Orientation-selective adaptation to first- and second-order stimuli in human visual cortex measured with FMRI

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Background

Neurons mediating second-order pattern perception are orientation-selective.

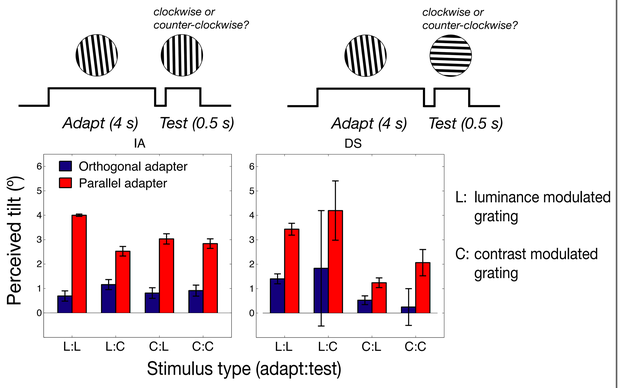
- Psychophysics suggests second-order filters are orientation-selective [1,2].
- Single-unit recordings from the visual cortex of cat [3] and monkey [4,5] have found orientation-tuned neurons sensitive to second-order features.

Neuronal populations tuned to second-order patterns should give a smaller FMRI response to repeated stimuli of a single orientation than to stimuli of varying orientations.

- The population response to a single repeated (adapted) orientation will be lower than the response to varying (non-adapted) orientations only if the neurons are orientation-selective.
- Selective adaptation of subpopulations of neurons can be measured with FMRI [6-8].

Psychophysics

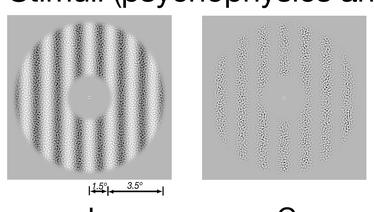
Tilt aftereffect shows cross-adaptation between first- and second-order stimuli



L: luminance modulated grating

C: contrast modulated grating

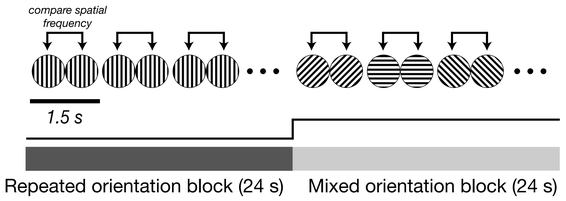
Stimuli (psychophysics and FMRI)



- *Carrier: isotropic bandpass filtered noise (center frequency 6 cpd, bandwidth 1 octave)*
- *Modulation frequency: 0.75 cpd (psychophysics); 0.70-0.75 cpd (FMRI)*
- *Carrier contrast: 50%*
- *Phase randomly changed every 250 ms*

FMRI

Experimental design

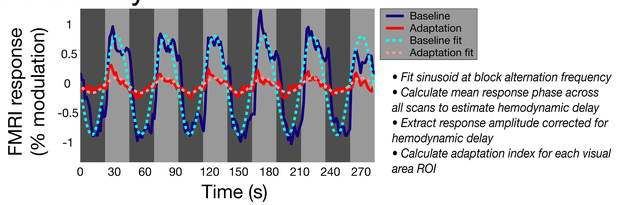


Stimulus conditions

	Adaptation orientation	
Modulator	*Vertical (90°)*	*Oblique (45°)*
Luminance	L-v	L-o
Contrast	C-v	C-o

Baseline condition: Mixed orientation vs. blank screen

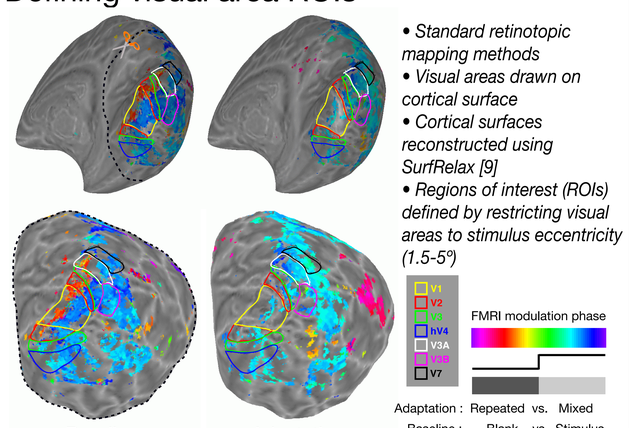
Data analysis



- *Fit sinusoid at block alternation frequency*
- *Calculate mean response phase across all scans to estimate hemodynamic delay*
- *Extract response amplitude corrected for hemodynamic delay*
- *Calculate adaptation index for each visual area ROI*

$$\text{Adaptation index} = \frac{\text{(projected amplitude, adaptation)}}{\text{(projected amplitude, baseline)}}$$

Defining visual area ROIs



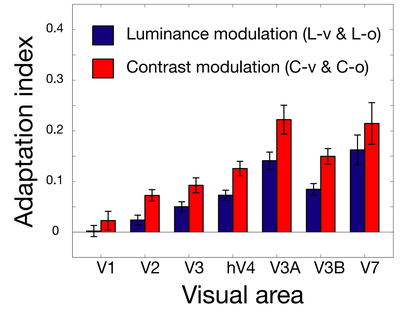
- *Standard retinotopic mapping methods*
- *Visual areas drawn on cortical surface*
- *Cortical surfaces reconstructed using SurfRelax [9]*
- *Regions of interest (ROIs) defined by restricting visual areas to stimulus eccentricity (1.5-5°)*

Adaptation : Repeated vs. Mixed

Baseline : Blank vs. Stimulus

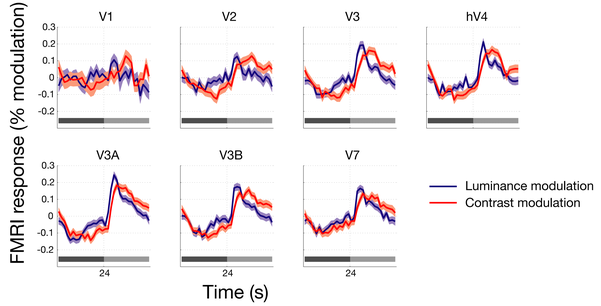
Results

Orientation-selective adaptation increases with level in cortical hierarchy

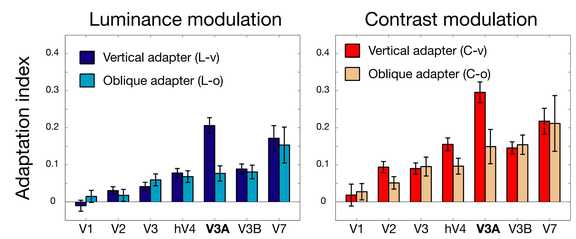


Orientation-selective adaptation: Weak or absent in V1, V2
Consistently strong in V3A/V3B
Similar pattern for L and C

Mean Time Course Across Subjects By Visual Area



An oblique adaptation effect in area V3A



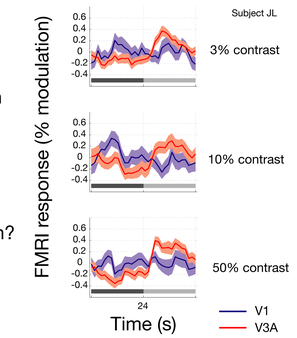
V3A: magnitude of orientation-selective adaptation is **stronger** for **vertical** orientation than for ***oblique*** orientation.

Selective adaptation in V1

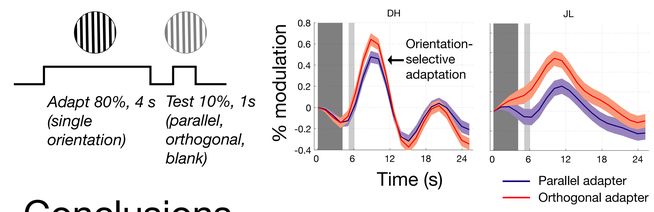
No orientation-selective adaptation in V1 to first-order stimuli? [10]
- V1 neurons not orientation selective?!
- Suboptimal adaptation stimuli? (spatial frequency, contrast)
- Response saturation?
- Is the 'adaptation' effect just attention?
- BOLD FMRI measures inputs, not outputs?
- V1 neurons less prone to adaptation than extrastriate neurons?

Repeat block design experiment using more 'optimal' V1 stimuli (1.5 cpd, no carrier):
No orientation-selective adaptation found in V1.
V3A, extrastriate areas *still* show adaptation.

Low contrast - weak adaptation?
High contrast - response saturation?
Adaptation only with high contrast adapter, low contrast test?



Event-related design



Conclusions

- The magnitude of orientation-selective adaptation is largest in higher visual areas, particularly V3A.
- The distribution of orientation-selective adaptation across visual areas is similar for first- and second-order stimuli.
- Results consistent with closely interacting mechanisms for first- and second-order pattern perception.
- Orientation-selective adaptation in V1 to first-order stimuli.
- V1 less susceptible to adaptation than extrastriate visual cortex.

Acknowledgments

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[1] Kwan L, Regan D (1998) Vision Res 38:3489-3855
[2] Arsenault AS, Wilkinson F, Kingdom FAA (1999) J. Opt. Soc. Am. A. 16:427-435
[3] Mareschal I, Baker CL (1998) Nature Neurosci. 1:150-154
[4] Grosof DH, Shapley RM, Hawken MJ (1993) Nature 365:550-2
[5] von der Heydt R, Peterhans E, Baumgartner G (1984) Science 224:1260-2
[6] Grill-Spector K, Malach R (2001) Acta Psychol (Amst). 107:293-321
[7] Engel SA, Furmanski CS (2001) J Neurosci. 21:3949-54
[8] Huk AC, Ress D, Heeger DJ (2001) Neuron 32:161-72
[9] Larsson J (2001) Imaging vision. PhD Thesis. Karolinska Institutet, Stockholm, Sweden. ISBN: 91-7349-090-3
http://www.cns.nyu.edu/~jonas/software.html
[10] Boynton GM, Finney EM (2003) J Neurosci. 23:8781-7
[11] Wichmann FA, Hill NJ (2001) Perception and Psychophysics 63:1293-1313
http://bootstrap-software.org/psignifit