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Relating linguistic features of speech with EEG using a dilated convolutional network

Background

State-of-the-art (SoA)

- Neural tracking of linguistics shown in linear models ([2, 3, 5])
- Linguistics processing can be a marker for speech understanding
- SoA studies: require control for acoustics to take into account correlation between speech features

Aim of the study

1. Measure neural tracking of linguistics in EEG using a deep learning model to overcome the linear assumptions made in SoA models
2. New method: control for lexical information to measure the semantic component of linguistic features
3. Measure the added value of linguistics over lexical features using a multi-input feature model [7]

Dataset

- Subjects: 60 young normal hearing native Flemish, screened with pure-tone audiometry and Flemish MATRIX test
- Stimulus (62 dBA, binaural): 10 children's stories (14 min each) without background noise, each narrated by a different single speaker.

Feature extraction

EEG was processed and linguistic and lexical features were extracted according to [5].

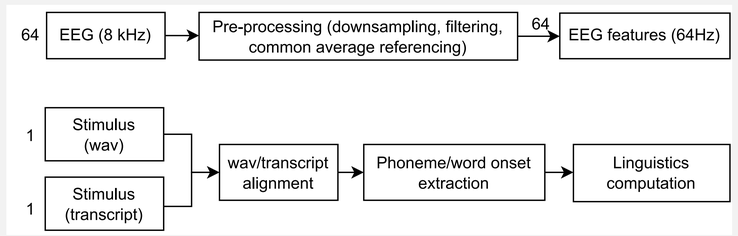
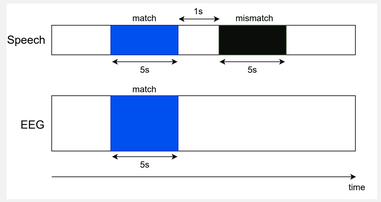


Figure: EEG and speech features extraction steps

- Lexical features: word onsets (WO), one-dimensional phoneme onsets (PO1D)
- Phoneme-based linguistics: phoneme surprisal (PS), cohort entropy (CE), for a phoneme i: $PS_i = -log_2(\frac{freq(cohort_i)}{freq(cohort_{i-1})})$, $CE_i = -\sum_{word}^{cohort_i} p(word) log_2(p(word))$
- Word-based linguistics: word frequency (WF), word surprisal (WS), for a word i: $WS_i = -log_{10}(p(w_i|w_{i-5}, .., w_{i-1}))$, $WF_i = -log_{10}(p(w_i))$

The match-mismatch task

We measure neural tracking of speech features in the EEG using the match-mismatch task [4, 6, 1].



Multi-input feature model [7]

We investigate the difference between the performance of the control models (2PO1D or 2WO, integrating twice onset information) and the linguistics model (PO1D+CE/PS or WO+WS/WF respectively).

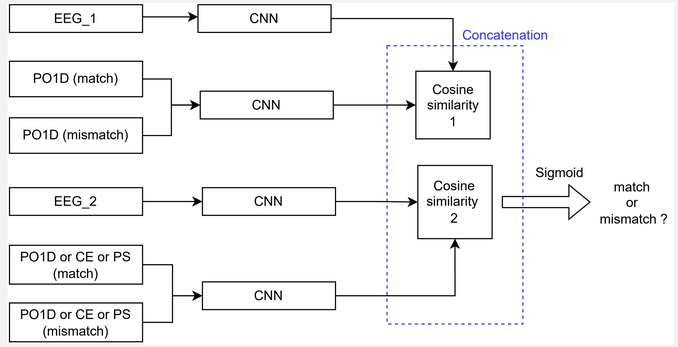


Figure: Multi-input feature model

Result 1: Word-level linguistic features

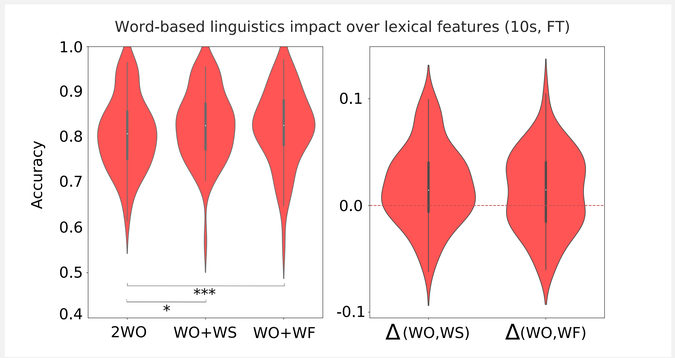


Figure: Impact of world-level linguistic features over word onsets. *(*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$)*

Result 2: Phoneme-level linguistic features

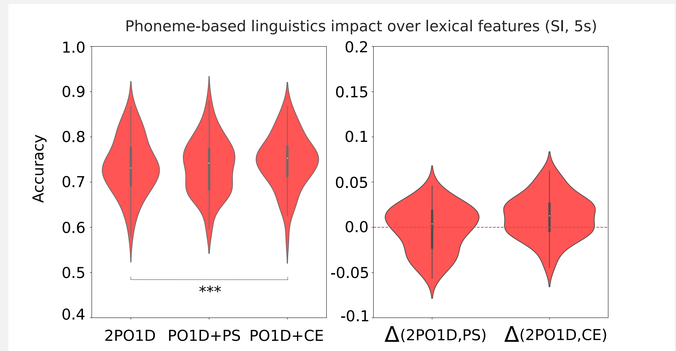


Figure: Impact of phoneme-level linguistic features over phoneme onsets. *(*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$)*

Discussion and Conclusion

- Phoneme-based linguistics models (PO1D+CE) have an added value over control models (2PO1D)
- Word-based linguistics models (WO+WS, WO+WF) have an added value over control models (2WO)
- We measured neural tracking of the semantic component of linguistics features
- We will next use this model to measure speech understanding and correlate results with behavioural measurements

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