 DOI: 10.3217/978-3-85125-962-9-154

Offline Prediction of Prolonged Acute Pain by means of Convolutional Neural Network Model applied to Electroencephalographic Oscillatory Connectivity

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***Introduction**:* Unresponsive patients are unable to self-report pain. Hence, the electroencephalogram (EEG) is a potential tool by which caretakers can assess their pain. However, building a pain assessment model always requires labelled data. Since data from unresponsive patients cannot be labelled based on self-report, we aimed to develop a model which can be generalized to novel individuals with no labelled data for training. For this purpose, we trained a convolutional neural network (CNN) model to classify pain and non-pain conditions from EEG signals across individuals.

***Material, Methods and Results**:* Forty-three healthy individuals participated in the experiment (22 females, mean age = 25.36). Due to technical or procedural issues, seven participants' data were excluded and thirty-six participants remained for analysis. There were five conditions involved in the experiment of which we used the pain condition induced by hot water (H) and the resting state with eyes-open (O) for the present analysis.

We segmented the signals into 5-sec trials with an overlap of 50%. As a measure of functional connectivity (FC), inter-site phase clustering (ISPC) was computed within each trial between all pairs of 32 EEG channels [1]. The ISPCs of each trial were reorganized as a 32×32 matrix as the input feature to the CNN model, whose rows and columns represent channels.

The CNN model involves three basic architectures of hidden layers and batch-normalization layers, followed by dropout layers. Fully connected layers and activation functions were applied for classification.

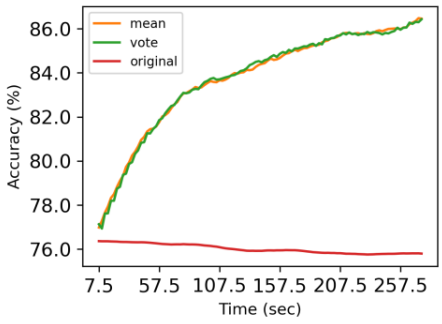

Figure 1. *Mean prediction accuracy versus duration of segment used to accumulate evidence. The model was trained using the data of n-1 participants and evaluated on the remaining 1 participant. This was repeated for all participants.*

We applied leave-one-out (LOO) tests to each participant. In each test, one participant was excluded from the model training and only used in testing, and the model was trained with the other thirty-five participants. Accumulative evidence was computed to evaluate the effect of the number of consecutive trials, where the prediction of one trial depends on the mean prediction score of each class across all trials before the target trial or the most common prediction of single trials before the target.

With every single trial for prediction, the accuracy reached 76.01%±11.72% of binary classification. When accumulative evidence is applied, the maximum level was 87.98%±13.17%. Moreover, mean accuracy reached 80% after 35 seconds.

***Discussion & Significance**:* The individual variation of neural responses to pain obstacles the generalization of the pain assessment model, so models using transfer learning are rare [2]. Recent research suggests that slow alpha frequency correlates with individual pain sensitivity [3]. And that the FC in the alpha band may be an ideal neural marker for pain prediction [1]. Hence, our current attempts showed the potential of alpha FC to reduce the effects of individual differences in pain prediction.

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