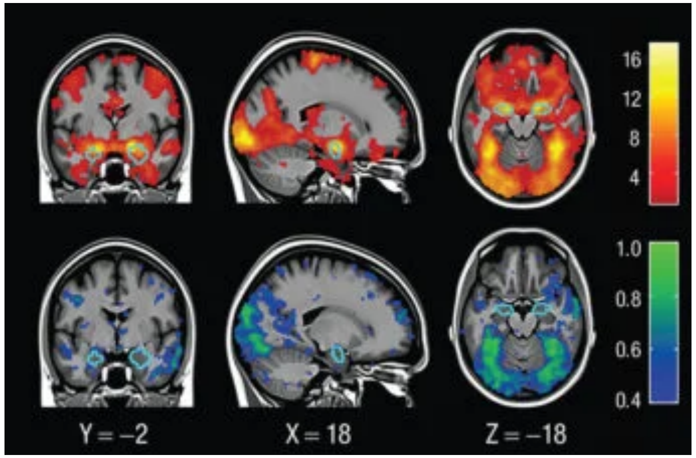
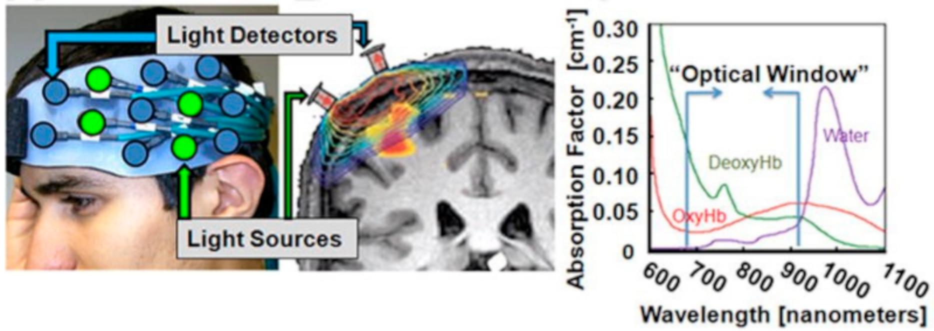
Improving Multi-Voxel Pattern Analysis with Modern Convolutional Neural Network Architecture

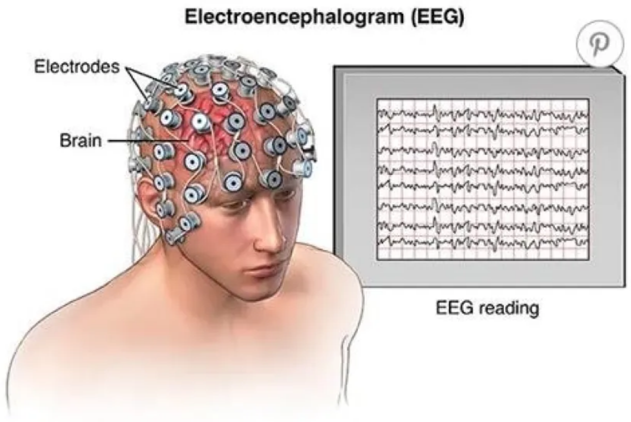
蕭翔允, 鄭九彰, 簡志宇

2024/06/17

Searching for Physical Signals of Psychological Processes

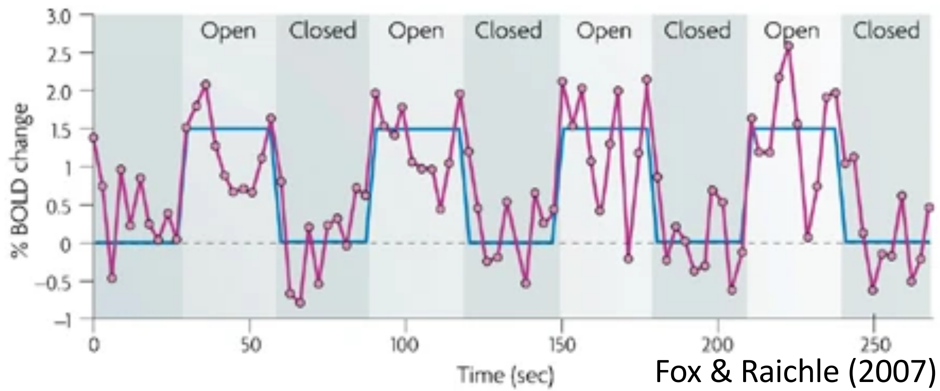




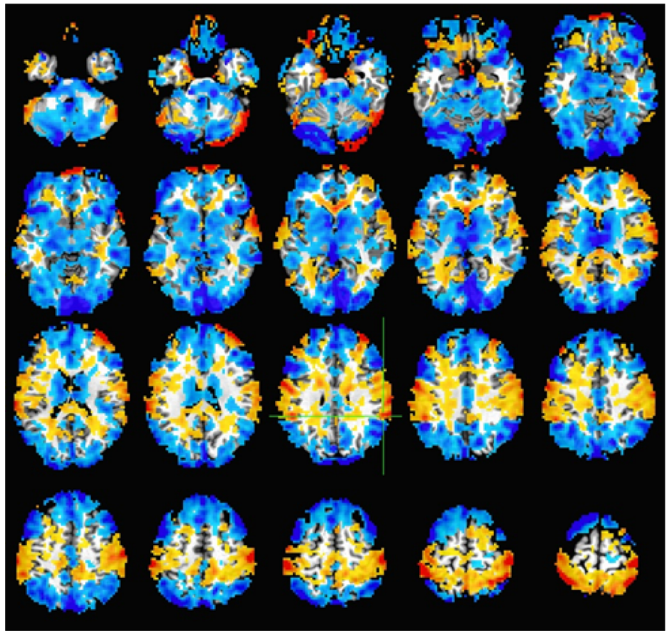


Functional MRI

- Non-invasive brain activity detection
- High temporal resolution



Fox & Raichle (2007)



Data Source

OpenNEURO

Files Download Derivatives Metadata

README

Collaborations and deceptions in strategic interactions revealed by hyperscanning fMRI

Aims:

The current study aims to investigate the neural mechanisms of interpersonal collaborations and deceptions, with an Opening Treasure Chest (OTC) game under the fMRI hyperscanning setup.

Prof. 陳德祐

Prof. 龔俊嘉

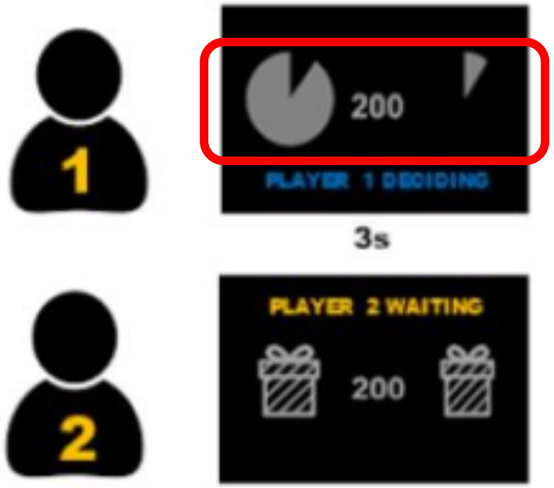
Prof. 翁明宏

openneuro.org/datasets/ds004103

Collaborations and deceptions in strategic interactions revealed by hyperscanning fMRI

Siao-Shan Shen, Jen-Tang Cheng, Yi-Ren Hsu, Der-Yow Chen, Ming-Hung Weng, Chun-Chia Kung

doi: https://doi.org/10.1101/2021.07.11.451985



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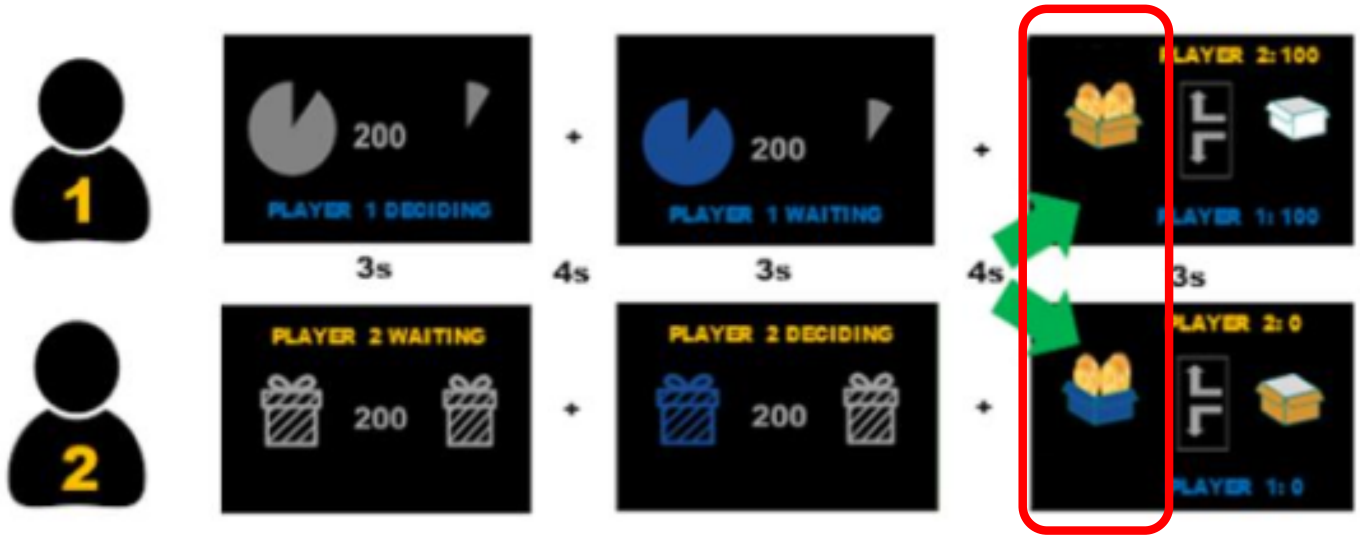

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doi: https://doi.org/10.1101/2021.07.11.451985

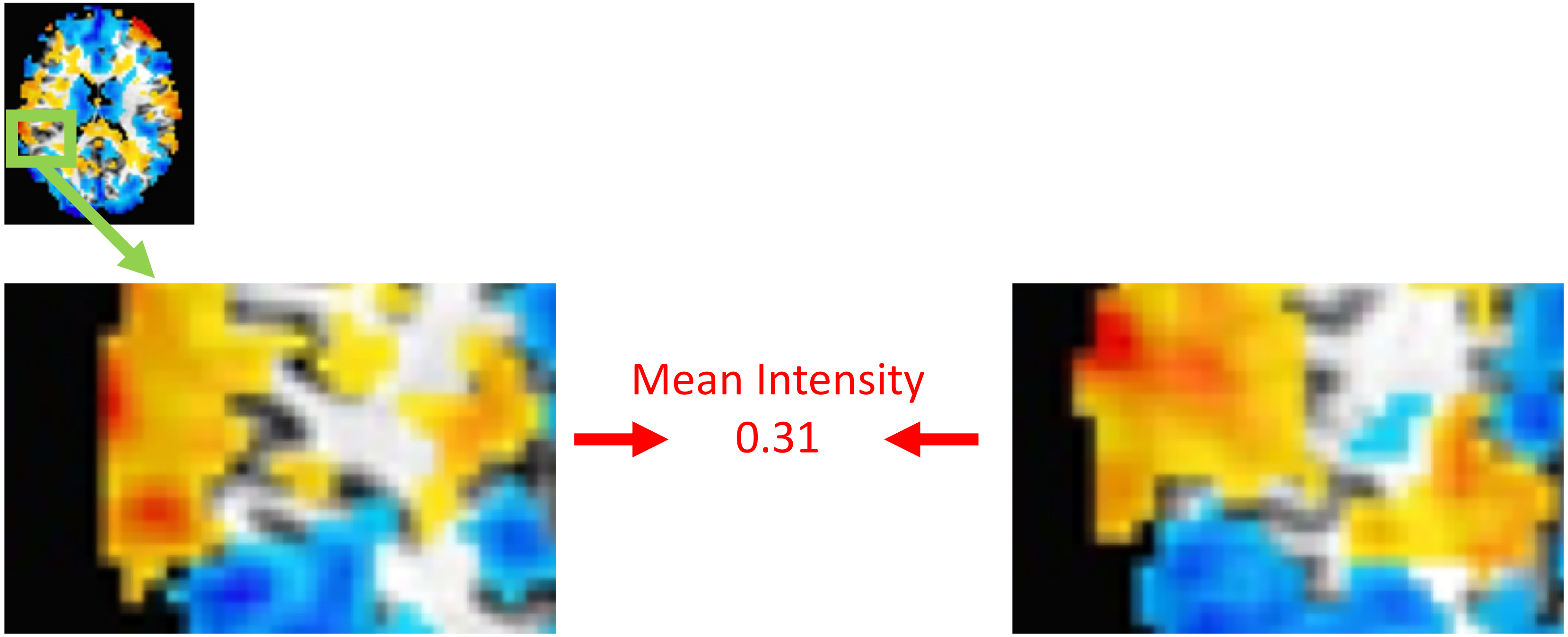
Major Goal

Cooperation

Competition

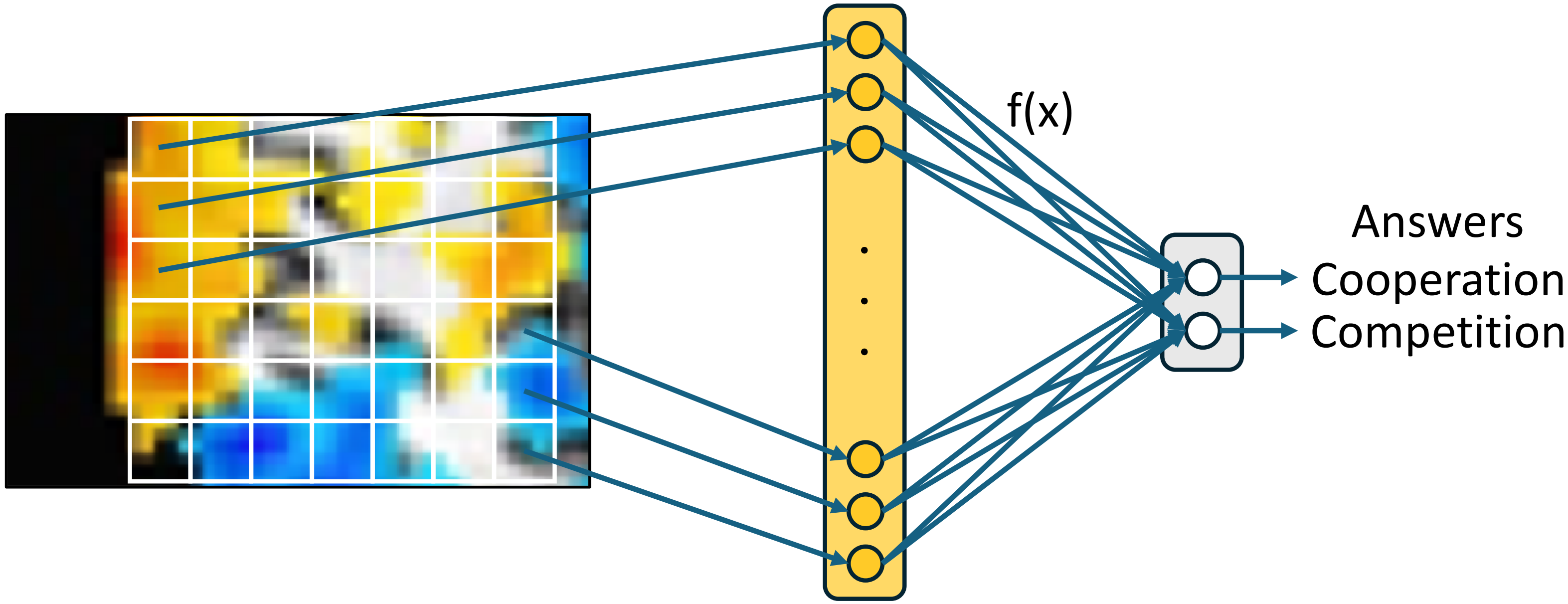
Region of Interest Analysis

- Averaging a dataset will make it less informative.

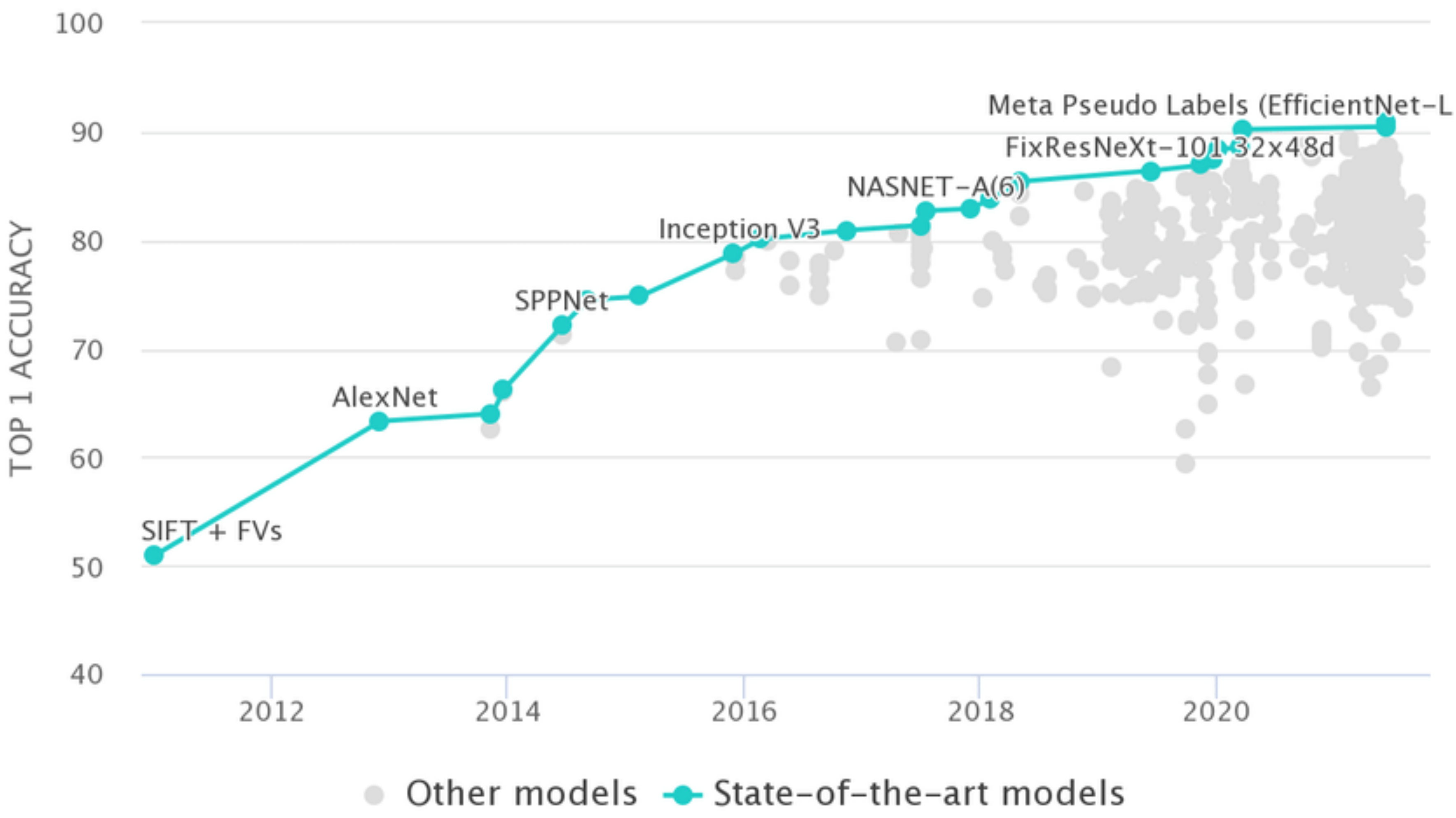


Multi-Voxel Pattern Analysis

- Machine Learning based Image Classification
- Empirical, Data-driven, Self-adaptive



Progress of Image Classification



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2019

Explore of CNN-MVPA

Contents lists available at ScienceDirect

Artificial Intelligence In Medicine

journal homepage: www.elsevier.com/locate/artmed

3D-CNN based discrimination of schizophrenia using resting-state fMRI

Muhammad Naveed Iqbal Qureshi[a,b,c,d,1], Jooyoung Oh[e,f,1], Boreom Lee[g,*]

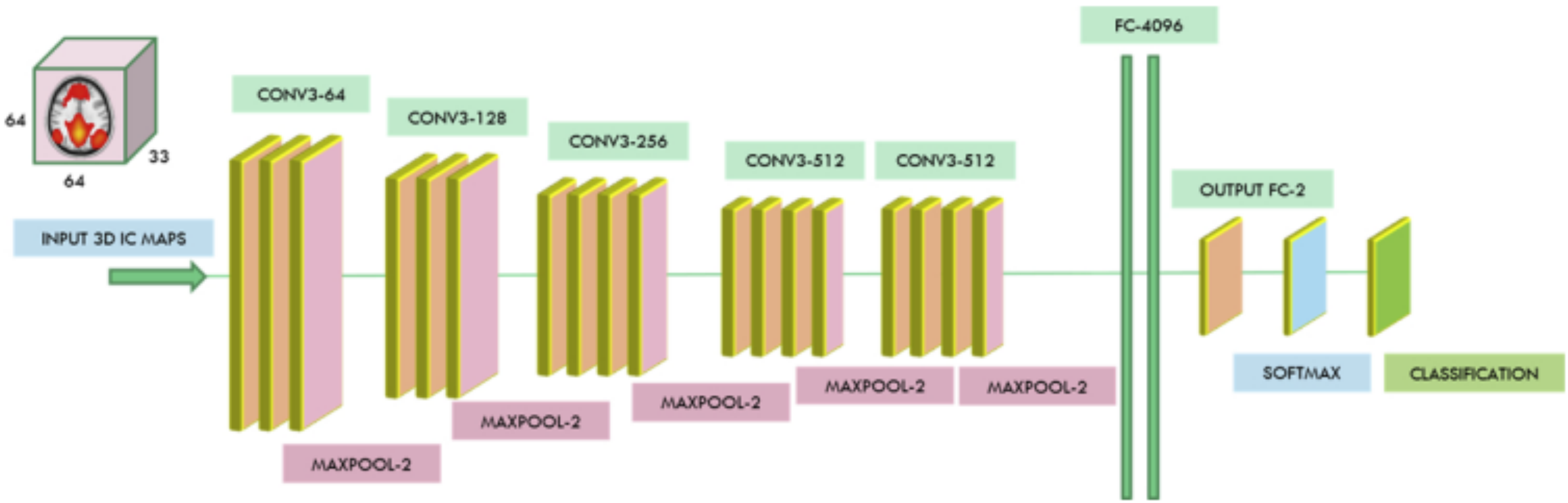


Fig. 2. VGG-Net based 3D-CNN architecture.

Explore of CNN-MVPA (2)

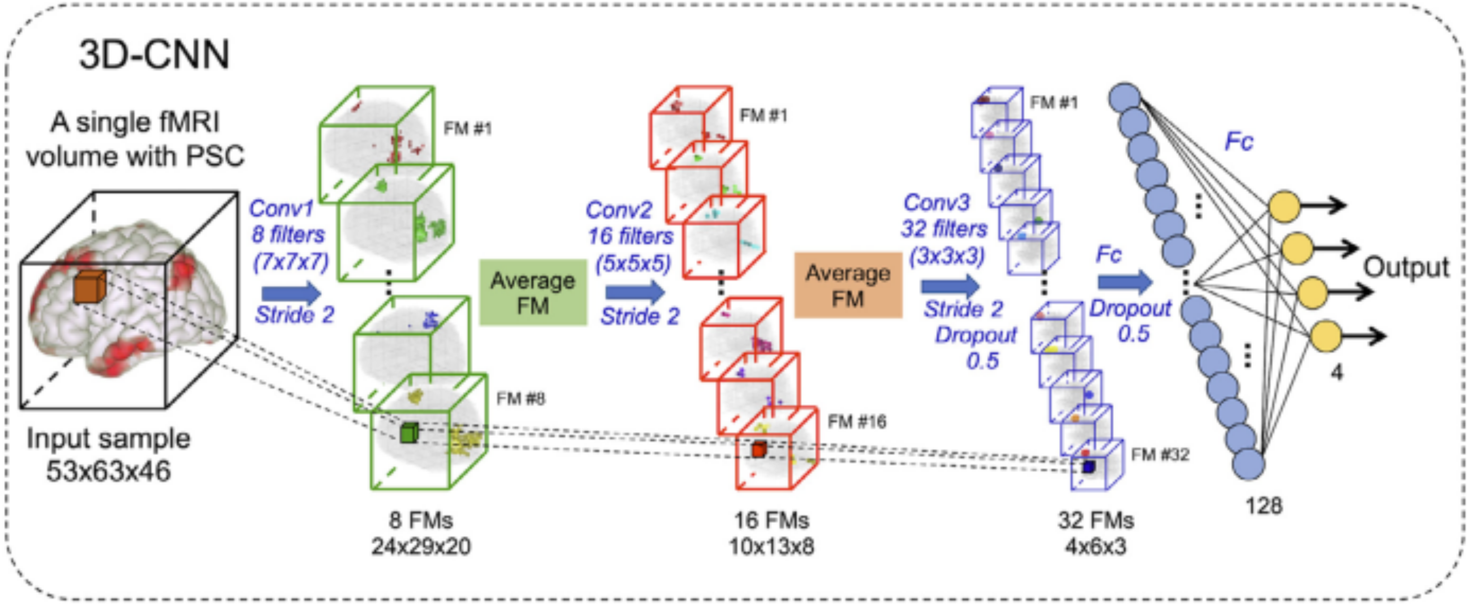
Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage

fMRI volume classification using a 3D convolutional neural network robust to shifted and scaled neuronal activations

Hanh Vu, Hyun-Chul Kim, Minyoung Jung, Jong-Hwan Lee*



Explore of CNN-MVPA (3)

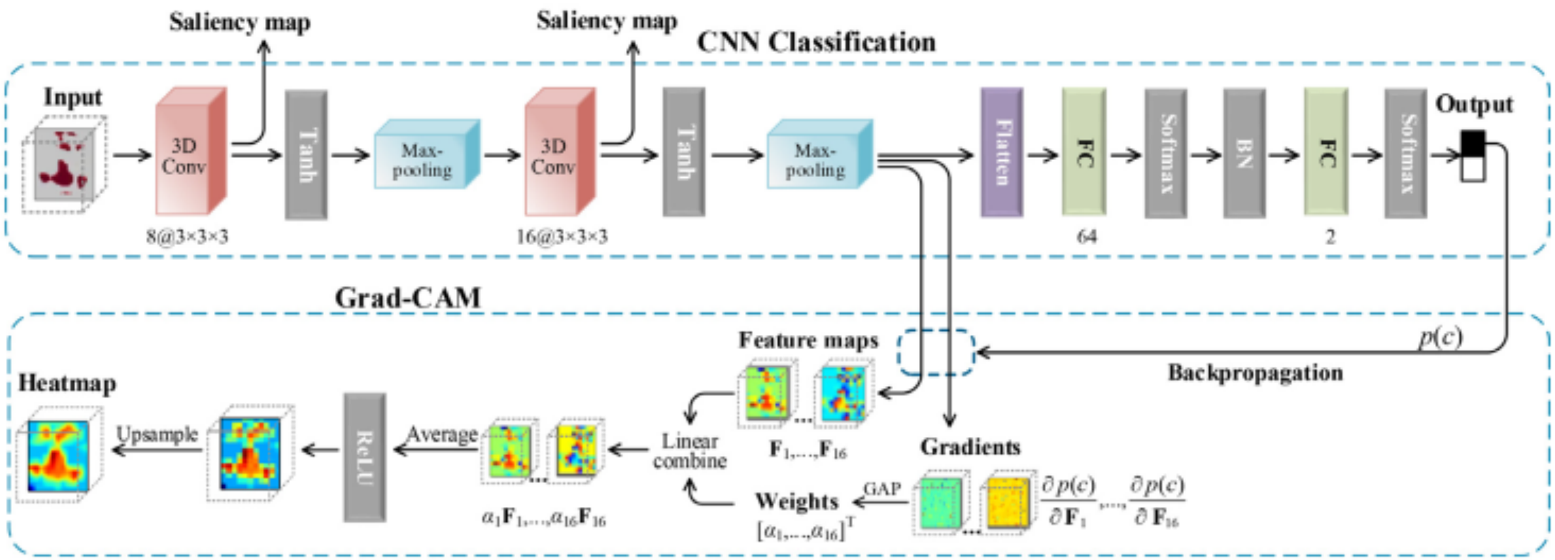
Contents lists available at ScienceDirect

Medical Image Analysis

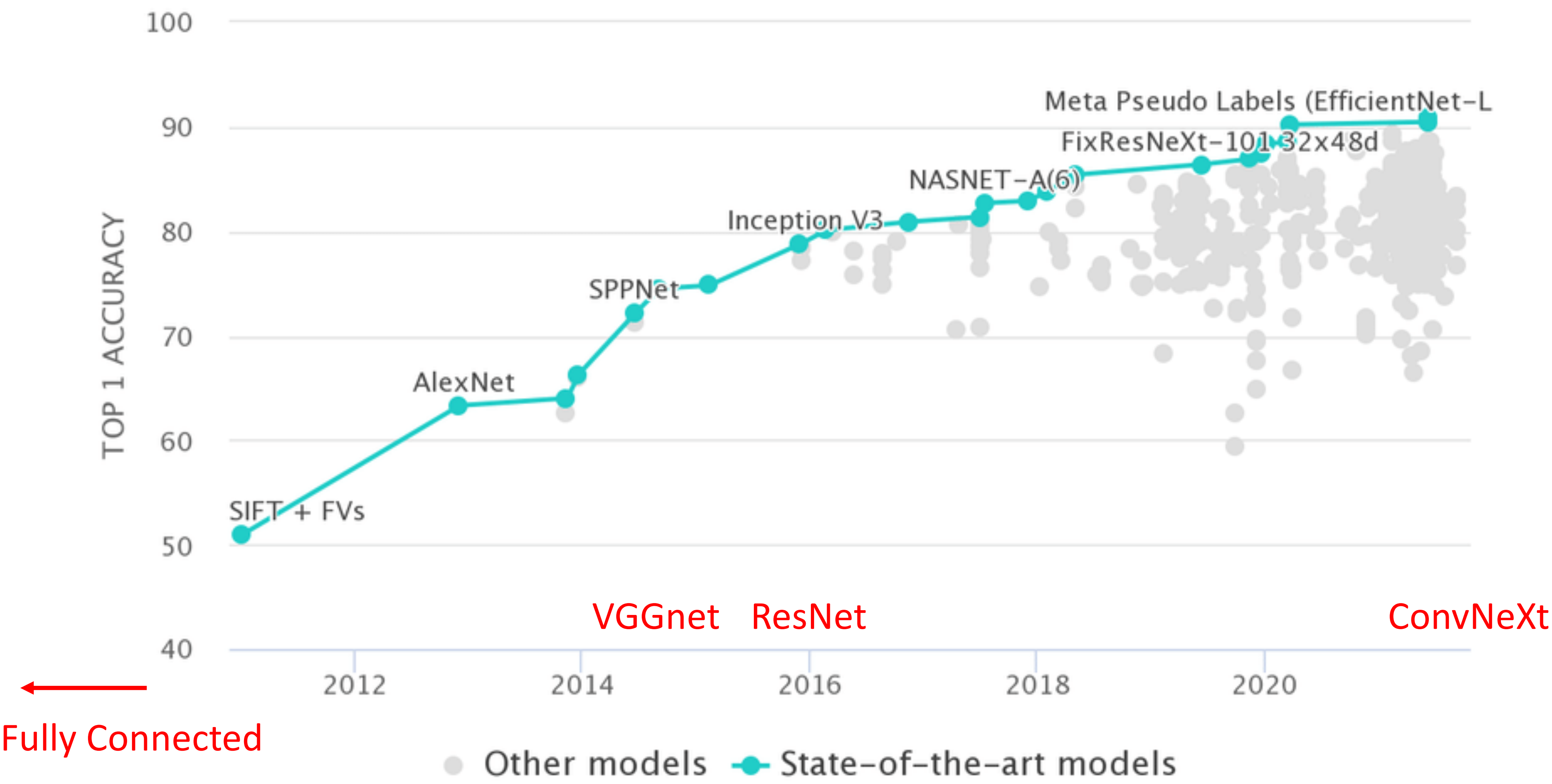
journal homepage: www.elsevier.com/locate/media

SSPNet: An interpretable 3D-CNN for classification of schizophrenia using phase maps of resting-state complex-valued fMRI data

Qiu-Hua Lin[a,*], Yan-Wei Niu[a], Jing Sui[b], Wen-Da Zhao[a], Chuanjun Zhuo[c], Vince D. Calhoun[d]



Progress of Image Classification



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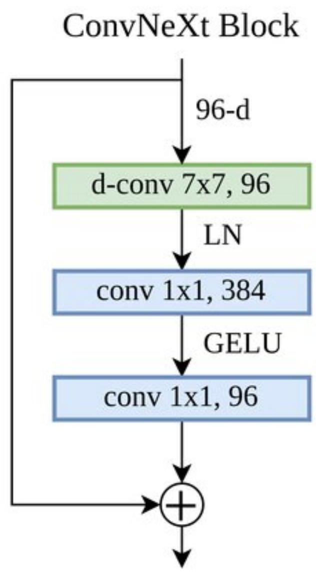
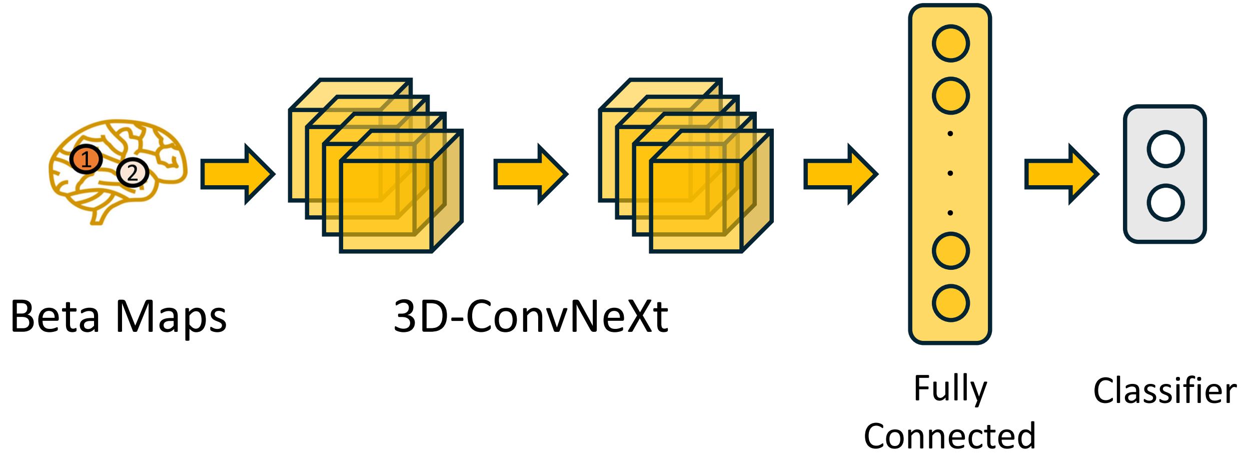
The ConvNeXt Model

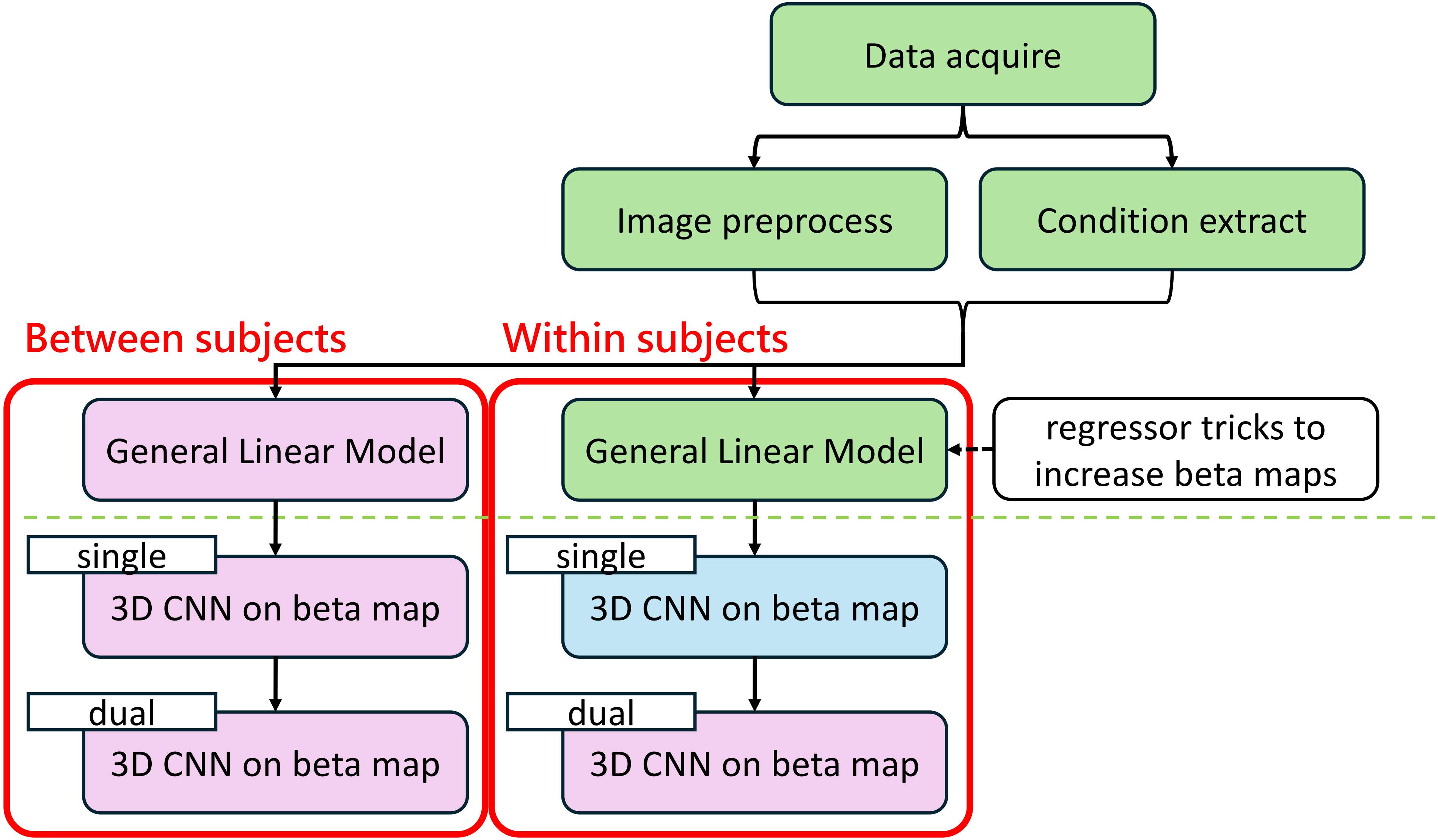
- Better Performance
- Training Stability
- Strong Adaptability
- Computational Efficiency





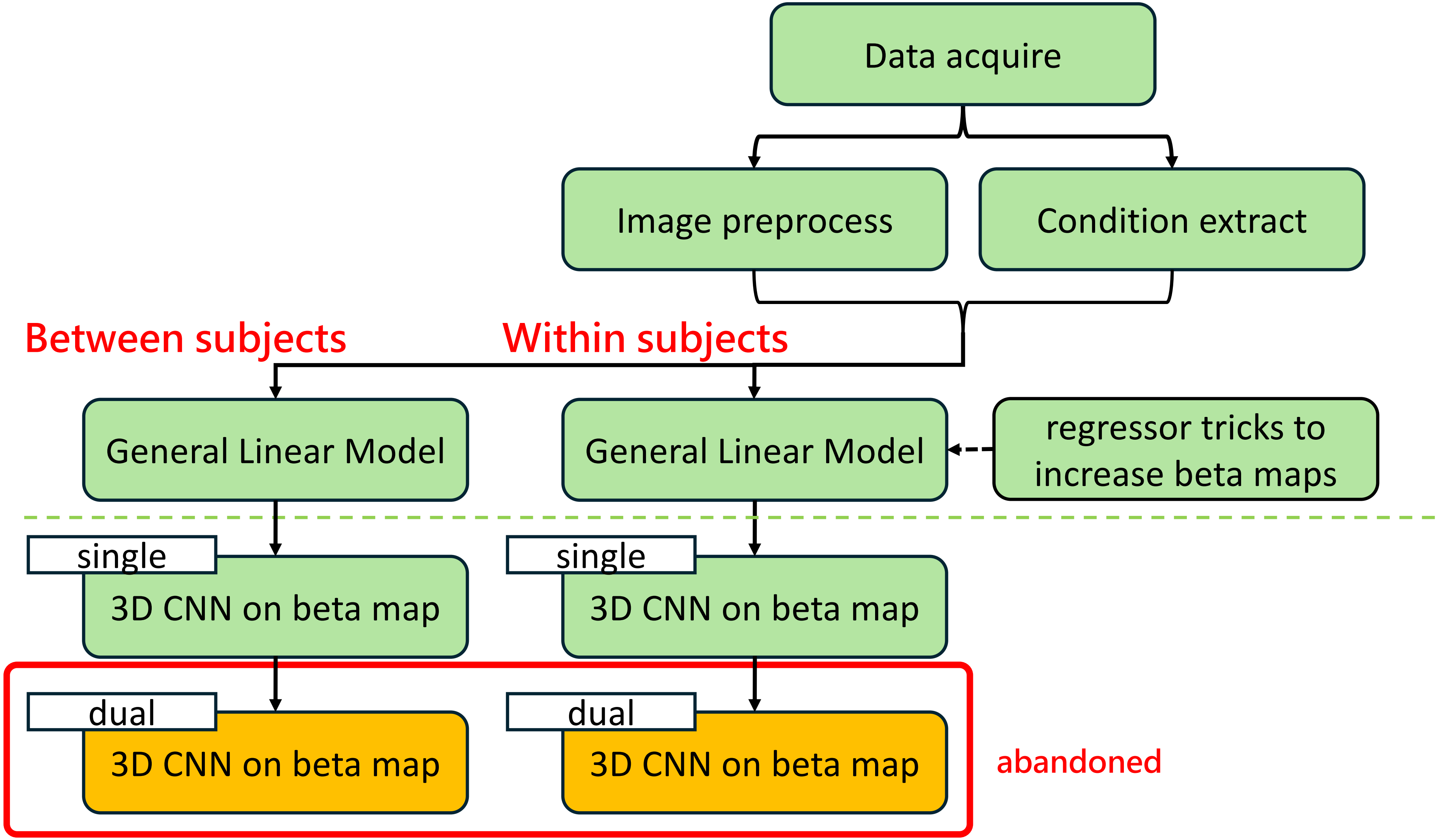
Milestone

Roadmap



Final

Roadmap

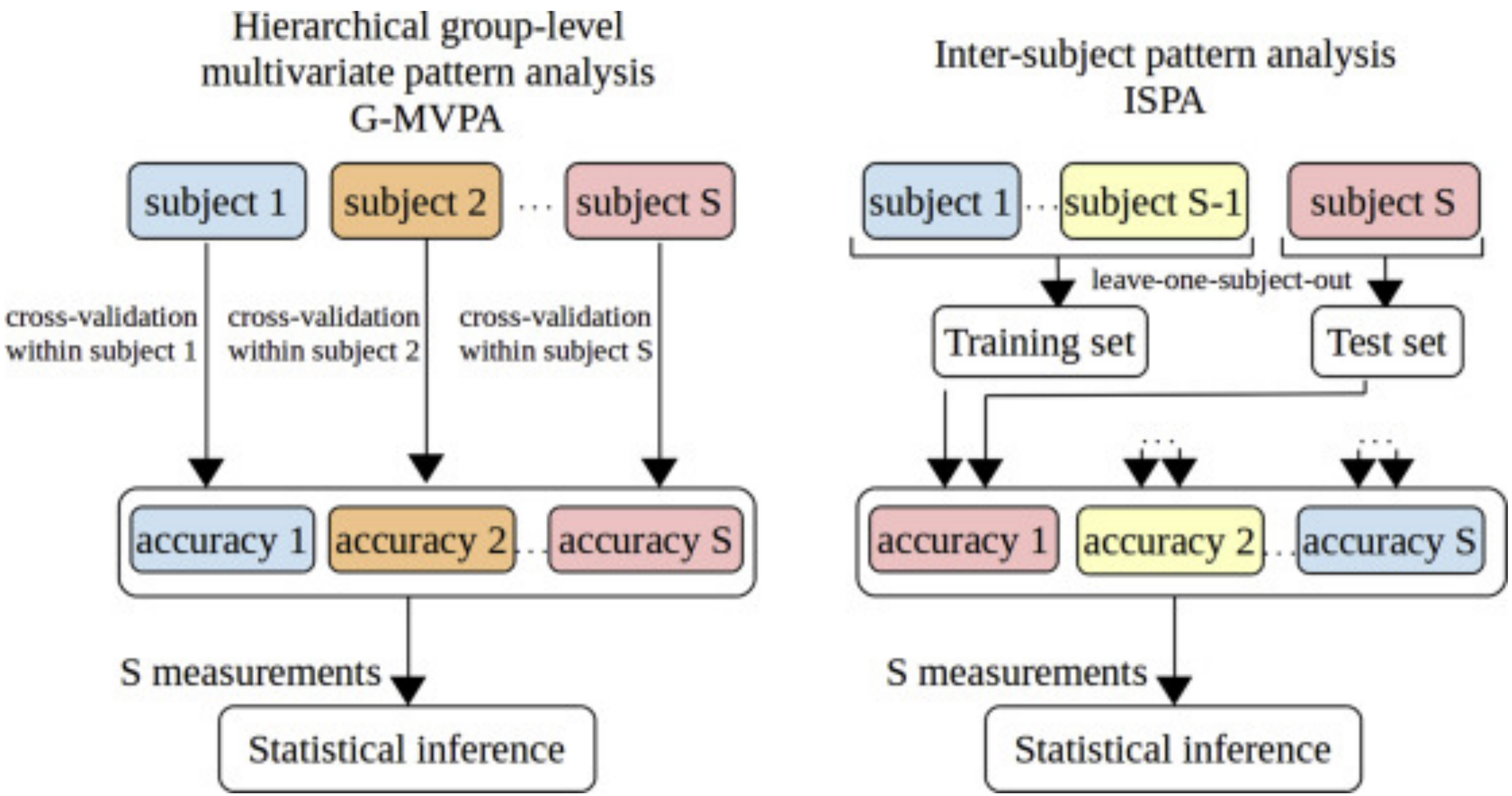


Major Goal

Cooperation

Competition

Within/Between-Subject Scheme

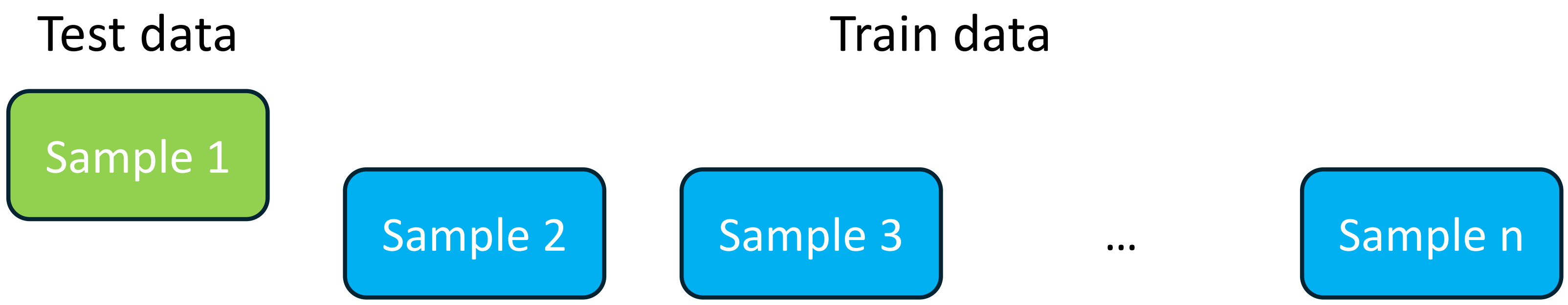


doi.org/10.1016/j.neuroimage.2019.116205

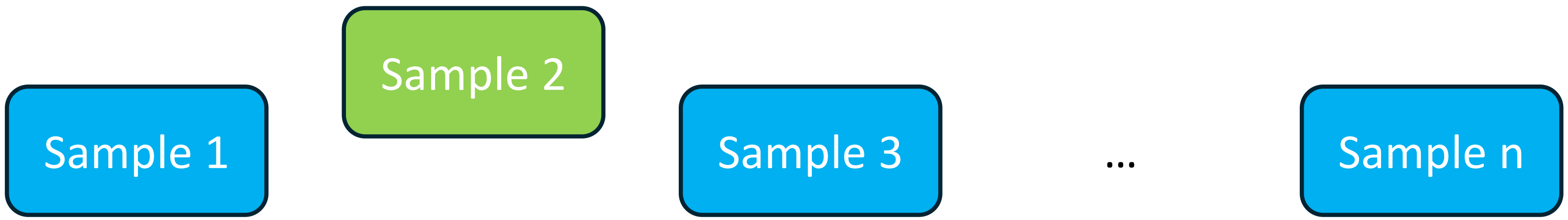
Leave-One-Out Strategy

Sample 1 Sample 2 Sample 3 … Sample n

Leave-One-Out Strategy

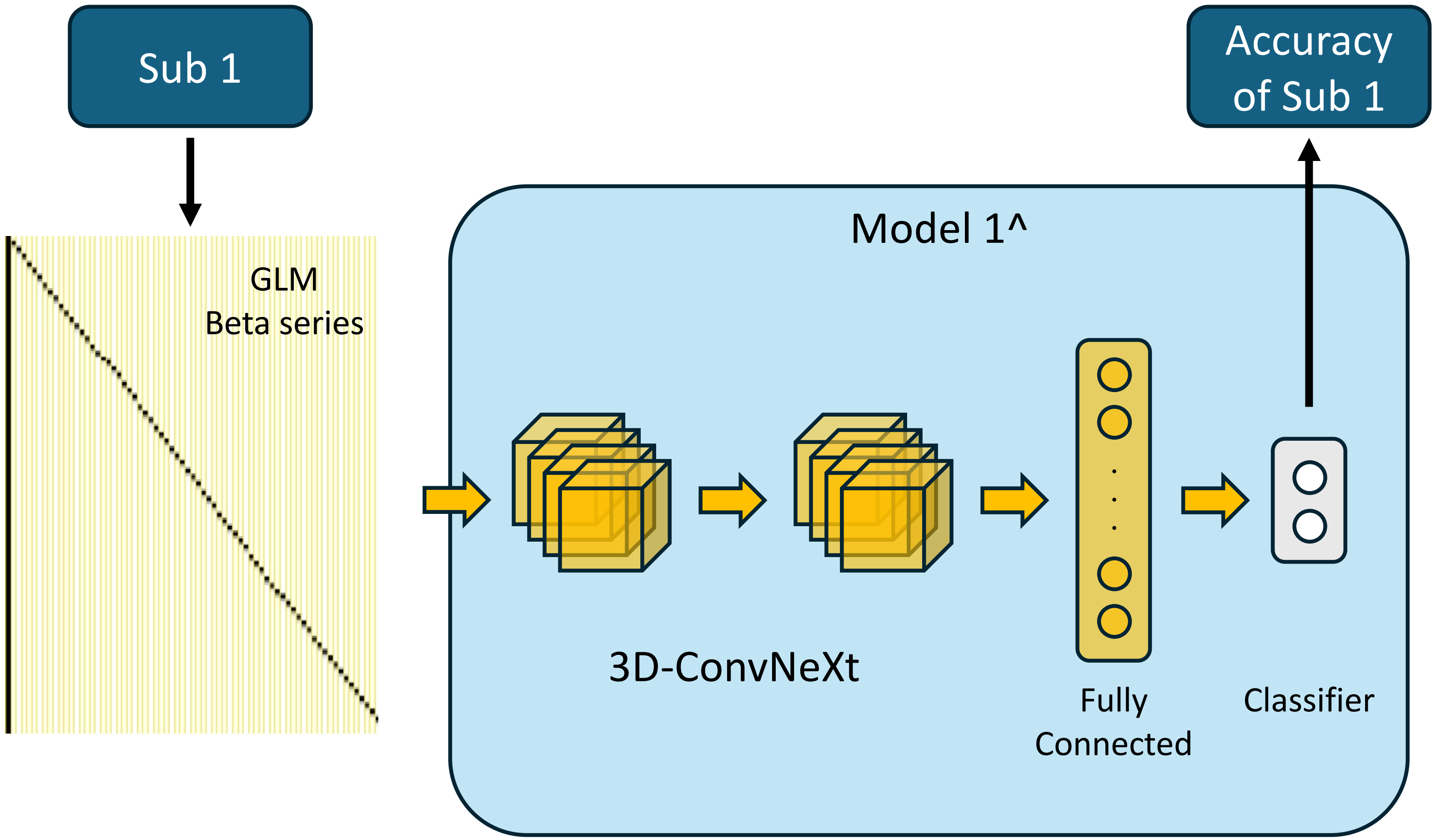


Leave-One-Out Strategy

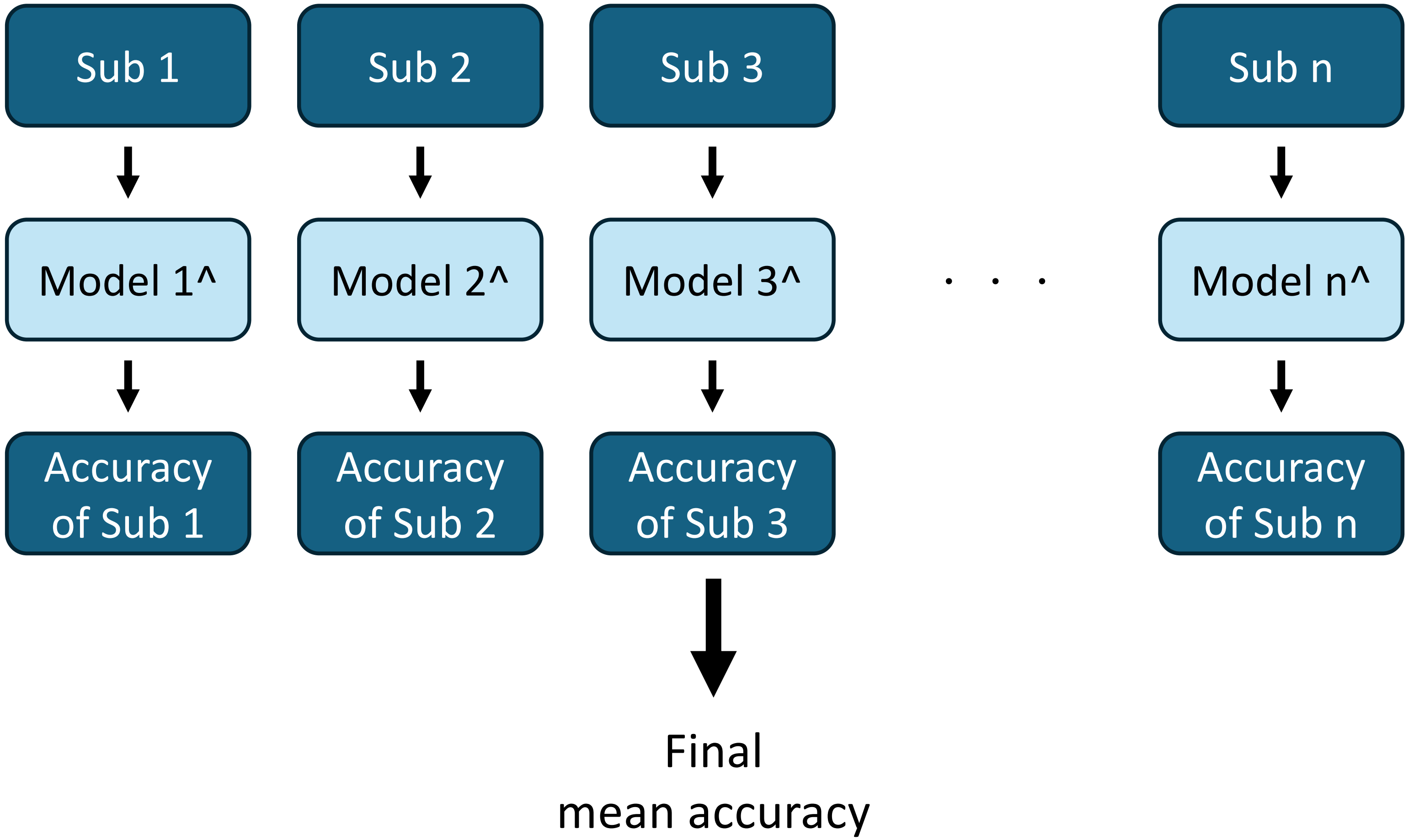


Leave-One-Out Strategy

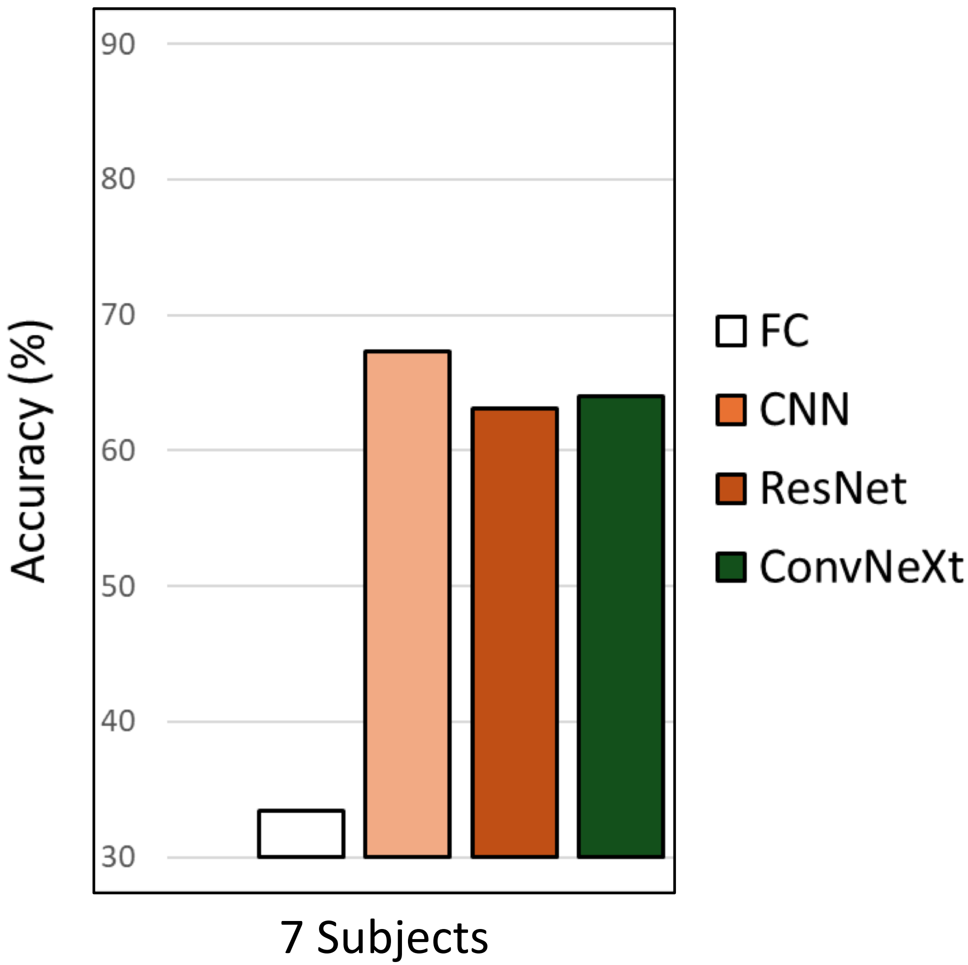
Within Subject Test



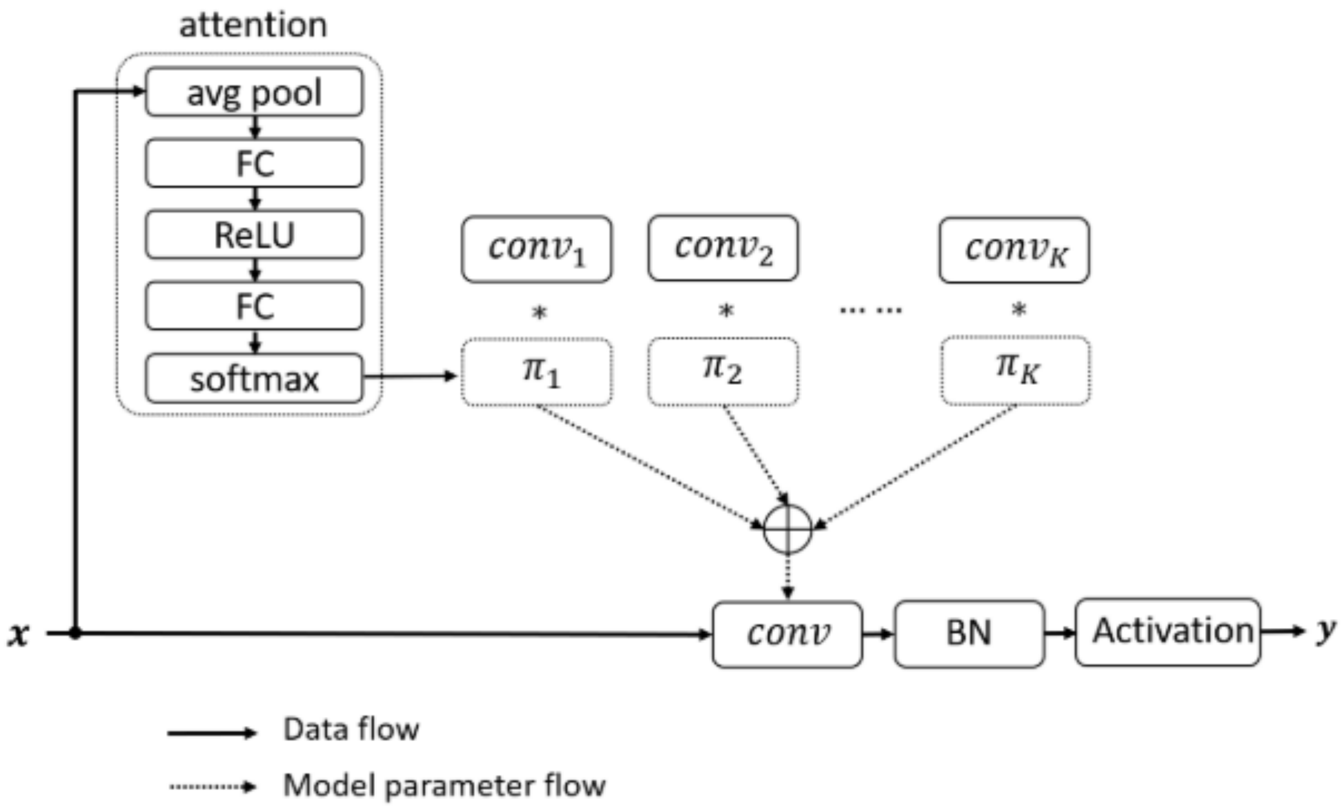
Within Subject Test



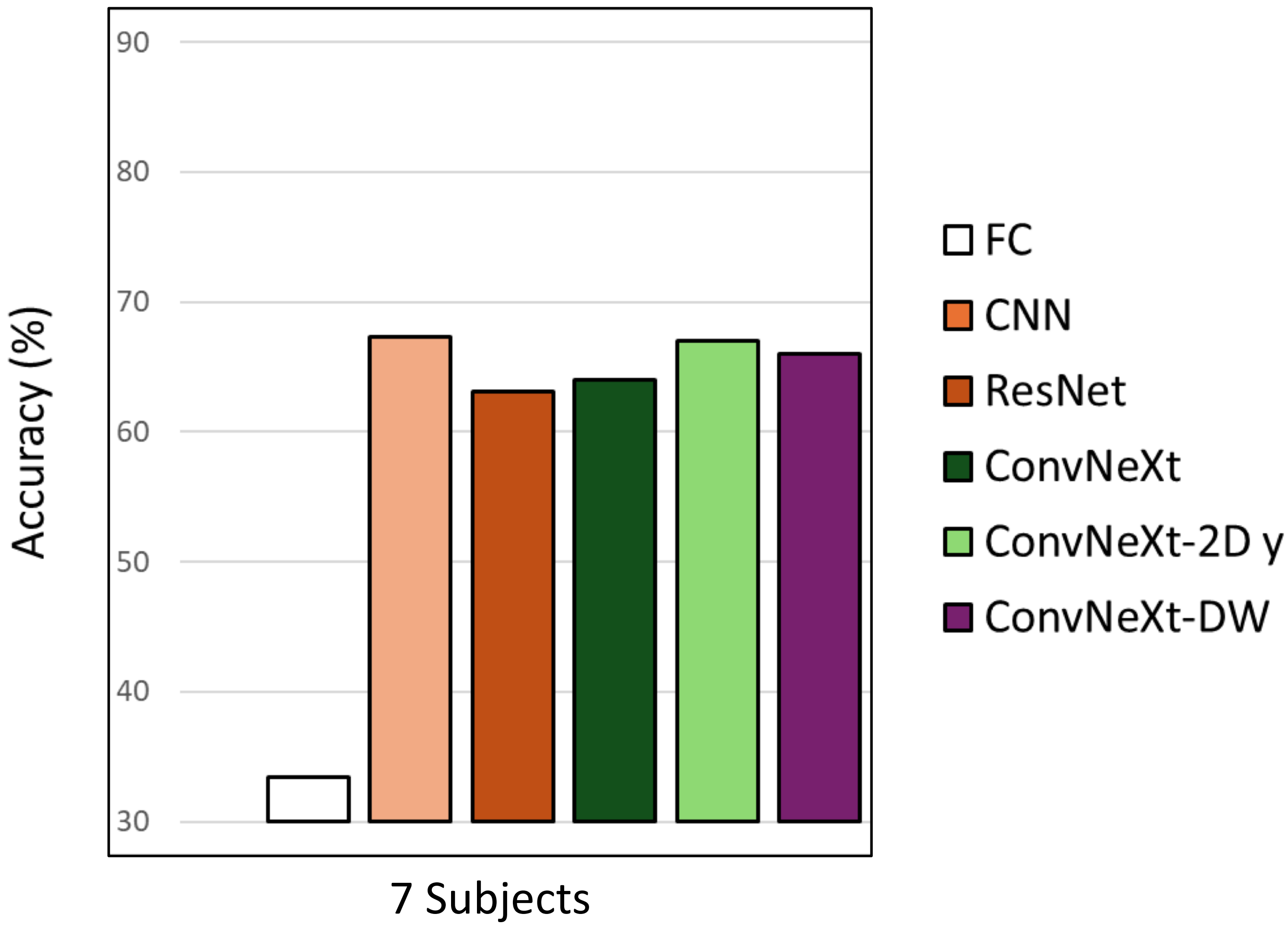
Within Subject Test Results



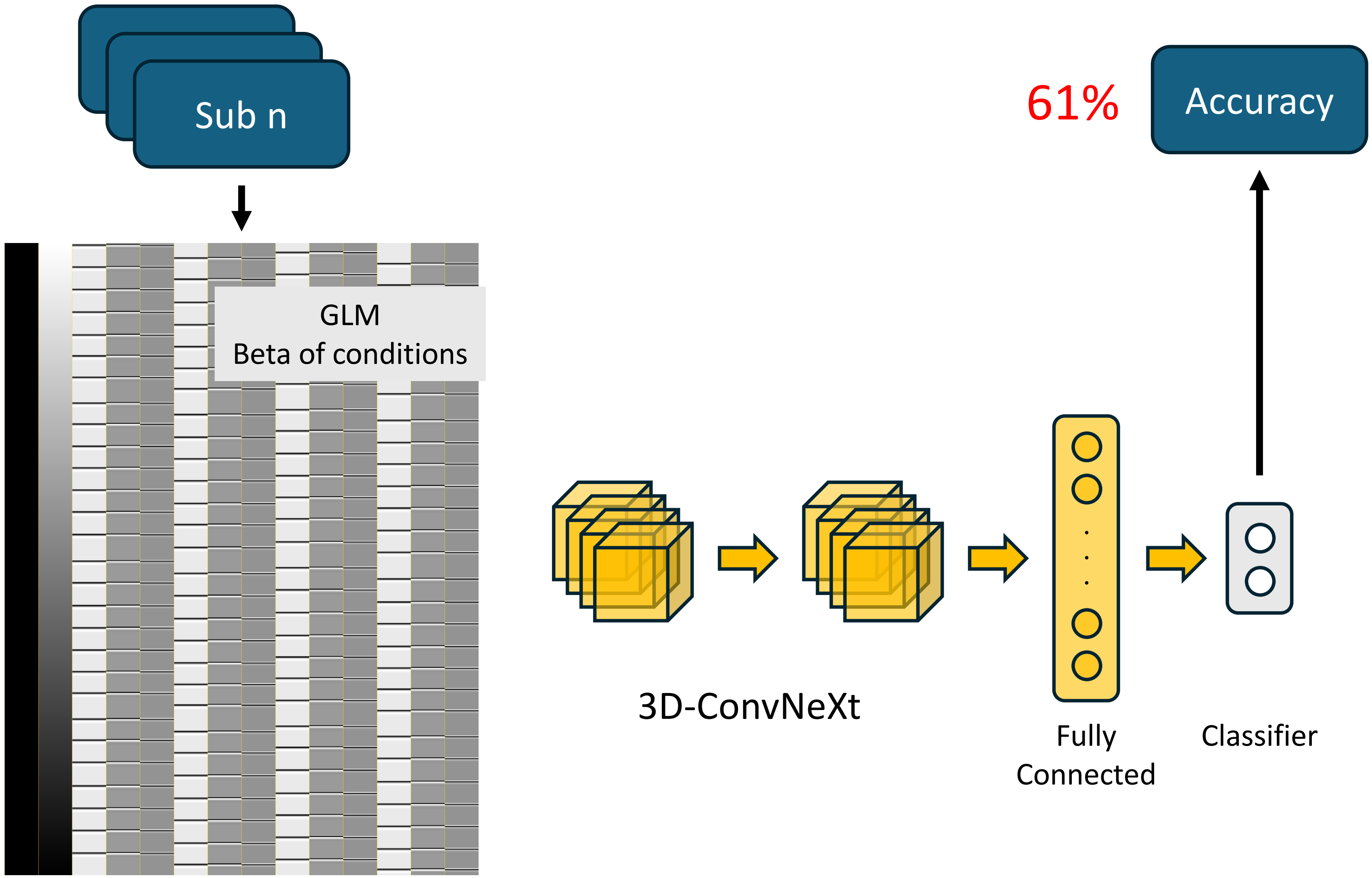
Dynamic Convolution



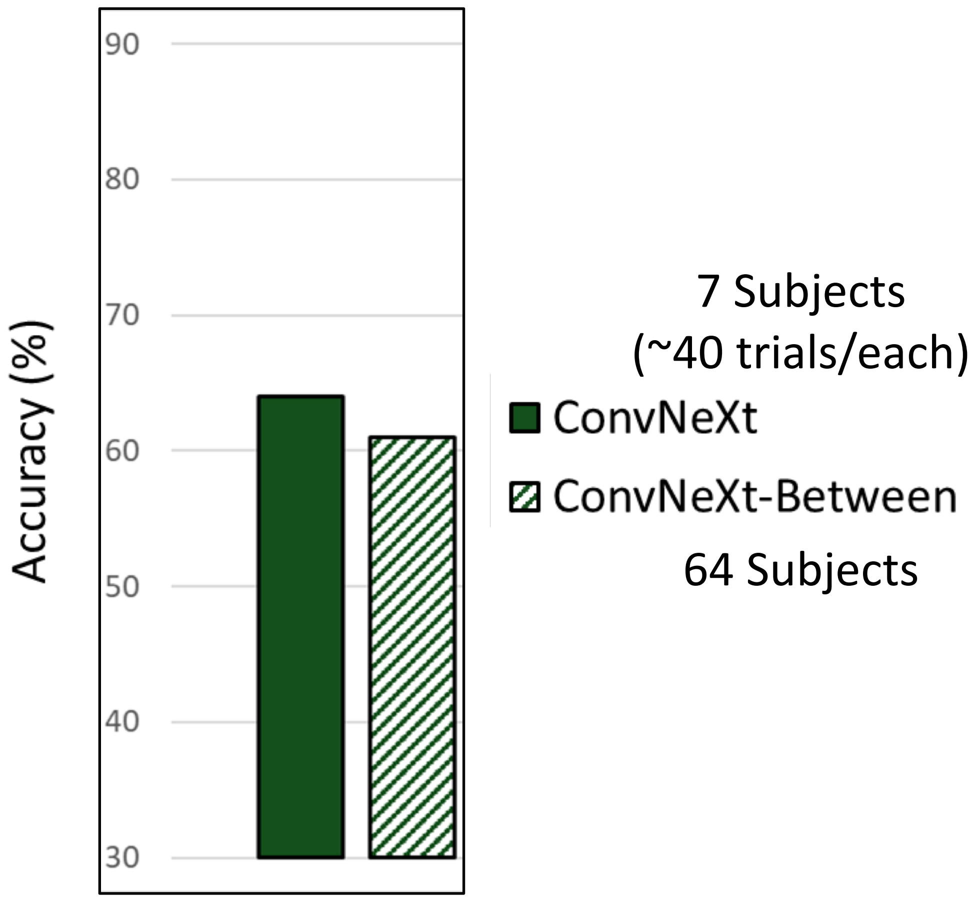
Within Subject Test Results



Between Subject Test



Between Subject Test Results



Within/Between Pattern

- Within subject classification show promising result.

- Between subject pattern might be diverse.

Similar conclusion to:

ELSEVIER

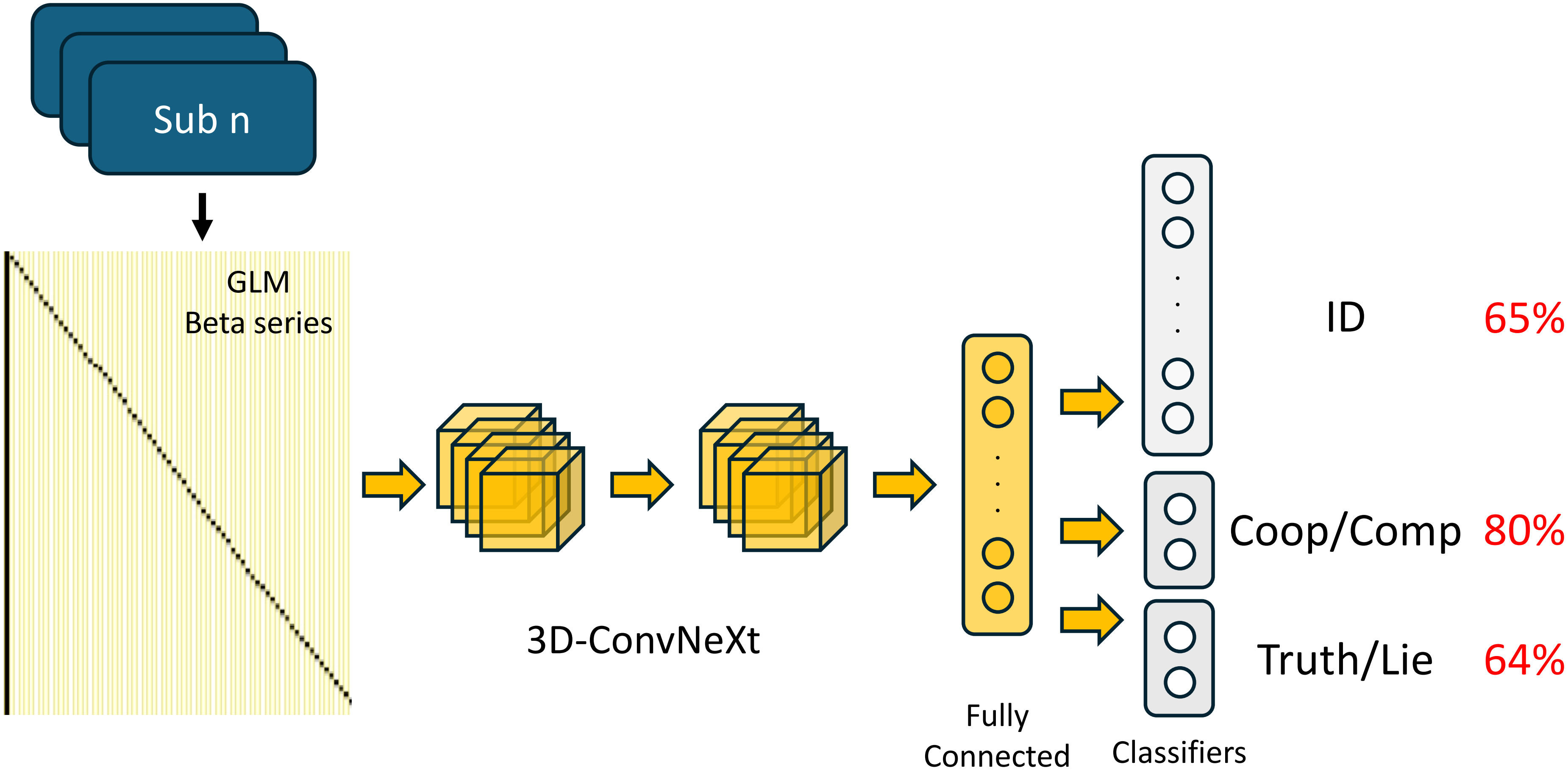
NeuroImage
Volume 97, 15 August 2014, Pages 271-283

What do differences between multi-voxel and univariate analysis mean? How subject-, voxel-, and trial-level variance impact fMRI analysis

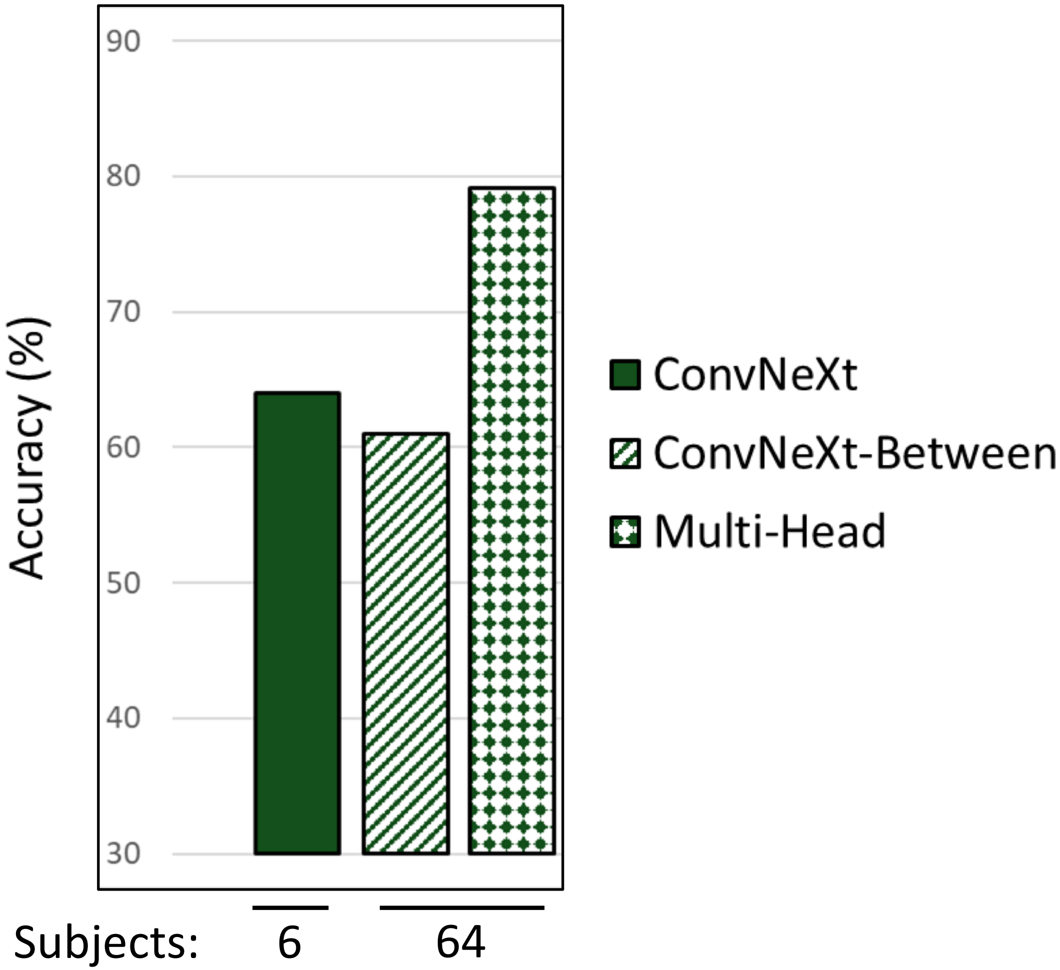
Tyler Davis [a,1], Karen F. LaRocque [b,1], Jeanette A. Mumford [d,e,f], Kenneth A. Norman [g,h], Anthony D. Wagner [b,c], Russell A. Poldrack [d,e,f]

https://doi.org/10.1016/j.neuroimage.2014.04.037

Multi-Head Structure



Multi-Head Structure Performance

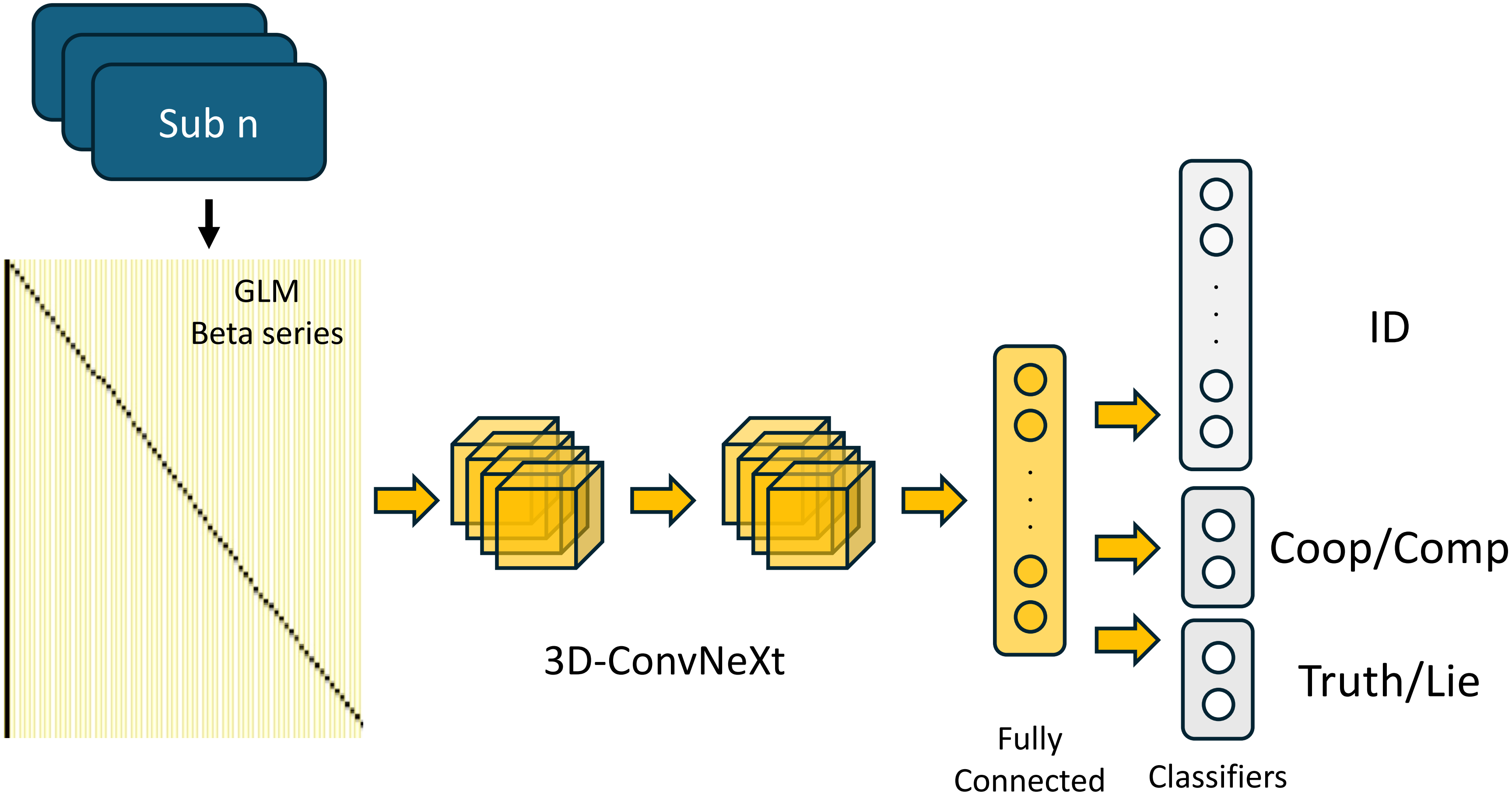


Within/Between Pattern (2)

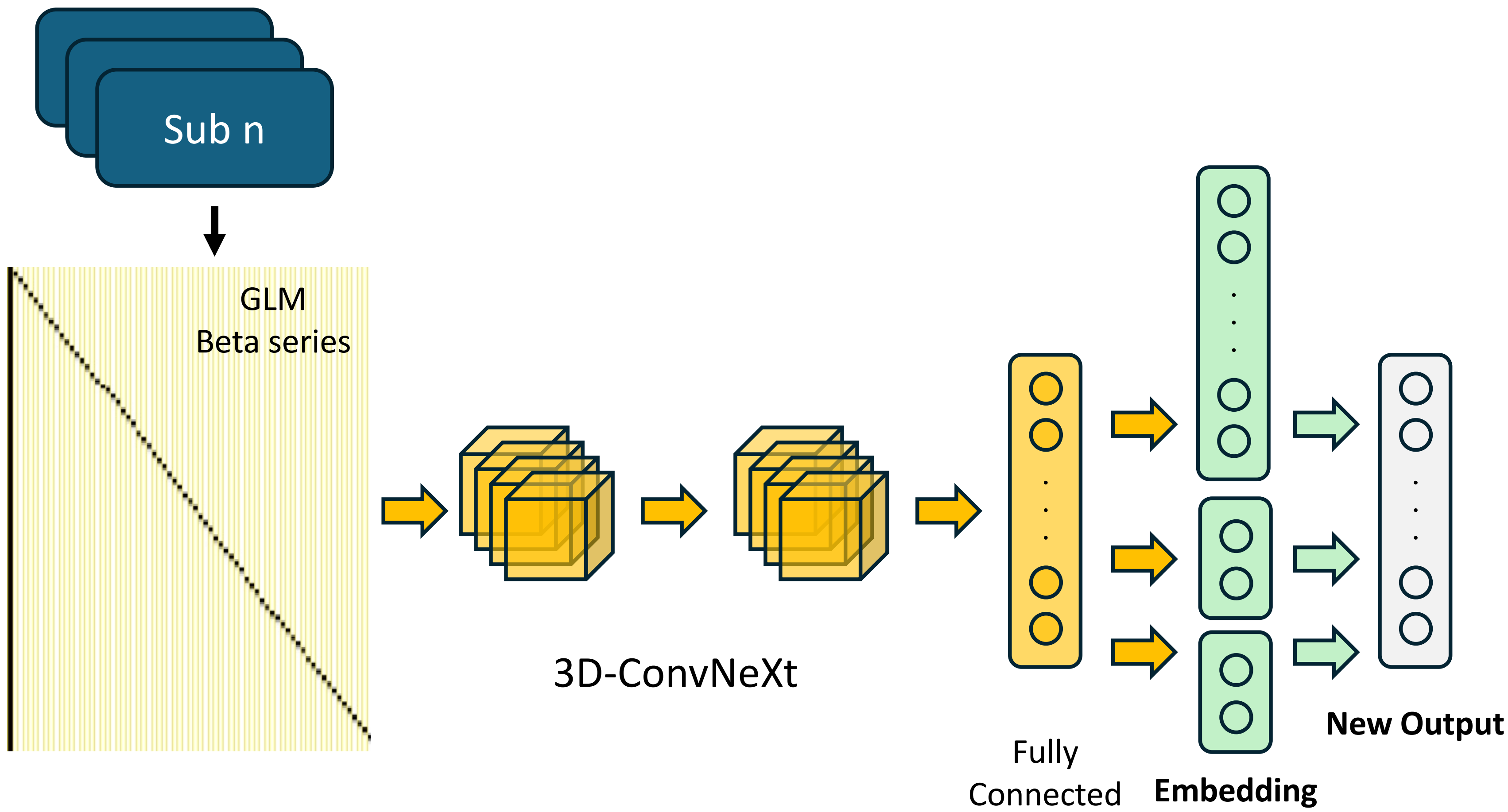
- Individual different can be detected with multi-head design.

- Multi-head structure can also handle several factors at once.

Multi-Head Structure

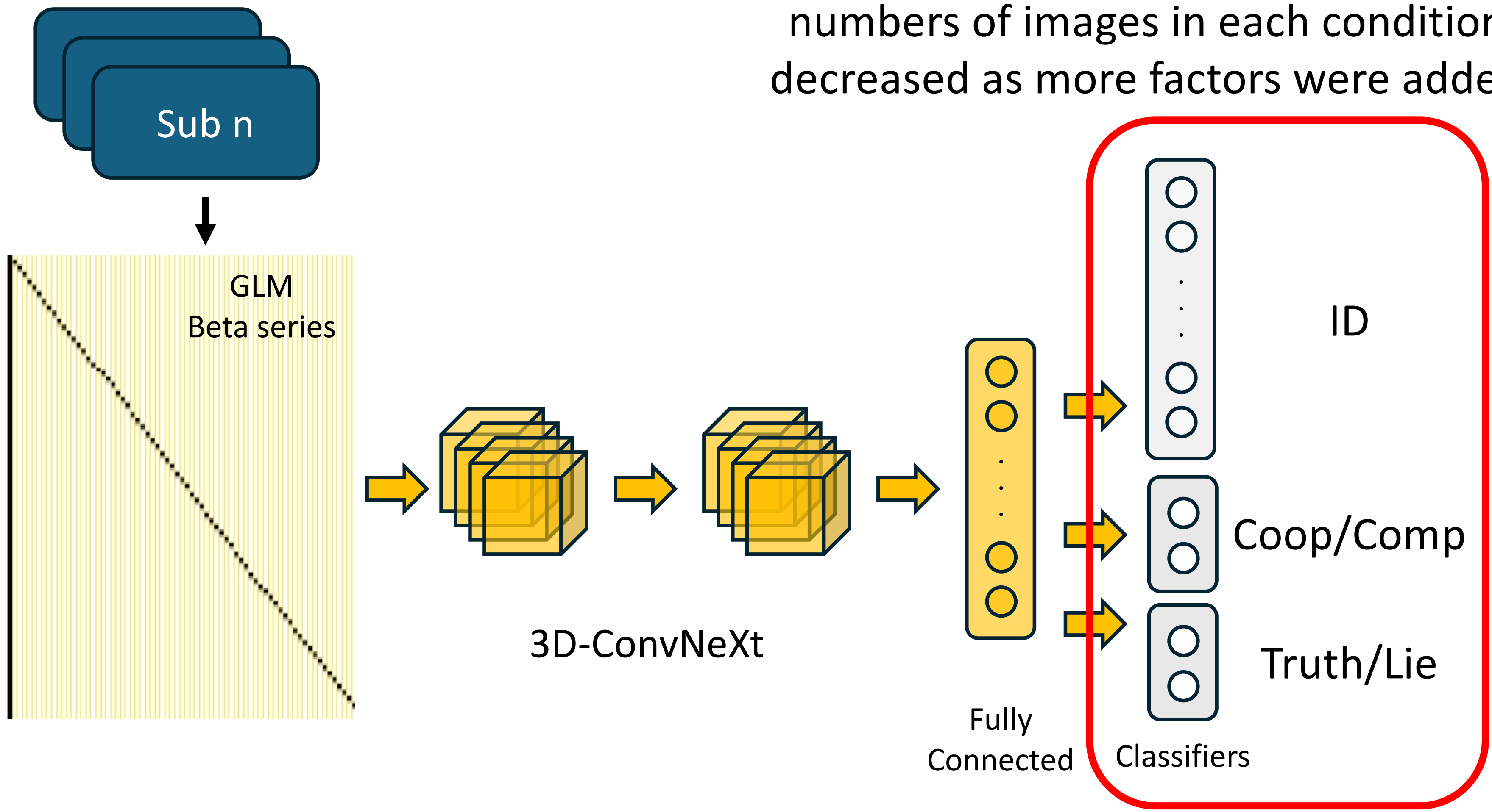


Multi-Head for Embedding



Multi-Head Structure

numbers of images in each condition
decreased as more factors were added



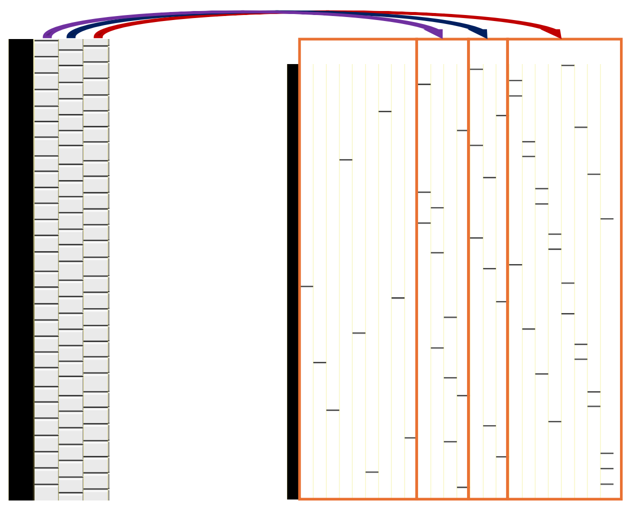
Subsampling GLM Trick for Training Data

Loop 12 times

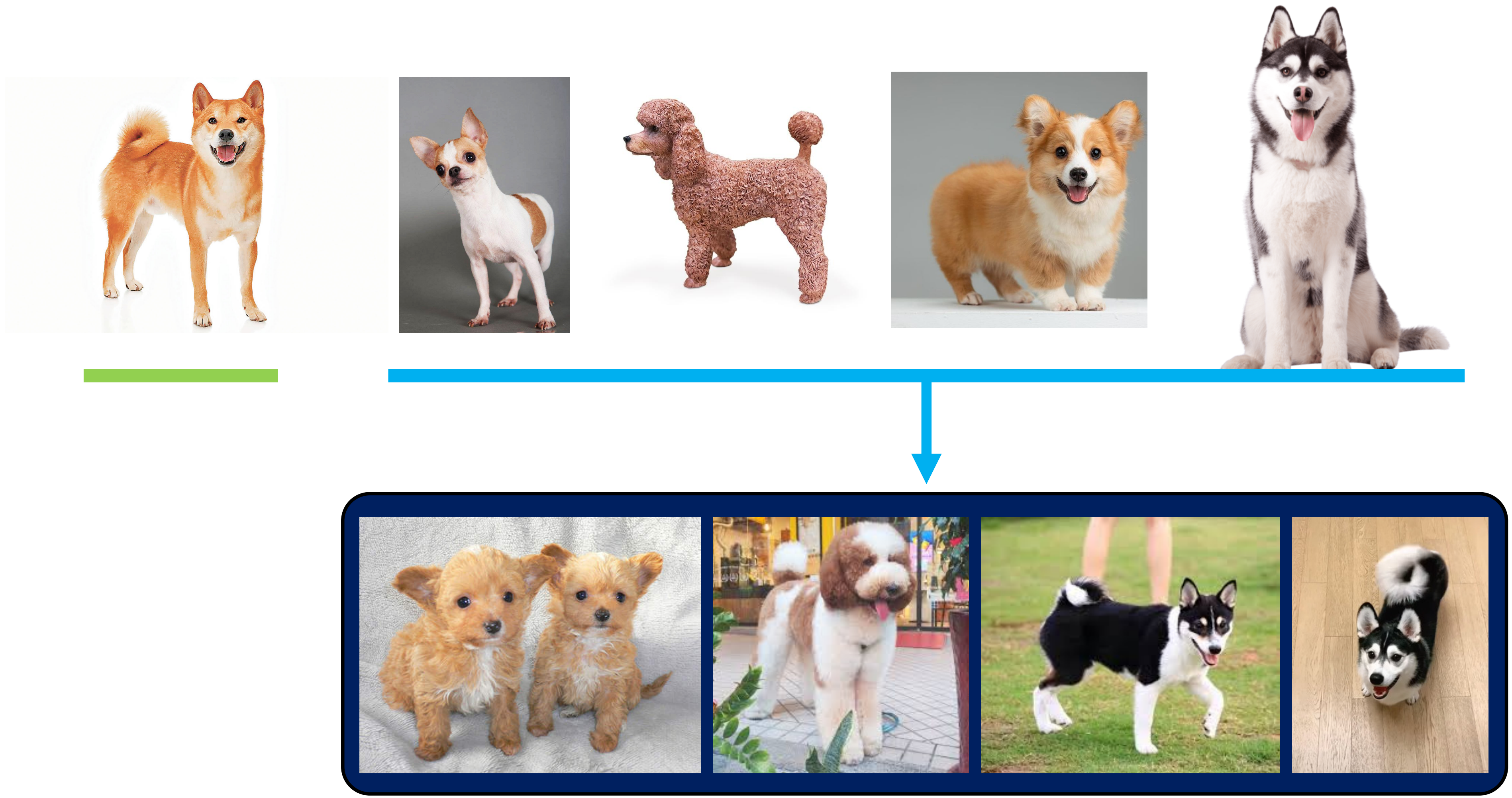
12 trials ⟶ 1 test 11 train

Up to 84 images!

12 trials ⟶ 3 test 9 train ⟶ Combinations of 3 out of 9



Hybrid to Create More Sample



Subsampling GLM Trick for Training Data

Loop 40 times

~20/20 trials → 1 test 39 train

~20/20 trials → 9 test ~16/16 train

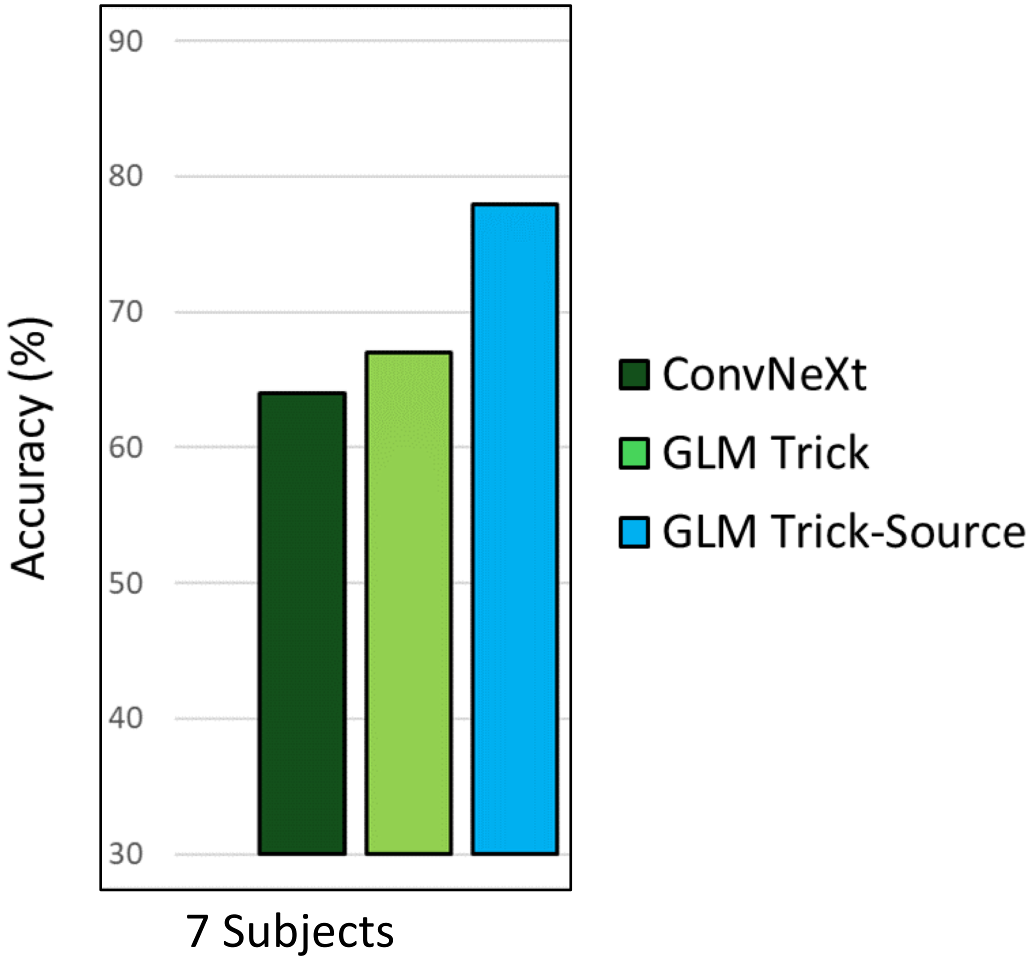
↓

Combinations of 3 out of 16

(Up to 560 images in each!)

Using 75 subsample images
in this experiment

Performance of Subsampling Trick

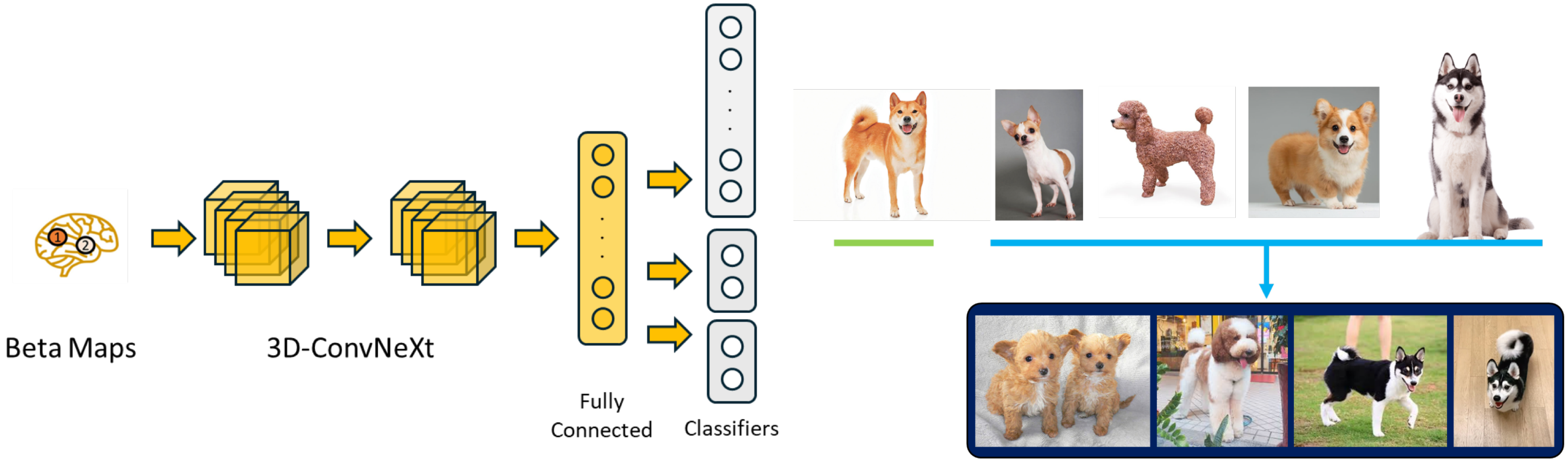


Summary

- Introduce new CNN architecture for MVPA
- Apply multi-head structure for complex conditions
- Design a subsampling trick to increase training data
- Advanced models can detect more hidden patterns underlying brain activation.
- Additional techniques are needed to better visualize and interpret those models.

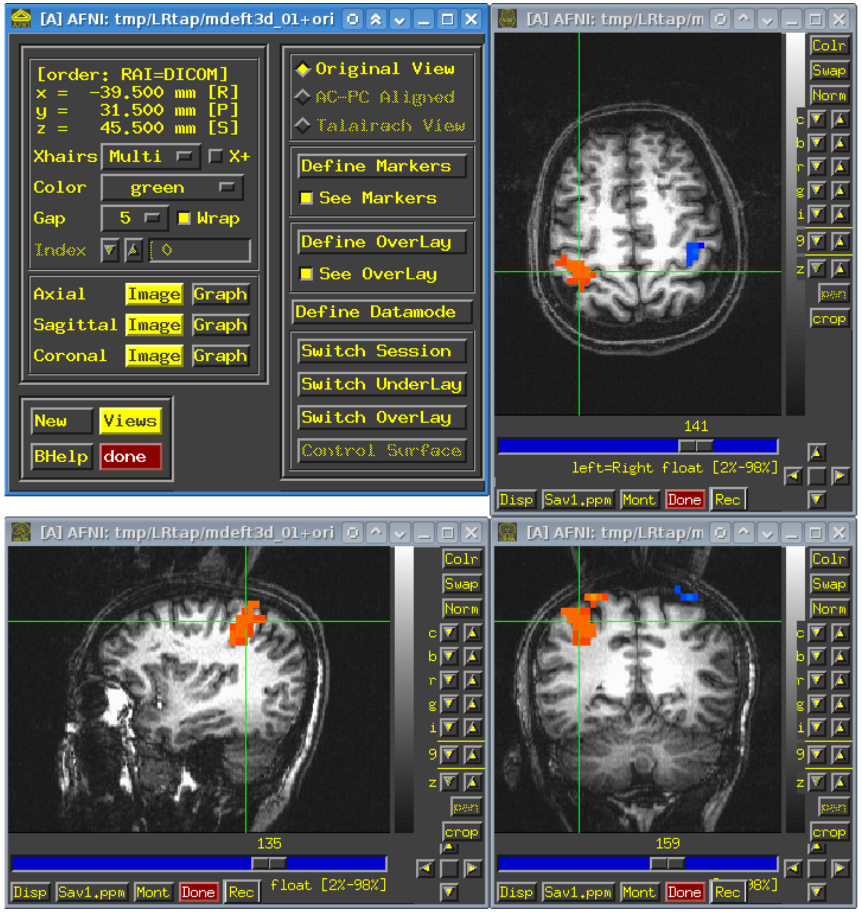
Thanks for your time and attention

Any question or suggestion is welcome!!



Multi-Head 3D-ConvNeXt

Data Preprocessing



afni.nimh.nih.gov

Major Python Packages

PyTorch

Major ANN programing tool

Nilearn

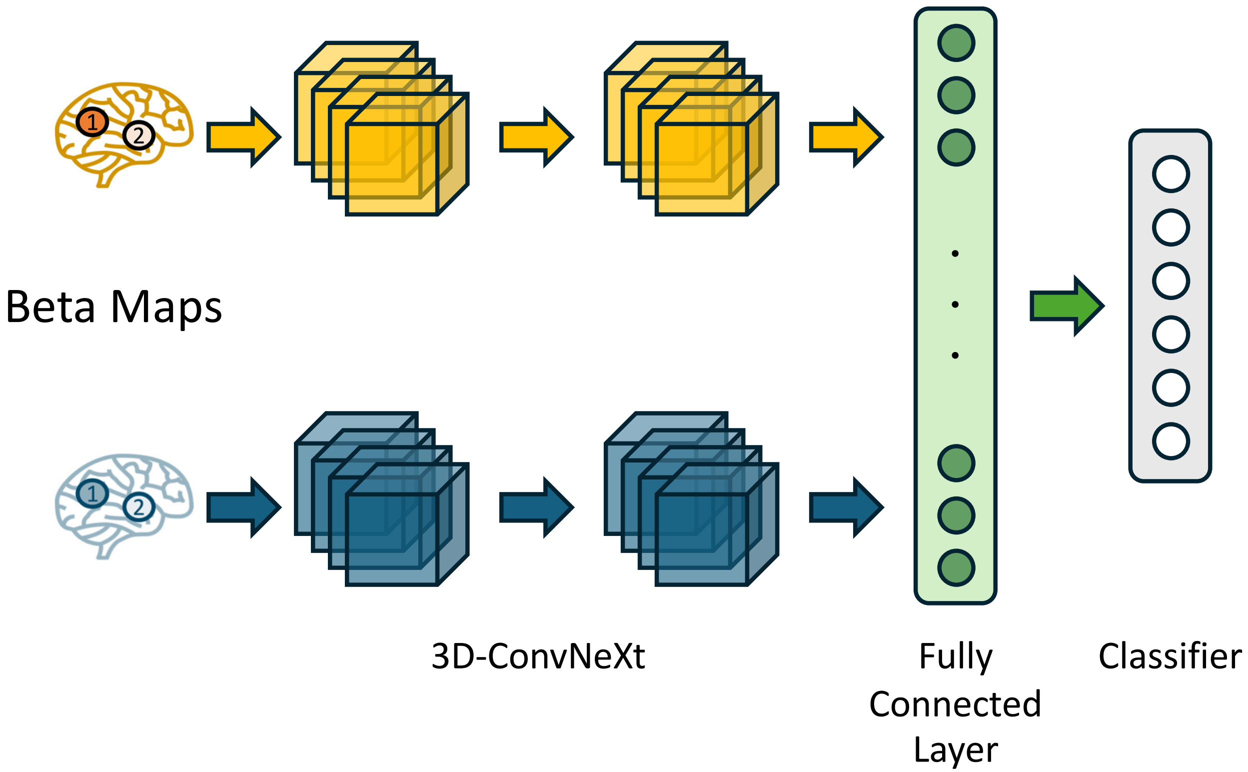
Designed for brain volumes analysis

**Able to directly handle AFNI output!!*

Also provides statistical and machine-learning tools

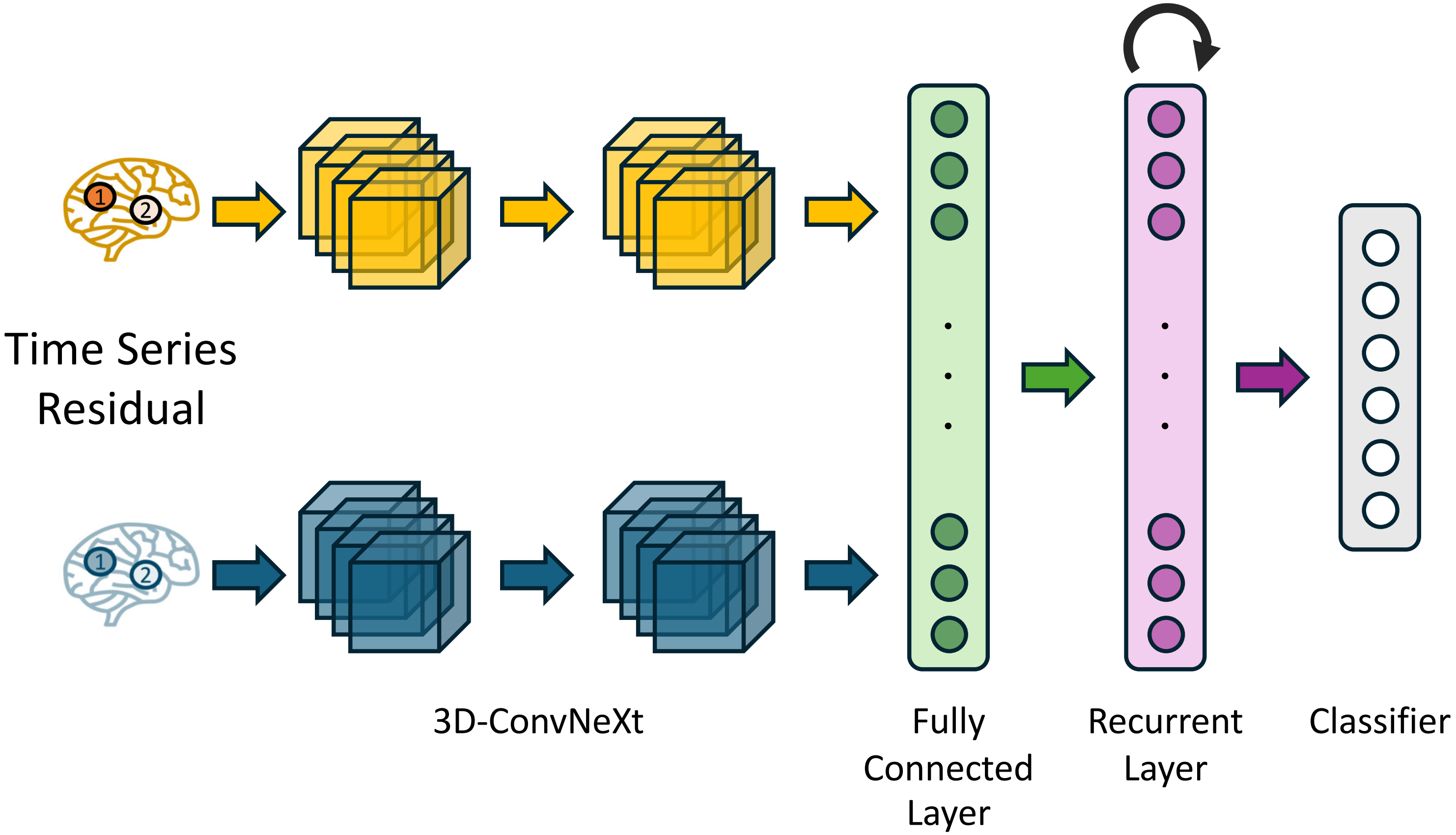
3D CNN on beta map

Tentative Architecture



3D CNN-RNN

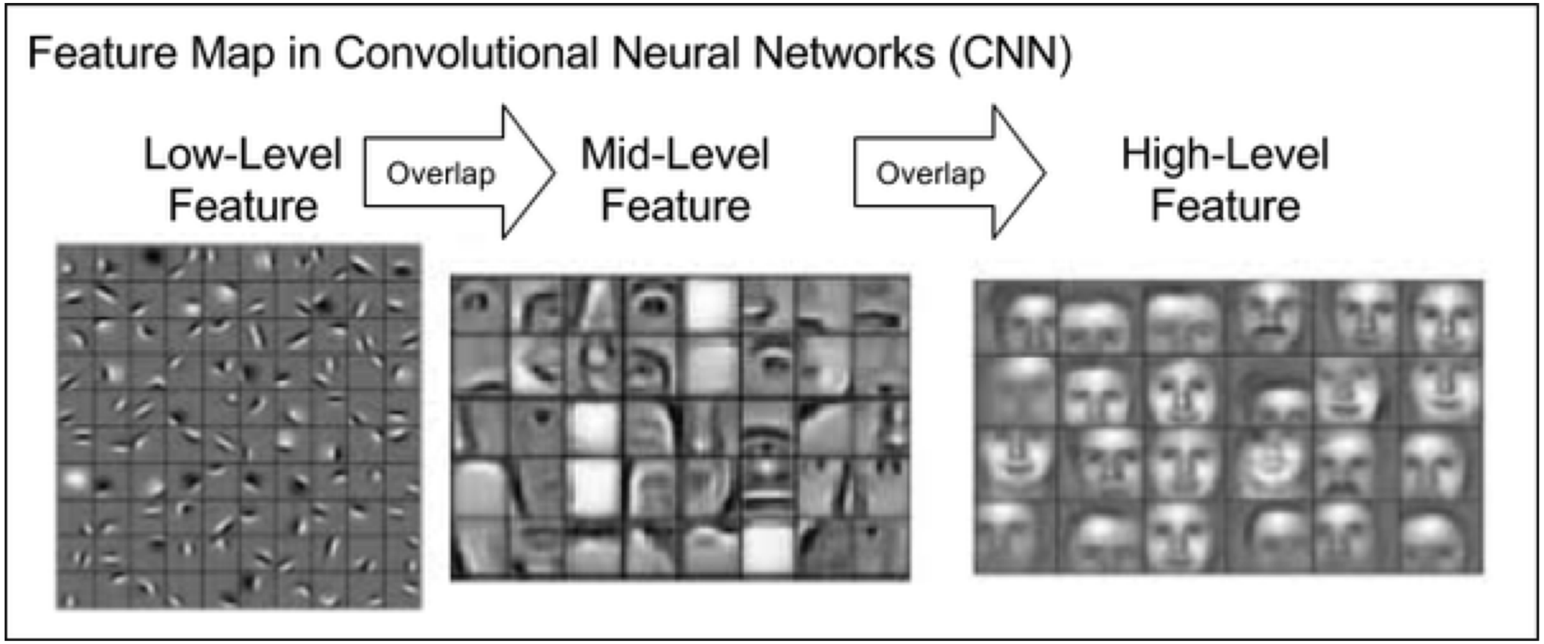
Tentative Architecture



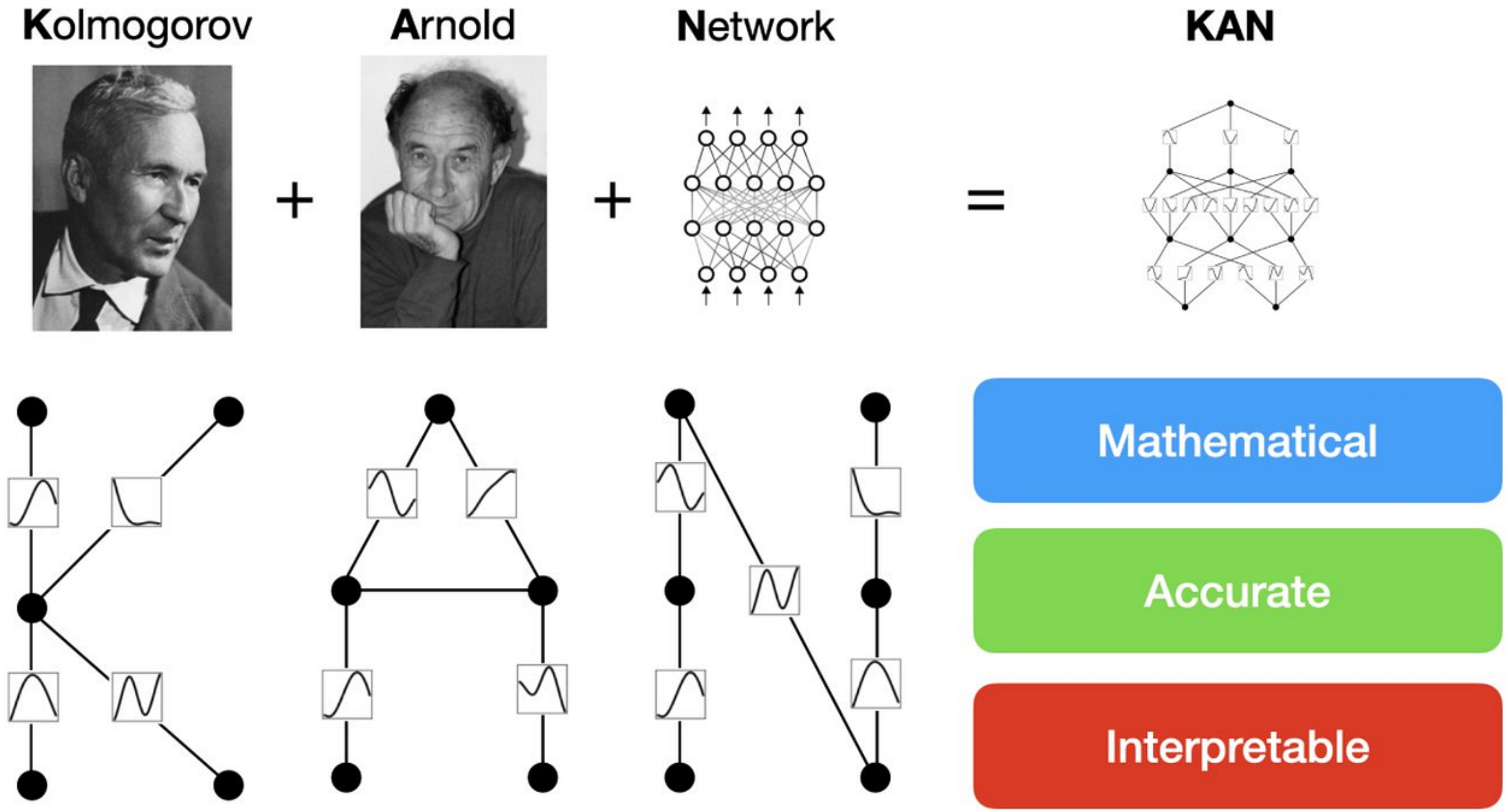
CNN Heat Map

arxiv.org/pdf/1512.04150

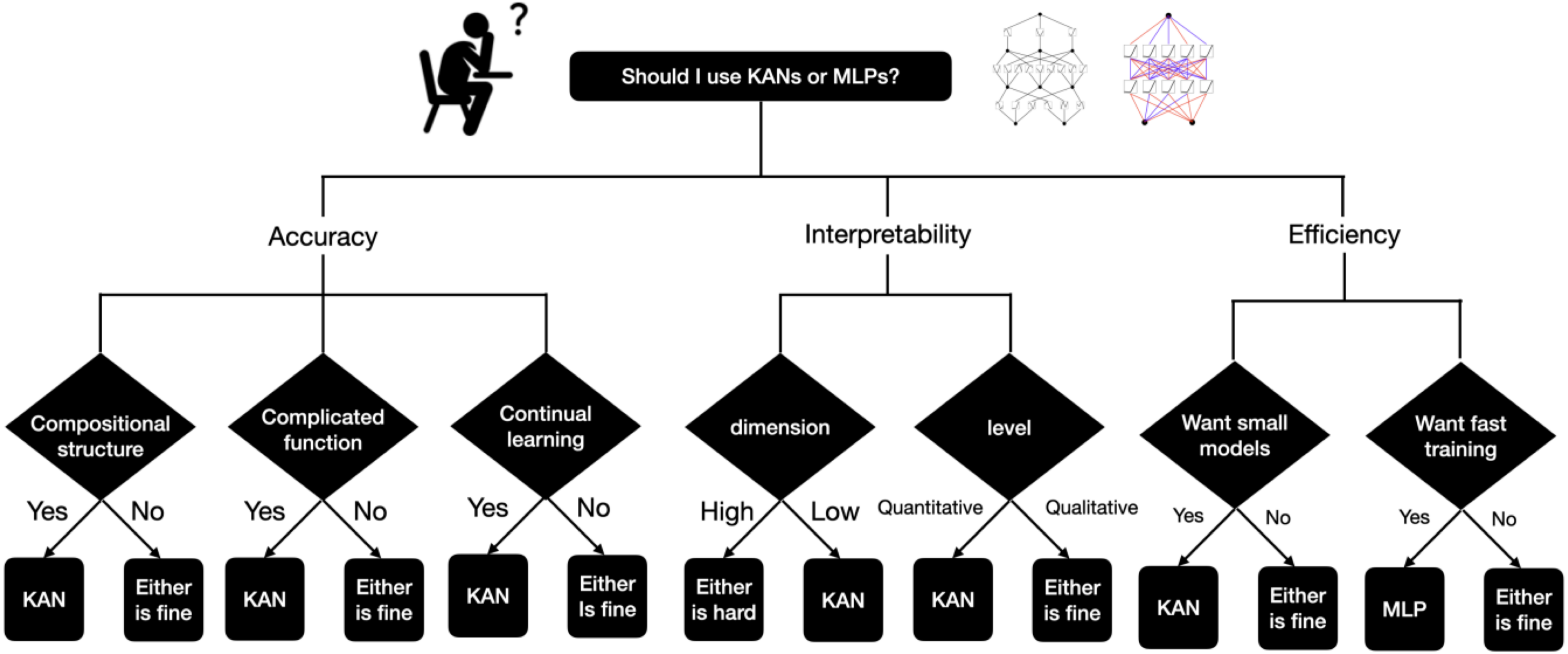
CNN Feature Map



First submitted to arXiv on April 30, 2024



Kolmogorov-Arnold Networks (KANs)



?
Should I use KANs or MLPs?
Accuracy
Interpretability
Efficiency
Compositional structure
Yes
No
KAN
Either is fine
Complicated function
Yes
No
KAN
Either is fine
Continual learning
Yes
No
KAN
Either Is fine
dimension
High
Low
Either is hard
KAN
level
Quantitative
Qualitative
KAN
Either is fine
Want small models
Yes
No
KAN
Either is fine
Want fast training
Yes
No
MLP
Either is fine

```python
class attention2d(nn.Module):
    def __init__(self, in_planes, ratios, K, temperature, init_weight=True):
        super(attention2d, self).__init__()
        assert temperature % 3 == 1
        self.avgpool = nn.AdaptiveAvgPool2d(1)
        if in_planes != 3:
            hidden_planes = int(in_planes * ratios) + 1
        else:
            hidden_planes = K
        self.fc1 = nn.Conv2d(in_planes, hidden_planes, 1, bias=False)
        self.fc2 = nn.Conv2d(hidden_planes, K, 1, bias=True)
```

```python
self.weight = nn.Parameter(torch.randn(K, out_planes, in_planes//groups, kernel_size, kernel_size)
```

```python
aggregate_weight = torch.mm(softmax_attention, weight)
```