

Tutorial on Adulteration of Phase Relations when using Independent Components Analysis/Blind Identification and other Regression Methods to “Correct for Artifact”

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Let us consider the rejection of eye movement artifact (EOG) using the ICA method which is the mathematical basis for Blind Source analysis. The ICA method decomposes a time series into a set of globally independent time series. Mathematically ICA can invert the equation and exactly reproduce the original time series based on the mathematical components. In this case the originally measured time or phase differences between each electrode are preserved and the cross-spectrum is unaltered. However, everything changes when the ICA or PCA or Blind Source, etc. methods are used to remove artifact by reconstructing 19 channels based on a smaller set of components, e.g., 17 or 18 channels and then deleting or omitting the EOG “components” to reconstruct 19 channels. This is because a regression process (interpolation) is used to minimize the deviation of the original 19 channel time series from the 17 or 18 “components” by which the remainder is used as weights to produce a second time series that has altered all of the phase relations in the original time series. The regression uses the average of the entire time series and therefore “smoothes” time or phase at each time point. Averaging a time series and computing deviations (whether information min-max, equimax, or simple linear regression) and then using the result to weight each time point by averages thereby smoothes each data point’s phase relations at each moment of time, distorting coherence, and destroys the time and phase relations present in the original time series.

Scientific Studies Demonstrating ICA/Regression Distortions of EEG:

Castellanos NP, Makarov VA. 2006. Recovering EEG brain signals: artifact suppression with wavelet enhanced independent component analysis. *J Neurosci Methods*. 15;158(2):300-312.

Kierkels J, Boxtel G, Vogten L. 2006. A model-based objective evaluation of eye movement correction in EEG recordings. *IEEE Trans Biomed Eng.*; 53:246–253.

Wallstrom G, Kass R, Miller A, Cohn J, Fox N. 2004. Automatic correction of ocular artifacts in the EEG: a comparison of regression-based and component-based methods. *Int J Psychophysiol* 2004;53:105–119.

Tutorial Demonstration of ICA Distortion

Step 1- Download the Original non-ICA Demo TBI patient EEG.edf in EDF format at: http://www.appliedneuroscience.com/Original_non-ICA_Demo_TBI_patient_EEG.edf

Step 2 - Download and install WinEEG from www.novatecheeg.com/downloads.html.

Step 3- In WinEEG, import the original EEG file “Original non-ICA Demo TBI patient EEG.edf” file by clicking in the menu - File > Open File browse and select the file labeled “Original non-ICA Demo TBI patient EEG.edf” file.

Step 4 - For the ICA method, select at least **1-2 minutes** of EEG including the eye movement artifact (see pages 12-13 of the WinEEG manual) by manually select from a beginning point by depressing the left mouse button and dragging over the eye movement artifact to the ending point. Note: mouse clicks in second area of the window will show yellow marker.

Step 5 - From the menu options select - Analysis > Artifacts correction...a window opens up and select ICA method (wait for processing) and press OK button.

Step 6 - Save the ICA corrected file by clicking from the menu - File > Export Data then select Full EEG file and format EDF. Name the file “ICA artifact corrected Demo TBI patient.edf”. Press OK button. This file can also be downloaded at:
http://www.appliedneuroscience.com/ICA_artifact_corrected_Demo_TBI%20patient.edf

You will now have two files: 1- The “Original non-ICA Demo TBI patient EEG.edf” file and, 2- The “ICA artifact corrected Demo TBI patient.edf” file

Step 7 – Launch Neuroguide and click File > Open > EDF and navigate to where the “Original non-ICA Demo TBI patient EEG.edf” file was saved (see Step #1) and import into Neuroguide. In the EDF Parameters window select the Collection Hardware for Lexicor (High Pass Off). Click OK and click Cancel in the subject information panel. Double click Linked Ears. Re-size neuroguide to the upper ½ of the computer screen.

Step 8 – Launch a 2nd Neuroguide and click File > Open > EDF and navigate to where the “ICA artifact corrected Demo TBI patient.edf” file was saved (see Step #6) and import into the 2nd Neuroguide. Click click OK and click Cancel in the subject information panel. Double click Linked Ears. Re-size neuroguide to the lower ½ of the computer screen.

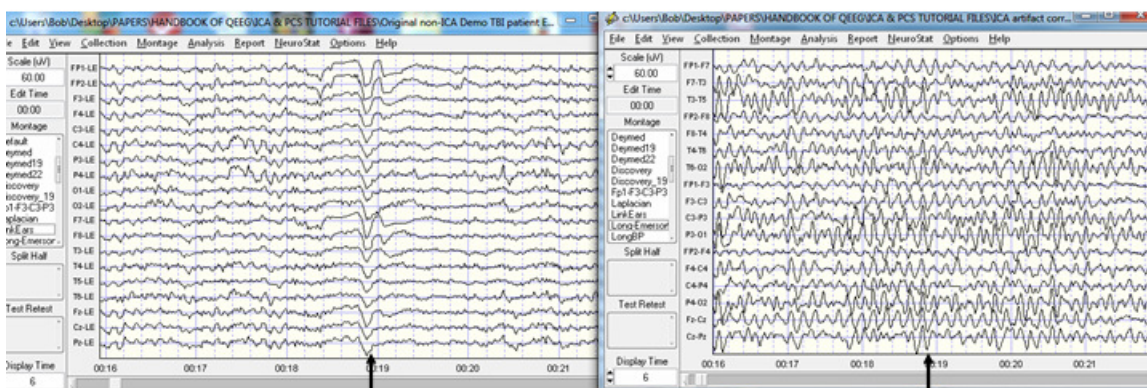
Step 9 - Click View > Dynamic JTFA > Phase (Absolute), Repeat Click View > Dynamic JTFA > View Time Series. Position the original time series at the top and the ICA corrected time series on the bottom. No distortion is defined as no difference between the top and bottom displays. This demonstration shows major and persistent differences between the original time series and the ICA reconstructed time series. Time and phase differences arise because of underlying neurophysiological factors such as conduction velocities, synaptic rise times, synaptic delays, etc. Any distortion of the original time series is an adulteration and precludes linking the time series to neurophysiological processes. In other words, ICA invalidates the EEG and all subsequent analyses of the EEG, especially those involving phase.

Figure One: Pre vs Post Artifact Correct Digital EEG

Pre vs Post ICA Artifact Correction

**Original EEG Data with
Eye Movement Artifact**

**ICA Corrected EEG & Removal of
Eye Movement Artifact**



**Eye Movement Artifact
at 19 seconds**

**No Eye Movement
Artifact at 19 seconds**

Figure Two – NeuroGuide JTFA Control Panel

Example of NeuroGuide JTFA Control Panel Selections

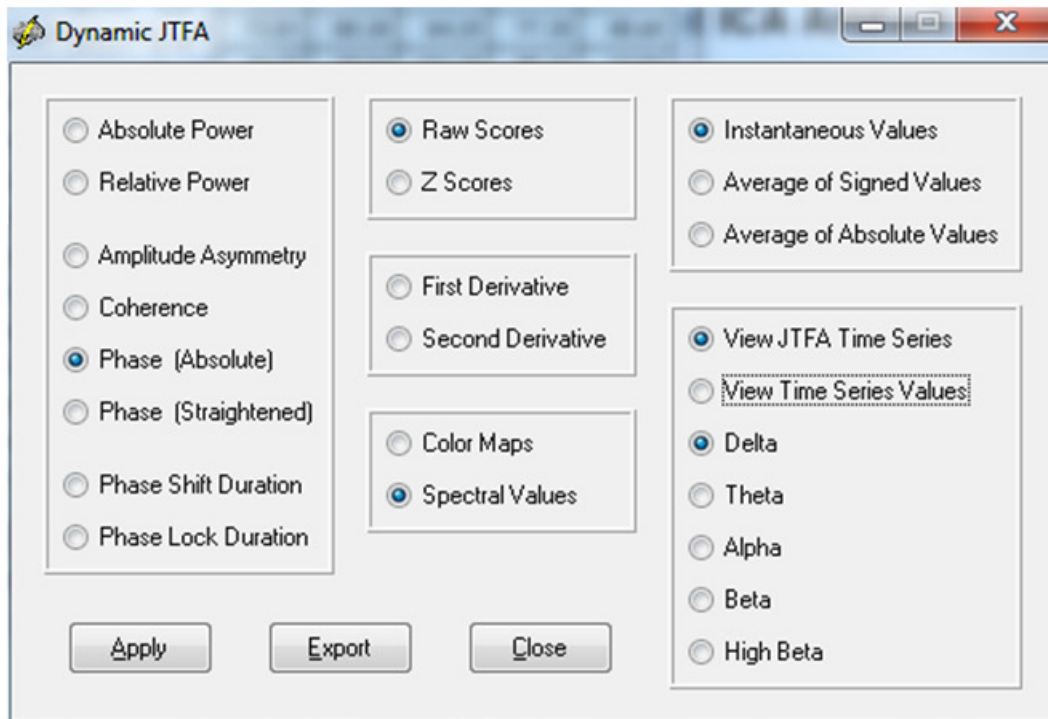
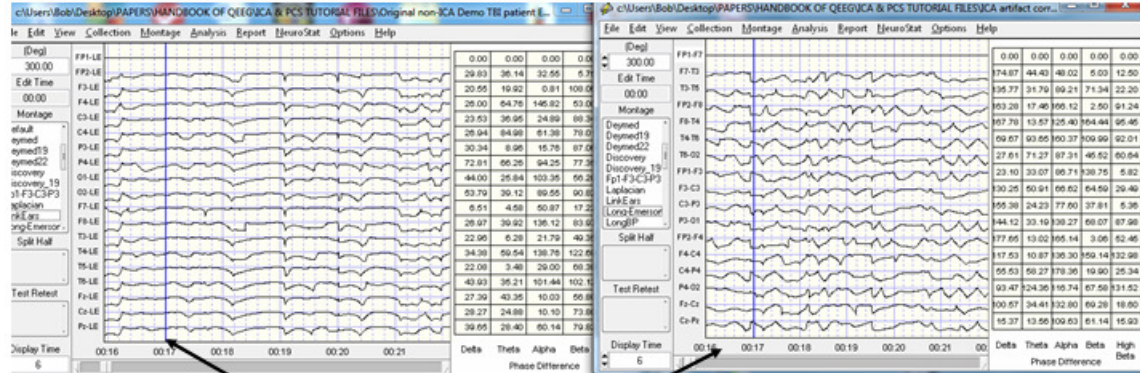


Figure Three- Absolute Phase Differences Between All Pairs of Electrodes are Not the Same After ICA Correction

Phase Differences Between Pre vs Post ICA Artifact Correction

Original EEG Data

ICA Corrected EEG



Depress Left Mouse Button at any Time Point and Verify that All Phase Differences Between All Channel Pairs are Not the Same

Statistical Tests of Absolute Phase Differences– Original EEG vs ICA “Corrected” Time Series

