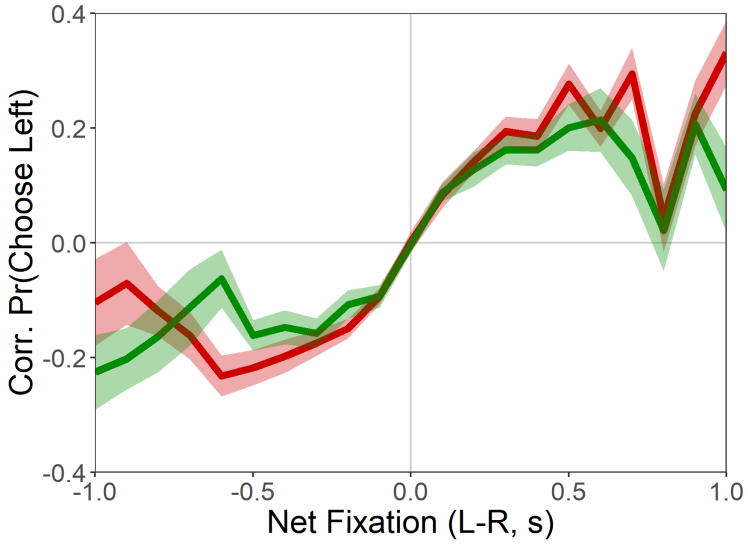


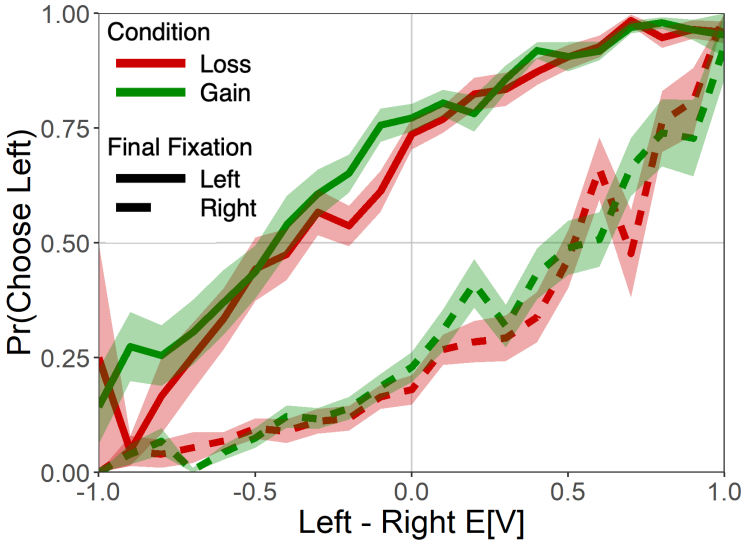
Attentional Choice Biases

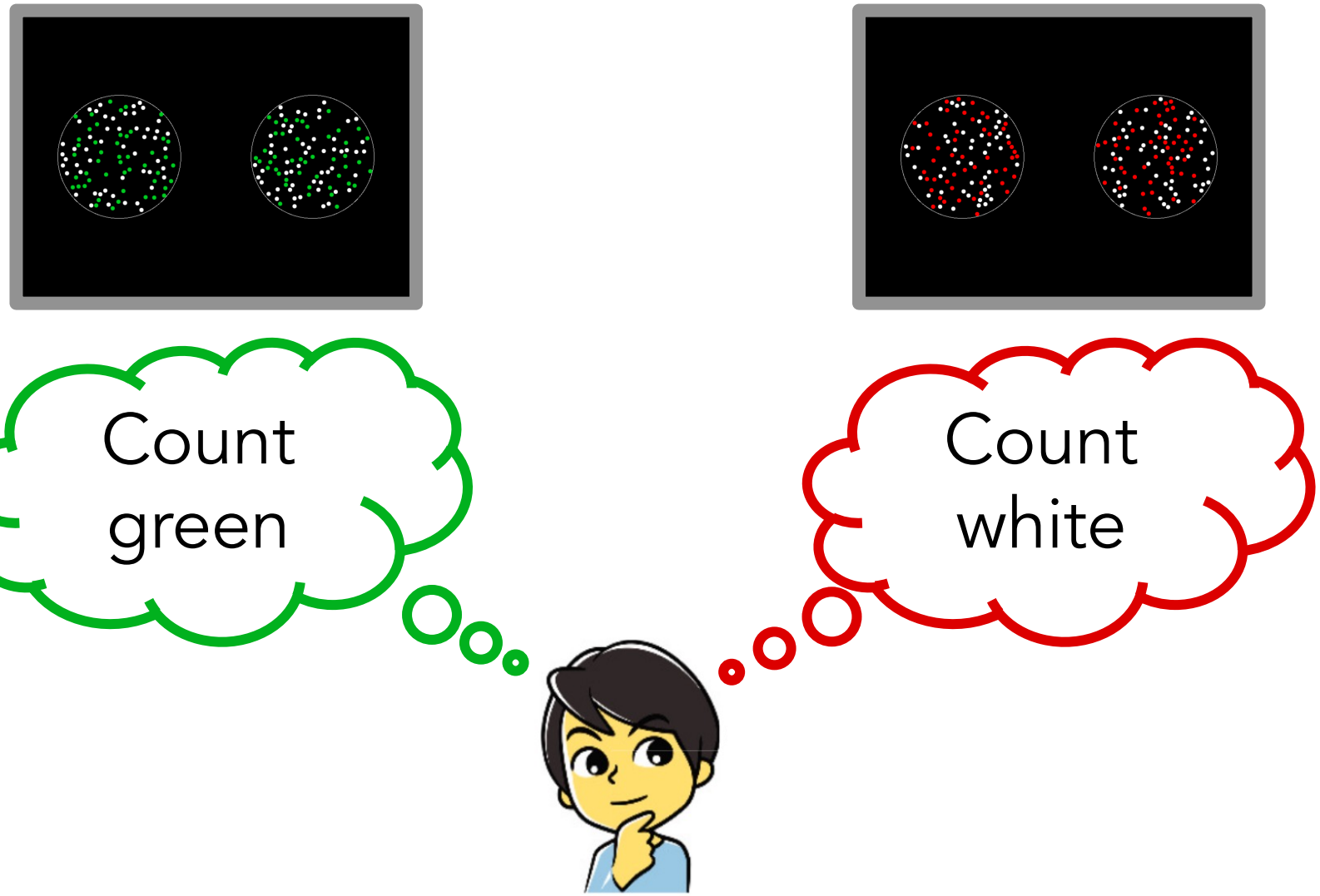




Attentional Choice Biases Do NOT Flip!

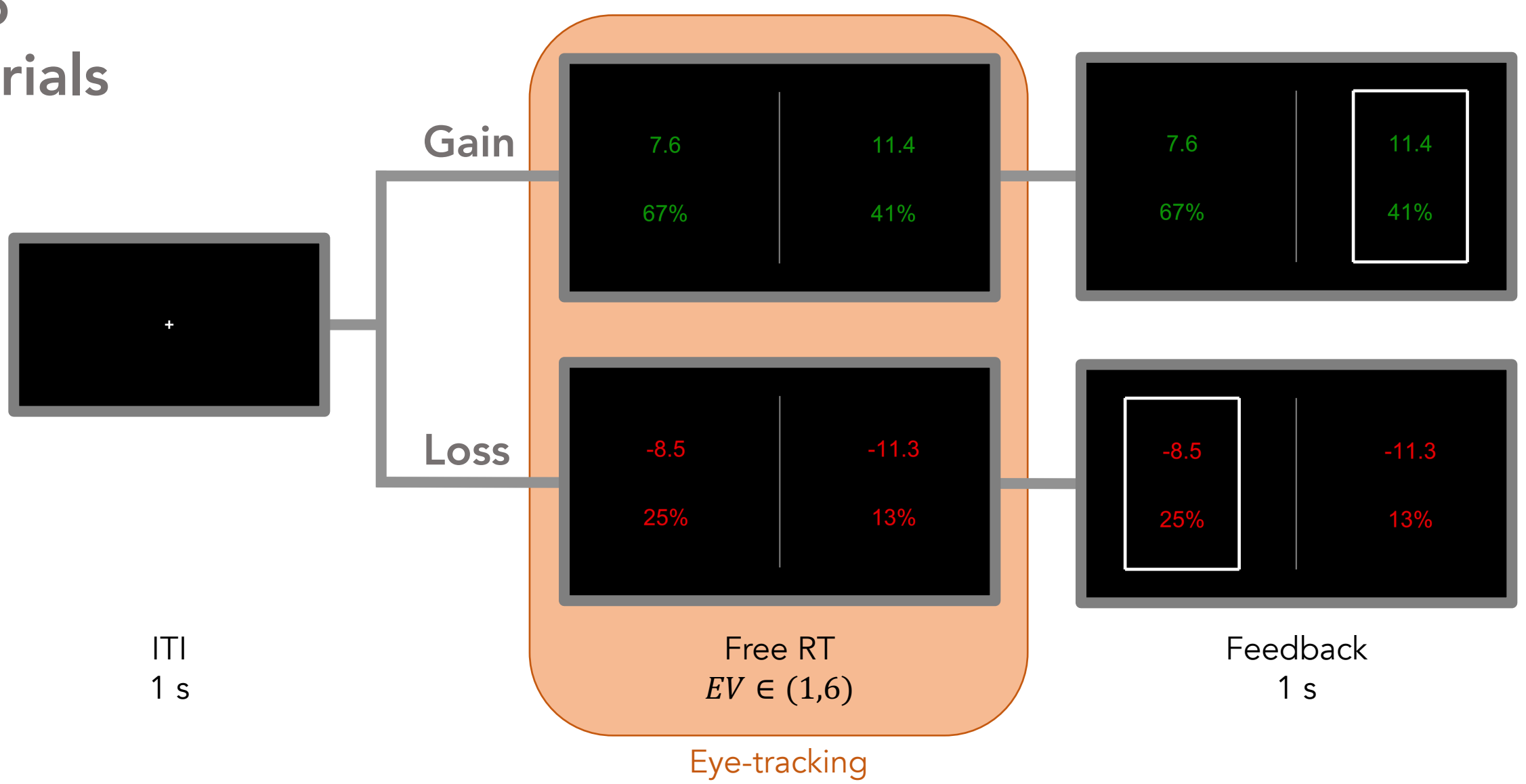




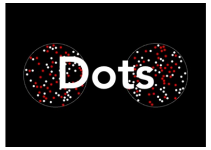


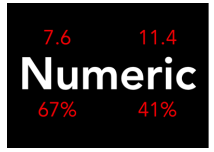
Thinking boy from Jang, Sharma, Drugowitsch (2021, eLife)

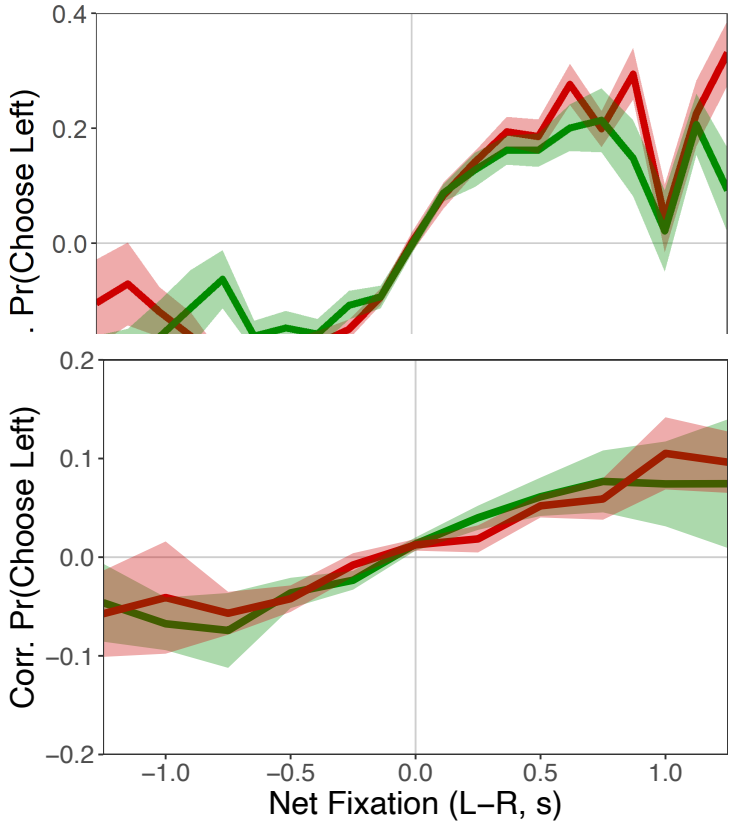
Study #2: "Numeric"
N=26
340 trials

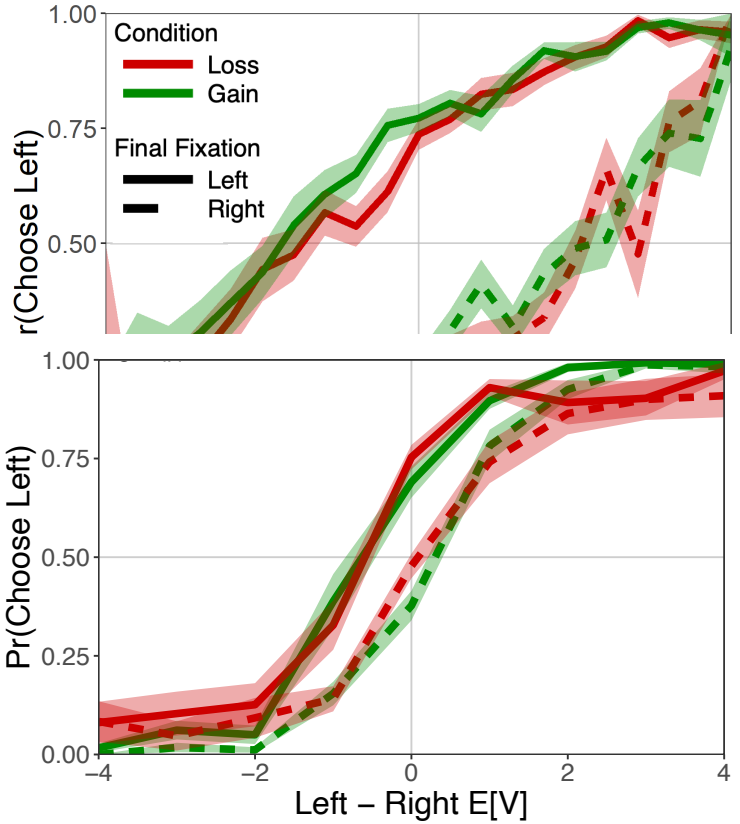


Attentional Choice Biases <u>STILL Do Not Flip!</u>









Preview of the Conclusion

Preview of the Conclusion

In choices between losses, behavior is best explained by a variation of the aDDM where negative value signals are replaced with positive, "goal-relevant" information about the options.

For choices involving gains, see Sepulveda, Usher, Davies, Benson, Ortoleva, De Martino (2020, eLife)

aDDM Parameter Estimates

$evidence_t = evidence_{t-1} + \mu_t + e_t$

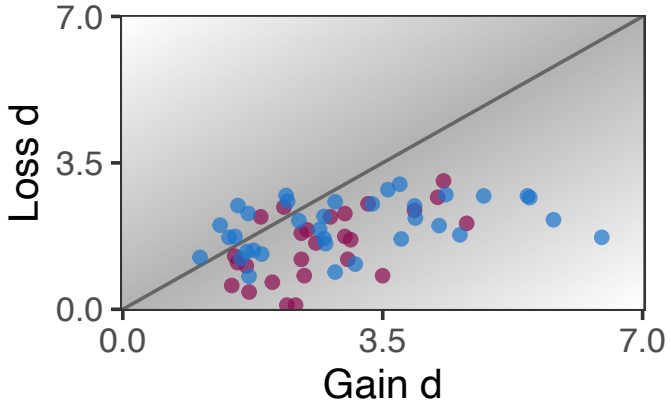
Looking left: $\mu_t = d(V_L - \theta V_R)$

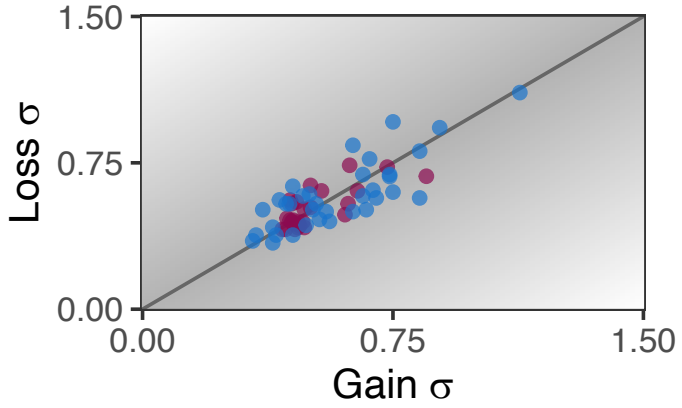
Looking right: $\mu_t = d(\theta V_L - V_R)$

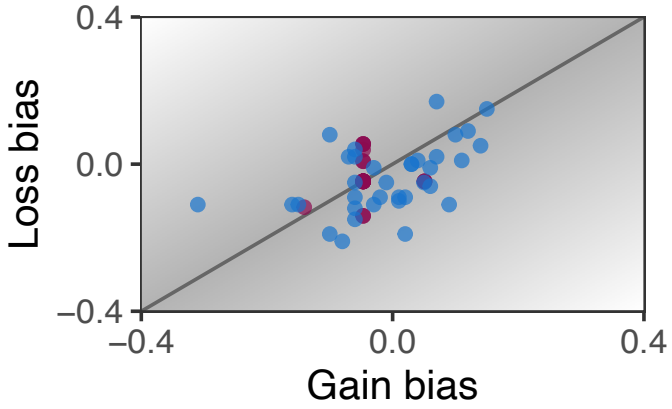
$e_t \sim N(0, \sigma^2)$

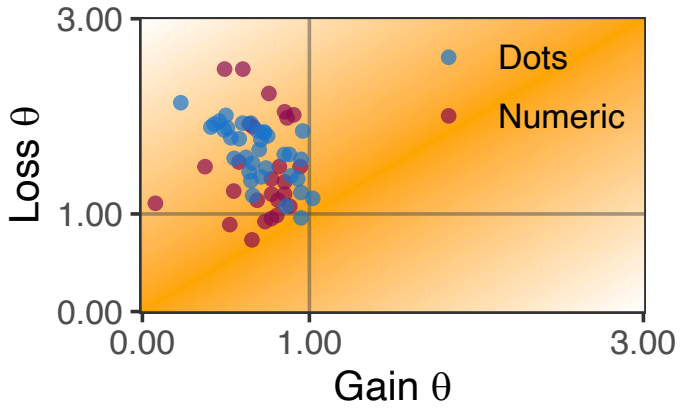
$evidence_0 = b$

*Each point is a single subject.



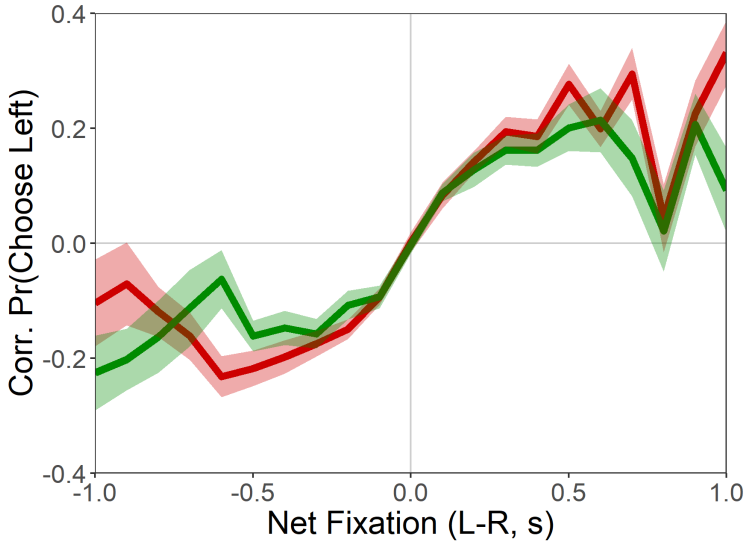


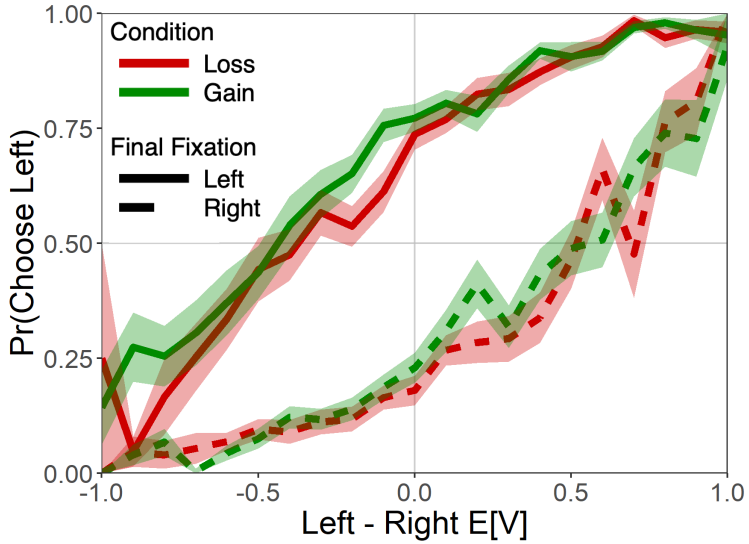




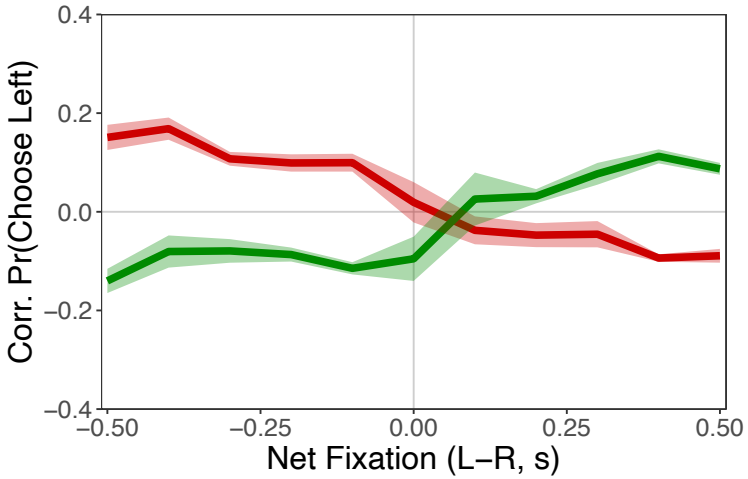
See Enkavi, Goldman, Yang, Rangel (*in prep*) for aDDM toolbox in Julia. It's super fast!

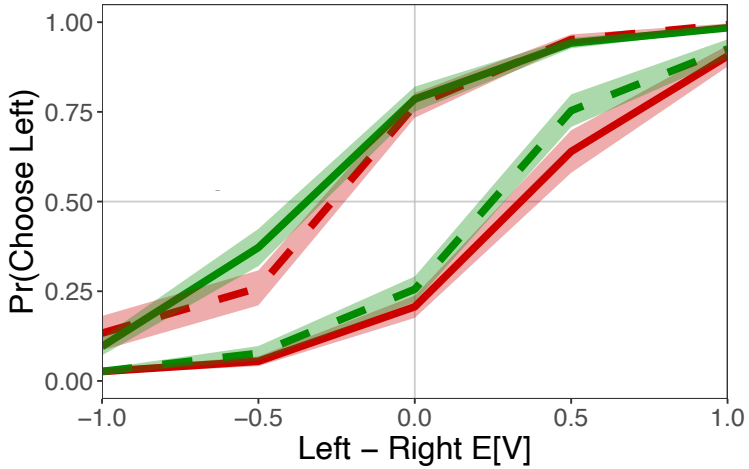
Observed Data
(Dots Task)



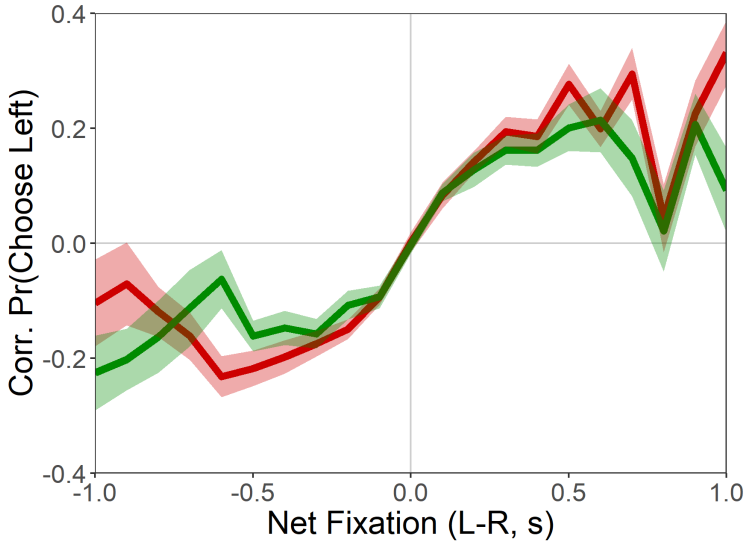


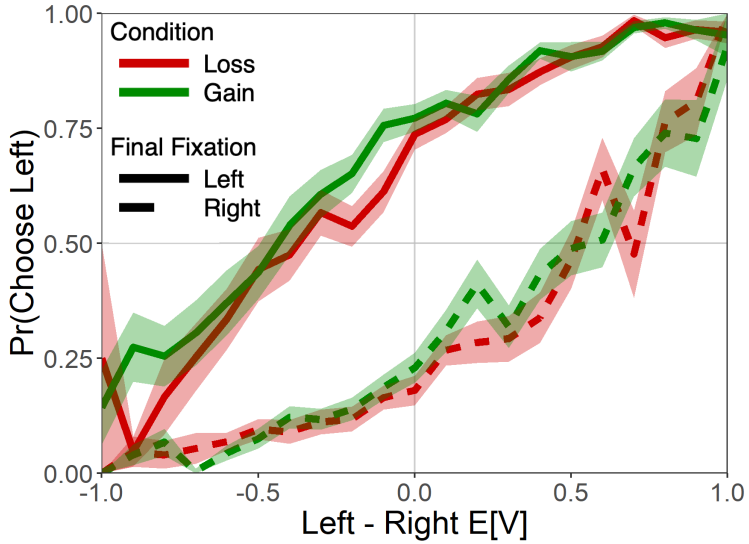
Simulations with
θ bounded in (0,1)



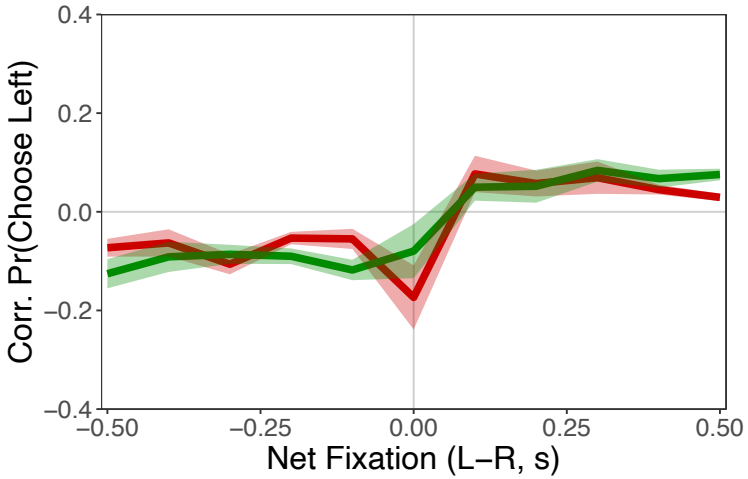


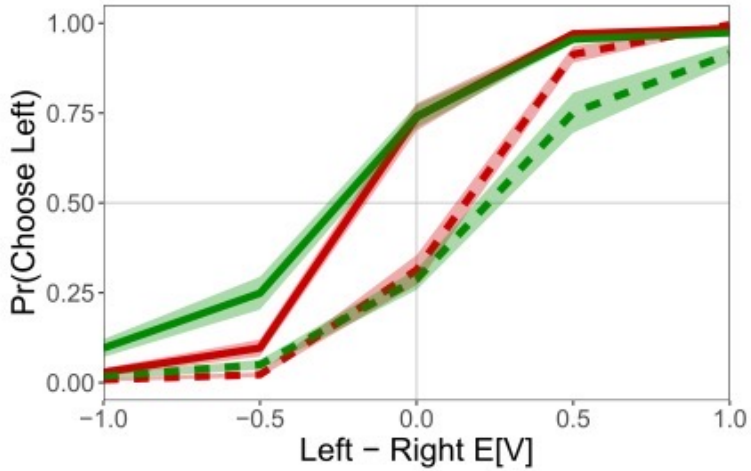
Observed Data
(Dots Task)



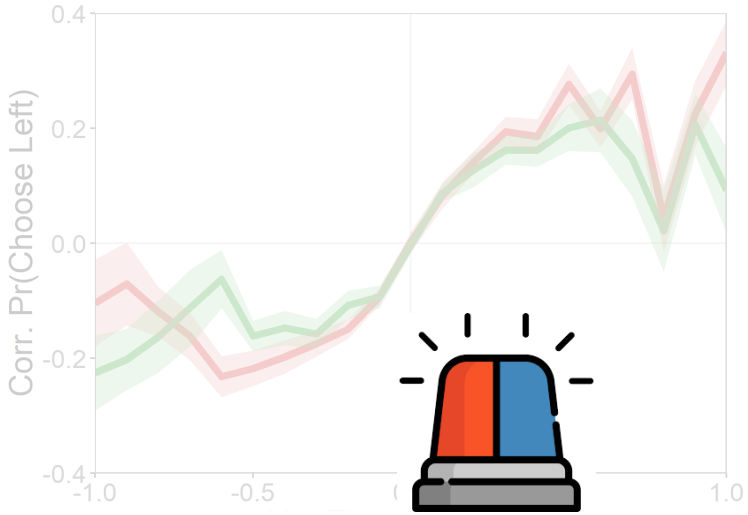


Simulations with
$\boldsymbol{\theta > 1}$ **in losses**





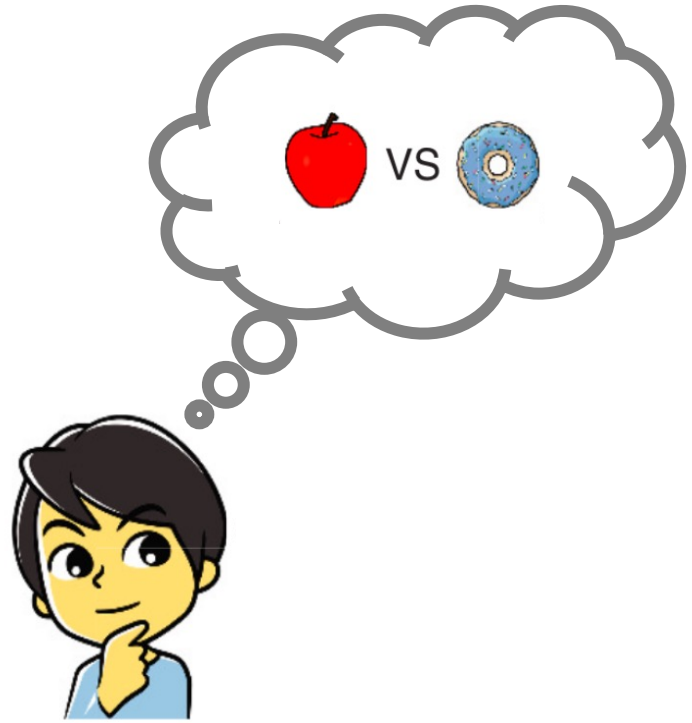
Observed Data
(Dots Task)



Intuition Police:
What the heck does $\theta > 1$ intuitively mean?

Simulations with
$\theta > 1$ in losses

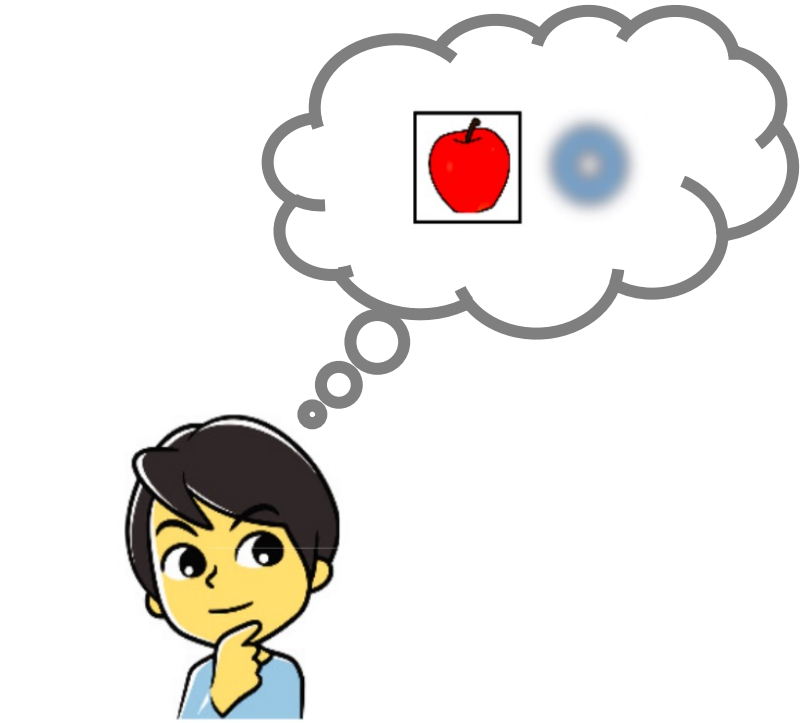
Intuition for $\theta \in (0,1)$



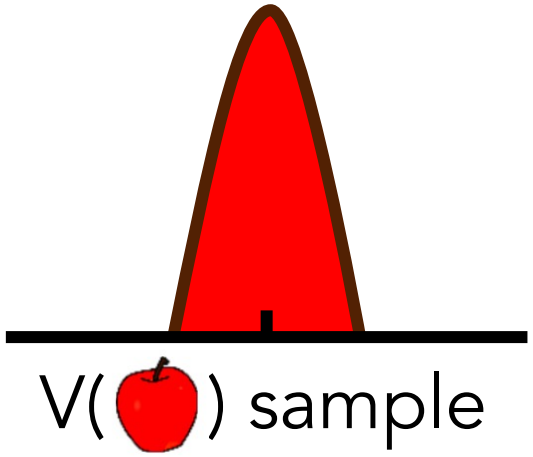
V( ) = V( )

See Jang, Sharma, Drugowitsch (2021, eLife); Callaway, Rangel, Griffiths (2021, PLoS Comput Bio)

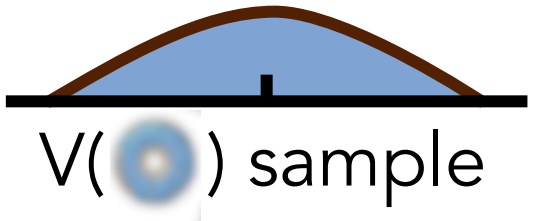
Intuition for $\theta \in (0,1)$



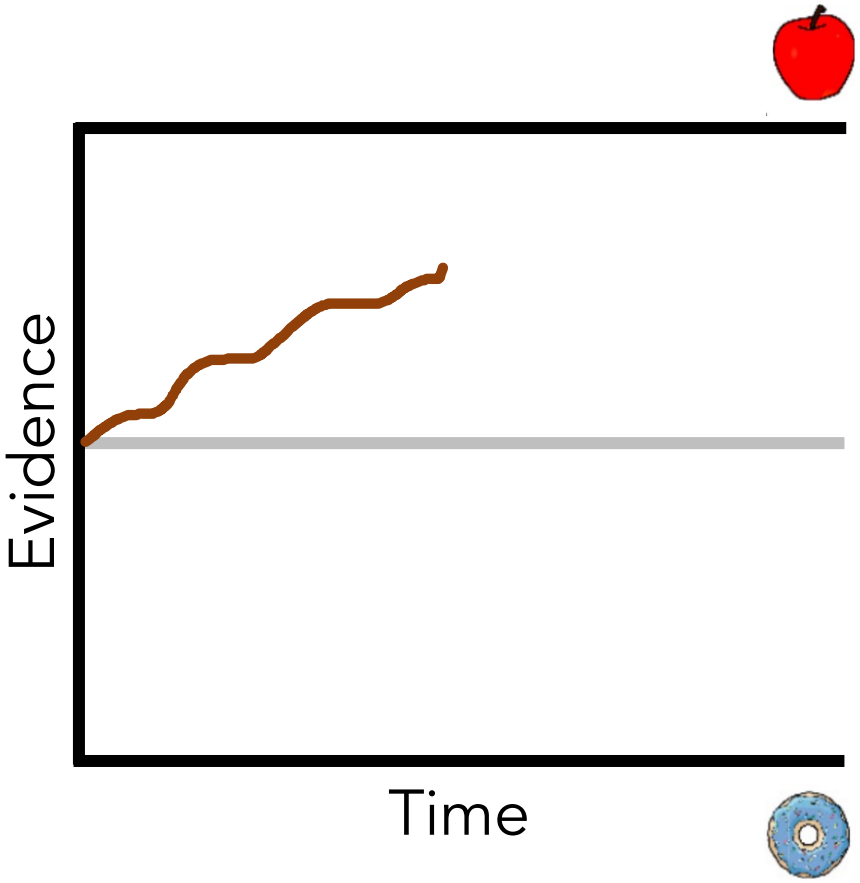
V( ) = V( )



V( ) sample

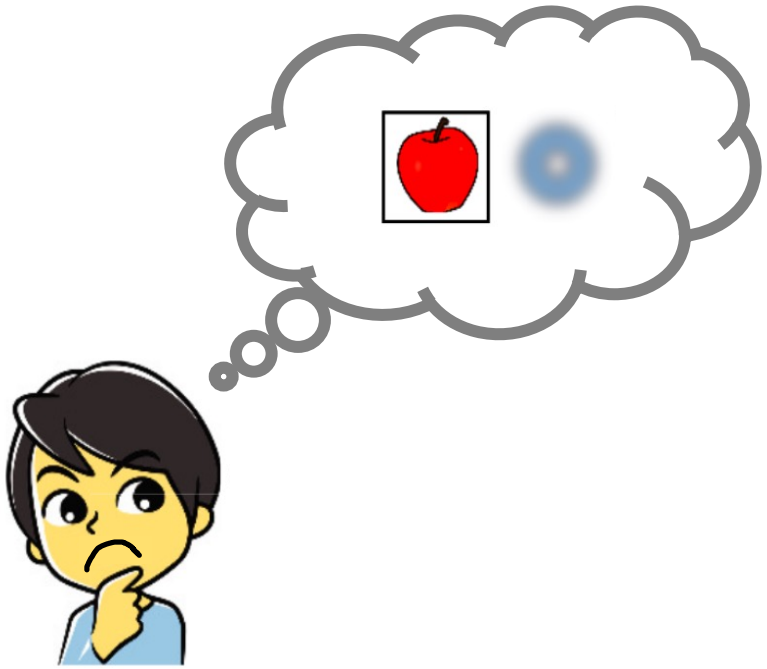


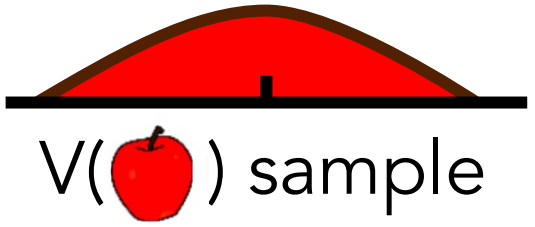
V( ) sample

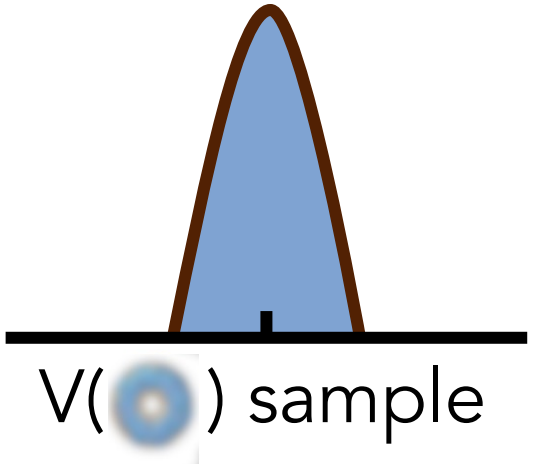


See Jang, Sharma, Drugowitsch (2021, eLife); Callaway, Rangel, Griffiths (2021, PLoS Comput Bio)

Intuition for $\theta > 1$







See Jang, Sharma, Drugowitsch (2021, eLife); Callaway, Rangel, Griffiths (2021, PLoS Comput Bio)

Moving Towards a More Intuitive Explanation

$$Evidence_t = Evidence_{t-1} + d(V_L - \theta V_R) + \epsilon_t$$

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"Goal-Relevant" Evidence Accumulation

$$Evidence_t = Evidence_{t-1} + d(G_L - \theta G_R) + \epsilon_t$$

Attention modulates information most relevant for the goal of the decision-maker, not value.

Sepulveda, Usher, Davies, Benson, Ortoleva, De Martino (2020, eLife); See also Kim, Shimojo, O'Doherty (2006, eLife)

"Goal-Relevant" Evidence Accumulation

$$Evidence_t = Evidence_{t-1} + d(G_L - \theta G_R) + \epsilon_t$$

Figures from Sepulveda, Usher, Davies, Benson, Ortoleva, De Martino (2020, eLife); See also Kim, Shimojo, O'Doherty (2006, eLife)

"Goal-Relevant" Evidence Accumulation in Losses

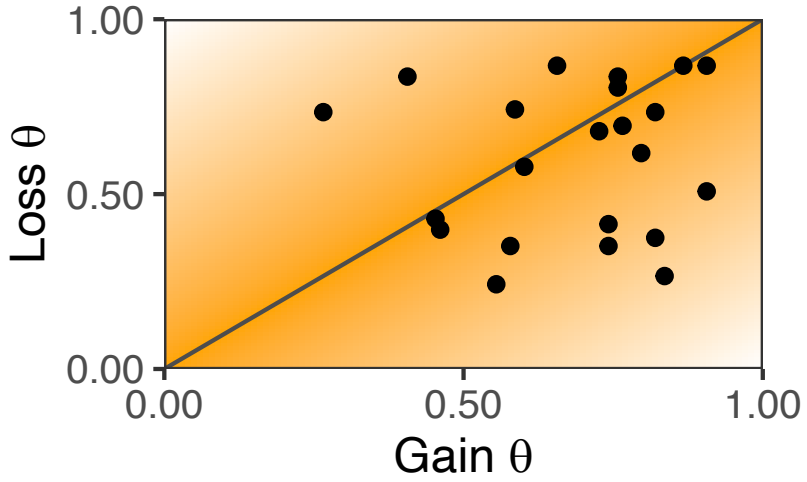
$$Evidence_t = Evidence_{t-1} + d(G_L - \theta G_R) + \epsilon_t$$

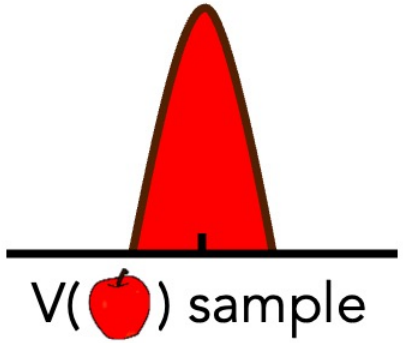
$$G_L = V_L - \min(V) \geq 0$$
$$G_R = V_R - \min(V) \geq 0$$

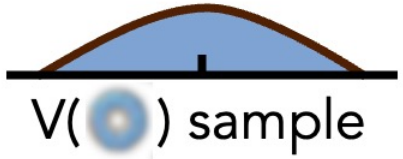
Sepulveda, Usher, Davies, Benson, Ortoleva, De Martino (2020, eLife); See also Kim, Shimojo, O'Doherty (2006, eLife)

"Goal-Relevant" Evidence Accumulation in Losses

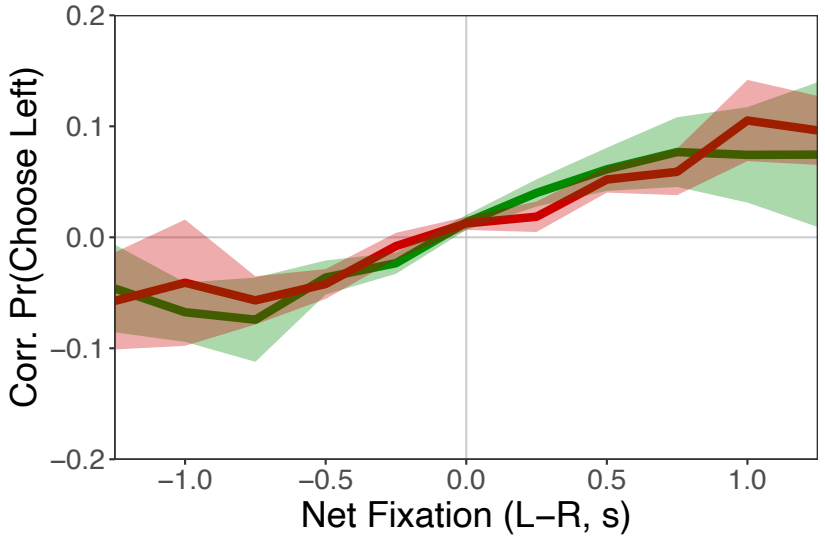
$AIC_{\text{Goal-Relevant aDDM}} < AIC_{\text{Unbounded } \theta \text{ aDDM}}$ (p=.07)

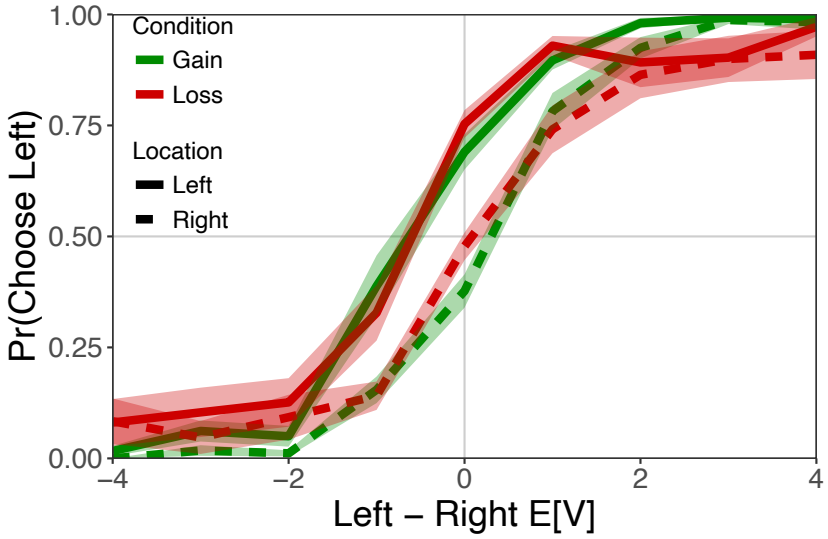




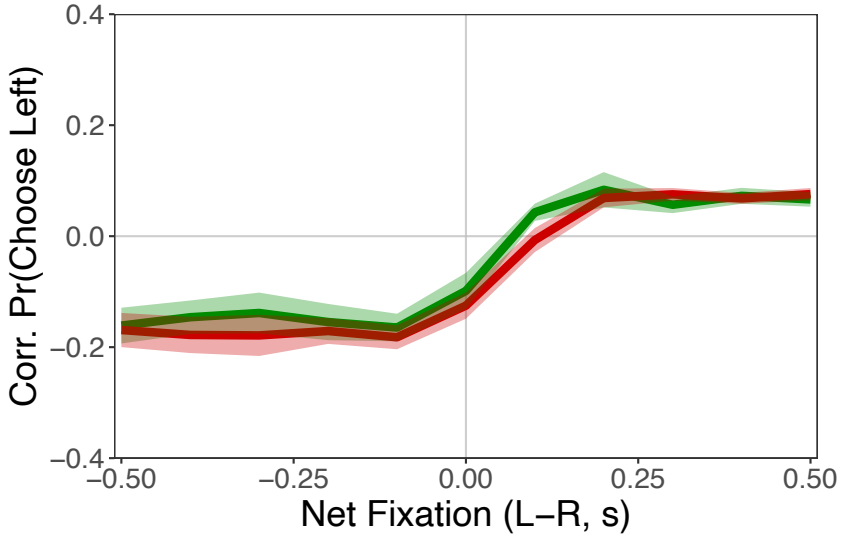


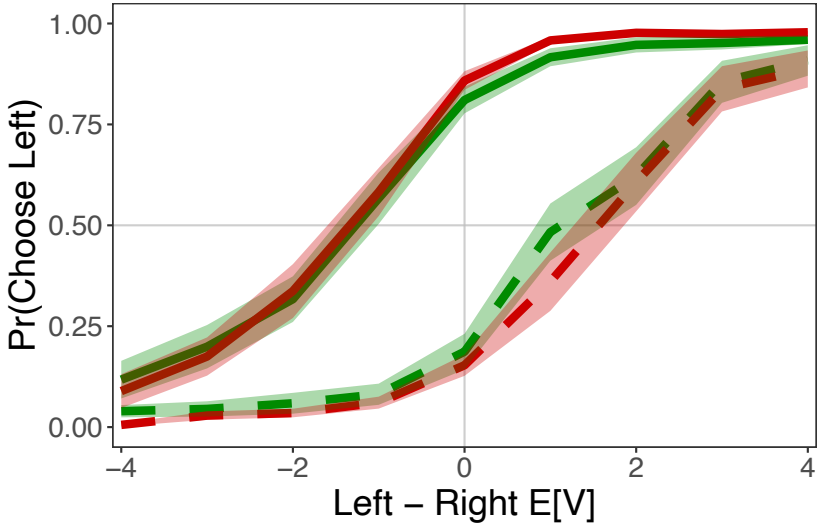
Observed Data
(Numeric Task)





Simulations with
Goal-Relevant Evidence

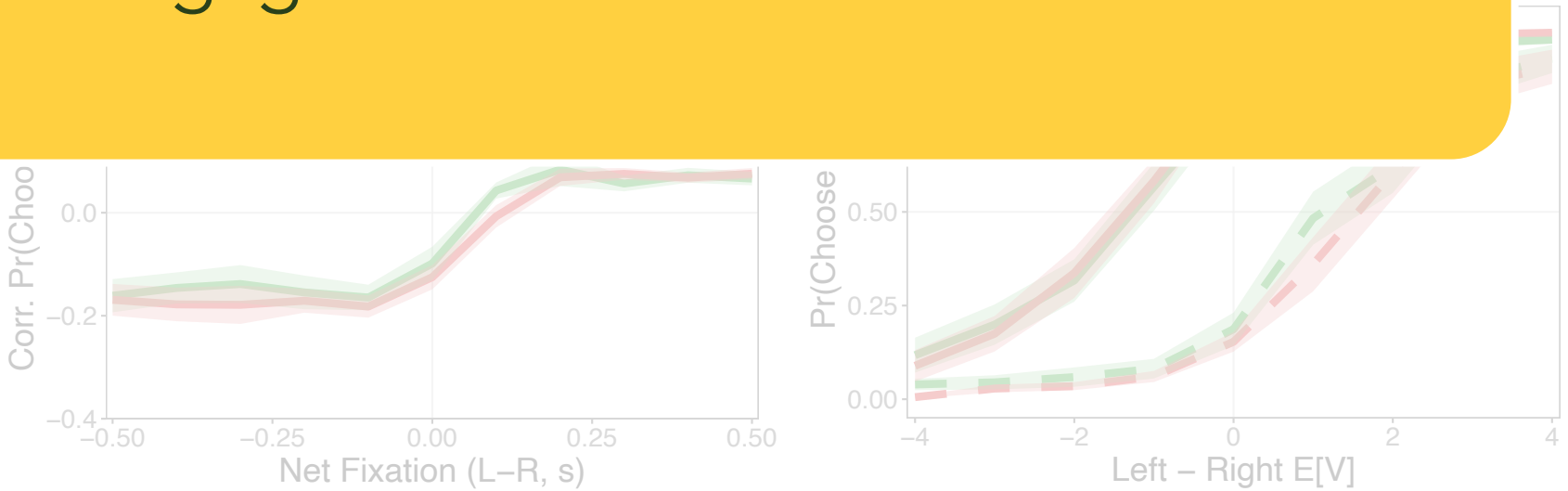




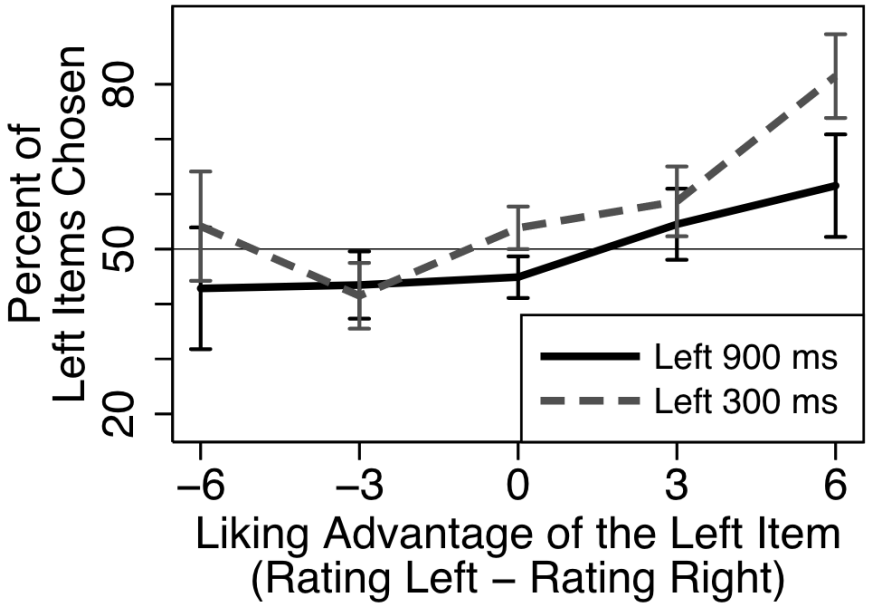
Observed Data
(Numeric Task)

In choices involving negative-outcome lotteries, people may be accumulating goal-relevant evidence instead of value samples.

Simulations with
Goal-Relevant Evidence



Are people always accumulating "goal-relevant" information in losses?



$\theta \in (0,1)$

Negative value signals, not goal-relevant evidence.

Armel, Beaumel, Rangel (2008, JDM)

Are people always accumulating "goal-relevant" information in losses?

PUZZLE:

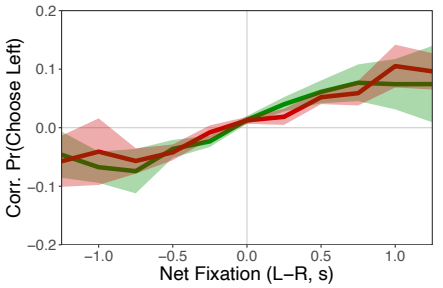
When do people switch between accumulating "goal-relevant" information and value signals?

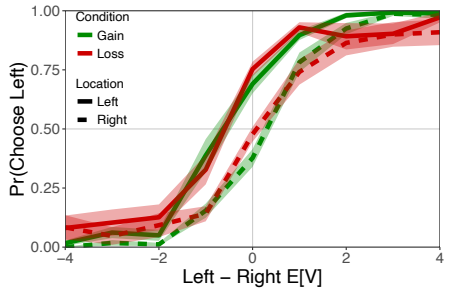
Is there something about the nature of the stimuli that causes this switch?

Armel, Beaumel, and Rangel (2008, JDM)

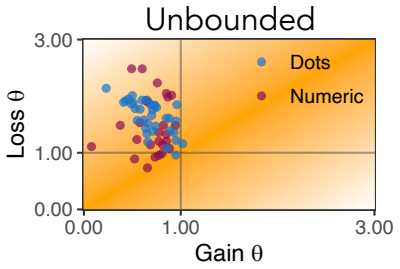
Conclusion

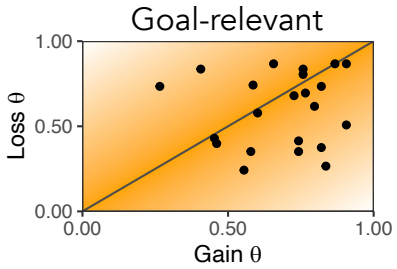
Contrary to one of the assumptions of the aDDM, attention to an option still pushes choice towards that option, even in losses.





The aDDM with an unbounded attentional parameter and with goal-relevant evidence are both capable of capturing this effect, though only the latter seems to make intuitive sense.





<u>Puzzle</u>: There seems to be evidence that in choices between losses, people might not always be accumulating goal-relevant evidence. Any ideas when they do?