 DOI: 10.3217/978-3-85125-467-9-119

Importance of the Window Size for Neurofeedback based on fMRI Functional Connectivity

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Introduction: Current researches suggest that fMRI-Neurofeedback can play an important role for therapeutic purposes, and first successful applications have been demonstrated (for a review see [1]). fMRI-based functional connectivity measures are neurofeedback candidates to treat pathological brain processes in psychiatric and neurological disorders. However, measuring dynamic changes in functional coupling using sliding-window correlation involves a trade-off between the window size, the neurofeedback time, and the reliability of the estimate. In order to investigate how the window size relates to (1) the estimation of correlation and (2) the differentiation between coupling strengths, we run several simulations with known coupling strengths and SNR.

Methods: We simulated neural activity using a simple vector autoregressive (VAR) model adapted from [2] with 7 nodes. To generate BOLD signal the VAR model output was convolved with hemodynamic response function generated using a difference-of-gamma approach. Data were simulated with a TR of 1s. First node drove activity in nodes 2 to 7 with a decreasing coupling strength. We simulated 1000 trials with 600 time points each. Five different levels of white noise were added to the data to obtain a SNR of 1, 2, 4, 6 and 10. Sliding-window correlation was measured with non-overlapping windows of 2 to 200s. We computed correlations between node 1 and each other node resulting in correlation of different strengths on average. (1) We studied the minimum window length for a correct estimation of the correlation strength by comparing the distribution of correlation obtained with the 200s window with the distribution of correlation obtained with all other window sizes. (2) We tested the ability to differentiate between correlation strengths for a given window size by classifying correlation values from two different coupling strengths with linear discriminant analysis and a 10-fold cross-validation. A classification accuracy of 70% was set as the minimum threshold to distinguish between two strengths.

Results: Distributions of correlation significantly differed (Kolmogorov-Smirnov test, $p<.05$) from the distribution of the 200s window correlation up to window of 150s (Fig. 1). The 70% threshold was passed with windows of 10, 8 or 6s, and a difference in mean correlation of 0.50 for SNR of 2, 4 and 6 respectively (Table 1).

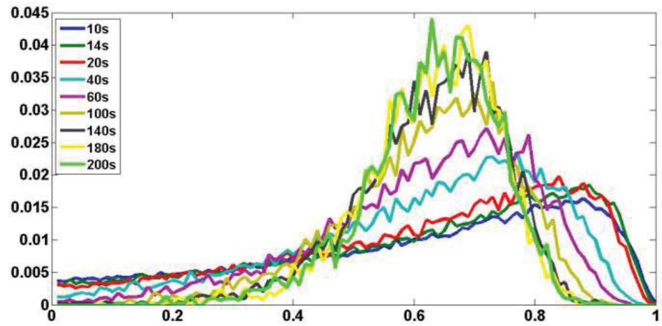

Figure 1. Probability density functions of the windowed correlation for a middle coupling strength (correlation between nodes 1 and 4).

1-2 vs.	1-3	1-5	1-7
8s	54	65	**74**
14s	55	**70**	**80**
20s	56	**73**	**83**
40s	59	**80**	**91**
100s	66	**91**	**97**
180s	**70**	**95**	**99**

Table 1. Classification accuracies (%) for classification of correlation values of nodes 1-2 vs. other correlations for different window sizes and SNR equals to 4.

Discussion: Our results show that small window can be used to distinguish between different correlation strengths and therefore can be used for neurofeedback. Accurate estimation of the correlation, however, requests much longer window. Several limitations should be noted, including the model used to simulate the data, and the 70% threshold to distinguish between coupling strengths. In the future, we will look at the influence of the TR and the effect of block design paradigms on correlation values.

Significance: Small window sizes can be used to compute correlation and to provide neurofeedback.

Acknowledgements: The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007– 2013) under grant agreements n°602450 and 602186.

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