Universität Bremen

Supervised and self-supervised contrastive machine learning using EEG for mental workload classification

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Introduction

- self-supervised learning is promising
  - unsupervised + supervised
  - has been done successfully with EEG
  - has not been done for mental workload classification

→ explore self-supervised learning for mental workload classification

→ comparison to supervised learning

n-back task

- used to create labeled EEG data
- 4 mental workload classes
  - $n \in \{0, 1, 2, 3\}$
- subject sees sequence of letters
- current letter == letter n steps before?
  - 0-back: is current letter x?

EEG data

labeled n-back data

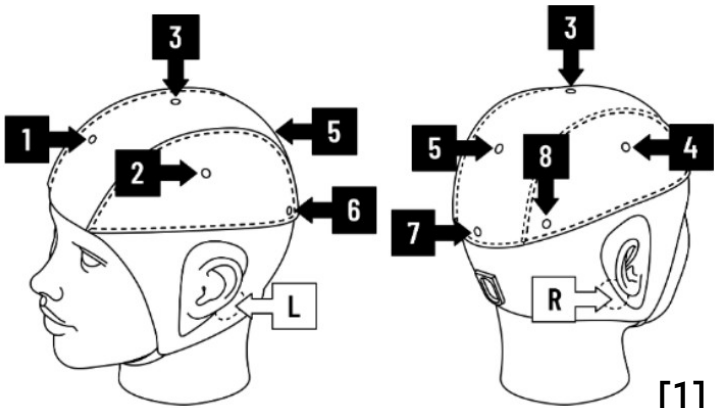
- 4 sessions
- ~50 min in total

unlabeled data

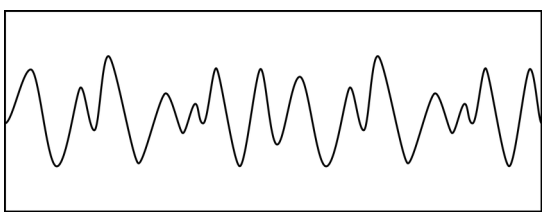
- mostly desk work
- 9 sessions
- ~10 h in total

band-pass filter

0.1-45Hz
or
0.1-55Hz



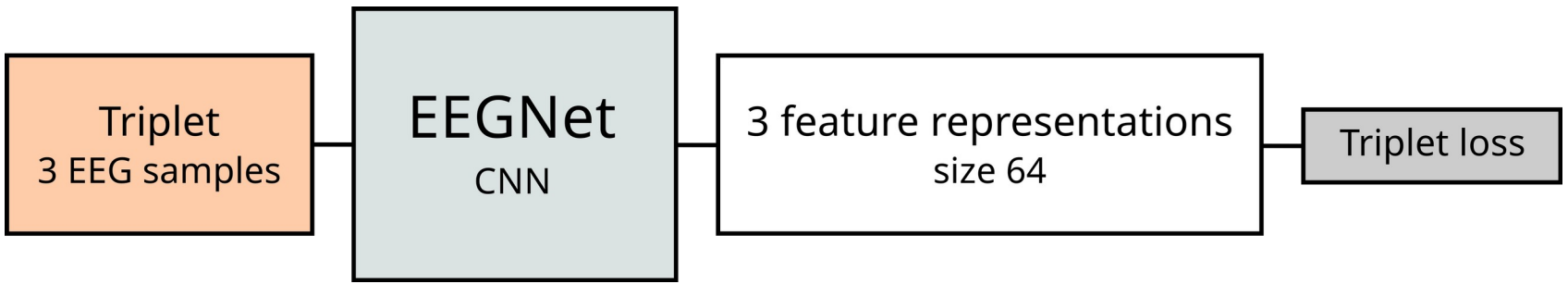
[1]


2s

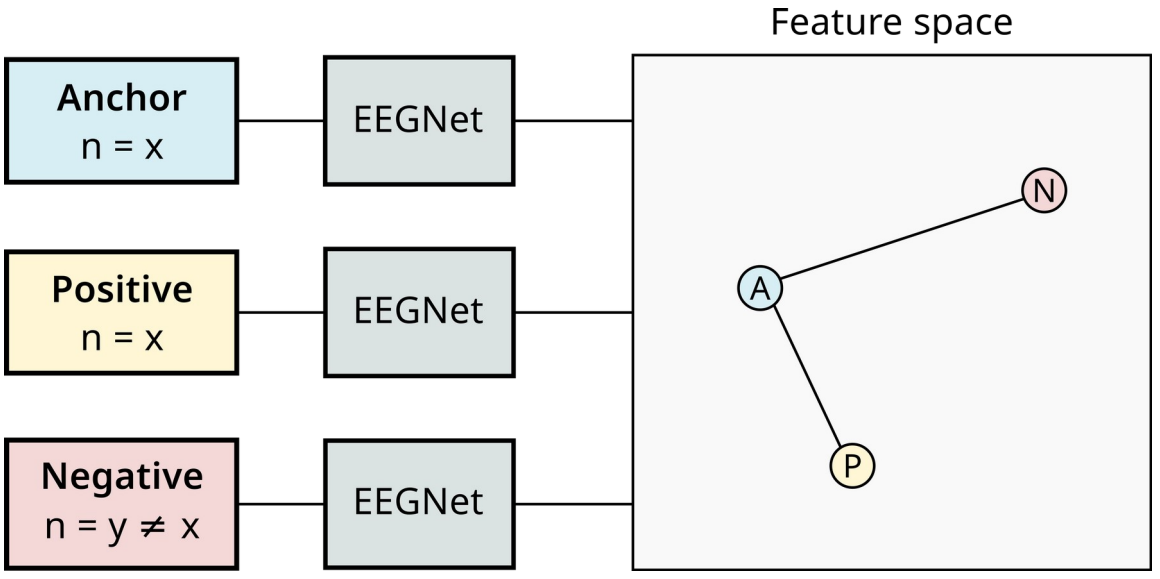
[1] „User Manual for Unicorn Brain Interface Hybrid Black“, V1.18.00, 2021, p. 12, g.tec neurotechnology GmbH Austria

Training encoders

- supervised encoders
  - using n-back data
- self-supervised encoders
  - using unlabeled data



Triplet loss



- minimize distance between anchor and positive sample
- maximize distance between anchor and negative sample

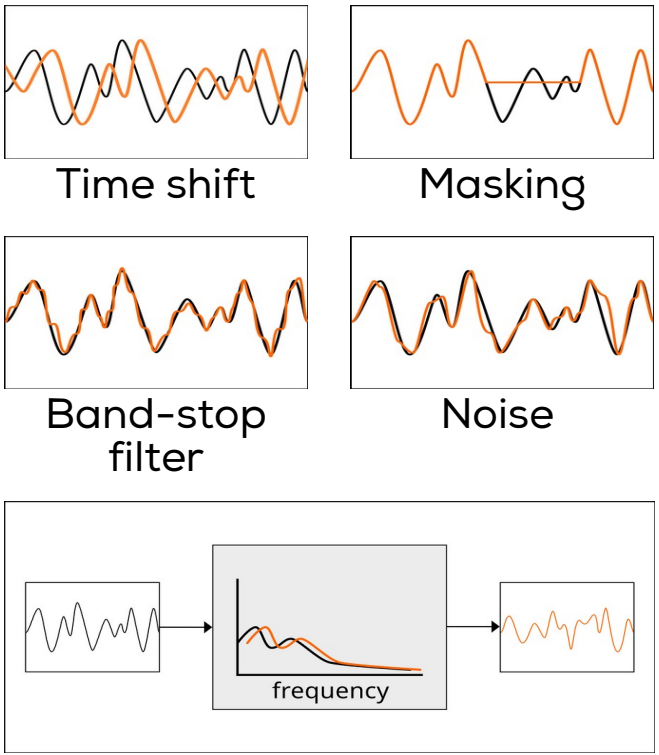
Triplets for self-supervised encoders

Anchor

Positive
augmented anchor

Negative
negative ≠ anchor

5 Augmentations



- apply 2 augmentations to create positive sample

Evaluation

Triplet placement in feature space

- triplet accuracy
  - is negative sample further away from anchor than positive sample?

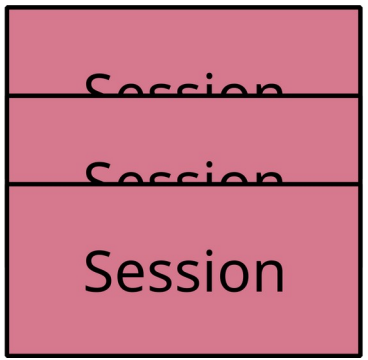
Mental workload classification

- k nearest neighbours (knn) in feature space
- trained classifier
  - small neural network that gets feature representation as input

EEG data - Supervised encoders

n-back data

Training and validation data 0.9/0.1 split



Test data

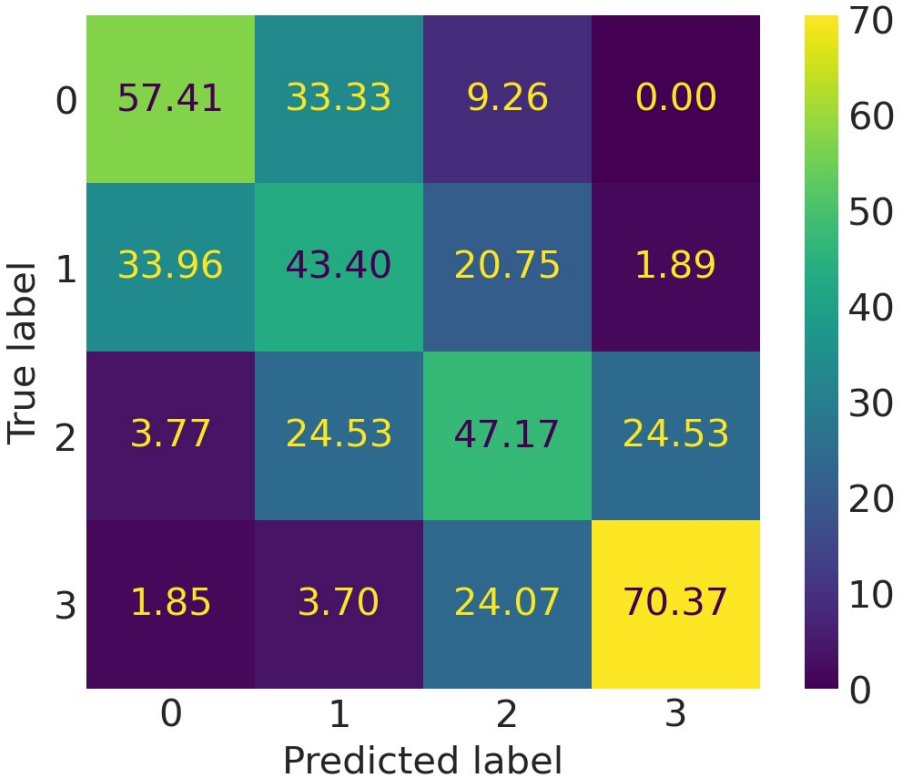
band-pass filter

0.1-45Hz ← better

or

0.1-55Hz

Results – Supervised encoders

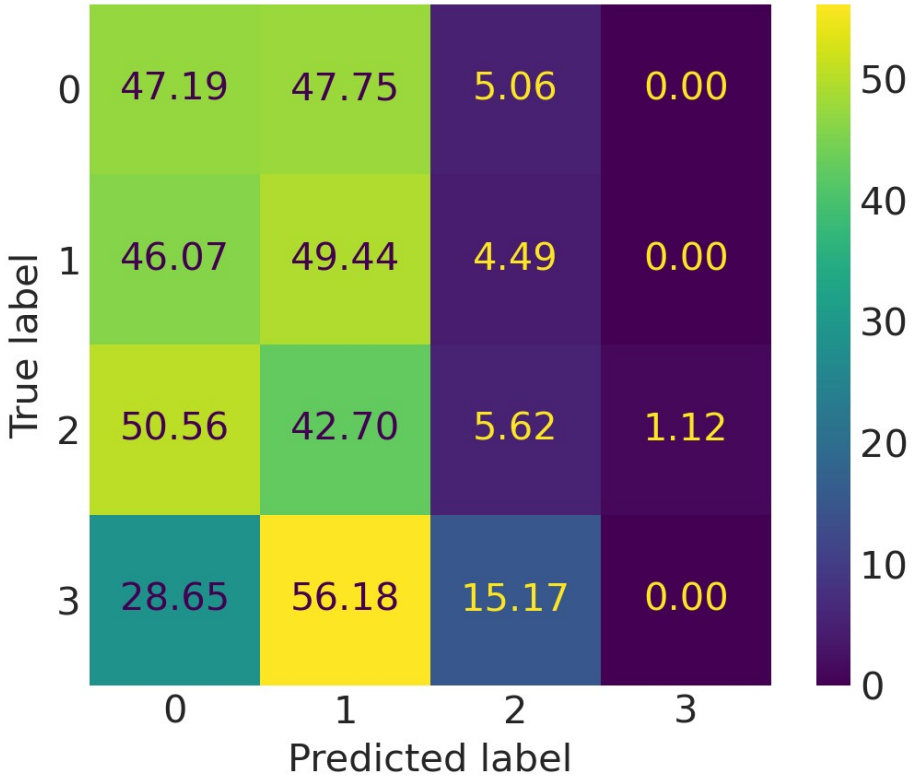


Validation
0.1–45Hz BP filter

triplet accuracy: 68%

knn accuracy: 50%

Results – Supervised encoders



Test

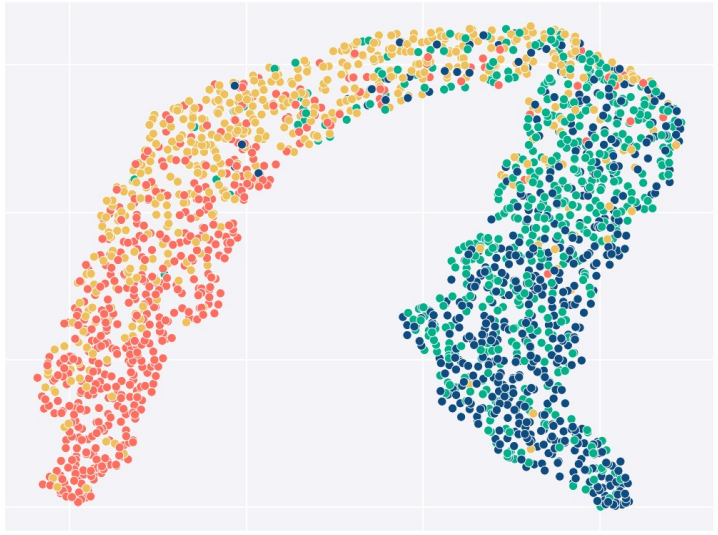
0.1-45Hz BP filter

triplet accuracy: 59%

knn accuracy: 30%

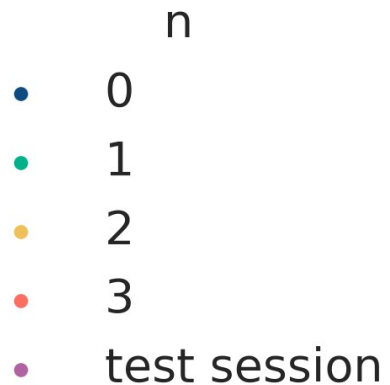
UMAP - Supervised encoders

training and validation data



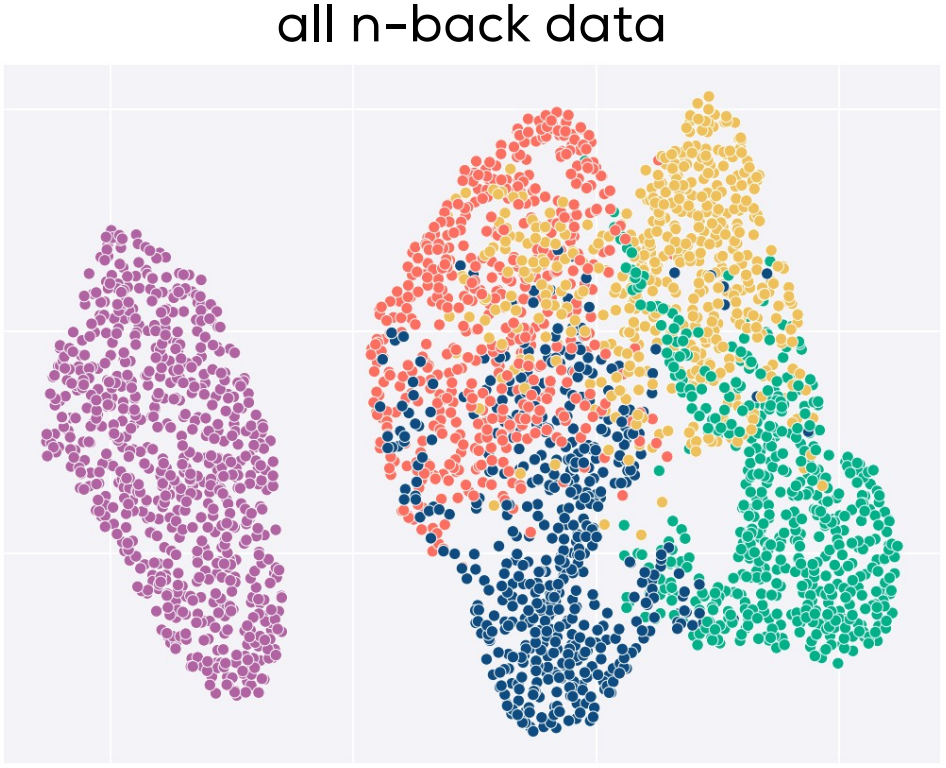
+ test data

0.1-45Hz
BP filter



- separate test session is treated differently
- encoders seem to learn session specific features

UMAP - Supervised encoders

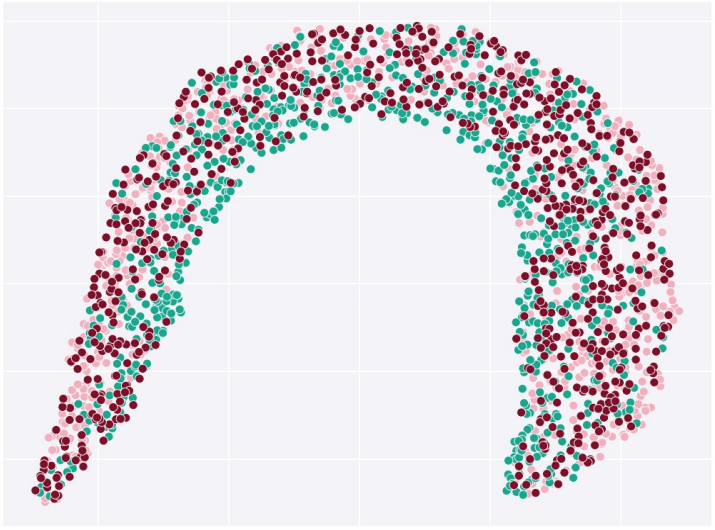


0.1-55Hz BP filter

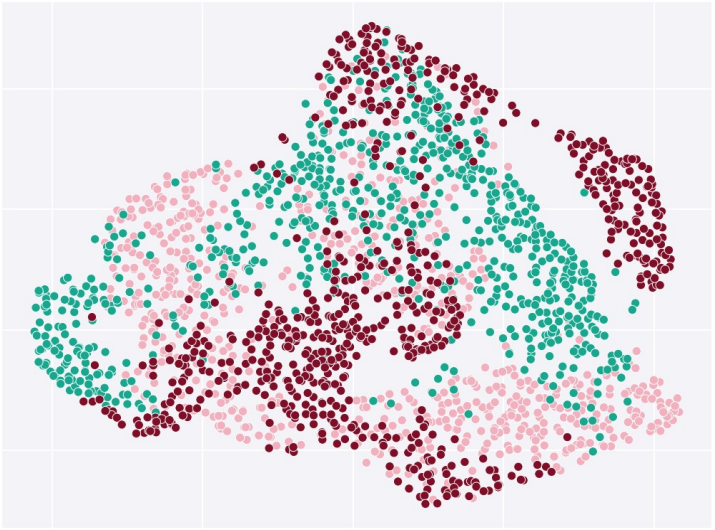
➔ even more session specific learning

UMAP - Supervised encoders

0.1-45Hz BP filter



0.1-55Hz BP filter



training and validation data

Session

1

2

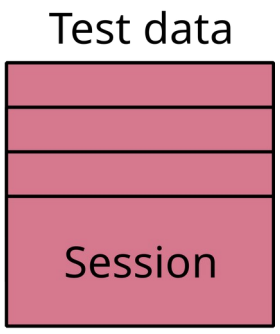
3

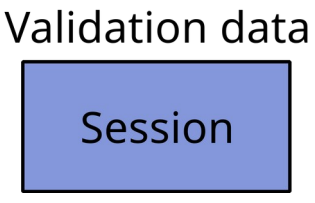
- 0.1-45Hz BP filter better suited to mitigate session specific learning

EEG data – Self-supervised encoders

Unlabeled data

n-back data





band-pass filter

0.1-45Hz ← better

or

0.1-55Hz

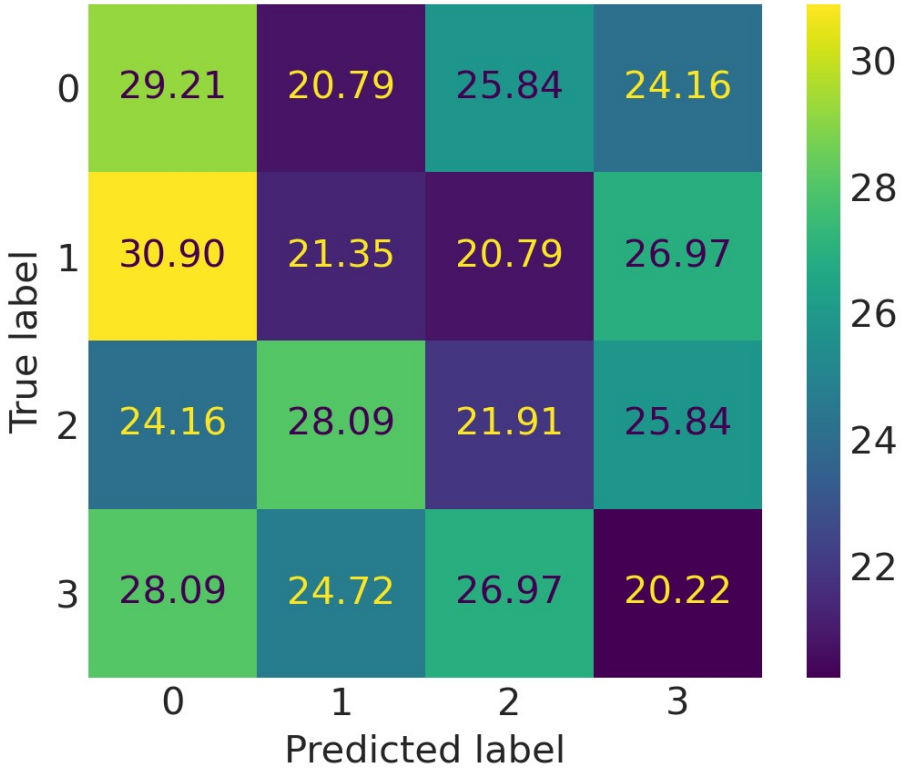
Results – Self-supervised encoders

0.1-45Hz BP filter

	Validation	Test
Triplet accuracy	88-97%	83-96%
Classifier accuracy	-	~25%

Results – Self-supervised encoders

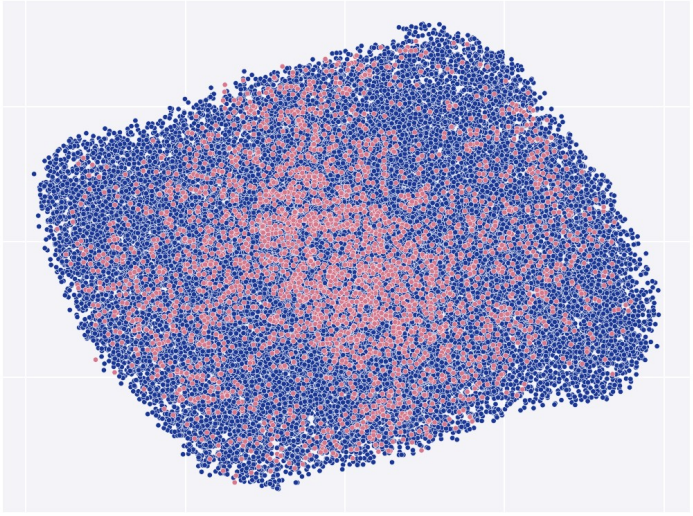
0.1-45Hz BP filter



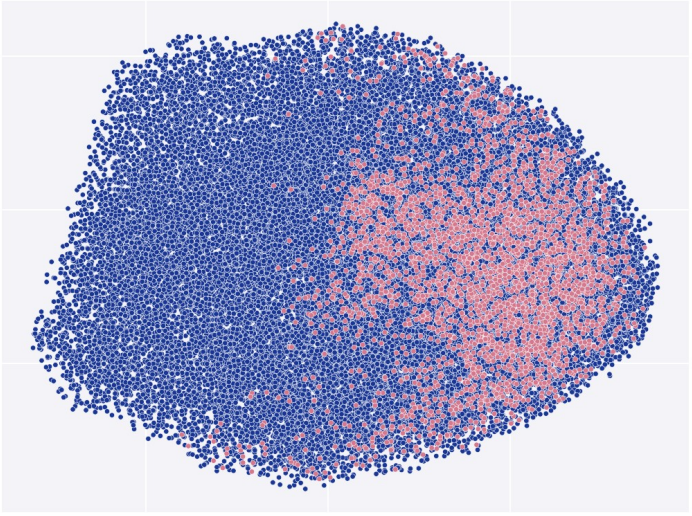
- learned very success-fully to generate feature representations
- feature representations not usable for mental workload classification

UMAP – Self-supervised encoders

0.1-45Hz BP filter



0.1-55Hz BP filter



- unlabeled data
- n-back data

- 0.1-45Hz BP filter equalizes differences between unlabeled and n-back data well

Conclusion

Session specific learning

- big differences between EEG sessions
- supervised test accuracy only 30%
- 0.1-45Hz BP filter equalizes differences better

→ more n-back sessions
→ not a big topic in existing literature

Conclusion

Self-supervised approach failed

- very high triplet accuracies
- feature representations could not be used for mental workload classification

→ similar approaches worked in other studies

→ why not here?

Thank you for listening!