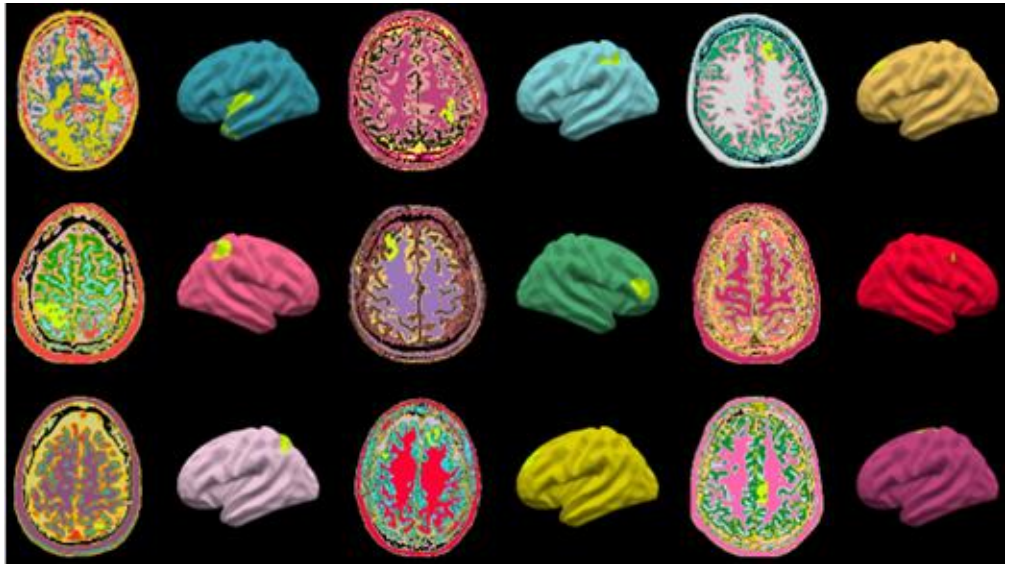
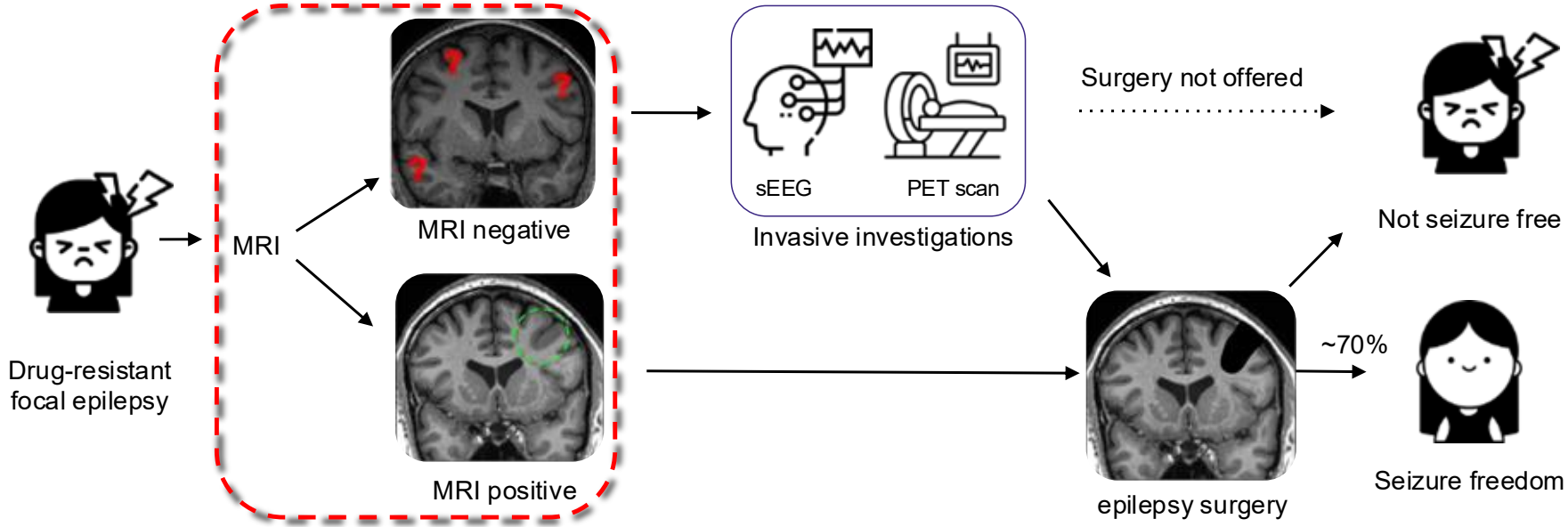
Neural Networks for Detection of Subtle Epilepsy Lesions in MRI and Translation to Clinical Evaluation



Dr Mathilde Ripart
KCL School of Biomedical Engineering & Imaging Sciences, UK
UCL Great Ormond Street Institute of Child Health, UK

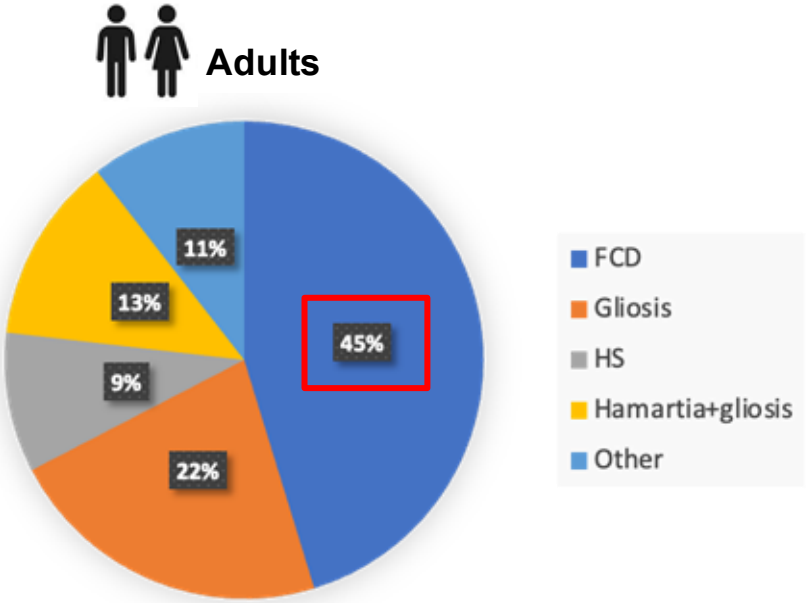
Multi-Centre Epilepsy Lesion Detection

Goal: Improving the presurgical planning of patients with drug-resistant focal epilepsy



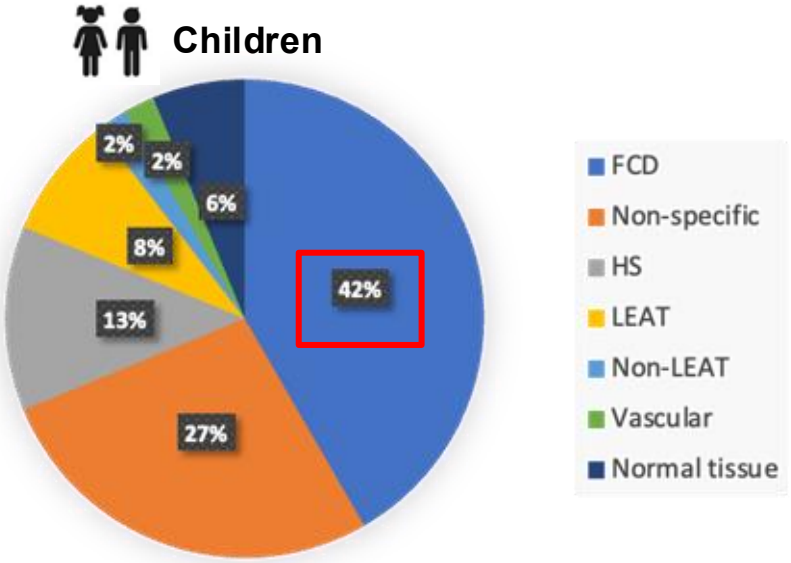
Can AI help us detect subtle lesions?

“MRI-negative” Epilepsy - “Missed” lesion



95 MRI negative

Adapted from Wang et al., 2013 Mod Path



87 MRI negative

Eriksson et al., 2023 Epilepsia

Focal cortical dysplasia (FCD)

Malformation of cortical development

Subtle imaging features:

- Abnormal cortical thickness
- Blurring of the grey-white matter boundary
- FLAIR/T2-weighted intensity changes
- Abnormal folding pattern
- Hemispheric asymmetry

Where is the FCD?

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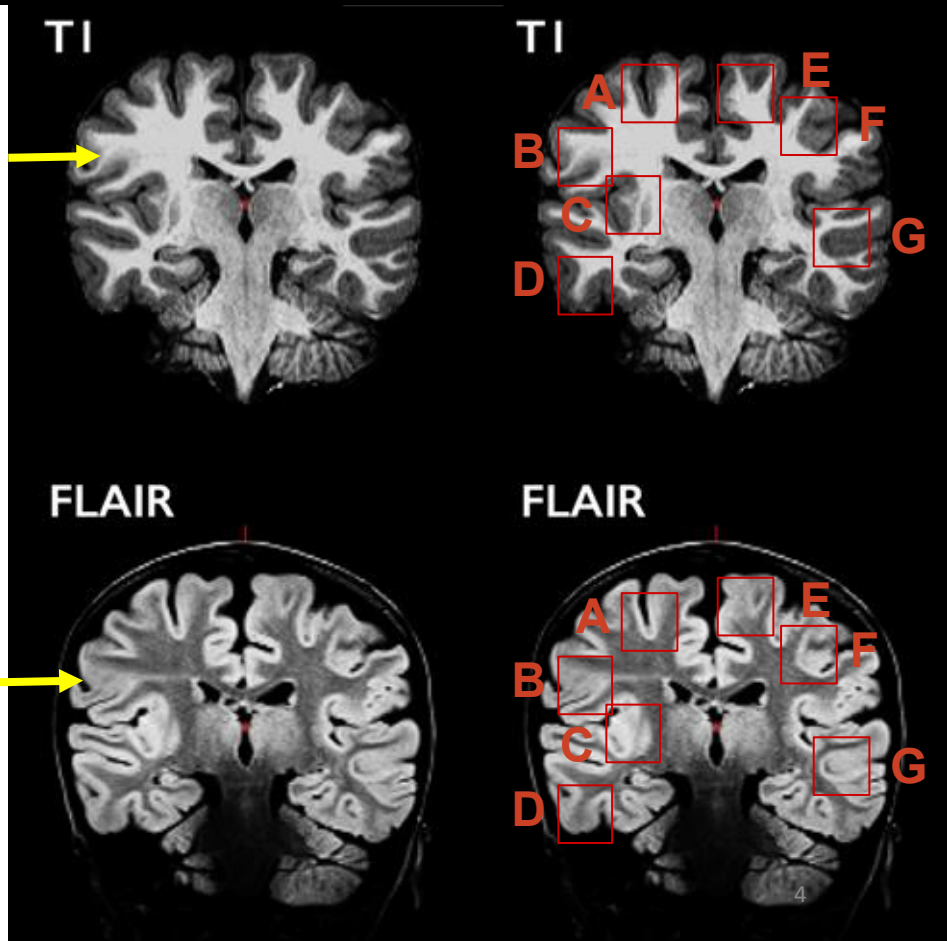

A public benchmark for human performance in the detection of FCD

Rater group	Pinpointing (%)	Detection (%)		
		OVO, 0.0	Standard, 0.7	Adjusted, 0.22
Overall				
Layperson	29 [23, 34]	33 [27, 38]	2 [0, 4]	27 [22, 33]
Non-expert	48 [46, 51]	54 [52, 56]	3 [2, 4]	45 [42, 47]
Expert	68 [63, 72]	74 [70, 79]	9 [6, 12]	68 [63, 73]

Lennart Walger. (2025). Epilepsia Open. 10.1002/epi4.70028.

Key points of this talk

- AI can detect subtle focal cortical dysplasia (FCD) on MRI - MELD MLP
- Graph Neural network for a more confident detection of FCD - MELD Graph
- Translation into clinical practice
- Going further - a deep learning model for the detection of multiple epilepsy lesions

Key points of this talk

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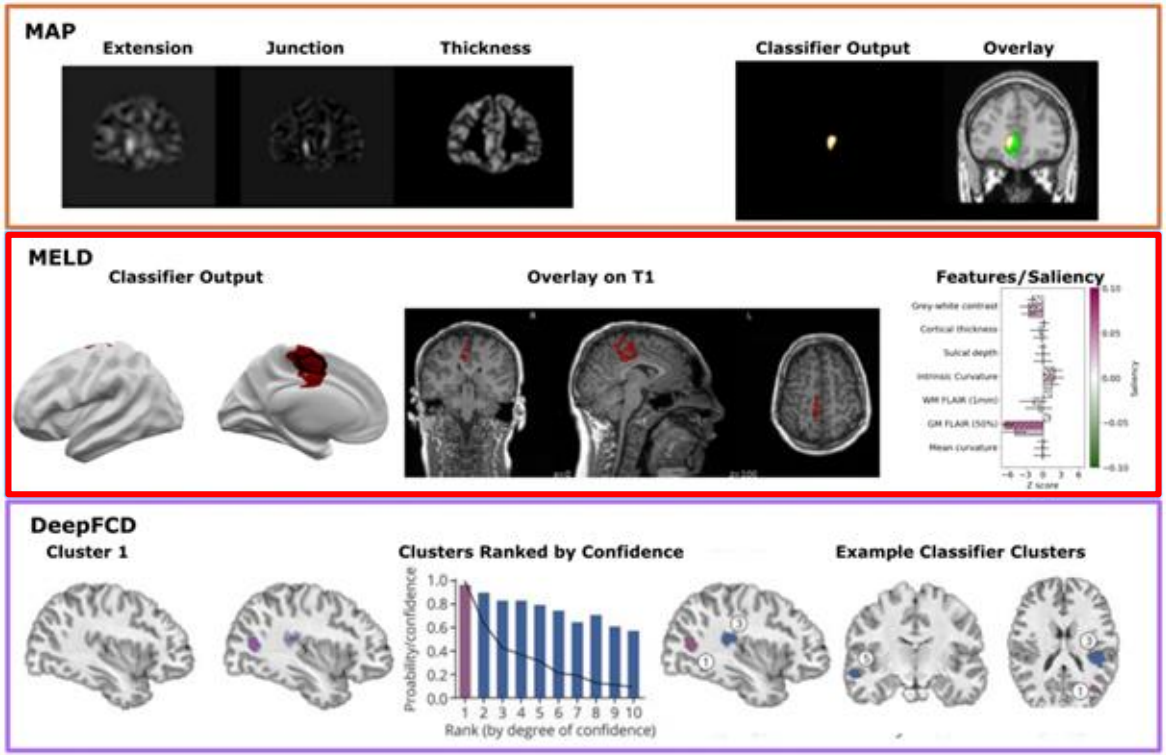
AI tools with multi-centre validation



David et al., Epilepsia 2021

Spitzer, Ripart et al., BRAIN 2022

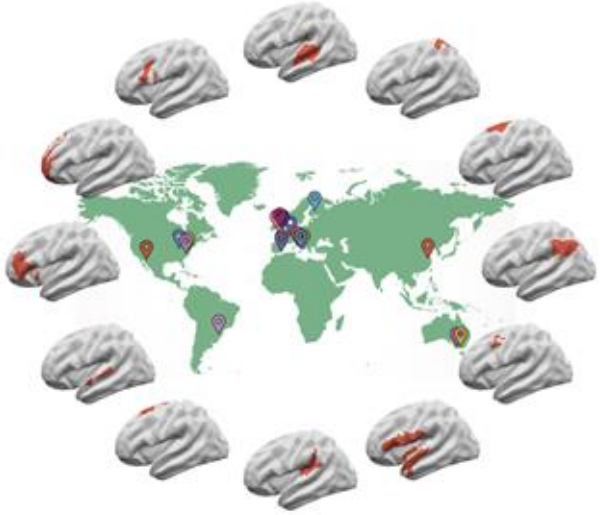
Gill et al., Neurology, 2021

Dr Hannah Spitzer

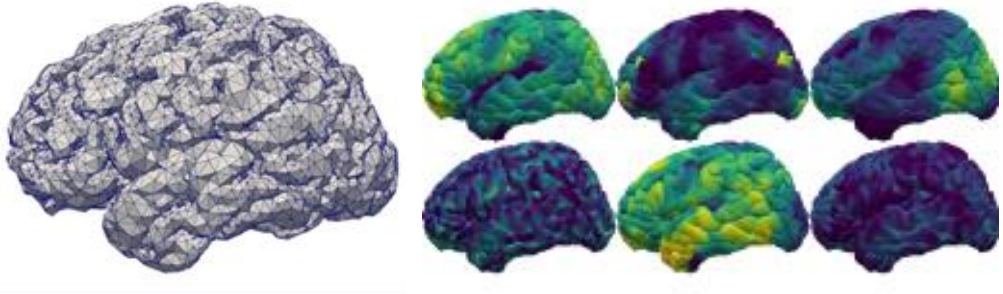
AI requires BIG DATA

MELD FCD dataset :

- 22 epilepsy surgery centres
- 1015 participants:
  - 618 patients with epilepsy due to FCD
  - 397 controls
- Paediatric & Adult
- 1.5T and 3T MRI

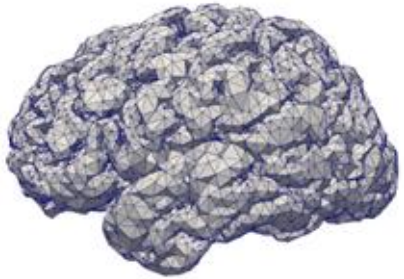


Surface based features

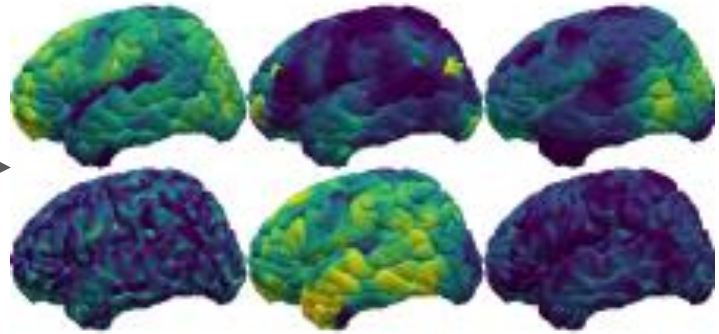


Surface-based features extraction

FreeSurfer cortical reconstruction



Surface based features

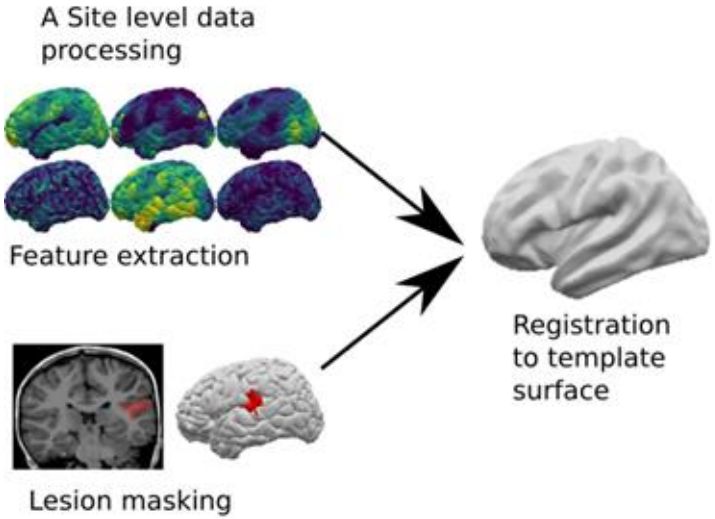


Surface based lesion

FCDs are non-uniformly distributed across the cortex

Wagstyl et al., Epilepsia, 2020

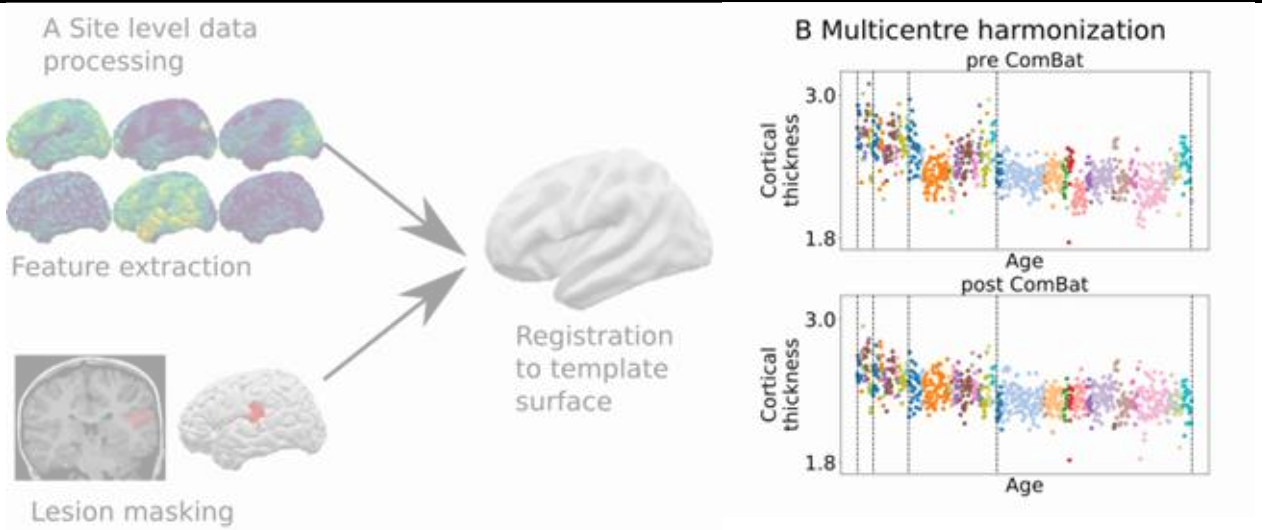
Automated lesion detection - Per Vertex “MLP”



Dr Hannah Spitzer

Spitzer, Ripart et al., *Brain* 2022

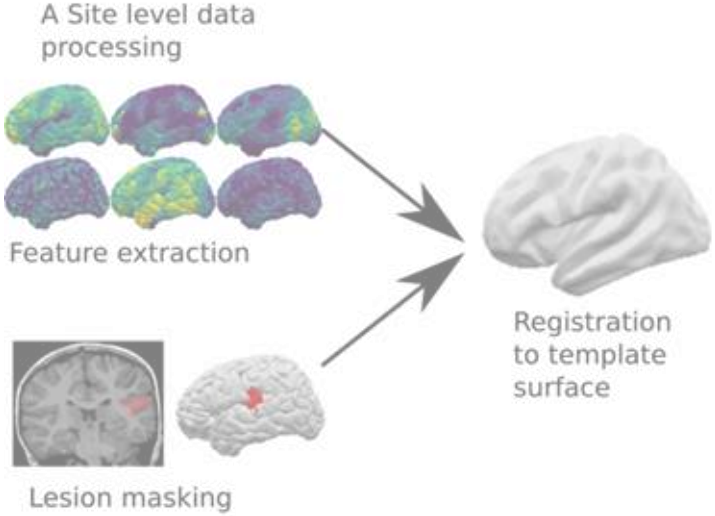
Automated lesion detection - Per Vertex “MLP”

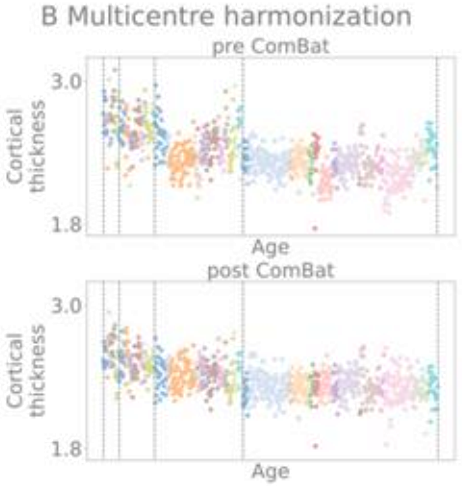


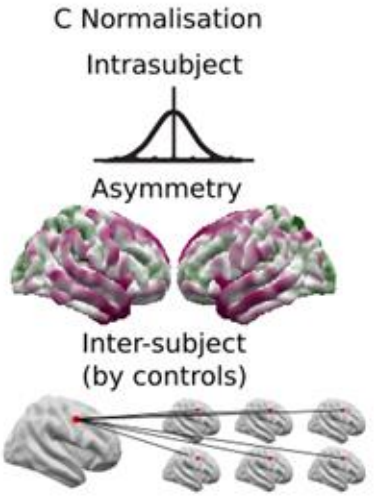
Dr Hannah Spitzer

Spitzer, Ripart et al., *Brain* 2022

Automated lesion detection - Per Vertex “MLP”







Dr Hannah Spitzer

Spitzer, Ripart et al., *Brain* 2022

Can you find the lesion: MRI

Patient 00:

- 18 year old male with focal epilepsy.
- Drug resistant epilepsy
- MRI

Q1. How confident are you about the lesion location?

1. Absolutely no idea - I can't see a lesion
2. Everything looks a bit abnormal
3. One or two areas look suspicious
4. I think I know where it is
5. I am very confident I know where the lesion is

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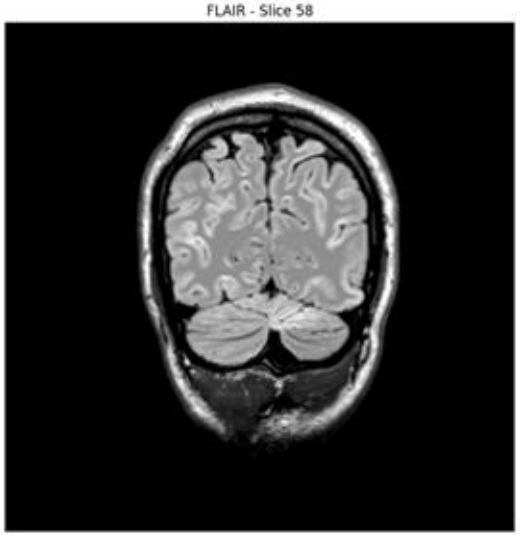

Can you find the lesion: Raw surface features

Q2. How confident are you about the lesion location?

1. Absolutely no idea
2. Everything looks a bit abnormal
3. One or two areas look suspicious
4. I think I know where it is
5. I am very confident

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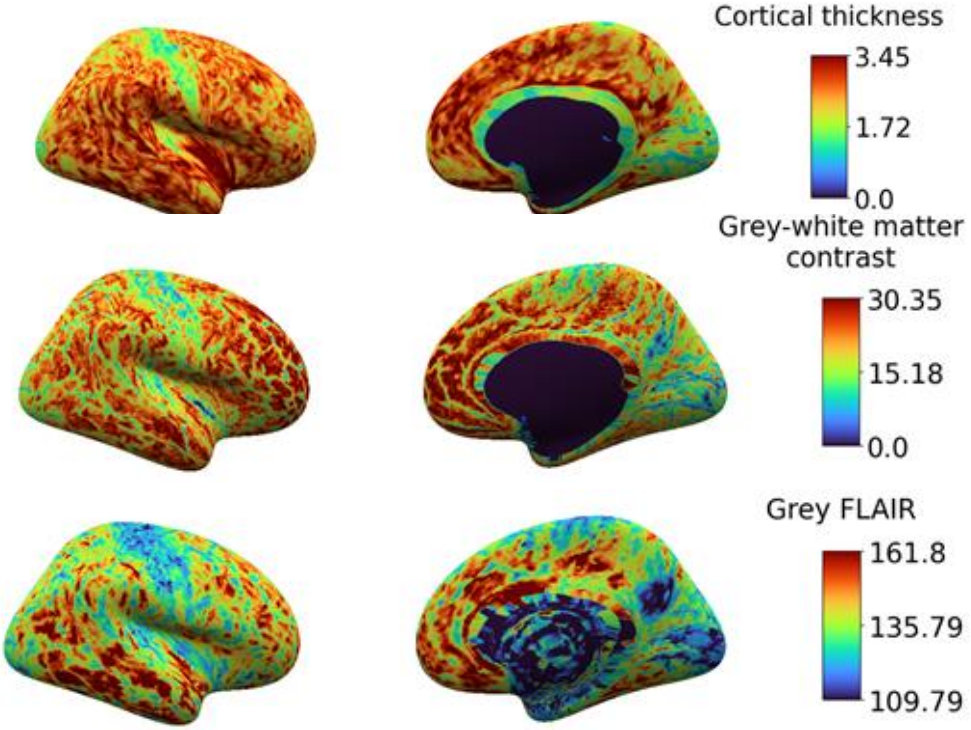
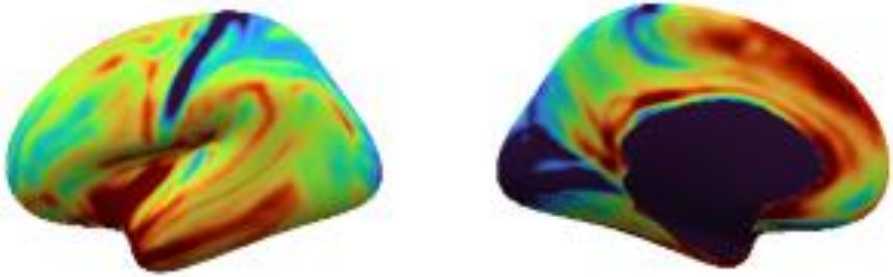


Adjusting for normal patterns

Control mean cortical thickness

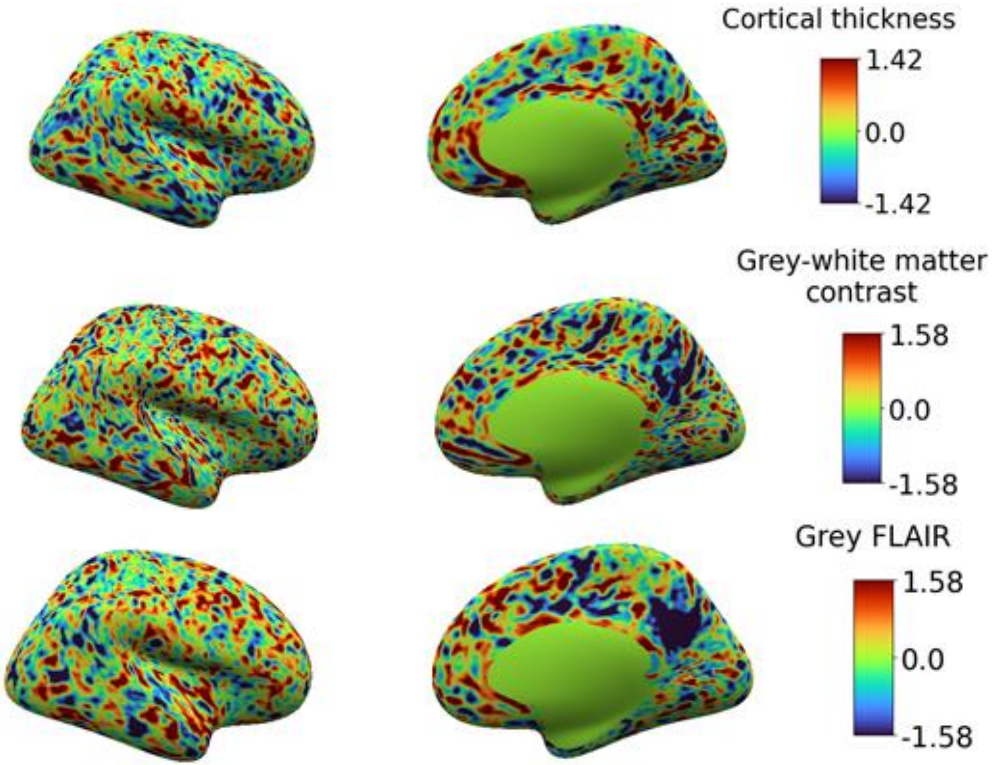


Can you find the lesion: Normalised surface features

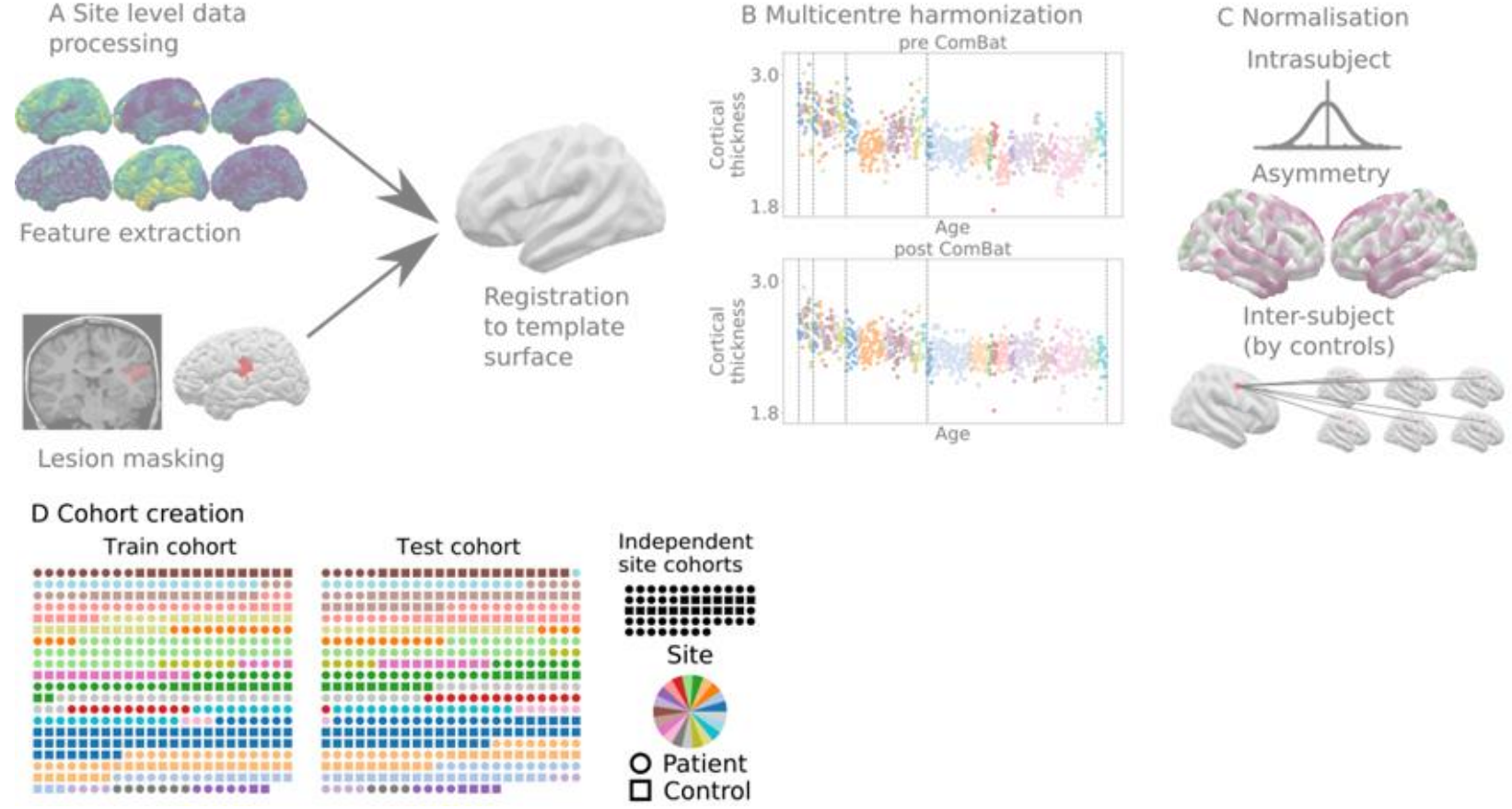
Q3. How confident are you about the lesion location?

1.Absolutely no idea
2.Everything looks a bit abnormal
3.One or two areas look suspicious
4.I think I know where it is
5.I am very confident

Join at menti.com | use code 8459 7868

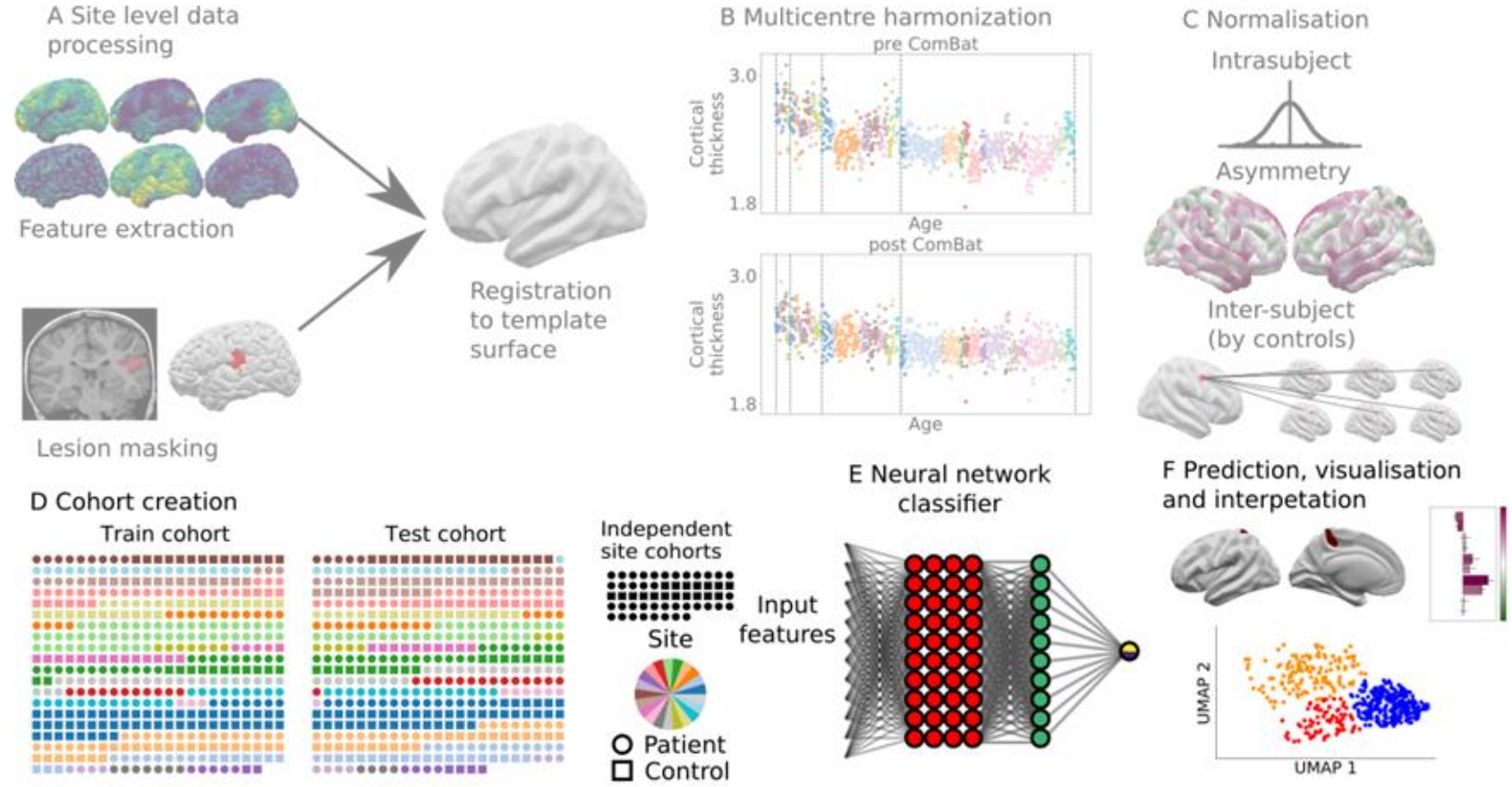


Automated lesion detection - Per Vertex “MLP”



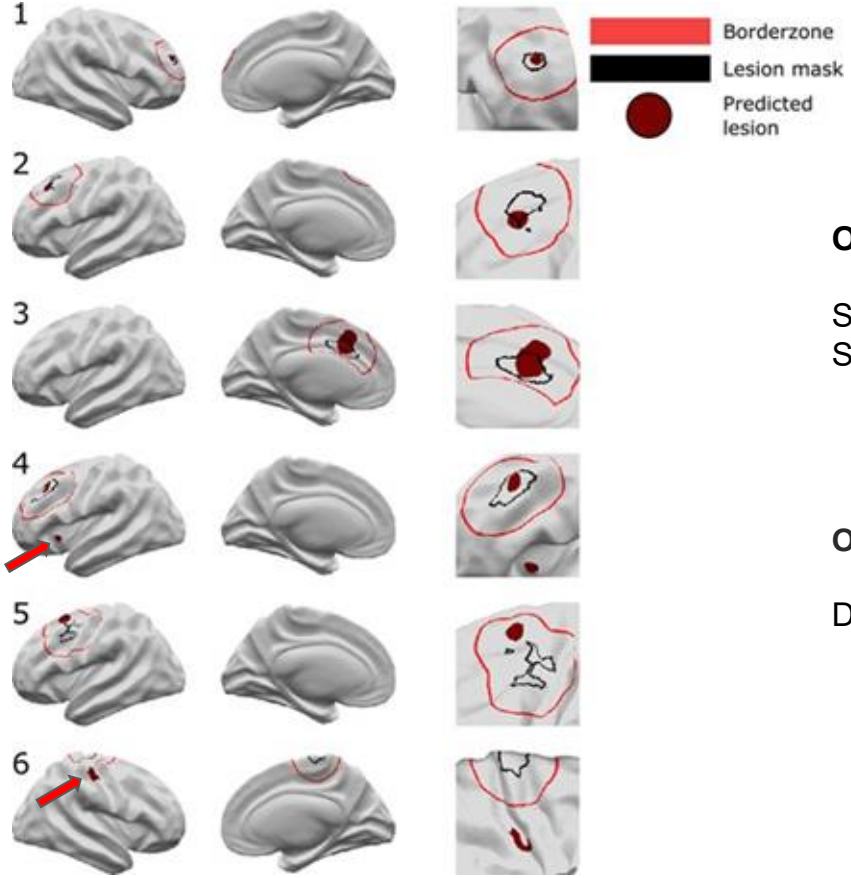
Spitzer, Ripart et al., *Brain* 2022

Automated lesion detection - Per Vertex “MLP”



Spitzer, Ripart et al., *Brain* 2022

Automated lesion detection - Per Vertex “MLP”



On the test dataset

Sensitivity 67% (n=260)
Specificity 54% (n=193)

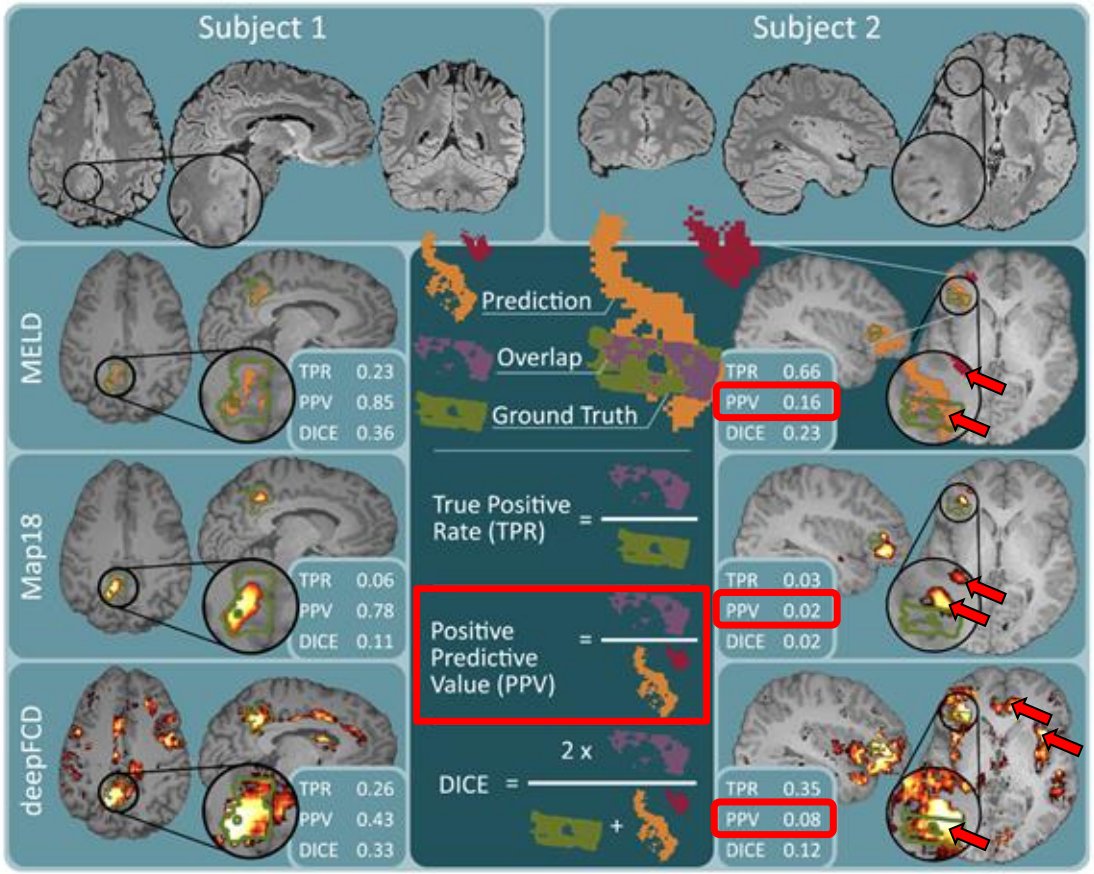
2 false positives per patient on average (up to 12!)

On the whole dataset

Detection in MRI negative: 63% (n=178)

Spitzer, Ripart et al., *Brain* 2022

False Positives are an outstanding challenge for all FCD detection algorithms



Spitzer, Ripart et al., *BRAIN 2022*

David et al., *Epilepsia 2021*

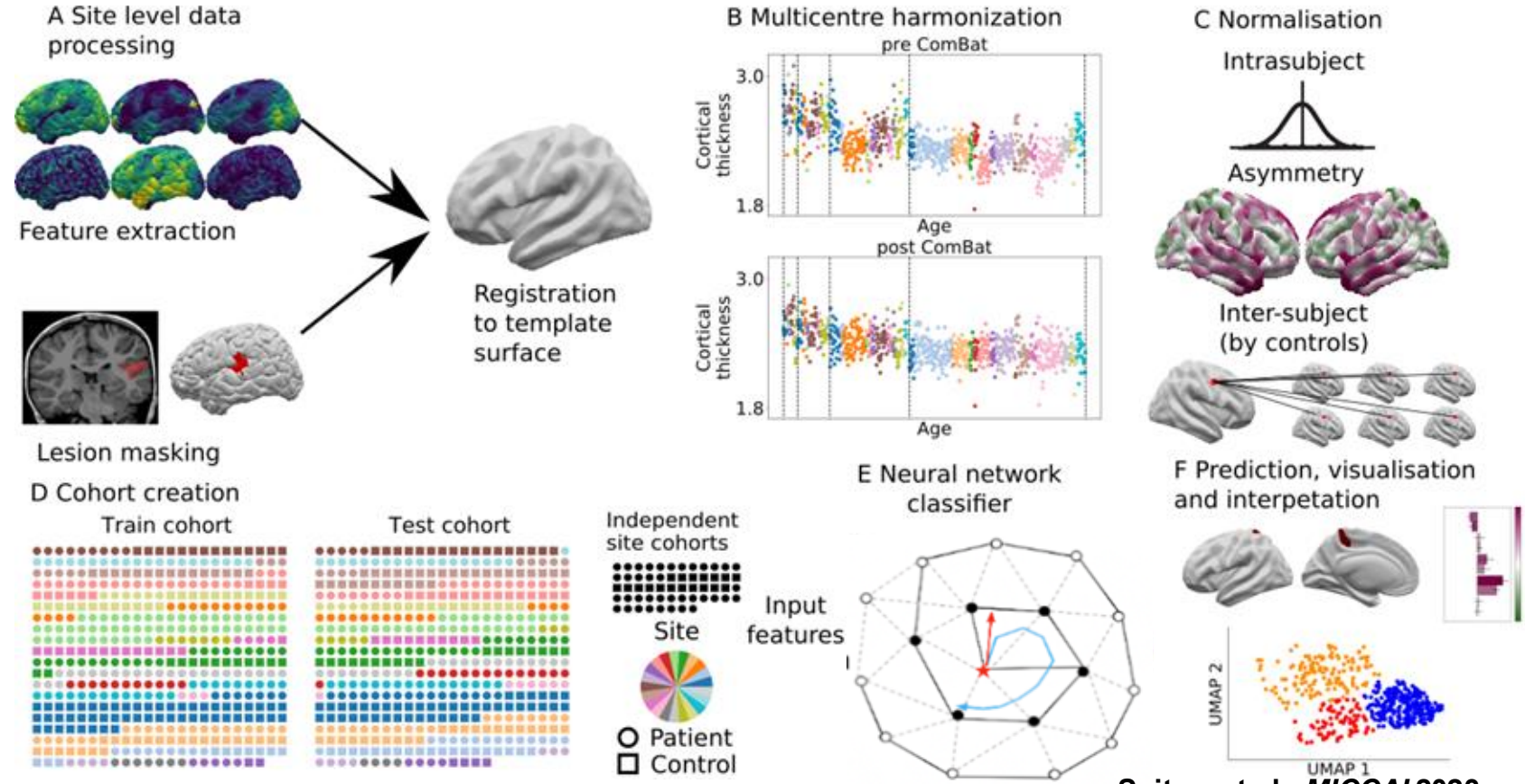
Gill et al., *Neurology 2021*

Walger et al., *Epilepsia 2023*

Key points of this talk

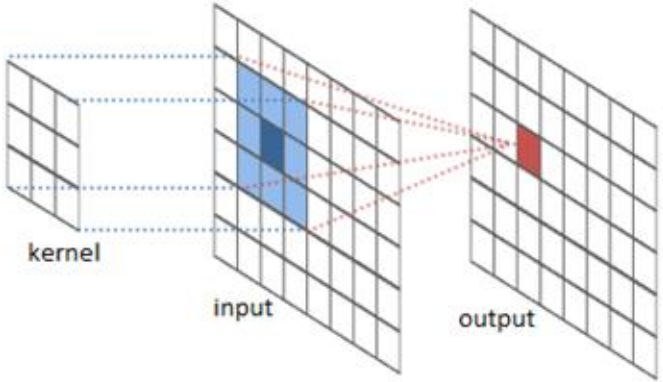
- AI can detect subtle focal cortical dysplasia (FCD) on MRI
- Graph Neural network for a more confident detection of FCD
- Translation into clinical practice
- Going further - a deep learning model for the detection of multiple epilepsy lesions

Automated lesion detection - MELD Graph

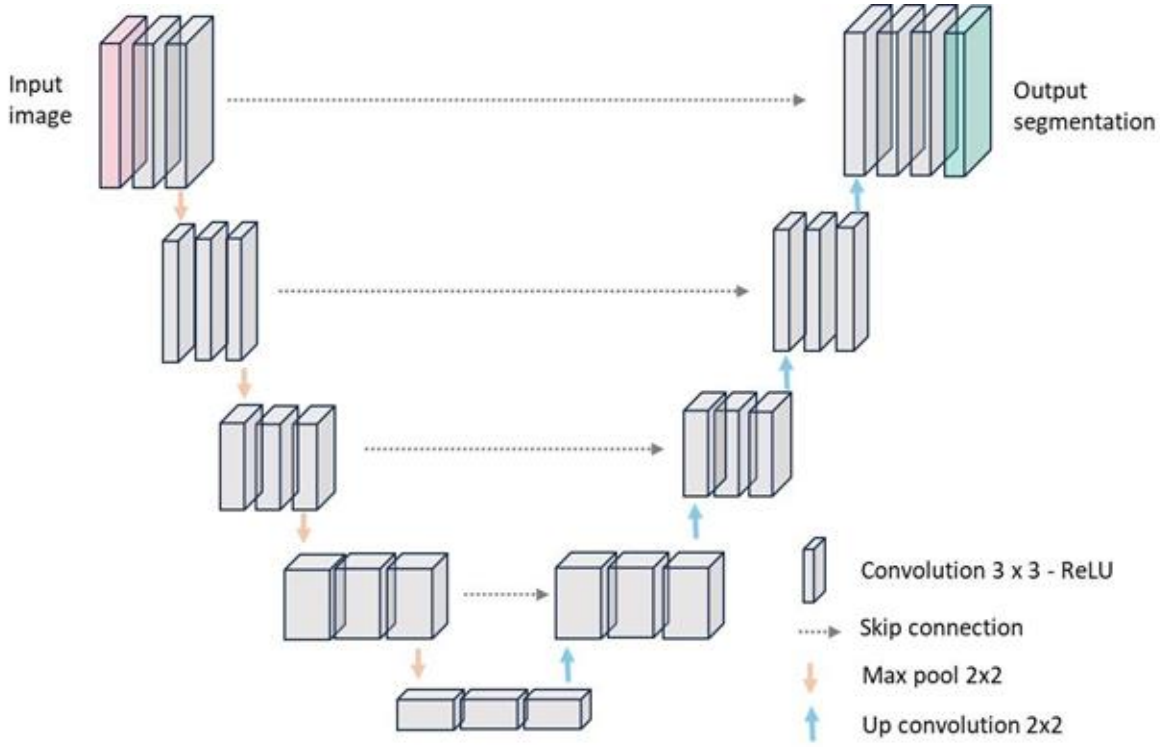


Spitzer et al., *MICCAI* 2023
Ripart et al., *JAMA Neurology 2025*

Parenthesis: Convolutional Neural Network for image segmentation

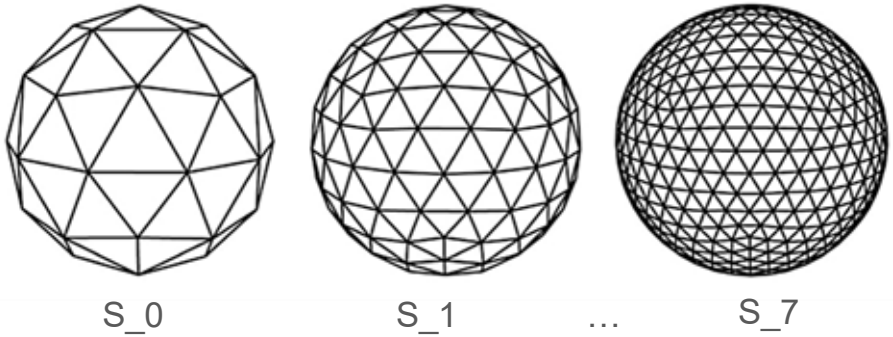


Convolution 3 x 3



Example of the U-Net

A Graph Convolutional U-Net for surface segmentation



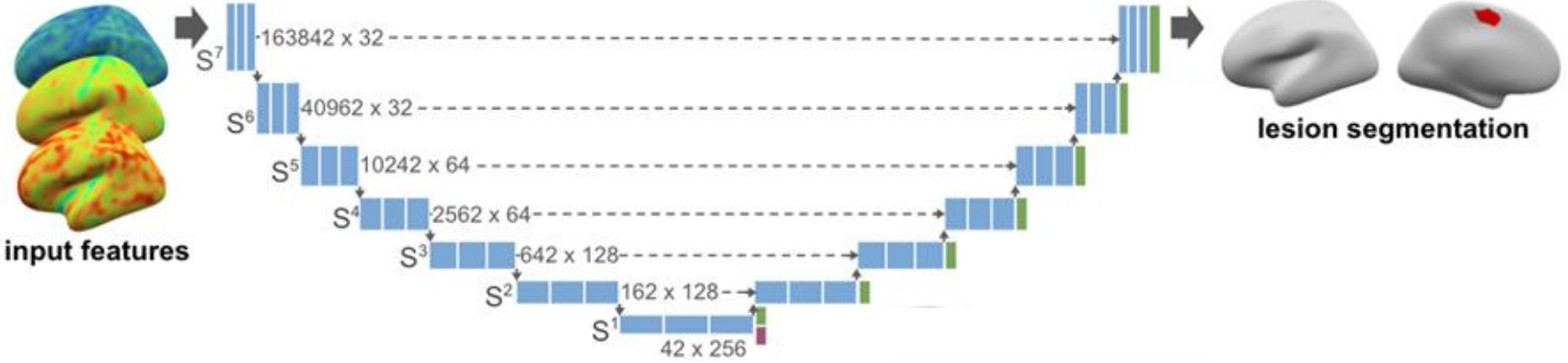
We created meshes at different resolutions based on icosahedral icoshpheres S_i

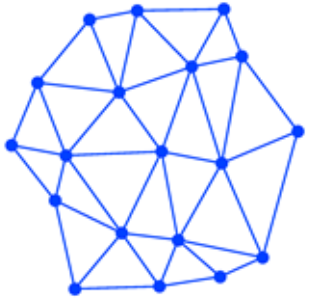
Advantage:

- Symmetrical
- Easy to resample to different resolutions

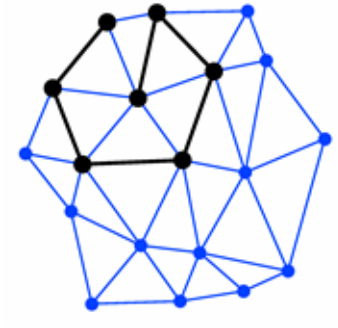
Credit Hannah Spitzer

A Graph Convolutional U-Net for surface segmentation





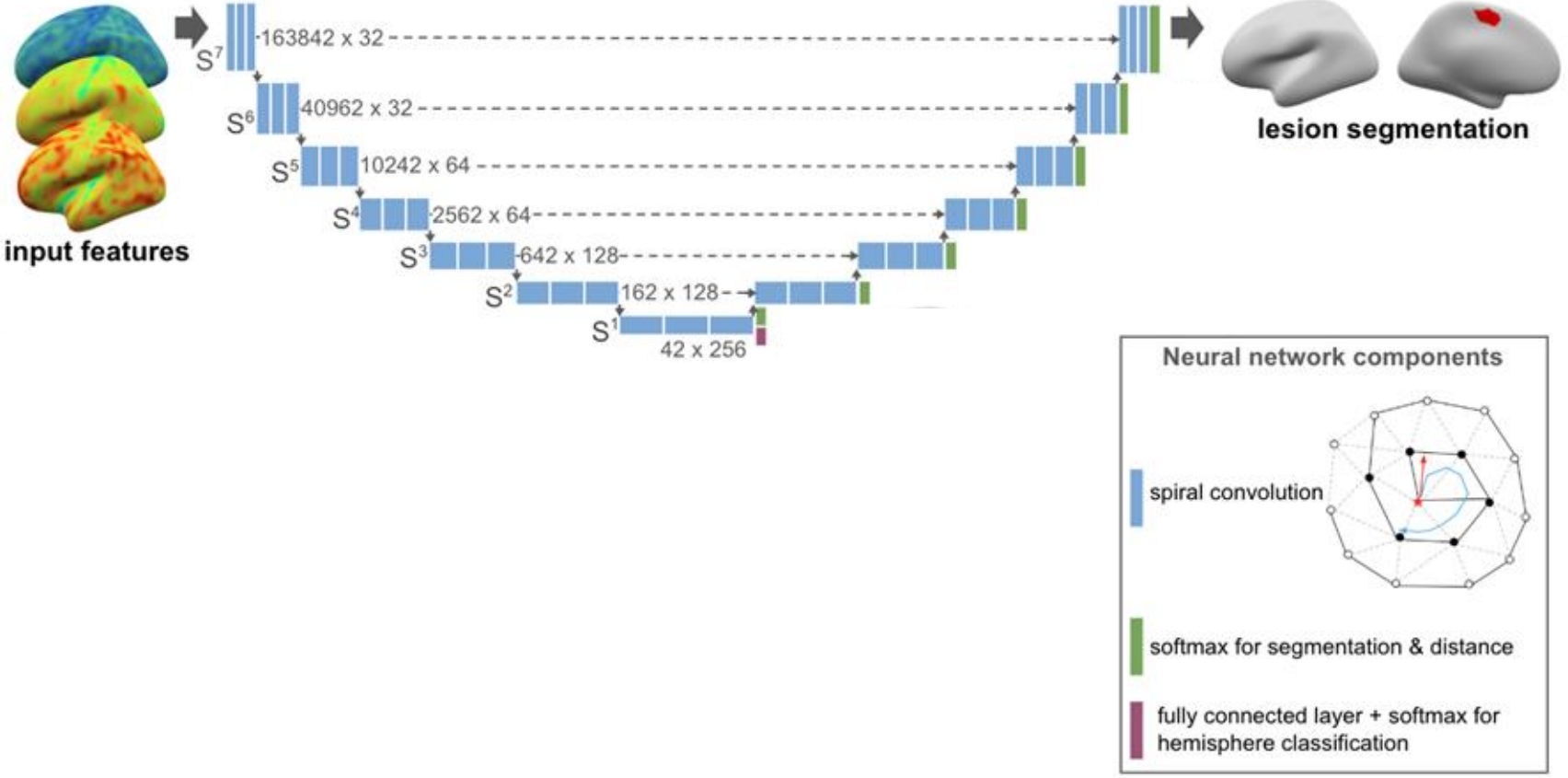
Up & Down sampling



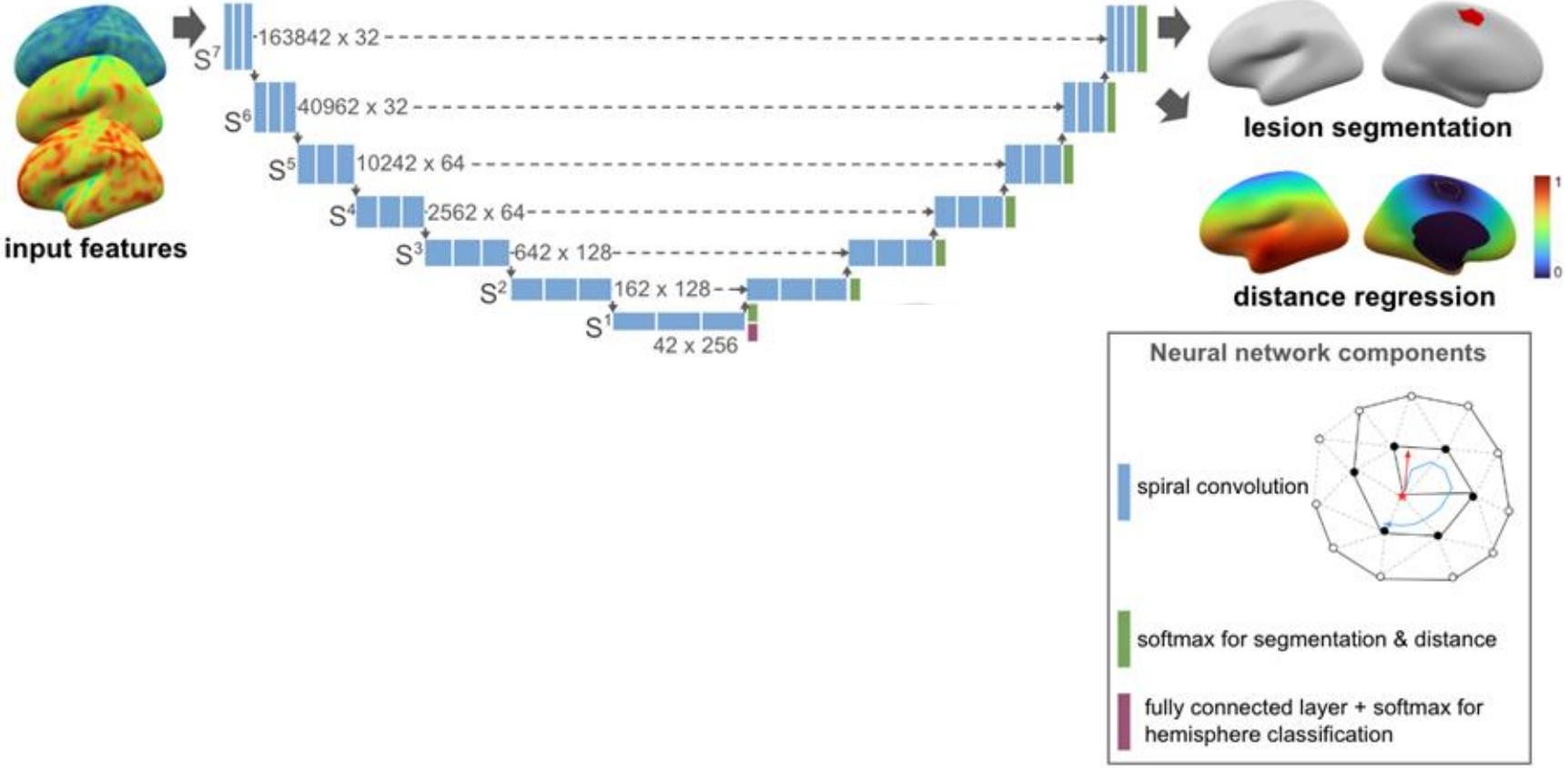
Spiral convolution

Credit Hannah Spitzer

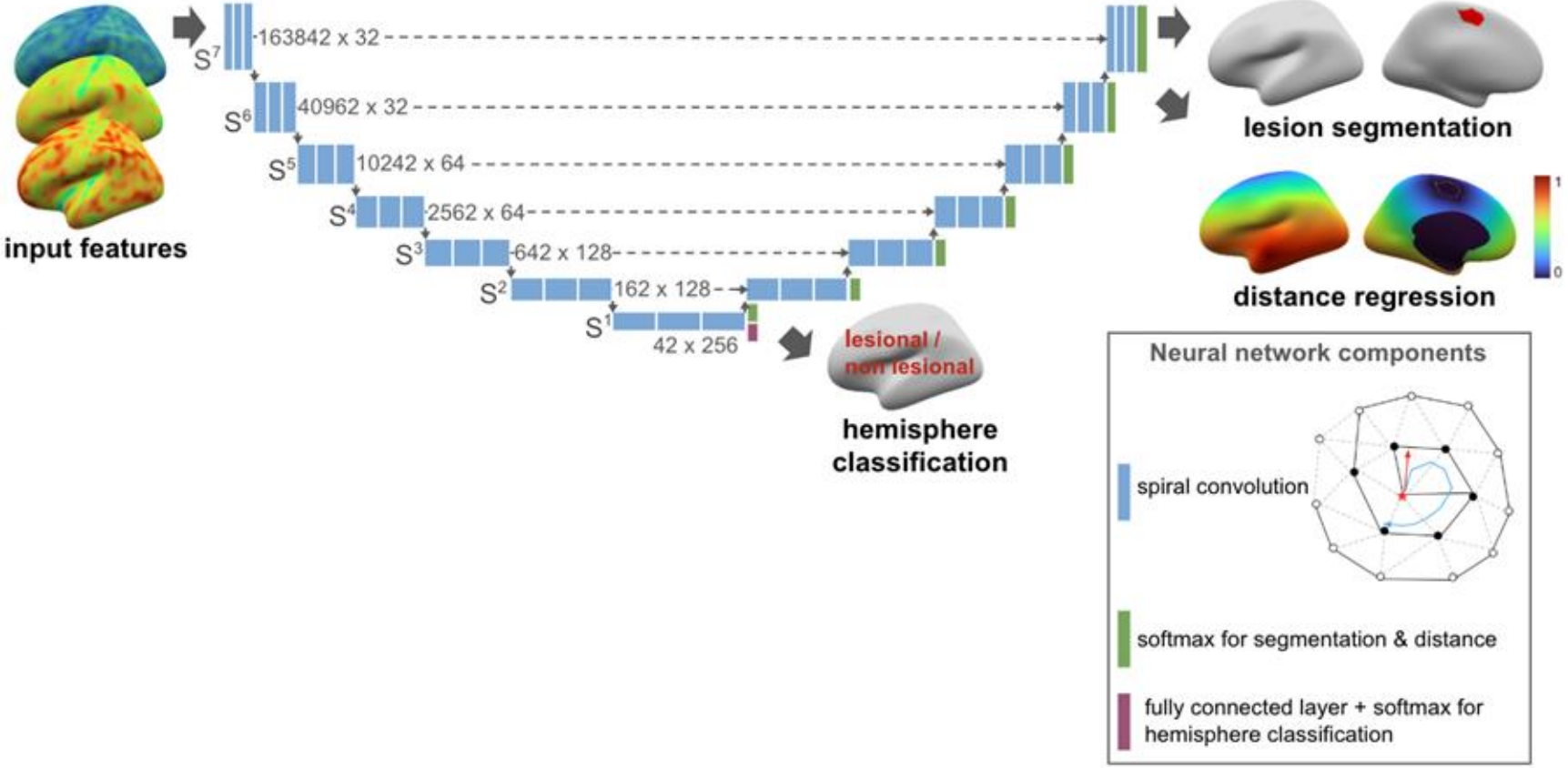
A Graph Convolutional U-Net for surface segmentation



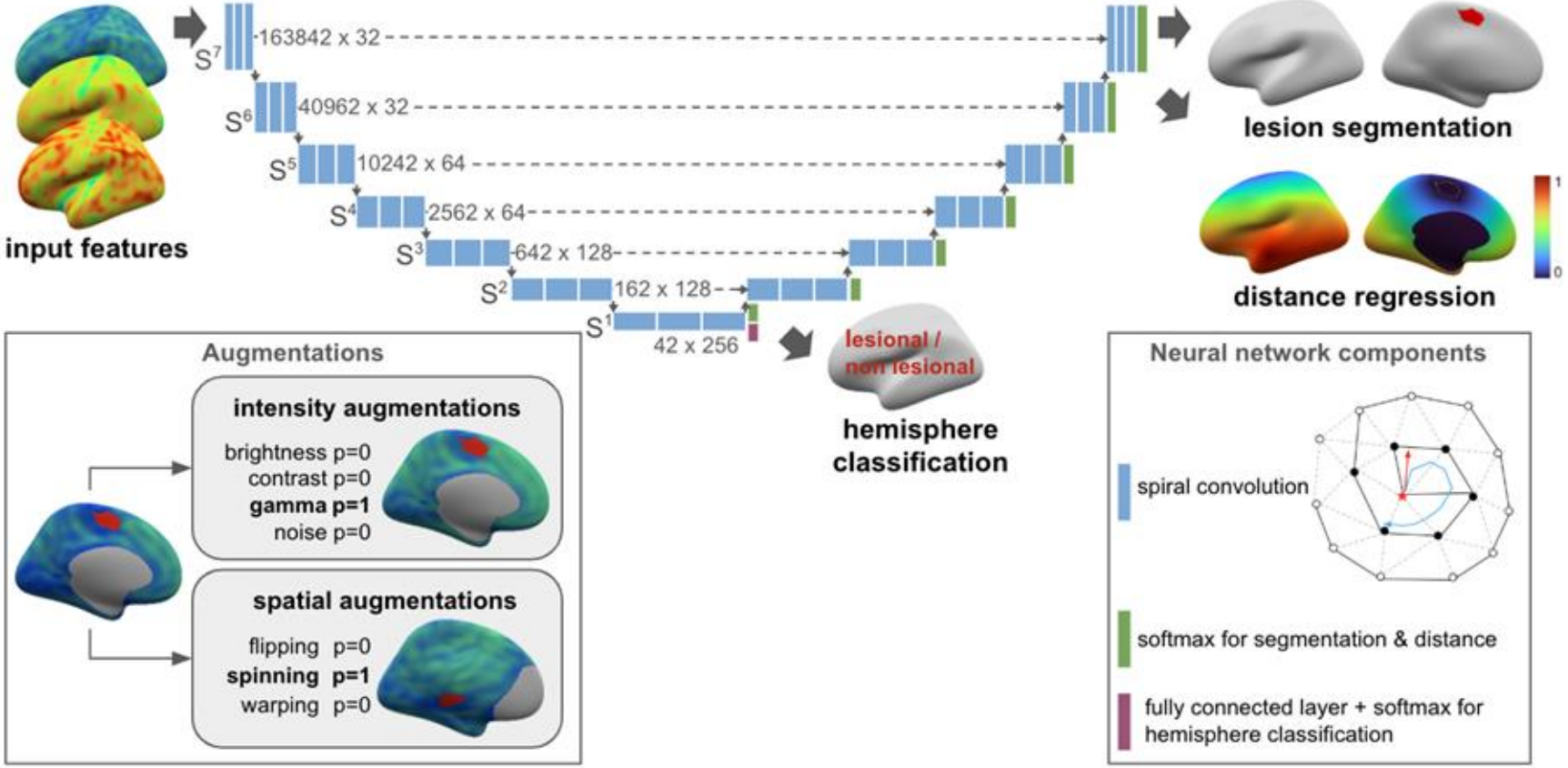
A Graph Convolutional U-Net for surface segmentation



A Graph Convolutional U-Net for surface segmentation



A Graph Convolutional U-Net for surface segmentation



A Graph Convolutional U-Net for surface segmentation

Table 1. Experiments

Experiment Name	Description
MLP [10]	vertex-wise multilayer perceptron
GC-nnU-Net	graph-based adaptation of nnU-Net
GC-nnU-Net+c	adding classification loss
GC-nnU-Net+d	adding distance loss
GC-nnU-Net+dc	adding distance loss and classification loss

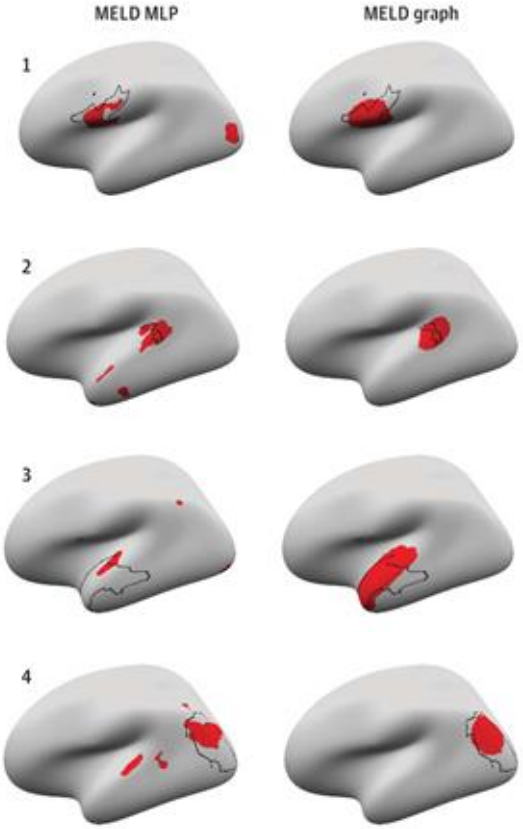
Table 2. Comparison of models on the test dataset.

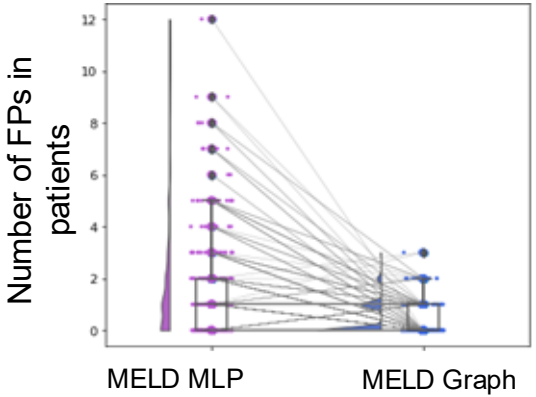
Experiment	AUC (+/- std)	Sensitivity	Specificity	Run time (min)
MLP [10]	0.64 (n.a.)	67%	49%	n.a.
GC-nnU-Net	$0.68^{\dagger\ddagger}$ (+/- 0.004)	67%	64%	396.1
GC-nnU-Net+c	$0.74^{\dagger}$ (+/- 0.008)	67%	66%	373.9
GC-nnU-Net+d	$0.69^{\dagger\ddagger}$ (+/- 0.007)	67%	65%	426.9
GC-nnU-Net+dc	$0.74^{\dagger}$ (+/- 0.005)	67%	71%	564.9

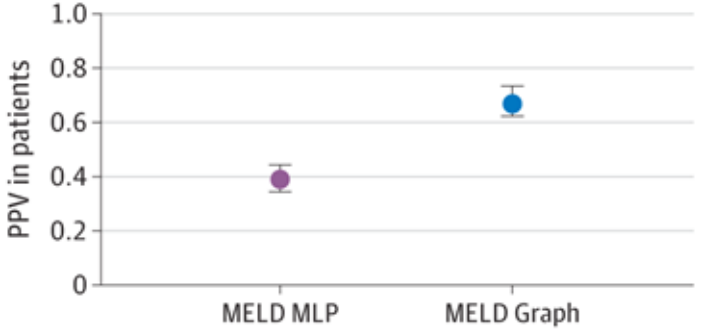
†Model performance significantly improved compared to MLP.
‡Model performance significantly worse compared to GC-nnU-Net+dc.

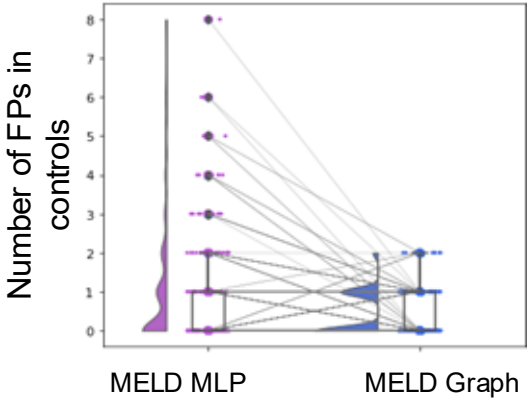
Spitzer et al., *MICCAI* 2023

Comparison of MELD MLP and MELD Graph









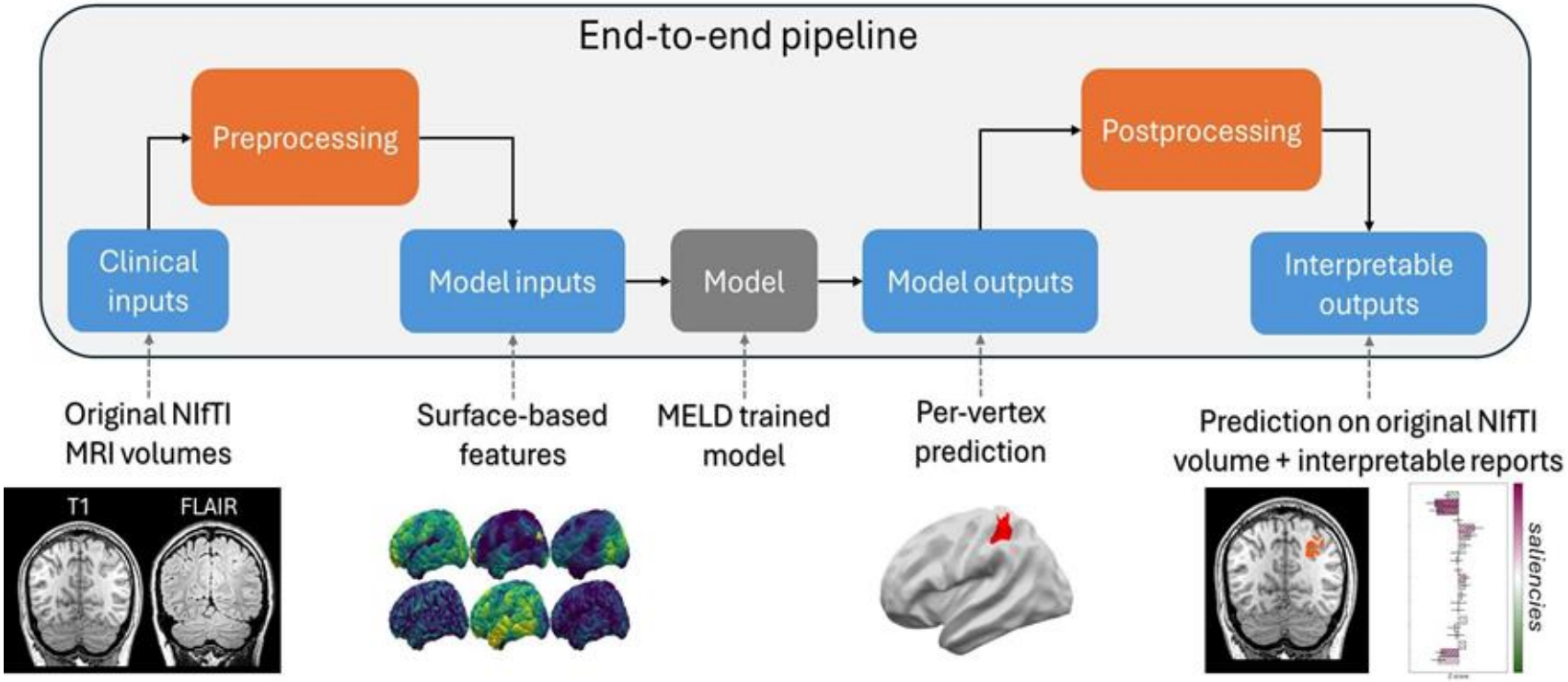
	MELD MLP	MELD Graph
Sensitivity	67%	72%
Specificity	54%	60%
PPV	39%	**69%**
Detection in MRI negative	63%	65%

Ripart et al., *JAMA Neurology 2025*

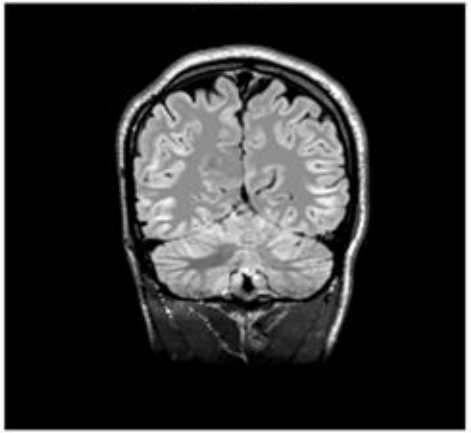
Key points of this talk

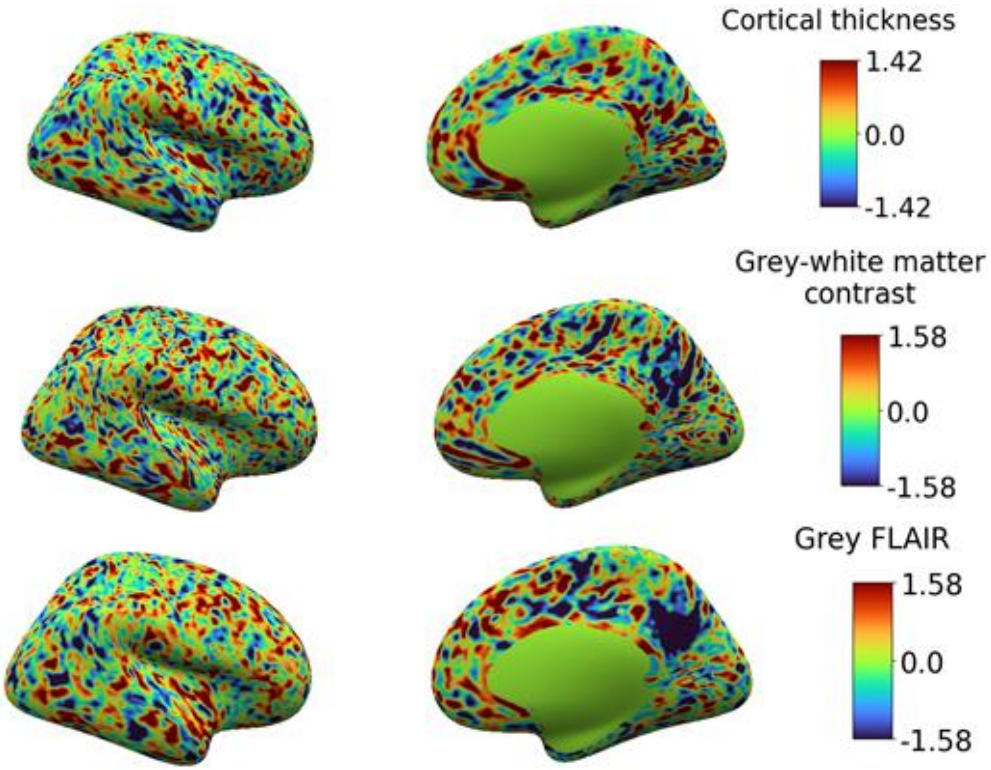
- AI can detect subtle focal cortical dysplasia (FCD) on MRI
- Graph Neural network for a more confident detection of FCD
- Translation into clinical practice
- Going further - a deep learning model for the detection of multiple epilepsy lesions

Integrating the model into an end-to-end pipeline

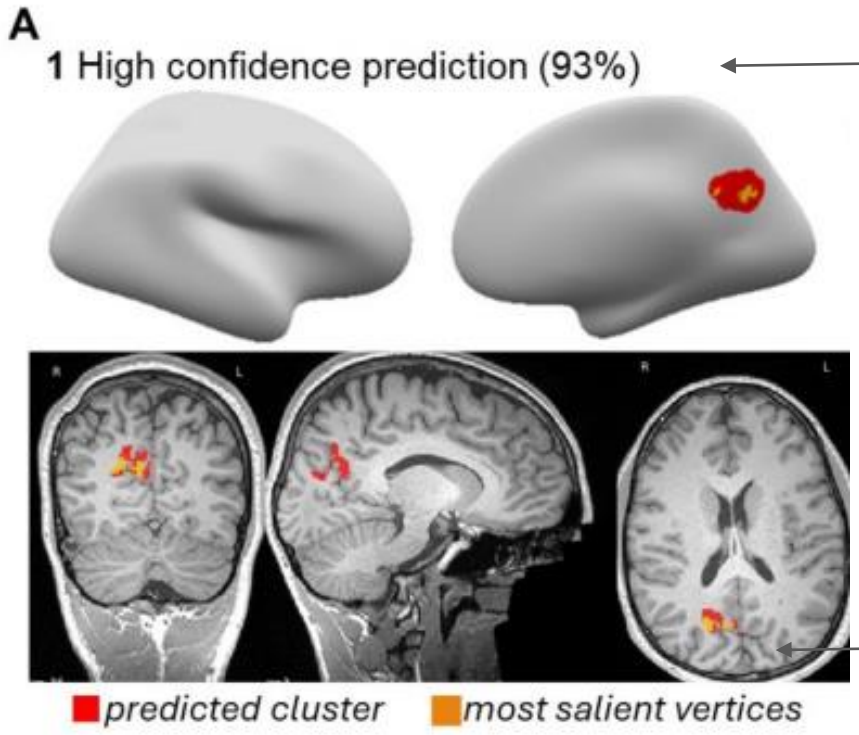


Can you find the lesion: back to the example





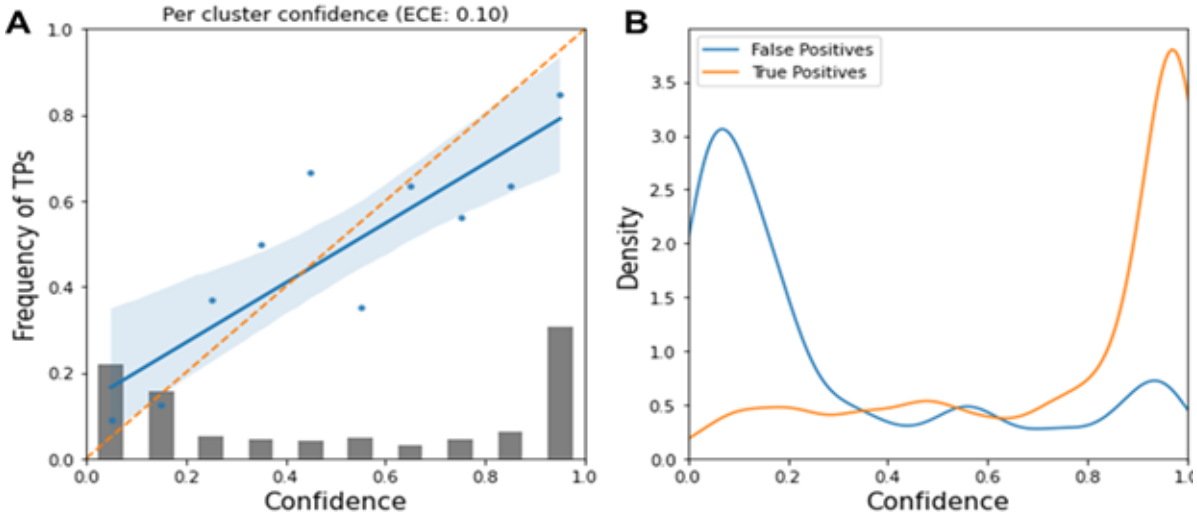
Can you find the lesion: Interpretable report



Confidence score

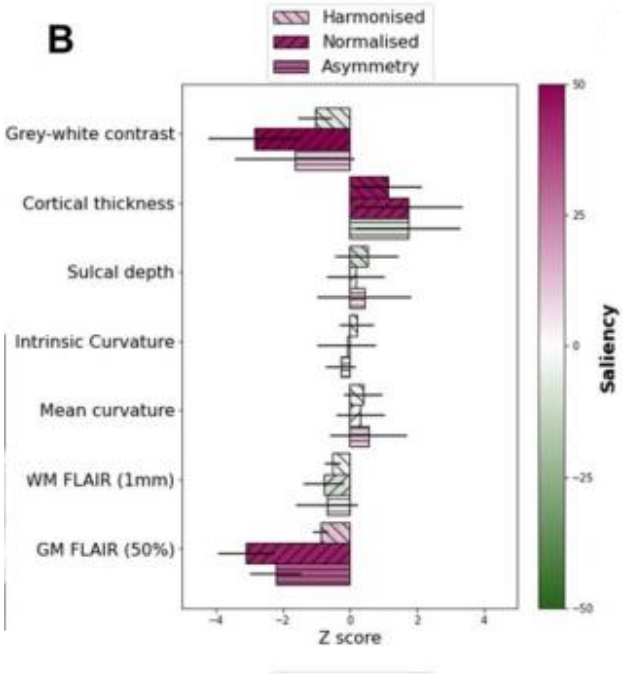
Spatial saliencies

Calibration of confidence scores



Confidence scores = average of prediction scores for each vertex in the predicted lesion

Can you find the lesion: Interpretable report



Feature saliencies

Can you find the lesion: Interpretable report

Q4. How confident are you about the lesion location?

1. Absolutely no idea
2. Everything looks a bit abnormal
3. One or two areas look suspicious
4. I think I know where it is
5. I am very confident

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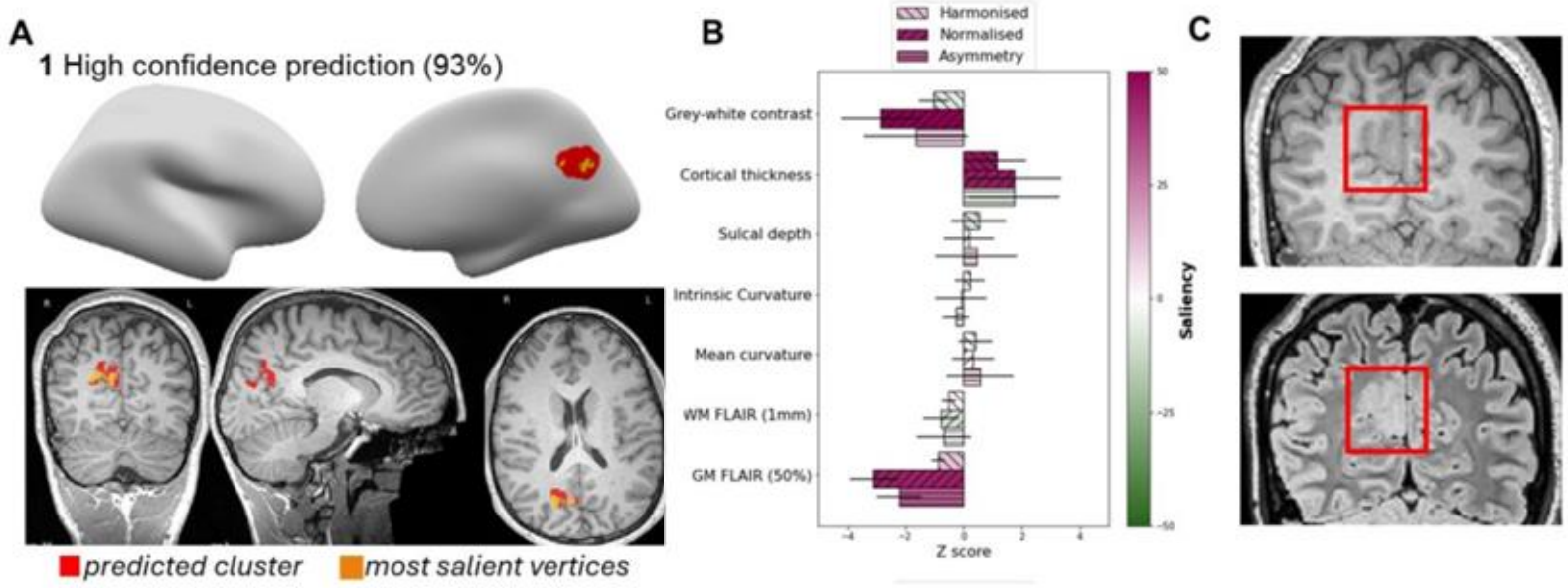


Translation into clinical practice

1. Neuroradiology

2. Neurosurgery

3. Global training

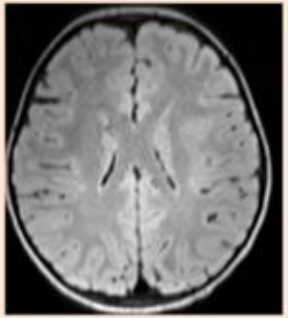
Disclaimer: **MELD Graph is not a regulated medical device**

Translation into clinical practice: GOSH radiologists

Patient

8 year old girl
Referred to specialist epilepsy surgery center
Drug resistant epilepsy

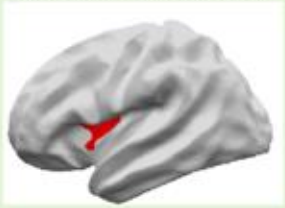
MRI negative



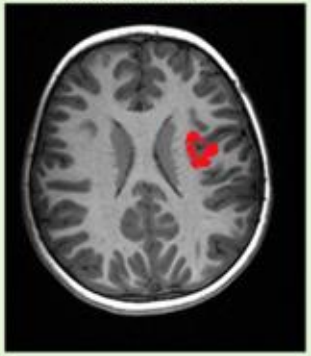
Original FLAIR MRI
No lesion detected

MELD FCD algorithm

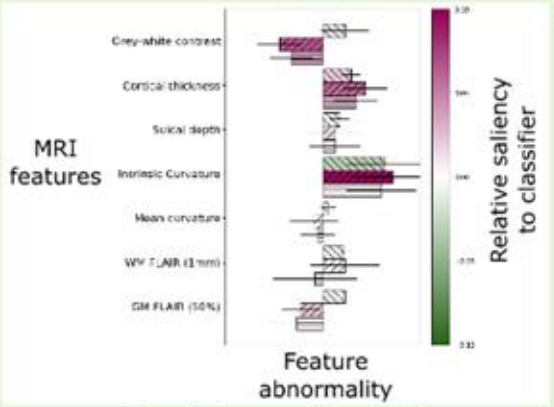
Surface-based view



Axial MRI view



Lesion feature report



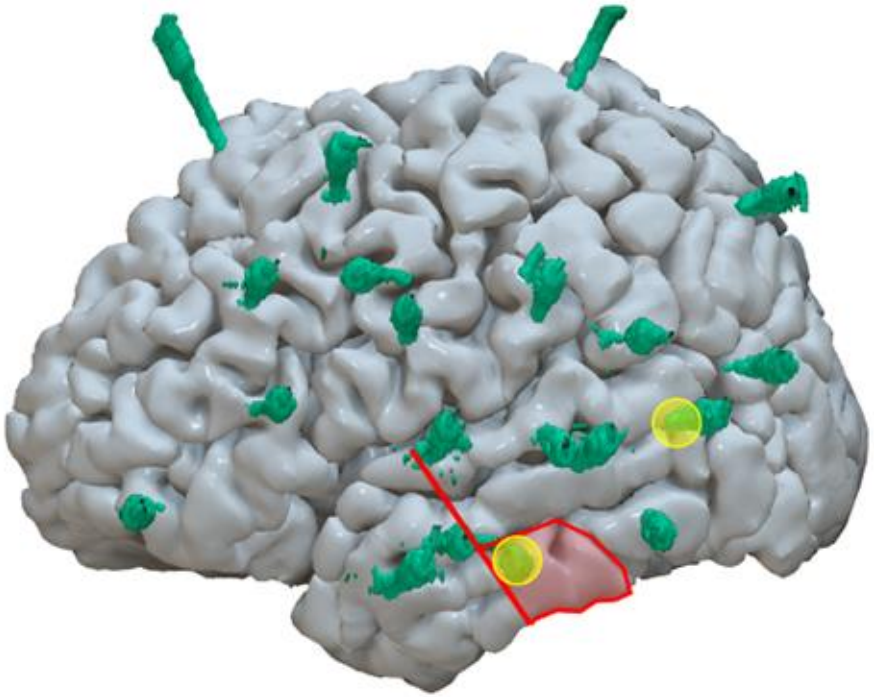
Focal abnormality (red) detected by MELD algorithm and confirmed by radiologist. Algorithm identified lesion from: grey-white blurring, increased cortical thickness and folding abnormalities

Dr Felice D'Arco

Dr Kish Mankad

Pastore et al.,
Neuroradiology 2024

Translation into clinical practice: GOSH neurosurgery



M.A.S.T

MELD as an Adjuct for SEEG Trajectories

Dr Aswin Chari

Dr Martin Tisdall

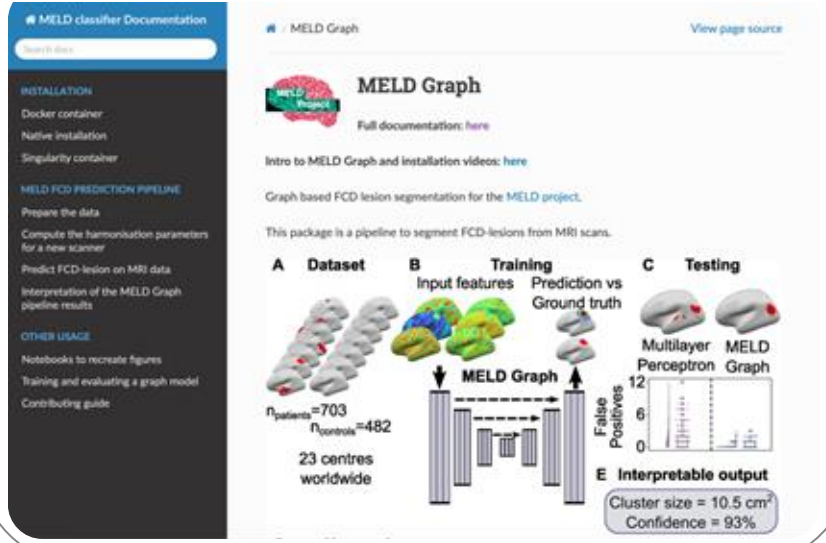
Chari et al., DMCN 2023

Translation into clinical practice: global training

Open source on GitHub

github.com/MELDProject

Documented on Readthedocs



YouTube Tutorials

MELD project

@MELDproject · 28 subscribers · 11 videos

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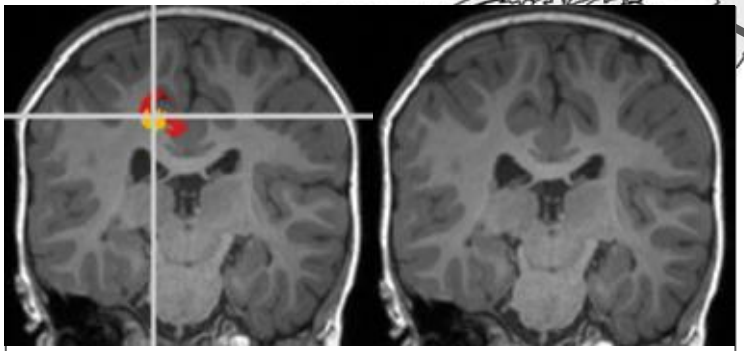
Wokshops ILAE EpiCARE

Next one:

ILAE School on Neuroimaging,
May 2026, Potsdam

MELD: cases from around the world

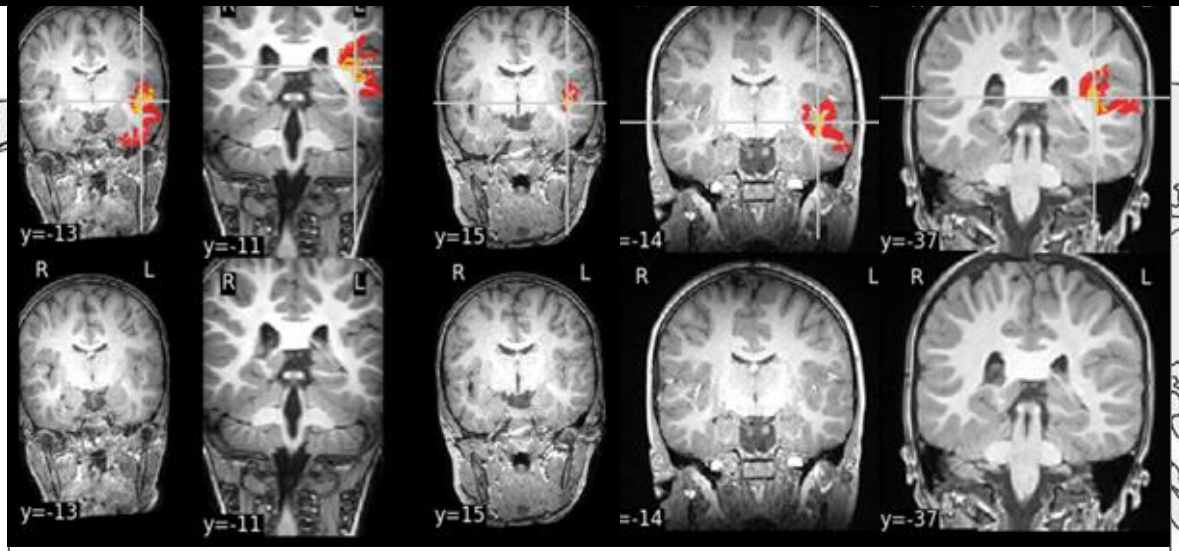
MELD: cases from around the world



20 seizures per day, MRI negative.
MELD cluster concordant with video telemetry
Thermocoagulated following sEEG
Child seizure free for a month after
A focal resection is planned.

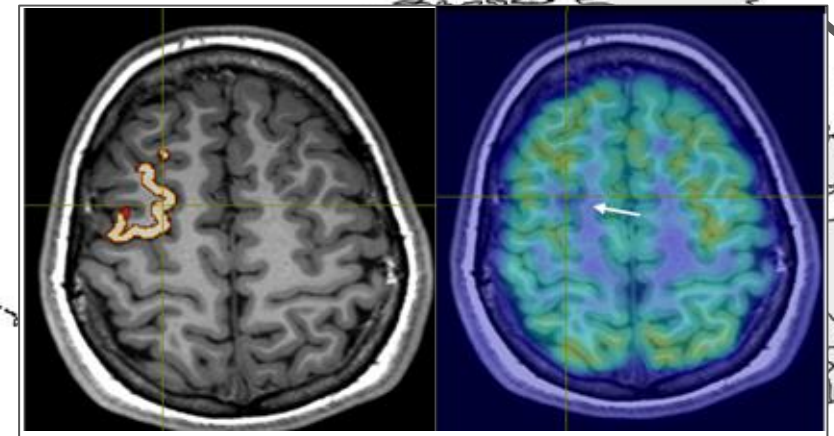
Bristol Royal Hospital for Children, UK
Dr Marcus Likeman

MELD: cases from around the world

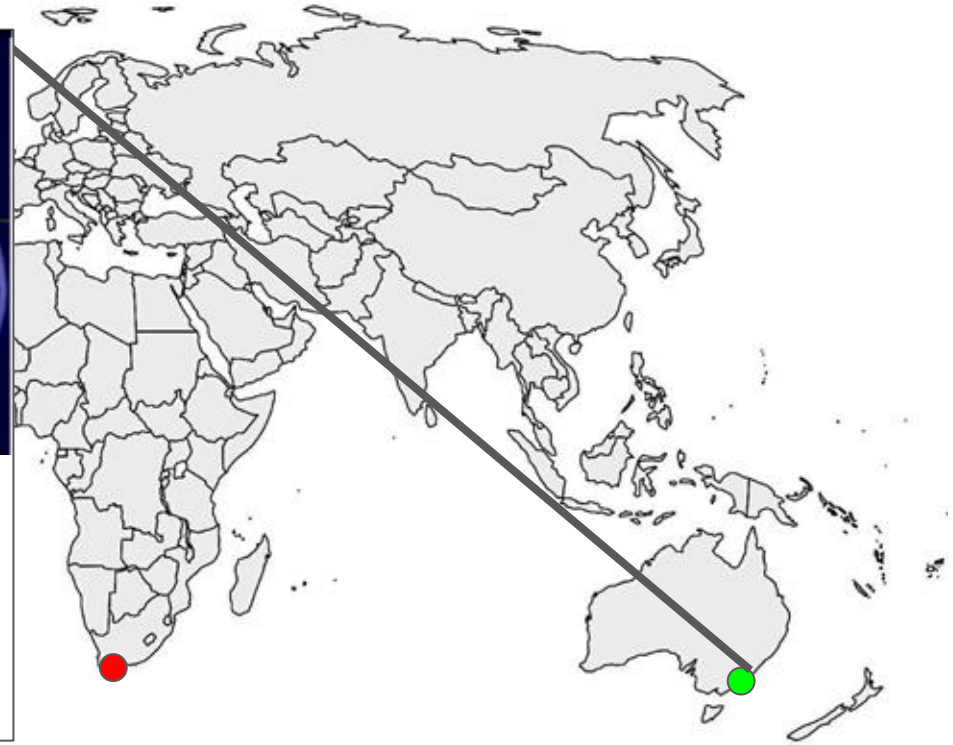


10yr old male. Up to 70 seizures/day. 7x MRI negative. MELD confirmed by neuroradiologist. **Mediclinic Constantiaberg, South Africa. Dr James Butler**

MELD: cases from around the world

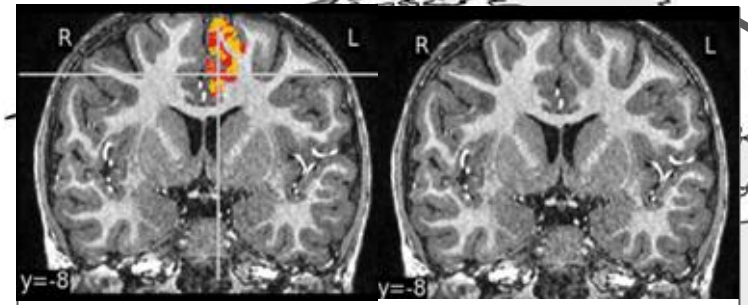


14 y old girl.
x3 MRI negative
MELD + PET: R frontal BOSD
Resective surgery - FCDIIA, seizure free off meds 6m
The Royal Children's Hospital, Melbourne
Dr Emma Macdonald-Laurs, Dr Aaron Warren



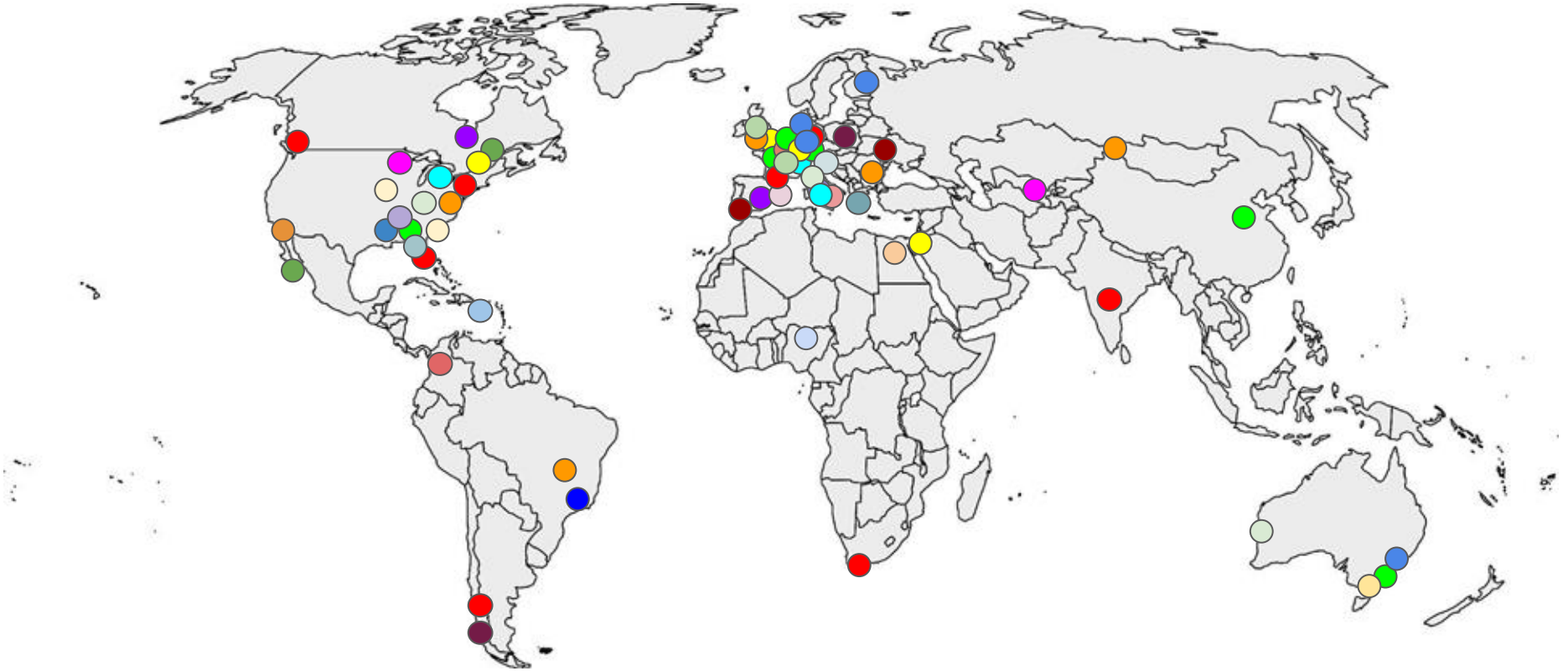
Macdonald-Laurs et al., Epilepsia 2025

MELD: cases from around the world



4 y old, EEG - unclear, Non-localising
semiology: spasm, lip smacking
MRI negative
MELD cluster confirmed by Dr Felice D'Arco
National Children's Medical Center,
Tashkent, Uzbekistan
Prof Furkat Samadov

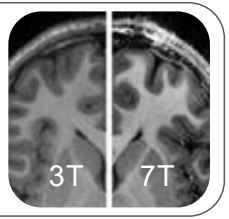
MELD: cases from around the world



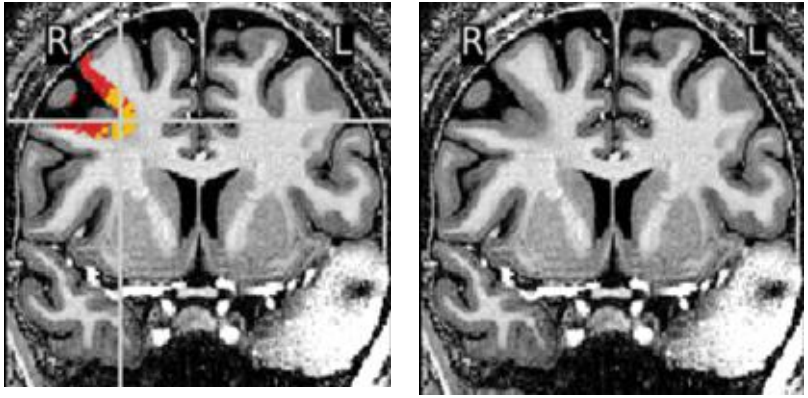
Wider research impact

Dr Cornelius Kronlage

*Can we use **ultra-high field MRI** for automated detection of focal epilepsy lesions ?*



Collaborations:
University of **Tübingen** (Martin, Hagberg, Scheffler)
University of **Bonn** (Rüber)
KCL (O'Muircheartaigh, Leary)
UCL (Piper, D'Arco)
University of **Cambridge** (Rodgers, Cope)

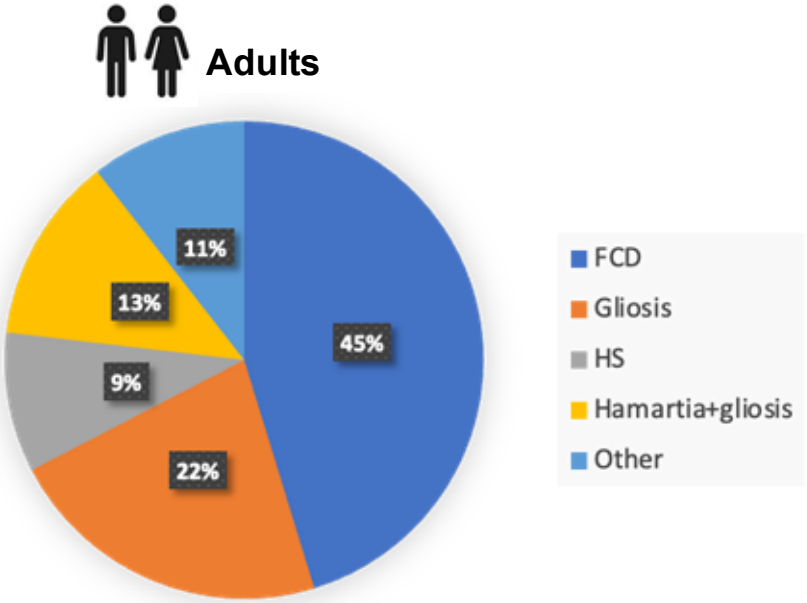


MELD-graph prediction on 0.8 mm 9.4T MP2RAGE

Key points of this talk

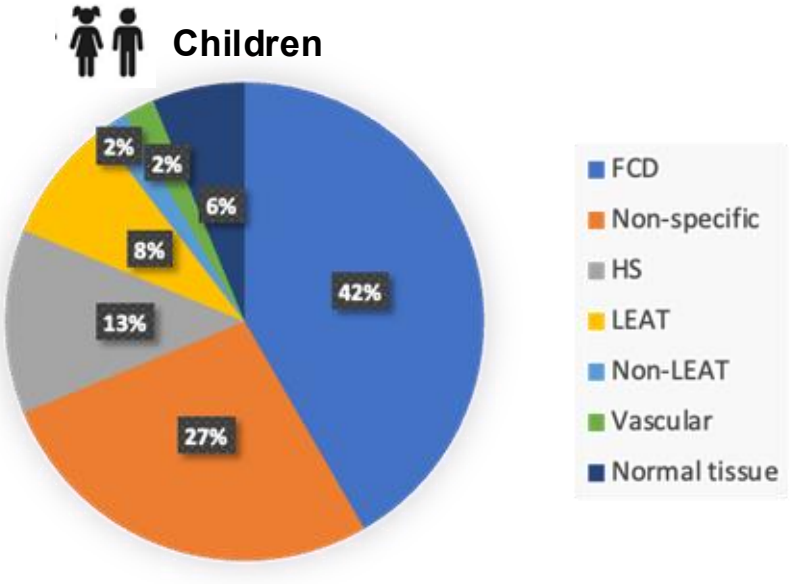
- AI can detect subtle focal cortical dysplasia (FCD) on MRI
- Graph Neural network for a more confident detection of FCD
- Translation into clinical practice
- Going further - a deep learning model for the detection of multiple epilepsy lesions

“MRI-negative” Epilepsy - “Missed” lesion



95 MRI negative

Adapted from Wang et al., 2013 Mod Path



87 MRI negative

Eriksson et al., 2023 Epilepsia

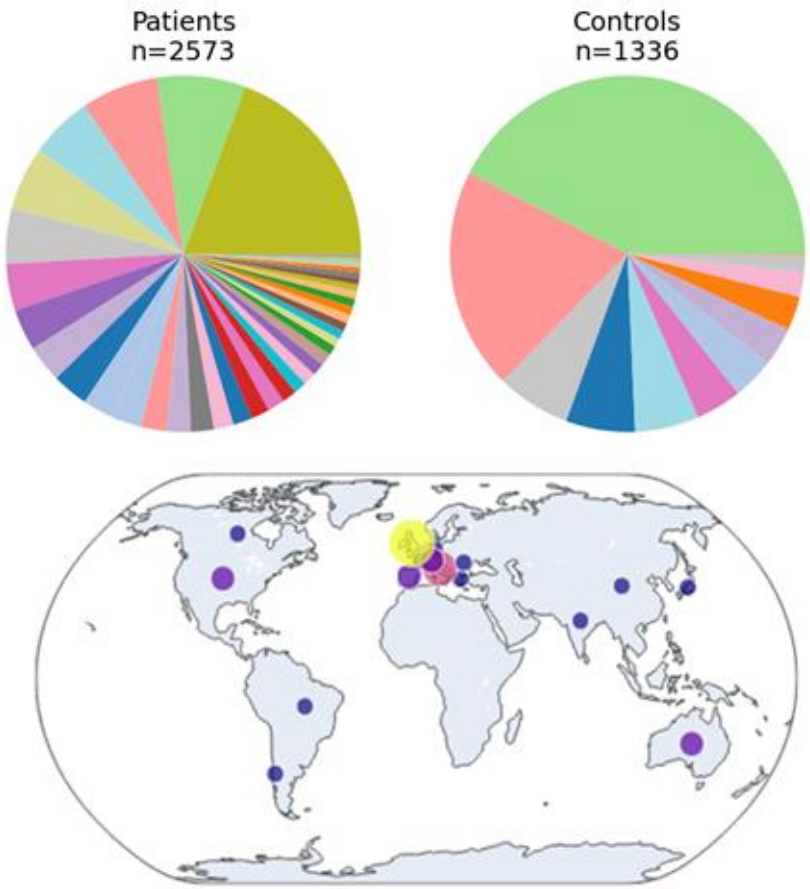
MELD Focal Epilepsies dataset

39 centres - 3909 subjects

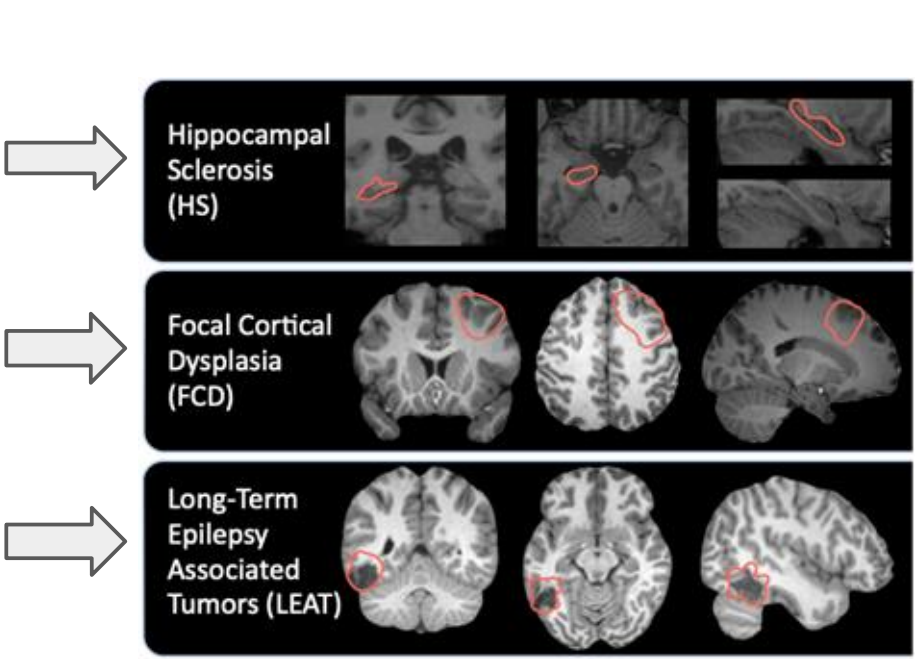
Over 2500 patients and 1300 controls

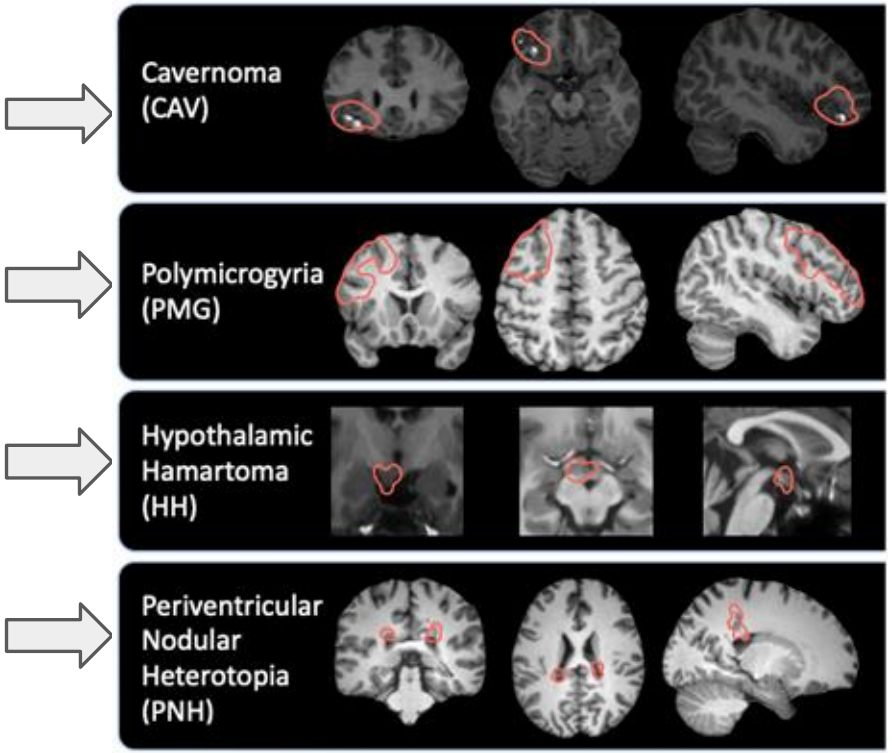
Large age range (0.1 - 69 years)

Multiple focal epilepsy pathologies



Focal epilepsies lesion location

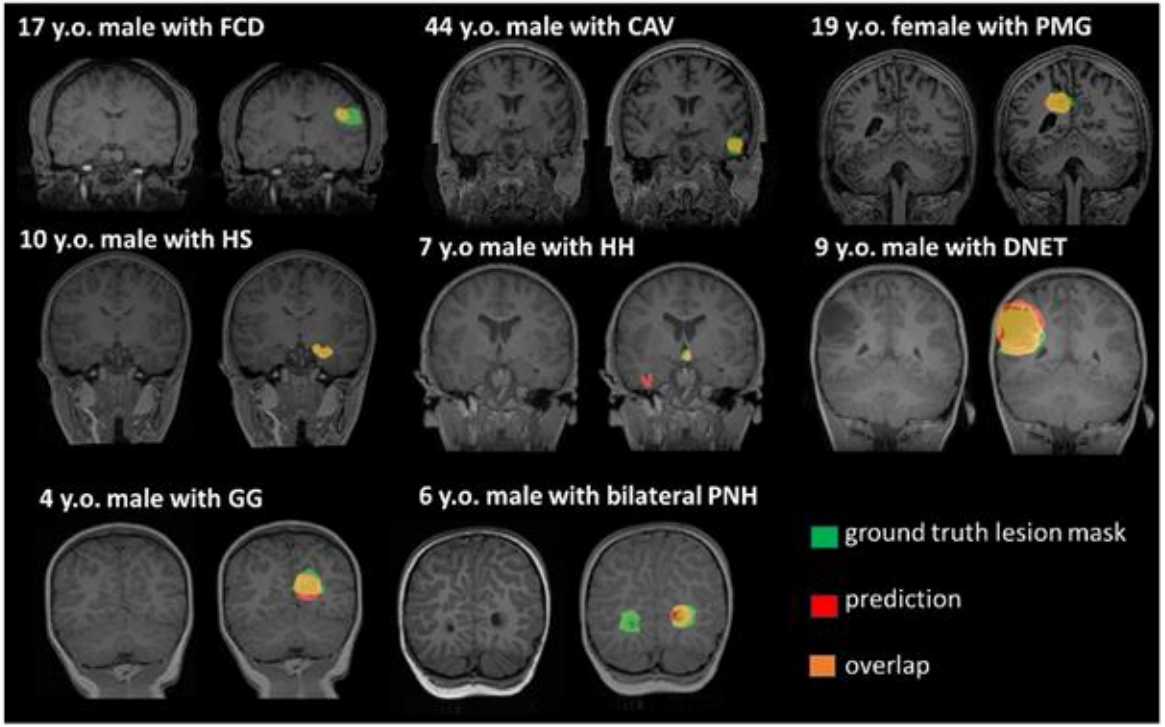




MELD Find: Focal-epilepsy Imaging Network Detection

Ripart et al., *MIDL 2024*

MELD Find: Focal-epilepsy Imaging Network Detection

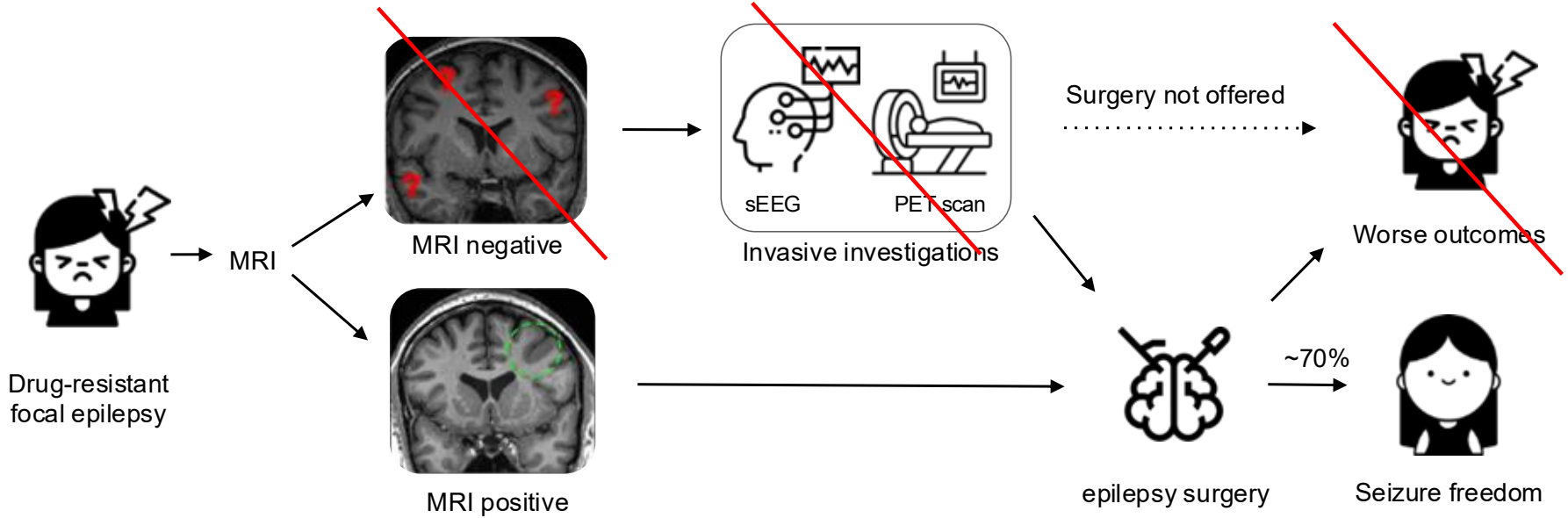


73% sensitivity
90% specificity

Ripart et al., *MIDL 2024*

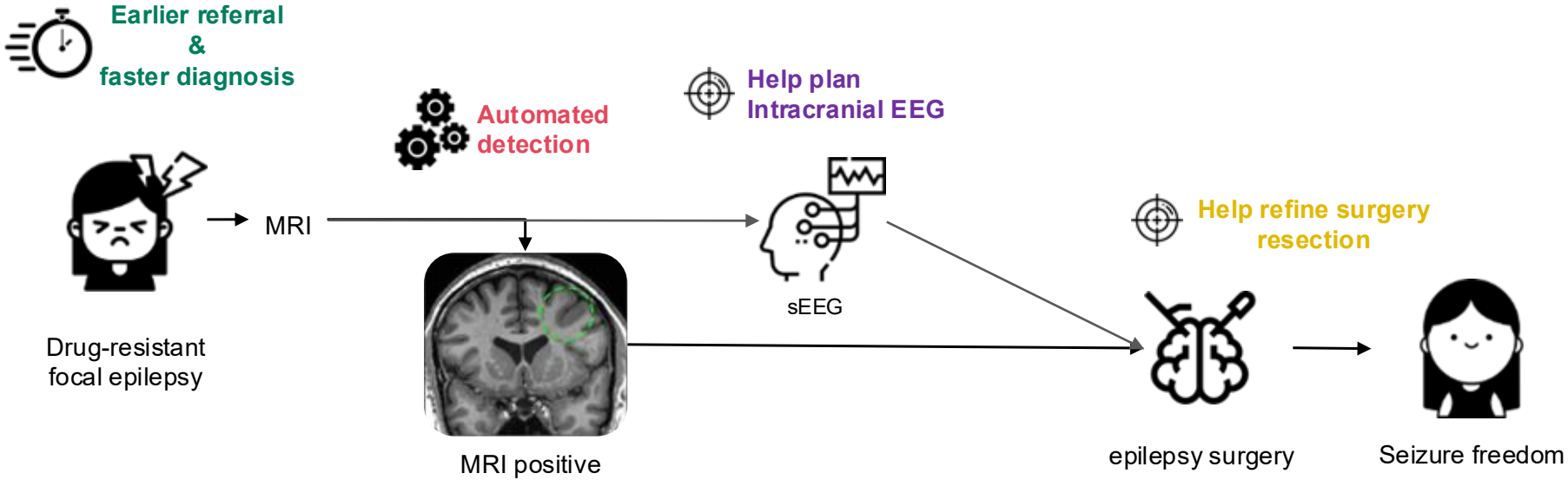
Multi-Centre Epilepsy Lesion Detection

Vision: A better chance of seizure freedom for all



Multi-Centre Epilepsy Lesion Detection

Vision: A better chance of seizure freedom for all



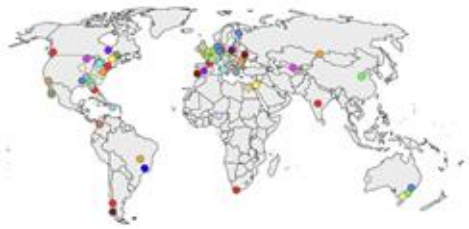
Acknowledgements

The **IMAGINE Lab**
led by

Dr Konrad Wagstyl

Dr Sophie Adler

MELD collaborators
& MELD tools users



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