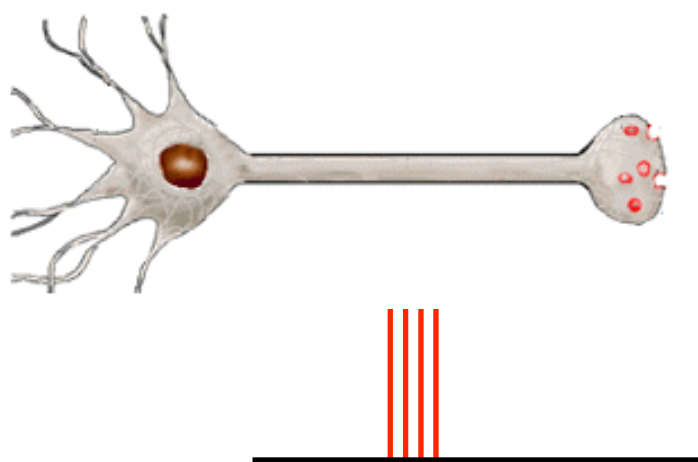
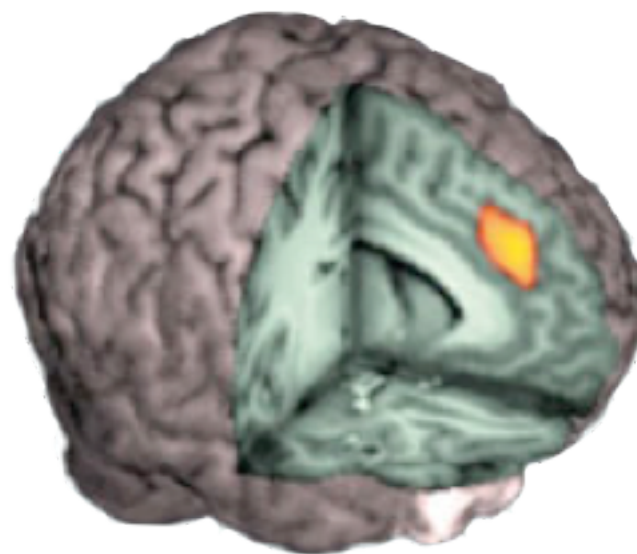
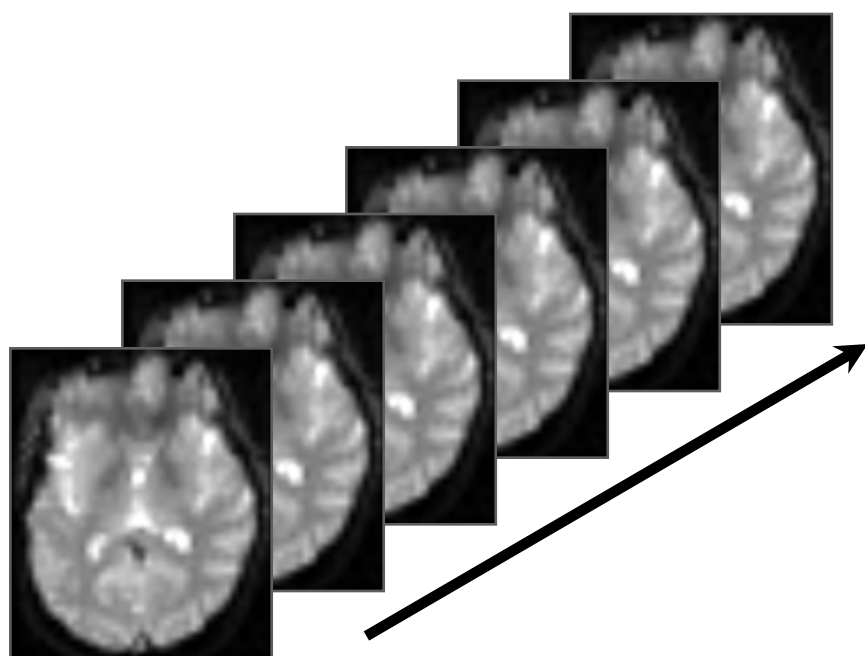


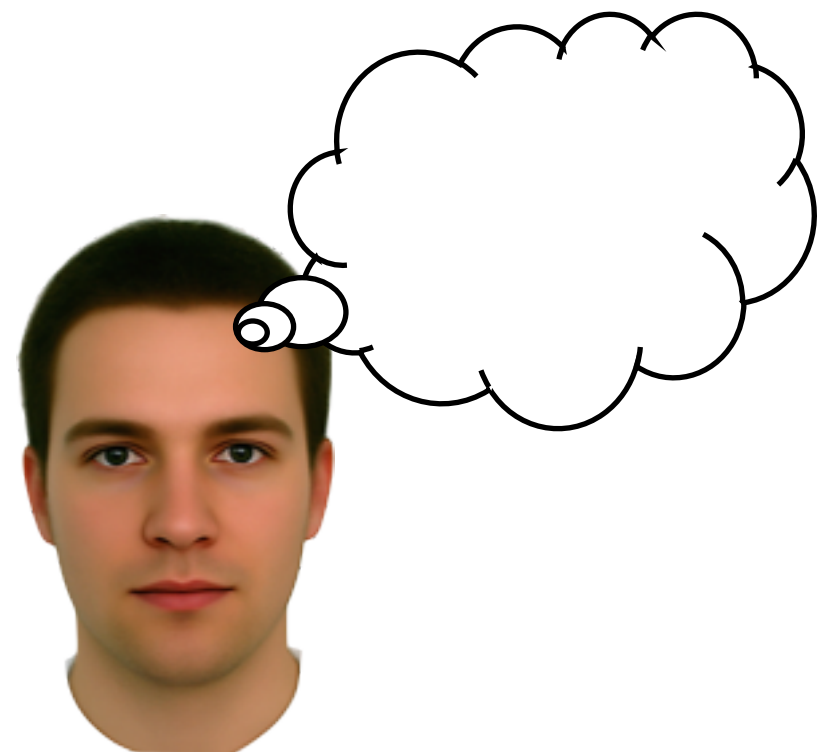
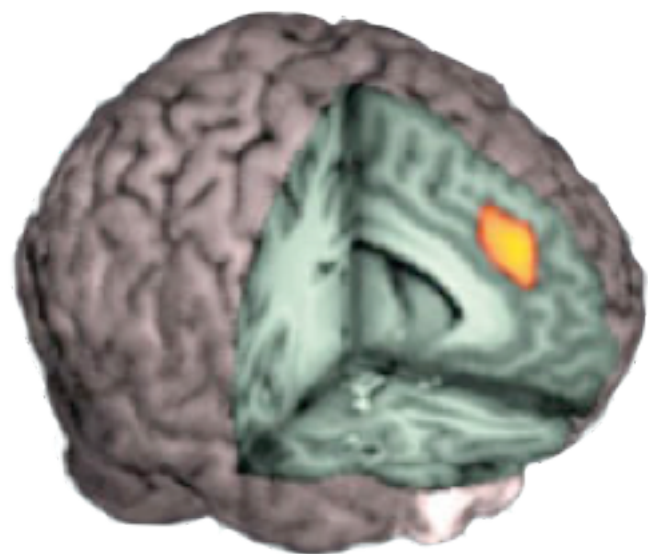
fMRI 101 – Part 2

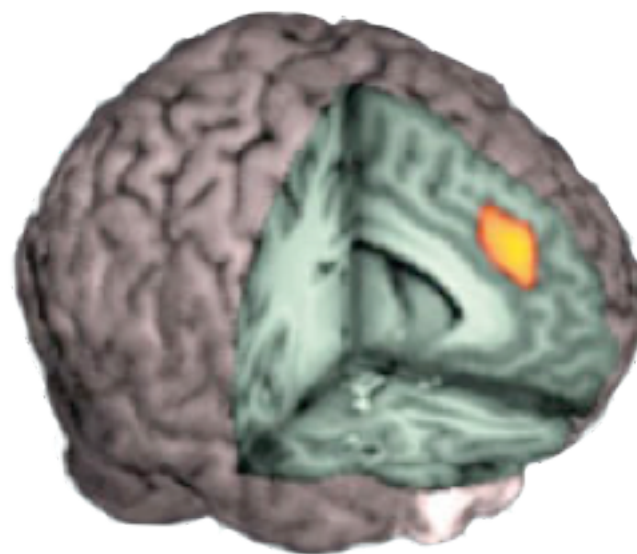
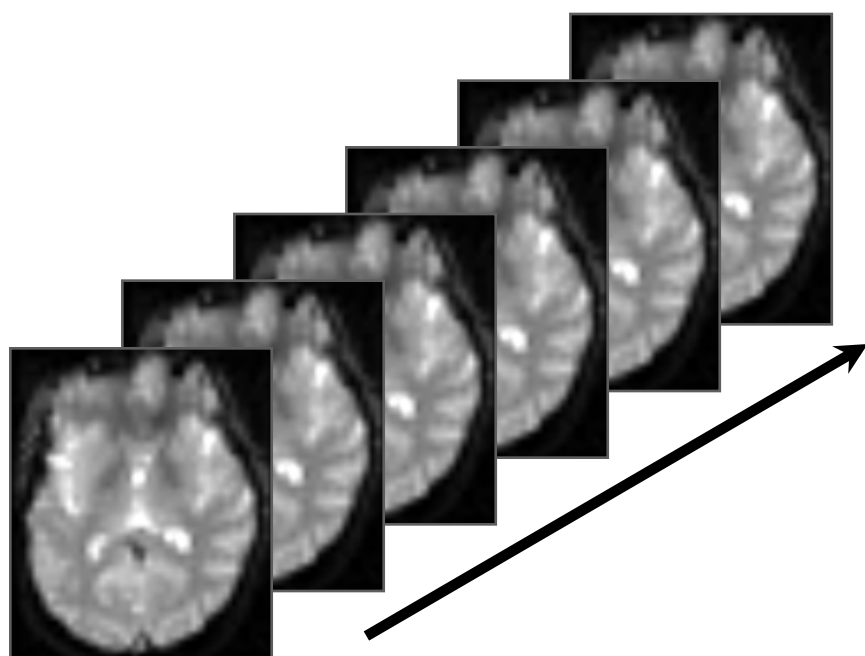
Geoffrey K Aguirre, MD, PhD







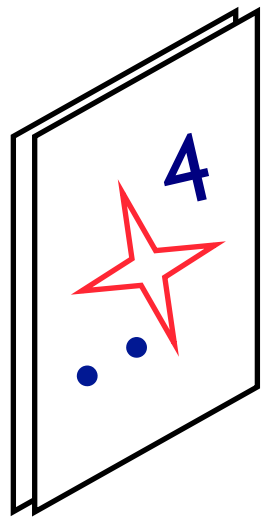




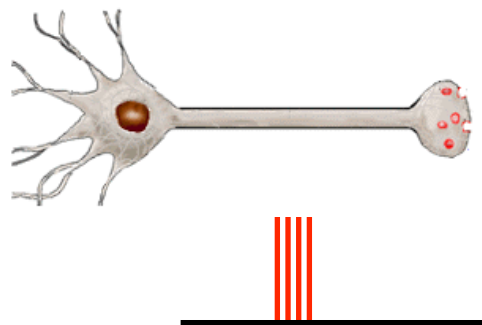
The “two systems” model

cognition /
consciousness

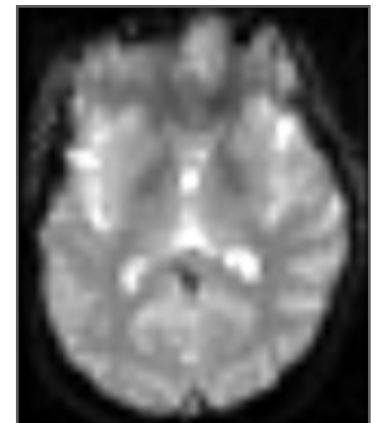
physics /
physiology

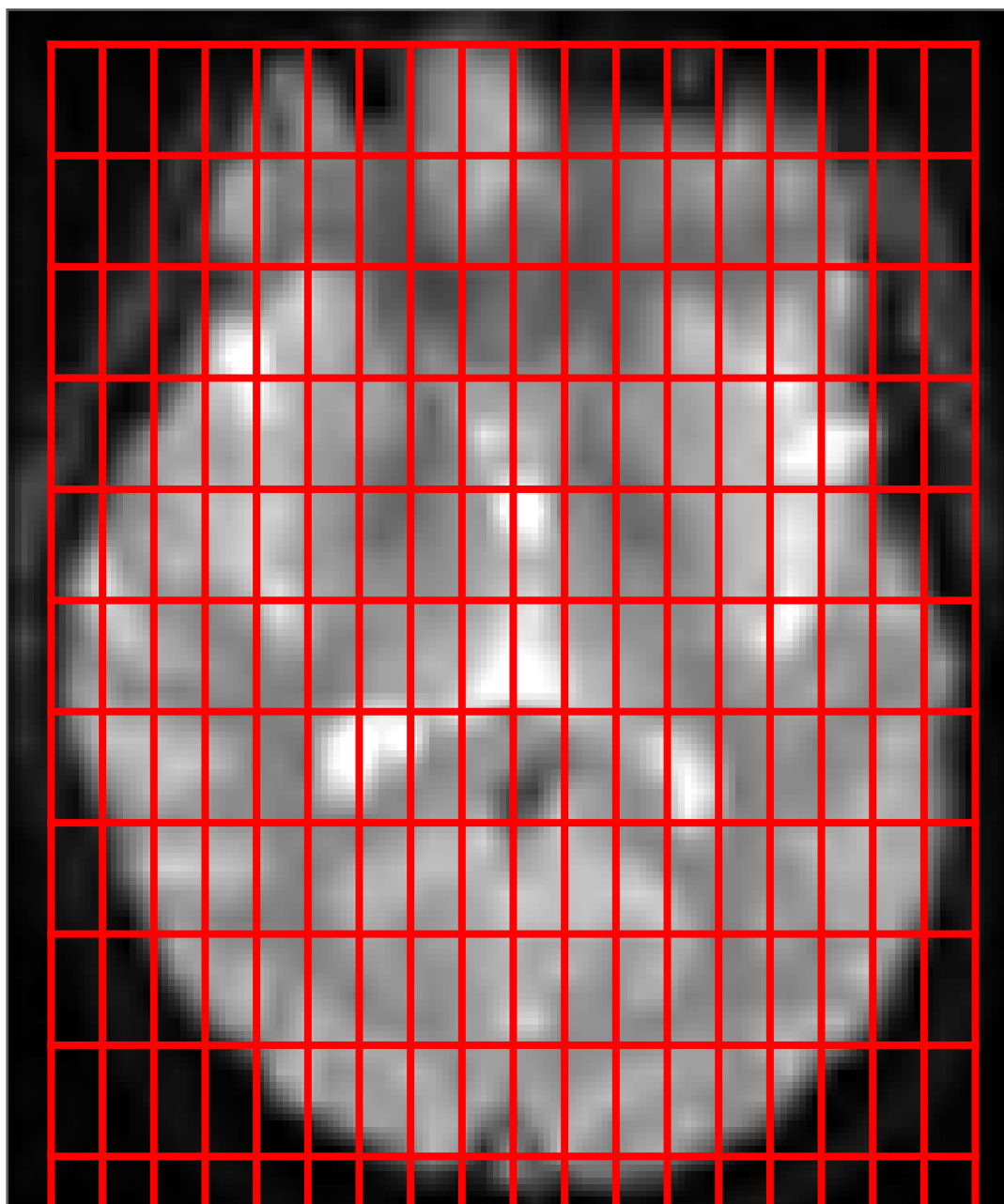


system #1



system #2

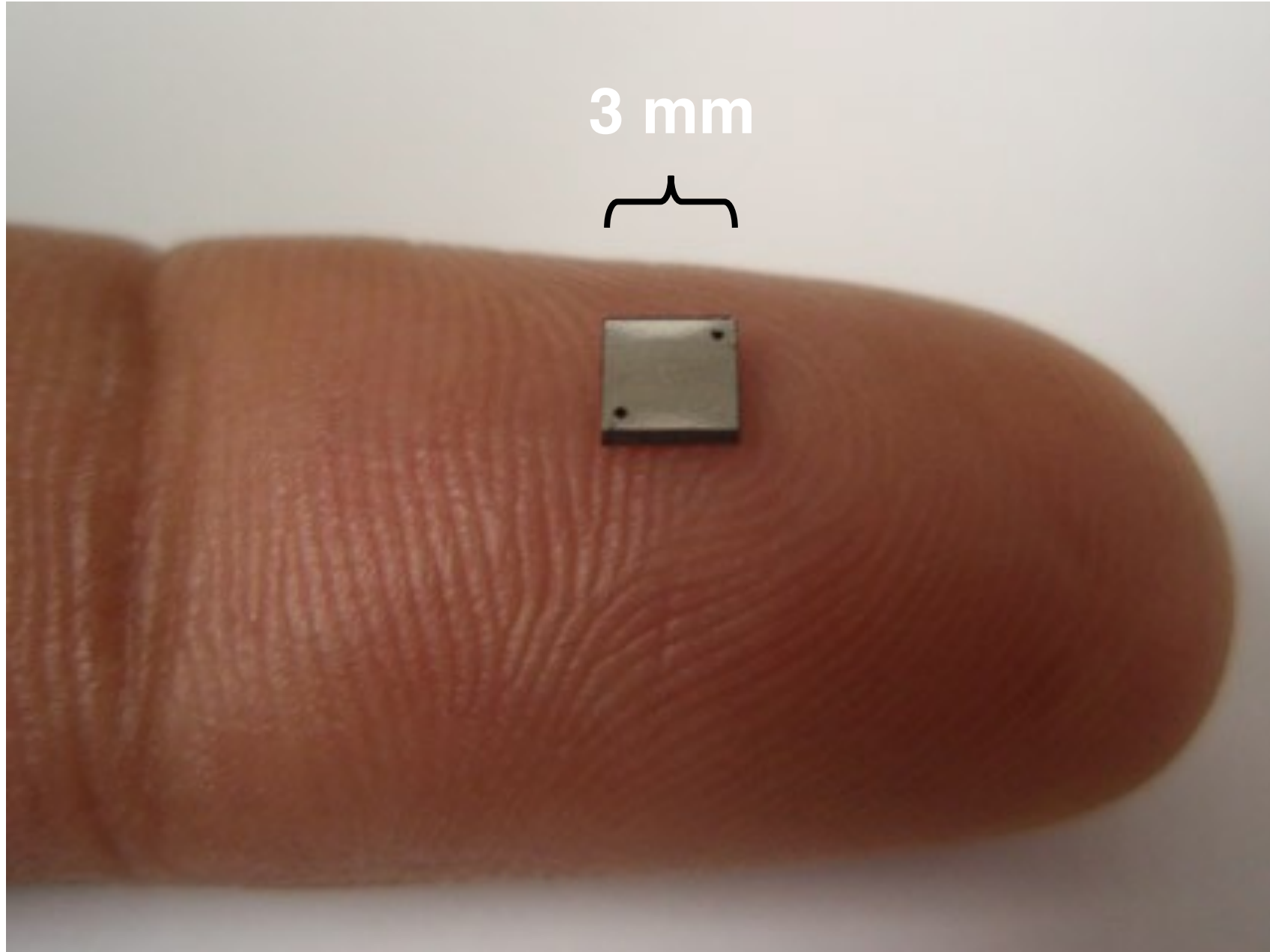
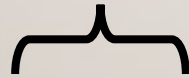


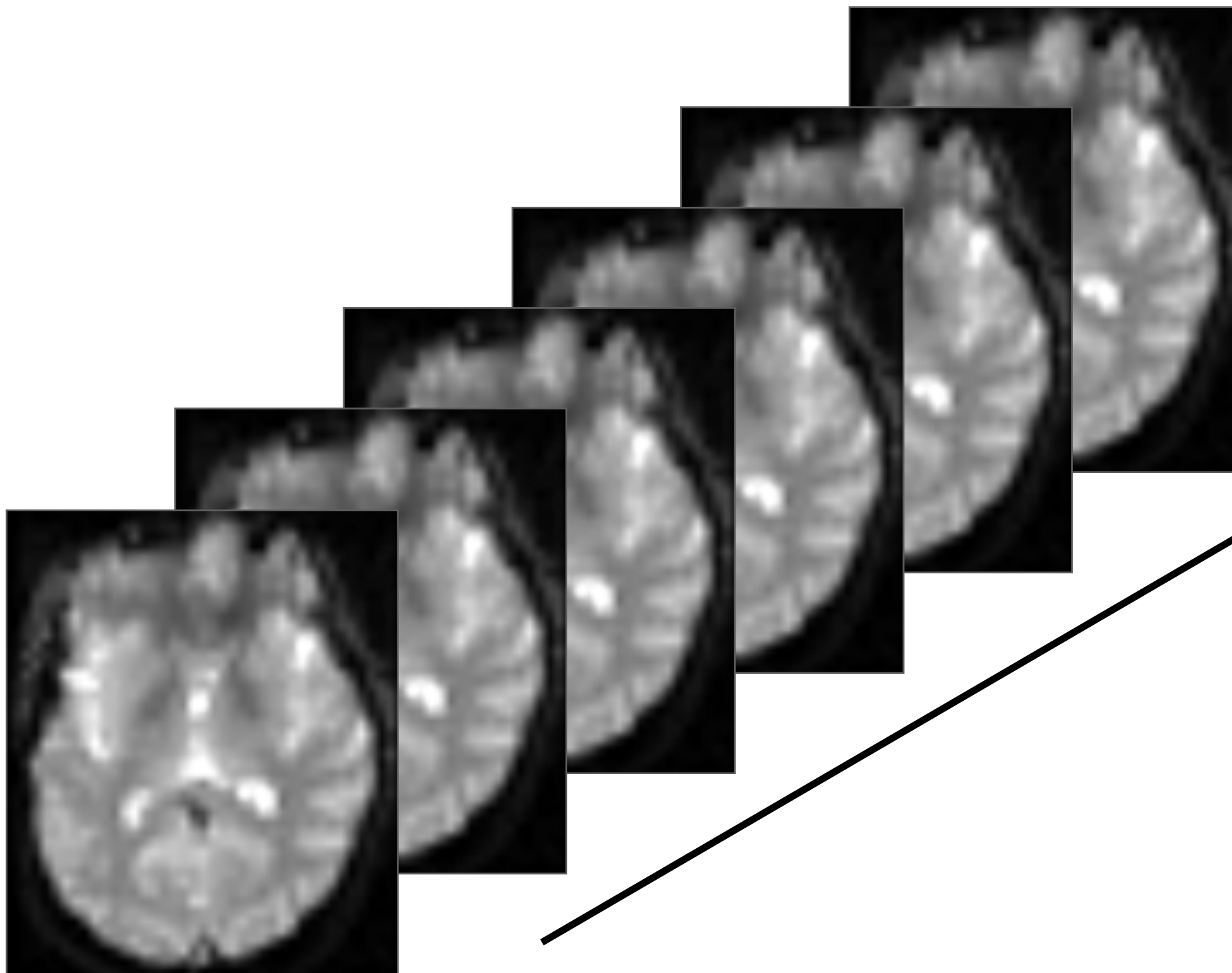


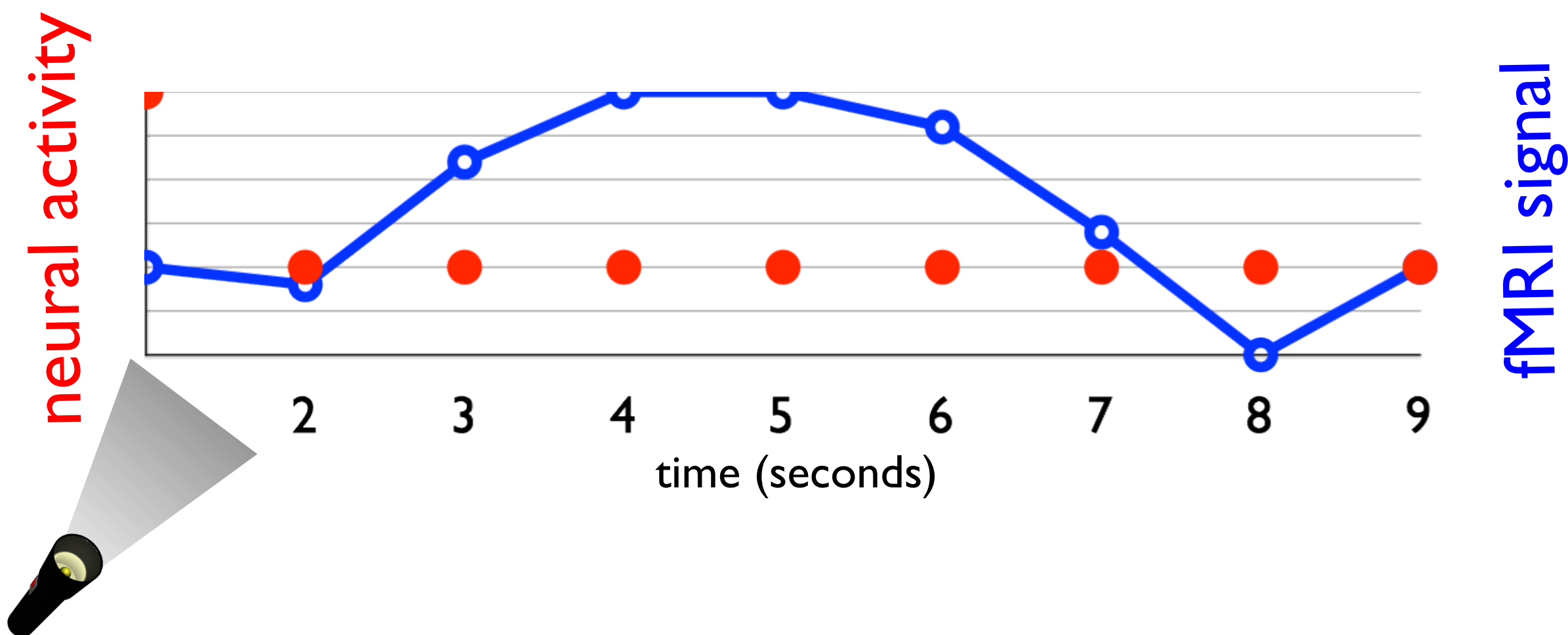
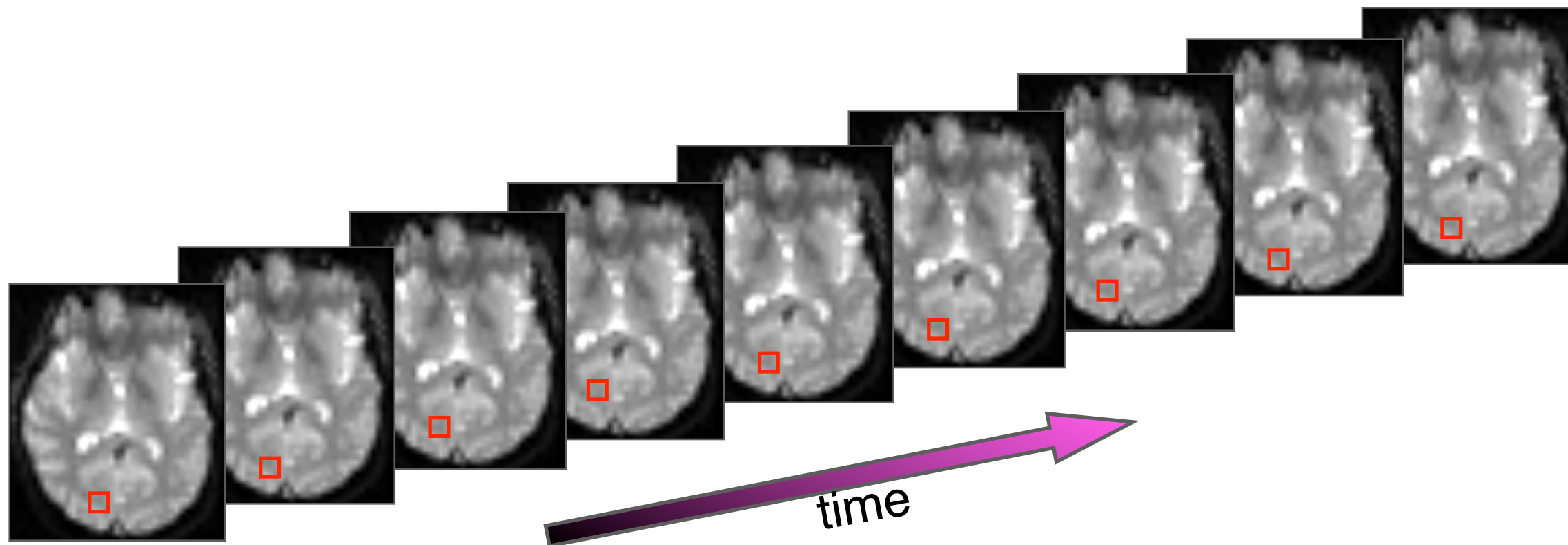
INDEX

RECOMMENDATIONS

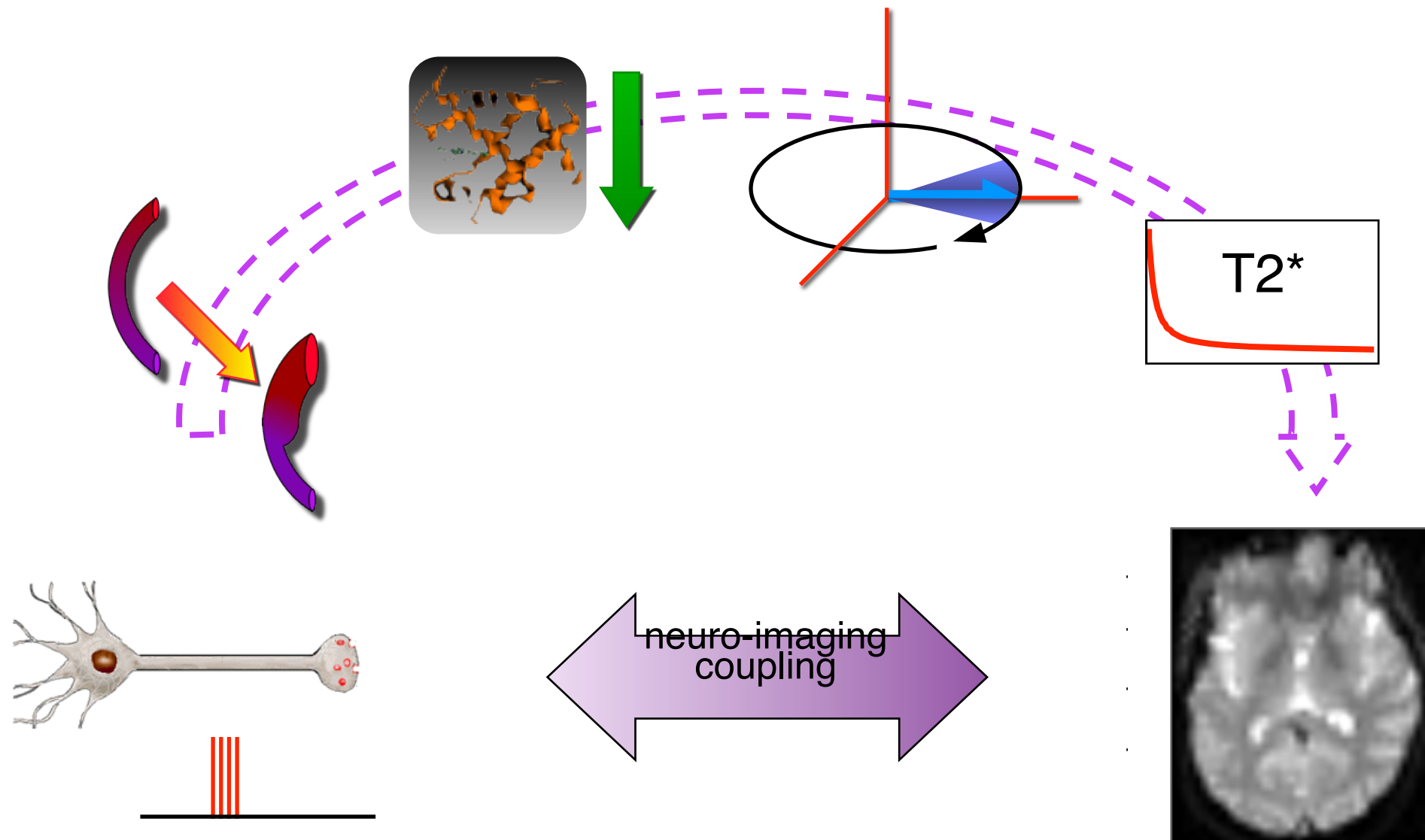
3 mm



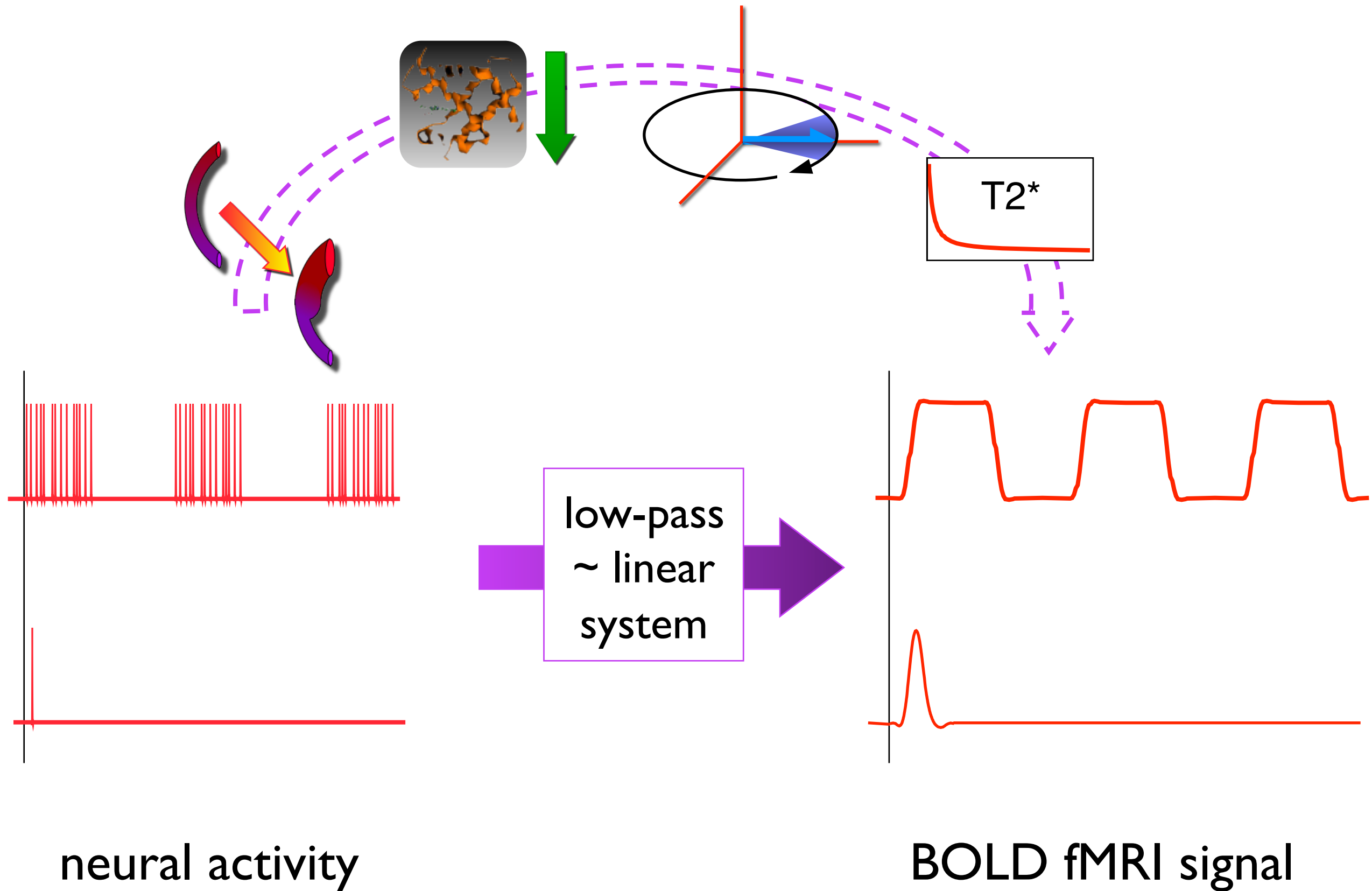




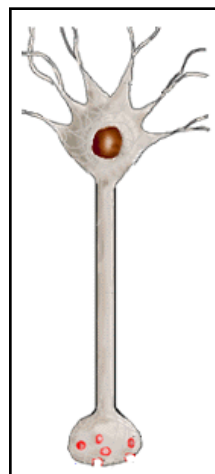
A hemodynamic proxy of neural activity



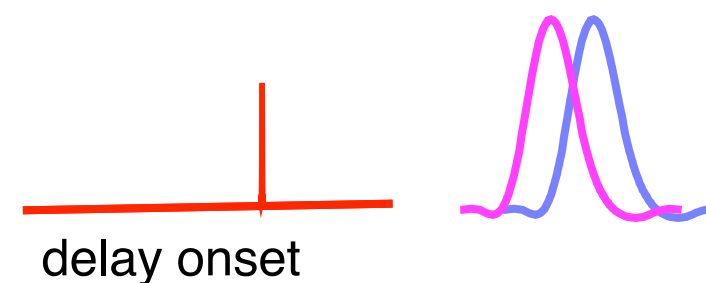
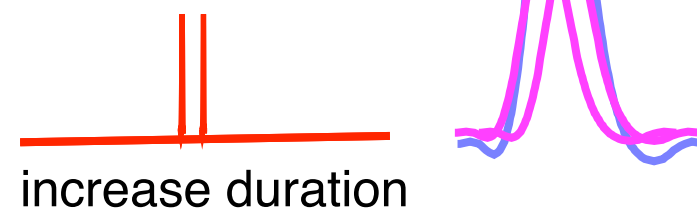
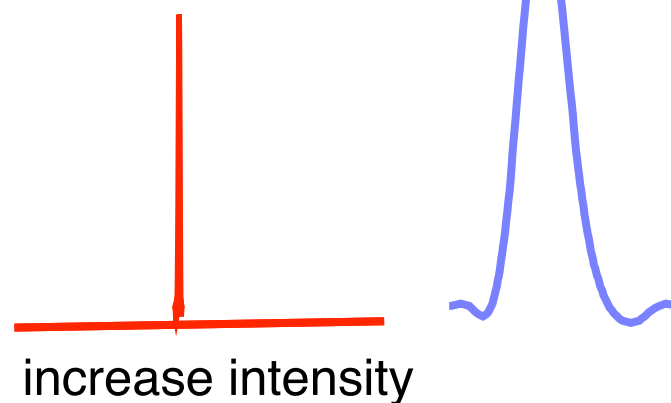
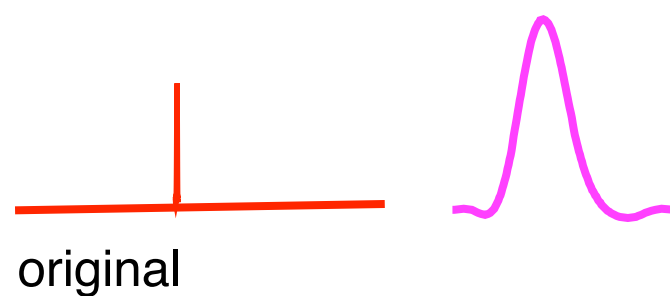
A nearly linear system



The BOLD fMRI system in time

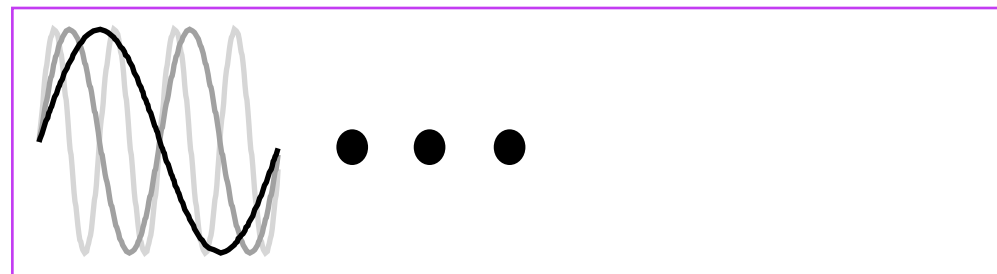
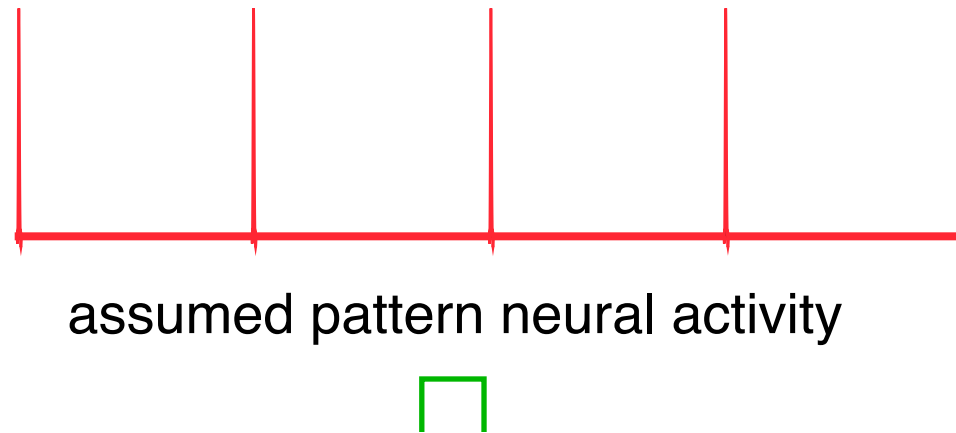


properties dominated by a
low-pass, linear system

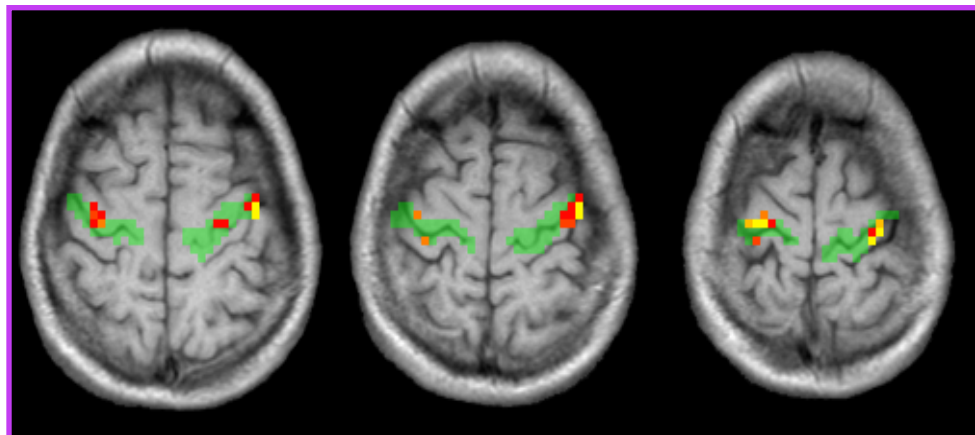
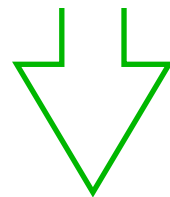


Measuring the HRF

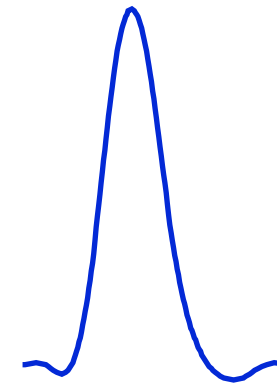
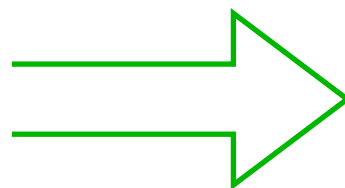
subject makes a bilateral
button press in response
to visual cue every 16
seconds



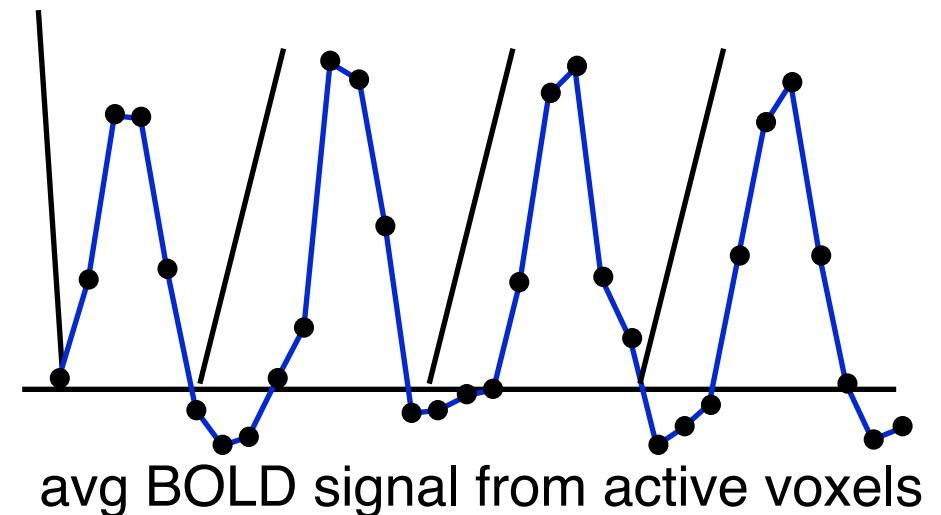
Fourier basis set analysis



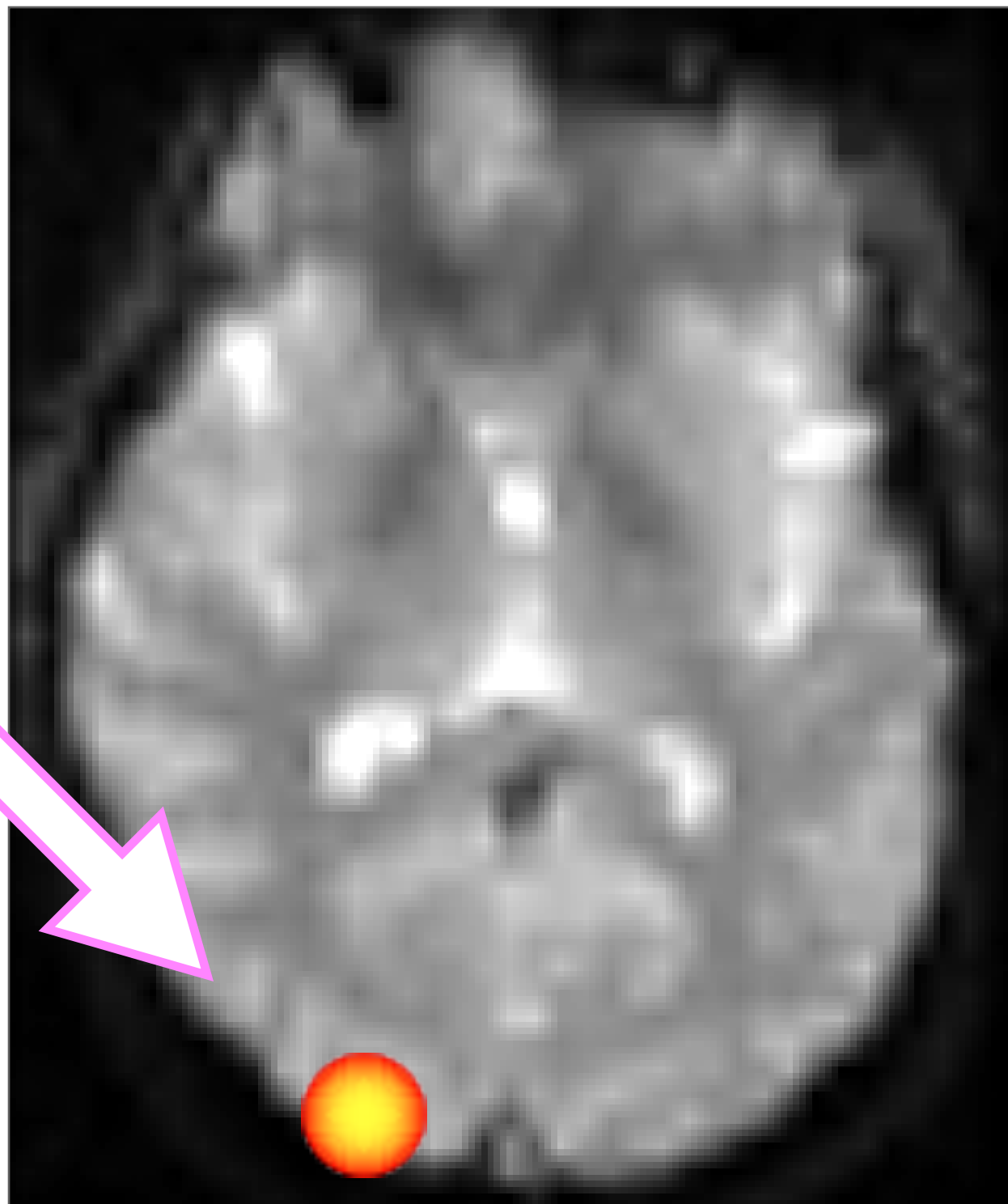
voxels with significant signal Δ
within 1° motor regions of interest



trial-averaged BOLD signal,
an estimate of the HRF



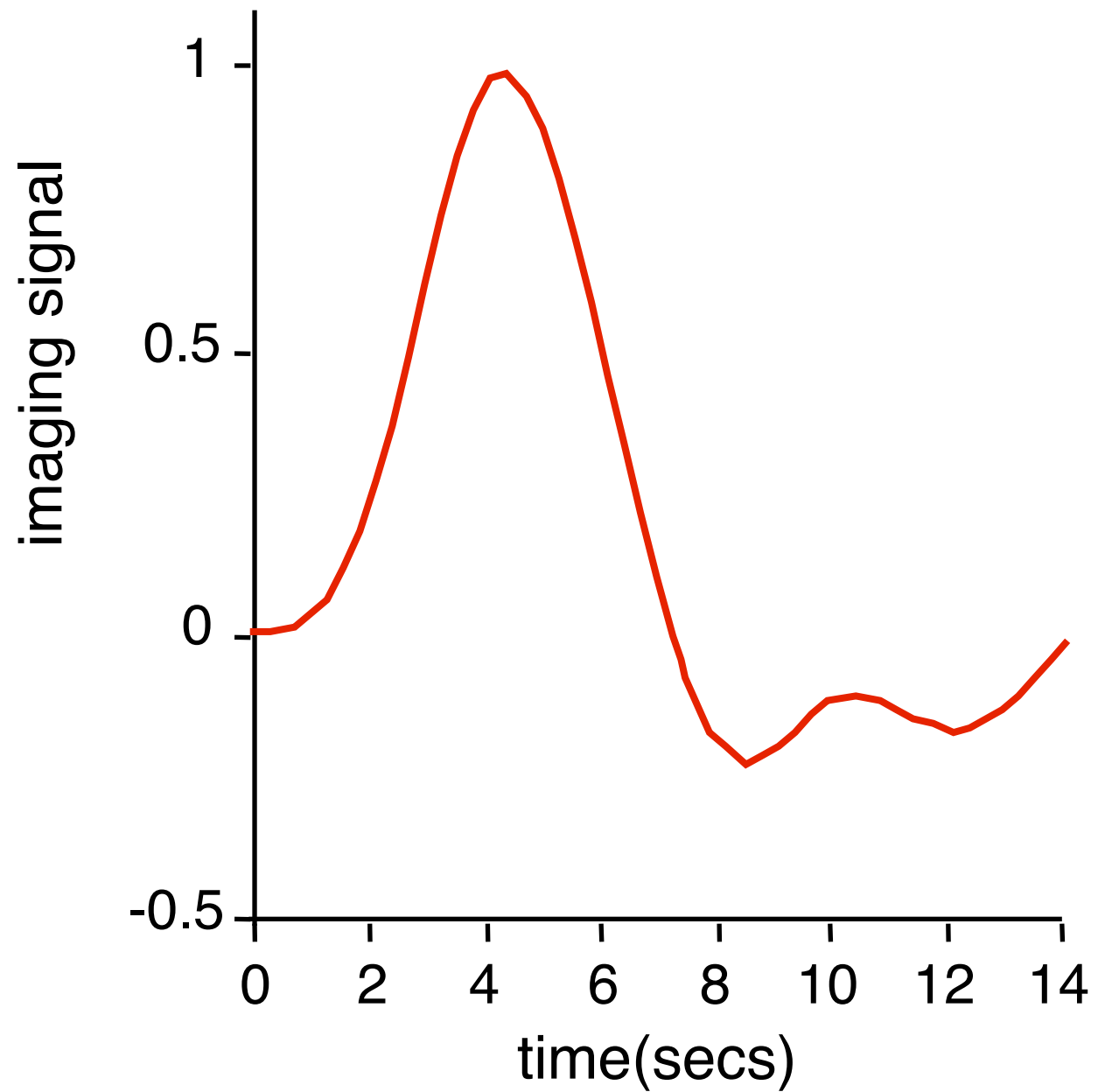
The BOLD fMRI system in space



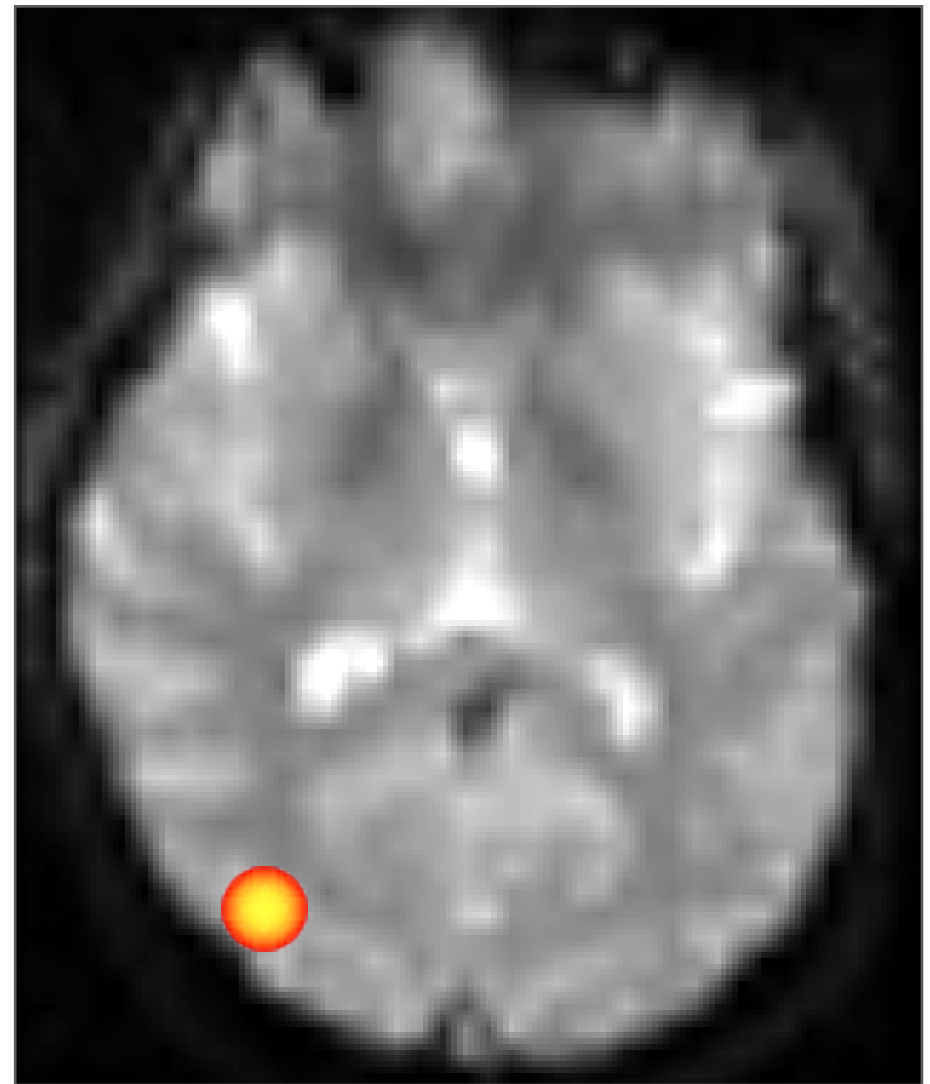
Spatial resolution of about 0.025 cm^3

In a typical $3 \times 3 \times 3 \text{ mm}$ voxel, there are $\sim 600,000$ neurons

Improved spatial resolution may be provided by perfusion imaging or sensitivity to the “initial dip”



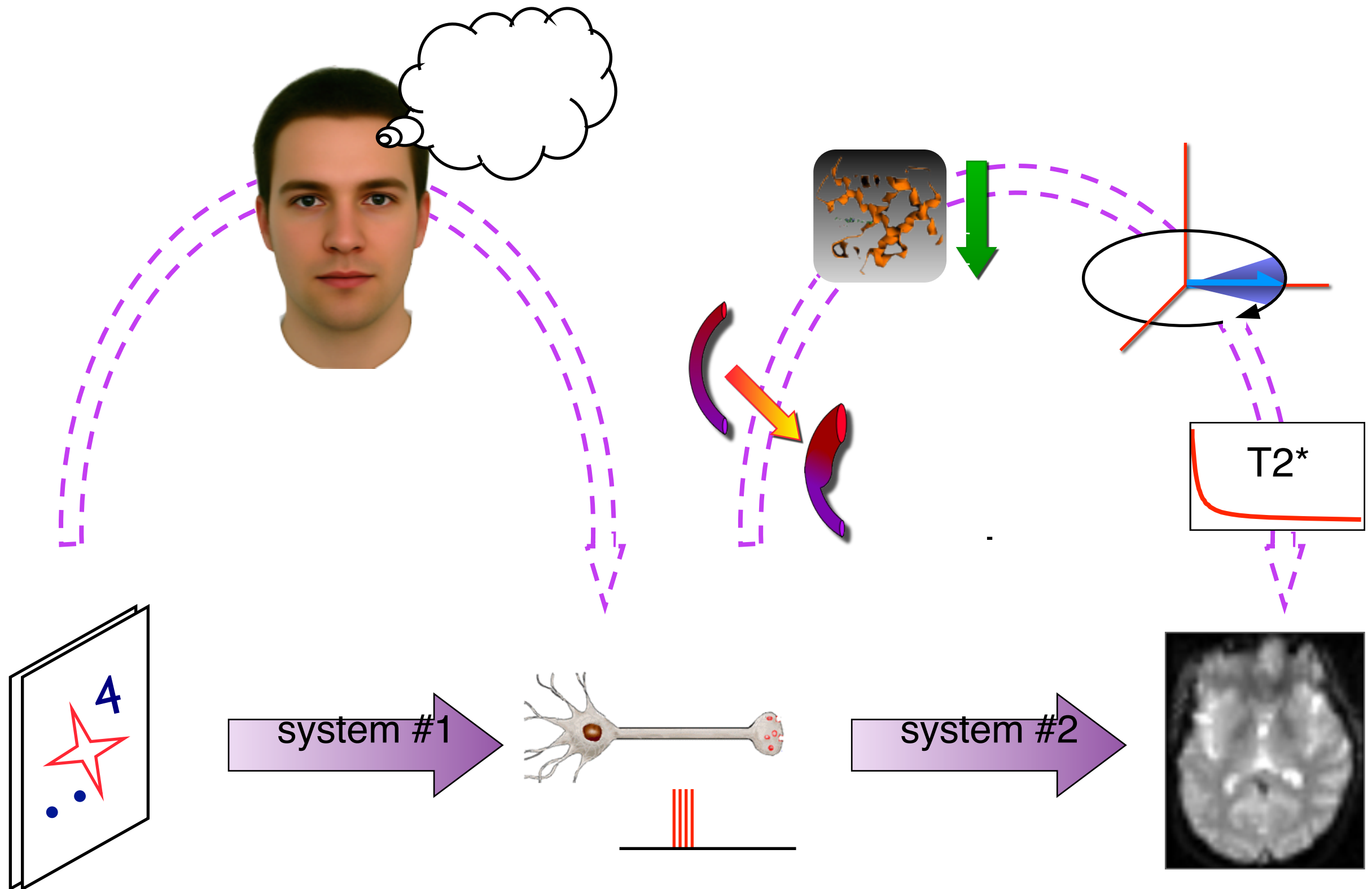
Temporal resolution of 3-4 s



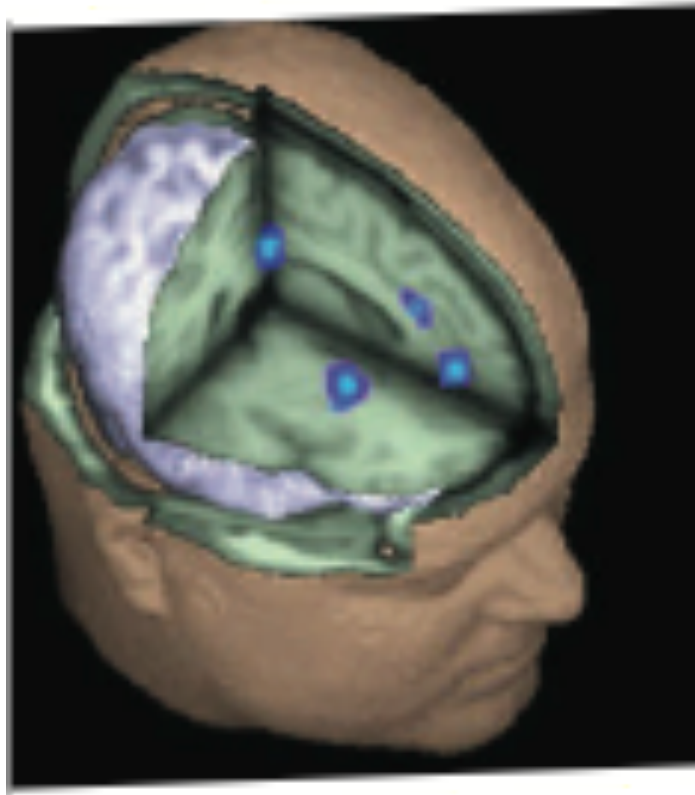
Spatial resolution of $\sim 0.025 \text{ cm}^3$
(3x3x3 mm, $\sim 600,000$ neurons)

cognition / consciousness

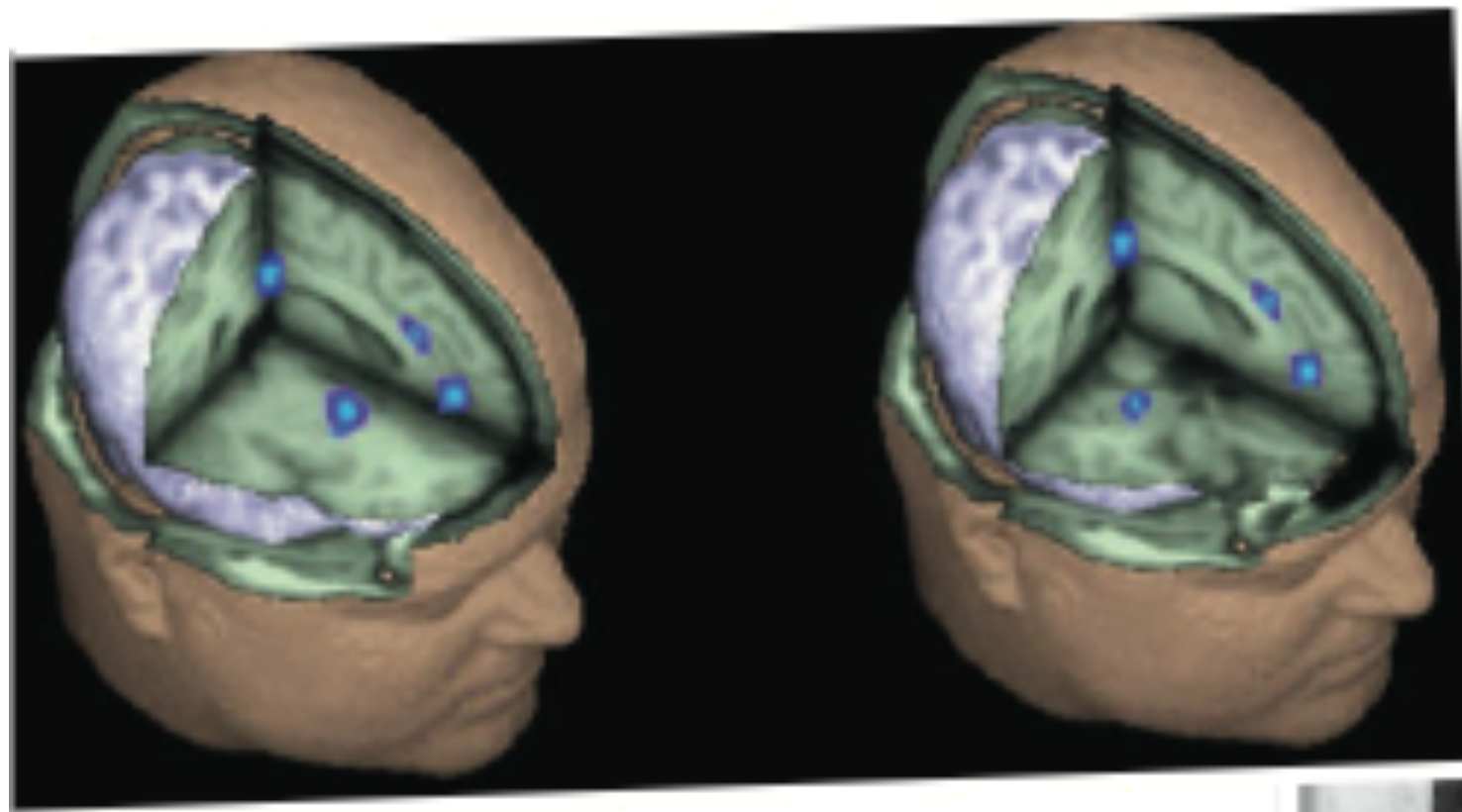
physics / physiology



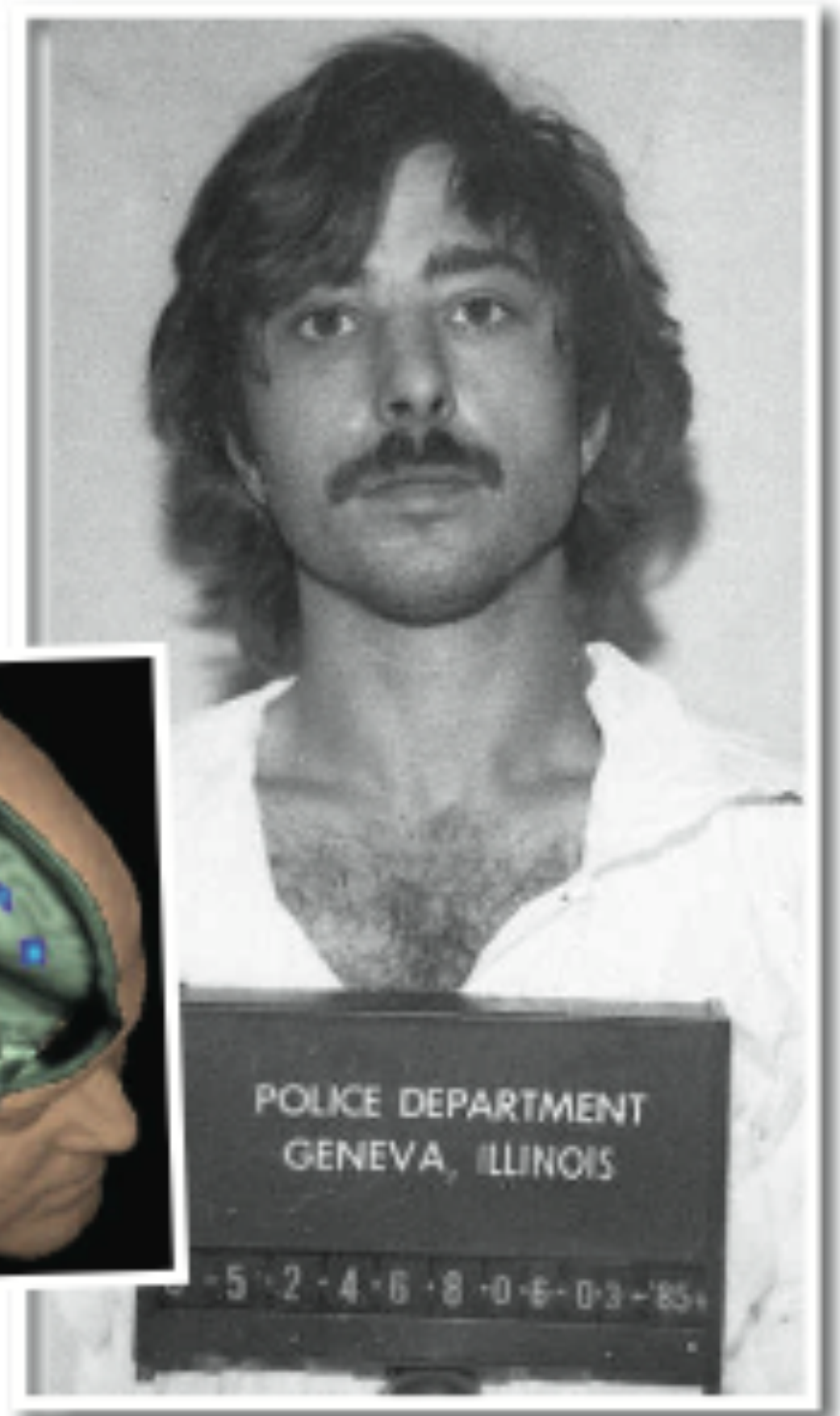
A prototypical experiment

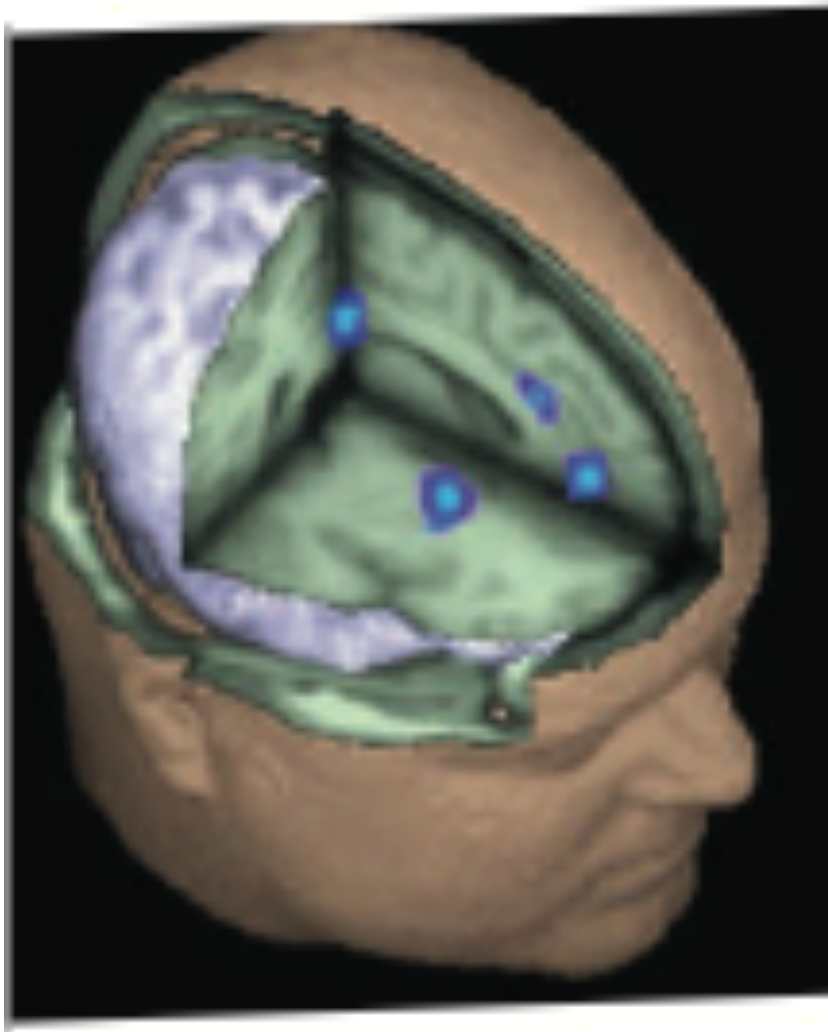


- fMRI data presented in sentencing phase of 2009 murder trial in Illinois
- Expert testified that defendant had behavioral **and** fMRI markers of psychopathy



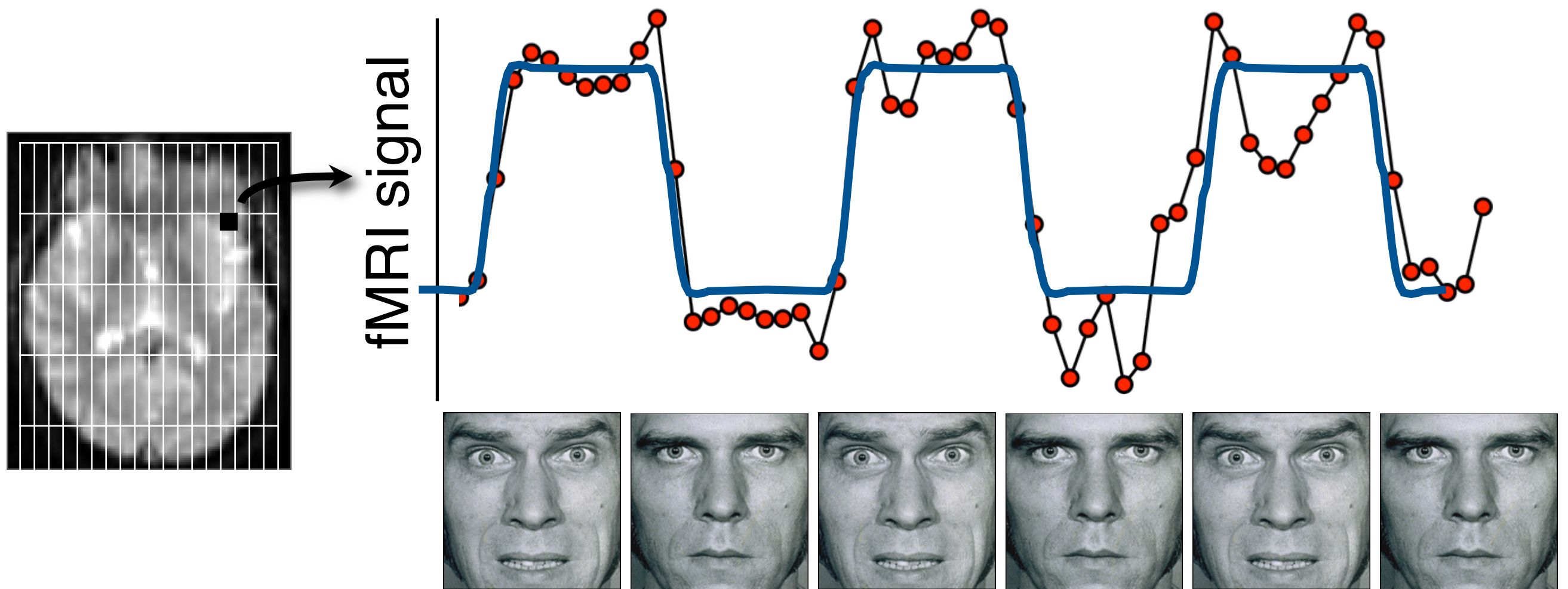
Above: criminal psychopaths show less activity than non-criminal control subjects in specific emotion-processing areas of the brain, according to Kent Kiehl's testing. Right: Brian Dugan in 1985.



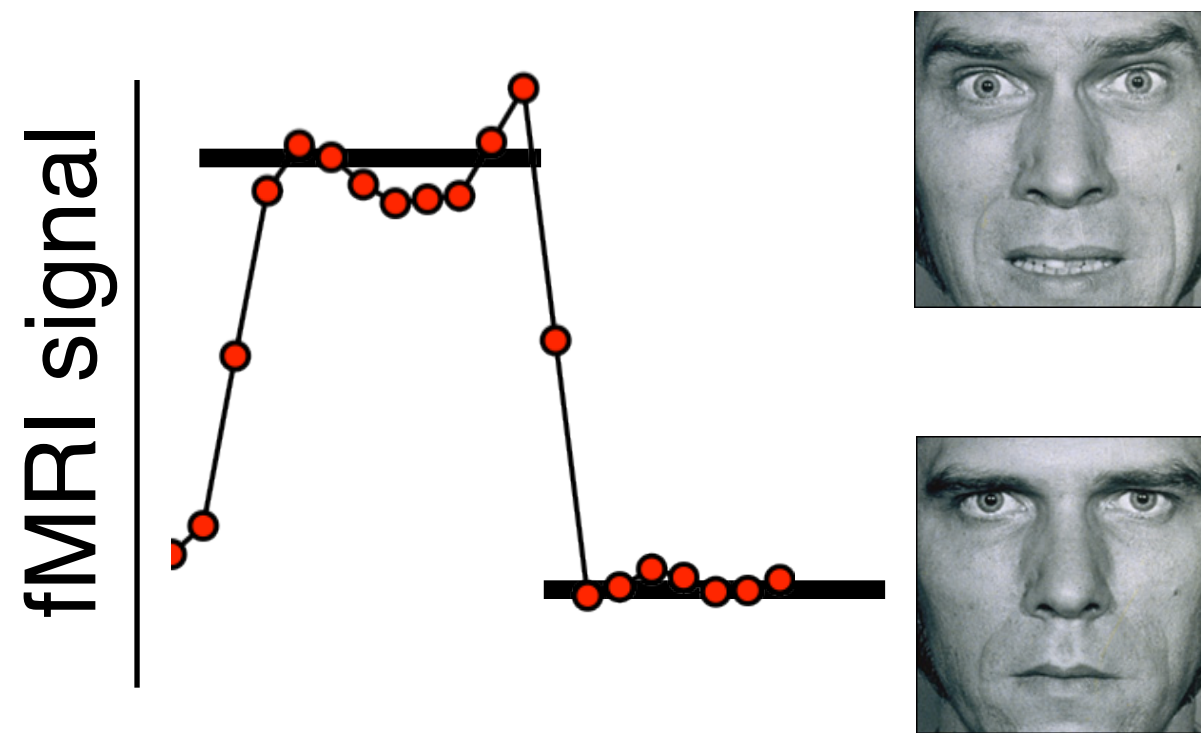


CLAIM: Psychopaths
show reduced responses
to emotional stimuli
within the amygdala

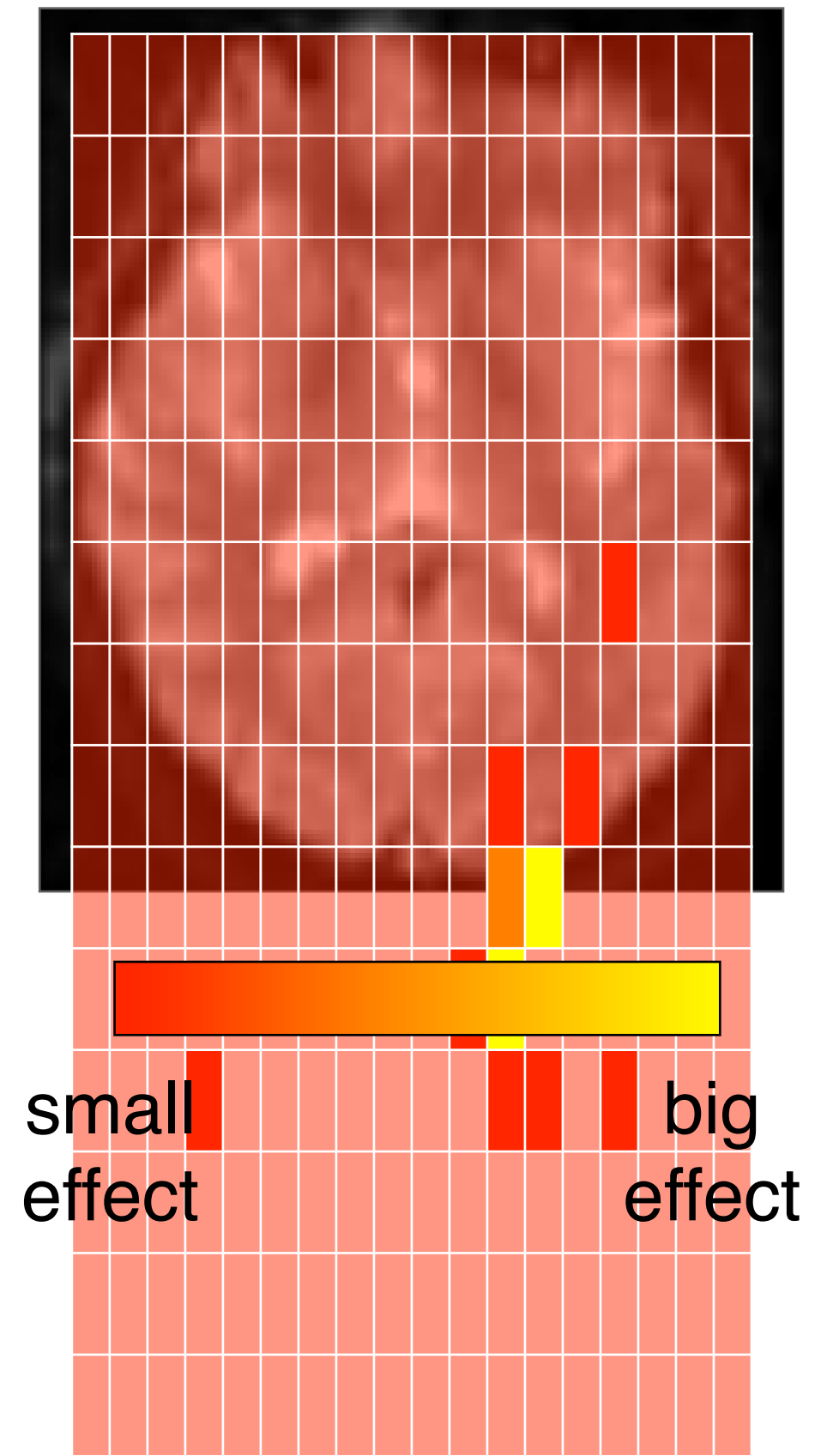
Compare conditions over time

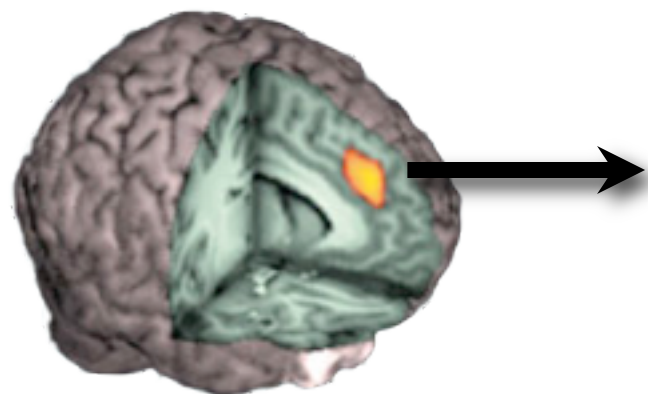


Color-coded statistical result:



How big
(or reliable)
was the difference?





Neuroaesthetics

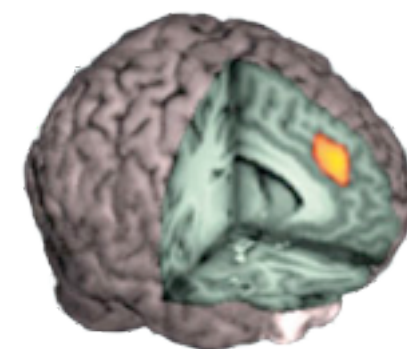
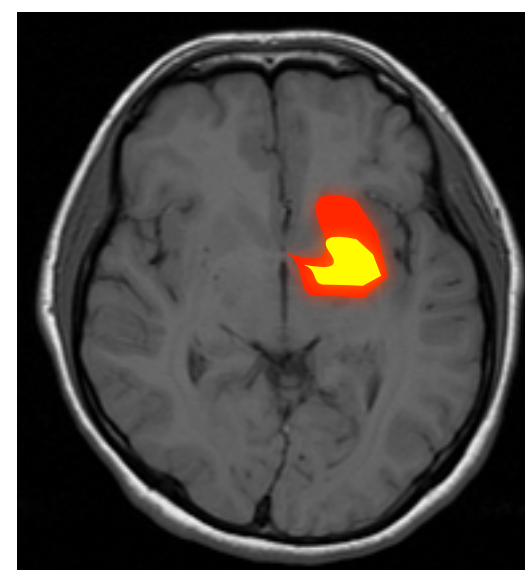
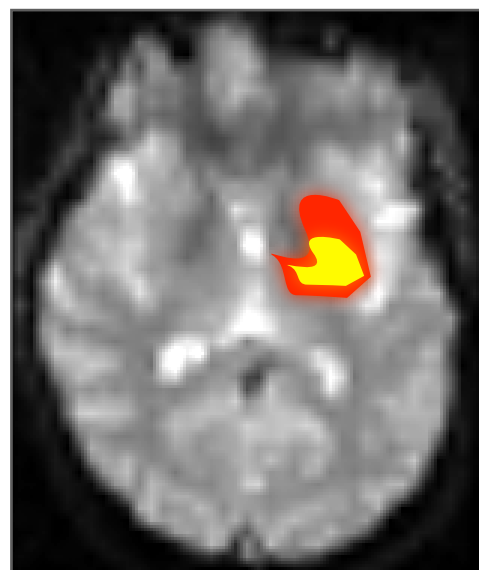
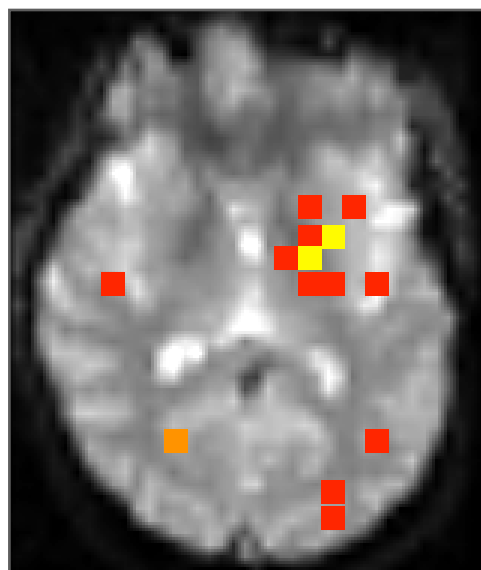
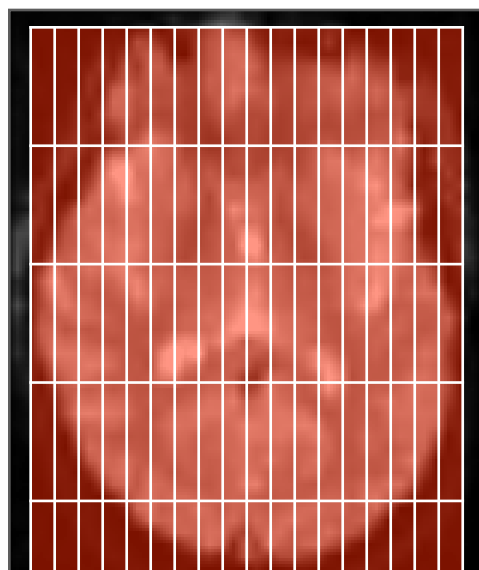
thresholding

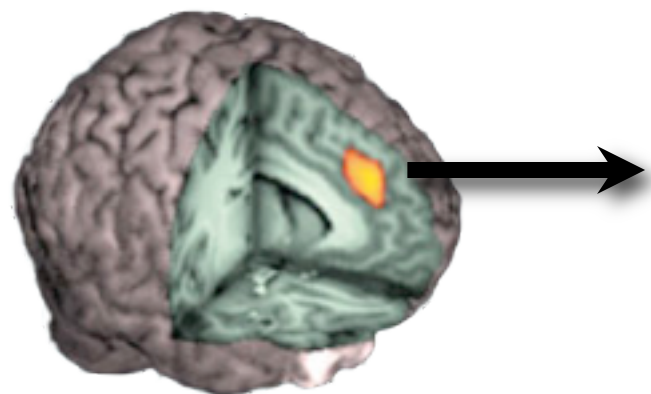


digital
smoothing

hi-res
anatomical

surface
reconstruction





Brain registration

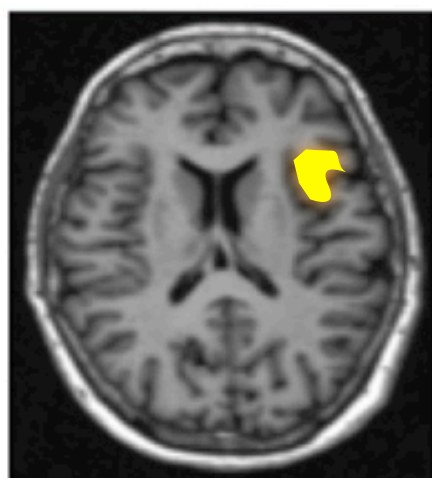
S1



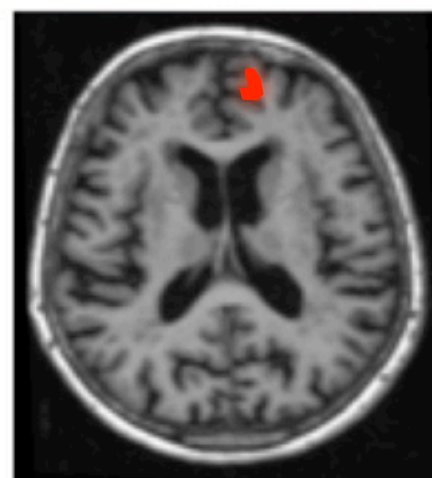
S2



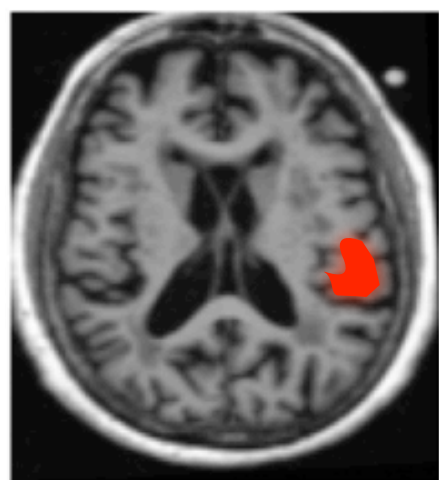
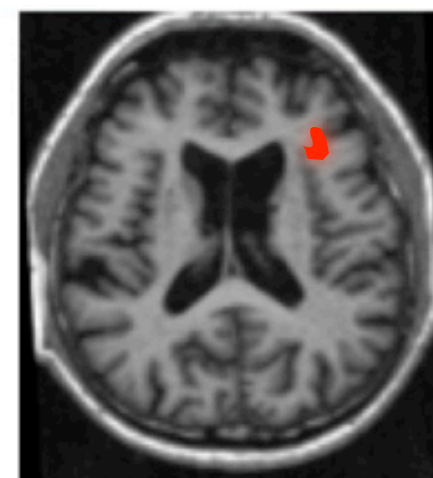
S3



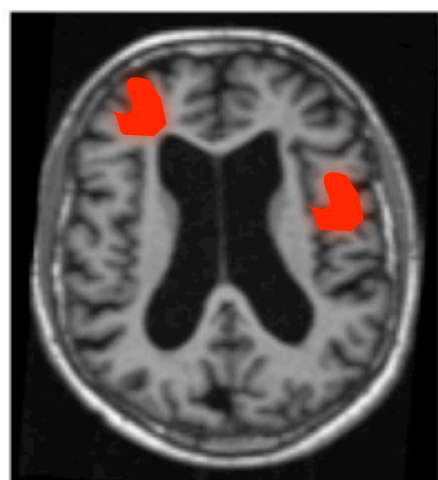
S4



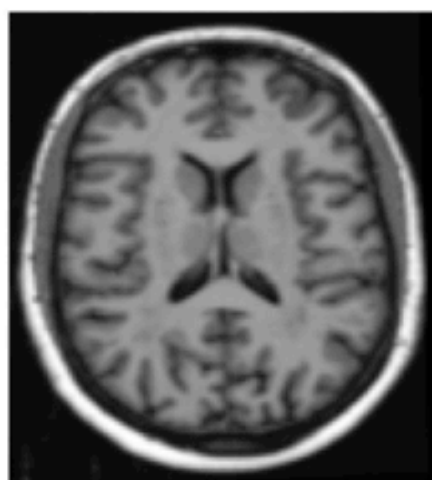
S5



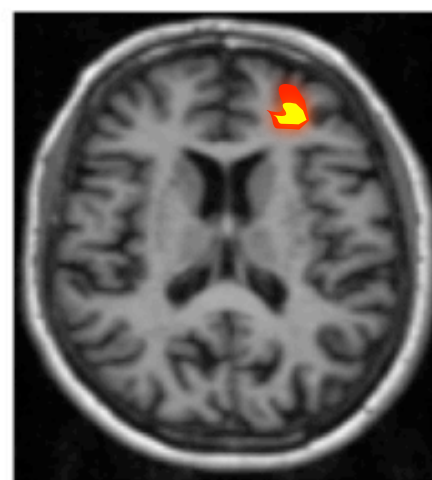
S6



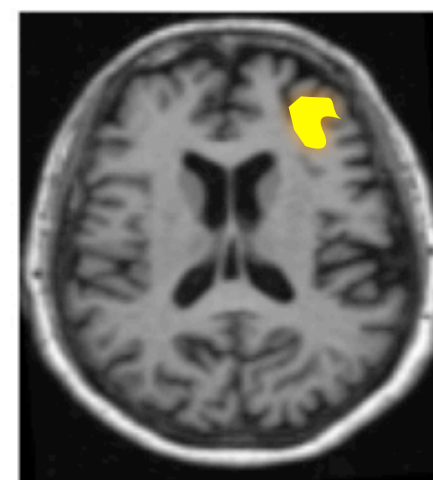
S7



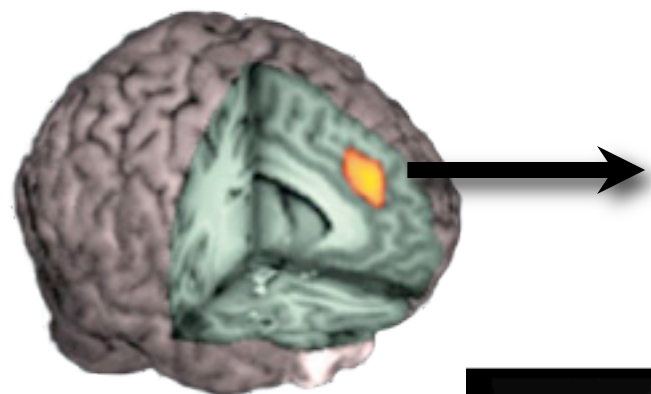
S8



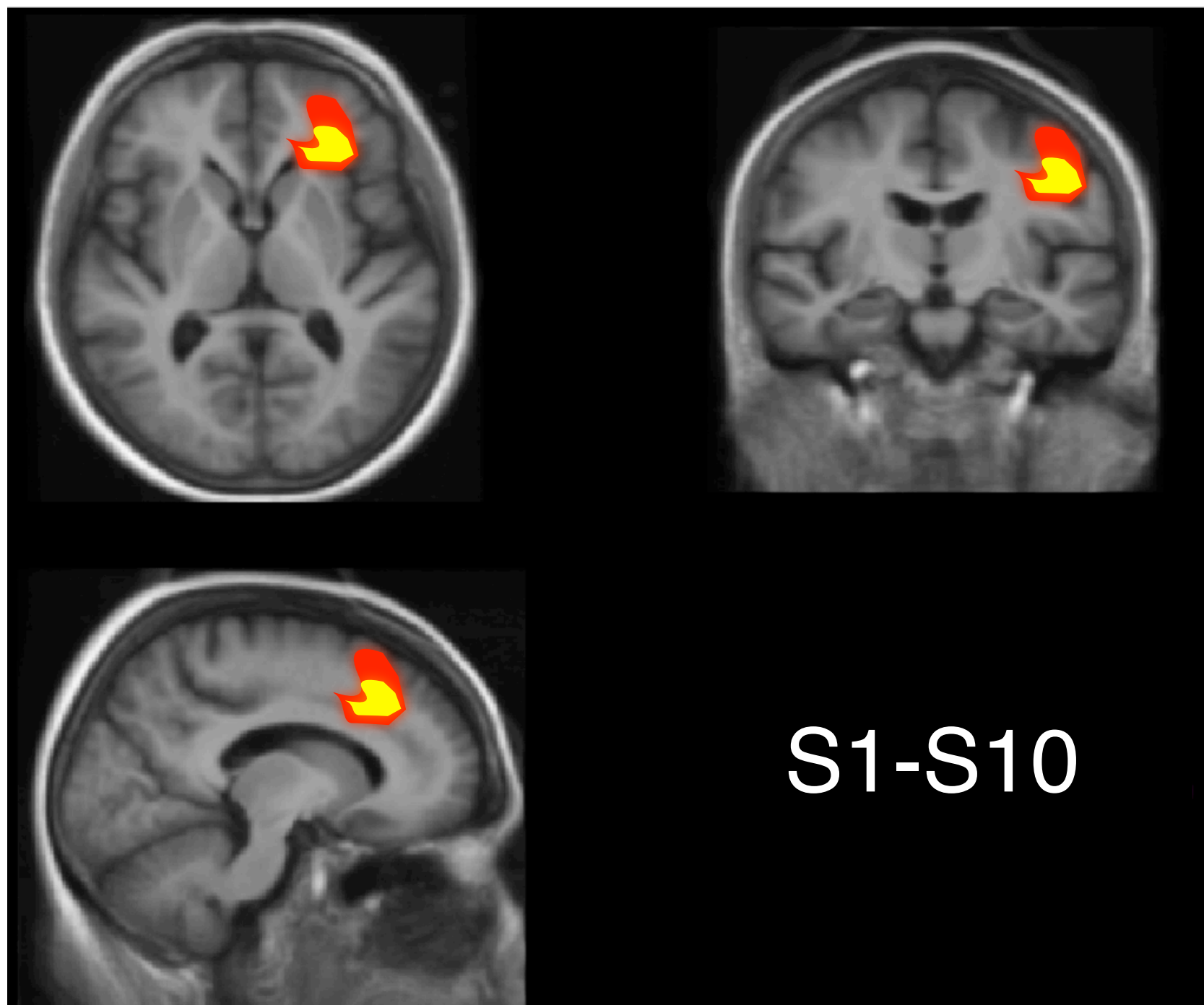
S9



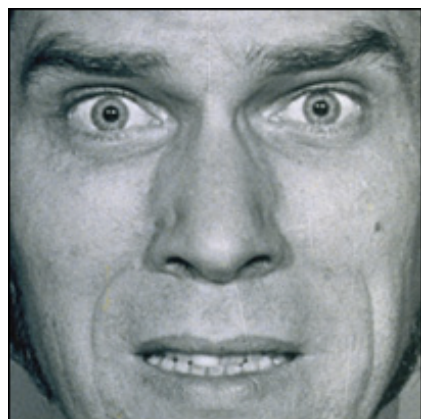
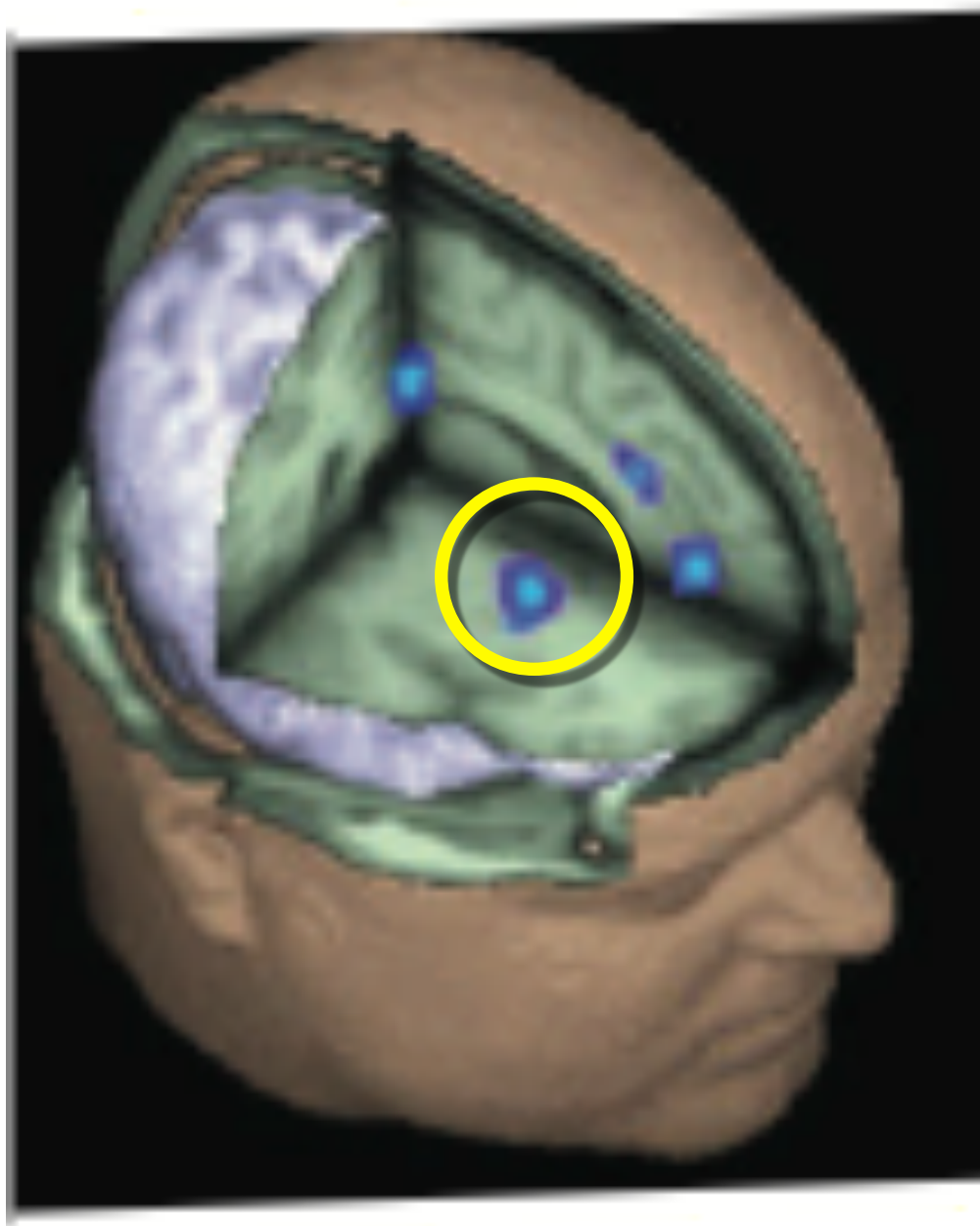
S10



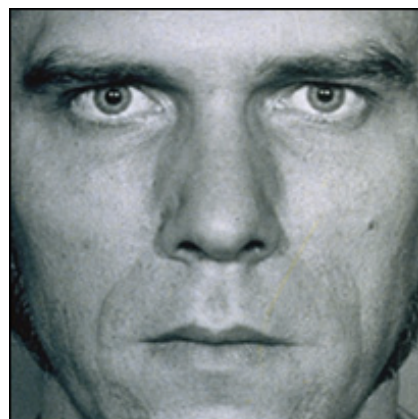
Brain registration



S1-S10

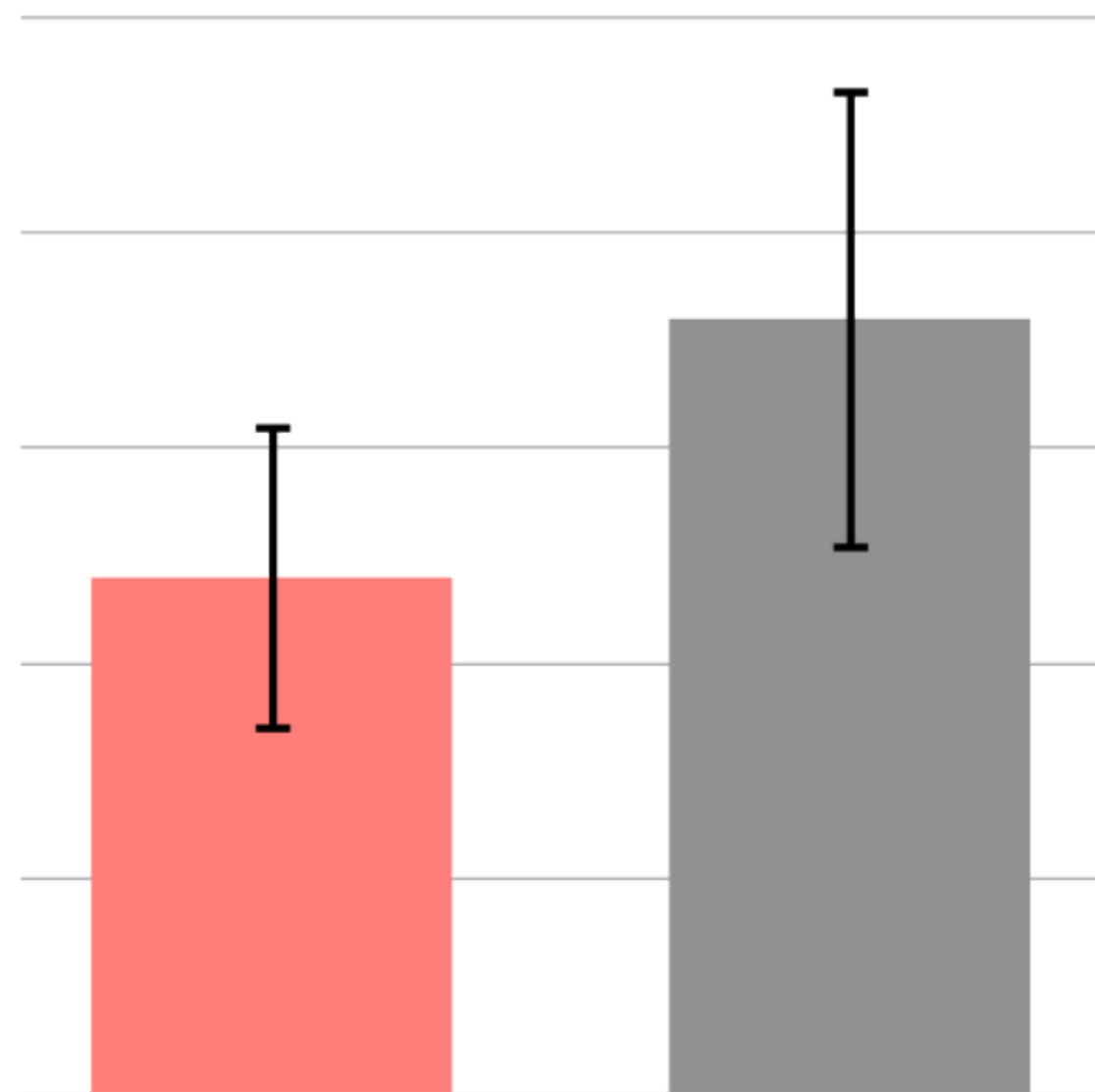


v



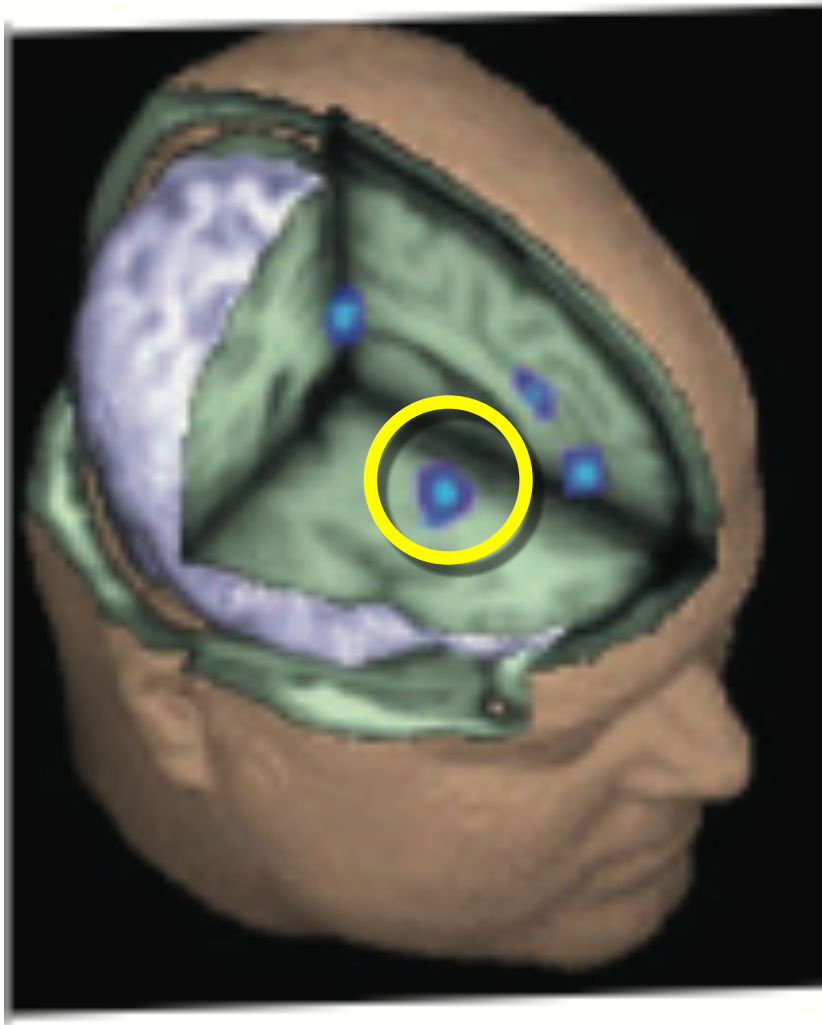
Fear vs Neutral faces

Average fMRI
response (\pm range)

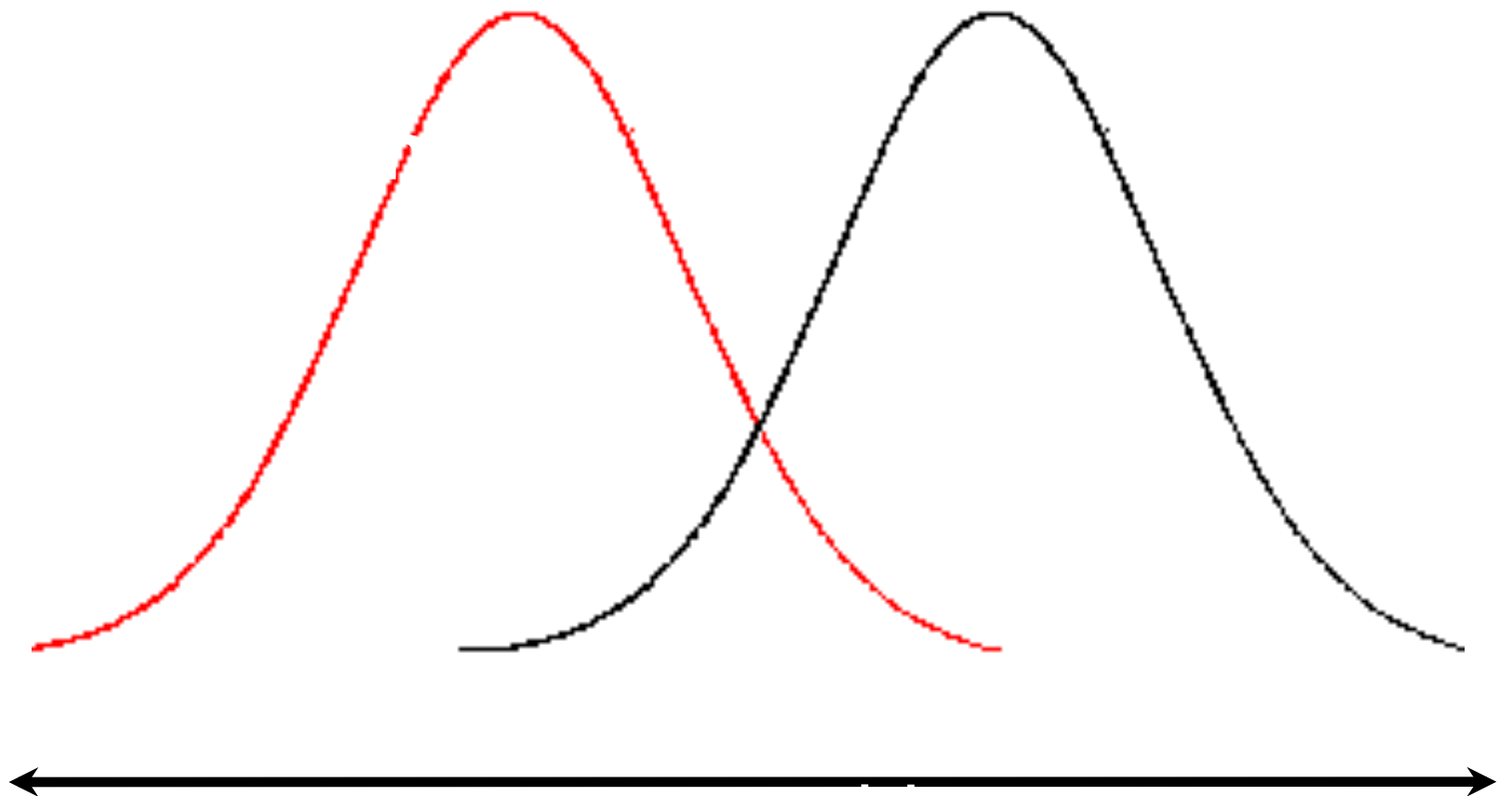


Ten psycho-
paths

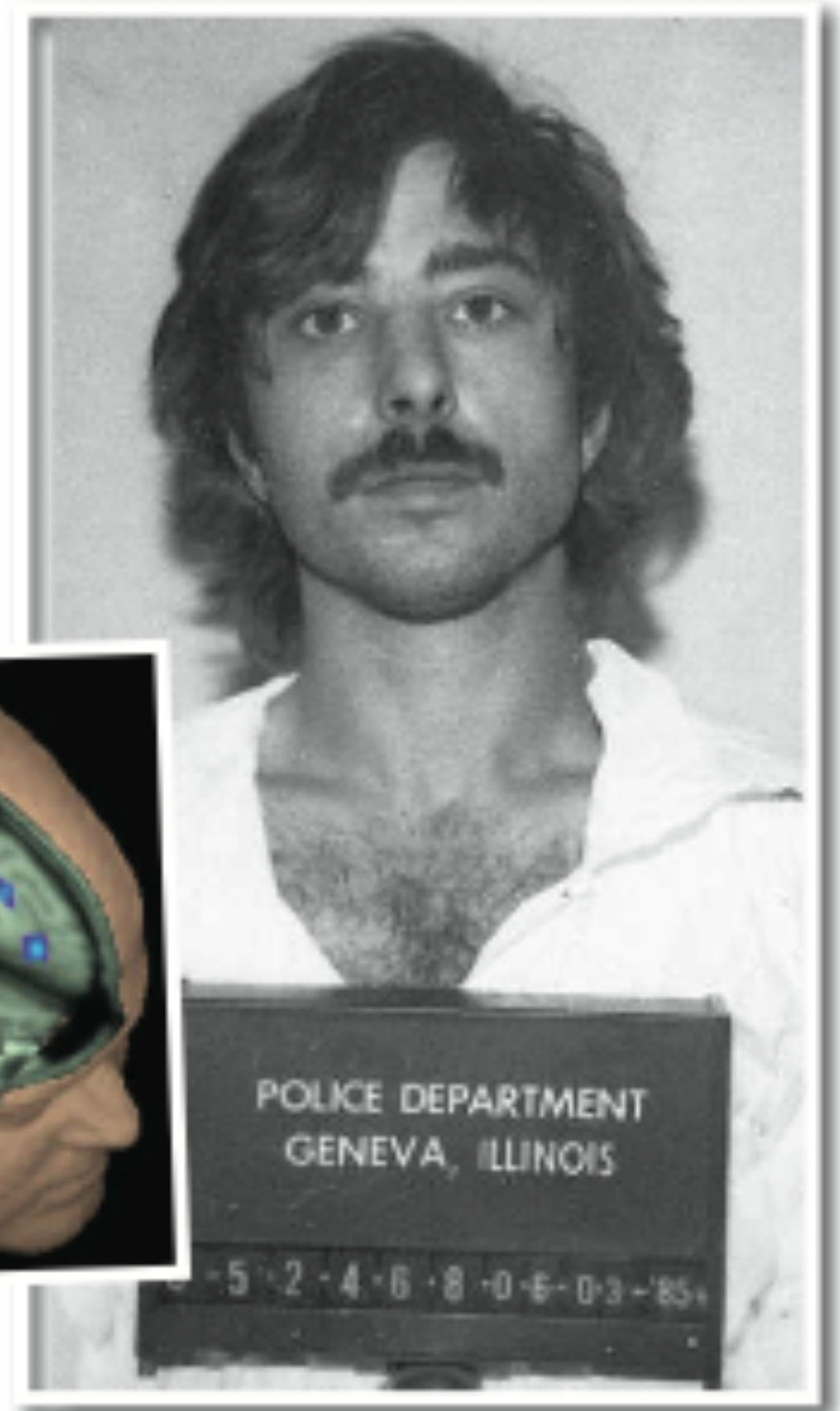
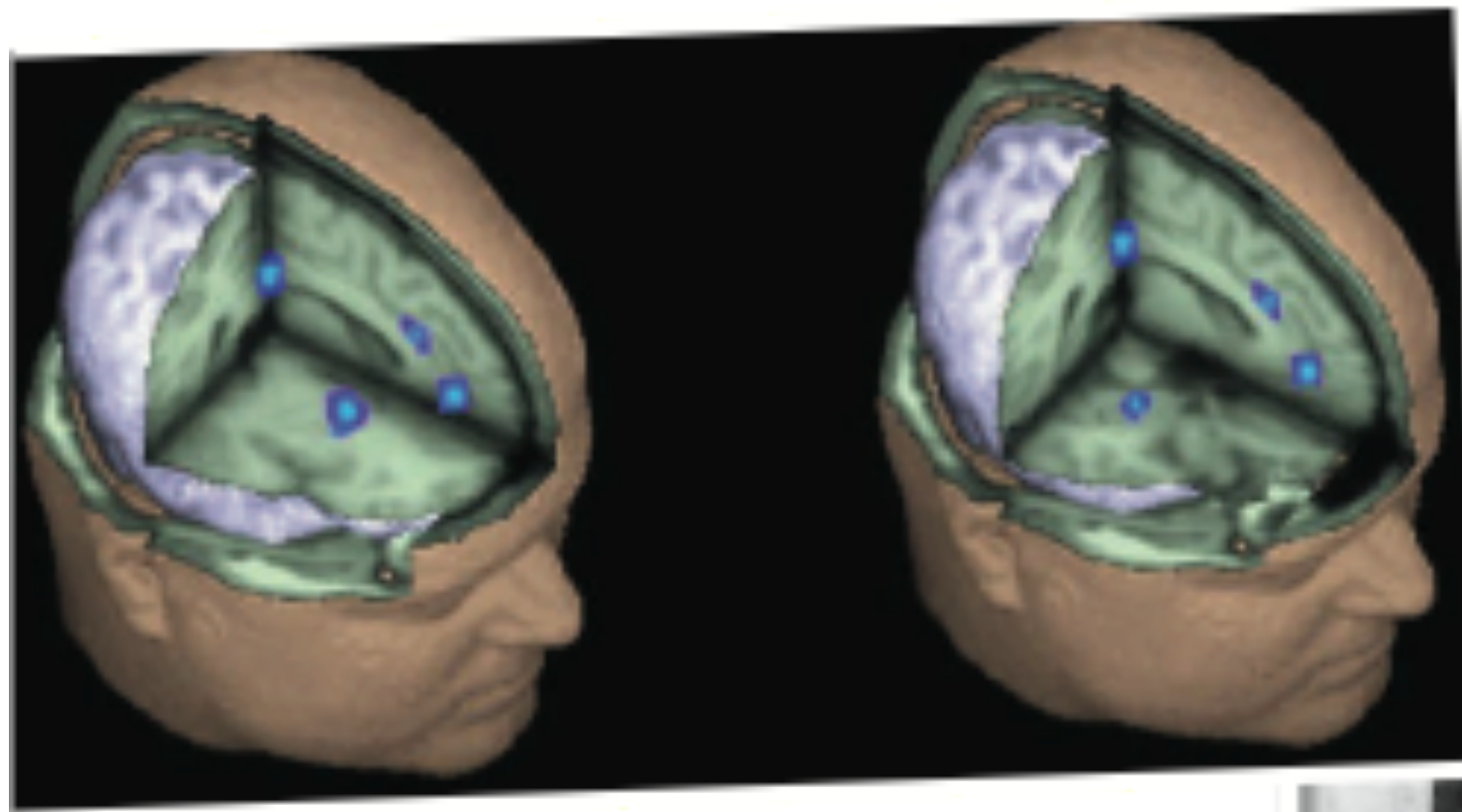
Ten normal
people



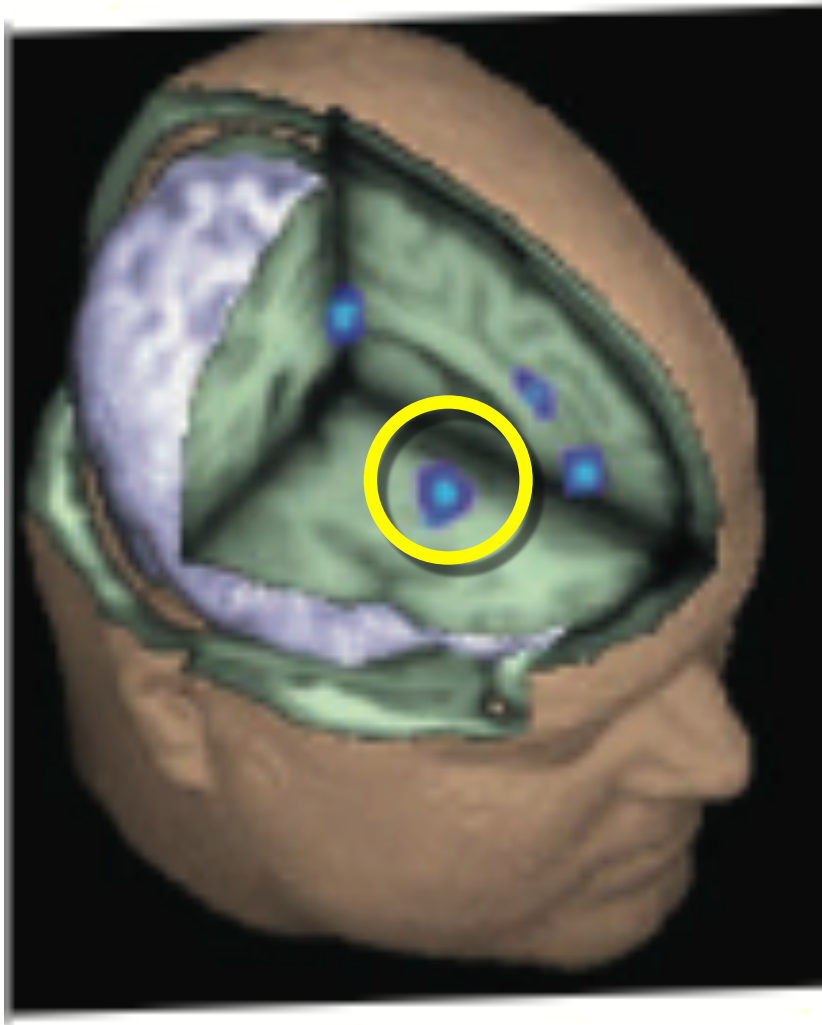
CLAIM 1: Psychopaths
show reduced responses
to emotional stimuli
within the amygdala



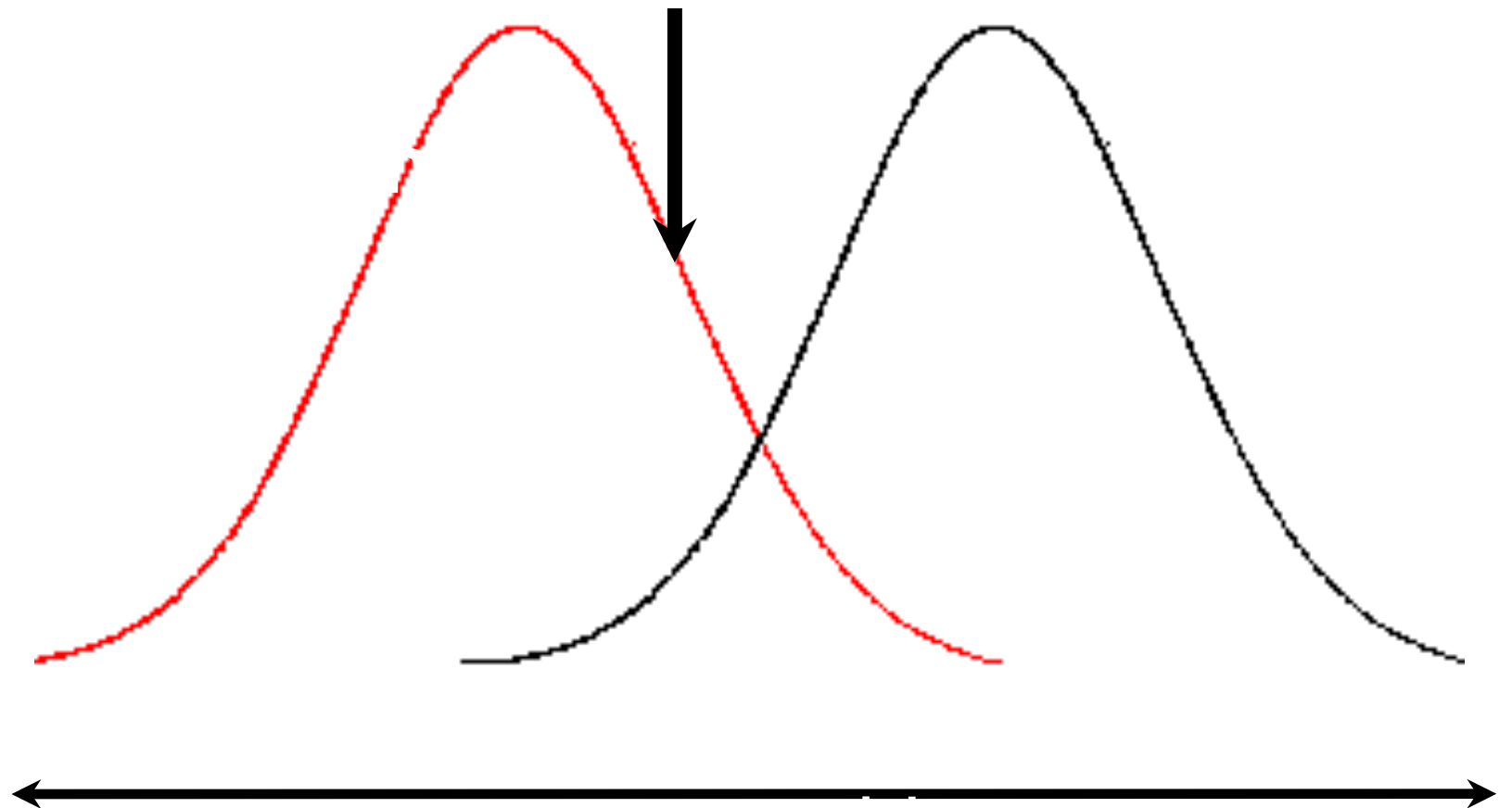
- What about this claim?



Above: criminal psychopaths show less activity than non-criminal control subjects in specific emotion-processing areas of the brain, according to Kent Kiehl's testing. Right: Brian Dugan in 1985.

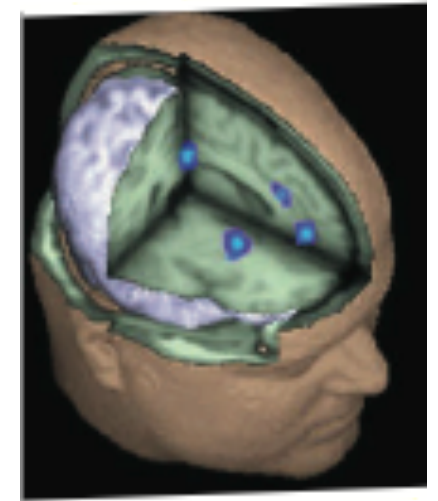
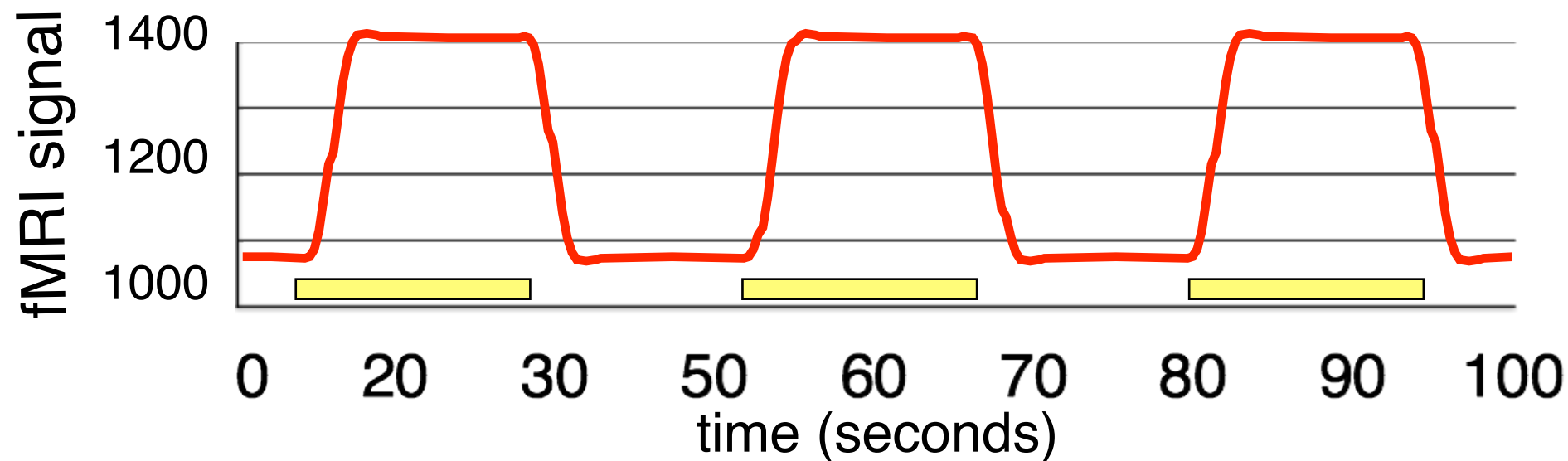


CLAIM 2: Brian Dugan is a psychopath, because he has reduced responses to emotional stimuli within the amygdala



A prototypical experiment

measure a magnitude of neural response within the cortex to a standardized emotional stimulus in a group of subjects

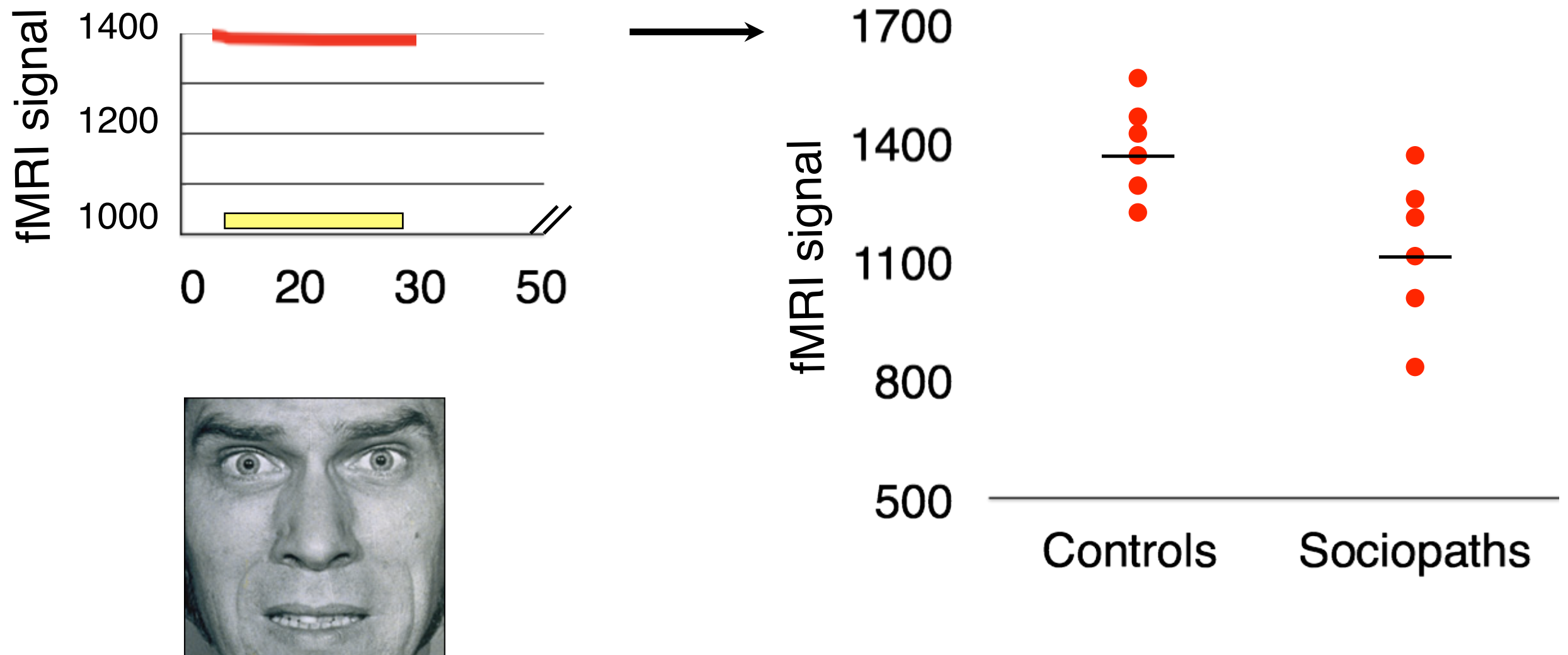


- relative signal
- indirect measure
- bulk activity change

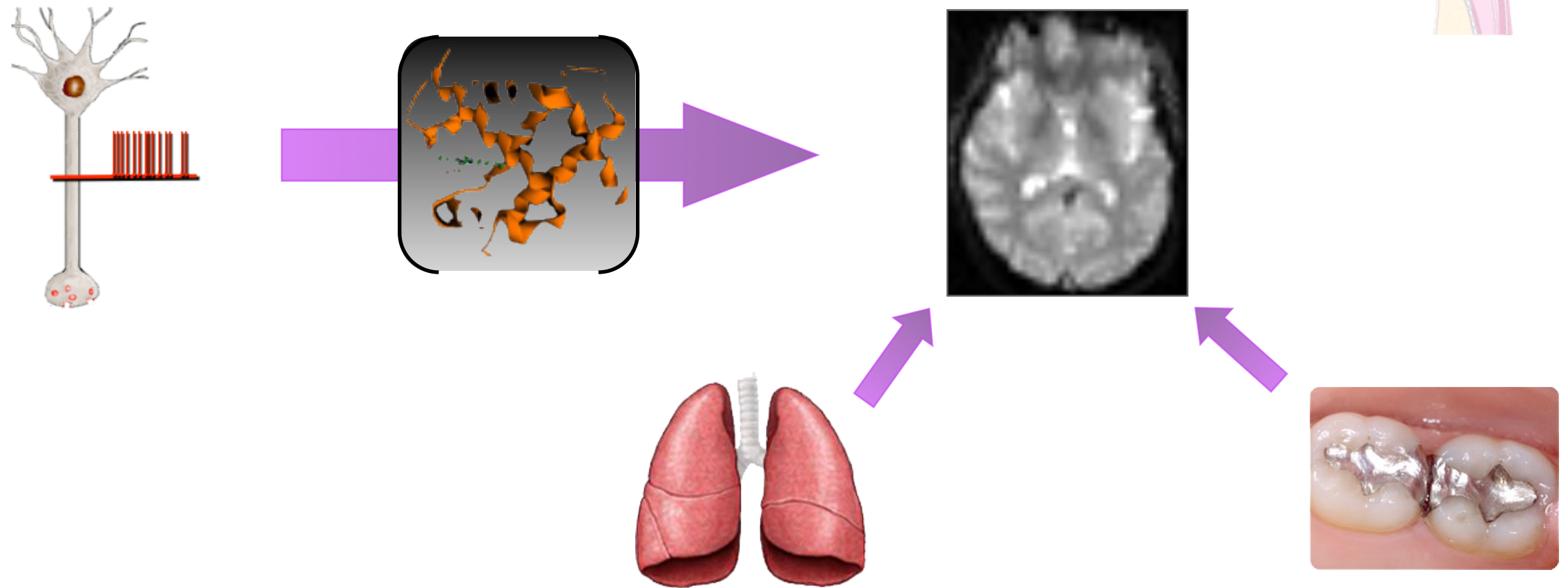
- subtraction design
- blocked order

A relative signal

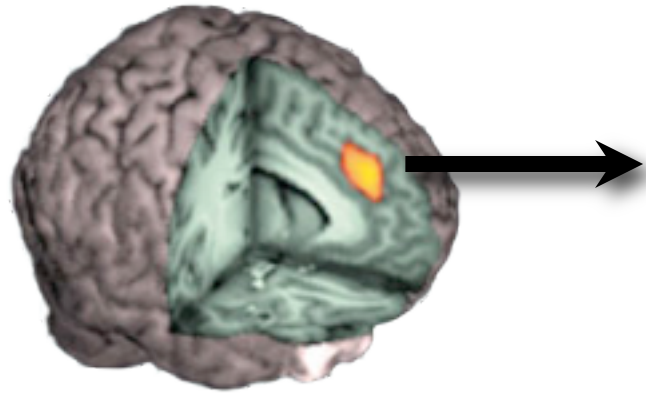
Goal: determine if the BOLD fMRI signal during emotional face perception is reduced in psychopaths compared to controls



A relative signal



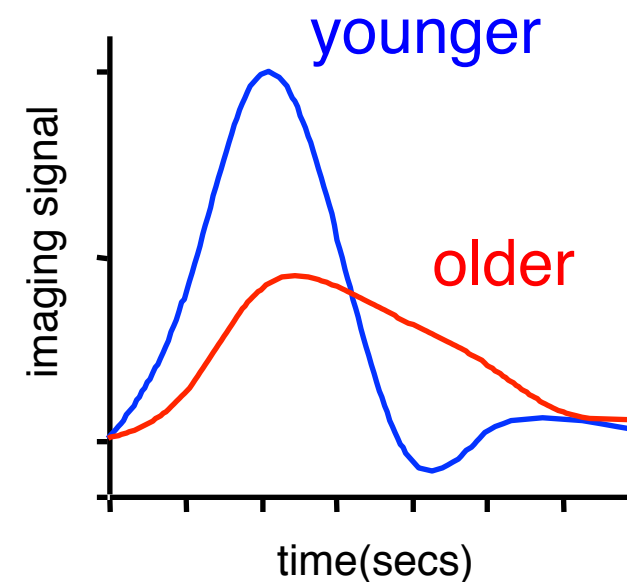
The BOLD fMRI signal has no direct, absolute interpretation. Must be compared between states studied close together in time.



Neural activity?

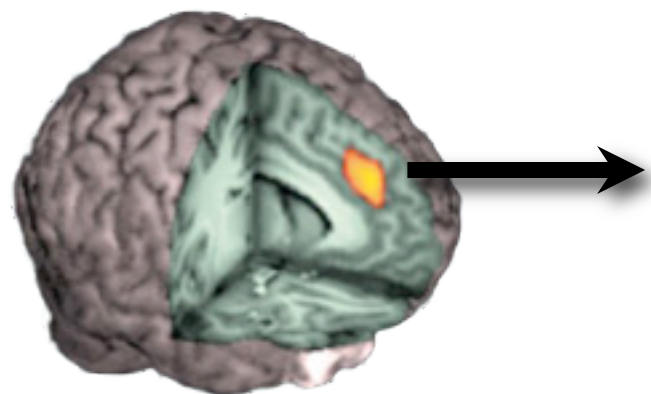
A hemodynamic proxy of neural activity

- fMRI measures blood flow; differences in vascular response can confound differences in neural activity



drugs, hormonal states, age, gender

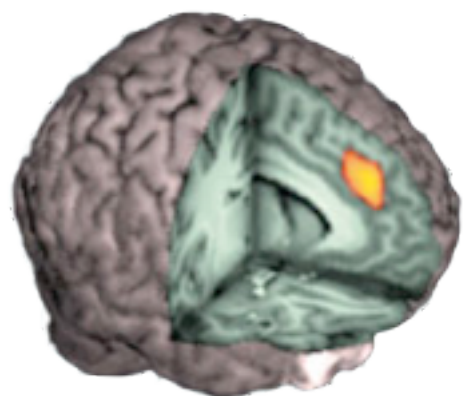




A generalizable result?

Studied population

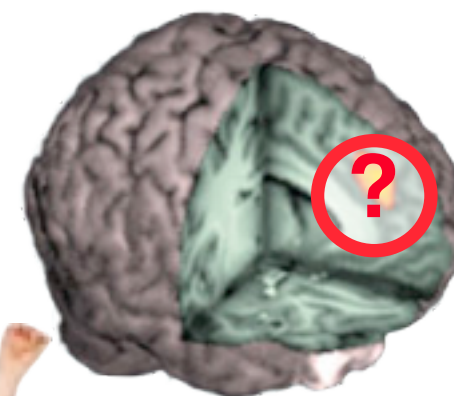
healthy college
students



middle-aged
lawyers

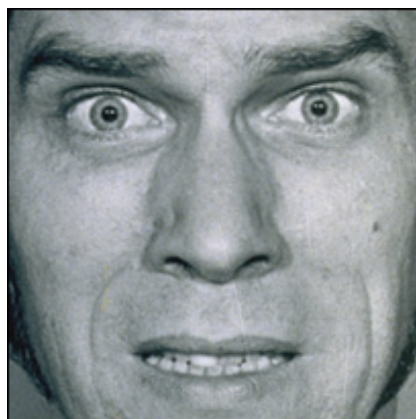
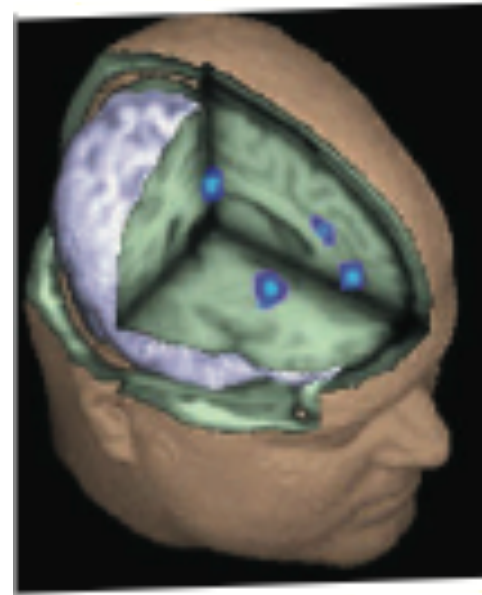
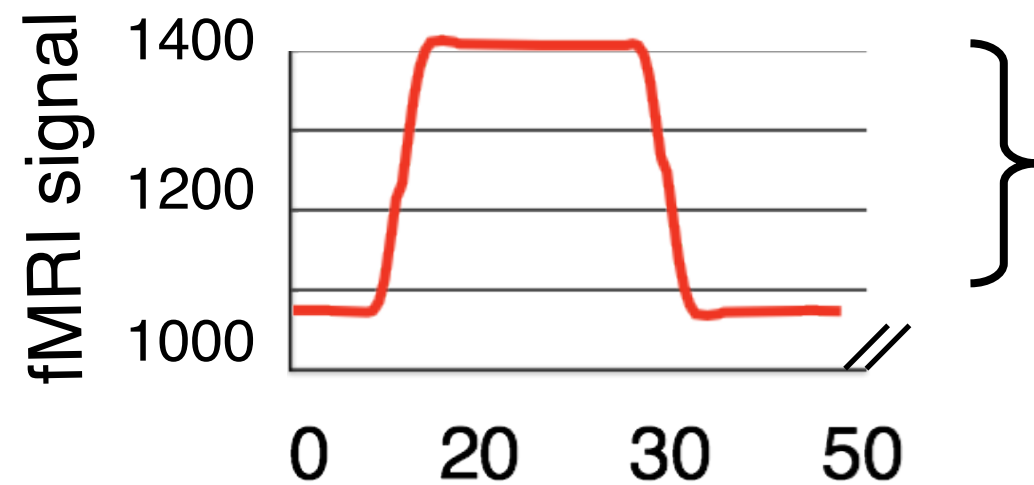


children

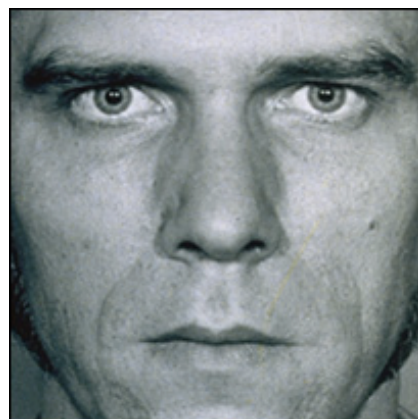


An integrated measure

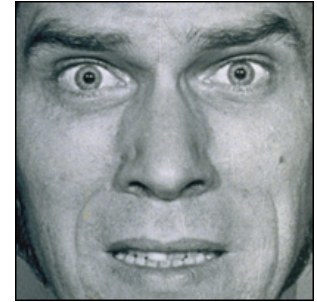
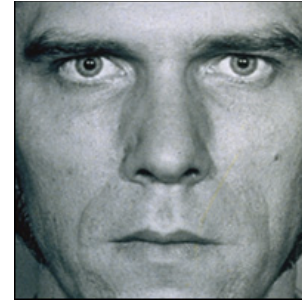
Goal: measure the difference in neural response to faces with different emotional content



>

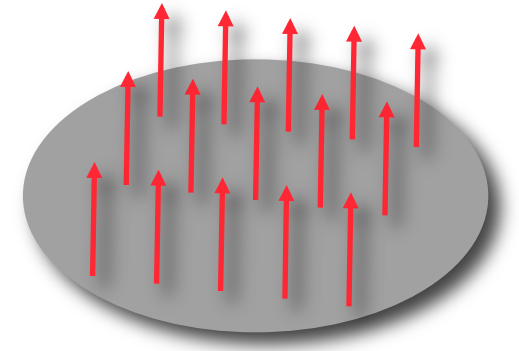
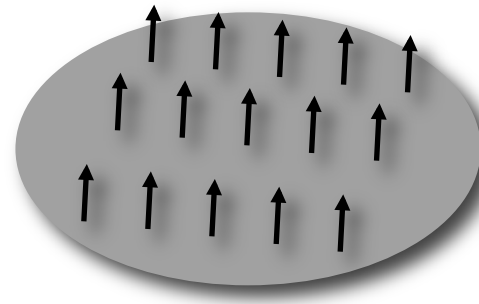


An integrated measure

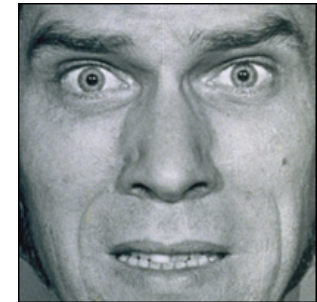
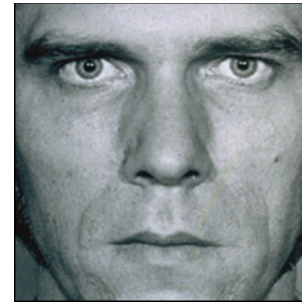


Detectable

- a bulk change in neural activity

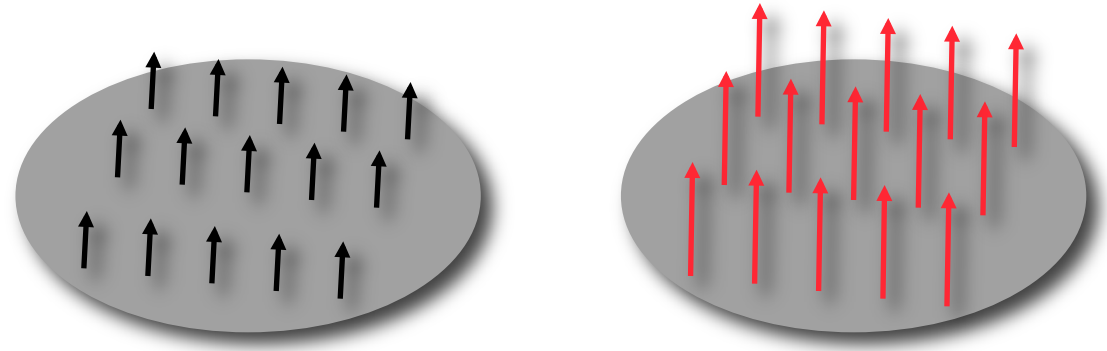


An integrated measure



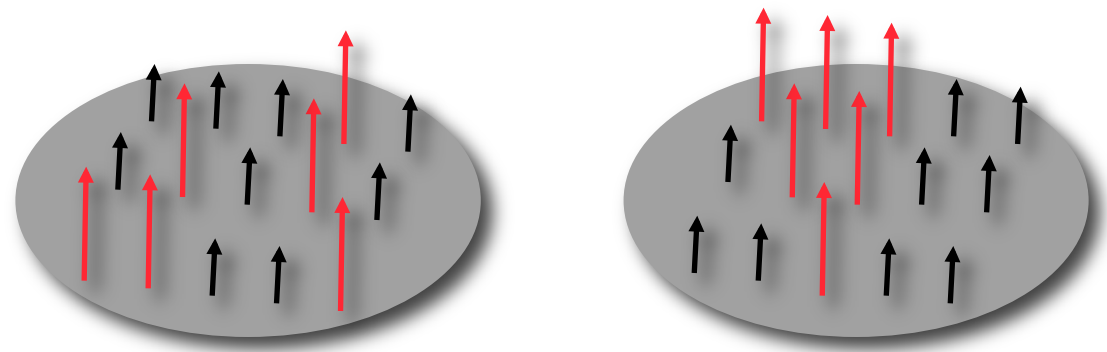
Detectable

- a bulk change in neural activity



Undetectable

- a change in population code



The BOLD fMRI signal integrates neural activity over seconds and millimeters.
(spike rate vs. local field potential)