Classification of short-term memory tasks in ROI-based fMRI data

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With the advance of experimental techniques, functional magnetic resonance imaging (fMRI) being one of them, measuring neural activity while a person is memorising and retrieving information has become possible. In recent years, functional activations have been intensely analysed by a range of machine learning [1] and deep learning [5] methods to study brain disorders. However, fMRI signals are notoriously challenging to analyse due to their very low temporal resolution and a non-trivial auto-correlation and cross-correlation structure. In this work, we apply several linear and non-linear classification methods to fMRI signals from the short-term memory distortion experiment [4]. The experiment consisted of two visual verbal tasks (based on semantically or phonetically associated words), two non-verbal tasks (local and global processing of pictures of similar objects), and spontaneous brain activity (resting state, RS), with matching, non-matching and intentionally confusing stimuli. The classification methods included among several others: Quadratic Discriminant Analysis (QDA), Random Forests, hyperparameter tuned Light Gradient Boosting Machine [3] (LGBM), and ResNets [2] of several depths. With these methods, we classified very short segments of brain activity (1-6 samples, corresponding to 2-11 seconds) from information encoding (memorisation) and retrieval (recollection) phases into stimuli types (2, 3, 4, or 5 classes).

We show that the best classifiers reach F1-scores up to .834 for the 2-class and up to .603 for the 5-class problem, see Fig. 1. The nonlinear classifiers (such as QDA, LGBM or ResNets) clearly beat linear ones, but none of them is universally best in our experiment. Most interestingly, our tests showed that information crucial for producing good classification results (aka explanations) is localised in a small number of ROIs. We also show how important it is for such explanations (like SHAP) to scrutinise time series for cross-correlations (e.g., the right inferior occipital gyrus, 54 in Fig. 2, has a low importance score due to a large correlation with the left inferior occipital gyrus, 53). The presented findings increase the efficiency of fMRI signal classification in cognitive experiments and give rise to the understanding of the cognition process related to short-term memory performance and distortions.