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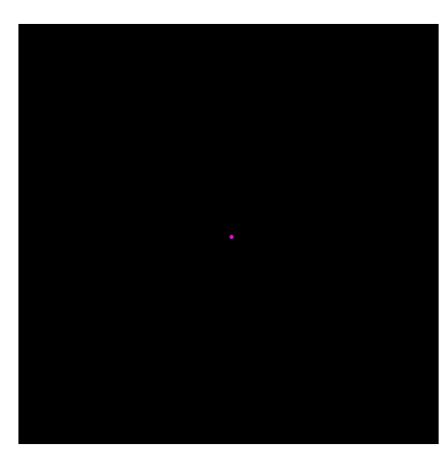
# Humans and mice fluctuate between external and internal modes of sensory processing

Veith Weilnhammer ERANET Meeting 02.09.2021



## **Bistable Perception**





### • Bistable perception:

Spontaneous transitions between to mutually exclusive perceptual states (Leopold et al. 2002).

### • Intermittend presentation:

Conscious experience is stabilized by perceptual history (Maloney et al. 2005, Pearson & Brascamp 2008).

### • Graded ambiguity:

How strong is perceptual history relative to the stimulus' signalto-ambiguity ratio?

### **Perceptual History vs. Signal-to-Ambiguity** В 2 sec

Block 1 • Stimulus-congruent Trial 1 SAR Adaptive Fix: 2.5 ± 0.125 sec Fixed Trial 2 2 3 5 6 Run С 100 5 Trial 10 Stimulus-Congruent 80 ę 60 Block 2 Trial 11 40 20 40 80 100 60 Adaptive SAR (%)

### • Stimulus-congruence:

Perceptual state matches stimulus information.

### • History-congruence:

Perceptual state matches preceding perceptual state

### • Psychophysical staircase:

SAR adjust the balance between stimulus- and history-congruence

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Weilnhammer et al. iScience 2021.

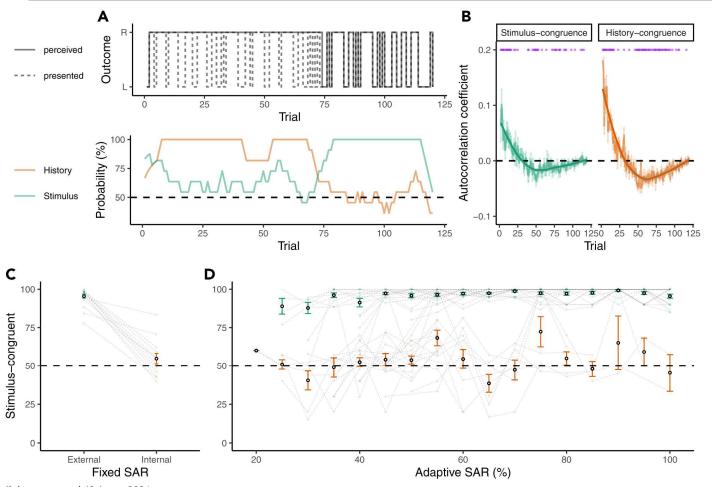
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### **Internal and External Mode**



### • Fixed SAR:

Bistable perception oscillates between internally- and externallyoriented modes.

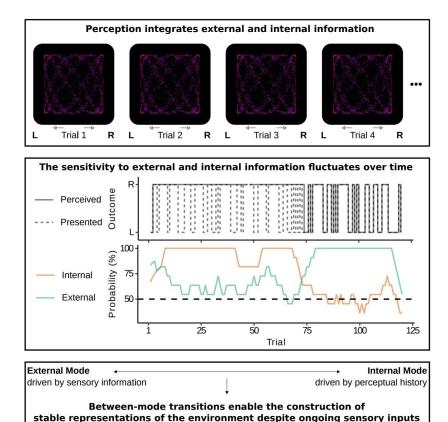
### • Duration: ~ 40 trials / ~ 3 min

Weilnhammer et al. iScience 2021.

## **Internal and External Modes**



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Weilnhammer et al. iScience 2021.

## Are internal and external modes specific to bistable perception?

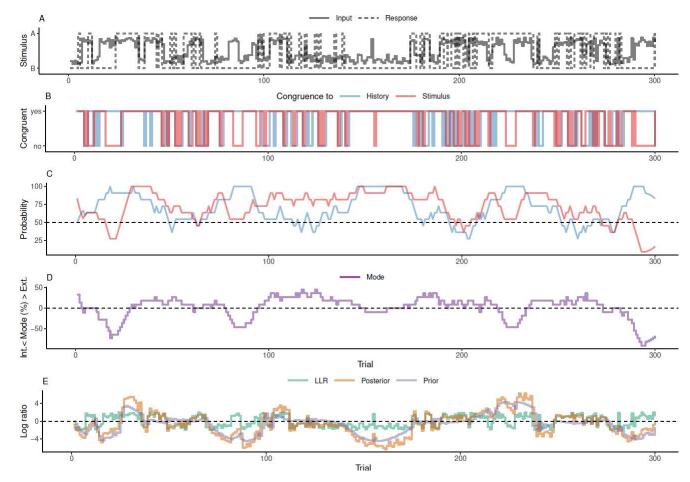
- Confidence database (N = 4500 humans, 22 million choices)
- IBL database (N = 196 mice, 2.5 million choices)

## What is the computational mechanism of between-mode transitions?

• Model simulations (N = 4500 agents, 22 million choices)

### Do between-mode transitions generate adaptive benefits for perceptual decisionmaking?

## Some definitions



Weilnhammer et al. bioRxiv 2021.





#### **Stimulus-congruence**:

Perception = external sensory evidence

#### **History-congruence**:

Perception = preceding perceptual state

#### Mode:

Dynamic prob. of stimulus-congruence -Dynamic prob. of history-congruence

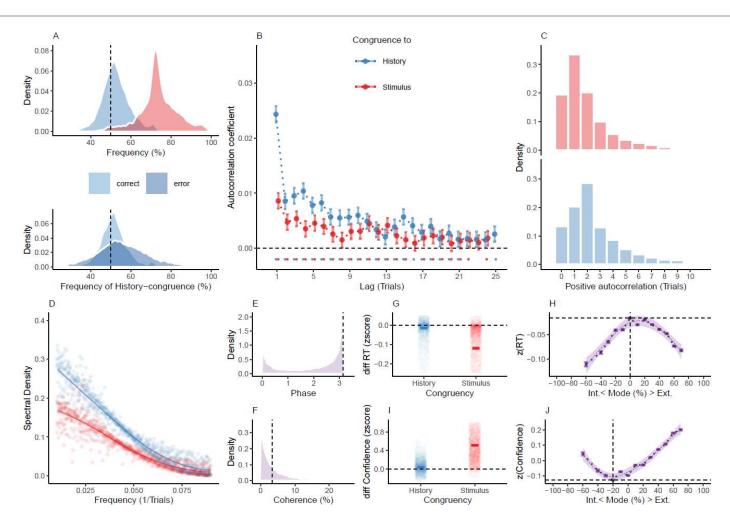
#### Modeling:

Bayesian modeling with likelihood, prior and posterior (as log ratios)

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Human data



# Human data – Serial dependency and Autocorrelation

yes Congruent no 100 150 50 0 В A С Congruence to 0.08 History 0.3 0.06 Density 0.03-Stimulus 0.2 Autocorrelation coefficient 0.02 0.1 0.00 100 40 80 60 Density Frequency (%) 0.3. correct error 0.2 0.06 0.04 0.02 0.1 0.00. 0.0 0.00 100 25 60 21 40 80 13 17 5 9 ò 2 3 5 9 10 4 6 8 Frequency of History-congruence (%) Lag (Trials) Positive autocorrelation (Trials)

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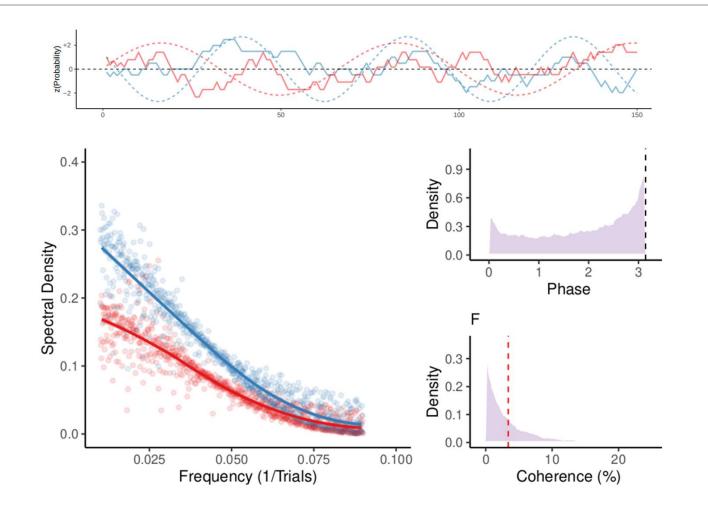
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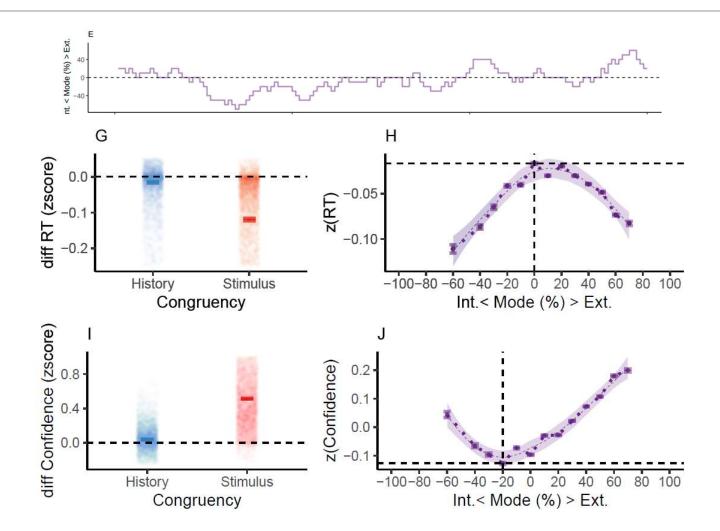
## Human data – 1/f noise







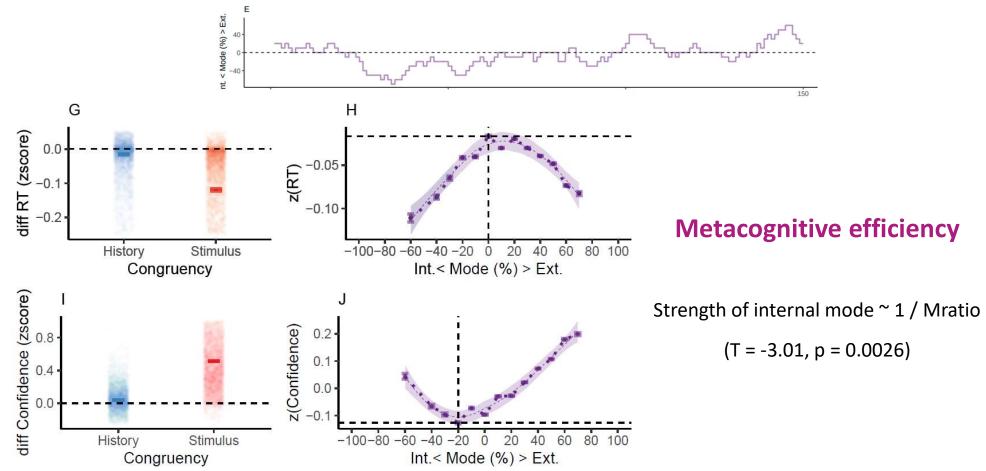
### Human data – RTs and Confidence







## Human data – Metacognitive efficiency

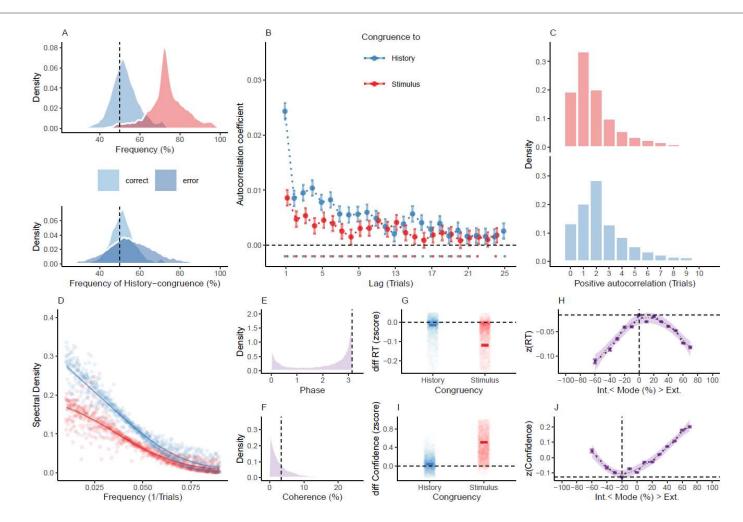


Weilnhammer et al. bioRxiv 2021.



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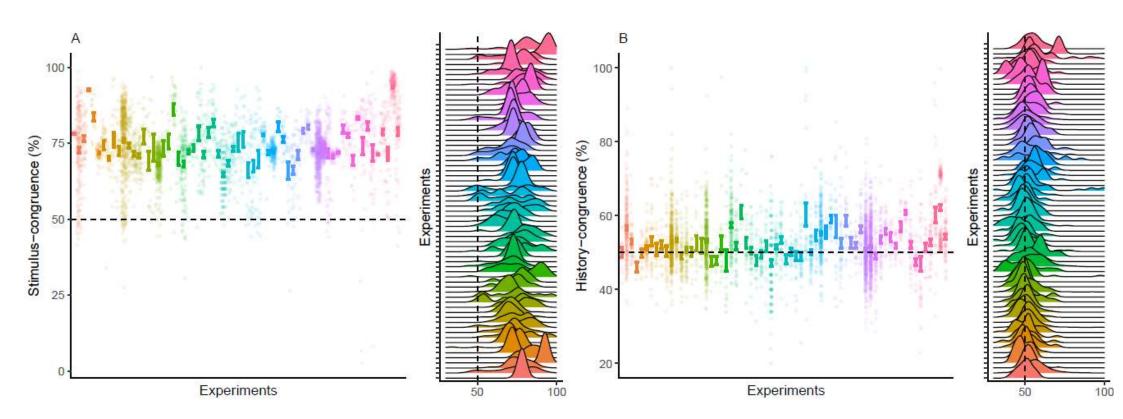
### Human data - Summary







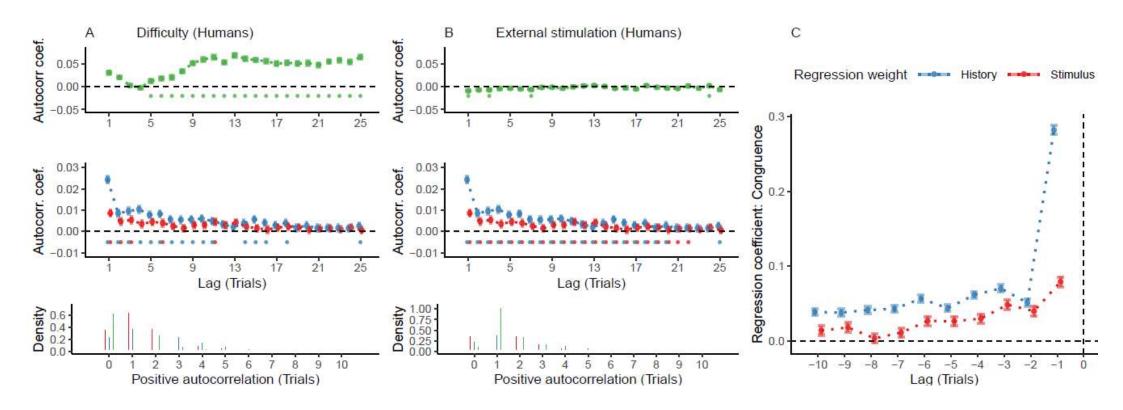
### Human data – Study effects?



# Human data – Difficulty and stimulus history?

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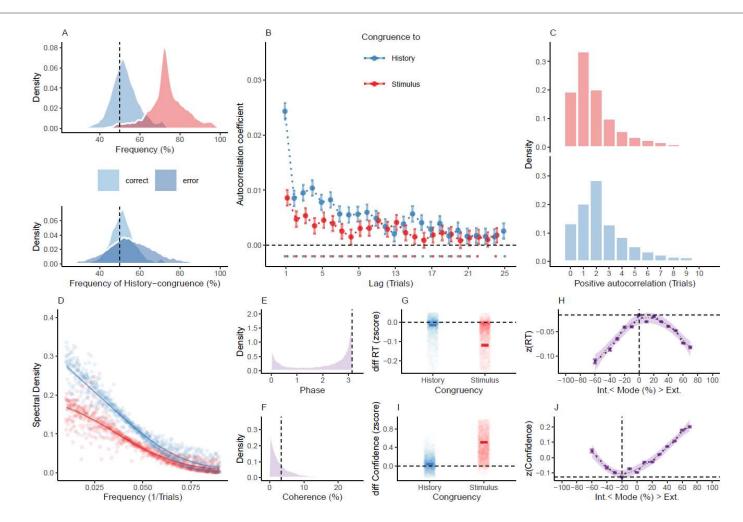






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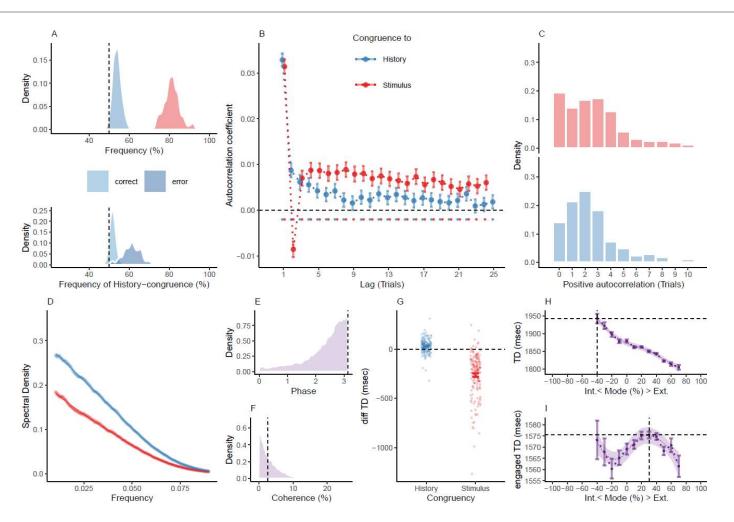
### Human data - Summary





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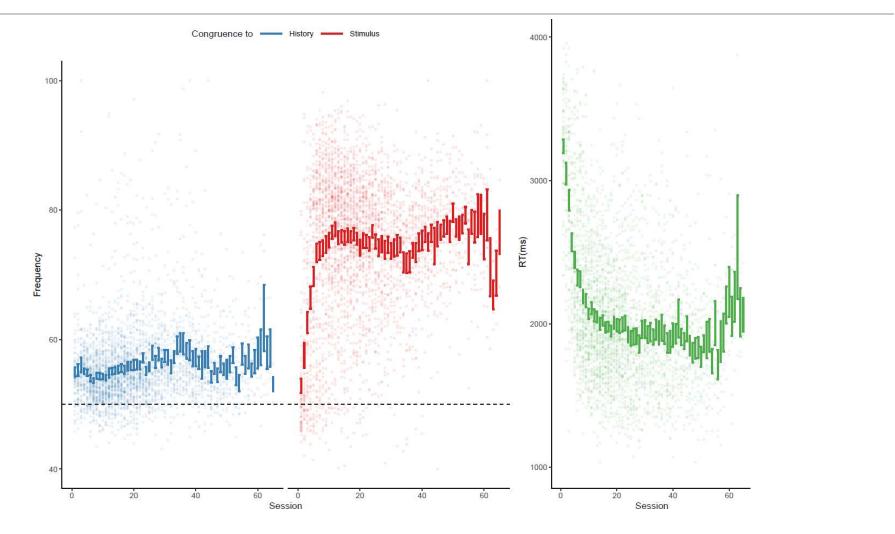




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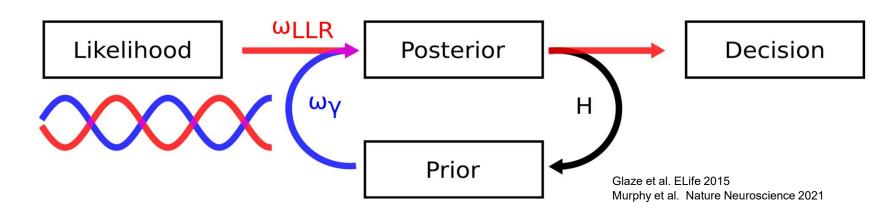
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## **Murine data – Training effects?**





## **Computational mechanisms**



$$L_t = LLR_t * \omega_{LLR} + \psi_t(L_{t-1}, H) * \omega_\psi$$

$$\psi_t(L_{t-1}, H) = L_{t-1} + \log(\frac{1-H}{H} + \exp(-L_{t-1})) - \log(\frac{1-H}{H} + \exp(-L_{t-1}))$$

$$\omega_{LLR} = amp_{LLR} * sin(f * t) + 1 \text{ and } \omega_{phi} = amp_{LLR} * sin(f * t + \pi) + 1.$$

Weilnhammer et al. iScience 2021. Glaze et al. eLife 2015

# Simulated data – Posterior human parameters

В A С Congruence to 0.100 0.03 History 0.3 0.075 0.050 Stimulus 0.2 Autocorrelation coefficient 0.025 0.1 0.000 40 100 60 80 Density Frequency (%) 0.09 0.00 0.03 0.3 0.2 0.00 100 40 60 80 0.00 0.1 Frequency of History-congruence (%) 0.0 correct error 25 13 21 0 1 2 3 4 5 6 7 8 9 10 17 Lag (Trials) Positive autocorrelation (Trials) D G E H 1.25 0.20 0.15 1.00 1.00 0.75 0.50 0.25 0.4 certainty (zscore) Simulated posterior certainty 0.10 Spectral Density .0 0.25 0.00 0.05 2 3 Phase diff posterior 0.00 1.00 0.05 Density 0.75 -0.05 0.25 -0.10-0.00 0.00 0.025 0.050 0.075 20 History Stimulus -100-80-60-40-20 0 20 40 60 80 100 10 Ó Frequency Coherence (%) Congruency Int.< Mode (%) > Ext.

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## Simulated data – Posterior human parameters

С В Α Congruence to 0.100 0.03 History 0.3 0.075 0.050 Stimulus 0.2 0.025 Autocorrelation coefficient 0.1 0.000 100 60 80 40 Density Frequency (%) 0.09 0.03 0.3 Hazard rate ~ 1/History-congruence 0.2 0.00 100 40 60 80 0.00 0.1 Frequency of History-congruence (%) Sensitivity parameter ~ Stimulus-congruence 0.0 erro 25 0 1 2 3 4 7 8 9 10 13 21 6 Lag (Trials) Positive autocorrelation (Trials) D G E 1.25-0.20 0.15 1.00 Density 0.75 0.4 certainty (zscore) Simulated posterior certainty 0.10 Spectral Density 0. 0.25 0.00 0.05 2 Phase Confidence(t-1) ~ History-congruence diff posterior 0.00 1.00 0.05 Density 0.75 -0.05 0.25 -0.10 0.00 0.00 0.025 0.075 -60 -40 -20 0 20 40 60 80 100 0.050 10 20 History Stimulus -100-80 Frequency Coherence (%) Congruency Int.< Mode (%) > Ext.

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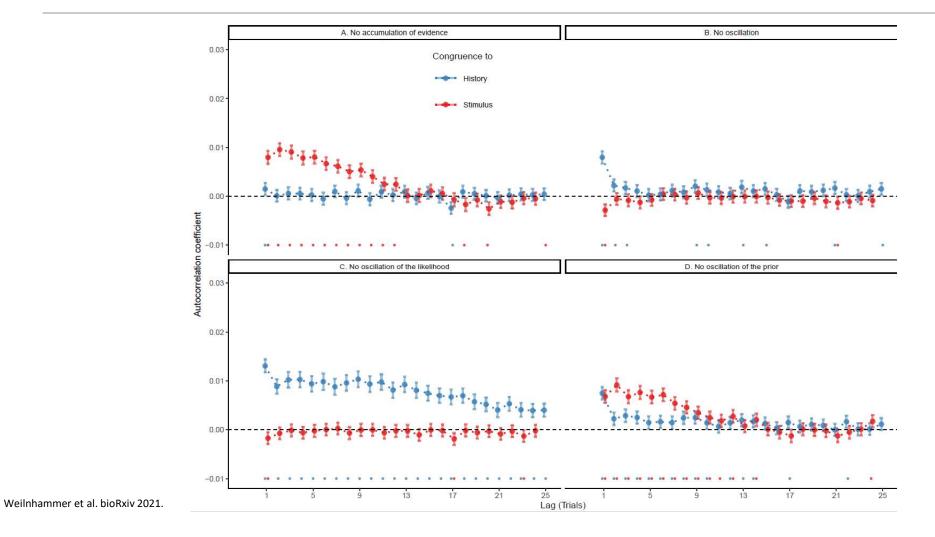
### **Model fit**

L ~ Confidence L~1/RT L(t-1) ~ History-congruence

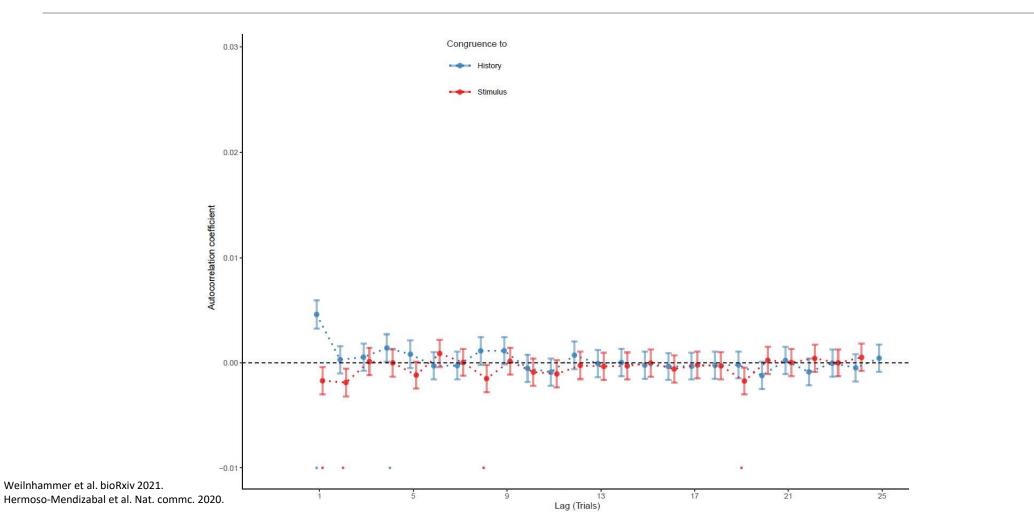




## Simulated data – Model components



### Simulated data – Rest/Rebound



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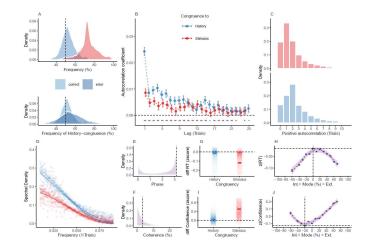
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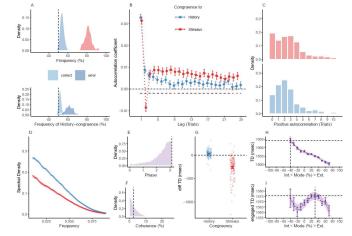
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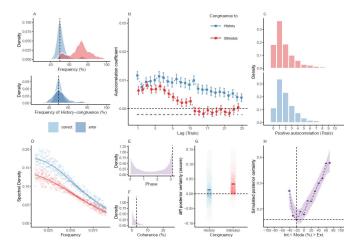
## Summary: Humans, mice and simulations

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## During external mode, perceptual errors are more informative of the likelihood

 Update beliefs about likelihood precision (e.g., reliability of sensory channels) during external mode

## During internal mode, perceptual errors are more informative of the prior

• Update internal representations about the environment during internal mode

Solution to the credit-assignment problem (analogy to wake-sleep algorithms)



