

The Impact of Sensory Evidence and Prior Predictions on Perceptual Decisions in Patients with Paranoid Schizophrenia

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Bayesian Perceptual Inference



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Hypotheses

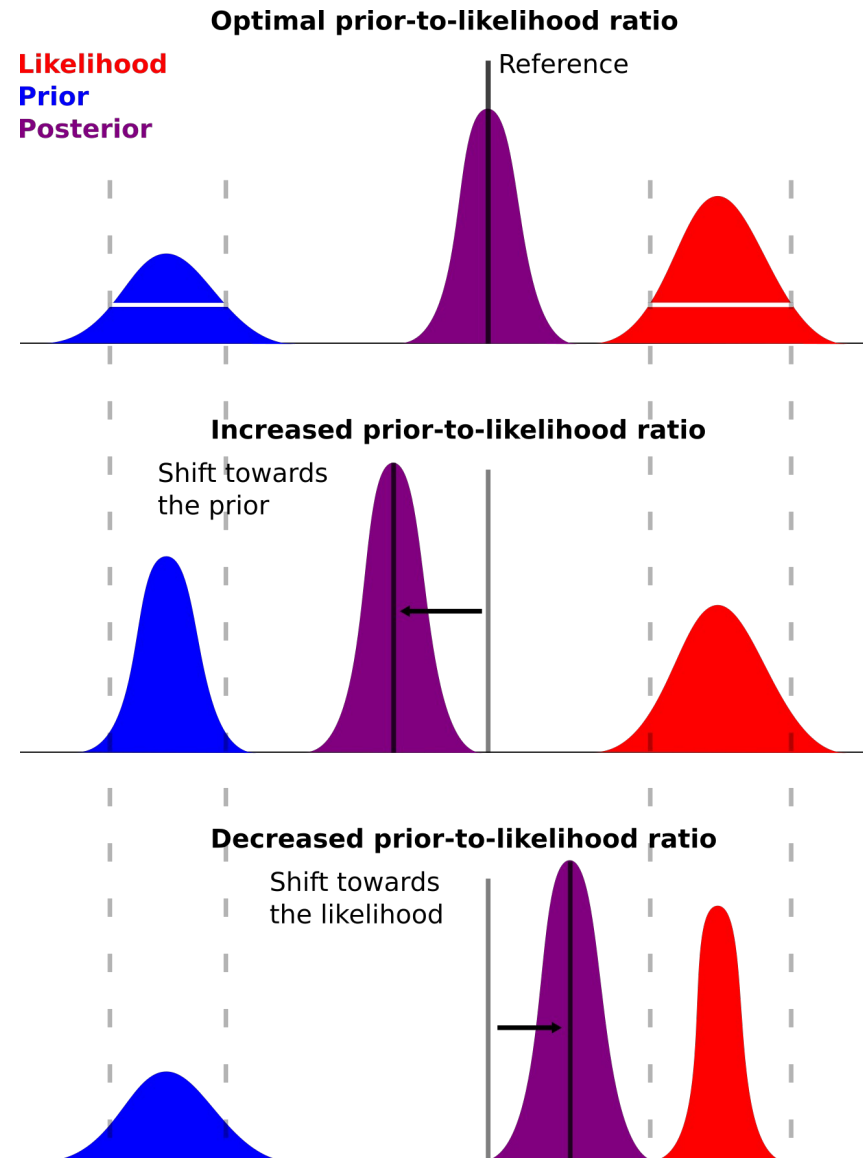
- Psychotic symptoms arise due to an alteration in perceptual inference.
- Delusions/hallucinations result from a shift in the relative precision of prior and likelihood (prior-to-likelihood ratio, **PLR**).
- Previous research showed opposing directions of shift in the prior-to-likelihood ratio.

Approach

- In this study, we use the phenomenon of **bistable perception** to characterize the PLR at the sensory level.

Questions

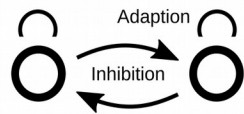
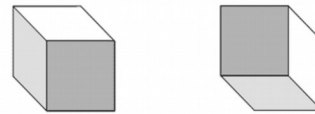
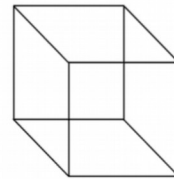
- Does the PLR differ between schizophrenia (**Scz**) patients and healthy controls?
- Does the PLR correlate with individual symptom severity?



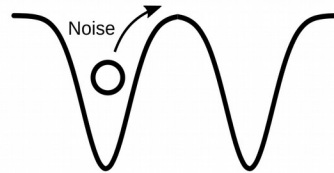
Models of Bistable Perception

Perceptual Bistability

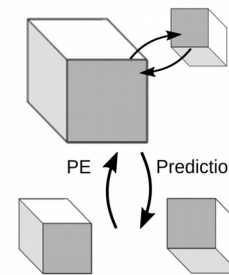
- A constant ambiguous sensory input elicits spontaneous fluctuations between two alternative, mutually exclusive interpretations.



Wilson 2007



Moreno-Bote 2007



Hohwy 2008
Weilnhammer 2017

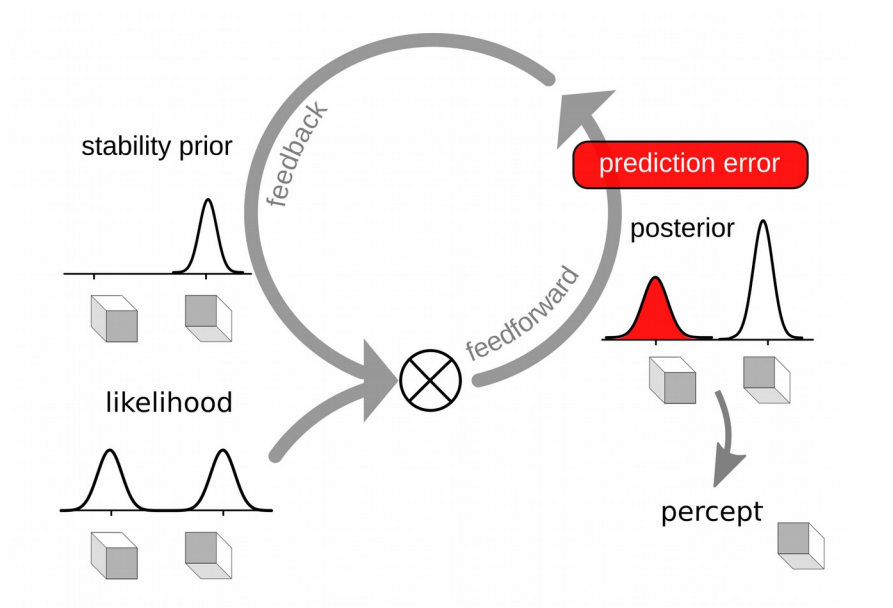
• Predictive Coding

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

Prediction Errors in Bistable Perception

Ambiguity

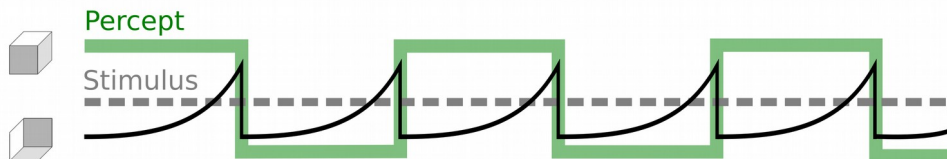
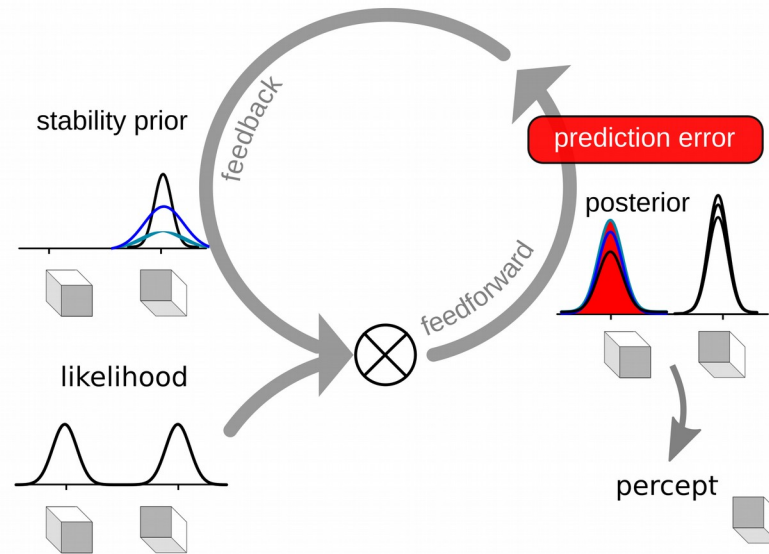
- Remaining evidence for the alternative stimulus interpretation constitutes a prediction error.



Prediction Errors in Bistable Perception

Ambiguity

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

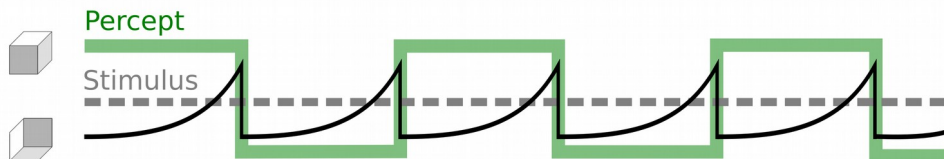
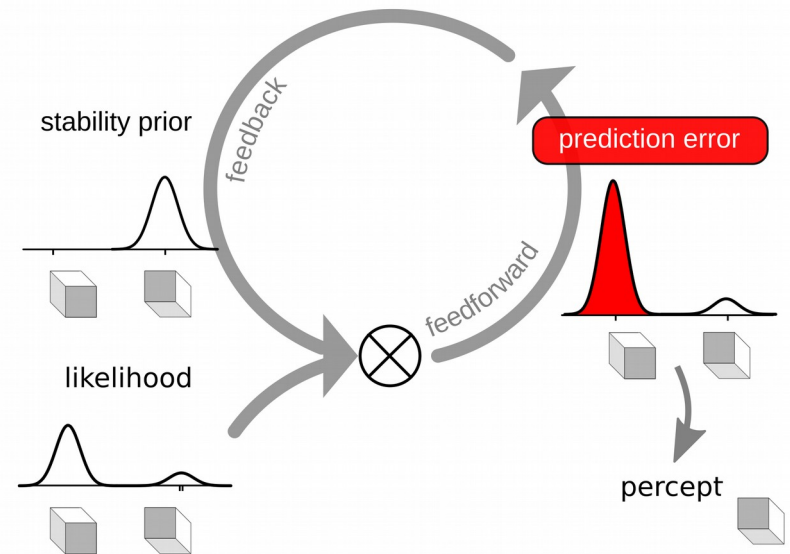
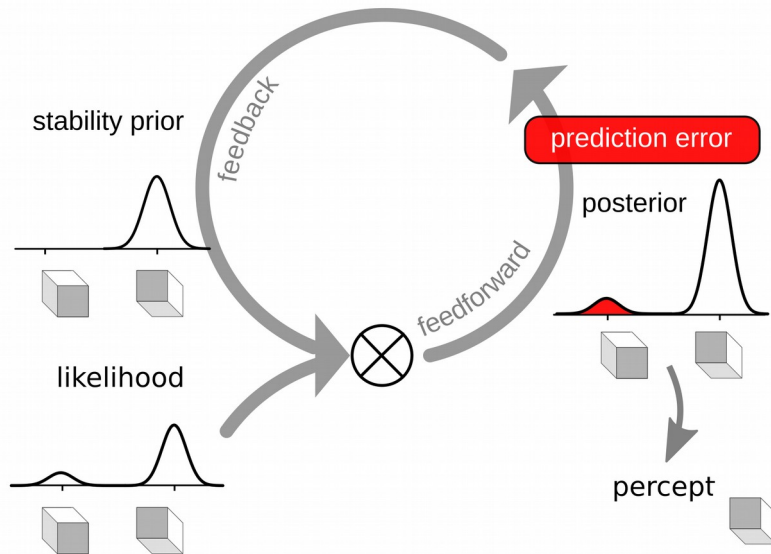


Prediction errors in ambiguity

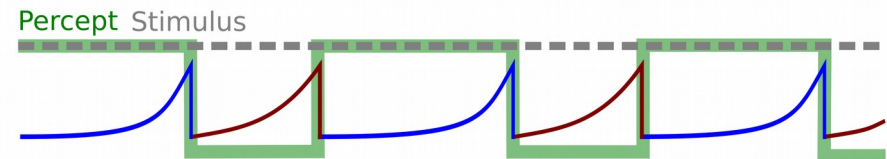
Prediction Errors in Bistable Perception

Graded Ambiguity

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



Prediction errors in ambiguity

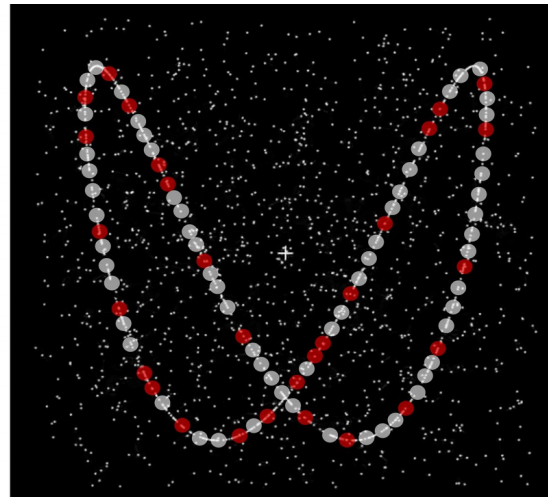
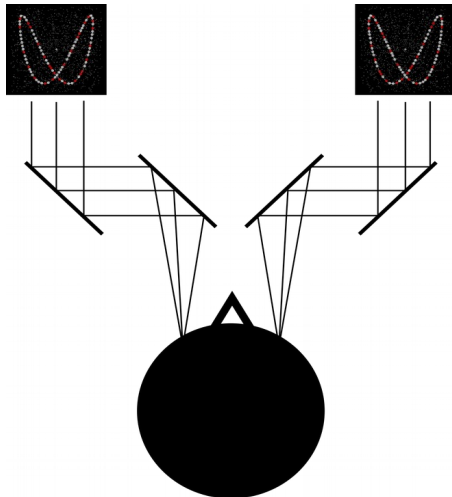


Prediction errors for congruent and incongruent perceptual phases

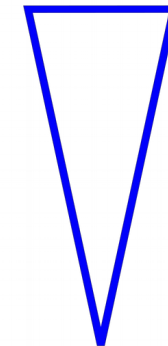
Paradigm

Structure-from-Motion

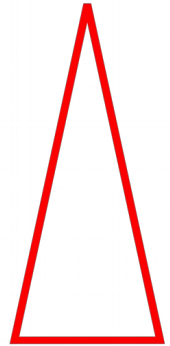
- We achieved graded ambiguity by disambiguating a fraction of the surface of a discontinuous rotating Lissajous figure.
- 3D-cues were achieved by using a mirror stereoscope.



Ambiguity



0 %
1.25 %
3.75 %
8.75 %
16.25 %
26.25 %
50 %
100 %



Congruent perceptual states

Unclear perceptual states

Phase duration

Perceptual bias

Methods

Sample

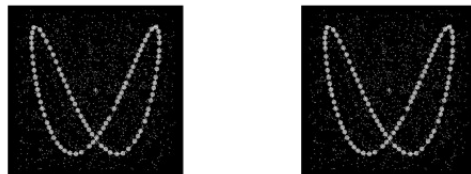
- We recruited 23 patients diagnosed with paranoid schizophrenia and 24 healthy controls.
- We obtained scores for **PANSS** (patients only) as well as **PDI** and **CAPS** (all participants).

Main Experiment

7 pairs per run (D1 - D7 in random order) | 3 runs

Full Ambiguity (40 sec)

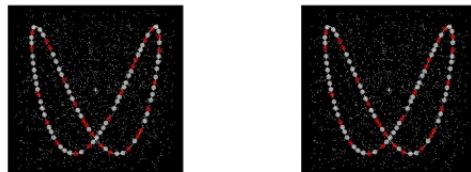
Left Eye = Right eye



Fixation (5 sec)

Graded Ambiguity (40 sec)

Left Eye ≠ Right eye



Stereo-Acuity Test

40 trials per staircase | 2 staircase runs

Trial t (1 sec)

Left Eye ≠ Right eye



Response (2 sec)

Trial t+1 (1 sec)

Left Eye ≠ Right eye



Results

Mixed ANOVA

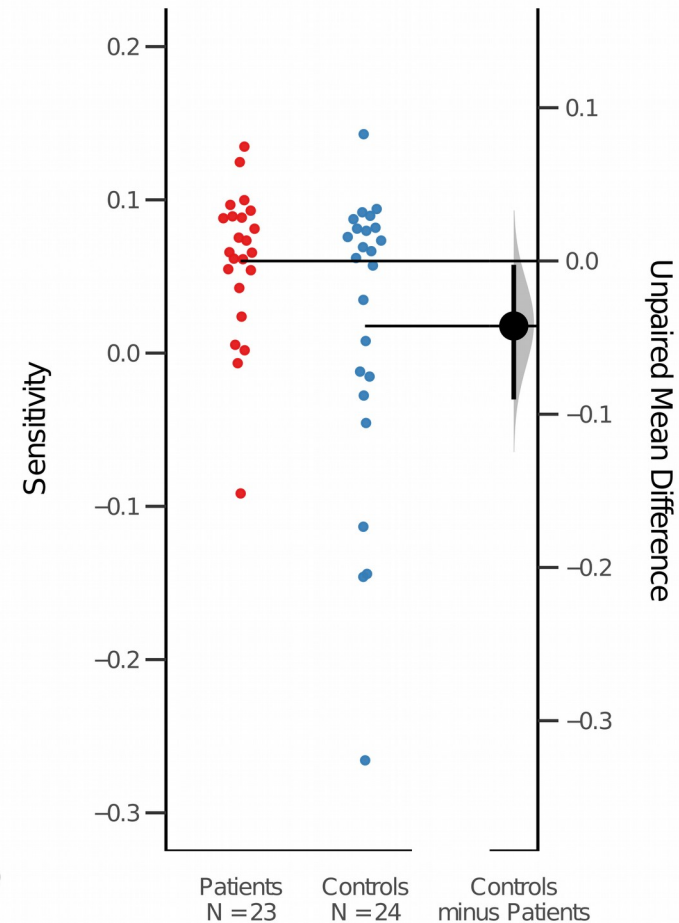
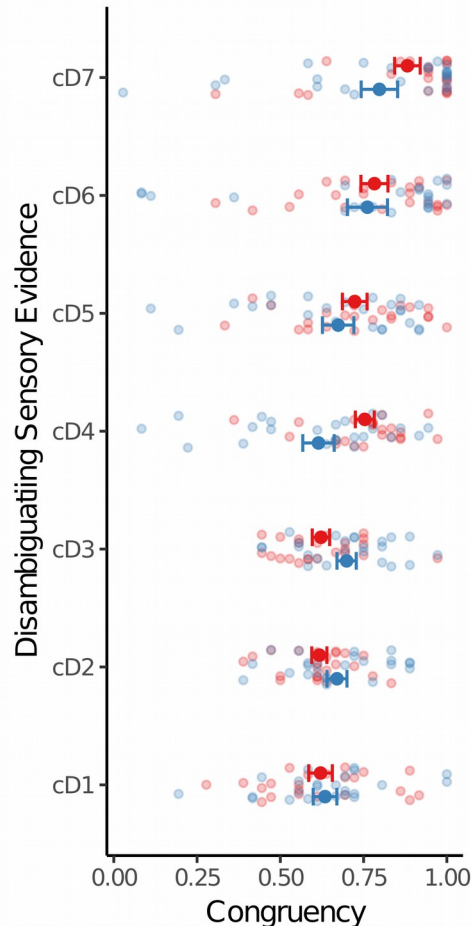
- Main effect of stimulus evidence (dSE) on **congruent perceptual states** ($F_6 = 11.44$, $p < 2.1 \times 10^{-11}$); “**Group x disambiguating sensory evidence**” interaction ($F_6 = 2.91$, $p = 0.01$).

- Not significant:

- Unclear perceptual states
- Average phase duration
- Perceptual Bias
- **Stereo-acuity thresholds**

Group
—●— Controls
—●— Patients

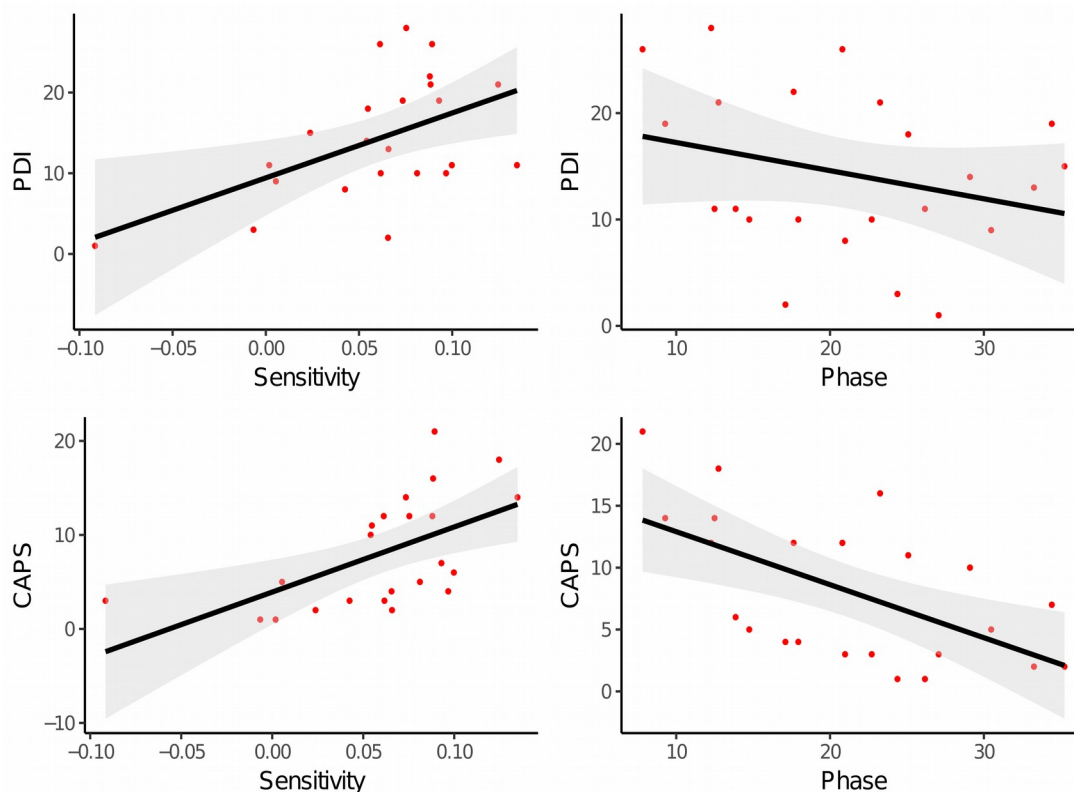
- **Sensitivity to dSE**
- Exponential fit to fraction of congruent perceptual states
- Significant difference in means between patients and controls (95% CI: 0.002 – 0.09)



Results

Correlations (Patients)

- The **sensitivity to disambiguating sensory evidence** was significantly correlated to
 - **PDI** ($R=0.52$, $p=0.02$) and **CAPS** ($R = 0.57$, $p=0.01$) and
 - **PANSS positive** ($R = 0.48$, $p = 0.03$) and **general** ($R = 0.48$, $p = 0.02$) sub-scales.
- **Average phase durations** were significantly correlated to CAPS ($R = -0.59$, $p = 0.01$).



- **Further correlations: n.s.**
 - Perceptual bias
 - Uncertain perceptual states
 - Stereo-acuity thresholds
 - Duration of illness
 - Medication (CPZ)
- **Correlations (Controls): n.s.**

Discussion

Summary

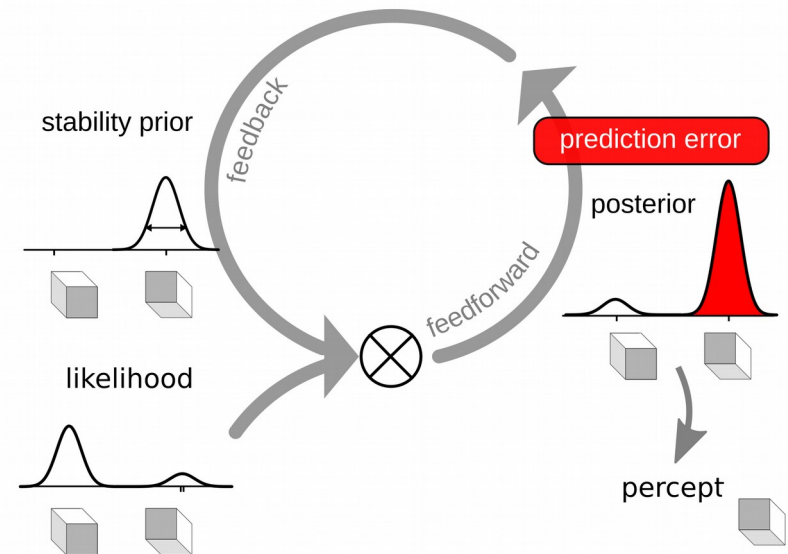
- We found an **increased sensitivity to SE in Scz** patients, which was correlated to the severity of **perceptual anomalies, delusional ideation** and the **PANSS positive** sub-scale.
- Moreover, the severity of **perceptual anomalies** was negatively correlated to **perceptual phase duration**.
- This is compatible with a **reduced prior-to-likelihood ratio in Scz**.

Limitations

- Sensitivity to dSE was not correlated to a specific symptom dimensions (delusions vs. hallucinations).
- Correlation to the PANSS general sub-scale

Future Directions

- Replication in an independent sample
- Psychiatric comparison group
- Combination with probabilistic learning



Thanks for your attention!

Collaborators:

- Lukas Röd
- Anna-Lena Eckert
- Philipp Sterzer



Visual Perception Laboratory

Berlin Institute of Health

Clinician Scientist Program

Presentations

- **Philipp Sterzer:** Predictions, perception and psychosis: A neuro-computational account of schizophrenia. Symposium 12. Time: 29/Aug/2019, Location: Alma 2.
- **Anna-Lena Eckert:** A novel tool to study prediction error processing in bistable perception, Time: 28/Aug/2019: 1:30pm-3:00pm · Location: Jubileumzaal.
- **Merve Fritsch:** The effect of transcranial magnetic stimulation of the right inferior frontal cortex on bistable perception, Time: 28/Aug/2019: 1:30pm-3:00pm · Location: Jubileumzaal.