# On the use of autoencoder to denoise diffusion MRI

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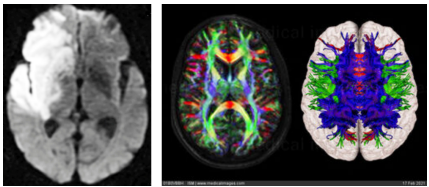
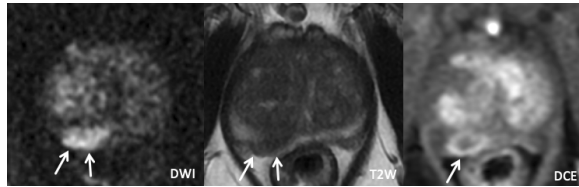
# Motivation: In vivo High Resolution Diffusion MRI at 7 T

# Various clinical applications of diffusion MRI [1, 2, 3, 4]

Brain: stroke & neurodegenerative diseases



Prostate cancer: detection and localization




[1] Courtesy: ChatGPT

[2] https://mriquestions.com/trace-vs-adc-map.html

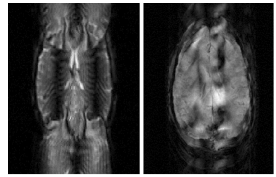
[3] https://www.psychologytoday.com/gb/blog/adventures-in-cognition/202102/why-white-matter-matters-diffusion-tensor-imaging

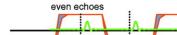
[4] https://rad.bwh.harvard.edu/prostate-mri/

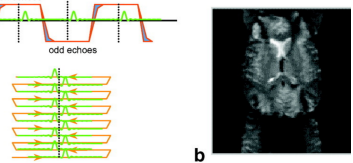
# Limitations in diffusion MRI [5]

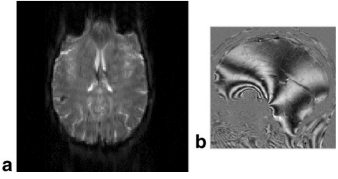
- Common pitfalls:
  - ⋆ motion artifacts
  - ⋆ eddy currents
  - ⋆ geometric distortion and susceptibility artifacts

- Be aware that diffusion-weighted imaging (DWI),
  - ⋆ primarily uses single-shot echo planar imaging (EPI)
  - ⋆ clinical spatial resolution of about 2 mm
  - ⋆ suffers from low signal-to-noise ratio (SNR)





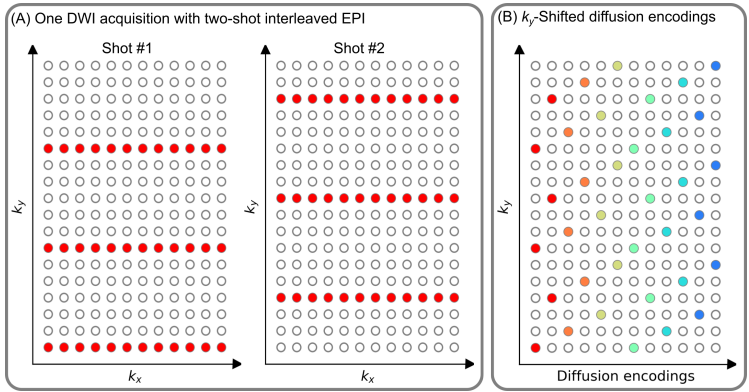




[5] Le Bihan D, et al. Artifacts and pitfalls in diffusion MRI. *J Magn Reson Imaging* (2006).

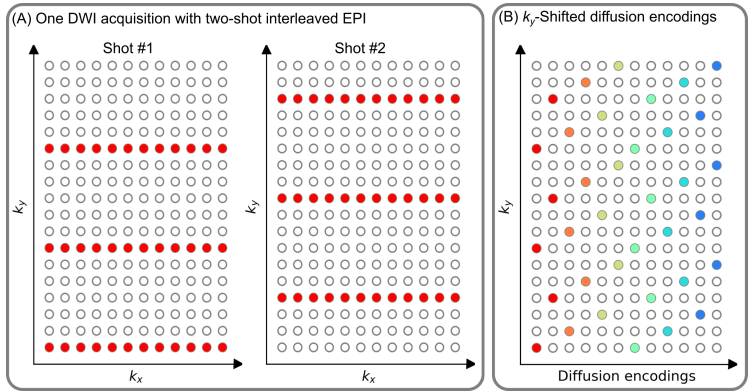
# Method

# Diffusion MRI Acquisition



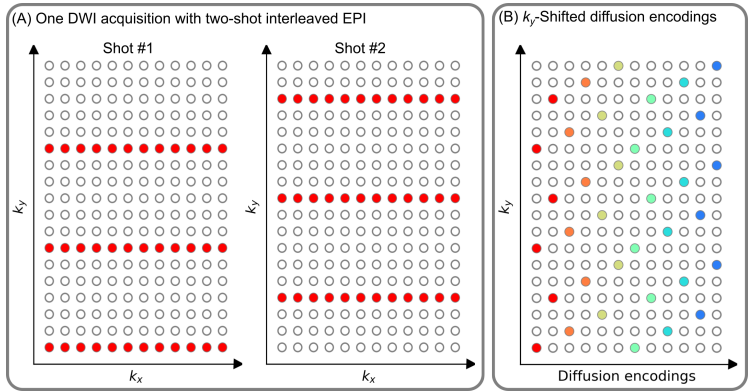

- 2-shot interleaved EPI with multi-band factor 2, yielding acceleration factor $6 \times 2$

# Diffusion MRI Acquisition



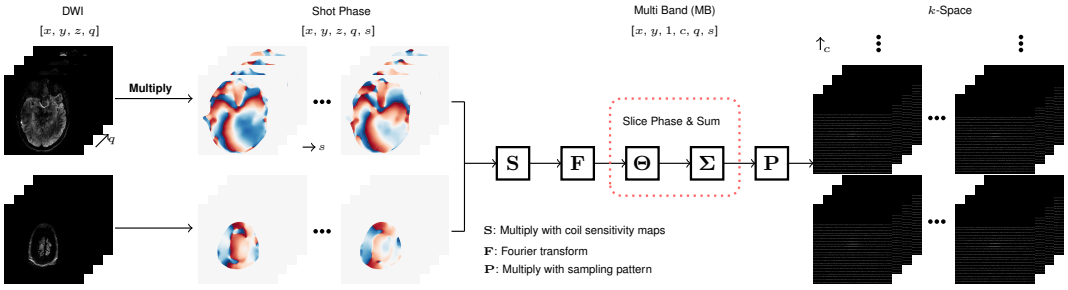

- 2-shot interleaved EPI with multi-band factor 2, yielding acceleration factor $6 \times 2$
- $k_y$-shift encoding to accomplish complementary $k$-$q$-space sampling

# Diffusion MRI Acquisition



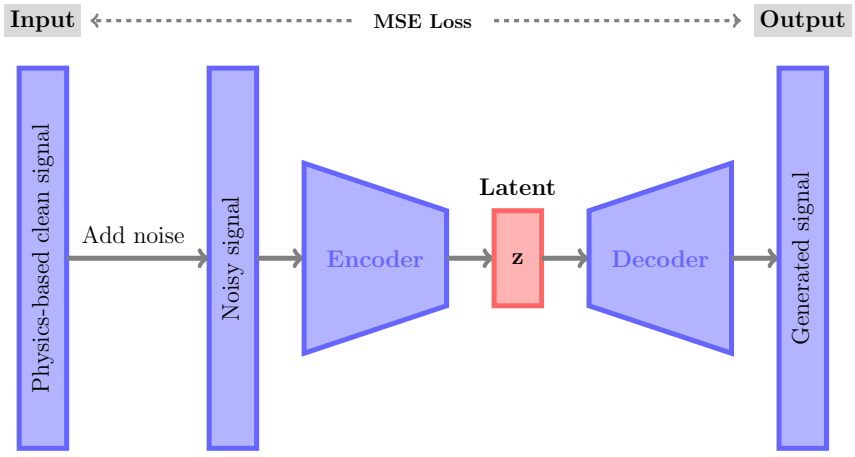

- 2-shot interleaved EPI with multi-band factor 2, yielding acceleration factor $6 \times 2$
- $k_y$-shift encoding to accomplish complementary $k$-$q$-space sampling
- 1.2 mm (isotropic), $2 \times b_0 + 30$ diffusion encodings with $b$-value $1000\,\mathrm{s\,mm^{-2}}$

# Diffusion MRI Forward Modeling and Image Reconstruction [6]




[6] Tan Z, et al. *under review*

# Denoise Diffusion MRI Using Autoencoder [7, 8, 9]




[7] Hinton GE, Salakhutdinov RR. Reducing the dimensionality of data with neural networks. *Science* (2006).

[8] Lam F, et al. Constrained magnetic resonance spectroscopic imaging by learning nonlinear low-dimensional models. *IEEE Trans Med Imaging* (2019).

[9] Mani M, et al. qModeL: A plug-and-play model-based reconstruction for highly accelerated multi-shot diffusion MRI using learned priors. *Magn Reson Med* (2021).

# Denoise Diffusion MRI Using Autoencoder: How to Train the Model

- Data generation:
  1. Simulation of DWI signal based on the DTI model [10]
  2. Each tensor element contains 10 entries, resulting in $10^6$ DWI signal entries
  3. Zero-mean Gaussian-distribution noise with 10 varying standard deviations are added to the simulated signal, yielding $10^7$ DWI signal
  4. 80 % of the data for training, and 20 % for testing

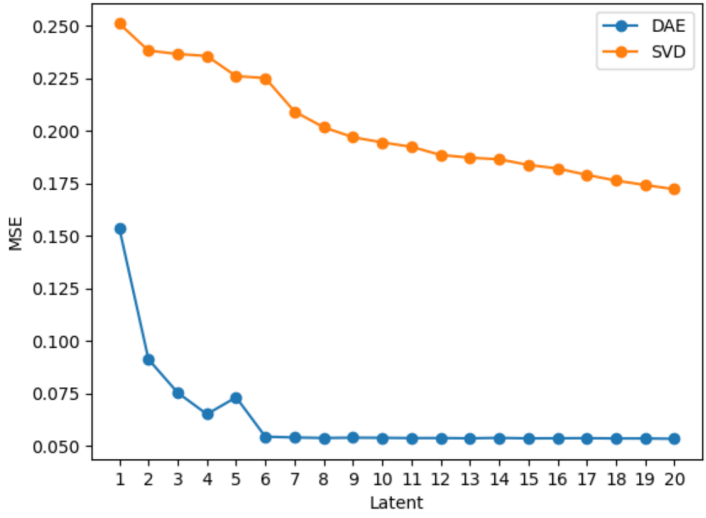
- Training setup:
  1. Optimizer: ADAM [11]
  2. Learning rate: 0.0001
  3. Epochs: 800
  4. 4 fully-connected encoder/decoder layers with ReLU, whereas the output layer uses Sigmoid as the activation function
  5. Latent size: 10

[10] Basser PJ, et al. MR diffusion tensor spectroscopy and imaging. *Biophys J* (1994).

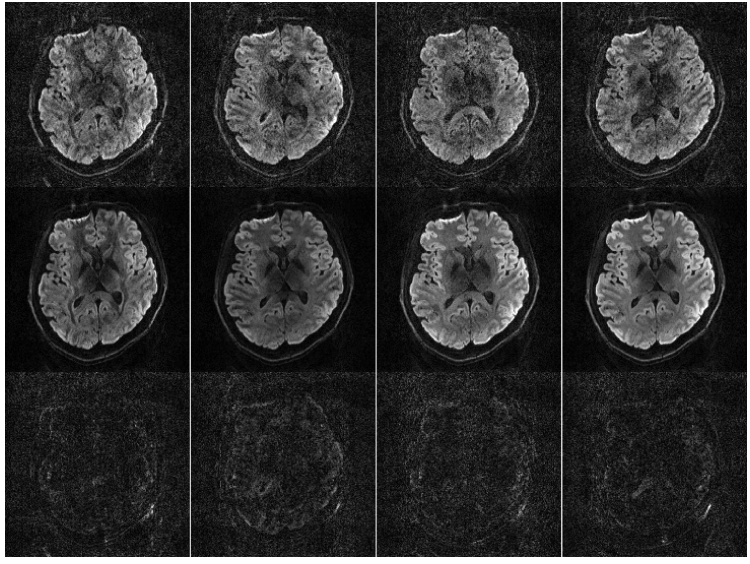
[11] Kingma DP, et al. Adam: A Method For Stochastic Optimization. *ICLR* (2015).

# Results

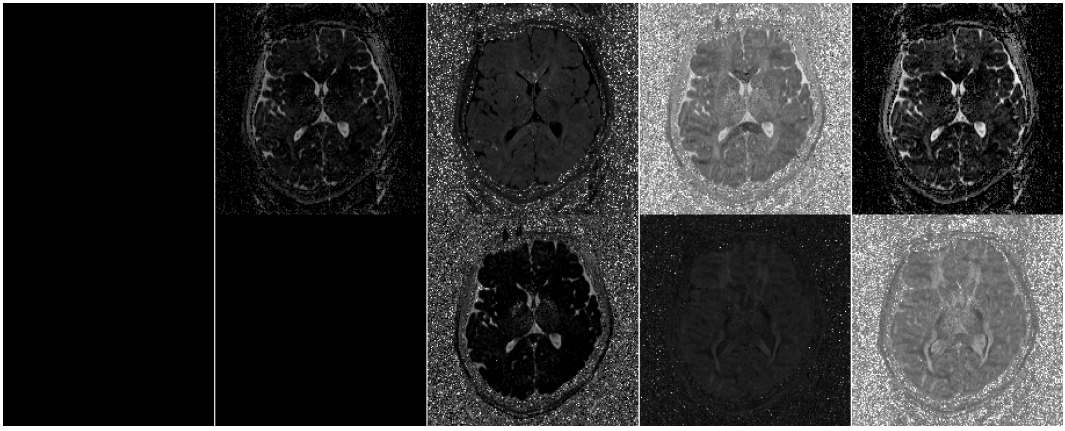
# Comparison with the Linear Subspace Method



# In vivo DWI Denoising



# In vivo DWI Denoising: Learned Latent Signal



# Conclusion

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- Multi-shot EPI:
  - ⋆ enables high spatial resolution DWI
- we open source our DWI reconstruction techniques →
- Autoencoder:
  - ⋆ enables DWI denoising
  - ⋆ learns a nonlinear subspace