Time Series Analysis for Near-Infrared Spectroscopy Data

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Near-infrared spectroscopy (NIRS) is an increasingly popular non-invasive brain imaging technique, often used in developmental cognitive neuroscience research [1]. As it is a relatively new method, standardized data analysis techniques are still lacking. Our understanding of the hemodynamic response in infants is also incomplete, rendering analysis methods that rely on strong assumptions about the underlying physiology impractical. Compromised data quality due to hair and strong movement artifacts, typical in babies, also plagues data analysis [1,2].

Here we put forward new analysis methods based on time series management and analysis techniques [3,4,5]. These techniques can efficiently operate on the original, fully detailed data set, taking into account the detailed trends that these data exhibit. Specifically, we have used similarity search to identify NIRS data that follow similar trends over time and subsequently group those together in clusters, and detect abnormal behaviors. We illustrate these novel methods (i) by comparing their results to previously published findings [2], as well as (ii) by applying them to previously unpublished data (both from experiments on newborn speech perception). In the first study, newborn infants listened to artificial speech sequences that either conformed to a repetition-based regularity (AAB: “babamu”, “nanape” etc.) or not (ABC: “bamuge”, “napefi” etc.), while their hemodynamic responses were measured in 12 channels per hemisphere over frontal, temporal and parietal sites. In the second study, the same sequences were used, but implemented by musical tones rather than speech.

As a first analysis, we used Euclidean distance in order to calculate the difference in the response of stimulus AAB and ABC. Based on the results in [2], we obtained significant differences between the conditions in left fronto-temporal and right frontal channels (Figure 1). Then, we performed a hierarchical cluster analysis to the AAB and ABC stimulation blocks in one significant channel. Preliminary results show that blocks of the same condition form a number of small clusters, although at the largest cluster levels such convergence is not always achieved (Figure 2). This implies that the responses to the AAB and ABC conditions indeed show different patterns. We are further refining this analysis to test for patterns characetristic not only of the two conditions, but of individual participants and different brain areas. If confirmed to be successful, this clustering algorithm has the potential to provide new analysis tools for NIRS data processing, possibly reliable at the individual level. Such an analysis would have immediate and important applications in basic as well as clinical NIRS research.

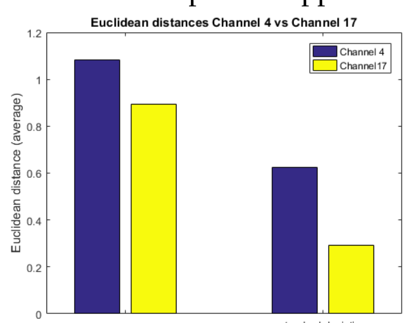

Figure 1. Euclidean distances between responses to the two conditions in channels 4 & 17

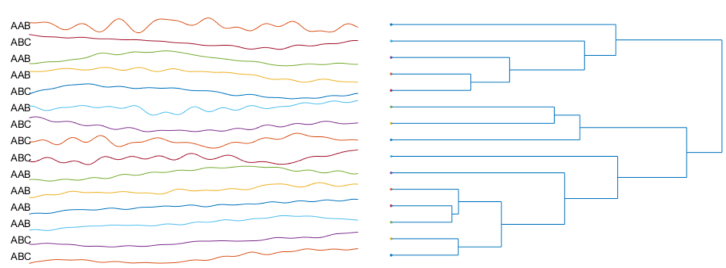

Figure 2. Dendogram of AAB and ABC responses in channel 4

References

[1] Gervain, J. et al. 2011. DCN, 1(1): 22-46. [2] Gervain, J. et al. 2012. JCN, 24(3): 564-574. [3] Camerra, A. et al. 2014. KAIS, 39(1). [4] Zoumpatianos, K. 2014. SIGMOD 2014. [5] Zoumpatianos, K. 2015. VLDB 2015.