On the role of expectation in visual perception: A top-down view of early visual cortex

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PRIOR KNOWLEDGE INFLUENCES PERCEPTION
Perception as inference: hypothesis testing.
- Perception as inference: hypothesis testing.
- Valid prior hypothesis -> reduced sensory response.

Den Ouden CerCor 2009
Perception as inference: hypothesis testing.

Valid prior hypothesis -> reduced sensory response.

- Reduced representation in early sensory regions?
- Improved representation, but reduced noise (prediction error)?
Orientation task: is the second grating rotated clockwise or anti-clockwise wrt the first?

Contrast task: does the second grating have lower or higher contrast than the first?
Activity in V1 is reduced for gratings with expected orientation.

This reduction is equally strong for the orientation and contrast tasks.
Multivariate pattern analyses (MVPA) can classify the perceived orientation from the pattern of BOLD activity in V1.
Orientation information in V1 is increased when orientation is expected.

This increase is equally strong for the orientation and contrast tasks.
Valid prior hypothesis -> reduced sensory response, but improved representation.

In line with predictive coding theories: reduced prediction error (Rao & Ballard 1999, Friston 2005).
HIERARCHICAL PERCEPTUAL INFERENCE

cf Lee & Mumford 2003, Ahissar & Hochstein 2004
Hypothesis: the effect of top-down predictions depends on the (mis)match with the bottom-up input; the prediction error.
Rao & Ballard 1999, Friston 2005

- Excitation of unexpected (absence of) signals
- Inhibition of expected signals
RECONSTRUCTING VISUAL REPRESENTATIONS

Kok & De Lange CurBio 2014
SIMULTANEOUS UP- AND DOWN-REGULATIONS IN V1

Kok & De Lange CurBio 2014

N=20
Excitation of unexpected (absence of) signals.

Inhibition of expected signals.

N=20
So far, I’ve discussed effects of expectation that seem independent of attention.

These effects are in line with predictive coding theories.

Attention boosts sensory signals.

In predictive coding, the sensory signal is the prediction error: input – prediction.

So, attention boosts prediction errors (Feldman & Friston 2010).
EXPECTATION AND ATTENTION INTERACT

Kok, Rahnev et al. CerCor 2012

Prediction cue → likelihood

Attention cue → task-relevance
Attention reverses prediction suppression.

Consistent with attention boosting PE at the predicted location.
Top-down predictions modulate processing in early sensory regions.

Suggests that brain performs hierarchical perceptual inference (Lee & Mumford 2003).

Dependent on (mis)match with bottom-up input, in line with predictive coding theories (Rao & Ballard 1999, Friston 2005).

Prediction and attention interact in a way that is consistent with casting attention as boosting (the precision of) prediction errors (Feldman & Friston, 2010).

For more on the task dependence of effects of expectation, see talk by Elexa St. John-Saaltink this afternoon.
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Co-Authors

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Thank you for your attention!

Elexa St. John-Saaltink
OP6 – Attention, 1 PM

Task demands modulate the effects of perceptual expectations in early visual cortex
Further evidence for ‘sharpening’: the expectation-induced reduction in BOLD amplitude is larger in voxels non-selective for the current orientation.
Effects of expectation on behaviour and classification accuracy (in V1) are correlated.
SIMULTANEOUS UP- AND DOWN-REGULATIONS IN V1

Kok & De Lange CurBio 2014

% signal change

– 0.2
– 0.1
– 0.0

Figure task

Letter task

Illusory figure

No illusory figure

N=20
**Expectation and Attention Interact**

Kok CerCor 2012

**Stimulus present**

- Predicted stimulus
- No prediction
- Unpredicted stimulus

**Stimulus absent**

- Predicted omission
- No prediction
- Unpredicted omission

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**V1**

- Unattended side
- Attended side

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**Parameter estimate**

- Unattended side
- Attended side

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**V1**

- Unattended side
- Attended side
A  **Stimulus trial (75%)**

- Auditory cue (200 ms)
- Grating 1 (550 ms)
- Grating 1 (100 ms)
- Grating 2 (500 ms)
- Grating 2 (100 ms)
- ITI (3250-6250 ms)

B  **Omission trial (25%)**

- Auditory cue (200 ms)
- ITI (1250 ms)
- ITI (3250-6250 ms)
B

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<th>BOLD amplitude (a.u.)</th>
<th>45° stimulus</th>
<th>135° stimulus</th>
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Stimulus

45° voxels 135° voxels
Prediction error

- Green line: predicted stimulus
- Red line: unpredicted stimulus