A Predictive-Coding Account of Altered Perceptual Inference in Schizophrenia

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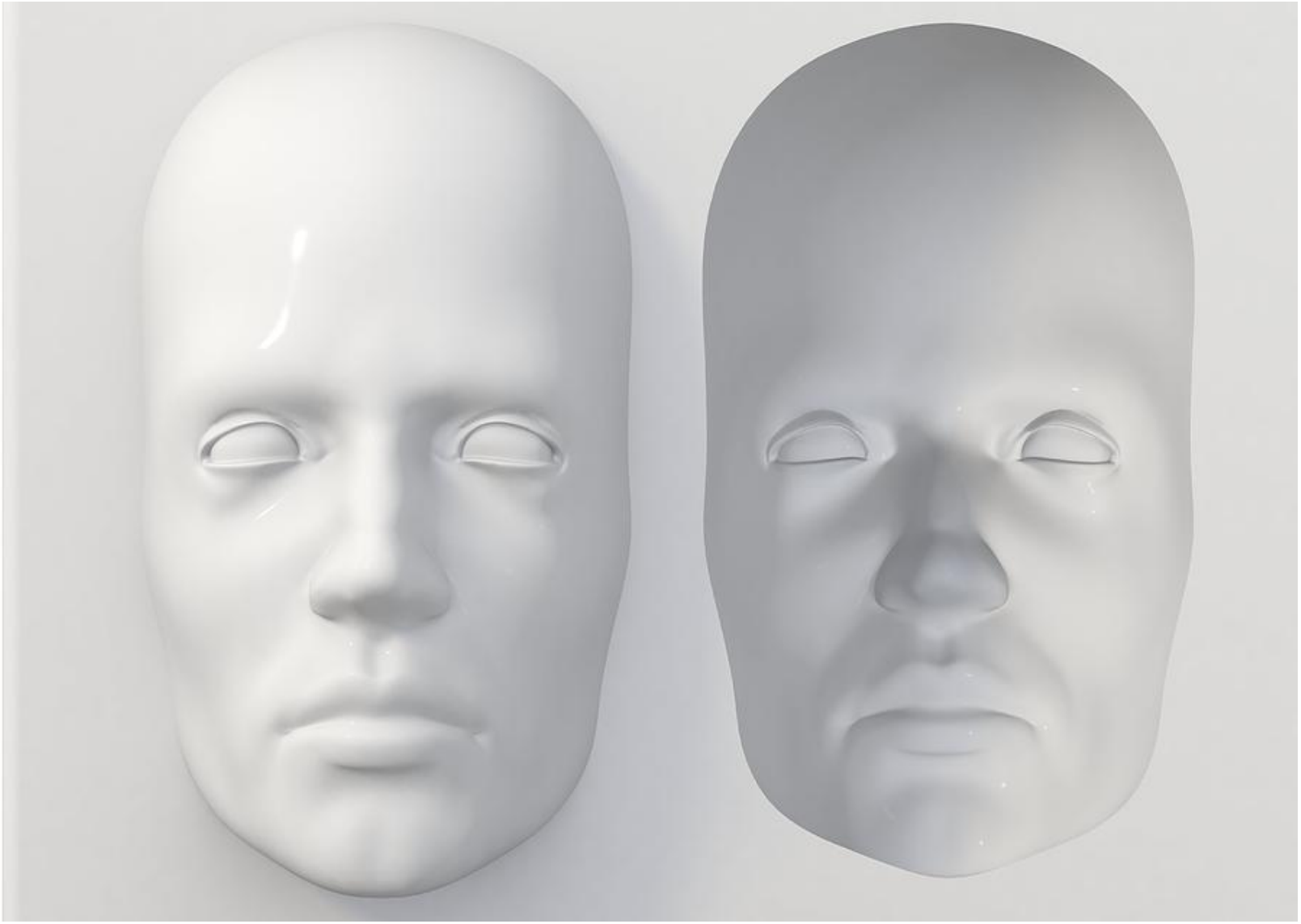
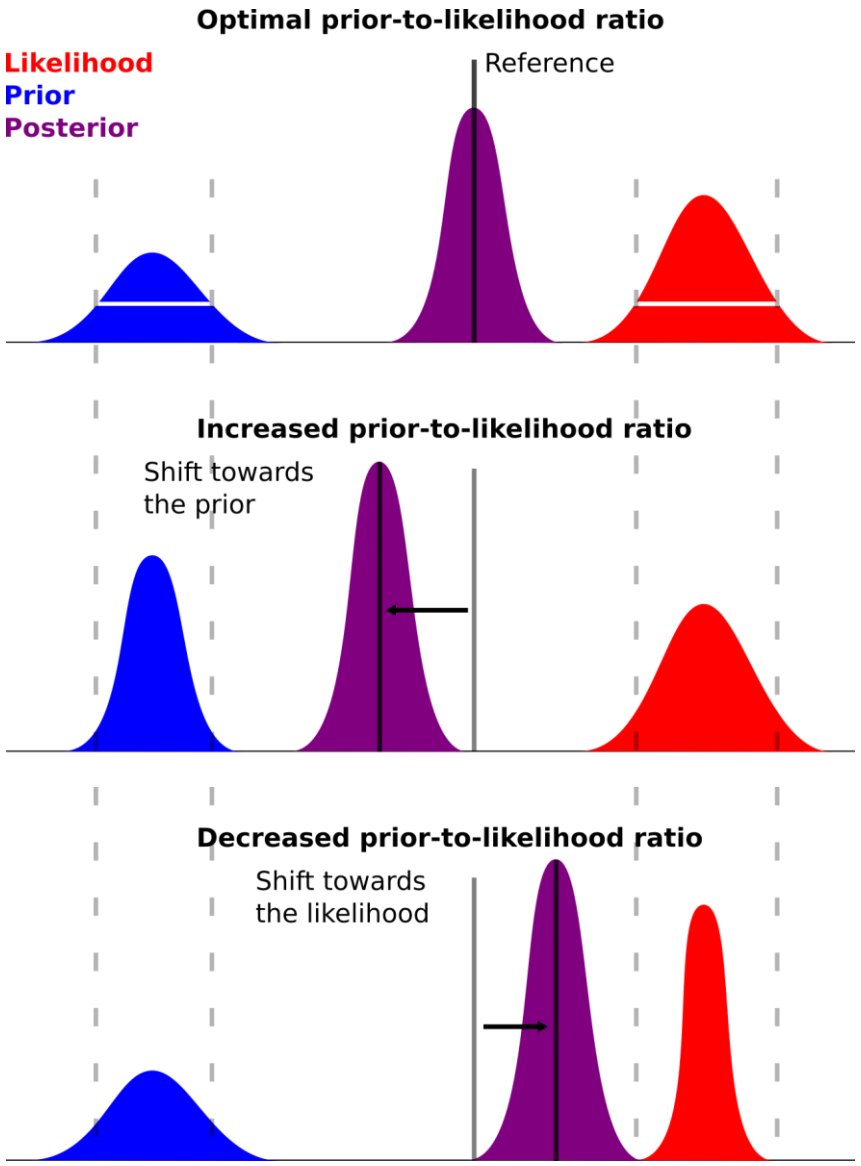
Bayesian Perceptual Inference



Bayesian Perceptual Inference

Hypotheses

- Psychotic symptoms due to an alteration in perceptual inference.
- Prior-to-likelihood ratio: Shift in the relative precision of prior and likelihood



Fletcher & Frith 2008, Sterzer et al. 2018, Corlett et al. 2019

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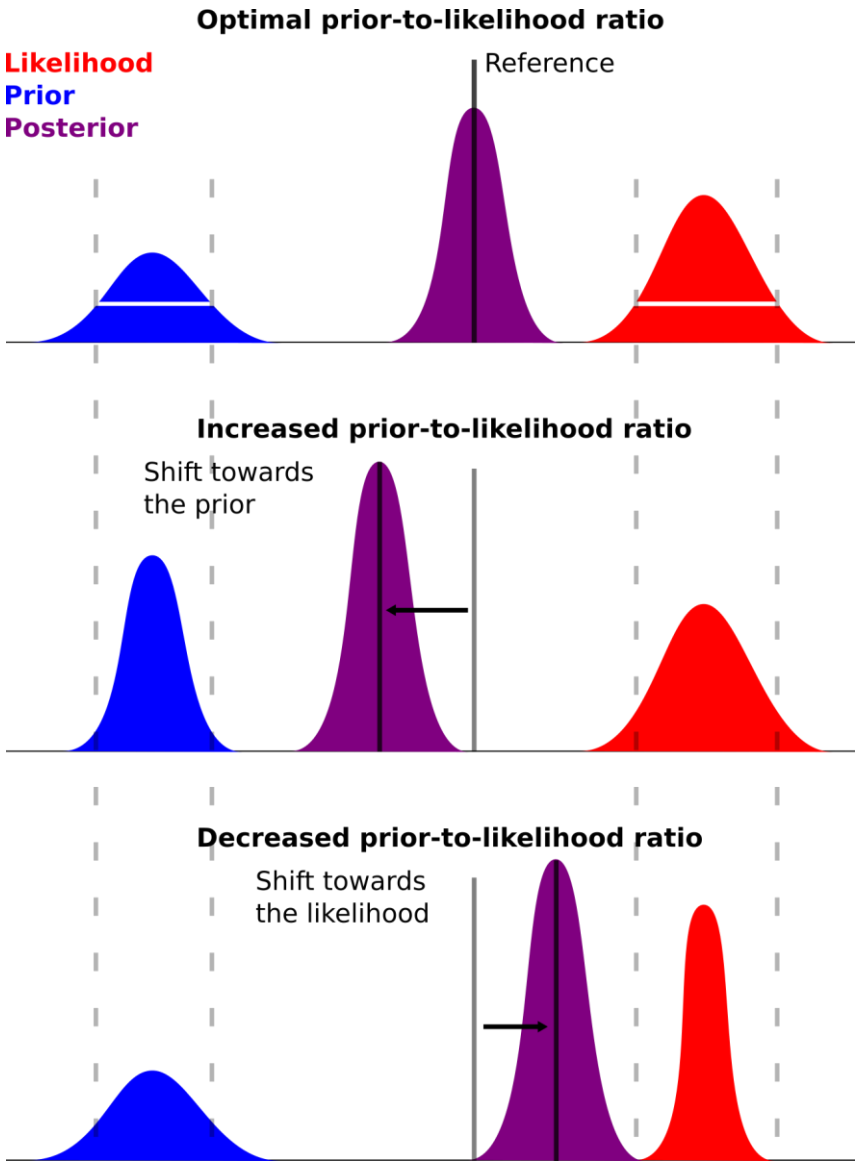
- Varying sensory evidence in ambiguous stimuli



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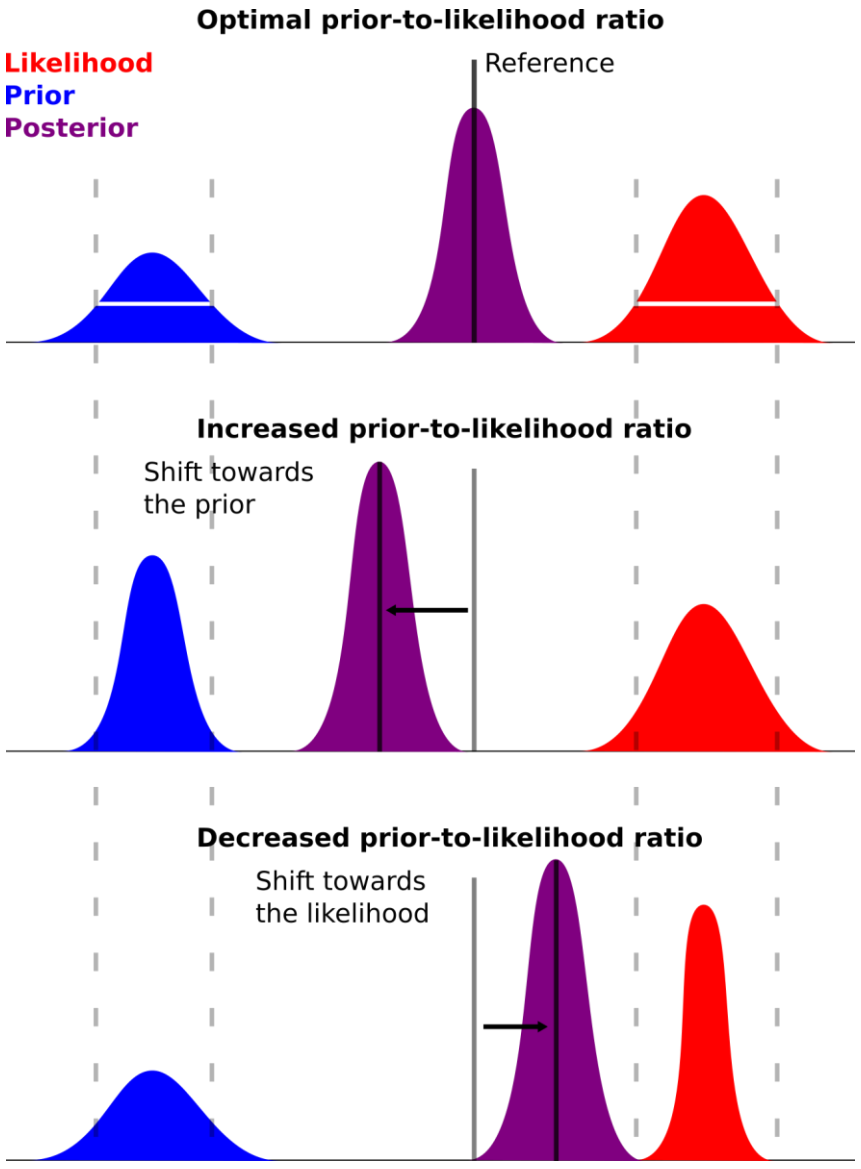
Questions

- Differences in PLR between schizophrenia (**Scz**) patients and controls?
- Correlation to symptom severity?



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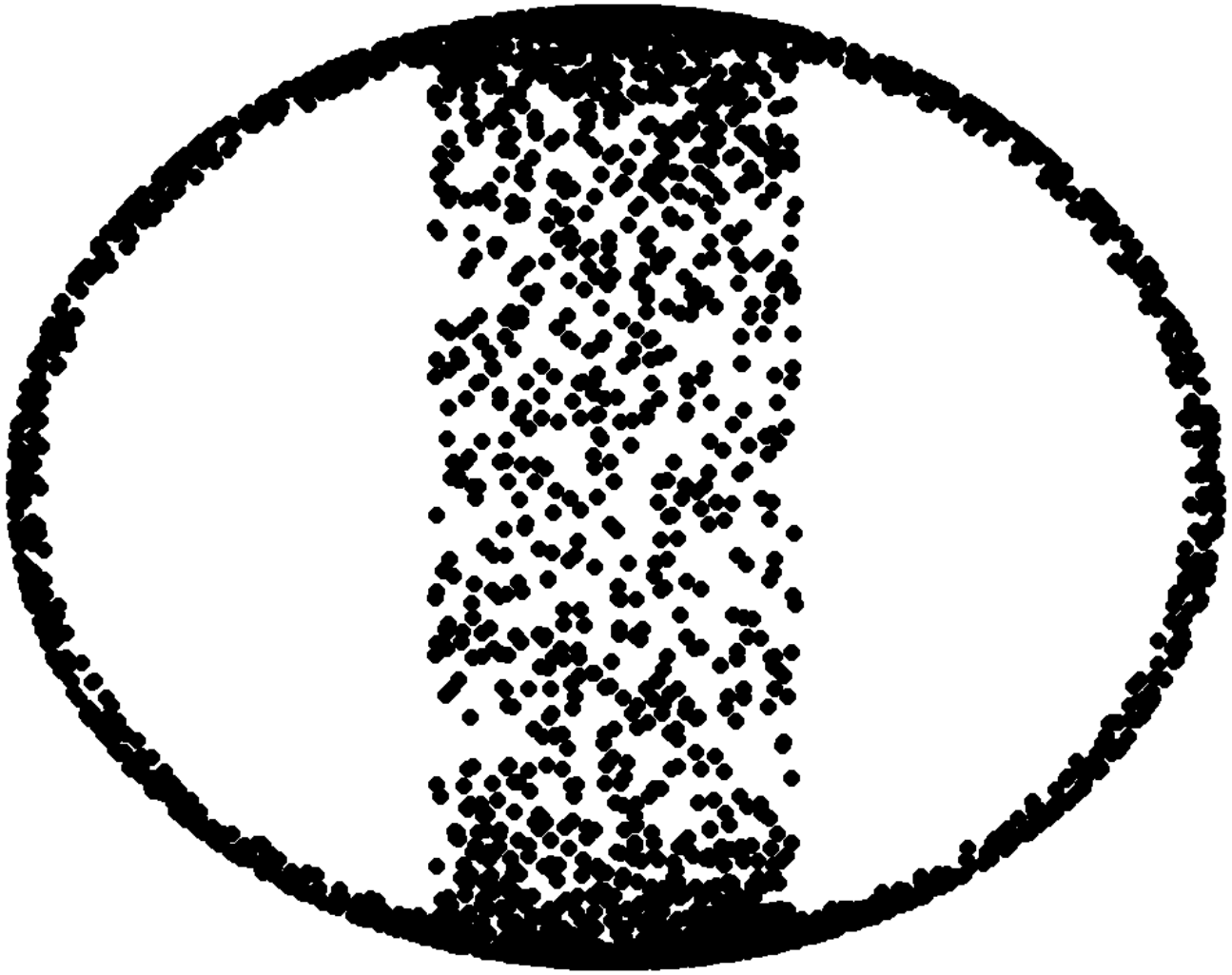
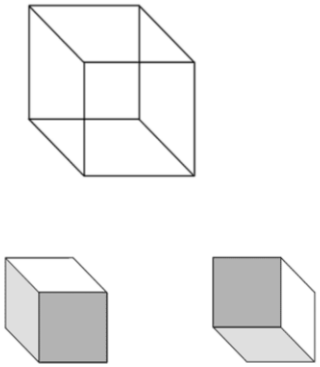
Models of Bistable Perception



Models of Bistable Perception

Perceptual Bistability

- Constant ambiguous sensory: Transitions between two alternative, mutually exclusive interpretations.



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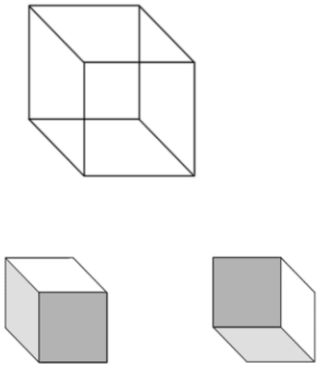
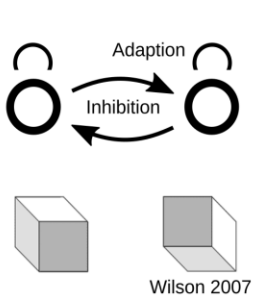
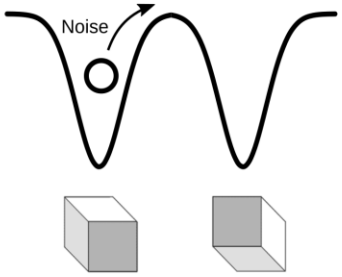
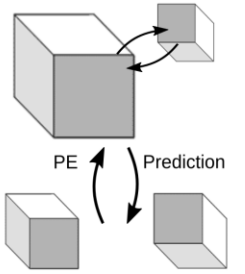




Wilson 2007



Moreno-Bote 2007



Hohwy 2008
Weilnhammer 2017

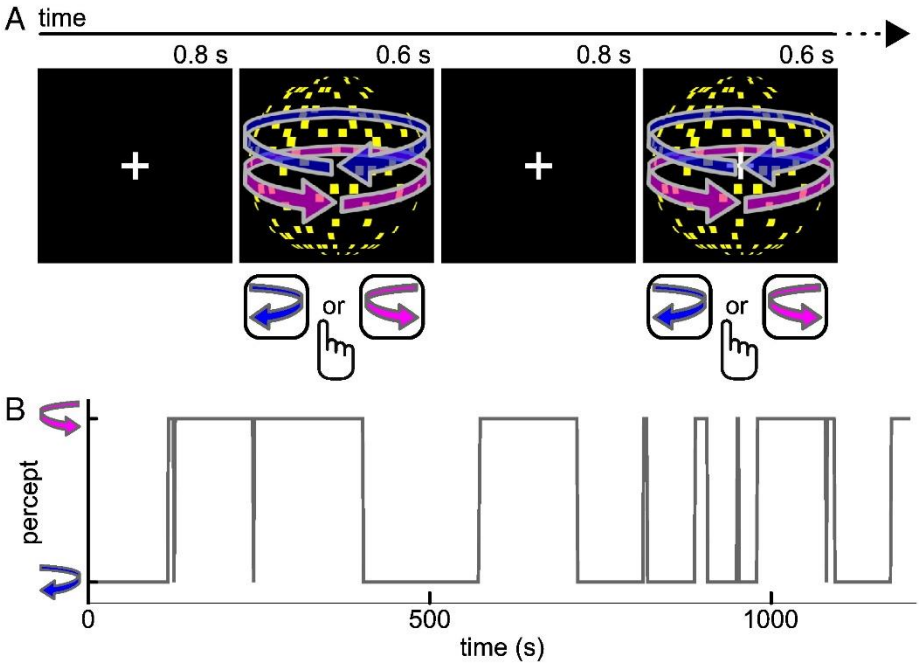
Predictive Coding

- Bistable perception arises from the interplay of perceptual predictions (prior) and sensory evidence (likelihood).

Prior Predictions in Bistability

Implicit priors

- Intermittent presentation leads to a stabilization of perception (“priming”)



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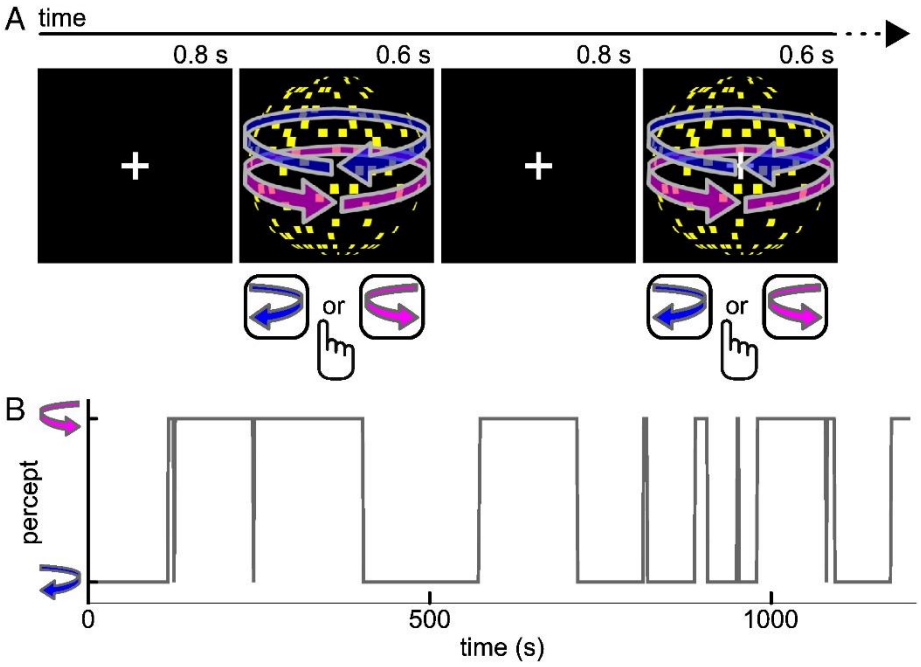

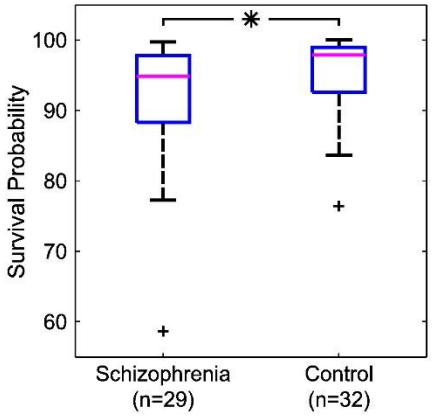

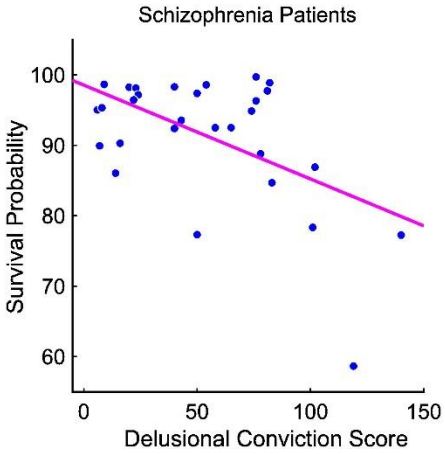

Schmack et al. 2013

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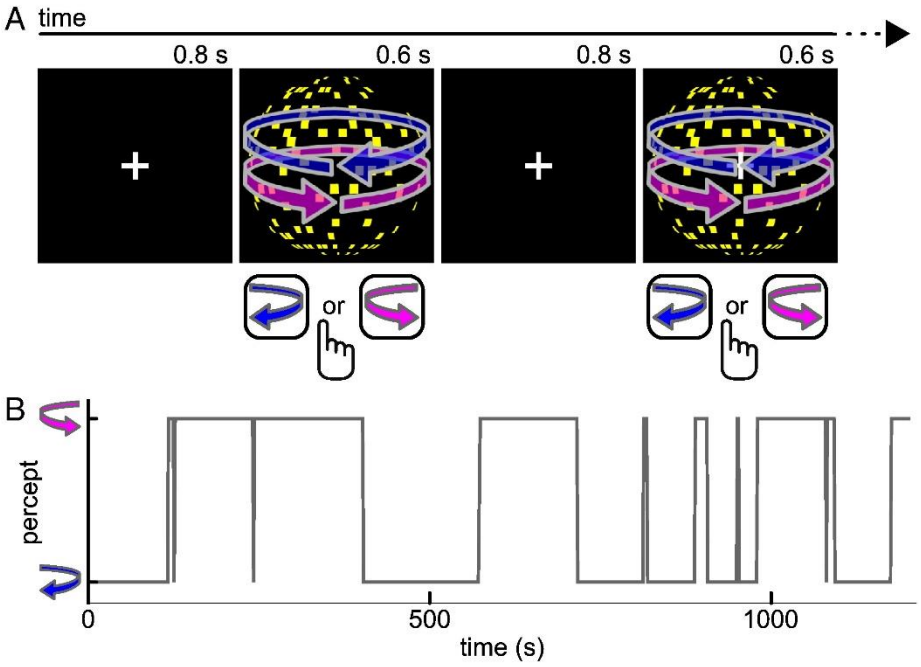
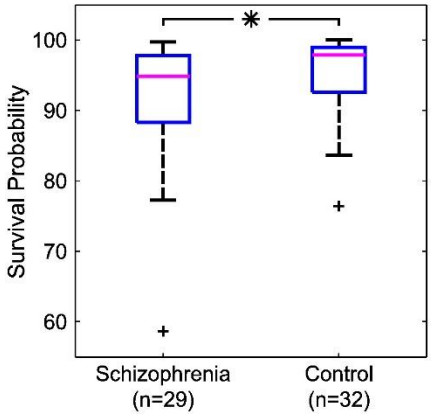
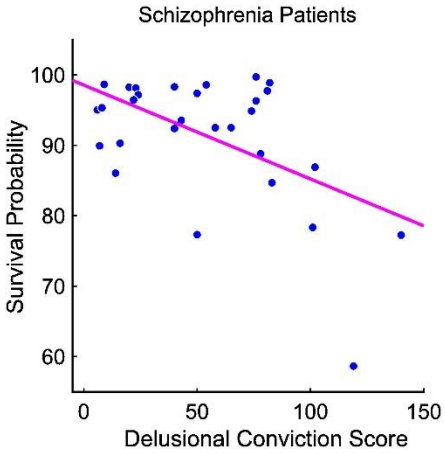






Schmack et al. 2015

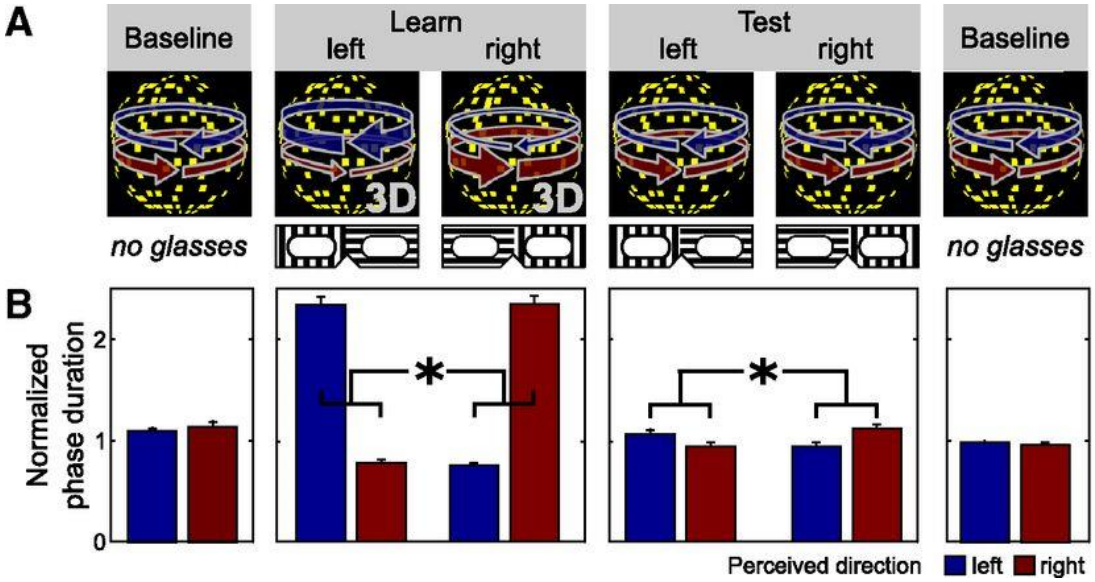
Scz: Reduced prior-to-likelihood ratio at sensory levels

- Reduced stabilization of perceptual time-courses
- Negative correlation of perceptual stability to delusional conviction

Prior Predictions in Bistability

Explicit Priors

- Cognitive manipulations modulate perceptual time-courses in bistability (“biases”)



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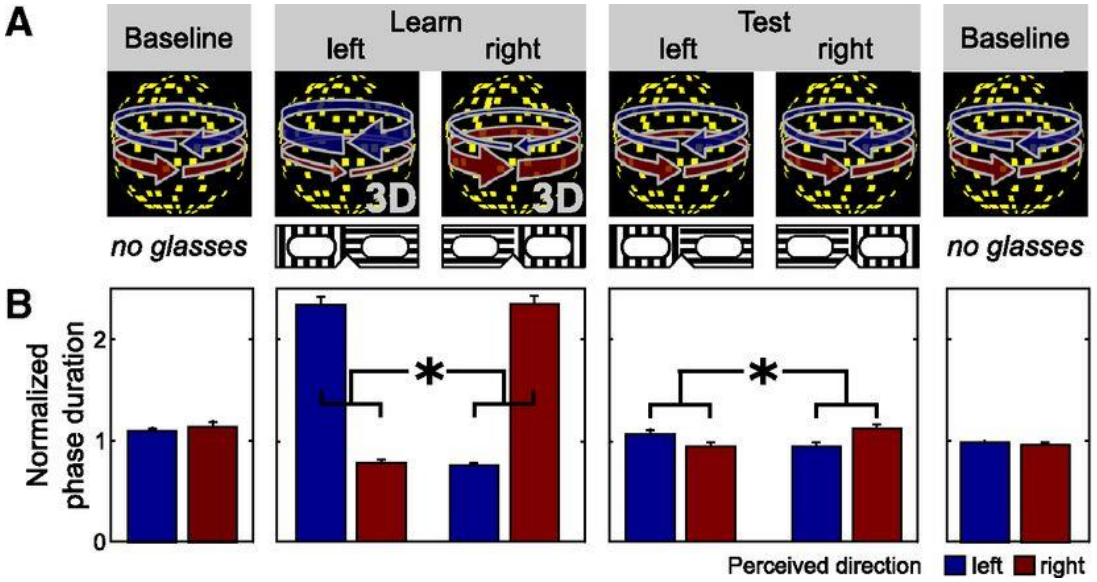

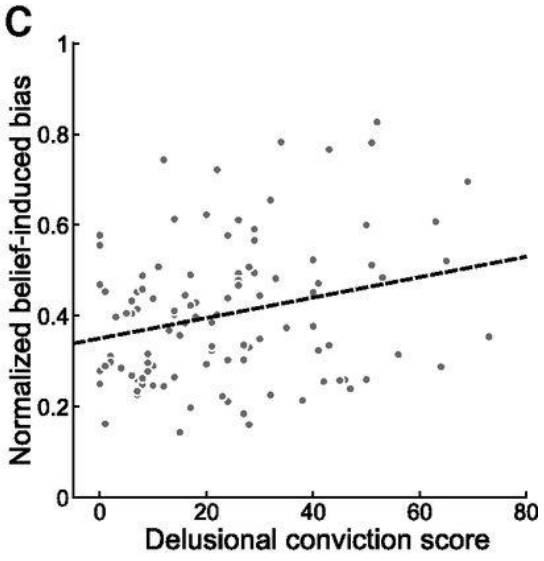

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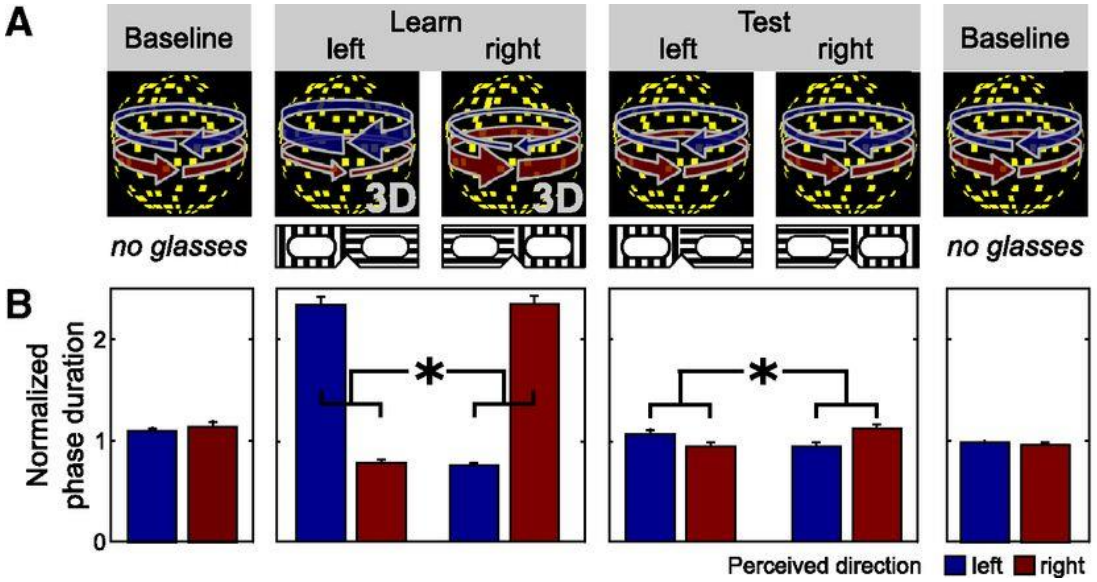
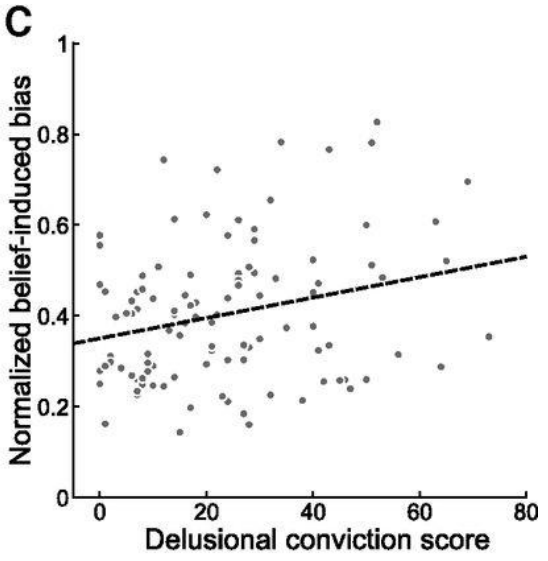




Schmack et al. 2013

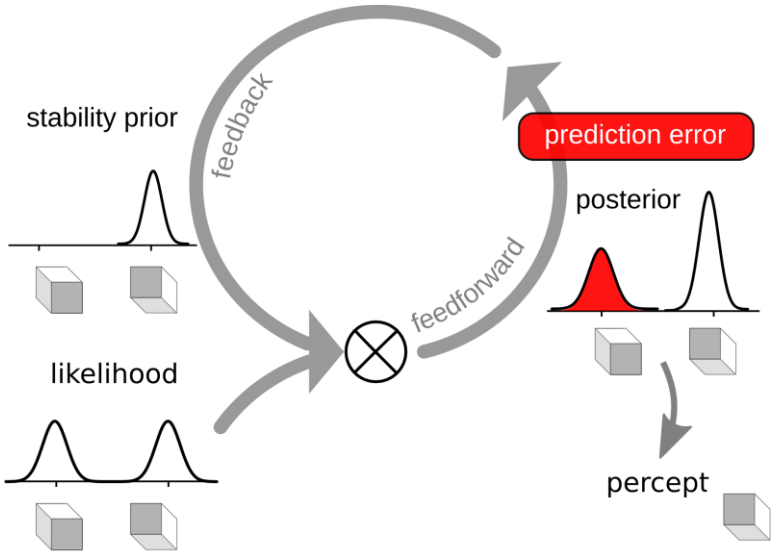
Delusions: Increased prior-to-likelihood ratio at higher levels

- Positive correlation of high-level biases to delusional conviction
- Compensation for reduced perceptual stability at sensory levels

Generative Models of Bistability

Predictive Coding

- Remaining evidence for the alternative stimulus interpretation constitutes a prediction error.

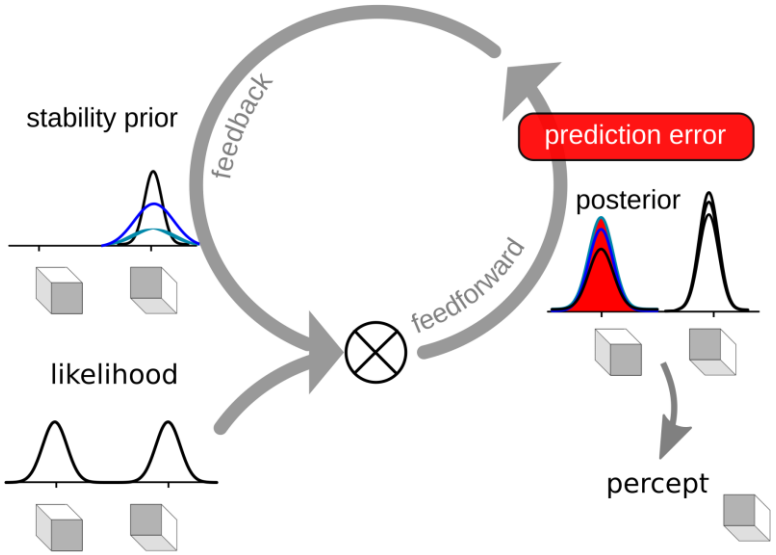


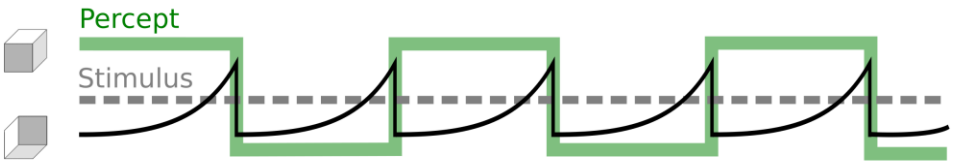
Weilnhammer et al. 2017, 2018, 2019 (in revision)

Predictive Coding

Ambiguity

- Escalating prediction errors are minimized by perceptual transitions.
- The **initial precision of the stability prior** scales with average **phase duration**.





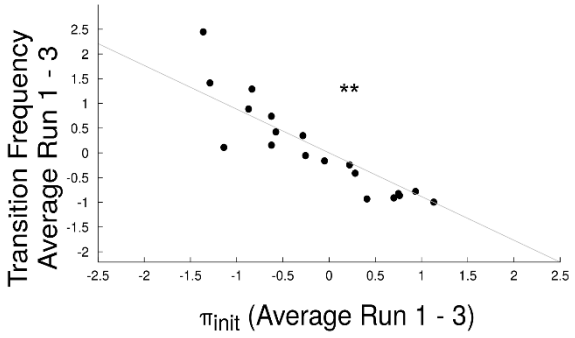
Prediction errors in ambiguity

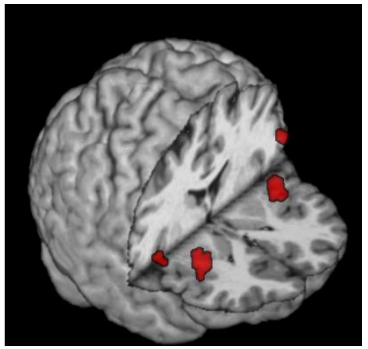
Weilnhammer et al. 2017, 2018, 2019 (in revision)

Predictive Coding

Implicit Priors

- The strength of predictions about the stability of the sensory environment determine the frequency of transitions in bistable perception:





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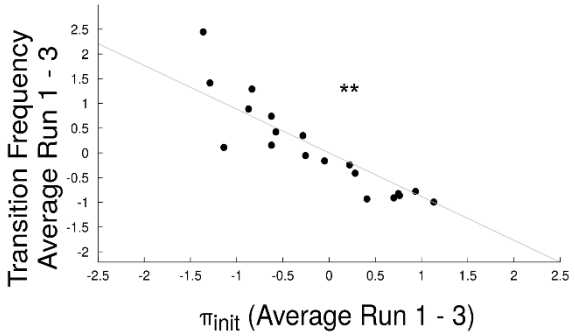
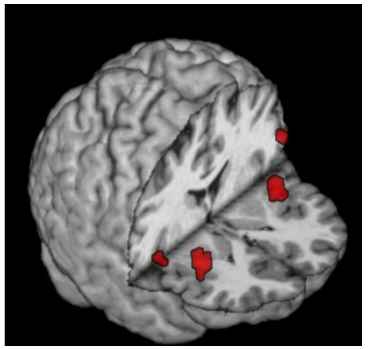
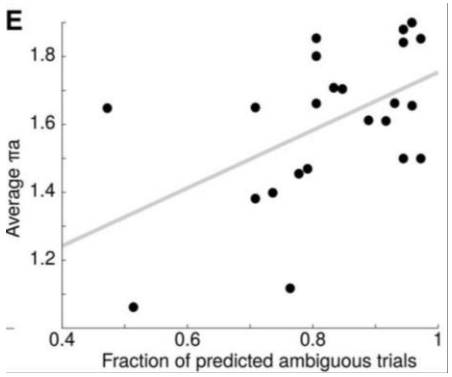


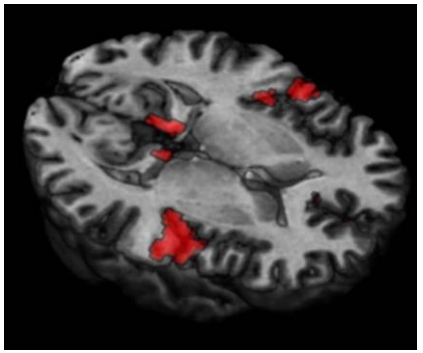


Weilnhammer et al. 2017

Explicit Priors

- The strength of explicit predictions (volatile cross-modal associations) determines biases in perceptual states:



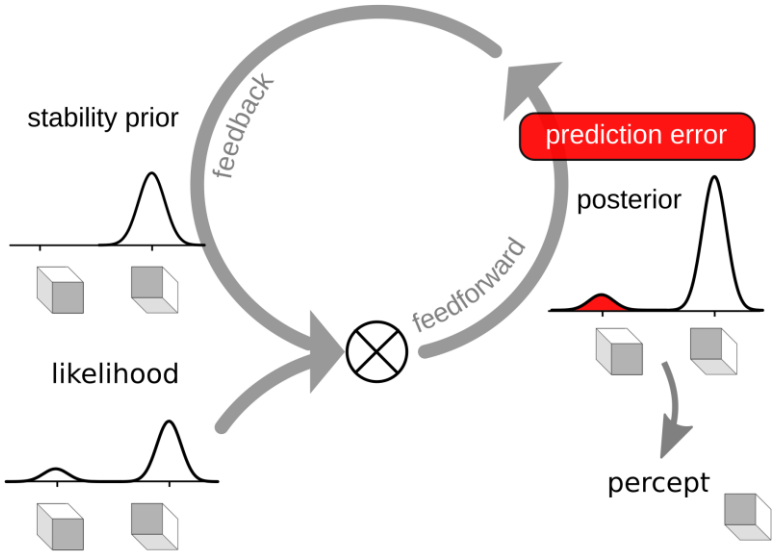


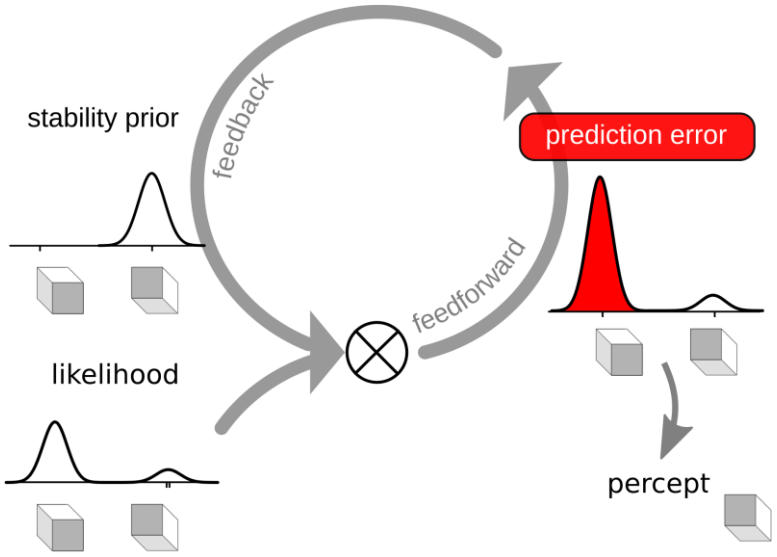
Weilnhammer et al. 2018

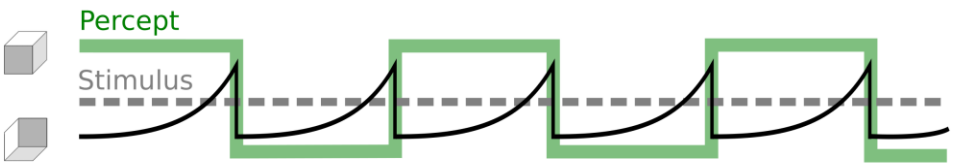
Predictive Coding

Graded Ambiguity

- Prediction errors are modulated by additional sensory evidence.
- Perceptual decisions reflect sensitivity to sensory evidence.







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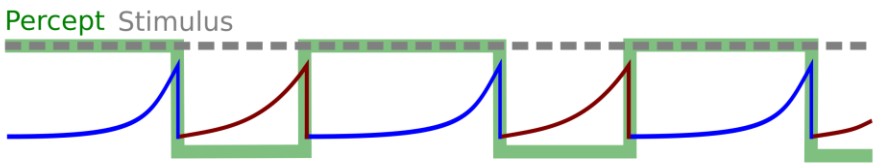
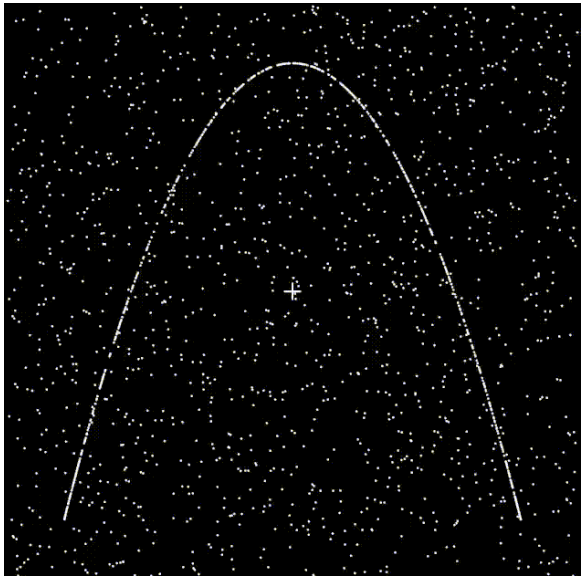


Prediction errors for congruent and incongruent perceptual phases

Paradigm

Structure-from-Motion

- Perceptual states elicited by a rotating Lissajous figure



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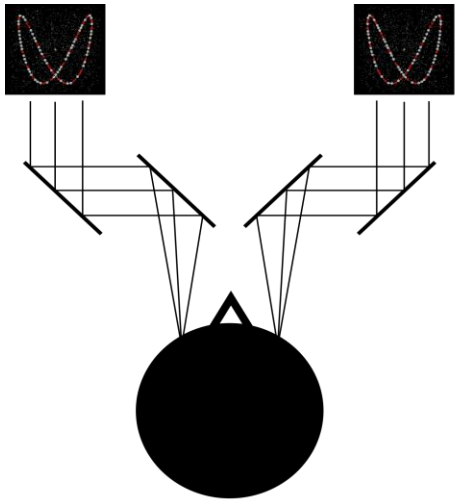

Paradigm

Structure-from-Motion

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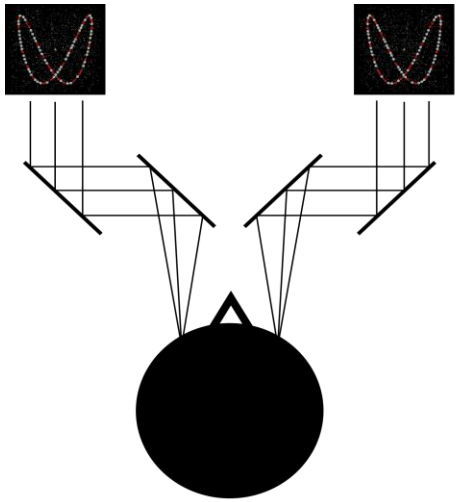
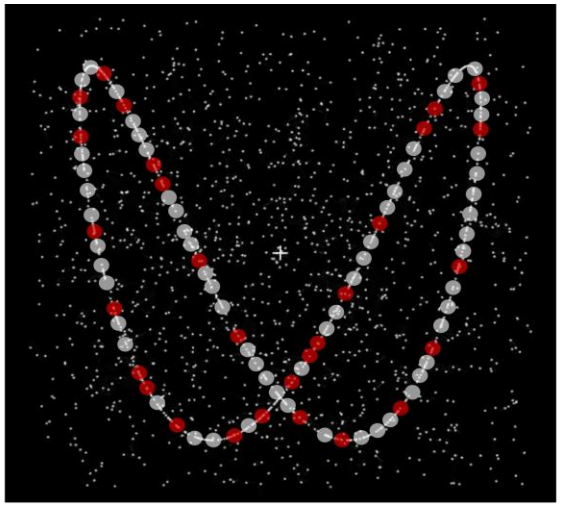
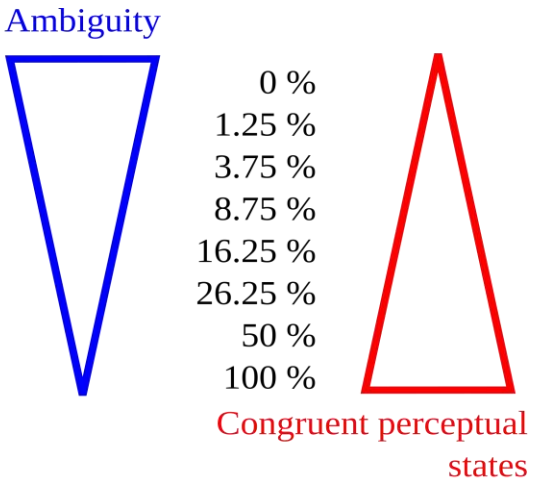
- Manipulation of stimulus evidence by additional 3D cues (mirror – stereoscope)
- Gradual Disambiguation: 3D-cues only in a fraction of Lissajous dots







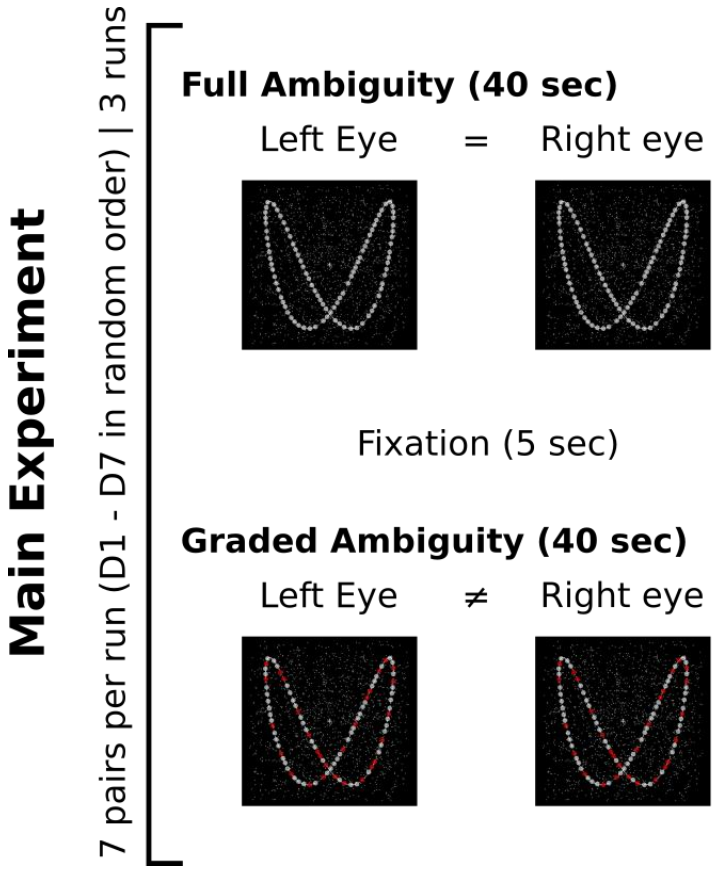
Weilnhammer et al. 2019 (in revision)

Methods

Sample

23 patients diagnosed with paranoid schizophrenia and 24 healthy controls.

- We obtained scores for **PANSS** (patients only) as well as **PDI** and **CAPS** (all participants).



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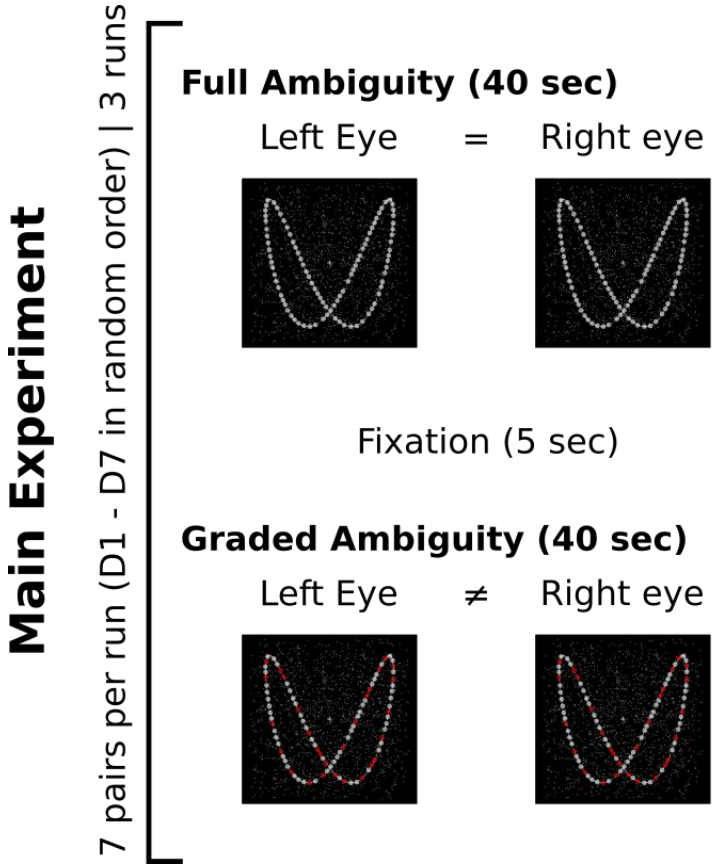
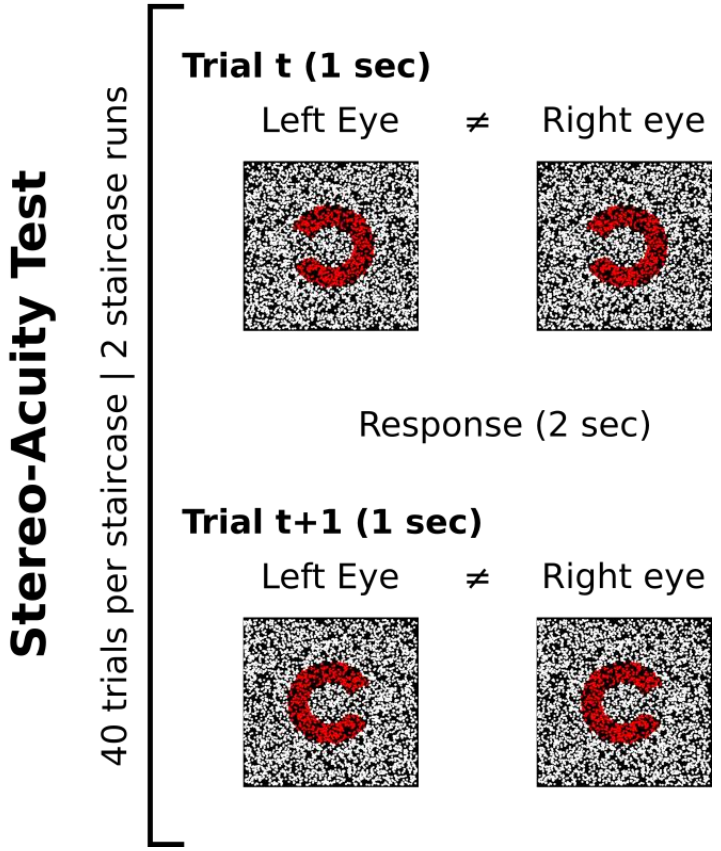


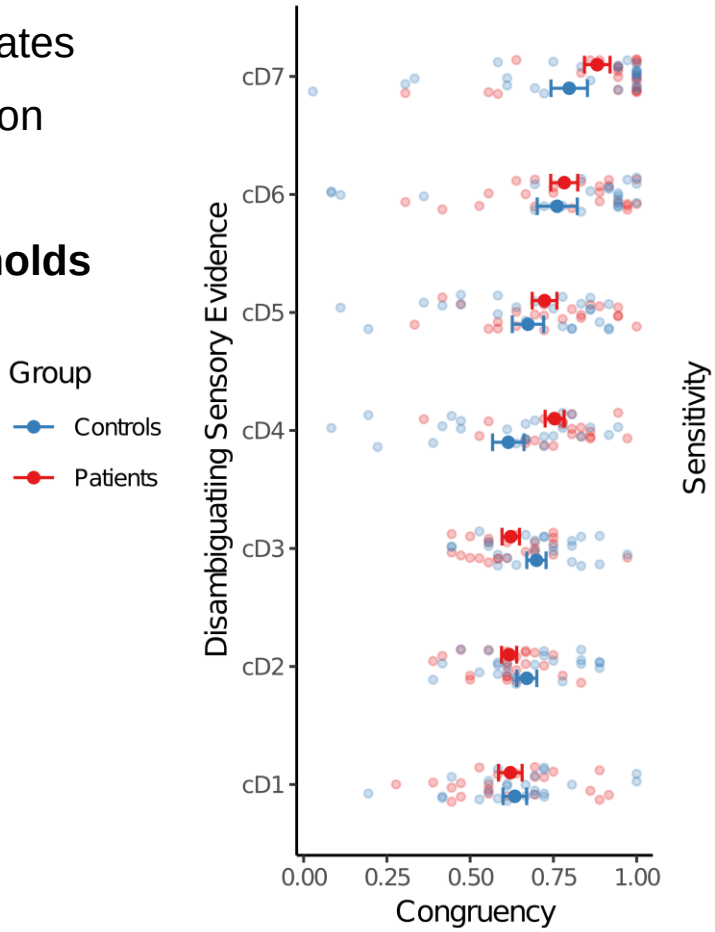


Weilnhammer et al. 2019 (in revision)

Results

Nonlinear mixed effects models

- Main effect of stimulus evidence (dSE) on **congruent perceptual states** (F_6 = 11.44, p < 2.1 x 10^{-11}); "**Group x disambiguating sensory evidence"** interaction (F_6 = 2.91, p = 0.01).
- Not significant:
  - Unclear perceptual states
  - Average phase duration
  - Perceptual Bias
  - **Stereo-acuity thresholds**



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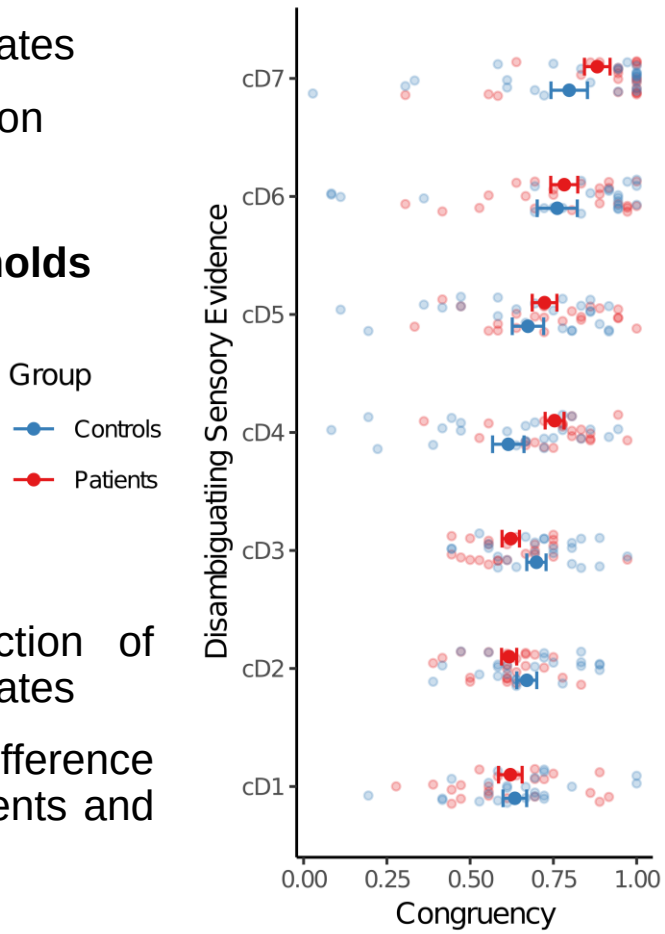
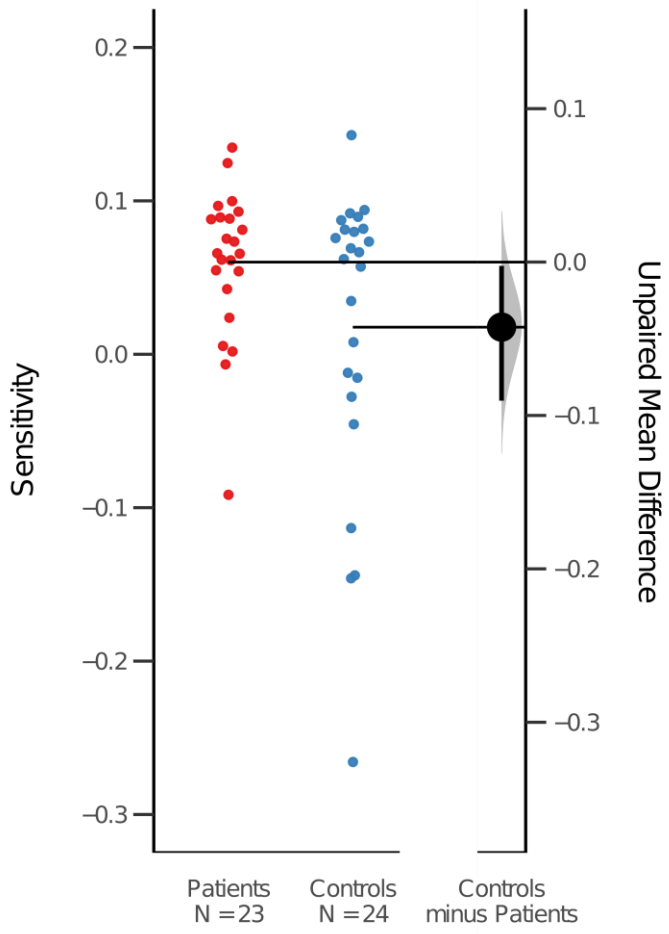




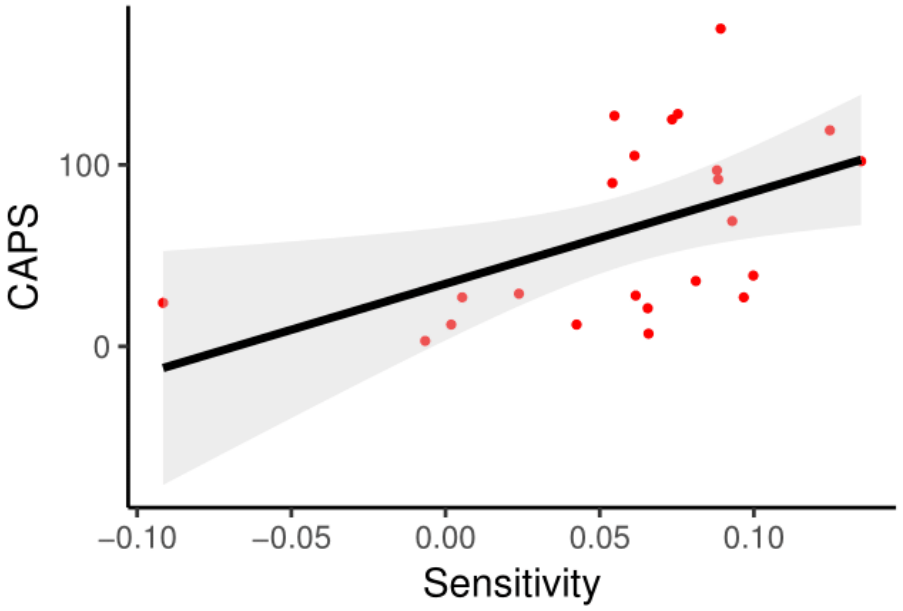
Sensitivity to dSE

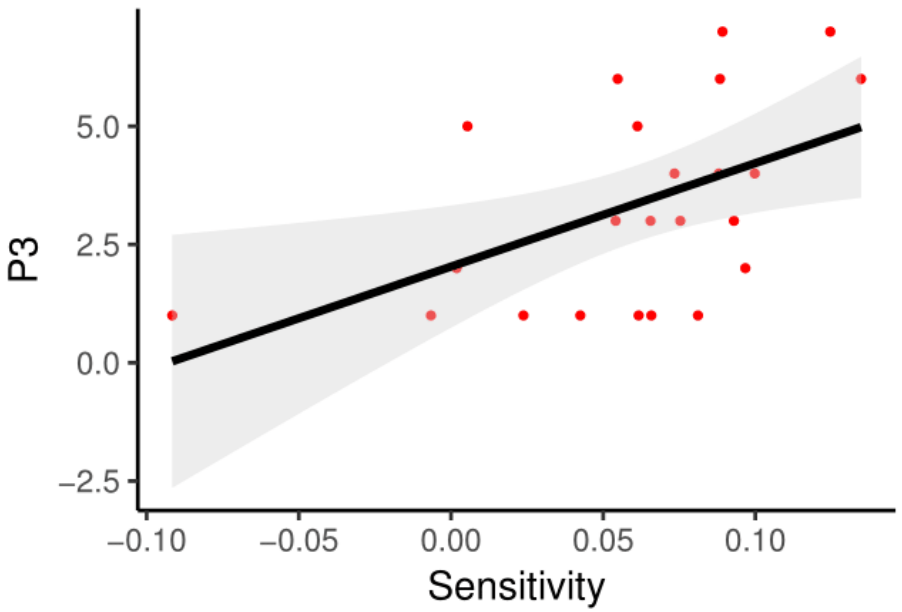
- Exponential fit to fraction of congruent perceptual states
- Borderline-significant difference in means between patients and controls

Results

Full and partial spearman correlations (Patients)

- The **sensitivity to disambiguating sensory evidence** was positively correlated to
  - **CAPS** (R = 0.57, p=0.01) and
  - **PANSS-subitem P3** (hallucinations, R = 0.52, p = 0.01).



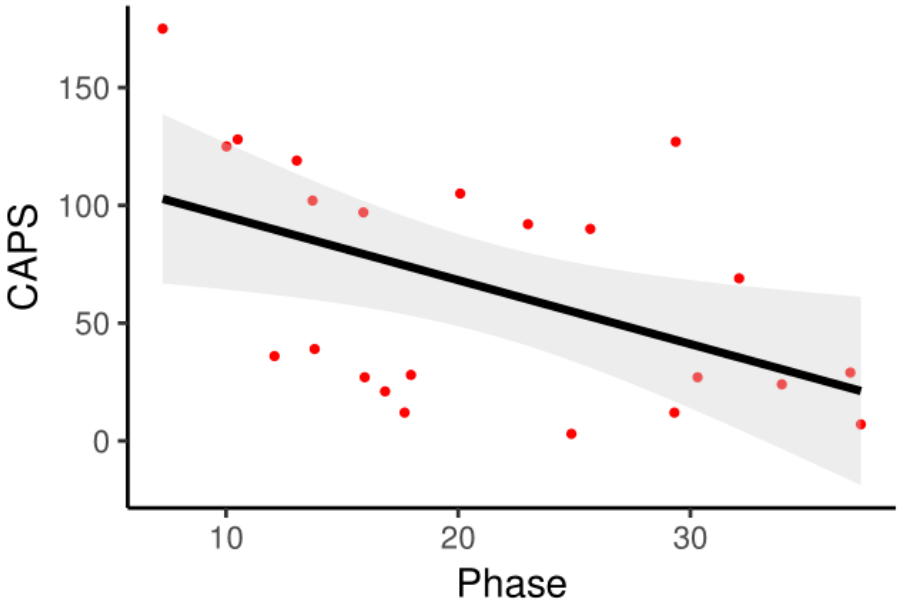


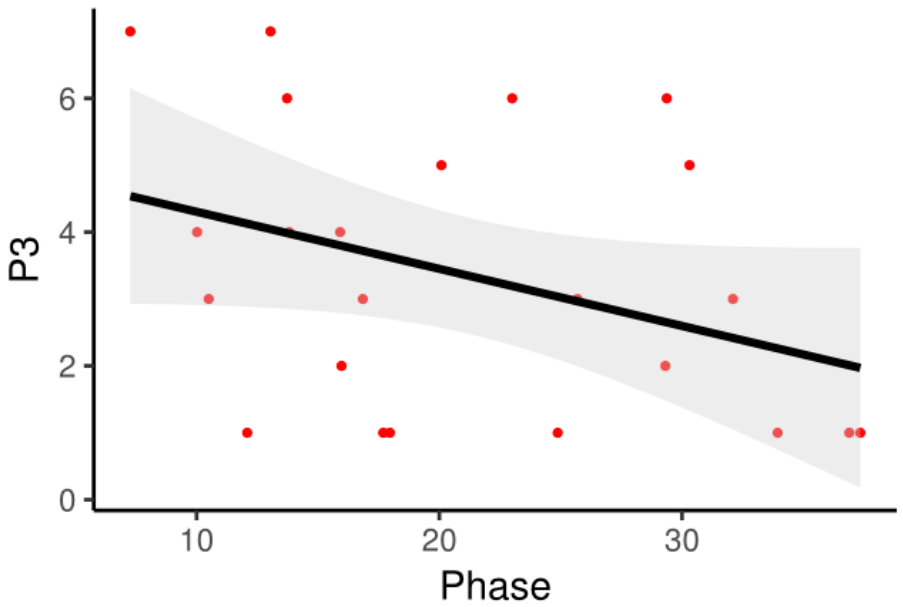
Weilnhammer et al. 2019 (in revision)

Results

Full and partial spearman correlations (Patients)

- **Average phase durations** were significantly negatively correlated to
  - **CAPS** (R = - 0.54, p = 0.007) and
  - PANSS-subitem P3 (hallucinations, R = -0.39, p = 0.07).



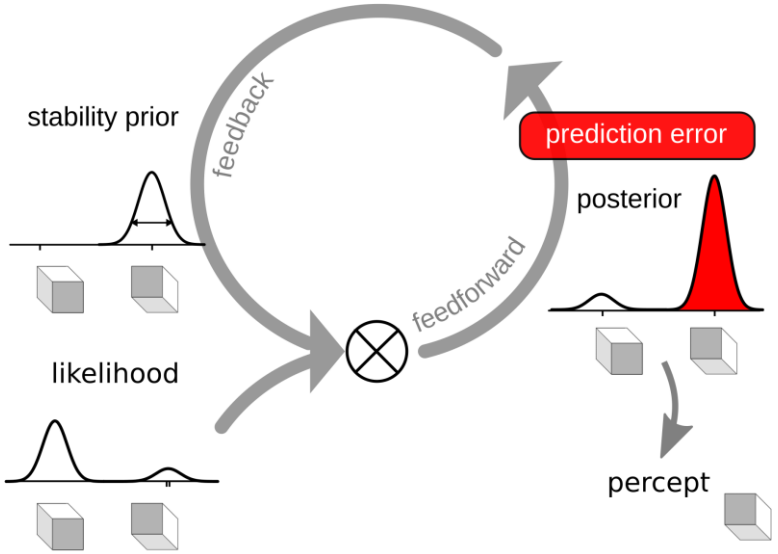


Weilnhammer et al. 2019 (in revision)

Discussion

Summary

- **Increased sensitivity to SE in Scz** patients correlated to the severity of **perceptual anomalies** and **hallucinations**.
- Moreover, the severity of **perceptual anomalies** and **hallucinations** was negatively correlated to **perceptual phase duration**.
- This is compatible with a **reduced prior-to-likelihood ratio in Scz**.

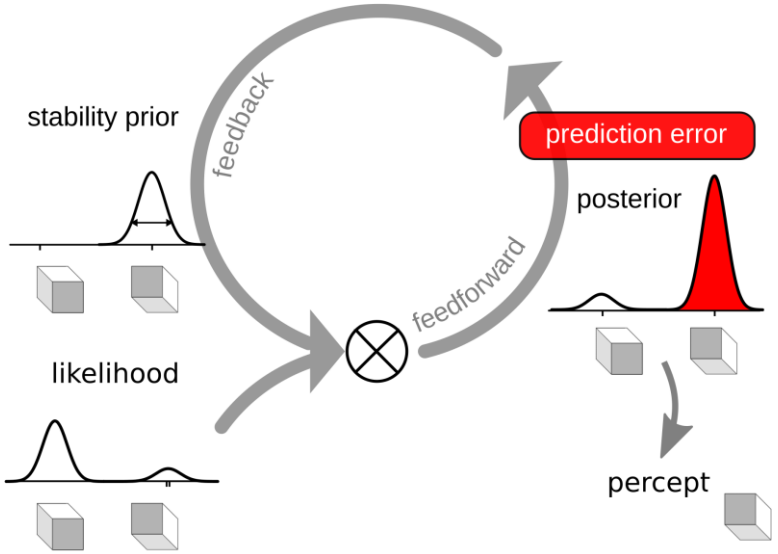


Discussion

- **Increased sensitivity to sensory evidence in Scz** correlated to severity of **perceptual anomalies** and **hallucinations**.
- Severity of **perceptual anomalies** and **hallucinations** negatively correlated to **perceptual phase duration**.
- Compatible with a **reduced prior-to-likelihood ratio in Scz** at lower hierarchical levels.
- Compensatory mechanism: **Enhanced priors** at higher hierarchical levels?

Limitations

- Neural mechanism: Isolated alteration in estimates for prior precision, likelihood precision or both?



Discussion

- **Increased sensitivity to sensory evidence in Scz** correlated to severity of **perceptual anomalies** and **hallucinations**
- Severity of **perceptual anomalies** and **hallucinations** negatively correlated to **perceptual phase duration**
- Compatible with a **reduced prior-to-likelihood ratio in Scz** at lower hierarchical levels
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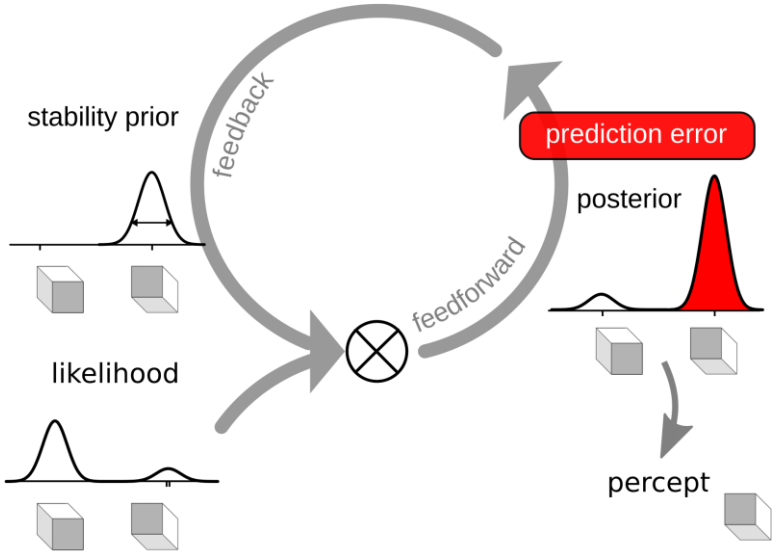

Future Directions

- Combination with intermittent presentation + probabilistic learning
- Priors at different hierarchical levels

Thanks for your attention!

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- Lukas Röd
- Anna-Lena Eckert
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- **Berlin Institute of Health**
- **Clinician Scientist Program**