

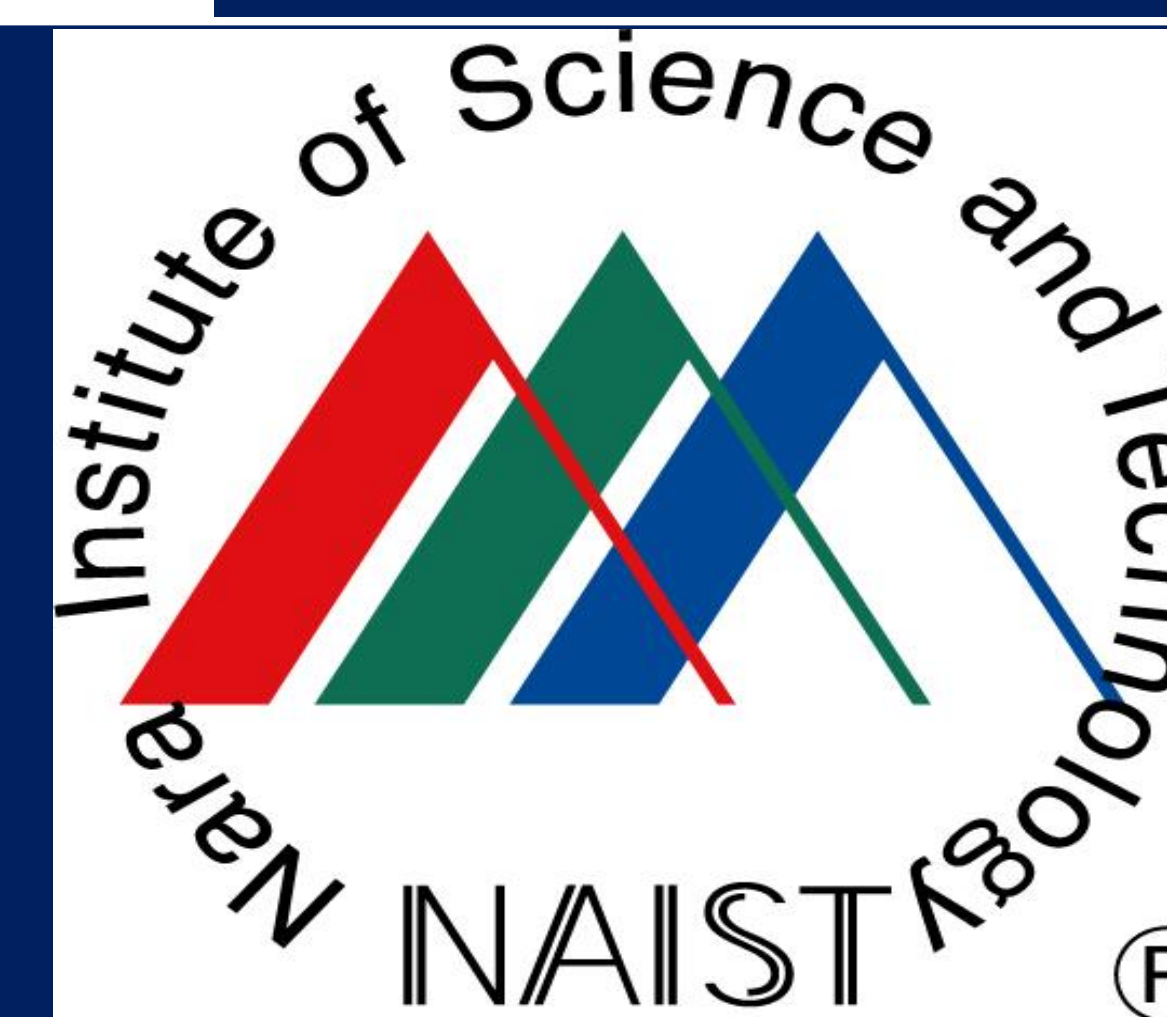
# Sentence classification based on phase patterns in EEG neural oscillation during imagined speech

調音動作想像時の脳波位相パターンを用いた文識別

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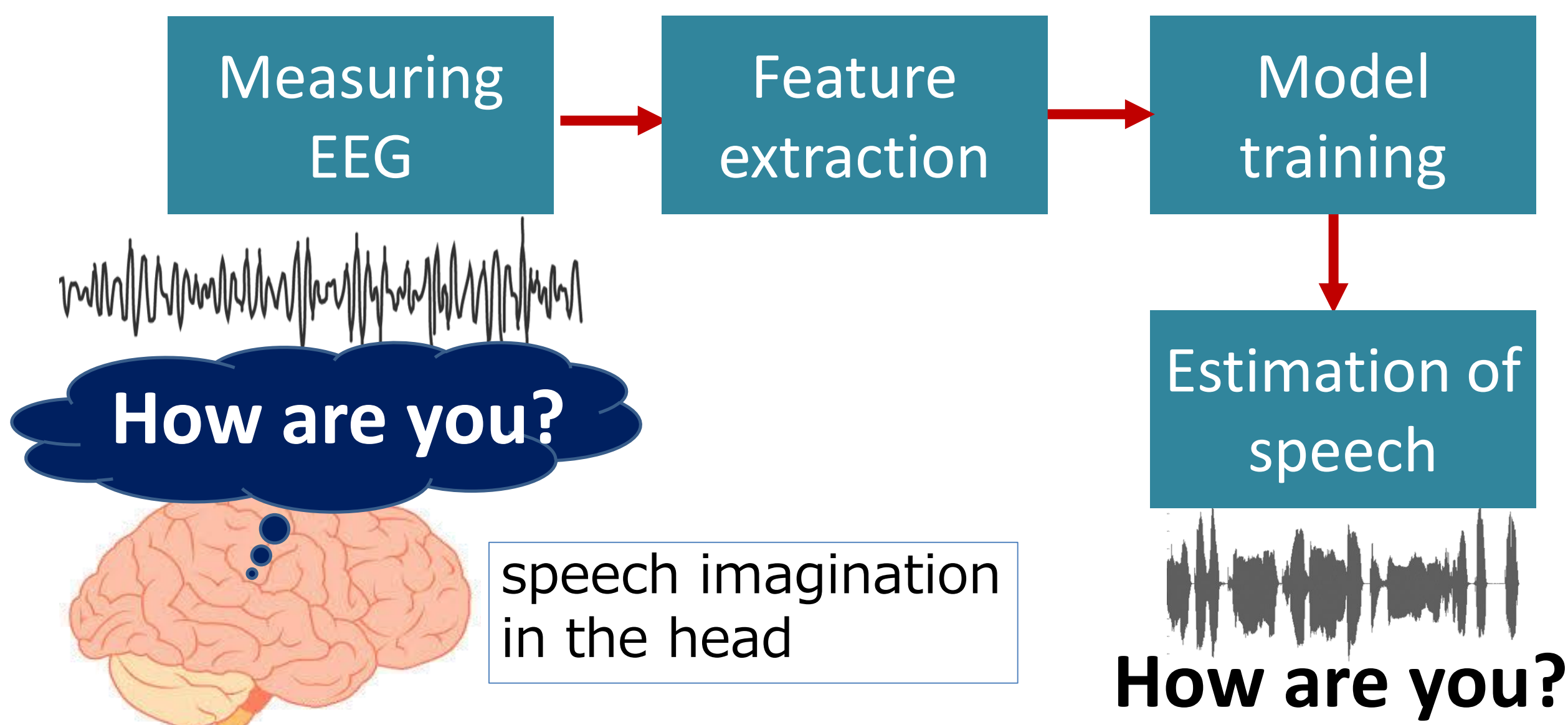
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## Introduction

### A big picture of our research



### Research purposes

Investigating...

(1) a phase synchronization during imaging articulatory movements of sentences

(2) accuracies of EEG-based imagined sentence classification using the phase synchronization as features

### Previous research & research focus

#### classification of heard speech

- EEG-based sentence classification (Watanabe et al, 2017)
- Utilizing a phase synchronization to sentence rhythms

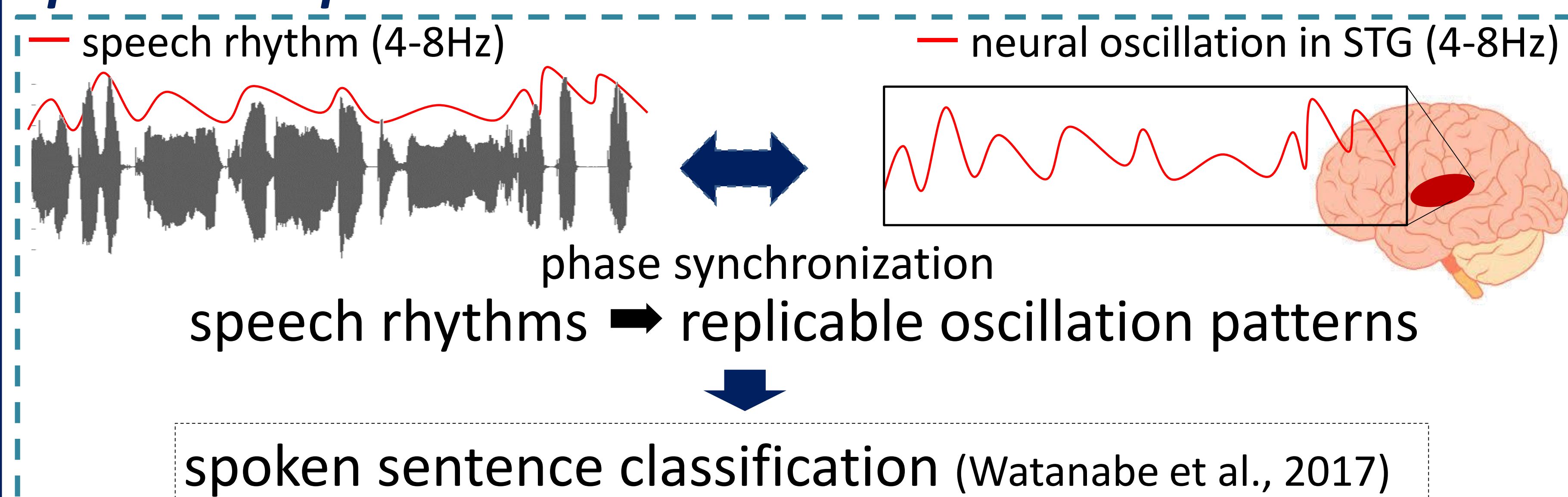
#### classification of imagined speech

- vowel classification (DaSalla et al., 2009)
- syllable classification (D'zmura et al., 2009)
- word classification (Martin et al., 2015)
- **sentence classification → no research**

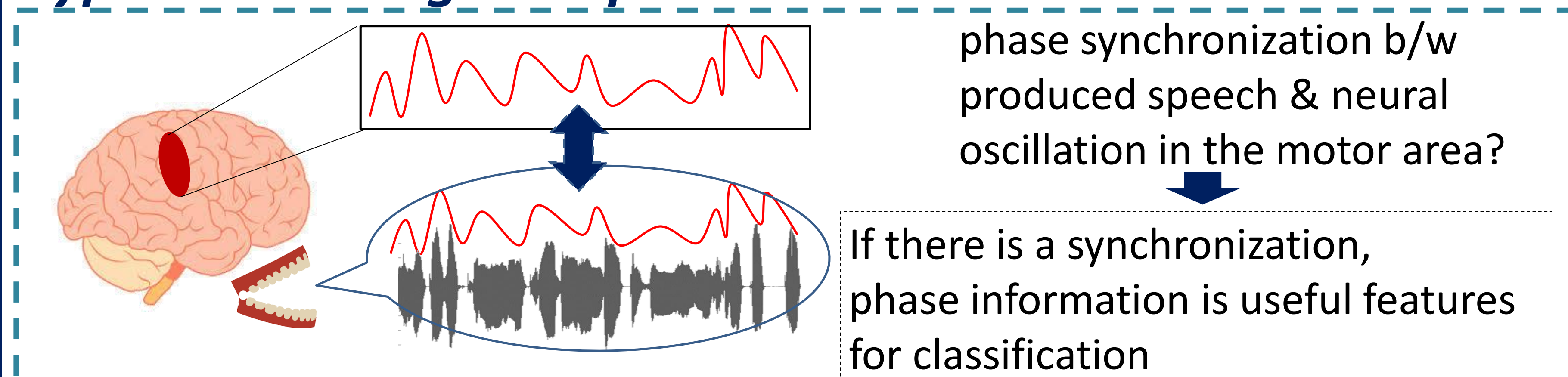
Applying an EEG-based sentence classification method to imagined speech recognition

## Research questions

### Speech comprehension



### Hypothesis: imagined speech



### Research questions

- RQ. 1 Do EEG phase patterns during imagined speech synchronize with produced speech rhythms?  
RQ.2 How accurately do EEG phase patterns classify imagined sentences?

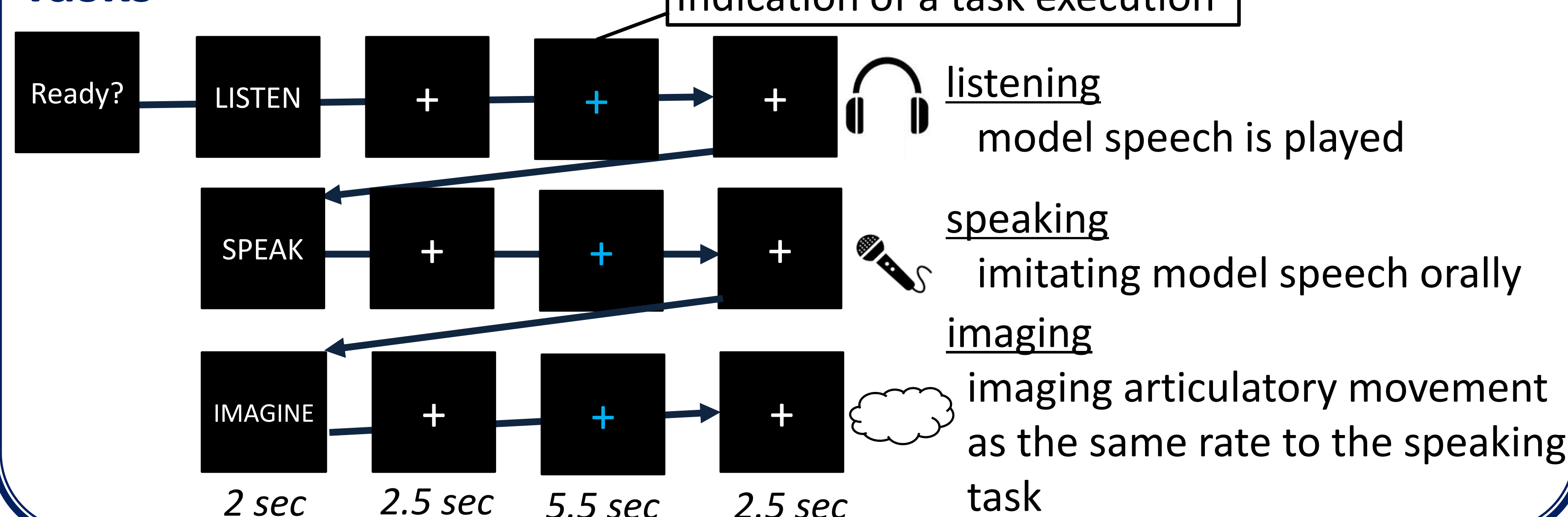
## EEG experiment

**Participant** 1 male, 1 female (L1: Japanese)

### Speech material

- あなたが昨日夢中で読んでいた本はおもしろかった。  
(The book that you were absorbed in yesterday is interesting.)
- ついさっき女の子が私に言ったことは本当の話。  
(What the girl said to me just now is true.)
- 向こうの壁に飾っているのは彼のお兄さんが描いた絵。  
(The picture on the other wall was drawn by his older brother.)

### Tasks



### Selected references

- H. Luo and D. Poeppel. (2007) Phase patterns of neuronal responses reliably discriminate speech in human auditory cortex, *Neuron*, vol.5, pp.1001–1010.  
M. D'Zmura, S. Deng, T.L.S. Thorpe, and R. Srinivasan. (2009) Toward EEG sensing of imagined speech, In *Human-Computer Interaction. New Trends*, Springer, Berlin, Heidelberg, pp.40–48.  
C.S. DaSalla, H. Kambara, M. Sato, and Y. Koike. (2009) Single-trial classification of vowel speech imagery using common spatial patterns, *Neural Networks*, vol.22, no.9, pp.1334–1339.  
H. Watanabe, H. Tanaka, S. Sakti, and S. Nakamura. (2017) Subject-independent classification of Japanese spoken sentences by multiple frequency bands phase pattern of EEG response during speech perception, In *Proceedings of Interspeech*, Stockholm, Sweden, pp.2431–2435.

## Analysis pipeline

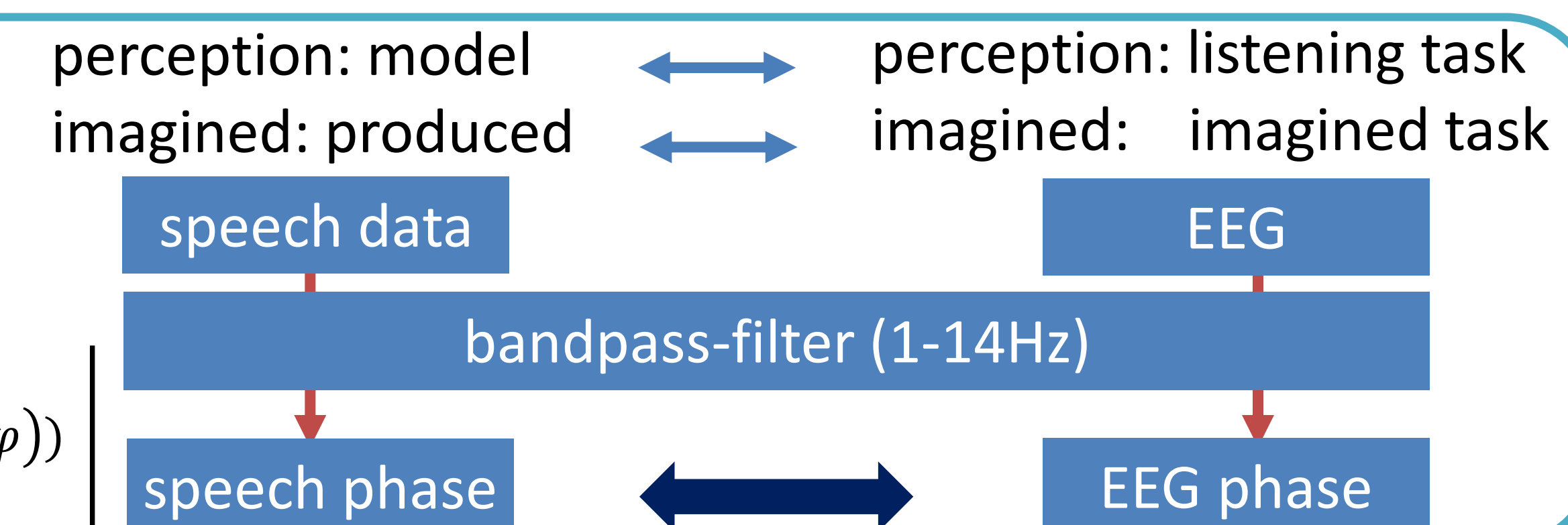
### preprocess

- perception data: 35 trials (subj 01), 38 trials (subj 02)
- imagined data: 39 trials (subj 01), 42 trials (subj 02)

### Synchronization analysis

#### phase-locking value (PLV)

$$PLV(ch) = \left| \frac{1}{T} \sum_{t=1}^T \exp(1i * (EEG_{\phi} - SPEECH_{\phi})) \right|$$



### Classification analysis: 3 sentence classification task

#### feature extraction

- Averaged across target channels
- FFT decomposition
- Phase extraction: [0, 2.8] sec, [2, 12] Hz

perception: fronto-central  
imagined: centro-parietal

#### model training

- Logistic regression
- SVM
- Random forest
- Template matching

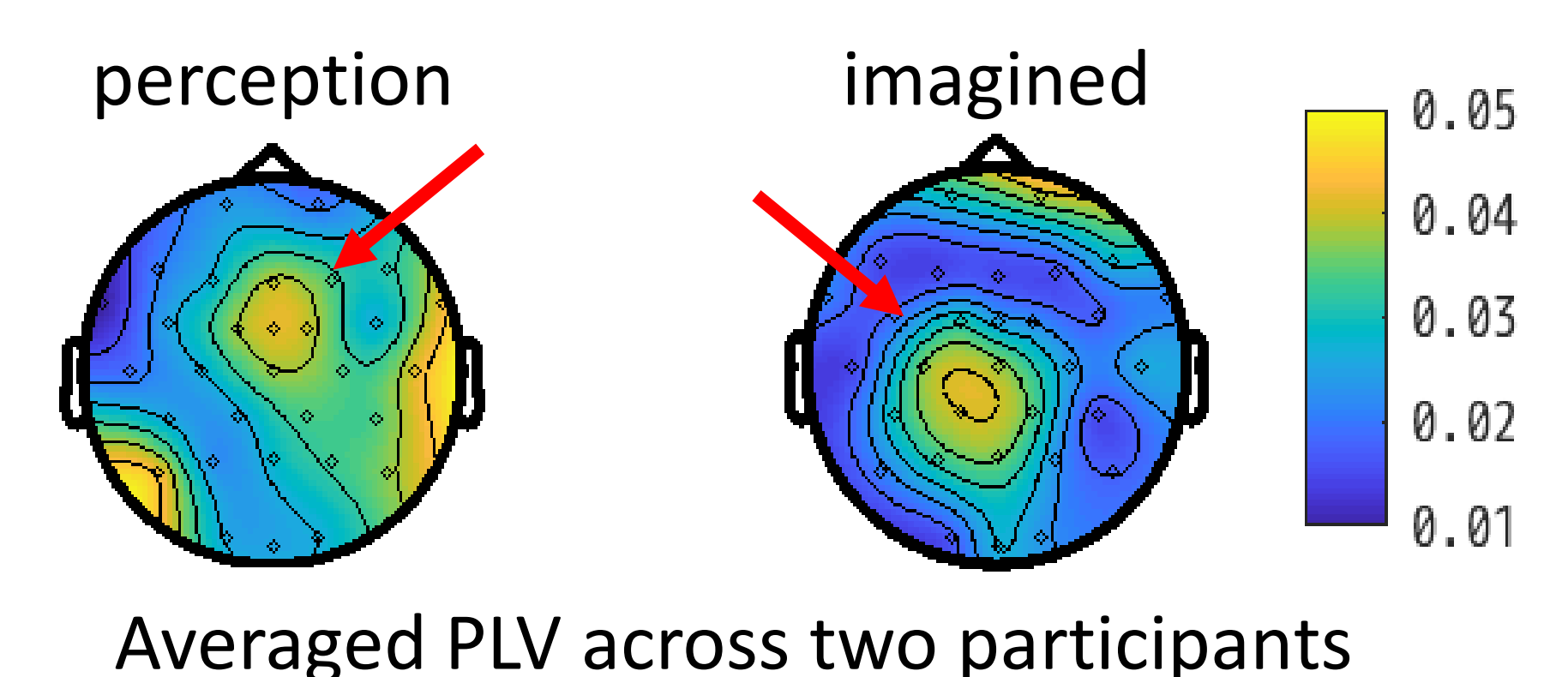
#### evaluation

- Leave-one-out cross-validation

## Result

### Synchronization analysis

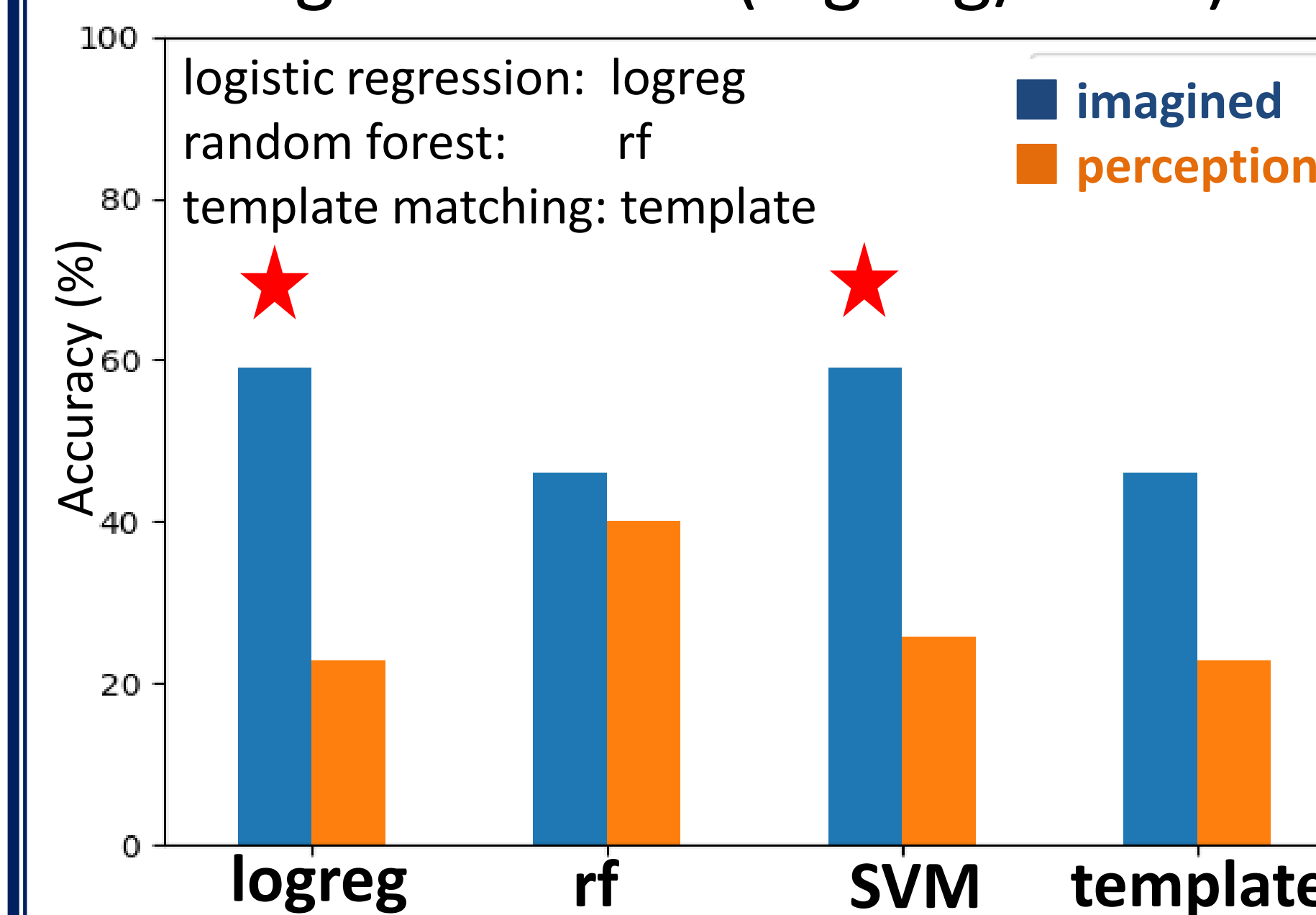
**Perception:** stronger PLV in fronto/ central region  
**Imagined:** stronger PLV in centro/ parietal region



### Classification analysis

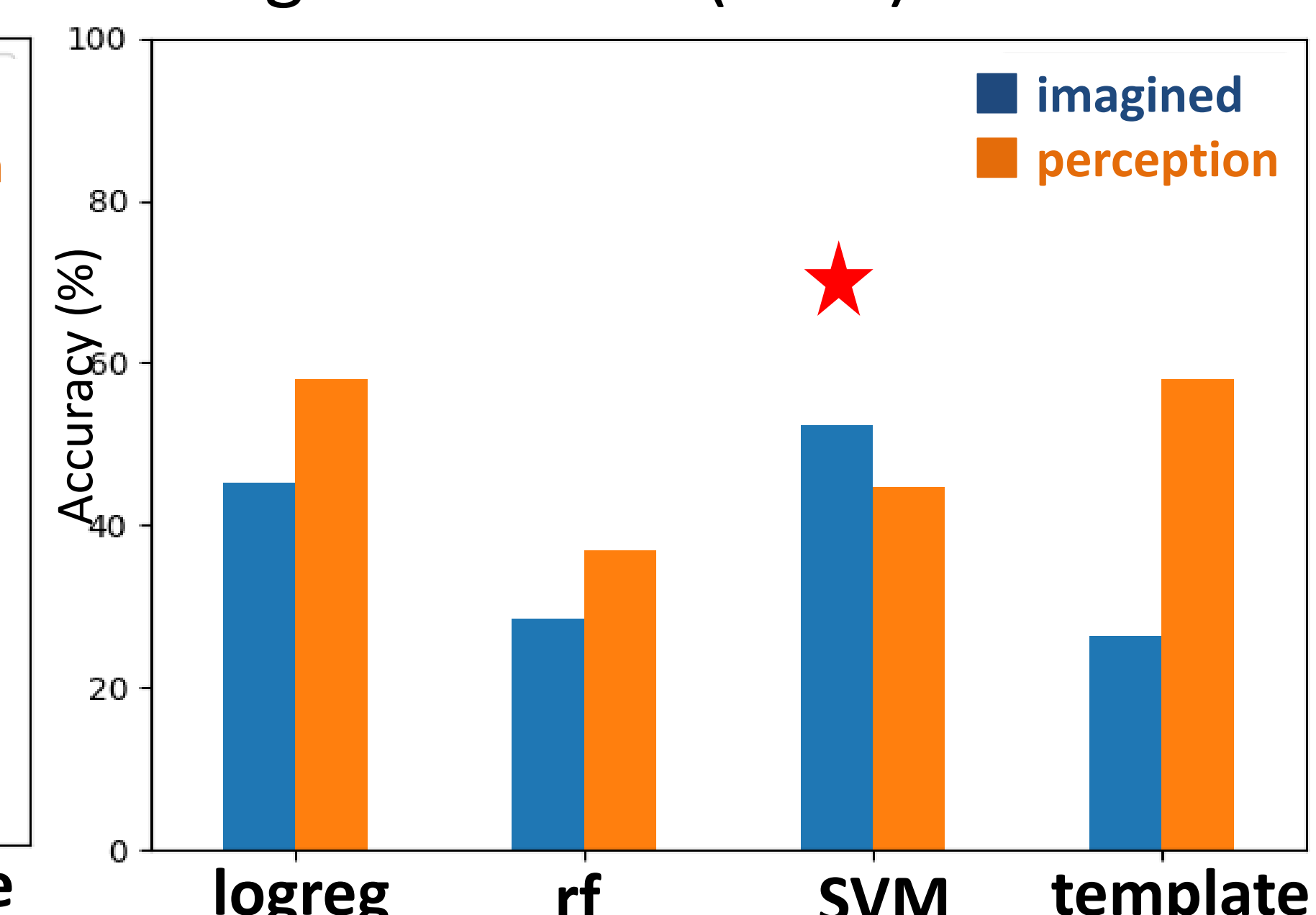
subj 01

percep: 40.0 % (rf)  
imagine: **59.0 %** (log reg/ SVM)



subj 02

percep: 57.9 % (logreg/template)  
imagine: **52.4 %** (SVM)



## Conclusion & Future directions

**RQ. 1** A tendency of phase synchronization b/w produced speech & EEG oscillations during imagined sentences

**RQ. 2** Best accuracies: [52.4 59.0 %] by SVM.

Phase patterns are reliable features for imagined sentence recognition

**Future directions:** (1) Increasing number of participants +  
(2) Source localization of this phase synchronization phenomenon