The NPXLab Suite 2018: a free features rich set of tools for the analysis of neuro-electric signals.

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Abstract: - In this manuscript an overview of the features of the NPXLab Suite, is provided. Designed to analyze electroencephalographic data (EEG), it has been successfully used in several scientific publications and downloaded from all over the world. It allows to compute Event Related Potentials, to perform Spectral Analysis, Statistical tests, to analyze Brain-Computer Interface signals as well as to manipulate files in an easy to use environment. Available for free at www.brainterface.com, it supports several different file formats also from commercial EEG/MEG system vendors.

Key-Words: - NPXLab, EEG, MEG, ERP, Spectral Analysis, 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 re-implement analysis tools, 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 supposed end users, which can be medical doctors, engineers, technicians, psychologists, computer scientists and so on. There are then tools which are very versatile but require some programming expertise and powerful computers such as EEGLab and Fieldtrip (Matlab) and others, like LORETA and Polyman which are distributed in classical binary form and immediately usable after having installed them thru 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 with a friendly and easy to use graphical interface is missing.

2 The NPXLab Suite

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 EEGLab and Fieldtrip [4, 5] (e.g. Matlab) even if, like LORETA and Polyman, it just runs on Microsoft Windows platforms, whereas Matlab-based programs run Windows, Linux and Macintosh, even if they require.

The NPXLab Suite (available at http://www.brainterface.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.

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 been 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 for free for non-commercial use.

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).

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 but also 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. This allows 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 the NPX file format preserving the functionalities of all of the previously released tools. Binary files, instead, can suffer of backward compatibility issues if some additional information requires file format extension. As an example of this one can consider the effort required to preserve compatibility between EDF and EDF+ files just to add the ability of storing events to EDFs.

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

2.1 The File Converter Tool

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 (EDF, EDF+, CSV, TXT, HDF5, Micromed, Brainamp, EBNeuro, Microsoft Waveform, GDF, BDF, etc…) and write them into 5 different ones, including NPX, ASCII 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 or remove sensors (e.g. noisy channels), assign coordinates and types to them in order to compute and visualize topographical maps.

2.2 The EEG Tool

The EEG tool, initially created to analyze Electroencephalographic signals, is able to process continuous signals of different nature 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 interface. It is not possible to describe all of them, so just few characteristics will be illustrated in the following paragraphs.

Actually it has been used to analyze also magneto-encephalographic (MEG), electro-cardiographic (EKG), electro-myographic (EMG), accelerometric, kinematic and NISR (near infra-red spectroscopy) signals.

2.2.1 Events

A very powerful feature is the ability to insert markers (instantaneous events such as triggers) and selections (events with a duration greater than zero, such as the execution of a mental task or an epileptic crisis) to identify portions of the data to be automatically processed.

This can be done in three main ways:

a) manually, by visual inspection and by means of a couple of simple mouse point and click operations;
b) Automatically, for example by analyzing the signals in order to detect artifacts, or when a certain threshold value is reached, or to find events similar to a template (e.g. a portion of a signal, such as an epileptic spike) across the whole recording. In this case the cross-correlation between the template and the whole signal is computed and events are inserted whenever a user settable correlation threshold value is reached;
c) Automatically, by processing already existing events. In some cases, in fact, it can be useful to split, move or count them, or to skip some of them. Moreover, it is possible to apply boolean operations such as OR, AND, NOT and XOR to identify, for example, when in a recording two events were active at the same time, or when a trigger occurred while no artifacts were occurring, and so on. The possibilities are virtually unlimited.

None of the tools described in the introduction and released by other laboratories or research centers has the ability, flexibility, and easiness of NPXLab in processing events. This is extremely important because this means that is very simple and fast to select portions of the signals that have to be processed, resulting in a great saving of time for the operators.

2.2.1 Spectral analysis

Spectral analysis benefits from advanced events managing because it oversimplify the selection of the epochs to be analyzed: one usually does not want to process a whole recording, but just a portion of it. Then, the spectral analysis facility, was designed so that an operator can select which portion of the recordings should be included and excluded from the analyses: it is sufficient to select the events selections that include relevant epochs and those that for example define time intervals contaminated by artifacts.
As in any spectral analysis tool it is possible to select different windowing functions, resolution, overlap, etc…
An important feature is that it is possible to compute and keep in memory different computed spectra, that can be compared 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..).

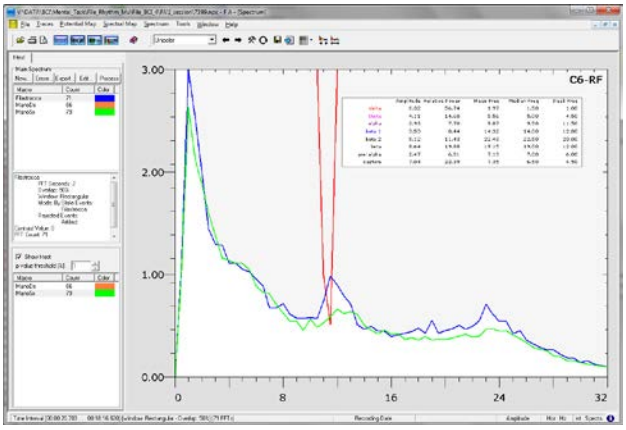

Fig. 1 - Spectra comparison relative to sensor C6 while performing two different mental tasks (green and blue curves). The red line visible at around 11.5Hz indicates that statistical difference is significant ($p<0.01$ in the figure) at that frequency.

In Fig. 1] the spectra comparison relative to sensor C6 while a subject performed two different mental tasks is shown: the green line represents an imagined motor task, whereas the blue one a mental rhyme generation. It can be observed a reduction in the EEG spectral power at about 11.5Hz.
Spectral coherence can be also computed on bipolar montages.

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 (studies signals) are usually very low in voltage as compared to the 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.
In NPXLab a relevant number of parameters can be set to perform the averaging either automatically or manually. In the first case by selecting the segmentation criteria and artifact removal strategies through a very complete set of options, whereas in the last case by selecting one by one the stimuli responses to be averaged. It is also possible to combine the two methods, thus starting with an automatic ERP computation and then reconsidering if a single trial has to be taken into account for the averaging or if it should be removed.
Among the various ways to visualize the processed signals there are also topographic maps as shown in Fig. 2].

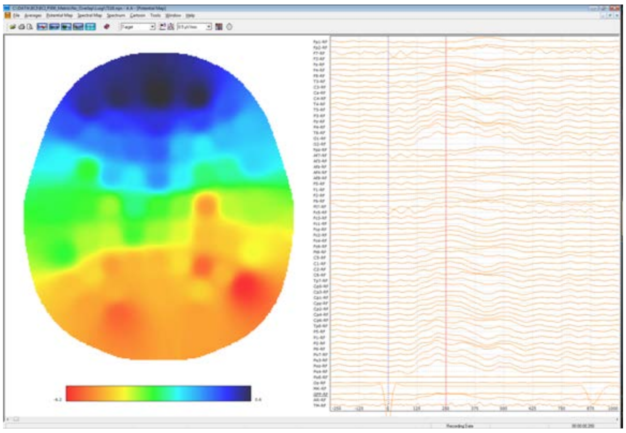

Fig. 2 – The Potential Map view of an ERP.

Similarly, to the EEG module it is also possible to perform spectral analysis, to filter signals, to manage events, etc...
Some ERPs protocols are designed to compare responses to different classes of stimuli for example to evaluate cognitive functions (e.g. P300, N400). In this case it is not only possible to compare two averages, but also to statistically assess the difference of two responses at a certain level of confidence: in NPXLab signals can be compared on a sample by sample base through a t-test. Statistical corrections for handling the multiple comparisons problem are provided, including Bonferroni, False Discovery rate, etc..

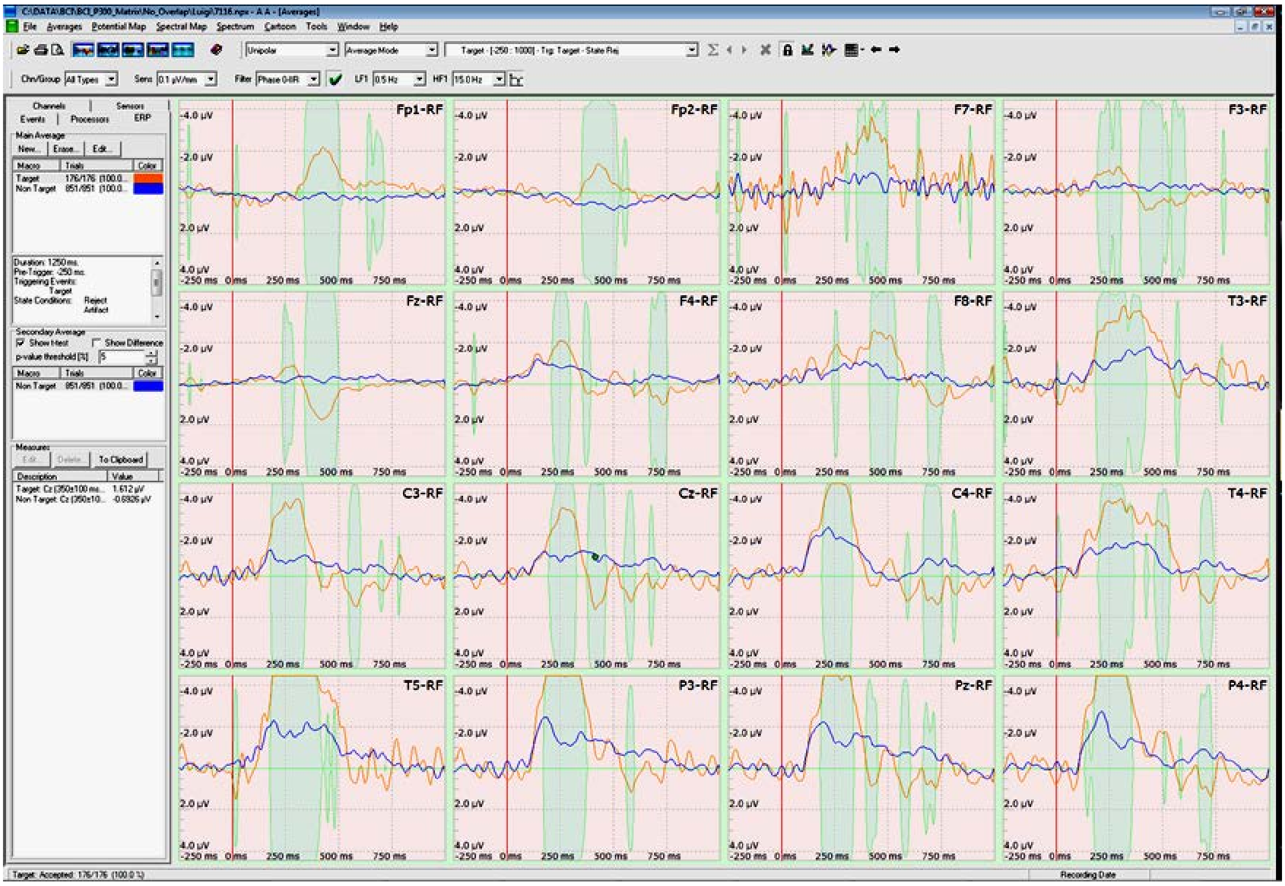

Fig. 3 - Statistical comparison of two evoked responses to two classes of stimuli (blue and orange lines) in a P300 protocol. Each of the 16 plots represents a different electrode. The presence of green “bubbles” indicates that responses are statistically different (t-test, $p < 0.05$). The larger the bubbles, the lower the p-value.

In Fig. 3] time series relative to two different classes of stimuli are shown and their statistical comparison is represented by light 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. The larger is the bubble the lower is the corresponding p-value.

In Fig. 4], instead, the same p-values are represented at different instant relative to the stimulation onsets (occurring a t=0ms) in successive topographic maps in the time range [-250ms; 1000ms) and sampled every 40 ms, from top left (t= -250ms) to bottom right (t=1000ms). Each map represents the statistical difference at certain time instant, and was built from the p-value of each sensor at the time indicated below the map. Interpolation rules (quadratic in the figure) are available to represent values between electrodes.

Only p-values less than 0.05 are represented in color scale to facilitate the localization of the areas where the responses to the two different classes of stimuli are different, otherwise they are in reported in black.

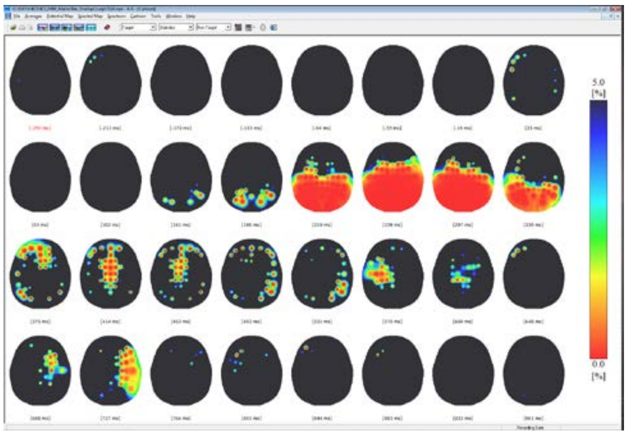

Fig. 4 - The same statistical comparison described in Fig. 3] but represented in a matrix of statistical maps (Cartoon mode view): each map indicate the p-values at a certain time relative to the stimulation. Only p-values < 0.05 are represented in color, whereas values greater than 0.05 are represented in black. Red areas represents brain regions in which p-values are very low, thus indicating great differences in evoked responses.

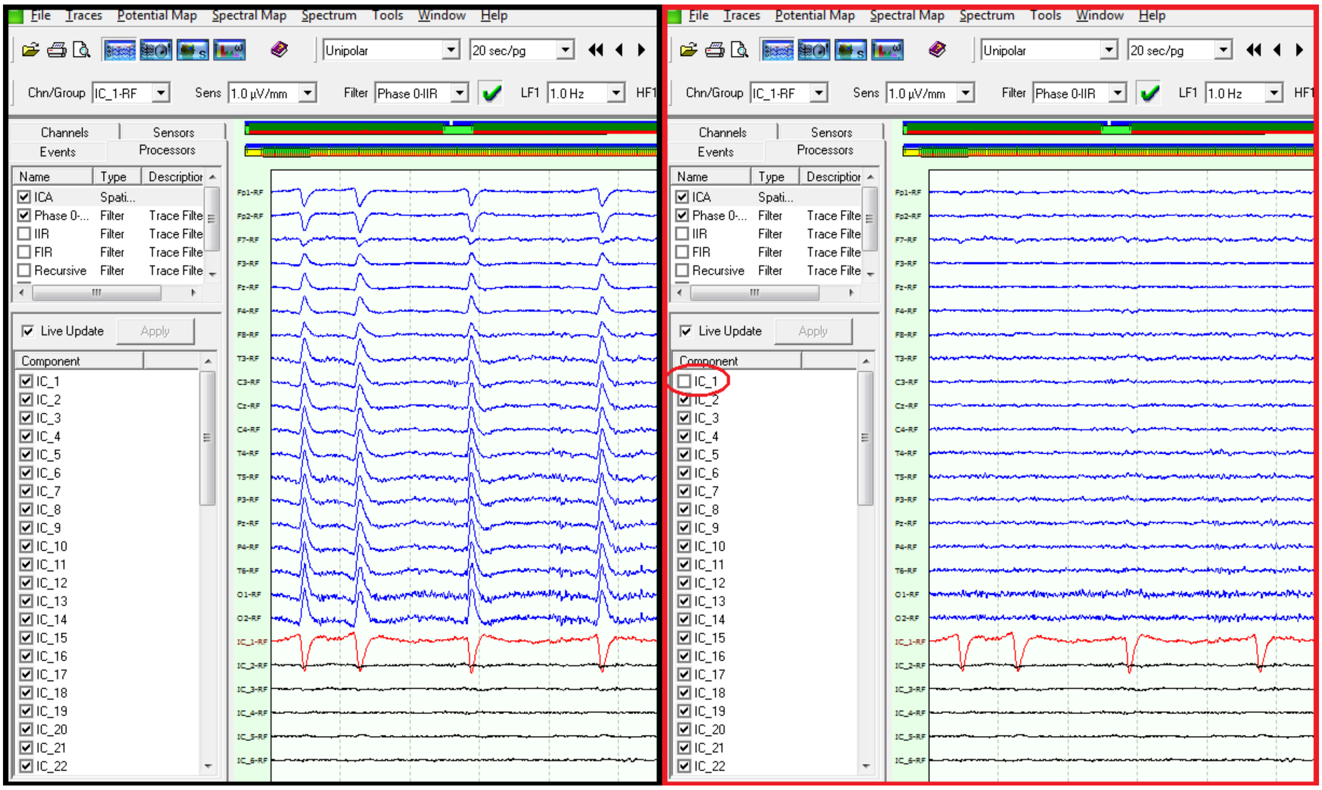

Fig. 5 - On the left and right panels, the same 5.5 seconds of the EEG recording before and after the removal of the eye blink source are shown: it can be clearly seen that the component IC_1, the red one in the figure, is strongly correlated with the eye blink artifacts. Then unselecting it (see the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

2.4 Independent Component Analysis

Independent Component Analysis (ICA) is a computational method for separating a multivariate signal into additive subcomponents. The basic idea behind it is that the signals that we record are generated from sources (the ICA components) that are mixed and summed up as defined by a mixing matrix. ICA analysis allows to compute the mixing and - its inverse - the unmixing matrices. It is then possible through these two matrices to compute the sources from the EEG signals or reconstruct the EEG from the ICA sources. It is then possible to compute the sources from the EEG, identify noise components and back-project the components in the EEG domain after having removed the noise: in this way it is possible to dramatically improve the signal to noise ratio.

It is computed from a tool, derived from EEGLab, that, at the end of the processing, stores the weights of the mixing into a NPX file.

In this way, all of the other tools, including the EEG and ERP viewers, 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 **Errore. L'origine riferimento non è stata trovata.** where a component (IC_1) attributed to eye blinks has been removed from the EEG trace by simply clicking on a checkbox.

ICA components, once computed, can be treated as common channels, so that one can average them, compute their spectra, etc…

2.5 Common Spatial Pattern

Common Spatial Pattern (CSP) is another method for separating multivariate signal into additive subcomponents which have maximum differences in variance between two windows. It is another spatial filter that has been used in Brain-Computer Interfaces, or to remove artifacts from EEG signals. In BCIs, it is used to compare signals acquired from a subject under different conditions, such as while performing two different mental tasks. The CSP tool of the NPXLab Suite allows to compute and

visualize CSP filters that can be used also in Brain-Computer Interfaces. Similarly to ICA weights, the weights from the computed matrices are stored into an NPX File in order to be retrieved by all the tools of the NPXLab Suite.
In Fig. 6] 10 out of 61 filters computed from a BCI experiment (two different mental tasks) are represented.

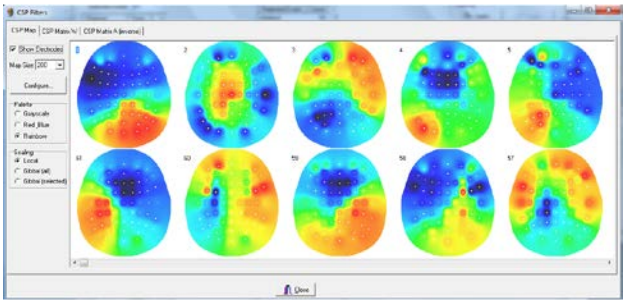

Fig. 6 – Ten filters computed from a BCI experiment in which a subject had to perform two different mental tasks.

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.

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. It is illustrated in Fig. 7].

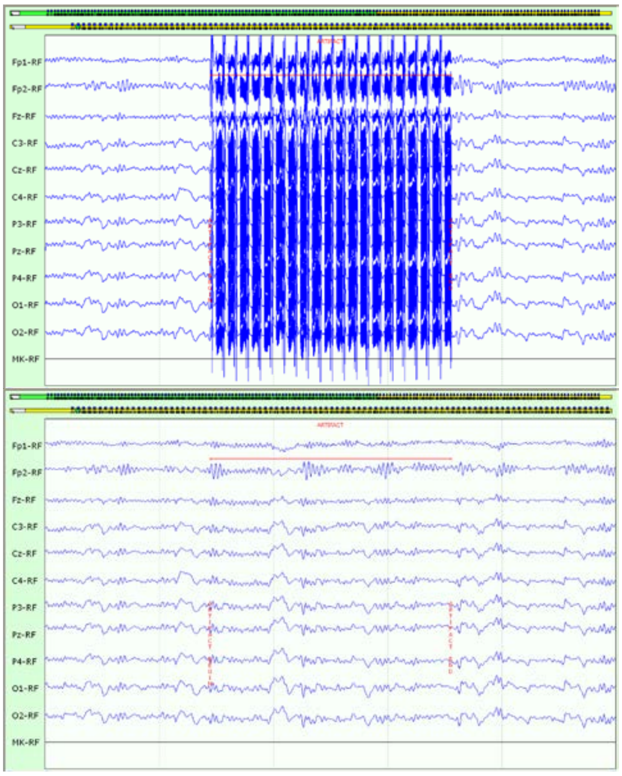

Fig. 7 – Effects of the method used to remove the Pulse Sequence Artifact to an EEG file acquired into a MRI scanner. On top 5 seconds of EEG signals acquired during a MRI scanning are shwn: it is clearly visible the large artifact in the central part of the plot, lasting about 2.4 seconds, which correspond on the time necessary to acquire a volume. On bottom the same data portion after the application of the artifact removal method implemented in the NPXLab Suite.

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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