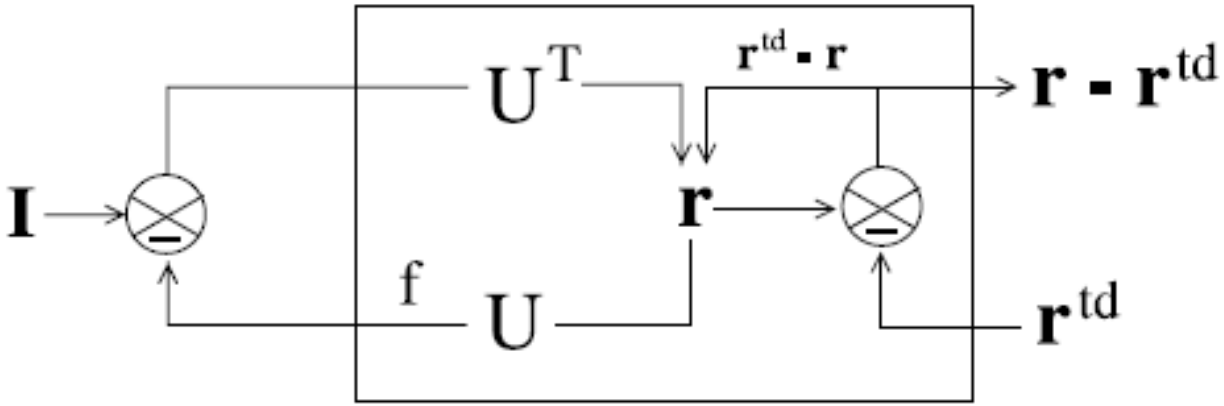
Donders Institute
for Brain, Cognition and Behaviour

Empirical support for predictive coding



Floris de Lange

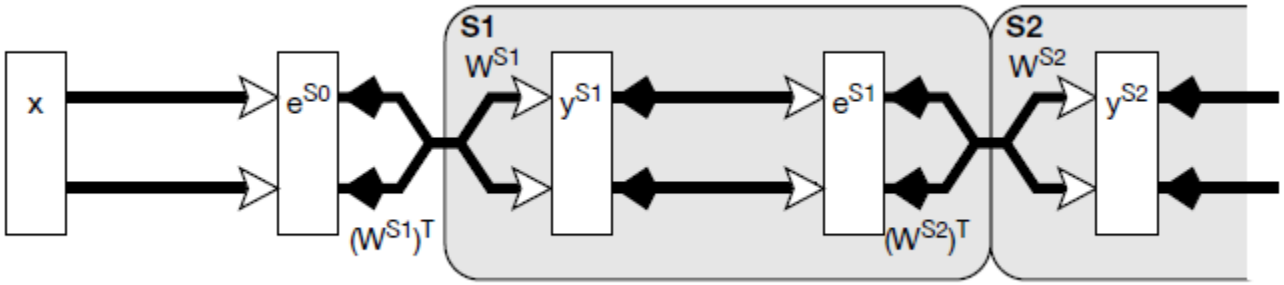
Donders Institute, Nijmegen, the Netherlands

Probabilistic inference and the brain

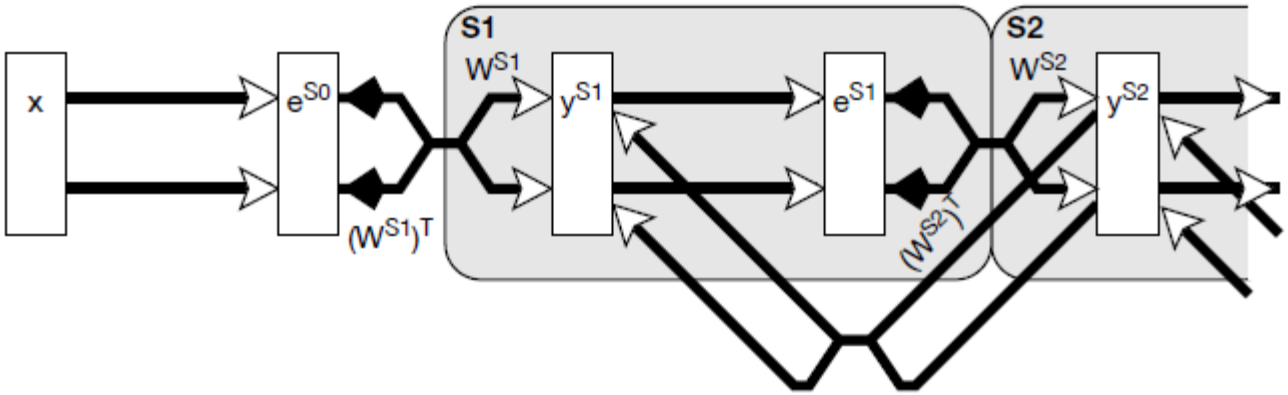
What is predictive coding?

- Predictive coding is a computational model of (visual) information processing
- It hypothesizes two types of neurons within each cortical module, and a specific type of message-passing between cortical modules (e.g., feedback suppresses signals predicted by higher-level cortical regions, errors are propagated feedforward)
- It can be seen as one implementation of the “Bayesian brain”

Different flavours of predictive coding



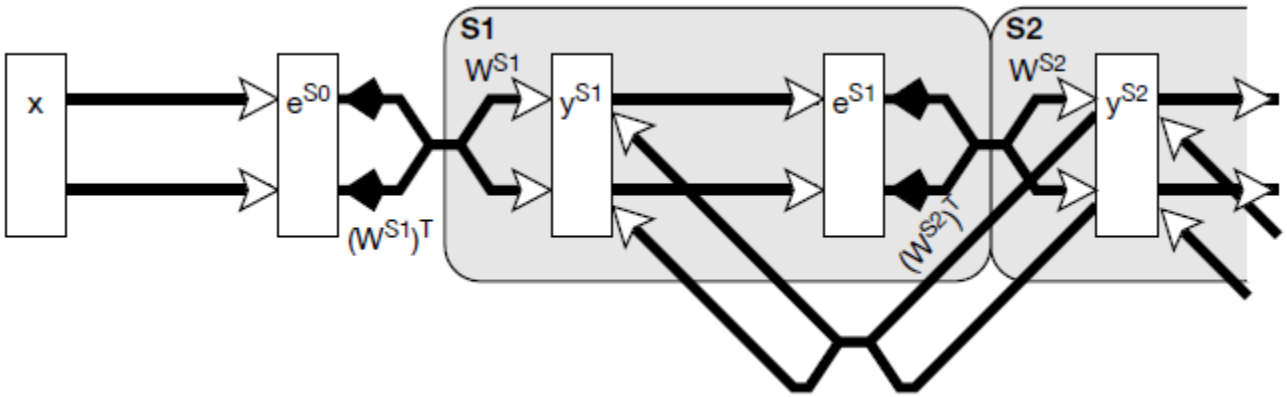
'classical' predictive coding (cf Rao & Ballard 1999, Friston 2005)



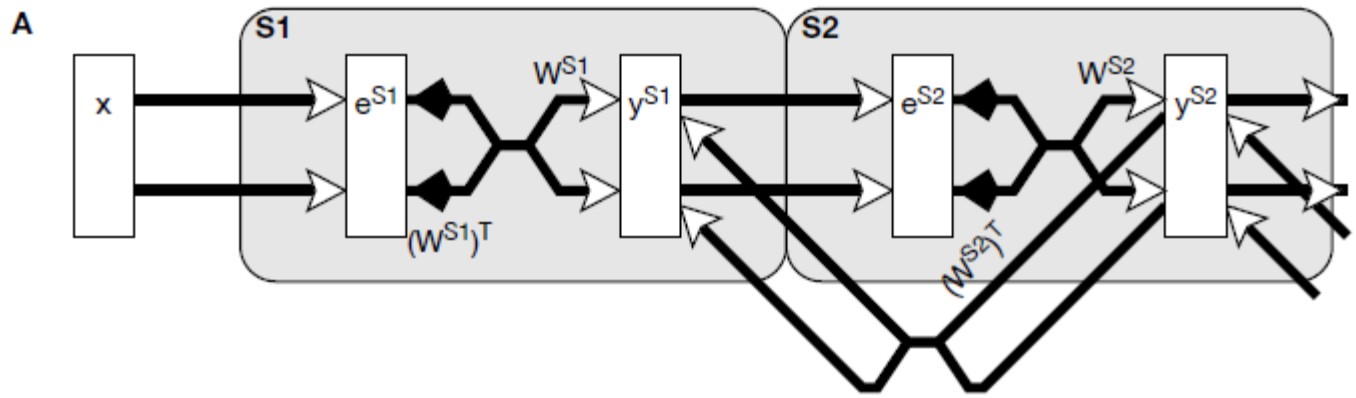
'reformulated' predictive coding (using excitation)

Spratling 2009

Different flavours of predictive coding



'reformulated' predictive coding (inter-cortical inhibition)

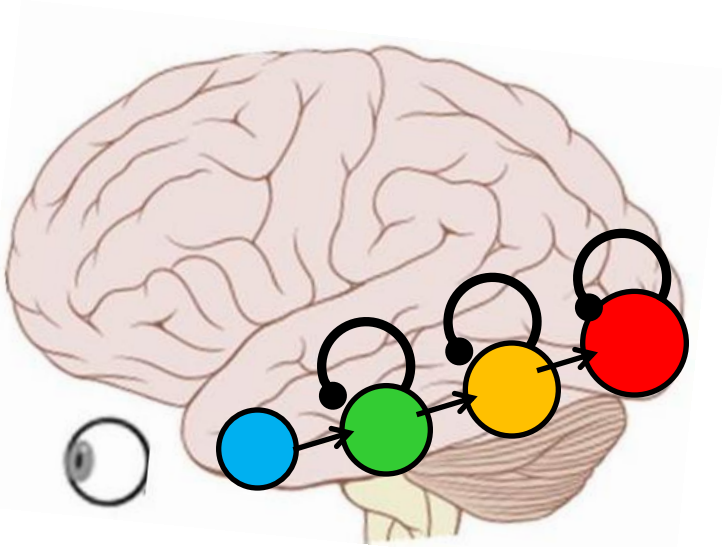


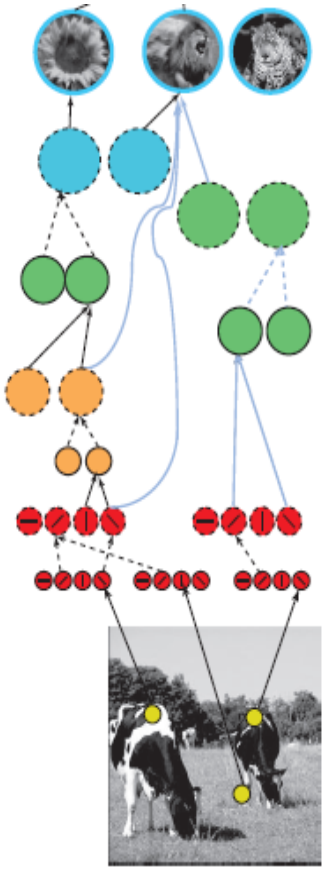
Biased competition (intra-cortical inhibition)

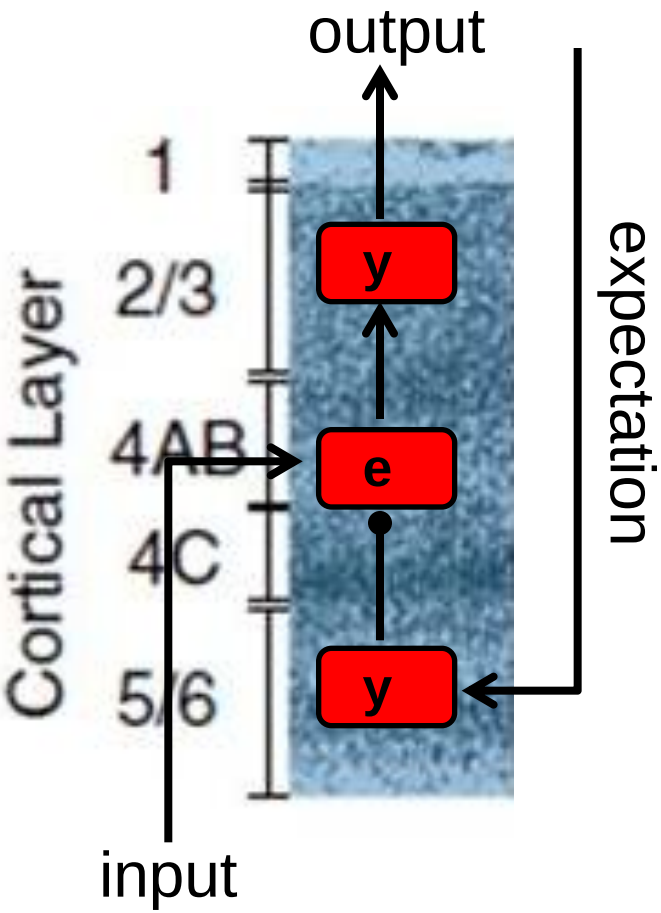
Spratling 2009

The PC/BC flavour of predictive coding

- Expectations select (activate) sensory representations
- These representations suppress (inhibit) their input



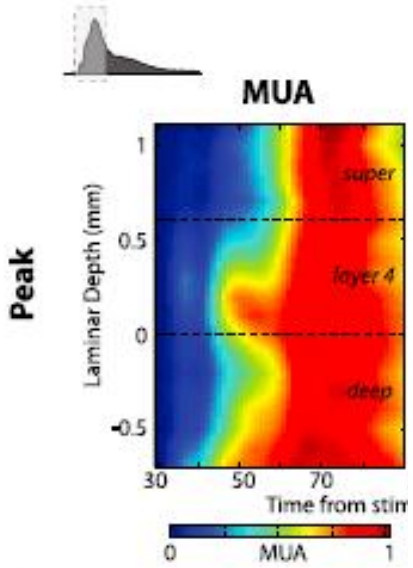


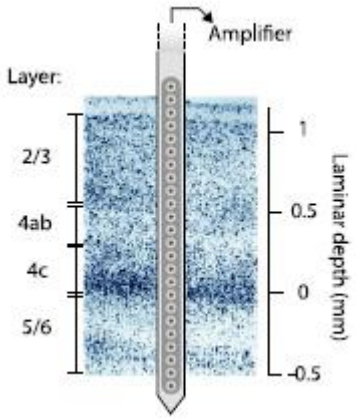


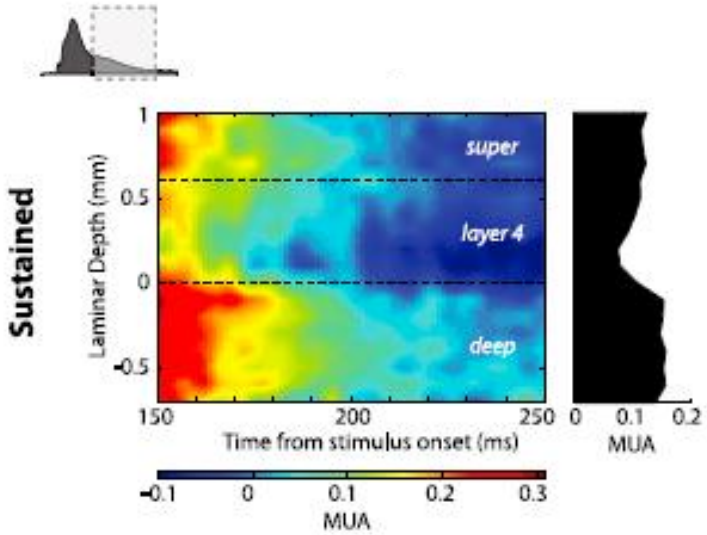
Predictions of the model

- Bottom-up signals first activate prediction error (e) units
- Activity of e units is transient, the activity of y units is sustained (as the system settles on an interpretation)
- Inhibition takes place chiefly within the cortical column, e.g. from L5/6 to L4
- Pure top-down prediction signals *only* activate prediction (y) units

Time course of activity within the cortical column

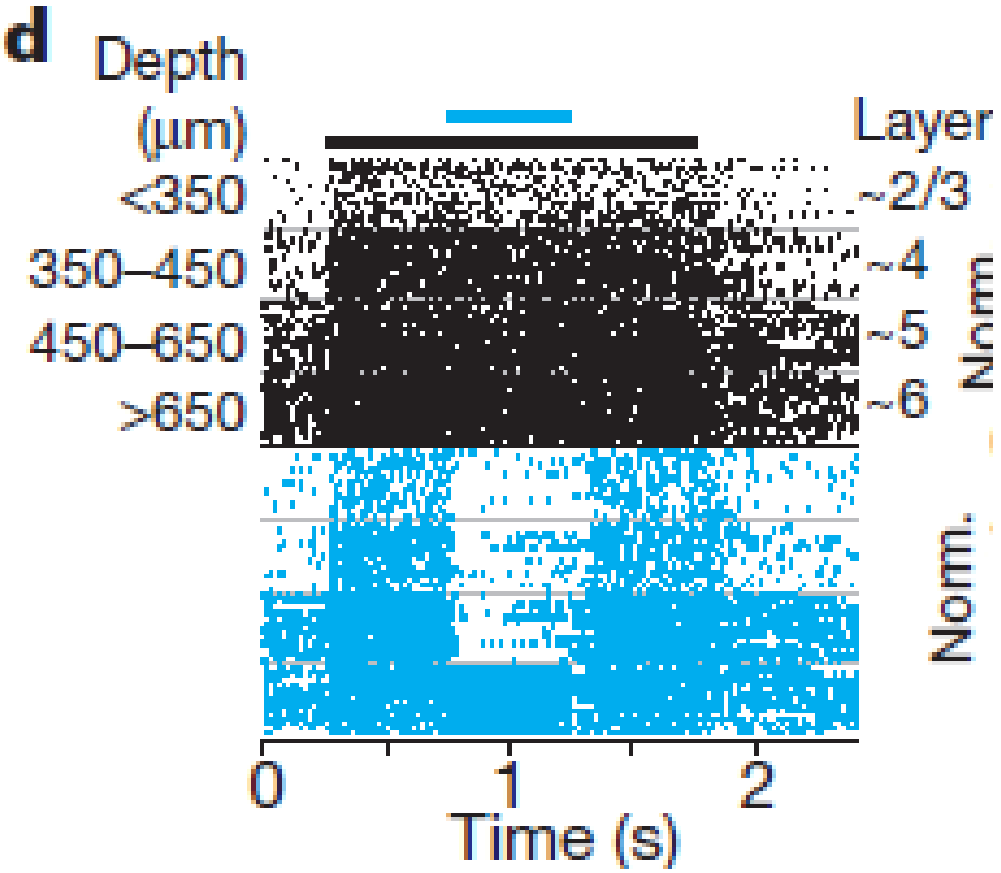


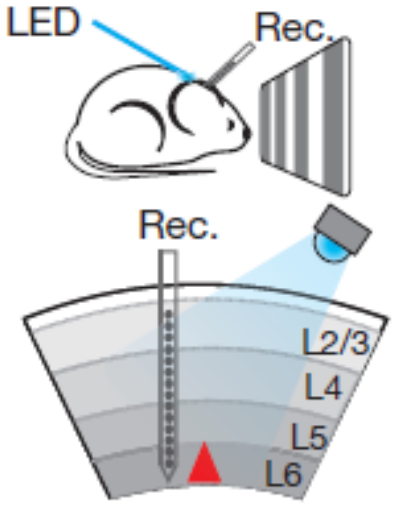




Self *et al* Curr Biol 2013

Intracortical inhibition from L6



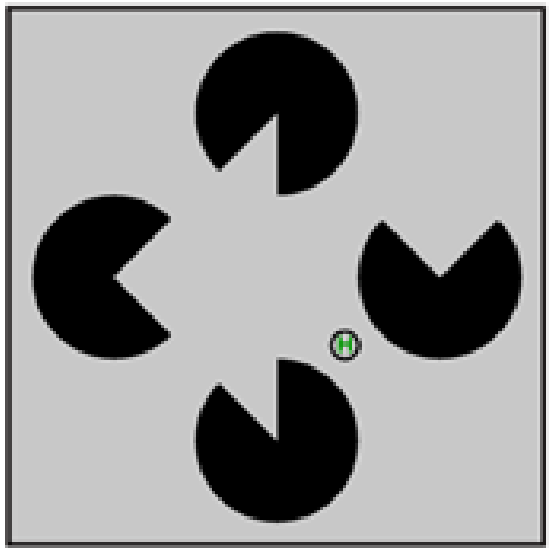


Olsen *et al* Nature 2012

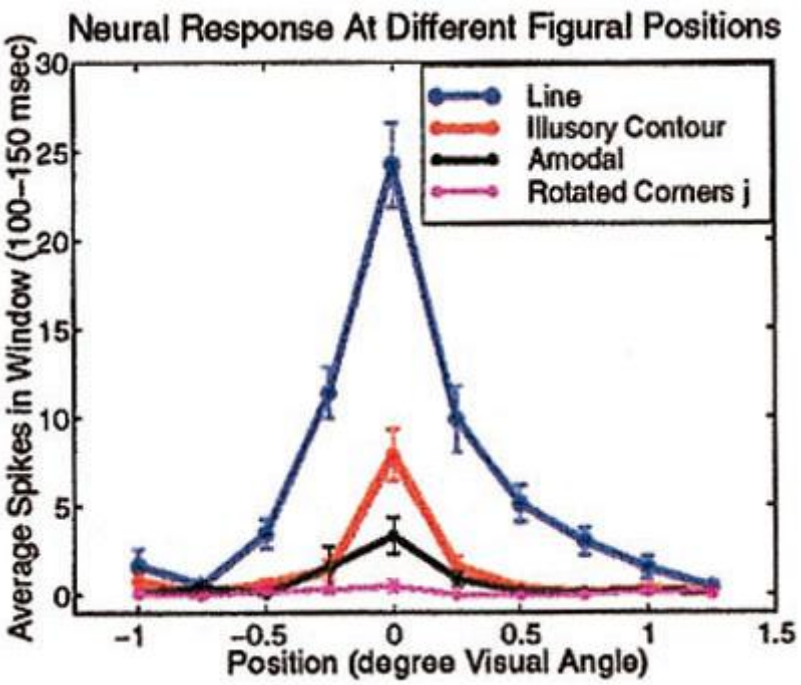
Can we activate the prediction units only?

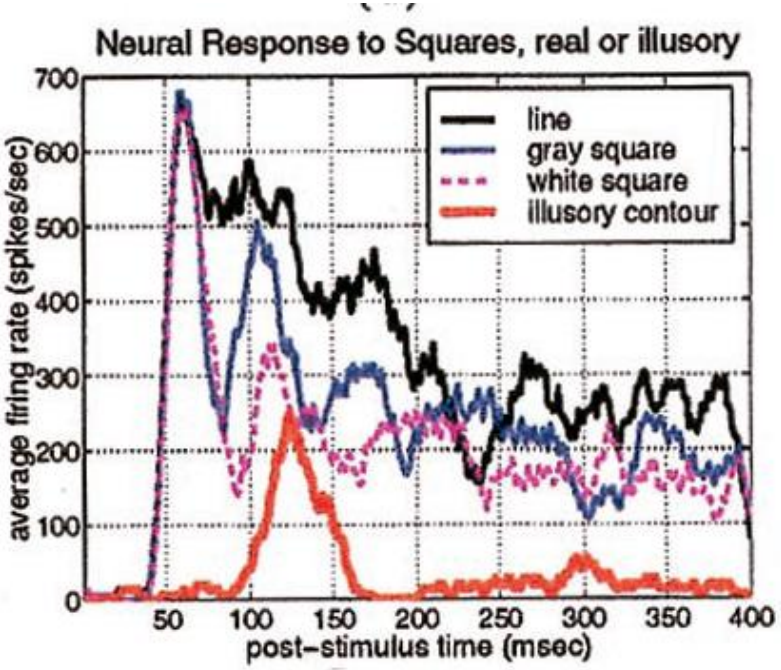
- Typically input generates a PE, which is then silenced by the eventual interpretation; so activation of the whole cortical column

- Exceptions:
  - Mental imagery?
  - **Illusory figures**?



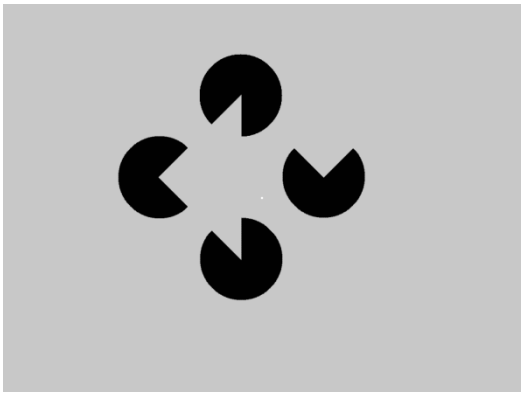
V1 activation for illusory contours





Lee & Nguyen *PNAS* 2001

Suppression and enhancement for illusory figures



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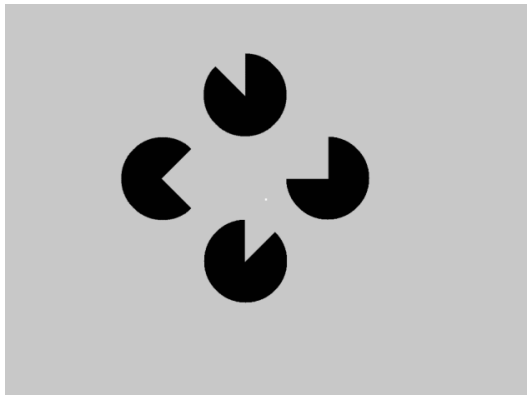

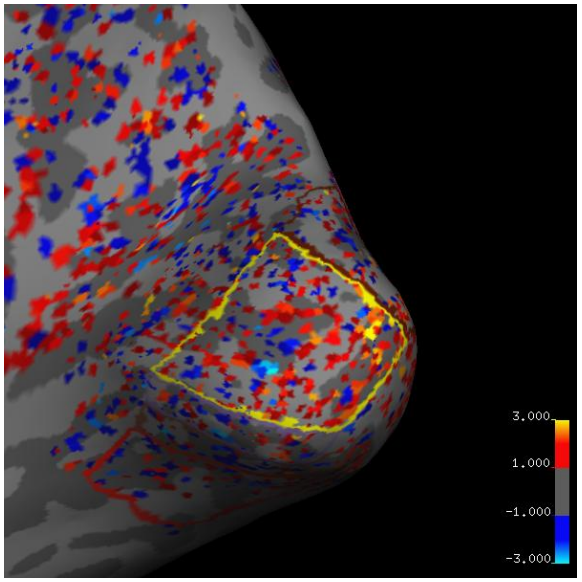

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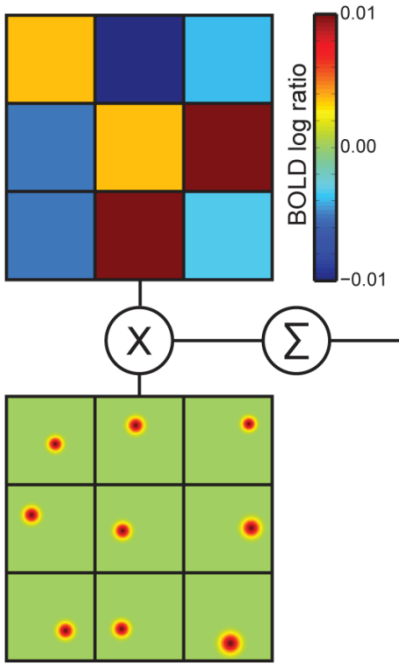

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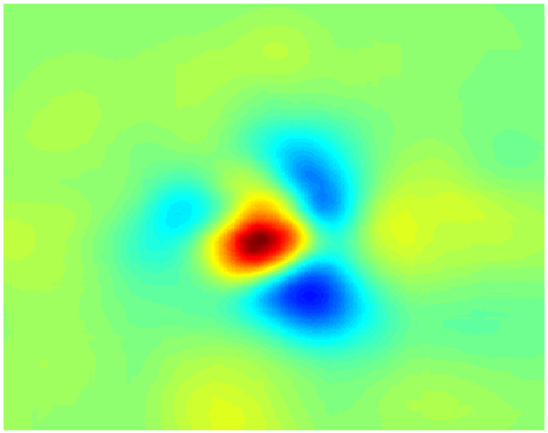
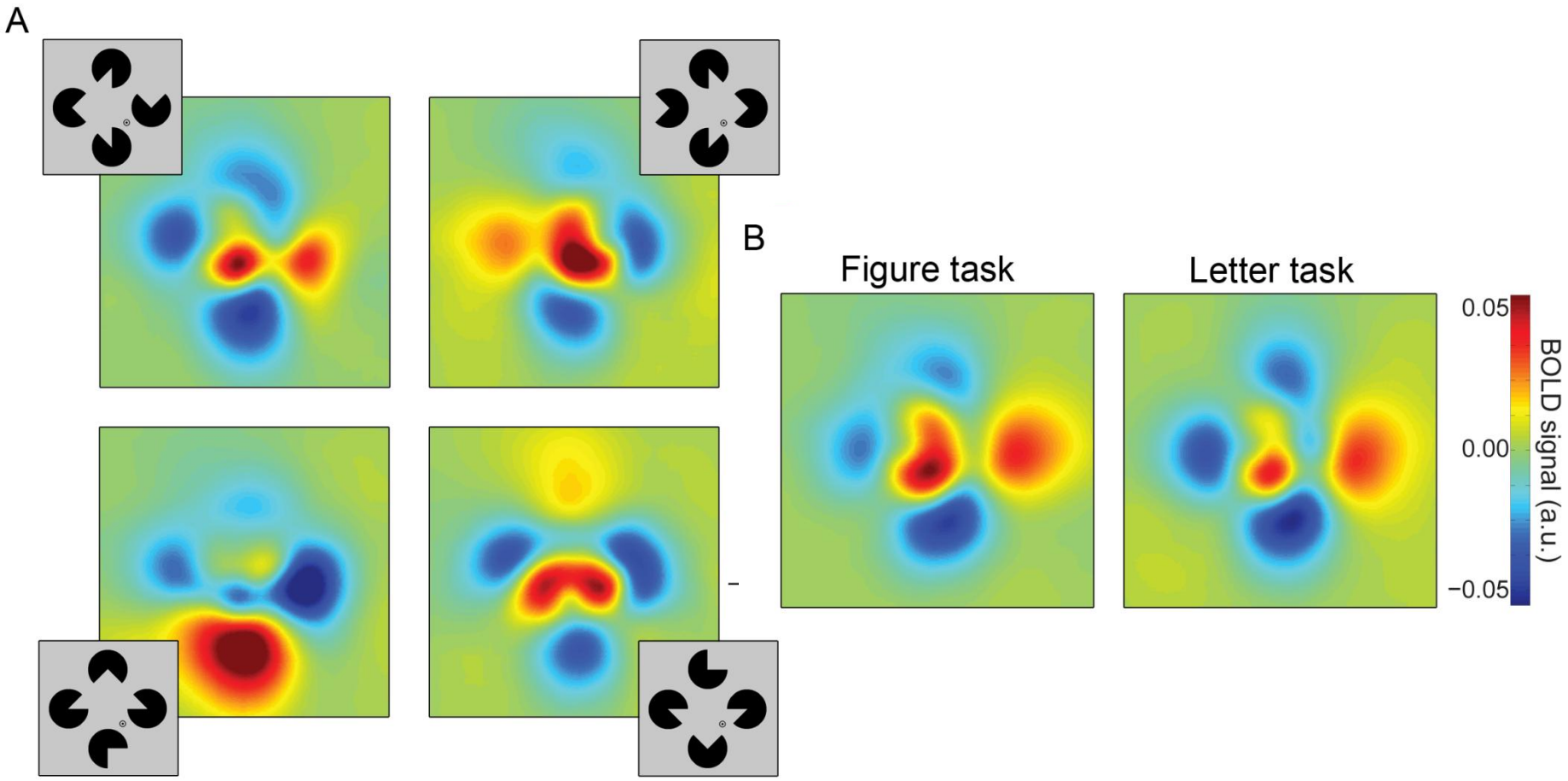


N=1

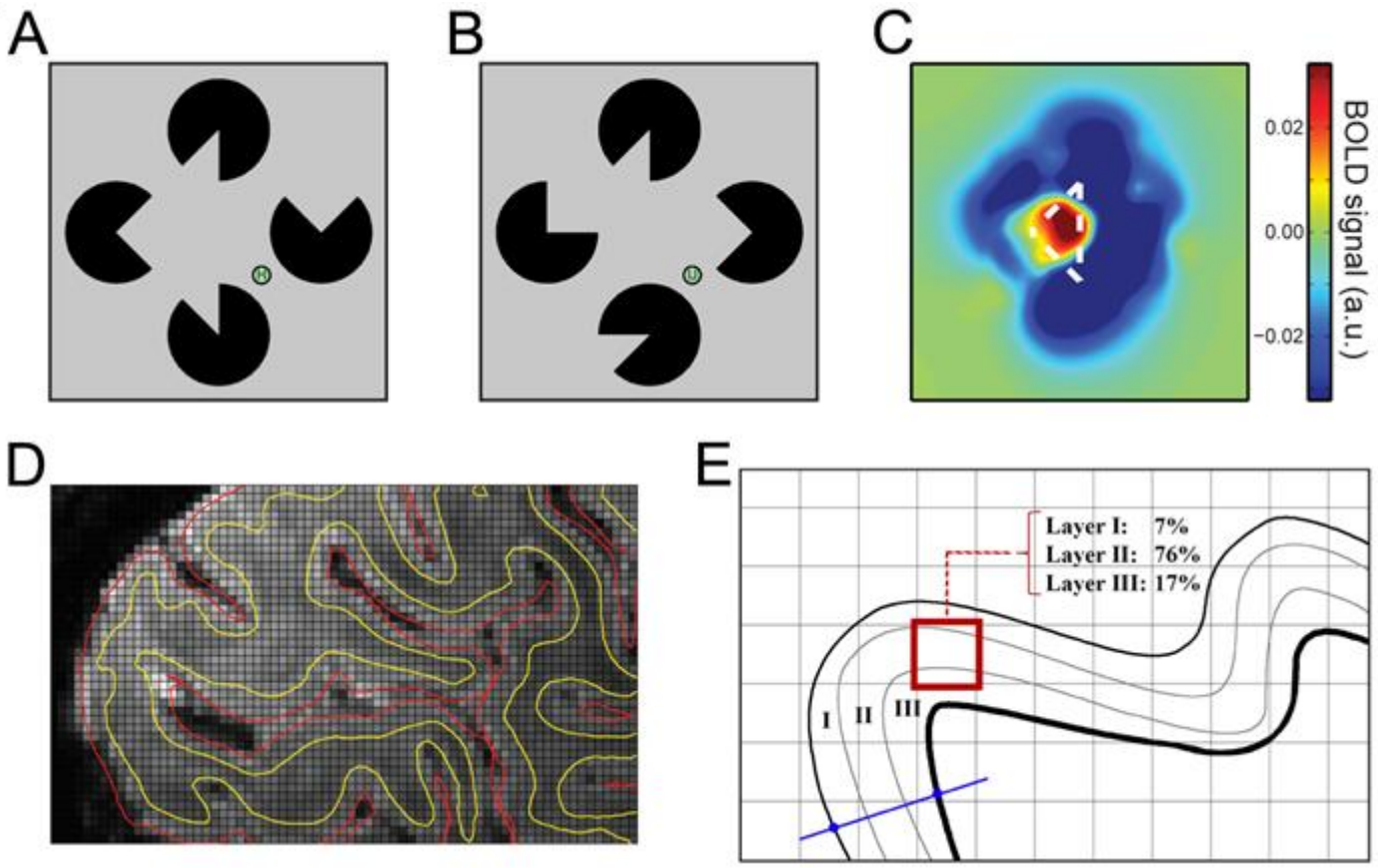
Cf. Dumoulin & Wandell 2008

What do illusory figures activate?



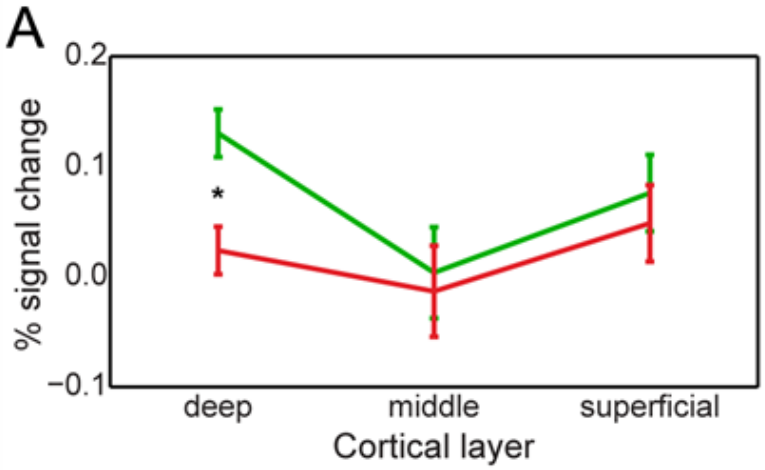
Kok & de Lange *Curr Biol* 2014

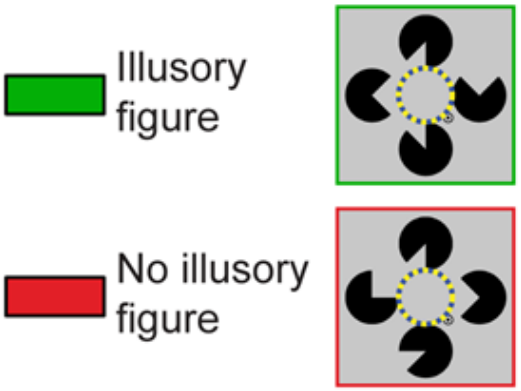
Recording layers at 7T (0.8 mm)



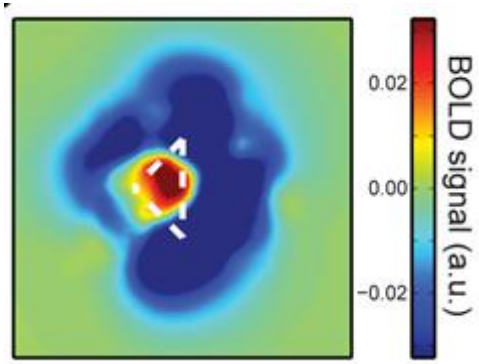
Kok et al *submitted*

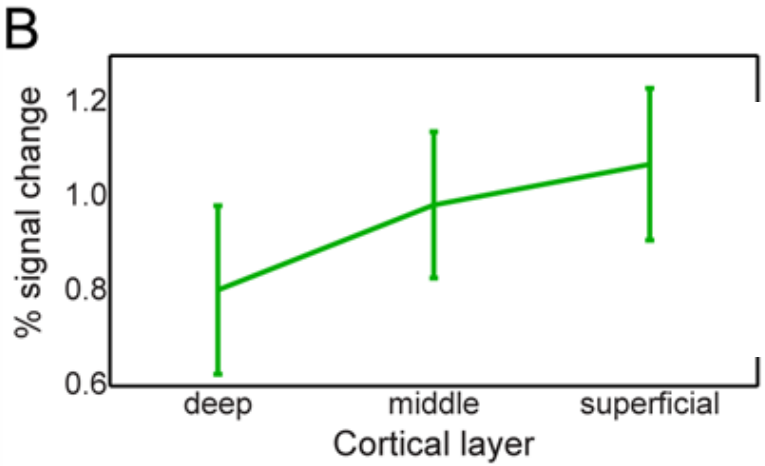
Top-down feedback only activates deep layers





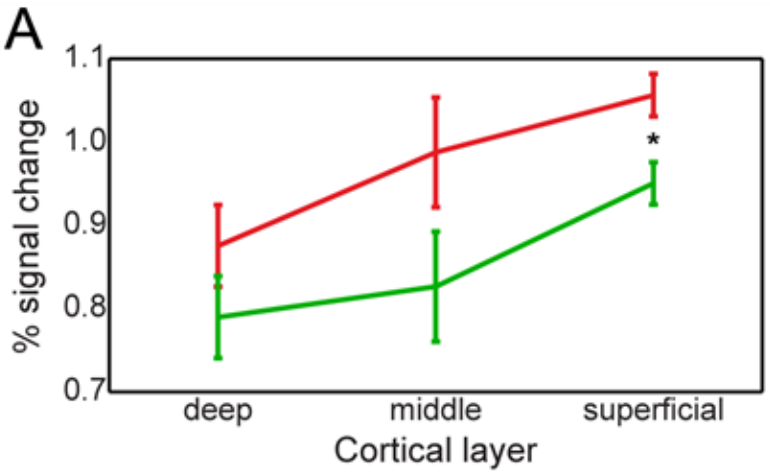
Indicates region of interest
(Not visible to participants)

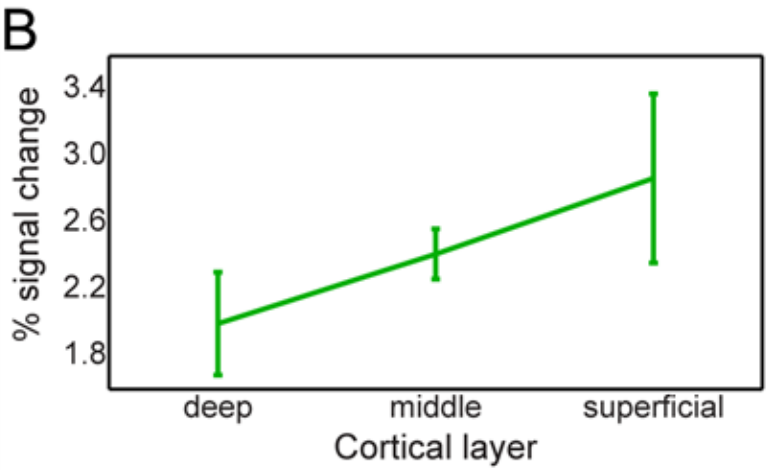


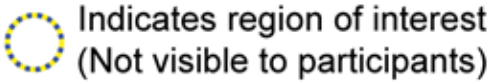


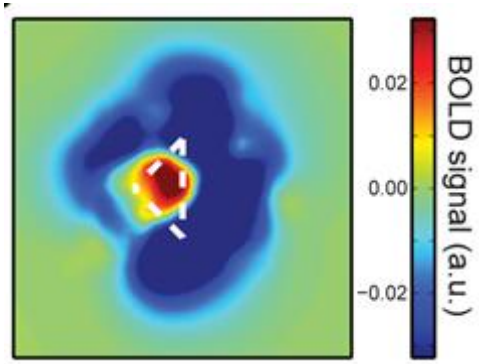
Kok et al *submitted*

Modulation of bottom-up input in all layers



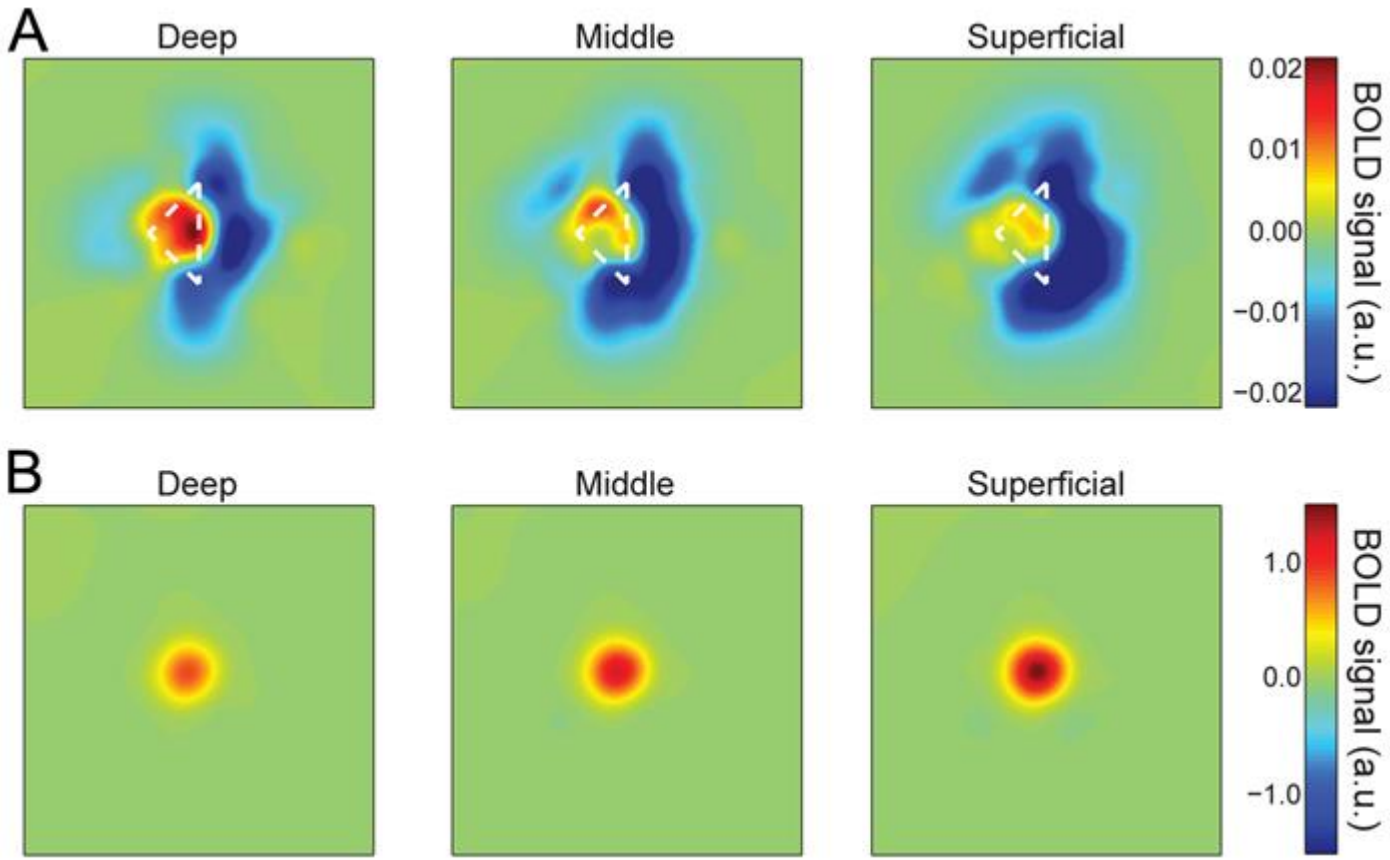






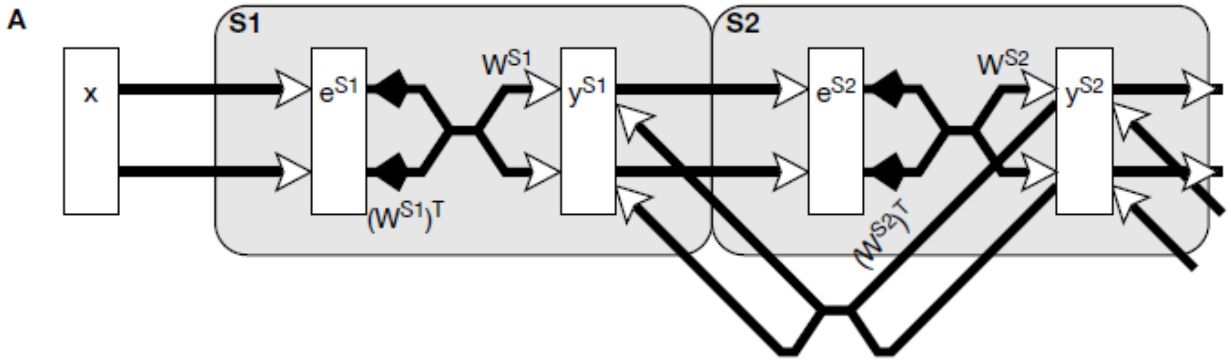
Kok et al *submitted*

Mapping the layer contributions

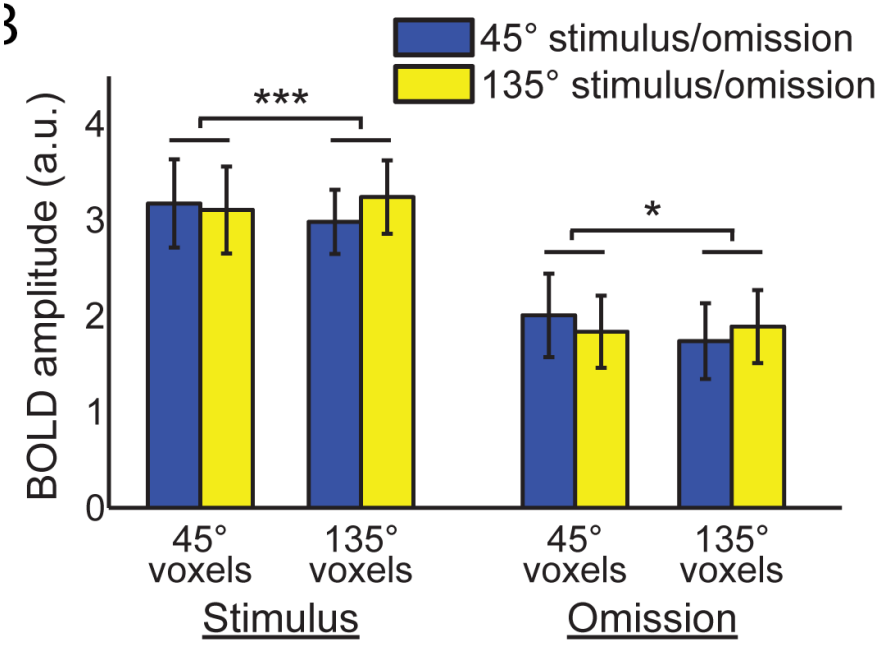


Kok et al *submitted*

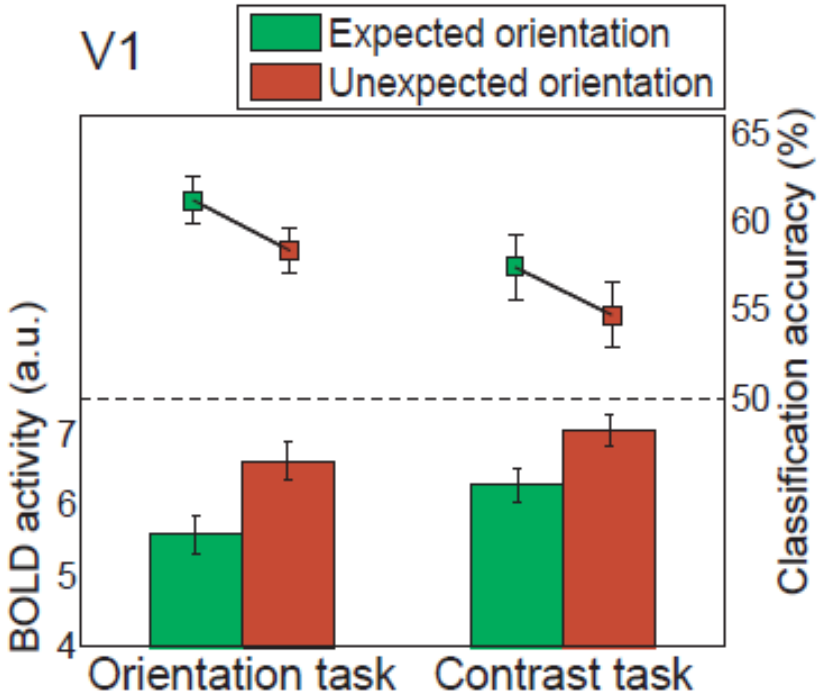
- There are several 'predictive coding' implementations
- Empirical data may be most consistent with an implementation scheme in which:
  - Higher-level representations (y^{S2}) *activate* lower-level representations (y^{S1})
  - Representations (y^{S1}) locally *inhibit* their input (e^{S1})



Indirectly supporting data



Kok, Failing, de Lange *J Cogn Neurosci* (2014)



Kok, Jehee, de Lange *Neuron* (2012)

Thanks to ..

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