Complex Principal Component Analysis on Near Infrared Spectroscopy Data

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In order to reduce brain cell damage, during adverse events like stroke or carotid artery disease, monitoring of brain oxygenation has an important role. In addition, in healthy subjects and patients, it allows acquiring knowledge about brain activities.
Near infrared spectroscopy (fNIRS) is a portable, non-invasive,rather low cost, few constrain and safe tool that can be used for continuous assessment of brain hemodynamics.

Contamination of the brain hemodynamic signal by scalp or systemic hemodynamic signal and systemic signals has been reported as a major problem of the NIRS technology. The aim of present study was quantitative evaluation of NIRS signals measured on the scalp in order to reconstruct brain and scalp oxygenation signals from mixture of multiple sources.

Materials and Methods

In order to simulate the oxy- and deoxyhemoglobin hemodynamic response to blood flow changes, Buxton's balloon model was used [1]. For quantification of the absorption changes of near infrared light in brain and scalp tissue, a method using multi distance optode (30 mm and 42 mm) of continuous wave near infrared spectroscopy (CW-NIRS) was used. Data was collected using the FORIE -3000 system (SHIMADZU, Japan) and principal component (PCA) was used. It was assumed that both scalp and brain signals are linearly combined with multiple signal sources. Furthermore, it was assumed that partial optical path length of scalp layer does not change whereas partial optical path length of brain tissue layer linearly increases with source detector (S-D) distance. The capability of source separation was examined. Changes of oxy- and deoxyhemoglobin are not independent. To account for the mutual influence, oxy- and deoxyhemoglobin were interpreted as real and imaginary part of a complex signal. Thus, complex independent component analysis (cICA) was employed with
a technique introduced by Funane et al [2]. Using real valued ICA was generalized to complex calculus.

Results

Results showed that using PCA, is not always possible to reconstruct brain and scalp signal. In contrast using real valued ICA level of accuracy can be achieved. Highest level of accuracy can be obtained using cICA.

Discussion

We proposed a new method for quantitative separation of the brain and scalp tissue contribution on CW-fNIRS, using dependence of complex independent component's weight on S-D distance. This is a robust method since drastical level of data enhancement based on using mutual information was used.

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