

The NPXLab Suite: a free platform for analyzing Neuro-electric Signals.

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Abstract: - In this manuscript a brief overview of the capabilities of the NPXLab Suite, is provided. Designed to analyze electroencephalographic data (EEG), it has been successfully used in several scientific publications and downloaded from more than 100 countries. It allows to compute Event Related Potentials, to perform Spectral Analysis, Statistical tests, to manipulate files in an easy to use environment. Available for free at www.braintinterface.com, it supports several different file formats also from commercial EEG/MEG system vendors. In this manuscript its main features are illustrated.

Key-Words: - NPXLab, EEG, ERP, Spectral Analysis, Freeware, ICA, File Conversion

1 Introduction

In recent years, some free tools for analyzing neuroelectric signals have been released by various research groups and labs. Some of them address specific scientific issues such as LORETA [1] that, according to the authors is "a particular 3D, discrete, distributed, linear solution to the inverse EEG/MEG problem", Polyman [2], for the study of polysomnograms, and OpenVibe [3] which is a software platform dedicated to designing, testing and using brain-computer interfaces. Other software platforms are more general like EEGLab [4], an interactive Matlab toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data, and Fieldtrip [5] another MATLAB toolbox for MEG and EEG analysis.

There are several advantages in sharing tools and methods across different laboratories: no need to implement an analysis tool, easier comparison of results from different research groups, validation of methods from a wide community of users just to name few.

There are different approaches, however, on the modality these tools are implemented and shared, depending mostly on the hypothetical final users, which can be a medical doctor, an engineer, a technician, a psychologist, a computer scientist and so on. There are then tools which are very versatile but require some programming expertise such as OpenVibe (C++ programming language), or EEGLab and Fieldtrip (Matlab) and others, like LORETA and Polyman which are distributed in classical binary form and immediately usable after

having installed it according to typical setup procedures. In this scenario a platform which can be used in a wide range of situations by people that has not particular programming skills and which provides advanced features is missing.

The NPXLab Suite [6] tries to fill this hole, providing advanced methods for the investigation of EEG/MEG signals such as ERP and spectral analysis, Independent Component Analysis and many others. Compared to the other general purpose platforms it provides a very friendly graphical user interface, it does not depend on external tools such [4, 5] (e.g. Matlab) even if, like LORETA and Polyman, it just runs on Microsoft Windows platforms, whereas Matlab-based programs run on Windows, Linux and Macintosh.

The NPXLab Suite (available at <http://www.braintinterface.com>), that exists since 2003 [7], is formed by a collection of tools aimed at analyzing signals in several different ways and has been successfully used in several scientific works [8-12] and projects, such as [13]. It has been downloaded from more than 100 countries at a rate of approximately 500 downloads per year.

In the next paragraphs, some aspects of it will be described even if they do not cover all the abilities of the Suite.

2 Main Tools

The NPXLab Suite is a collection of tools and software modules - NPXLab is the first one to be released - developed to analyze EEG and MEG

signals, even if it can be used for EKG, EMG, fNIRS and virtually any kind of sampled signal. It was implemented in C++ programming language for efficiency reasons (more than 100K lines of code) and released free for non-commercial use. Its name originates from the NPX file format (Neuro Physiological signals in XML format) which was originally implemented for physiological data.

The Suite, however, can properly handle also a dozen of widely used commercial file formats are supported as well as EDF/EDF+ [14], CSV and ASCII. The adoption of the XML file format (as opposed to binary) as an infrastructure to the whole suite is motivated by the fact that any sort of information can be added to a file even manually with a text editor without breaking the backward compatibility, thus allowing a painless growth of the suite: in the past, for example, weights from Independent Component (ICA) and Common Spatial Patterns (CSP) analysis tools were added to a file preserving the functionalities of the other tools. Binary files, instead, can suffer of back-compatibility issues if some

additional information need to be added. As an example of this one can consider the effort required to preserve compatibility between EDF and EDF+ files.

2.1 File Converter

To gain all the advantages of the NPXLab Suite one needs to process files in NPX format, otherwise some processing cannot be stored in the original file (e.g. ICA or CSP spatial filters). For this reason, a file conversion tool capable of transforming data files from different sources into NPX is provided. This program, then, allows reading signals stored in 13 different file formats and write them into 5 different ones, including NPX and the popular EDF+. During the conversion, it is also possible to process files by means of either time domain and or spatial domain filters, rename sensors, assign coordinates and types to them in order to compute and visualize topographical map in other tools of the Suite.

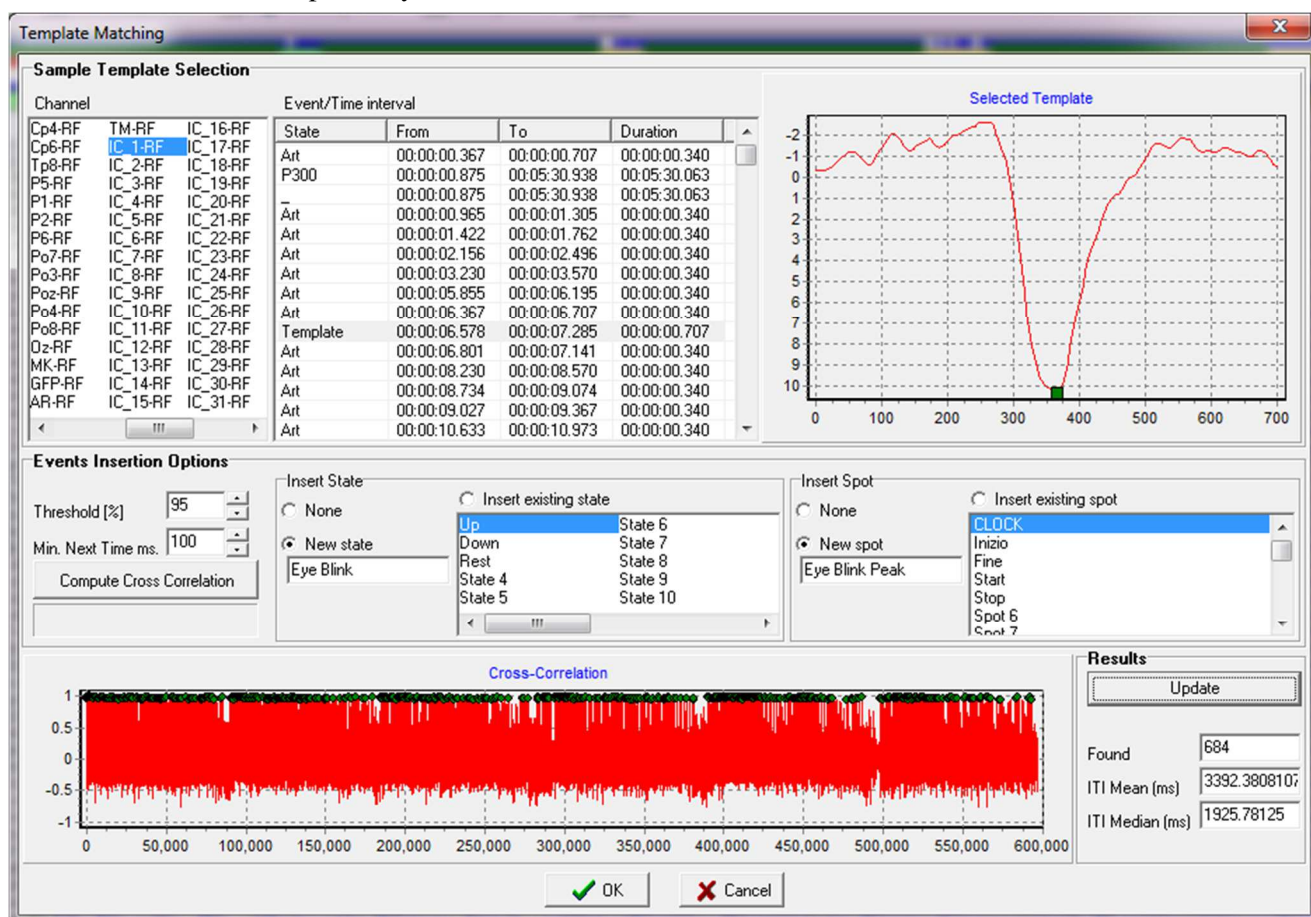


Fig. 1 – Through the Template Matching form one can select an event (Template, top central list, signal in top right chart) from a channel (an ICA component in the figure) and compute the cross-correlation across the whole recording (top chart, red lines, 594000 samples). Whenever the correlation overpass a Threshold value, an event is automatically inserted (green circle). In the figure, 684 eye blinks attributed to ICA component 1 were identified.

2.2 EEG

The EEG tool, initially created to analyze Electroencephalographic signals, is able to process continuous signals in various ways: time domain filters (including IIR, FIR, recursive, zero-phase, etc.), spatial filters (such as Laplacian, ICA, CSP, etc...) and spectral analysis are easily accessible through an easy to use user interface.

A very powerful feature is the ability to insert markers to identify events or select portions of the data to be processed.

This can be done in three main ways:

- manually, by visual inspection and simple mouse point and click operation;
- Automatically, by analyzing the signals in order to detect artifacts, or to find events similar to a template one across the whole recording. In figure template matching to find for example the occurrences of an epileptic spike or an eye blink...). See Fig. 1;
- Automatically, by processing previous markers also using Boolean operations (e.g. identify when in the recording two events are active at the same time).

No other existing tool has the ability and flexibility of NPXLab in processing events. This is extremely important because it is then very simple to select the portions of the signals that have to be processed.

It is then easy to compute for example several spectra from different selections and it is also possible to compare them, even statistically (t-test) to see, frequency by frequency, sensor by sensor, if they are statistically different, also after correction for repeated measures (Bonferroni, etc..).

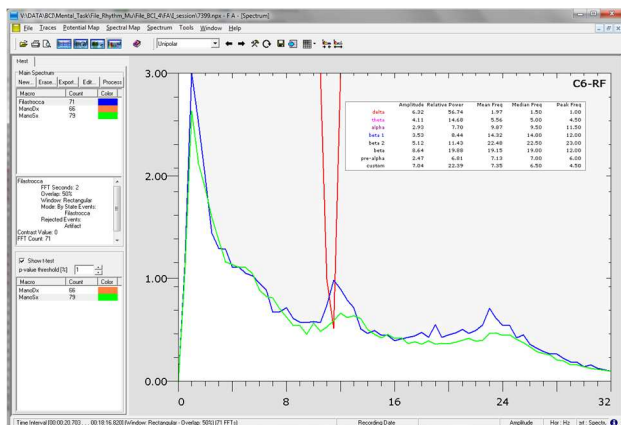


Fig. 2 - Spectra comparison relative to sensor C6 while performing two different mental tasks (green and blue curves). The red line visible at around 11.5Hz indicates that statistical difference is significant ($p < 0.01$ in the figure) at that frequency.

In Fig. 2 the spectra comparison relative to sensor C6 while a subject was performing two different mental tasks is shown.

More than 100 forms for setting processing and visualization options are available thus providing a very easy to use and intuitive graphical user interface (GUI).

2.3 ERP

Event Related Potentials (ERPs) are a very common way to investigate brain function and represent the measured response to specific sensory, cognitive, or motor stimuli. Because these responses (signal of interest) are usually very low in voltage as compared to EEG background activity (which in this case is considered noise), several stimuli are provided to the patients/subjects and their responses are averaged in order to increase the SNR. Several parameters can be set to perform the averaging either automatically or manually for example by selecting one by one the responses to be averaged.

Among the various ways to visualize the processed signals there are also topographic maps as shown in Fig. 3.

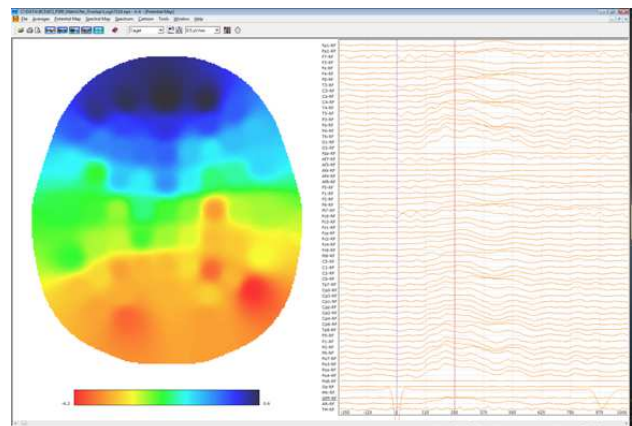


Fig. 3 – The Potential Map view of an ERP.

Similarly, to the EEG module it is also possible to perform spectral analysis, to filter signals, etc...

Some ERPs protocols are designed to compare responses to different classes of stimuli to evaluate cognitive functions and in this case it is important to provide a statistical method to assess the difference of two responses at a certain level of confidence. NPXLab can easily do this: signals are compared sample by sample through a t-test.

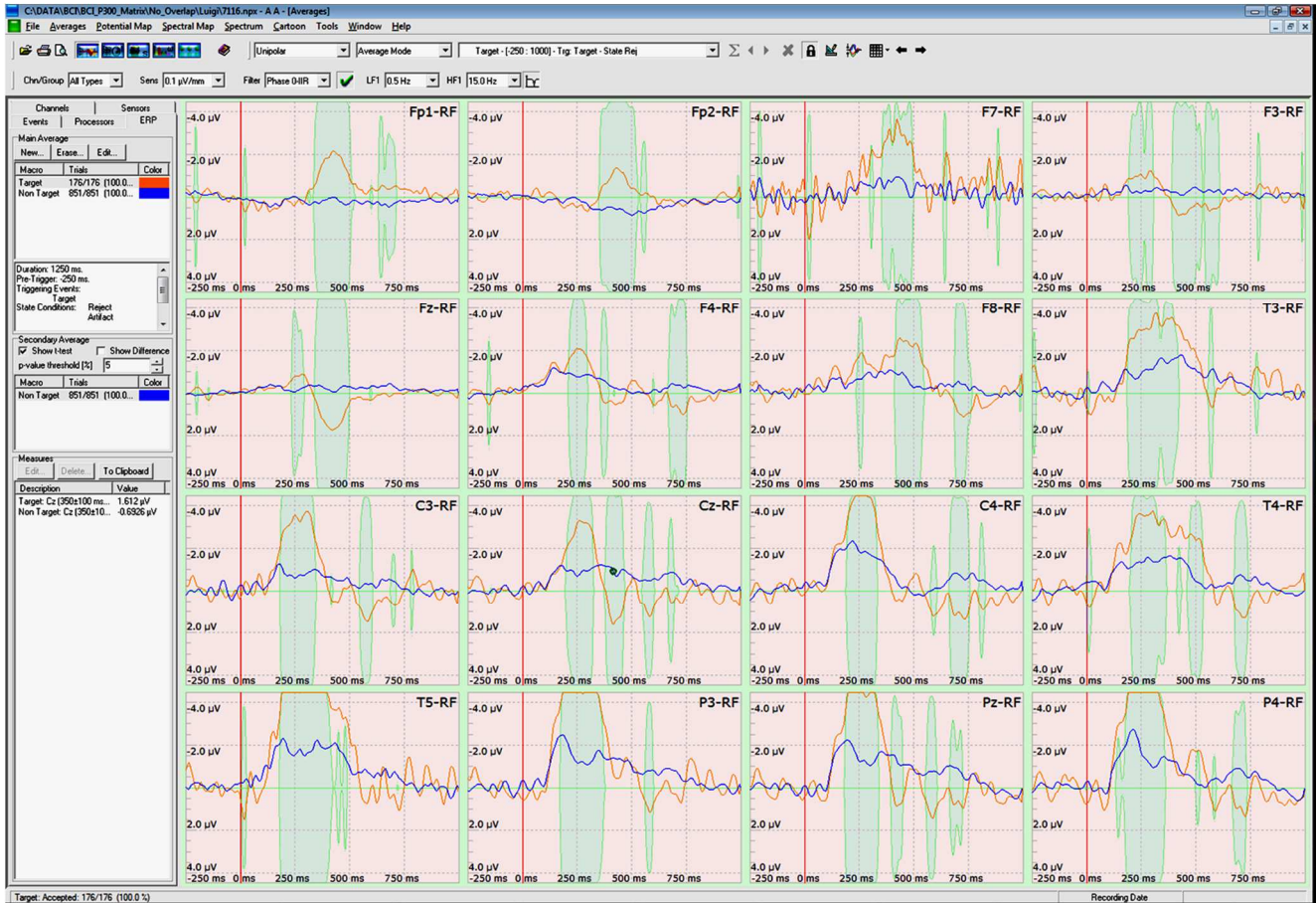


Fig. 4 - Statistical comparison of two evoked responses to two classes of stimuli (blue and orange lines) in a P300 protocol. Each of the 16 plots represents a different electrode. The presence of green “bubbles” indicates that responses are statistically different (t-test, $p < 0.05$). The larger the bubbles, the lower the p-value.

In Fig. 4 time series relative to two different classes of stimuli are shown and their statistical comparison is represented by green bubbles: if they are present, the two responses are statistically different ($p < 0.05$ after Bonferroni correction), whereas if the p-values are higher than 0.05 bubbles are absent.

In Fig. 5, instead, the same p-values are represented at different instant relative to the stimulation onsets in topographic maps in the time range [-250ms; 1000ms). Only p-values less than 0.05 are represented in color to facilitate the localization of the areas and time instant where the responses to the two different classes of stimuli are different.

2.4 ICA

Independent Component Analysis is computed from a tool that at the end of the processing stores weights into a NPX file. In this way, all of the other tools, including the EEG and ERP, can use ICA either to select physiological components or to remove those components that are associated to noise, thus improving the SNR ratio of the signals. An example

of this is shown in Fig. 5 – where a component (IC_1) attributed to eye blinks has been removed by simply clicking on a checkbox.

2.5 Brain-Computer Interface

Machine learning methods as well as special functions and tools are also provided to implement, evaluate and optimize the performances of Brain-Computer Interfaces (BCI). Seven different classifiers (SWLDA, FLDA, BLDA, SVM, SRLDA, RLDA and Artificial Neural Networks), can be used to either train or test ERP based BCIs such, as P300 Spellers, mu-rhythms, Steady State Evoked Potentials (SSxEP) and so on. These tools have been also used as standard platform in the DECODER EU project, to support diagnoses in non-responsive patients, in order to discriminate between vegetative vs. minimally conscious patients [13]. Finally, statistical test to assess the confidence of the results in also included in the NPXLab suite.

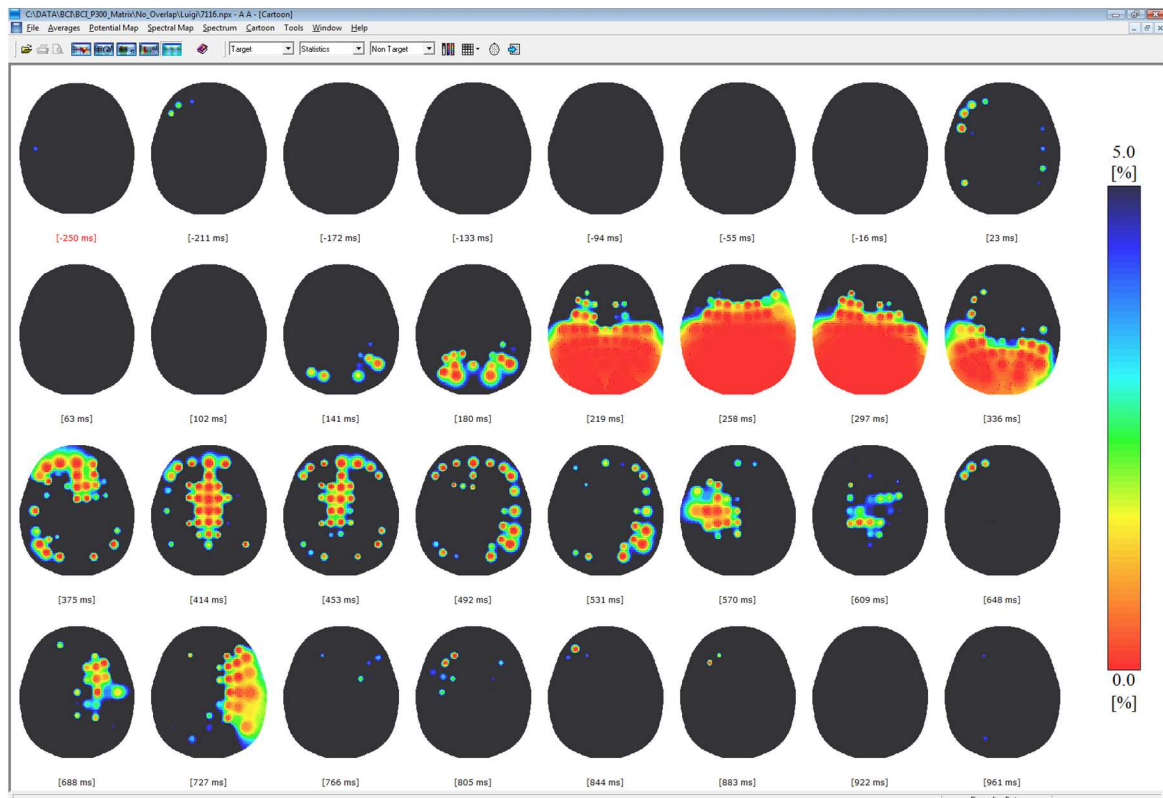


Fig. 6– The same statistical comparison described in Fig. 4 but represented in a matrix of statistical maps (Cartoon mode view): each map indicate the p-values at a certain time relative to the stimulation. Only p-values < 0.05 are represented in color, whereas values greater than 0.05 are represented in black. Red areas represents brain regions in which p-values are very low, thus indicating great differences in evoked responses.

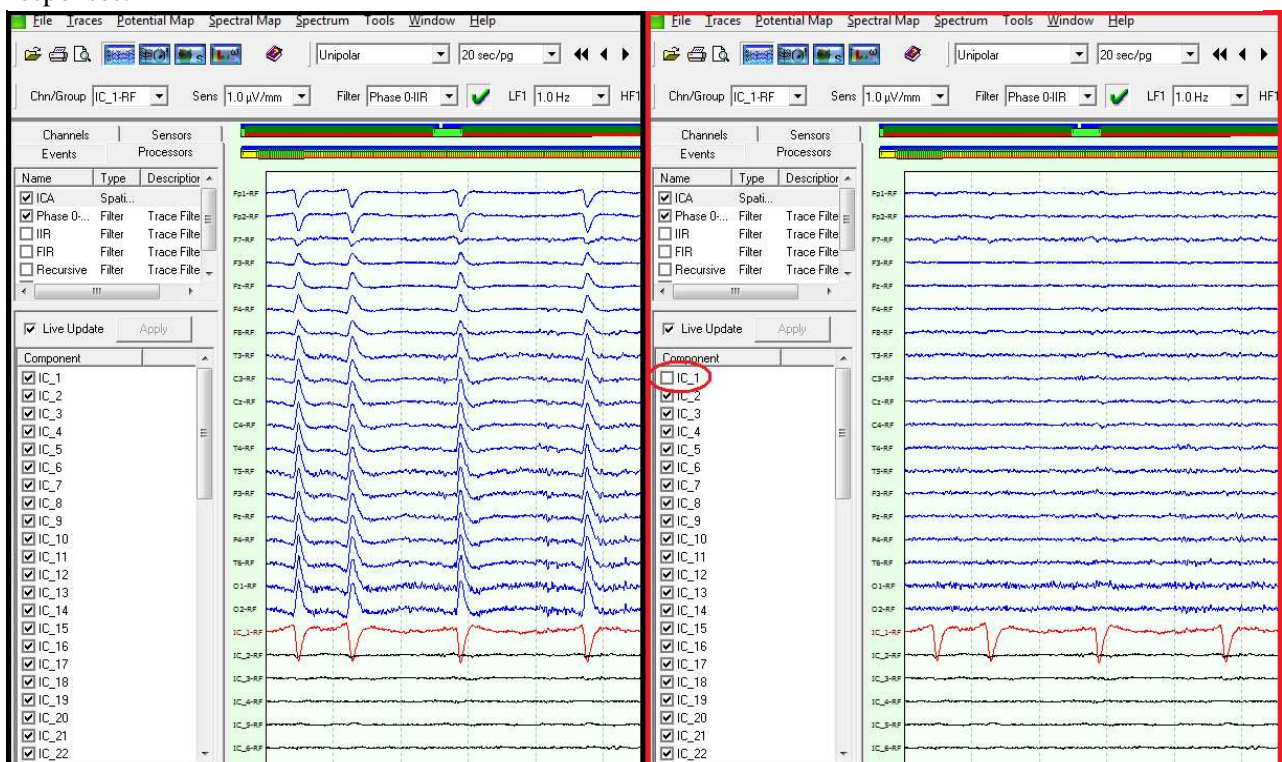


Fig. 5 – On the left and right panels, the same 5.5 seconds of the EEG recording before and after the removal of the eye blink source are shown: it can be clearly seen that the component IC_1, the red one in the figure, is strongly correlated with the eye blink artifacts. Then unselecting it (see the red ellipse in the right figure) will result in an EEG trace with is free from that artifact. This operation produces instantaneous effect.

2.6 EEG – fMRI artifact removal tool

Another tool of the suite was designed to solve some typical problems that occur when simultaneously recording EEG and fMRI signals: in this case, several sources of noise, the most famous ones being, the Pulse Sequence Artifact (PSA) and the Ballisto-Cardiographic Artifact (BCA) [10] are caused by the mutual interaction of the magnetic and electric fields. The PSA can be up to three orders of magnitude larger than the EEG signals whereas the BCA is generally larger than the EEG electrical activity but does not exceeds one order of magnitude. Removing these sources of noise is fundamental, but might not be an easy task to solve. For this reason, a method has been proposed [10] and implemented in one the NPXLab Suite tools to automate this procedure.

3 Discussion

The NPXLab Suite is a set of free software tools running on Microsoft Windows that have been implemented and released in more than one decade in and that will be supported and extended in the future. It has been downloaded from more than 100 countries worldwide at a rate of about 500 installations per year. Compared to other solution it is the most complete among those that do not depend on external tools such as Matlab and that do not need any particular programming skill. Being programmed in C++ its performances are also among the most efficient ones and it requires less computer resources in term of processing power and memory as compared to tools such as EEGLab which, however, is able to perform a wider set of analyses.

4 Conclusion

The NPXLab represents a reliable and efficient solution for those who need to perform several analyses in the EEG/MEG research fields and that do not want to depend or learn to use external tools. It has been successfully used in several scientific publications [8-13] because of its versatility and completeness. As it can read and write data from several different file formats it has also been used in some project which involved laboratories that acquired signals with different devices, thus allowing a painless extension of the database.

Several analyses, such as Spectral Analysis, Time and Spatial domain filtering, artifact removal, event related potentials, and many others can be performed very easily with a very friendly user interface, thus representing a solid and free solution for the analysis of data acquired in neurophysiological experiments,

especially for those people that do not have programming skill or do not need the rely on the power of external tools such as Matlab or LabView.

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