BOLD signal dependence on blood flow and metabolism

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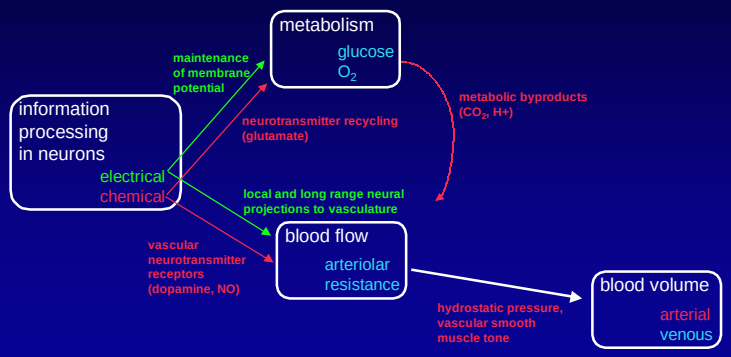
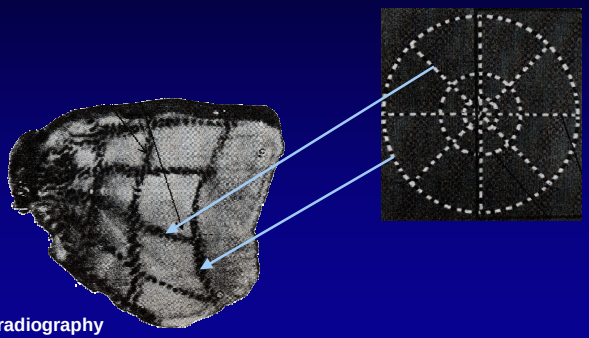
Outline

- physiological events accompanying neuronal activation
- factors affecting BOLD signal sensitivity
- BOLD response dynamics

Physiological Events Accompanying Neuronal Activation



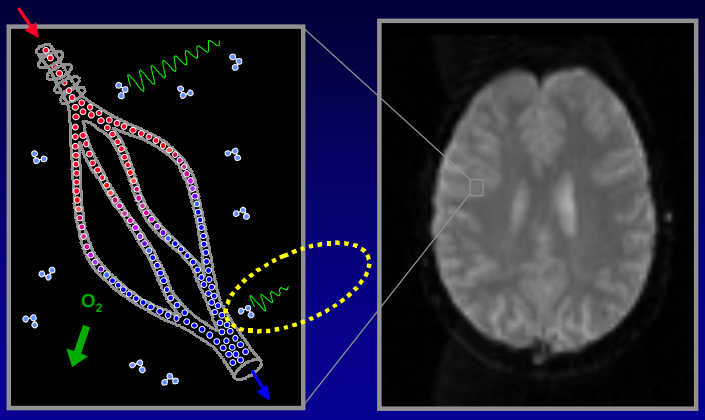
Stimulus-driven glucose uptake:



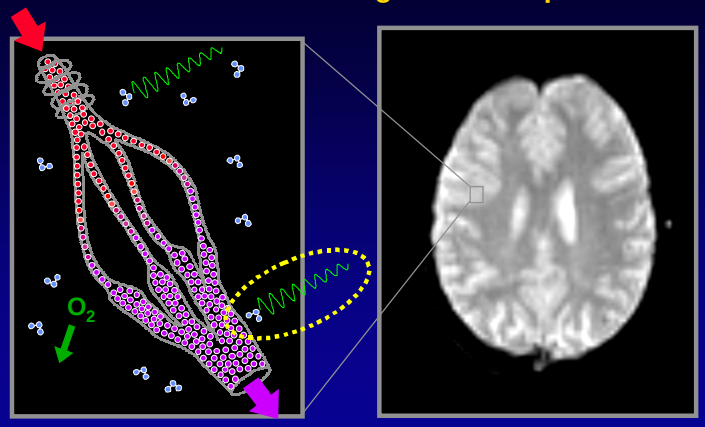
2DG autoradiography during visual stim. in monkey

tootell *et al*. 1988

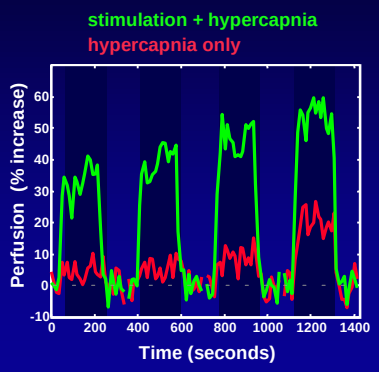
Deoxygenated blood attenuates T_2^*-weighted MR images

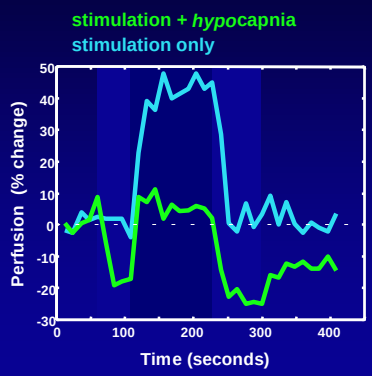


decrease of venous dHb during increased perfusion:



Cerebral blood flow is affected by both systemic and focal influences:





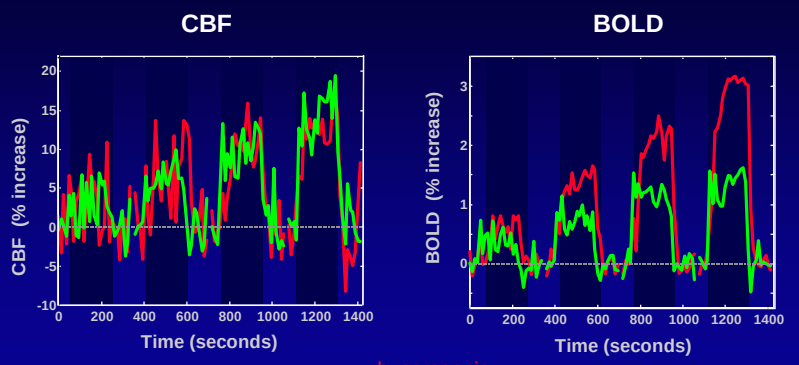
Outline

- physiological events accompanying neuronal activation
- **factors affecting BOLD signal sensitivity**
- BOLD response dynamics

Factors affecting BOLD signal

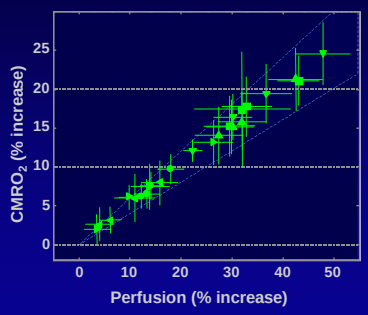
- physiology
  - blood flow, metabolism, blood volume
- equipment
  - magnetic field value
- pulse sequence
  - gradient-echo vs. spin-echo
  - echo time
  - resolution

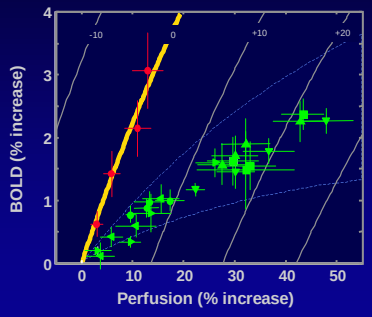
Oxidative metabolism attenuates the BOLD signal:



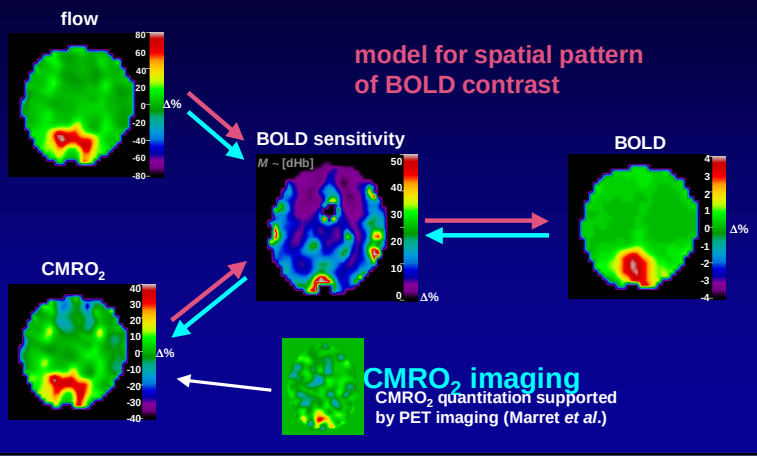
N=12

CBF-CMRO$_2$ coupling determines the BOLD signal during activation:

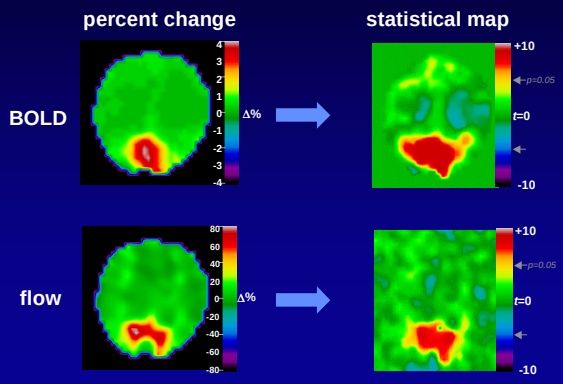




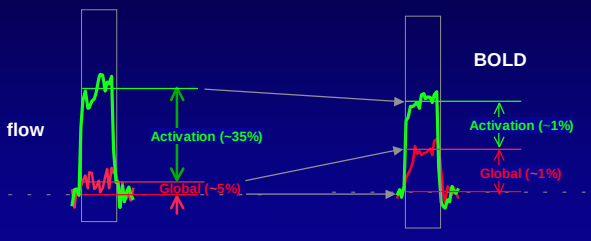
Spatial patterns of BOLD, flow, and metabolism:



Images of Δ%BOLD show different spatial patterns than BOLD statistical maps:

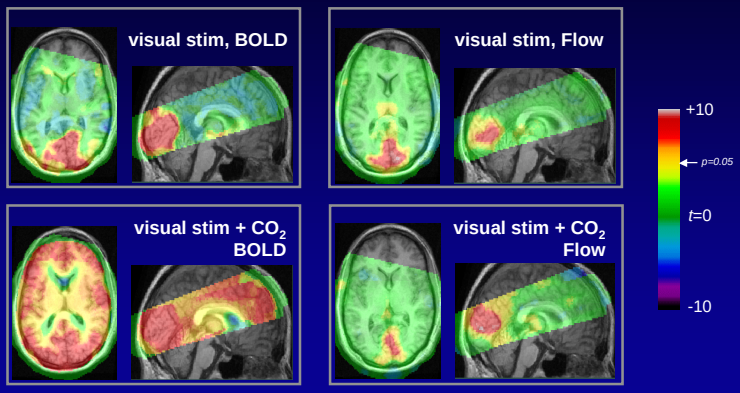


Systemic vasoactive effects (respiratory, drug) are amplified in BOLD imaging:



- due to lack of metabolic signal attenuation during systemically driven flow increases

If there are *stimulus-correlated systemic effects*, flow contrast will provide much higher specificity than BOLD



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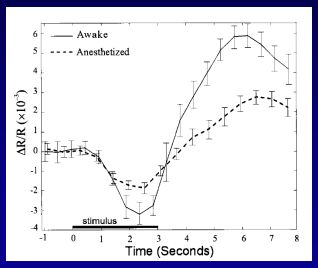
- factors affecting BOLD signal sensitivity
- **BOLD response dynamics**

Temporal Response Waveforms

- initial dip
- overshoot and undershoot
- delayed CBV effects
- stimulus-dependent response waveforms

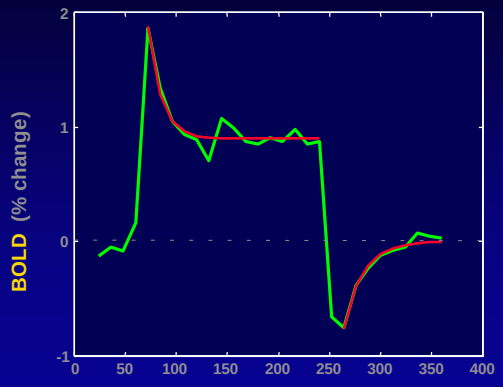
Initial deoxyhemoglobin surge (fMRI initial dip)



Shtoyerman, Grinvald *et al*.

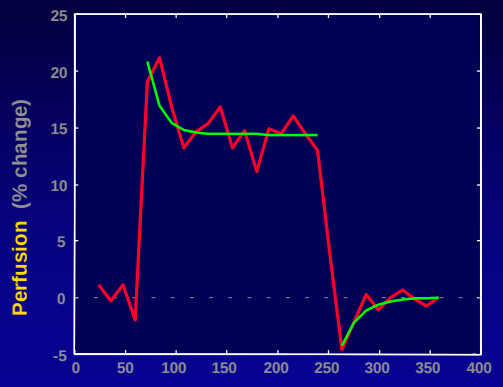
- attributed to early metabolic response
- appears to be highly spatially localized
- may be idiosyncrasy associated with specific visual input and/or anesthetic state

BOLD overshoot in V1:



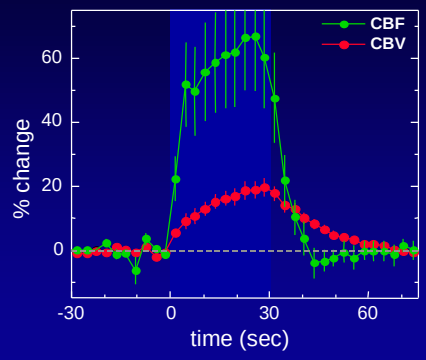
48 signal averages

Perfusion overshoot in V1:



48 signal averages

Slow-onset CBV response
(rat forepaw stimulation)

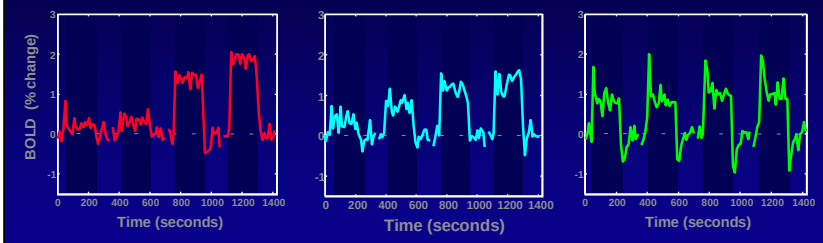


Mandeville *et al*.
MRM 1999

BOLD response waveforms for different stimuli at graded contrast levels:

N=12

- not all patterns produced BOLD overshoot
- contrast-sensitivity markedly different

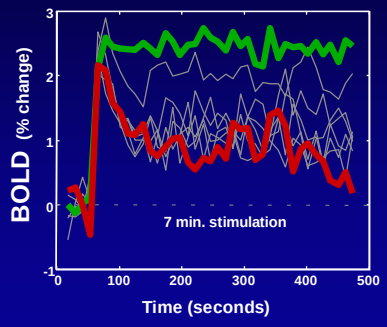


no overshoot

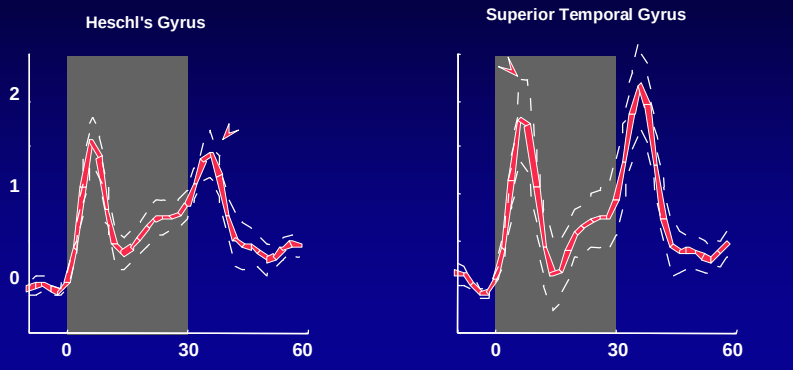
no overshoot

overshoot

Frequency-dependent step responses in V1



Response waveforms in auditory areas during high-frequency noise bursts



courtesy of Mike Harms

Practical Questions

- what does BOLD signal mean, in physiological terms?
- what factors affect BOLD sensitivity to hemodynamic changes?
- how can I compare BOLD responses
  - within regions (different conditions)
  - across regions

More practical Questions…

- how do temporal response waveforms relate to underlying neurophysiology?
- what features of the BOLD response are *general*, and which are *idiosyncratic*?
  - dips, over/undershoots, offset responses…
- what factors affect the *specificity* of BOLD contrast as a marker for neuronal activation?
  - gross regional specificity, high spatial resolution