

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	(1, 100, 10)
		Conv2DTranspose	C	(1, 32)	$T // 100$	ELU	padding=same	(1, T, C)
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	66.47 \pm 16.31	65.67 \pm 18.38	59.01 \pm 8.30	43.84 \pm 21.86
		20 (C)	65.23 \pm 16.14	64.72 \pm 18.39	60.03 \pm 9.24	49.09 \pm 23.28
		64	63.18 \pm 16.01	61.25 \pm 18.56	60.00 \pm 8.34	50.94 \pm 18.84
		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)	65.90 \pm 16.50	64.13 \pm 17.66	59.79 \pm 13.72	61.10 \pm 23.64
		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)	61.03 \pm 14.47	63.59 \pm 14.52	72.03 \pm 14.04	72.62 \pm 14.14
		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	-	-	68.97 \pm 11.84	68.07 \pm 12.34
		256	-	-	68.81 \pm 12.25	68.04 \pm 12.70

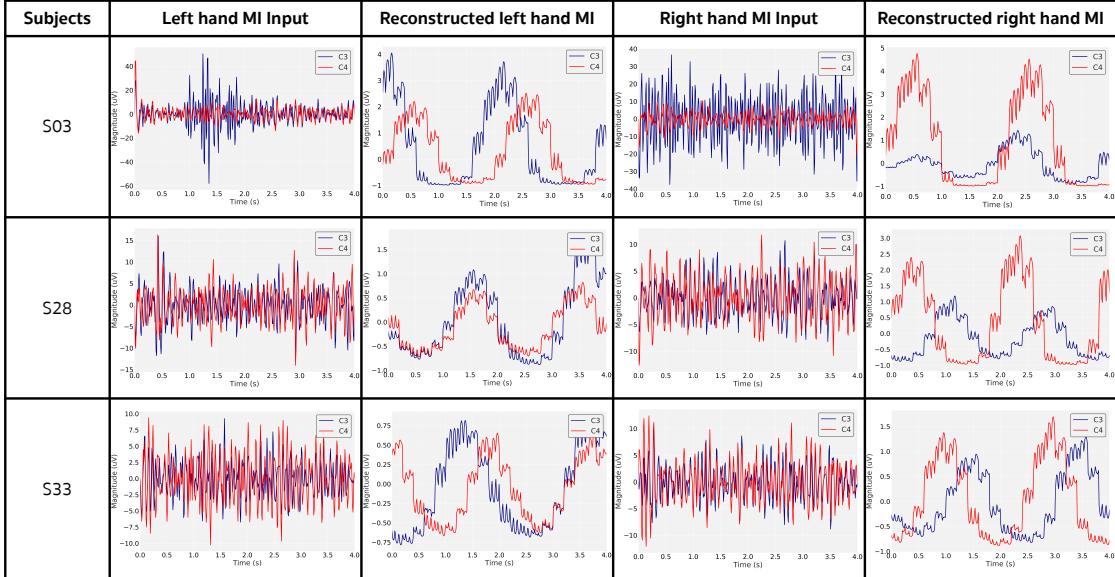


Fig. S1: Visualization of a time series of a single-trial EEG of the OpenBMI dataset on both the input and reconstructed EEG-MI signals in certain channels (C3 and C4) using the proposed method. The plot illustrated how the reconstructed signals from different classes interact in different patterns.

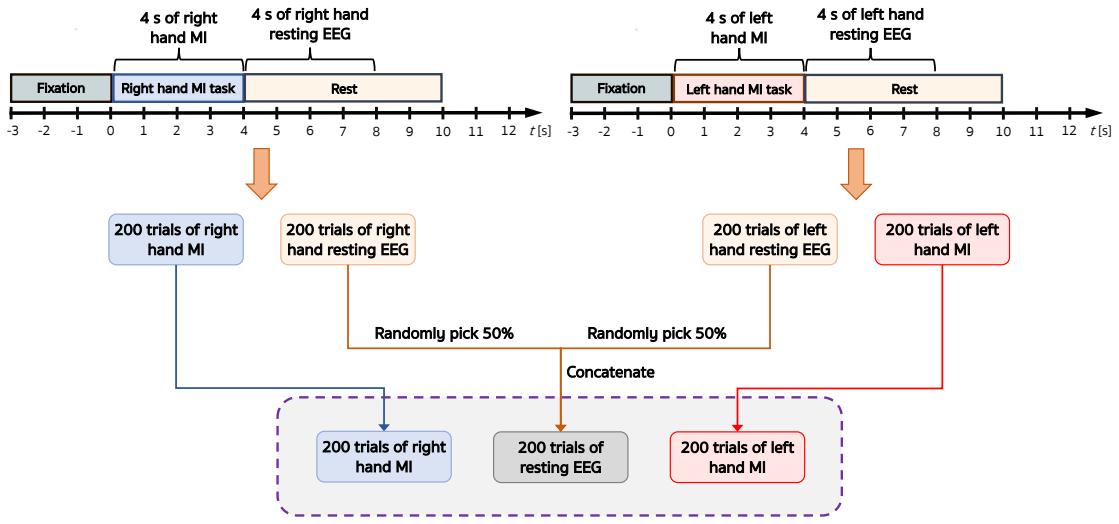


Fig. S2: An experimental procedure demonstrates how the OpenBMI dataset was used to segment a subject's EEG signal into three classes.

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.

β_1	β_2	β_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	66.10 \pm 15.25	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	64.13 \pm 17.66	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	64.54 \pm 14.65	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	61.22 \pm 15.03	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	63.59 \pm 14.53
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	64.28 \pm 15.27	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.

β_1	β_2	β_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	54.16 \pm 18.23	59.79 \pm 13.72	61.10 \pm 23.64	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	60.03 \pm 9.24	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	72.62 \pm 14.14
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	72.20 \pm 14.19	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	60.69 \pm 13.04	58.25 \pm 25.13	70.86 \pm 13.66	71.14 \pm 14.03