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RNN-LSTM neural network for predicting fMRI neurofeedback scores from EEG signals

Caroline Pinte[1], Claire Cury[1], Pierre Maurel[1]
1 - University of Rennes, CNRS, Inria, Inserm, IRISA UMR 6074, Empenn Team ERL U 1228, Rennes, France.

Introduction In the context of neurofeedback (NF), simultaneous acquisitions with electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) provide more effective NF training due to their complementarity [1]. However, the use of MRI is expensive and draining for the subject. Therefore, we would like to reduce its use. Following the work of Cury et al. [2], we propose a method based on a recurrent neural network (RNN) that consists in learning a model from simultaneous EEG-fMRI acquisitions to predict NF-fMRI scores with EEG signals alone.

Materials and Methods We acquired simultaneous EEG-fMRI data on 15 healthy subjects, in a motor imagery context, following the XP2 protocol described in [3]. This includes fMRI and EEG data for three NF runs of five minutes per subject, with their respective NF scores whose calculation is detailed in the same article. Our method consists in extracting, for each EEG electrode, traditional features such as mean, standard deviation, skewness, kurtosis, α, β, and σ band powers. We then proceed to train a long short-term memory recurrent neural network (RNN-LSTM). The training, validation and test datasets are each composed of 15 runs, one per subject. After the model is trained, NF-fMRI scores can be predicted, to which the true NF-EEG scores are added for comparison with the NF-EEG-fMRI ground truth.

Results and Conclusions

The predictions of our current best model have an RMSE of 1.35 and a correlation of 0.57 with the ground truths on average over the 15 test runs. However, there are large variations in performance across subjects, ranging from a correlation of 0.79 for the example in *Fig. 1* to correlations close to 0.30 for some subjects, which is not yet satisfying. Indeed, there are still many ways to improve the model, which suffers in particular from a sensitivity to the learning parameters, from the noisy nature of the EEG modality, and from the lack of data. To conclude, the interest of this method compared to the previous modeling [2] is to test the contribution of deep learning, mainly to train a single model for all subjects, which would eventually allow the use of the model to predict these fMRI scores directly online.

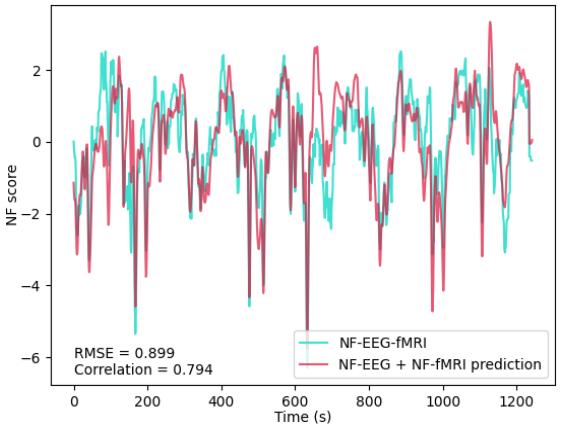

Fig. 1: Prediction of NF-fMRI scores for the best subject, to which the true NF-EEG scores are added, and compared with the true combined NF-EEG-fMRI scores.

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