# 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.***

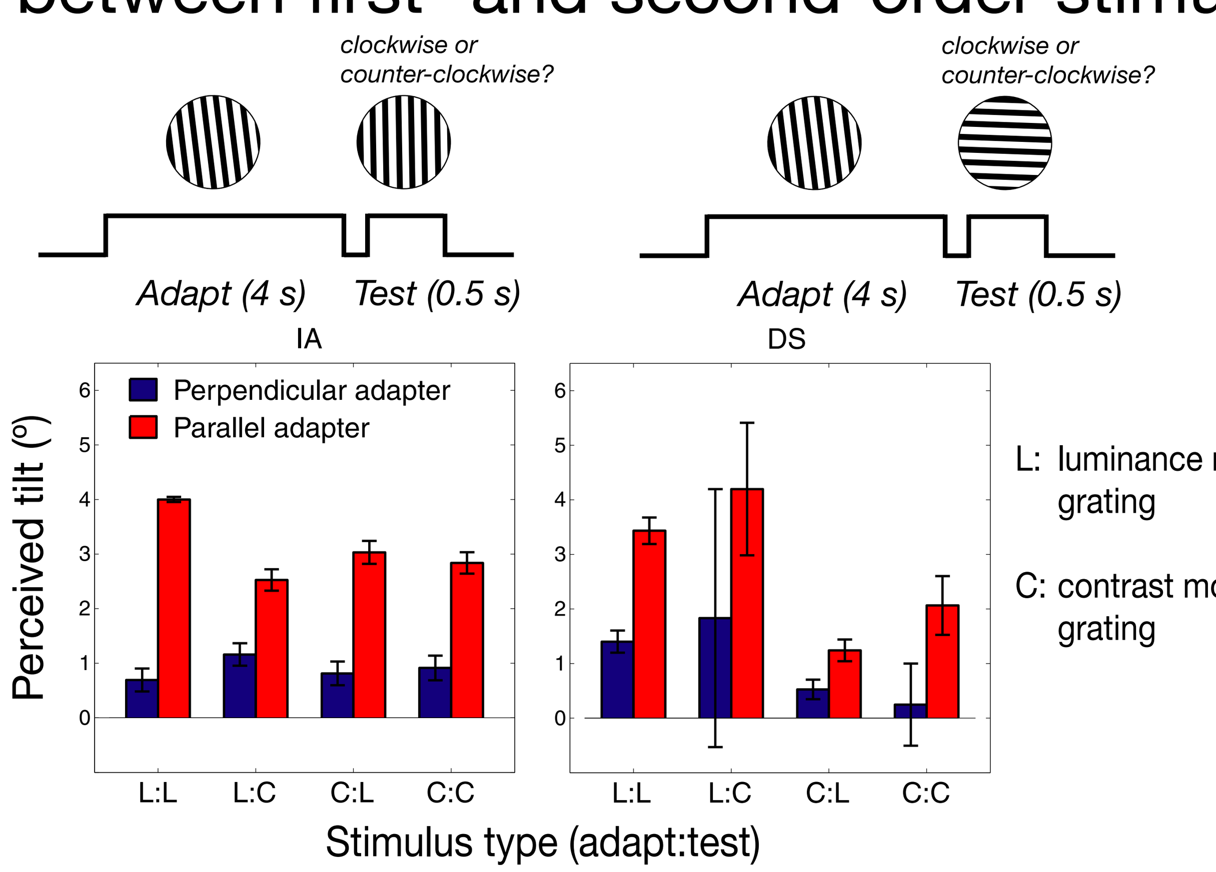
• Psychophysics suggests second-order filters are orientation-selective [1,2].
• Single-unit recordings from the visual cortex of cat [3] and monkey [4,5] have found orientation-tuned neurons sensitive to second-order features.

***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

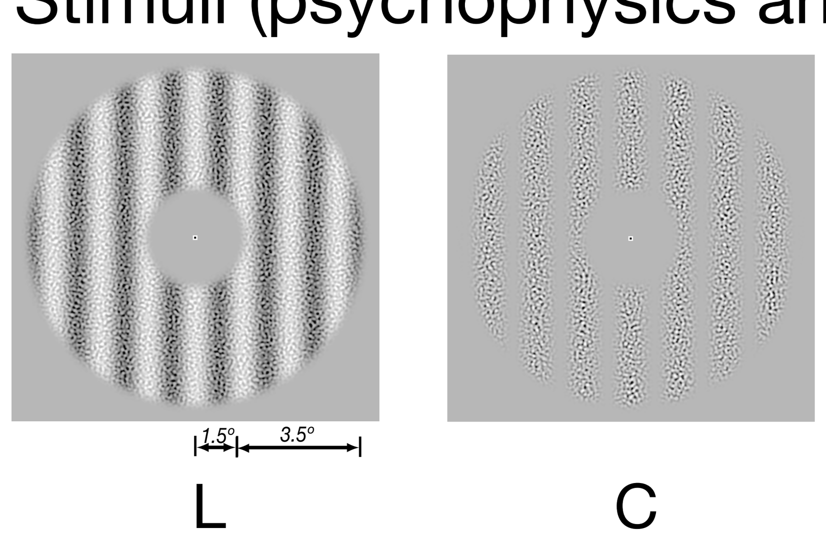
### Tilt aftereffect shows cross-adaptation between first- and second-order stimuli




L: luminance modulated grating

C: contrast modulated grating

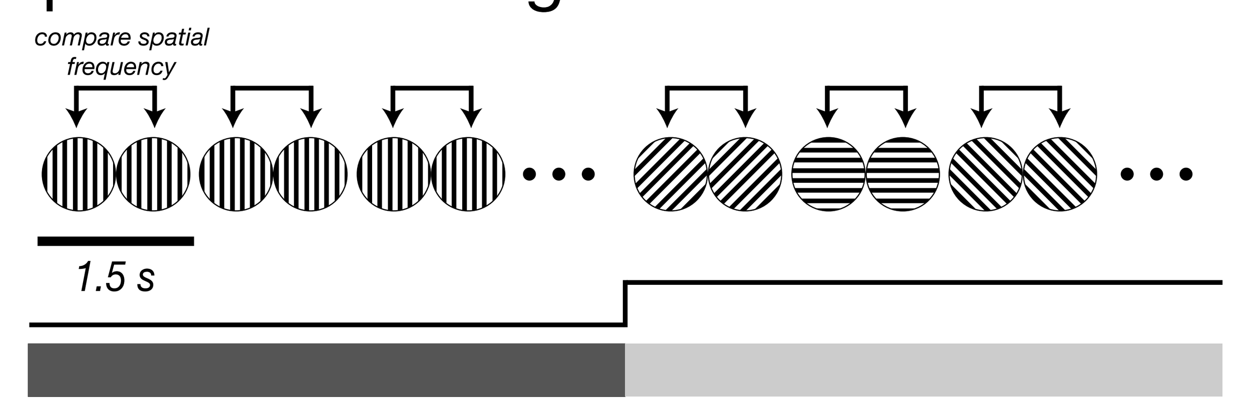
### Stimuli (psychophysics and FMRI)




• *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



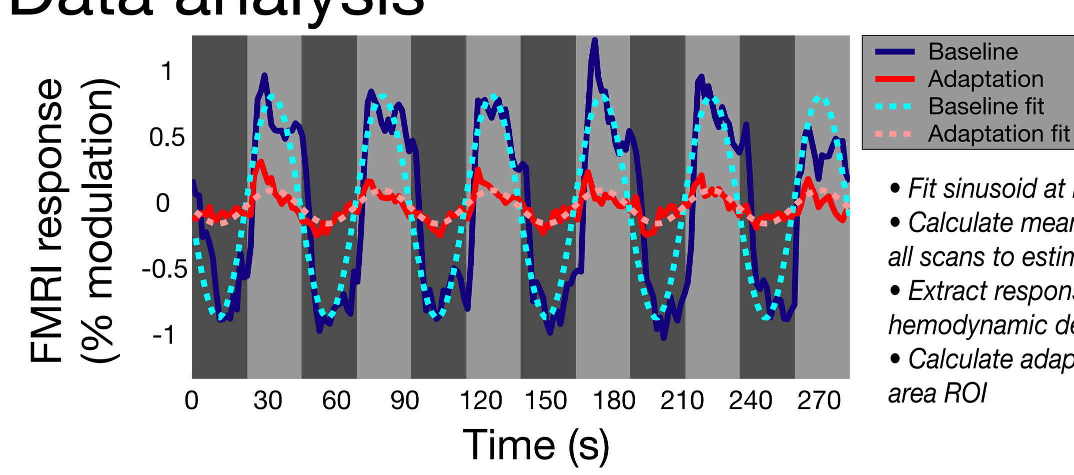

Repeated orientation block (24 s) Mixed orientation block (24 s)

### Stimulus conditions

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

*Baseline condition:*
Mixed orientation vs. blank screen

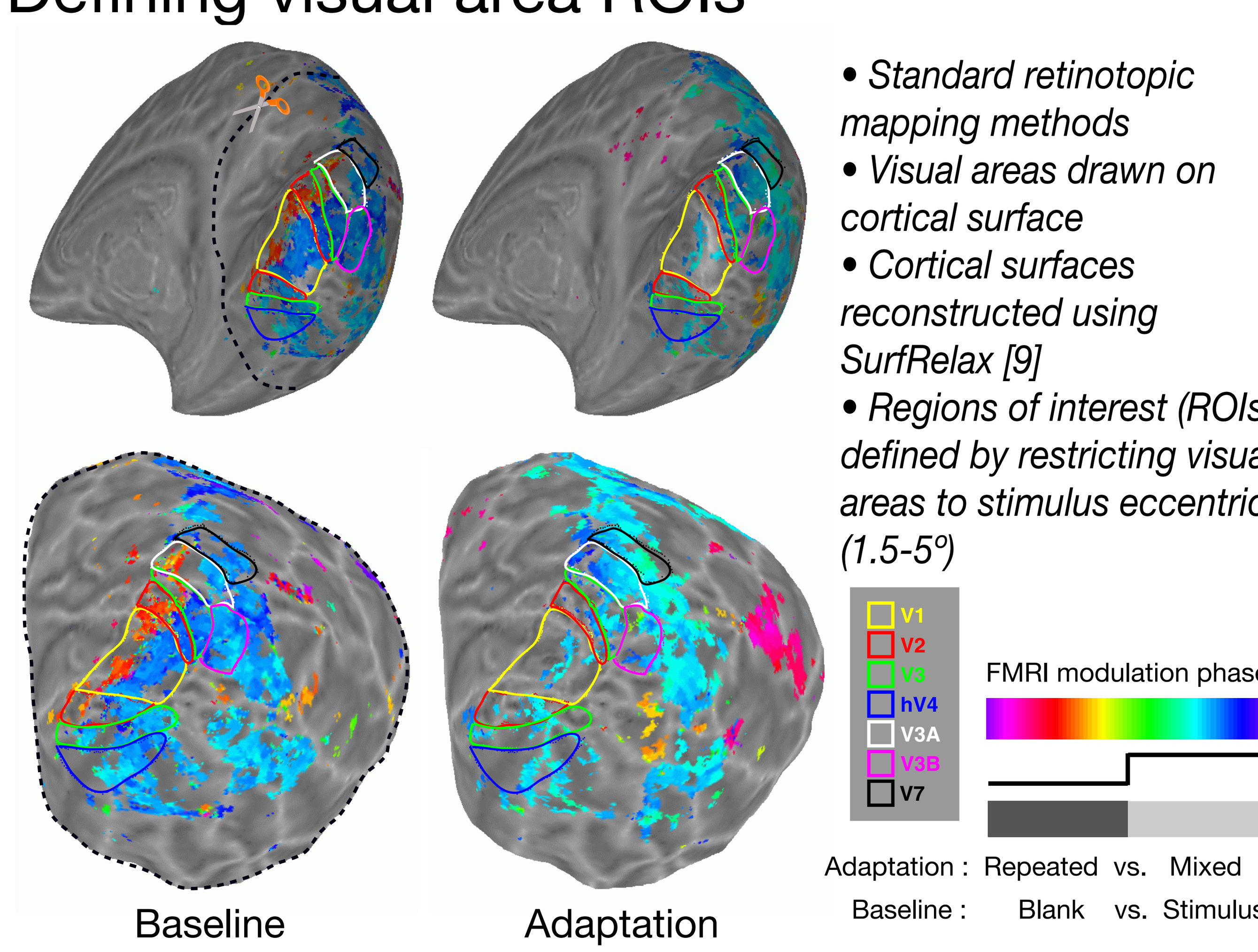
### Data analysis




• *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*

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

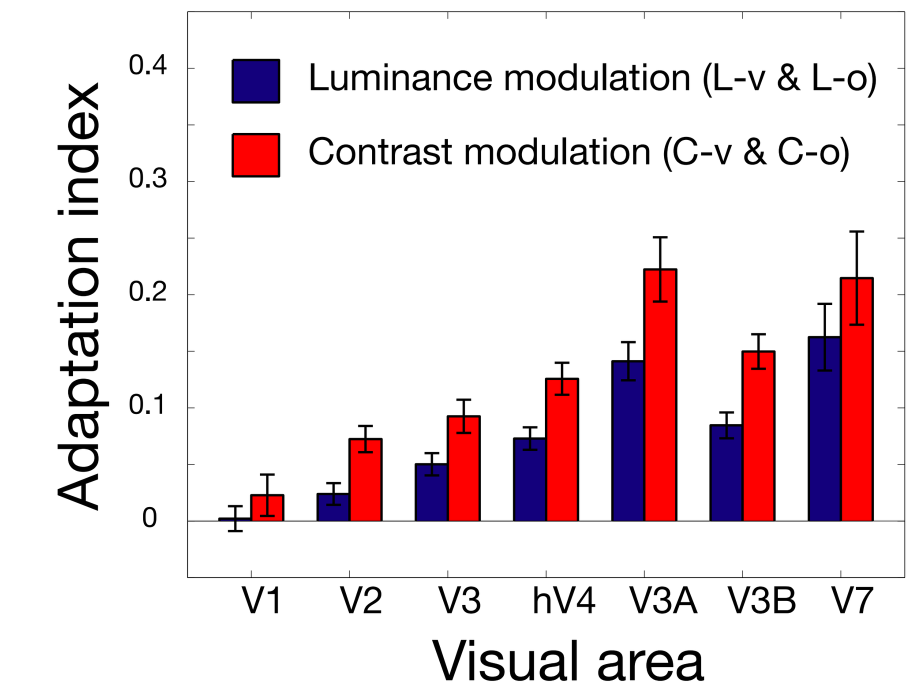
### Defining visual area ROIs



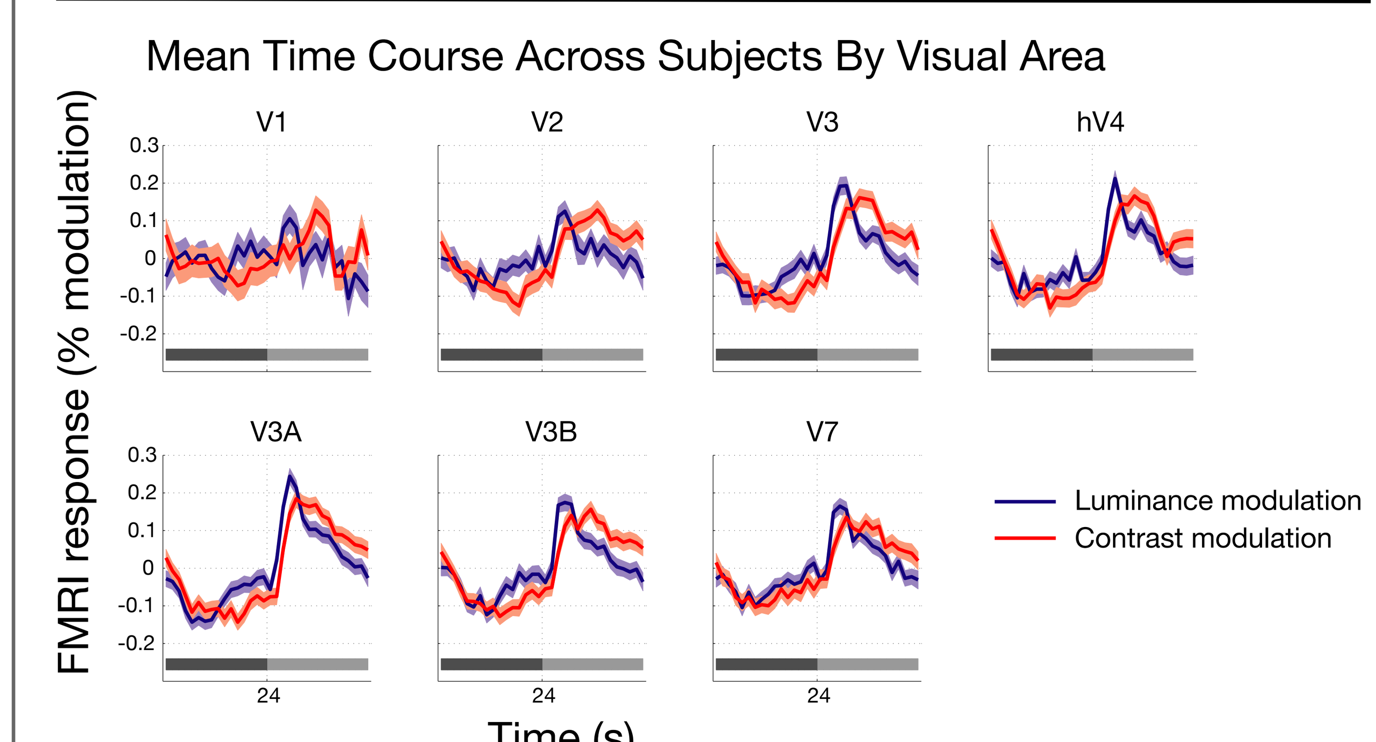

• *Standard retinotopic mapping methods*
• *Visual areas drawn on cortical surface*
• *Cortical surfaces reconstructed using SurfRelax [9]*
• *Regions of interest (ROIs) defined by restricting visual areas to stimulus eccentricity (1.5-5º)*

## Results across subjects

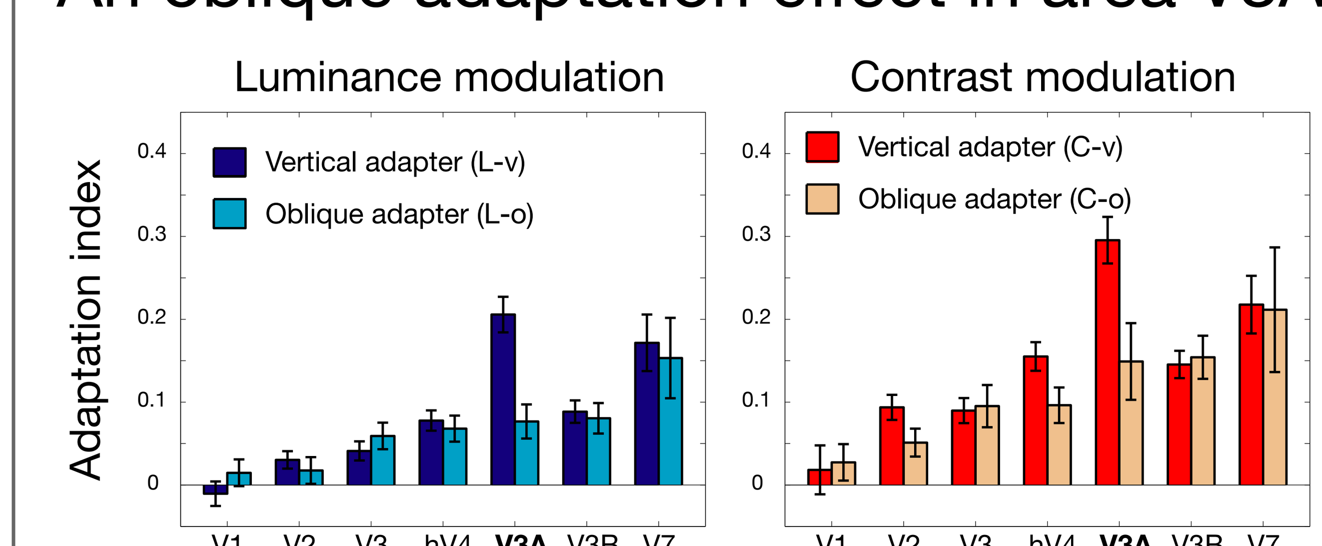
### Orientation-selective adaptation increases with level in cortical hierarchy




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

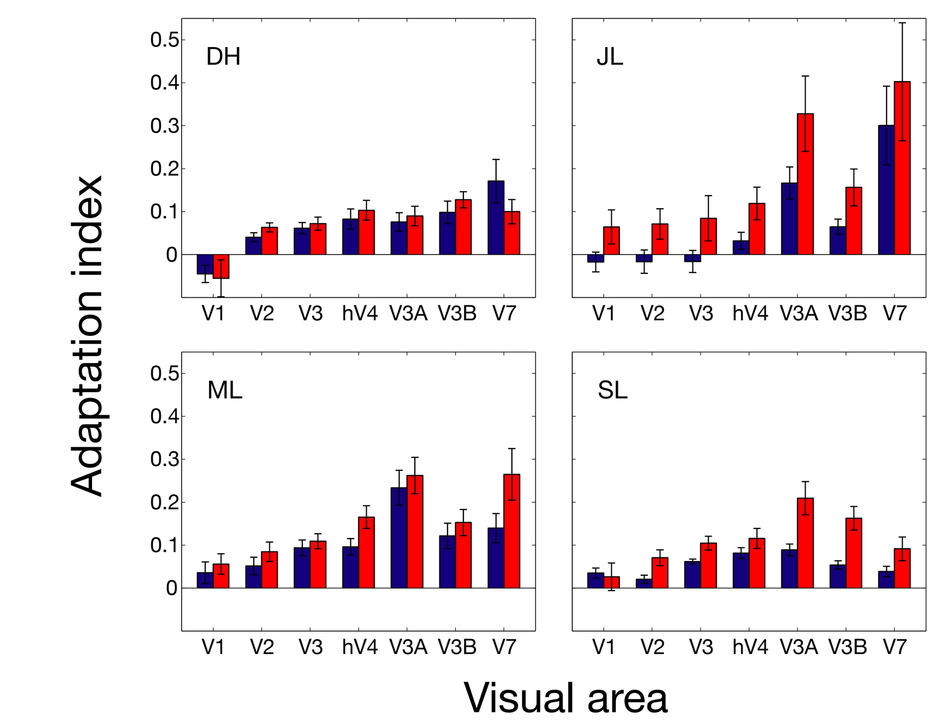



### An oblique adaptation effect in area V3A




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

## Results by subject




## 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.
• Adaptation shows an oblique effect in area V3A.

### Methods: details

***Psychophysics***
• *Orientation discrimination task: judge whether L or C test grating rotated clockwise or counter-clockwise of vertical/horizontal*
• *Adaptation grating shown for 4 s before each trial; adapter orientation 7º counter-clockwise of vertical or horizontal; pre-adaptation for 100 s at start of each session*
• *Test grating orientation ~horizontal on 50% of trials, ~vertical on remaining 50%*
• *8 conditions: horizontal or vertical adapter orientation; L or C adapter; L or C test grating; only a single adapter type per test session/day; 200 trials/condition (5 blocks, 40 trials/block)*
• *Psychometric function fit by bootstrap [10]; estimate perceived tilt as 50%-point on the psychometric function*
***FMRI***
• *2AFC spatial frequency discrimination task every TR (1.5 s); each grating shown for 350 ms separated by 50 ms blank screen; task difficulty kept constant by staircase to control attention*
• *Same stimuli as psychophysics; 4 orientations (0º, 45º, 90º, 135º); 13 spatial frequencies*
• *Single orientation in adaptation block (vertical: 90º or oblique: 45º); 3 remaining orientations in non-adaptation block*
• *Each scan comprised 1 adaptation block (discarded) followed by 6 adaptation/non-adaptation blocks in alternation; 16 volumes per block (208 volumes per scan); total duration 312 s*
• *Baseline condition: randomly alternating orientations versus blank; same block alternation as adaptation scans*
• *8 adaptation+2 baseline scans/session for each subject, condition, and adaptation orientation (4x2x2=16 sessions)*
• *BOLD EPI, Siemens Allegra 3T; TR: 1.5 s; TE: 30 ms; flip angle: 75º; voxel size: 3x3x3 mm; 24 slices perpendicular to calcarine sulcus*

### Acknowledgments

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