

The role of neuroimaging beyond T1-weighted MRI in the diagnosis and prediction of neuropsychiatric disorders

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26.10.23



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Overview

1. Background: Defining the scope of the lecture.
2. State-of-the-art: How is neuroimaging beyond T1-weighted MRI currently being used with respect to neuropsychiatric disorders.
3. The future: Challenges and opportunities in using neuroimaging for predicting neuropsychiatric disorders moving forward.



Background

- The role of neuroimaging beyond T1-weighted MRI in the diagnosis and prediction of neuropsychiatric disorders



Background

- The role of **neuroimaging** beyond T1-weighted MRI in the diagnosis and prediction of neuropsychiatric disorders



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Bert from FreeSurfer 7.3

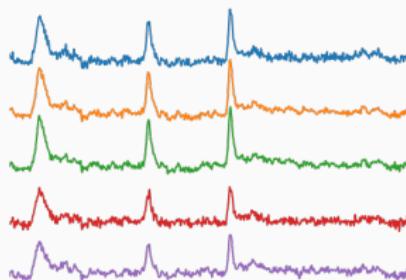


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Bert from FreeSurfer 7.3



Sample from the MNE library

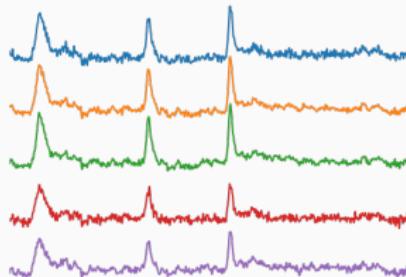


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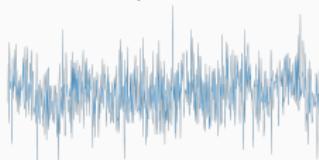
- The role of neuroimaging beyond T1-weighted MRI in the diagnosis and prediction of neuropsychiatric disorders



Bert from FreeSurfer 7.3



Sample from the MNE library



Sample from Tremlay et al., 2016

Tremblay, R., Lee, S., & Rudy, B. (2016). GABAergic interneurons in the neocortex: from cellular properties to circuits. *Neuron*, 91(2), 260-292

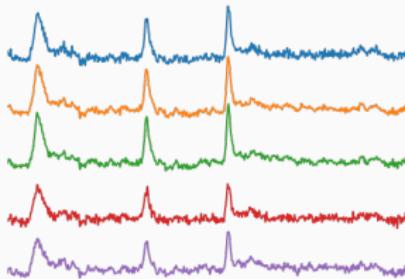


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Sample from Tremblay et al., 2016



Meta Quest Pro

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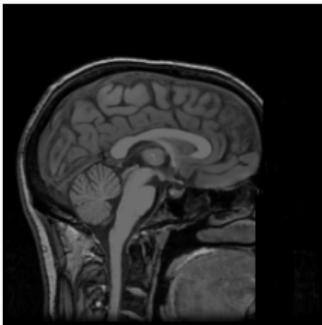


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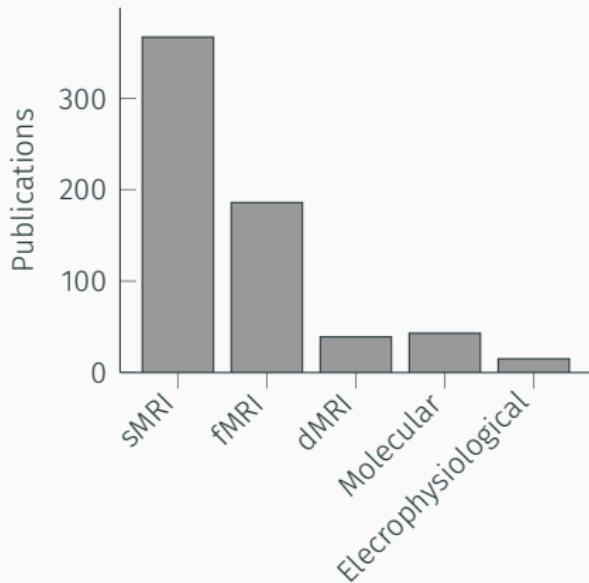


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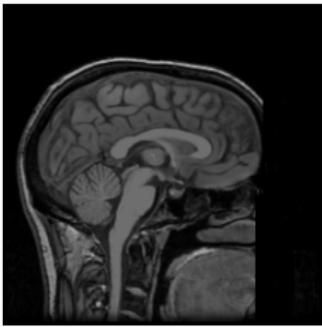


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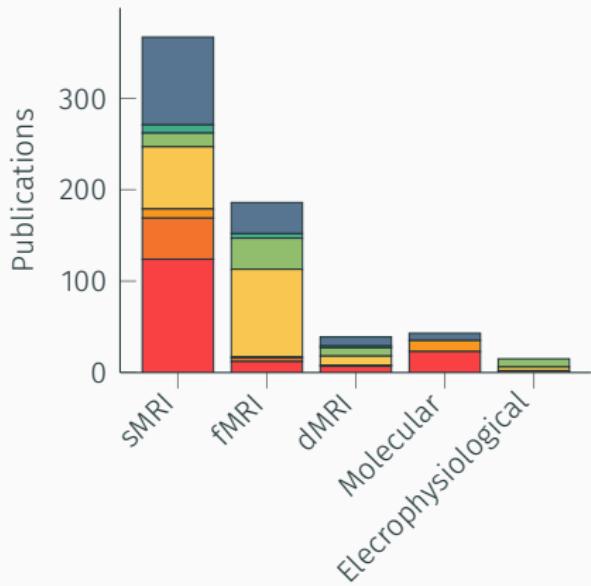


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Alzheimer's disease and other
causes of dementia

Multiple Sclerosis

Parkinson's Disease



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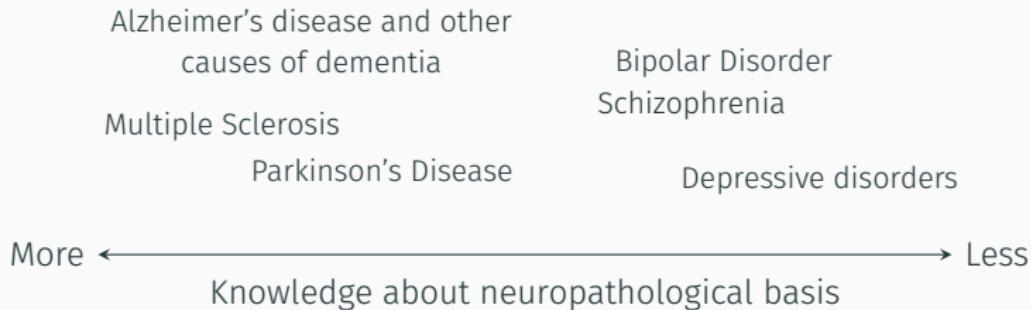
Bipolar Disorder
Schizophrenia

Depressive disorders



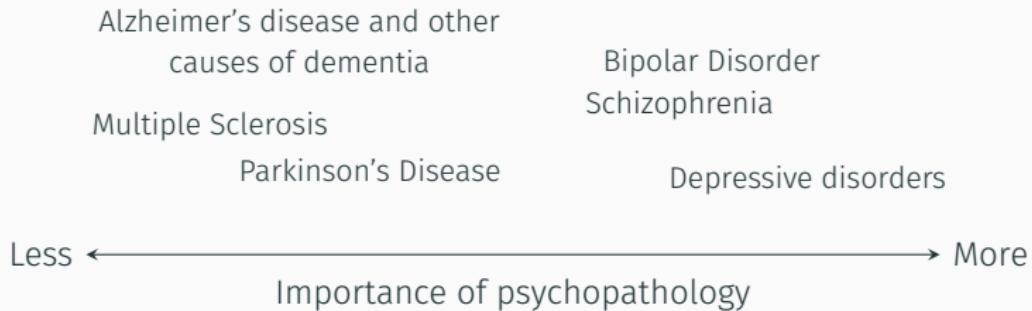
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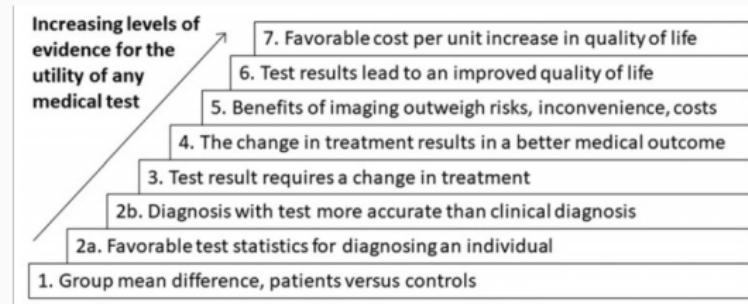


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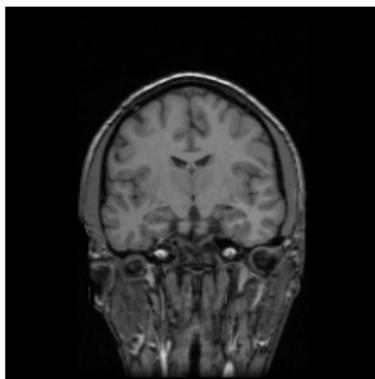


Vogel & Black (2024)



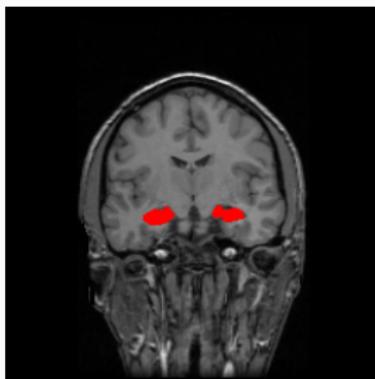
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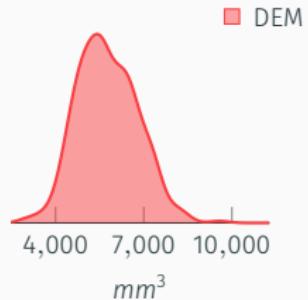
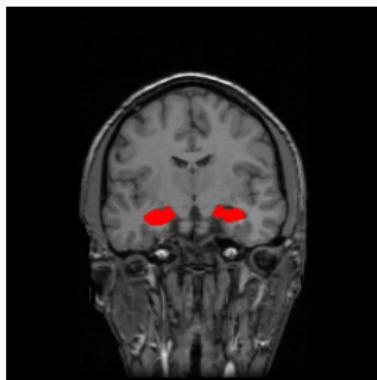
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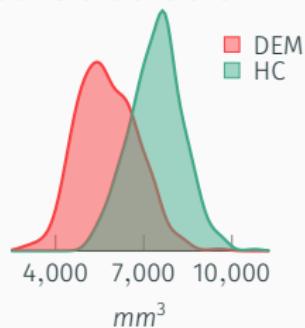
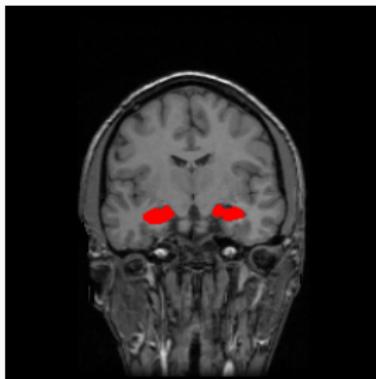
Data from ADNI

Jack Jr, C. R., Bernstein, M. A., Fox, N. C., Thompson, P., Alexander, G., Harvey, D., ... & Weiner, M. W. (2008). The Alzheimer's disease neuroimaging initiative (ADNI): MRI methods. Journal of Magnetic Resonance Imaging: An Official Journal of the International Society for Magnetic Resonance in Medicine, 27(4), 685-691



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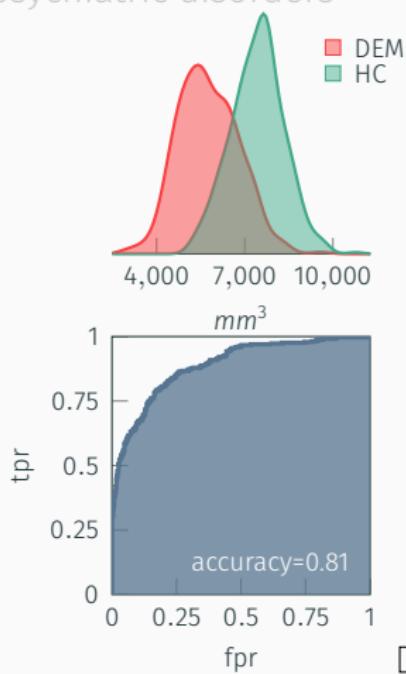
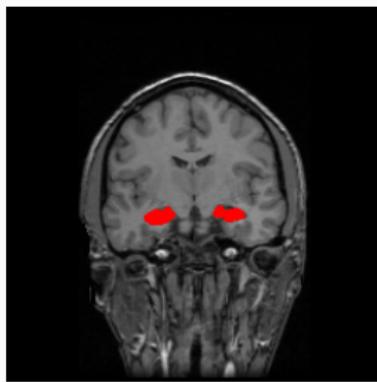
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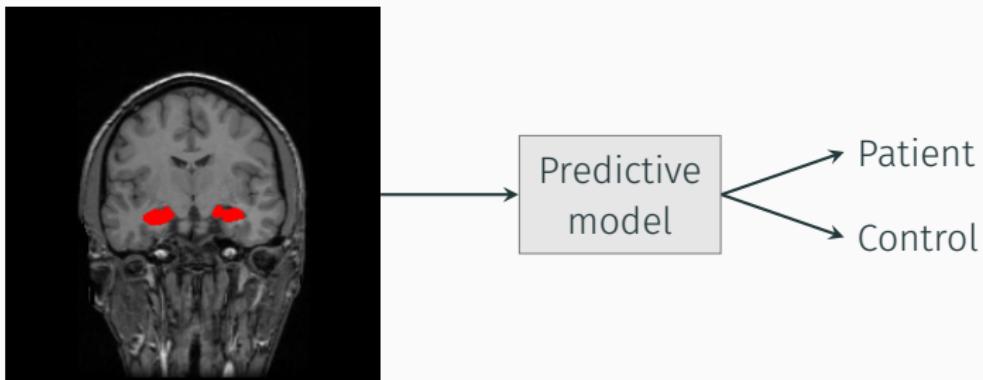
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The current roles of neuroimaging modalities

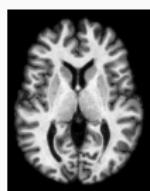


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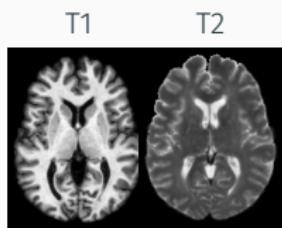
Other structural MRI modalities (T2, FLAIR)



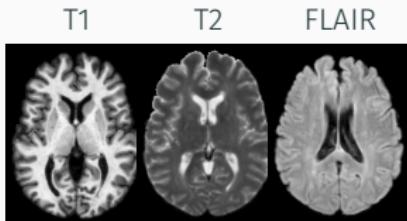
T1



Other structural MRI modalities (T2, FLAIR)



Other structural MRI modalities (T2, FLAIR)

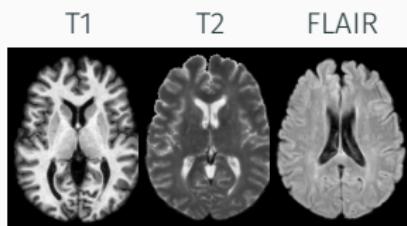


Adapted from Shoeibi et al., 2021

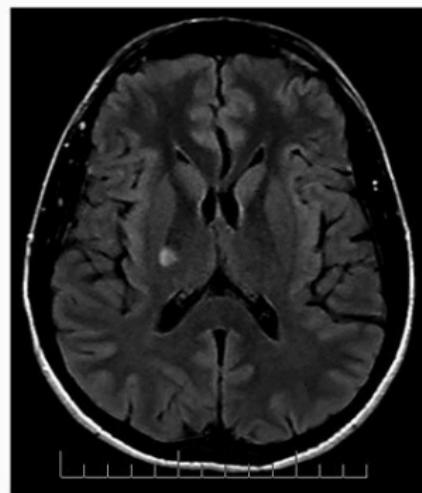
Shoeibi, A., Khodatars, M., Jafari, M., Mordian, P., Rezaei, M., Alizadehsani, R., ... & Acharya, U. R. (2021). Applications of deep learning techniques for automated multiple sclerosis detection using magnetic resonance imaging: A review. *Computers in Biology and Medicine*, 136, 104697.



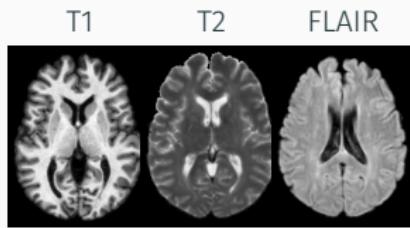
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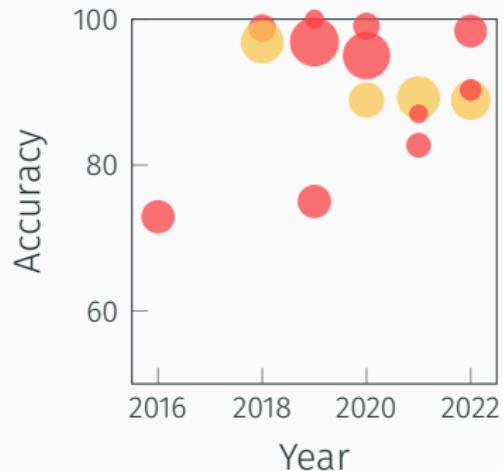
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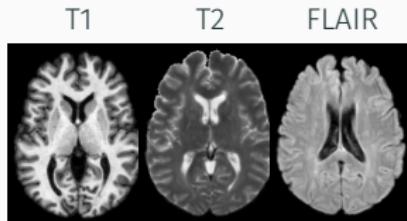
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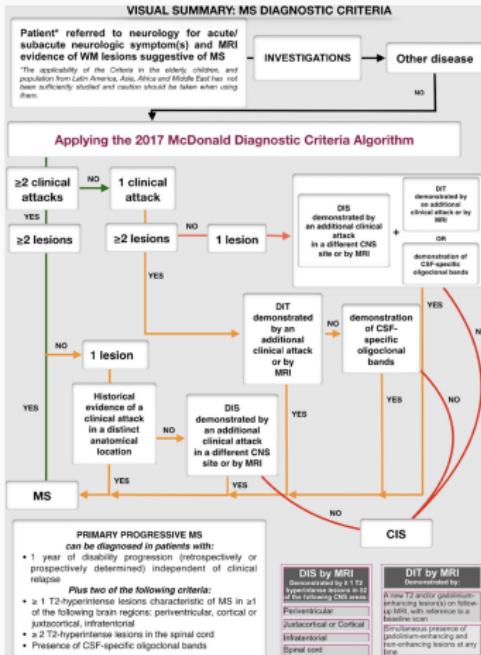
Adapted from Shoeibi et al., 2021



Other structural MRI modalities (T2, FLAIR)



Adapted from Shoeibi et al., 2021



De Angelis et al., 2019

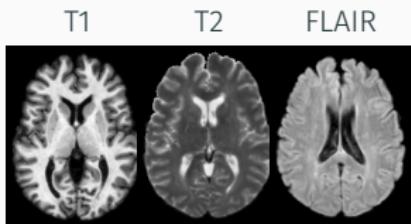


De Angelis, F., Brownlee, W. J., Chard, D. T., & Trip, S. A. (2019). New MS diagnostic criteria in practice. Practical Neurology, 19(1), 64-67



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Other structural MRI modalities (T2, FLAIR)

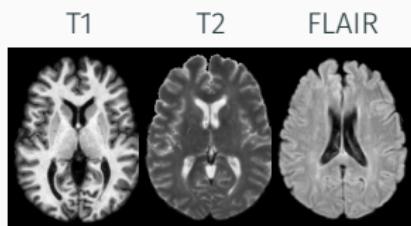


T2 use-case in PD: WML/Motoric problems

Adapted from Shoeibi et al., 2021



Other structural MRI modalities (T2, FLAIR)



Adapted from Shoeibi et al., 2021

T2 use-case in dementia: WML/Subtyping



Diffusion MRI (DTI?)



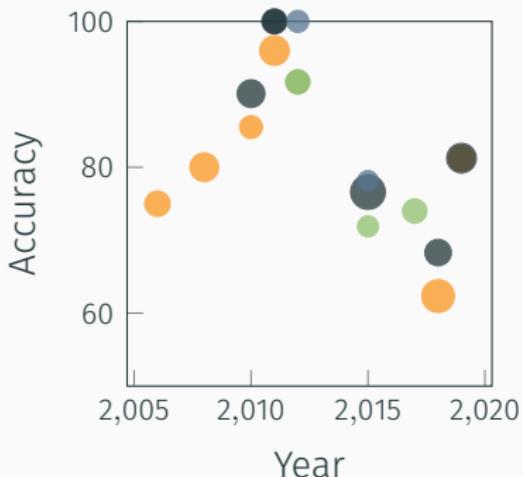
Explanation of DTI



Diffusion MRI (DTI?)



Explanation of DTI



Diffusion MRI (DTI?)



Explanation of DTI

Lack of prediction studies



Diffusion MRI (DTI?)



Explanation of DTI

DTI use case 1



Diffusion MRI (DTI?)



Explanation of DTI

DTI use case 2



Molecular imaging (PET/SPECT)



Explanation of PET



Molecular imaging (PET/SPECT)



Explanation of PET

PET/SPECT in meta-analysis



Molecular imaging (PET/SPECT)



Explanation of PET

PET in AD



Molecular imaging (PET/SPECT)



Explanation of PET

SPECT in PD



Molecular imaging (PET/SPECT)



Explanation of PET

Mental disorders?



Functional Magnetic Resonance Imaging (fMRI)



Explanation of fMRI



Functional Magnetic Resonance Imaging (fMRI)



Explanation of fMRI

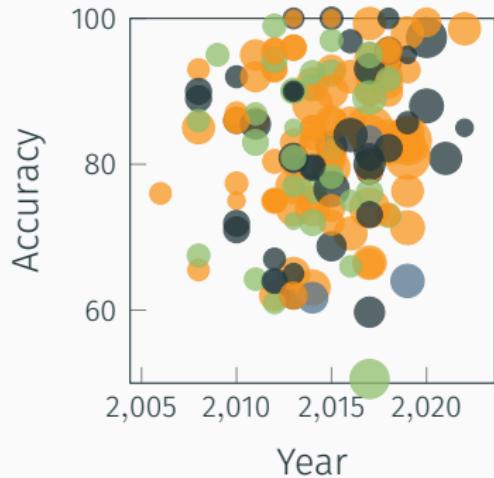
Task vs rest



Functional Magnetic Resonance Imaging (fMRI)



Explanation of fMRI



Functional Magnetic Resonance Imaging (fMRI)



Explanation of fMRI

fMRI use-case 1



Functional Magnetic Resonance Imaging (fMRI)



Explanation of fMRI

fMRI use-case 2



Electrophysiological mapping (EEG/MEG)



Alzheimer's disease

- Pathological changes are apparent in a variety of neuroimaging modalities, to a level which can support individual diagnostics.
-

Method	Sensitivity	Specificity	Accuracy	Pros	Cons	Refs.
MRI	80–95%	55–98%	89–97%	Spatial resolution	Temporal resolution, MR exposure	[36,105–108]
FDG-PET	43–100%	57–100%	50–100%	Clear image	FDG injection	[44,47,57,63,109]
fNIRS	82–94%	72–88%	50–90%	High speed, portability	Spatial resolution	[110,111]
fMRI	84–94%	68–91%	75–93%	Spatial resolution	Not portable/Expose MR	[78,80,112]
EEG	35–88%	82–100%	62–92%	High speed, portability	Spatial resolution	[99,101,103,113,114]



Multiple sclerosis

- Lesions apparent in T2-weighted and FLAIR images are used clinically to support diagnostics.
- DTI reveals group-wise differences also in apparently healthy white matter.
- A stereotypical trajectory that has been observed in patients using fMRI is heightened activation up until a point where it is no longer possible to compensate for structural damage, after which the activation generally resides.

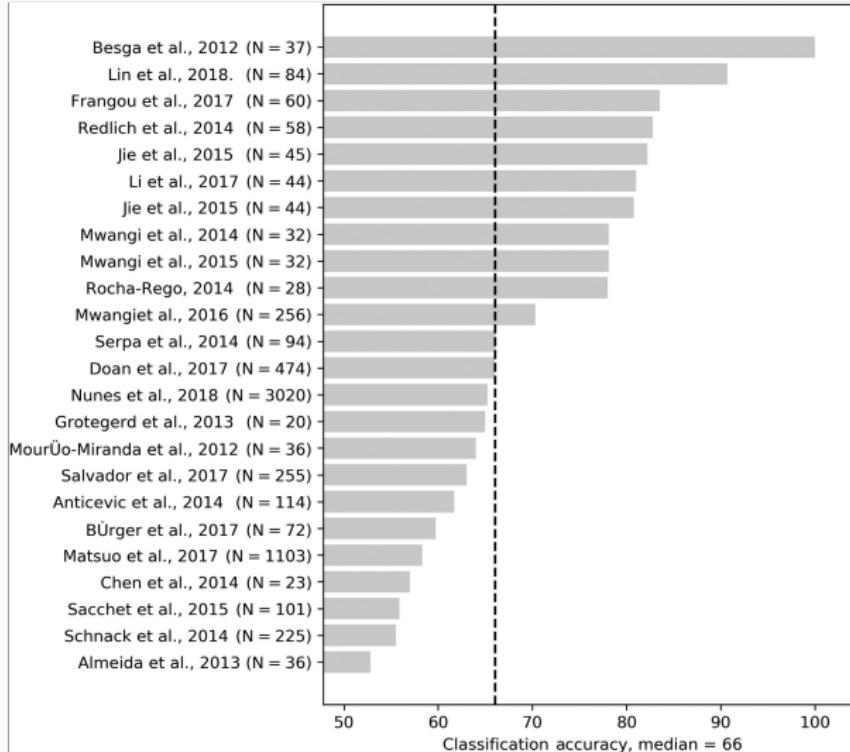


Parkinson's disease

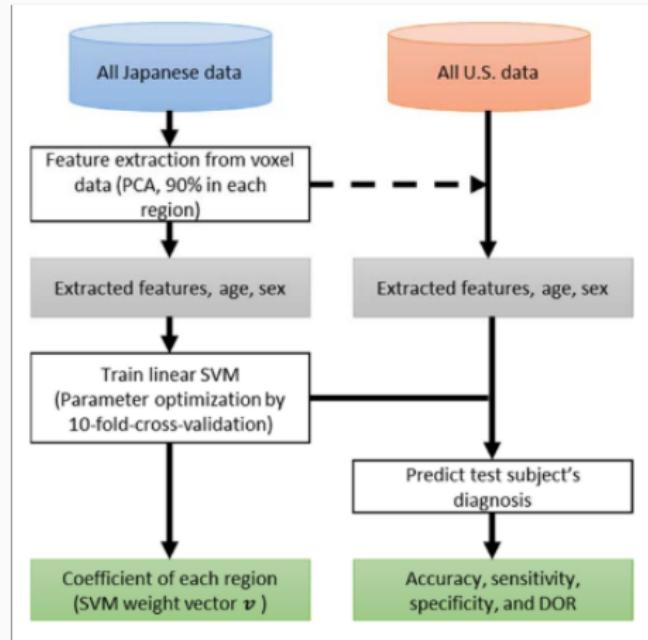
- DTI has been shown useful for classifying patient subtypes and correlates with motor and cognitive function in PD patients.
- fMRI has been shown useful for differentiating patient subtypes, supporting the notion of PD subtypes as network models.
- PET imaging can be used to reveal subtypes



Bipolar disorder



Bipolar disorder



Schizophrenia



Major depressive disorder

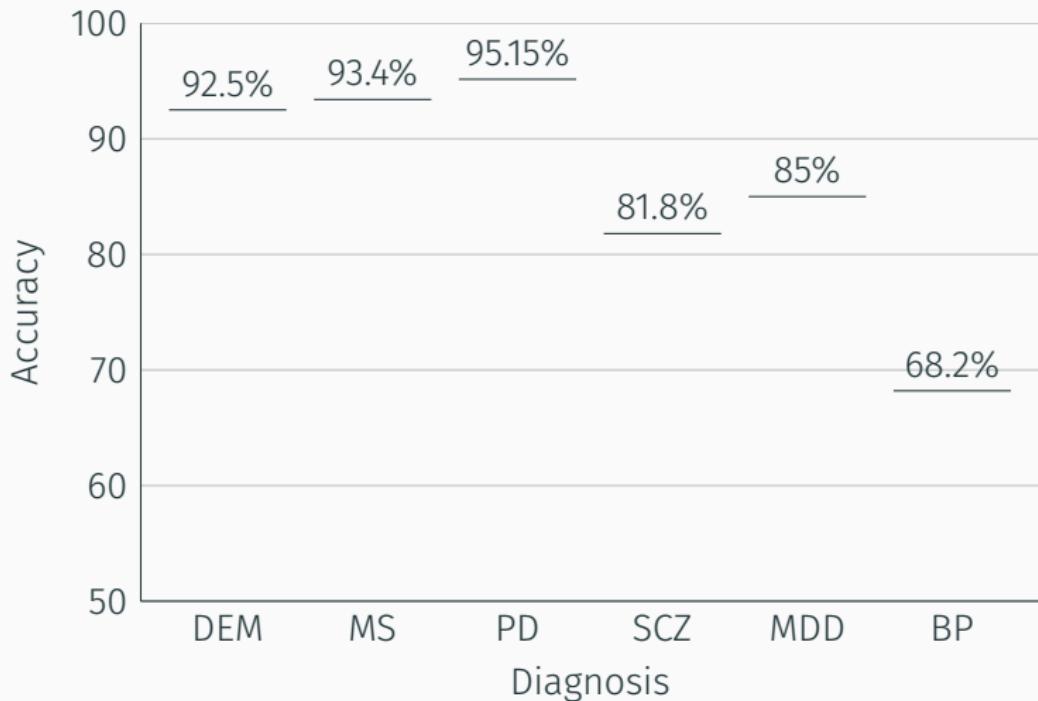


The future of neuroimaging-based prediction

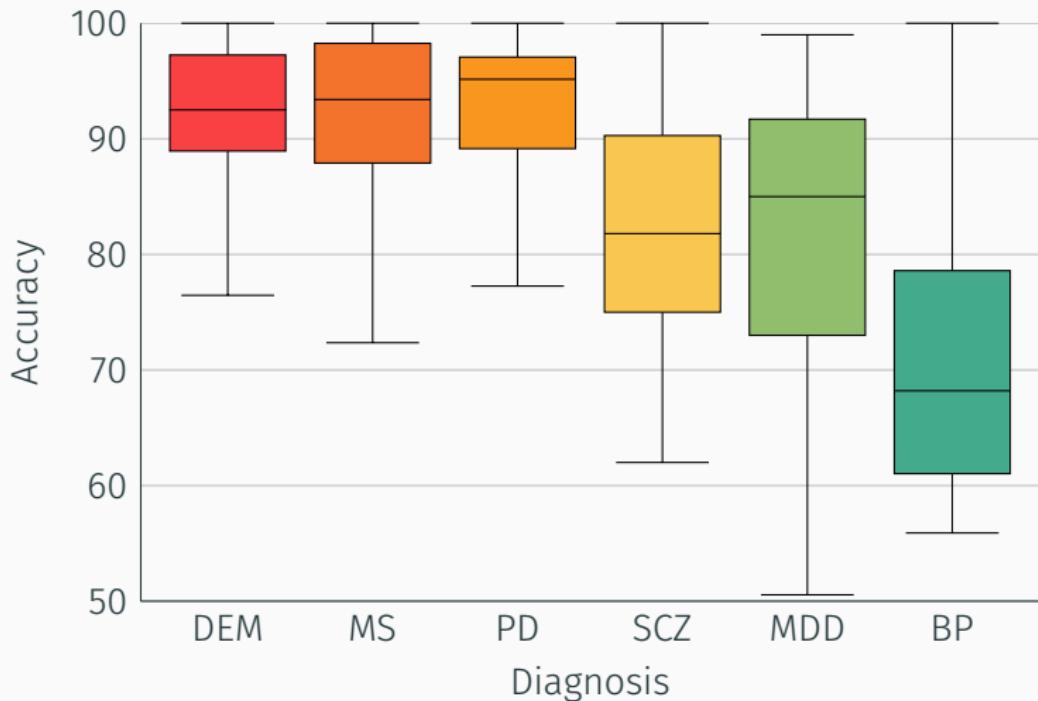


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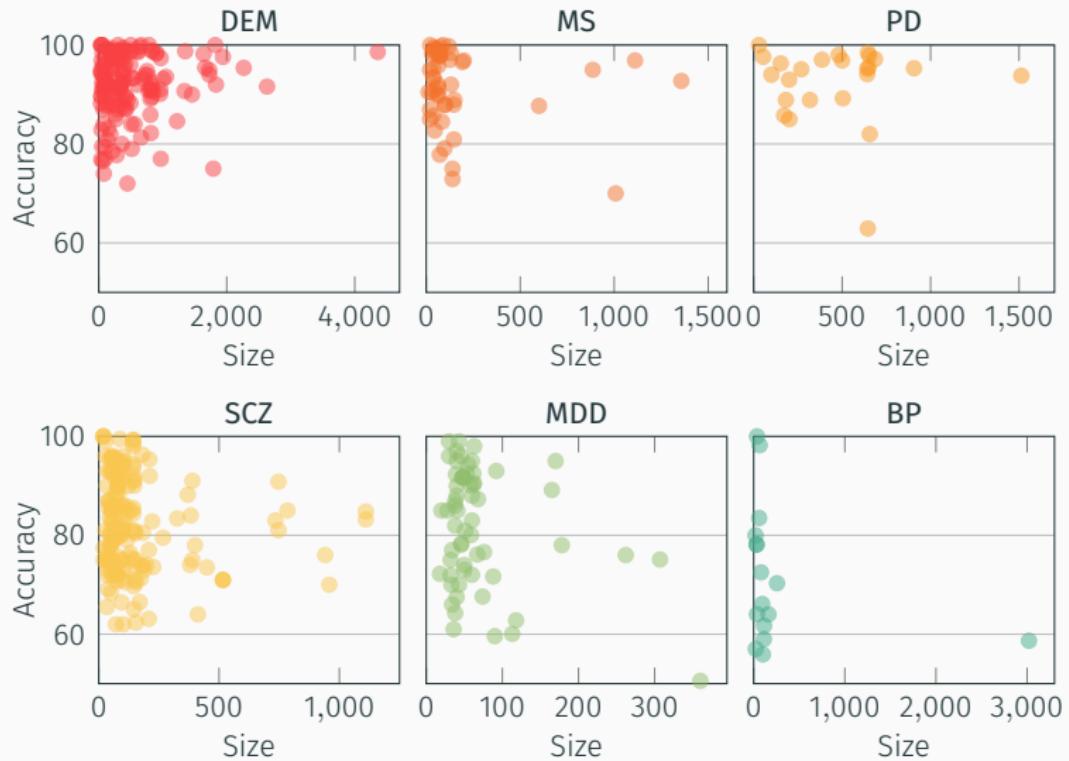
Challenges: Predictiveness



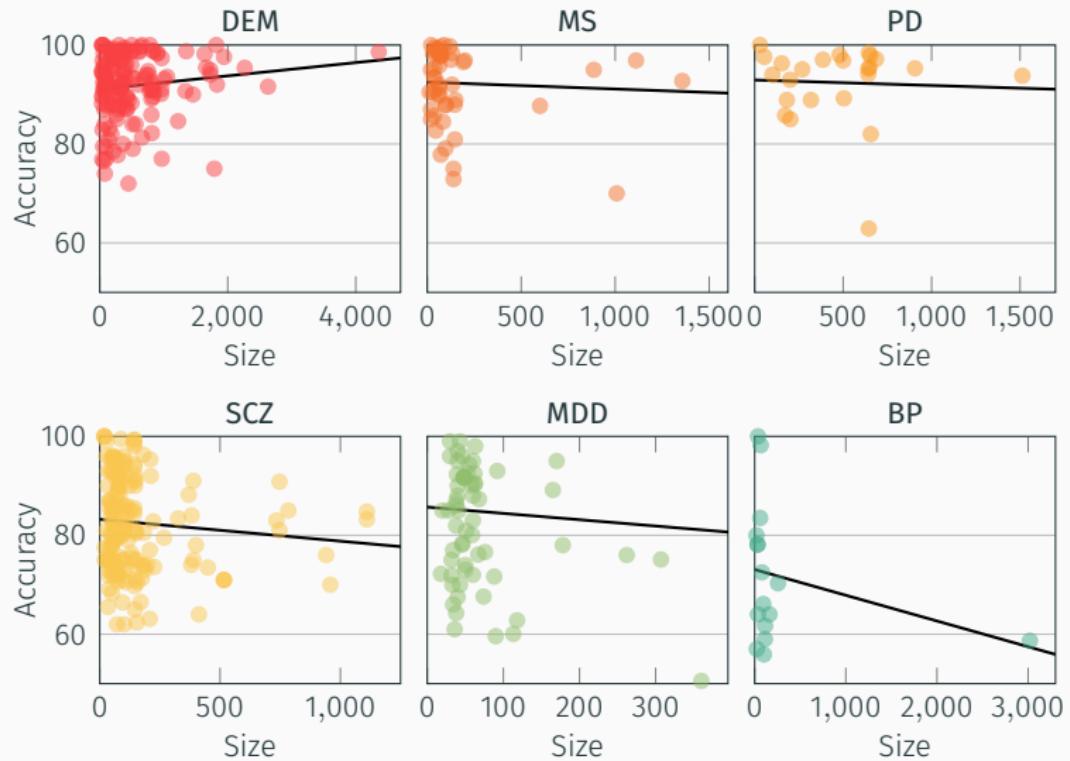
Challenges: Predictiveness



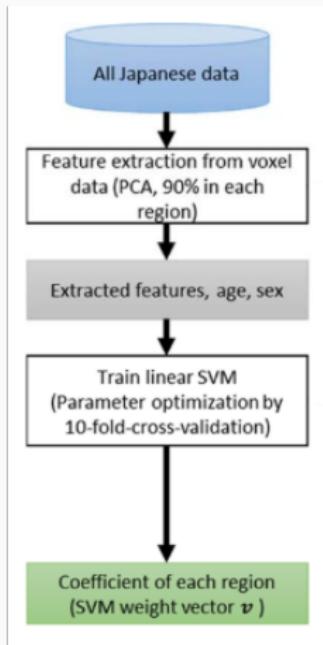
Challenges: Predictiveness



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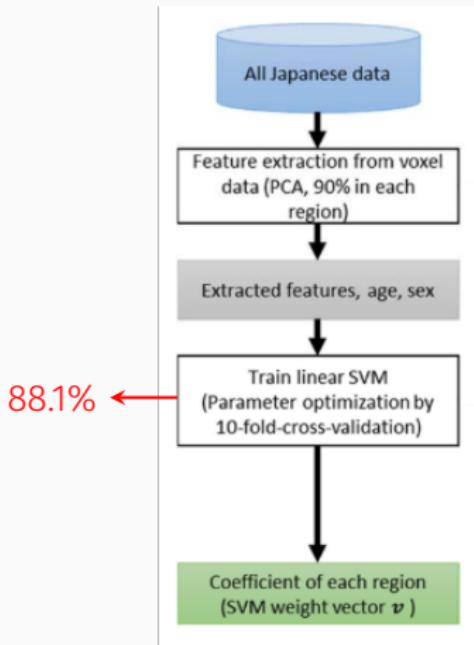


Matsuo et al., 2019

Matsuo, K., Harada, K., Fujita, Y., Okamoto, Y., Ota, M., Narita, H., ... & Watanabe, Y. (2019). Distinctive neuroanatomical substrates for depression in bipolar disorder versus major depressive disorder. *Cerebral Cortex*, 29(1), 202-214



Challenges: Predictiveness

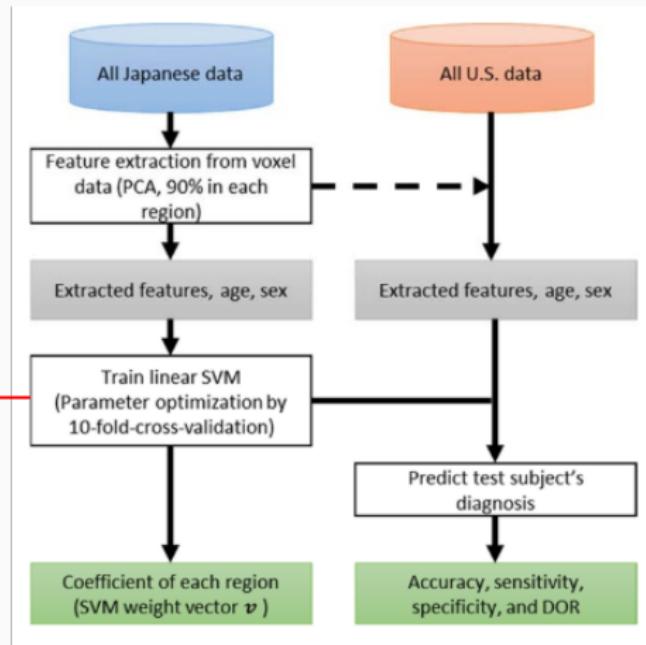


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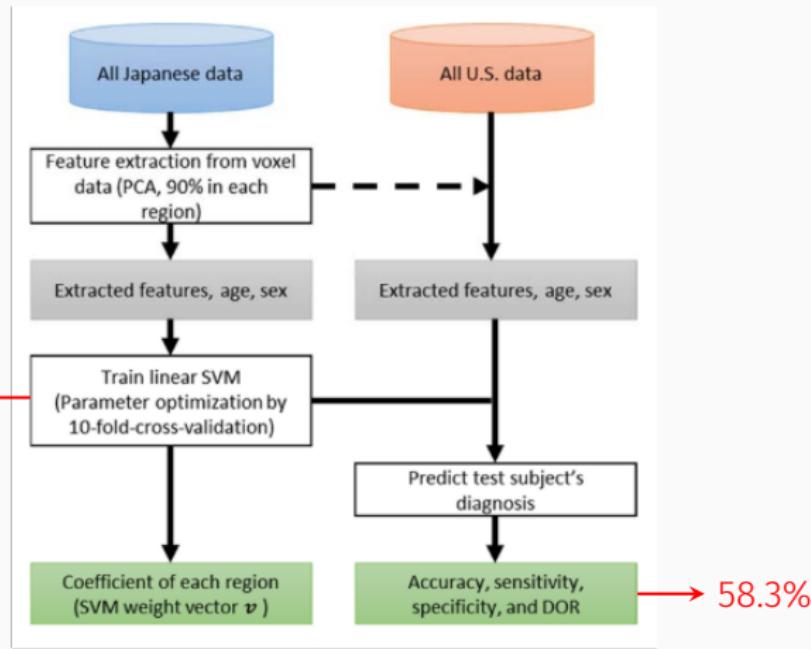


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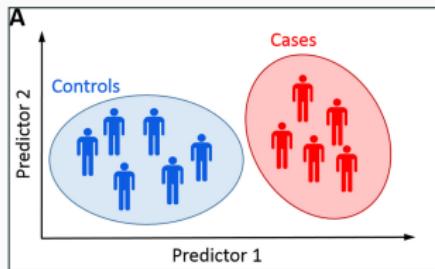


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Challenges: Predictive targets

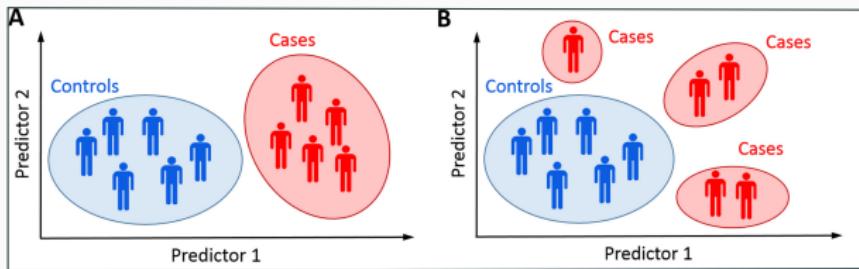


Marquand et al., 2016

Marquand, A. F., Rezek, I., Buitelaar, J., & Beckmann, C. F. (2016). Understanding heterogeneity in clinical cohorts using normative models: beyond case-control studies. *Biological psychiatry*, 80(7), 552-561



Challenges: Predictive targets

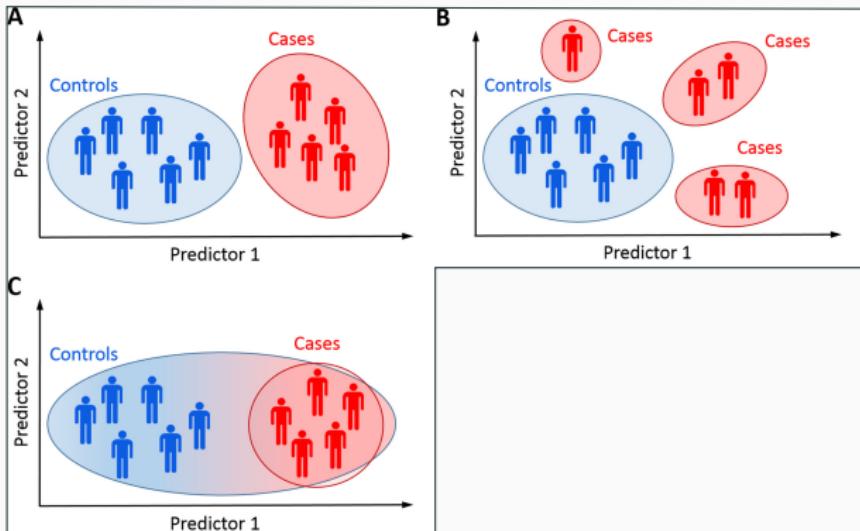


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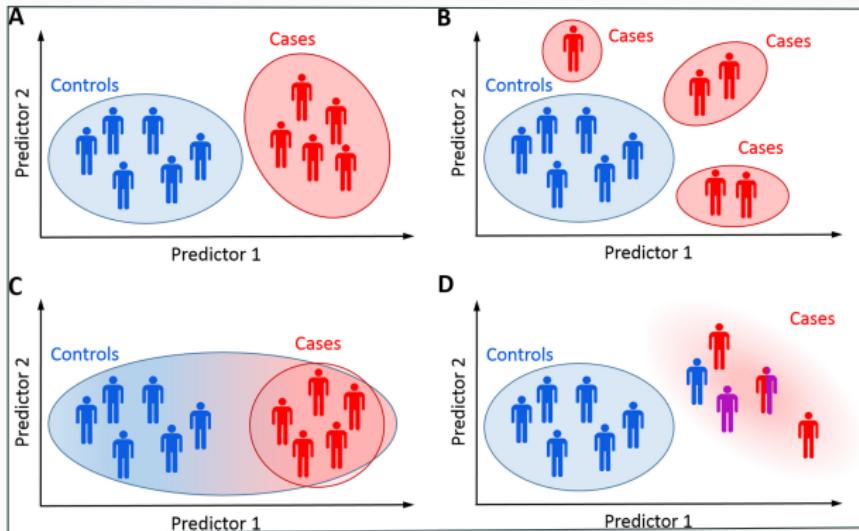


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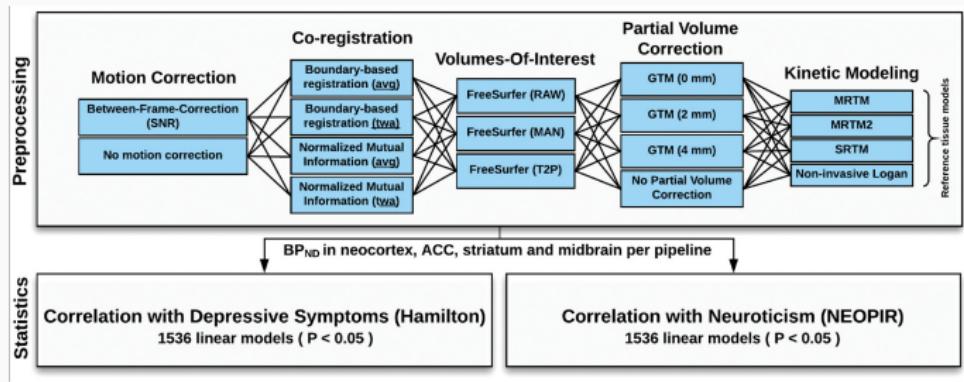


Challenges: Predictive targets

Diagnostic labels vs prognosis, treatment, differential



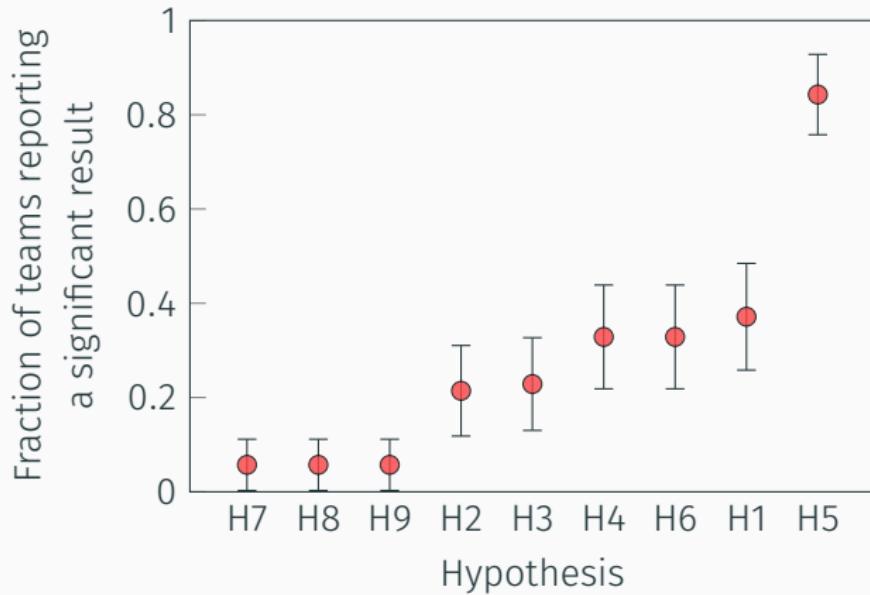
Challenges: Preprocessing and degrees of freedom



Nørgaard et al., 2020

Nørgaard, M., Ganz, M., Svarer, C., Frokjaer, V. G., Greve, D. N., Strother, S. C., & Knudsen, G. M. (2020). Different preprocessing strategies lead to different conclusions: a [11C] DASB-PET reproducibility study. *Journal of Cerebral Blood Flow & Metabolism*, 40(9), 1902-1911.

Challenges: Preprocessing and degrees of freedom

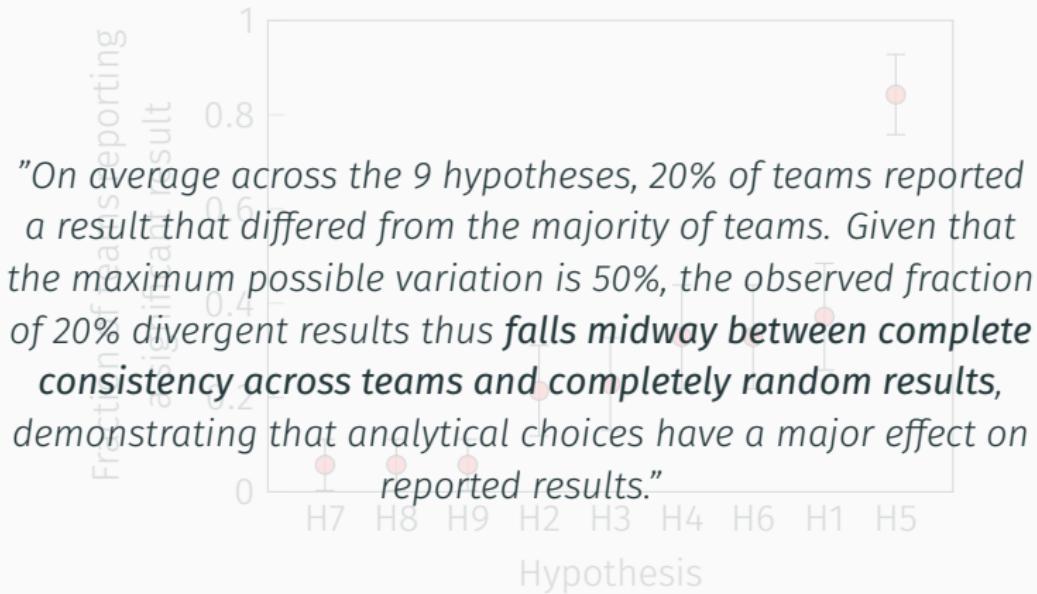


Adapted from Botvinik-Nezer et al., 2020

Botvinik-Nezer, R., Holzmeister, F., Camerer, C. F., Dreber, A., Huber, J., Johannesson, M., ... & Rieck, J. R. (2020). Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, 582(7810), 84-88



Challenges: Preprocessing and degrees of freedom



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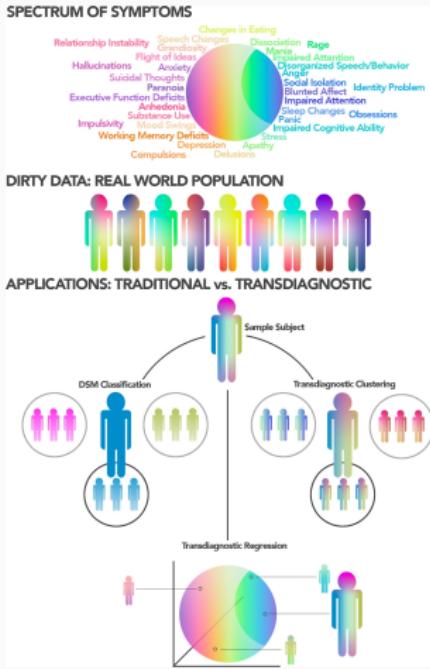


Challenges: Interpretability





The role of prediction



Prediction versus interpretability

