ARAMIS LAB
BRAIN DATA SCIENCE

10th September 2024

How can I detect that something is wrong in my pizza?

Or: Anomaly detection in neuroimaging and computer-aided diagnosis for brain disorders

Inria Junior Seminar

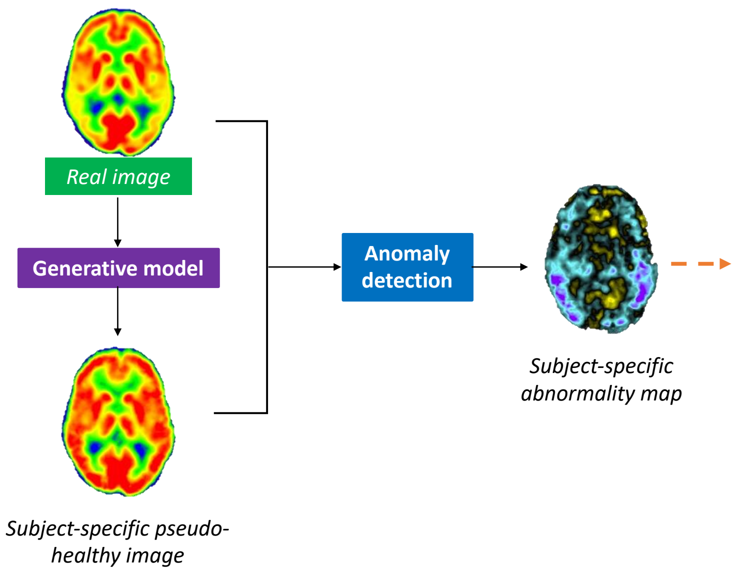
Maëlys Solal

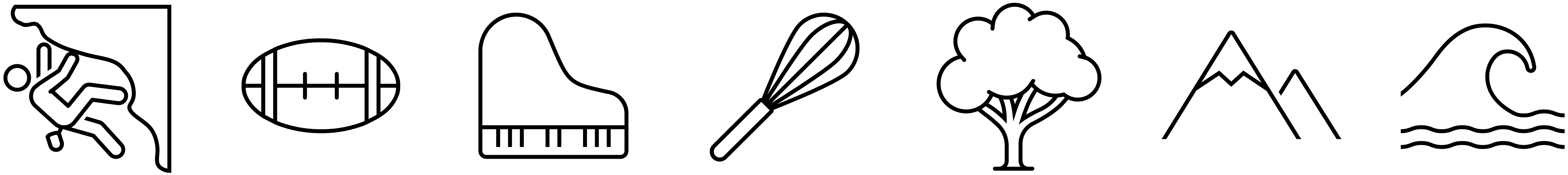
Who am I?

Who am I?

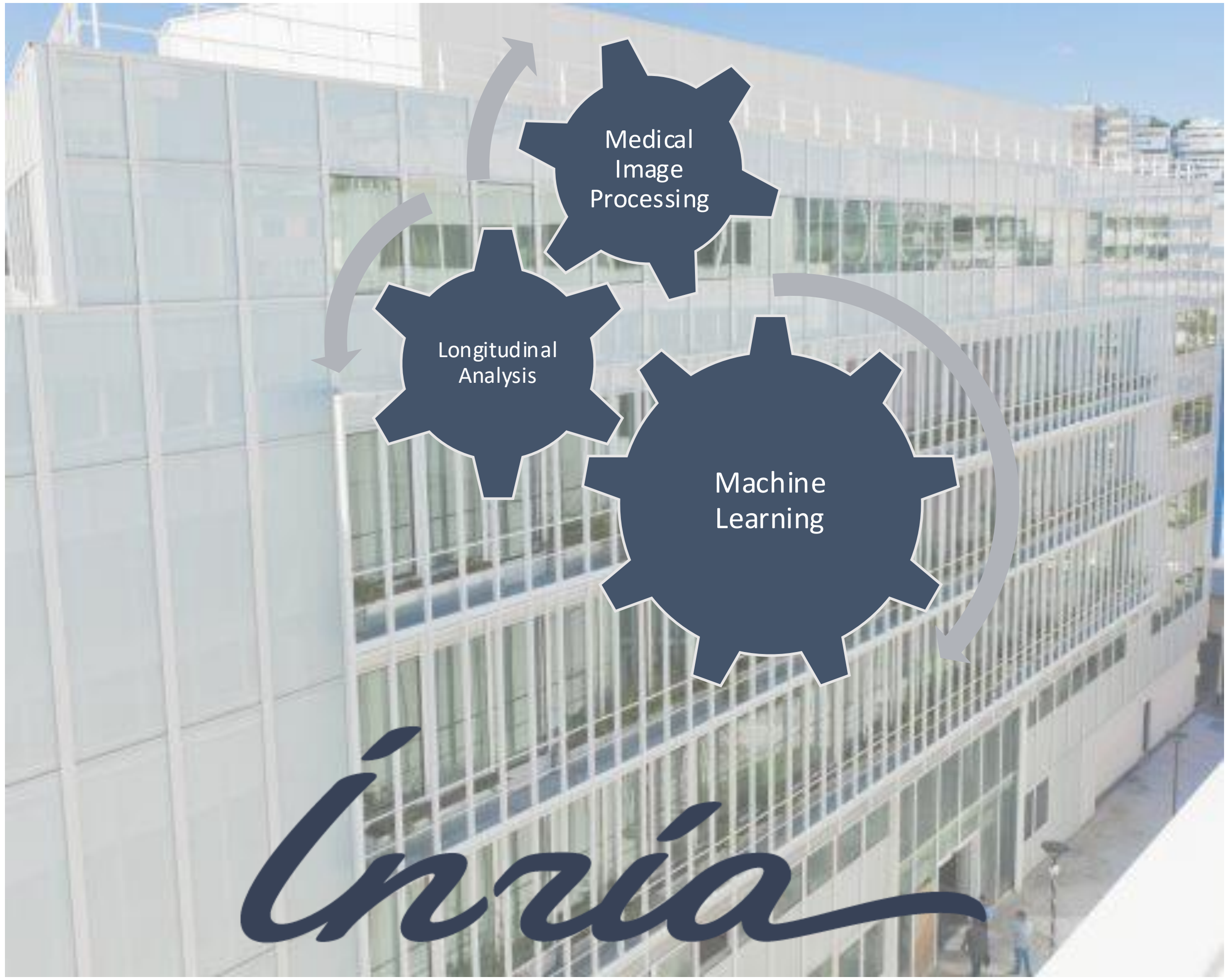
PhD student, starting my 2nd year
ARAMIS Lab

PhD topic: Robust anomaly detection for multimodal neuroimaging
Supervisor: Ninon Burgos, CR from CNRS





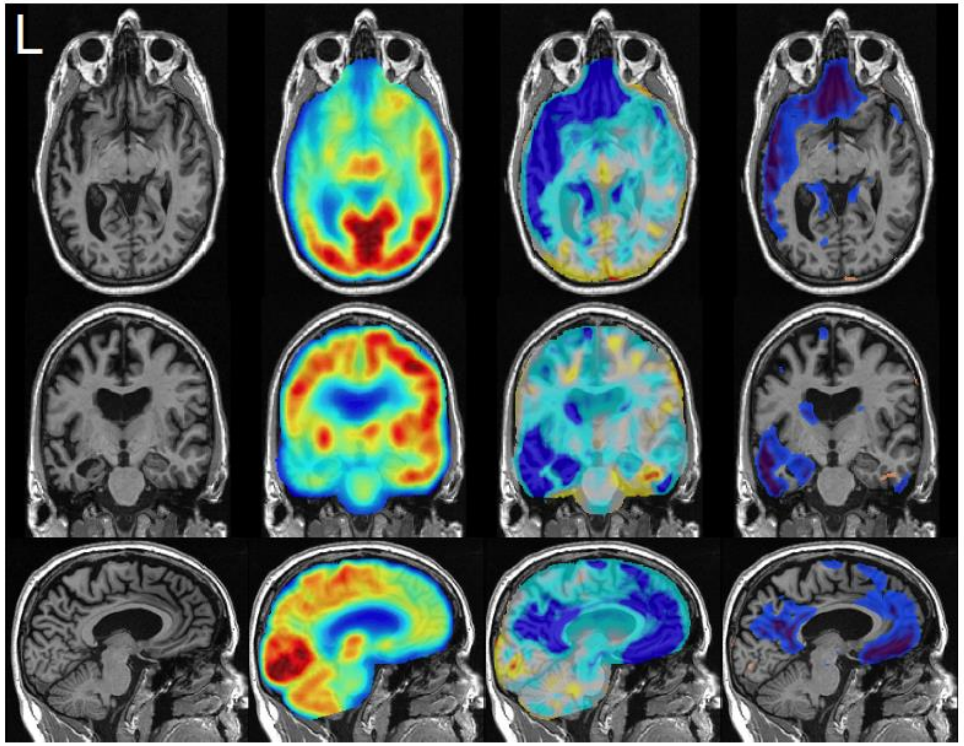
Inria & Paris Brain Institute: Methodology & Applications



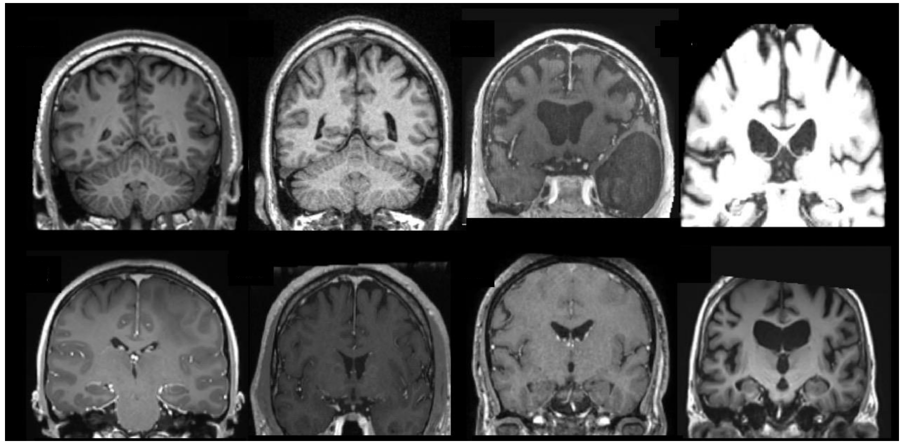
- Alzheimer's disease
- Fronto-temporal dementia
- Multiple sclerosis
- Parkinson's disease

Paris Brain Institute
ICM
Search, find, cure, for you, with you

Neuroimaging biomarkers and decision support systems



Anomaly detection



ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS
Entrepôt de Données de Santé

Decision support systems for clinical routine data

Olivier Colliot

Ninon Burgos

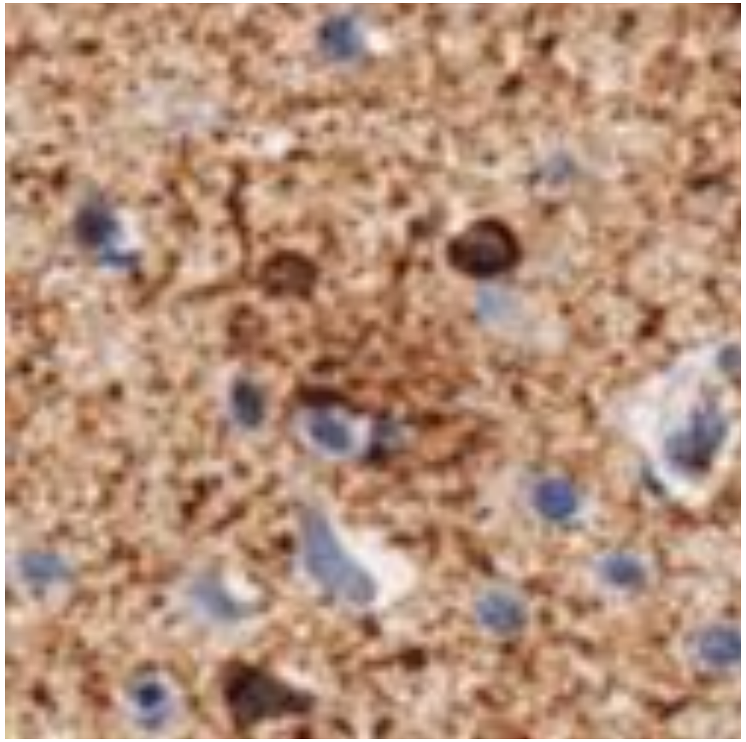
High-dimensional multimodal data (genetic, environment, imaging)

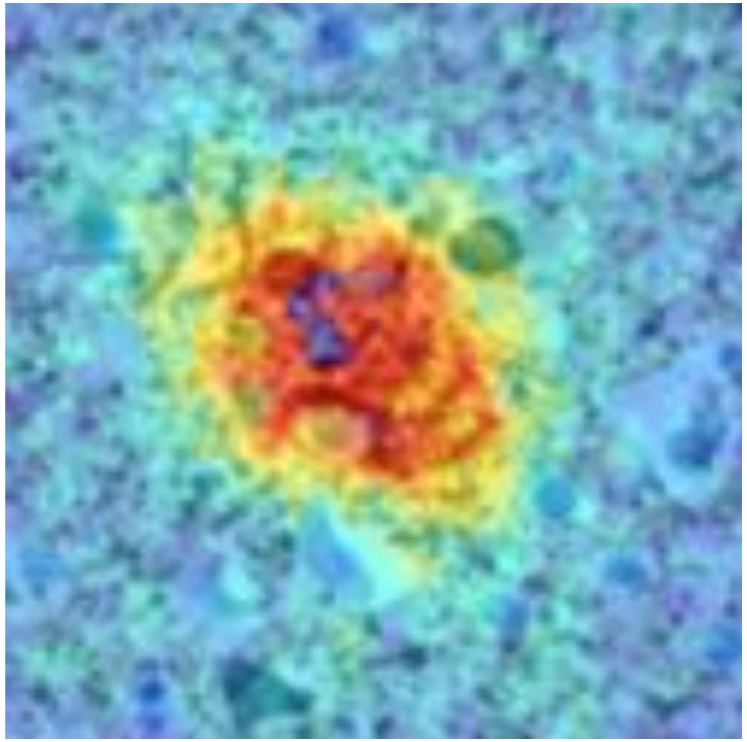
Olivier Colliot

Baptiste Couvy-Duchesne

New statistical models for high-dimensional association

Computational pathology and high-content microscopy

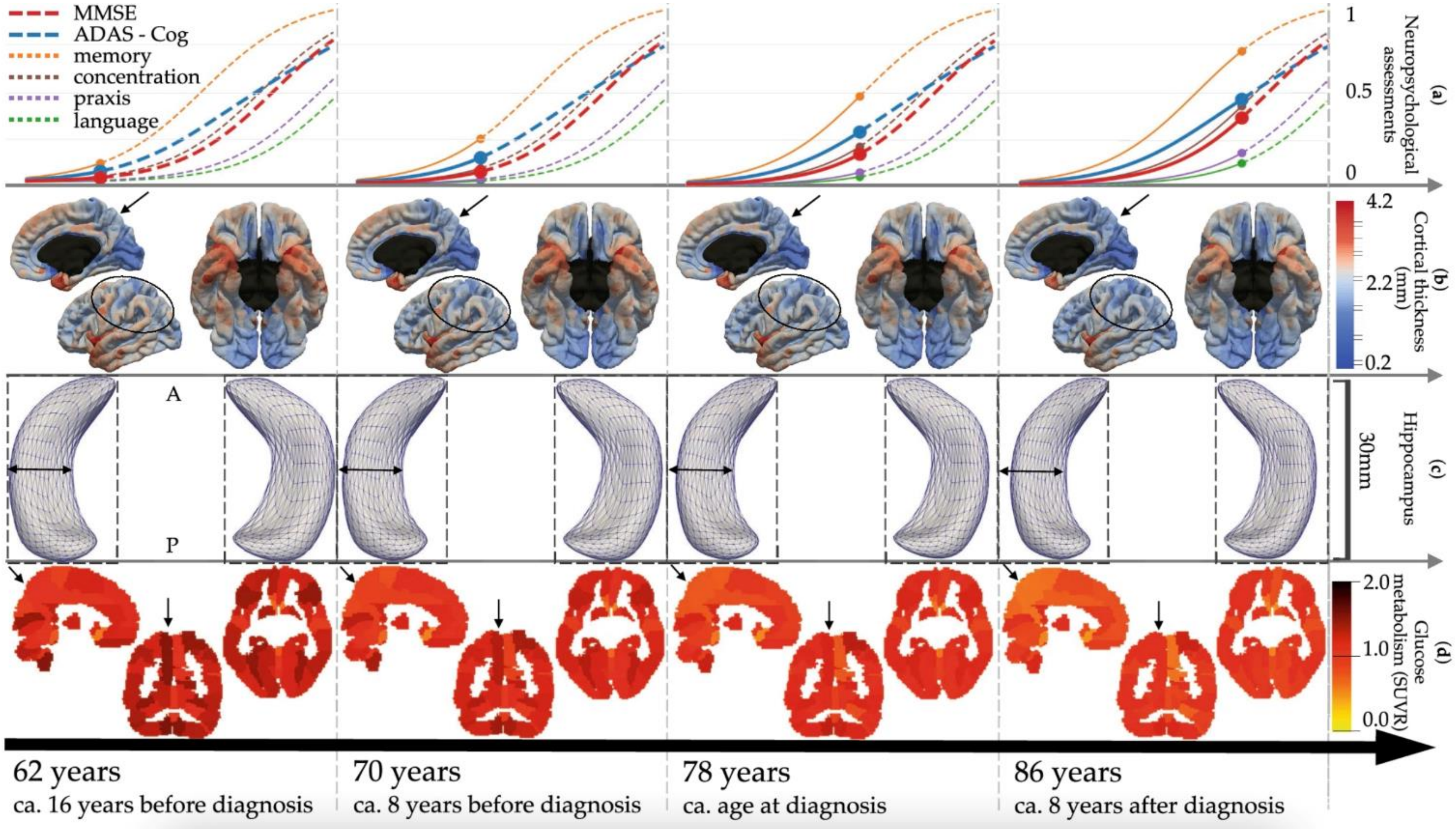

Plaque object in WSI patch


Attention map


Stanley Durrleman


Daniel Racoceanu

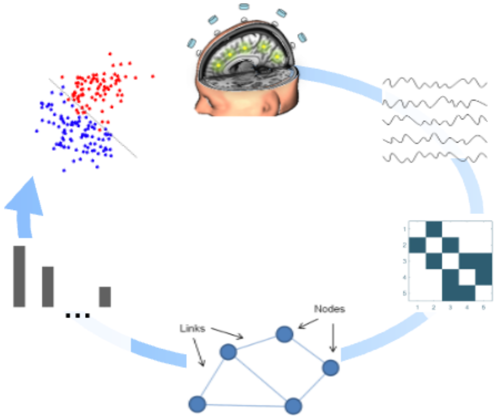
Disease progression modelling for trial design



Stanley Durrleman

Sophie Tezenas
du Montcel

NERV Lab. Systems neuroengineering, complex networks and brain computer-interfaces



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Motivations for Anomaly Detection in Medical Imaging

Anomaly detection for the diagnosis of brain disorders

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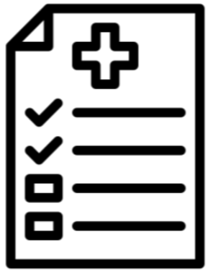
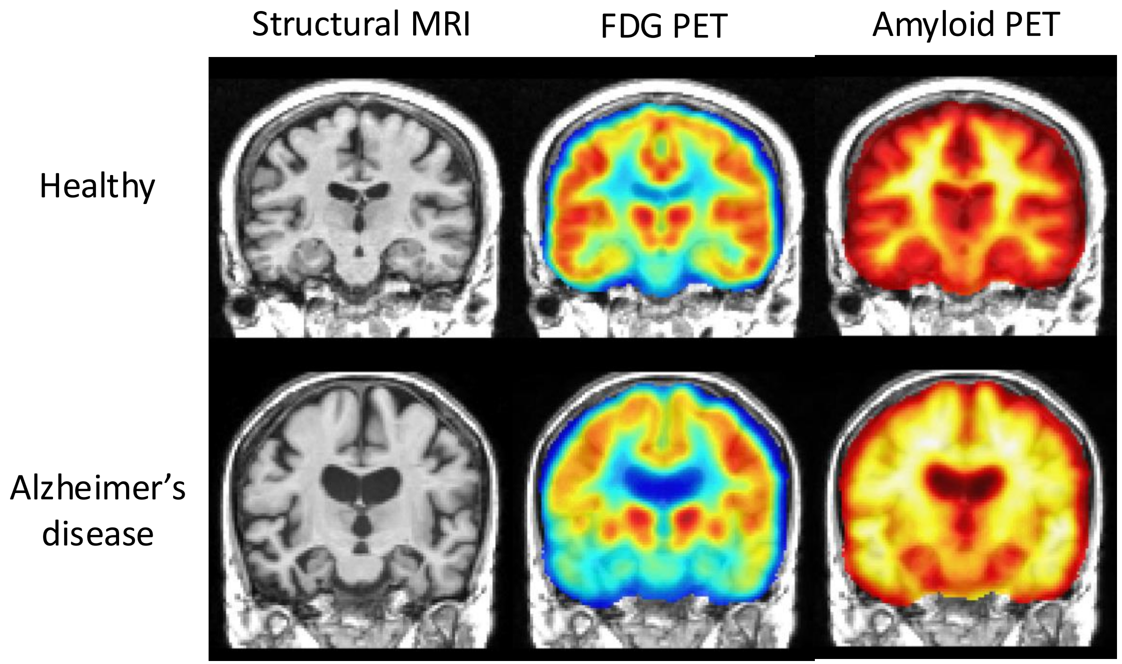
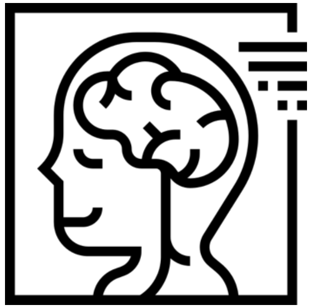
Alzheimer's disease
Neurodegenerative disorder
10% of people $\geq$ 65 years old



Currently
Diagnosis from clinical symptoms & cognitive tests



Research Gap. Onset of clinical symptoms is preceeded by neurophysiological changes (years or decades prior)

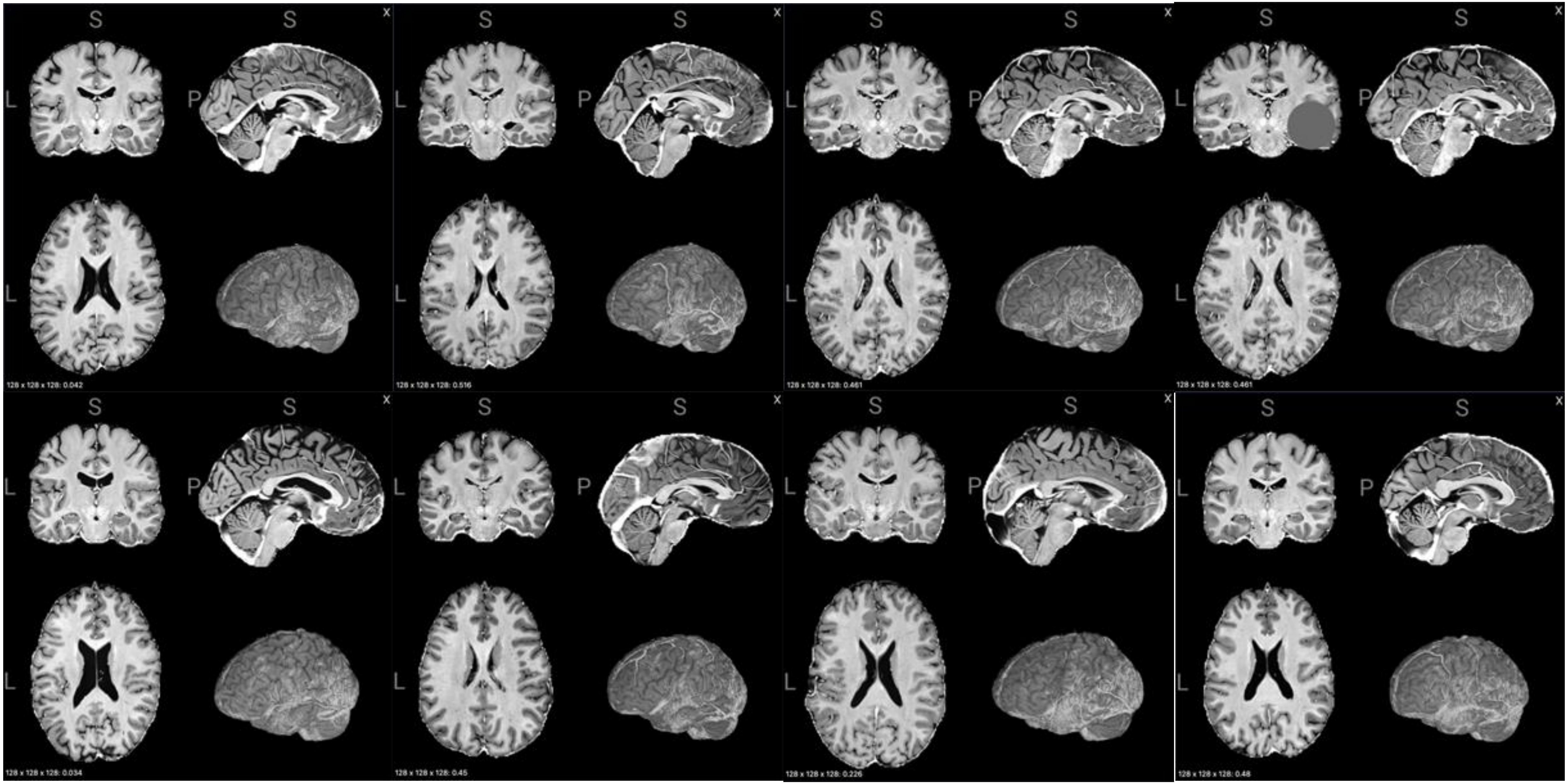


In the future
Improved diagnosis and treatment, with neuroimaging?

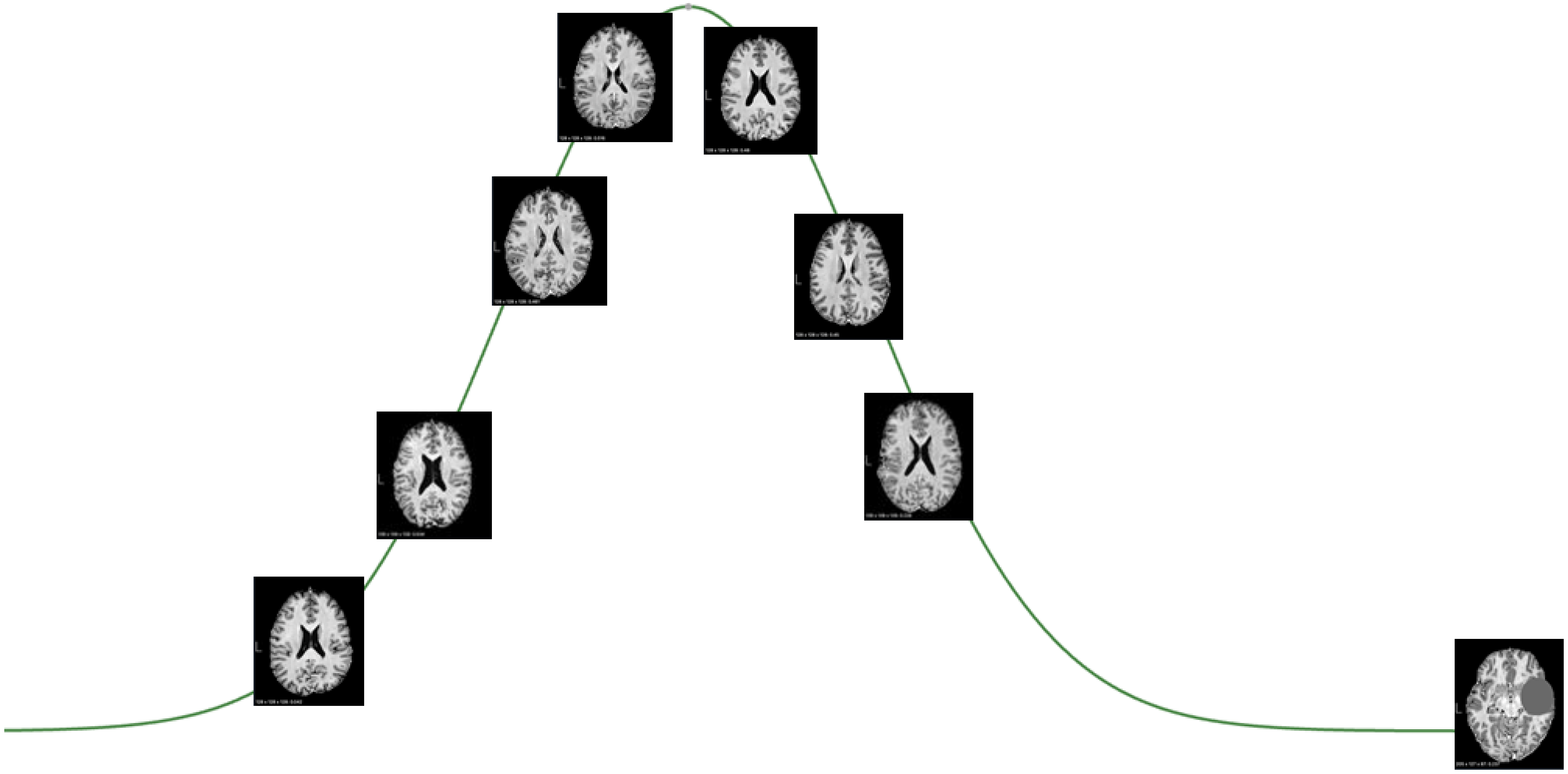
→ **How can we improve the analysis of neuroimaging data to aid the diagnosis of brain disorders?**

Which pizza is out-of-distribution / anomalous?

Which brain is out-of-distribution / anomalous?



Out of Distribution Detection



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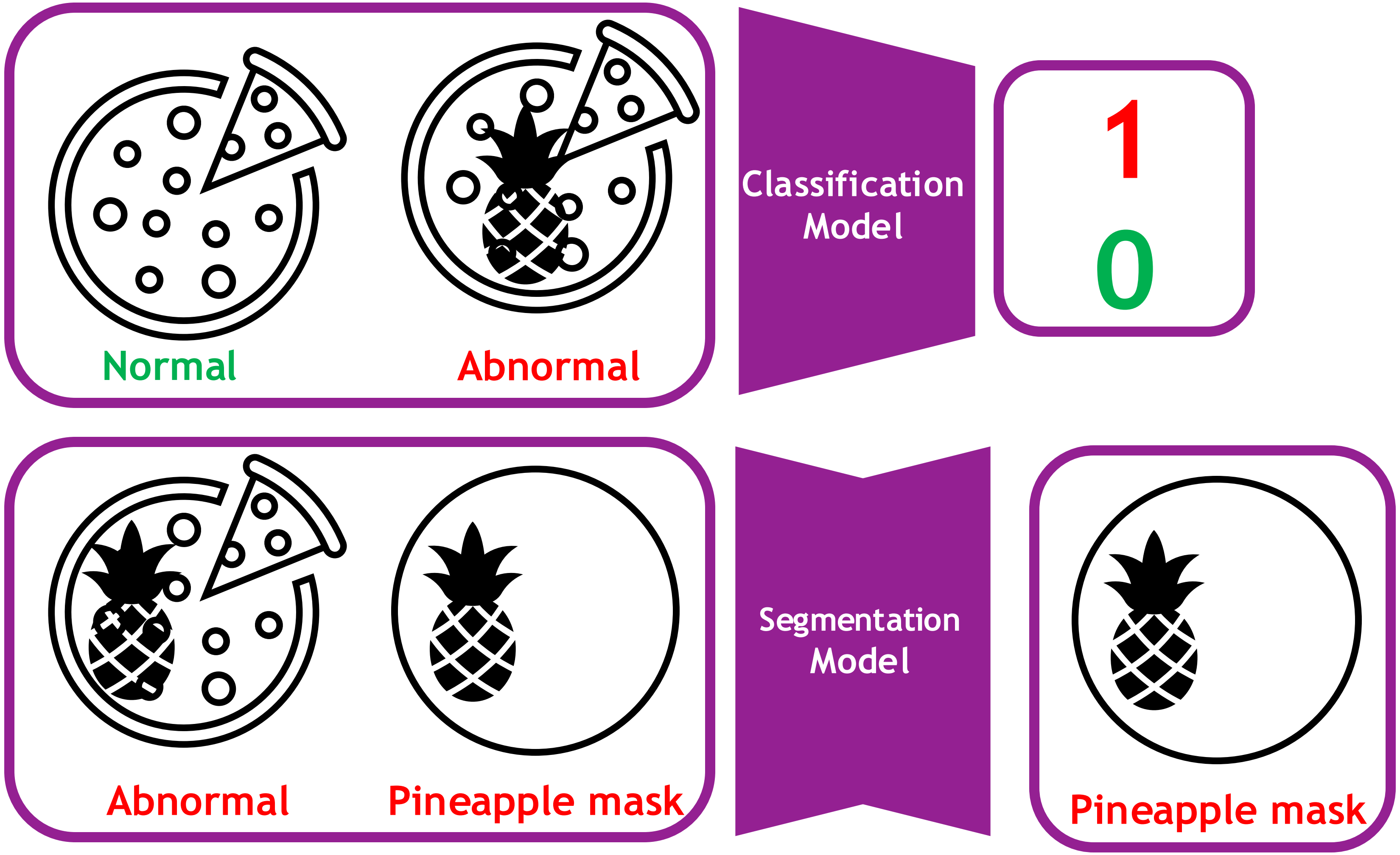
State of the Art in Anomaly Detection for Medical Imaging

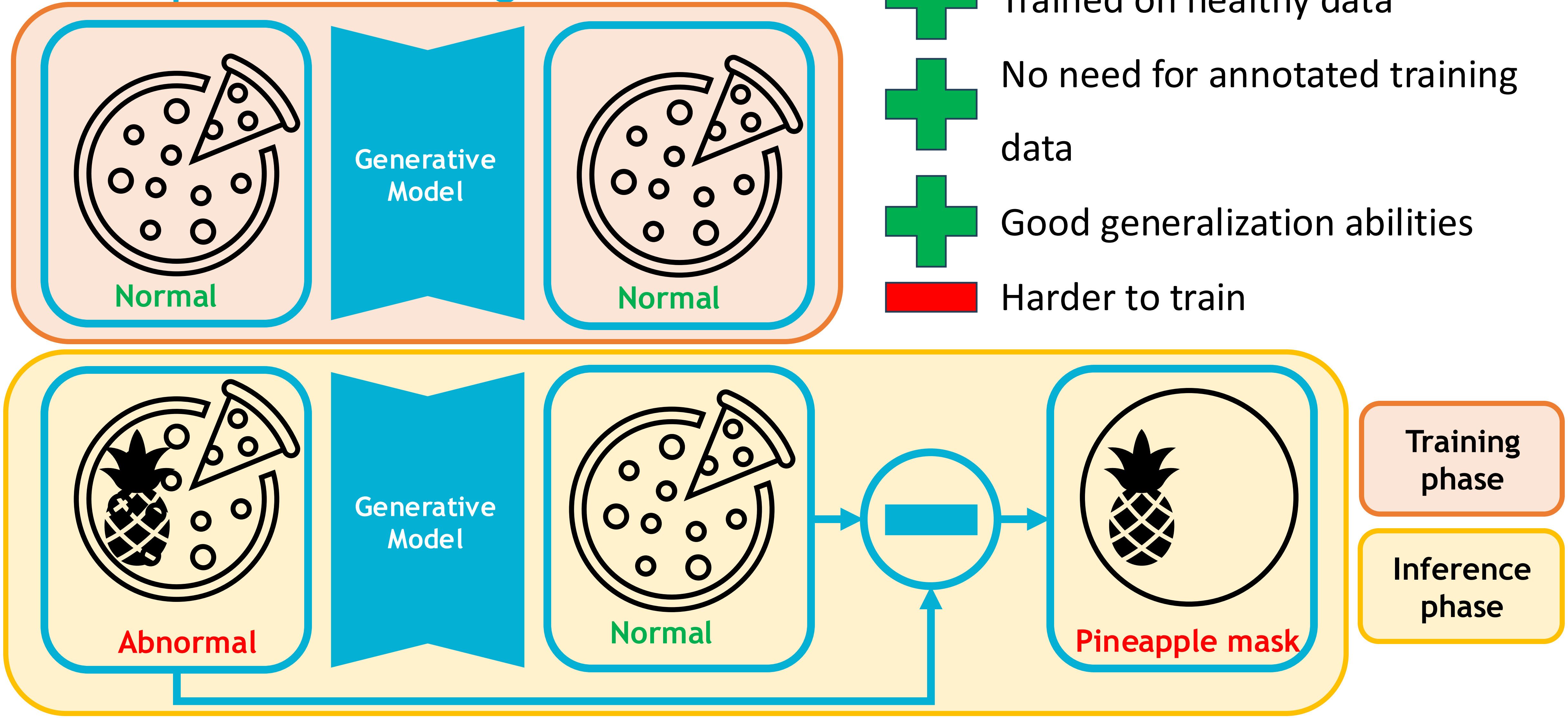
Supervised Learning



- + Highly accurate
- − Requires annotated training data
- − Difficult to generalise to different types of anomalies

State of the Art in Medical Anomaly Detection

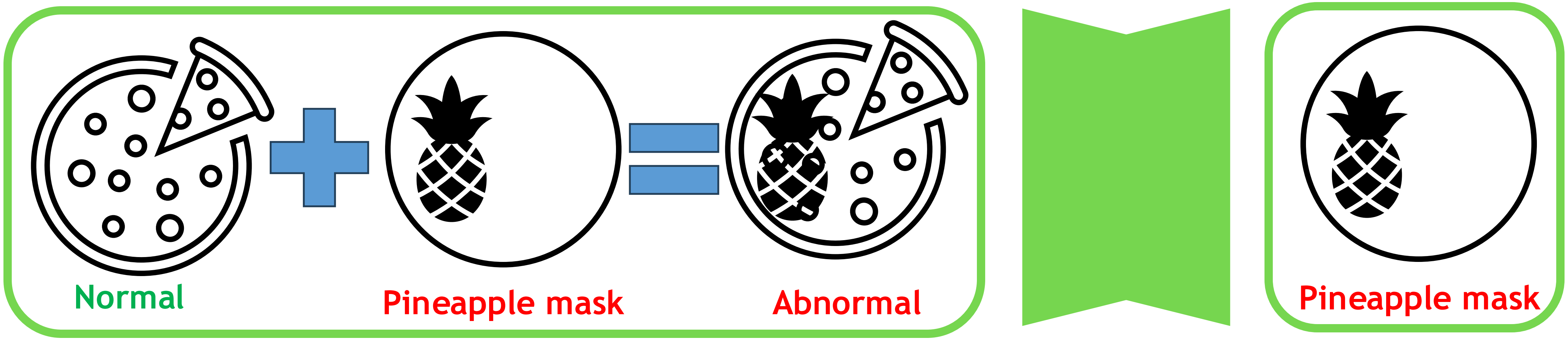
Unsupervised Learning



- + Trained on healthy data
- + No need for annotated training data
- + Good generalization abilities
- − Harder to train

State of the Art in Medical Anomaly Detection

Self-supervised Learning



- Trained on synthetic abnormal scans
- Difficult to generalise to different types of anomalies

State of the Art in Medical Anomaly Detection

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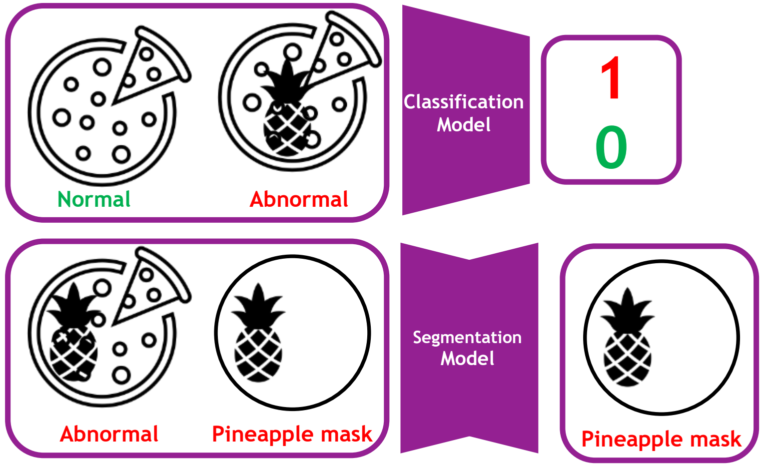
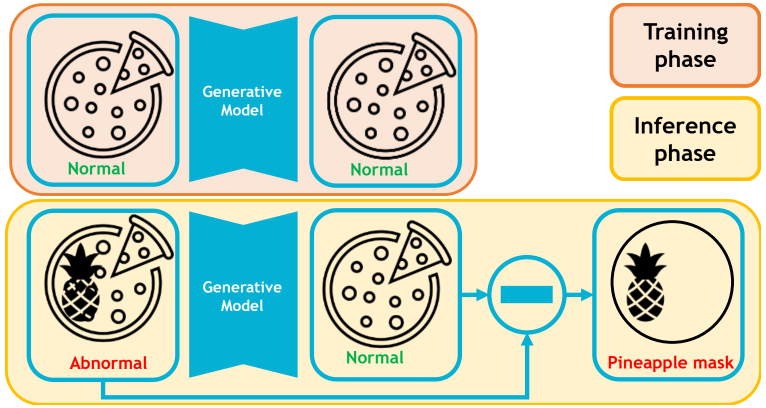
Supervised Learning



Highly accurate

Requires annotated training data
Difficult to generalise

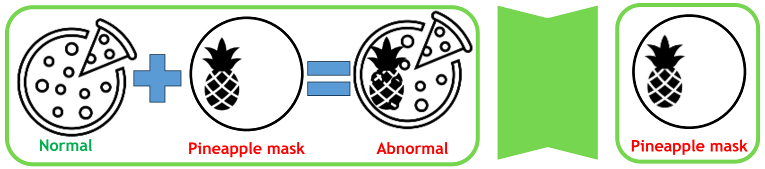
Unsupervised Learning



Trained on healthy data
No need for annotated training data
Good generalization abilities

Harder to train

Self-supervised Learning



Trained on synthetic abnormal scans

Difficult to generalise to different types of anomalies

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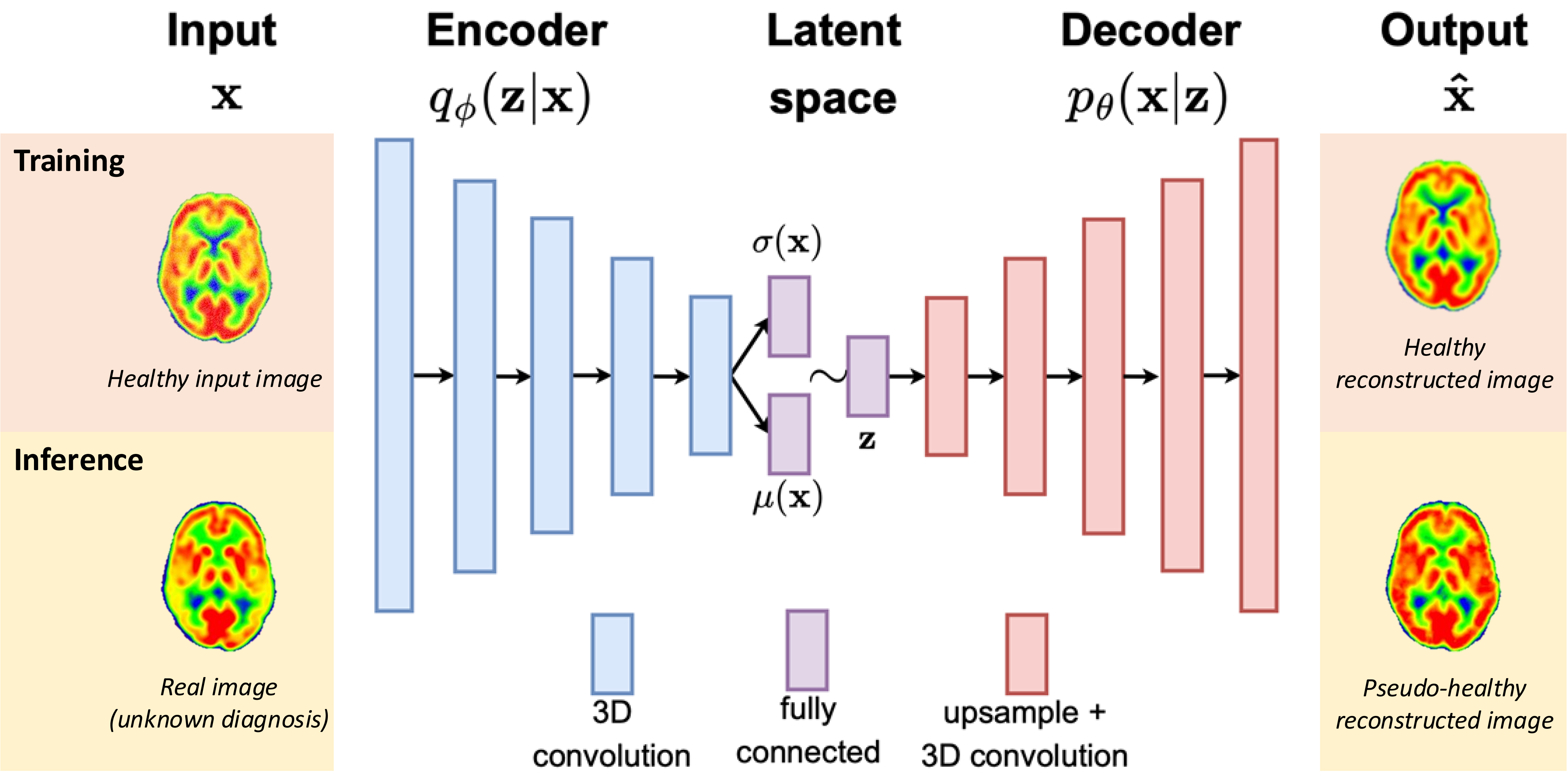
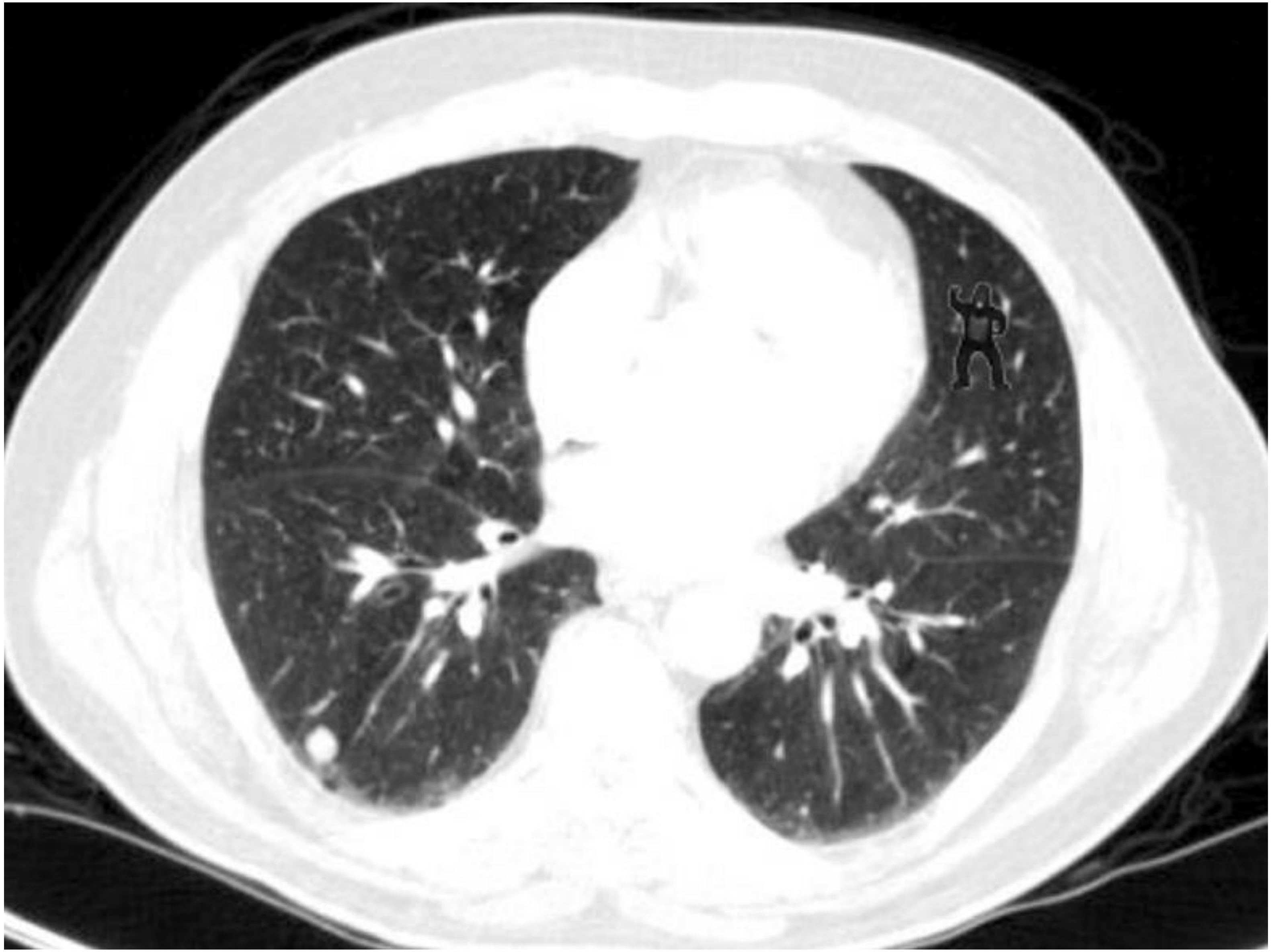
Unsupervised Anomaly Detection via Pseudo-Healthy Reconstruction, an Example

Variational Autoencoder (VAE)

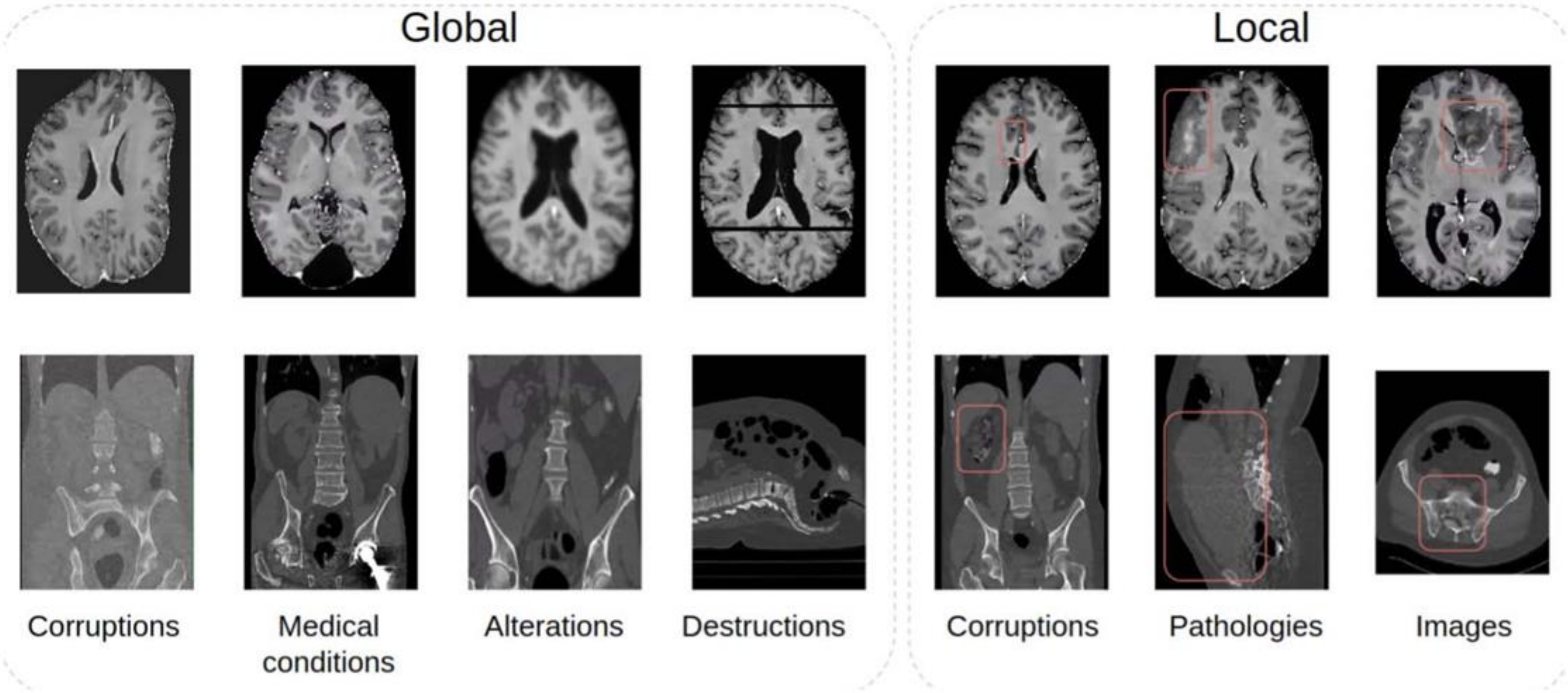


$$\mathcal{L}_{\theta,\phi}(\boldsymbol{x}) = \mathbb{E}_{q_\phi(\mathbf{z}|\boldsymbol{x})}[\log p_\theta(\boldsymbol{x}|\mathbf{z})] - \mathcal{D}_{KL}(q_\phi(\mathbf{z}|\boldsymbol{x})||p_\theta(\mathbf{z}))$$

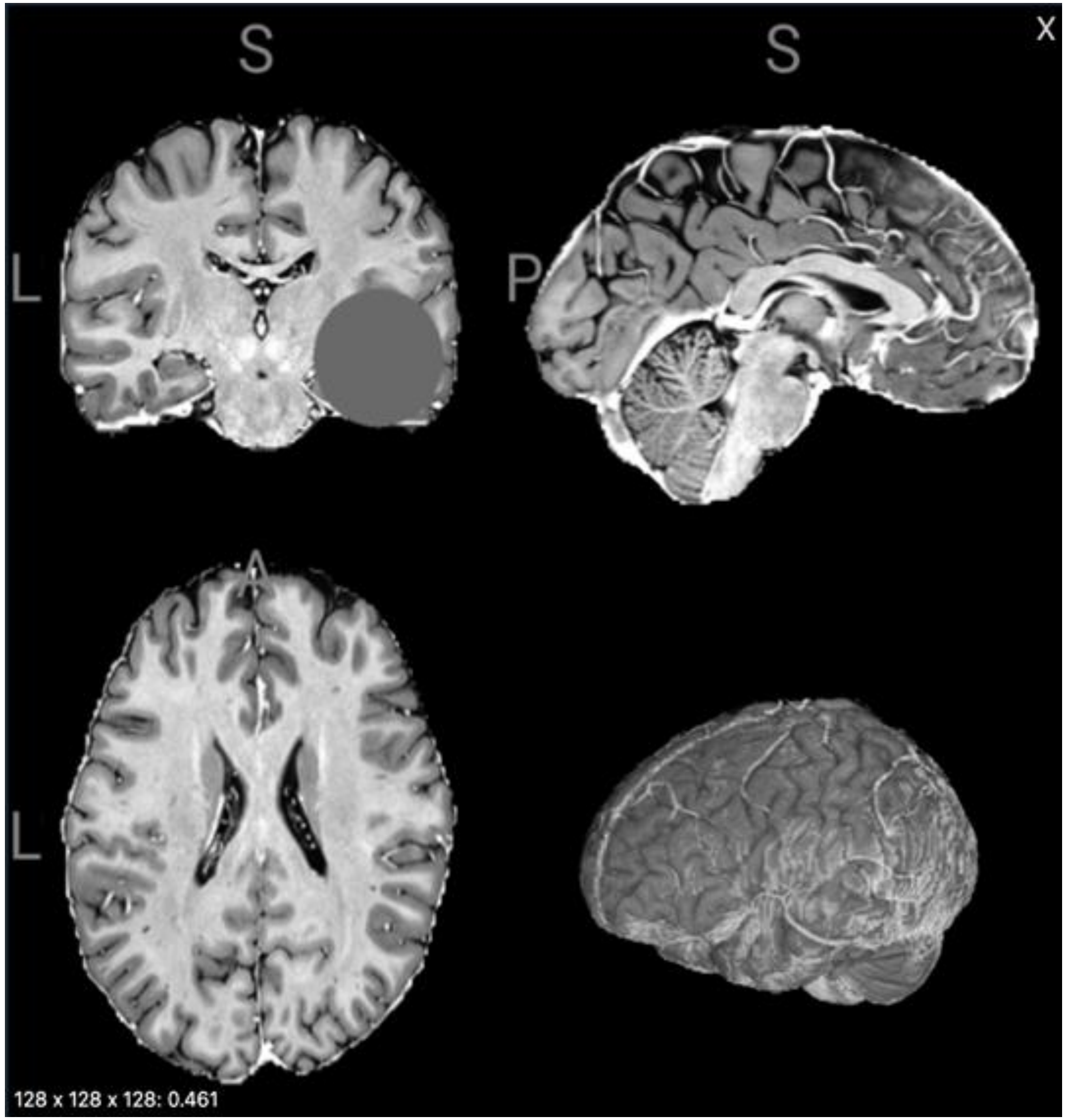
Medical Out-of-Distribution Challenge (MOOD)



MOOD Types of Anomalies



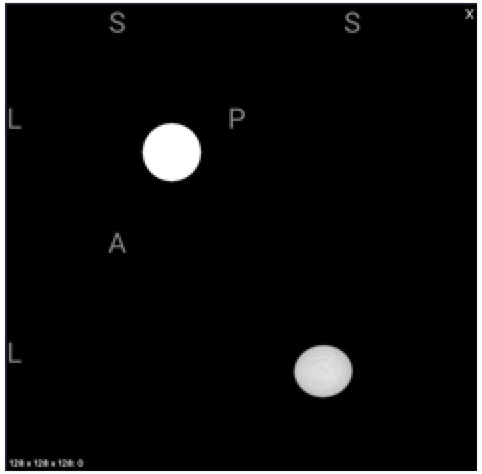
MOOD Tasks



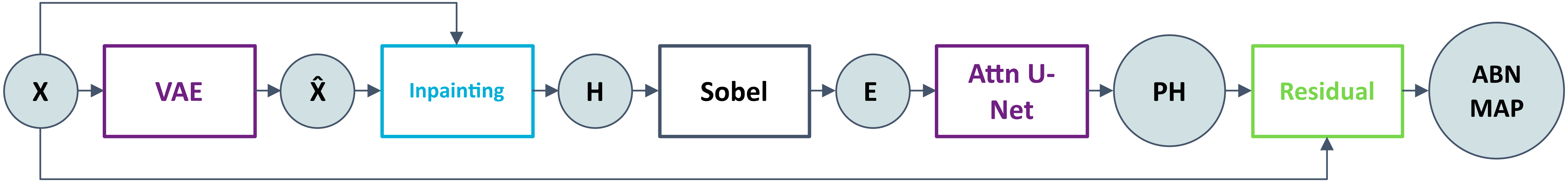
1. Sample-level: label 1 or 0 if image is out-of-distribution

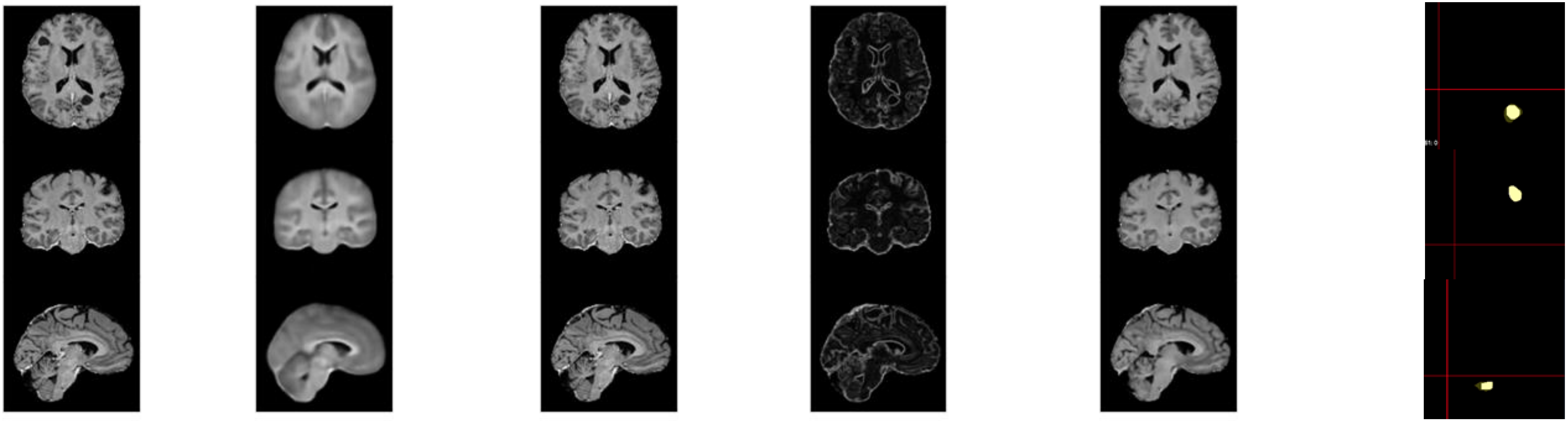
1

2. Object-level: mask of anomalies



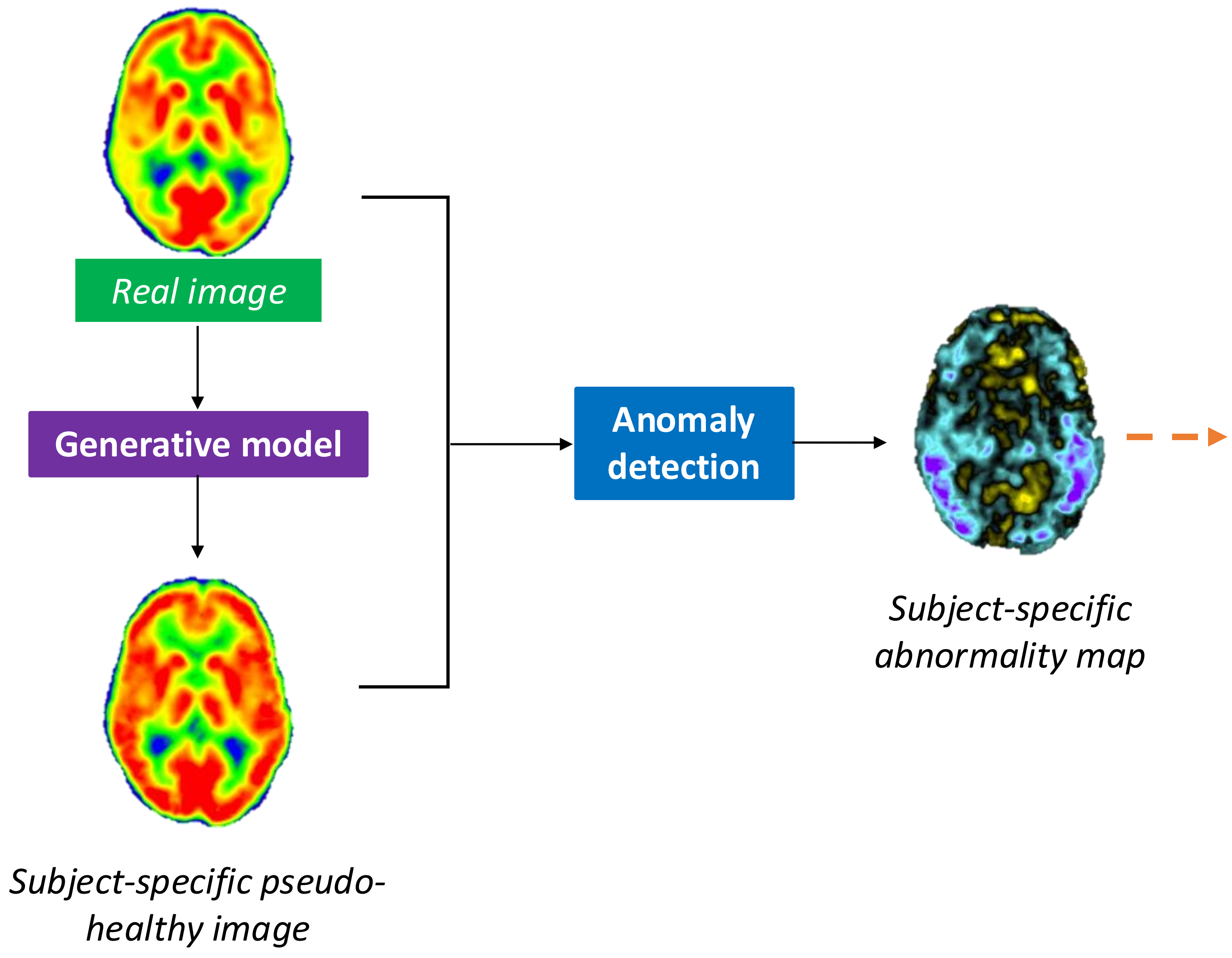
Proposed Approach





Perspectives

Perspectives: PhD objectives



Research objectives:

1. Improve the quality of pseudo-healthy images
2. Generate robust abnormality maps by modelling uncertainty
3. Extend the detection of anomalies to multimodal neuroimaging data
4. Validate the approach with the support of clinicians

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Thank you for listening

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