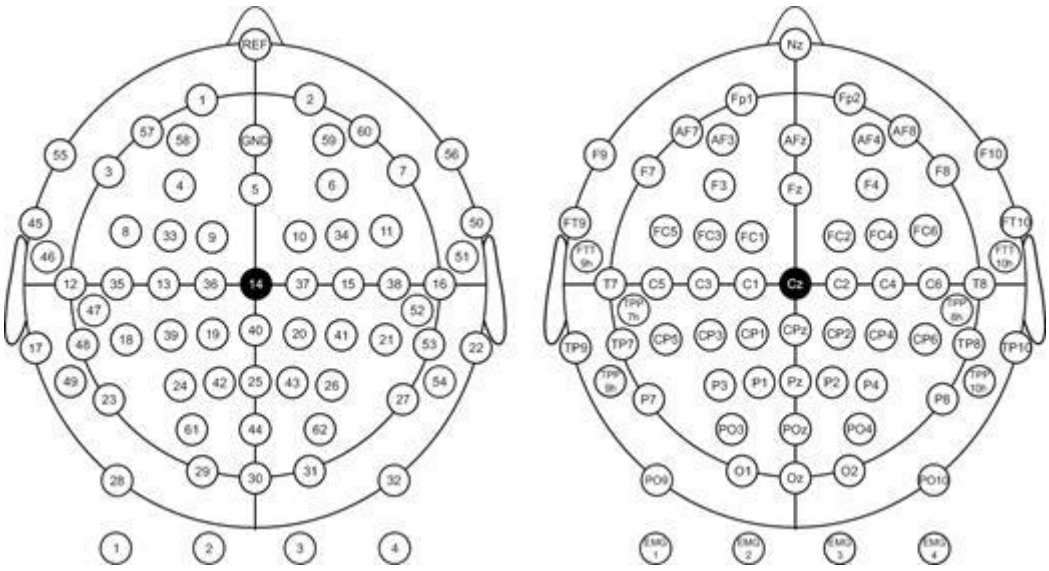
Big Data of ERP speller

Participants

Fifty-four healthy subjects (ages 24-35; 25 females) participated in the experiment. Thirty-eight subjects were naive BCI users. The others had previous experience with BCI experiments. None of the participants had a history of neurological, psychiatric, or any other pertinent disease that otherwise might have affected the experimental results. The subjects were seated comfortably in a chair with armrests at 60 (± 5) cm in front of a 21-inch LCD monitor (refresh rate: 60 Hz; resolution: 1,600 × 1,200). The approximate horizontal and vertical visual angles were 37.7 and 28.1 degrees, respectively. During the experiment, subjects were instructed to relax their muscles and minimize their eye and muscle movements.

EEG data recording

EEG signals were recorded with a sampling rate of 1,000 Hz and collected with 62 Ag/AgCl electrodes. The EEG amplifier used in the experiment was a BrainAmp (Brain Products; Munich, Germany). The channels were nasion-referenced and grounded to electrode AFz. Additionally, an EMG electrode recorded from each flexor digitorum profundus muscle with the olecranon used as reference. The EEG/EMG channel configuration and indexing numbers are described in Fig. 1. The impedances of the EEG electrodes were maintained below 10 kΩ during the entire experiment.



ERP paradigm

The interface layout of the speller followed the typical design of a row-column speller. The six rows and six columns were configured with 36 symbols (A to Z, 1 to 9, and _). Each symbol was presented equally spaced (see Fig. 2A). To enhance the signal quality, two additional settings were incorporated into the original row-column speller design, namely, random-set presentation [45] and face stimuli [39]. These additional settings help to elicit stronger ERP responses by minimizing adjacency distraction errors and by presenting a familiar face image. The stimulus-time interval was set to 80 ms, and the inter-stimulus interval (ISI) to 135 ms. A single iteration of stimulus presentation in all rows and columns was considered a sequence. Therefore, one sequence consisted of 12 stimulus flashes. A maximum of five sequences (i.e., 60 flashes) was allotted without prolonged inter-sequence intervals for each target character. After the end of five sequences, 4.5 s were given to the user for identifying, locating, and gazing at the next target character. The participant was instructed to attend to the target symbol by counting the number of times each target character had been flashed.

In the training session, subjects were asked to copy-spell a given sentence, "NEURAL_NETWORKS_AND_DEEP_LEARNING" (33 characters including spaces) by gazing at the target character on the screen. The training session was performed in the offline condition, and no feedback was provided to the subject during the EEG recording. In the test session, subjects were instructed to copy-spell "PATTERN_RECOGNITION_MACHINE_LEARNING" (36 characters including spaces), and the real-time EEG data were analyzed based on the classifier that was calculated from the training session data. The selected character from the subject's current EEG data was displayed in the top left area of the screen at the end of the presentation (i.e., after five sequences). Per participant, the collected EEG data for the ERP experiment consisted of 1,980 and 2,160 trials (samples) for training and test phase, respectively.

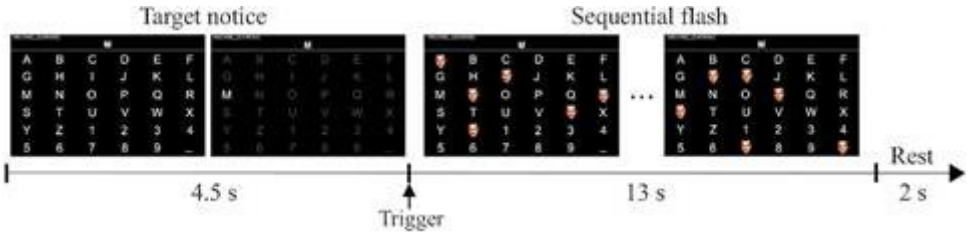


Table 1:

Questionnaire prior to experiments

Questionnaire I						
Personal Information						
1	Age					
2	Gender (Male = 0, Female = 1)					
3	BCI experience (number of experiences; naive = 0)					
4	Right-handed = 0, Left-handed = 1, Ambidexter = 2					
Physiological and psychological condition						
1	How long have you slept?					
	(1∼4 h = 1, 5∼6 h = 2, 6∼7 h = 3, 7∼8 h = 4, >8 h = 5)					
2	Did you drink coffee in the last 24 hours?					
	(in hours since last consumption; none = 0)					
3	Did you drink alcohol in the last 24 hours?					
	(in hours since last consumption; none = 0)					
4	Did you smoke in the last 24 hours?					
	(in hours since last consumption; none = 0)					
5	Condition checklists	Low				High
	-Comfort	1	2	3	4	5
	-Motivation	1	2	3	4	5
	-Concentration	1	2	3	4	5
	-Eye fatigue	1	2	3	4	5

Questionnaire I						
	-Drowsiness	1	2	3	4	5
	-Physical condition	1	2	3	4	5
	-Mental condition	1	2	3	4	5

Subjects were asked to supply their personal information and to report their physiological and psychological condition.

Table 2:
Questionnaire during the experiments

Questionnaire II						
Paradigm: ERP, MI or SSVEP						
Phase (offline training or online test)						
1	Are you able to participate in the following experiment?					
2	Condition check list	Low				High
	-Comfort	1	2	3	4	5
	-Motivate	1	2	3	4	5
	-Concentration	1	2	3	4	5
	-Eye fatigue	1	2	3	4	5
	-Drowsiness	1	2	3	4	5
	-Physical condition	1	2	3	4	5
	-Mental condition	1	2	3	4	5
3	Did you ever doze off or fall asleep during the experiment?					
	(number of times; none = 0)					

4	Was it easy to perform the given tasks?
5	How many attempts have you missed?
	(number; none = 0)
6	Expected accuracy for this experiment (%)

Subjects were asked to provide information regarding their current condition and self-evaluate their accuracy in the previous experiment.

Table 3:
Experimental procedures

	Experimental procedure	**Required time (min)**	**Cumulative time (min)**
Prep. (33)	Instructions, self-assessment with questionnaire I	5	5
	EEG and EMG electrode placement	25	30
	Acquisition of artificial noise data	3	33
ERP (36)	Resting state data	1	34
	ERP speller in offline phase	12	46
	Resting state data	1	47
	Questionnaire II	2	49
	Short break	3	52
	Resting state data	1	53
	ERP speller in online phase	13	66
	Resting state data	1	67

	Experimental procedure	Required time (min)	Cumulative time (min)
	Questionnaire II	2	69
	Break	10	79
Motor-imagery (51)	Impedance check	5	84
	Resting state data	1	85
	Motor-imagery task in offline phase	22	107
	Resting state data	1	108
	Questionnaire II	2	110
	Short break	3	113
	Resting state data	1	114
	Motor-imagery task in online phase	22	136
	Resting state data	1	137
	Questionnaire II	2	139
	Break	10	149
SSVEP (51)	Impedance check	5	154
	Resting state data	1	155
	SSVEP task in offline phase	20	175
	Resting state data	1	176
	Questionnaire II	2	178
	Short break	3	181

	Experimental procedure	Required time (min)	Cumulative time (min)
	Resting state data	1	182
	SSVEP task in online phase	20	202
	Resting state data	1	203
	Questionnaire II	2	205
	Total		205