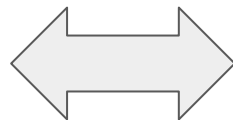
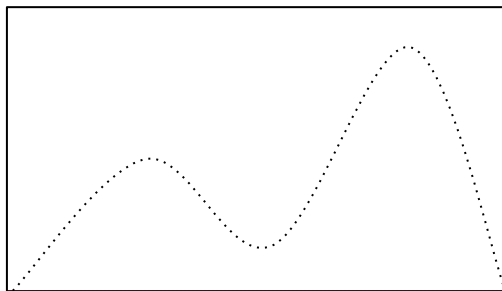


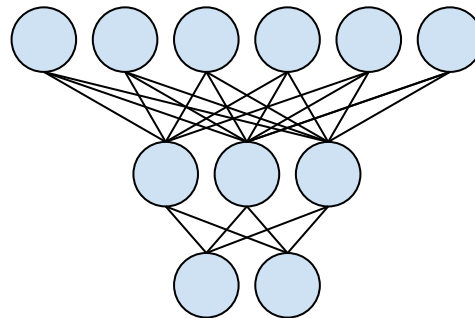
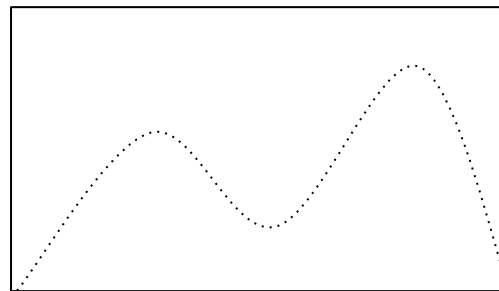
Our statement:

Image translation (via distribution matching) should not be used for direct interpretation.

Training Data



Model Output



Losses like in CycleGAN just match distributions

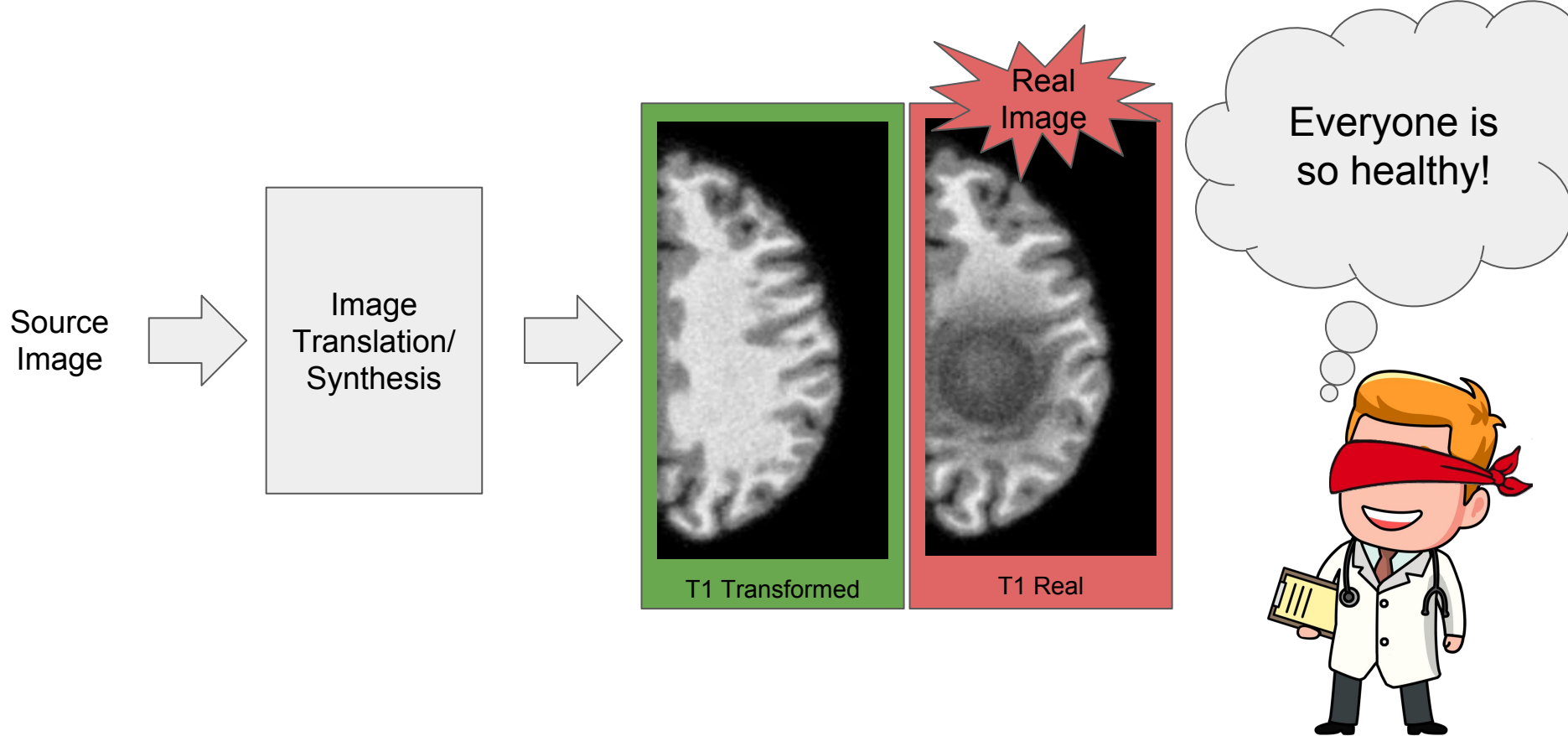


[Karras, 2018]



[CycleGAN, Zhu 2017]

They are very good at distribution matching



But a bias in training data can lead to incorrect translation

Time t



Even with all the training data in the world today.

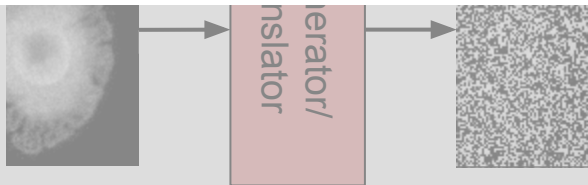
Time $t+1$



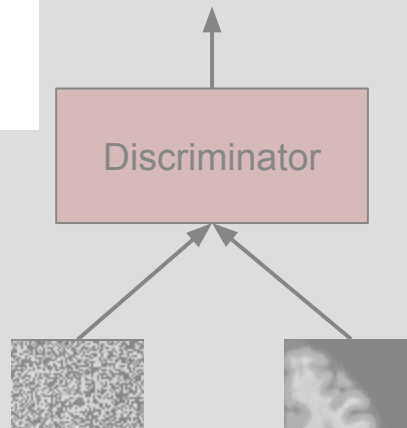
There will be new diseases tomorrow that are out of distribution.

What is image translation via distribution matching?

$$f_{a,b}(a) \quad \min_{a \sim D_a} \mathbb{E} [-\log(D(f_{a,b}(a)))]$$



Real or Fake ?



$$D \quad \max_{b \sim D_b} \mathbb{E} [\log D(b)] + \mathbb{E}_{a \sim D_a} [\log(1 - D(f_{a,b}(a)))]$$

discriminator

Fake

Real

Model Breakdown

Optimizing

$$D \quad \max_{b \sim \textcolor{red}{D}_b} \mathbb{E} [\log D(b)] + \mathbb{E}_{a \sim D_a} [\log(1 - D(f_{a,b}(a)))]$$

Optimizing

$$f_{a,b}(a) \quad \min_{a \sim D_a} \mathbb{E} [-\log(D(f_{a,b}(a)))]$$

- $f_{a,b}(a)$ should produce examples in D_b
- D_a can be anything non-finite, like a Gaussian
- No guarantee mapping maintains phenotypes

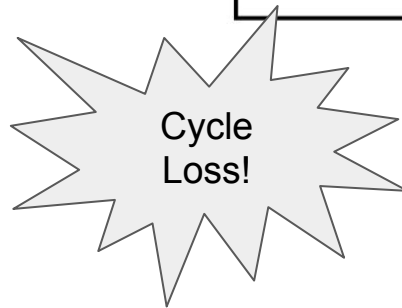
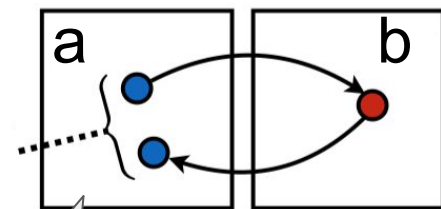
Optimizing

$$D \quad \max_{b \sim D_b} \mathbb{E} [\log D(b)] + \mathbb{E}_{a \sim D_a} [\log(1 - D(f_{a,b}(a)))]$$

Optimizing

$$f_{a,b}(a) \quad \min_{a \sim D_a} \mathbb{E} [-\log(D(f_{a,b}(a)))] + ||f_{b,a}(f_{a,b}(a)) - a||_1$$

- Add a reconstruction loss regularizer for the func $f_{a,b}(a)$
- Loss term still matches distribution D_b
- No guarantee mapping maintains phenotypes



Optimizing

$$D \quad \max_{(a,b) \sim (D_a, D_b)} \mathbb{E} [\log D(b, a)] + \mathbb{E}_{a \sim D_a} [\log(1 - D(f_{a,b}(a), a))]$$

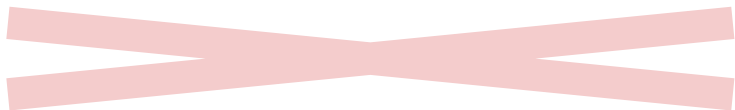
Optimizing

$$f_{a,b}(a) \quad \min_{a \sim D_a} \mathbb{E} [-\log(D(f_{a,b}(a)))]$$

- D is given paired examples allowing detection of what to preserve
- D_b still plays a role in what D learns
- No guarantee mapping maintains phenotypes

Optimizing

D

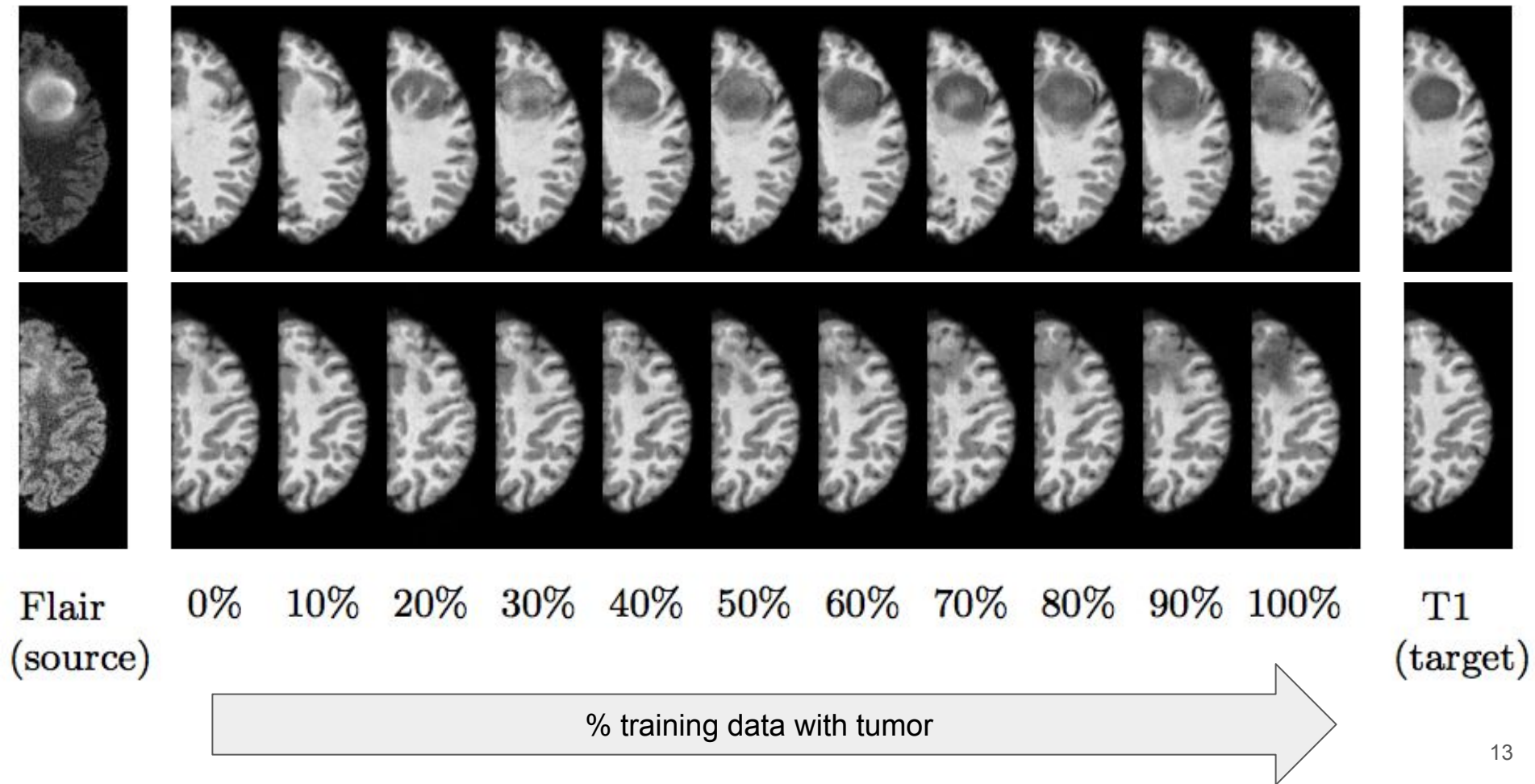


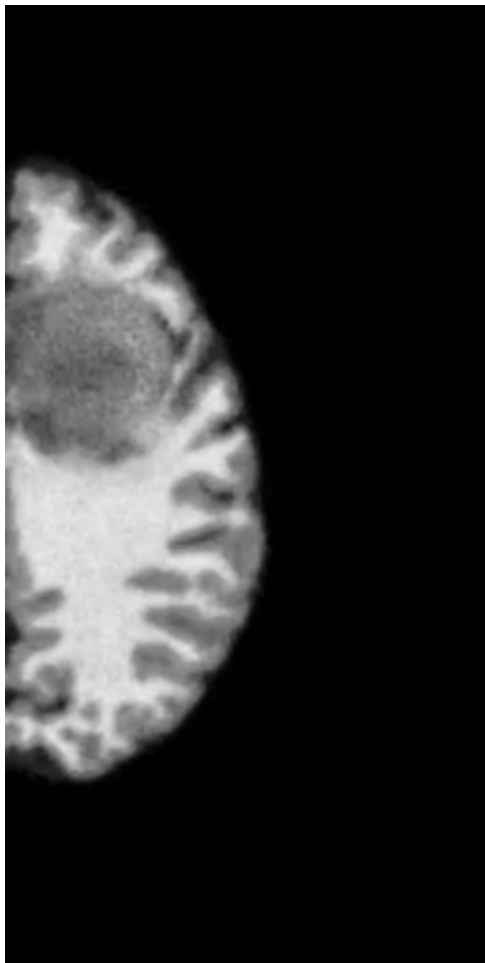
$$f_{a,b}(a) \min_{(a,b) \sim (D_a, \textcolor{red}{D}_b)} \mathbb{E} ||f_{a,b}(a) - b||_1$$

- $f_{a,b}(a)$ should produce examples in D_b
- Pixel-wise loss
- No guarantee mapping maintains phenotypes

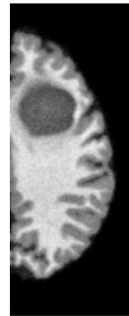
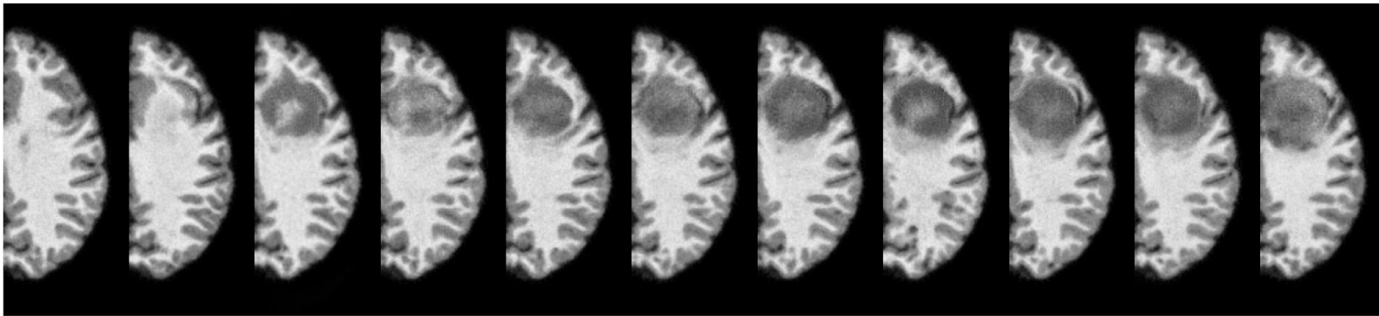
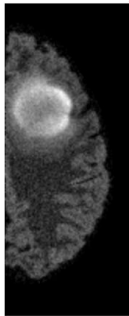
Visual Evaluation

CycleGAN results

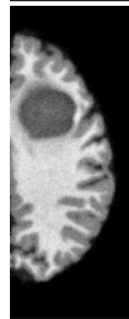
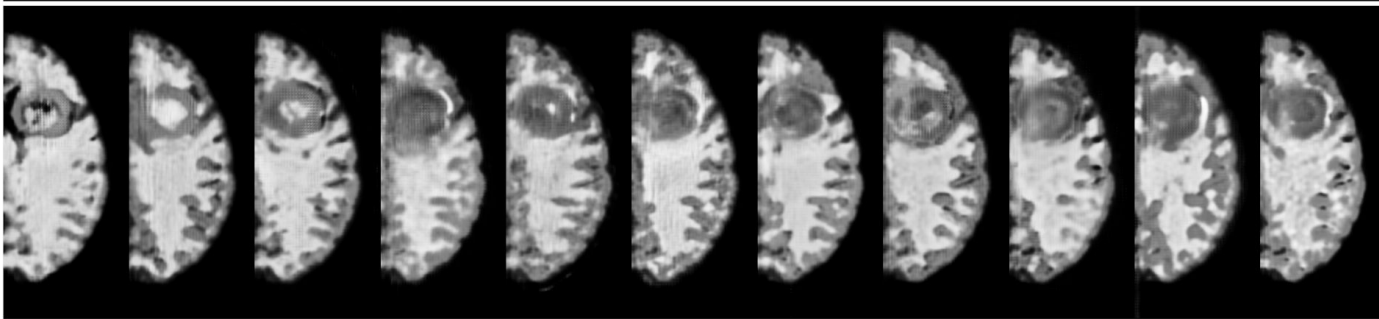
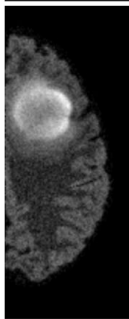




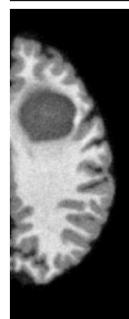
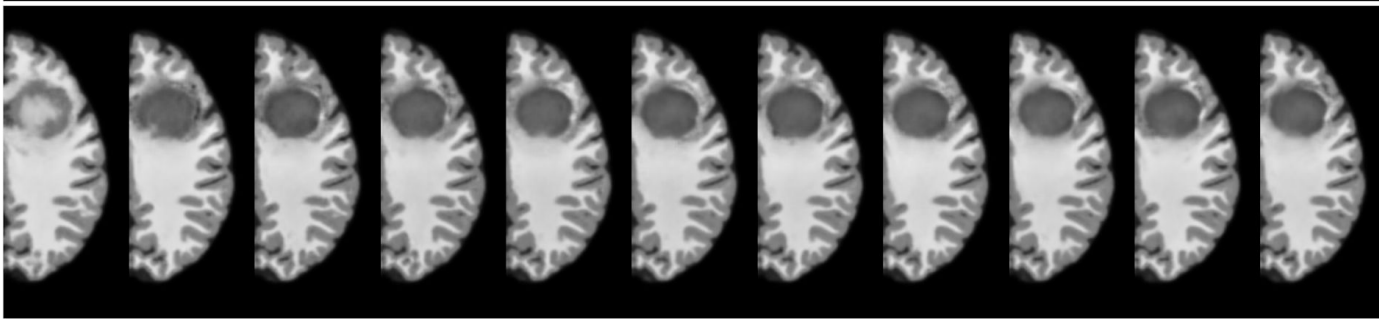
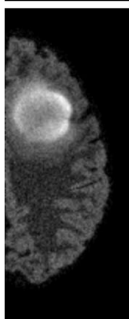
CycleGAN



CondGAN



L1

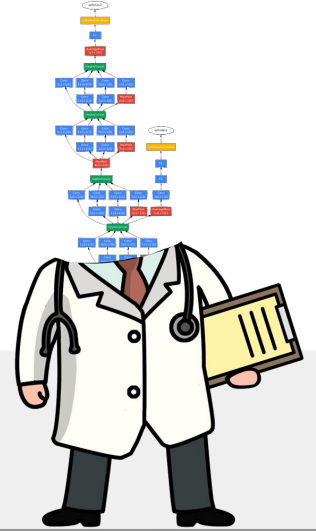
Flair
(source)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Example with a tumor from the holdout set

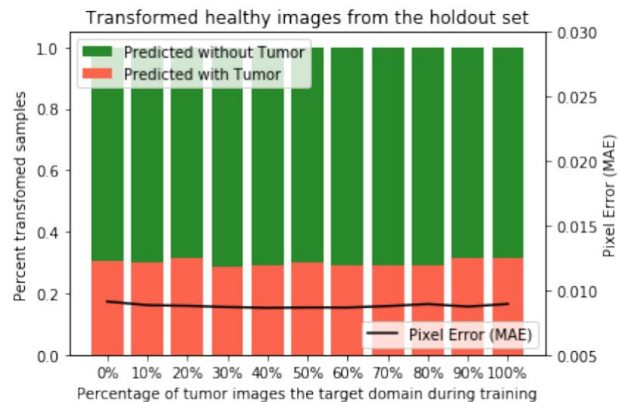
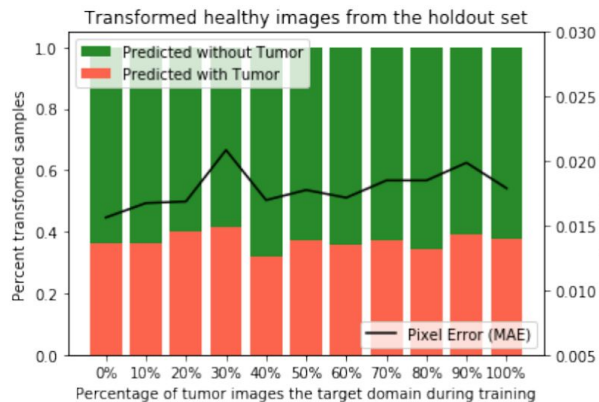
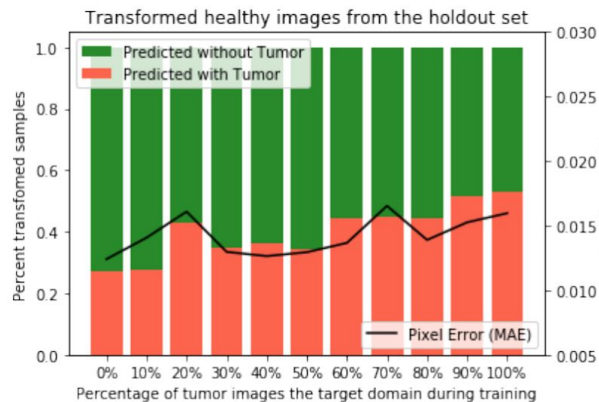
T1
(target¹⁵)

Quantitative Evaluation

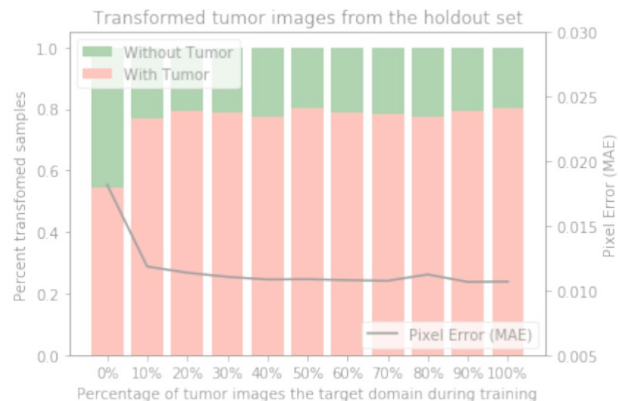
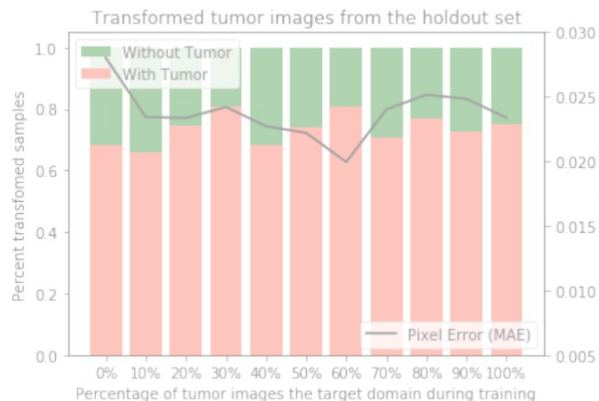
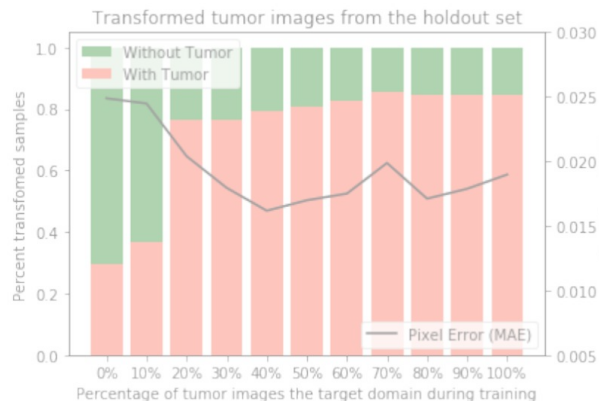


Predicted as a: tumor healthy

Test data is healthy



Test data has tumor



(a) CycleGAN

(b) Cond-GAN

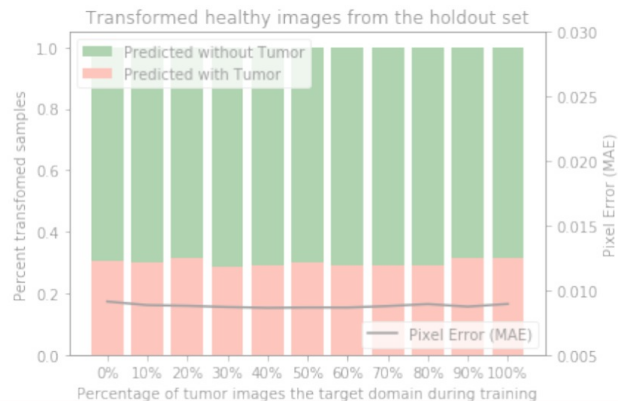
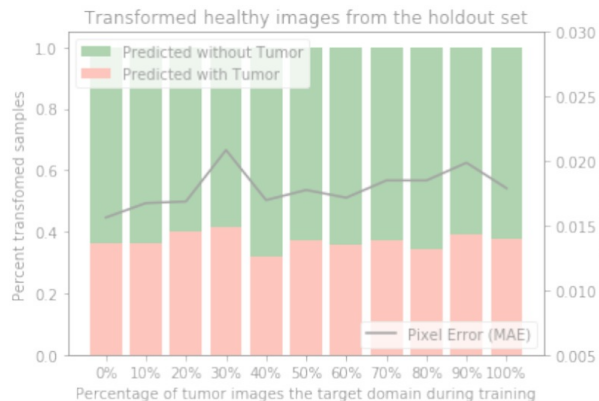
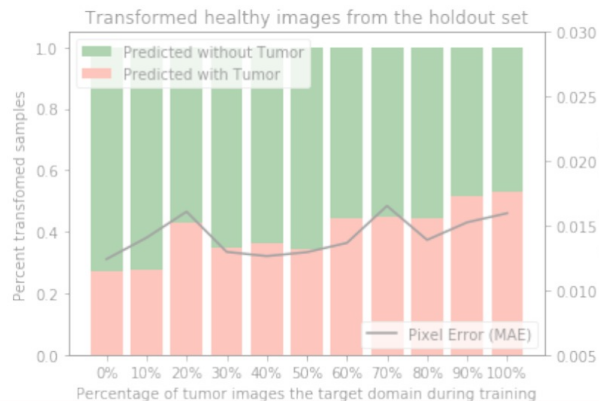
(c) L1

Predicted as a:

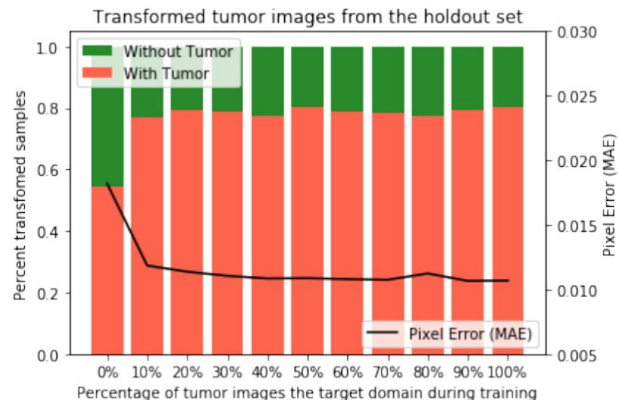
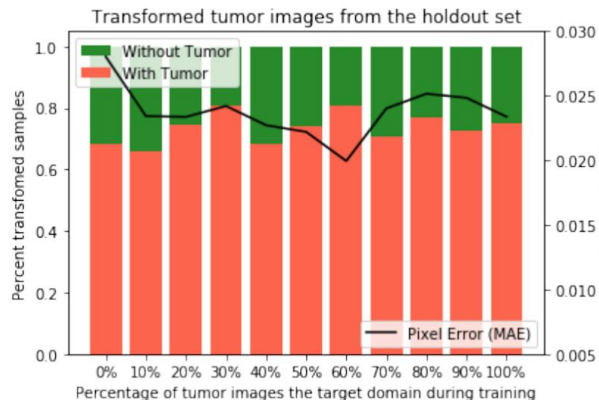
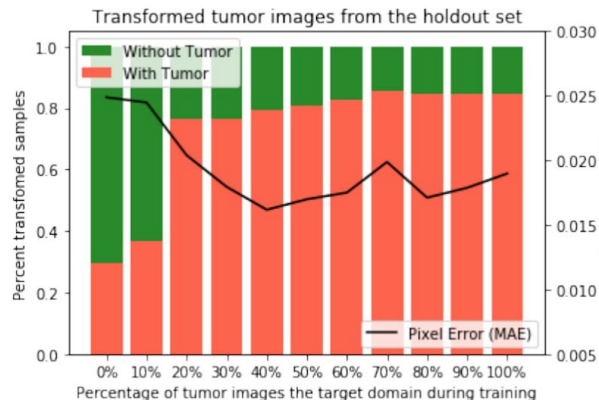
tumor

healthy

Test data is healthy



Test data has tumor



(a) CycleGAN

(b) Cond-GAN

(c) L1

Our statement:

Image translation (via distribution matching) should not be used for direct interpretation.

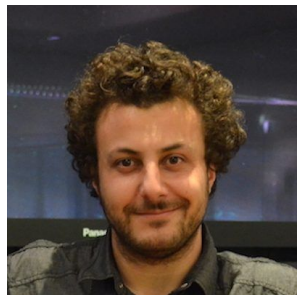
Where do go from here?

1. How to guarantee image translation? (I doubt it)

2. Where should distribution matching be used in medical imaging?
 - a. Data augmentation (for classification, segmentation, registration)
 - b. Better features (for unsupervised learning)
 - c. To correct model predictions [Zhang MICCAI 2017]

Limitations

- We test only a subset of loss terms which compose most methods
- The synthetic BRATS 2013 data had tumors added to healthy brains (in real data the entire brain is sick)



Joseph Paul Cohen,
PhD



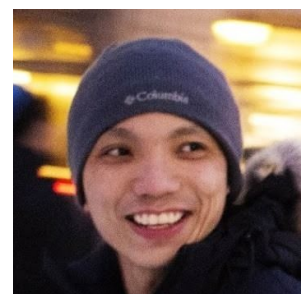
Pr. Yoshua
Bengio, PhD



Francis Dutil



Martin Weiss



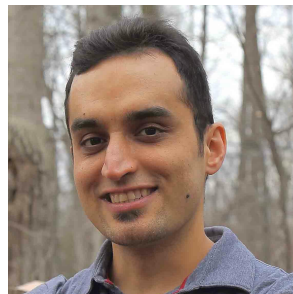
Shawn Tan



Tristan Sylvain



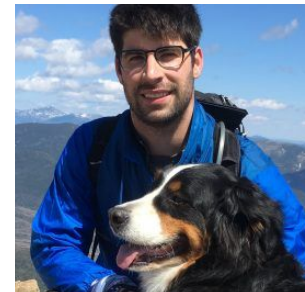
Margaux Luck, PhD



Sina Honari

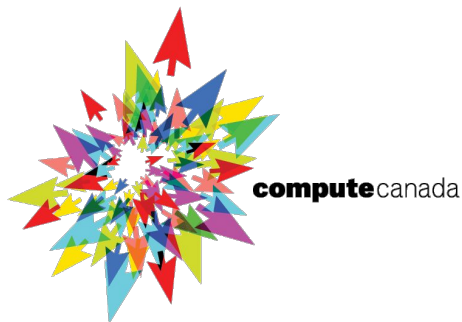


Assya Trofimov

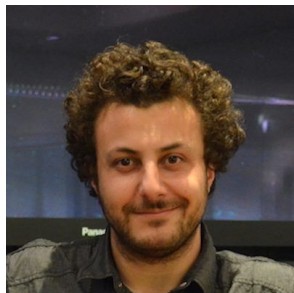


Vincent Frappier, PhD

Thanks!



Distribution Matching Losses Can Hallucinate Features in Medical Image Translation



Joseph Paul Cohen



Margaux Luck



Sina Honari

See us at poster M-60
<https://arxiv.org/abs/1805.08841>