Neural network transfer learning with fast calibration for mental imagery decoding

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INTRODUCTION

Problem setting

In this work, we use deep learning for cross-dataset transfer learning in mental imagery decoding tasks. We investigate which datasets are well suited for transfer, both as donors and as receivers. Additionally, we discuss the technical aspects of our work and how models can be re-used.

Challenges

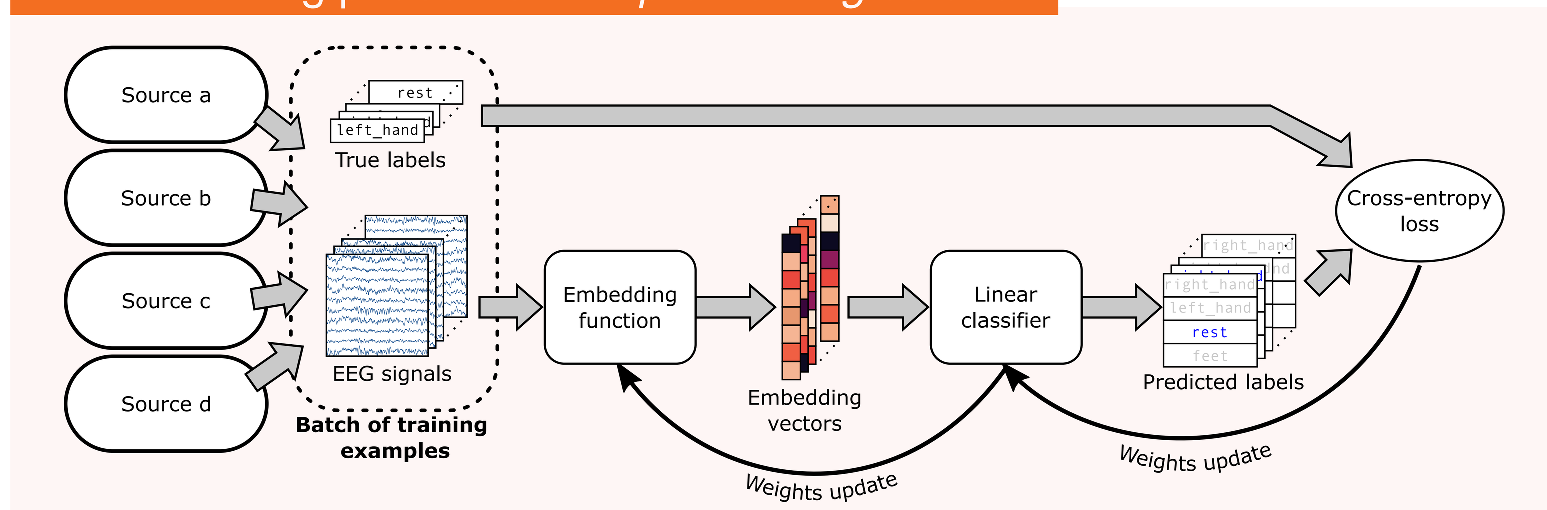
Deep learning models typically require long training times and are data-hungry. These make their use for BCI difficult because of the time needed to record examples and the constraints induced by experiments involving human subjects. A solution to both issues is transfer learning but it comes with its own challenges which are the compatibility between data sources for the transfer and the technical difficulties of re-using models.

Approach

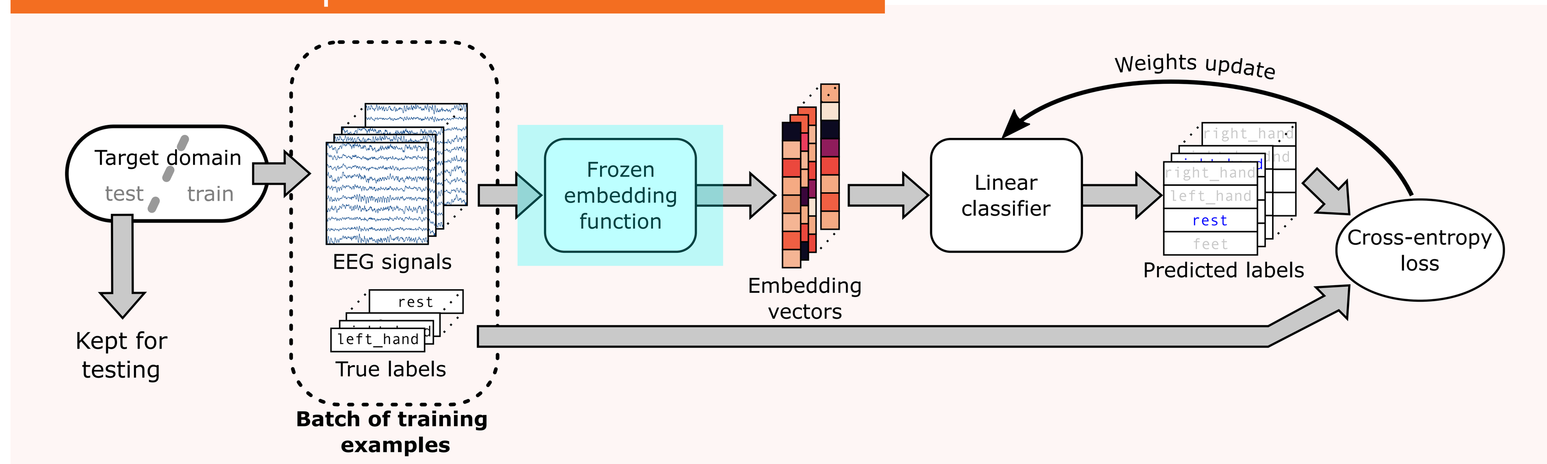
Our transfer cross-validation procedure is: for every pre-training dataset and test dataset pair, first, train a model on the pre-training dataset, then train only a new classification layer on a few trials from the test dataset and test on other trials from the same session of the test dataset [1]. We explain our workflow and how our pre-trained models can easily be loaded for future use.

METHODS

A. Pre-training phase - on the *pre-training dataset*



B. Calibration phase - on the *test dataset*



MATERIALS

DATASETS

Dataset	#subjects	#trials	classes
AlexMI	8	20	f,r,rh
BNCI2014001	10	288	f,lh,rh,t
BNCI2014004	10	1800	lh,rh
BNCI2015001	13	400	f,rh
BNCI2015004	10	160	f,n,rh,s,wa
Cho2017	53	100	lh,rh
Lee2019_MI	55	200	lh,rh
Ofner2017	15	60	r,ree,ref, rhc,rho,rp,rs
PhysionetMI	109	23	bh,f,lh,r,rh
Schirrmeister2017	14	120	f,lh,r,rh
Weibo2014	10	80	bh,f,lh,lhrf, r,rh,rhlf
Zhou2016	4	480	f,lh,rh

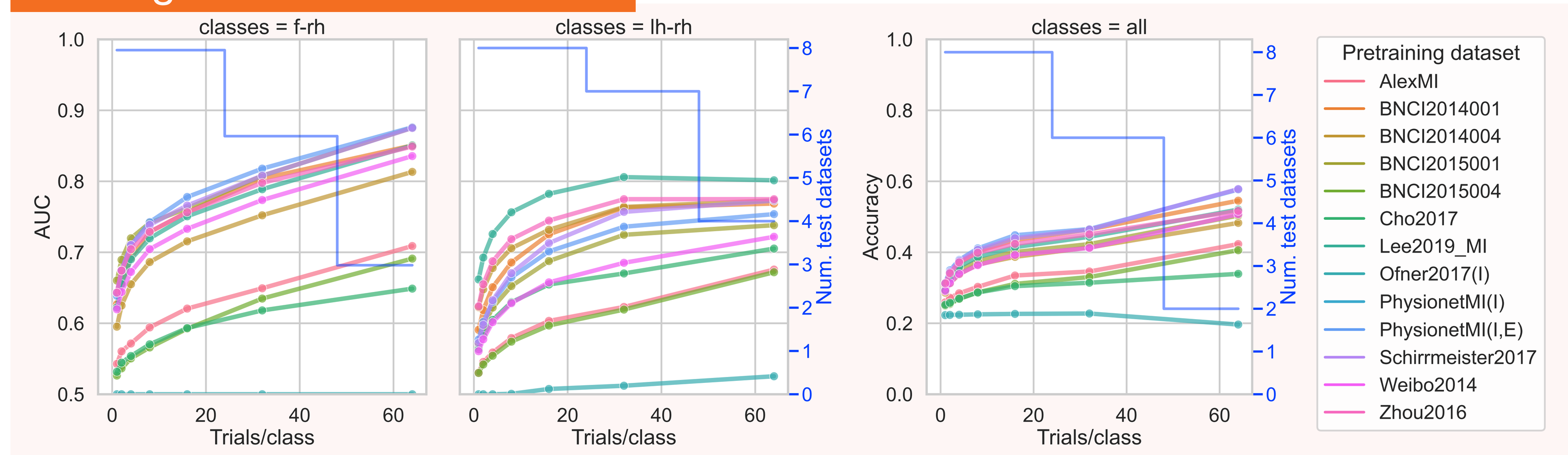
- Neural network architecture: **EEGNet** [2];
- Training and testing on 12 mental imagery datasets from the **MOABB** library [3].

CLASSES

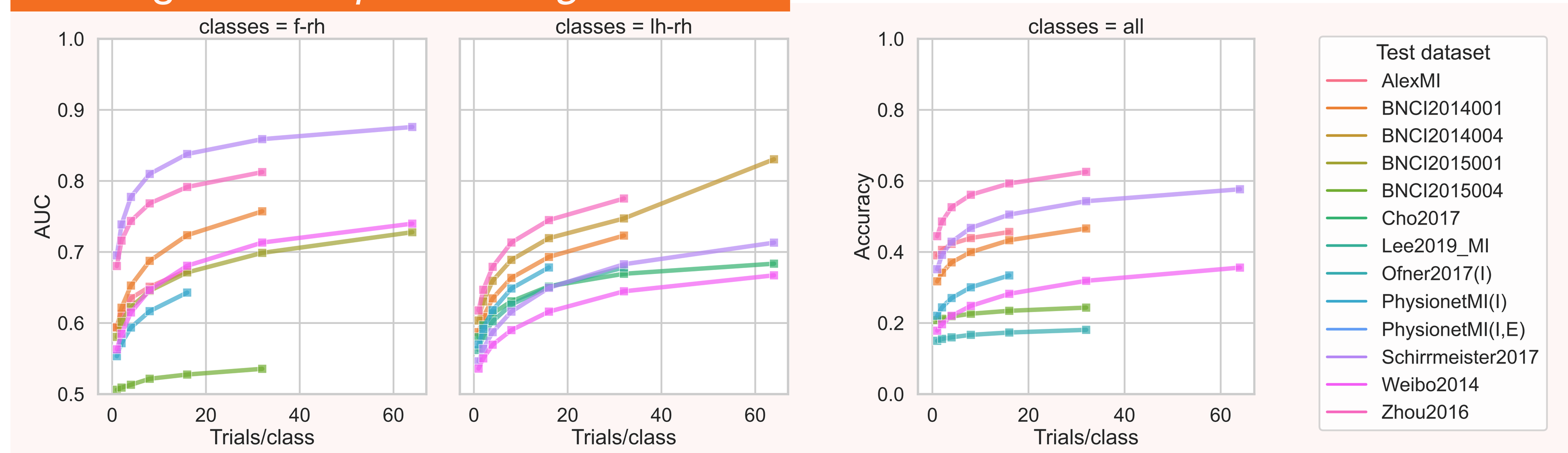
- **bh**: hands
- **f**: feet
- **lh**: left hand
- **lhrf**: left hand right foot
- **n**: navigation
- **r**: rest
- **ree**: right elbow extension
- **ref**: right elbow flexion
- **rh**: right hand
- **rhc**: right hand close
- **rhlf**: right hand left foot
- **rho**: right hand open
- **rp**: right pronation
- **rs**: right supination
- **s**: subtraction
- **t**: tongue
- **wa**: word ass

RESULTS

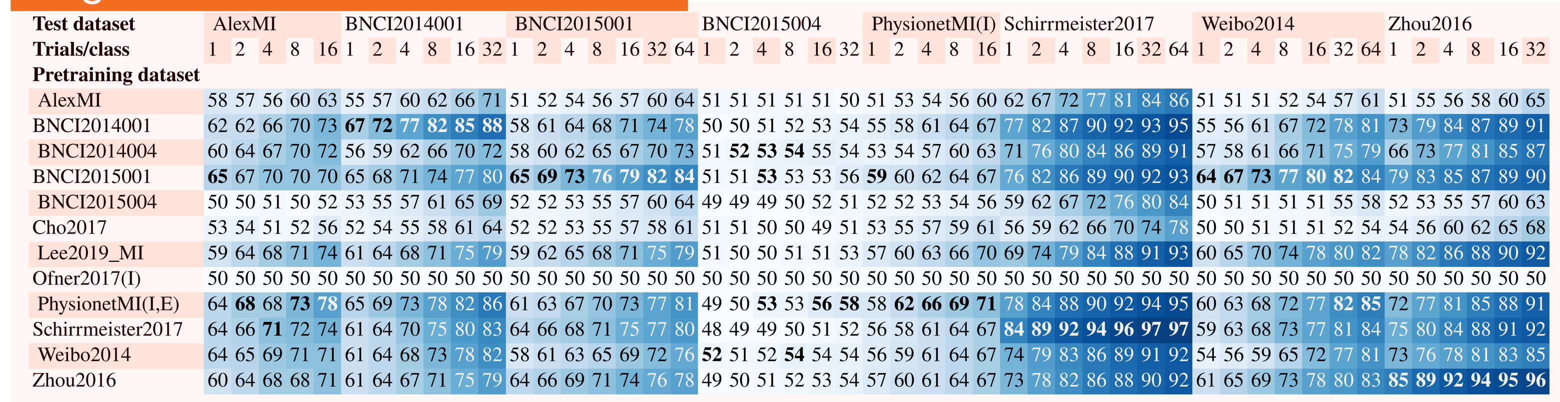
Average across *test datasets*



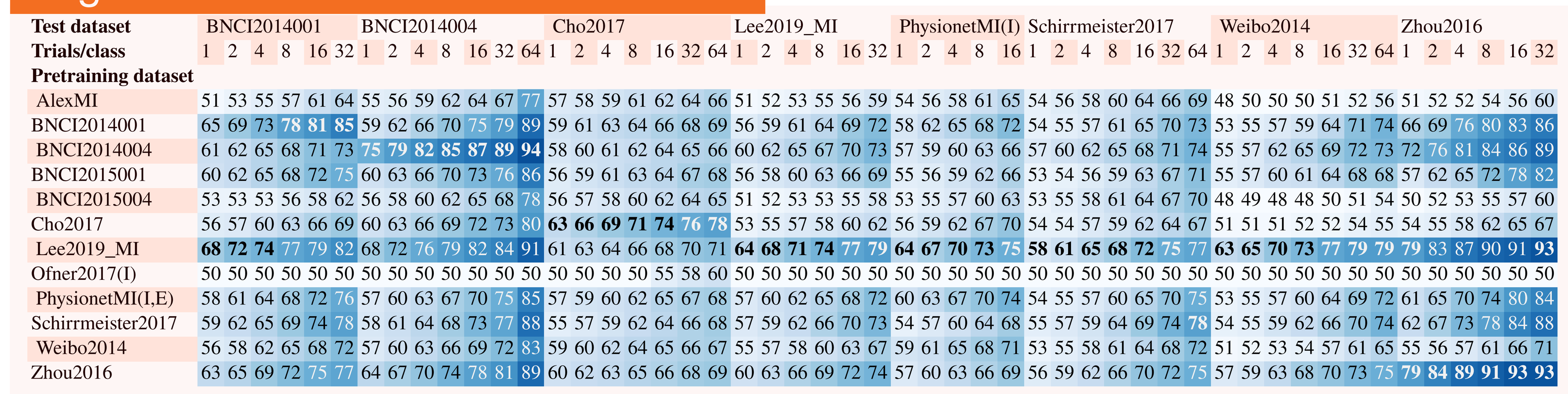
Average across *pre-training datasets*



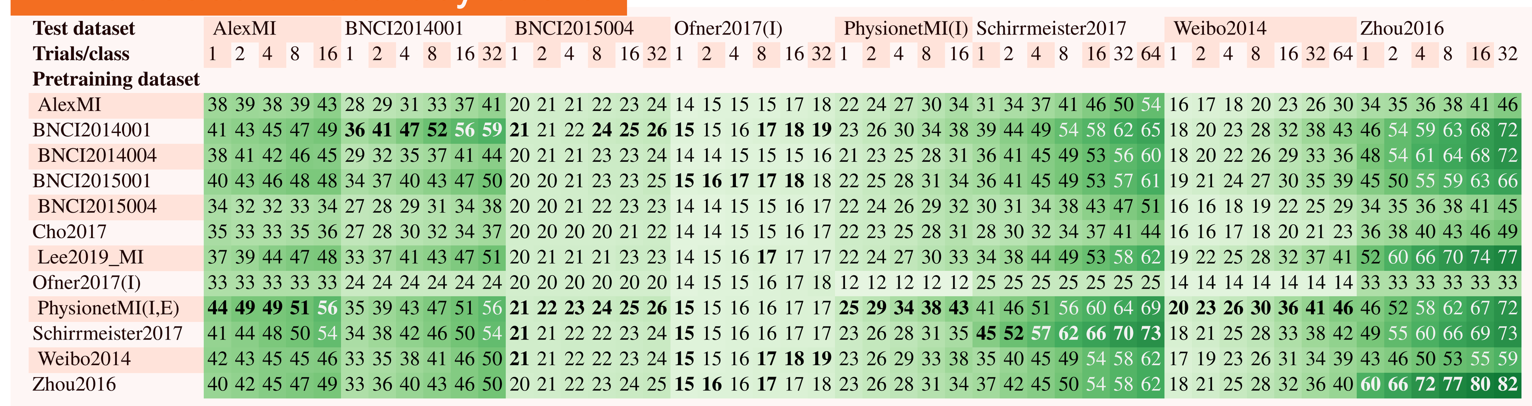
Right-hand vs feet - AUC score



Right-hand vs left hand - AUC score



All classes - Accuracy score



BEST DONORS

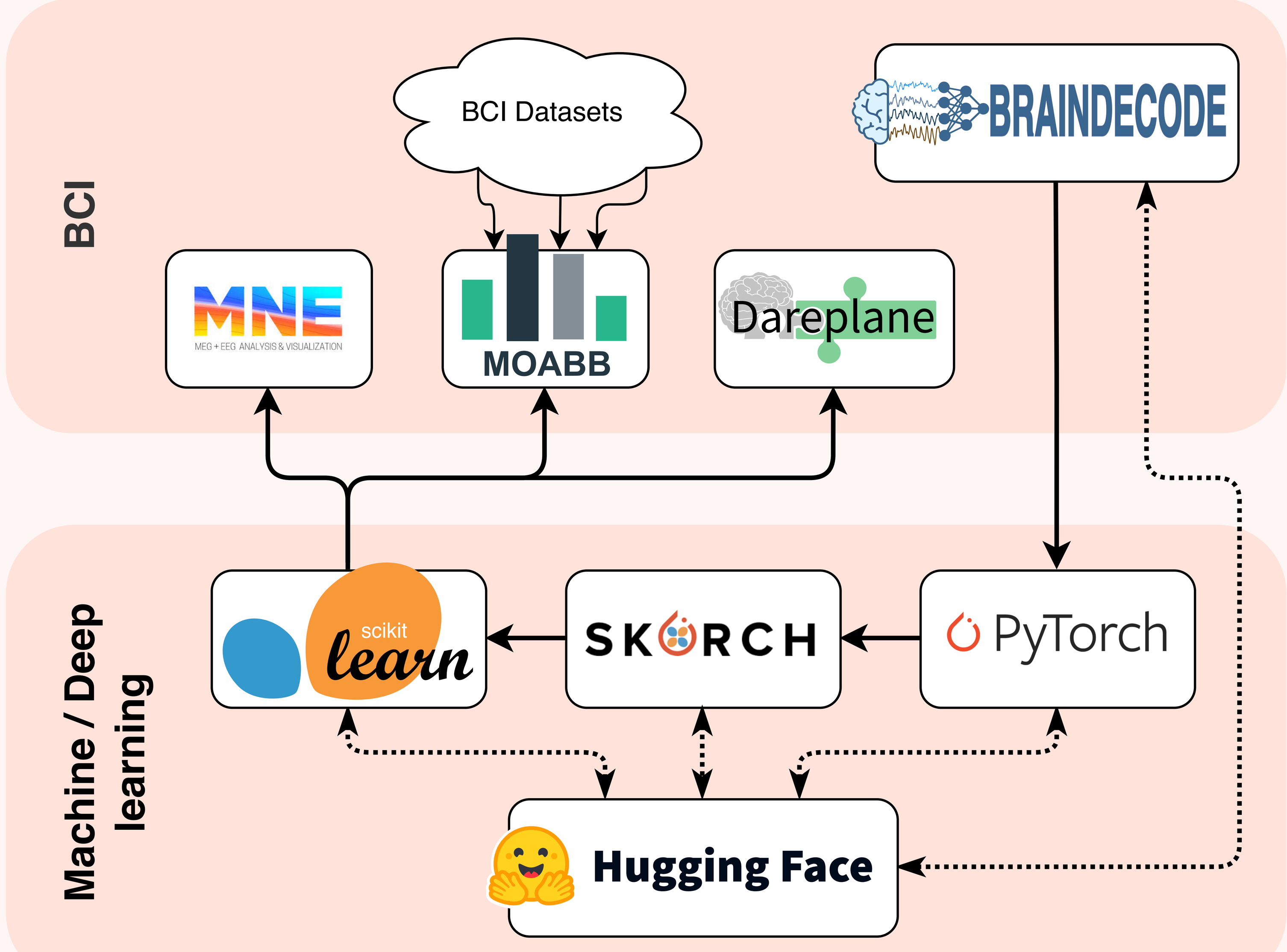
- **f-rh**: No clear winner, still BNCI2015001 best if few trials and PhysionetMI best if more trials;
- **lh-rh**: Lee2019 by a large margin.

BEST RECEIVERS

- **f-rh**: Schirrmeister2017 (probably simpler because executed movements);
- **lh-rh**: Zhou2016 if few trials, BNCI2014004 if more trials.

FRAMEWORK

Open-source libraries ecosystem



DISCUSSION

- Deep learning-based cross-mental-imagery-dataset transfer works well, even simple pipelines;
- The infrastructures are there to *effortlessly* share and reuse models;
- We must make it a standard practice within the BCI community to share our pre-trained models;
  - Using pre-trained models allows for fast prototyping;
  - Using pre-trained models lowers the threshold for new studies (data size needed);
- Both our method and workflow can be used on other paradigms than mental imagery and other types of transfer than cross-dataset.

USE MY PRE-TRAINED MODELS

```python
import torch
from huggingface_hub import hf_hub_download
from braindecode.models import EEGNetv4

path = hf_hub_download(
    repo_id='PierreGtch/EEGNetv4',
    filename='EEGNetv4_Lee2019_MI/model-params.pkl')
net = EEGNetv4(3, 2, 385).eval()
net.load_state_dict(torch.load(path, map_location='cpu'))
```

Full notebook:

REFERENCES

[1] Guetschel et al. *2022 IEEE MetroXRAINE* doi:10.1109/metroxraine54828.2022.9967496

[2] Lawhern et al. (2018) *J Neural Eng* doi:10.1088/1741-2552/aace8c

[3] Jayaram & Barachant (2018) *J Neural Eng* doi:10.1088/1741-2552/aadea0

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