Generalizable Semantic Decoding from iEEG using Deep Nonlinear CNNs

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Motivation

- Chronic severe aphasia after stroke is a common debilitating problem.
- While BCI devices offer hope, speech decoders based on motor or phonological decoding may not perform well in most of this population.
- Developing a model to decode semantic information directly from intracranial EEG (iEEG) could support a flexible and powerful language neuroprosthesis.

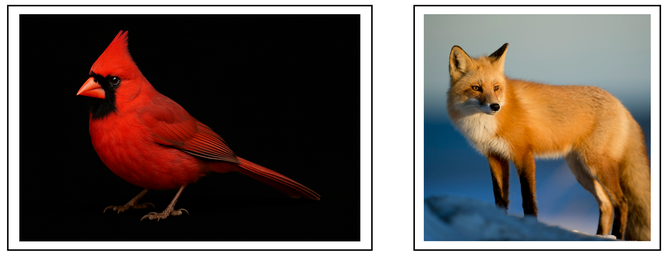

Figure 1. Stimulus images were generated using either generative AI models (left) or real stock photographs (right).

Experiment

- iEEG data were acquired from four patients undergoing sEEG recordings.
- Pictures of concrete objects (Fig. 1) were presented in a rapid serial visual task.
- 3000 trials, 100 concepts, 500ms ITI.
- Subjects were asked to count images corresponding to specific semantic categories.

Analysis

- Raw data was minimally filtered and resampled down to 500Hz (250 data points per epoch).
- Semantic embedding vectors created with RoBERTa, PCA reduced to 32-dimensions.
- Ridge regression performed with Scikit-learn, alpha chosen to minimize validation loss.
- Deep convolutional neural network (CNN), containing 14 layers of CNNs, was trained using PyTorch (see Fig. 2).

Testing

- 10-fold held back validation on three stimulus sets:
  - ***Same Image:*** The exact same stimulus, but a different trial.
  - ***Same Concept:*** An untrained image of a concept, trained on a different image.
  - ***New Concept:*** Completely untrained image and concept.

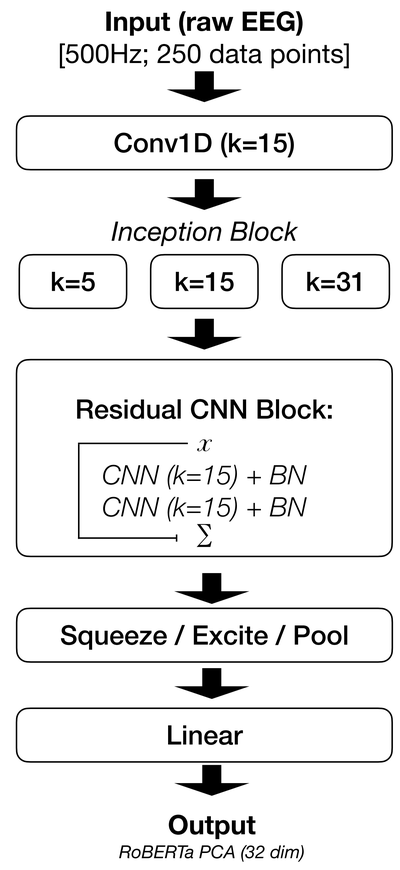

Figure 2. Flowchart of the CNN. Inception blocks allow for multiscale resolution, deep layers provide expressive capacity, and residual connections enable training of deep networks.

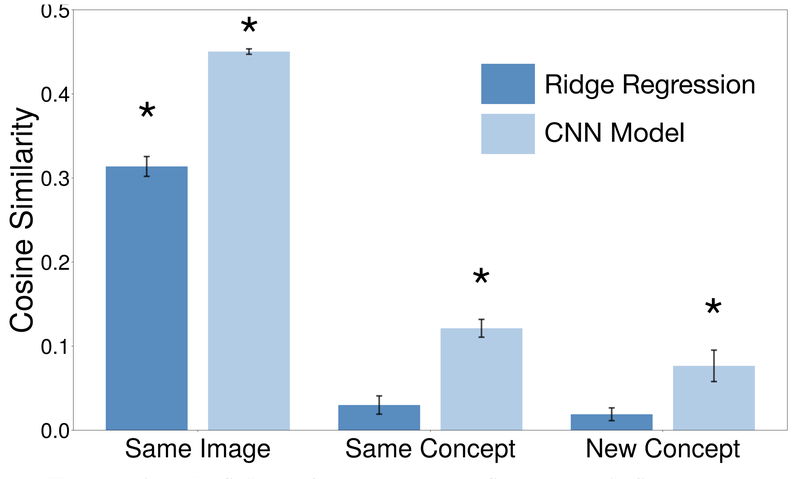

Figure 3. Model performance predicting validation stimuli.

Results / Conclusions

- Both Ridge and CNN models were able to decode iEEG responses to trained stimuli.
- The CNN model was also able to predict untrained images and completely novel concepts.