

## Supplementary Materials

Table S1: MIN2Net architecture, where  $C$  is the number of channels,  $T$  is the number of time points,  $z$  is the size of latent vector and  $N$  is the number of classes. Noted that the data format of Conv2D is “channels last”

Blocks	Layer	Filter	Size	Stride	Activation	Options	Output
Encoder	Input		(1, $T, C$ )				(1, $T, C$ )
	Conv2D	$C$	(1, 64)	1	ELU	padding=same	(1, $T, C$ )
	BatchNormalization						(1, $T, C$ )
	AveragePooling2D		(1, $T // 100$ )				(1, 100, $C$ )
	Conv2D	10	(1, 32)	1	ELU	padding=same	(1, 100, 10)
	BatchNormalization						(1, 100, 10)
Autoencoder	AveragePooling2D		(1, 4)				(1, 25, 10)
	Flatten						(250)
Decoder	Latent	FC	( $z$ )				( $z$ )
		FC	(250)				(250)
		Reshape	(1, 25, 10)				(1, 25, 10)
		Conv2DTranspose	10	(1, 64)	4	ELU	padding=same
		Conv2DTranspose	$C$	(1, 32)	$T // 100$	ELU	padding=same
Metric learning	Latent						( $z$ )
Supervised Learning	Latent						( $z$ )
	FC		$N$		softmax		( $N$ )

$z$  is equal to  $C$  and 256 for 2- and 3-class classification, respectively.

Since the latent vector ( $z$ ) of MIN2Net plays a substantial role in preserving the meaningful features from high-dimensional EEG signals, we experiment to find the optimal size of the MIN2Net’s latent vector. Table S2 presents the two- and three-class classification results when different sizes of the latent vector ( $z$ ) are contributed in MIN2Net. It can be seen that when marking the size of latent vector as  $C$  (where  $C$  is the number of channels), the MIN2Net gained the optimal performance in the binary subject-independent classification for all used datasets. For the binary subject-dependent classification, the latent vector size of 8 produced the best performance of MIN2Net on the BCIC IV 2a dataset. Additionally, the optimal performance of MIN2Net on the three-class subject-independent for the OpenBMI dataset was obtained by selecting a 64 latent vector size. As a result of this finding, setting the size of the latent vector to  $C$  could aid MIN2Net in preserving meaningful features from EEG-MI signals and could even be used as a starting point for evaluating new MI datasets.

Table S2: Classification performance (Accuracy  $\pm$  SD and F1-score  $\pm$  SD) in % of MIN2Net using the subject-dependent and subject-independent manners comparisons on four different sizes of latent vector ( $z$ ). Bold denotes the best numerical values.

Dataset	Task	# latent vector	Subject-dependent		Subject-independent	
			Accuracy	F1-score	Accuracy	F1-score
BCIC IV 2a	two-class	8	<b>66.47 <math>\pm</math> 16.31</b>	<b>65.67 <math>\pm</math> 18.38</b>	59.01 $\pm$ 8.30	43.84 $\pm$ 21.86
		20 ( $C$ )	65.23 $\pm$ 16.14	64.72 $\pm$ 18.39	<b>60.03 <math>\pm</math> 9.24</b>	49.09 $\pm$ 23.28
		64	63.18 $\pm$ 16.01	61.25 $\pm$ 18.56	60.00 $\pm$ 8.34	<b>50.94 <math>\pm</math> 18.84</b>
		256	62.16 $\pm$ 15.04	60.67 $\pm$ 17.35	59.46 $\pm$ 8.40	51.80 $\pm$ 17.73
SMR-BCI	two-class	8	63.95 $\pm$ 15.59	61.63 $\pm$ 16.88	54.21 $\pm$ 11.82	49.79 $\pm$ 21.90
		15 ( $C$ )	<b>65.90 <math>\pm</math> 16.50</b>	<b>64.13 <math>\pm</math> 17.66</b>	<b>59.79 <math>\pm</math> 13.72</b>	<b>61.10 <math>\pm</math> 23.64</b>
		64	61.36 $\pm$ 14.09	59.27 $\pm$ 16.28	57.43 $\pm$ 12.46	50.31 $\pm$ 28.41
		256	63.14 $\pm$ 13.69	59.38 $\pm$ 17.00	57.98 $\pm$ 11.60	53.75 $\pm$ 25.55
OpenBMI	two-class	8	60.39 $\pm$ 14.54	62.03 $\pm$ 15.53	70.94 $\pm$ 13.70	71.29 $\pm$ 13.75
		20 ( $C$ )	<b>61.03 <math>\pm</math> 14.47</b>	<b>63.59 <math>\pm</math> 14.52</b>	<b>72.03 <math>\pm</math> 14.04</b>	<b>72.62 <math>\pm</math> 14.14</b>
		64	59.13 $\pm$ 13.18	61.36 $\pm$ 13.80	70.66 $\pm$ 13.66	70.24 $\pm$ 14.43
		256	58.18 $\pm$ 12.58	59.97 $\pm$ 13.45	70.58 $\pm$ 13.62	70.08 $\pm$ 14.71
OpenBMI	three-class	8	-	-	61.83 $\pm$ 9.05	59.11 $\pm$ 9.82
		20 ( $C$ )	-	-	64.89 $\pm$ 10.77	62.93 $\pm$ 11.68
		64	-	-	<b>68.97 <math>\pm</math> 11.84</b>	<b>68.07 <math>\pm</math> 12.34</b>
		256	-	-	68.81 $\pm$ 12.25	68.04 $\pm$ 12.70

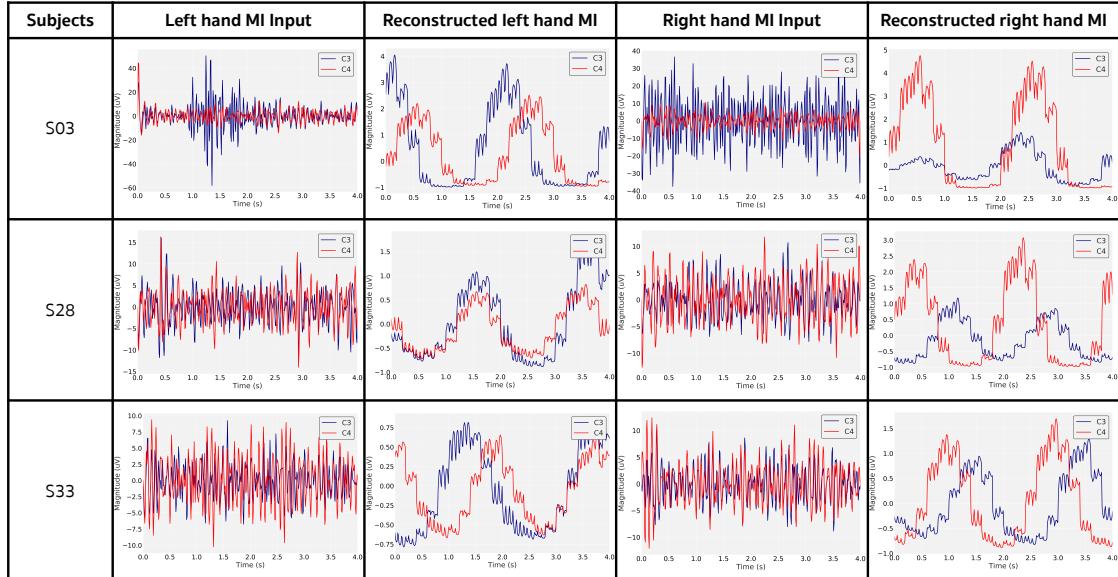


Fig. S1: Visualization of a time series of a single-trial EEG of the OpenBMI dataset on both the input and reconstructed EEG-MI signals in certain channels ( $C3$  and  $C4$ ) using the proposed method. The plot illustrated how the reconstructed signals from different classes interact in different patterns.

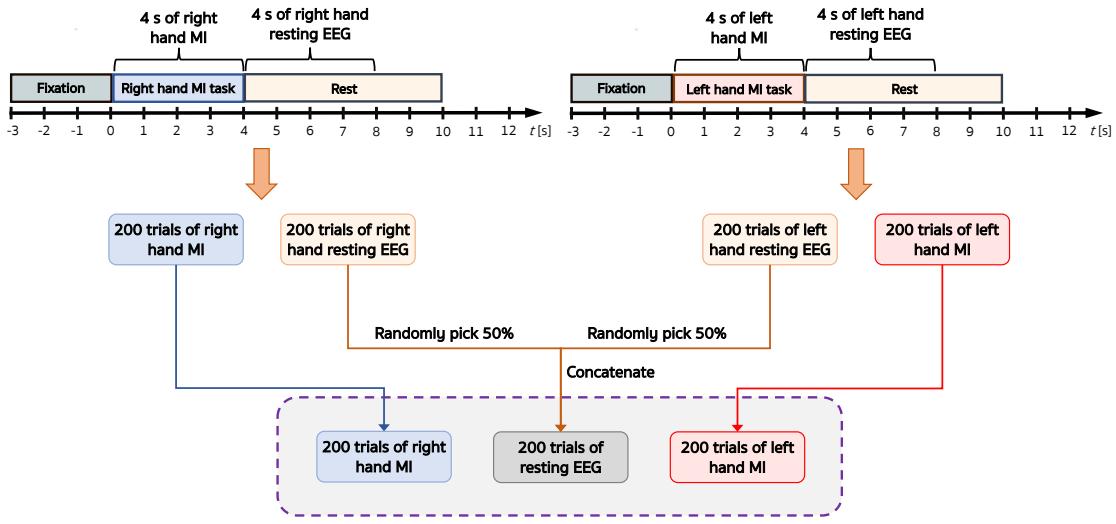


Fig. S2: An experimental procedure demonstrates how the OpenBMI dataset was used to segment a subject's EEG signal into three classes.

Table S3: Classification accuracy and F1-score (in %,  $\pm$  SD) on the subject-dependent manner for the two-class classification of MI. Bold denotes the best numerical values.

$\beta_1$	$\beta_2$	$\beta_3$	BCIC IV 2a		SMR BCI		OpenBMI	
			Accuracy	F1-score	Accuracy	F1-score	Accuracy	F1-score
0.1	0.1	0.1	63.23 $\pm$ 12.63	63.17 $\pm$ 13.64	63.83 $\pm$ 15.74	60.04 $\pm$ 18.21	60.71 $\pm$ 13.89	63.16 $\pm$ 13.97
0.1	0.1	0.5	63.04 $\pm$ 14.94	62.93 $\pm$ 16.32	<b>66.10 <math>\pm</math> 15.25</b>	63.23 $\pm$ 17.48	61.16 $\pm$ 15.27	63.57 $\pm$ 15.43
0.1	0.1	1.0	63.40 $\pm$ 15.65	63.45 $\pm$ 16.51	65.90 $\pm$ 16.50	<b>64.13 <math>\pm</math> 17.66</b>	60.53 $\pm$ 15.65	62.91 $\pm$ 16.04
0.1	0.5	0.1	59.60 $\pm$ 11.79	58.75 $\pm$ 13.16	60.95 $\pm$ 16.19	57.25 $\pm$ 18.44	60.24 $\pm$ 14.05	63.13 $\pm$ 13.82
0.1	0.5	0.5	<b>64.54 <math>\pm</math> 14.65</b>	63.97 $\pm$ 15.92	65.45 $\pm$ 16.41	61.32 $\pm$ 19.40	60.96 $\pm$ 14.33	63.36 $\pm$ 14.70
0.1	0.5	1.0	63.67 $\pm$ 14.80	63.42 $\pm$ 16.22	65.79 $\pm$ 15.75	62.74 $\pm$ 17.82	60.71 $\pm$ 14.94	63.38 $\pm$ 15.06
0.1	1.0	0.1	57.69 $\pm$ 11.57	55.90 $\pm$ 13.85	60.12 $\pm$ 16.01	58.03 $\pm$ 17.68	58.21 $\pm$ 13.10	61.18 $\pm$ 13.36
0.1	1.0	0.5	61.36 $\pm$ 13.16	60.24 $\pm$ 14.95	63.38 $\pm$ 18.19	60.30 $\pm$ 20.28	60.63 $\pm$ 14.55	62.98 $\pm$ 14.83
0.1	1.0	1.0	63.18 $\pm$ 14.13	62.20 $\pm$ 16.14	65.81 $\pm$ 16.70	61.88 $\pm$ 19.37	60.93 $\pm$ 14.66	63.37 $\pm$ 14.99
0.5	0.1	0.1	59.34 $\pm$ 10.01	59.29 $\pm$ 10.81	63.31 $\pm$ 15.08	59.94 $\pm$ 17.31	58.98 $\pm$ 13.06	60.73 $\pm$ 13.75
0.5	0.1	0.5	62.81 $\pm$ 13.99	63.40 $\pm$ 15.06	65.38 $\pm$ 15.46	61.25 $\pm$ 18.31	61.12 $\pm$ 14.43	63.38 $\pm$ 14.61
0.5	0.1	1.0	63.50 $\pm$ 14.78	63.64 $\pm$ 16.23	64.67 $\pm$ 16.46	61.81 $\pm$ 18.83	<b>61.22 <math>\pm</math> 15.03</b>	63.46 $\pm$ 15.13
0.5	0.5	0.1	58.35 $\pm$ 10.56	57.67 $\pm$ 11.76	60.55 $\pm$ 15.66	57.52 $\pm$ 18.21	57.68 $\pm$ 12.66	59.85 $\pm$ 13.25
0.5	0.5	0.5	62.61 $\pm$ 12.99	62.59 $\pm$ 14.23	63.71 $\pm$ 15.92	59.56 $\pm$ 18.61	60.49 $\pm$ 13.72	62.98 $\pm$ 13.76
0.5	0.5	1.0	63.77 $\pm$ 13.99	63.62 $\pm$ 15.00	64.17 $\pm$ 16.00	60.29 $\pm$ 18.71	61.03 $\pm$ 14.47	<b>63.59 <math>\pm</math> 14.53</b>
0.5	1.0	0.1	58.44 $\pm$ 10.07	57.32 $\pm$ 11.77	56.00 $\pm$ 14.11	51.71 $\pm$ 17.99	56.35 $\pm$ 11.78	58.50 $\pm$ 12.64
0.5	1.0	0.5	63.06 $\pm$ 12.96	61.82 $\pm$ 14.44	58.76 $\pm$ 13.79	54.93 $\pm$ 17.46	58.68 $\pm$ 13.41	60.98 $\pm$ 14.07
0.5	1.0	1.0	63.87 $\pm$ 13.84	63.11 $\pm$ 15.31	60.14 $\pm$ 14.78	55.52 $\pm$ 18.25	59.28 $\pm$ 13.70	61.75 $\pm$ 14.18
1.0	0.1	0.1	56.81 $\pm$ 8.08	56.93 $\pm$ 10.62	59.98 $\pm$ 13.81	55.51 $\pm$ 17.97	56.69 $\pm$ 12.27	58.15 $\pm$ 13.16
1.0	0.1	0.5	62.21 $\pm$ 12.72	63.10 $\pm$ 14.23	62.81 $\pm$ 14.46	58.12 $\pm$ 18.76	60.31 $\pm$ 13.73	62.50 $\pm$ 14.16
1.0	0.1	1.0	63.46 $\pm$ 14.33	<b>64.28 <math>\pm</math> 15.27</b>	63.12 $\pm$ 15.11	59.10 $\pm$ 18.69	60.61 $\pm$ 14.28	63.13 $\pm$ 14.44
1.0	0.5	0.1	58.40 $\pm$ 10.01	57.88 $\pm$ 11.19	56.05 $\pm$ 13.92	51.75 $\pm$ 17.79	56.36 $\pm$ 12.07	58.29 $\pm$ 13.34
1.0	0.5	0.5	61.23 $\pm$ 10.96	60.86 $\pm$ 12.10	61.02 $\pm$ 13.69	56.11 $\pm$ 17.90	59.40 $\pm$ 13.29	61.31 $\pm$ 14.06
1.0	0.5	1.0	63.94 $\pm$ 13.39	64.14 $\pm$ 13.99	61.83 $\pm$ 13.99	56.93 $\pm$ 18.19	60.18 $\pm$ 13.74	62.41 $\pm$ 14.29
1.0	1.0	0.1	58.30 $\pm$ 10.27	57.63 $\pm$ 11.31	55.98 $\pm$ 13.62	51.69 $\pm$ 17.68	56.16 $\pm$ 11.50	58.02 $\pm$ 12.89
1.0	1.0	0.5	61.88 $\pm$ 11.36	60.51 $\pm$ 12.91	60.00 $\pm$ 13.62	54.71 $\pm$ 18.50	58.36 $\pm$ 13.10	60.38 $\pm$ 13.95
1.0	1.0	1.0	62.39 $\pm$ 12.62	61.94 $\pm$ 13.71	61.19 $\pm$ 13.13	55.91 $\pm$ 17.62	59.78 $\pm$ 13.73	61.90 $\pm$ 14.33

Table S4: Classification accuracy and F1-score (in %,  $\pm$  SD) on the subject-independent manner for the two-class classification of MI. Bold denotes the best numerical values.

$\beta_1$	$\beta_2$	$\beta_3$	BCIC IV 2a		SMR BCI		OpenBMI	
			Accuracy	F1-score	Accuracy	F1-score	Accuracy	F1-score
0.1	0.1	0.1	58.81 $\pm$ 8.76	43.39 $\pm$ 23.51	58.07 $\pm$ 11.86	56.10 $\pm$ 24.06	71.59 $\pm$ 13.94	71.95 $\pm$ 14.75
0.1	0.1	0.5	59.17 $\pm$ 8.34	50.28 $\pm$ 18.35	57.64 $\pm$ 12.80	58.07 $\pm$ 23.21	71.45 $\pm$ 14.24	71.97 $\pm$ 14.40
0.1	0.1	1.0	57.62 $\pm$ 8.16	46.87 $\pm$ 20.60	58.71 $\pm$ 12.18	60.82 $\pm$ 20.14	71.40 $\pm$ 14.35	71.94 $\pm$ 14.51
0.1	0.5	0.1	55.09 $\pm$ 7.35	38.30 $\pm$ 24.19	57.76 $\pm$ 11.80	57.09 $\pm$ 24.45	69.79 $\pm$ 14.49	69.36 $\pm$ 15.74
0.1	0.5	0.5	58.02 $\pm$ 9.05	45.10 $\pm$ 22.86	60.00 $\pm$ 13.04	60.58 $\pm$ 22.04	70.02 $\pm$ 14.53	69.40 $\pm$ 16.45
0.1	0.5	1.0	57.78 $\pm$ 8.31	44.05 $\pm$ 22.07	58.71 $\pm$ 12.52	60.72 $\pm$ 20.57	71.13 $\pm$ 13.97	71.51 $\pm$ 14.13
0.1	1.0	0.1	52.89 $\pm$ 7.87	<b>54.16 <math>\pm</math> 18.23</b>	59.79 $\pm$ 13.72	<b>61.10 <math>\pm</math> 23.64</b>	69.54 $\pm$ 14.28	68.83 $\pm$ 15.80
0.1	1.0	0.5	53.49 $\pm$ 7.05	40.93 $\pm$ 26.35	58.07 $\pm$ 11.36	58.40 $\pm$ 21.67	69.86 $\pm$ 14.22	69.32 $\pm$ 15.74
0.1	1.0	1.0	53.87 $\pm$ 7.38	36.79 $\pm$ 23.55	59.50 $\pm$ 13.03	60.57 $\pm$ 22.31	69.95 $\pm$ 14.58	69.35 $\pm$ 16.39
0.5	0.1	0.1	57.89 $\pm$ 8.42	37.33 $\pm$ 25.69	59.38 $\pm$ 12.87	56.70 $\pm$ 26.25	62.43 $\pm$ 14.61	61.88 $\pm$ 15.24
0.5	0.1	0.5	59.10 $\pm$ 8.64	43.27 $\pm$ 23.35	59.10 $\pm$ 13.50	58.32 $\pm$ 24.60	71.85 $\pm$ 14.18	71.35 $\pm$ 15.98
0.5	0.1	1.0	<b>60.03 <math>\pm</math> 9.24</b>	49.09 $\pm$ 23.28	58.52 $\pm$ 12.91	58.82 $\pm$ 22.89	71.83 $\pm$ 13.95	71.25 $\pm$ 15.35
0.5	0.5	0.1	57.65 $\pm$ 8.08	37.54 $\pm$ 25.74	57.90 $\pm$ 11.16	56.79 $\pm$ 23.30	70.89 $\pm$ 14.13	71.46 $\pm$ 14.09
0.5	0.5	0.5	58.21 $\pm$ 8.87	42.65 $\pm$ 23.81	58.86 $\pm$ 12.58	56.13 $\pm$ 25.06	71.30 $\pm$ 14.04	72.15 $\pm$ 13.76
0.5	0.5	1.0	59.14 $\pm$ 8.79	47.03 $\pm$ 21.61	58.81 $\pm$ 14.01	58.18 $\pm$ 23.42	72.03 $\pm$ 14.04	<b>72.62 <math>\pm</math> 14.14</b>
0.5	1.0	0.1	57.69 $\pm$ 7.54	39.64 $\pm$ 23.36	58.21 $\pm$ 11.86	57.68 $\pm$ 22.22	70.47 $\pm$ 13.59	71.07 $\pm$ 13.80
0.5	1.0	0.5	58.02 $\pm$ 7.53	41.43 $\pm$ 23.78	58.88 $\pm$ 11.74	57.75 $\pm$ 23.18	70.45 $\pm$ 13.87	70.77 $\pm$ 14.28
0.5	1.0	1.0	58.40 $\pm$ 8.52	45.02 $\pm$ 21.63	59.60 $\pm$ 12.63	58.46 $\pm$ 22.85	70.83 $\pm$ 13.63	70.99 $\pm$ 13.97
1.0	0.1	0.1	55.91 $\pm$ 6.70	34.63 $\pm$ 24.83	57.26 $\pm$ 10.06	54.40 $\pm$ 23.60	54.52 $\pm$ 11.08	54.17 $\pm$ 11.57
1.0	0.1	0.5	58.18 $\pm$ 8.70	40.77 $\pm$ 25.77	58.00 $\pm$ 11.06	56.38 $\pm$ 24.07	71.12 $\pm$ 14.55	71.42 $\pm$ 15.02
1.0	0.1	1.0	59.20 $\pm$ 8.20	45.32 $\pm$ 23.50	58.50 $\pm$ 11.28	57.52 $\pm$ 23.90	<b>72.20 <math>\pm</math> 14.19</b>	72.40 $\pm$ 14.70
1.0	0.5	0.1	58.27 $\pm$ 8.64	38.16 $\pm$ 26.01	58.05 $\pm$ 11.31	57.61 $\pm$ 21.90	70.50 $\pm$ 13.92	71.27 $\pm$ 14.26
1.0	0.5	0.5	58.84 $\pm$ 8.61	42.66 $\pm$ 23.50	60.12 $\pm$ 12.22	58.41 $\pm$ 23.23	70.66 $\pm$ 13.80	70.98 $\pm$ 14.41
1.0	0.5	1.0	59.10 $\pm$ 9.39	43.13 $\pm$ 25.48	59.40 $\pm$ 11.67	58.41 $\pm$ 23.11	71.19 $\pm$ 13.67	71.50 $\pm$ 14.07
1.0	1.0	0.1	58.26 $\pm$ 8.64	38.33 $\pm$ 25.80	57.74 $\pm$ 10.48	57.56 $\pm$ 21.05	70.26 $\pm$ 13.59	71.05 $\pm$ 13.60
1.0	1.0	0.5	57.95 $\pm$ 7.76	38.65 $\pm$ 24.68	59.14 $\pm$ 11.34	58.22 $\pm$ 22.10	70.56 $\pm$ 13.33	70.86 $\pm$ 13.60
1.0	1.0	1.0	58.55 $\pm$ 8.99	43.96 $\pm$ 22.80	<b>60.69 <math>\pm</math> 13.04</b>	58.25 $\pm$ 25.13	70.86 $\pm$ 13.66	71.14 $\pm$ 14.03