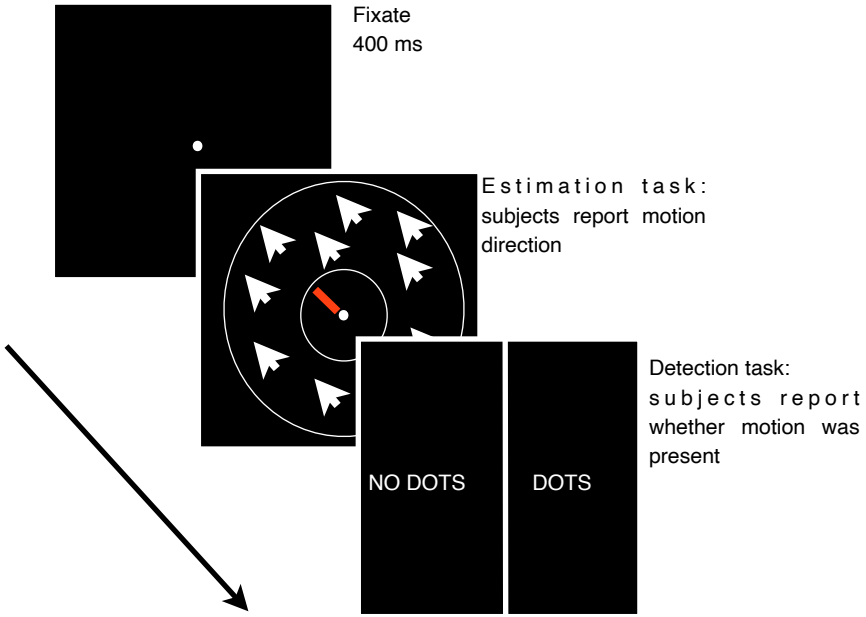
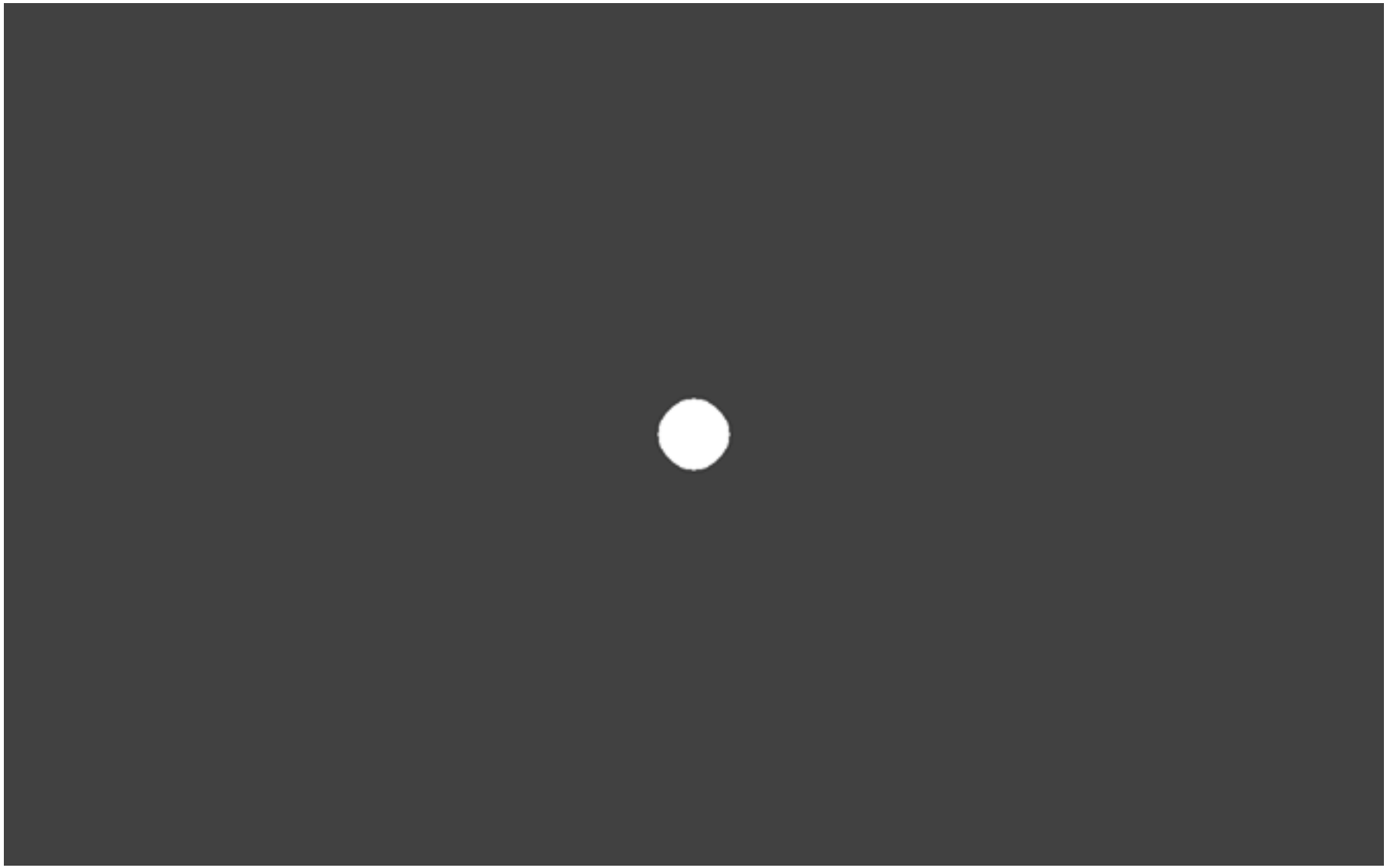
Do people form new priors for everything? How fast?

[Chalk, Seitz and Seriès, JOV 2010]

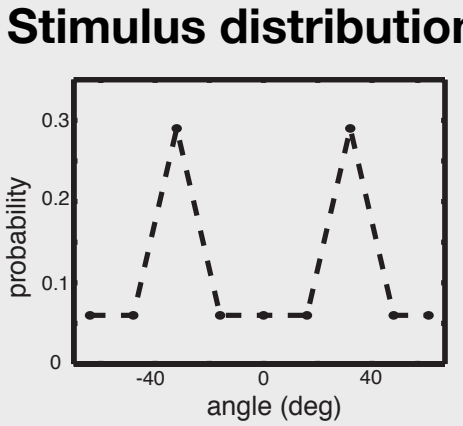
- On each trial, participants were presented with either a low contrast random dot motion stimulus (100% coherence) or a blank screen.
- Participants reported direction of motion (estimation), before reporting whether a stimulus was present (detection).

Behavioural Task





- Two motion directions were presented in a larger number of trials than other directions.



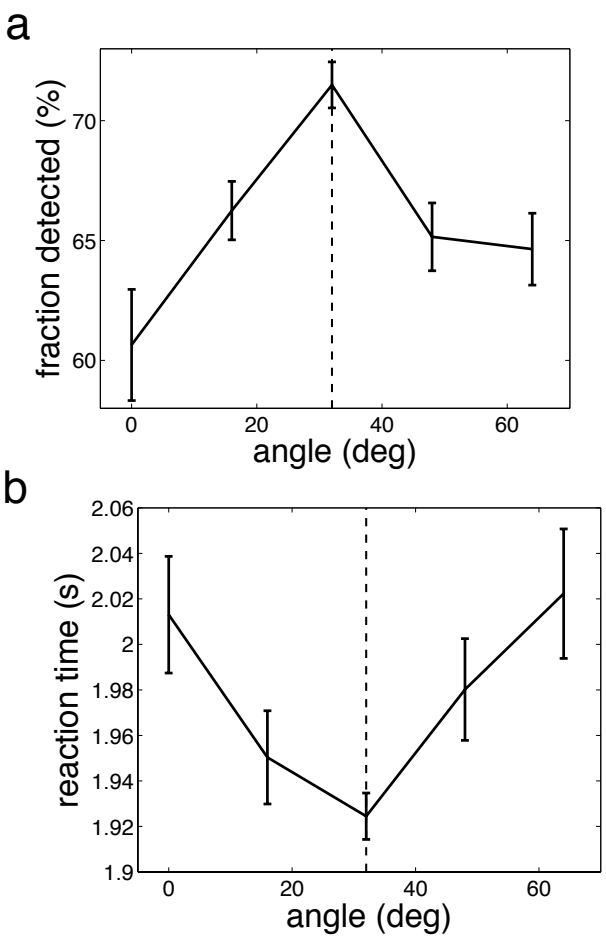
Questions

1. Are participants going to learn implicitly which directions are most likely to be presented?

2. How would these learned expectations bias their perception of subsequently presented motion stimuli?

Result 1/3: Detection is better and faster for the expected directions

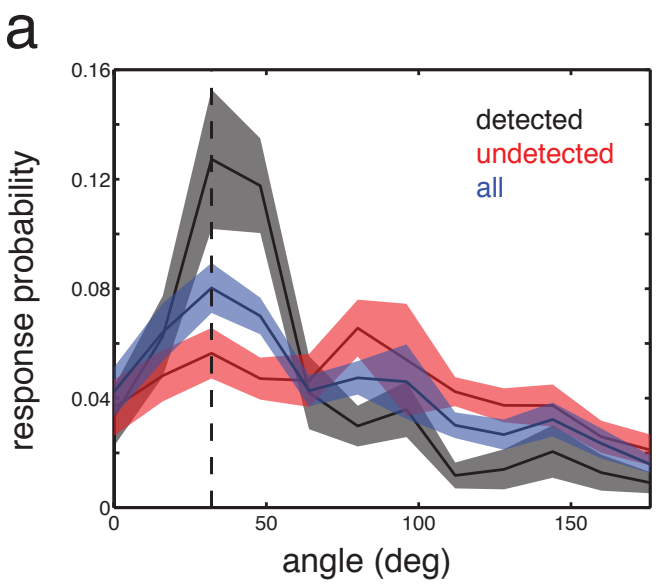
- Detection performance was best for most frequently presented directions
- Reaction times were shorter
- Similar to the effects of selective attention (Posner et al. 1980) - suggesting that subjects were attending to expected directions.
- Knowledge about the statistics of the stimulus was however not conscious.



Result 2/3: Participants ‘hallucinate’ motion in expected directions

- On trials where no stimulus was presented, but where participants reported seeing a stimulus, they were strongly biased to report motion in the two most frequently presented directions.
- This effect was fast to develop, occurring in less than 200 trials / few minutes.

Distribution of estimates when no stimulus displayed

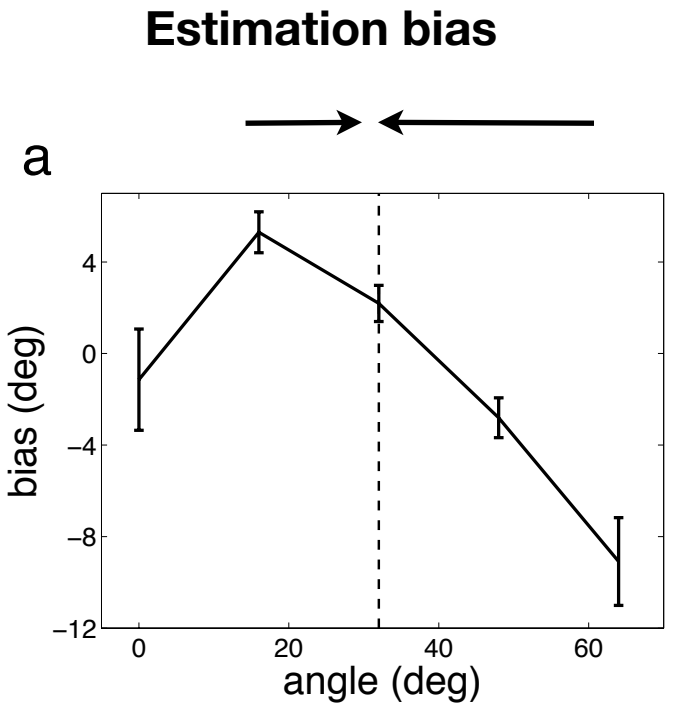


Result 3/3: Expectations bias perception of motion direction

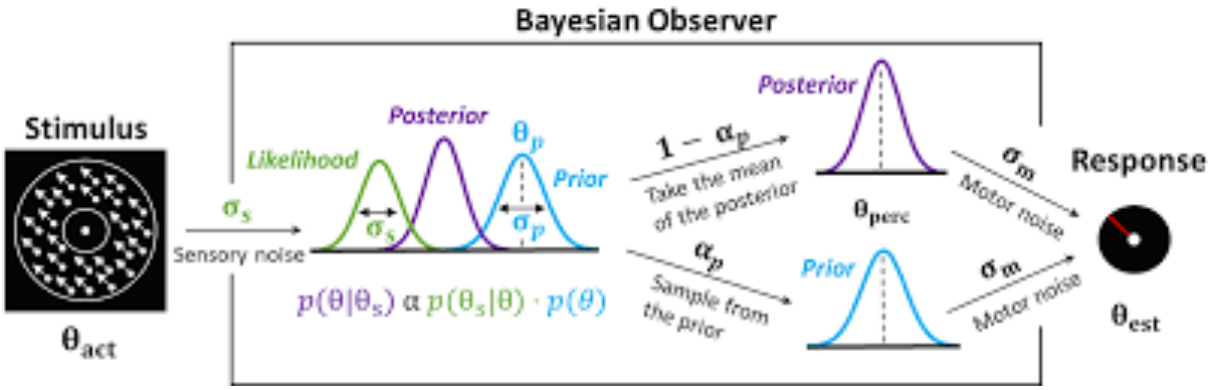
[Chalk, Seitz, Seriès, JOV 2010]

- Estimates of motion direction were biased towards most frequently presented directions:

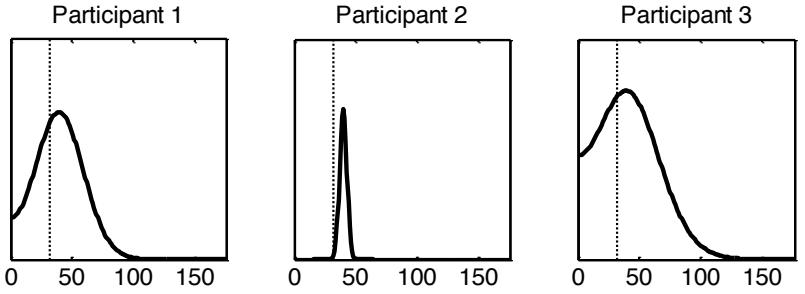
  subjects perceive motion direction to be more similar to expected direction than it really is.



Modelling the estimation biases

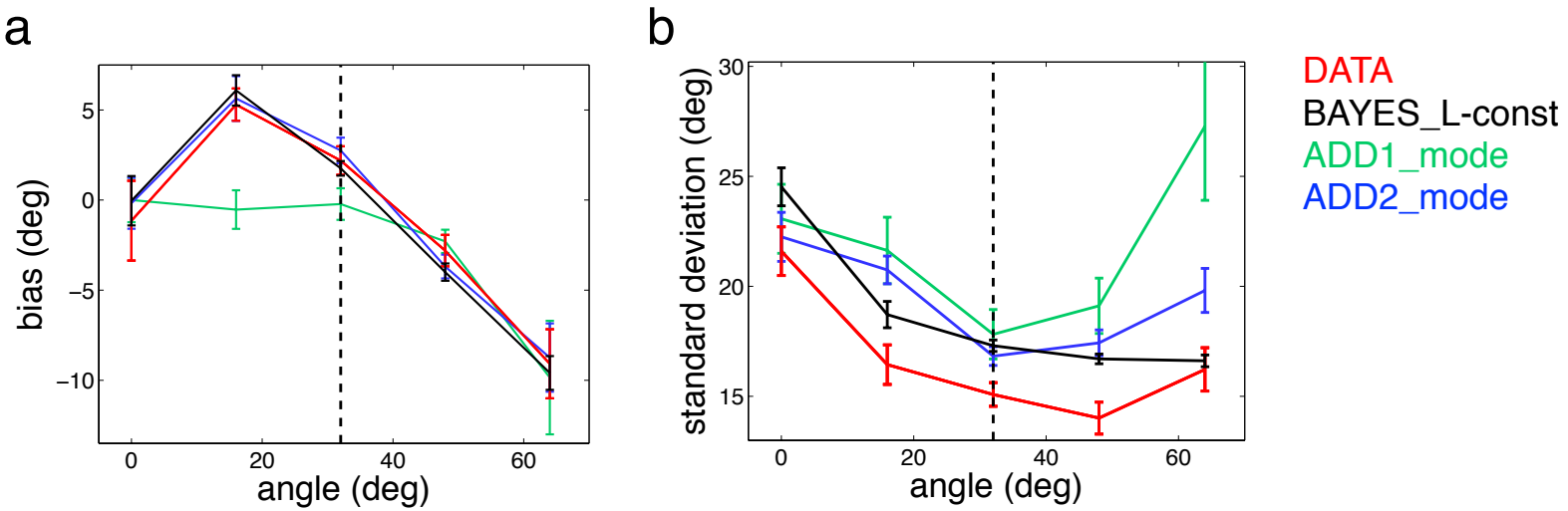


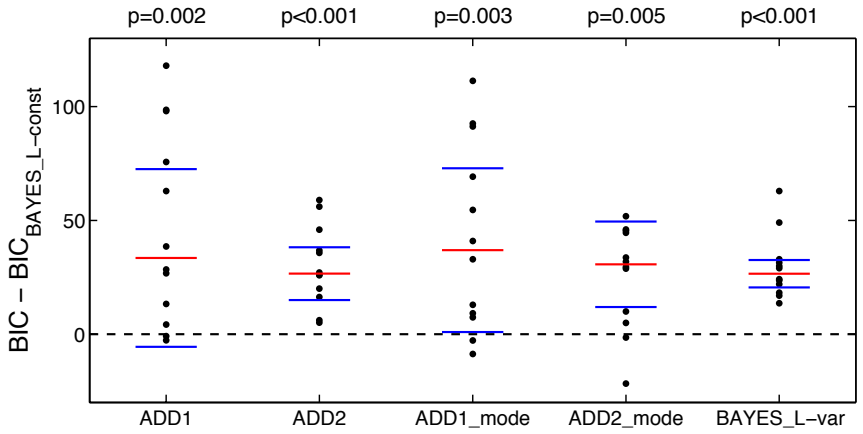
- Bayesian Modeling: subjects learn an expected distribution of the stimuli (prior) and combine it with sensory evidence
- Extract prior for each individual.



- Model Comparison: Bayesian model describes the data better than response strategy models. Individual priors look like approximation of stimulus

Model comparison





$$BIC = -2 \cdot \ln(L) + k \cdot \ln(n)$$

- Bayesian model describes the data better than response strategy models.

[Chalk, Seitz and Seriès, JOV 2010]

Conclusions: Fast learning of a Direction Prior

- Participants rapidly learn multimodal stimulus expectations (< 200 trials).
- These expectations bias their perception of simple motion stimuli, causing them to 'hallucinate' motion in the expected direction, and perceive motion stimuli as closer to the expected directions than they actually are.
- The biases we observed can be explained assuming that participants combine a 'learned prior' about the stimulus statistics with their sensory evidence in a probabilistically optimal way.
- A number of open questions (specificity of prior, time scale, neural implementation - substrate of expectation)
- in particular: can one learn any prior like this ? or are some priors fixed?

Are priors constantly updating? Even those supposedly corresponding to natural scene statistics? (1)

ATTACHED-SHADOW ORIENTATION PERCEIVED AS DEPTH BY CHICKENS REARED IN AN ENVIRONMENT ILLUMINATED FROM BELOW

WAYNE HERSHBERGER

not in chickens, innate

Hershberger, W. (1970)

nature Publishing Group http://www.nature.com/natureneuroscience

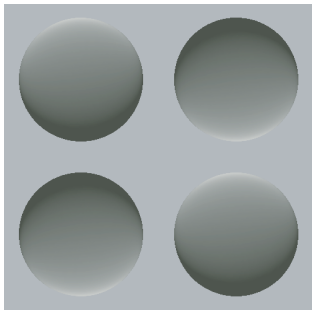
Experience can change the 'light-from-above' prior

Wendy J Adams[1], Erich W Graf[1] & Marc O Ernst[2]

To interpret complex and ambiguous input, the human visual system uses prior knowledge or assumptions about the world. We show that the 'light-from-above' prior, used to extract information about shape from shading is modified in response to active experience with the scene. The resultant adaptation is not specific to the learned scene but generalizes to a different task, demonstrating that priors are constantly adapted by interactive experience with the environment.

The circular patches in **Figure 1a** have competing interpretations. However, patches that are brighter at the top are generally seen as convex and the others as concave, consistent with an assumption of light from above[1,2]. The Bayesian approach has successfully described performance in many perceptual tasks where stimulus information is combined with prior assumptions[3–5]. However, whether visual priors are hard-wired or learned in response to environmental statistics is not known[6]. We investigate the adaptability of the 'light-from-above' prior by adding shape information via haptic (active touch) feedback.

a



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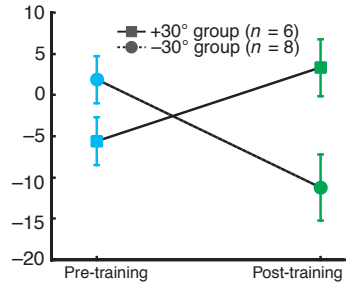
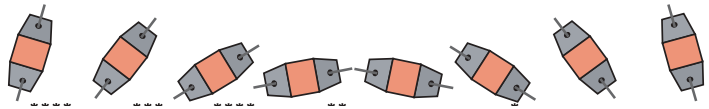
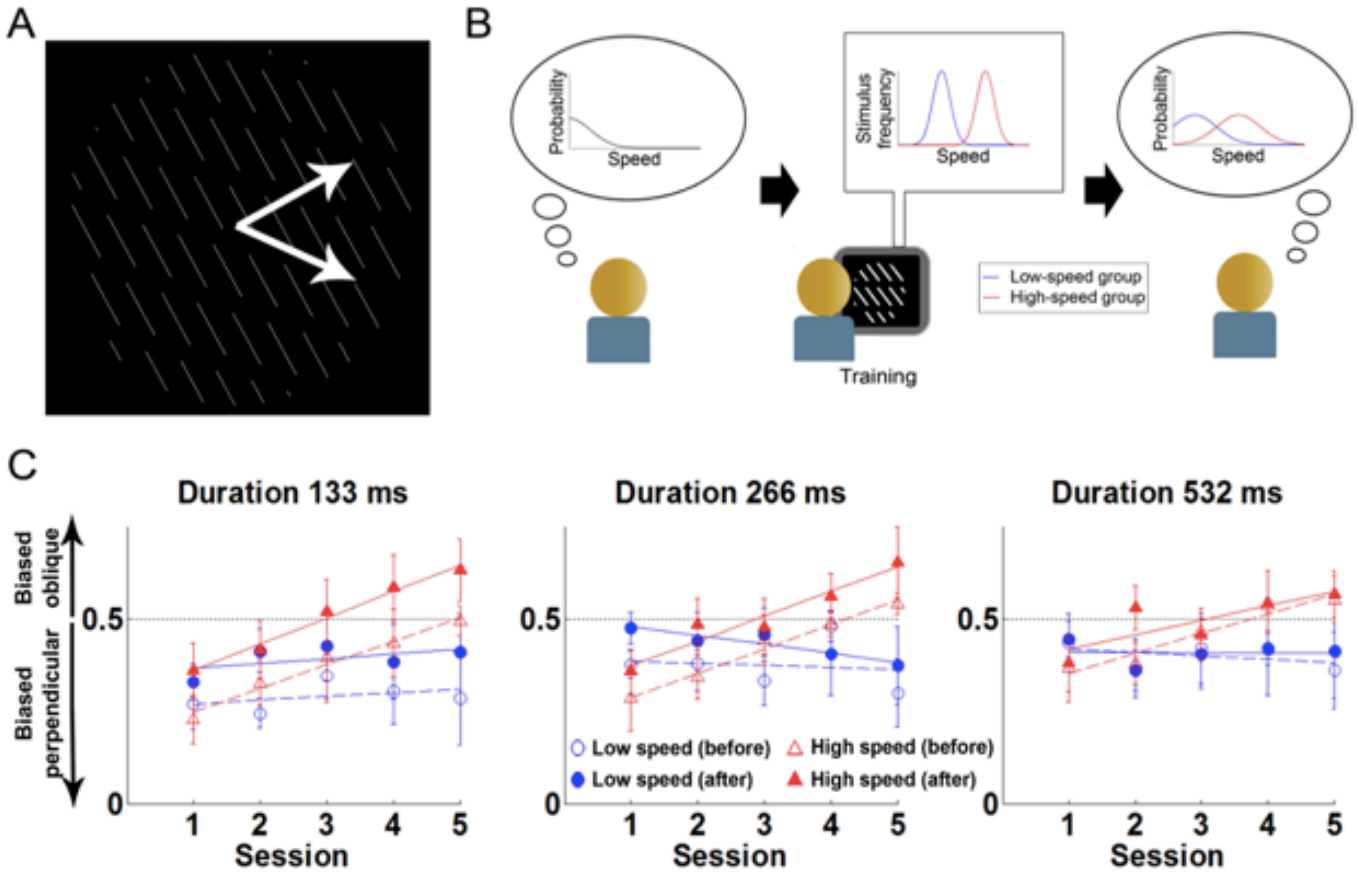




[Adams, Graf and Ernst Nature Neuroscience 2

Are priors constantly updating? Even those supposedly corresponding to natural scene statistics? (2)

The slow speed prior can be updated in a few sessions, just through exposure.
[Sotiropoulos, Seitz & Seriès (2011), Current Biology]



Extensions and open questions

- **What are the limits of prior learning? complexity?**

  [Gekas et al 2014; Acerbi et al 2014 ..]
- **How many priors can one learn simultaneously?**

  [Gekas et al 2014]
- **Are priors specific to learned conditions? stimulus? task?**

  experimental context?

  [Adams & Kerrigan 2013, Mamassian, Orban & Lengyel; Roach et al 2017]
- **Time scales of learning? unlearning?**

  [Lowenstein, Gekas et al 2015]
- **Heuristics or true Bayesian inference?**

  [Ravi & Loewenstein, Karvelis et al]

(Perceptual) Behavioural studies: What have we learned?

- Bayesian model offer elegant/ parsimonious description of behaviour (descriptive tool)

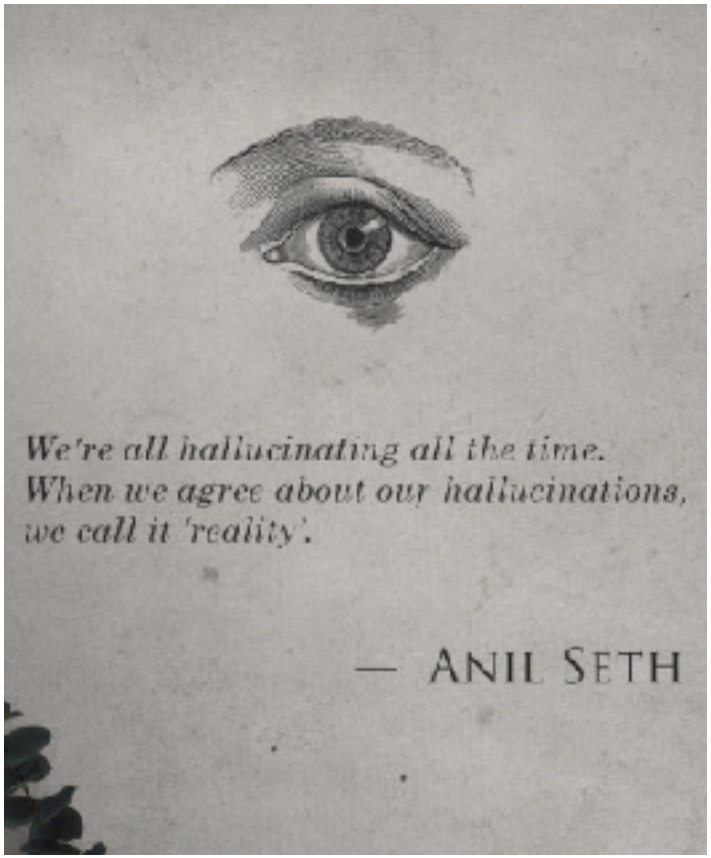
- Transparent assumptions and emphasis on “why” question.

- Behaviour consistent with Bayes in that:
  - Brains take into account uncertainty, and combine sources of information optimally (cue combination)
  - Use priors that are constantly updated
  - Used priors consistent with (approximation) of statistics of environment at different time scales. --> increase accuracy.

- Those priors (but also cost functions, likelihood) can be measured in individuals -- Bayesian modelling as a tool to describe the internal model used by individuals, possibly differentiating groups.

Perception as a “controlled hallucinations”

- The brain uses an internal model/ expectations to reconstruct the source of the input.
- Brain is **better** at processing data that is conform to the expectations.
- Brain is **biased** towards perceiving the world as being more similar to its expectations that it really is.



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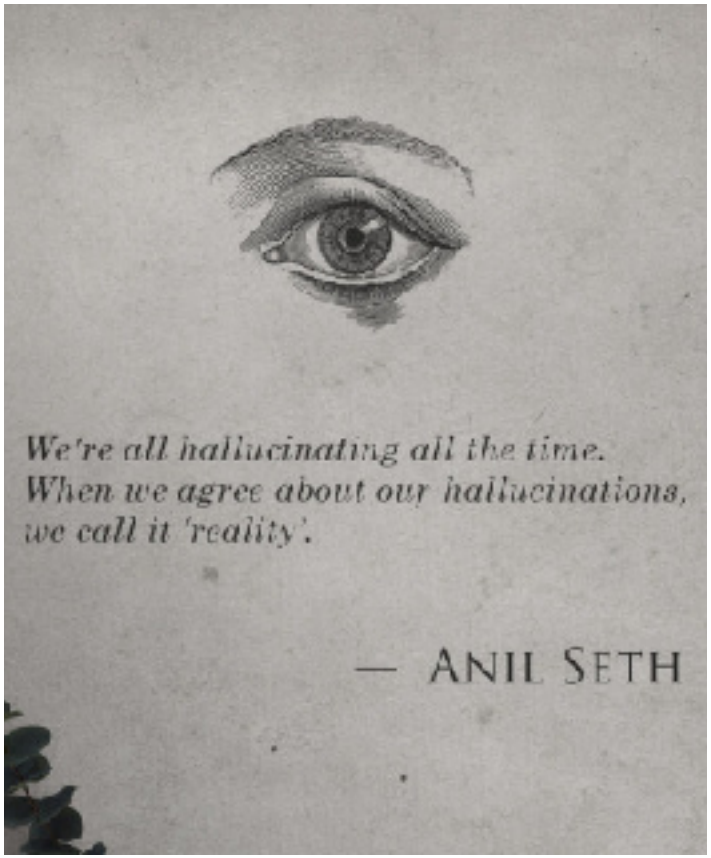

Approach and methods also extend to other domain of cognition