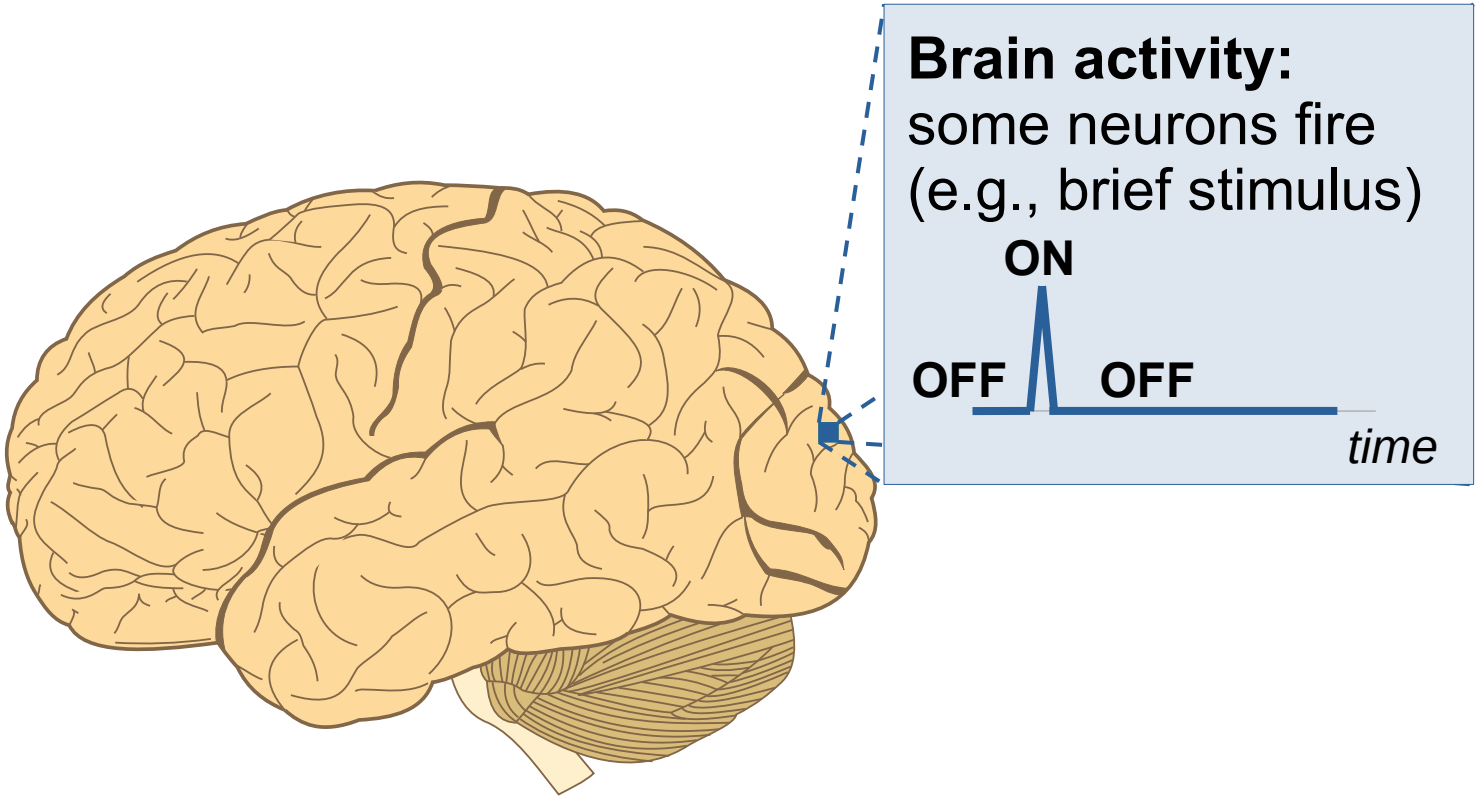
A very brief intro to FMRI and some processing

Outline

- **What does functional magnetic resonance imaging (FMRI) measure?**
  - Going from: Neuron firing → blood oxygenation response
- **What are good properties of FMRI?**
  - Safe, non-invasive, whole brain, time-resolved
- **What are some challenging properties of FMRI?**
  - Susceptible to motion, artifact and distortions
- **How does all this inform our processing and quality checks?**
  - Motivate some standard steps and things to look out for

A cartoon picture of task-based FMRI



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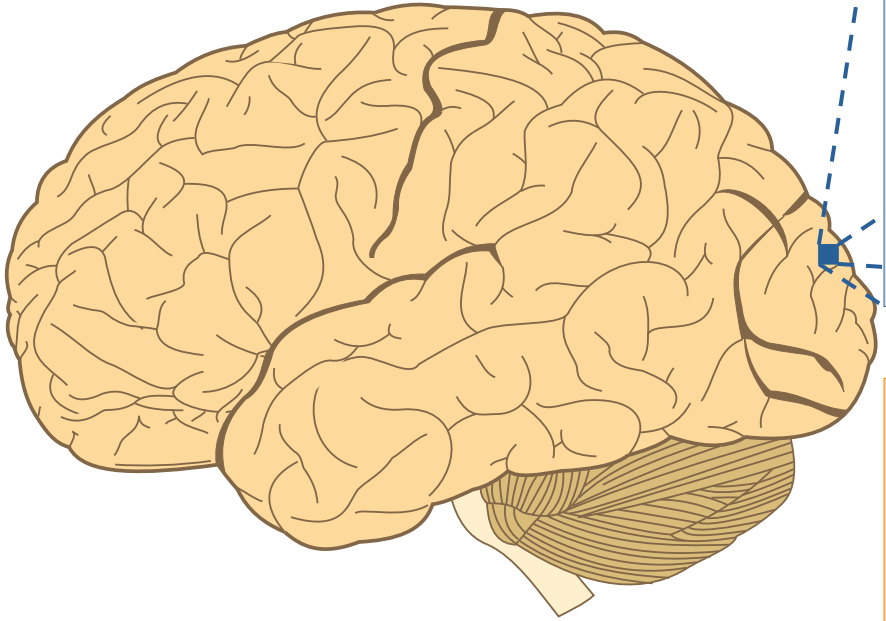

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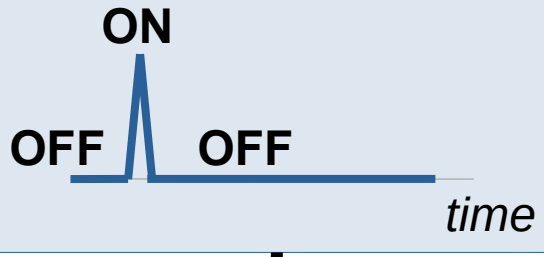
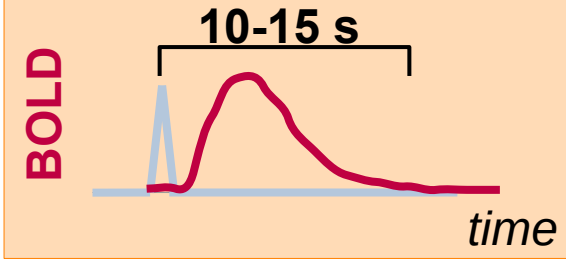


BOLD response:
blood oxygenation
changes locally



BOLD = Blood Oxygen Level-Dependent

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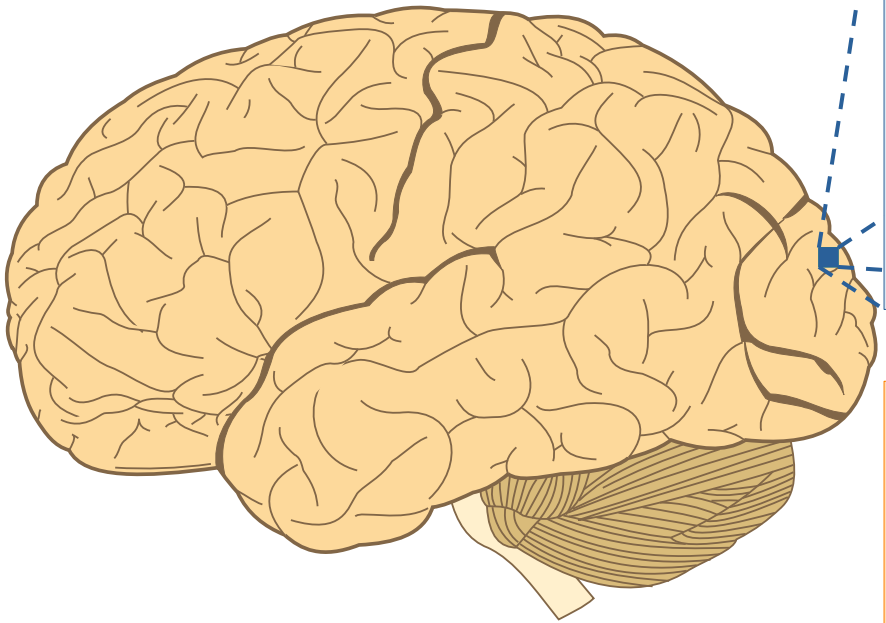

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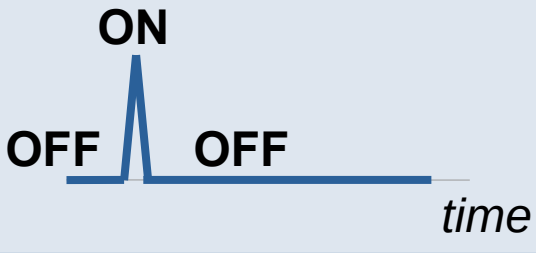

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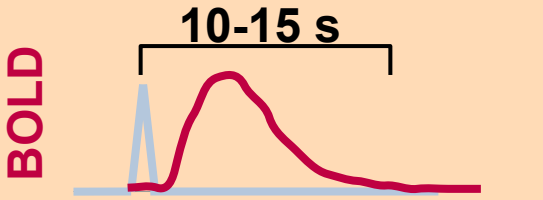

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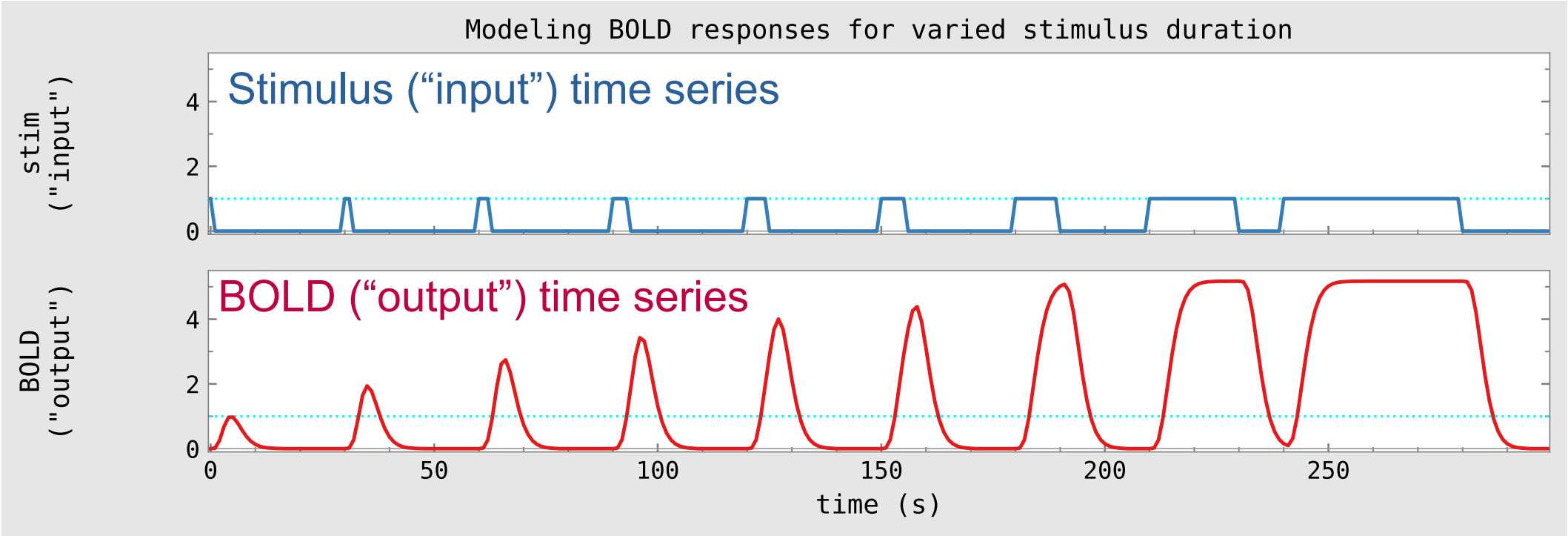
Modeling stimulus to BOLD response (idealized)

Q: For a longer stimulus, what happens to the BOLD response?
A: It is also longer *and* increases, up to a plateau.

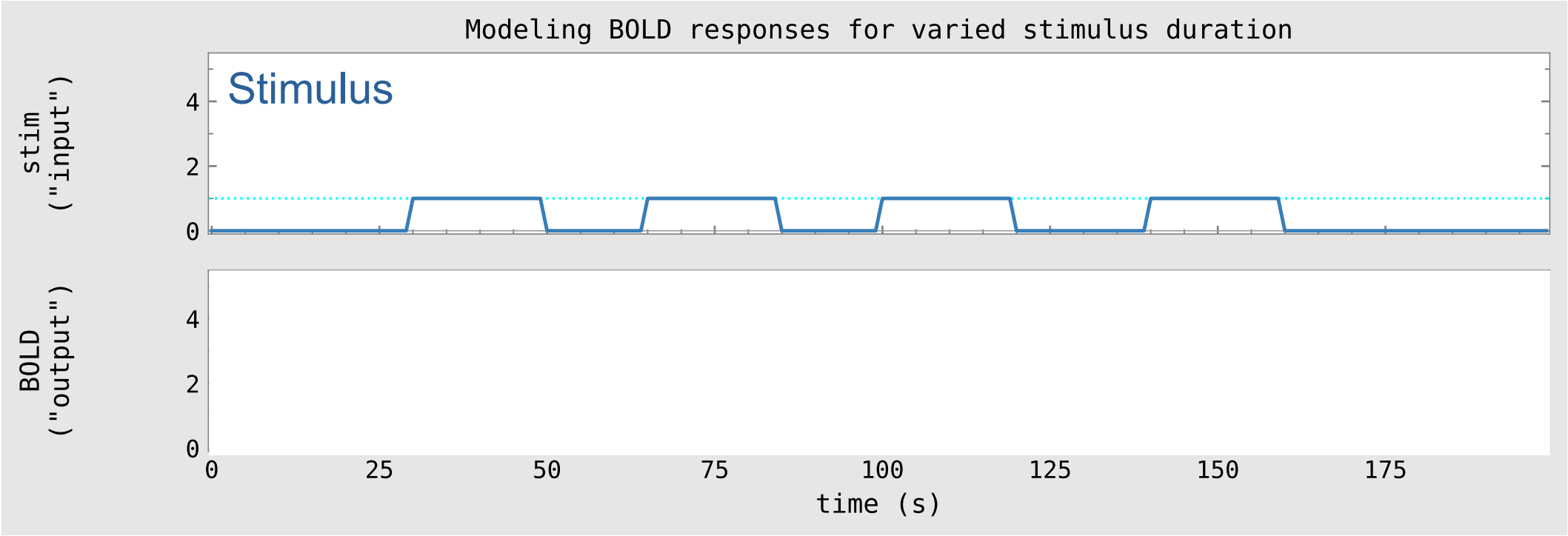


Note: The BOLD peak is a few seconds after the stim start, and slowly decreases after the stim ends.

Modeling stimulus to BOLD response (idealized)

** Pop quiz **

What should the **BOLD response** for this set of stimuli look like?



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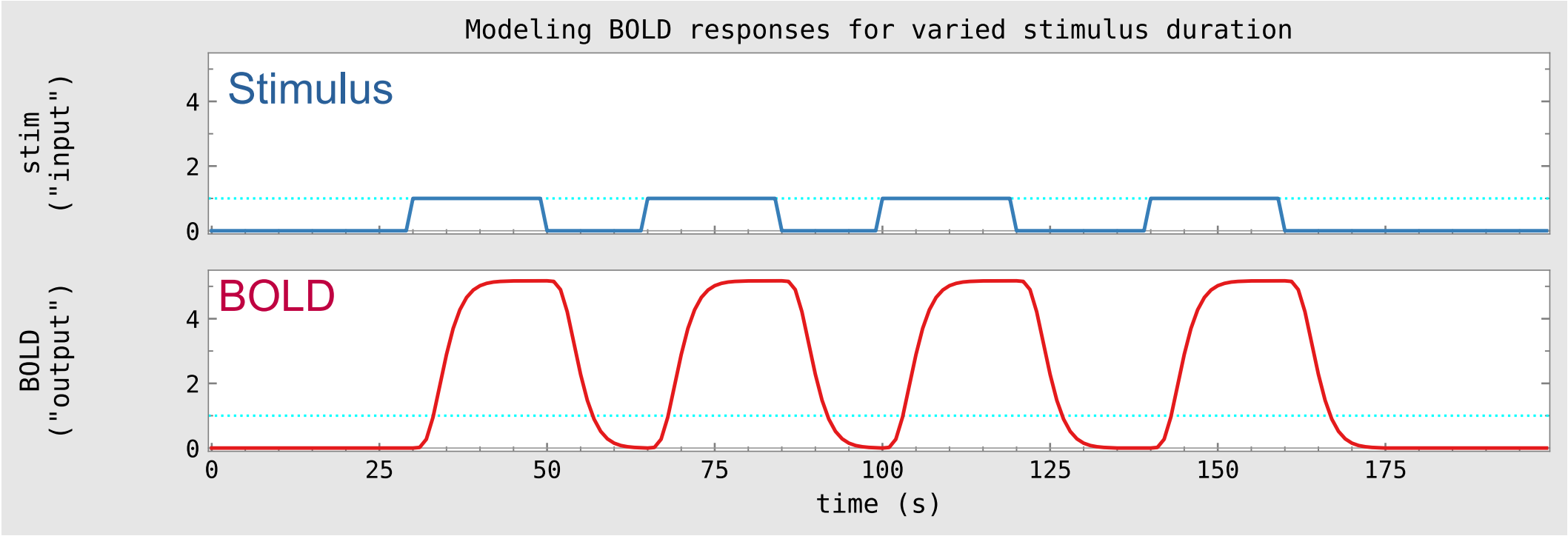

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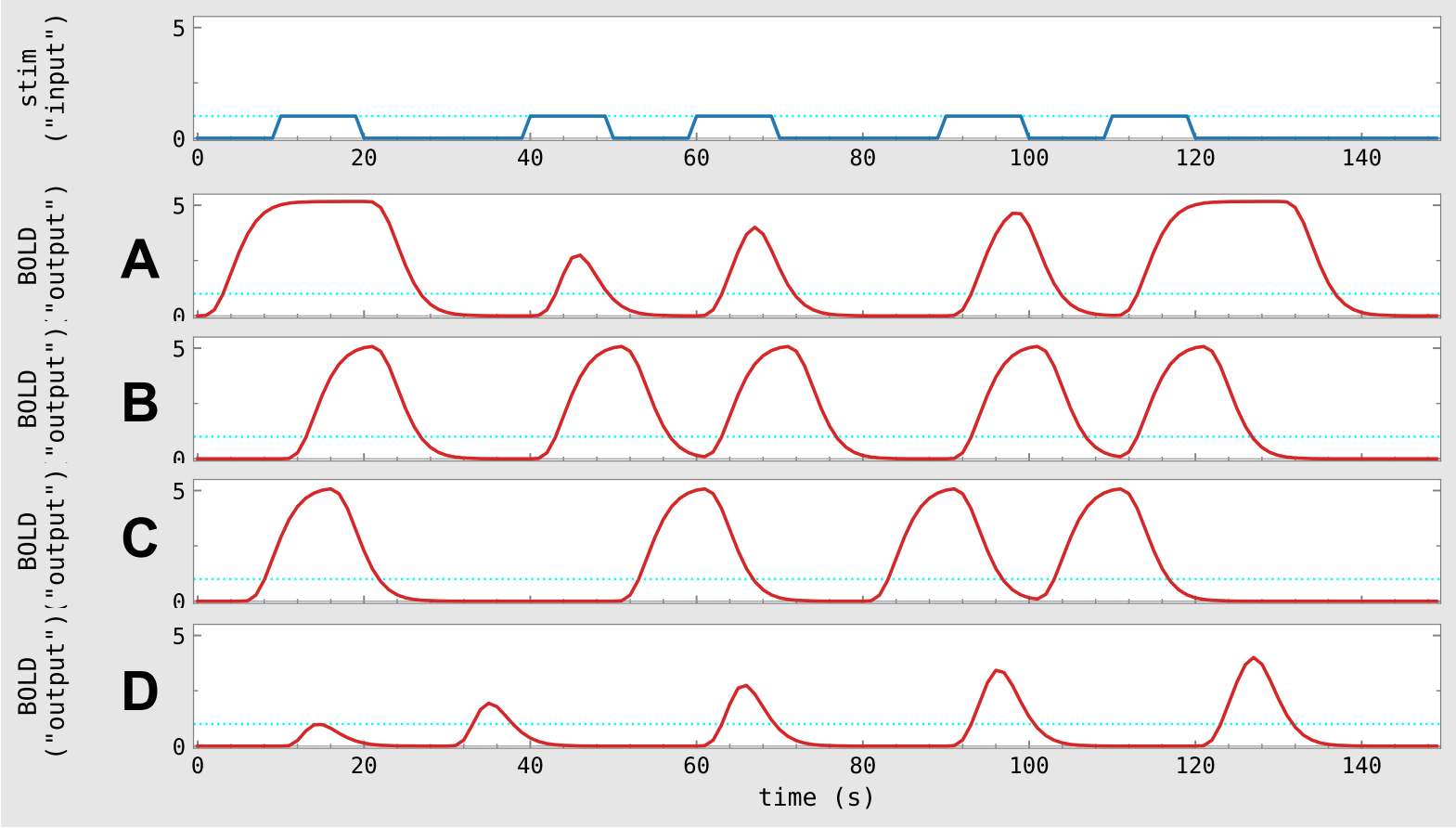

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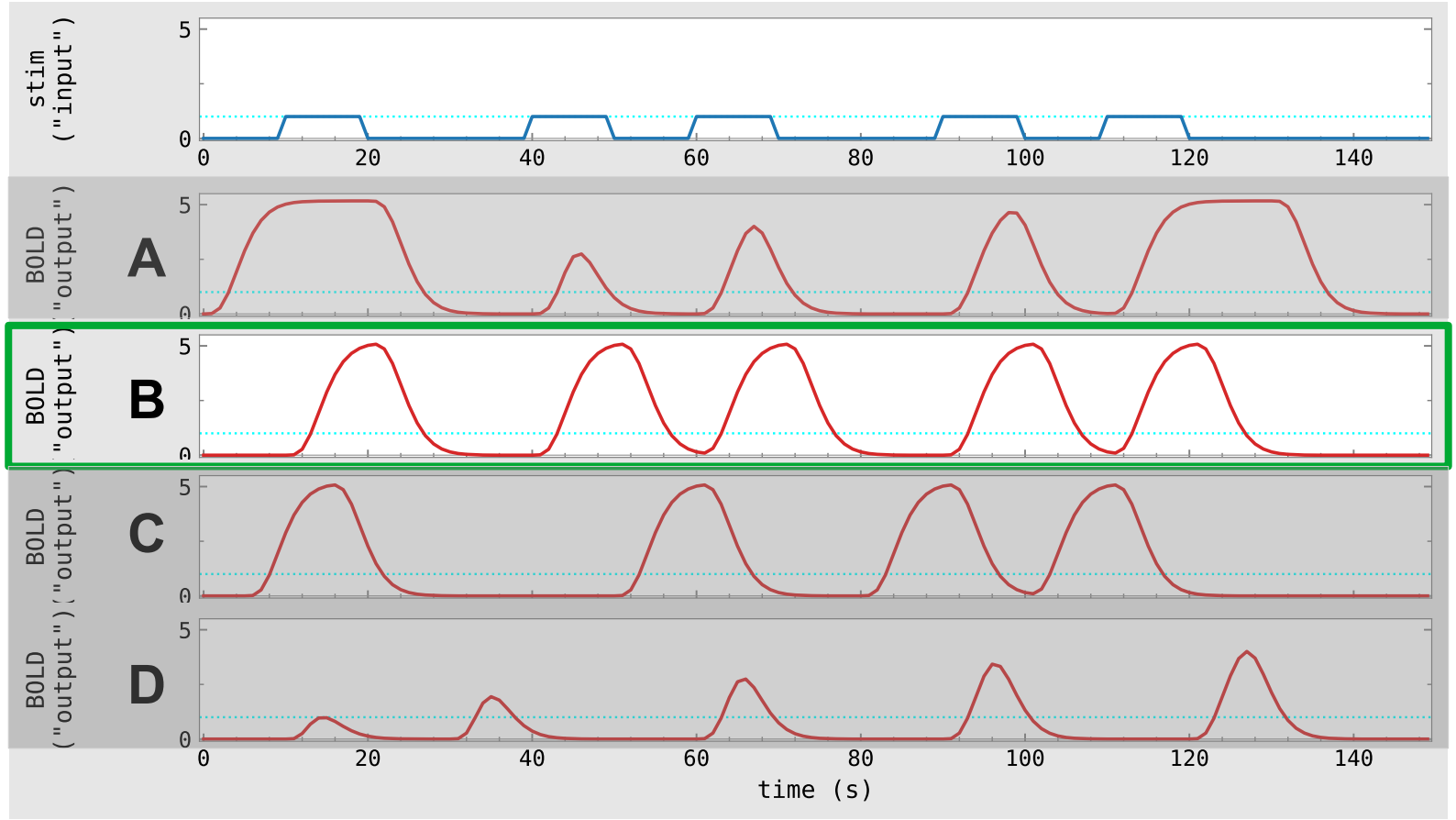
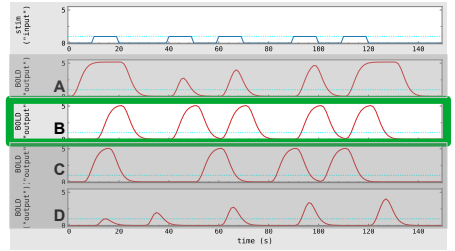


FMRI studies: looking for expected BOLD in data

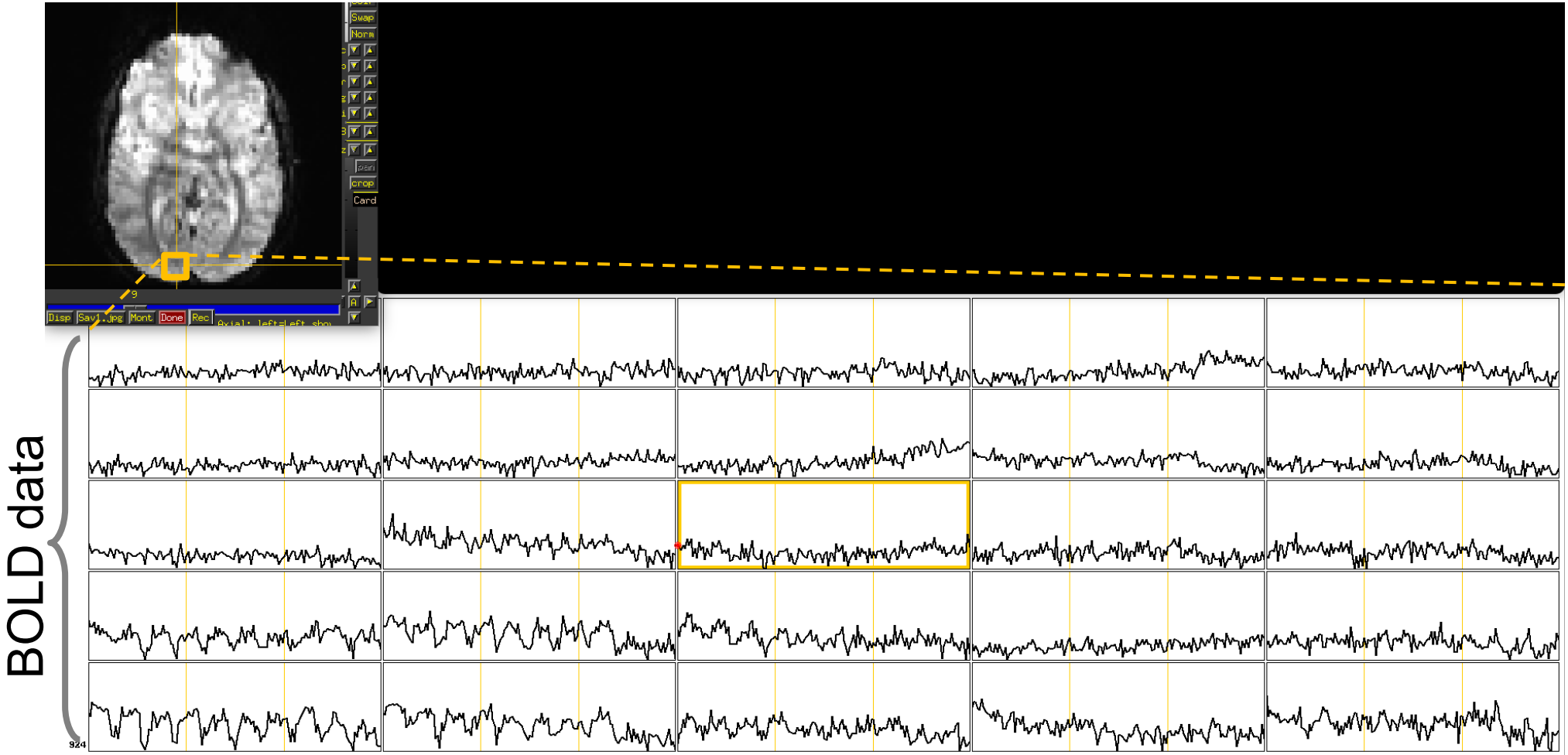


Actually, such pattern matching is at the root task FMRI analysis:

1. Make a stim pattern for a task (e.g., button pushing)
2. Estimate the "idealized" BOLD response to it
3. Measure BOLD responses in the brain while a participant does the task in MRI scanner
4. Find where BOLD responses look like the idealized response---*there be interesting brain activation!*

Task FMRI: search subject BOLD for ideal response

Some real BOLD time series in a FMRI dataset (NB: *noisy!*).



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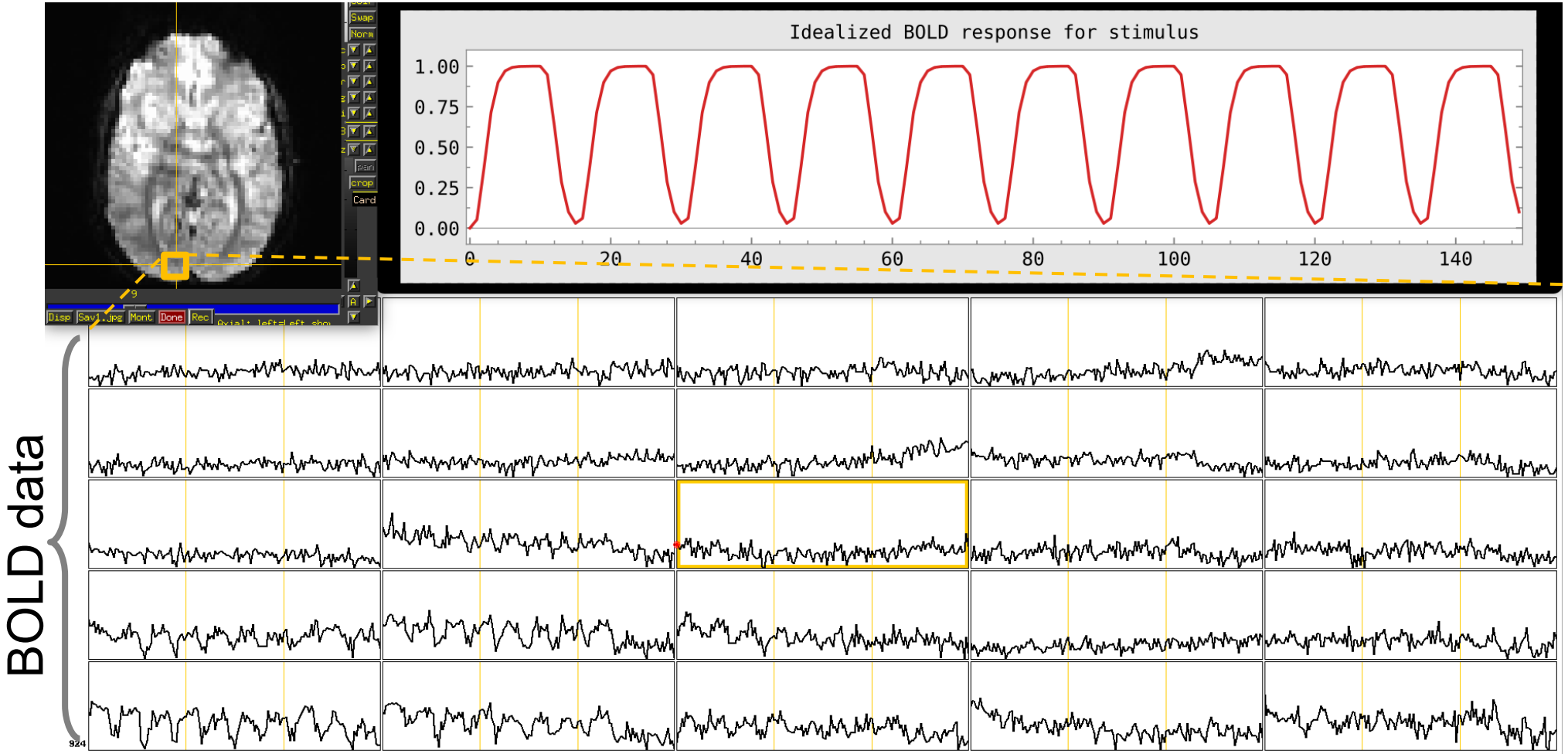

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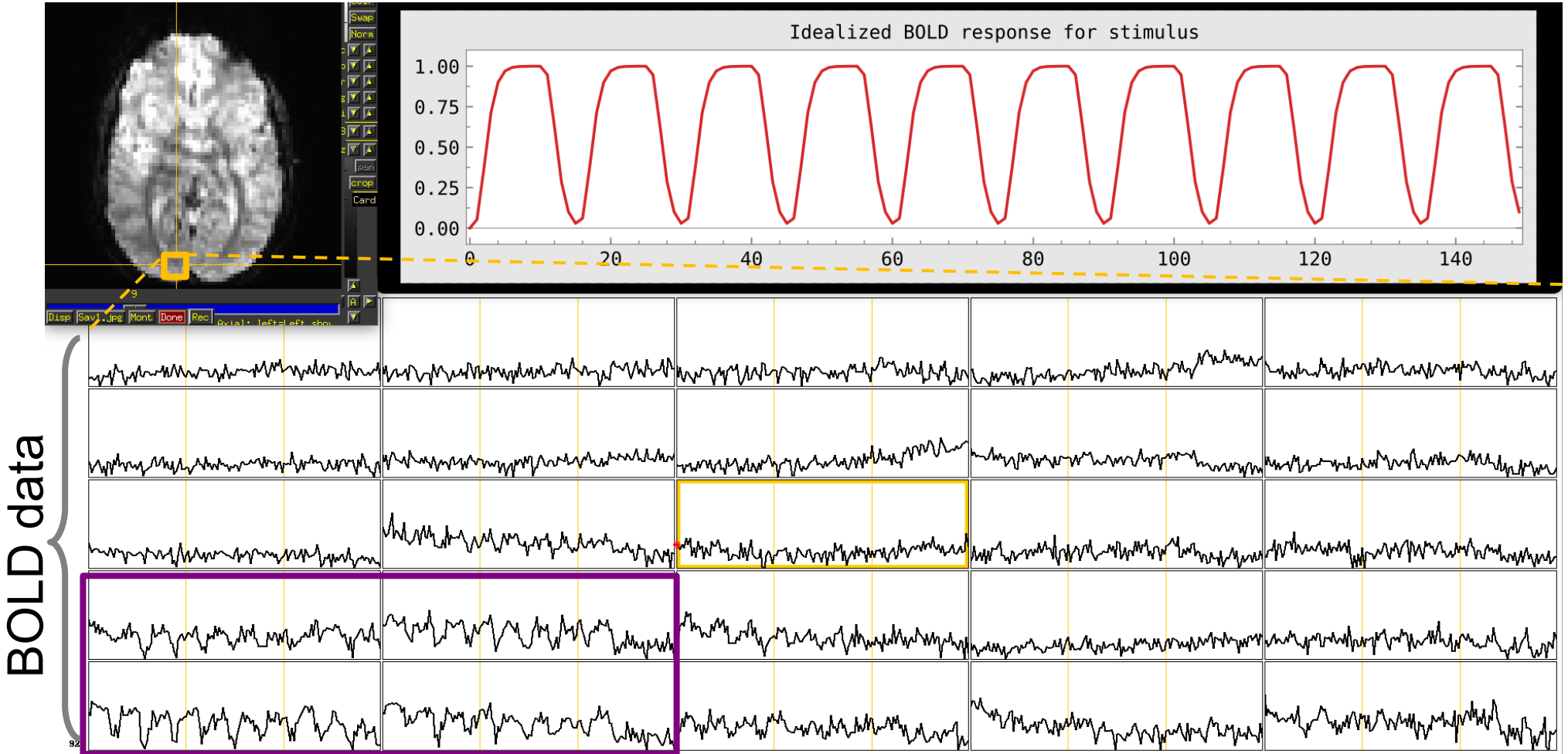

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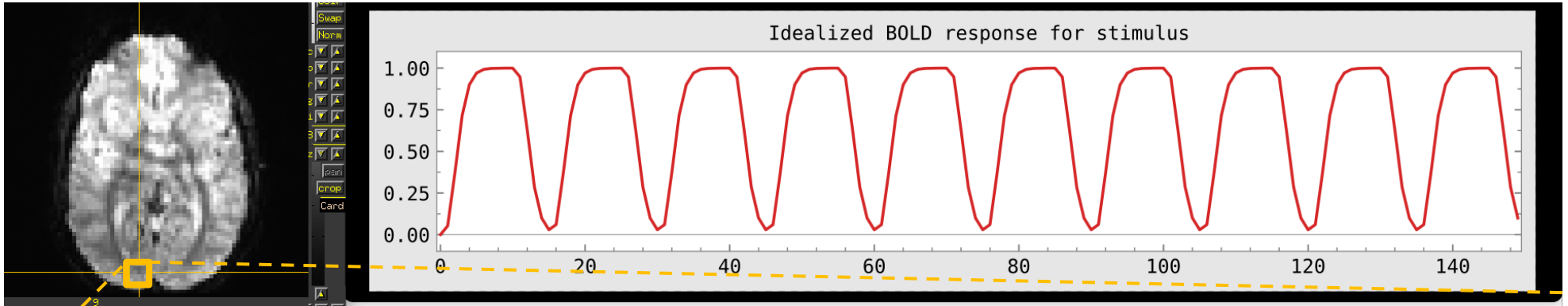

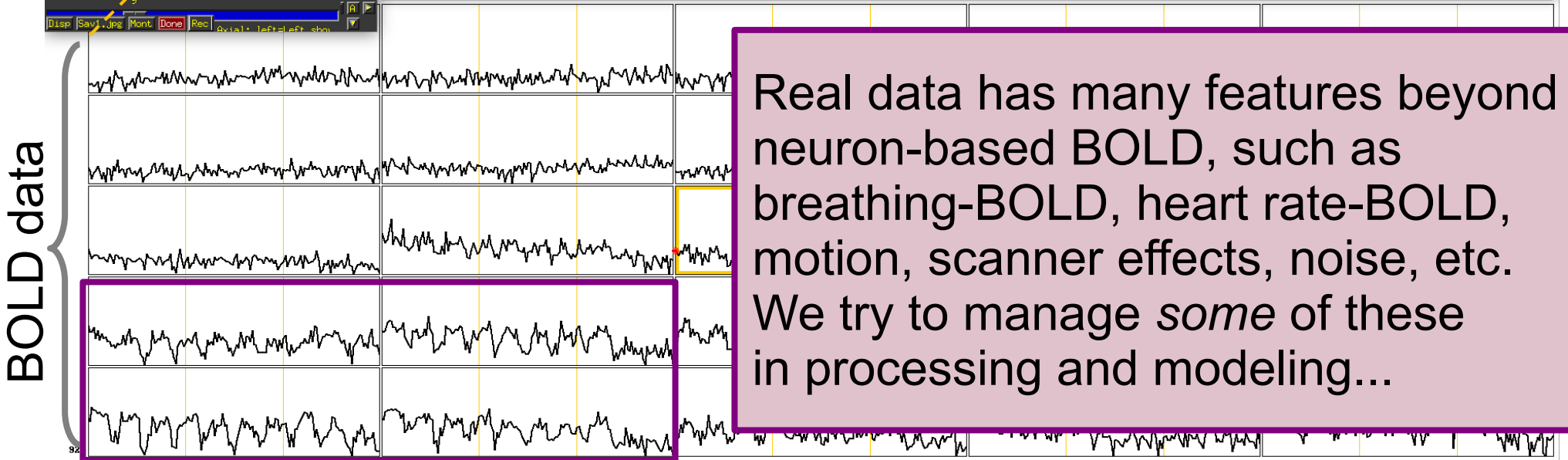

Real data has many features beyond neuron-based BOLD, such as breathing-BOLD, heart rate-BOLD, motion, scanner effects, noise, etc. We try to manage *some* of these in processing and modeling...

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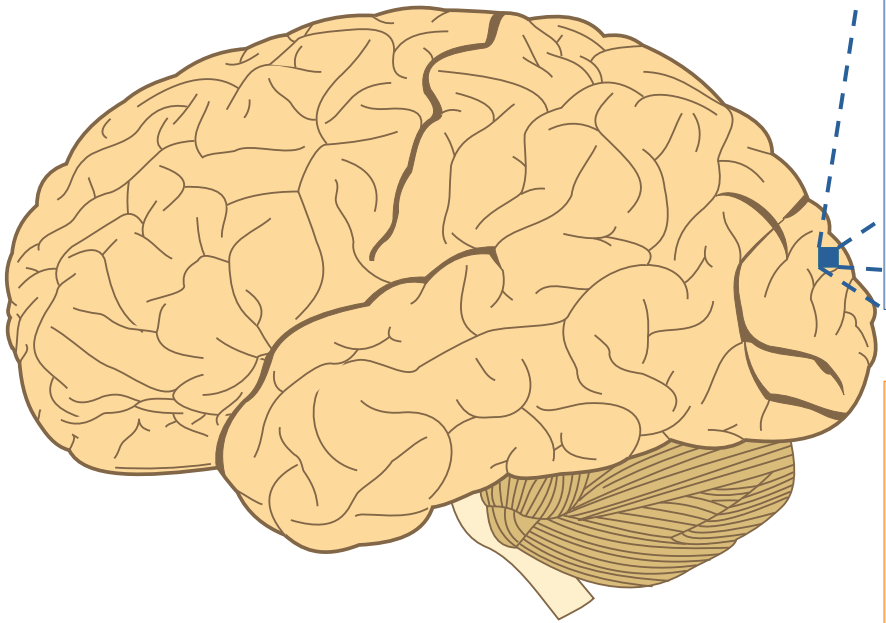

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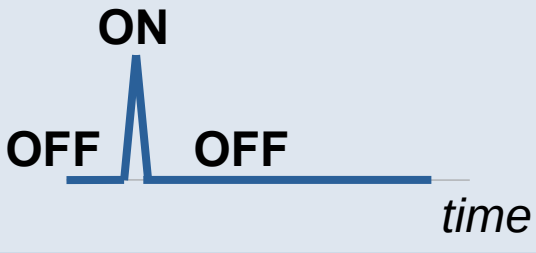

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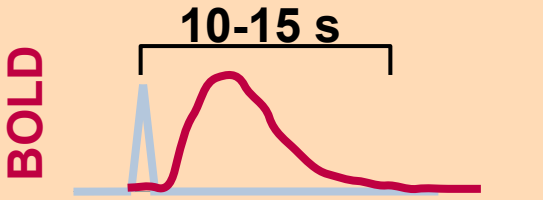

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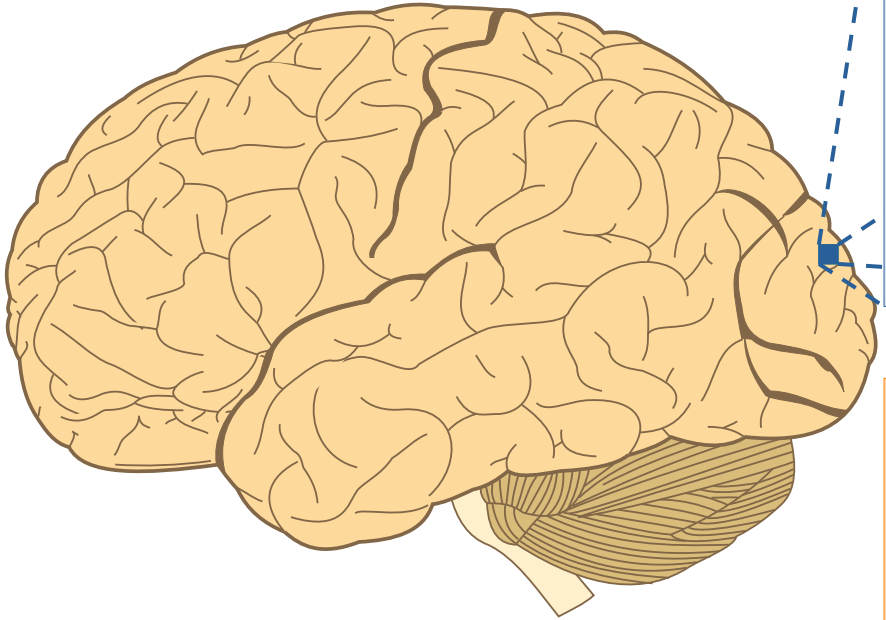

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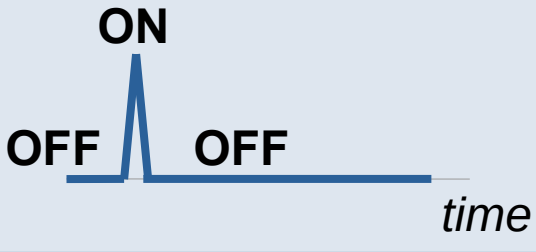

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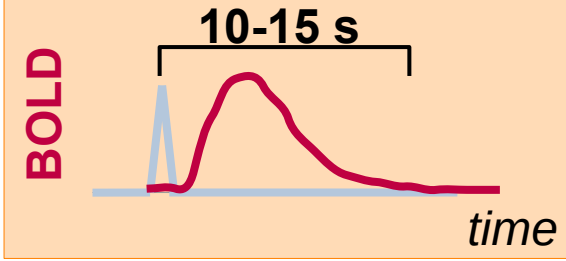

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Study function:
Provide stimuli,
measure BOLD
over time, &
find patterns that
match the stim
(= activity)

BOLD = Blood Oxygen Level-Dependent

Practical aspects of FMRI

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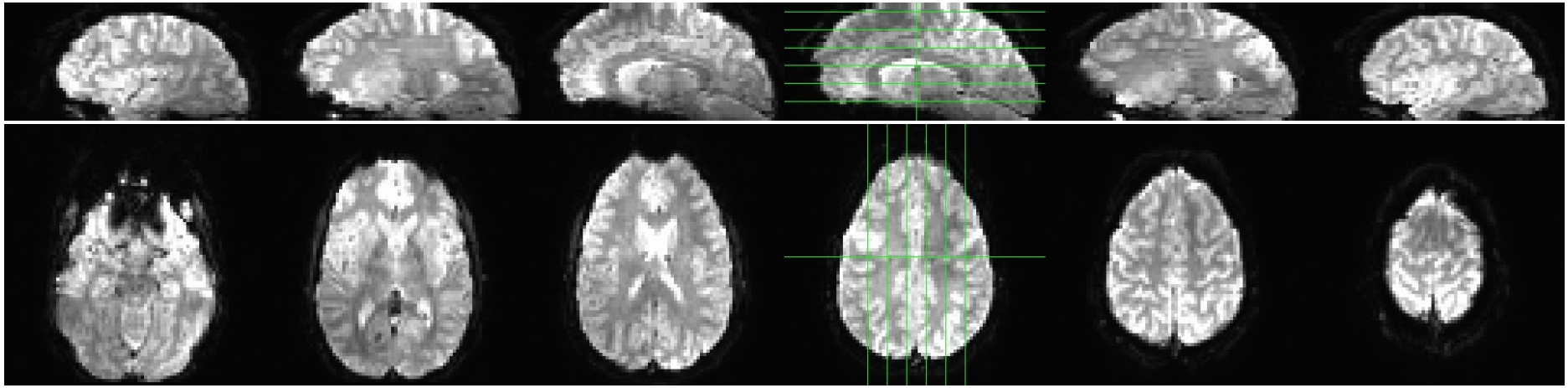
… of FMRI

Positive features of FMRI

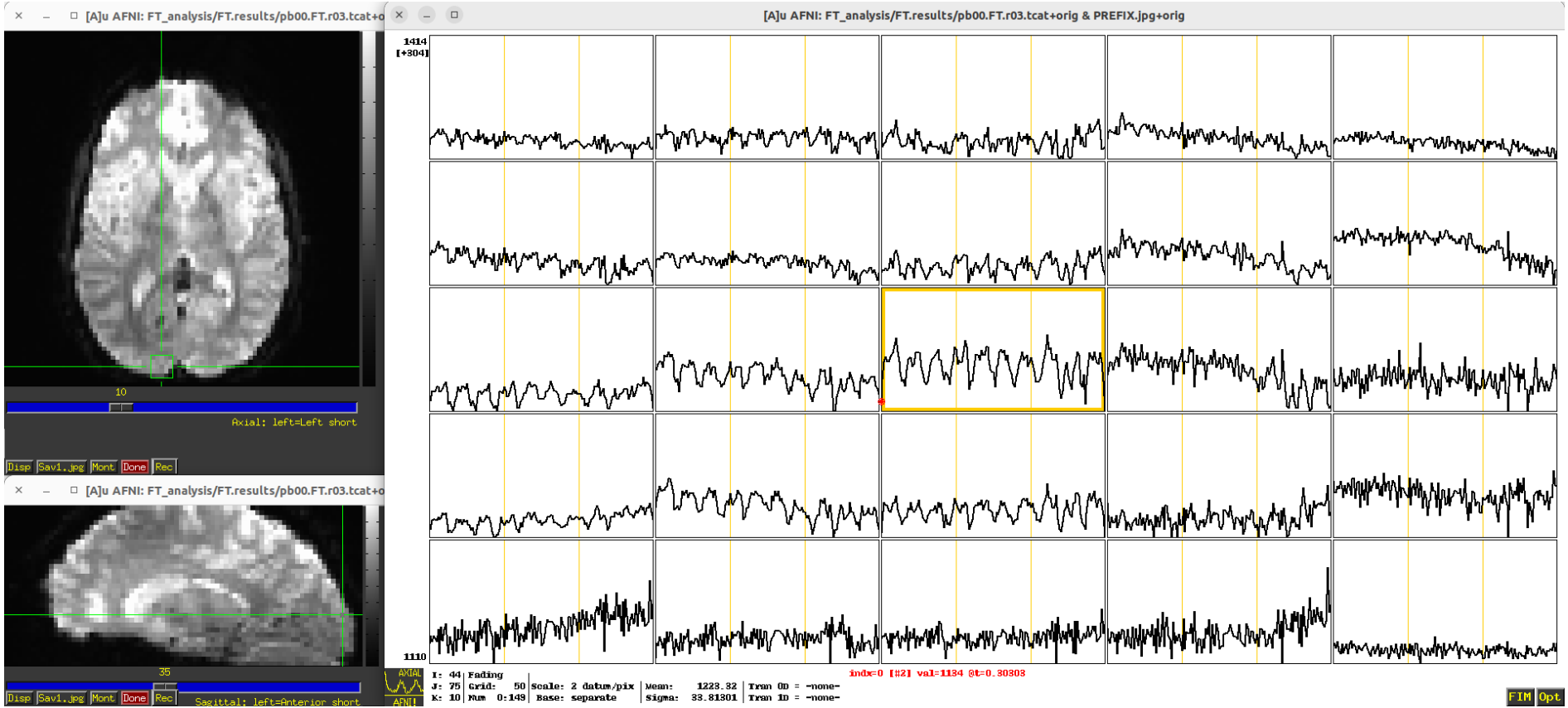
Positive features of FMRI

- Non-invasive and non-ionizing (just radio frequencies)
- Can have flexible task designs:
  reading, viewing images, finger tapping/button pushing, imagining, neurofeedback, movies, and much more
- Whole brain coverage, surface and interior:
  - 2-3 mm resolution (spatial specificity, ≈ cortical thickness)



Positive features of FMRI (cont'd)

- Reasonable temporal sampling --- whole volume every 1-2 s
- Data are noisy, but can still have useful signal-to-noise ratio (SNR)



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- Time series are very sensitive to participant motion (even <1 mm!)
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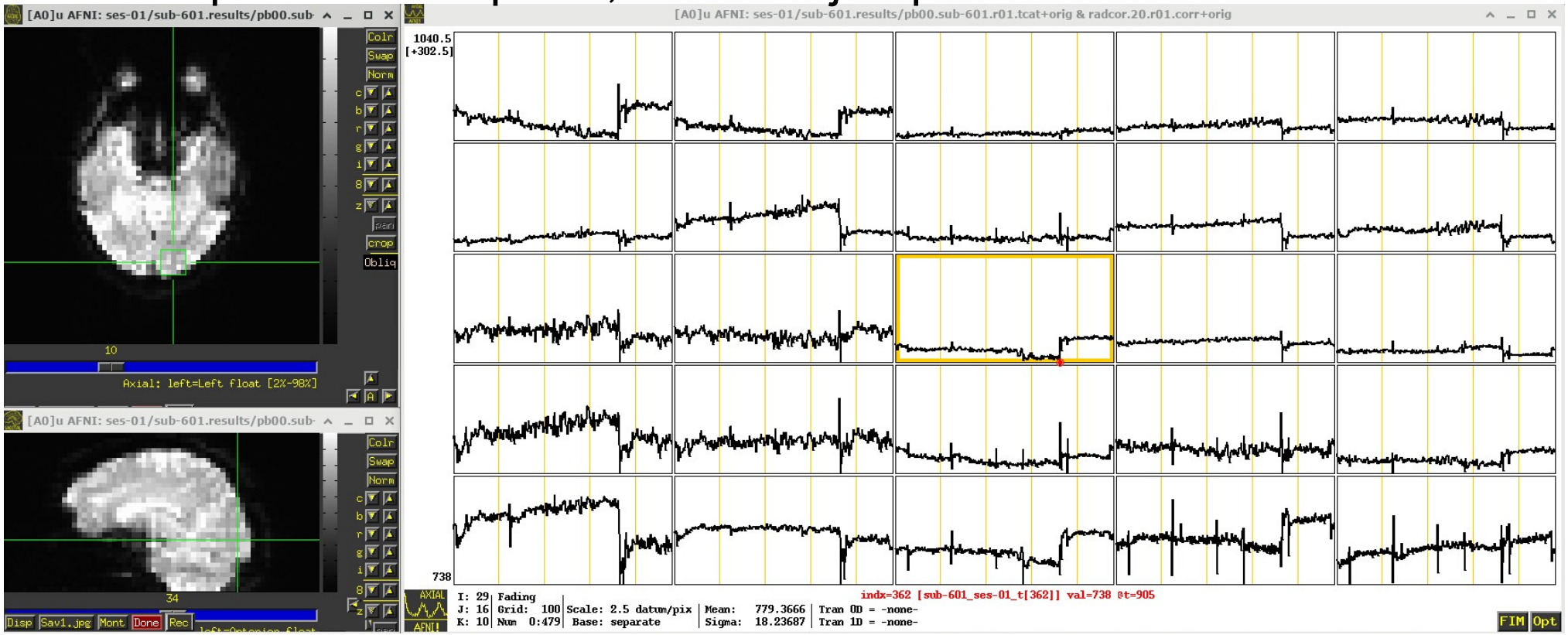

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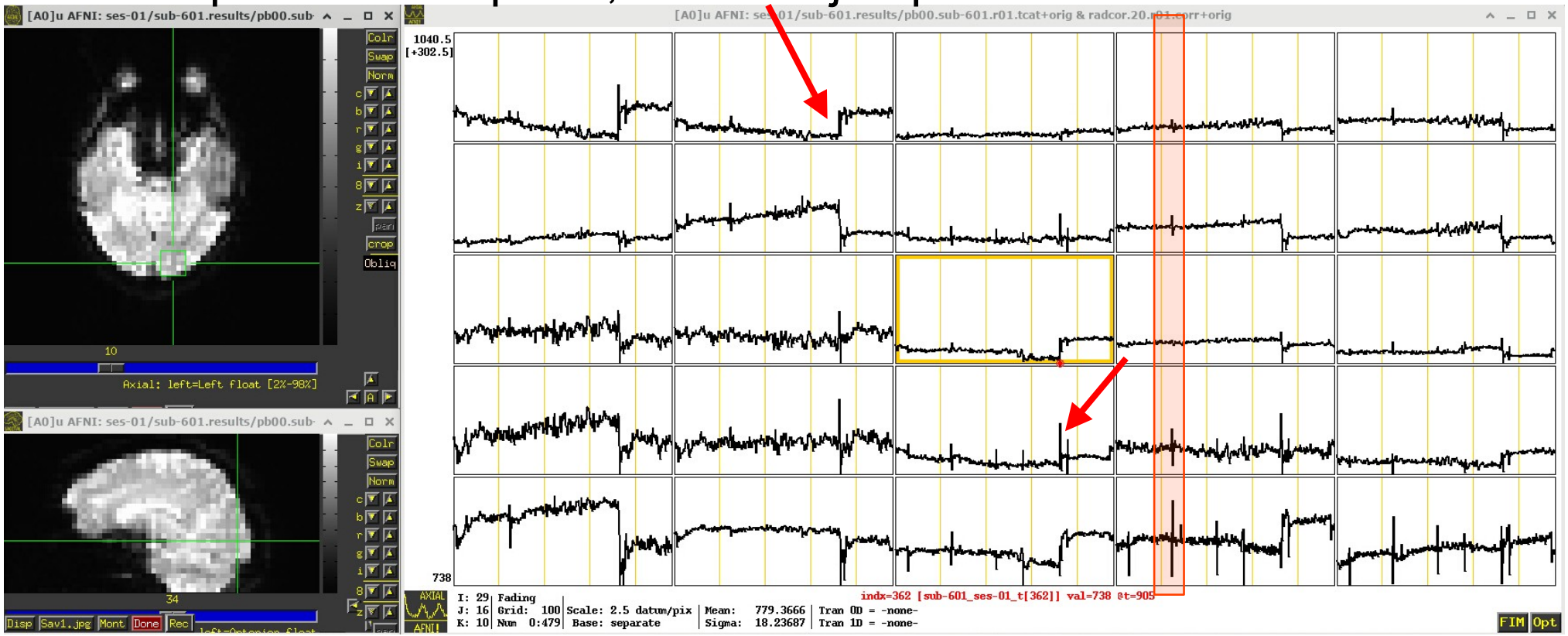

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- Spatial volumes are very sensitive to participant motion (<1 mm!)
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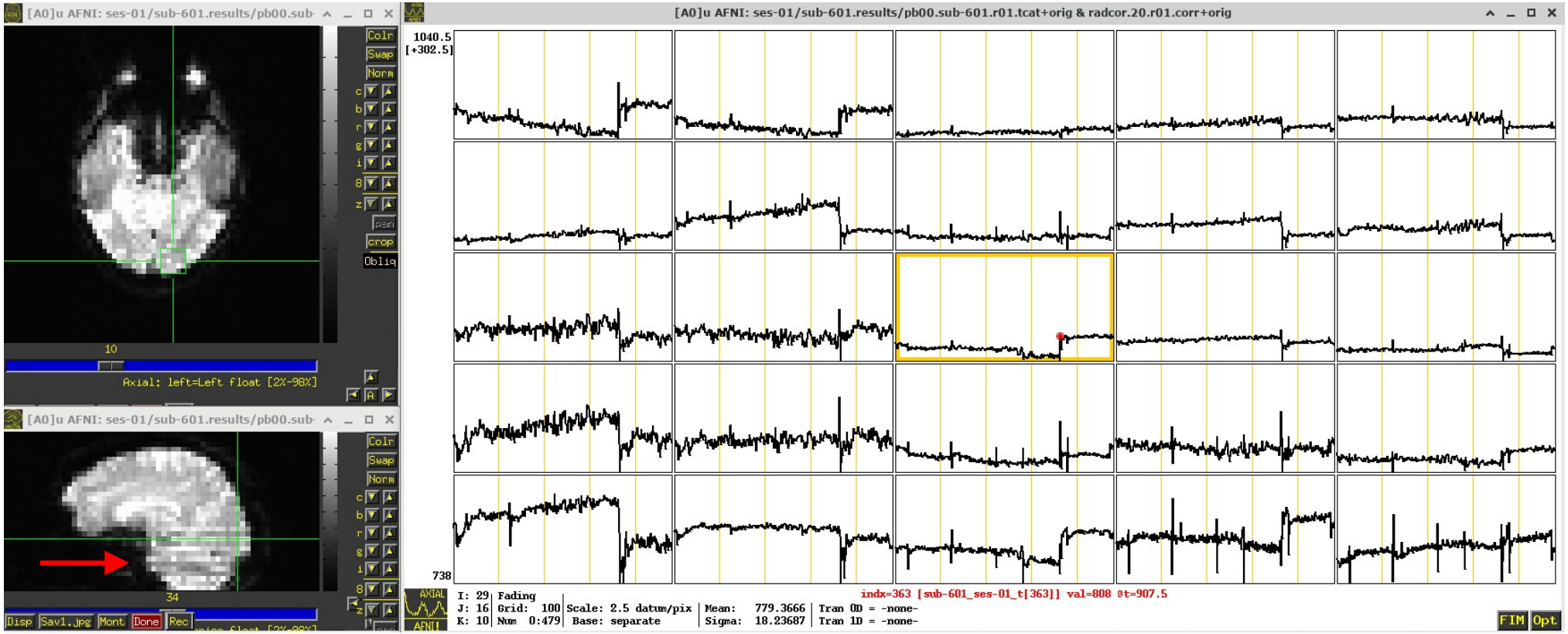

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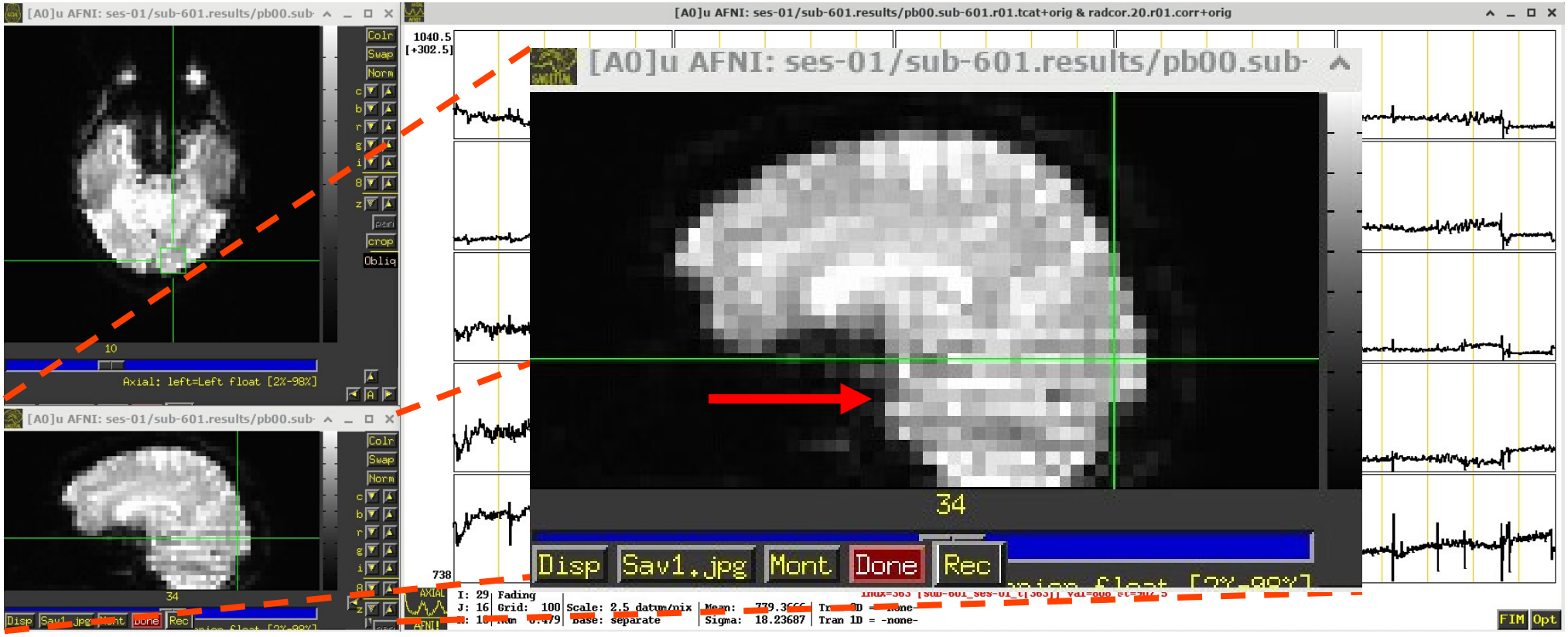
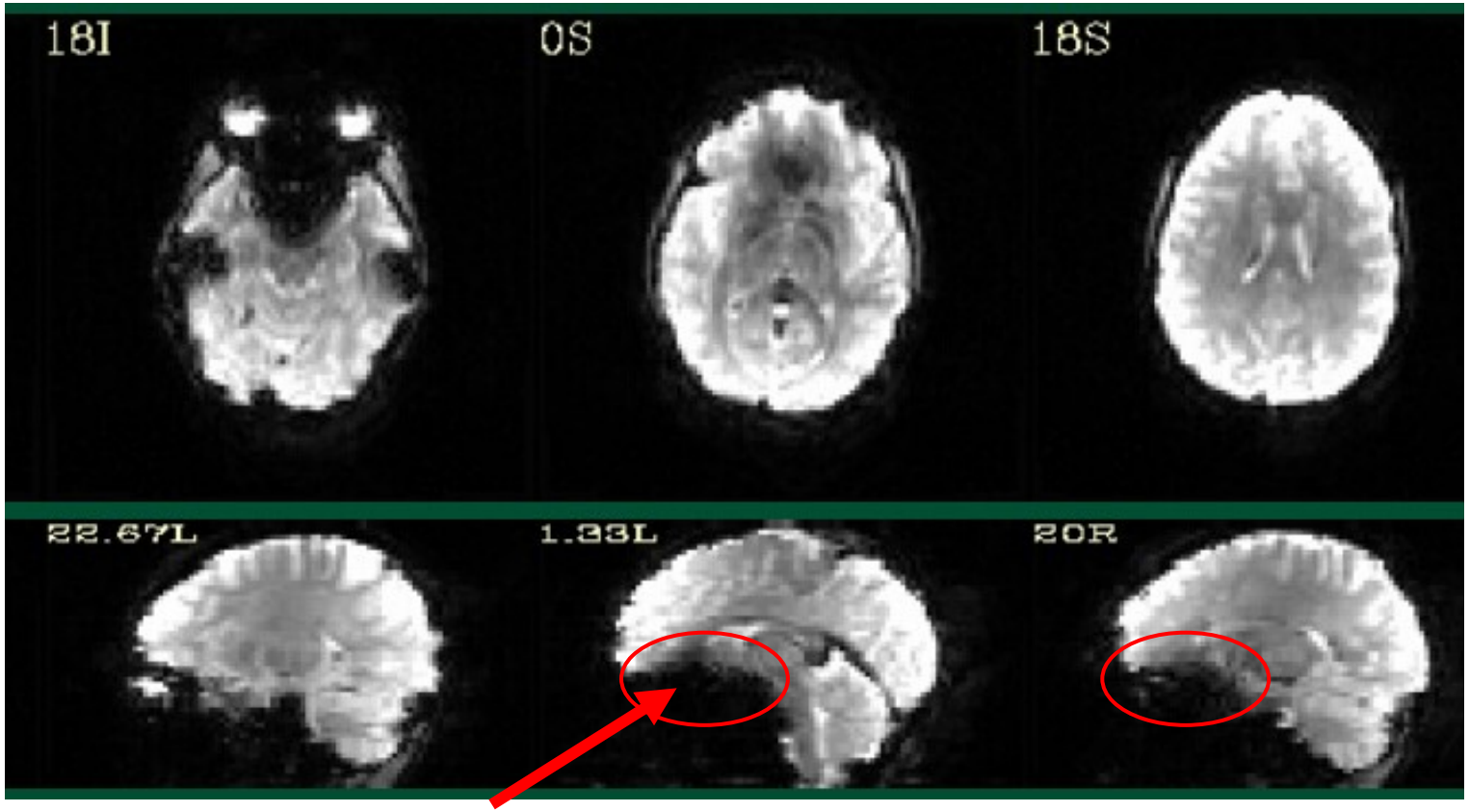


Challenging features of FMRI (cont'd)

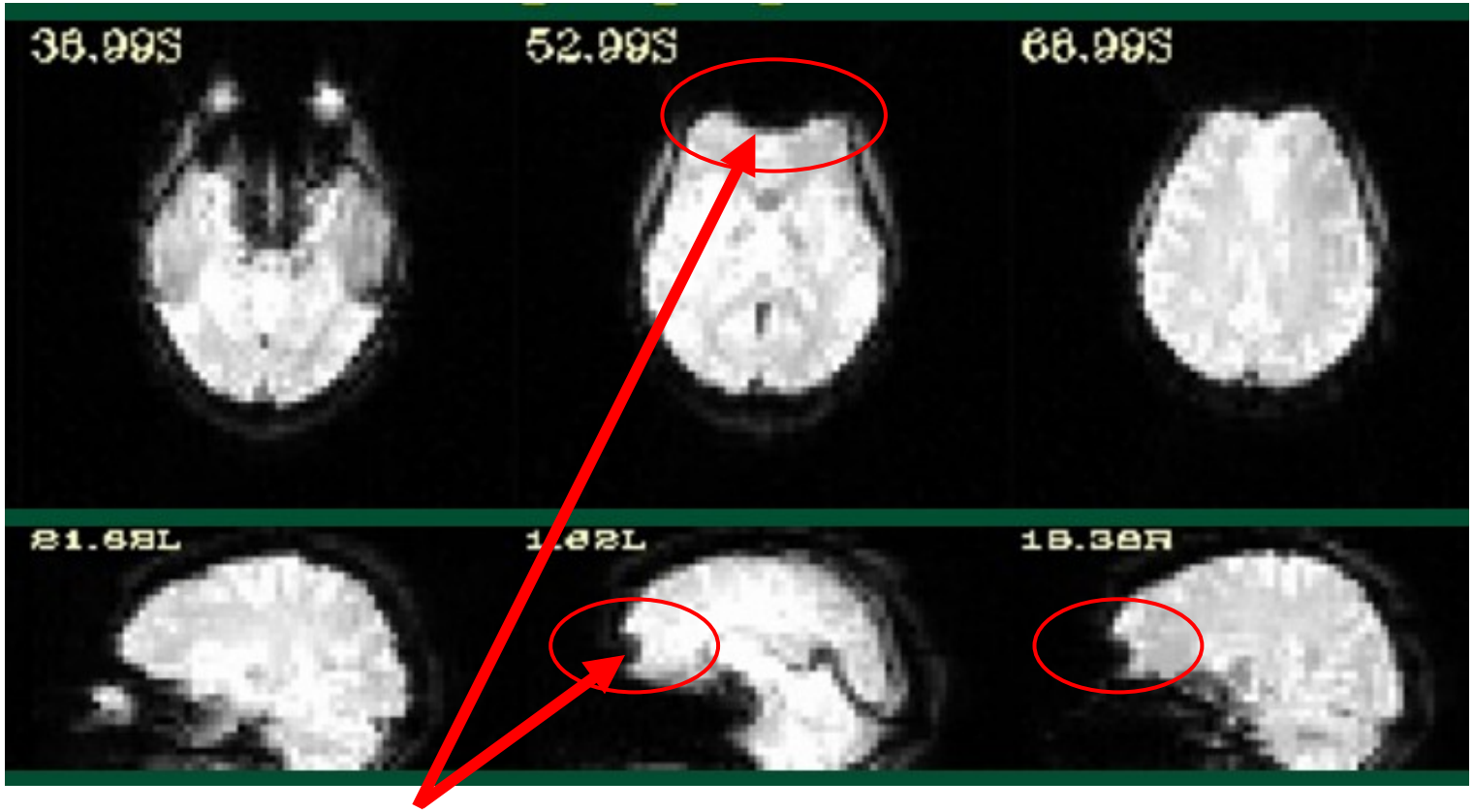
- Magnetic field effects can lead to signal loss:



There is brain here...

Challenging features of FMRI (cont'd)

- Magnetic field effects can lead to geometric distortion:



Brain appears to be "squashed in" here

Processing FMRI

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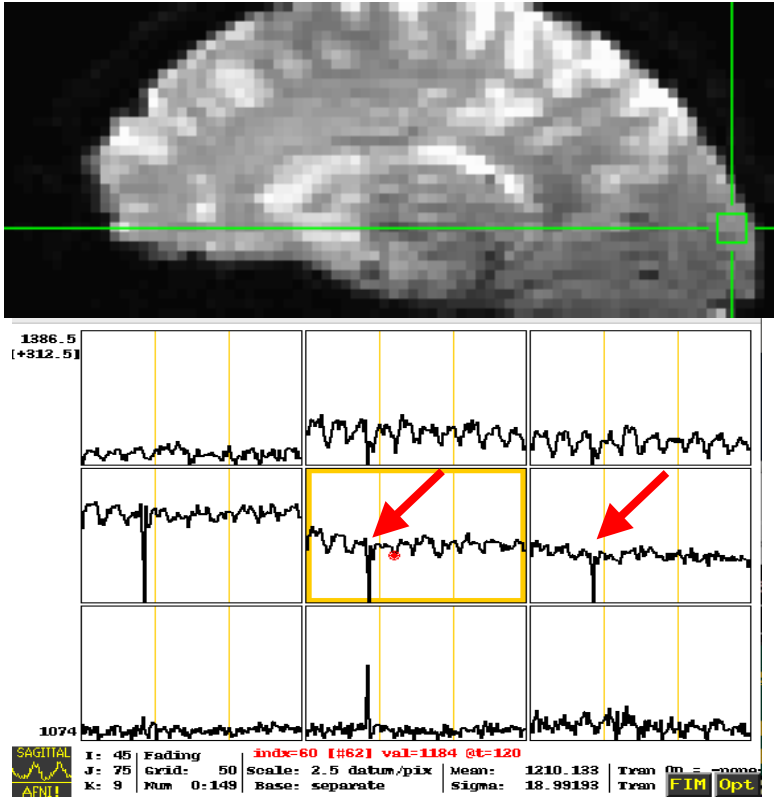
Processing steps FMRI

- **Motion correction** → align/register volumes across time
  - Estimate motion history, reduce spikes, reduce baseline changes

Before correction



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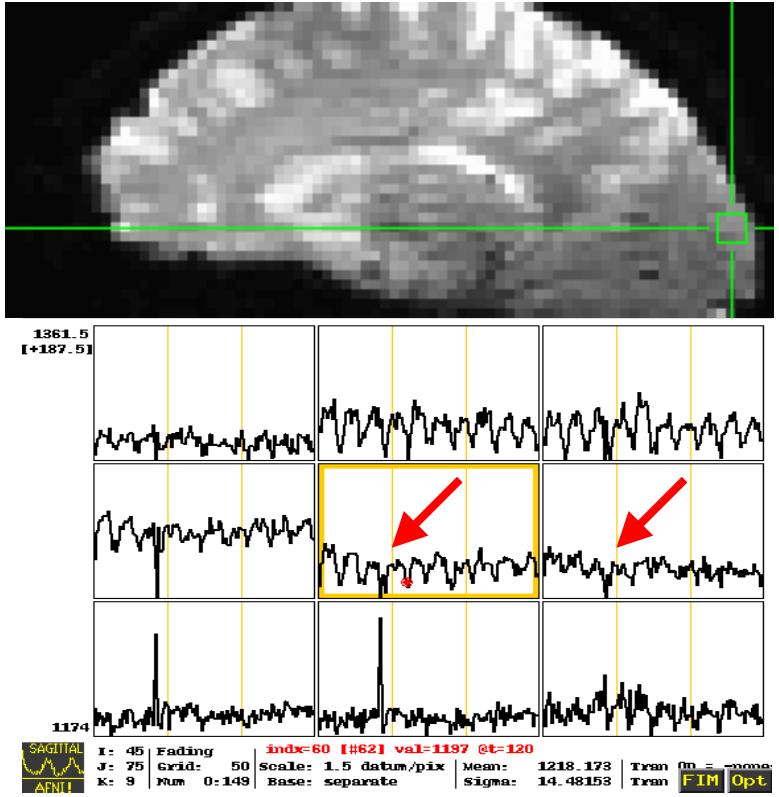
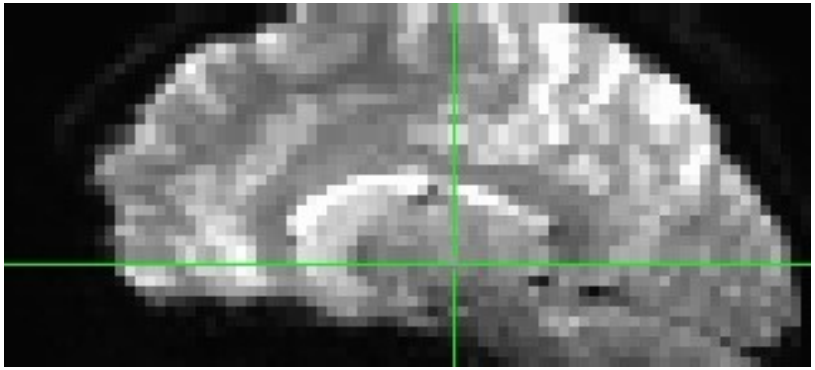


Processing steps FMRI

- **Align FMRI to anatomical** → spatial specificity and clarity
  - Reduce distortion, identify anatomy

FMRI



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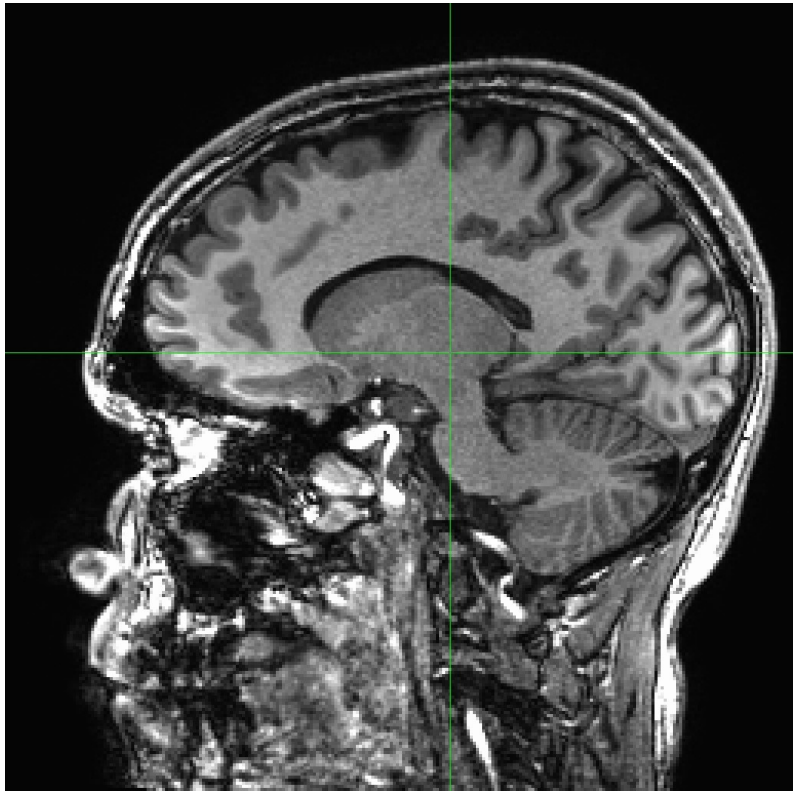

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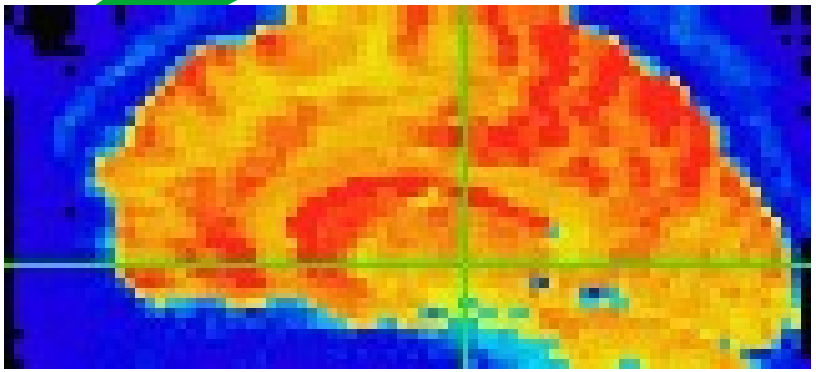

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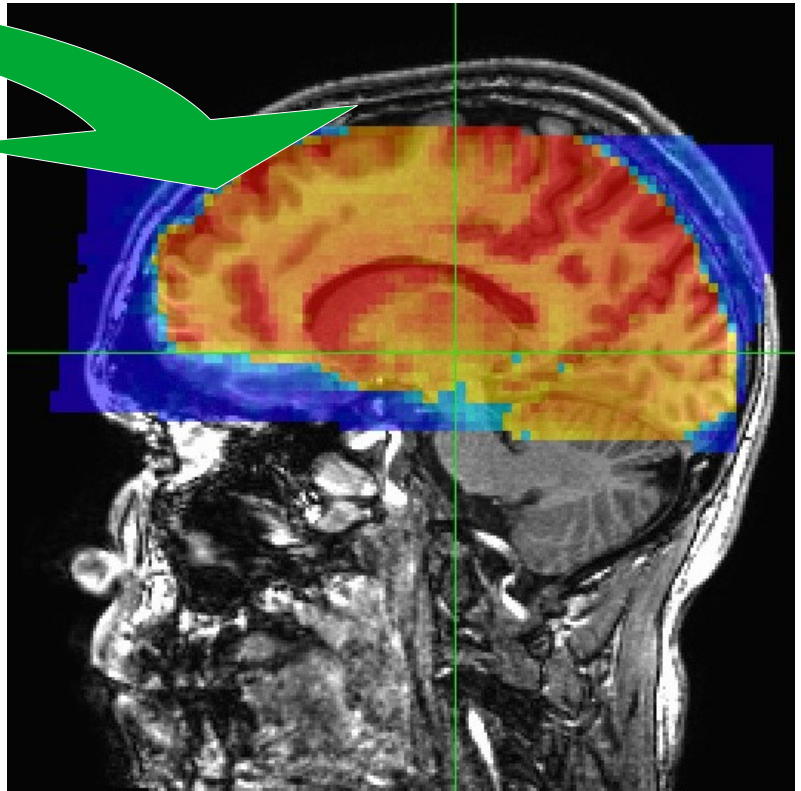

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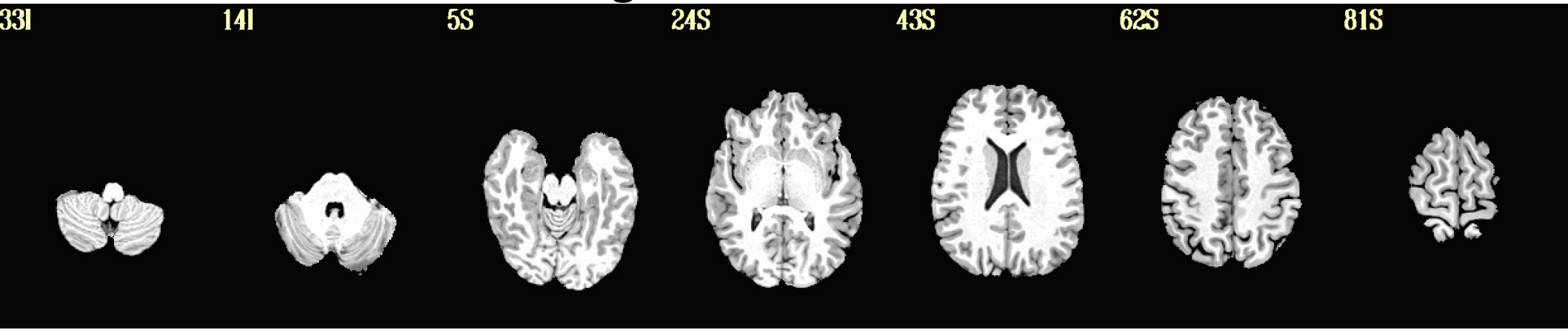
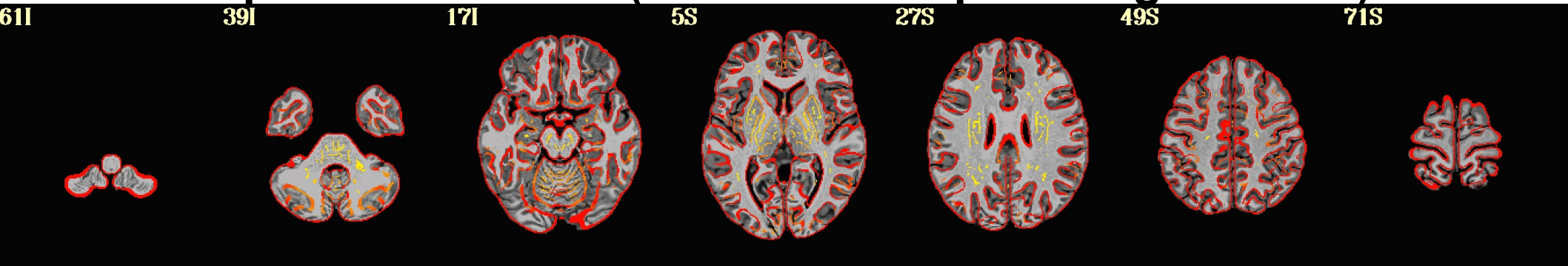
  - All brains have anatomical variability: shape, size, gyral patterns, etc.

Original anatomicals



Warped anatomicals (reference template edges in red)



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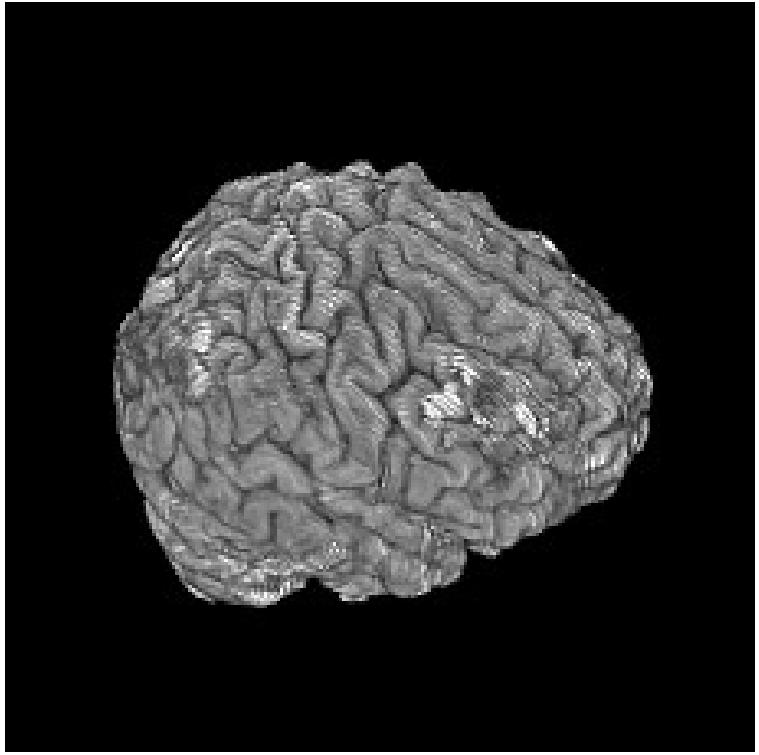
Nonlinear (diffeomorphic) warping starts with bulk alignment, and then refines locally.
Primary goal is to match sulcal and gyral features.



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  - Necessary approximations and assumptions
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- *… but it is as just as important to keep visualizing, checking, evaluating and understanding our data throughout all its stages*