An introduction to RL

II CMB workshop

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Why computational models?

- *All models are wrong, but some are useful (Box, 1974)*
- *All models are wrong, but some make you think!* (me, some days ago).
- But... which models make you think?

Why computational models?

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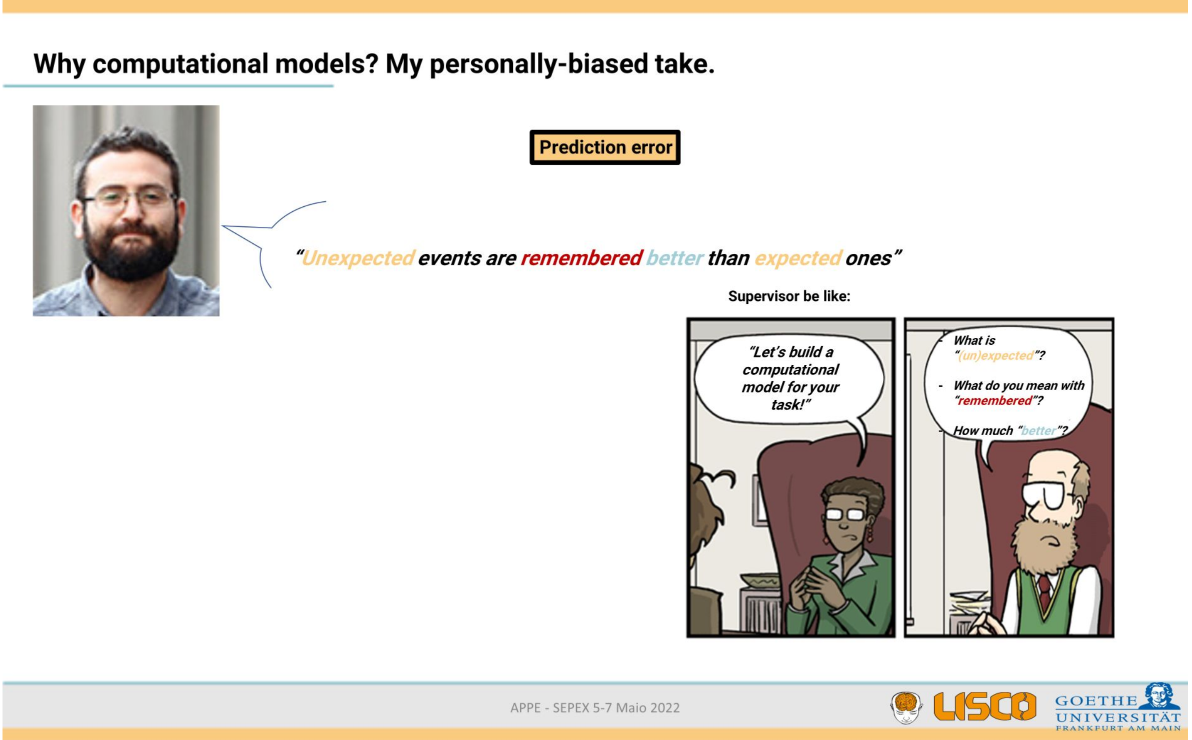
This is (*clearly*) me in the last CMB workshop

(CIMCYC, 2022; Colored picture)

Why computational models?

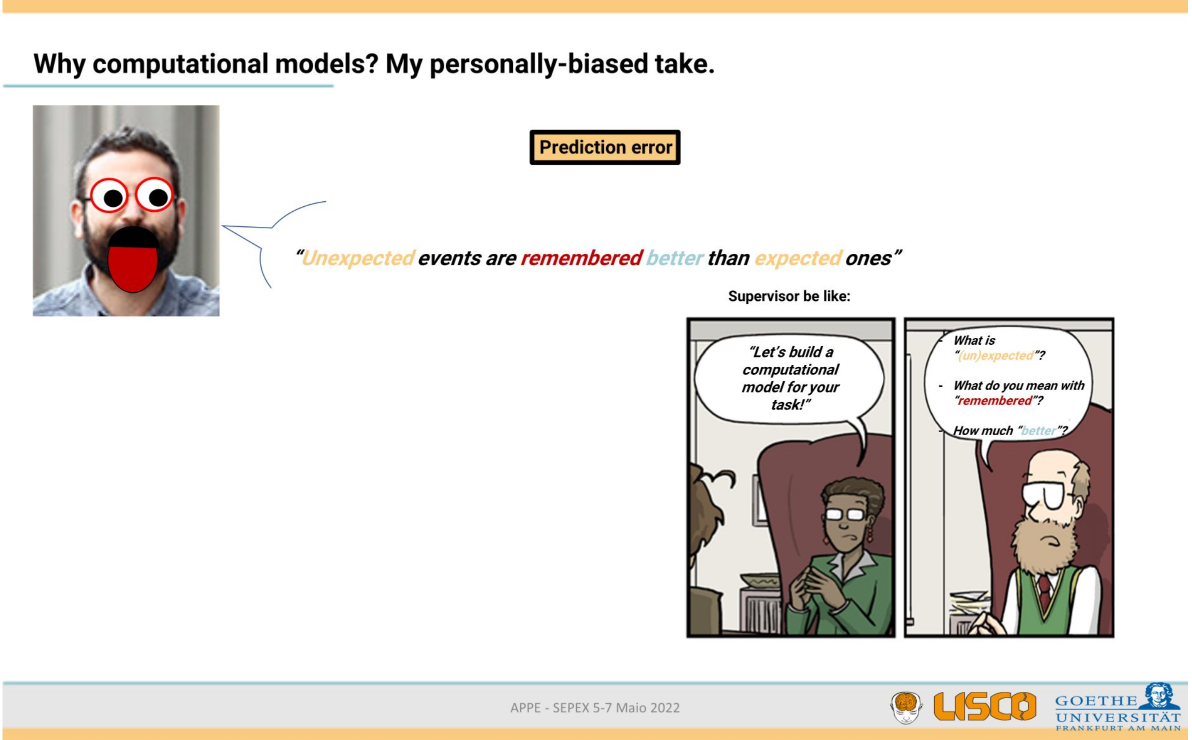
- But... which models make you think?



Why computational models?

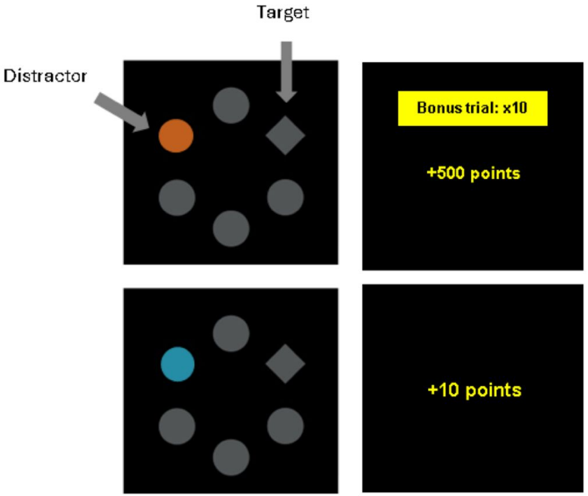
- But… which models make you think?

Existential *crisis* intensifies



Why computational models?

- My research problems, my (wrongs) models



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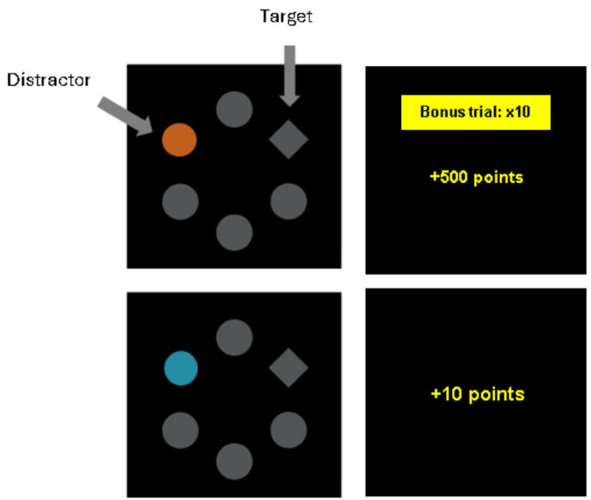
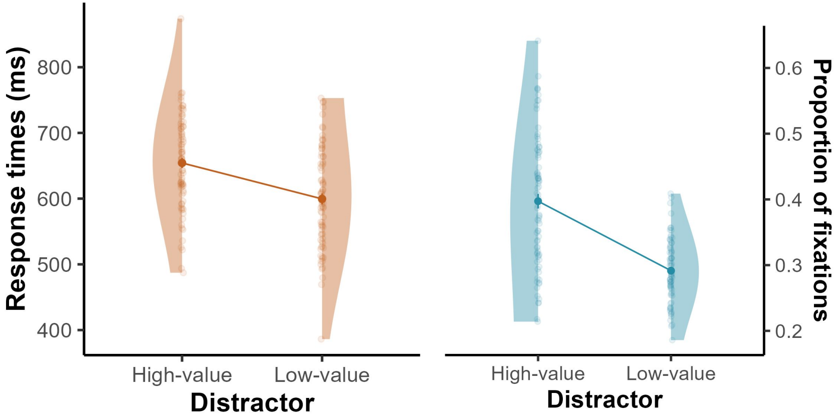


People attend to the high-value distractor even if it means losing reward



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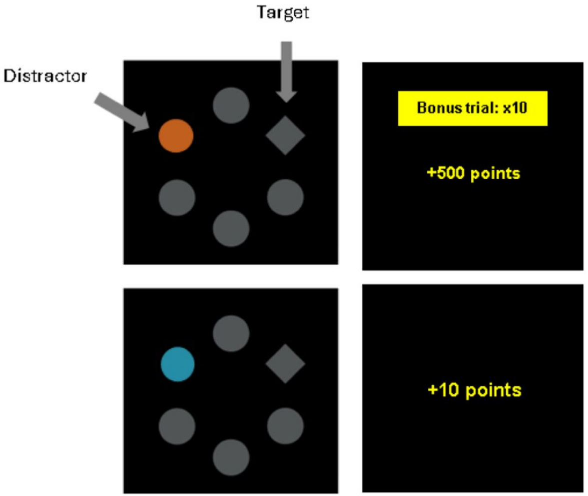
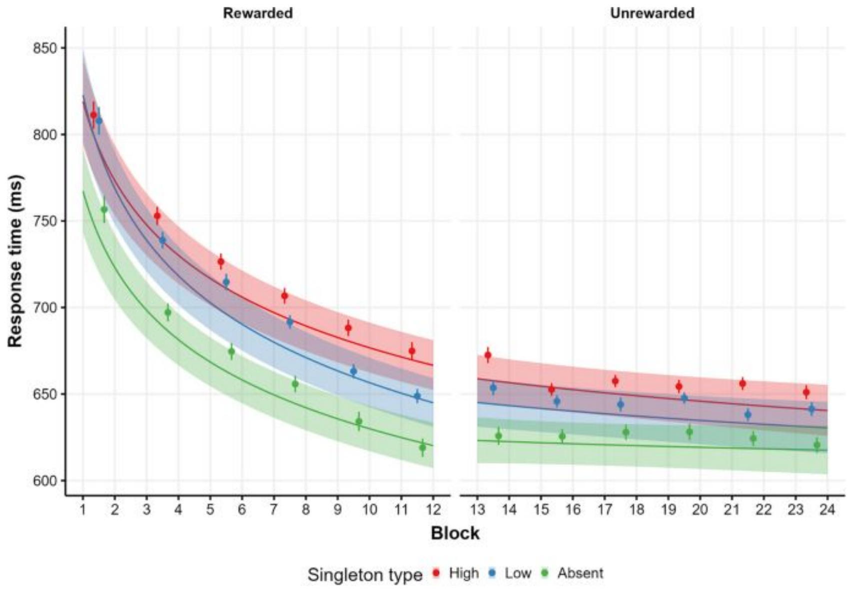


Needs experience to develop   And is *persistent* to omission of reward



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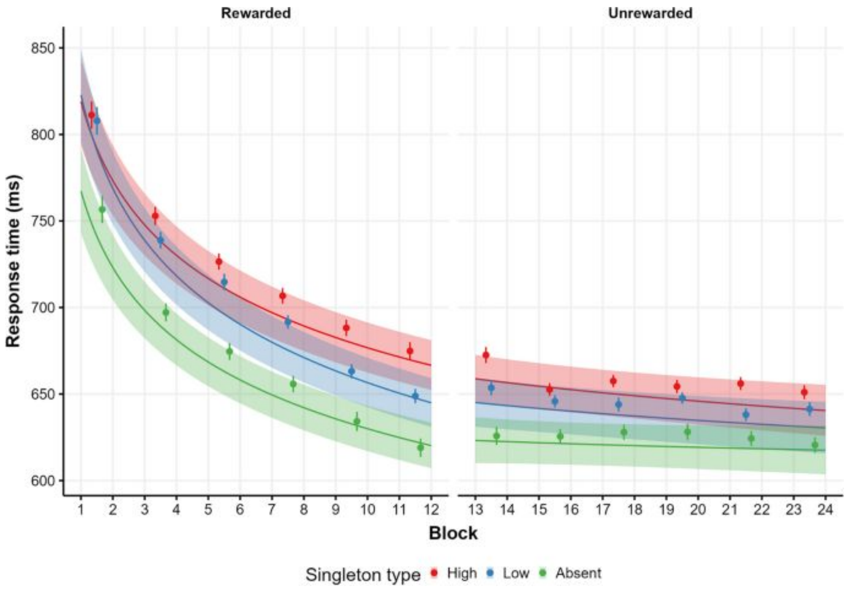
What is the *structure* of my model?



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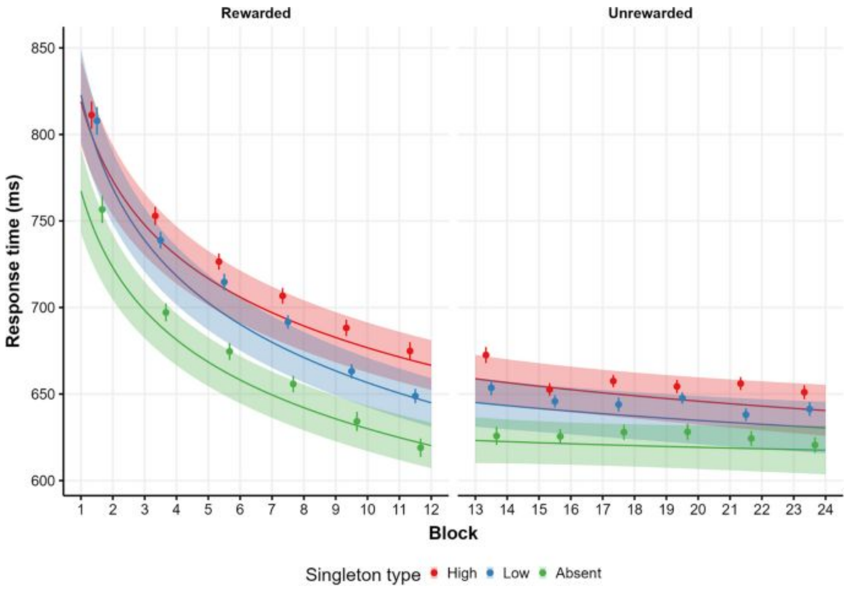

$$RT_i \sim N(\mu, \sigma)$$

μ What is the size of the effect?

$$= \beta_{distractor} \cdot x_{distractor} + \beta_{Block} \cdot x_{Block} + \beta_{Block \cdot Distractor} \cdot x_{Block} \cdot x_{Distractor}$$

How does the effect change through blocks?

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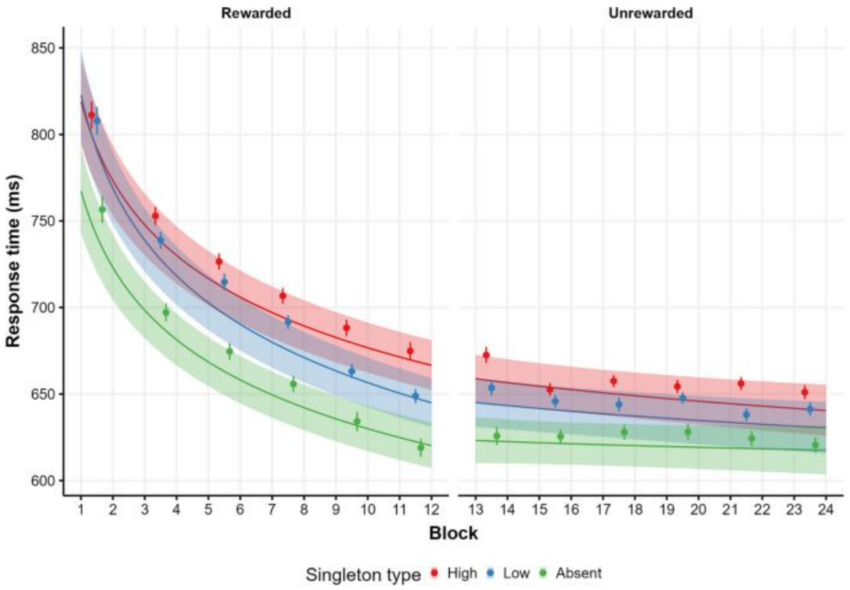

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How does the effect change through blocks?

Inferences in this model are just *fancy descriptives*

Why computational *cognitive* models?

- Computational models are any statistical model that *describes* the data-generating process in computational terms.

- A computational *cognitive* model is a statistical or mathematical model that aims to ***explain*** the data-generating process based on theory.

Why computational *cognitive* models?

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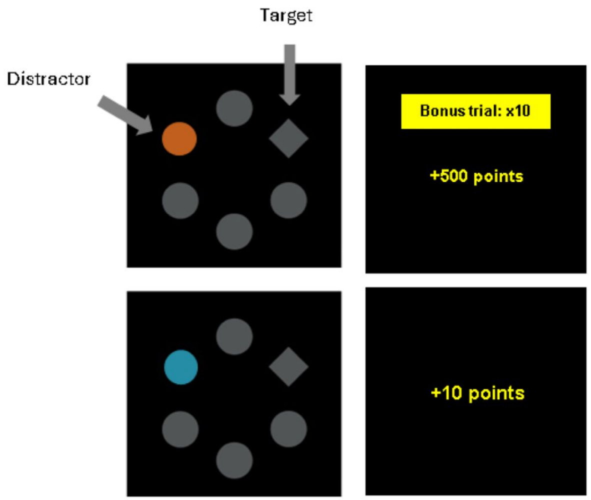

*"An a priori neutral stimulus that **gains learned value through experience** is **attended to more** than other equally physically salient stimuli."*

Modelling attention with RL

*"An a priori neutral stimulus that **gains learned value through experience** is **attended to more** than other equally physically salient stimuli."*

- What is ***learned value***?
- What is ***experience***?
- What is **attention**?

Modelling attention with RL

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- What is ***experience***?

Modelling attention with RL

- What is ***learned value***?
- What is ***experience***?

The Rescorla-Wagner model (1972) of Pavlovian learning

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\lambda_i - v_{d,1-i})$$

Modelling attention with RL

- What is ***learned value***?
- What is ***experience***?

The Rescorla-Wagner model (1972) of Pavlovian learning

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\overbrace{\lambda_i - v_{d,1-i}}^{\boldsymbol{\delta_i}})$$

$v_{d,i}$ $v_{d,1-}$

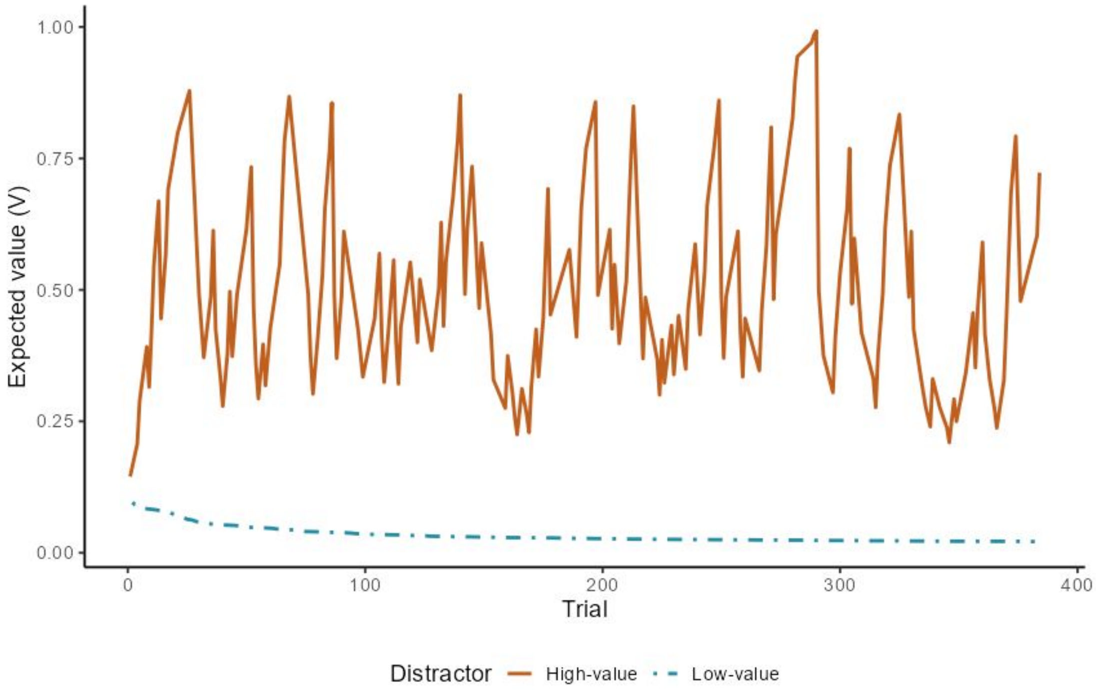
The **value of distractor d in trial i** is based on the **value of distractor d in the previous trial (1-i)**, plus the difference between the ***expected value for distractor d in trial 1-i*** and the ***actual perceived value observed in trial i***, the ***prediction error***.

λ_i $\boldsymbol{\delta_i}$

Modelling attention with RL

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\overbrace{\lambda_i - v_{d,1-i}}^{\delta_i})$$

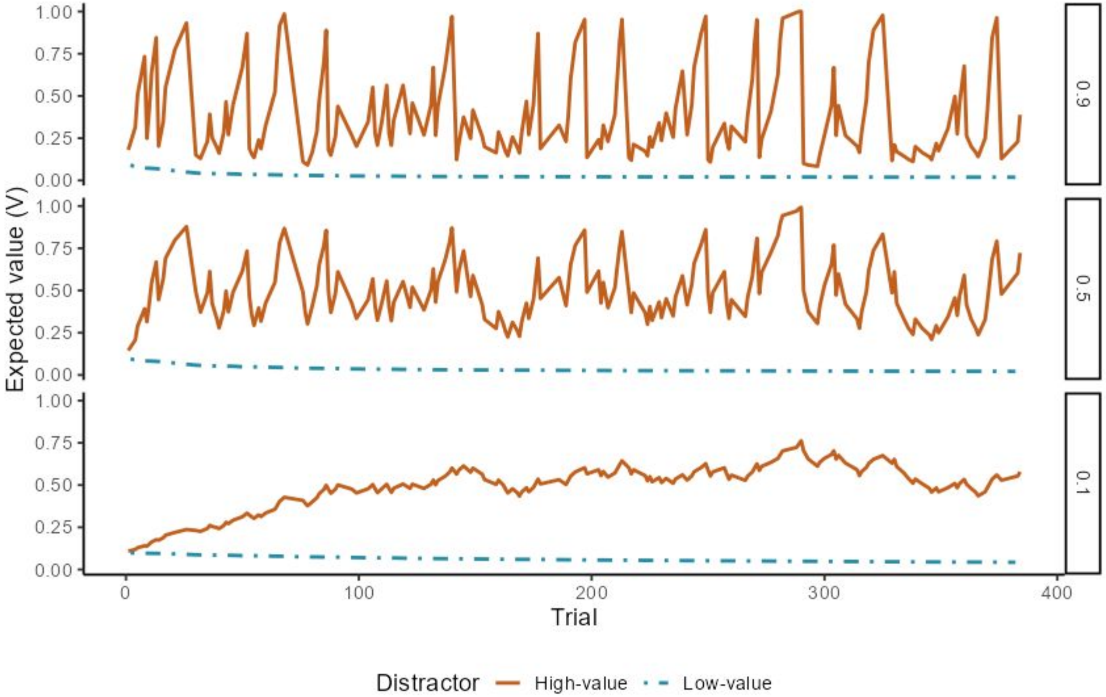
Let's simulate!



Modelling attention with RL

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\overbrace{\lambda_i - v_{d,1-i}}^{\delta_i})$$

The learning rate



Prediction errors *has a big impact on value updating, and learning is faster and more volatile*

+

−

Prediction errors *have less impact on value updating, and learning is slower, but more stable*

Why computational *cognitive* models?

- What is **attention**?

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\underbrace{\lambda_i - v_{d,1-i}}_{\delta_i})$$

$$\boxed{\alpha = |v_{d,1-i}|}$$

Attention matches *expected value*

Mike Le Pelley

Modelling attention with RL

- What is **attention**?

Mike Le Pelley

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\underbrace{\lambda_i - v_{d,1-i}}_{\delta_i})$$

$$\boxed{\alpha = |v_{d,1-i}|}$$

Mapping ***attention*** to *behavior*:

$$p_i \sim Bernouilli(\theta)$$

$$\theta = logit^{-1}(\beta_{attention} \cdot \alpha)$$

The latent attention (α) increases the probability of looking at the distractor in a particular trial (p_i).

Modelling attention with RL

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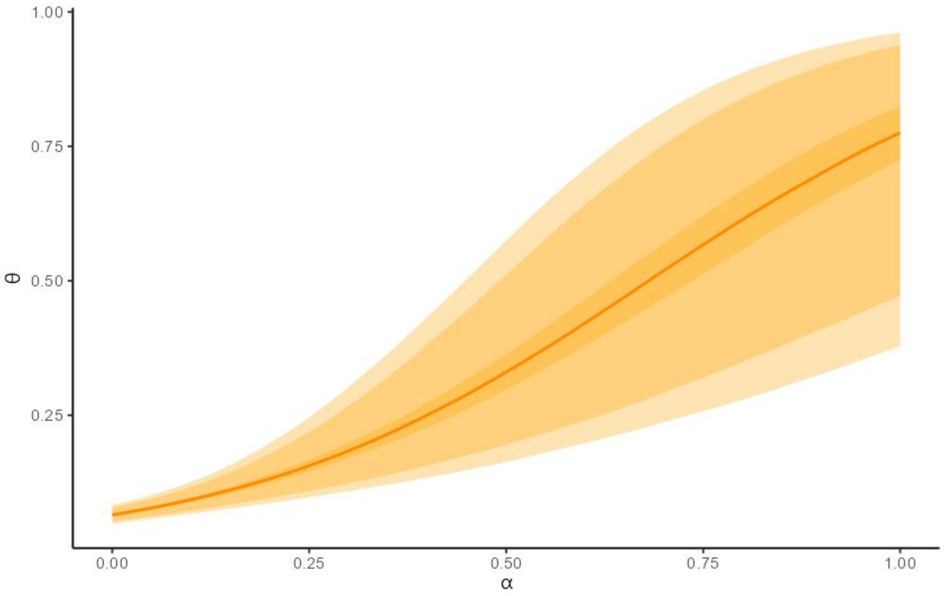
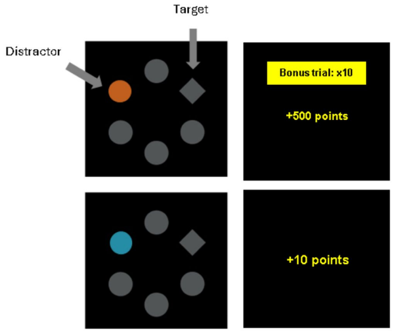
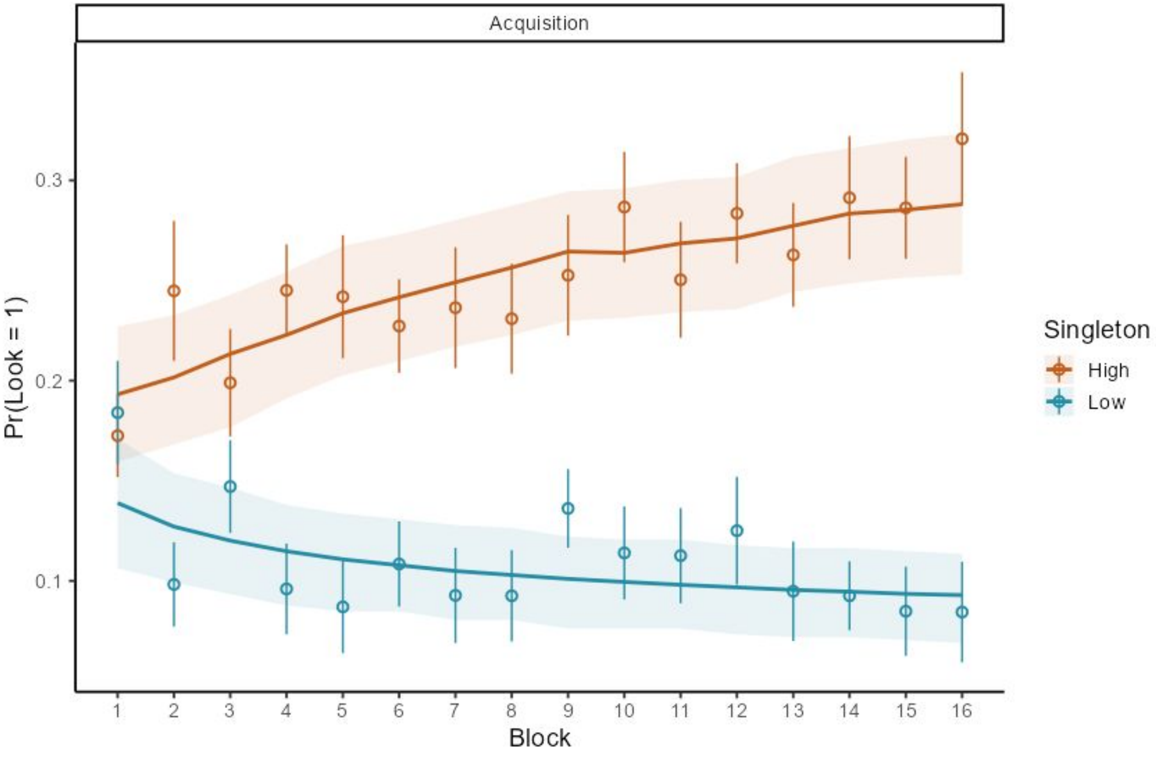
$$\theta = logit^{-1}(\boldsymbol{\beta}_{\boldsymbol{attention}} \cdot \boldsymbol{\alpha})$$



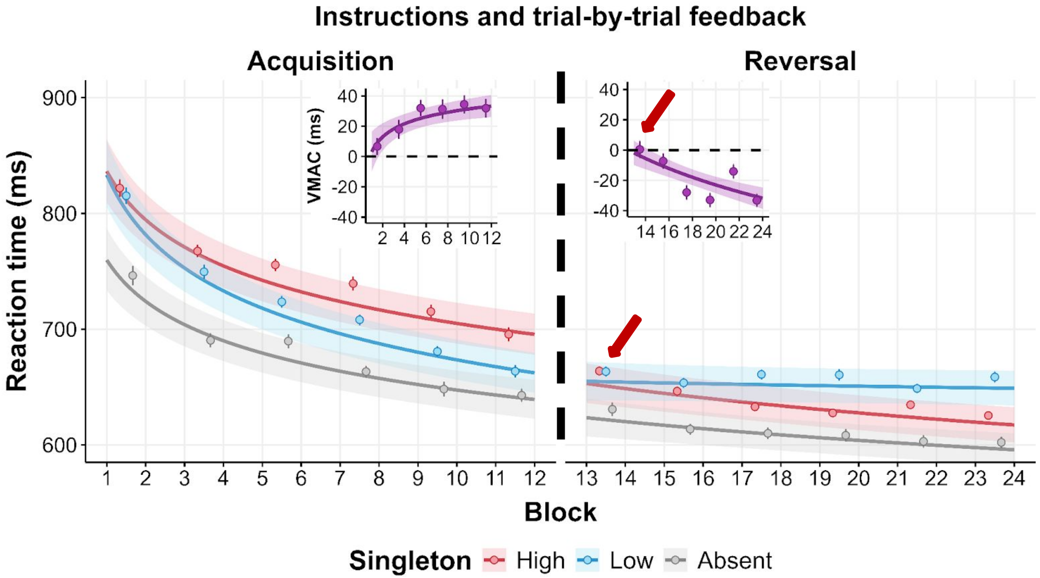
Modelling attention with RL





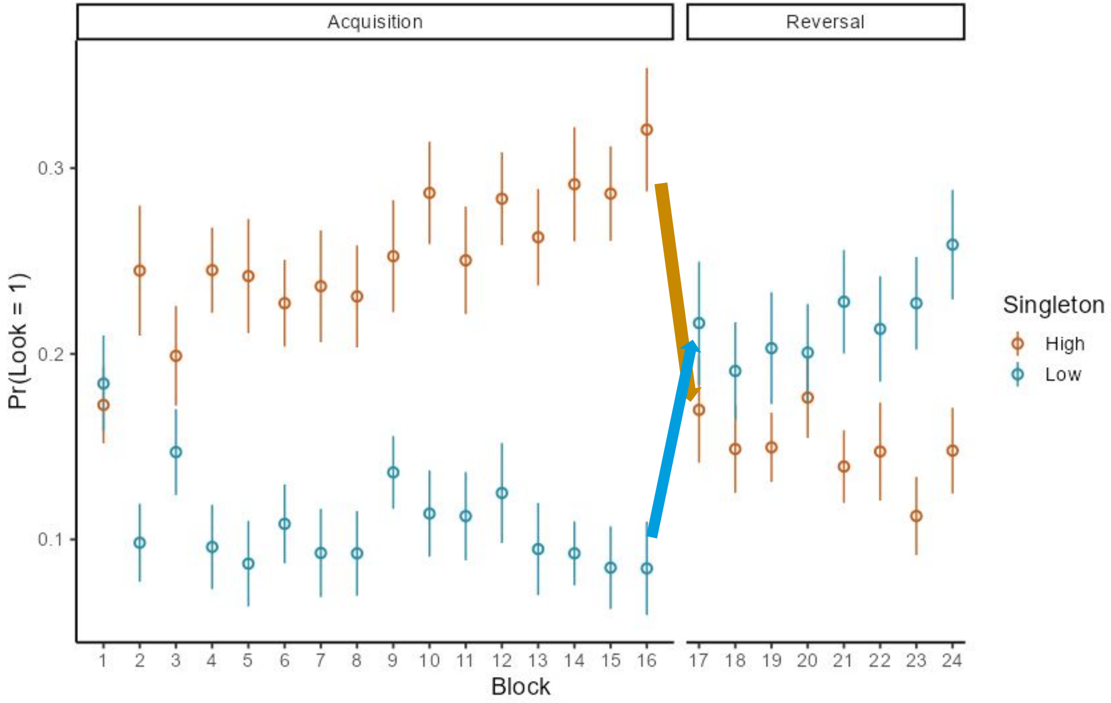
Testing hypothesis with the same data

Pablo



Reversal is ***extremely fast***

Testing hypothesis with the same data



Reversal is ***extremely fast***

Testing hypothesis with the same data

Fran

$$v_{high-value} = p_{reversal} \cdot v_{low-value} + (1 - p_{reversal}) \cdot v_{high-value}$$

$$v_{low-value} = p_{reversal} \cdot v_{high-value} + (1 - p_{reversal}) \cdot v_{low-value}$$

Testing hypothesis with the same data

Fran

Verbal instructions update the expected value of the distractors!

$$v_{high-value} = p_{reversal} \cdot v_{low-value} + (1 - p_{reversal}) \cdot v_{high-value}$$

$$v_{low-value} = p_{reversal} \cdot v_{high-value} + (1 - p_{reversal}) \cdot v_{low-value}$$

… or maybe learning is just faster at the beginning of the reversal?

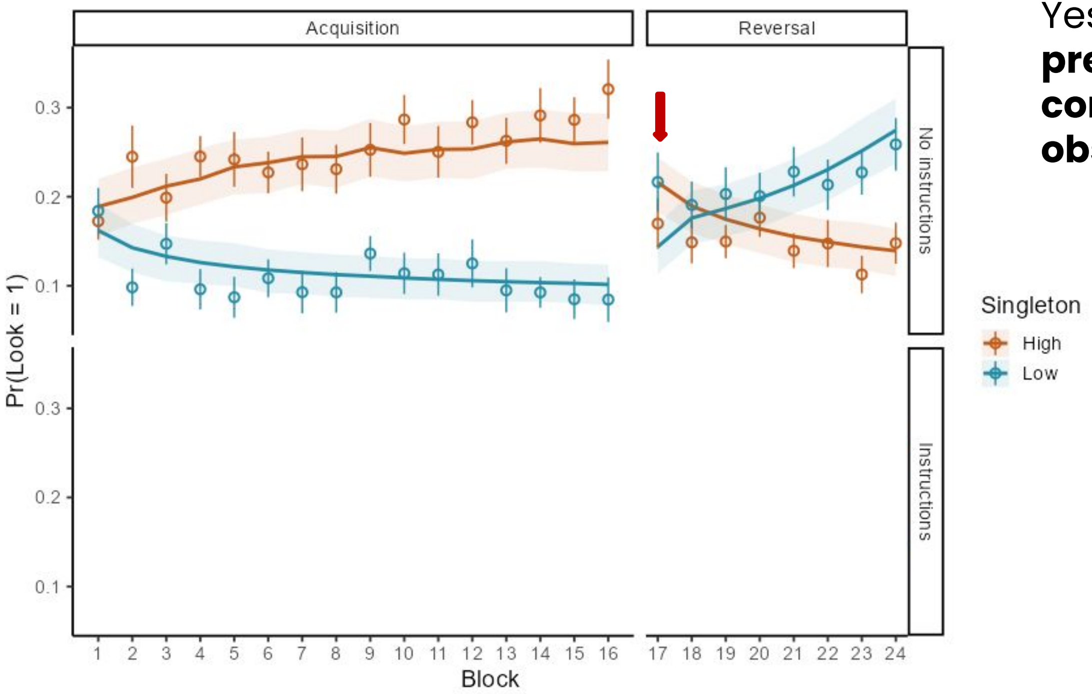
David

$$v_{d,i} = v_{d,1-i} + \beta\alpha(\overbrace{\lambda_i - v_{d,1-i}}^{\delta_i})$$

At the beginning of the reversal stage, the ***prediction error is larger***

Testing hypothesis with the same data

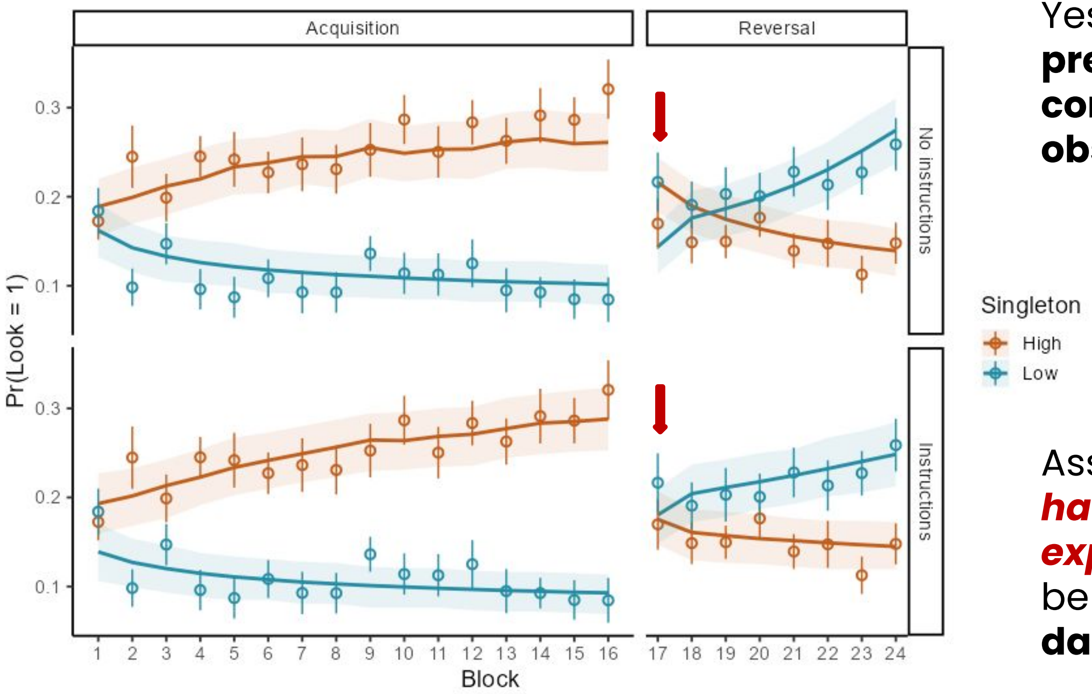
Model 1: Instructions have *no* effect



Yes, ***learning is faster***, but **predictions do not completely match observed data**

Testing hypothesis with the same data

Model 2: Instructions have an effect



Yes, ***learning is faster***, but **predictions do not completely match observed data**

Assuming that ***instructions have a direct effect*** on ***expected value*** seems to be a **better match for the data**

Take-home messages

- A model makes you think if…
  - Makes you **operationalize your constructs**
  - Makes you **define how your target constructs are related** at the latent, cognitive level
  - Allows you to make **specific predictions** based on theory
  - And most importantly, a model that makes you think ***always*** allows you to **test counterfactual predictions** based on a different state of the world, **a different theory**.

Thank you!

… and let’s start the hands-on session!

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