# Supplementary Materials On: "A Simple Subject Independent Channel Selection in EEG for Motor Imagery Task"

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## I. Selected Channels

Table I
Channel Ranking as per Subject Independent for BCIC 3 4a Dataset

| Rank | Ch Num | Ch Name | Rank | Ch Num | Ch Name | Rank | Ch Num | Ch Name |
|---|---|---|---|---|---|---|---|---|
| 1 | 52 | ’C3’ | 41 | 90 | ’P1’ | 81 | 40 | ’FT8’ |
| 2 | 54 | ’Cz’ | 42 | 79 | ’PCP5’ | 82 | 101 | ’PPO6’ |
| 3 | 56 | ’C4’ | 43 | 74 | ’CP4’ | 83 | 113 | ’Oz’ |
| 4 | 45 | ’CFC1’ | 44 | 59 | ’CCP7’ | 84 | 95 | ’P8’ |
| 5 | 63 | ’CCP2’ | 45 | 83 | ’PCP4’ | 85 | 104 | ’PO3’ |
| 6 | 62 | ’CCP1’ | 46 | 75 | ’CP6’ | 86 | 116 | ’OI2’ |
| 7 | 53 | ’C1’ | 47 | 29 | ’FFC6’ | 87 | 114 | ’O2’ |
| 8 | 72 | ’CPz’ | 48 | 89 | ’P3’ | 88 | 67 | ’TP9’ |
| 9 | 55 | ’C2’ | 49 | 49 | ’CFC8’ | 89 | 31 | ’FT9’ |
| 10 | 46 | ’CFC2’ | 50 | 66 | ’CCP8’ | 90 | 115 | ’OI1’ |
| 11 | 44 | ’CFC3’ | 51 | 24 | ’FFC5’ | 91 | 30 | ’FFC8’ |
| 12 | 34 | ’FC3’ | 52 | 68 | ’TP7’ | 92 | 102 | ’PPO8’ |
| 13 | 35 | ’FC1’ | 53 | 93 | ’P4’ | 93 | 108 | ’PO4’ |
| 14 | 61 | ’CCP3’ | 54 | 99 | ’PPO1’ | 94 | 112 | ’O1’ |
| 15 | 73 | ’CP2’ | 55 | 84 | ’PCP6’ | 95 | 103 | ’PO7’ |
| 16 | 47 | ’CFC4’ | 56 | 76 | ’TP8’ | 96 | 11 | ’FAF1’ |
| 17 | 71 | ’CP1’ | 57 | 78 | ’PCP7’ | 97 | 23 | ’FFC7’ |
| 18 | 36 | ’FCz’ | 58 | 20 | ’F4’ | 98 | 96 | ’P10’ |
| 19 | 81 | ’PCP1’ | 59 | 28 | ’FFC4’ | 99 | 41 | ’FT10’ |
| 20 | 43 | ’CFC5’ | 60 | 18 | ’Fz’ | 100 | 22 | ’F8’ |
| 21 | 91 | ’Pz’ | 61 | 100 | ’PPO2’ | 101 | 109 | ’PO8’ |
| 22 | 26 | ’FFC1’ | 62 | 58 | ’T8’ | 102 | 86 | ’P9’ |
| 23 | 82 | ’PCP2’ | 63 | 50 | ’T7’ | 103 | 15 | ’F5’ |
| 24 | 60 | ’CCP5’ | 64 | 85 | ’PCP8’ | 104 | 12 | ’FAF2’ |
| 25 | 37 | ’FC2’ | 65 | 98 | ’PPO5’ | 105 | 10 | ’FAF5’ |
| 26 | 48 | ’CFC6’ | 66 | 42 | ’CFC7’ | 106 | 14 | ’F7’ |
| 27 | 38 | ’FC4’ | 67 | 88 | ’P5’ | 107 | 117 | ’I1’ |
| 28 | 25 | ’FFC3’ | 68 | 105 | ’PO1’ | 108 | 13 | ’FAF6’ |
| 29 | 65 | ’CCP6’ | 69 | 107 | ’PO2’ | 109 | 7 | ’AF3’ |
| 30 | 64 | ’CCP4’ | 70 | 106 | ’POz’ | 110 | 8 | ’AF4’ |
| 31 | 27 | ’FFC2’ | 71 | 21 | ’F6’ | 111 | 9 | ’AF8’ |
| 32 | 80 | ’PCP3’ | 72 | 77 | ’TP10’ | 112 | 4 | ’AFp2’ |
| 33 | 70 | ’CP3’ | 73 | 19 | ’F2’ | 113 | 6 | ’AF7’ |
| 34 | 33 | ’FC5’ | 74 | 17 | ’F1’ | 114 | 2 | ’AFp1’ |
| 35 | 69 | ’CP5’ | 75 | 97 | ’PPO7’ | 115 | 5 | ’Fp2’ |
| 36 | 57 | ’C6’ | 76 | 87 | ’P7’ | 116 | 3 | ’Fpz’ |
| 37 | 51 | ’C5’ | 77 | 111 | ’OPO2’ | 117 | 1 | ’Fp1’ |
| 38 | 92 | ’P2’ | 78 | 32 | ’FT7’ | 118 | 118 | ’I2’ |
| 39 | 39 | ’FC6’ | 79 | 94 | ’P6’ | | | |
| 40 | 16 | ’F3’ | 80 | 110 | ’OPO1’ | | | |

Table II
SELECTED CHANNEL RANK FOR SUBJECT INDEPENDENT MODEL FOR PHYSIONET DATASET

| Rank | Ch Num | Ch Name | Rank | Ch Num | Ch Name | Rank | Ch Num | Ch Name |
|---|---|---|---|---|---|---|---|---|
| 1 | 11 | Cz | 23 | 52 | P2 | 45 | 64 | Iz |
| 2 | 10 | C1 | 24 | 2 | FC3 | 46 | 7 | FC6 |
| 3 | 12 | C2 | 25 | 49 | P3 | 47 | 40 | FT8 |
| 4 | 9 | C3 | 26 | 42 | T8 | 48 | 34 | Fz |
| 5 | 13 | C4 | 27 | 6 | FC4 | 49 | 33 | F1 |
| 6 | 18 | CPz | 28 | 54 | P6 | 50 | 32 | F3 |
| 7 | 8 | C5 | 29 | 50 | P1 | 51 | 35 | F2 |
| 8 | 16 | CP3 | 30 | 48 | P5 | 52 | 36 | F4 |
| 9 | 17 | CP1 | 31 | 55 | P8 | 53 | 31 | F5 |
| 10 | 20 | CP4 | 32 | 1 | FC5 | 54 | 30 | F7 |
| 11 | 19 | CP2 | 33 | 47 | P7 | 55 | 37 | F6 |
| 12 | 21 | CP6 | 34 | 43 | T9 | 56 | 27 | AFz |
| 13 | 14 | C6 | 35 | 44 | T10 | 57 | 25 | AF7 |
| 14 | 15 | CP5 | 36 | 57 | PO3 | 58 | 26 | AF3 |
| 15 | 41 | T7 | 37 | 59 | PO4 | 59 | 38 | F8 |
| 16 | 4 | FCz | 38 | 39 | FT7 | 60 | 22 | Fp1 |
| 17 | 3 | FC1 | 39 | 58 | POz | 61 | 28 | AF4 |
| 18 | 46 | TP8 | 40 | 62 | Oz | 62 | 23 | Fpz |
| 19 | 5 | FC2 | 41 | 56 | PO7 | 63 | 29 | AF8 |
| 20 | 45 | TP7 | 42 | 60 | PO8 | 64 | 24 | Fp2 |
| 21 | 53 | P4 | 43 | 63 | O2 | | | |
| 22 | 51 | Pz | 44 | 61 | O1 | | | |

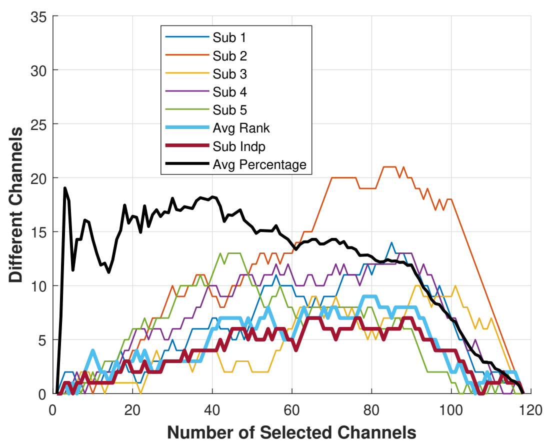


Figure 1. Number of different channels selected because of filtering the signal before channel selection for the BCICIVa [**?**]. It can be seen that with or without filtering algorithms share almost 85% of the channels.

## II. COMPARISON ALGORITHMS

### A. CSP Rank

Let $\mathbf{X}_y \in \mathbb{R}^{N \times M \times T \cdot S}$ is the EEG signal where $N, T$, and $S$ has the usual meaning. Then covariances are defined as

$$C_y = \frac{1}{T \cdot S} \sum_{i=1}^{T \cdot S} \frac{\mathbf{X}_y(:,:,i) \cdot \mathbf{X}_y(:,:,i)'}{trace(\mathbf{X}_y(:,:,i) \cdot \mathbf{X}_y(:,:,i)')} \tag{1}$$

and

$$C = C_1 + C_2 \tag{2}$$

and spatial filters are defined as

$$W_y = eig(C_y, C) \tag{3}$$

$$\bar{W}_y = sort(W_y) \tag{4}$$

The above equation returns spatial filter matrix $W_y \in \mathbb{R}^{N \times N}$ for each label. We take 2 spatial filters with highest eigen values and 2 with lowest from both labels and take square root sum to constitute the channel rank.

Implementation is a little modification to the work presented in *Arpaia, P., Donnarumma, F., Esposito, A. and Parvis, M., 2021. Channel selection for optimal EEG measurement in motor imagery-based brain-computer interfaces. International Journal of Neural Systems, 31(03), p.2150003, doi: 10.1142/S0129065721500039.*

## III. PhisioNet Accuracy Table

Accuracy

| | 35 Subjects | | | | 50 Subjects | | | | 85 Subjects | | | | 94 Subjects | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 Chs | 25 Chs | 40 Chs | 55 Chs | 10 Ch | 25 ch | 40 ch | 55 ch | 10 Ch | 25 ch | 40 ch | 55 ch | 10 Ch | 25 ch | 40 ch | 55 ch |
| Rand Avg | 75.37 | 87.03 | 92.46 | 95.56 | 72.89 | 85.15 | 90.82 | 94.01 | 68.24 | 80.70 | 86.23 | 89.62 | 66.81 | 79.01 | 84.46 | 87.48 |
| CSP Rank | 83.91 | 93.67 | 98.77 | 99.72 | 79.42 | 90.23 | 95.93 | 97.43 | 70.89 | 83.00 | **89.99** | 91.09 | 66.93 | 80.83 | **87.36** | 87.58 |
| NMI | **83.92** | **94.81** | 97.93 | 99.56 | **80.41** | 91.71 | 95.57 | 97.35 | **71.20** | 83.65 | 89.60 | 91.16 | 67.44 | 81.09 | 86.72 | 88.67 |
| FS | 81.07 | 93.81 | 97.53 | 99.85 | 77.46 | 90.61 | 94.97 | 97.62 | 68.98 | 83.27 | 89.13 | 92.03 | 65.20 | 80.76 | 86.97 | 89.02 |
| Sub Indp | 82.17 | 94.63 | **99.18** | **100.00** | 78.58 | **91.93** | **96.75** | **97.82** | 70.98 | **84.09** | 89.72 | **92.34** | **67.61** | **81.53** | 87.03 | **90.12** |

SD

| | 35 Subjects | | | | 50 Subjects | | | | 85 Subjects | | | | 94 Subjects | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 Ch | 25 ch | 40 ch | 55 ch | 10 Ch | 25 ch | 40 ch | 55 ch | 10 Ch | 25 ch | 40 ch | 55 ch | 10 Ch | 25 ch | 40 ch | 55 ch |
| rand | ***5.30*** | ***4.17*** | 2.82 | 2.56 | ***5.89*** | ***4.54*** | ***3.48*** | ***3.24*** | ***7.36*** | ***6.85*** | ***6.59*** | ***6.26*** | ***8.31*** | ***8.40*** | ***8.38*** | ***8.93*** |
| csp_rank | 7.82 | 5.61 | 2.81 | 1.15 | 9.52 | 7.11 | 5.01 | 3.73 | 13.24 | 10.72 | 8.56 | 8.84 | 17.82 | **12.36** | 11.62 | 14.12 |
| nmi | 6.94 | 4.90 | 3.15 | 1.45 | 7.99 | 6.39 | 4.53 | 3.72 | 13.81 | 11.35 | 8.87 | 8.61 | 17.86 | 13.41 | 12.46 | 11.36 |
| fishers | **5.59** | 5.20 | 3.54 | 0.88 | **7.33** | 6.64 | 4.98 | 3.61 | 12.43 | **10.60** | **8.47** | 8.04 | 16.77 | 12.78 | **10.70** | 12.39 |
| sub_indp | 7.46 | **4.44** | ***2.06*** | ***0.00*** | 8.39 | **5.66** | **4.16** | **3.45** | **11.86** | 10.76 | 9.78 | **7.64** | **15.77** | 13.50 | 12.66 | **10.18** |

Figure 2. It shows that for different numbers of best-performing subjects, the proposed model consistently outperforms, indicating its generalizability over subjects. In addition, the standard deviation (in the interest of brevity, it has been provided in supplementary materials) of these accuracies is also lower which further enforces the generalizability of the proposed model.