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

Veith Weilnhammer

ERANET Meeting 02.09.2021

Bistable Perception

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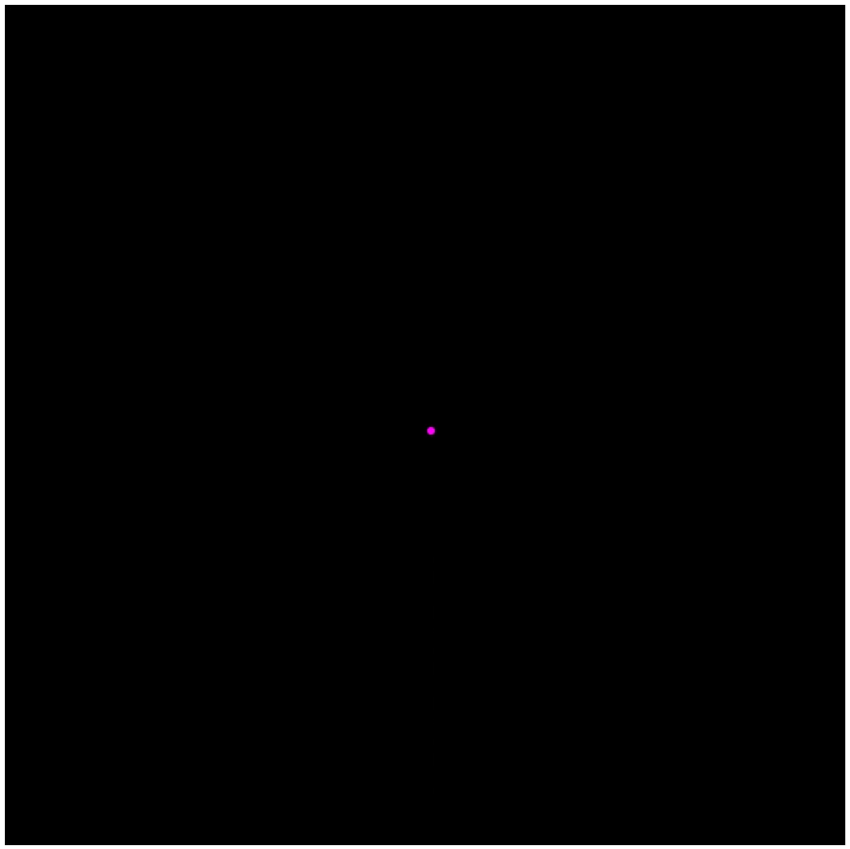

- **Bistable perception:**

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' signal-to-ambiguity ratio?

Perceptual History vs. Signal-to-Ambiguity

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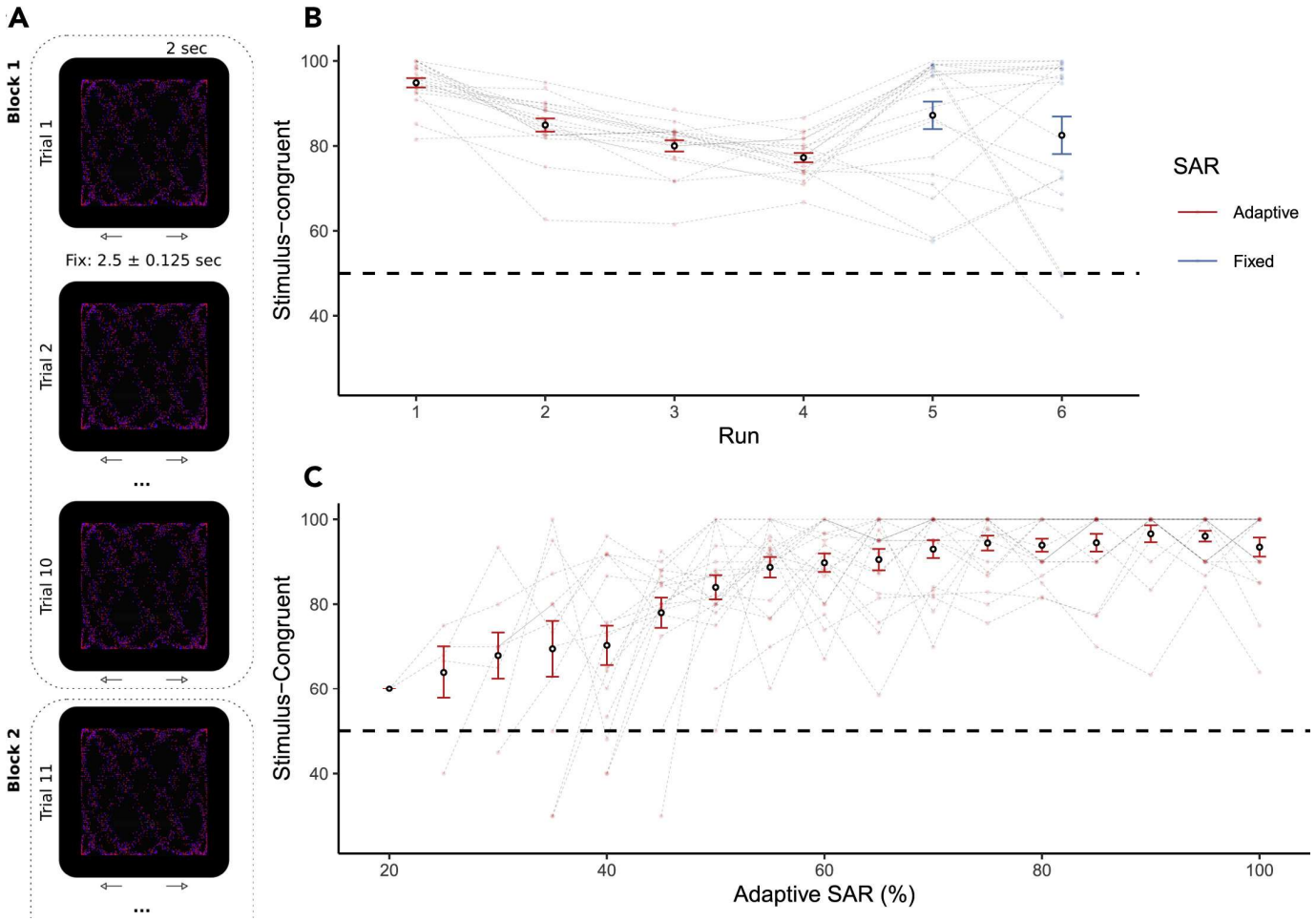


Weilnhammer et al. iScience 2021.

- **Stimulus-congruence:**

Perceptual state matches stimulus information.

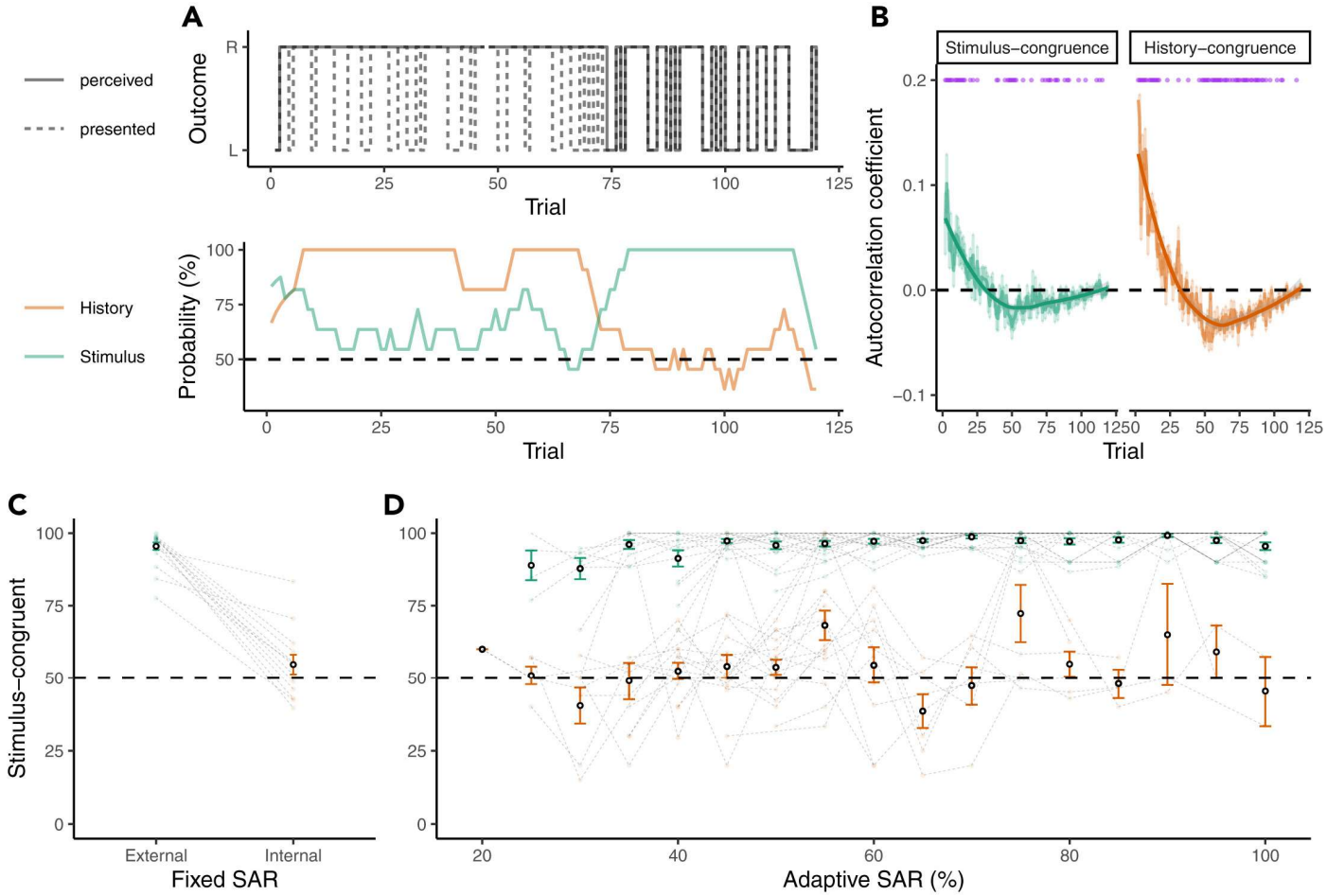
- **History-congruence:**

Perceptual state matches preceding perceptual state

- **Psychophysical staircase:**

SAR adjust the balance between stimulus- and history-congruence

Internal and External Mode



Weilnhammer et al. iScience 2021.

- **Fixed SAR:**

Bistable perception oscillates between internally- and externally-oriented modes.

- **Duration:** ~ 40 trials / ~ 3 min

Internal and External Modes

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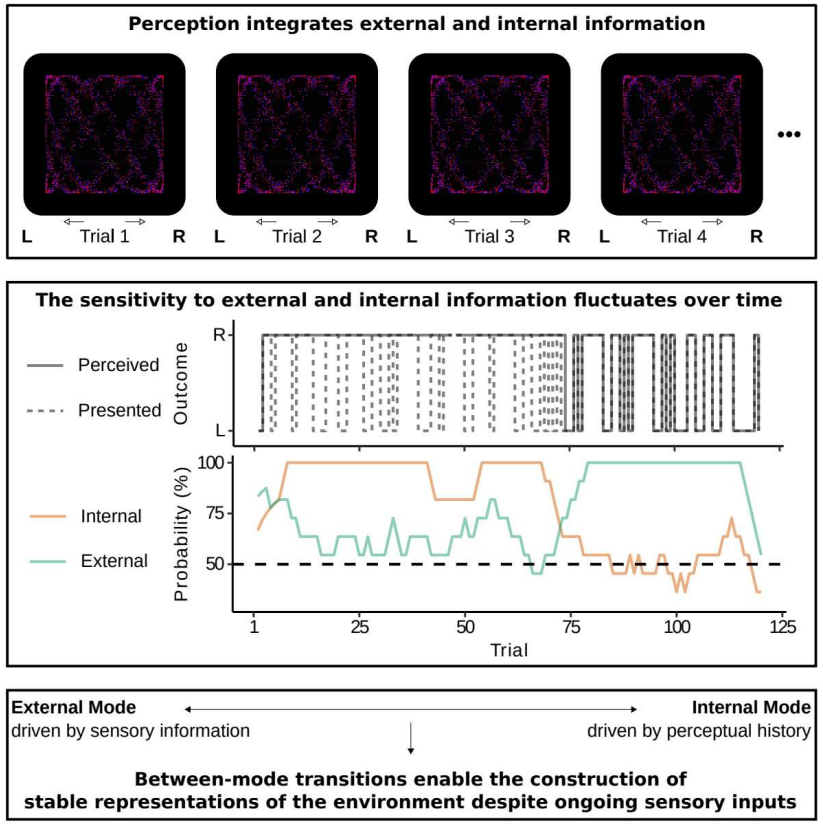


Weilnhammer et al. iScience 2021.

Are internal and external modes specific to bistable perception?

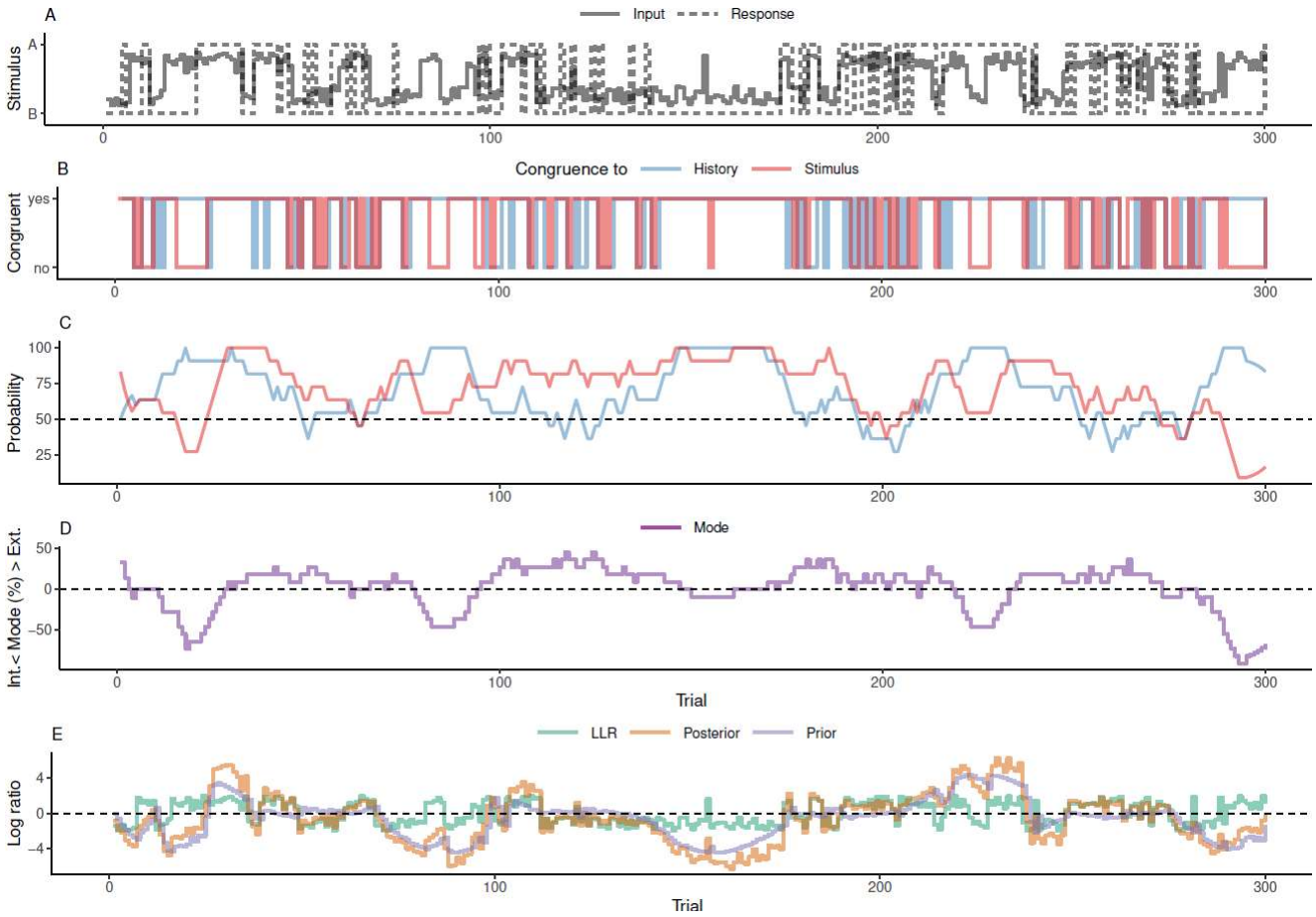
- Confidence database (N = 4500 humans, 22 million choices)
- IBL database (N = 196 mice, 2.5 million choices)

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 decision-making?

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)

Human data

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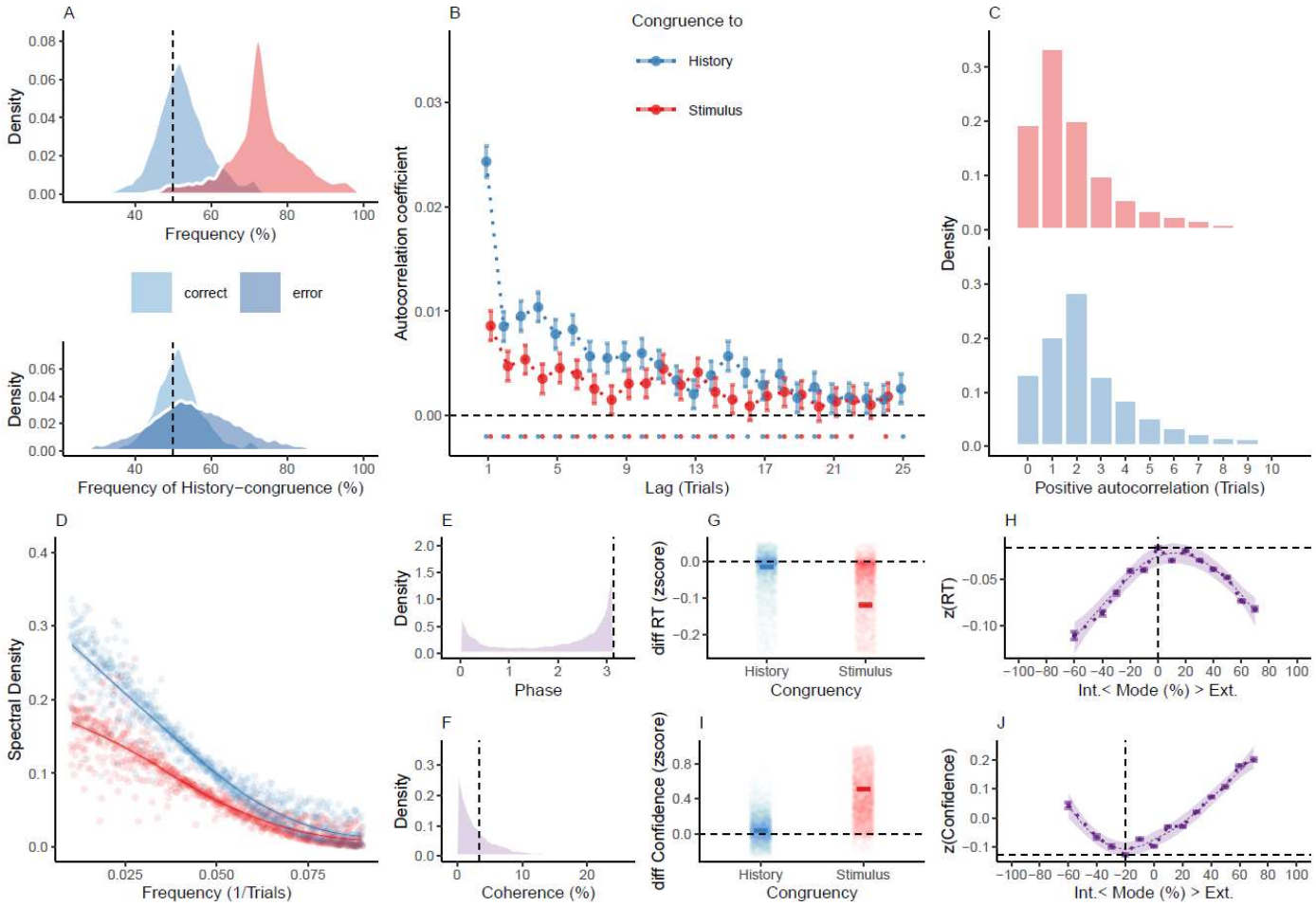

Weilnhammer et al. bioRxiv 2021.

Human data – Serial dependency and Autocorrelation

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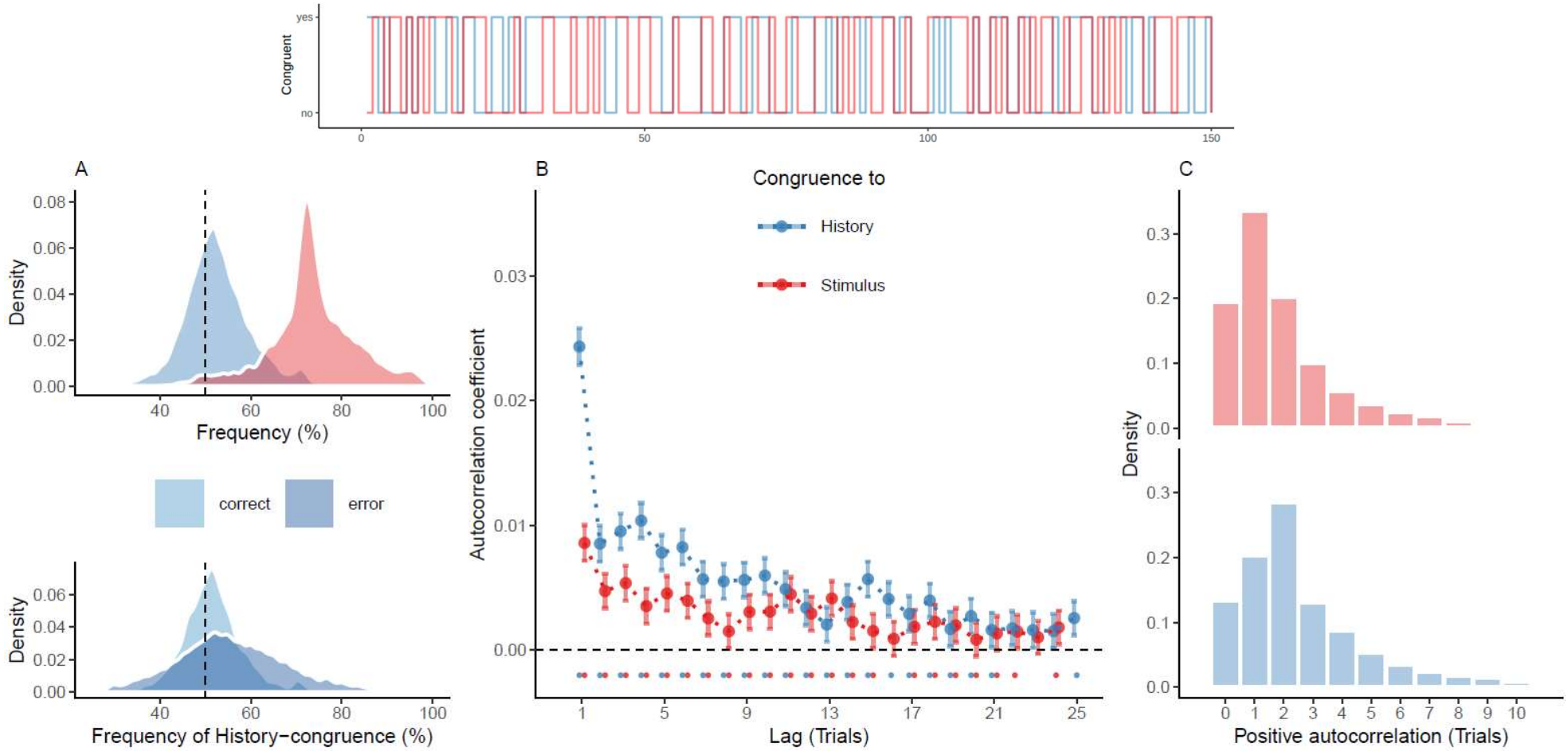

Weilnhammer et al. bioRxiv 2021.

Human data – 1/f noise

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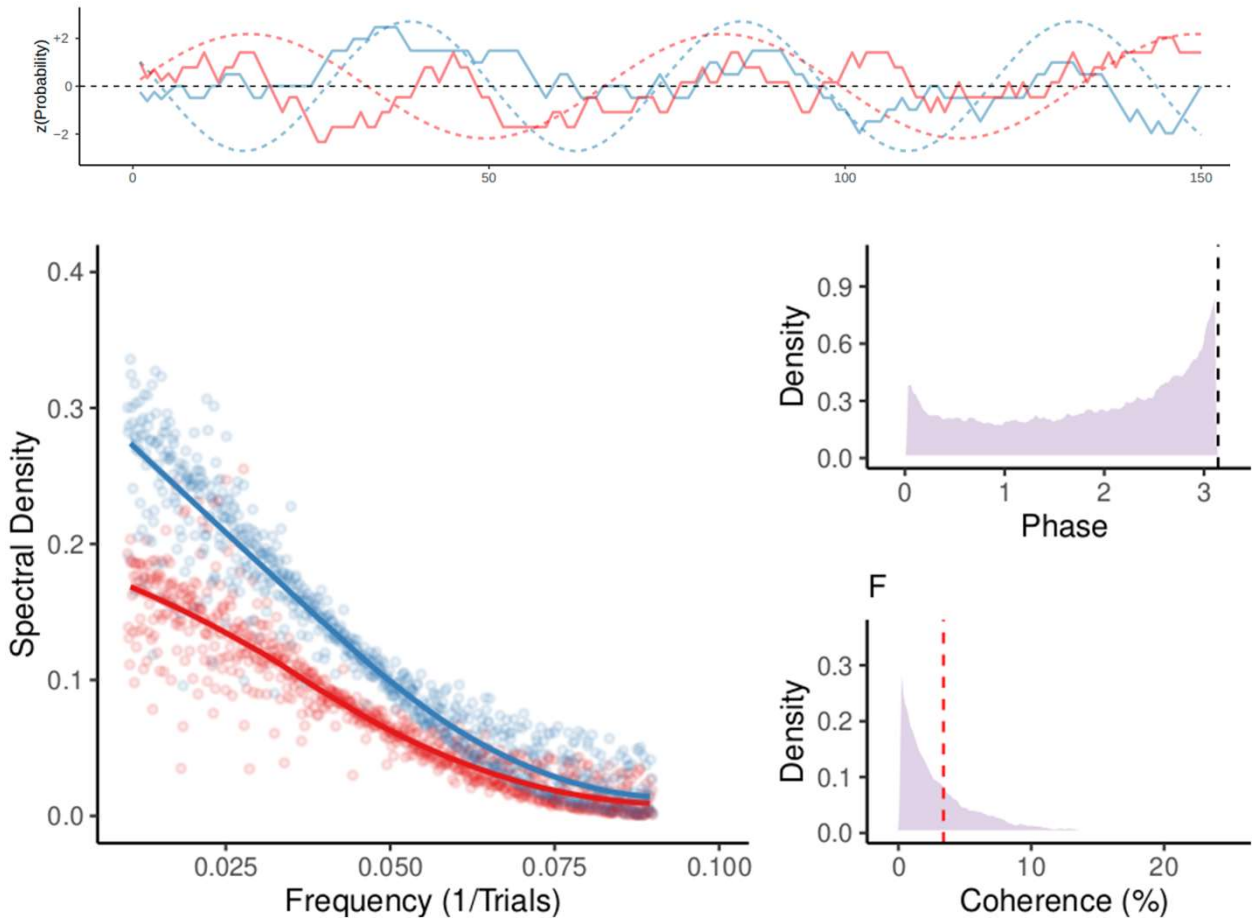
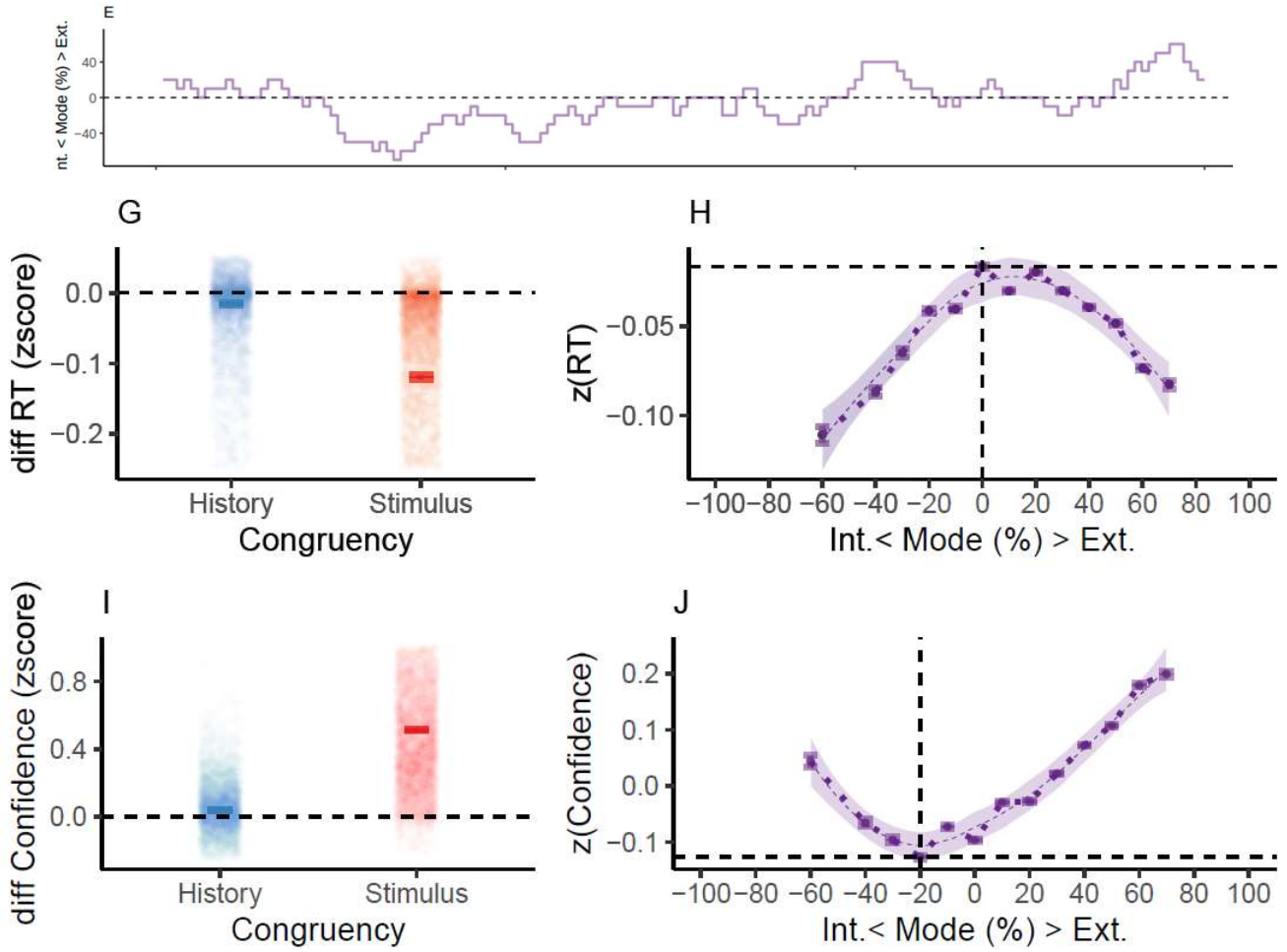


Weilnhammer et al. bioRxiv 2021.

Human data – RTs and Confidence



Weilnhammer et al. bioRxiv 2021.

Human data – Metacognitive efficiency

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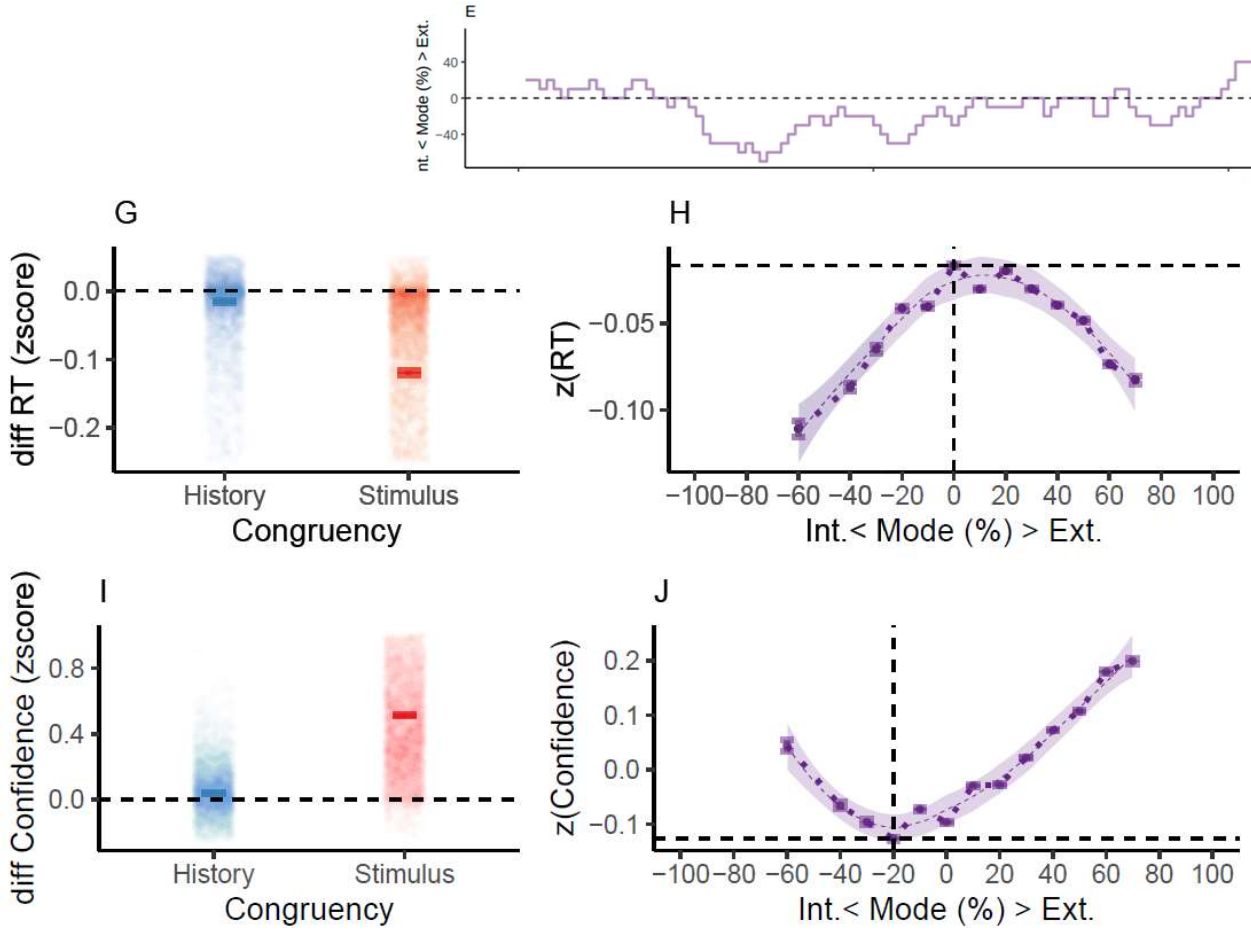

Metacognitive efficiency

Strength of internal mode ~ 1 / Mratio

(T = -3.01, p = 0.0026)

Weilnhammer et al. bioRxiv 2021.

Human data - Summary

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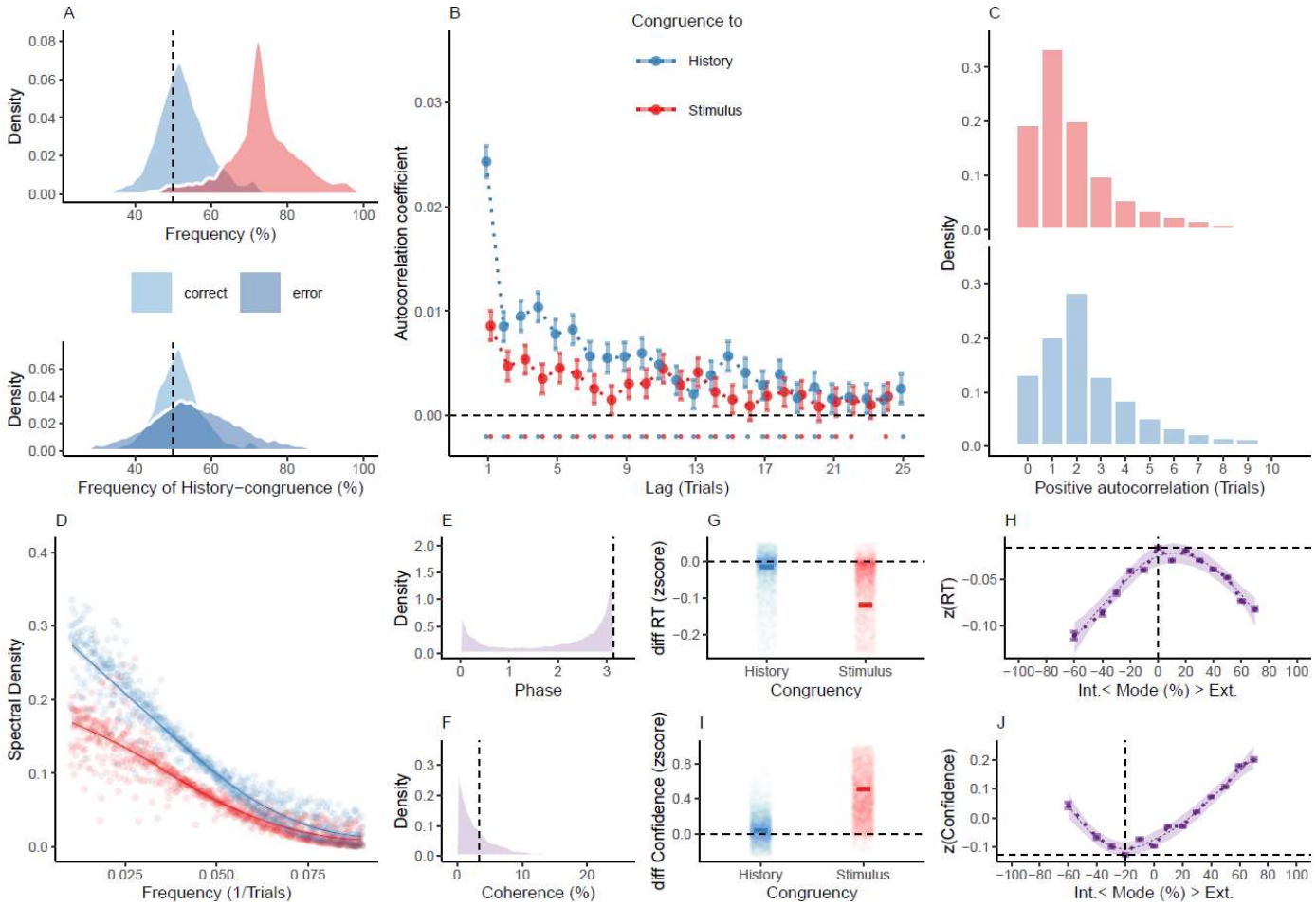

Weilnhammer et al. bioRxiv 2021.

Human data – Study effects?

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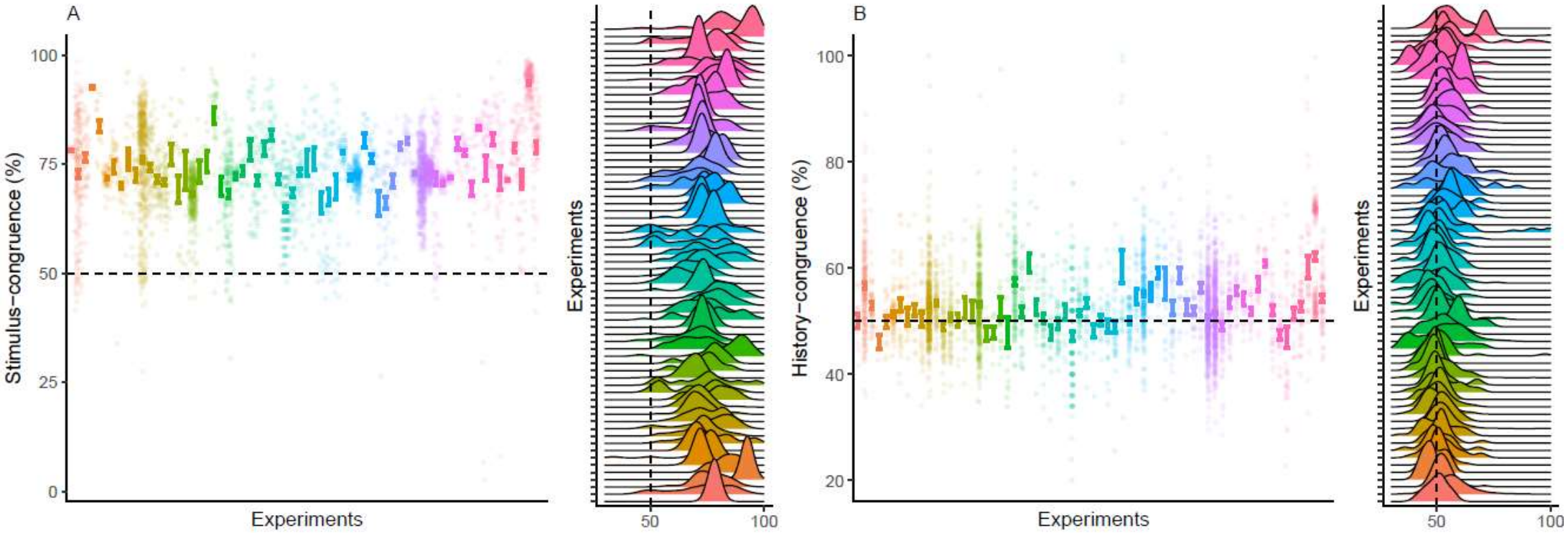

Weilnhammer et al. bioRxiv 2021.

Human data – Difficulty and stimulus history?

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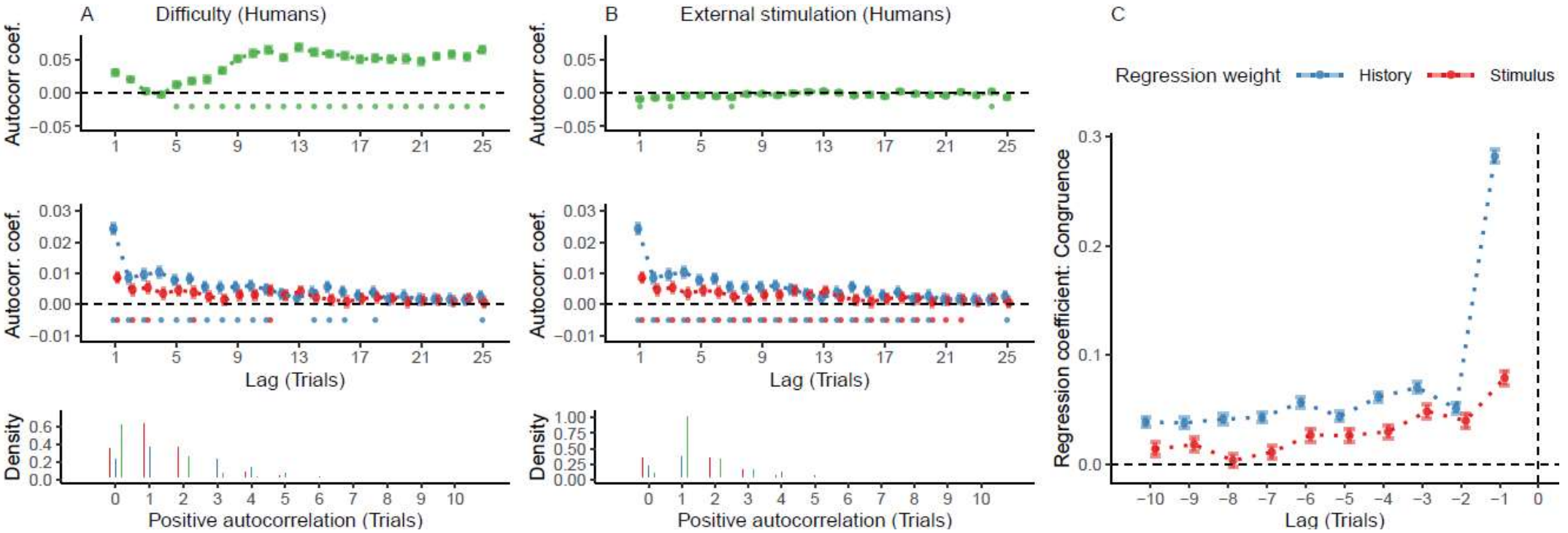

Weilnhammer et al. bioRxiv 2021.

Human data - Summary

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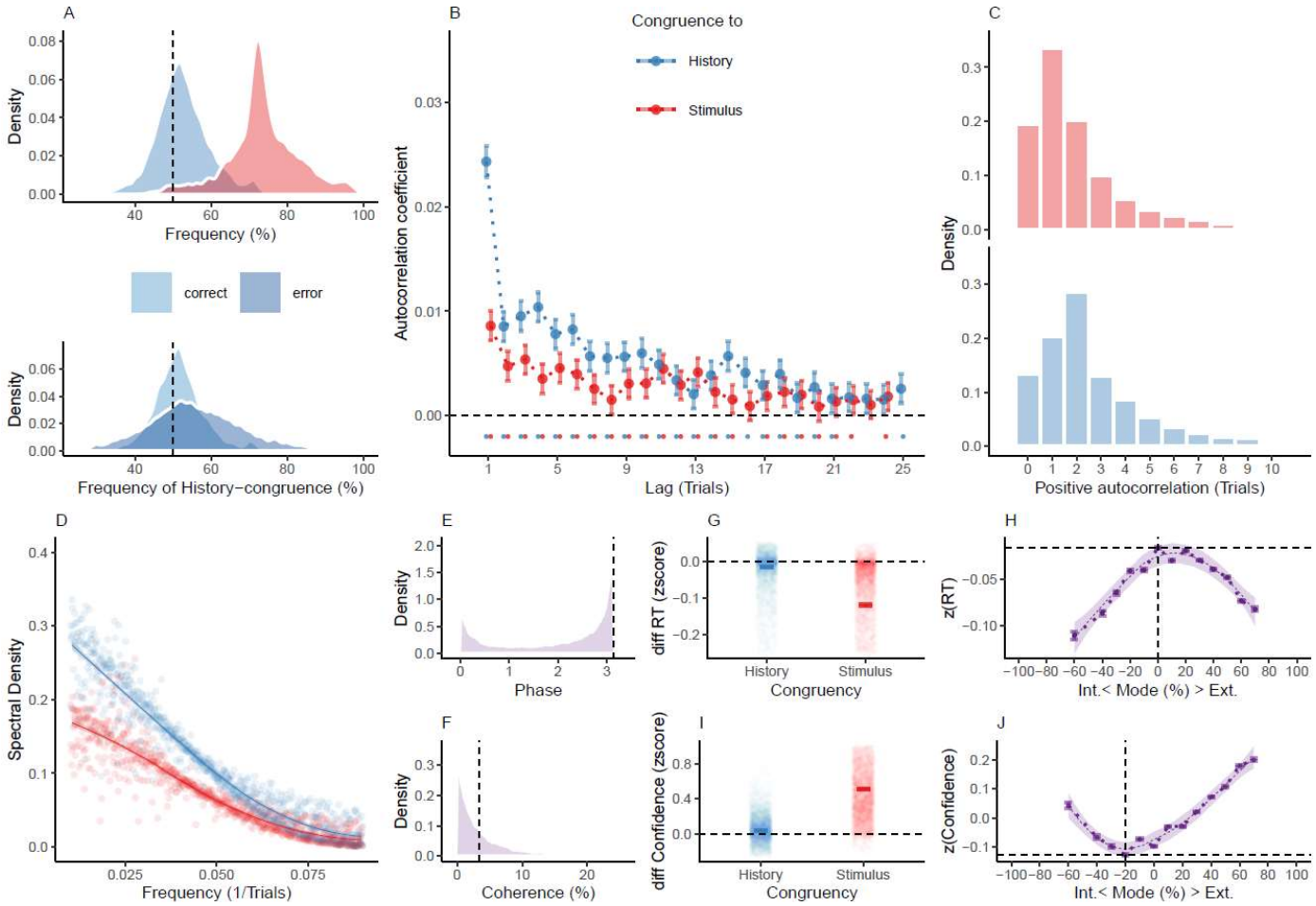

Weilnhammer et al. bioRxiv 2021.

Murine data

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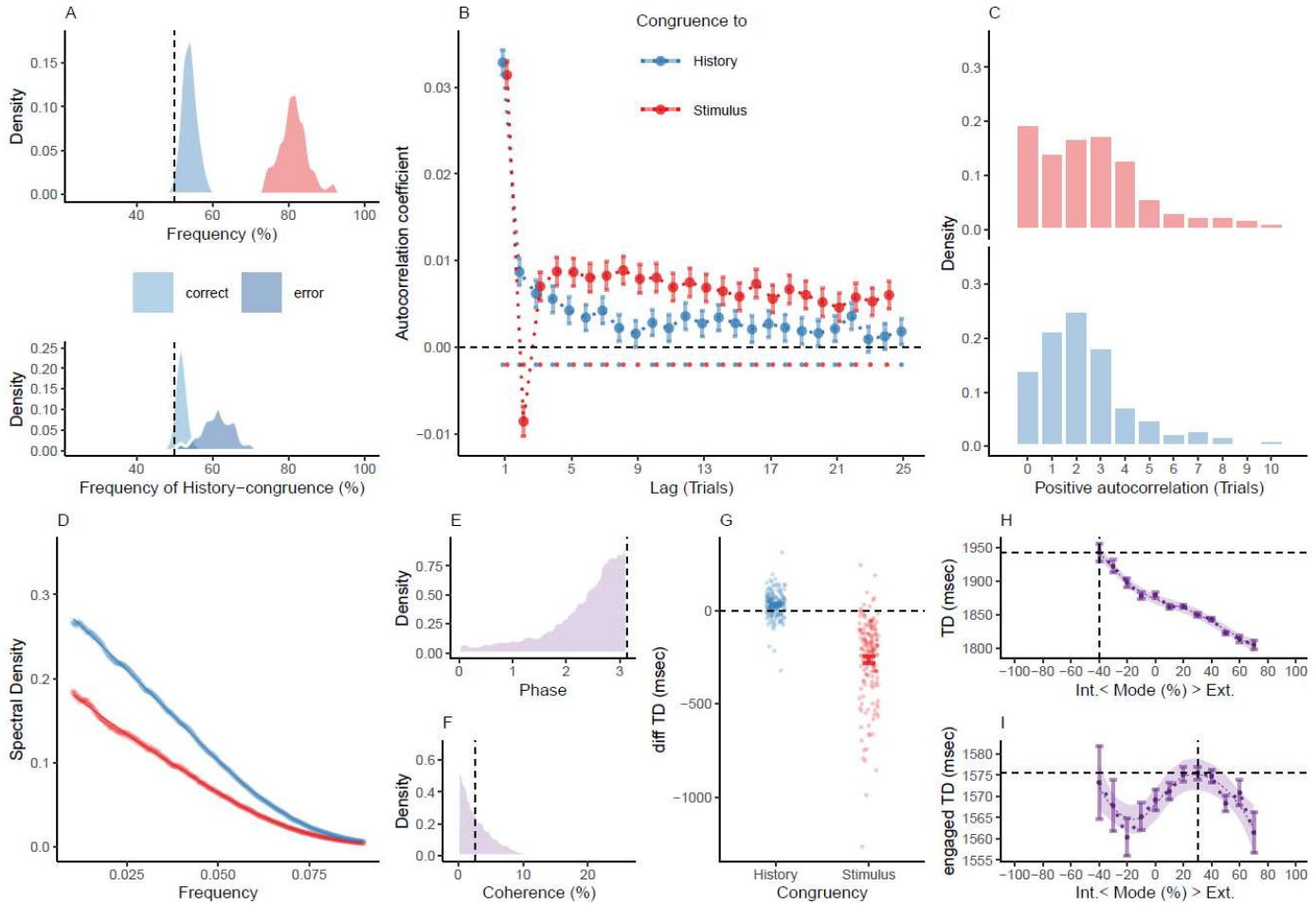

Weilnhammer et al. bioRxiv 2021.

Murine data – Training effects?

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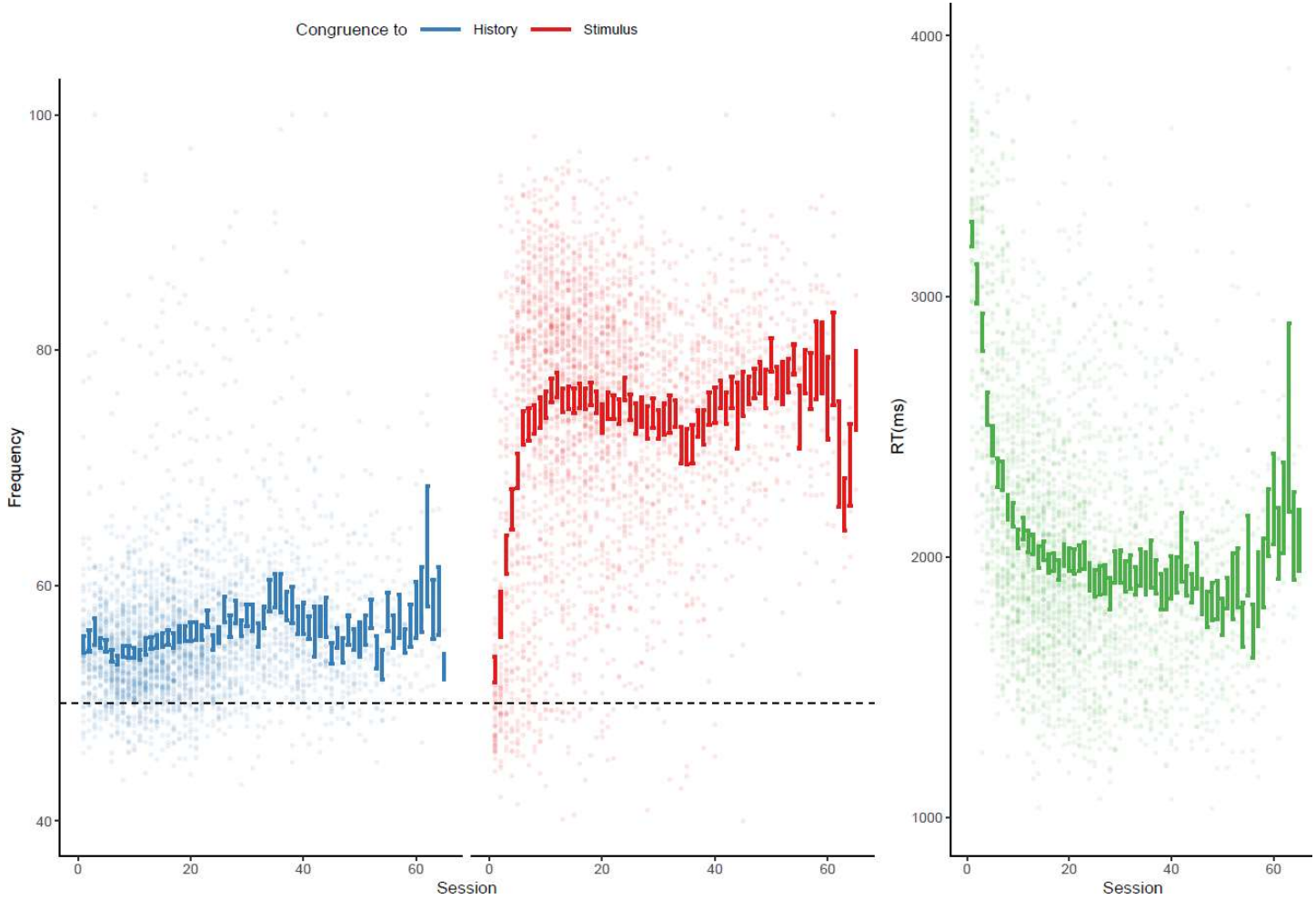
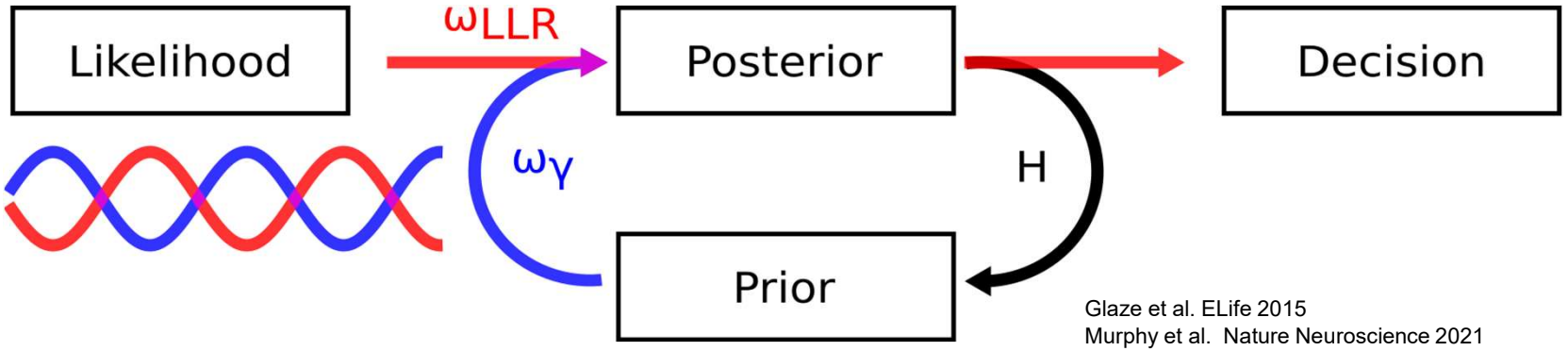


Weilnhammer et al. bioRxiv 2021.

Computational mechanisms



Glaze et al. ELife 2015
Murphy et al. Nature Neuroscience 2021

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

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

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

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

Simulated data – Posterior human parameters

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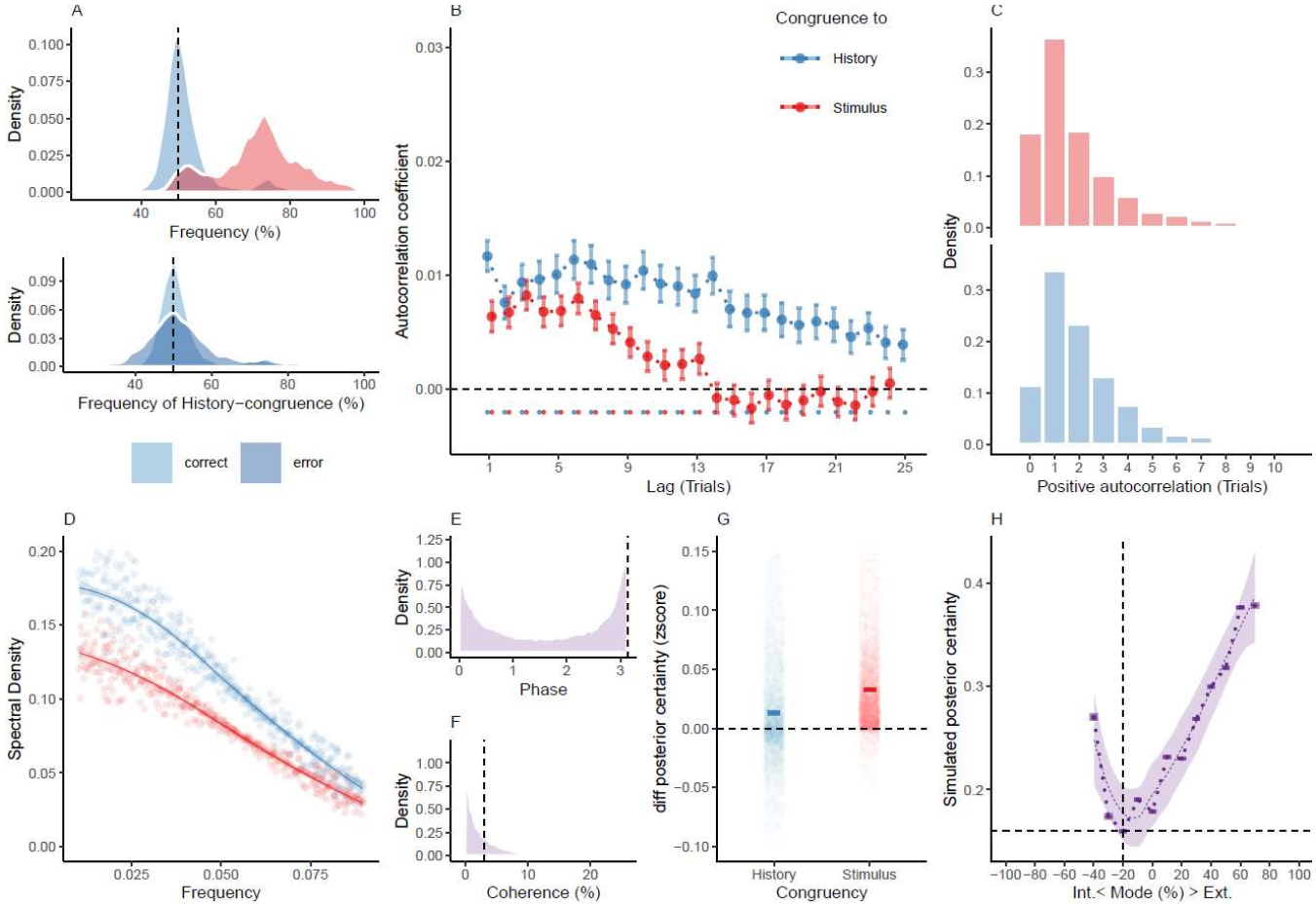

Weilnhammer et al. bioRxiv 2021.

Simulated data – Posterior human parameters

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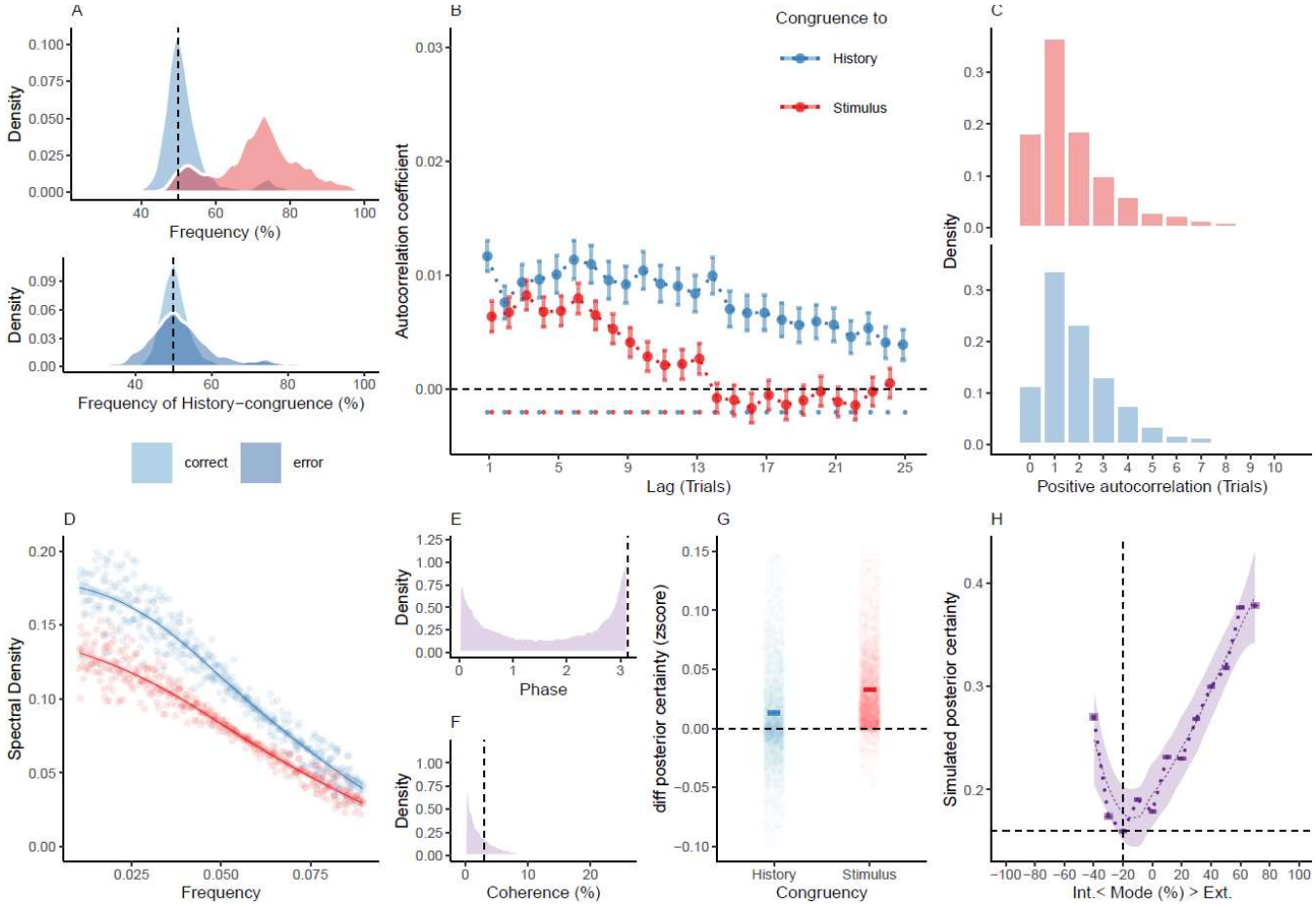


Model fit

Hazard rate ~ 1/History-congruence

Sensitivity parameter ~ Stimulus-congruence

L ~ Confidence

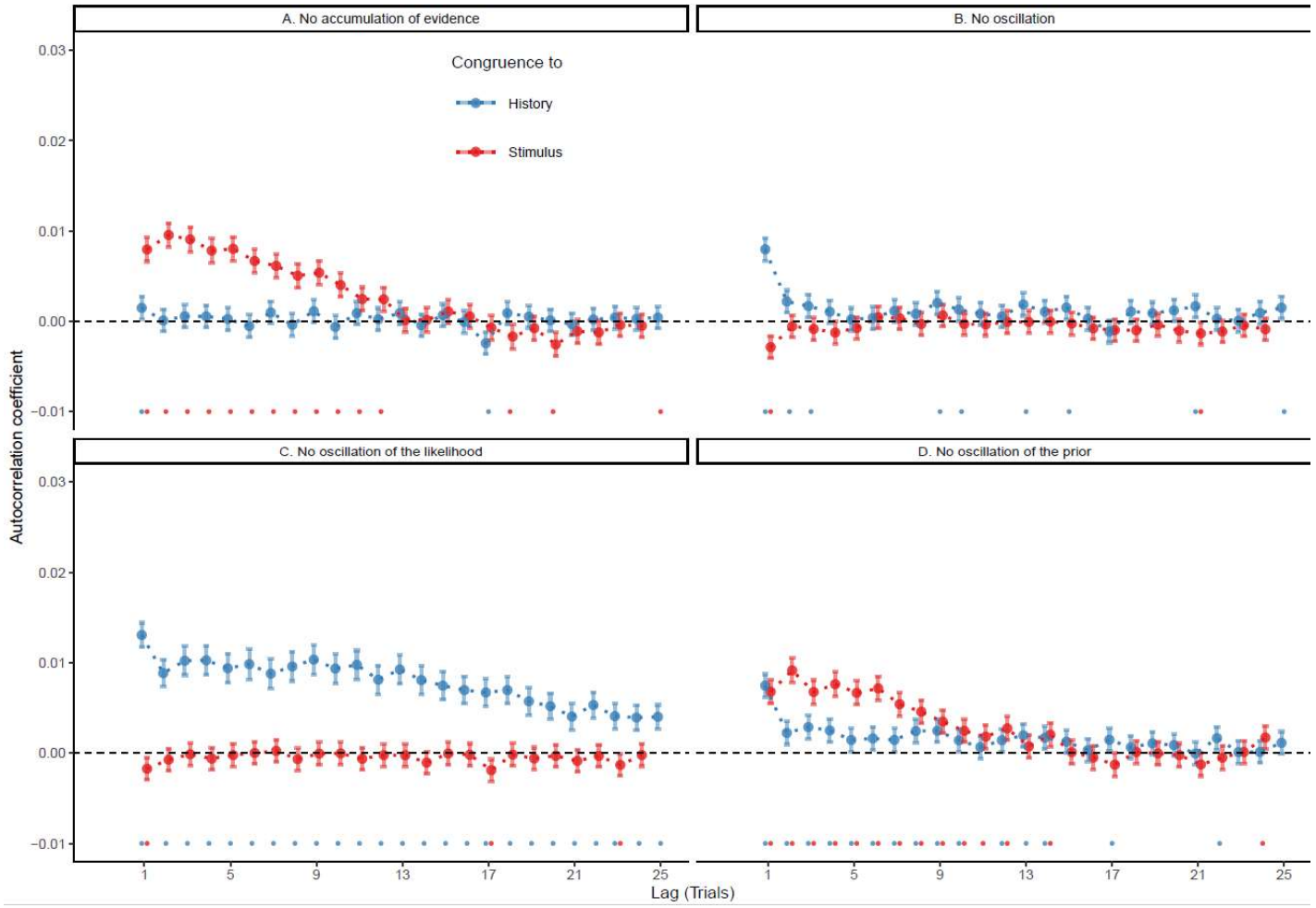
L ~ 1/RT

L(t-1) ~ History-congruence

Confidence(t-1) ~ History-congruence

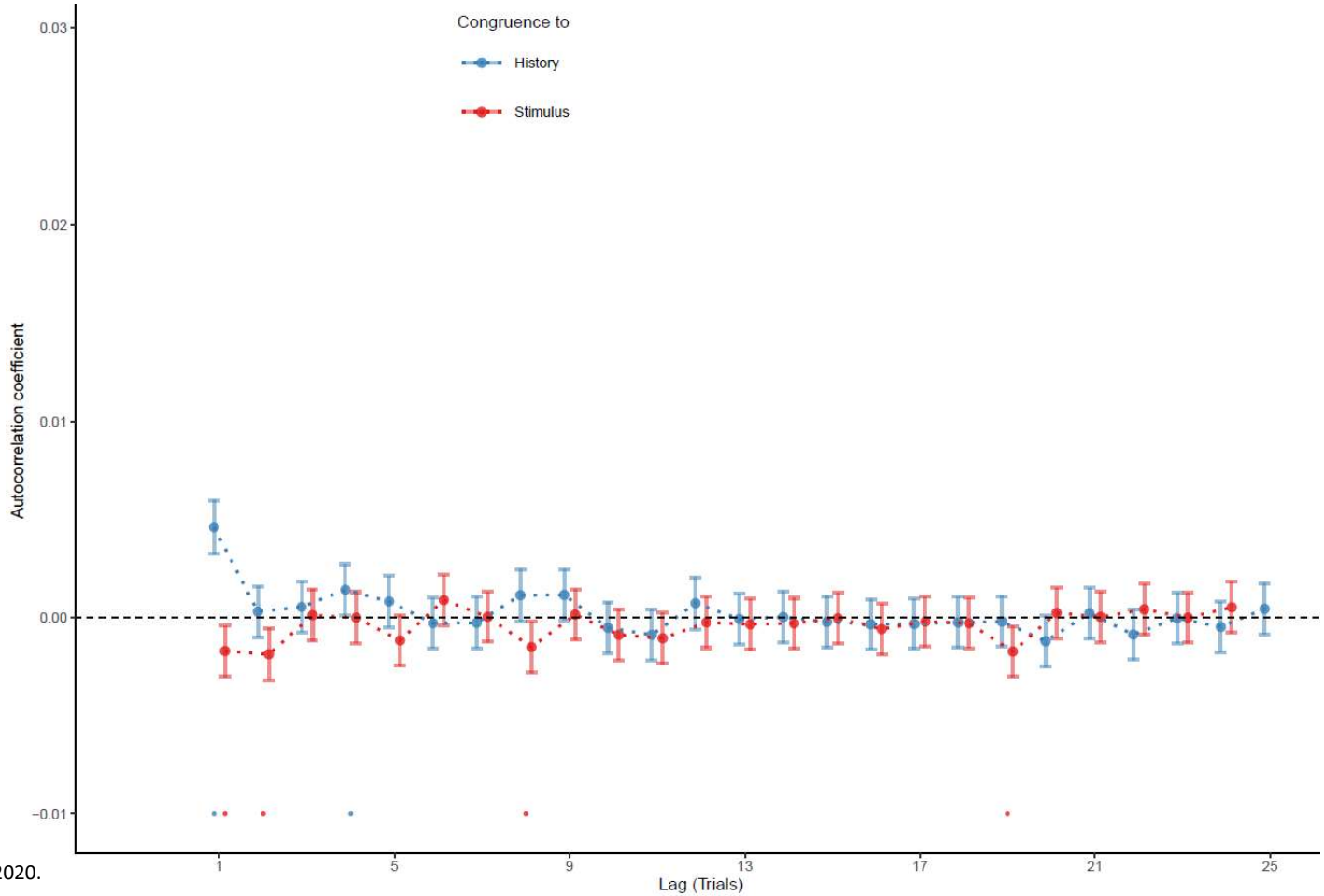
Weilnhammer et al. bioRxiv 2021.

Simulated data – Model components



Weilnhammer et al. bioRxiv 2021.

Simulated data – Rest/Rebound



Weilnhammer et al. bioRxiv 2021.
Hermoso-Mendizabal et al. Nat. commc. 2020.

Summary: Humans, mice and simulations

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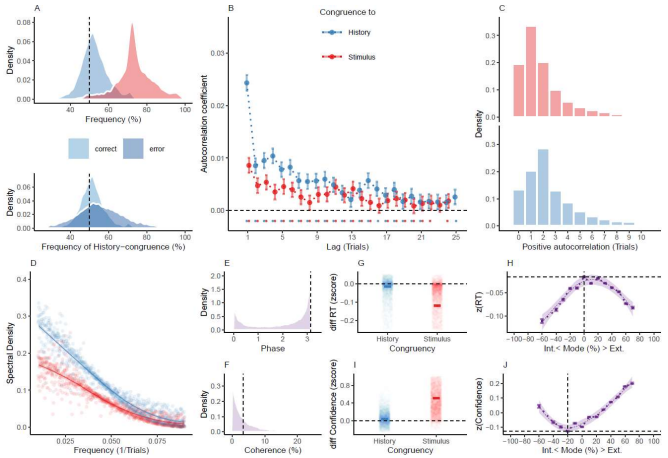

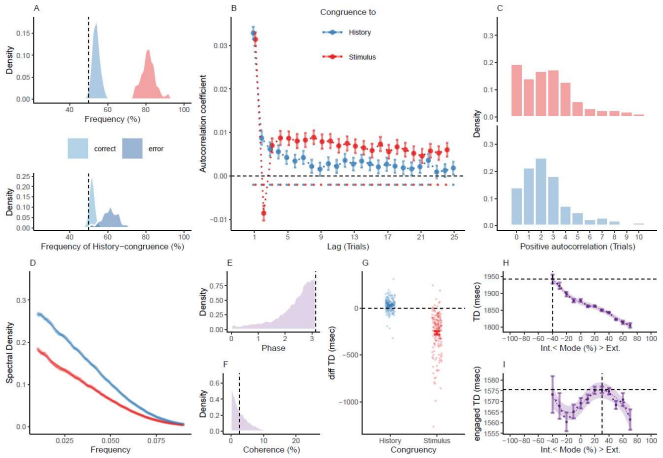

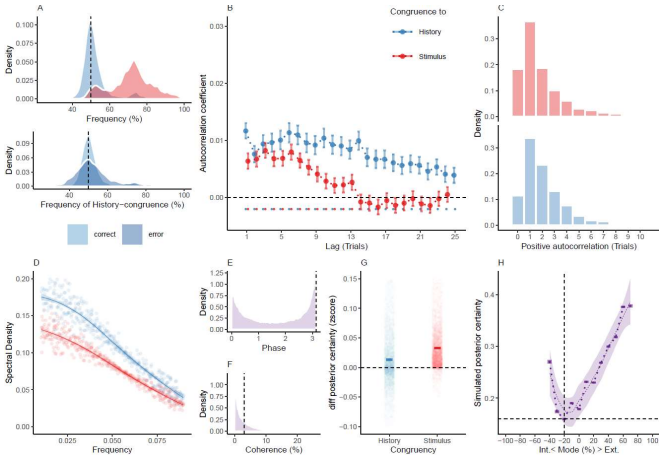

Weilnhammer et al. bioRxiv 2021.

But why?

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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)

?

THANKS!

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