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Bayesian models of atypical sensory perception in autism

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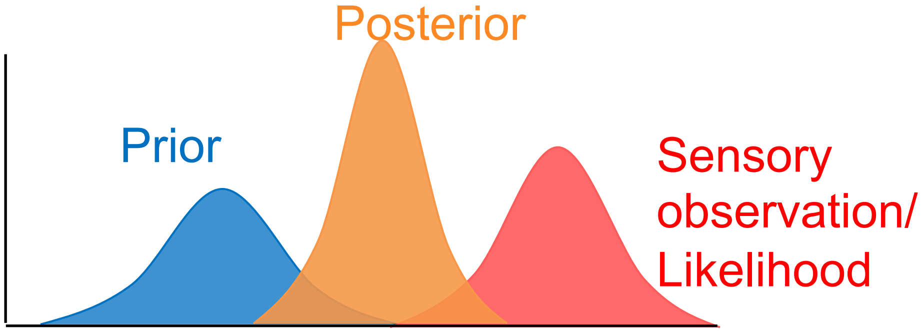
Background

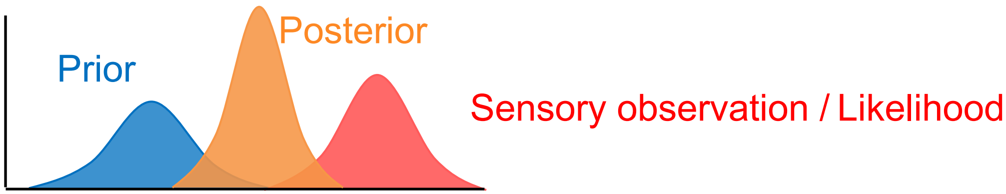
Atypical sensory perception such as sensory sensitivities, weak central coherence and intolerance of uncertainty is estimated to occur in as many as 90% of autistic individuals [1].

Several Bayesian theories have been proposed to explain atypical sensory processing in autism but remains unresolved as to whether such disruptions are caused at the sensory level (likelihood) or in forming a weak model of the sensory environment (priors).

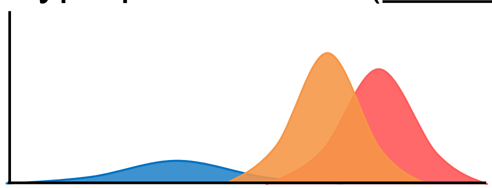


Current Bayesian models of perception in Autism

Typical Learning:

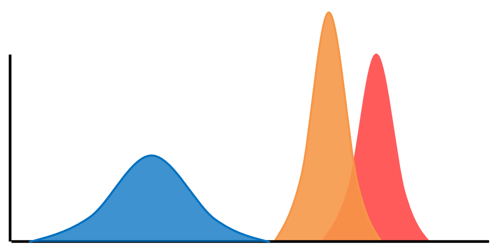


Hypo-priors model (Pelicano & Burr, 2012)[2]:



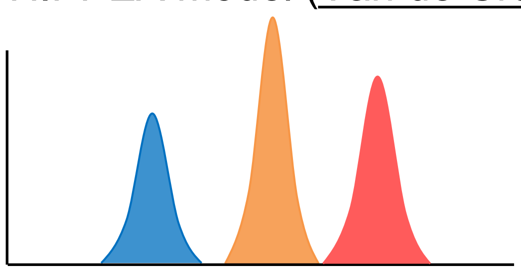
Forming a weak model of the world (high variance in the prior) can increase reliance on new sensory observations

Precise likelihood model (Brock, 2012)[3]:



Less noise in new sensory observations (less variance) can increase reliance on new sensory observations

HIPPEA model (Van de Cruys et al. 2013)[4]:



The weighting of the difference between prior expectations and new information (i.e. prediction errors) is disrupted. Called high, inflexible precision of prediction errors (HIPPEA).

Research Questions

1. Do individuals with a diagnosis of autism spectrum disorder (ASD) rely more on new information (i.e. likelihood) vs their model of the world (i.e. priors) compared to neurotypical (NT) individuals?

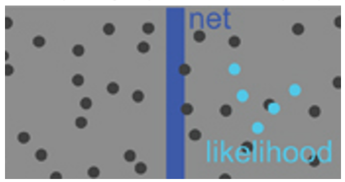
2. Does the ASD group show differences in their prior and likelihood representations compared to the NT group?

Methods

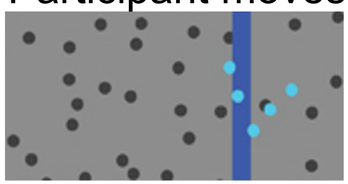
Behavioural Paradigm : Coin Task (Vilares et al. 2012)[5]

- Participants were instructed that someone was throwing a coin to the centre of a pond (i.e. middle of the computer screen). They would see splashes the coin made each time and their job was to guess where the coin fell in. A single trial was as below:

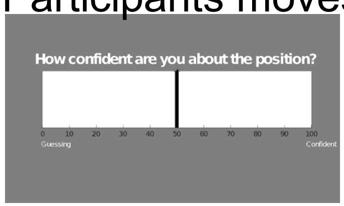
1 — 1. Trial Start: Five blue dots (splashes / likelihood) shown



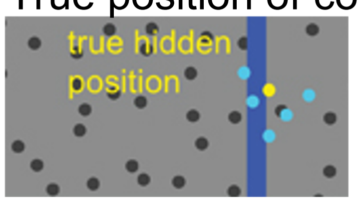
2 — 2. Participant moves the blue bar (net) to where they think the coin fell in



3 — 3. Participants moves black bar to indicate their confidence



4 — 4. True position of coin is shown



1500ms

1 — 1. New Trial

Coin Task: Trial Types

- Participants were also told there would be two people throwing the coin and one thrower may be better than the other at throwing to the middle. (Figure 1)

- Thus, there were four types of trials arising from a narrow or wide uncertainty of the Prior (i.e. thrower A or B) and a narrow or wide uncertainty of the likelihood (i.e. splashes) (Figure 2)

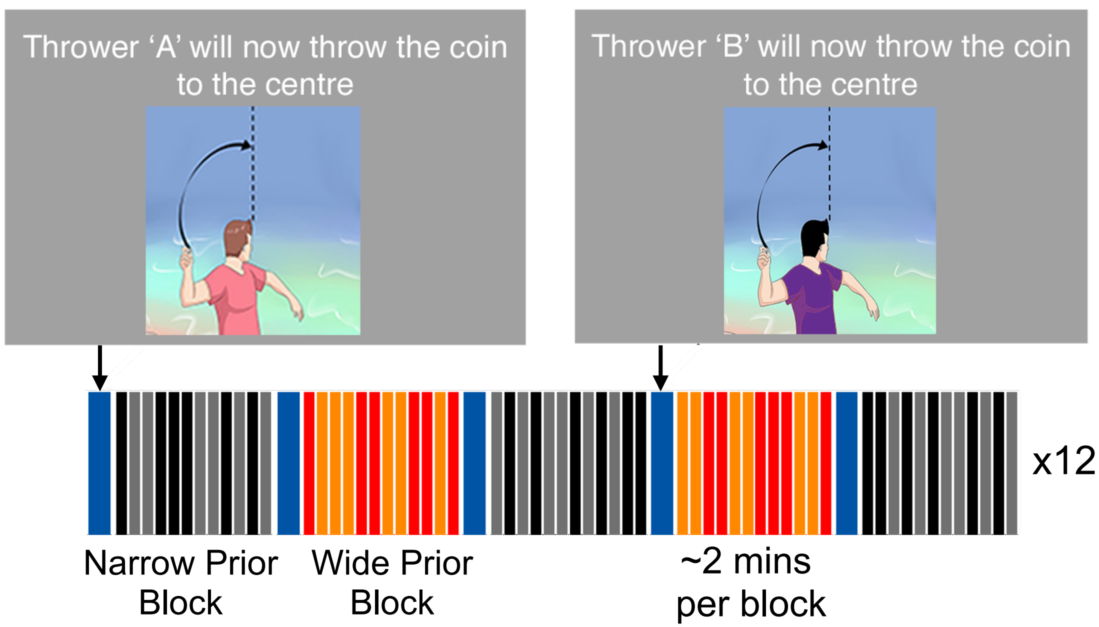


Figure 1: Trials setup with 12 alternating blocks of each type of Prior

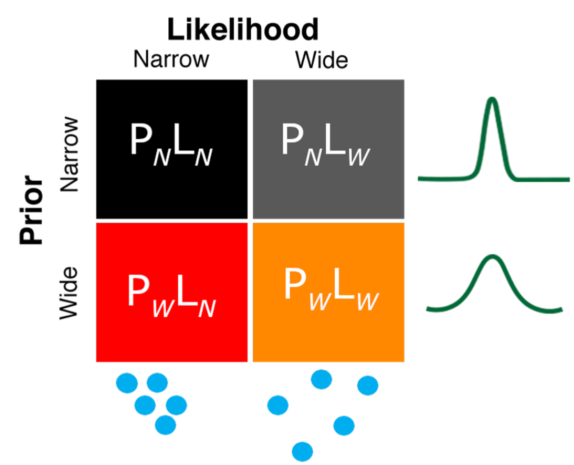


Figure 2 : Four types of trials

Procedure

Recruitment

NT = 48 and ASD = 32

Participants completed demographic, autism trait[6], sensory sensitivities[7], anxiety[8] and depression[9] **questionnaires** (~30mins)

Practice Task (~10mins)

Main experimental session (~1 hr.)

- Participants completed the Coin-Task described in previous slides
- Participants completed the task while undergoing a magnetic resonance imaging (MRI) scan or outside of the scanner at a computer

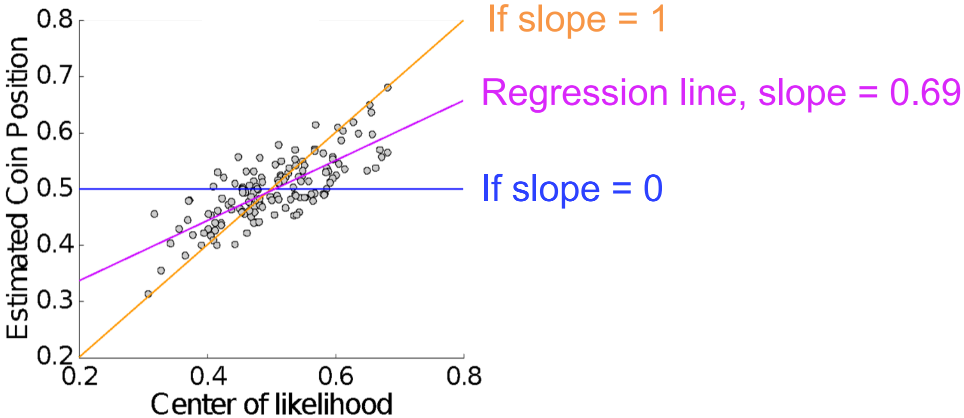
'No Prior' Task (~15mins)

- Participants estimated the middle of the five blue dots (i.e. splashes), the variance of these estimates was obtained as the likelihood variance
- Participants completed this task outside of the MRI.

Calculating participant's Likelihood Reliance and Prior Variance

(For more details on modelling Likelihood Reliance & Prior Variance see : Körding et al. 2004 / Vilares et al. 2012)

- For each condition we can regress the participant's estimates of the position of the coin on the true centre of the likelihood for each trial :



- The slope of the regression can be used as a measure of 'Likelihood Reliance':

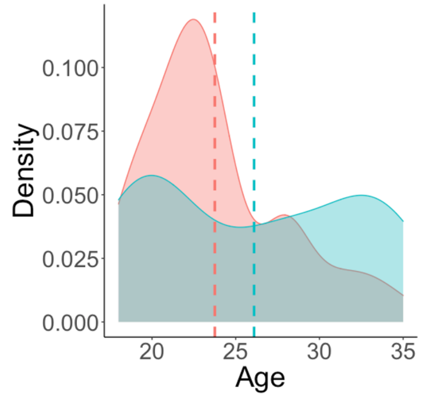
If the slope → 1, participants rely highly on the likelihood
slope → 0, participants rely highly on the prior information

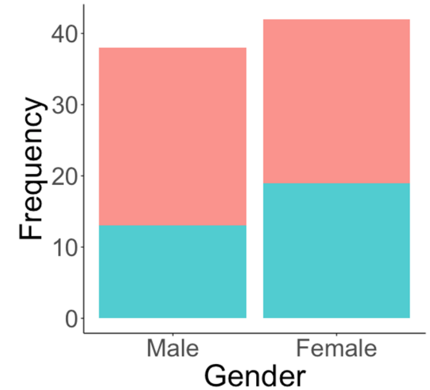
- Using the slope of the regression, and an estimate of participants likelihood variance (σ^2_L) from the 'No Prior' task we can calculate participants subjective prior variance (σ^2_P), as follows:

$$\sigma^2_P = \sigma^2_L * \text{slope} / (1 - \text{slope})$$

Results

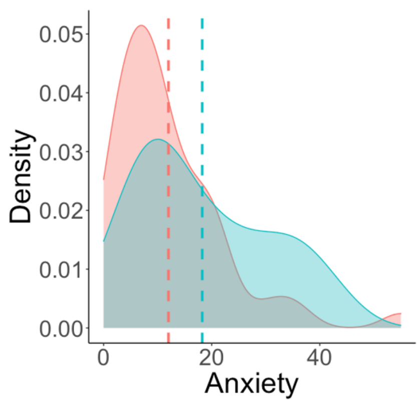
Demographic profile of participants

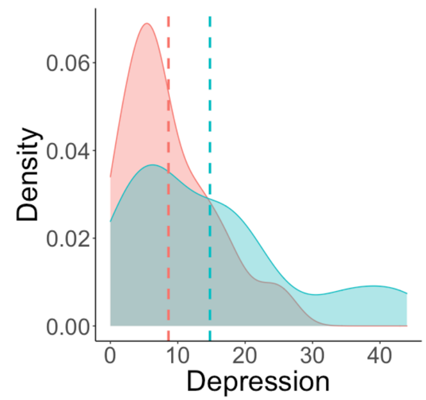


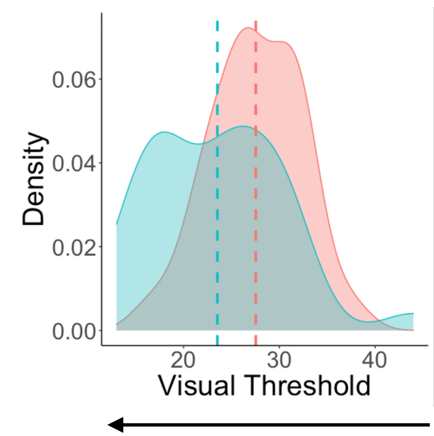


ASD = 32
NT = 48

Dashed lines indicate group means





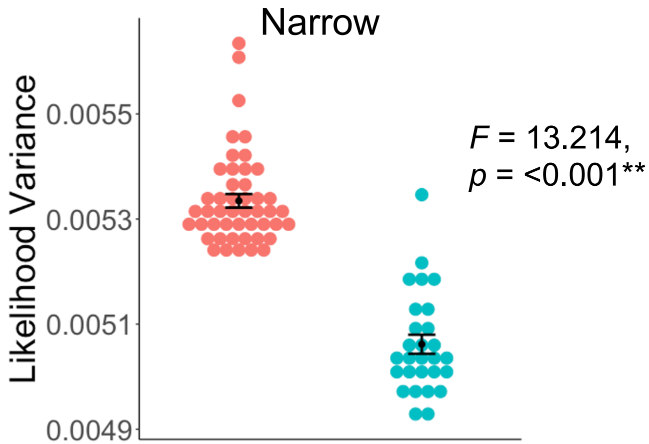


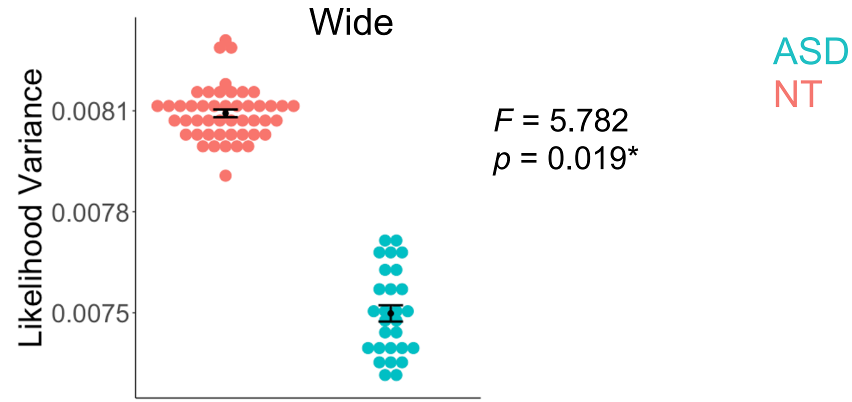
Hypersensitivities increase

- ASD group showed significantly more anxiety (t = -2.417, p = 0.018) and depression (t = -2.848, p = 0.018) and were older (t = -2.030, p = 0.046) than the NT group, thus these were included as covariates in further analyses

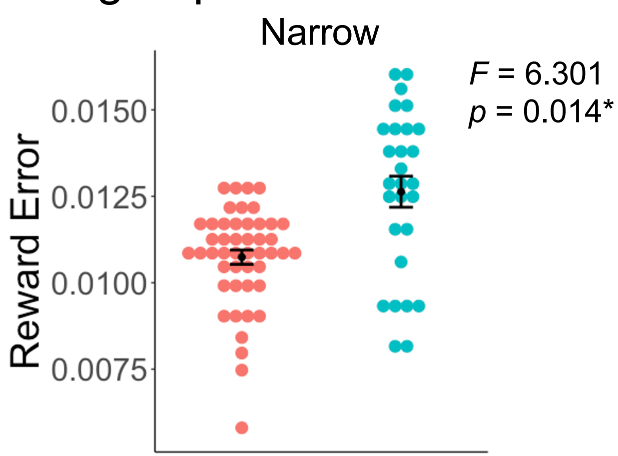
Narrower likelihood variance for ASD in the ‘No-Prior’ Task

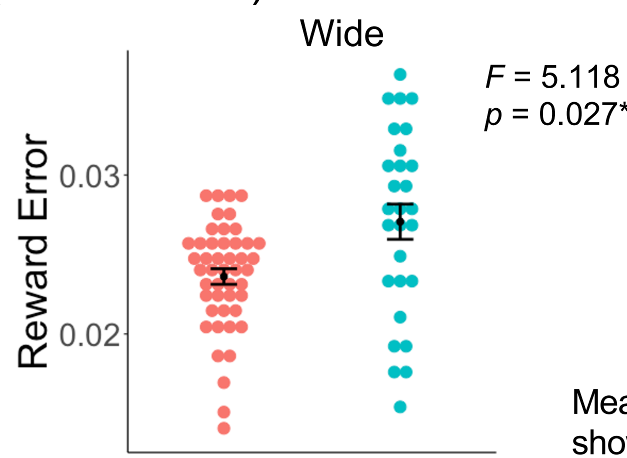
- The ASD group showed narrow likelihood variance compared to the NT group





- The ASD group showed less accuracy (more errors) in the estimated likelihood

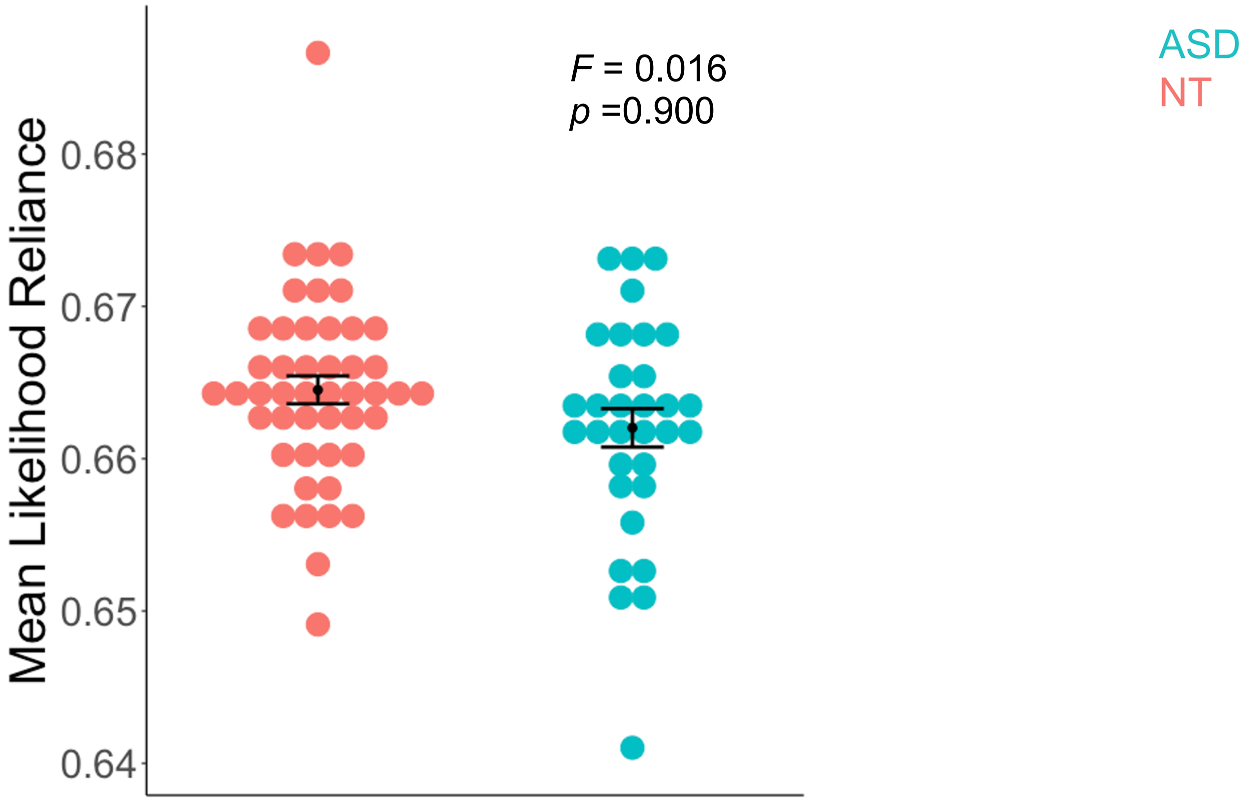




Mean +/- 95% CI shown

Note: Values displayed are predicted values from multivariate models accounting for age, anxiety, depression and average time spent on each trial

No group differences in likelihood reliance

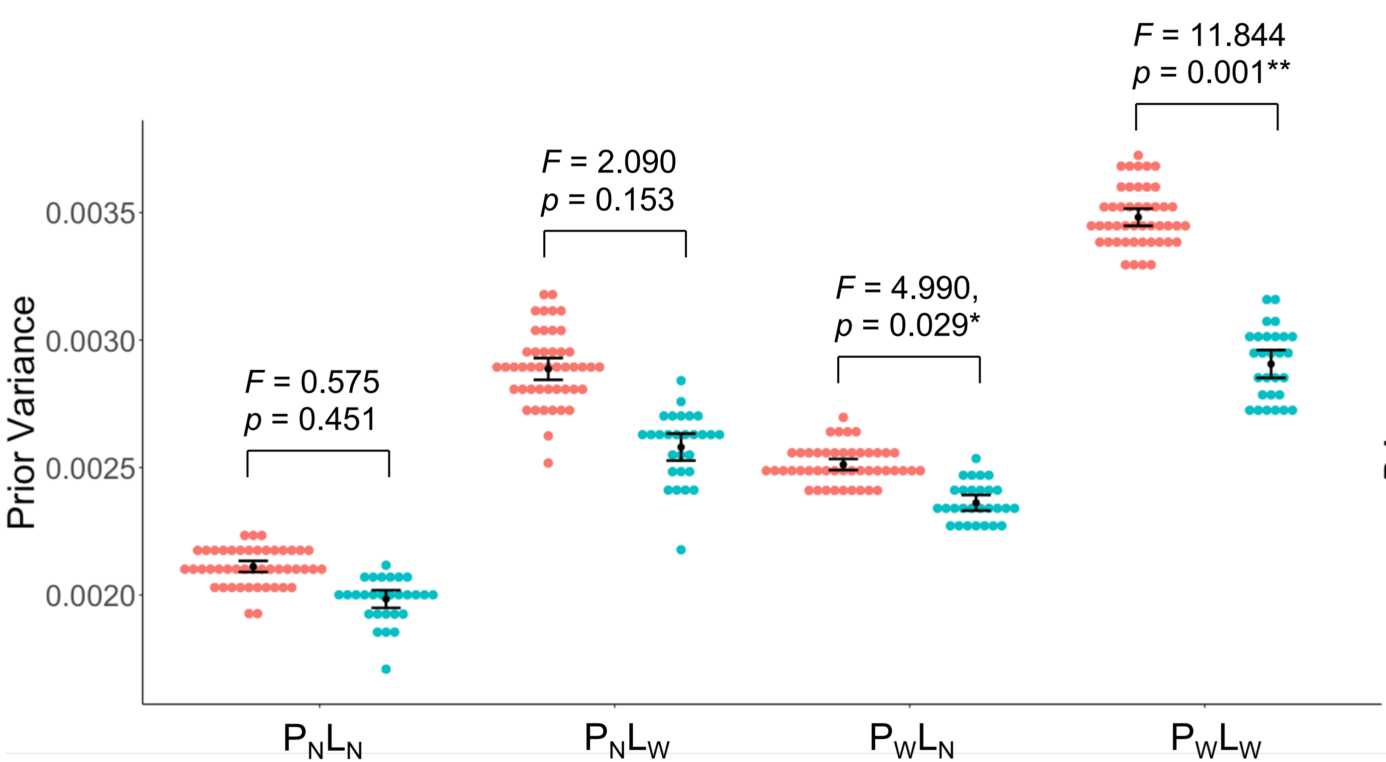


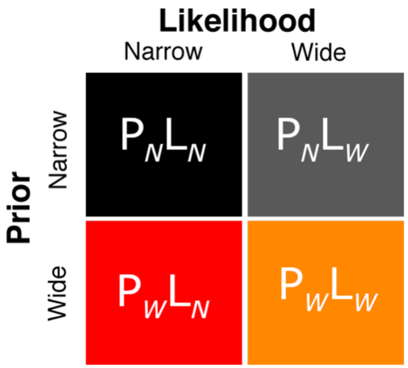
- We also found no differences in the accuracy between groups on the main task

‡Model accounts for age, anxiety, depression

Narrower subjective priors in ASD when the prior is wide

- Only for conditions with a high prior uncertainty (P_W), the ASD group showed significantly narrow subjective prior variance compared to the NT group.

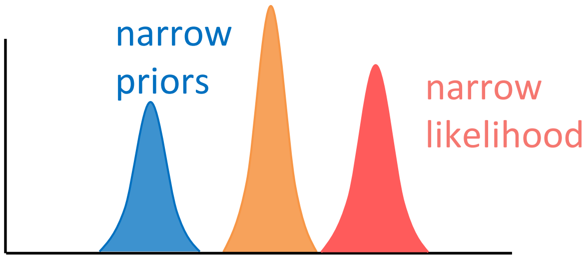




‡Models account for age, anxiety, depression

Conclusions

- Unexpectedly, the task did not find any differences between ASD and NT groups on likelihood reliance.
- The ASD group showed narrow variance of their likelihood estimates compared to the NT group as described by the 'Precise Likelihood Model'[3].
- Contrary to the above model however the ASD group did not show increased reliance on the likelihood but also showed narrow priors related to this task.
- This may be instead explained by the high, inflexible precision of prediction errors (HIPPEA) model[4] as below:



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