# EEG Conformer: Convolutional Transformer for EEG Decoding and Visualization

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**Publication Topics**

Temporal Features, Convolutional Neural Network, Data Augmentation, EEG Signals, Motor Imagery, Average Accuracy, Classification Performance, Common Spatial Pattern, Convolution Module, Deep Learning, EEG Classification, EEG Data

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301

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**EEG conformer**: Convolutional transformer for **EEG** decoding and visualization

Y Song, Q Zheng, B Liu, X Gao - IEEE Transactions on Neural …, 2022 - ieeexplore.ieee.org

… Therefore, inspired by the works above, we propose the **EEG Conformer** as an efficient …

4, we explore the effect of depth on **EEG Conformer** by gradually increasing the layers of self-…

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# II. Purpose

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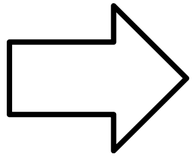
## Standard EEG Model

- CNNs
- Good at Local Feature Extraction
- Problem at Long Term Depedencies



## EEG Conformer

- CNN + Transformer
- Good at Local Feature Extraction
- Can learn Global Dependencies

# III. Dataset

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**Dataset I**

- BCI Competition IV 2a & 2b
- 4-class classification
- Motor imagery task (left-hand, right-hand, both feet, and tongue

**Dataset II**

- BCI Competition IV 2b
- Binary classification
- Motor imagery tasks (left and right hand)

**Dataset III**

- SEED dataset
- 3-class classification
- Emotions(positive, neutral, and negative)

# III. Preprocessing

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**Band-pass Filtering**

**Filter out extraneouse high and low-frequency noise**

**Standardization**

**Reduce the fluctuation and nonstationarity with “Z-Score”**

# IV. Architecture

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**Convolution Module**

- Temporal Convolution
- Spatial Convolution
- Average Pooling
- Tokenization

**Self-Attention Module**

- Q, K, V
- Multi-Head Attention

**Classifier Module**

- Fully-connected Layer

# IV. Architecture

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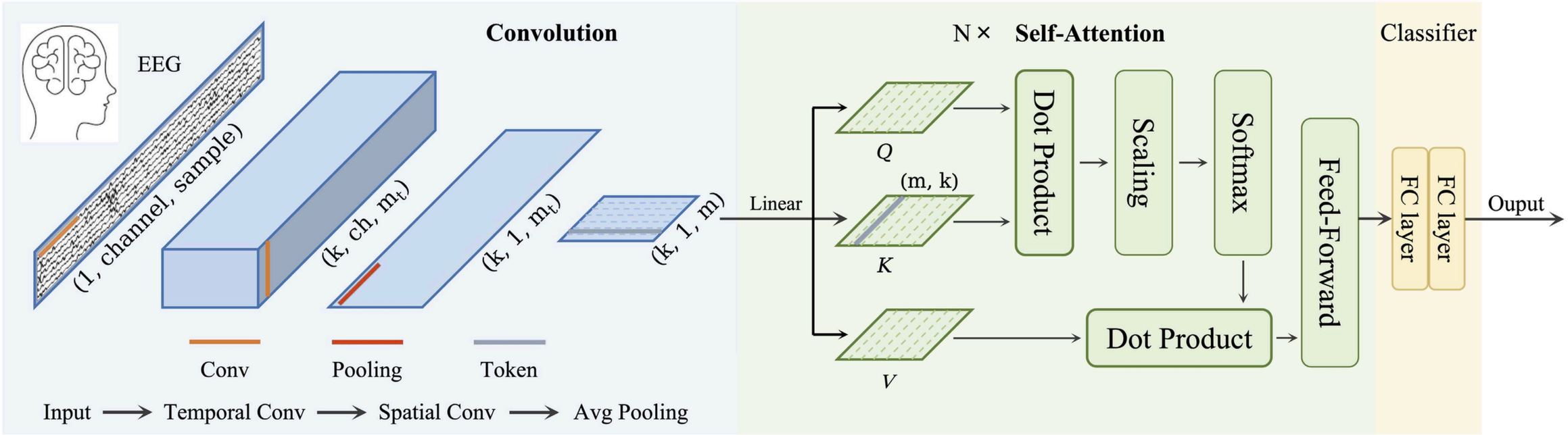

# IV. Architecture

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**Attention-Score**

**Multi-head Attention**

# V. Performance

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## Kappa Coefficient

**is average accuracy of all trials.**
**is accuracy of random guesses.**

# V. Performance

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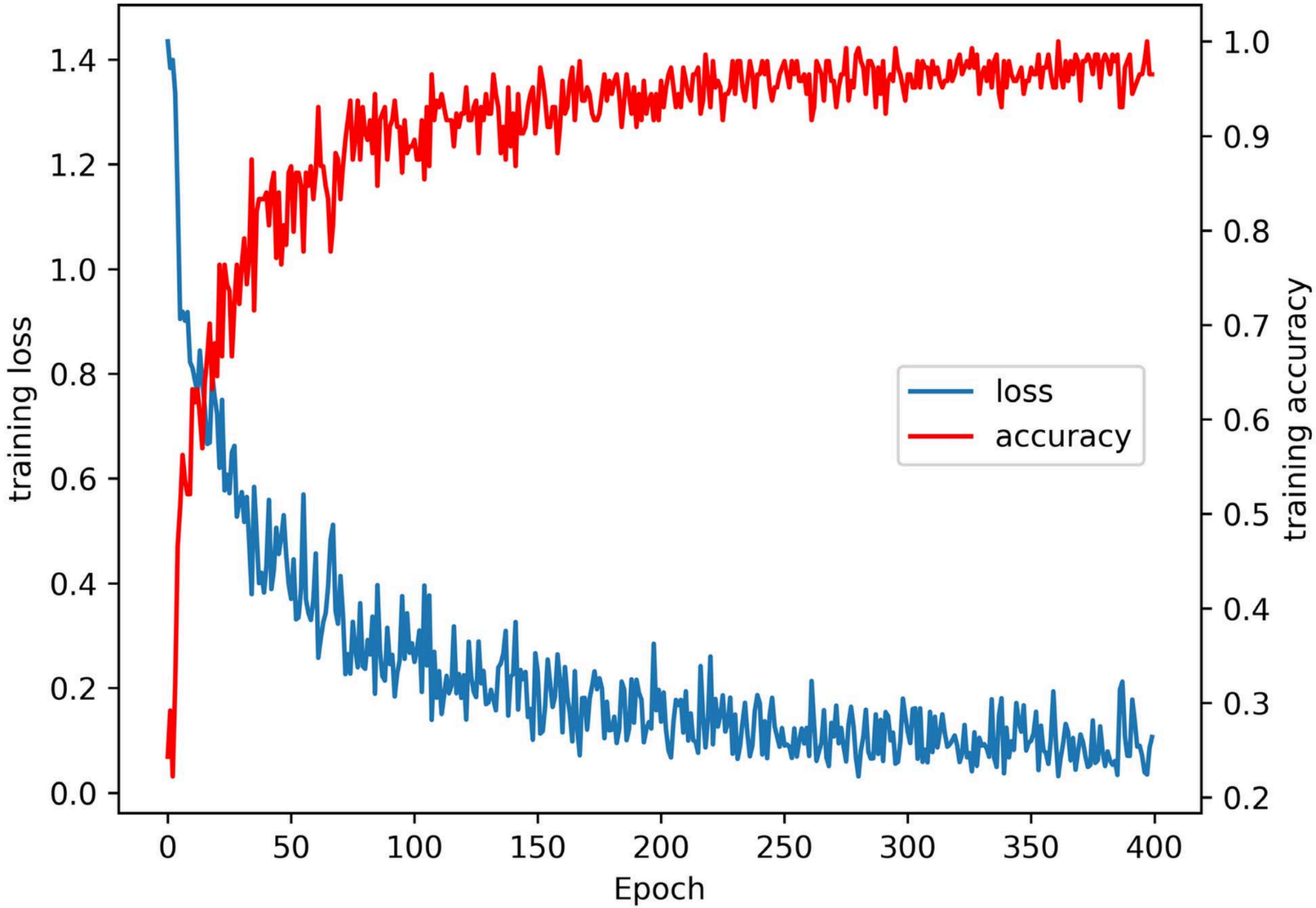

# V. Performance

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TABLE II
COMPARISONS WITH STATE-OF-THE-ART METHODS ON DATASETS I

| datasets | methods | S01 | S02 | S03 | S04 | S05 | S06 | S07 | S08 | S09 | average | kappa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | FBCSP [8] | 76.00 | 56.50 | 81.25 | 61.00 | 55.00 | 45.25 | 82.75 | 81.25 | 70.75 | 67.75 | 0.5700 |
| | ConvNet [16] | 76.39 | 55.21 | 89.24 | 74.65 | 56.94 | 54.17 | 92.71 | 77.08 | 76.39 | 72.53 | 0.6337 |
| | EEGNet [17] | 85.76 | 61.46 | 88.54 | 67.01 | 55.90 | 52.08 | 89.58 | 83.33 | 86.81 | 74.50 | 0.6600 |
| | C2CM [28] | 87.50 | **65.28** | 90.28 | 66.67 | 62.50 | 45.49 | 89.58 | 83.33 | 79.51 | 74.46 | 0.6595 |
| | FBCNet [38] | 85.42 | 60.42 | 90.63 | 76.39 | **74.31** | 53.82 | 84.38 | 79.51 | 80.90 | 76.20 | 0.6827 |
| | DRDA [39] | 83.19 | 55.14 | 87.43 | 75.28 | 62.29 | 57.15 | 86.18 | 83.61 | 82.00 | 74.74 | 0.6632 |
| | **Conformer** | **88.19** | 61.46 | **93.40** | **78.13** | 52.08 | **65.28** | **92.36** | **88.19** | **88.89** | **78.66** | **0.7155** |

TABLE III
COMPARISONS WITH STATE-OF-THE-ART METHODS ON DATASETS II

| datasets | methods | S01 | S02 | S03 | S04 | S05 | S06 | S07 | S08 | S09 | average | kappa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| II | FBCSP [8] | 70.00 | 60.36 | 60.94 | 97.50 | 93.12 | 80.63 | 78.13 | 92.50 | 86.88 | 80.00 | 0.6000 |
| | ConvNet [16] | 76.56 | 50.00 | 51.56 | 96.88 | **93.13** | 85.31 | 83.75 | 91.56 | 85.62 | 79.37 | 0.5874 |
| | EEGNet [17] | 75.94 | 57.64 | 58.43 | 98.13 | 81.25 | 88.75 | 84.06 | 93.44 | 89.69 | 80.48 | 0.6096 |
| | DRDA [39] | 81.37 | 62.86 | 63.63 | 95.94 | 93.56 | 88.19 | 85.00 | **95.25** | 90.00 | 83.98 | 0.6796 |
| | **Conformer** | **82.50** | **65.71** | **63.75** | **98.44** | 86.56 | **90.31** | **87.81** | 94.38 | **92.19** | **84.63** | **0.6926** |

# V. Performance

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TABLE IV
COMPARISONS WITH STATE-OF-THE-ART METHODS ON DATASETS III

| datasets | methods | accuracy | kappa |
|---|---|---|---|
| III | SVM [36] | 86.08 | 0.7912 |
| | GELM [40] | 91.07 | 0.8661 |
| | DGCNN [41] | 90.40 | 0.8560 |
| | R2G-STNN [42] | 93.38 | 0.9007 |
| | RGNN [43] | 94.24 | 0.9136 |
| | **Conformer** | **95.30** | **0.9295** |

# VI. Ablation Analysis(on Dataset I)

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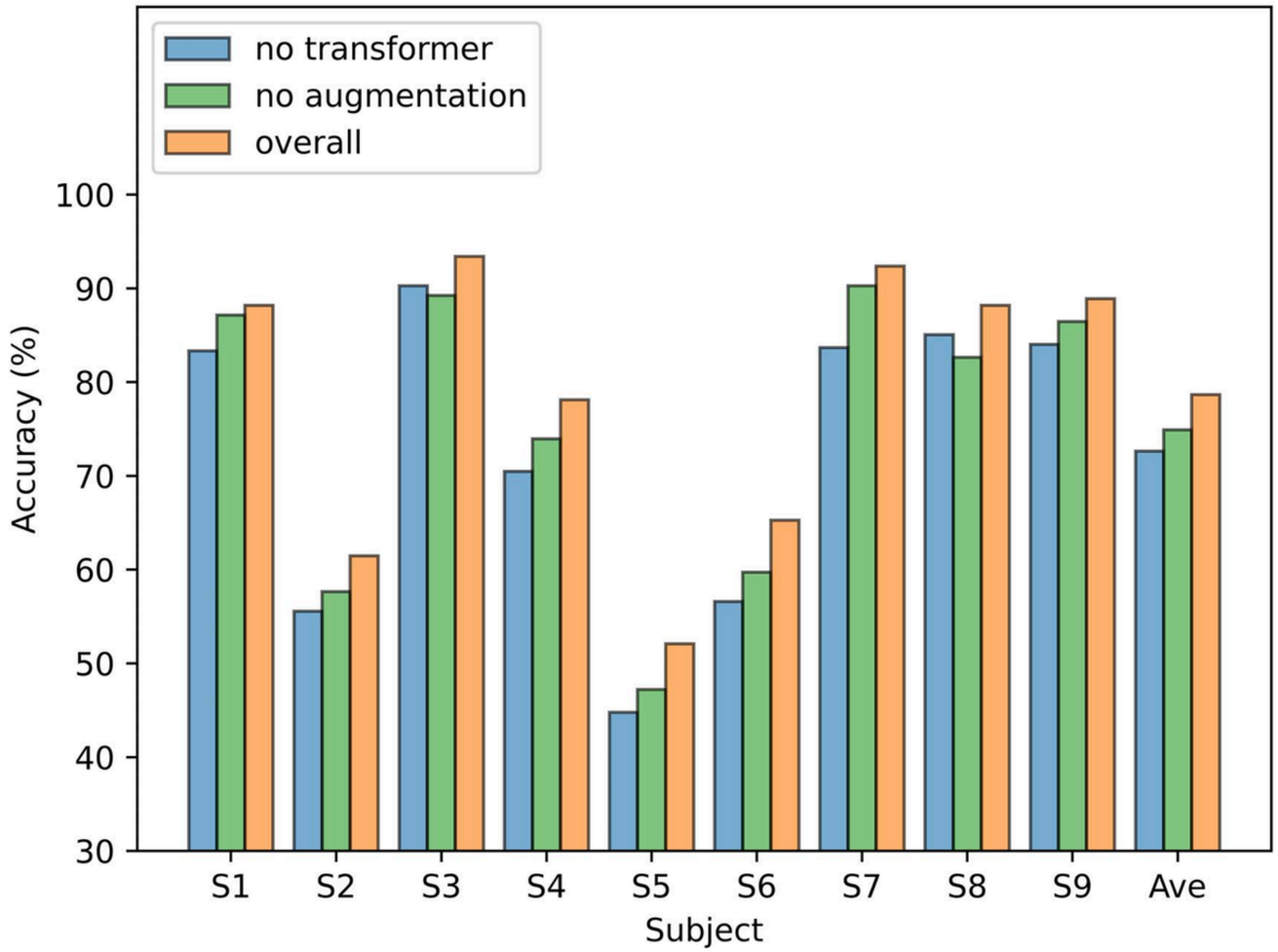

# VII. Parameter Sensitivity

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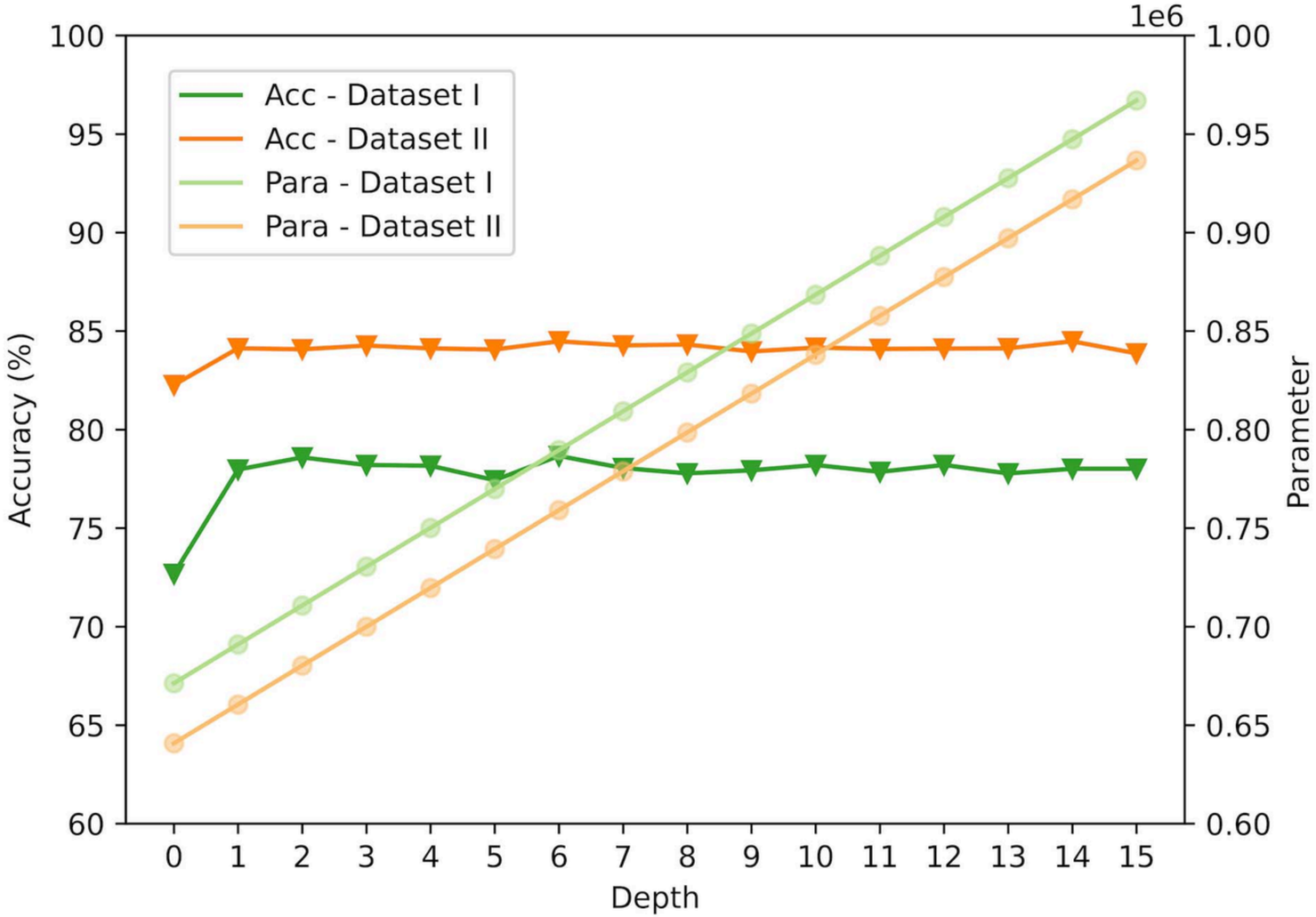

# VIII. Heads sensitivity

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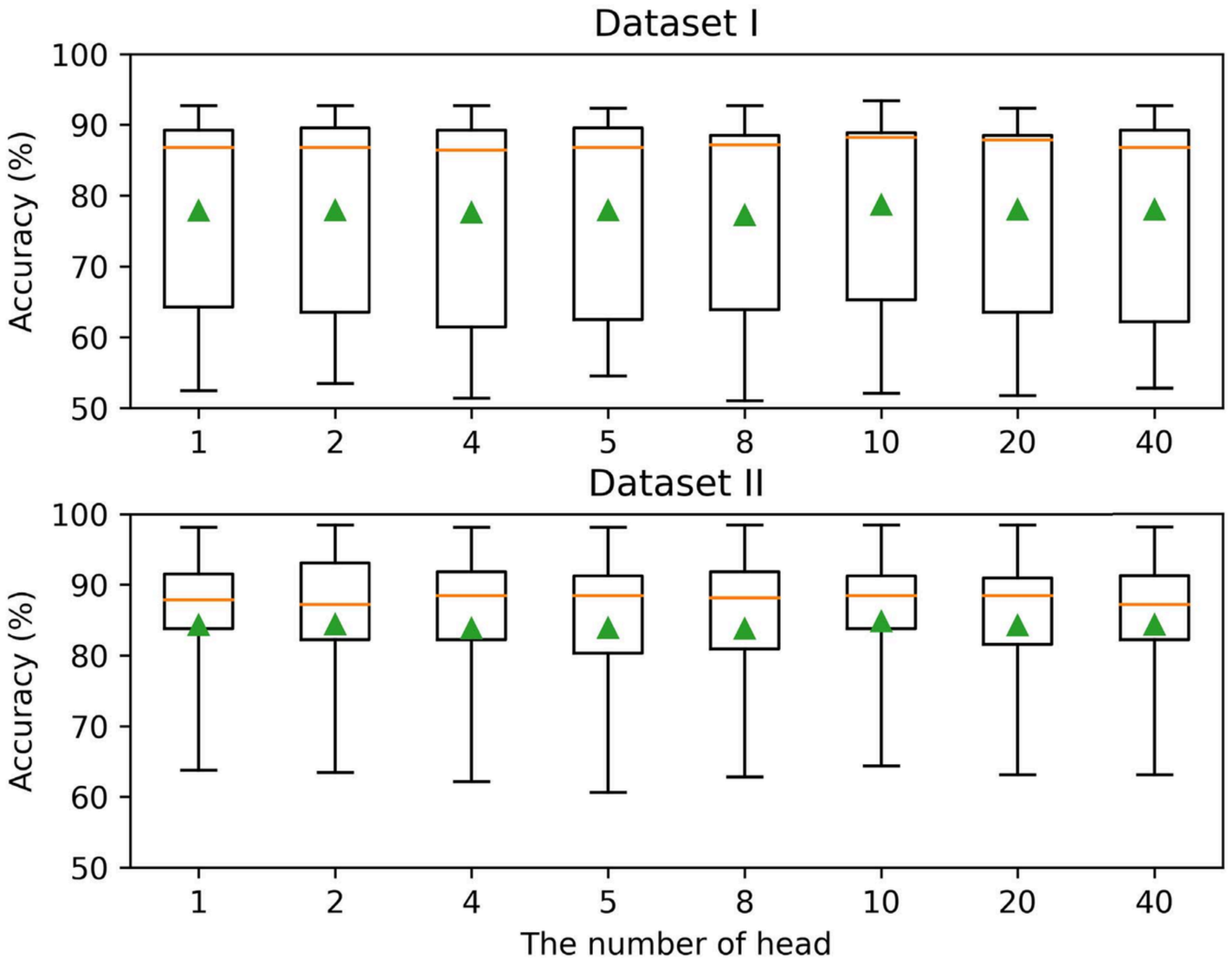

# IX. Kernel sizes in the pooling layer

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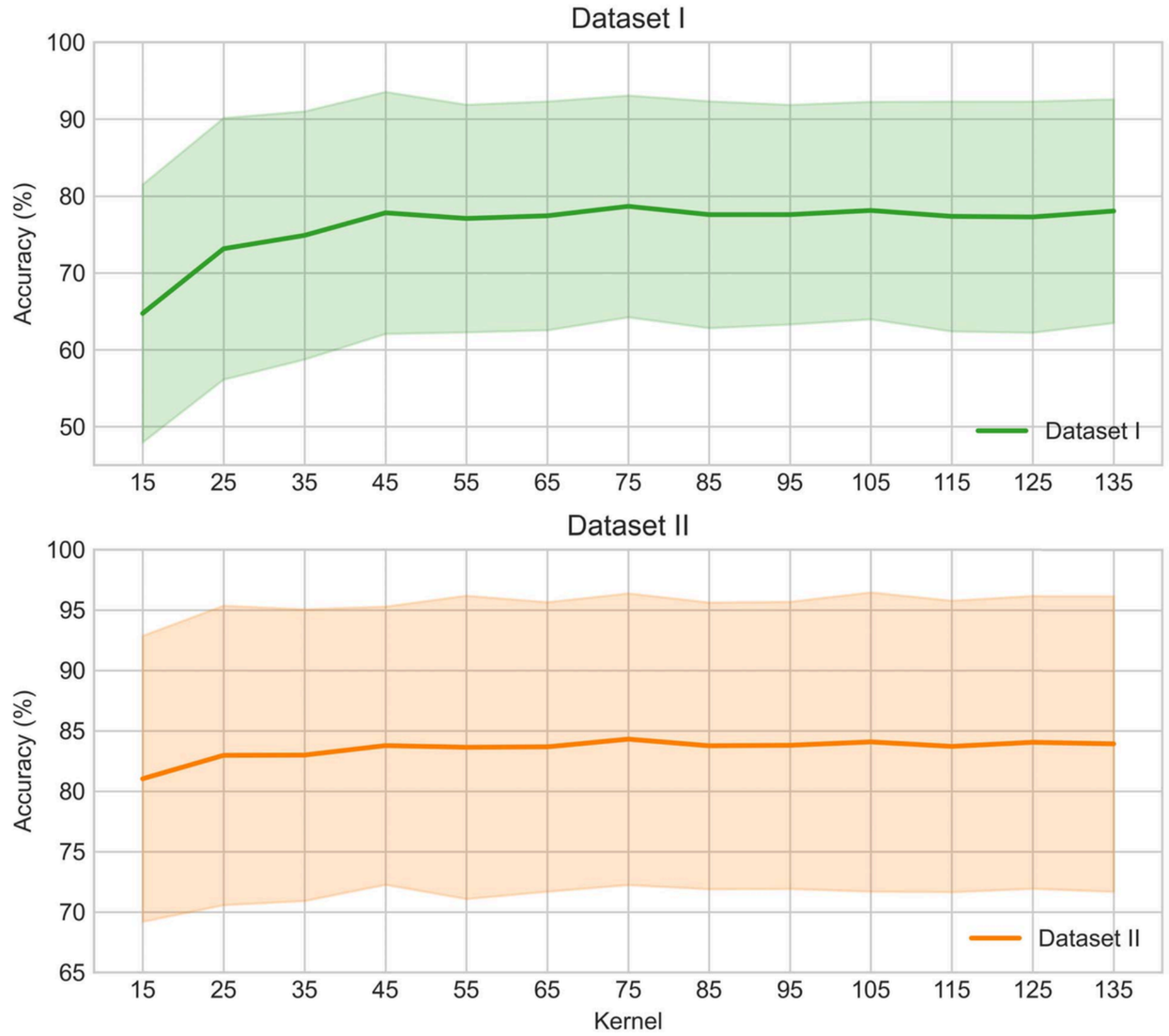

# X. t-SNE

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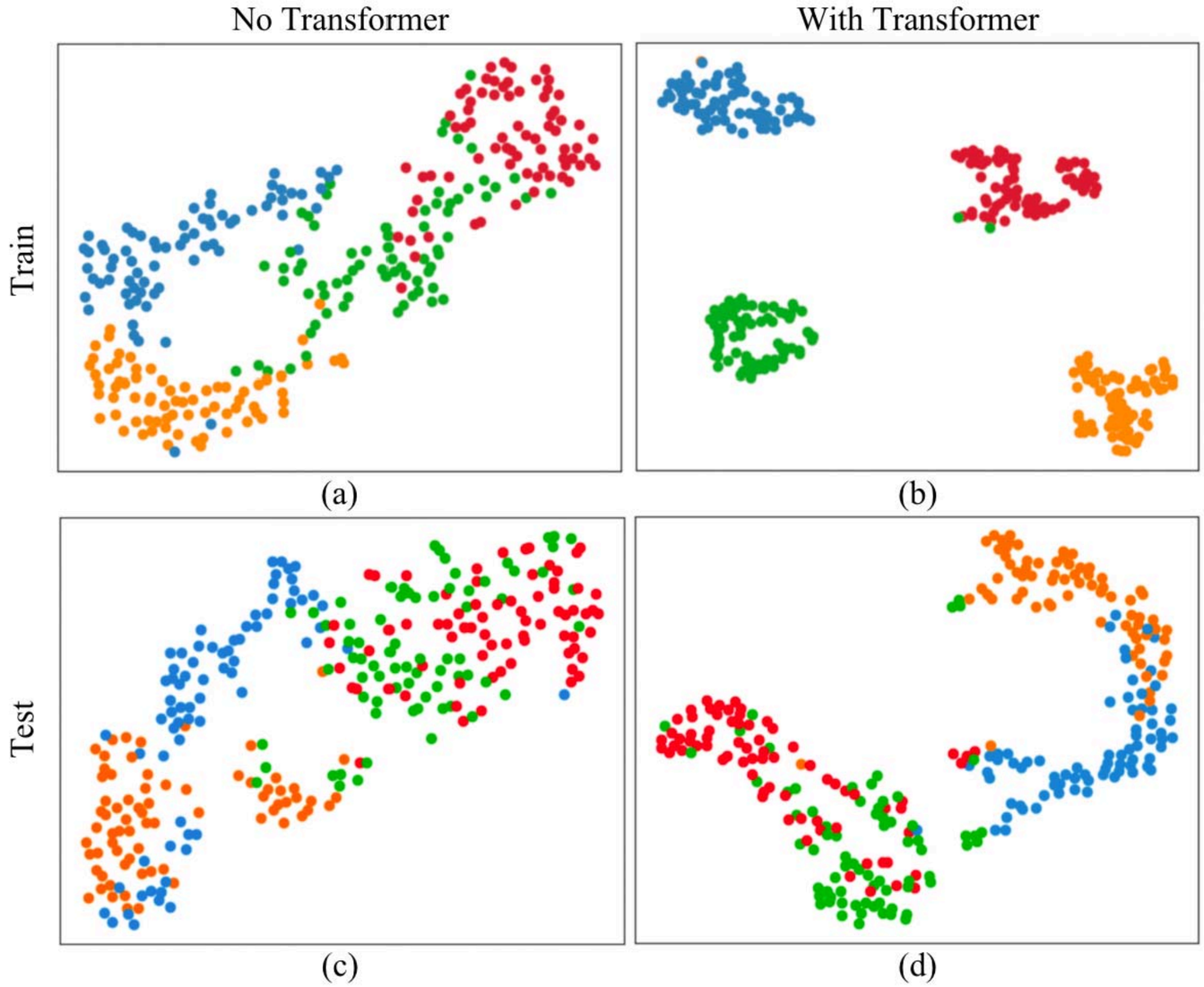

# XI. Visualization

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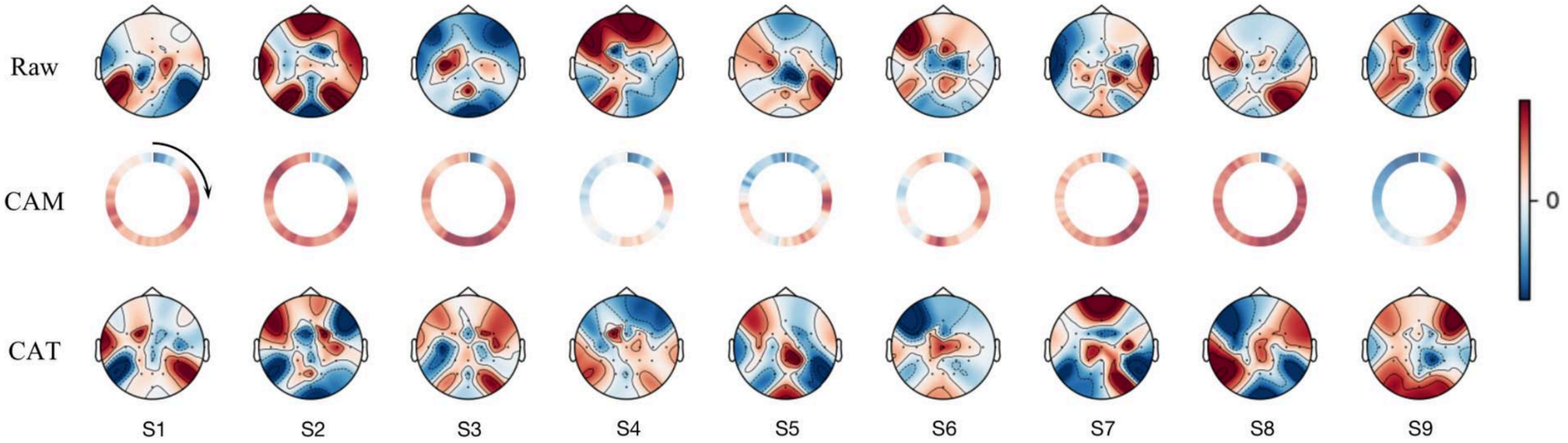

# XI. Visualization

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