# Sparse Multi-Channel Variational Autoencoder for the Joint Analysis of Heterogeneous Data

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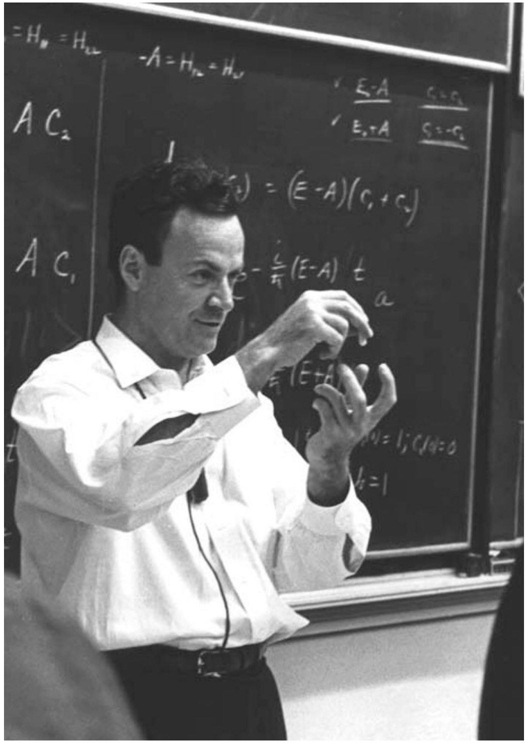
Session: *Generative Models*

# Why I like Generative Models

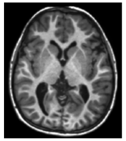
"What I cannot create, I do not understand"

R. P. Feynman



# The Generative Multi-Channel Model

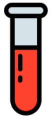
For C channels …



$\mathbf{x}_1$

$\mathbf{x}_2$

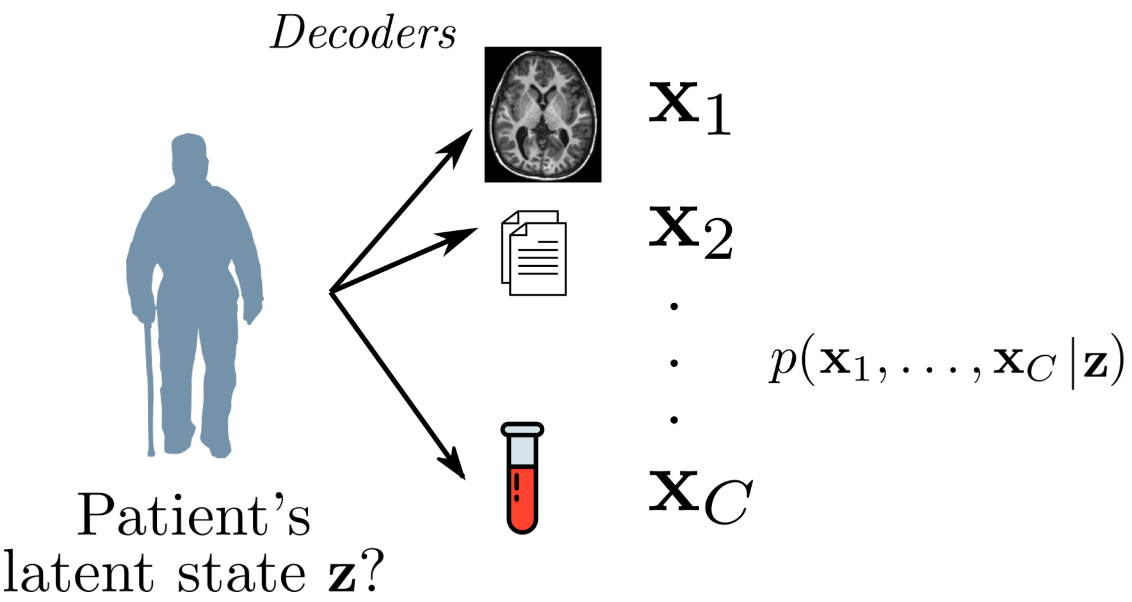
$\vdots$



$\mathbf{x}_C$

# The Generative Multi-Channel Model

For C channels we assume the following generative process:




Decoders: reconstruction of data from the latent space $\mathbf{z}$

# The Generative Multi-Channel Model

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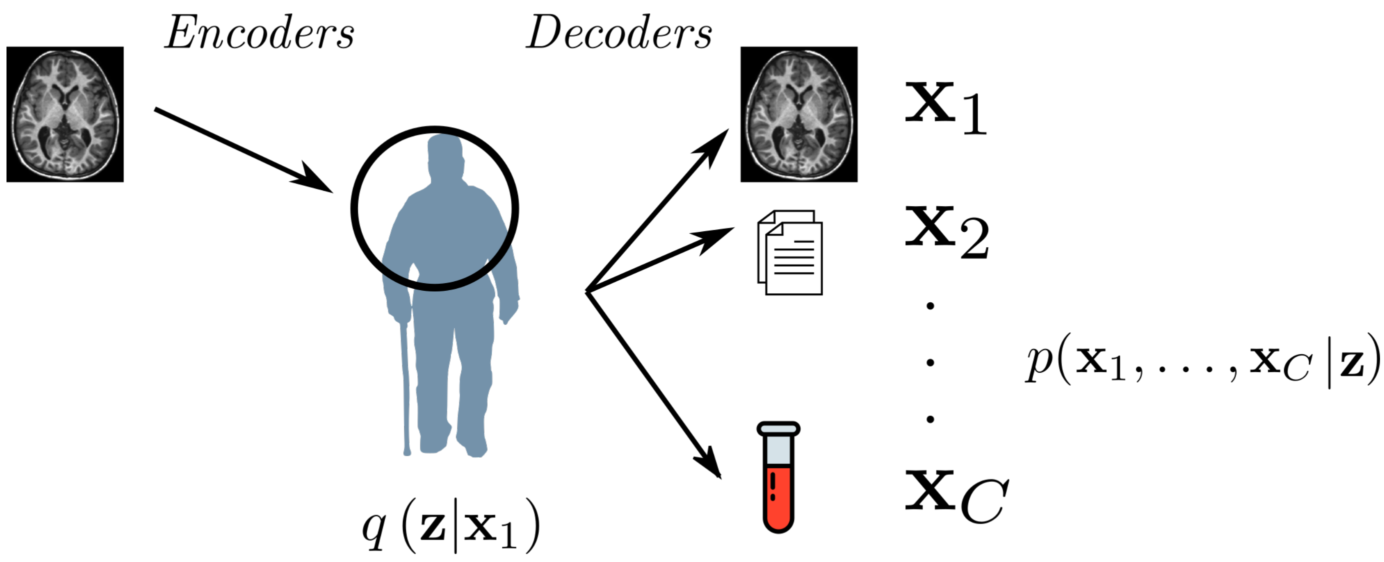
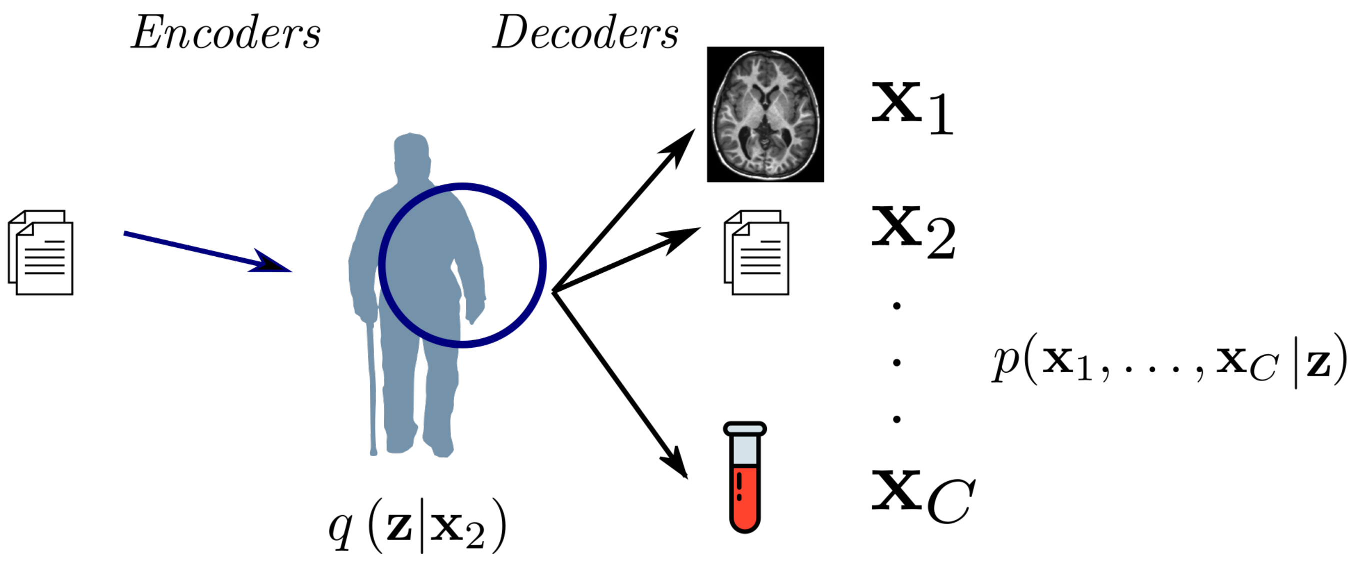



Decoders: reconstruction of data from the latent space $\mathbf{z}$
Encoders: inference of the latent space $\mathbf{z}$ from the data

# The Generative Multi-Channel Model

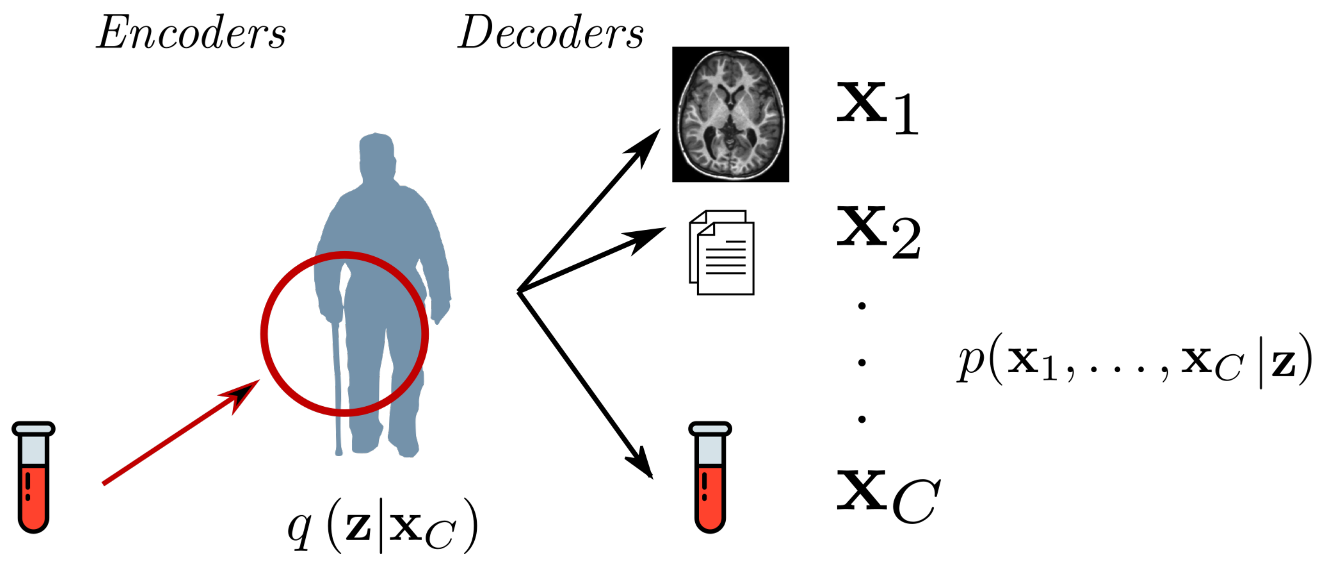
For C channels we assume the following generative process:




Decoders: reconstruction of data from the latent space z
Encoders: inference of the latent space z from the data

# The Generative Multi-Channel Model

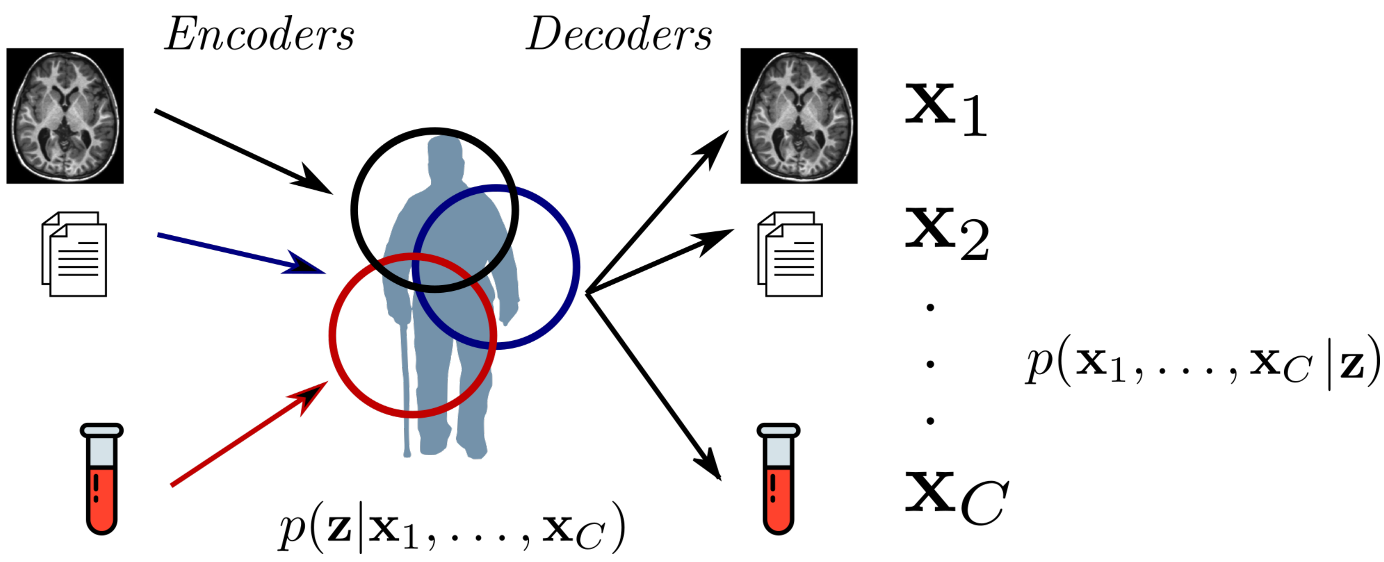
For C channels we assume the following generative process:




Decoders: reconstruction of data from the latent space z
Encoders: inference of the latent space z from the data

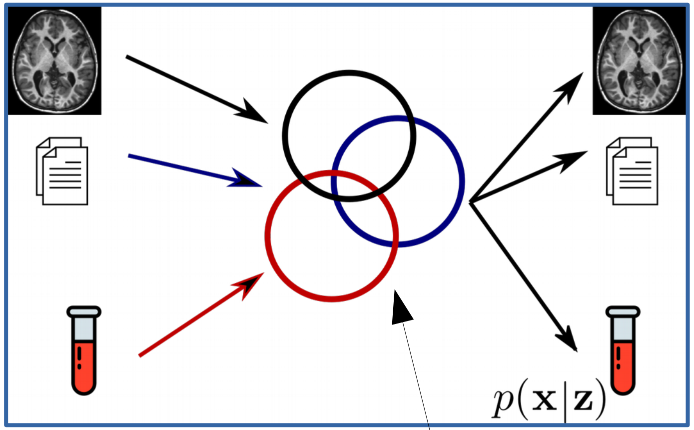
# The Generative Multi-Channel Model

Every channel is informative



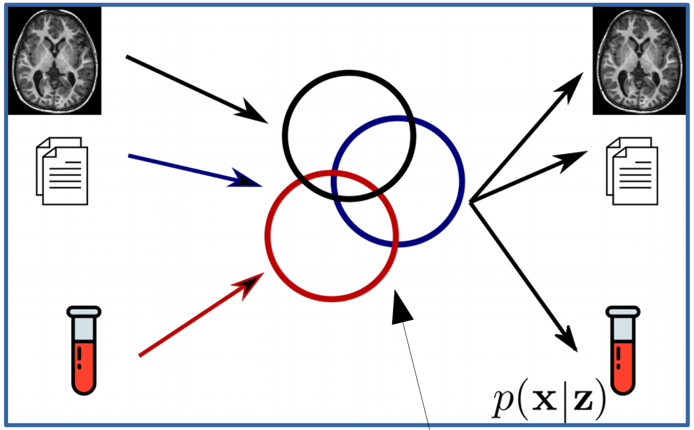

Decoders: reconstruction of data from the latent space z
Encoders: inference of the latent space z from the data

# The Generative Multi-Channel Model




$$\underset{q\in\mathcal{Q}}{arg\,min}\ \mathbb{E}_c\, \mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right) \| \, p\left(\mathbf{z}|\mathbf{x}_1, \ldots, \mathbf{x}_C\right)\right)$$

# The Generative Multi-Channel Model

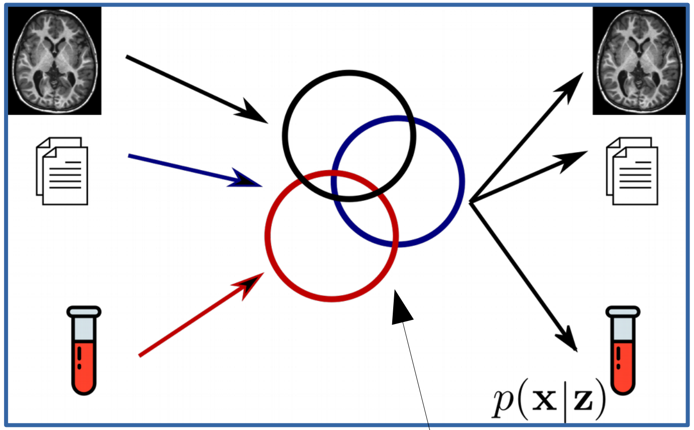



Evidence Lower Bound

$$\frac{1}{C}\sum_{c=1}^{C}\mathbb{E}_{q(\mathbf{z}|\mathbf{x}_c)}\left[\sum_{i=1}^{C}\ln p(\mathbf{x}_i|\mathbf{z})\right]-\mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right)\|\,p\left(\mathbf{z}\right)\right)$$

$$\underset{q\in\mathcal{Q}}{arg\,min}\;\mathbb{E}_c\,\mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right)\|\,p\left(\mathbf{z}|\mathbf{x}_1,\ldots,\mathbf{x}_C\right)\right)$$

# The Generative Multi-Channel Model



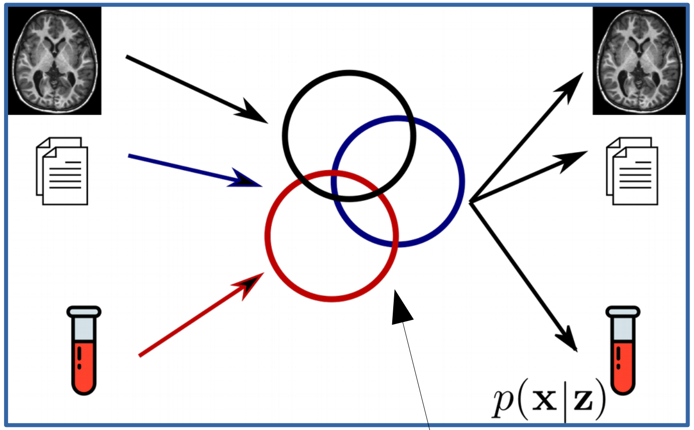

Evidence Lower Bound

$$\frac{1}{C}\sum_{c=1}^{C}\mathbb{E}_{q(\mathbf{z}|\mathbf{x}_c)}\left[\textstyle\sum_{i=1}^{C}\ln p(\mathbf{x}_i|\mathbf{z})\right] - \mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right)\parallel p\left(\mathbf{z}\right)\right)$$

Encoding from a given channel

$$\underset{q\in\mathcal{Q}}{arg\,min}\ \mathbb{E}_c\,\mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right)\parallel p\left(\mathbf{z}|\mathbf{x}_1,\ldots,\mathbf{x}_C\right)\right)$$

# The Generative Multi-Channel Model




Evidence Lower Bound

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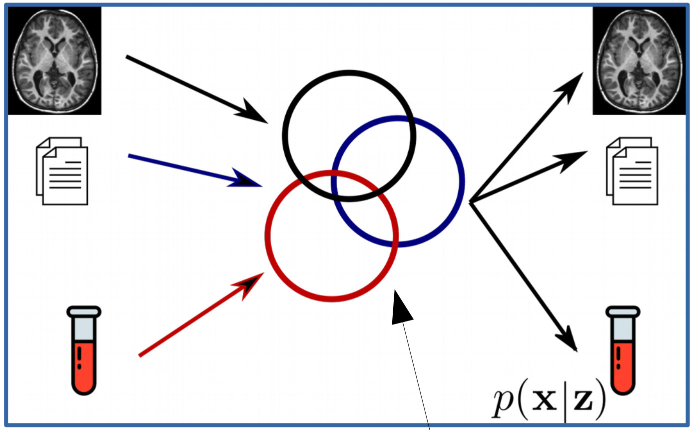
Encoding from a given channel

Reconstruction of all the channels

$$\underset{q\in\mathcal{Q}}{arg\,min}\;\mathbb{E}_c\,\mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right)\|\, p\left(\mathbf{z}|\mathbf{x}_1,\ldots,\mathbf{x}_C\right)\right)$$

# The Generative Multi-Channel Model




Evidence Lower Bound

$$\frac{1}{C}\sum_{c=1}^{C}\mathbb{E}_{q(\mathbf{z}|\mathbf{x}_c)}\left[\sum_{i=1}^{C}\ln p(\mathbf{x}_i|\mathbf{z})\right]-\mathcal{D}_{\mathrm{KL}}\left(q\left(\mathbf{z}|\mathbf{x}_c\right)\parallel p\left(\mathbf{z}\right)\right)$$

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Encoding from a given channel

Reconstruction of all the channels

Regularization inducing sparsity:

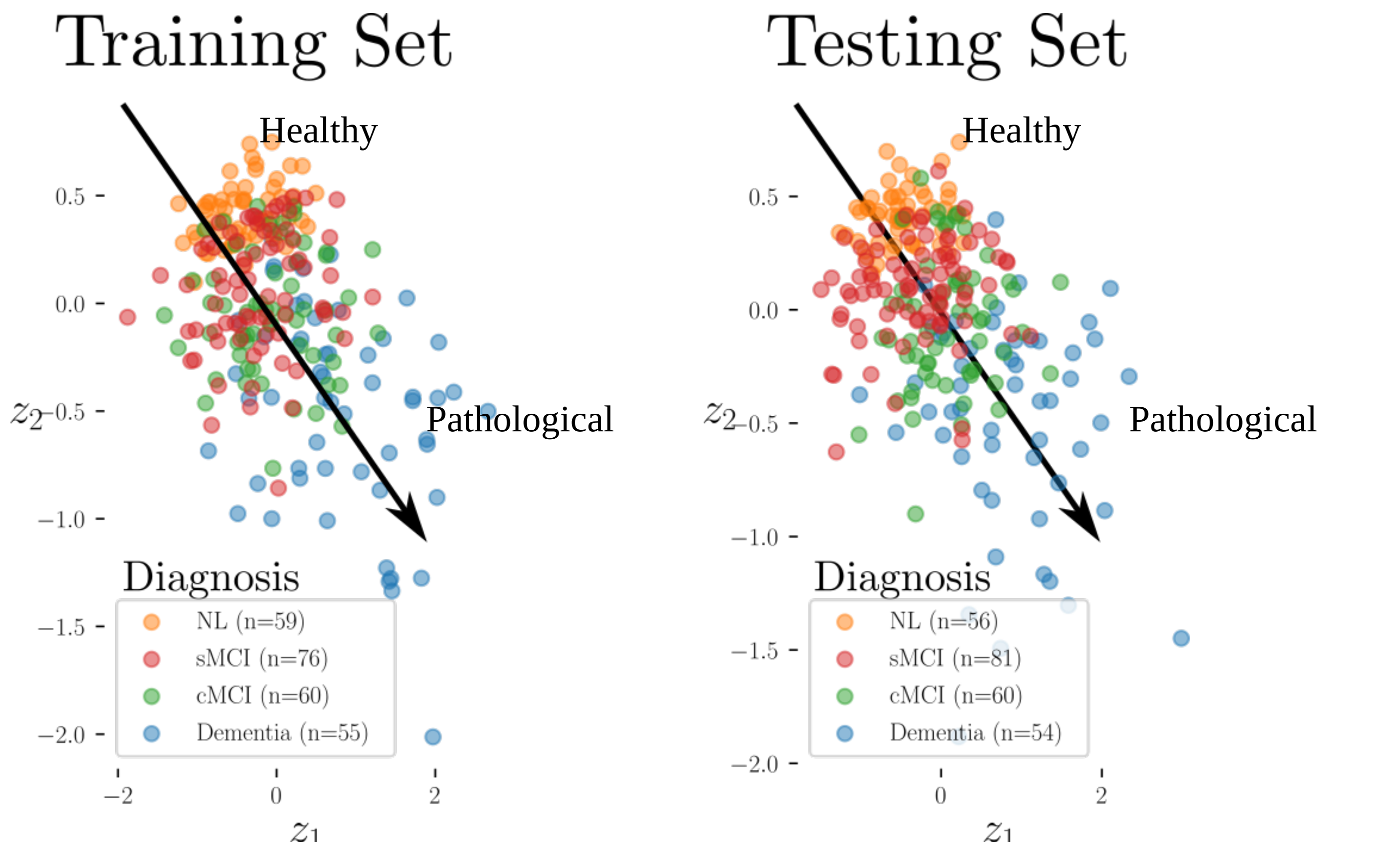
- *variational dropout* on **z**
- model selection
- interpretability
- pruning factor ~50%

*Variational Dropout* bibliography: Wang et al., ICML 2013; Kingma et al., NIPS 2015; Molchanov et al., ICML 2017.

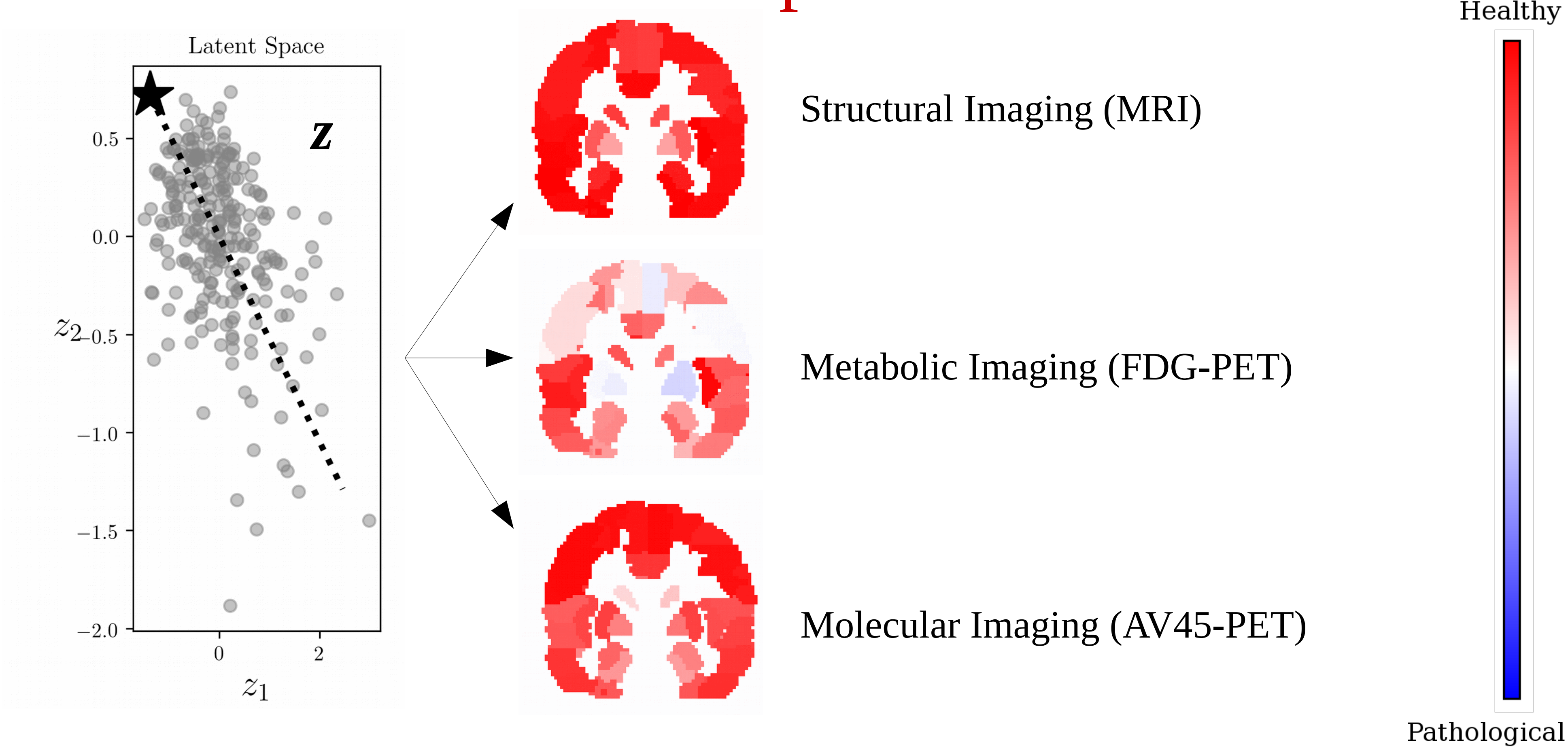
# Unsupervised clustering in Alzheimers' Disease

Joint modeling of: **Clinical scores** + {Structural + Metabolic + Molecular} **Imaging**.

**Diagnosis** status **unknown** to the model



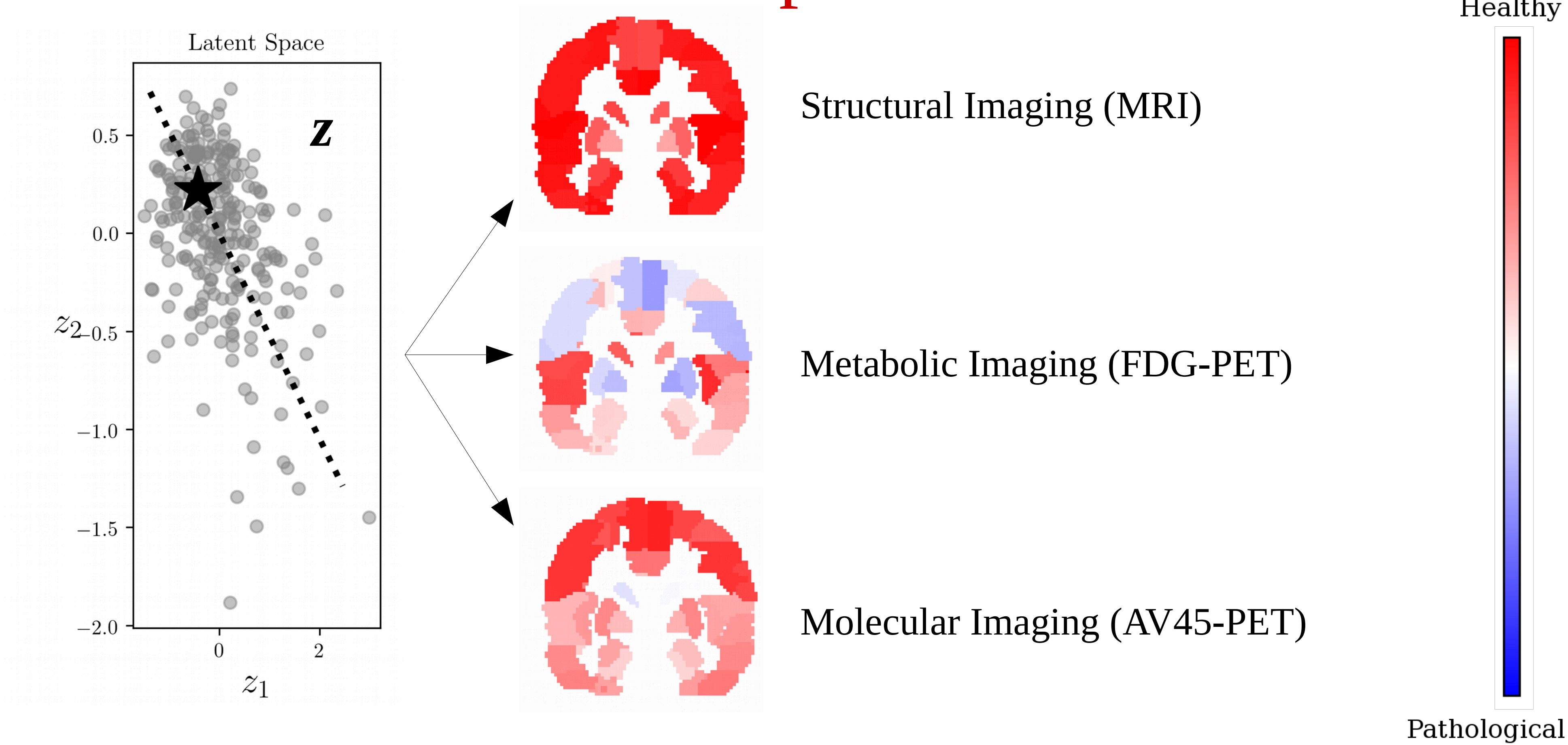
# Generation from latent space




- Improved interpretability
- Simulations for clinical trials

Adapted from: M. Lorenzi, Collège de France, 23/4/2019

# Generation from latent space

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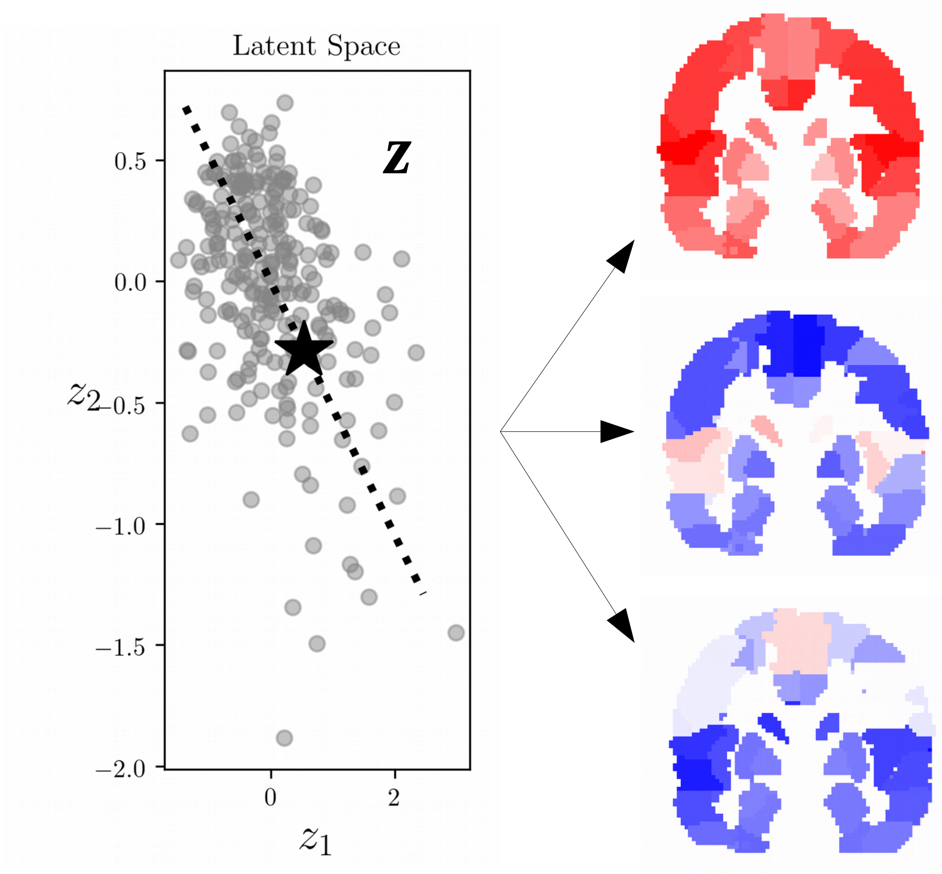
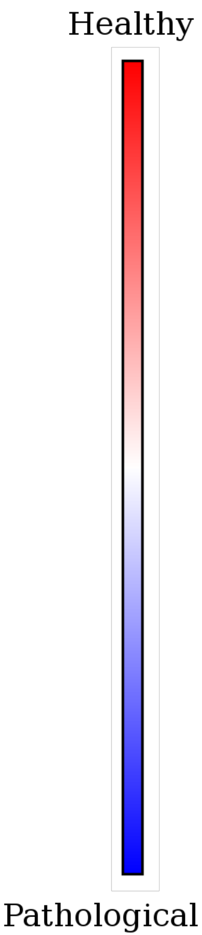
# Generation from latent space




Structural Imaging (MRI)

Metabolic Imaging (FDG-PET)

Molecular Imaging (AV45-PET)

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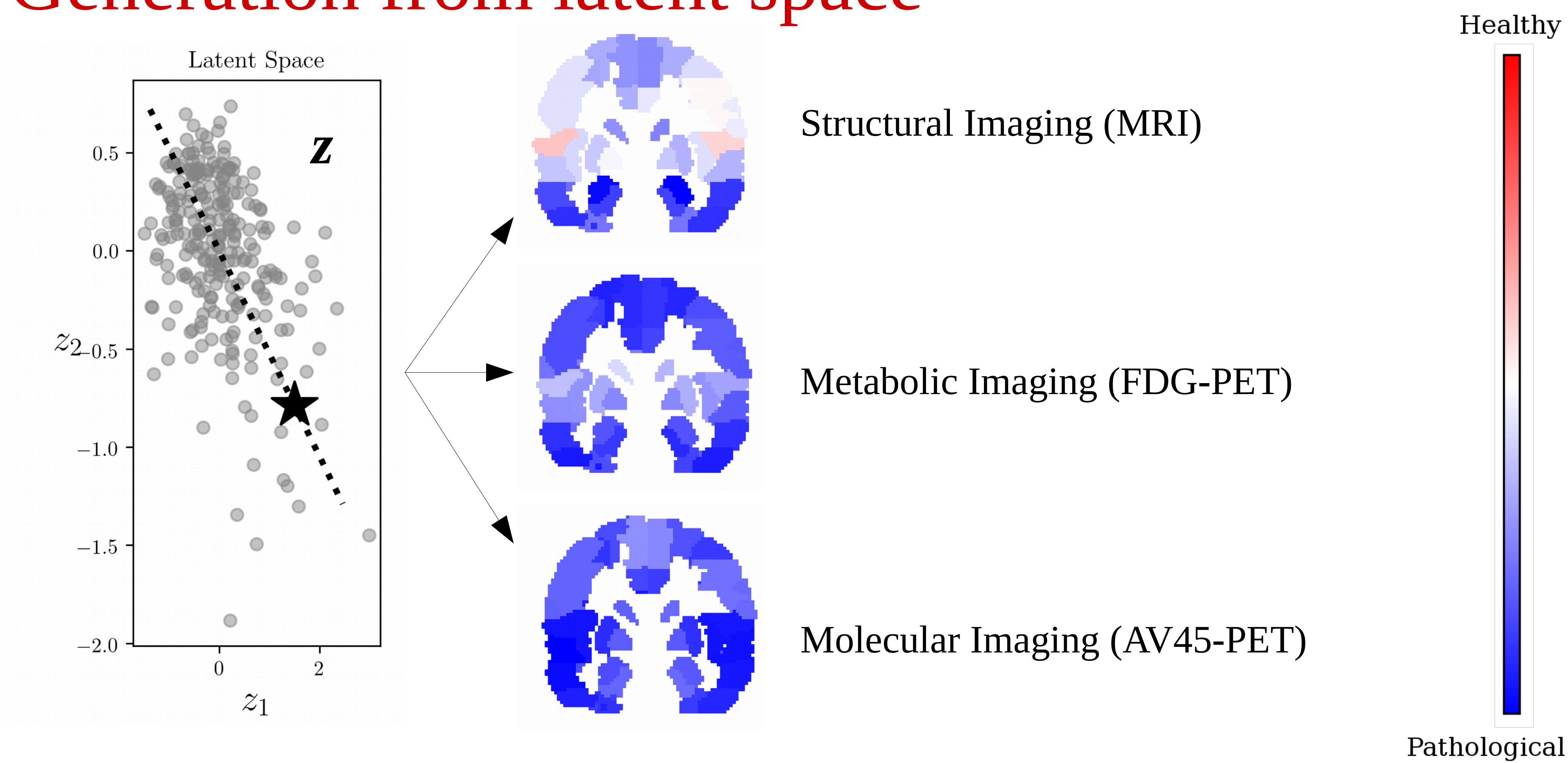


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If you're interested in:

VAEs, Sparse Code, Interpretability, Prediction of Missing Data, Medical Applications, …

see you at Poster **#57**, Pacific Ballroom
06:30 pm - ...

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**Thank you!**