Crossing the streams: Sampling from past experience during perceptual inference

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Background

How do expectations combine with percepts? Learned expectations can disambiguate and facilitate perceptual inference. (e.g., Bar, 2004; Palmer, 1975)

This influence of learned expectations is typically modeled as a *static* change to the evidence accumulation process. (but see Hanks et al, 2011)

We propose that the expectation-setting process can be *dynamic*: an inference over mnemonic evidence for the likely content of a percept.

Hypotheses:

1. Perceptual decisions will be separately and dynamically modulated by the predictiveness of expectations and the coherence of perceptual information.

2. These behavioral effects will be mediated by anticipatory neural responses: expectation-driven reinstatement of the predicted percept, before it appears.

Task

Cued perceptual inference task

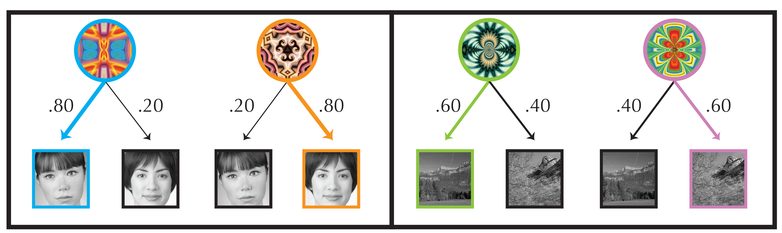
trial-by-trial variation in

(1) predictiveness of past experience (2) perceptual coherence

Learning: learn which image is predicted by which fractal cue

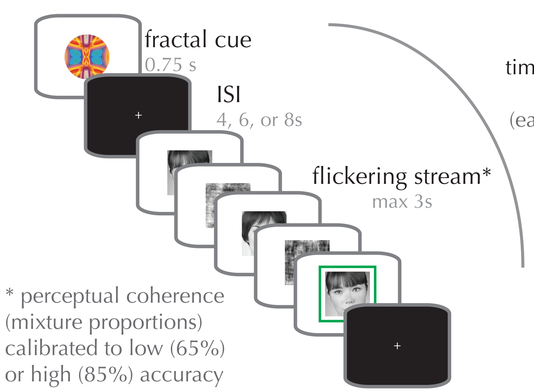
100 trials/block x 2 blocks, each with 4 cues & 4 images - 2 scenes, 2 faces

cue predictiveness: 50/50; 60/40; 70/30; 80/20



Test: identify predominant image in noisy flickering stream

80 trials/block x 2 blocks, immediately post-learning



time window for response starts at **cue onset** (early responses allowed)

* perceptual coherence (mixture proportions) calibrated to low (65%) or high (85%) accuracy

cue predictiveness and perceptual coherence counterbalanced across stimuli and blocks

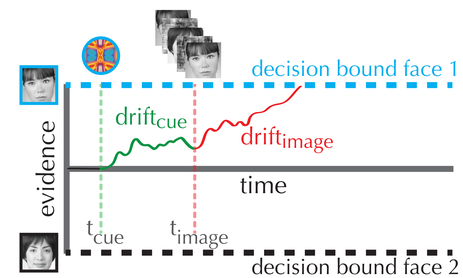
Multi-stage diffusion-decision model (MSDDM)

2 drift rates:

1 starts post-cue

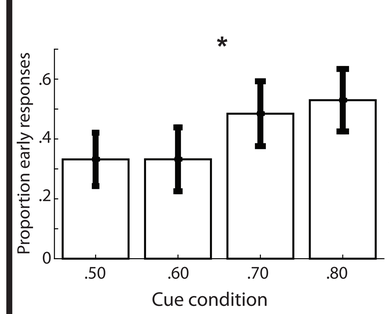
1 starts post-image

(Srivastava, Feng, Shenhav, 2015)

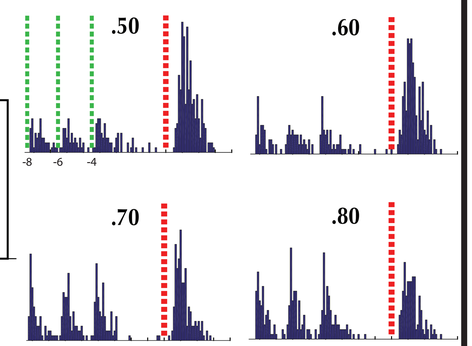


Behavioral results

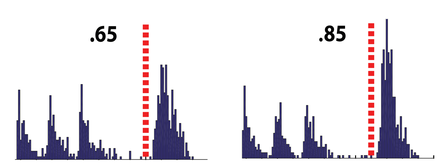
Pre-stimulus responses increase with cue reliability ...



* p = 0.036 across subjects

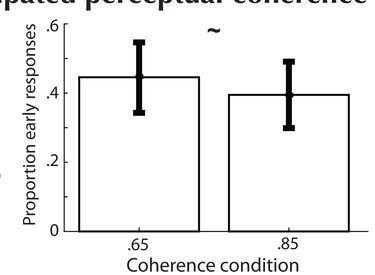


... and decrease with anticipated perceptual coherence

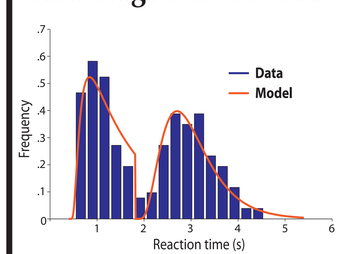


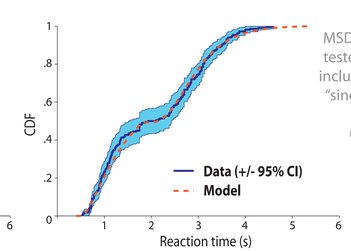
~ p = 0.078 across subjects

(* p = 0.018 for last half of test-phase trials)



Multi-stage DDM model fit





MSDDM fit is superior to all tested comparison models, including two unconnected "single" DDMs (all BIC ≥ 30)

(Displayed: Model fit to cue = 0.6 and coh = 0.65, across subjects)

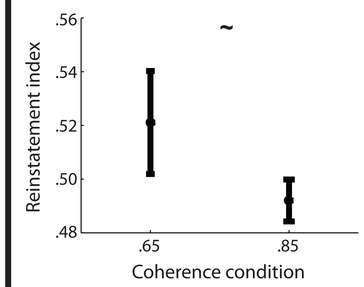
fMRI (in progress; n=12)

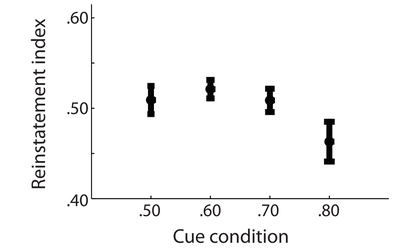
What does expectation-formation look like in the brain, and can we use these neural signatures to predict behavior?

Reinstatement index: Average same-category (face, scene) classifier evidence across TRs between cue and stimulus (or early response)

Cues trigger reinstatements in advance of the stimulus ...

* p=0.042 across subjects (average R=-0.3)



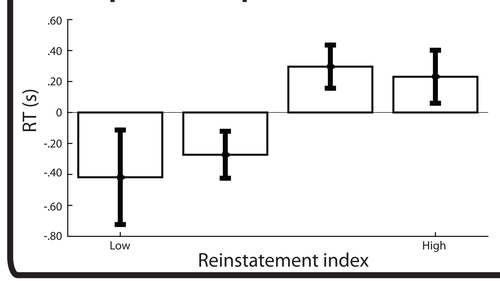


... which scale with the (anticipated) coherence of upcoming perceptual information

~ p=0.057 across subjects

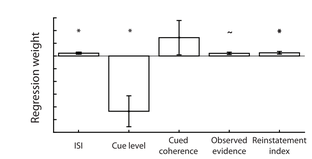
* p=0.021 for last half of test-phase trials

... and predict response time



RTs (residual, after subtracting off other effects) against reinstatement index

* p=0.0493 across subjects



Discussion & next steps

Expectation: sampling from episodic memory? Accumulation of episodic evidence can guide decisions. (Ratcliff 1978; Lengyel & Dayan 2008; Bornstein & Daw 2013)

- Evaluate anticipatory *item*-specific reinstatement and hippocampal activity.

Fold neural measures into MSDDM. Does adding trial-specific neural reinstatement improve the fit of the MSDDM? (see also Turner et al 2015)

Serial or parallel sampling? MSDDM is *serial*: expectation sampling stops when perceptual sampling begins.

- Currently developing a *parallel* sampling model: expectation and perceptual evidence integrated simultaneously.

- Can we find neural signatures of expectation-informed sampling *during* perceptual evidence accumulation?