Neuroimaging in Multiple Sclerosis

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Personal Background

2004 - 2008

2009 - 2014

2014 - 2017
Structural MRI

- 3D array of voxels
- Grayscale intensities provide contrast between different tissue types
- Standard size approximately 256 x 256 x 176 voxels

Axial slice of a T1 image
Structural MRI in Multiple Sclerosis

- Used to study lesion accumulation in brain and spinal cord

MS lesion dynamics

Inflammation
Structural MRI in Multiple Sclerosis

- Used to study lesion accumulation in brain and spinal cord

MS lesion dynamics

Inflammation → Tissue damage and demylenation
Structural MRI in Multiple Sclerosis

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**MS lesion dynamics**

- Inflammation
- Tissue damage and demyelination
- Tissue repair and remyelination
Structural MRI in Multiple Sclerosis

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**MS lesion dynamics**

- Inflammation
- Tissue damage and demylenation
- Tissue repair and remylenation
Quantifying MS Treatment Efficacy

- Do chronic lesions show evidence of repair in response to treatment?
Quantifying MS Treatment Efficacy

- Do chronic lesions show evidence of repair in response to treatment?

- Initial comparison of average chronic lesion intensity before and after treatment was highly significant.
Quantifying MS Treatment Efficacy

- Do chronic lesions show evidence of repair in response to treatment?

  ![Brain scans](image)

- **Statistical challenges**: confounding, automatic lesion segmentation, image preprocessing
Preprocessing README

- **12 steps** before analysis
- Current analysis is a **t-test!**
- Each induces errors/uncertainty that is not easy to account for
- Typically, researchers **ignore preprocessing uncertainty**
Registration Error

- Image alignment sometimes off by one slice

Pre-treatment:

Post-treatment:
Registration Error

Pre-treatment:

Post-treatment:

Leads to bias in favor of a treatment effect!
Registration Error

Pre-treatment:

Post-treatment:
Registration Error

Pre-treatment:

Post-treatment:
Moving Forward

- Many opportunities for statisticians to contribute in meaningful ways to neuroimaging research
  - Need more sophisticated methods to account for preprocessing errors
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- Steep learning curve (anatomy, physics, engineering)
Moving Forward

• Many opportunities for statisticians to contribute in meaningful ways to neuroimaging research
  • Need more sophisticated methods to account for preprocessing errors
  • Steep learning curve (anatomy, physics, engineering)
  • Any methods/models we build must be fast with high-quality, well-tested software
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Happy 75\textsuperscript{th} Anniversary!