



Bayesian models of atypical sensory perception in autism

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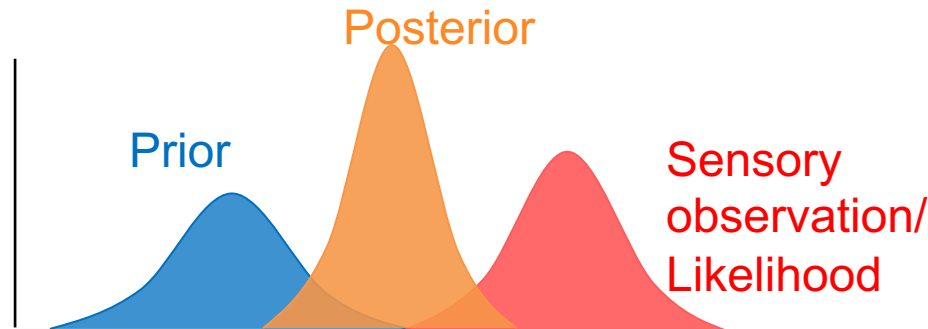
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Background

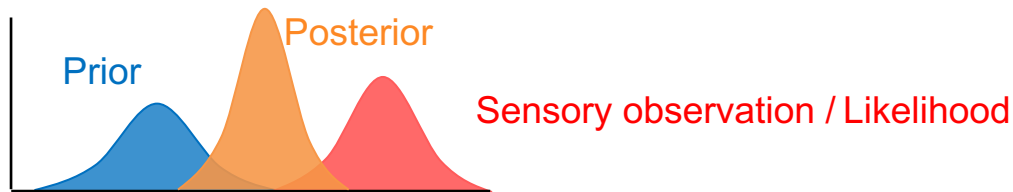
Atypical sensory perception such as sensory sensitivities, weak central coherence and intolerance of uncertainty is estimated to occur in as many as 90% of autistic individuals ¹.

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).

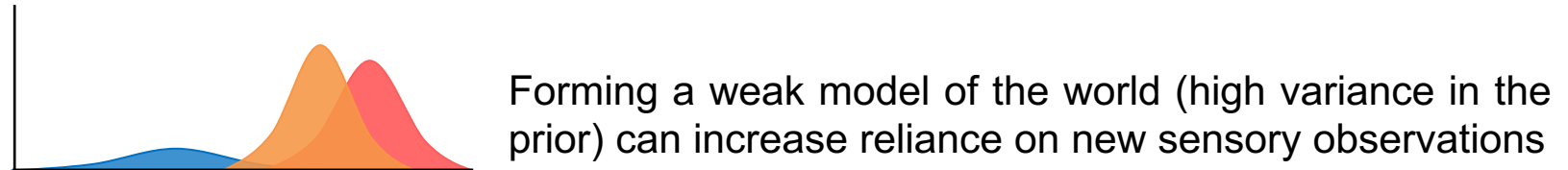


Current Bayesian models of perception in Autism

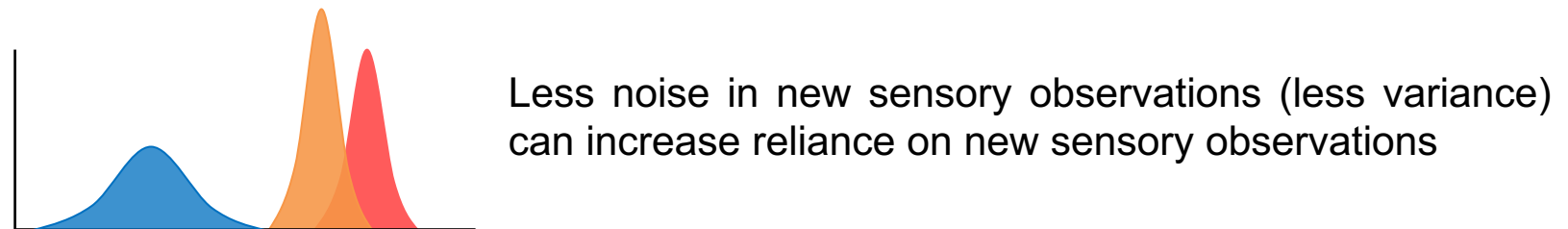
Typical Learning:



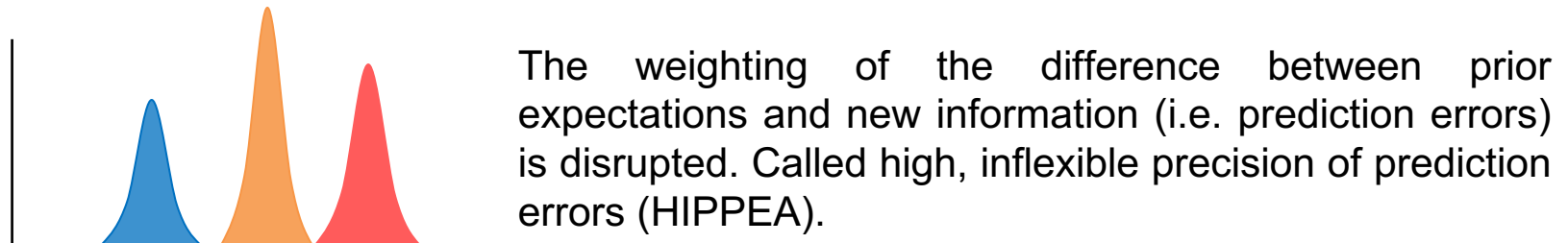
Hypo-priors model (Pelicano & Burr, 2012)²:



Precise likelihood model (Brock, 2012)³:



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



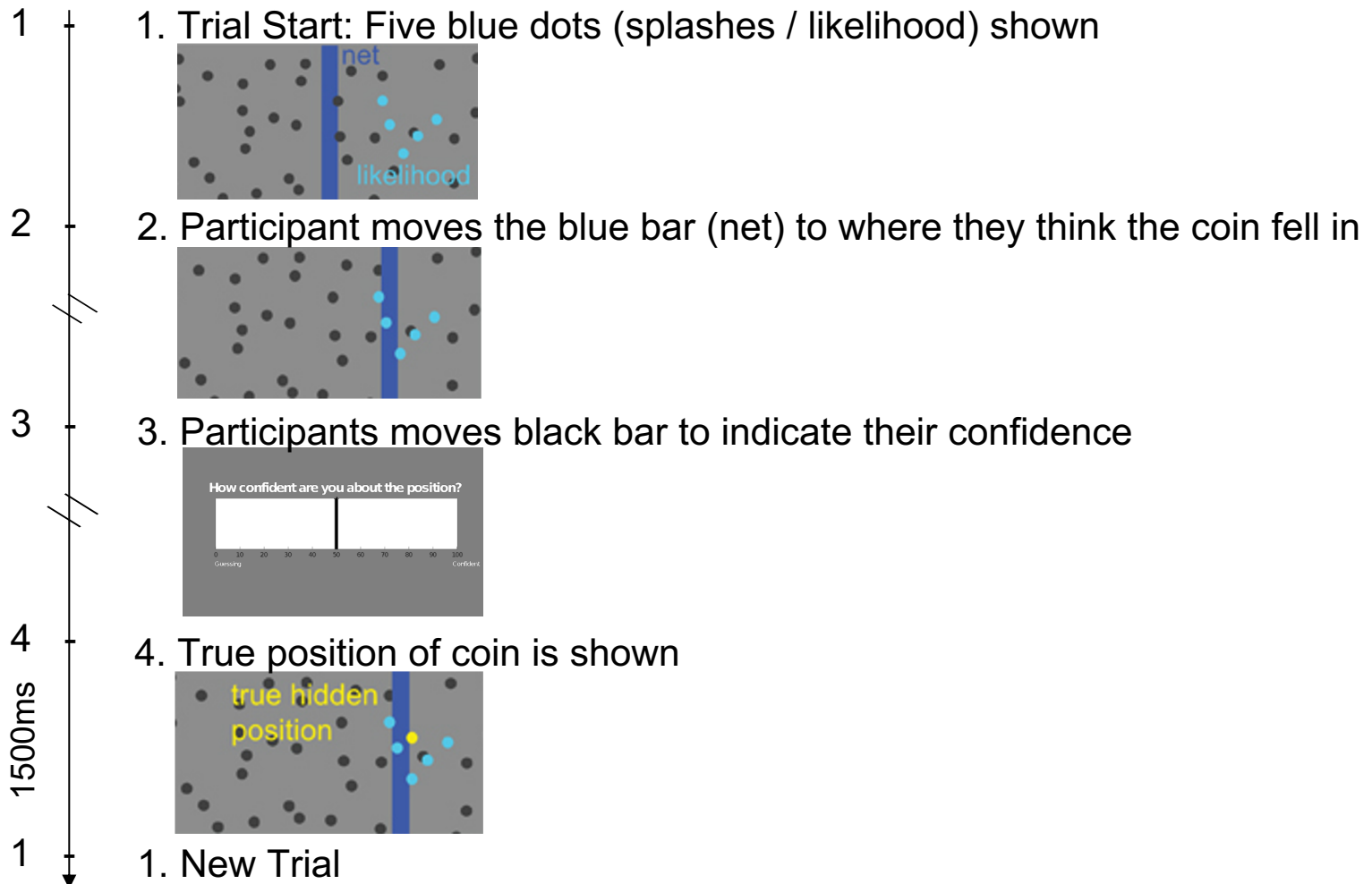
Research Questions

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:



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)

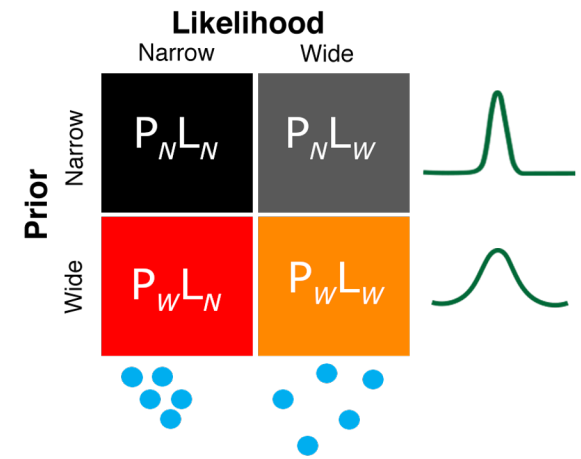
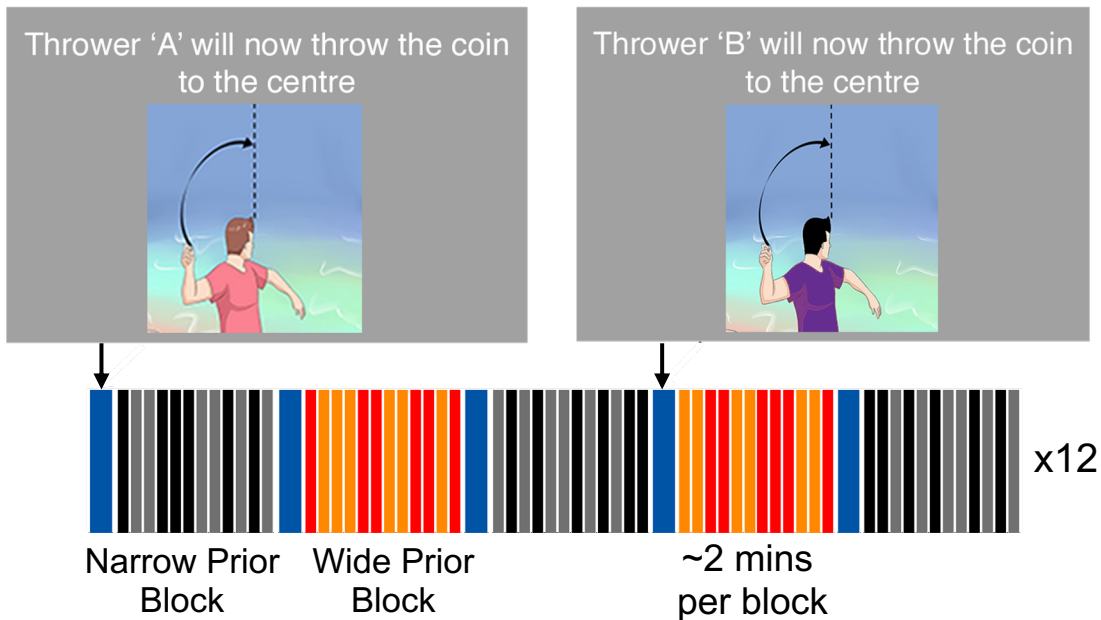


Figure 2 : Four types of trials

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

Procedure

Recruitment

NT = 48 and ASD = 32



Participants completed demographic, autism trait⁶, sensory sensitivities⁷, anxiety⁸ and depression⁹ **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



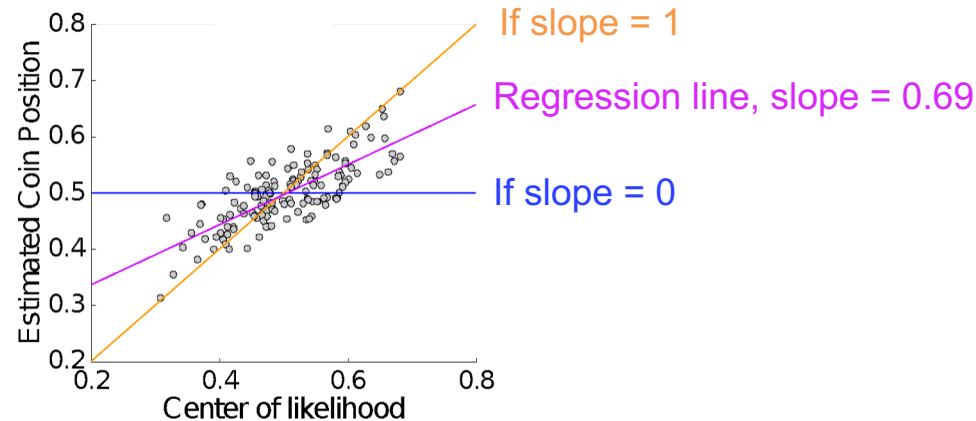
'No Prior' Task (~15mins)

- 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 :

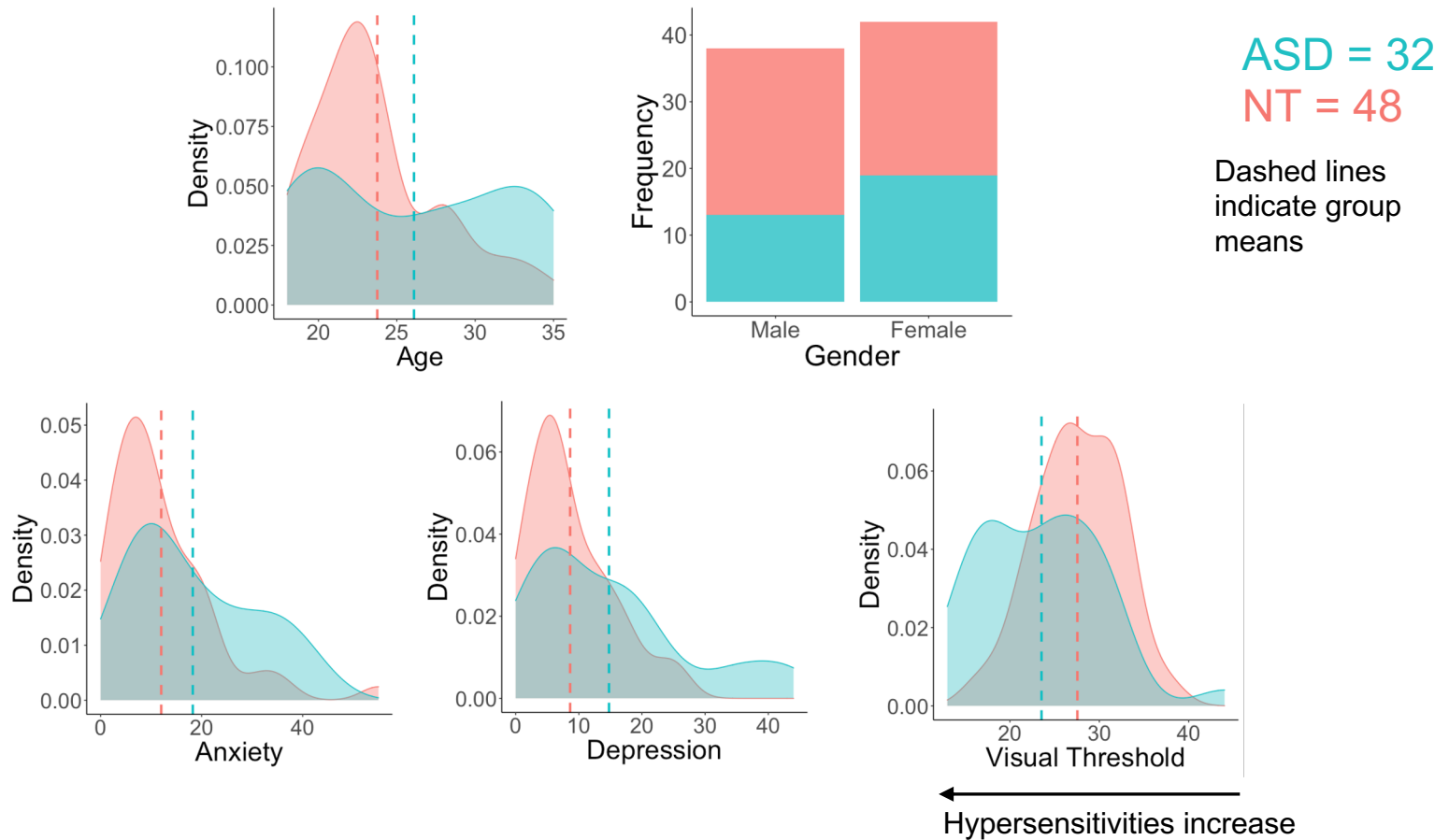


- The slope of the regression can be used as a measure of 'Likelihood Reliance':
If the **slope** \rightarrow 1, participants rely highly on the likelihood
slope \rightarrow 0, participants rely highly on the prior information
- Using the slope of the regression, and an estimate of participants likelihood 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

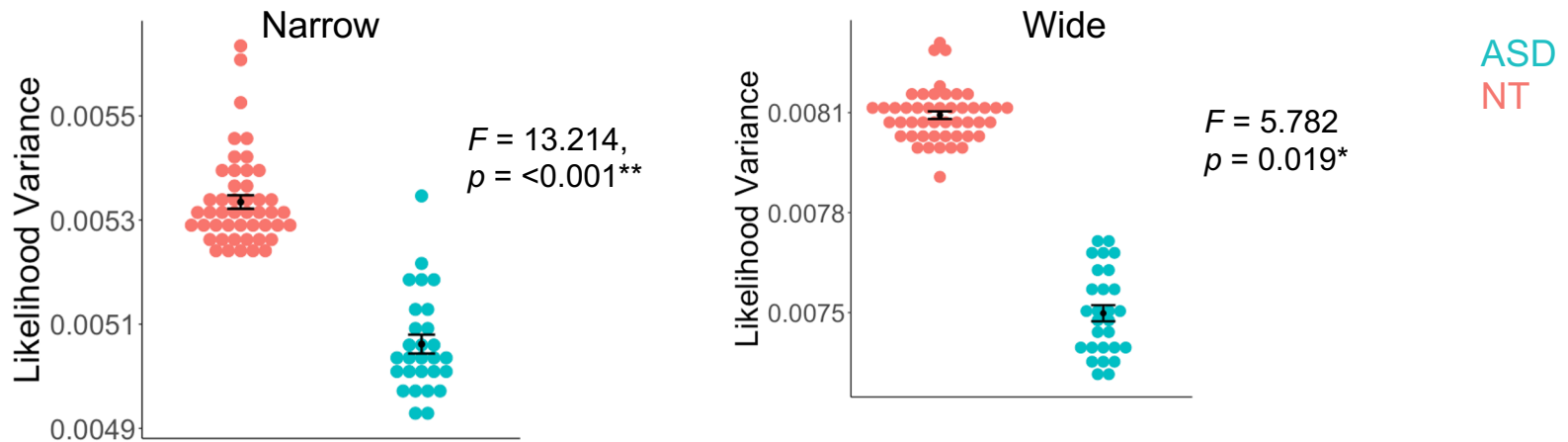
Demographic profile of participants



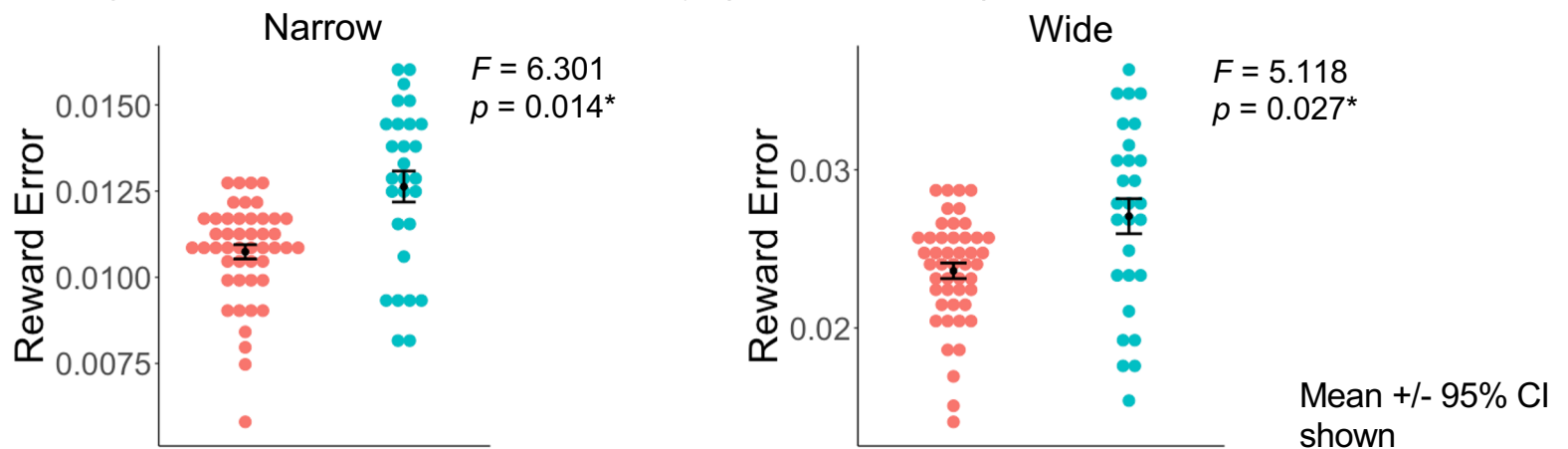
- ASD group showed significantly more anxiety ($t = -2.417$, $p = 0.018$) and depression ($t = -2.848$, $p = 0.018$) and were older ($t = -2.030$, $p = 0.046$) than the NT group, thus these were included as covariates in further analyses

Narrower likelihood variance for ASD in the 'No-Prior' Task

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

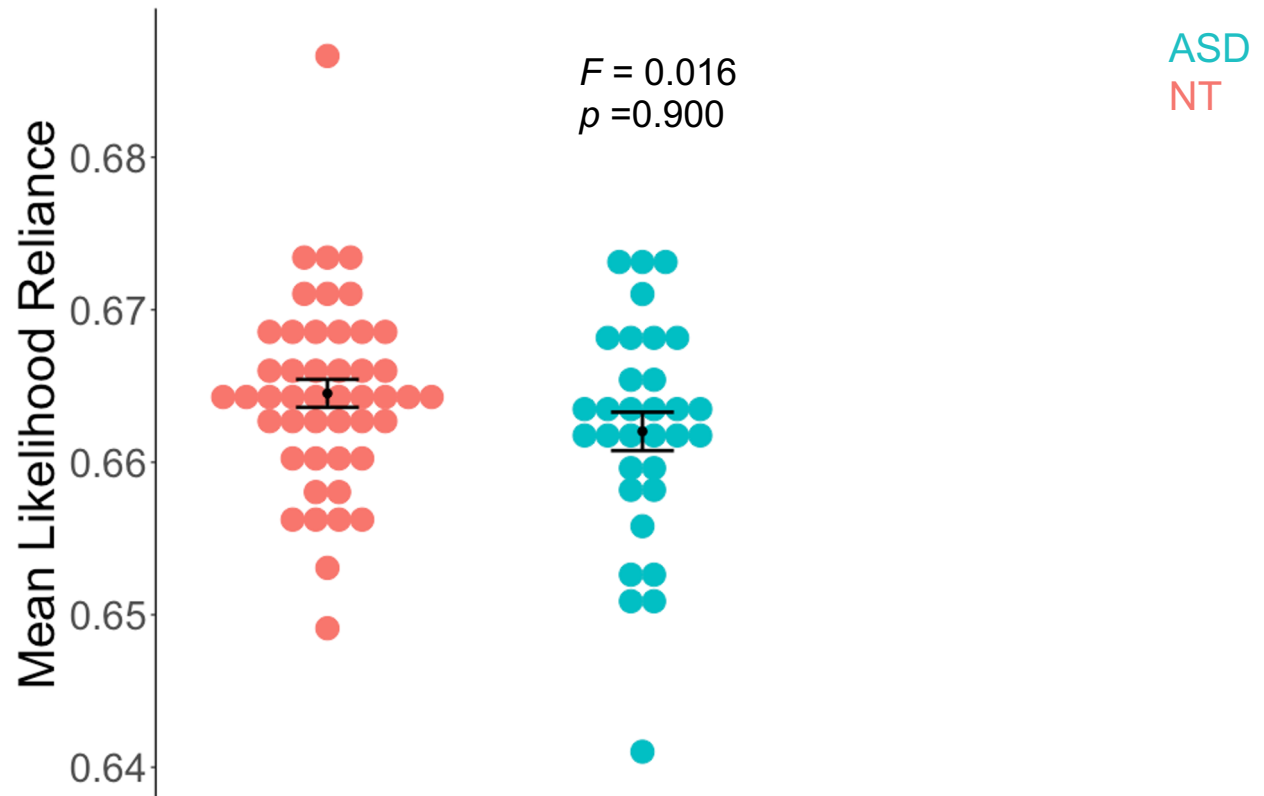


- The ASD group showed less accuracy (more errors) in the estimated likelihood



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

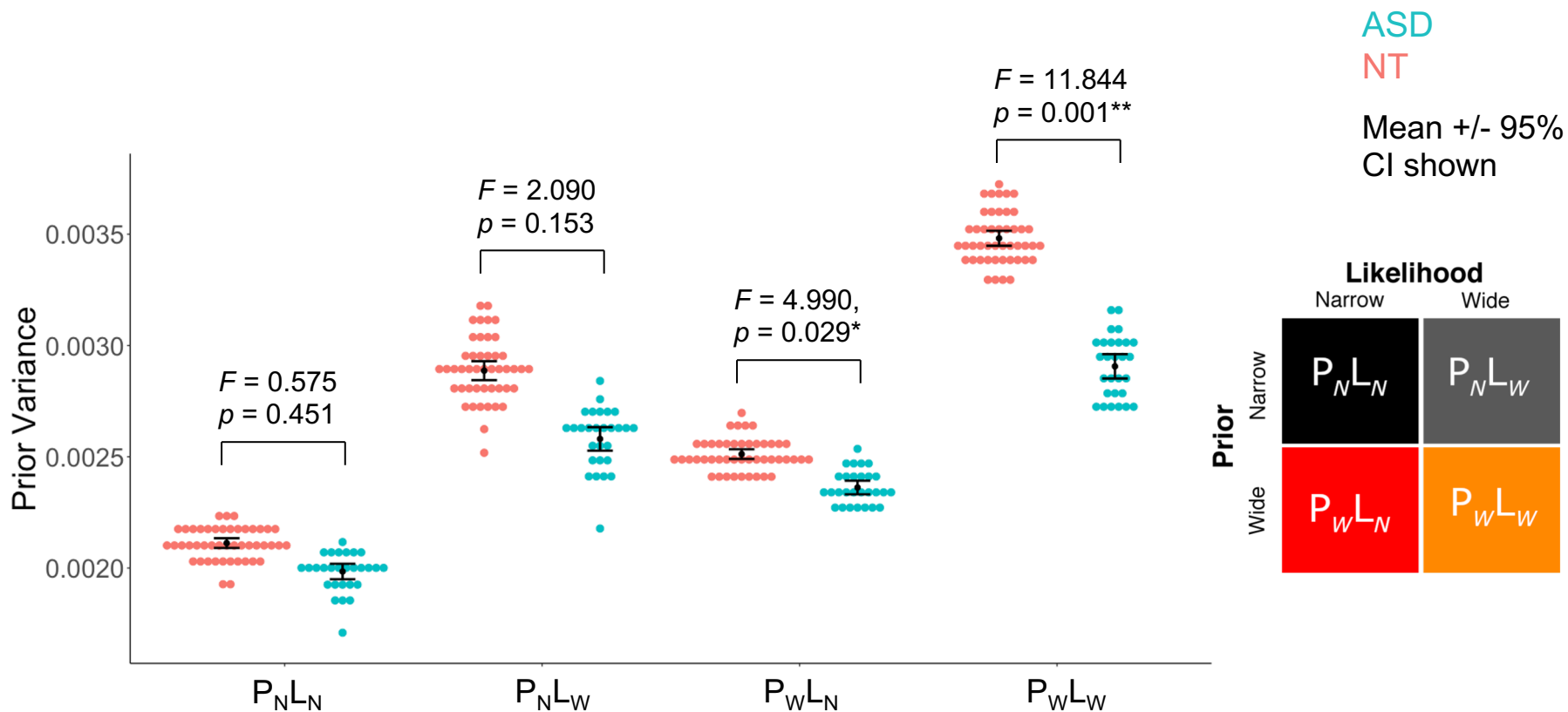
No group differences in likelihood reliance



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

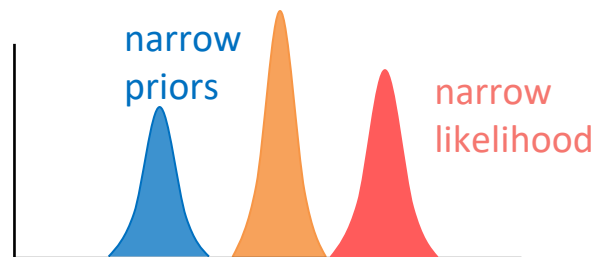
Narrower subjective priors in ASD when the prior is wide

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



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) model⁴ as below:



References

1. Robertson, C.E. and Baron-Cohen, S., 2017. Sensory perception in autism. *Nature Reviews Neuroscience*, 18(11), p.671.
2. Pellicano, E. and Burr, D., 2012. When the world becomes 'too real': a Bayesian explanation of autistic perception. *Trends in cognitive sciences*, 16(10), pp.504-510.
3. Brock, J., 2012. Alternative Bayesian accounts of autistic perception: comment on Pellicano and Burr. *Trends in cognitive sciences*, 16(12), p.573.
4. Van de Cruys, S., de-Wit, L., Evers, K., Boets, B. and Wagemans, J., 2013. Weak priors versus overfitting of predictions in autism: Reply to Pellicano and Burr (TICS, 2012). *i-Perception*, 4(2), pp.95-97.
5. Vilares I, Howard JD, Fernandes HL, Gottfried JA, Kording KP. Differential representations of prior and likelihood uncertainty in the human brain. *Curr Biol*. 2012;22(18):1641–1648. doi:10.1016/j.cub.2012.07.010
6. Simon Baron-Cohen, et al. (2001) The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientists and Mathematicians. *J Autism Dev Disord* 5-17.
7. Tavassoli, T., Hoekstra, R.A., Baron-Cohen, S., 2014. The Sensory Perception Quotient (SPQ): development and validation of a new sensory questionnaire for adults with and without autism, *Mol Autism*, p. 29.
8. Beck, A.T., Steer, R.A. and Brown, G.K., 1996. Beck depression inventory-II. *San Antonio*, 78(2), pp.490-498.
9. Steer, R.A. and Beck, A.T., 1997. Beck Anxiety Inventory.
10. Körding, K., Wolpert, D. Bayesian integration in sensorimotor learning. *Nature* **427**, 244–247 (2004) doi:[10.1038/nature02169](https://doi.org/10.1038/nature02169)
11. Lawson, R.P., G. Rees, and K.J. Friston, *An aberrant precision account of autism*. *Front Hum Neurosci*, 2014. **8**.