How proficiency shapes the hierarchical cortical encoding of non-native speech

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INTRODUCTION

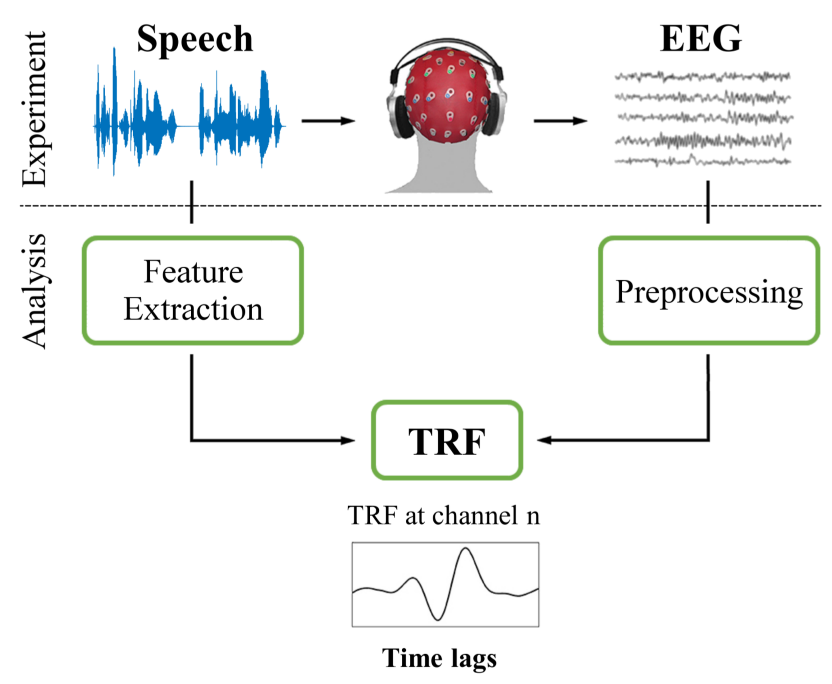
• Learning a second language (L2) is a challenging process that differs from native language (L1) acquisition.
• L2 speakers are usually recognisable by their accent, even when proficient.
• Targeted experiments showed different cortical responses to L1 and L2 speech sounds (e.g. syntactic MMN). Yet, it remains unclear how "nativeness" and proficiency affect the **cortical processing of natural speech**.
• Recent work demonstrated a neurophysiological framework to investigate the hierarchical processing of natural speech [1,2].
• Here we investigate the effects of **proficiency** and **nativeness**.

METHODS

EEG experiment

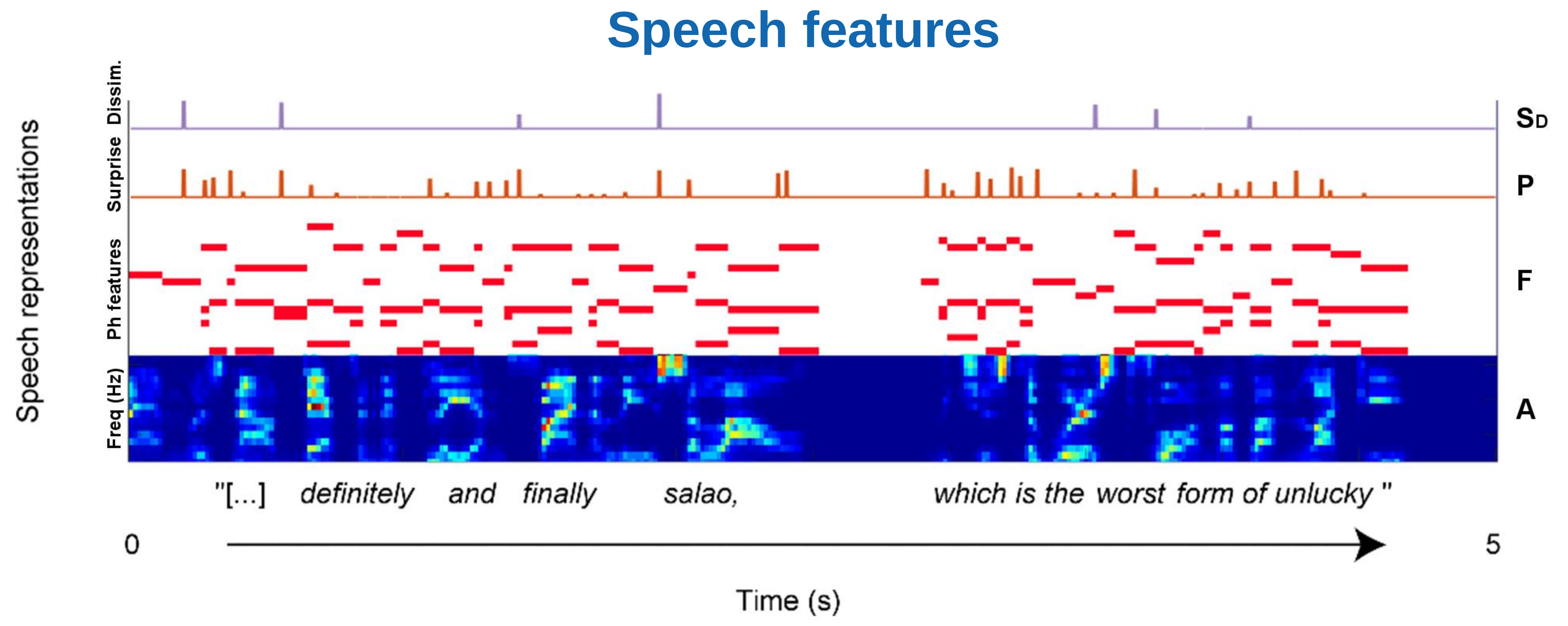
• Presentation of continuous speech from an audio-book for ~1.5h
• 64-channel EEG, **N=74** (22 L1 + 52 L2)
• L1: native English speakers; L2: native of Chinese, non-native of English
• Task 1: Repeated phrase detection
• Task 2: Frequent word detection
• Proficiency level tested offline: A1, A2, B1, B2, C1, and C2 levels

Analysis framework



- Temporal response functions (TRFs) were estimated using a multiple linear regression that includes time-shifted versions of the input (time lags)
- Output: TRF weights and EEG prediction correlations

Speech features



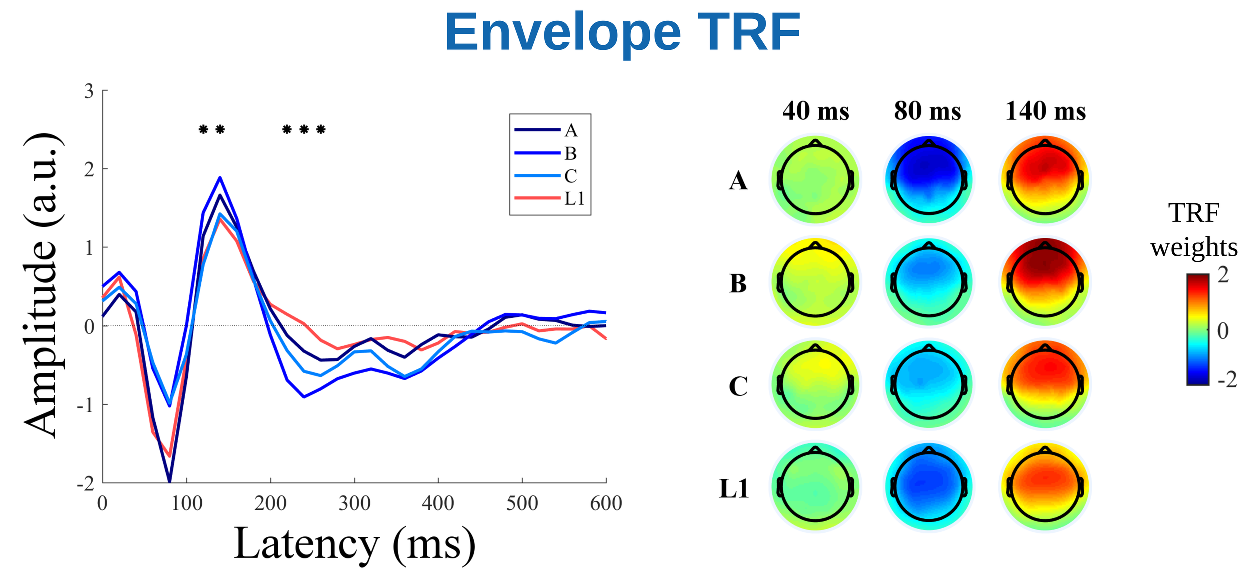
- A: Acoustic envelope, its half-way rectified first derivative, and spectrogram
- F: Phonetic features [1]
- P: Phonotactic surprise [2]
- SD: Semantic dissimilarity [4]

Hypotheses

- L2 encoding of linguistic properties becomes more L1-like with proficiency
- Stronger L2 semantic-level responses for the high-proficiency group
- Partial convergence (L2 -> L1) of phoneme and phonotactics signals
- Robust classification of proficiency
- Independent effects of proficiency and nativeness

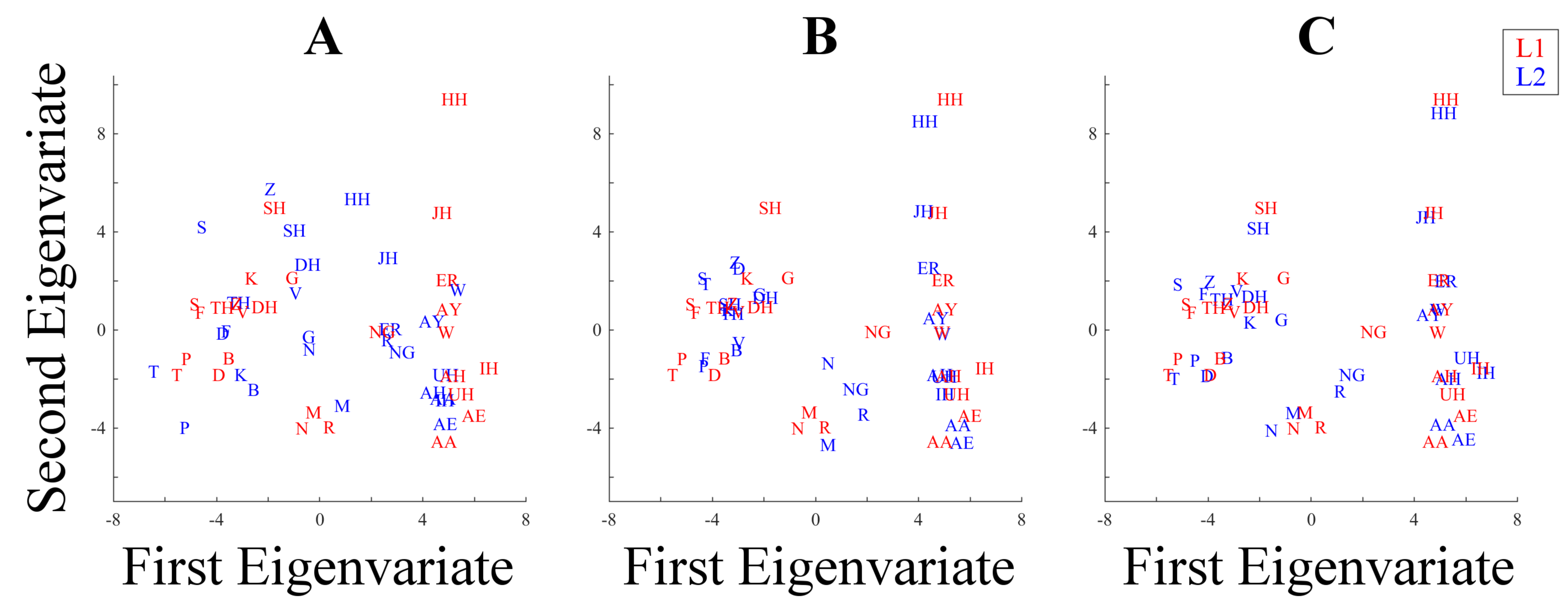
RESULTS

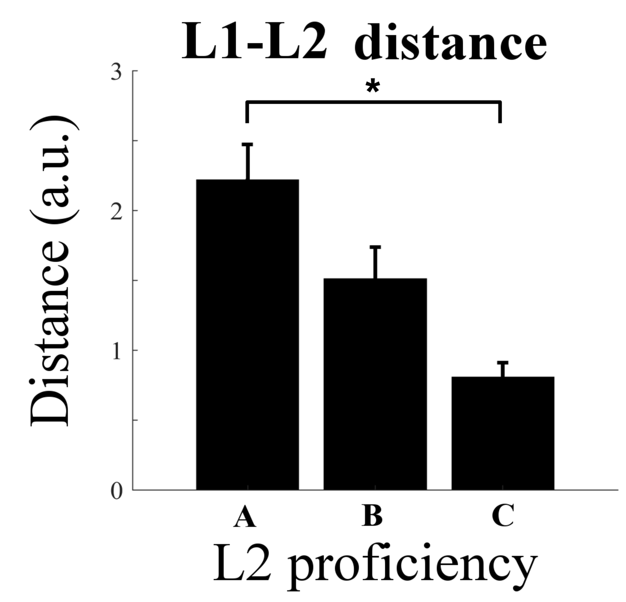
Envelope TRF



RESULTS

Phoneme TRF



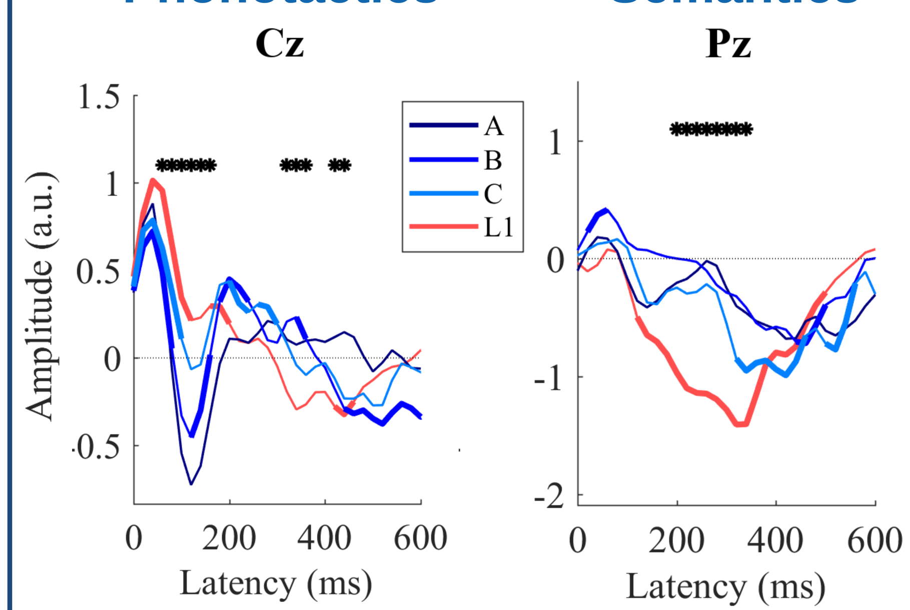


• Multi-dimensional scaling (MDS) was performed on the TRF weights.

• MDS-space for L2 participants was projected to the L1 MDS-space

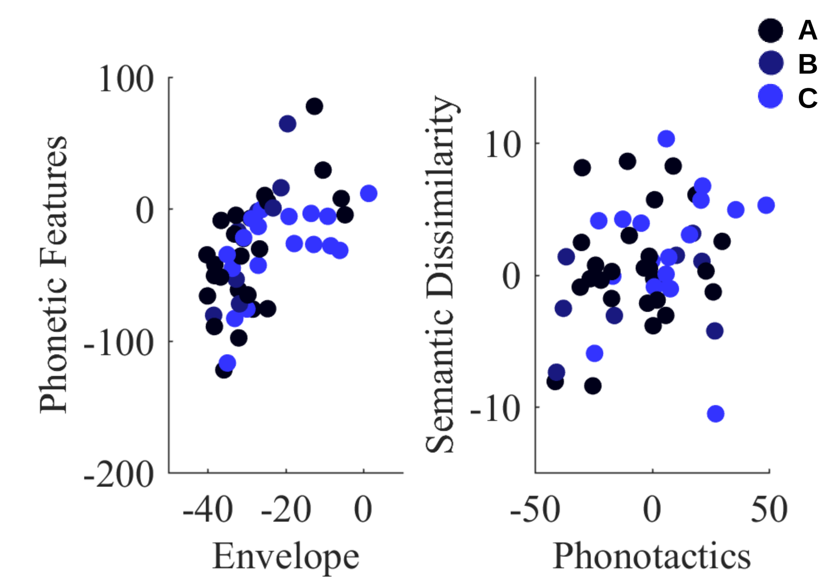
• Proficiency progressively reduced L1-L2 distances (ANOVA, $p = 2.5*10^{-5}$)

Phonotactics | Semantics



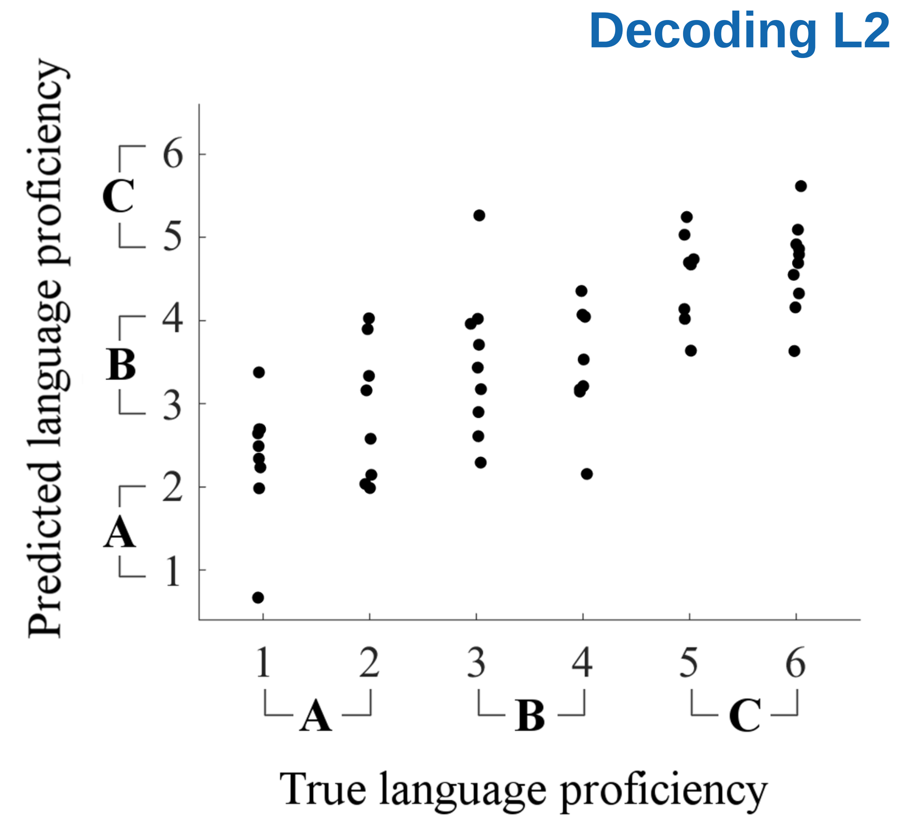
• Significant correlations between TRF amplitude and proficiency (*$p < 0.05$)

Effect of proficiency



• PCA of TRF weights for each given speech feature (e.g. envelope TRF)
• First PCs are good predictors of proficiency

Decoding L2 proficiency



• SVM regression (cross-validation)

• Regression: ***r* = 0.76**, $p = 6*10^{-11}$
MSE = 1.4

• **A vs. C** class. accuracy: **94%**

• Significant L1 vs. L2 class.:
L1 vs. C accuracy: 73%

DISCUSSION

• L2 **encoding** of phonemes, phonotactics, and semantics **becomes stronger and more L1-like with proficiency**
• Combining objective measures of speech processing at various hierarchical levels allows for the **robust decoding** of language proficiency in L2 listeners
• Brain signals for C L2-listeners differ from those for L1. Our results highlight specific **differences between the effects of proficiency and nativeness**

REFERENCES

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