



# Improved decoding of the speech envelope using a deep neural network

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## Introduction

### Neural tracking

- Finding neural tracking of speech features in the brain
- Can be used as diagnostic tool for speech understanding [Vanthornhout et al., 2018, Accou et al., 2021]

### Problems

- Relatively simple linear models are used
- Subject-specific models, which requires collection of training data for each (test-)subject

**Proposed solution:** A very large augmented auditory inference (VLAAl) network

- Non-linear complex model to decode the envelope from EEG
- Subject-independent model to reduce amount of data needed per subject

## Dataset & Preprocessing

### Subjects

- 106 normal hearing native Flemish speakers
- Screened with pure-tone audiogram and Flemish MATRIX test

### Stimuli

- 2-8 children's stories narrated by a single speaker in Dutch
- $\approx$  15 minutes in length

This amounts to  $\approx$  195 hours of EEG data (1 hours and 50 minutes of EEG data per subject on average).

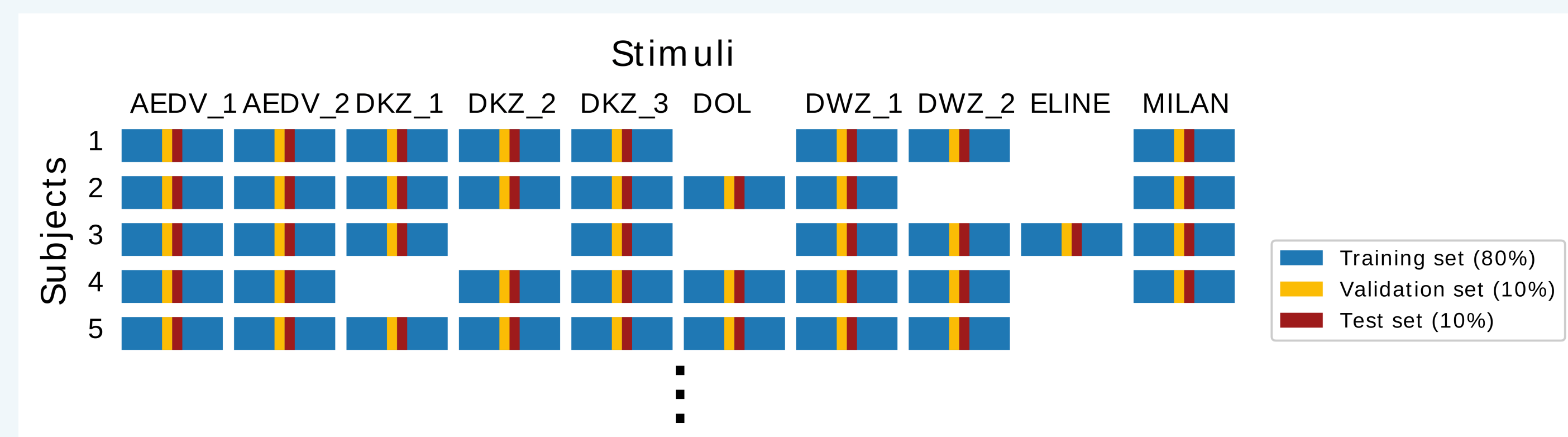


Figure 1: A visualization of the recordings (blue boxes). Test- and validation-set are extracted from the middle of the recording

### Preprocessing steps

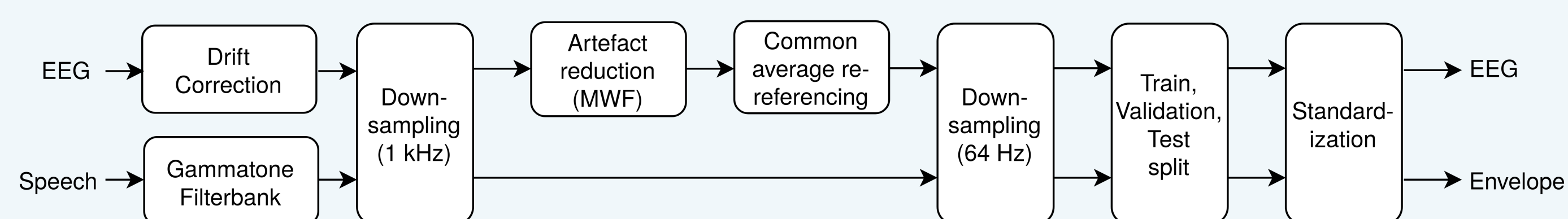


Figure 2: All preprocessing steps performed on the dataset.

To train and evaluate the models in the experiment section, windows of 5 seconds with an overlap of 80% were used

## Model architecture

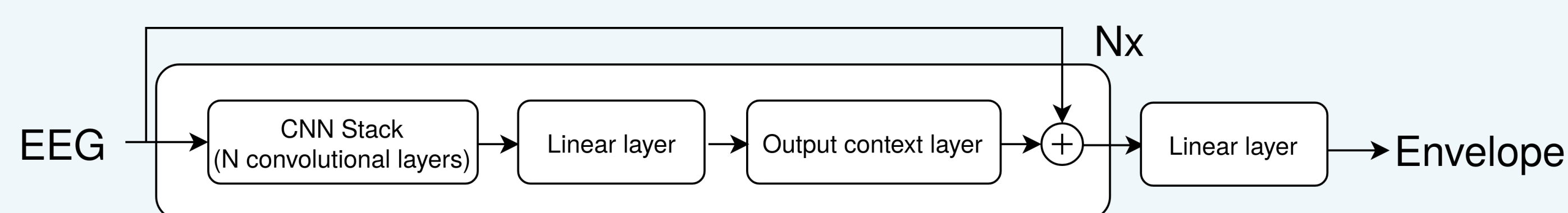


Figure 3: The architecture of the new proposed VLAAl network.

The VLAAl network consists of 3 modules which can be repeated  $Nx(=4)$  times:

- CNN stack**  
This module consists of 5 convolutional layers with a kernel size of 8. The first 3 and last 2 layers have 256 and 128 filters respectively. After each convolutional layer, layer normalization, a LeakyReLU activation and zeropadding with 7 samples at the end of the sequence were applied.
- Linear layer**  
A linear combinations of the output filters of the CNN stack
- Output context layer**  
Predicting a better sample based on 31 previous samples + the current sample.

VLAAl is trained with negative Pearson coefficient as a loss function

## Comparison to baseline models

All models utilized in this section were trained with EEG data of all participants (i.e. **subject-independent** models).

The proposed VLAAl network is compared to 3 baseline models:

- Linear decoder**  
A linear decoder with an integration window of 500 ms, trained with negative pearson coefficient as loss.
- CNN**  
The CNN model of Thornton et al. [2022], which was based on the EEGNET architecture [Lawhern et al., 2018]
- FCNN**  
The FCNN model of Thornton et al. [2022], which was based on the architecture of de Taillez et al. [2017].

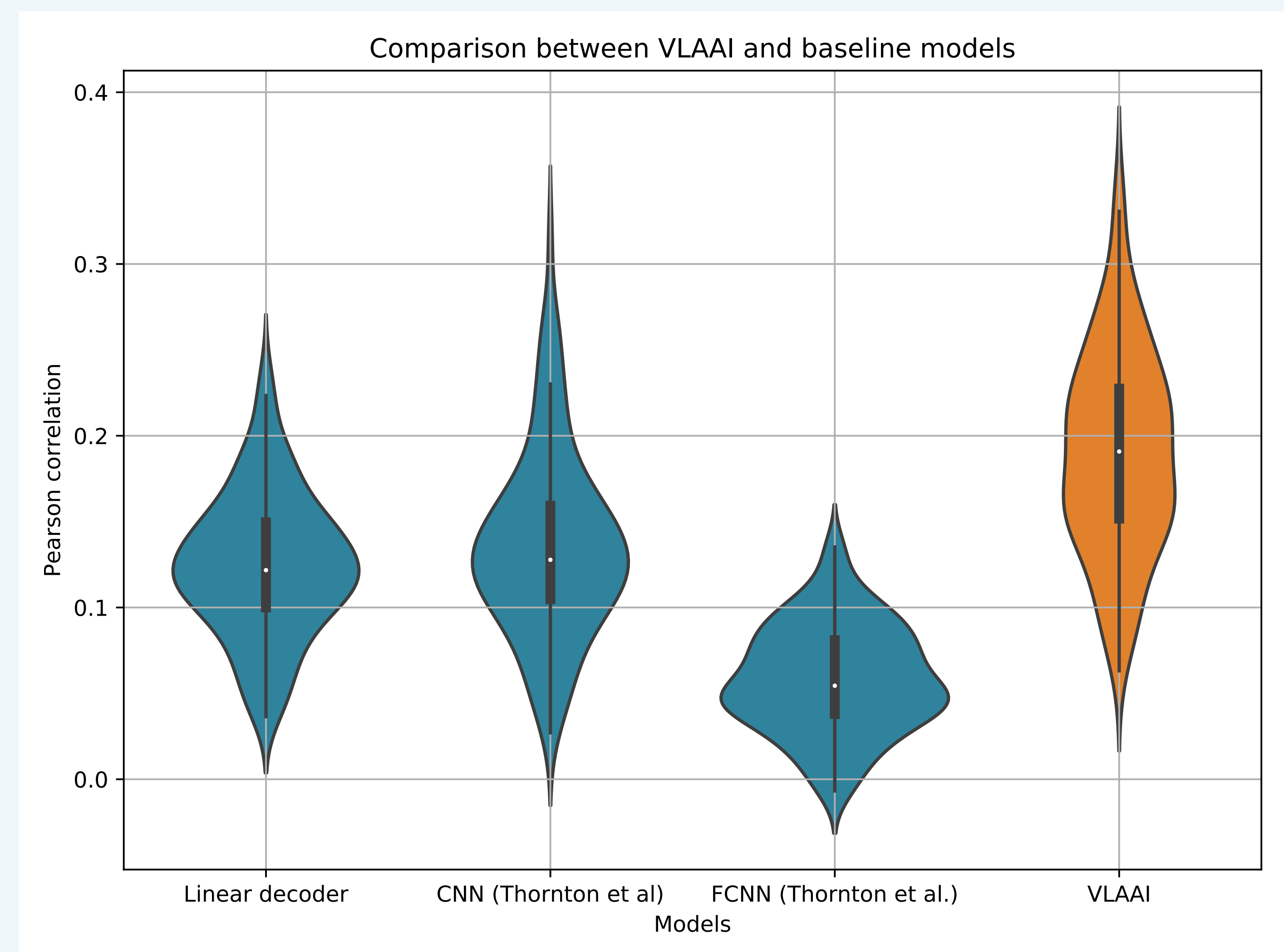


Figure 4: Comparison between the VLAAl network with 3 baseline models for 5 second segments. Each point in the boxplot represents the reconstruction score for a subject, averaged across stimuli.

Models were compared using a Wilcoxon rank-sum test using Holm-Bonferroni correction. All models performed significantly different ( $p \leq 0.05$ ). The VLAAl network significantly outperforms all baseline models

## Discussion

- While Thornton et al. [2022] could be replicated using their own provided data, the FCNN model performed worse when trained/applied on the datasets presented here (see Figure 4). A possible explanation is that the hyperparameters for regularizing the population models in Thornton et al. [2022] are not optimal for our dataset
- The VLAAl network outperforms the baseline models substantially (a relative improvement in median accuracy of 56.74% compared to the linear decoder baseline). A better decoder model, such as VLAAl, might reveal neural tracking and/or effects that were hidden previously

## Acknowledgments & References

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