Data Science 8

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Master's Degree Programme in Cognitive Science

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Hierarchical Gaussian Filtering: applications

NEUROSCIENCE

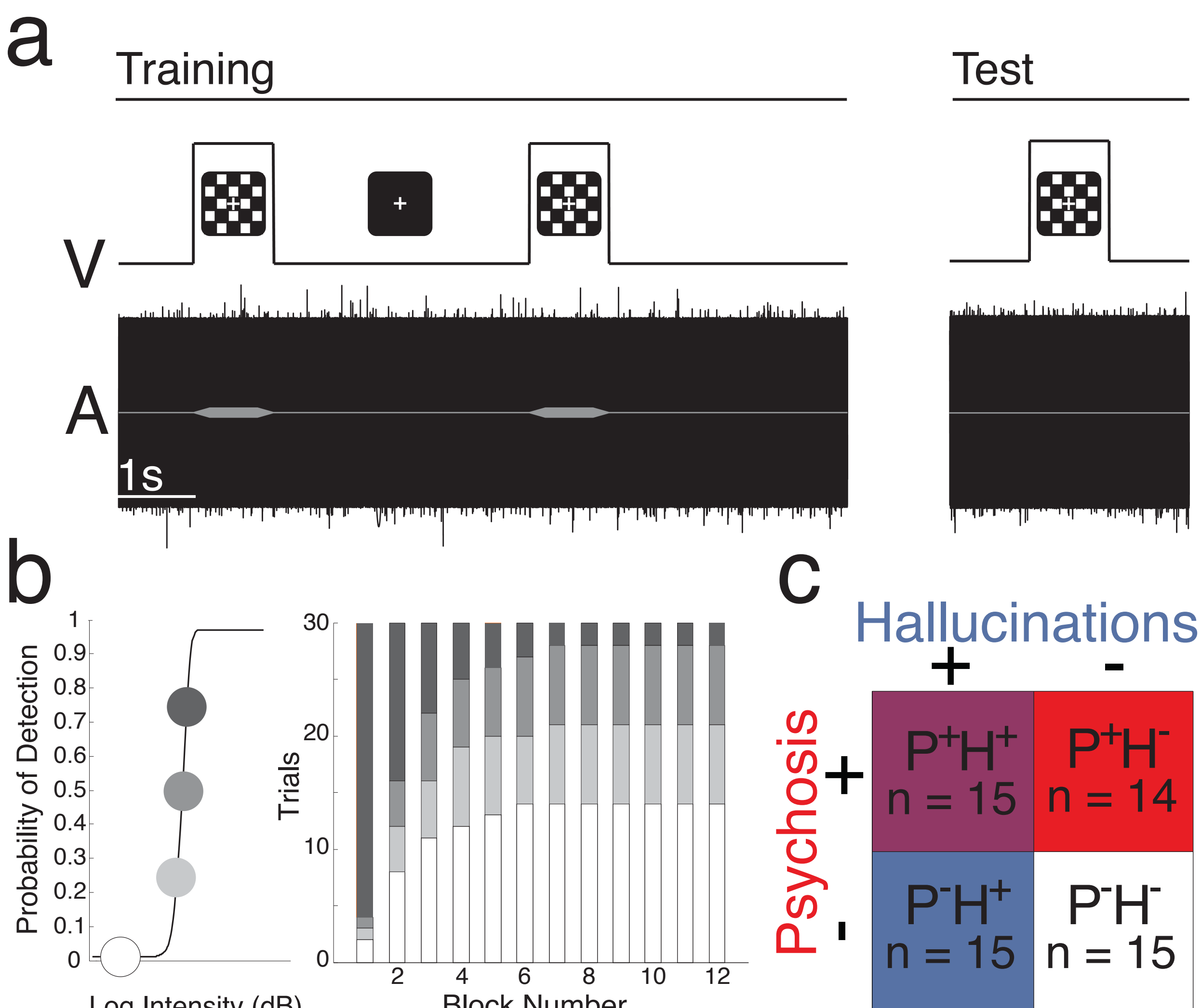
Pavlovian conditioning–induced hallucinations result from overweighting of perceptual priors

A. R. Powers,[1] C. Mathys,[2,3,4] P. R. Corlett[1*]

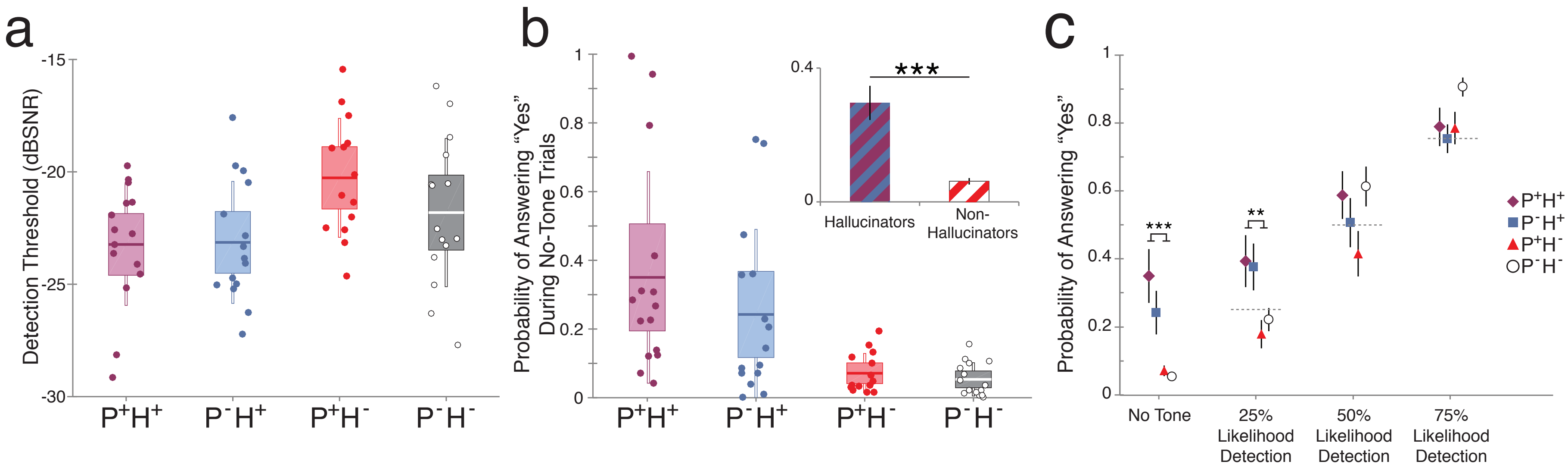
Some people hear voices that others do not, but only some of those people seek treatment. Using a Pavlovian learning task, we induced conditioned hallucinations in four groups of people who differed orthogonally in their voice-hearing and treatment-seeking statuses. People who hear voices were significantly more susceptible to the effect. Using functional neuroimaging and computational modeling of perception, we identified processes that differentiated voice-hearers from non–voice-hearers and treatment-seekers from non–treatment-seekers and characterized a brain circuit that mediated the conditioned hallucinations. These data demonstrate the profound and sometimes pathological impact of top-down cognitive processes on perception and may represent an objective means to discern people with a need for treatment from those without.

Powers *et al.*, *Science* **357**, 596–600 (2017)

Conditioned hallucinations
(Powers, Mathys, & Corlett, Science, 2017)



Conditioned hallucinations



Conditioned hallucinations

- Belief/percept formation model specifically created for this task
- Probability that the subject will respond “yes” to detection on a given trial:

$$P(\text{"yes"}|belief) = sigmoid(belief)$$

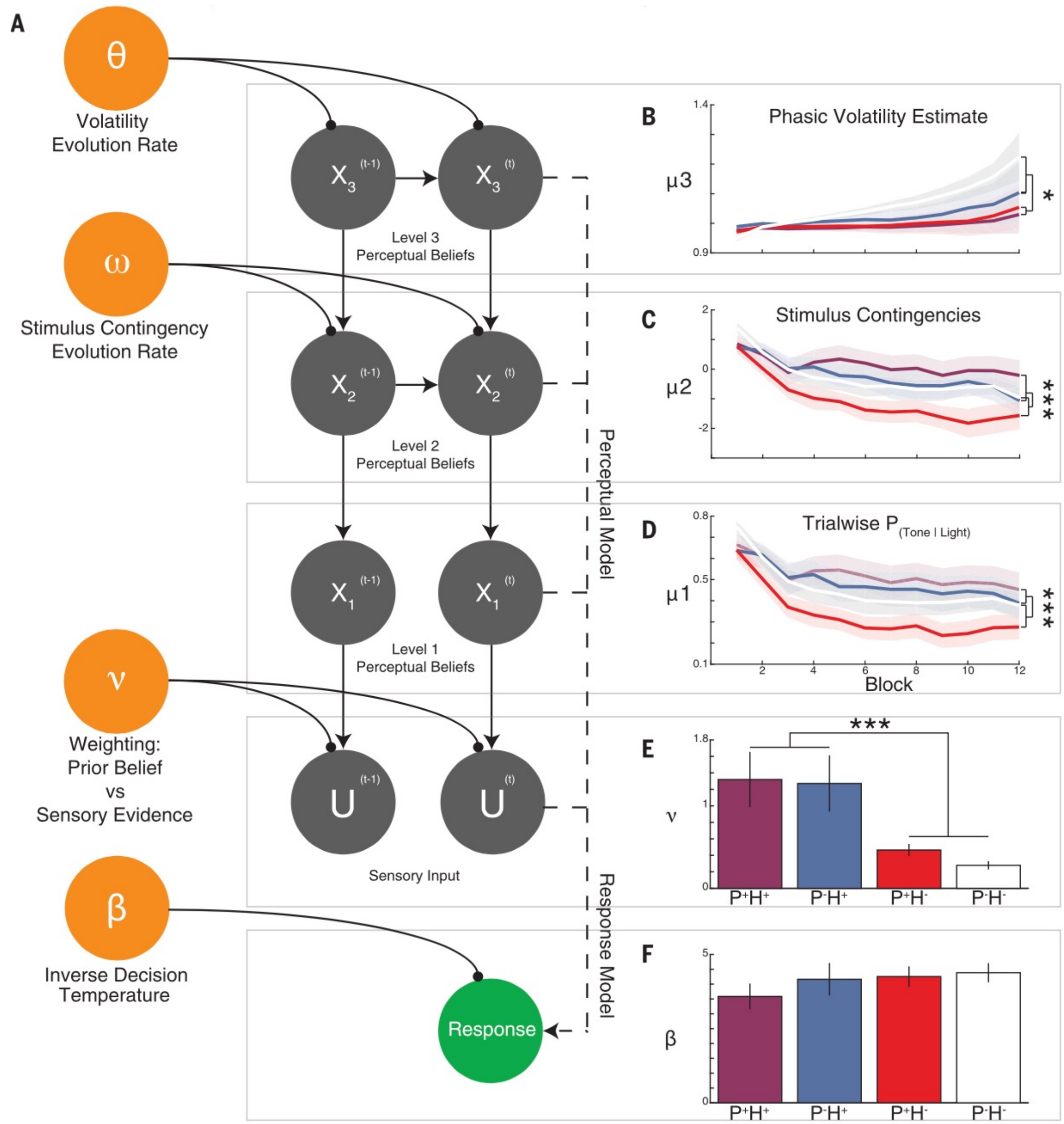
- $belief$ is formalized as the Bayesian posterior mean of a beta distribution

$$belief = prior + \frac{1}{1+\nu}(input - prior)$$

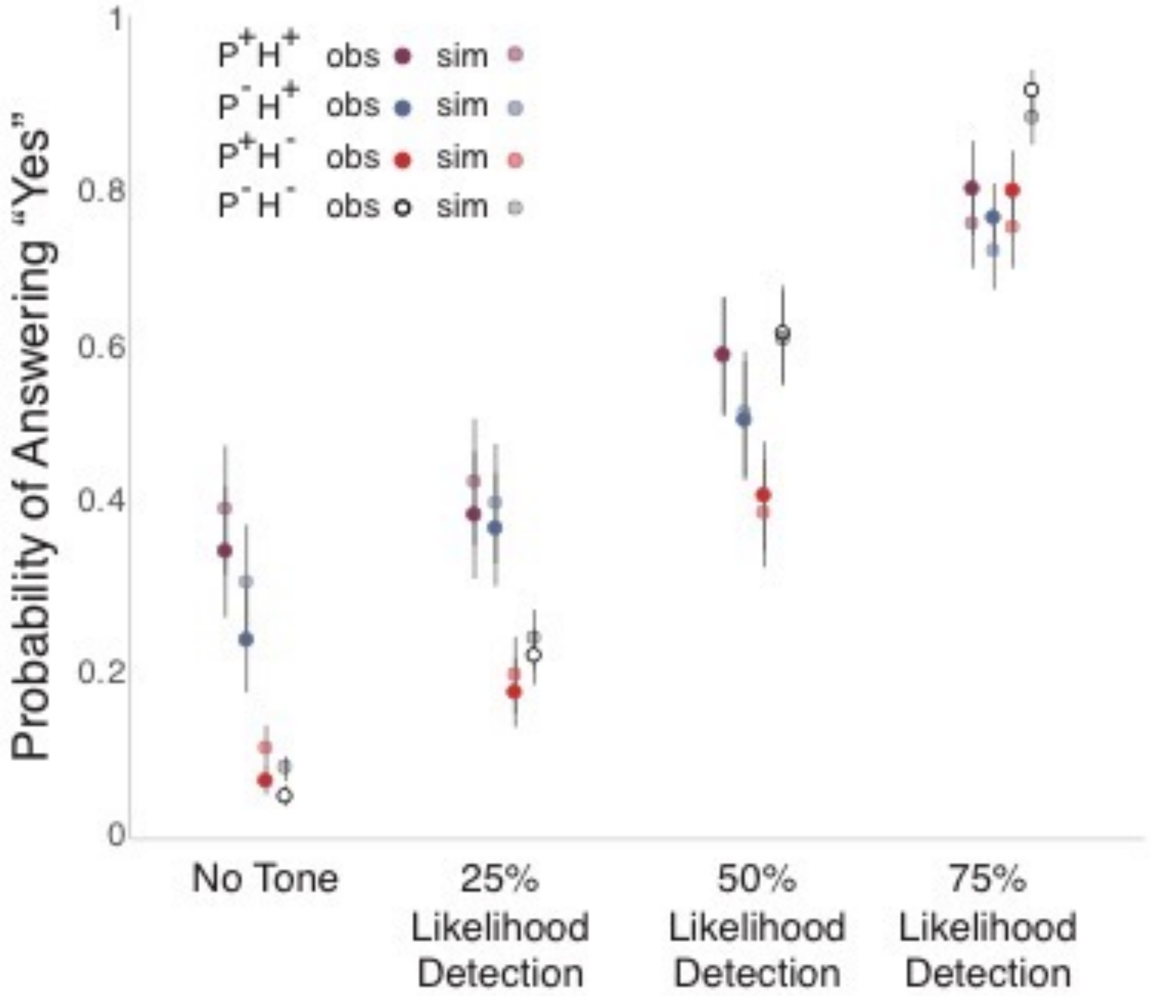
where

- $input$ is given by experimental design: the true positive rate of the tone presented without light at each trial: 25%, 50%, or 75%
- $prior$ is the prior from learning using the HGF: $\hat{\mu}_1$
- ν is a subject-specific parameter indicating the relative weight of the prior compared to the input.
- For $\nu = 1$, prior and input have equal weight; for $\nu > 1$ the prior has more weight than the input; and for $\nu < 1$ the input has more weight than the prior.

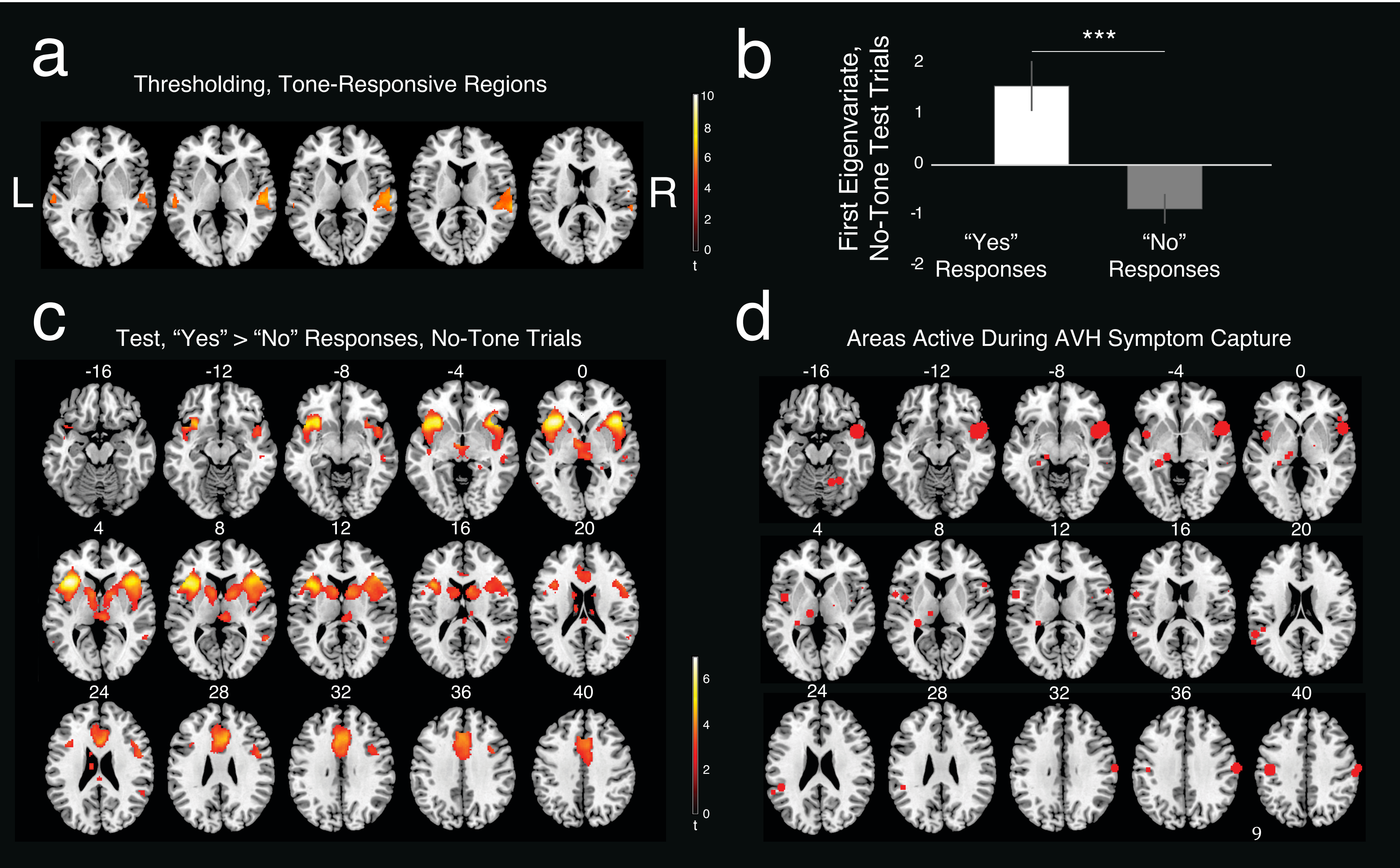
Conditioned hallucinations



Conditioned hallucinations



Conditioned hallucinations



Conditioned hallucinations

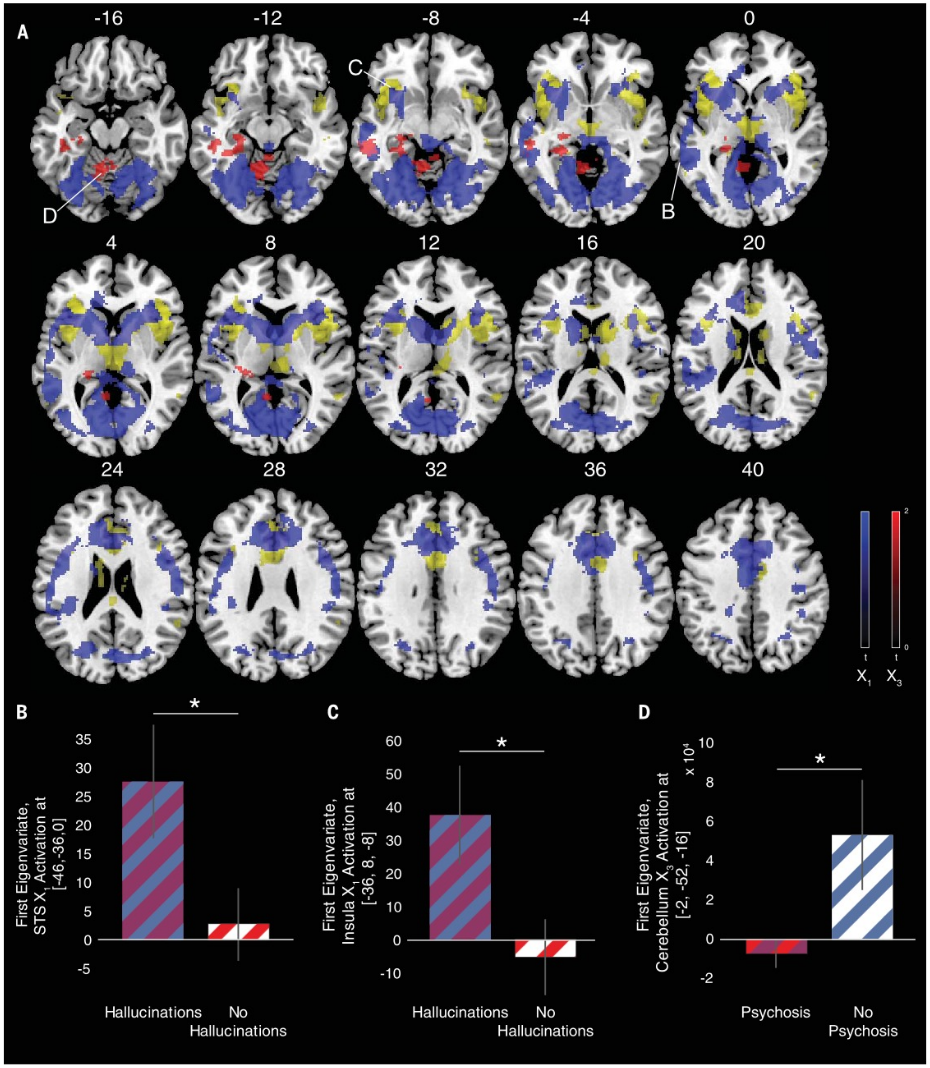


Fig. 4. HGF imaging results. (**A**) HGF trajectories for X_1 (blue) and X_3 (red) regressed onto blood oxygen level–dependent time courses for the conditioned hallucinations task. Regions that identified significantly active during conditioned hallucinations (from Fig. 3C) are highlighted in yellow for reference. All images are cluster-extent thresholded at starting value 0.05; critical k_e for X_1 = 545 and X_3 = 406. (**B** and **C**) Parameter estimates of X_1 fit extracted from 5-mm sphere centered on (B) STS and (C) anterior insula activation differ based on hallucination status. (**D**) Parameter estimates of X_3 fit extracted from 1-mm sphere centered on cerebellar vermis activation differ based on psychosis status. Error bars represent 1 SEM.

PLOS COMPUTATIONAL BIOLOGY

RESEARCH ARTICLE

Aberrant computational mechanisms of social learning and decision-making in schizophrenia and borderline personality disorder

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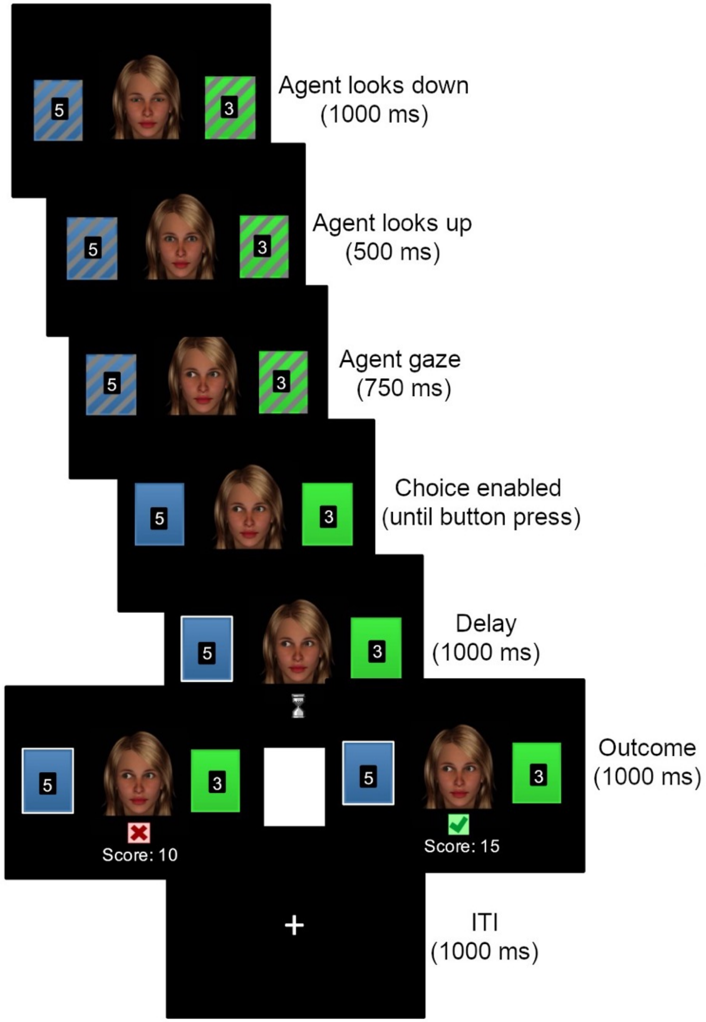
Author summary

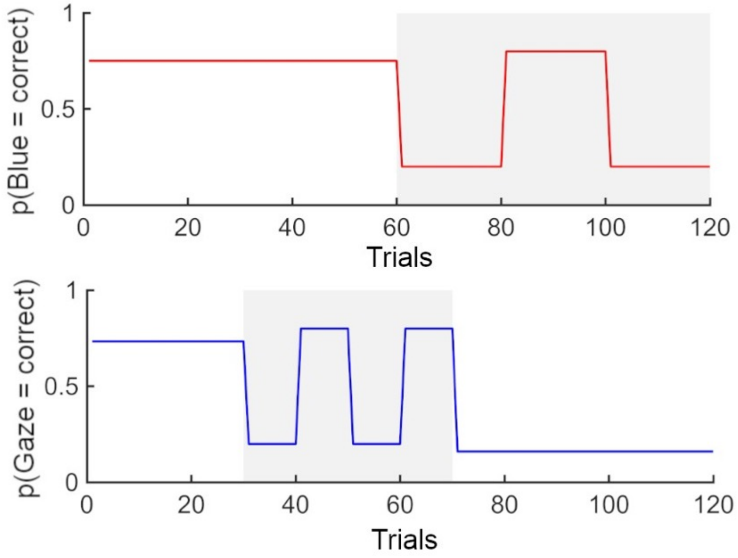
People suffering from psychiatric disorders frequently experience difficulties in social interaction, such as an impaired ability to use social signals to build representations of others and use these to guide behavior. Compuational models of learning and decision-making enable the characterization of individual patterns in learning and decision-making mechanisms that may be disorder-specific or disorder-general. We employed this approach to investigate the behavior of healthy participants and patients diagnosed with depression, schizophrenia, and borderline personality disorder while they performed a probabilistic reward learning task which included a social component. Patients with schizophrenia and borderline personality disorder performed more poorly on the task than controls and depressed patients. In addition, patients with borderline personality disorder concentrated their learning efforts more on the social compared to the non-social information. Computational modeling additionally revealed that borderline personality disorder patients showed a reduced flexibility in the weighting of newly obtained social and non-social information when learning about their predictive value. Instead, we found exaggerated learning of the volatility of social and non-social information. Additionally, we found a pattern shared between patients with borderline personality disorder and schizophrenia who both showed an over-reliance on predictions about social information during decision-making. Our modeling therefore provides a computational account of the exaggerated need to make sense of and rely on one's interpretation of others' behavior, which is prominent in both disorders.

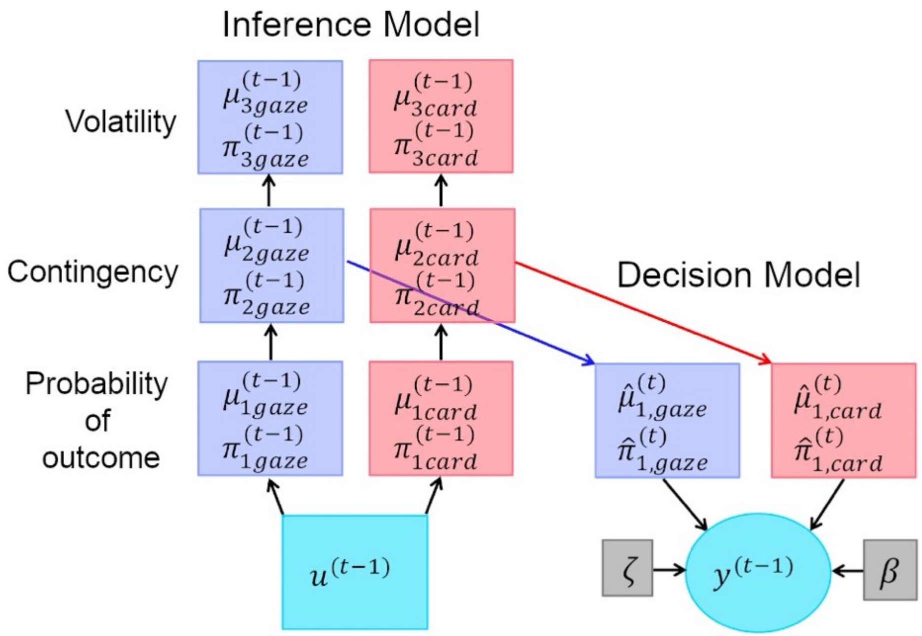
Social inference in borderline personality disorder, schizophrenia, and major depression.



Henco et al, PLOS Comput Biol, 2020

Social inference in borderline personality disorder, schizophrenia, and major depression.





Henco et al, PLOS Comput Biol, 2020

Social inference in borderline personality disorder, schizophrenia, and major depression.

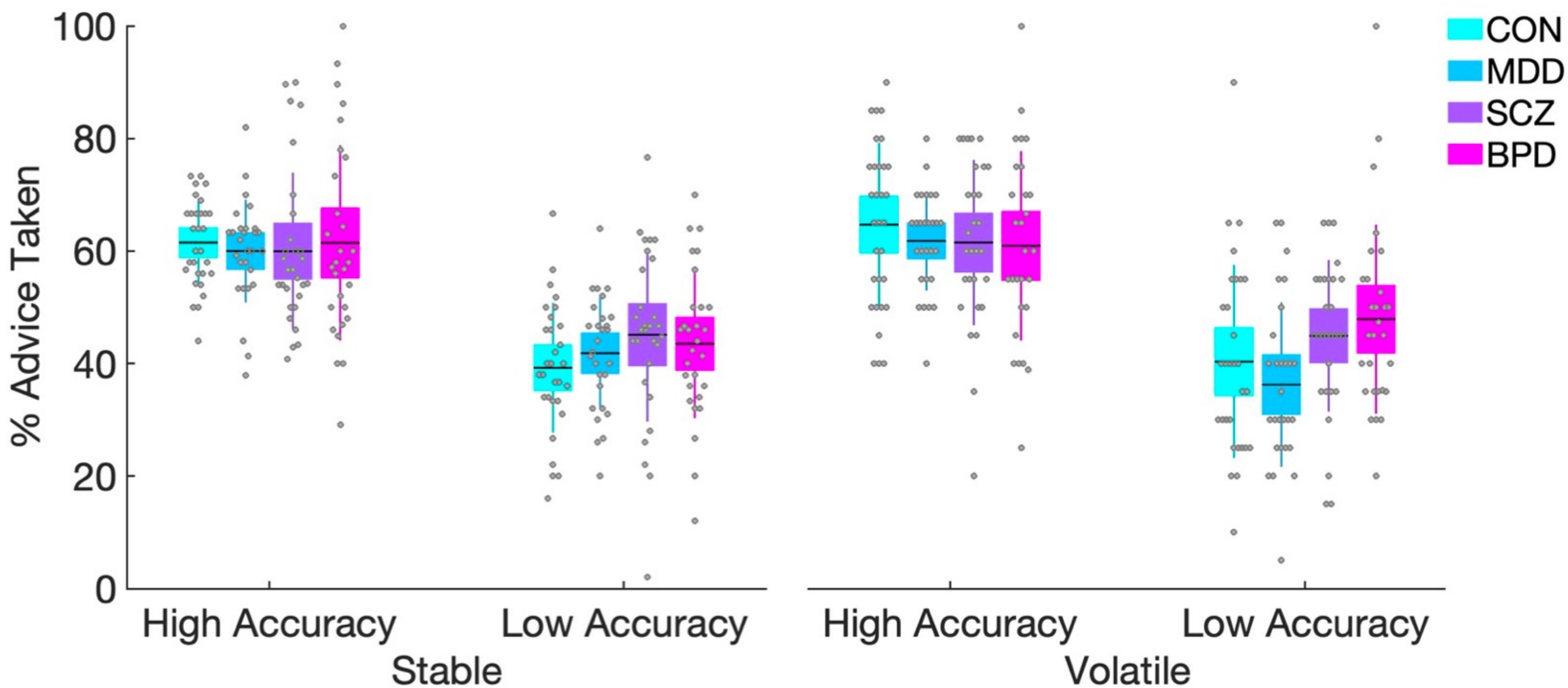


Fig 3. Behavioral results with regard to advice taking. All participants followed the advice significantly more during phases of high compared to low accuracy. The descriptive data shows a trend of BPD patients to follow the advice more during volatile phases of low accuracy (right most plot) but the interaction was not significant. Means are plotted with boxes marking 95% confidence intervals and vertical lines showing standard deviations.

Henco et al, PLOS Comput Biol, 2020

Social inference in borderline personality disorder, schizophrenia, and major depression.

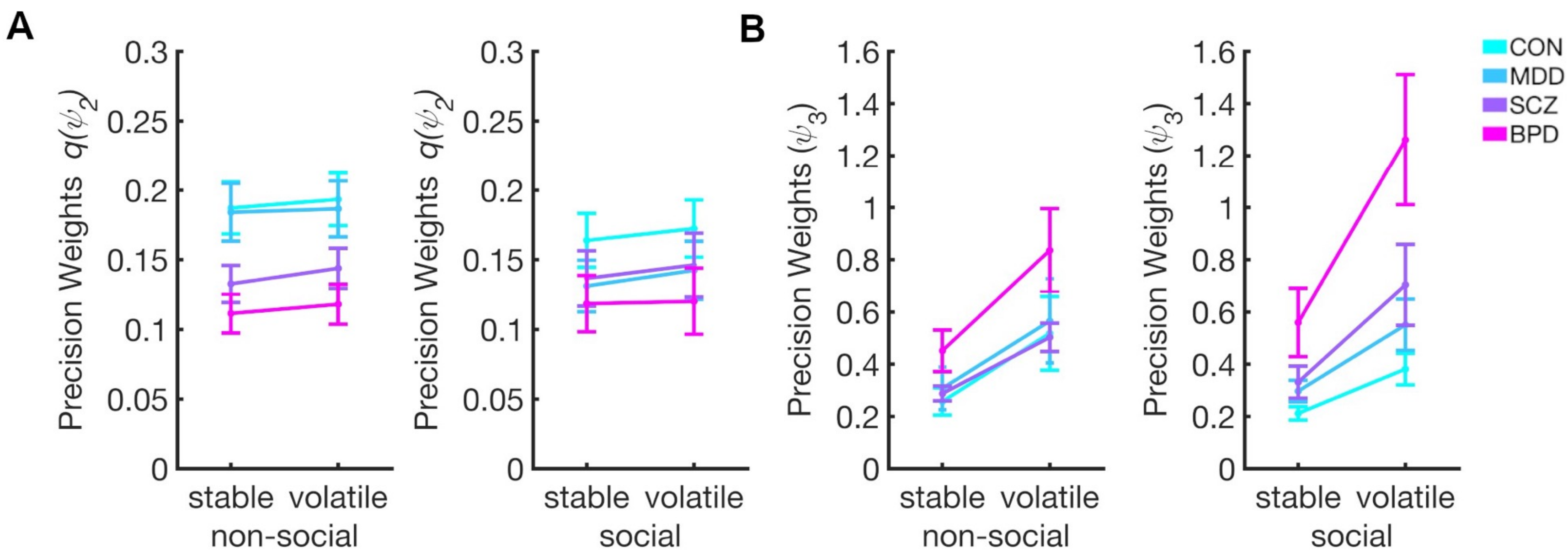


Fig 4. Results for mixed ANOVA using precision weights for updating beliefs about social and non-social contingency and volatility. (A) Precision weights $q(\psi_2)$ and (B) precision weights ψ_3. Overall, $q(\psi_2)$ and ψ_3 increase when transitioning from stable to volatile phase. Patients with BPD show reduced overall $q(\psi_2)$. At same time, patients with BPD show higher ψ_3 compared to the other groups and a more pronounced increase in response to volatility. Bars indicate SEM. See also S1 Fig, S7 Table and S8 Table for all results.

Henco et al, PLOS Comput Biol, 2020

Social inference in borderline personality disorder, schizophrenia, and major depression.

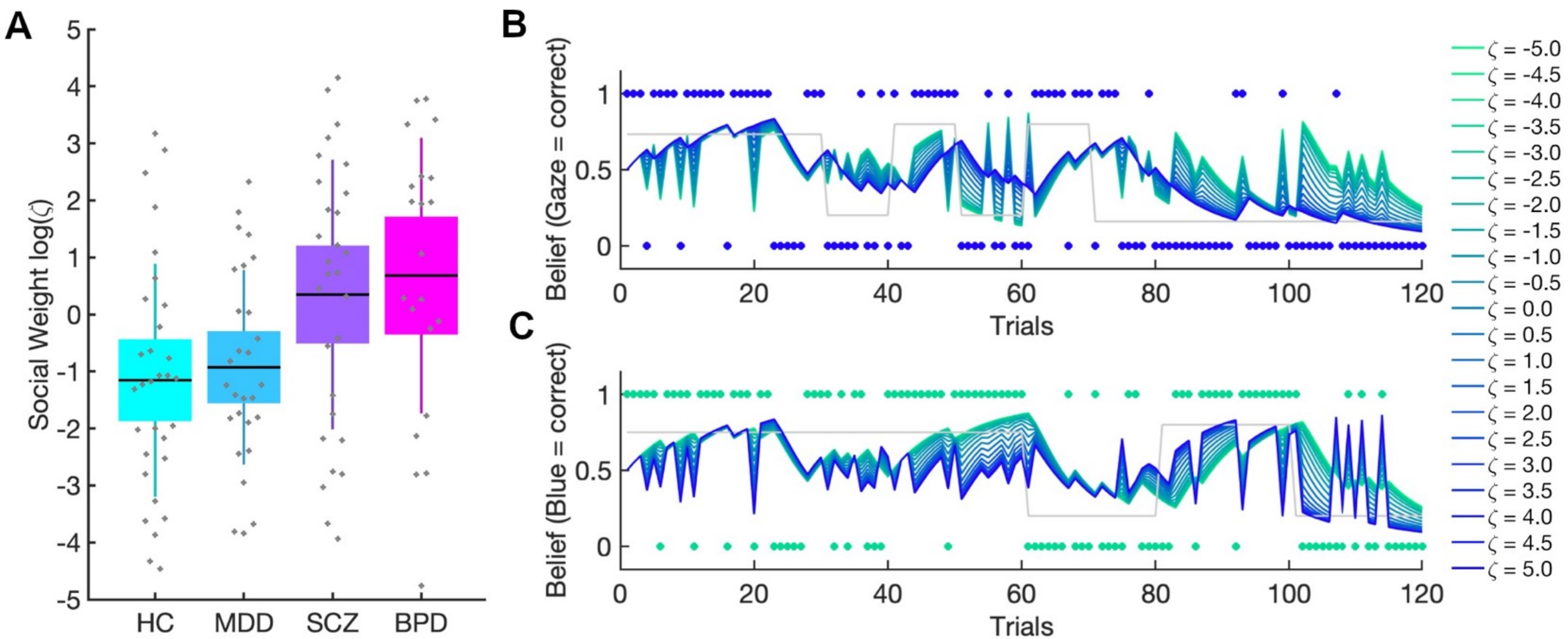


Fig 5. Social weighting factor log(ζ). (A) Patients with BPD gave the social information significantly more weight compared to HC and patients with MDD. Patients with SCZ also had higher ζ compared to HC. Boxes mark 95% confidence intervals and vertical lines standard deviations. (B), Simulation results show the impact of varying weighting factor log(ζ) on combined belief $b^{(t)}$ (see methods Eq 1). The combined belief $b^{(t)}$ was simulated for agents with same perceptual parameters but different ζ values (highest values (log(ζ) = 5) coded in dark blue, lowest values (log(ζ) = -5) in green). (B) shows that the combined belief $b^{(t)}$ of agents with high ζ values is aligned with the social input structure (blue dots) whereas these agents show a stochastic belief structure with regard to the non-social input structure (green dots) in Panel C. Conversely, agents with low ζ values show a belief structure closely aligned to the non-social input structure (C), and a stochastic belief structure with regard to the social input (Panel B). The grey lines represent the ground truth of the respective probability schedules. See also S9 Table for all results.

Henco et al, PLOS Comput Biol, 2020

Henco et al. (2020): main points

- Patients diagnosed with major depressive disorder (MDD, N = 29), schizophrenia (SCZ, N = 31), and borderline personality disorder (BPD, N = 31) as well as healthy controls (CTL, N = 34) performed a probabilistic reward learning task in which participants could learn from social and non-social information.
- SCZ and BPD performed more poorly on the task than CTL and MDD
- BPD performed better in the social compared to the non-social domain. In contrast, CTL and MDD showed the opposite pattern, and SCZ showed no difference between domains.
- In effect, BPD gave up a possible overall performance advantage by concentrating their learning in the social at the expense of the non-social domain.
- BPD showed slower learning from social and non-social information and an exaggerated sensitivity to changes in environmental volatility.
- Compared to CTL and MDD, BPD and SCZ showed a stronger reliance on social relative to non-social information when making choices.