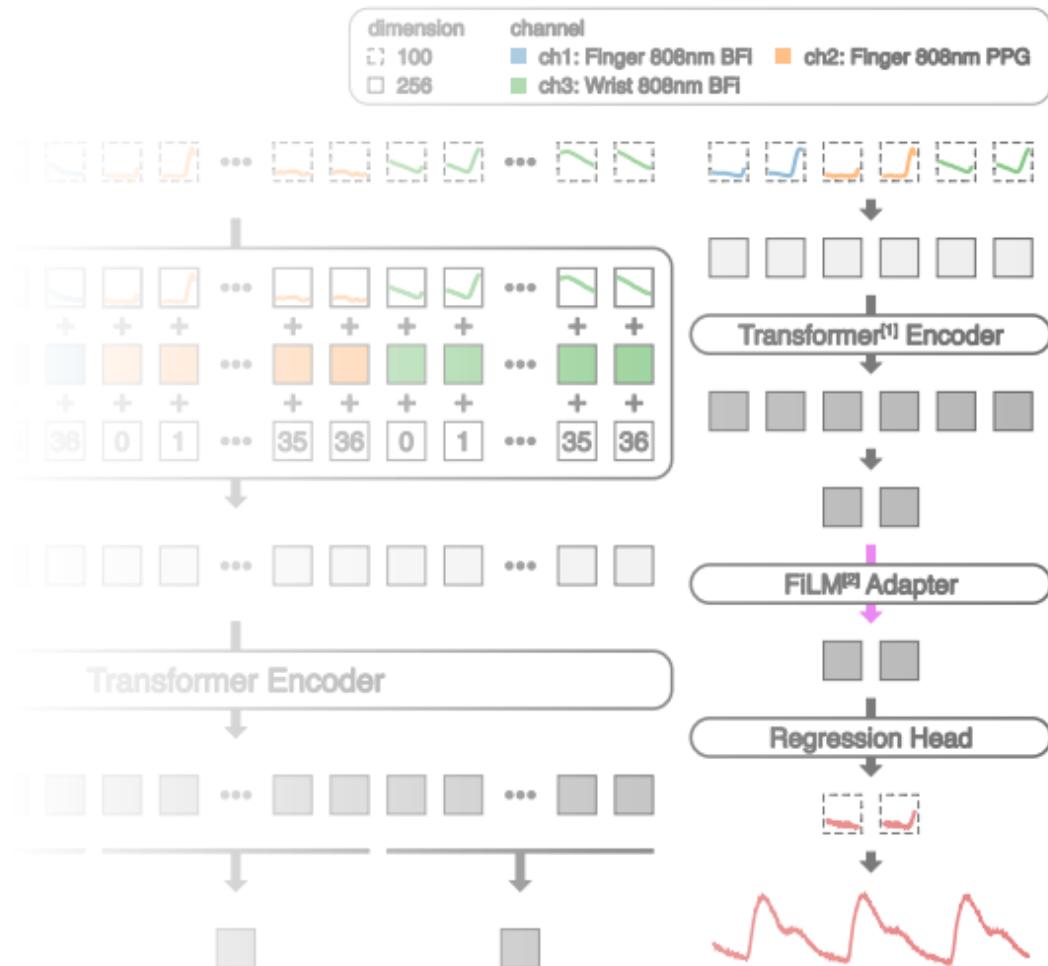


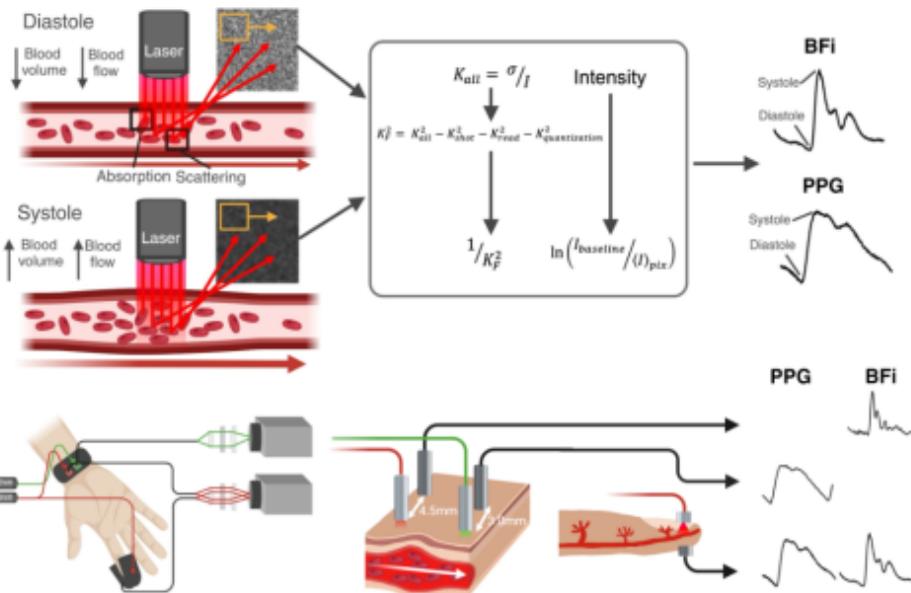
Transformer-Based Cuffless Blood Pressure Estimation

Driven by Speckle Contrast
Optical Spectroscopy (SCOS)

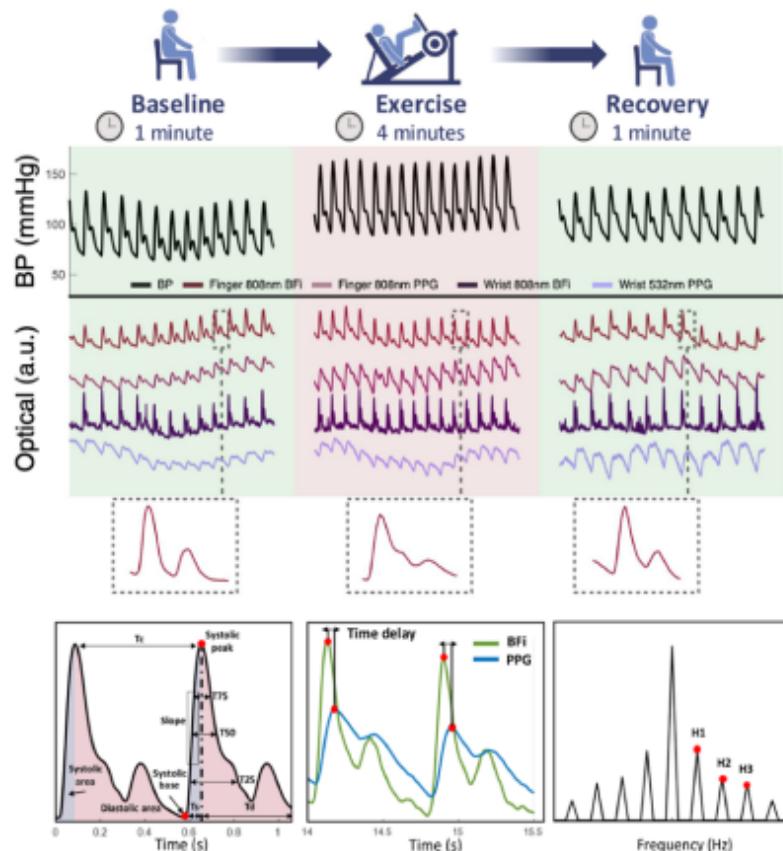
Tianrui Qi
Dec 12, 2025



Background

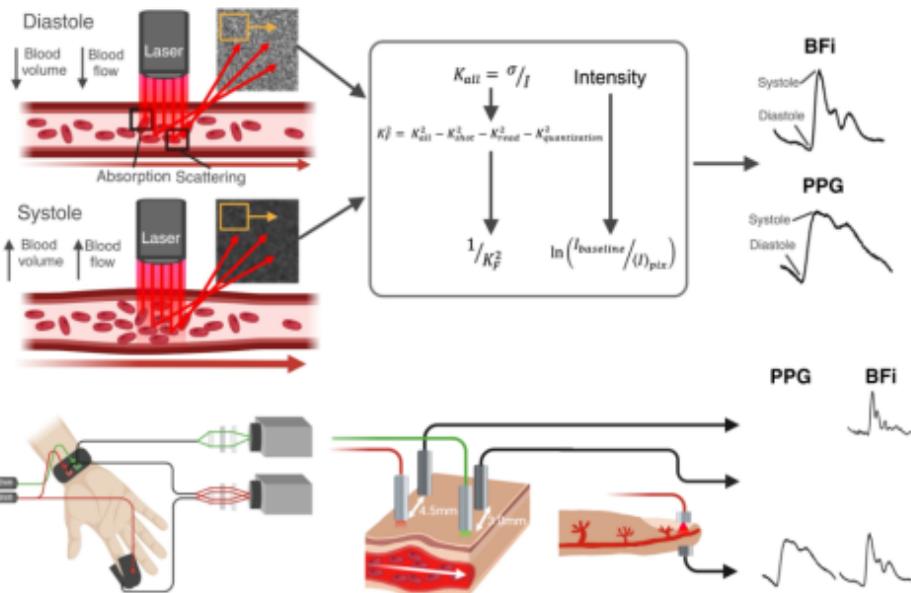


Garrett, A. et al. Biomed. Opt. Express 16, 3004–3016 (2025).



Garrett, A. et al. Biomed. Opt. Express 16, 3004–3016 (2025).

Data: Preparation



Garrett, A. et al. Biomed. Opt. Express 16, 3004–3016 (2025).

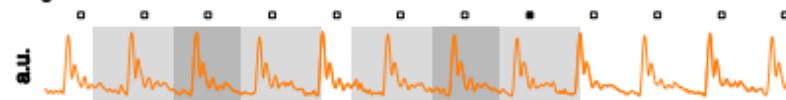
Measurement

○ passed quality control ■ failed quality control

Finger 808nm BFI



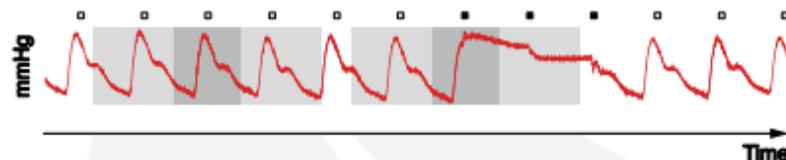
Finger 808nm PPG



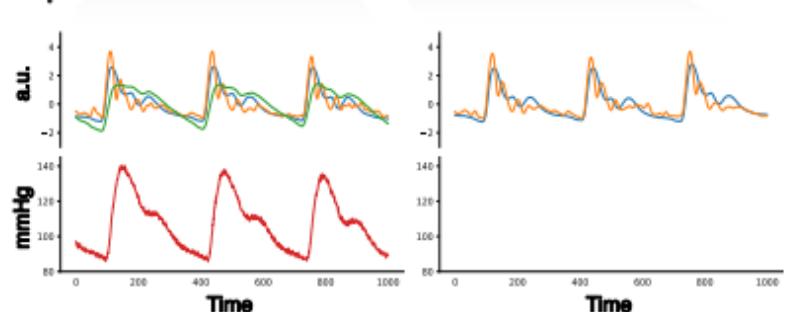
Wrist 808nm BFI



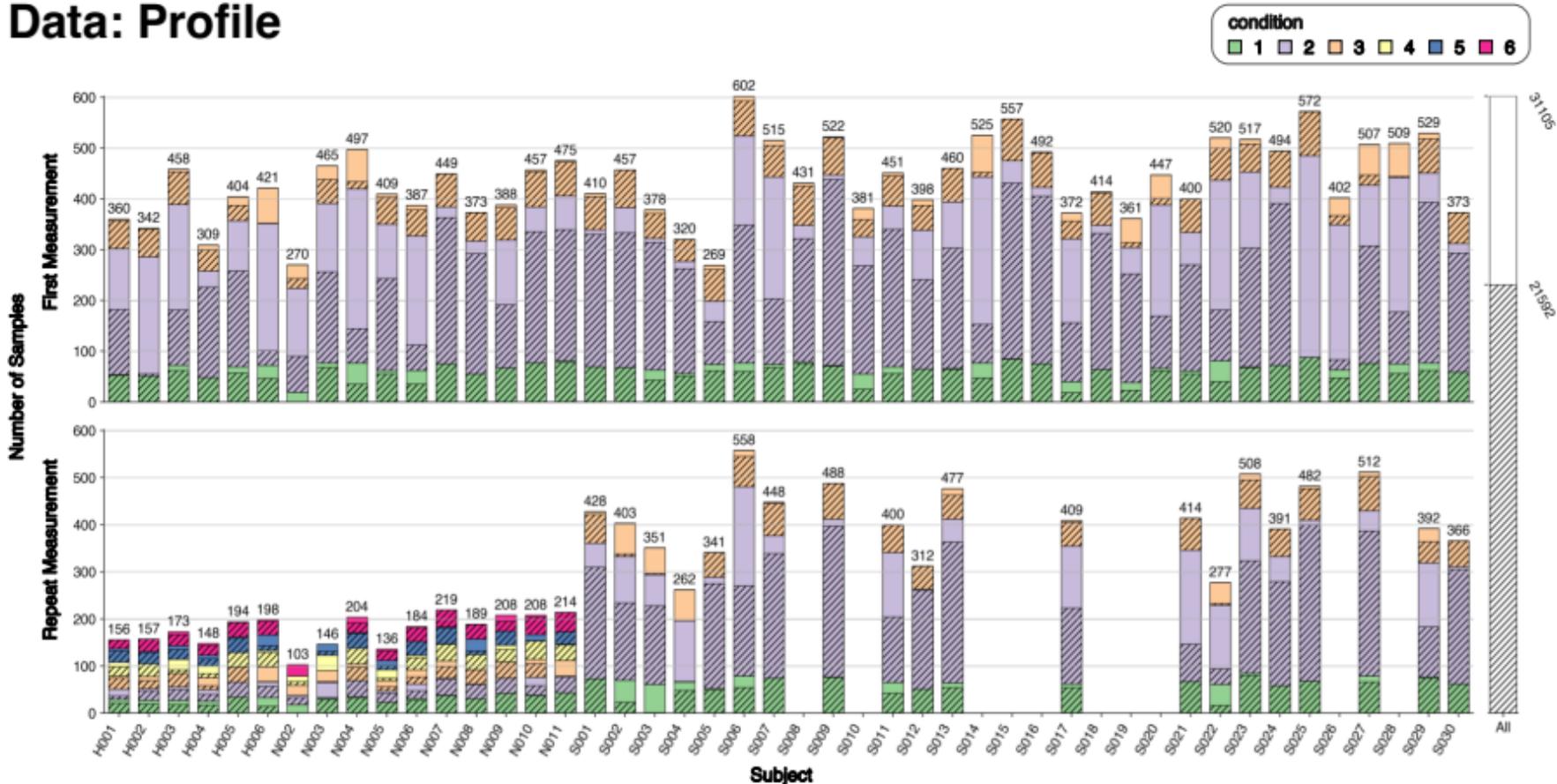
Blood Pressure



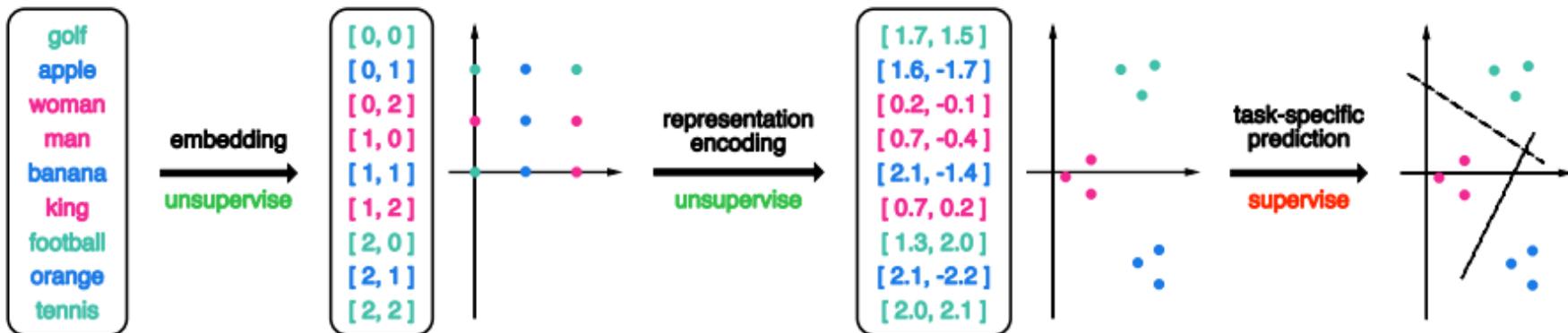
Sample



Data: Profile



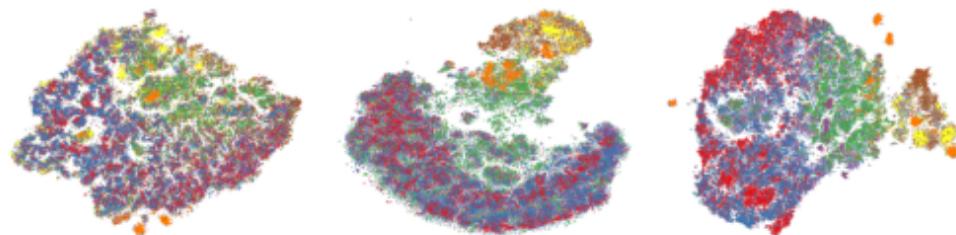
Model: Representation Learning



DNABERT

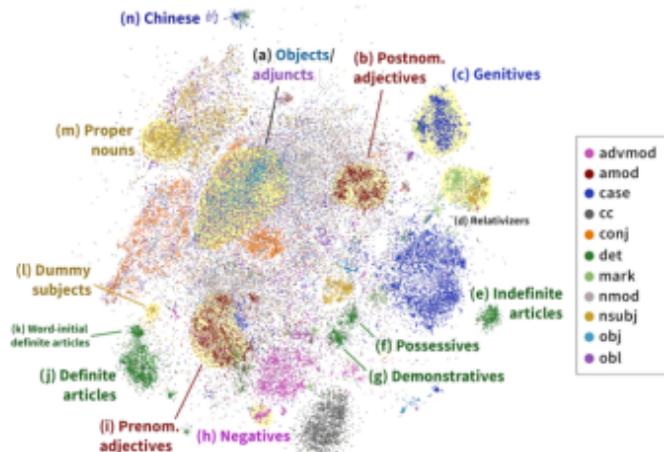
Nucleotide Transformer

HyenaDNA



- Protein Coding
- lncRNA
- Processed Pseudogene
- Unprocessed Pseudogene
- snRNA
- miRNA
- TEC
- snoRNA
- MiscRNA

Nguyen, E. et al. arXiv:2306.15794 (2023).



Chi, E. A. et al. arXiv:2005.04511 (2020).

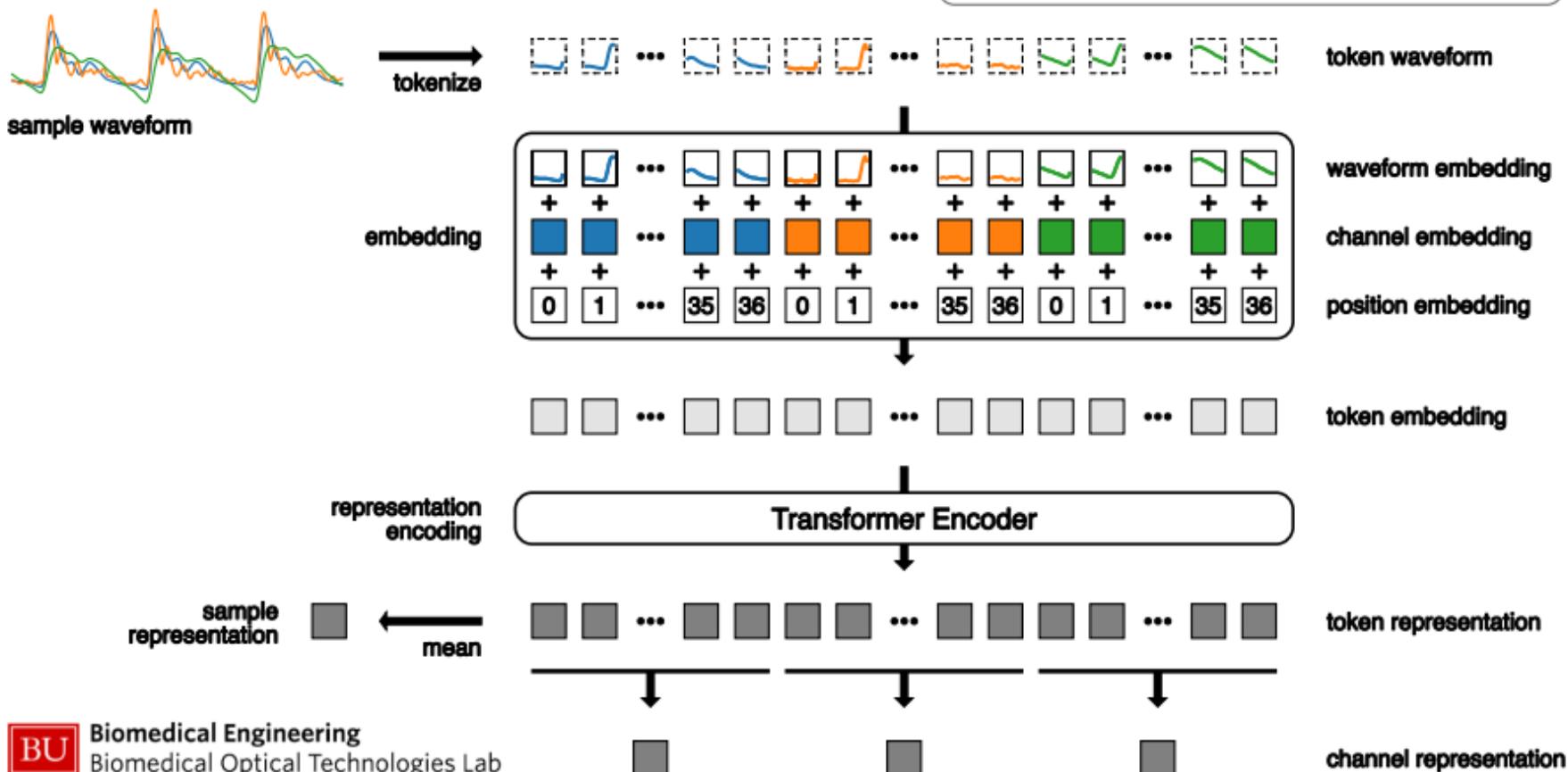


Biomedical Engineering

Biomedical Optical Technologies Lab

Model: Architecture

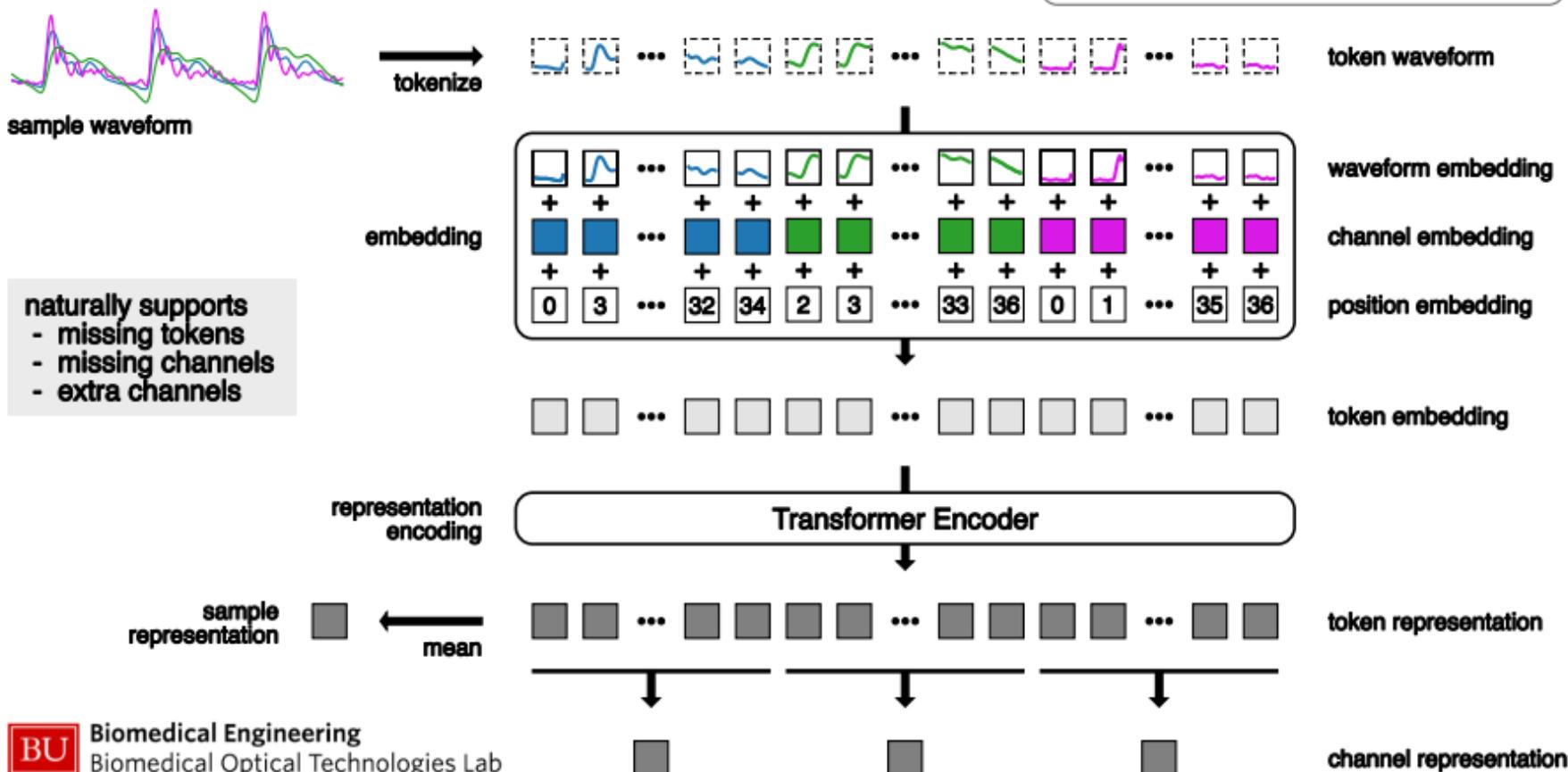
Yang, C. et al. BIOT: Cross-data biosignal learning in the wild. arXiv:2305.10351 (2023).



Model: Input Flexibility

Yang, C. et al. BIOT: Cross-data biosignal learning in the wild. arXiv:2305.10351 (2023).

dimension	channel	
 100	 ch1: Finger 808nm BFI	 ch2: missing
 256	 ch3: Wrist 808nm BFI	 ch4: extra



Model: Stage 1

[1] Vaswani, A. et al. Attention Is All You Need. arXiv:1706.03762 (2017).

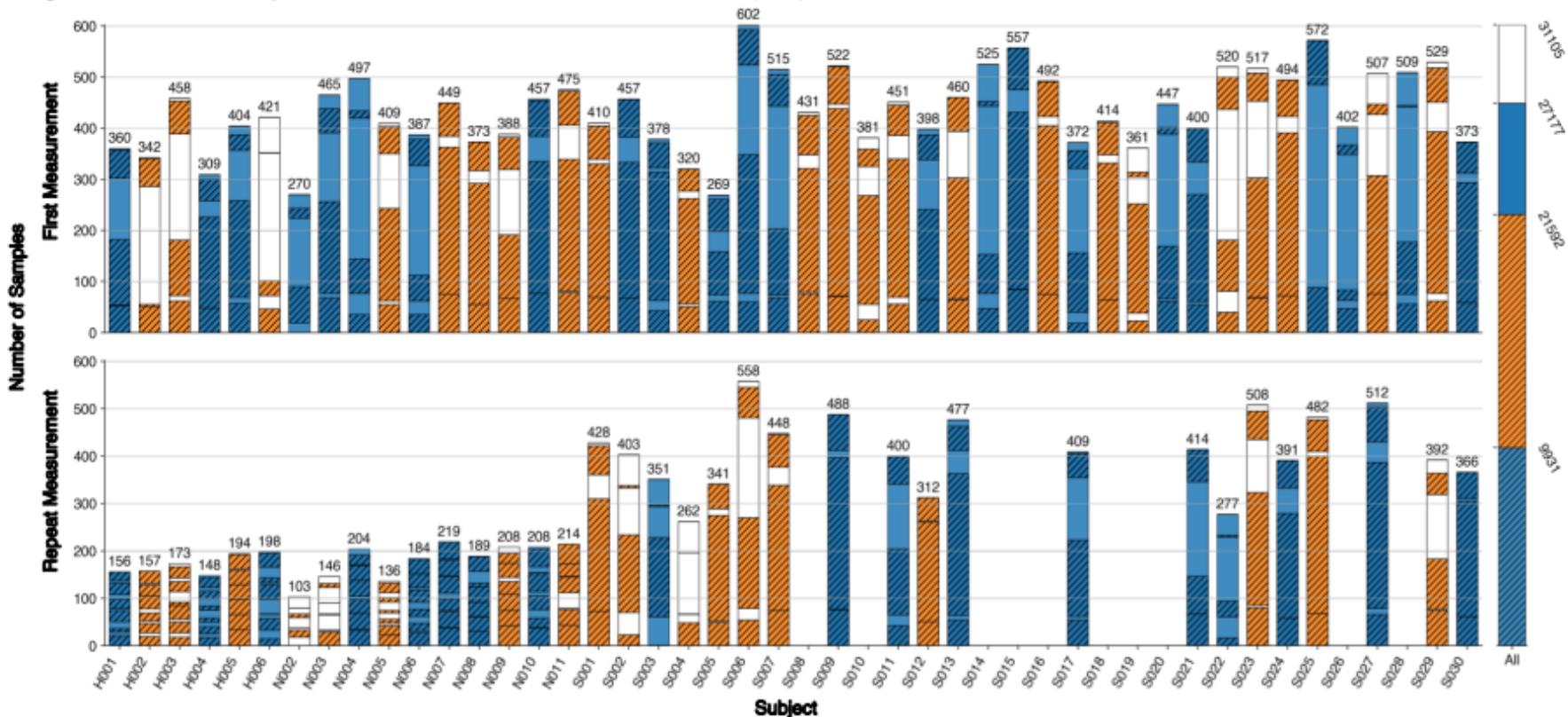
→ trainable → fixed



Data: Stage 1 Split

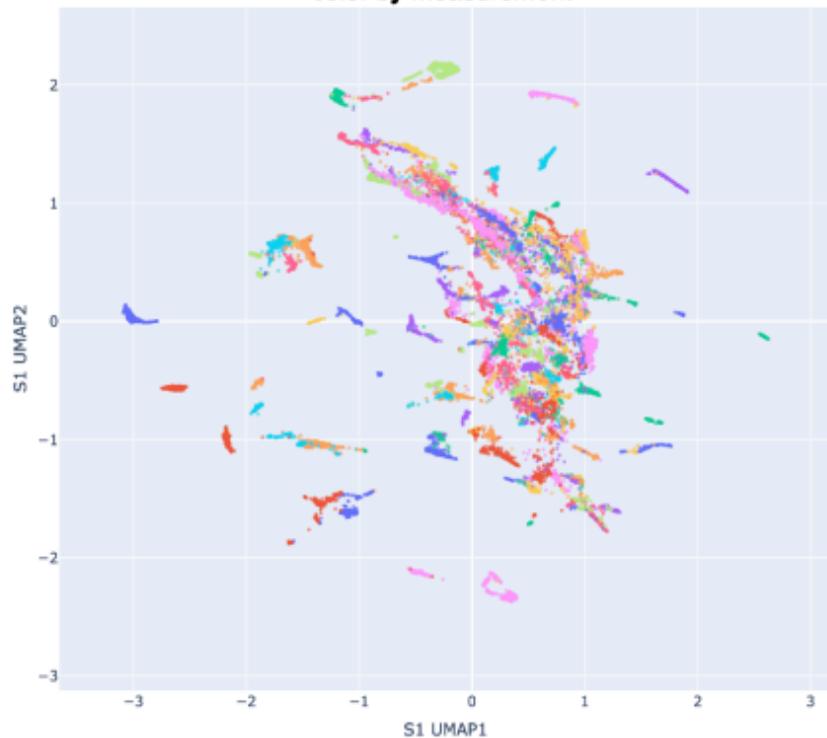
In implementation, we use (at least one optical ch passed QC), which adds ~1k more training samples. For simplicity, the figure below displays (BP & at least at least one optical ch passed QC).

Wang, Y. et al. How to evaluate your medical time series classification? arXiv 2410.03057 (2024).

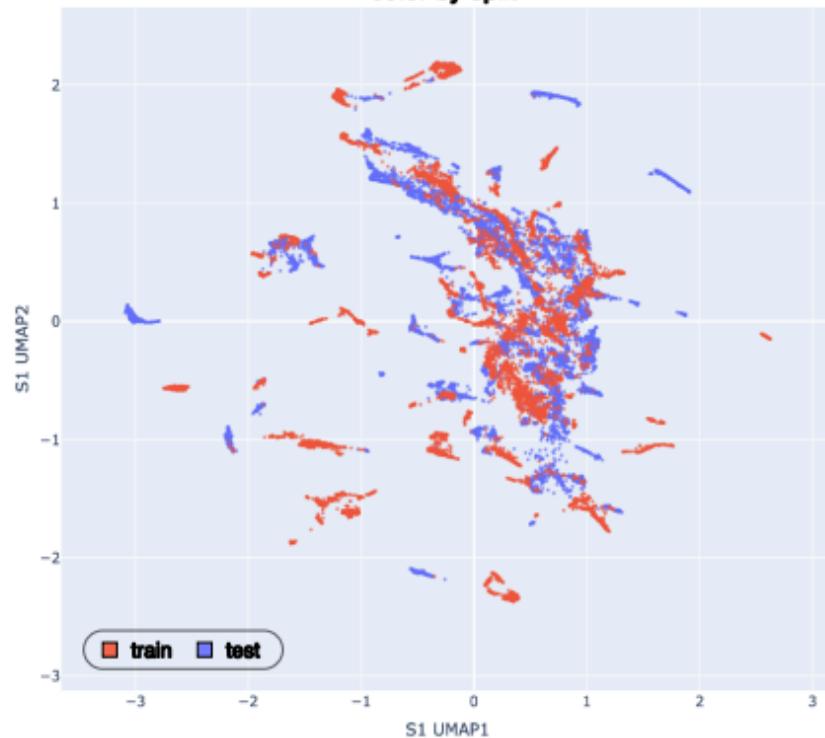


Result: Stage 1 Representation generalizes well across train and test splits

color by measurement

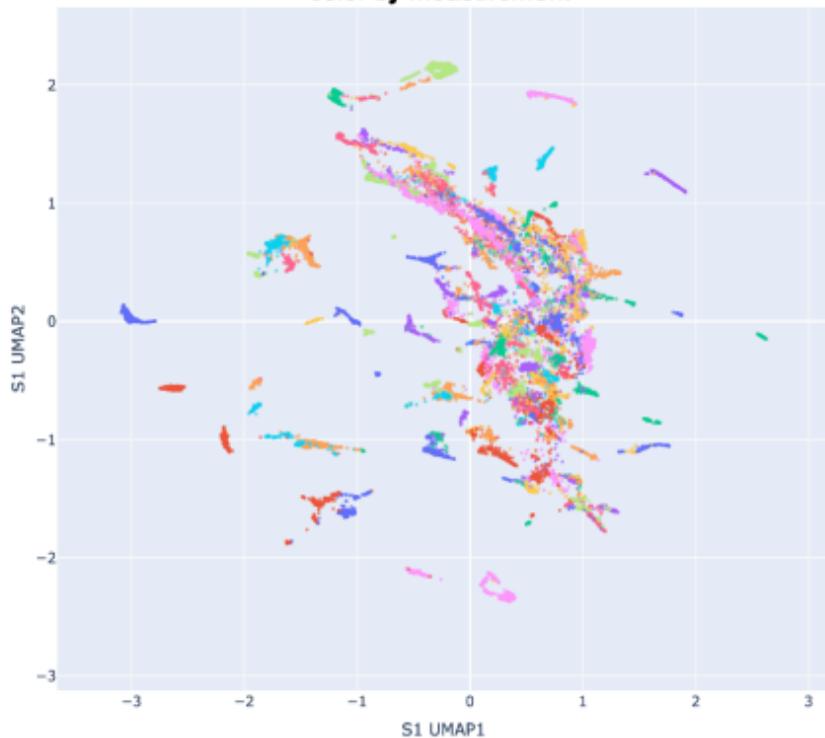


color by split

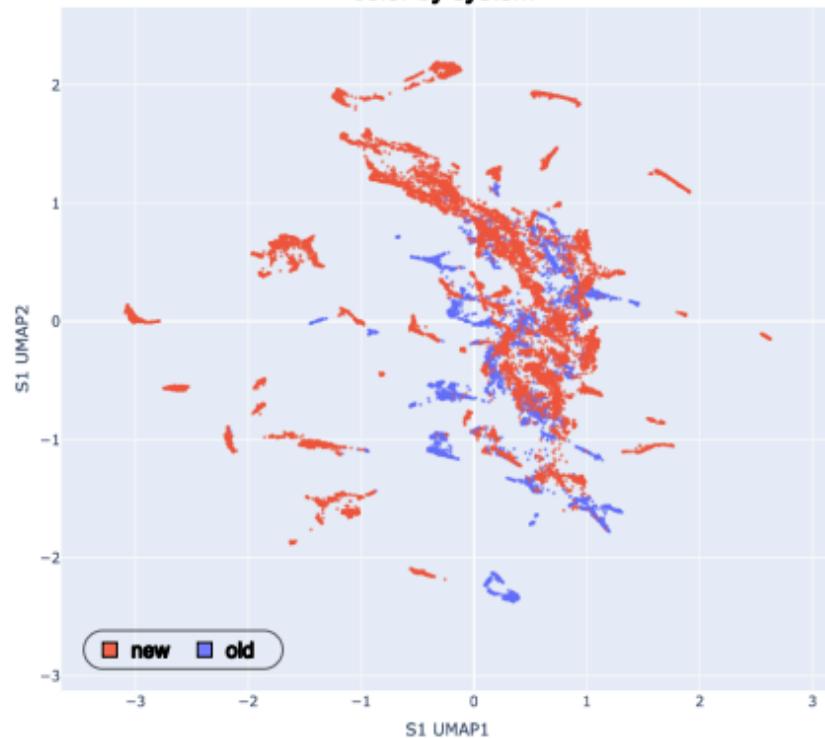


Result: Stage 1 No clear separation between samples from old and new system

color by measurement

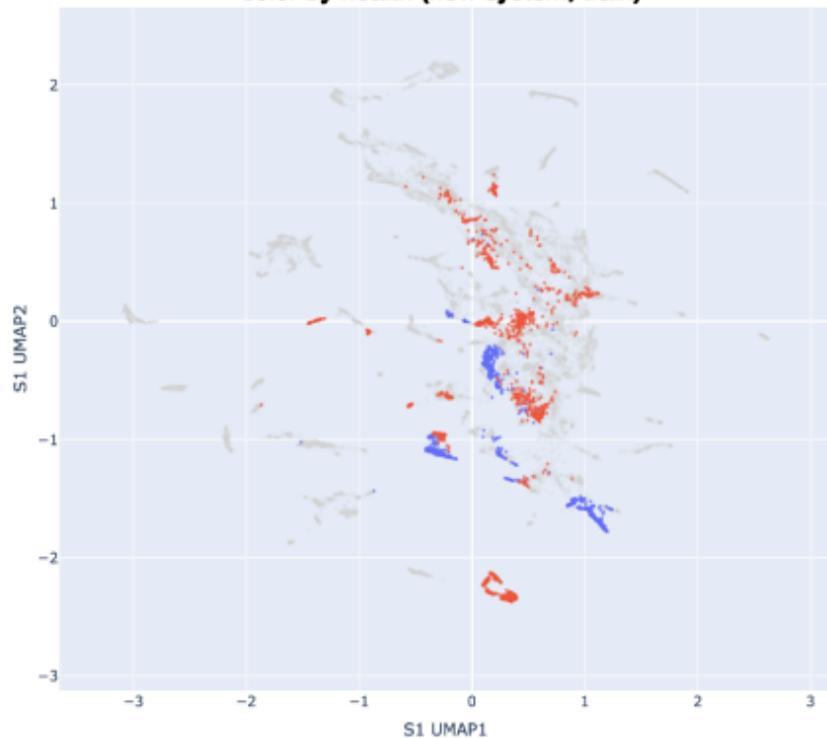


color by system

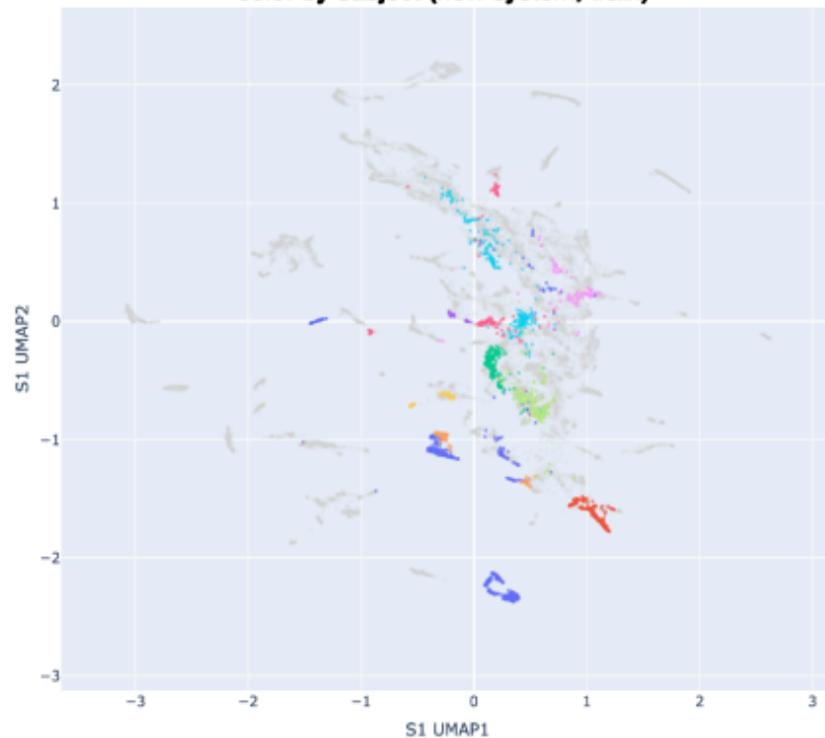


Result: Stage 1 With current number of subjects, health-related clustering is inconclusive

color by health (new system, train)

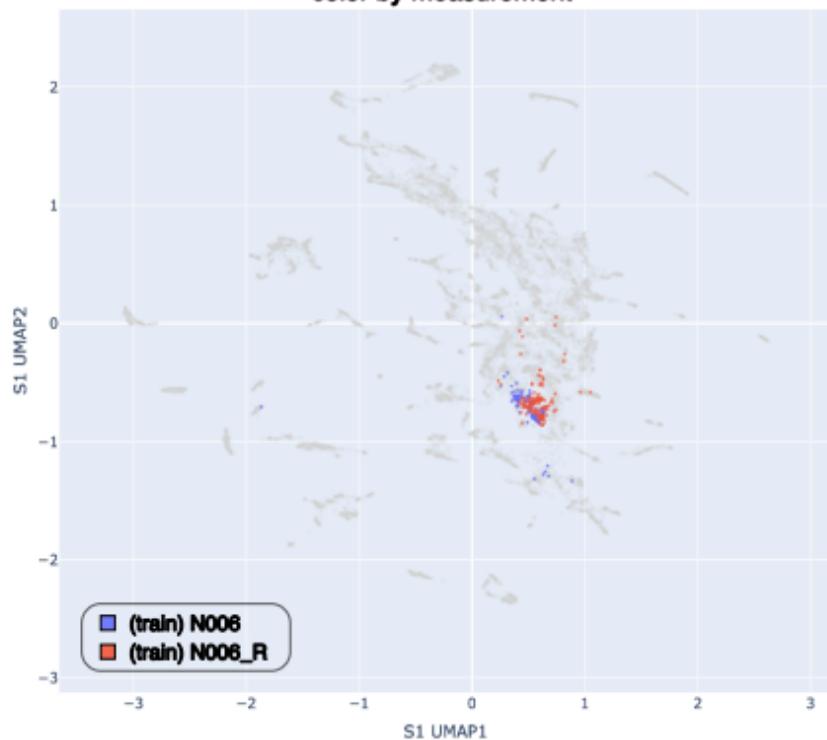


color by subject (new system, train)

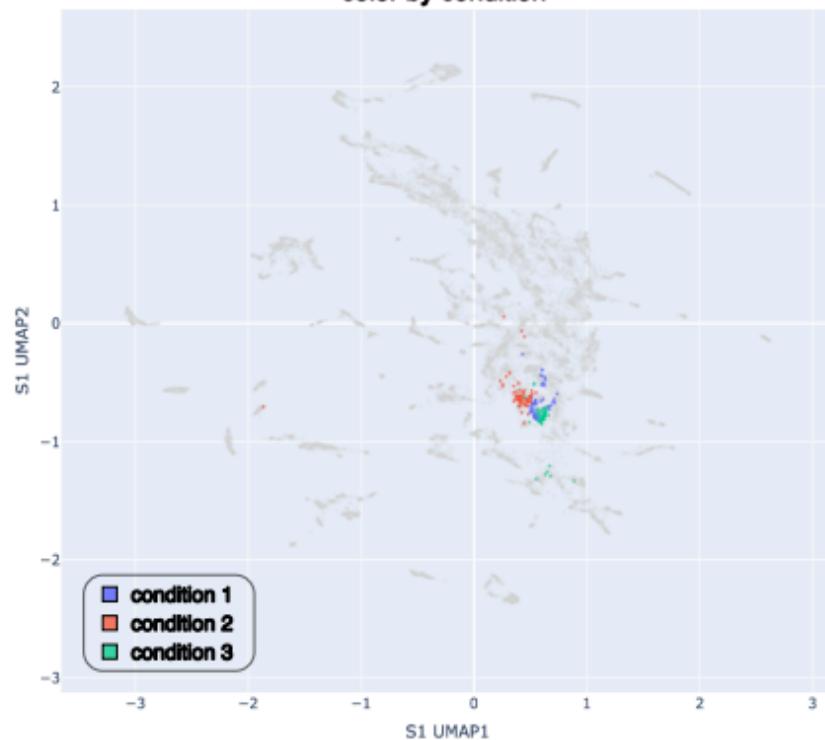


Result: Stage 1 Samples from same subject and condition cluster together

color by measurement

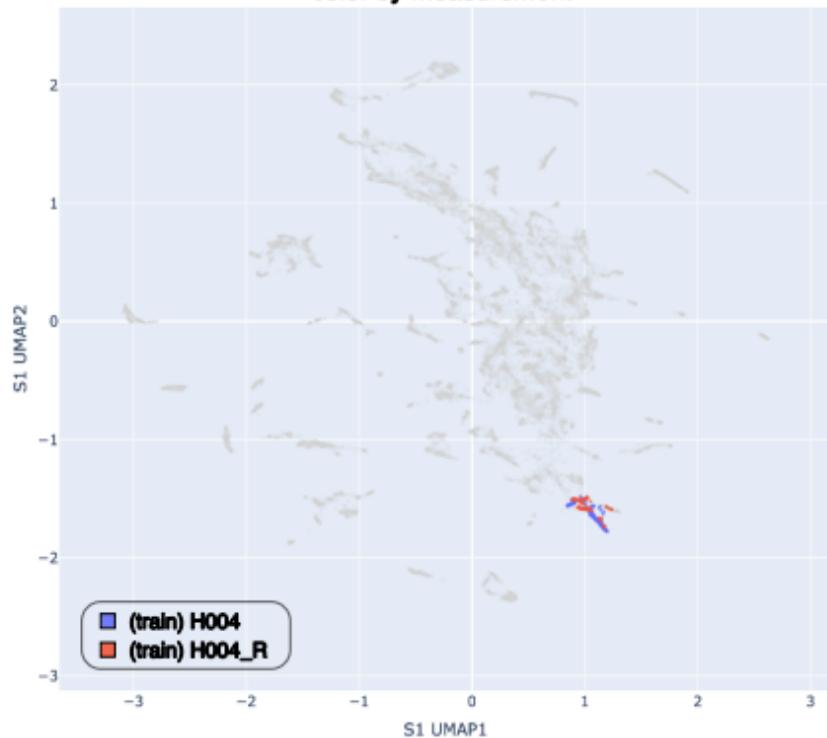


color by condition

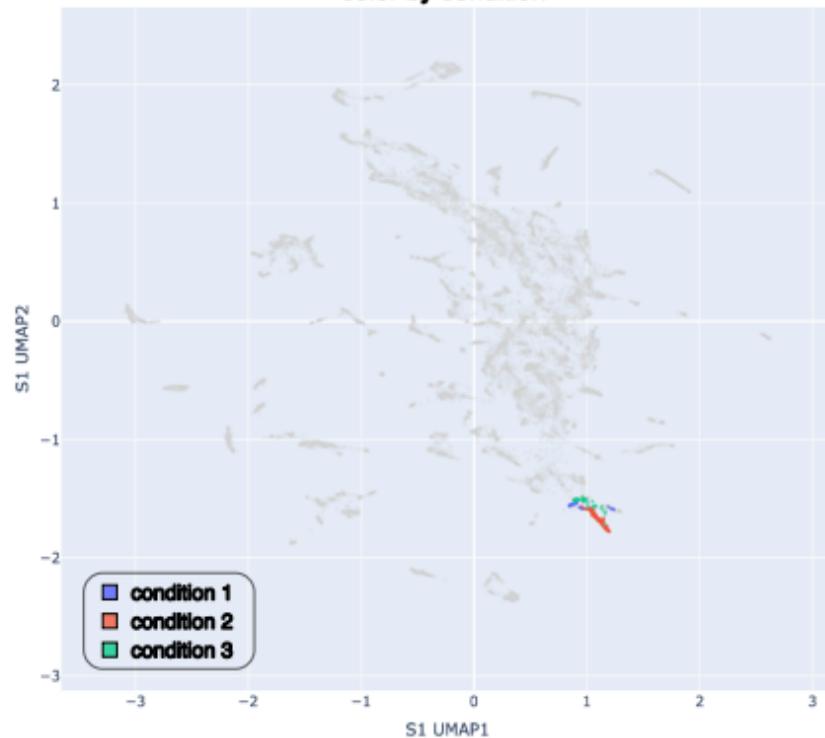


Result: Stage 1 Samples from same subject and condition cluster together

color by measurement

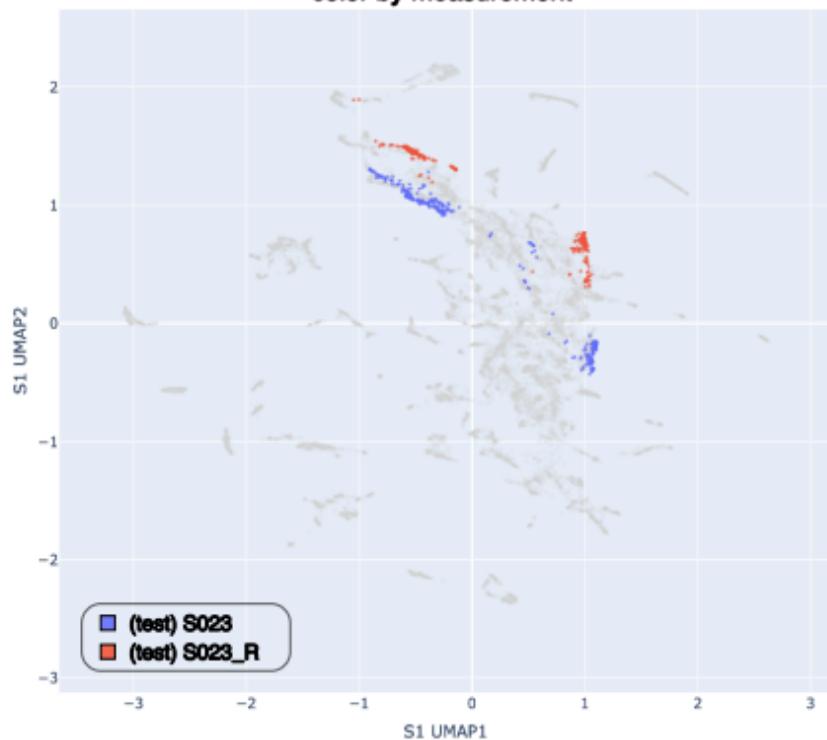


color by condition

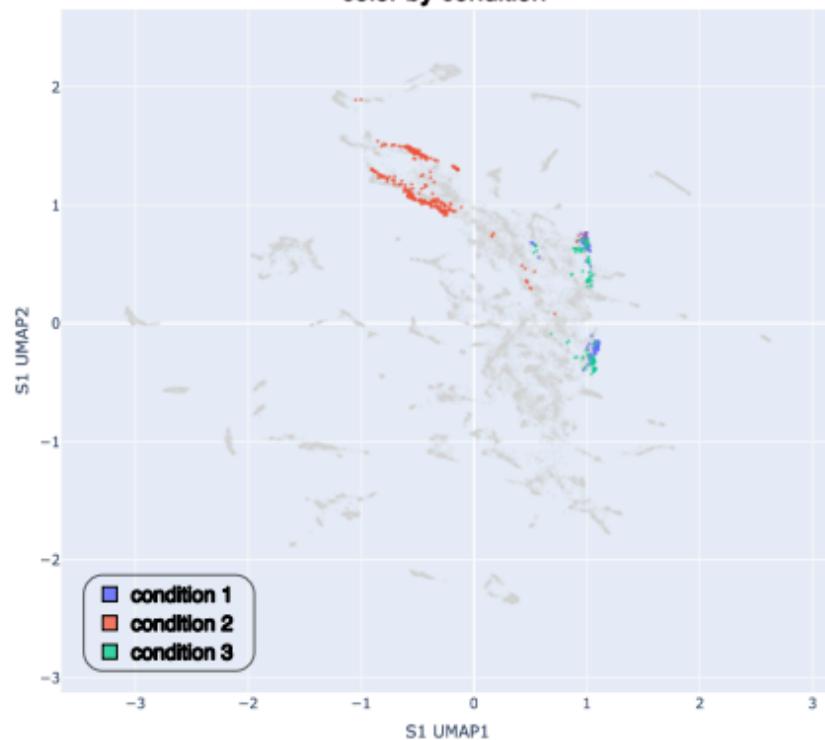


Result: Stage 1 Samples from same subject and condition cluster together

color by measurement

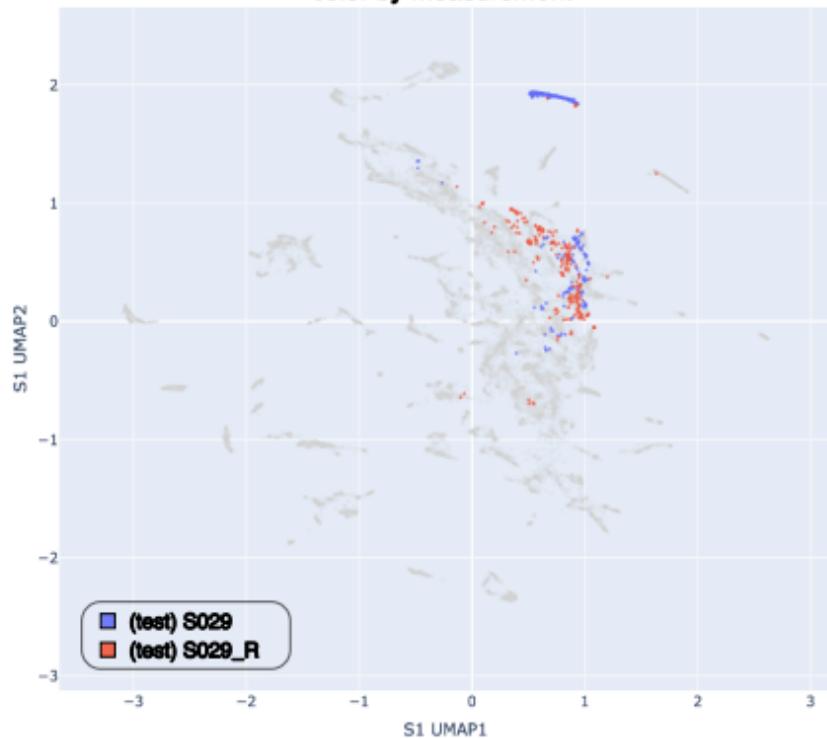


color by condition

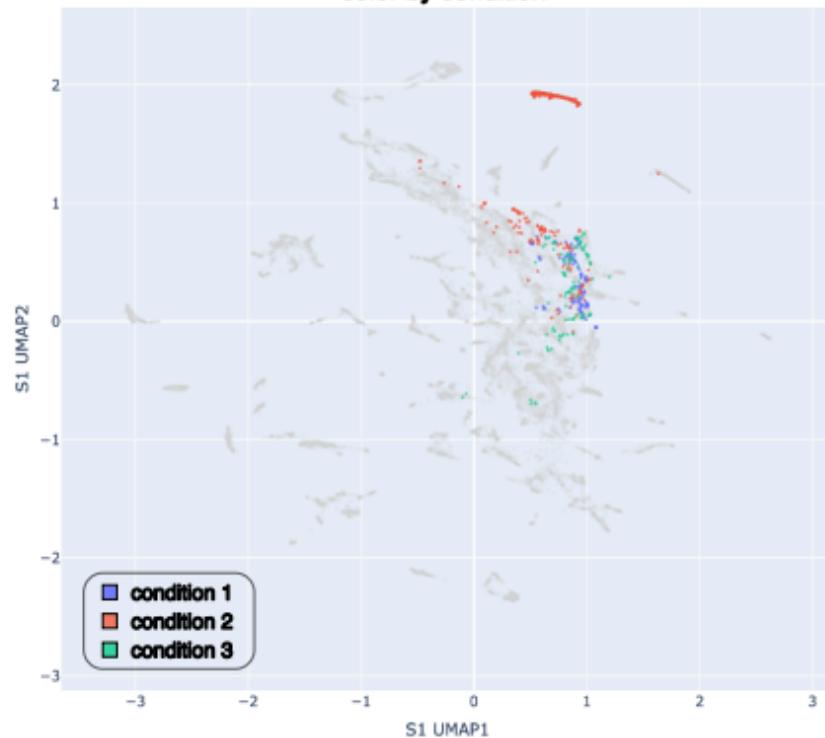


Result: Stage 1 Samples from same subject and condition cluster together

color by measurement

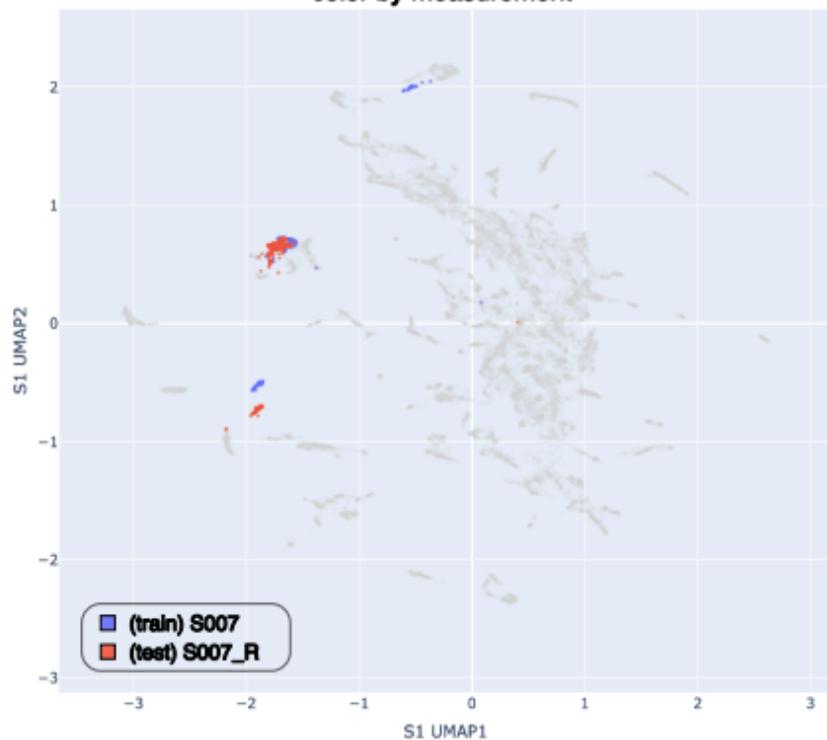


color by condition

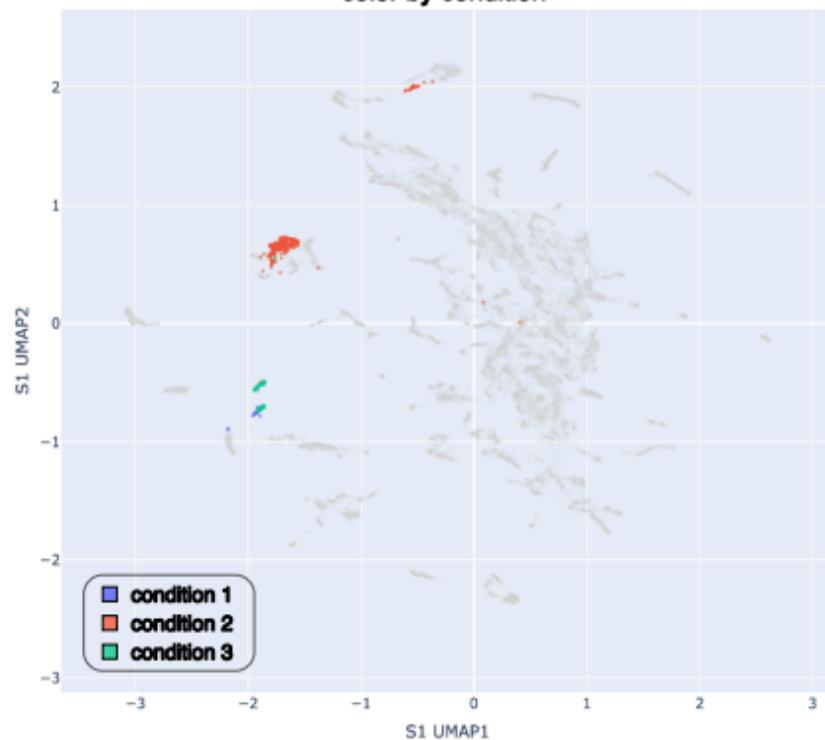


Result: Stage 1 Samples from same subject and condition cluster together

color by measurement

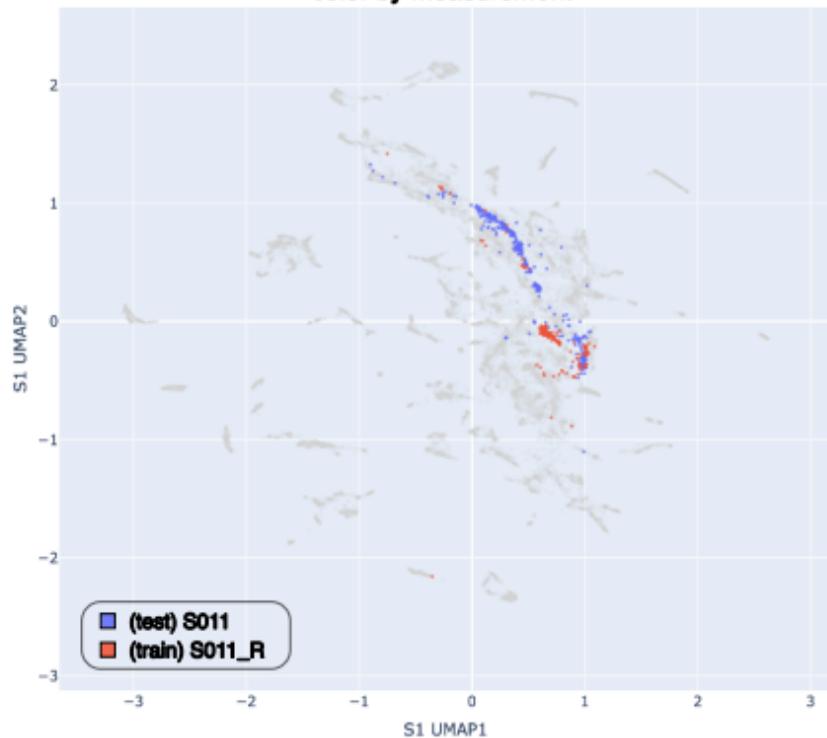


color by condition

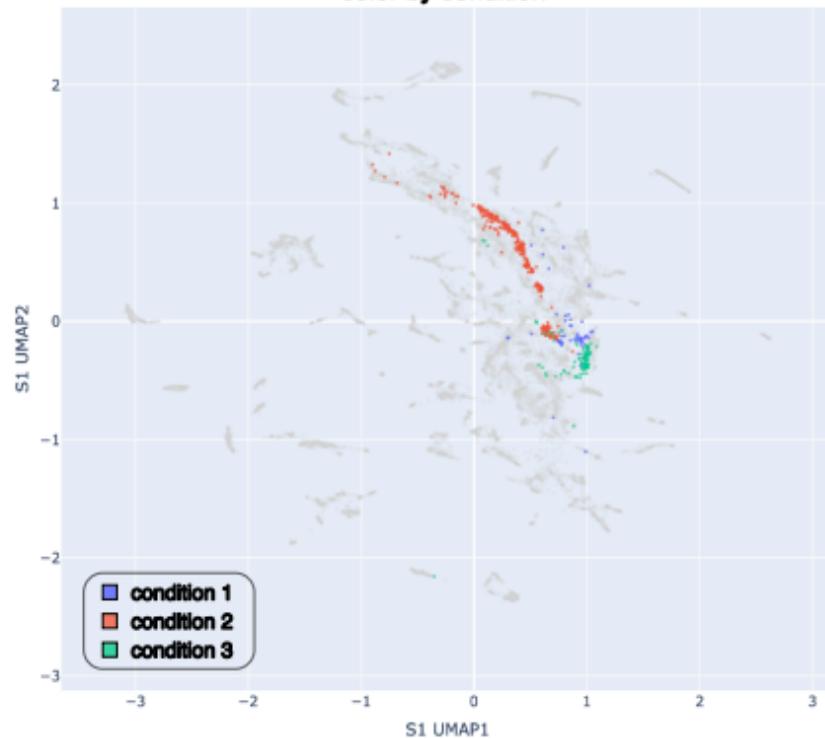


Result: Stage 1 Samples from same subject and condition cluster together

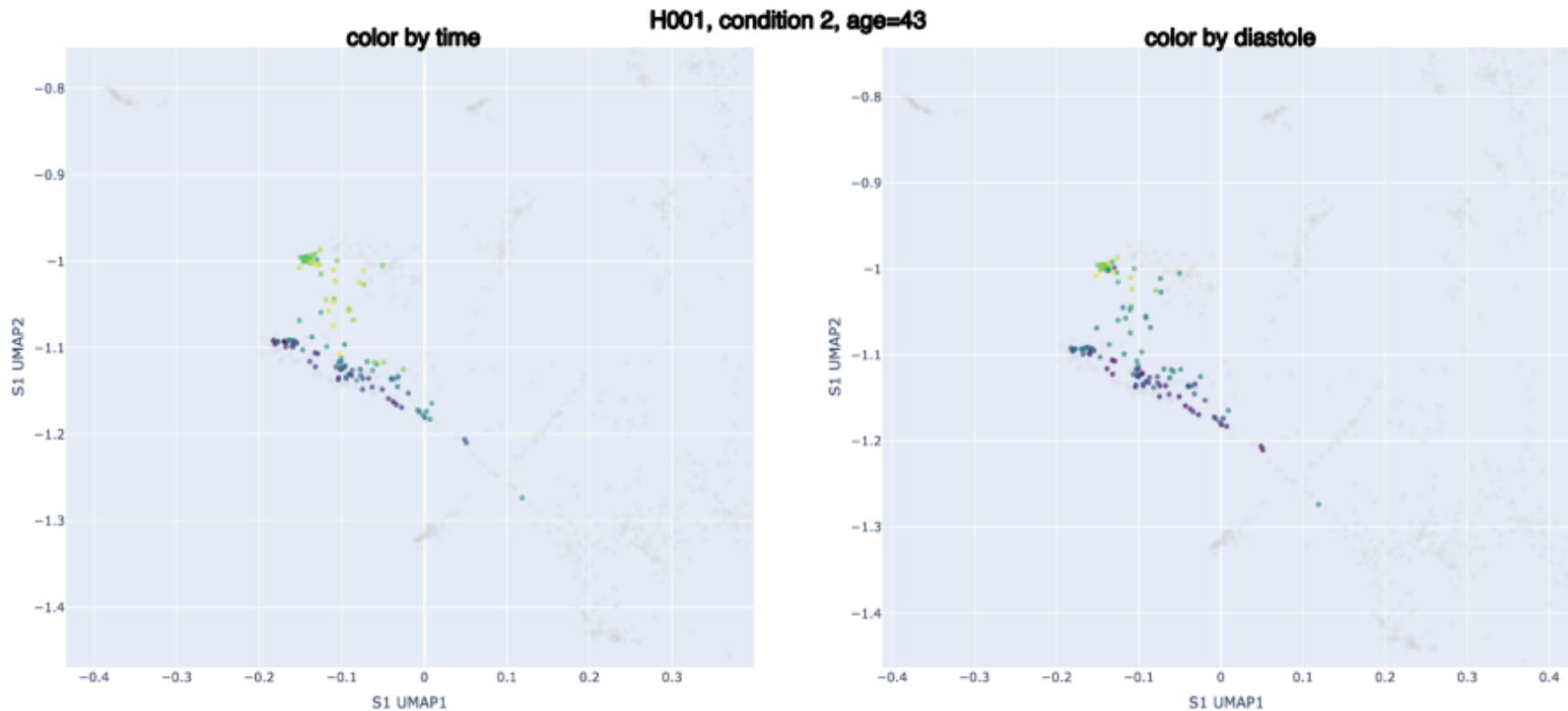
color by measurement



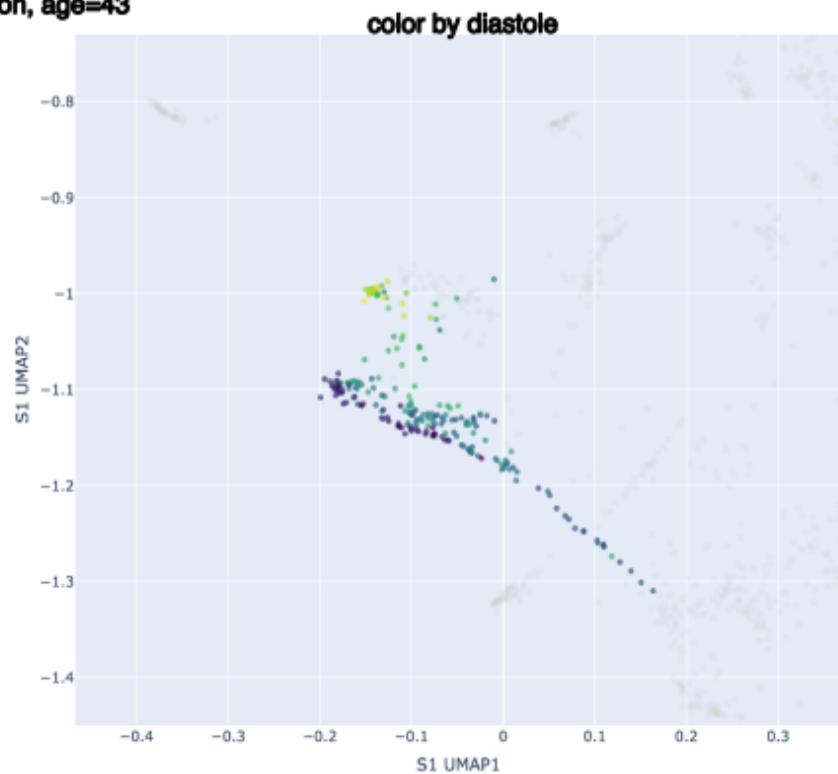
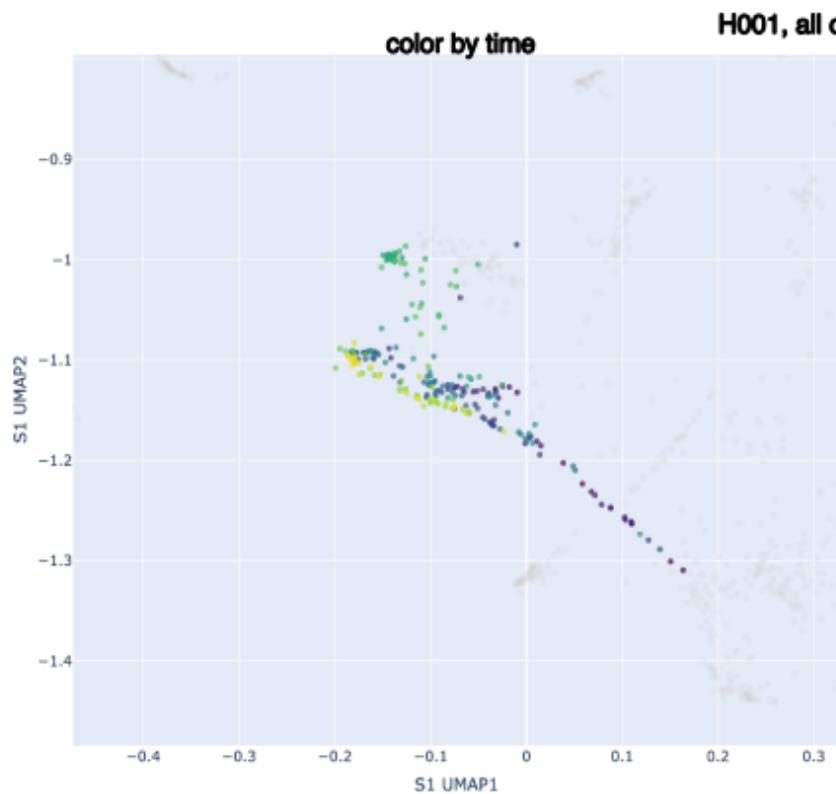
color by condition



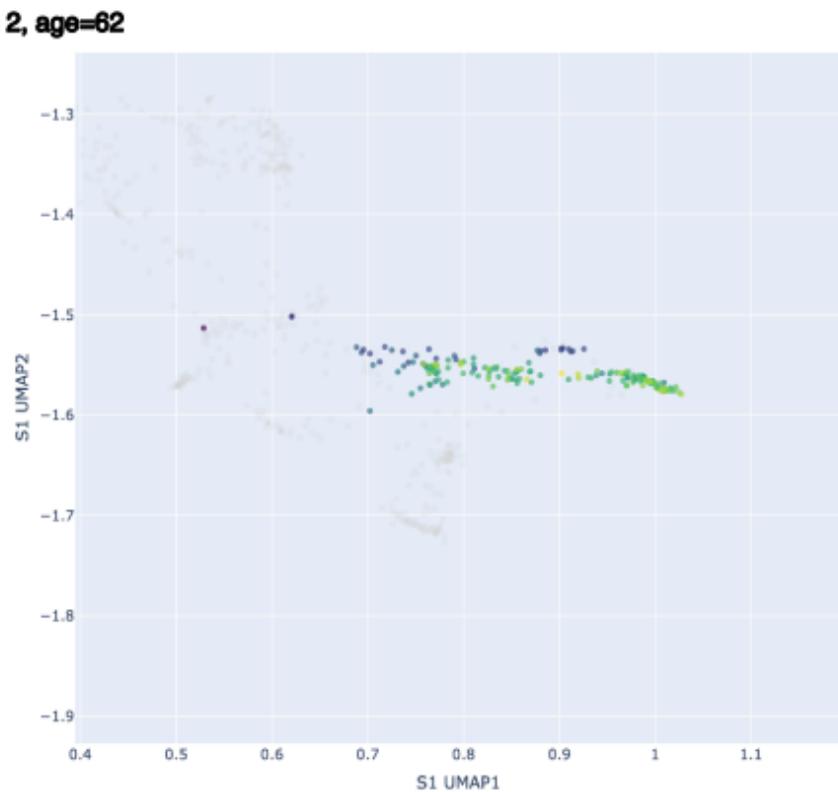
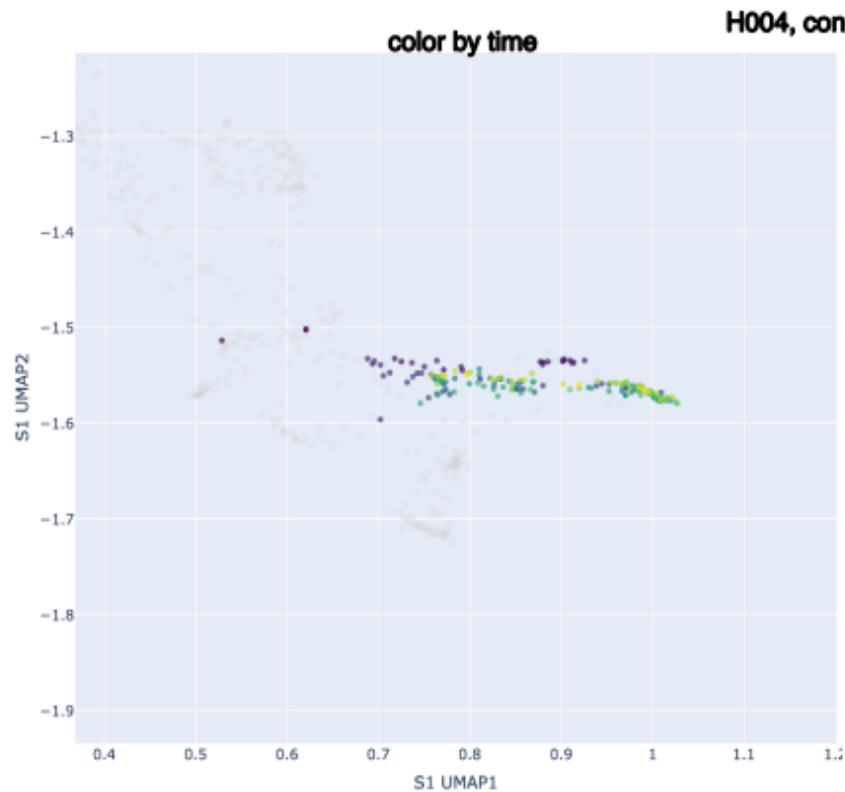
Result: Stage 1



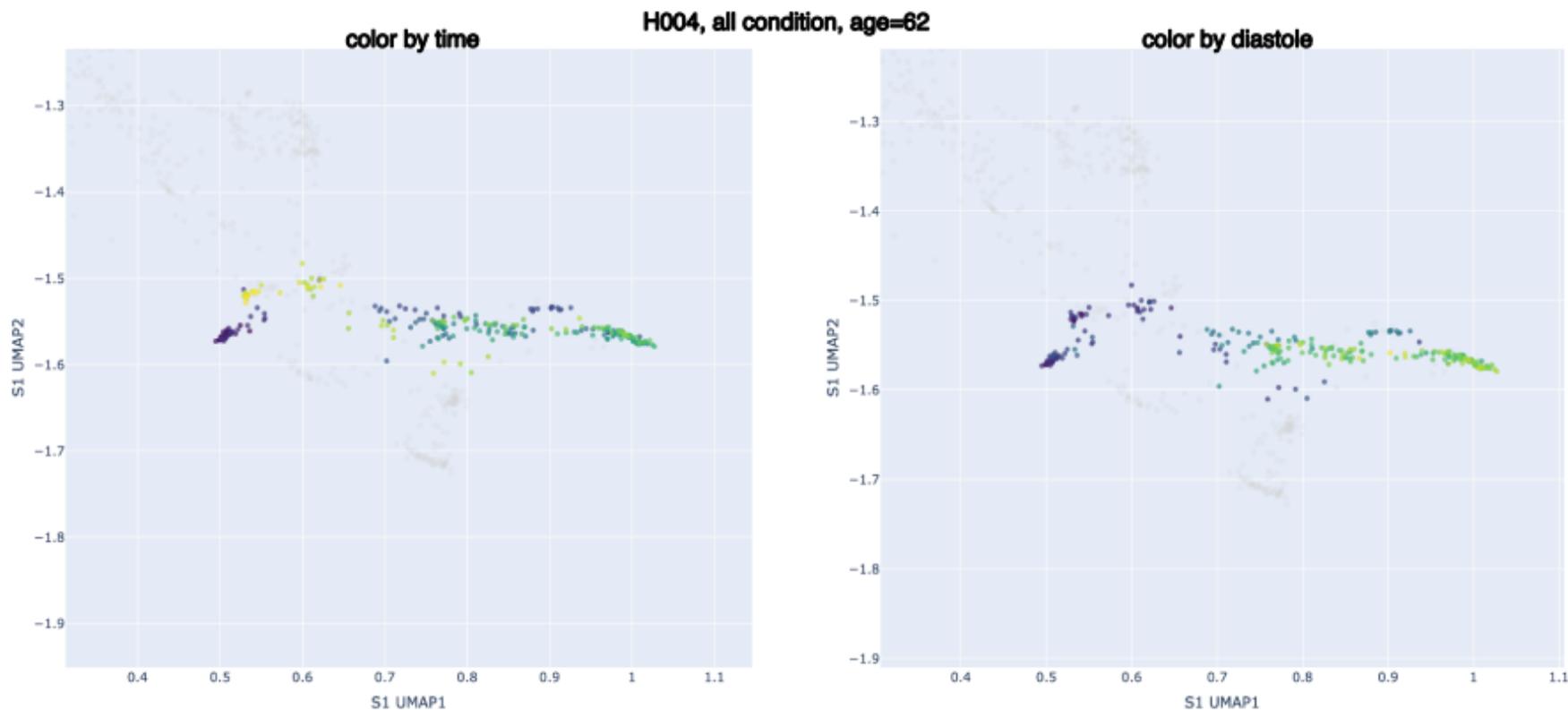
Result: Stage 1



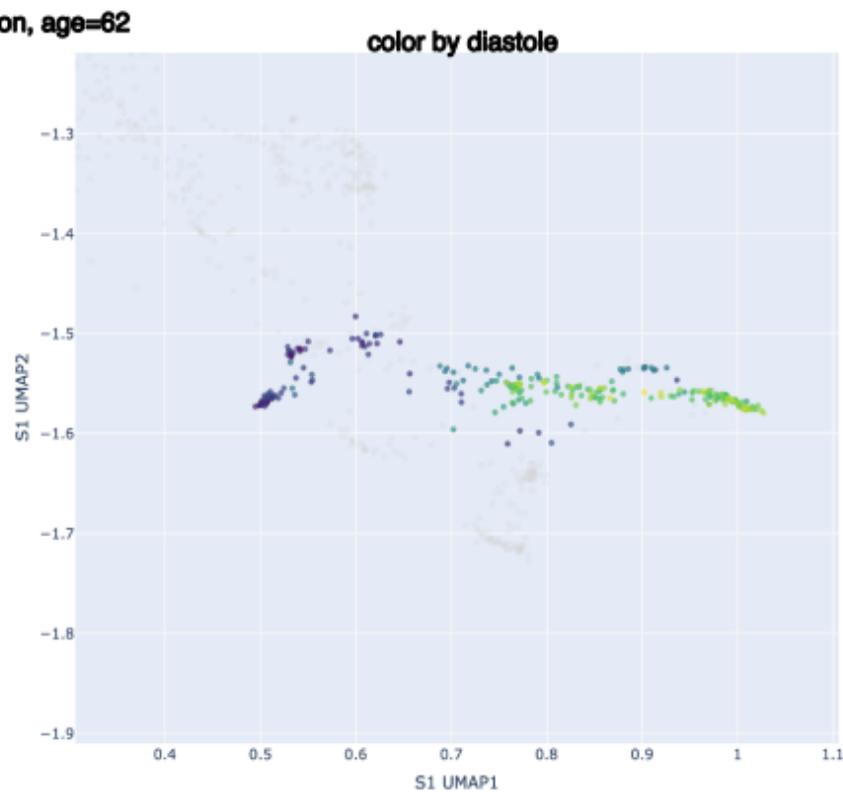
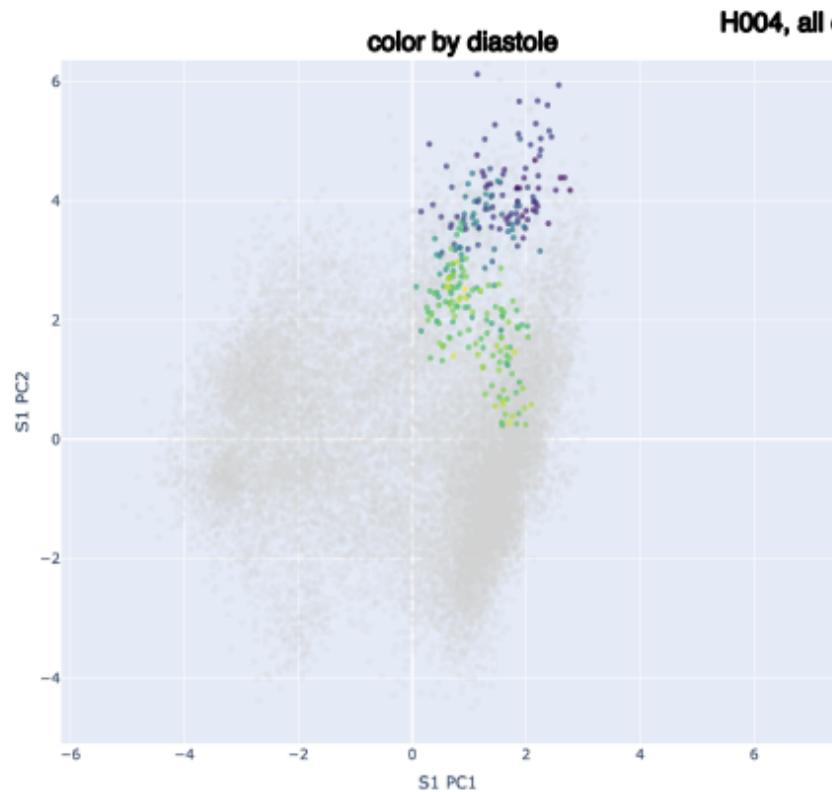
Result: Stage 1



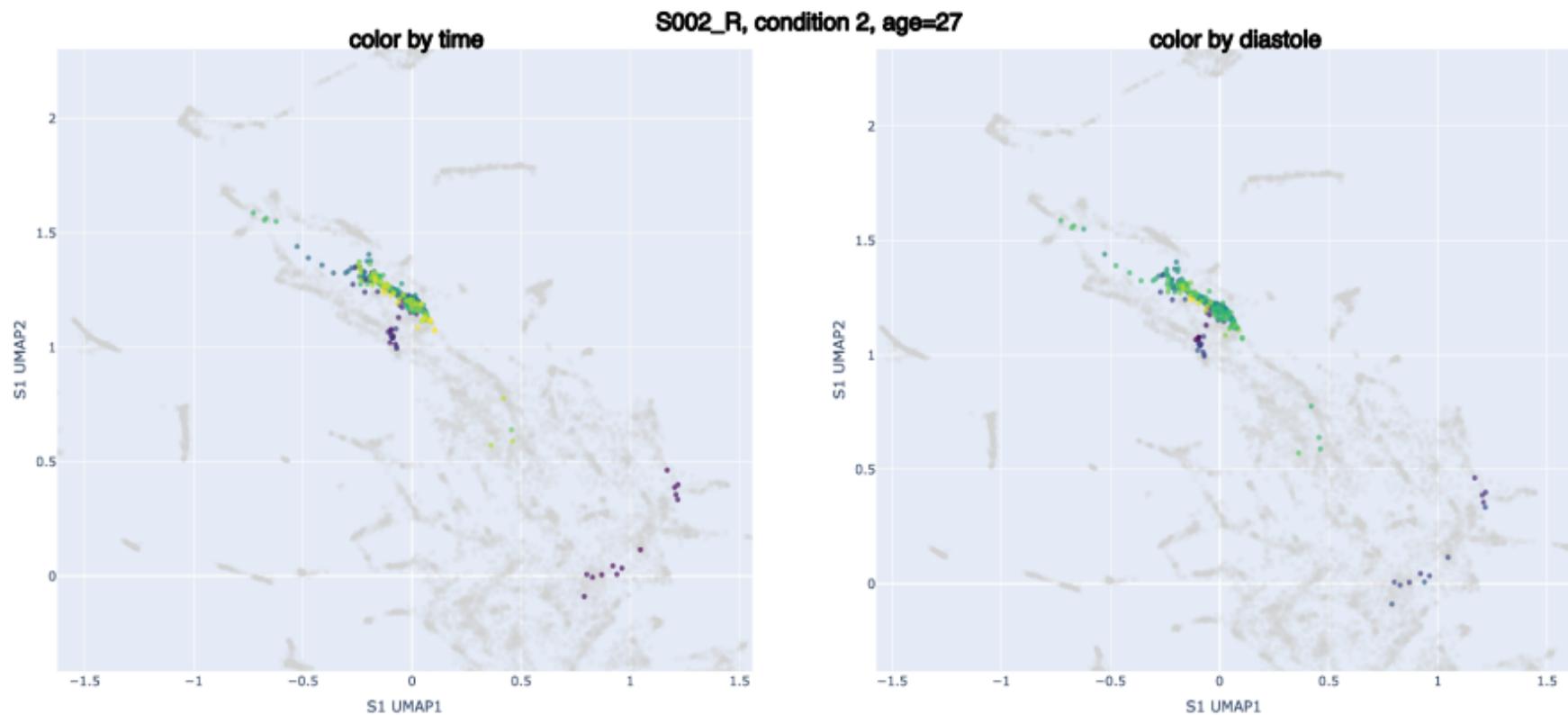
Result: Stage 1 Smapple with similar BP from different condition group together



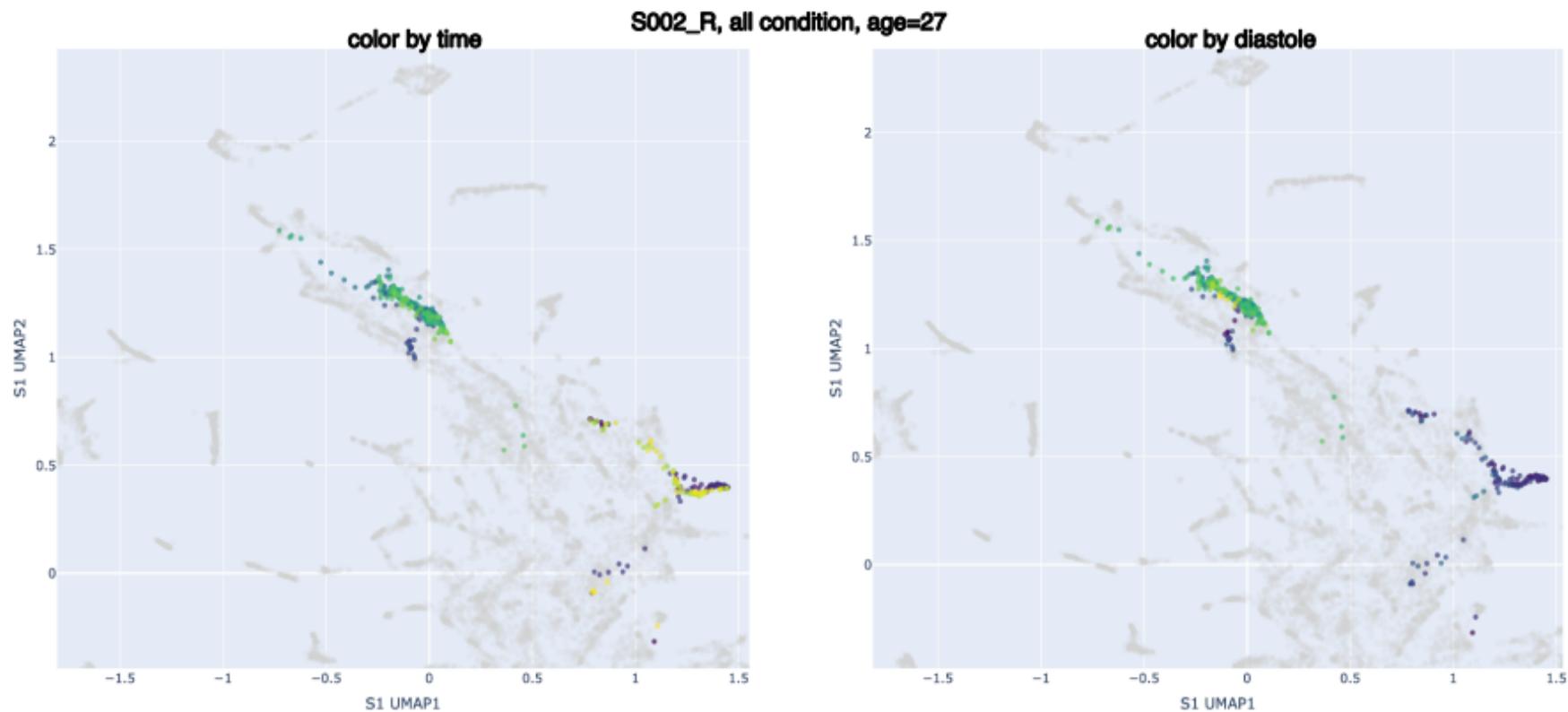
Result: Stage 1



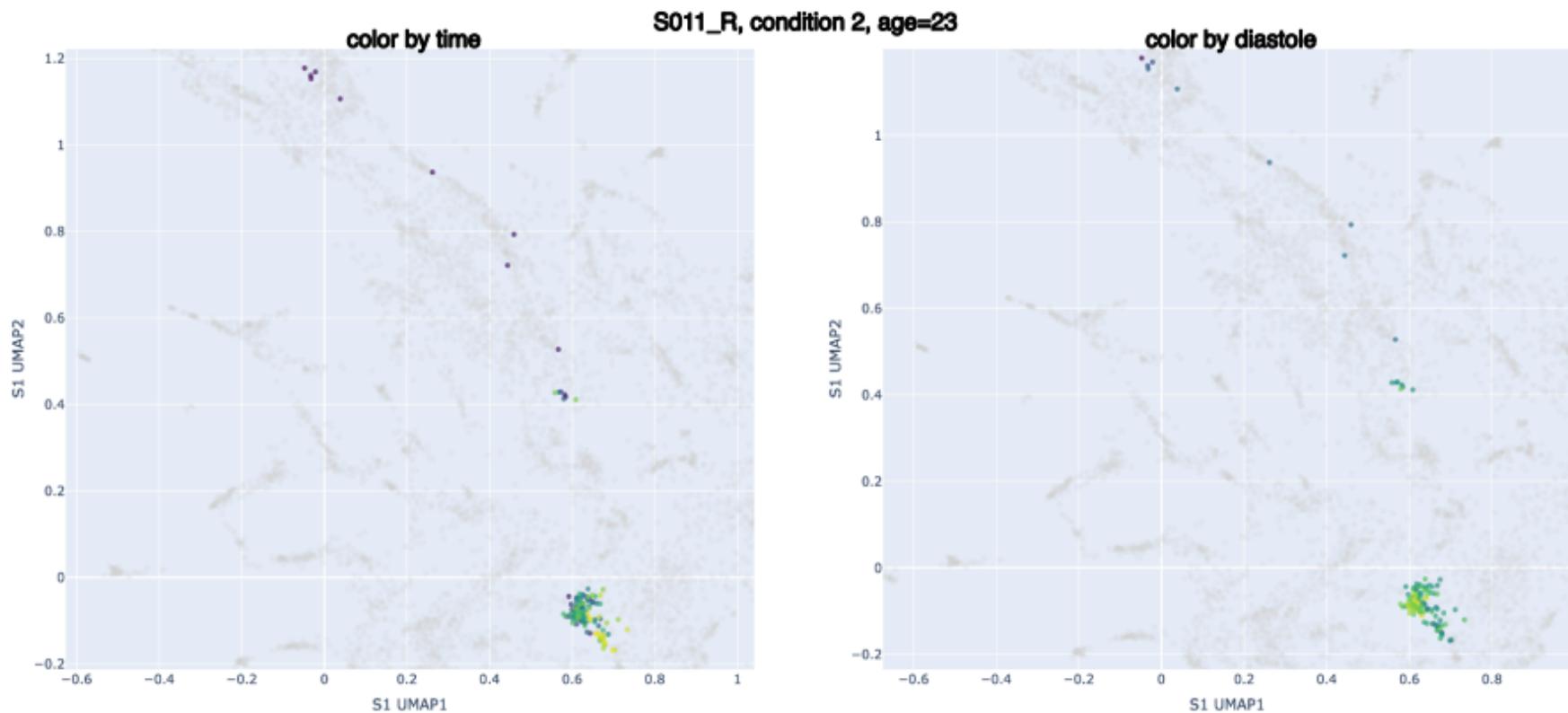
Result: Stage 1



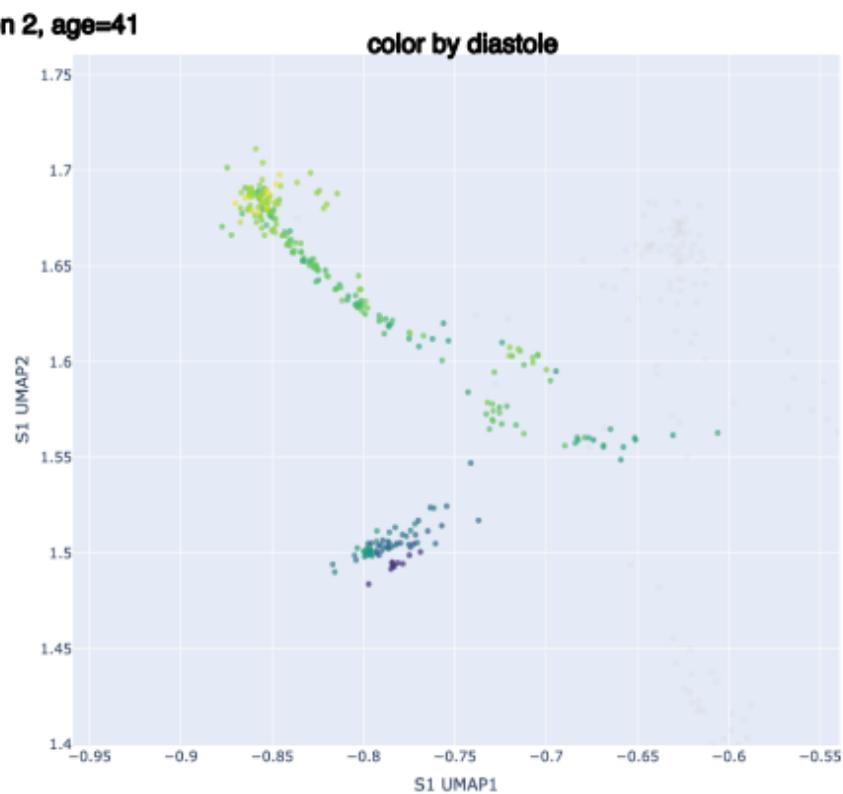
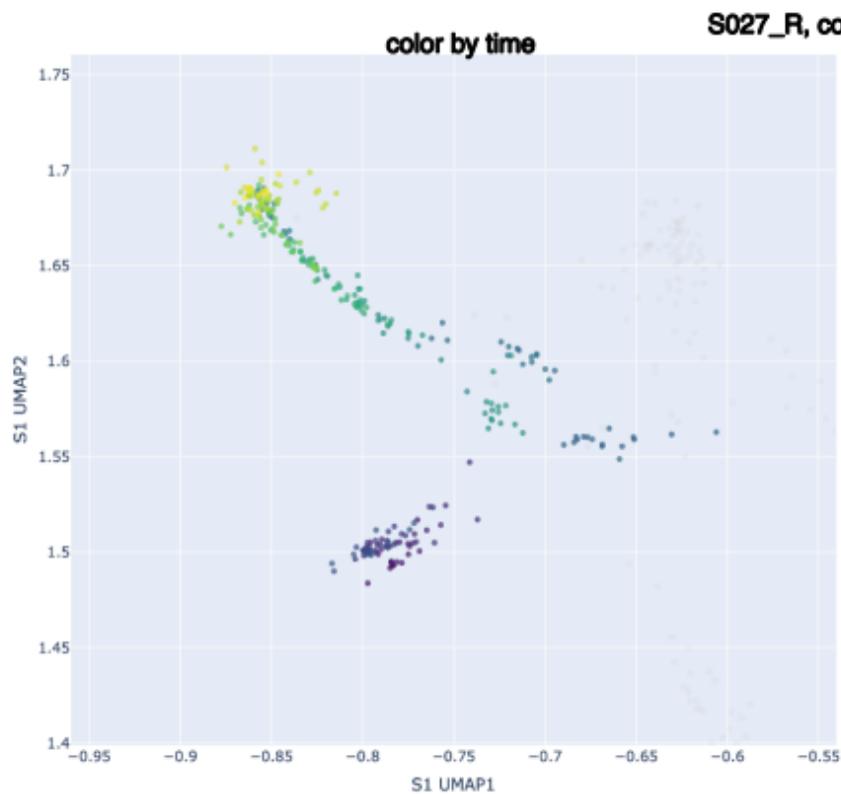
Result: Stage 1 Smapple with similar BP from different condition group together



Result: Stage 1

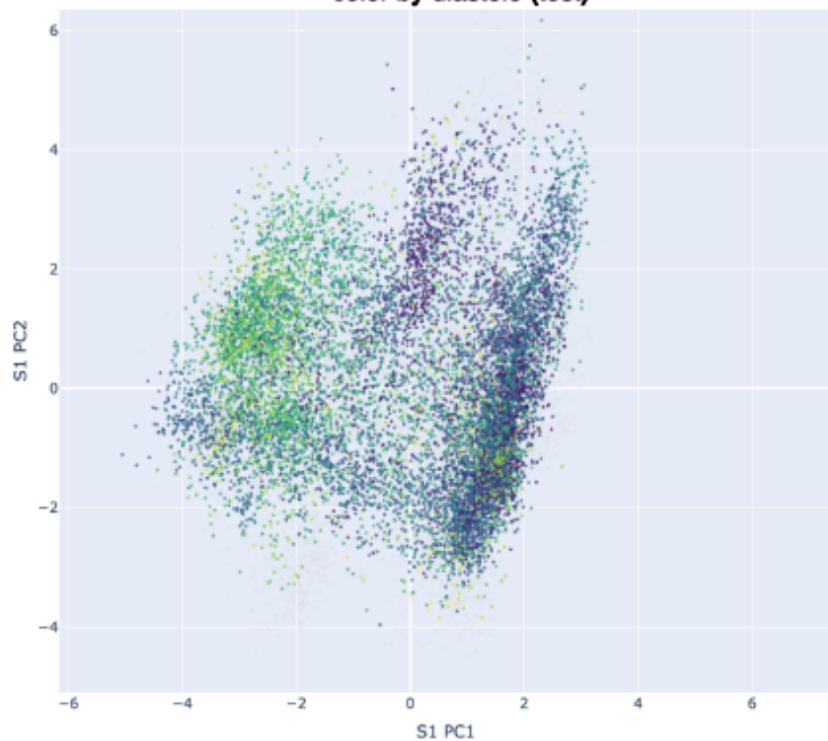


Result: Stage 1

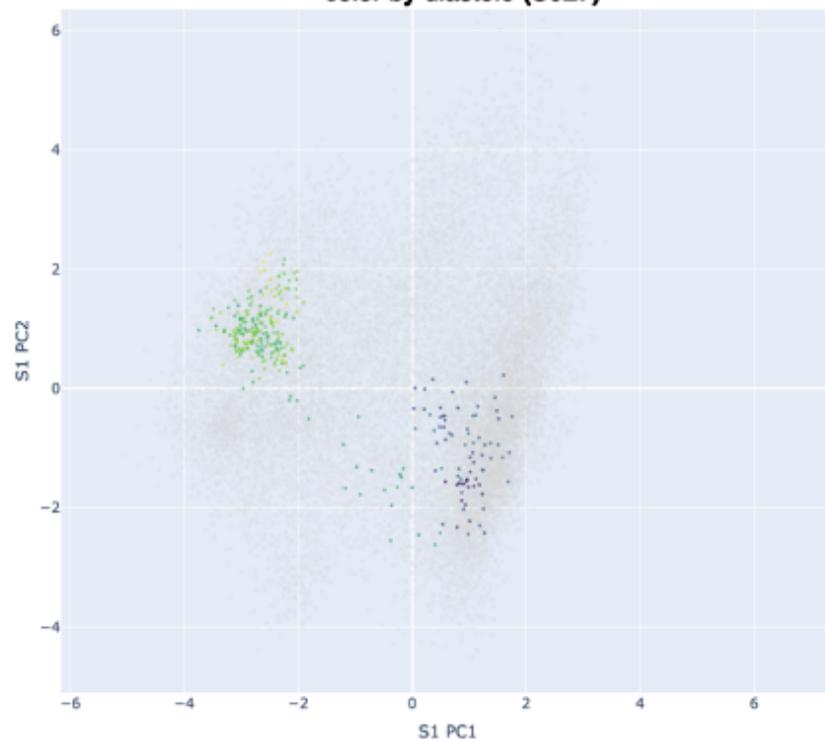


Result: Stage 1 First two PC exhibit trend relate to blood pressure

color by diastole (test)

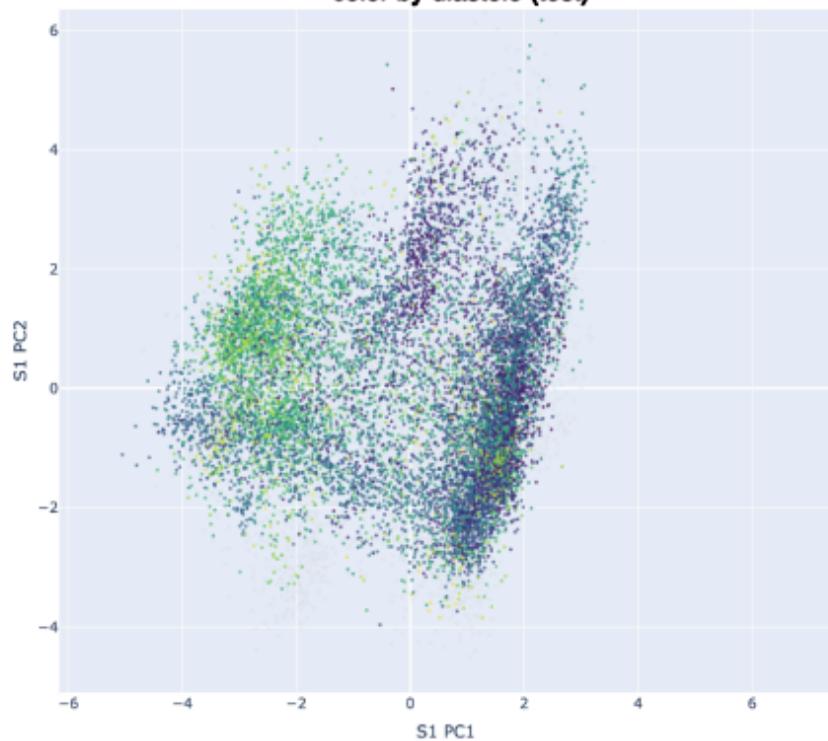


color by diastole (S027)

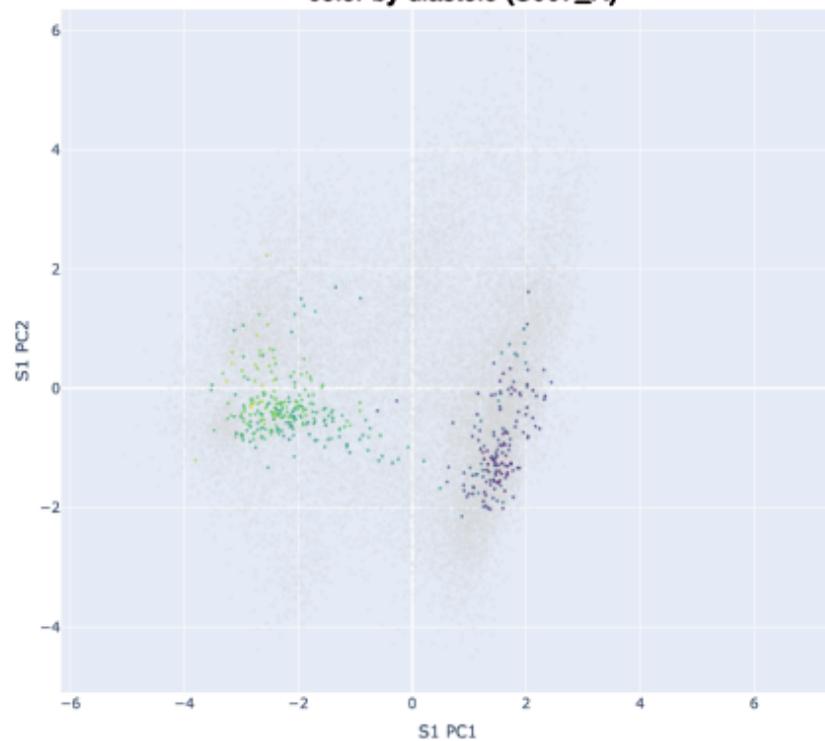


Result: Stage 1 First two PC exhibit trend relate to blood pressure

color by diastole (test)



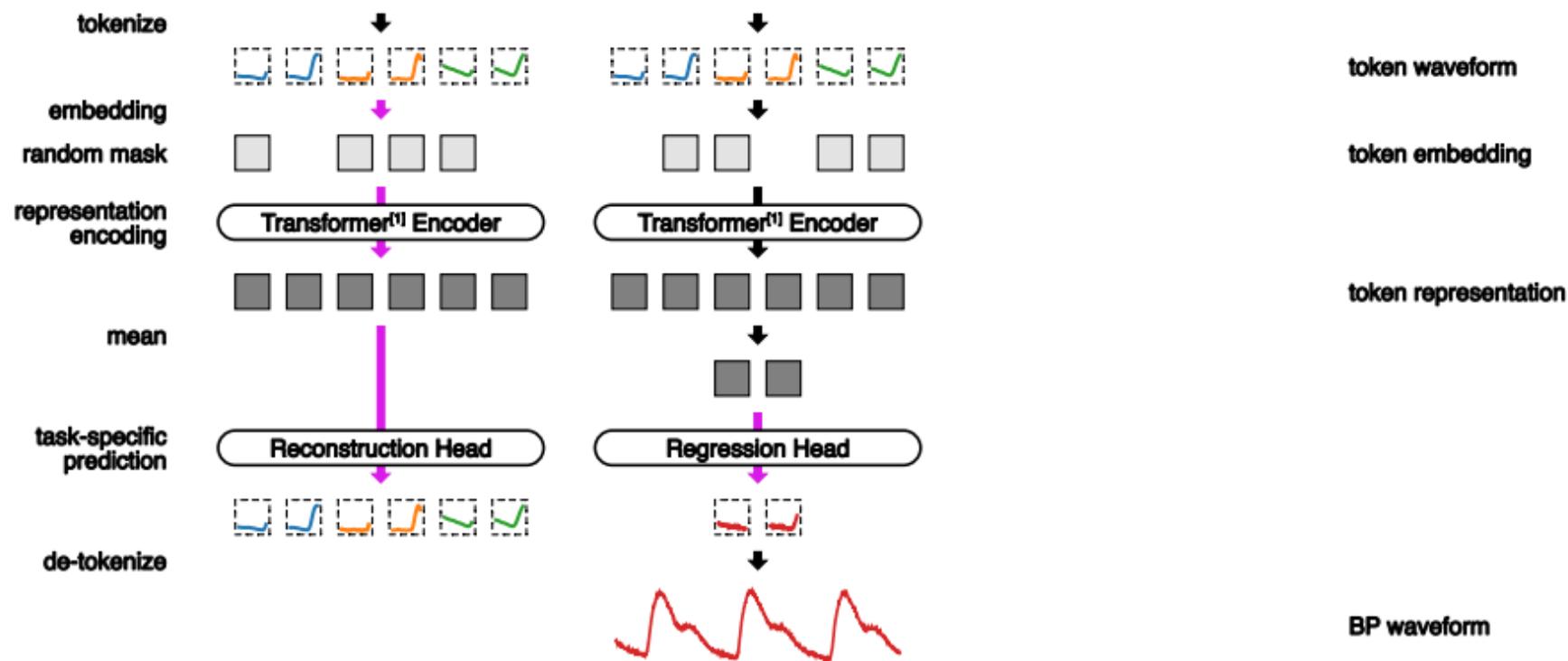
color by diastole (S007_R)



Model: Stage 2

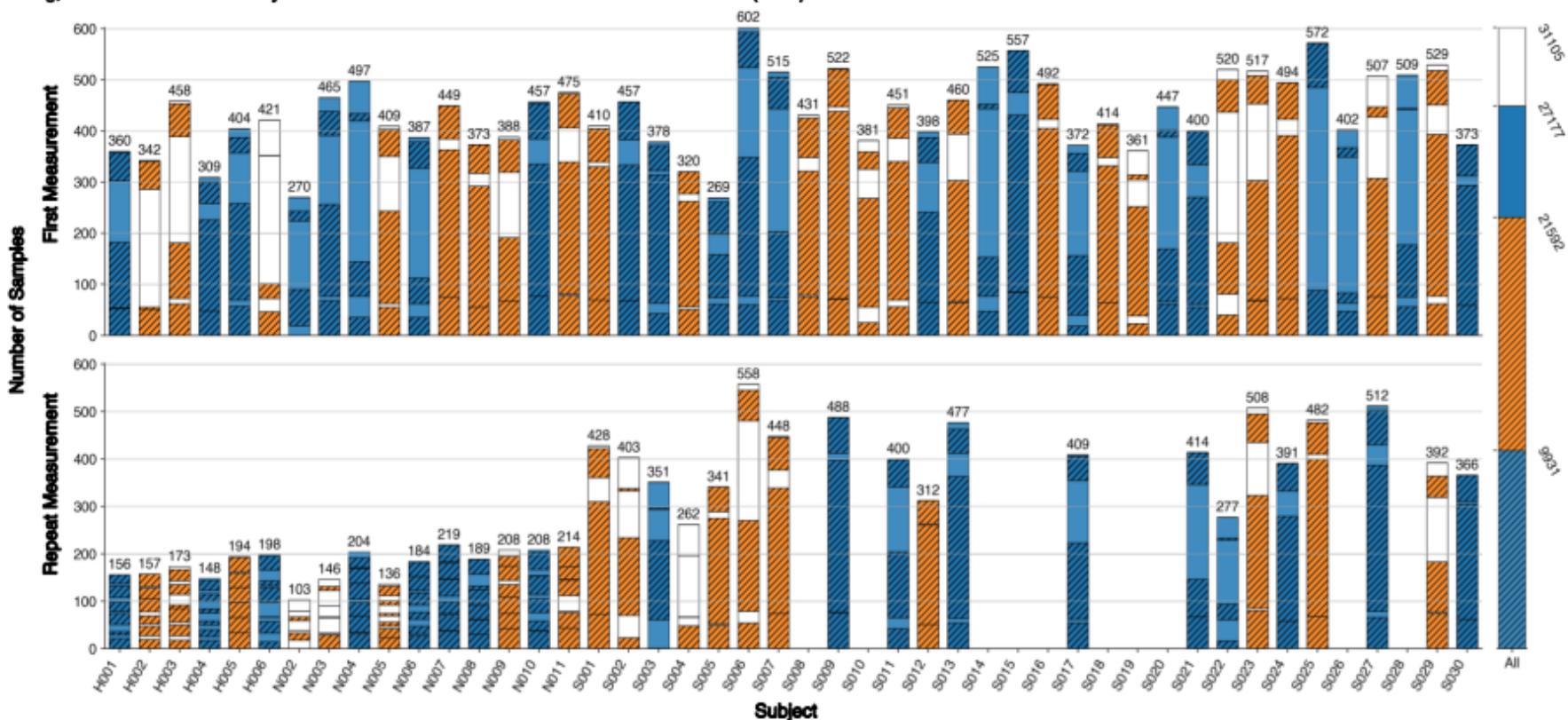
[1] Vaswani, A. et al. Attention Is All You Need. arXiv:1706.03762 (2017).

→ trainable → fixed

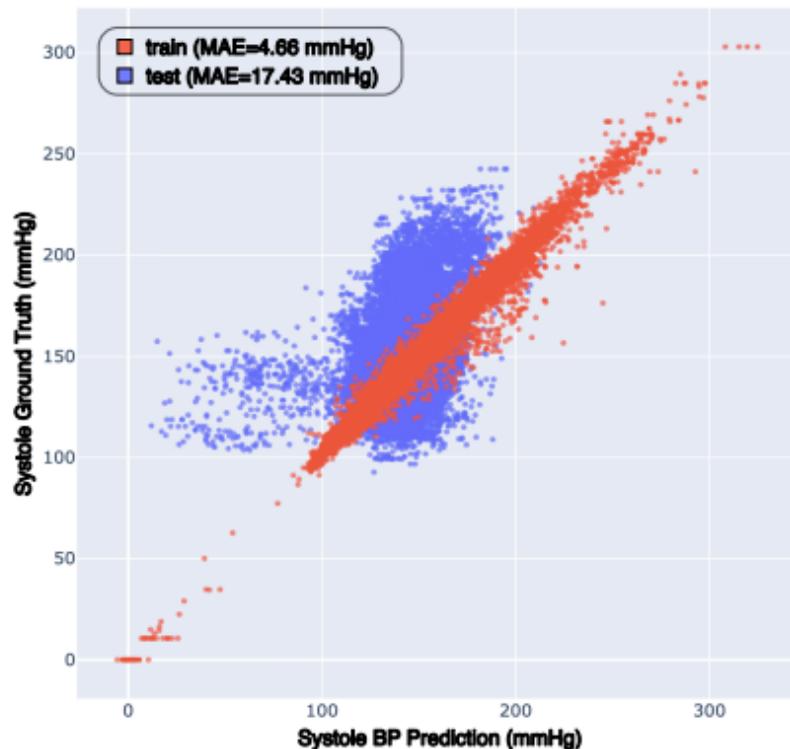
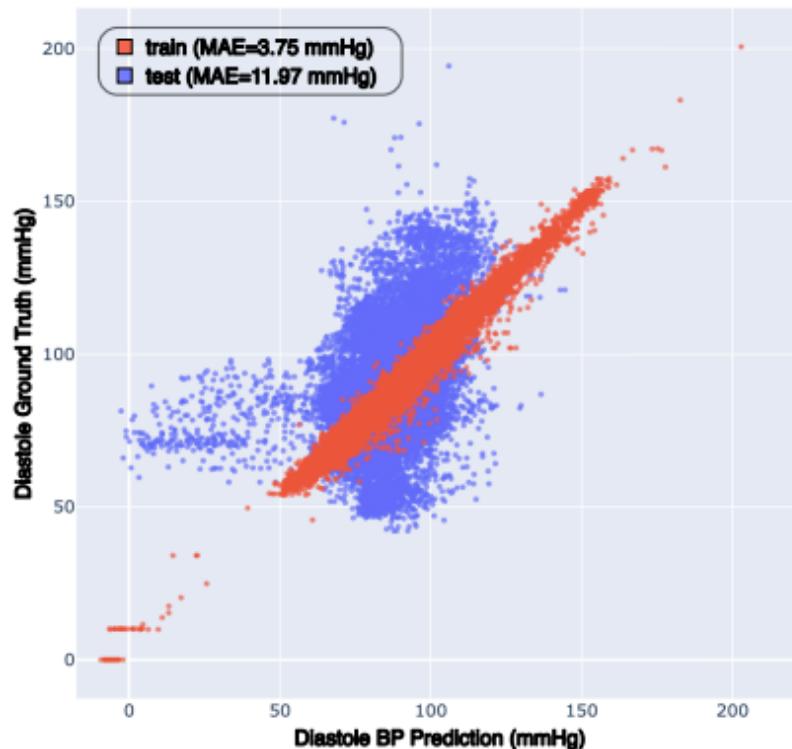


Data: Stage 2 Split

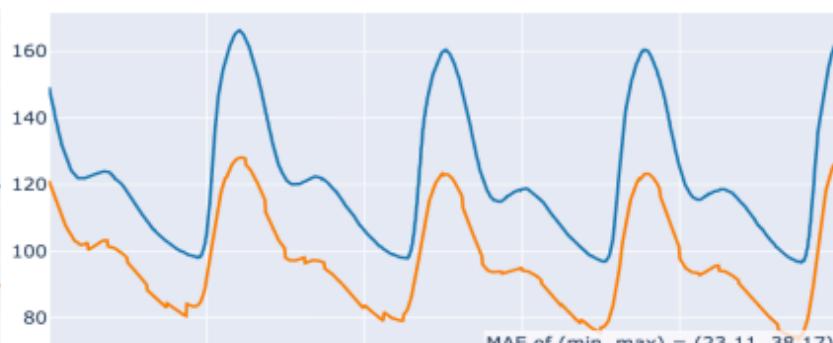
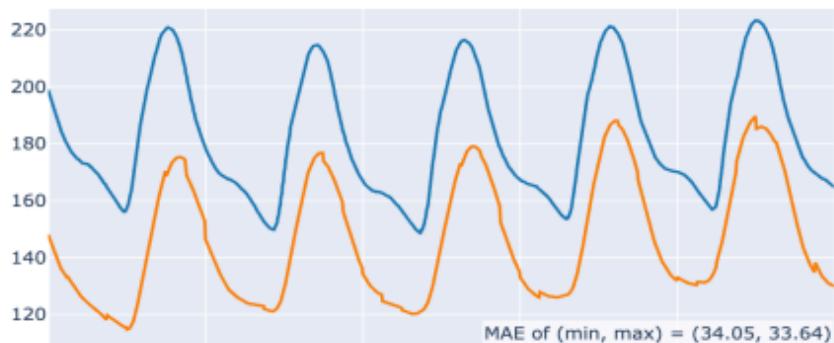
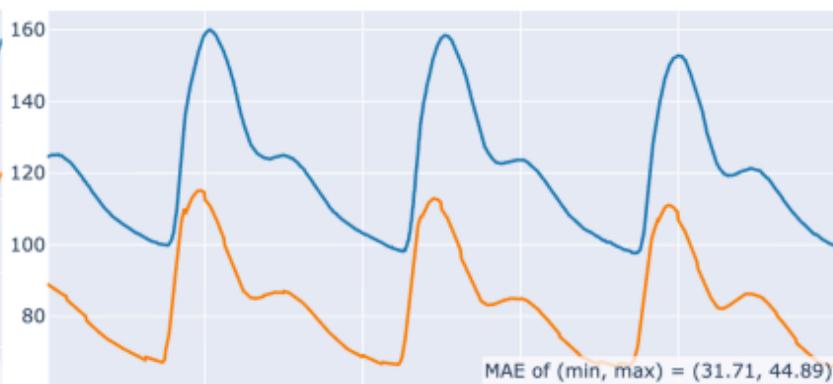
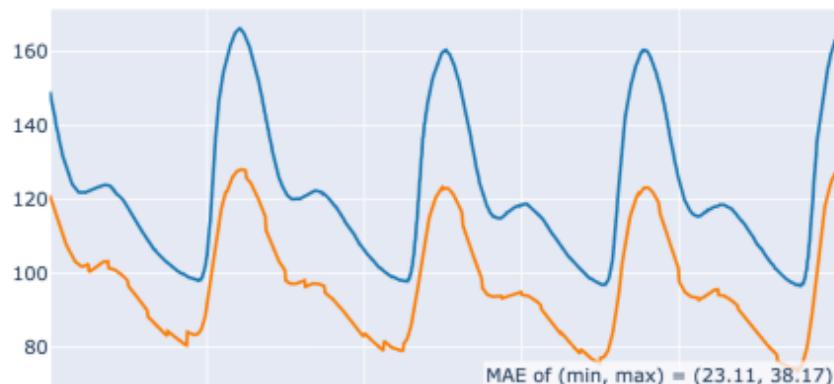
Wang, Y. et al. How to evaluate your medical time series classification? arXiv 2410.03057 (2024).



Result: Stage 2 Systolic and diastolic prediction does not generalize to test set

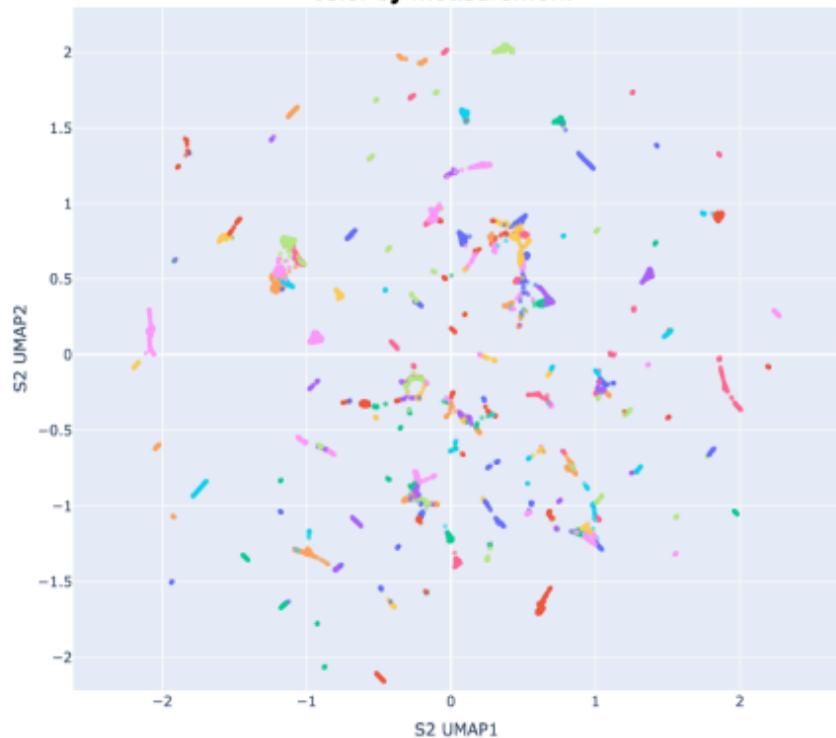


Result: Stage 2 Model captures wave shape, but absolute BP values are shifted

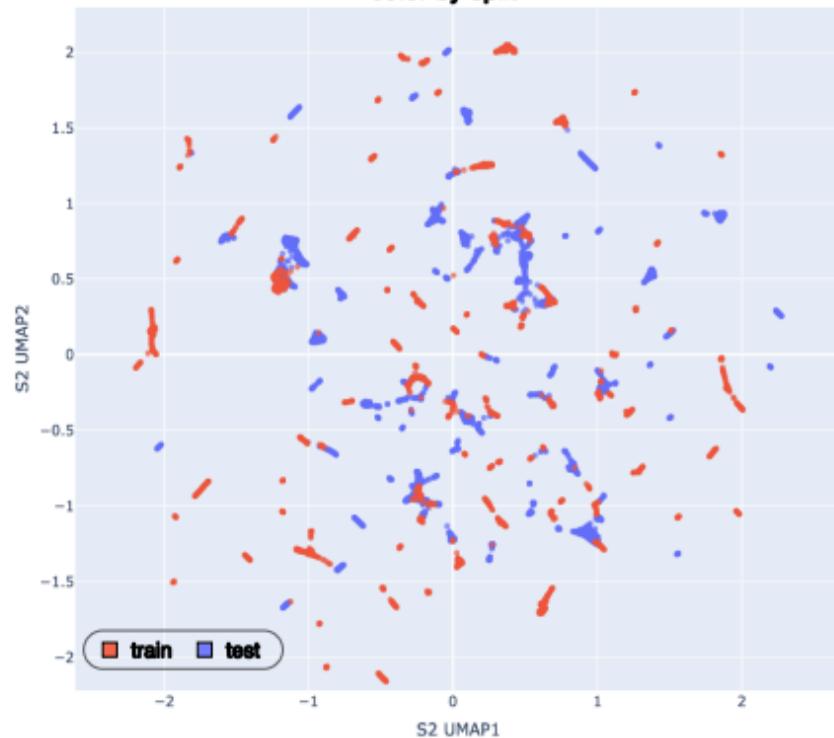


Result: Stage 2 Representations become more subject-specific

color by measurement

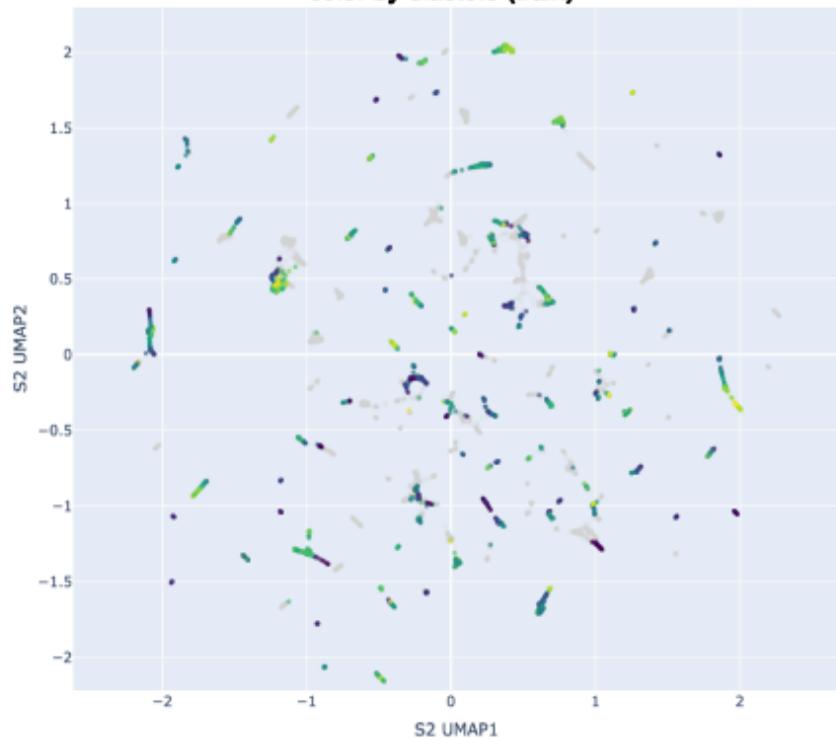


color by split

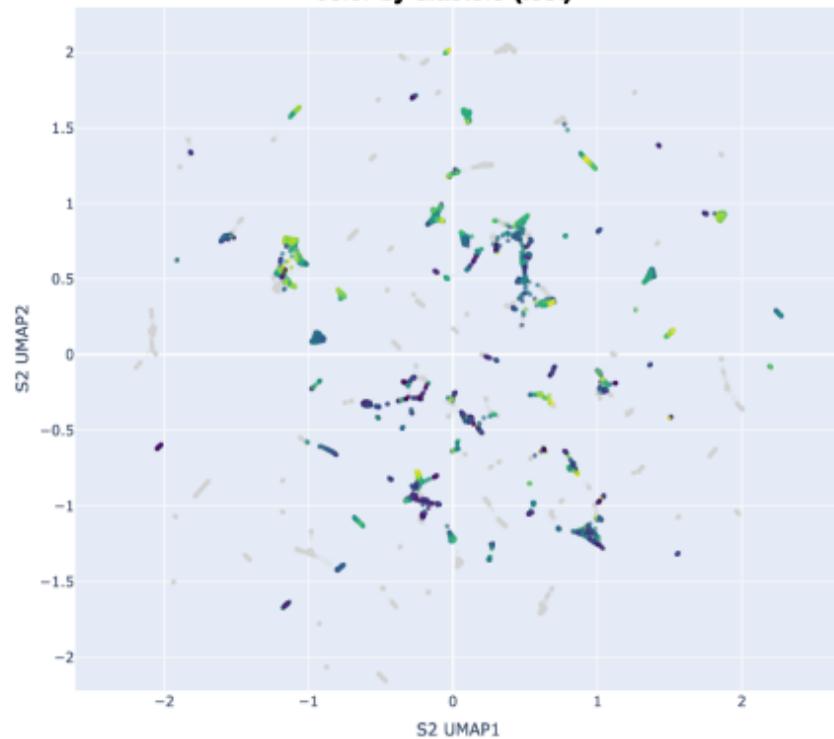


Result: Stage 2 Representation follows BP variation

color by diastole (train)

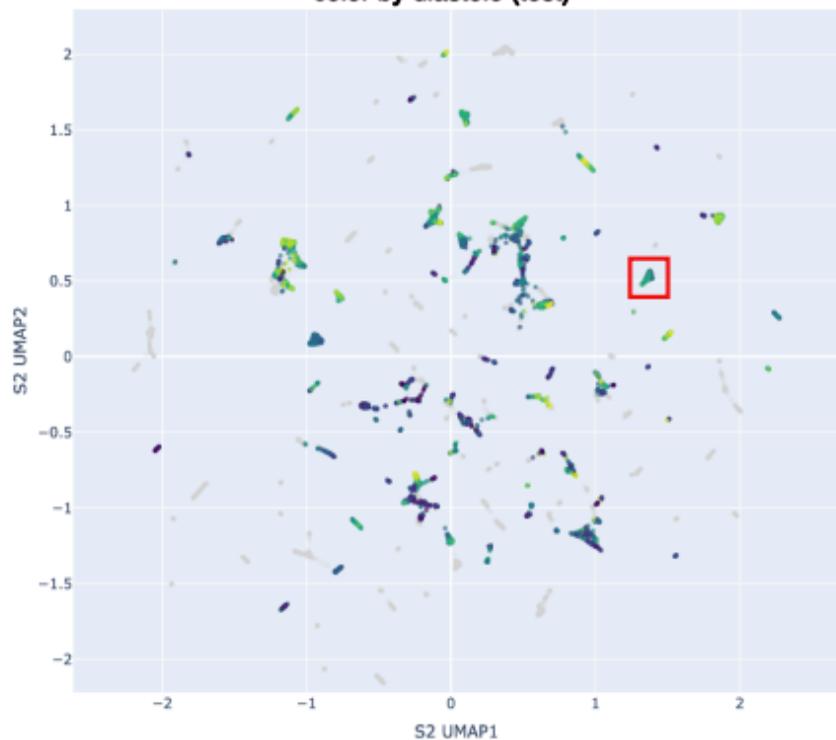


color by diastole (test)

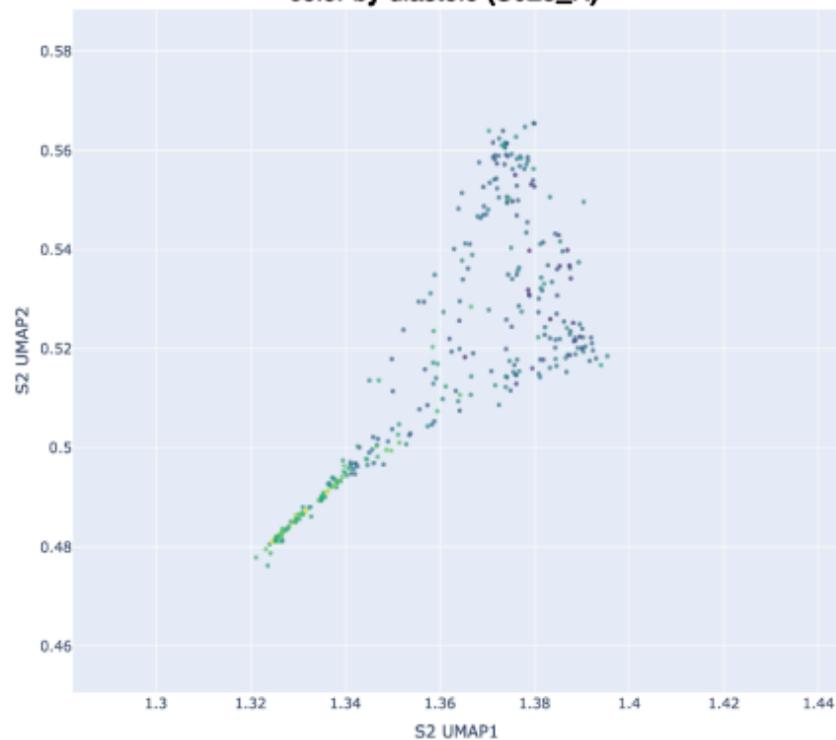


Result: Stage 2 Representations become more subject-specific

color by diastole (test)

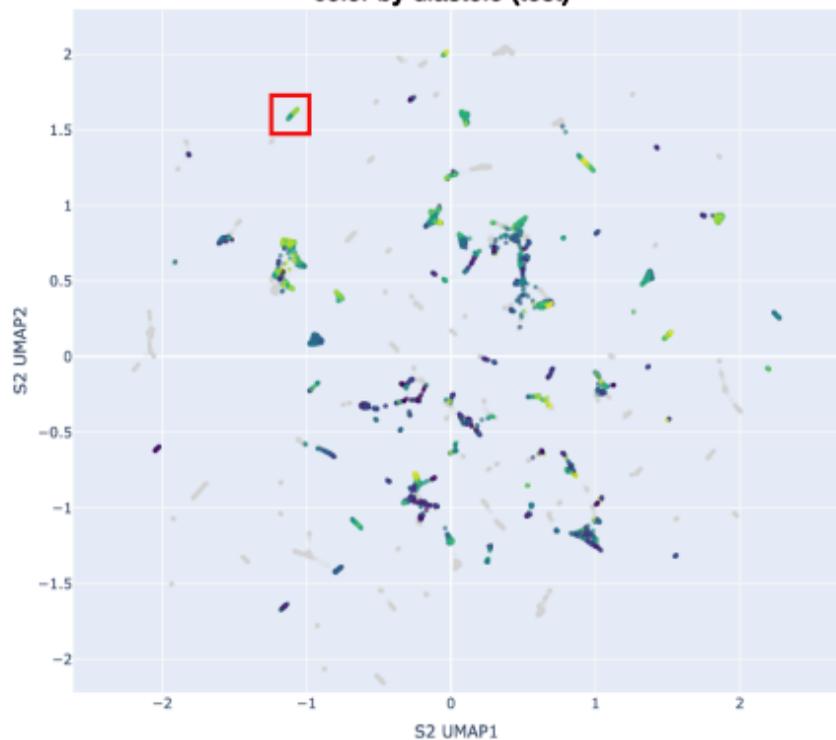


color by diastole (S025_R)

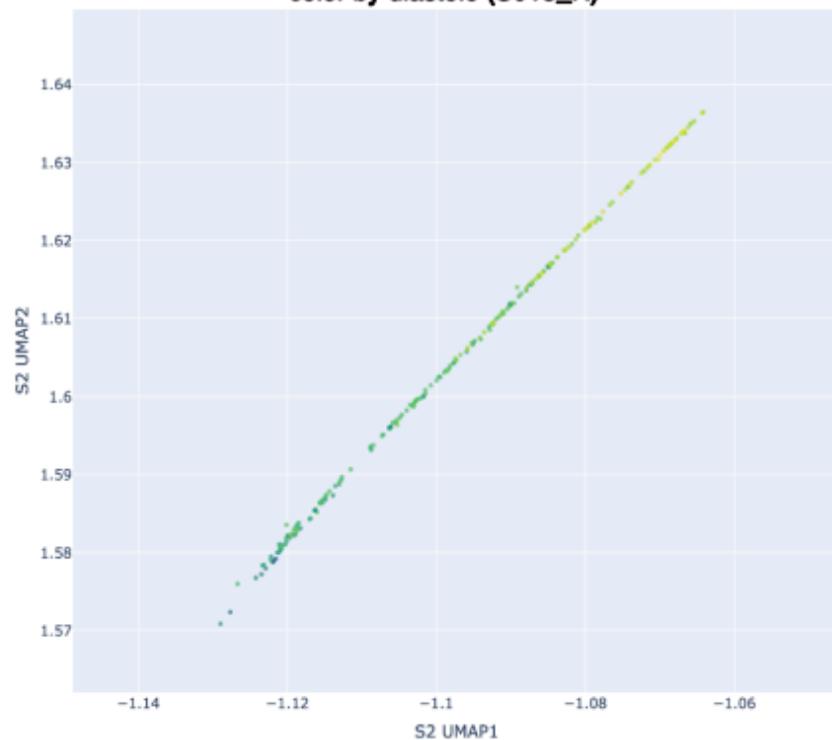


Result: Stage 2 Representations become more subject-specific

color by diastole (test)

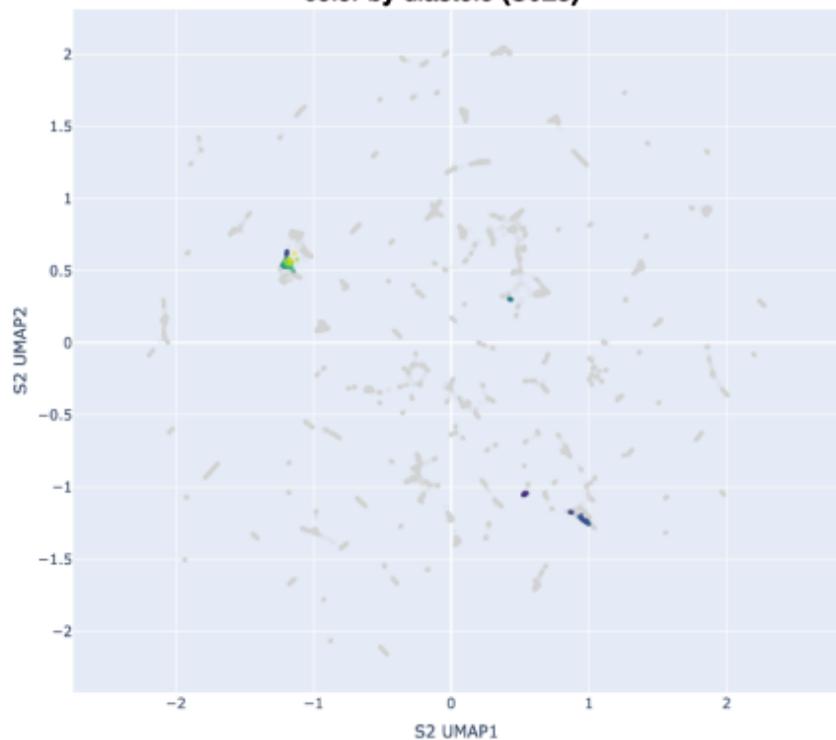


color by diastole (S013_R)

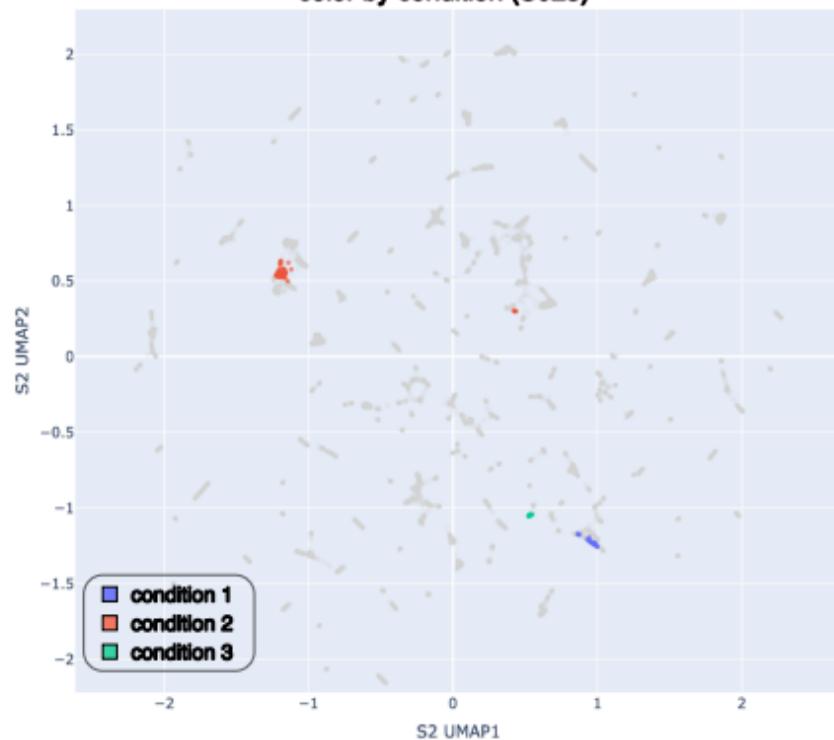


Result: Stage 2 Different condition within a measurement no longer group together

color by diastole (S023)

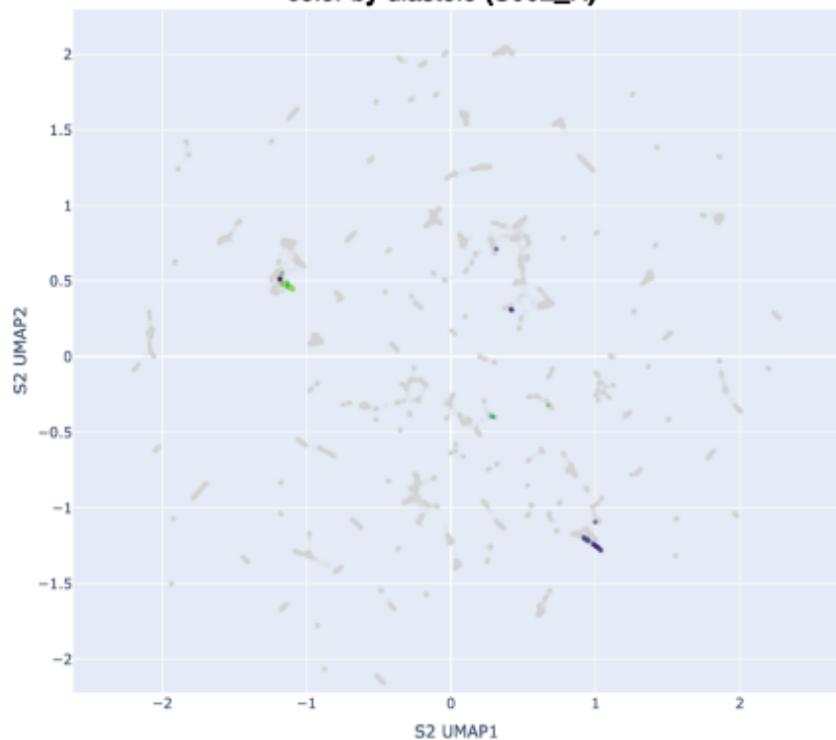


color by condition (S023)

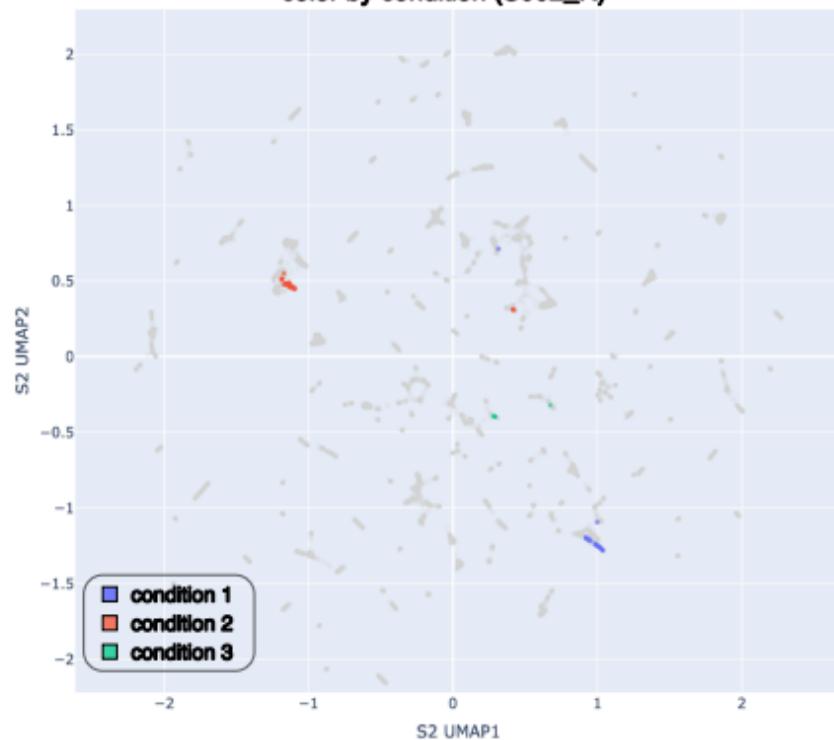


Result: Stage 2 Different condition within a measurement no longer group together

color by diastole (S002_R)



color by condition (S002_R)

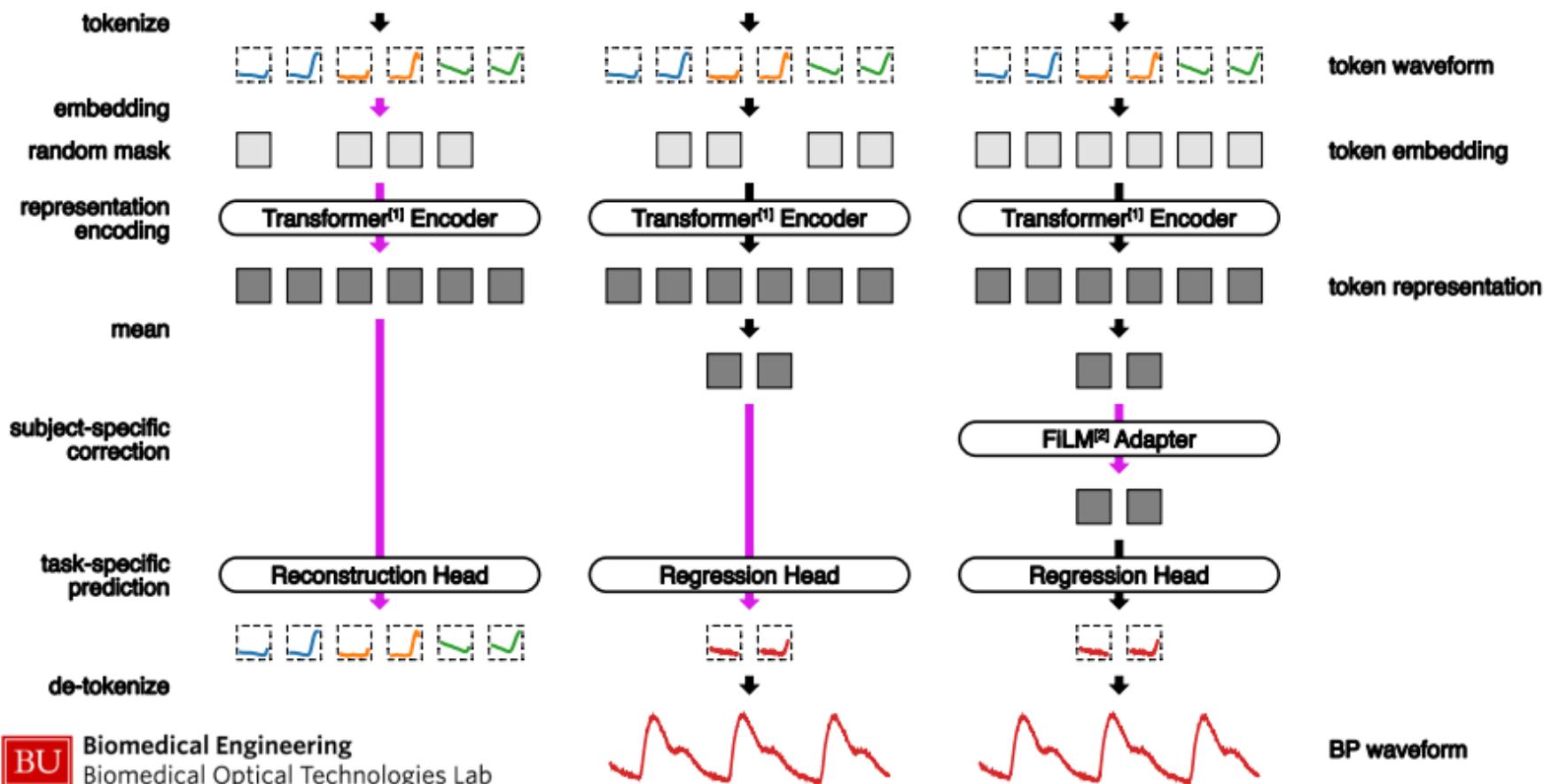


Training

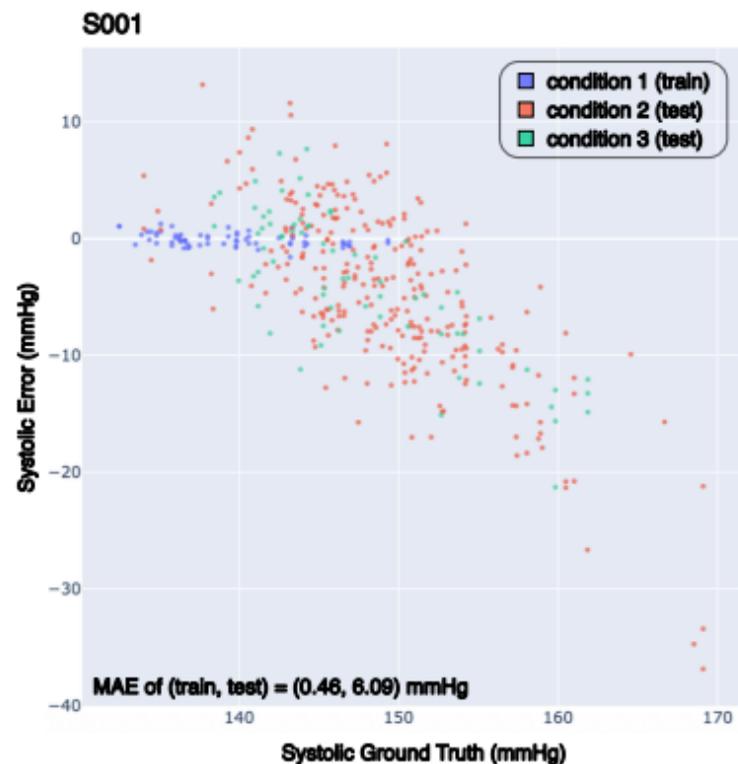
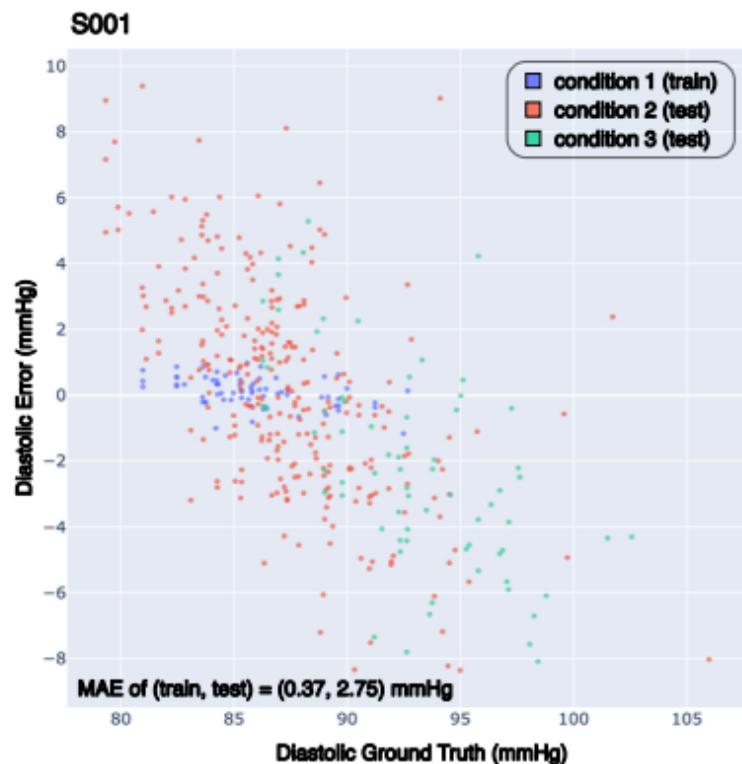
[1] Vaswani, A. et al. Attention is All You Need. arXiv:1706.03762 (2017).

[2] Perez, E. et al. FiLM: Visual Reasoning with a General Conditioning Layer. arXiv:1709.07871 (2017).

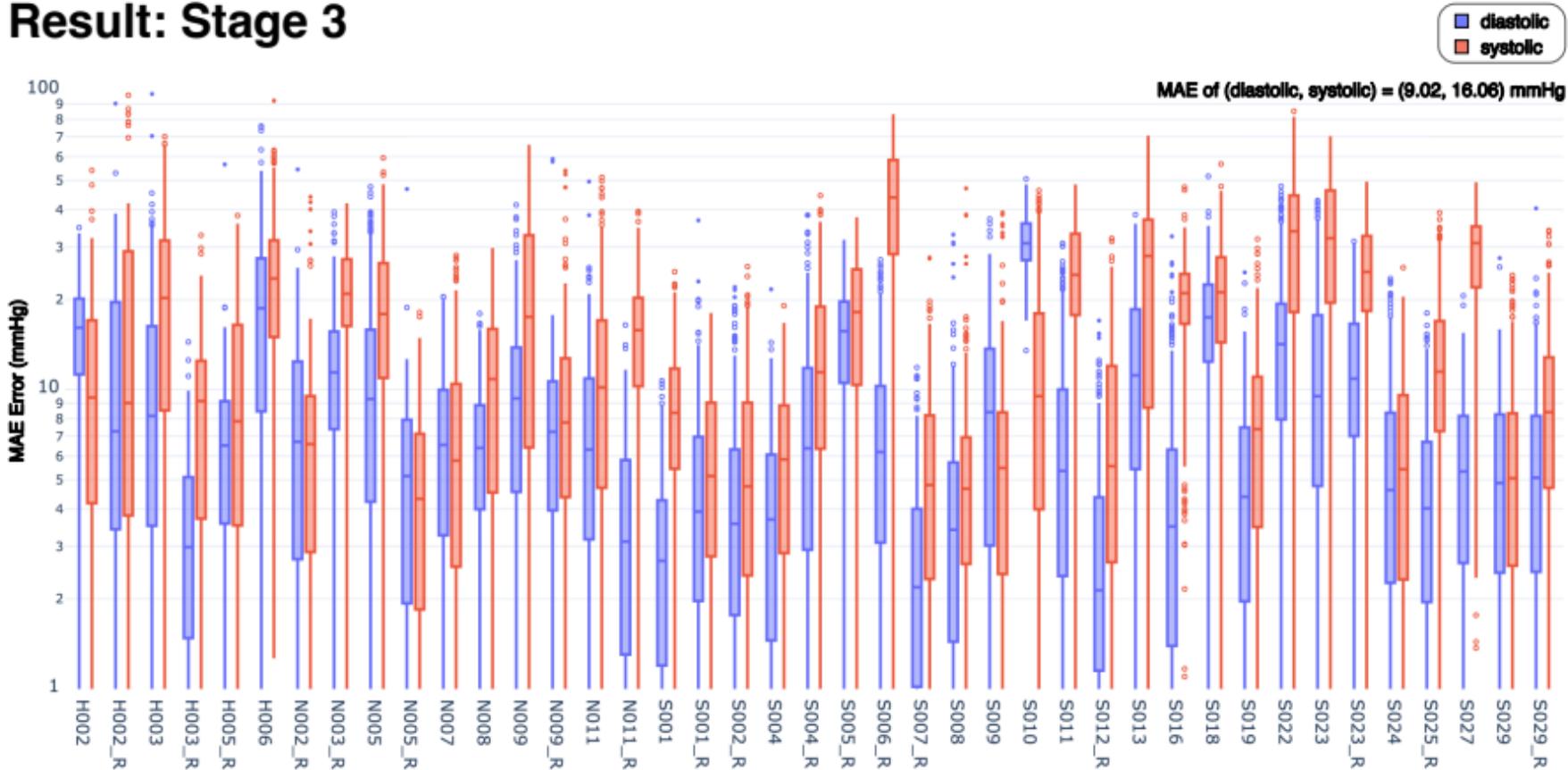
→ trainable → fixed



Result: Stage 3



Result: Stage 3

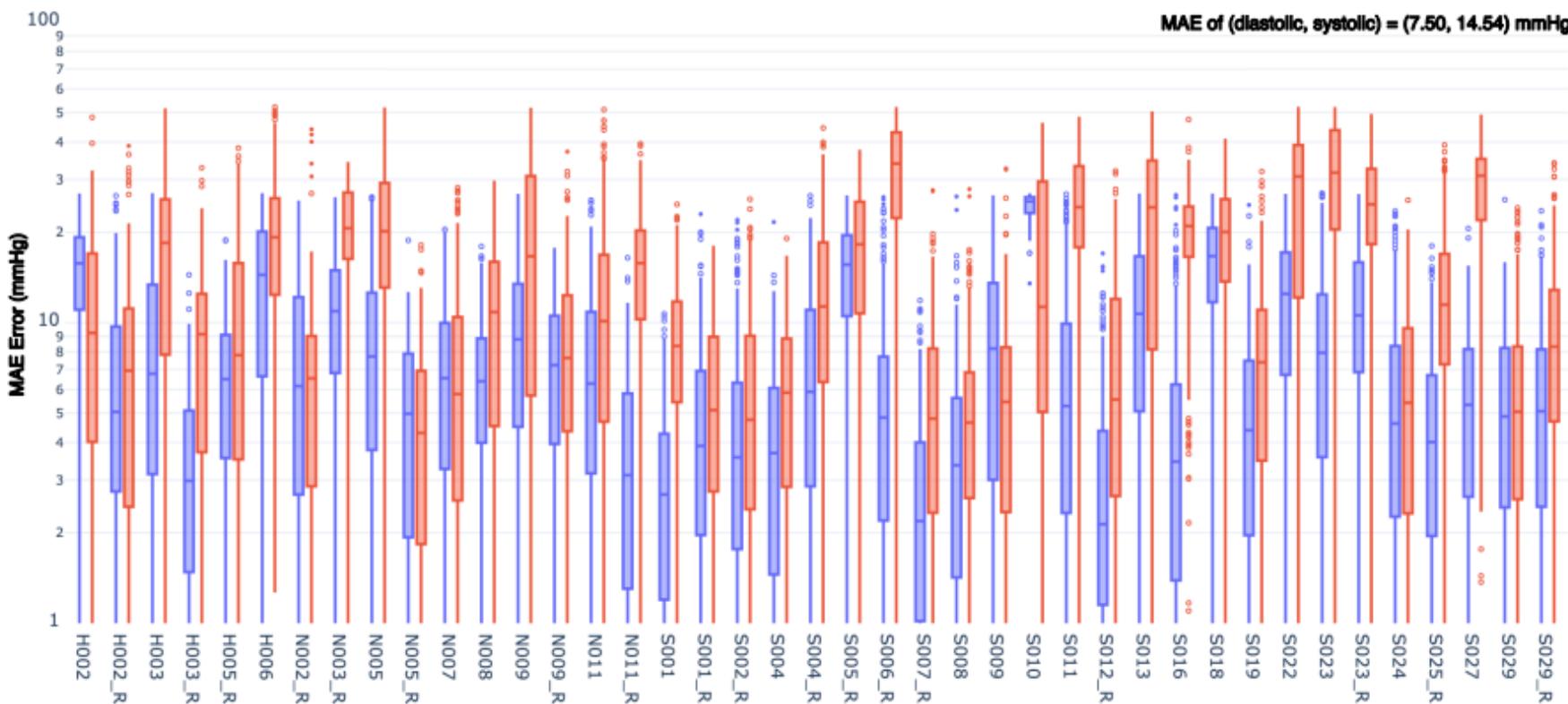


Result: Stage 3

Filtered extreme value of BP: keep 13095 samples (92.5%); removed 984

■ diastolic
■ systolic

MAE of (diastolic, systolic) = (7.50, 14.54) mmHg



Biomedical Engineering

Biomedical Optical Technologies Lab