

Supplementary Material

In this supplementary section, we show data that are not presented in the manuscript and help readers follow our experiments.

S1. The Results of the Word-Expression Experiments

We show the results of subject B – subject E in this section (The results of subject A are shown in Fig. 4).

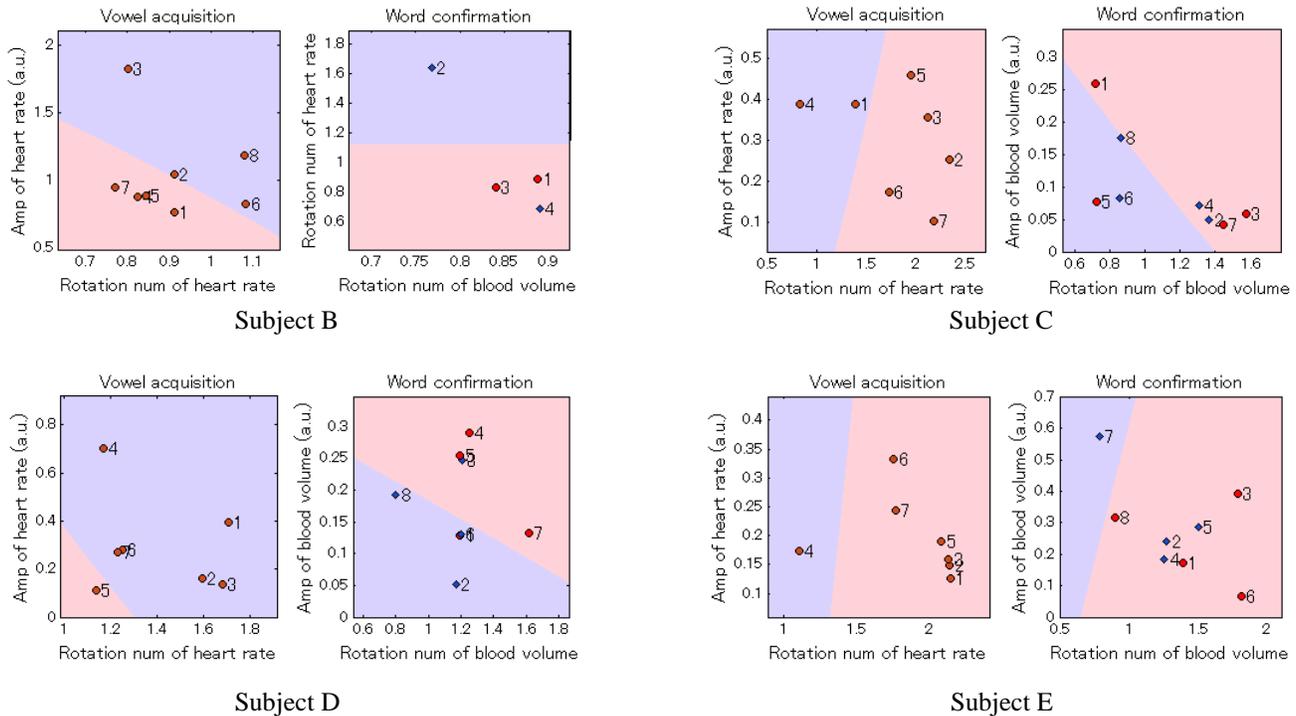


Fig. S1. Feature vectors. The pink regions represent “yes” and the light purple regions represent “no.” In the figures of word confirmation, the red circles represent “yes” answers to the affirmative question, while the blue diamonds represent “no” answers to the negative question. Thus, the red circles in the “yes” region and the blue diamonds in the “no” region are regarded as affirmative.

Table S1.1.

“Yes/no” answers and corresponding vowels in the vowel acquisition, and the vectors regarded as affirmative answers in the word confirmation. The numbers represent the vector number in Fig. S1.

Subject	“Yes/no” answers and vowels	Affirmative vectors
B	“1-yes,” “2-no,” “3-no” (U) “4-yes,” “5-yes” (A) “6-no,” “7-yes”, “8-no” (O or NN)	1, 2, 3
C	“1-no,” “2-yes,” (E) “3-yes,” “4-no,” “5-yes,” (I) “6-yes,” “7-yes” (A)	1, 3, 6, 7, 8
D	“1-no,” “2-no,” (O) “3-no,” “4-no,” (O)* “5-yes,” “6-no,” “7-no” (U)	2, 4, 5, 6, 7, 8
E	“1-yes,” “2-yes,” (A) “3-yes,” “4-no,” “5-yes,” (I) “6-yes,” “7-yes” (A)	1, 3, 6, 7, 8

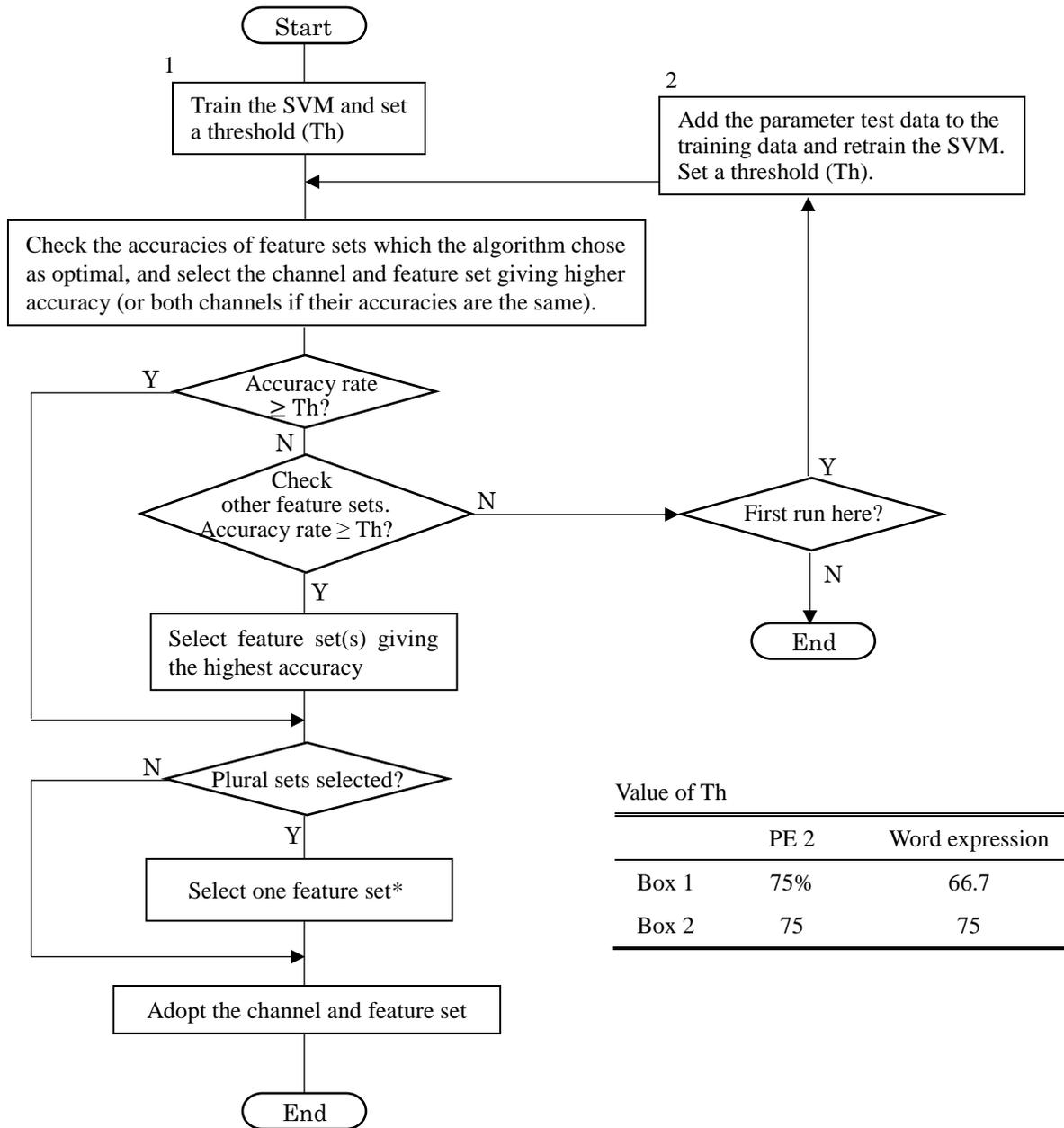
* In the acquisition of ‘O’ as the second vowel, corresponding sequence of “yes/no” is {“no,” “yes,” “no”} according to Fig. 2. However, the sequence is simplified to {“no,” “no”} when the partners are convinced that an expressed word contains at least two vowels. In that case, (End) is excluded from the second position. This situation is the same as that of the acquisition of ‘O’ at the first position.

Table S1.2.
Parameters in the word confirmation.

Subject	Parameters (SVM training data, side of forehead, feature set, time window)
B	original, right, 1, 0 – 16 s for the heart rate and 3 – 19 s for the blood volume
C	addition, left, 2, 4 – 19 s
D	original, left, 2, 7 – 22 s
E	original, right, 2, 3 -21 s

S2. Parameter Selection (training data for the SVM, channel and feature set)

channel: probe positions on the right or left forehead



	Value of Th	
	PE 2	Word expression
Box 1	75%	66.7
Box 2	75	75

*: If there are multiple selected channels and feature sets, reduce them each to one by applying the following criteria successively: (a) the balance of “yes/no” answers to the test data, (b) the “yes/no” separation of the training data, and (c) the geometric margin.

Fig. S2. Flowchart of parameter test in II. Methods, D. Experiments.

S2.1 Results of Parameter Test in PE 2

Table S2.1.

Parameter selection in PE 2. Numerical values represent the classification accuracy of parameter test.

Subject	Day	Training Data	Left Feature set 1	Left Feature2	Left Feature3	Right Feature1	Right Feature2	Right Feature3
A	1st day	Original	62.5	25.0	37.5	62.5	62.5	75.0
	2nd day	Original	62.5	100	62.5	62.5	50.0	50.0
	3rd day	Original	50.0	62.5	50.0	50.0	75.0	50.0
	4th day	Original	50.0	37.5	25	50	62.5	37.5
		Addition	87.5	62.5	75.0	100	100	62.5
B	1st day	Original	25.0	50.0	50.0	50.0	50.0	50.0
		Addition	75.0	87.5	100.0	87.5	87.5	87.5
	2nd day	Original	50.0	62.5	37.5	50.0	62.5	50.0
		Addition	75.0	75.0	87.5	75.0	75.0	87.5
	3rd day	Original	62.5	75.0	62.5	75.0	50.0	75.0
	4th day	Original	50.0	62.5	62.5	50.0	87.5	62.5
C	1st day	Original	50.0	37.5	50.0	37.5	25.0	50.0
		Addition	87.5	87.5	87.5	75.0	62.5	100
	2nd day	Original	50.0	37.5	50.0	25.0	37.5	62.5
		Addition	75.0	75.0	75.0	87.5	75.0	87.5
	3rd day	Original	37.5	50.0	62.5	25.0	62.5	50.0
		Addition	87.5	87.5	87.5	87.5	75	62.5
	4th day	Original	25.0	37.5	25.0	50.0	25.0	25.0
		Addition	75.0	62.5	75.0	87.5	50.0	87.5
D	1st day	Original	37.5	50.0	62.5	75.0	62.5	25.0
	2nd day	Original	75.0	25.0	37.5	75.0	62.5	37.5
	3rd day	Original	66.7	50.0	83.3	83.3	83.3	66.7
	4th day	Original	66.7	50.0	50.0	33.3	50.0	33.3
		Addition	83.3	83.3	50.0	83.3	83.3	50.0
E	1st day	Original	75.0	25.0	100	75.0	50.0	25.0
	2nd day	Original	50.0	50.0	50.0	66.7	66.7	50.0
		Addition	66.7	50	100	83.3	100	83.3
	3rd day	Original	50.0	33.3	33.3	50.0	50.0	50.0
		Addition	50	66.7	50	66.7	50	100
	4th day	Original	0	16.7	66.7	33.3	33.3	66.7
		Addition	50.0	33.3	66.7	50.0	83.3	66.7

 : Adopted forehead side and feature set.  : Feature set chosen as optimal by the optimization algorithm.
Red boldface: accuracy \geq Th in the case of "Original." **Black boldface:** accuracy \geq Th in the case of "Addition."

Table S2.2.

Reduction of channels (side of forehead) and feature sets each to one when multiple of them were selected.

Subject	Day	Training Data	Accuracy	Forehead side and feature set (Y/N balance*, Y/N Separation of training data, Geometric margin)	Selection
B	1st	Addition	87.5%	L, FS2 (2, 85.7%, 0.0198) R, FS2 (2, 85.7%, 0.0322)	√
	2nd	Addition	75	L, FS1 (0) R, FS1 (2)	√
	3rd	Original	75	L, FS2 (2, 83.3%, -) R, FS1 (2, 100%, 0.0550) R, FS3 (2, 100%, 0.0594)	√
D	4th	Addition	83.3	L, FS1 (1, 83.3%, 0.0200) R, FS1 (1, 83.3%, 0.0318)	√

*: Y/N balance = | number of correct "Yes" - number of correct "No"; 0 is the best, 1 is the second best, 2 is the third best.

S2.2 Results of Parameter Test in Word-expression Experiments

Table S2.3.
Parameter selection. Numerical values represent the classification accuracy of parameter test.

Subject	Session (Day)	Training Data	Left Feature1	Left Feature2	Left Feature3	Right Feature1	Right Feature2	Right Feature3
A	Word Expression (3rd day)	Original	50.0	50.0	100	25.0	50.0	25.0
	Confirmation (4th day)	Original	33.3	66.7	50.0	50.0	50.0	66.7
B	Word Expression (1st day)	Original	25.0	50.0	75.0	25.0	25.0	75.0
	Confirmation (3rd day)	Original	75.0	25.0	75.0	100	0	75.0
C	Word Expression (3rd day)	Original	83.3	50.0	50.0	33.3	66.7	66.7
	Confirmation (4th day)	Original	50.0	50.0	33.3	50.0	50.0	33.3
		Addition	50.0	83.3	66.7	33.3	50.0	50.0
D	Word Expression (2nd day)	Original	50.0	50.0	50.0	50.0	66.7 †	50.0
		Addition	66.7	50.0	83.3	66.7	66.7	83.3
	Confirmation (3rd day)	Original	50.0	83.3	66.7 ††	50.0	33.3	50.0
E	Word Expression (3rd day)	Original	50.0	33.3	66.7	50.0	66.7	50.0
	Confirmation (4th day)	Original	75.0	50.0	75.0	75.0	100	75.0

The value of Th in Fig. S2: 66.7% in Box 1 and 75.0% in Box 2.

†: The other accuracies were all as low as 50.0%, which seemed that the original SVM training data were not good. Therefore, we added the parameter test data to it and retrained the SVM. This is equivalent to setting Th in Box 1 to 75%.

††: The value of Th in Box 1 was left at the previous day's value of 75%, and this case was not selected.

Red boldface: accuracy \geq Th in the case of "Original." **Black boldface:** accuracy \geq Th in the case of "Addition."

Table S2.4. Reduction of channels (side of forehead) and feature sets each to one when multiple of them were selected.

Subject	Day	Training Data	Accuracy	Forehead and feature set (Y/N Balance, Y/N Separation of training data, Geometric margin)	Selection
A	4th	Original	66.7%	L, FS2 (2)	√
				R, FS3 (0)	
B	1st	Original	75	L, FS3 (1, 100%, 0.0678)	√
				R, FS3 (1, 100%, 0.0723)	
D	2nd	Addition	83.3	L, FS3 (1, 75.0%)	√
				R, FS3 (1, 91.7%)	

S3. Example of an Expressed Word obtained through the Special Dictionary with Vowel Entries

3rd Vowel "A" 1st Vowel "E" 2nd Vowel "A"

選択された母音

1文字目 あ い う え お 2文字目 あ い う え お

3文字目 あ い う え お

単語候補 検索された単語 21 語

辞書名	候補
動詞	出回る 手渡す 隔たる
動詞	枝分かれする
形容詞	汚らわしい 目覚しい
食べ物	枝豆
名詞	絵葉書 毛皮 背中 手洗 テーマパーク 手掛かり 手触り 手回し 値上がり 根回 隔たり 目方 目覚まし メダカ

Killifish

Fig. S3. Candidate words obtained by inputting three vowels “E,” “A,” and “A.” The partner consulted the dictionary by entering the three vowels, and the dictionary returned candidate words. Among all candidate words, only “Killifish” was an animal.