Optimising Searchlight Representational Similarity Analysis (RSA) for EMEG

Methods and Materials

The Optimal Searchlight Size for Speech

No Optimal Searchlight for Non-speech

Conclusions

The optimal searchlight size in space is 30mm radius, which is larger than for fMRI (often on the order of 10mm). This may be because distributed source estimation using MNE has poorer spatial resolution than most high field fMRI. The optimal time window for the searchlight is 15ms, in line with the rate of information encoding in neural circuits (4). We argue that these optimal parameters are set by the physical properties of EMEG measurements, which are weakly distributed and not specifically in language areas. Right: brain regions which show large test-retest reliability are mainly areas that support language processing. This indicates where stable neural representations of inflections are encoded in the brain. Left: test-retest reliability is much lower for non-speech (MR) than for speech, and not significantly above zero.

For the /i/ presentation of the stimuli:  \[ P(i) = S(i) + n(i) \]
For the /j/ presentation of the stimuli:  \[ P(j) = S(j) + n(j) \]
P = observed patterns (sample distribution);  
S = “true” neural activation patterns (signal distribution);  
n = random noise (noise distribution).

Assume the unknown “true” pattern is reproduceable in test-retest, i.e.  \[ S(i) = S(j) \], but random noise  \[ n(i) \neq n(j) \]. So,  \( P(i) \) and  \( P(j) \) will be more similar if the signal-to-noise ratio  \( \text{SNR} = S/n \) is high. This, in turn, implies that the amount of information in the sample distribution is high.

Selecting the optimal spatio-temporal searchlight parameters

We randomly split 12 repetitions into two sets of six, and computed RDMs for each set separately, and then correlated RDMs from both sets to yield a test-retest reliability metric. We performed this analysis at time windows starting from the onset of inflectional affixes, and moved the searchlight over the whole brain. We then did a t-test of the averaged correlation values over the brain against zero across participants. Finally, we selected the optimal searchlight size by maximising the test-retest reliability value among different combinations of searchlight parameters in space and in time.

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The Representational Dissimilarity Matrix (RDM)

Each entry in the RDM is a correlation distance (e.g. one minus the correlation value) between spatio-temporal patterns elicited by a pair of experimental conditions (or stimuli) within a specific experimental condition. Elements on the main diagonal of this matrix are zeros by definition. In the off-diagonal parts of the RDM, a large value indicates that the two conditions have elicited distinct spatio-temporal activation patterns, and vice versa for small values. RDMs computed using this method are symmetric about the main diagonal.

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Regular

Irregular

Music Rain (MR)

Music Rain (MR)

Experimental Conditions

We selected 20 verbs (10 regular & 10 irregular) with -s, -ed suffixes. We randomly split 12 repetitions into two sets of six, and computed RDMs for each set separately, and then correlated RDMs from both sets to yield a test-retest reliability metric. We performed this analysis at time windows starting from the onset of inflectional affixes, and moved the searchlight over the whole brain. We then did a t-test of the averaged correlation values over the brain against zero across participants. Finally, we selected the optimal searchlight size by maximising the test-retest reliability value among different combinations of searchlight parameters in space and in time.

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Test-retest reliability was used as a measure for the amount of information in activation patterns, and to optimise the searchlight size:

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Multivariate Pattern Analysis (MVPA) has been applied in many areas of neuroimaging, including fMRI, EEG and recently MEG. A notoriously difficult problem with MVPA of neuroimaging data is the curse of dimensionality, which reflects the difficulty in fitting models with very large numbers of dimensions (voxels) to imaging datasets, which have very few training examples (volumes).

To overcome this, a critical step in MVPA is dimension reduction, which can be achieved, for example, through principal component analysis or preselecting data according to existing priors. Another useful approach is the searchlight algorithm that uses anatomically local multivariate patterns to assess the neural population code (1). By moving the position of the searchlight in space, one can derive a whole brain map. The searchlight algorithm was originally derived for fMRI, and we have now applied it to spatio-temporal patterns in source space estimates of combined MEG and EEG (EMEG) data (2). To account for the temporal dimension in these data, in addition to moving the searchlight in space, a sliding temporal window is applied to cover different time points.

Here, we investigated the optimal spatio-temporal parameters for the searchlight of Representational Similarity Analysis (RSA). We did this in an EMEG experiment, in which participants listened passively to short phrases.