Extraction of ERPs with NE devices

Neuroelectrics White Paper WP201403

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Is it possible to extract ERPs with a wireless system like Enobio or Starstim using LSL synchronization?

In this paper we analyze whether it is possible to extract Event Related Potential (ERP) waveforms using Enobio/Starstim. In order to conduct this feasibility analysis we have acquired data following two different protocols, which are expected to elicit ERPs associated to the presentation of different stimuli. For this we recorded EEG data with one PC, and implemented the stimuli presentation in a different PC using the Presentation© software (NeuroBehaviouralSystems). Both computers were physically linked with a regular Ethernet cable. The synchronization between the stimuli presentation and the EEG signal acquisition device, which is required for the extraction of the ERPs, has been done through the so-called Lab Streaming Layer (LSL) protocol (see also NE WP201401). LSL is expected to be more accurate than TCP, and is usually employed for stimuli synchronization. After recording we pre-processed the signals, extracted epochs, and averaged them in order to extract the ERPs. The tests were conducted with 3 different subjects, which allows extracting as well inter-subject grand averages.

The experimental protocol followed the so-call auditory oddball paradigm. Here the stimuli are auditory. Particularly, we have followed the 3-stimulus oddball paradigm, where three different types of stimuli denoted as frequent, infrequent and novel, are used. Frequent and infrequent stimuli were implemented through pure sinusoidal tones at respectively 700 Hz and 1 KHz. Novel stimuli were implemented through 20 different complex sounds, e.g. sweep, whistle, bang. We presented through headphones 555 frequent stimuli, for 65 infrequent and novel. The inter-stimuli interval was 700 ms and therefore the complete protocol lasted for approximately 8 minutes. We expected to extract a waveform formed by 2 positive peaks P1, and P3a with a negative N2 in between. The latency of these peaks is normally c. 100, 200, and 300 ms.

The recorded data was processed with the following stages. First, the signals were band-pass filtered between 0.1 and 20 Hz with a Butterworth filter. Second, the eye movement artifacts were corrected. The signals were thence cut in epochs, which were detrended and demeaned. After this, all epochs with amplitude values larger than 100 μV were rejected. The final stage implemented the averaging. All epochs corresponding to frequent stimuli were averaged. A subset of these frequent epochs was selected in order to have an analogous number of epochs of all stimuli types. Epochs of each type were then averaged on their own in order to display P1, N2 and P3 ERPs. Lastly, we extracted the wave differences by subtracting the average over all frequent epochs from the infrequent and novel epochs. This step served the visualization of the Mismatch Negativity and P3a ERPs.

In the following figures we display the auditory ERPs in 2 different subjects.

Subject 1

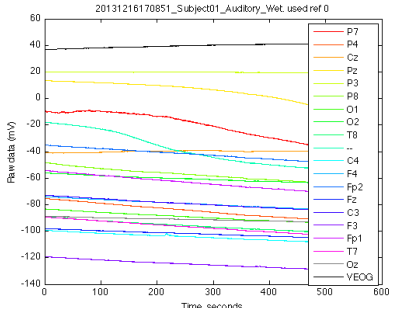

Figure 1. Raw data.

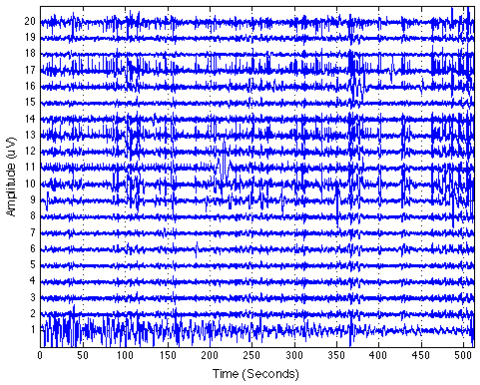

Figure 2. Data after BP filtering.

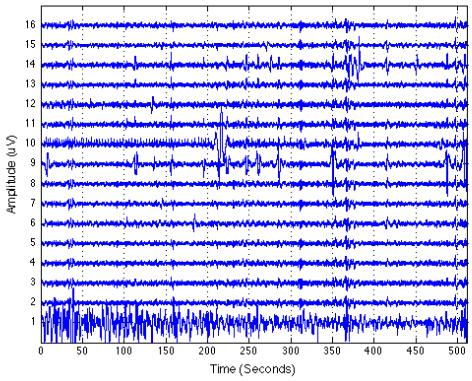

Figure 3. Data after correcting artifacts.

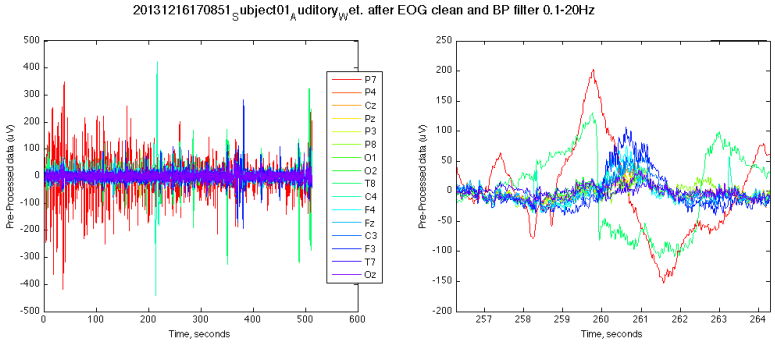

Figure 4. Data after pre-processing with detail (right).

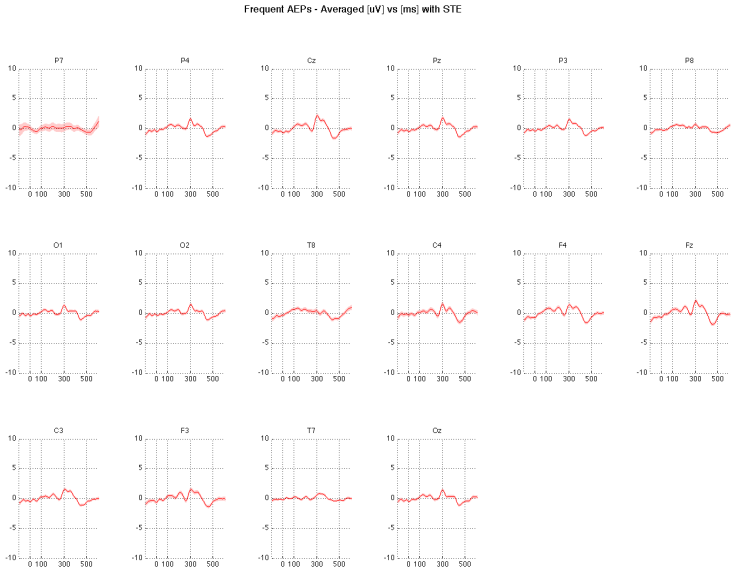

Figure 5. ERPs after averaging (with standard error) for all frequent stimuli.

Subject 1

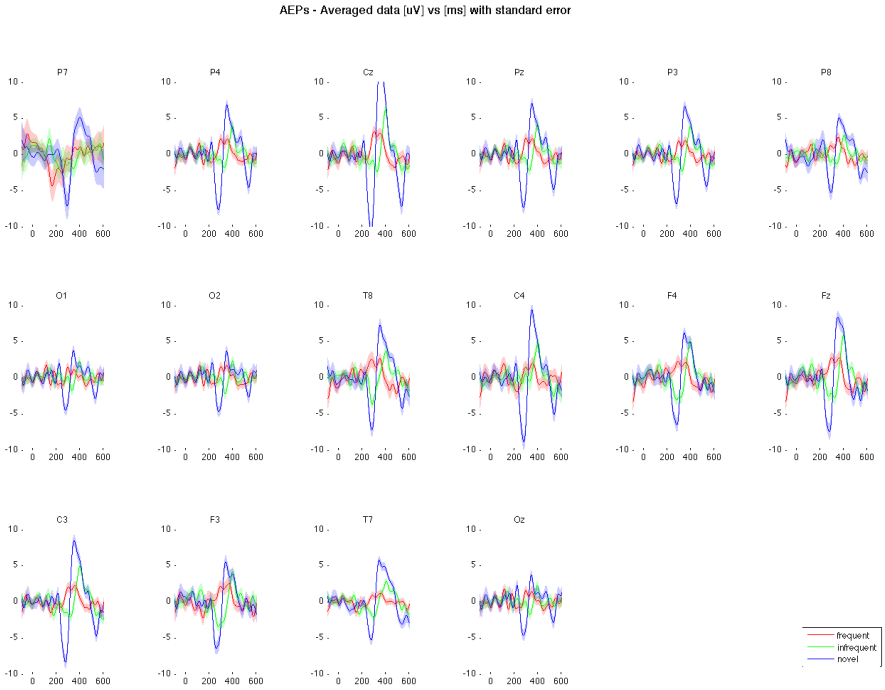

Figure 6. ERPs after averaging (with standard error) for 3 different types of stimuli.

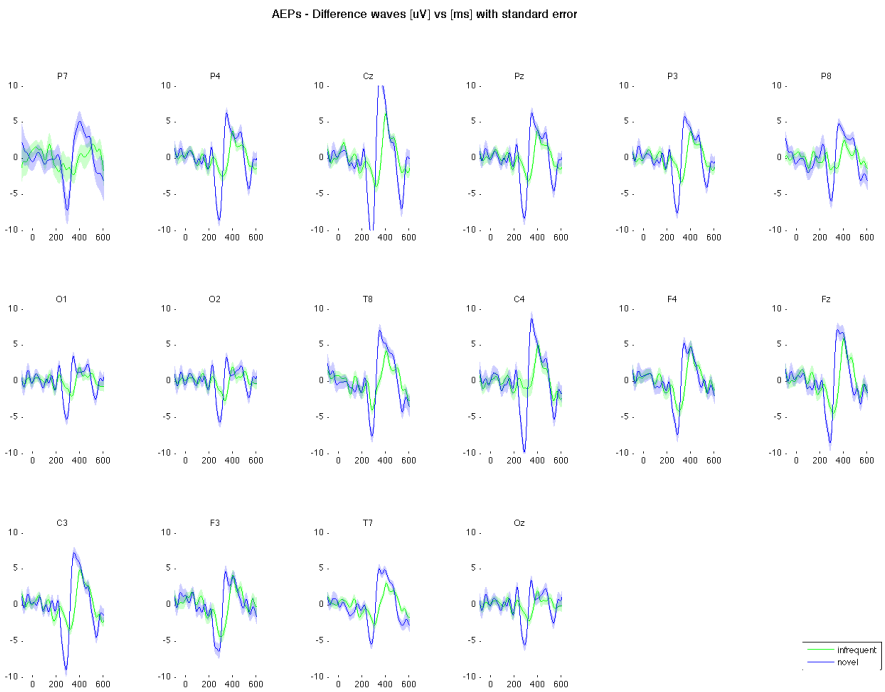

Figure 7. ERPS on difference waves (with standard error) for infrequent and novel stimuli.

Subject 2

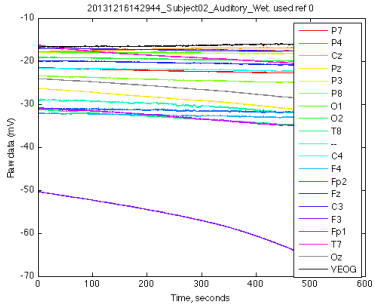

Figure 8. Raw data.

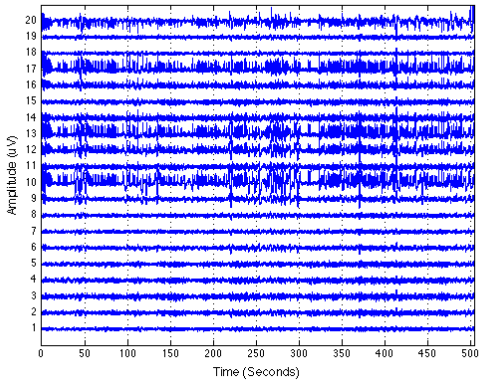

Figure 9. Data after BP filtering.

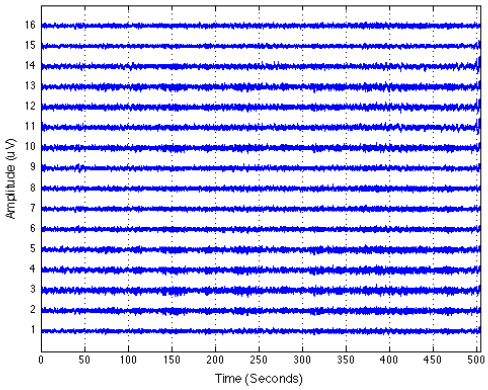

Figure 10. Data after correcting artifacts.

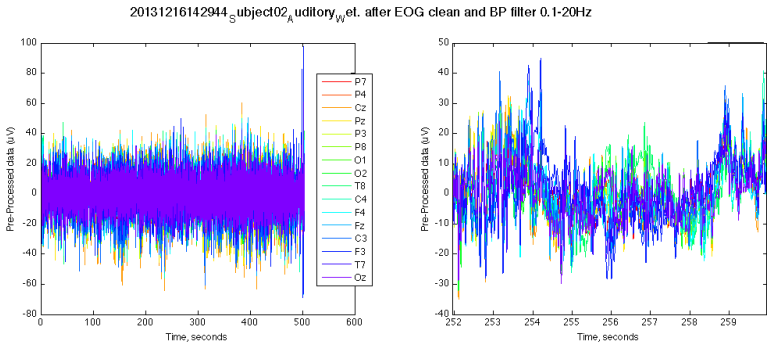

Figure 12. Data after pre-processing with detail (right).

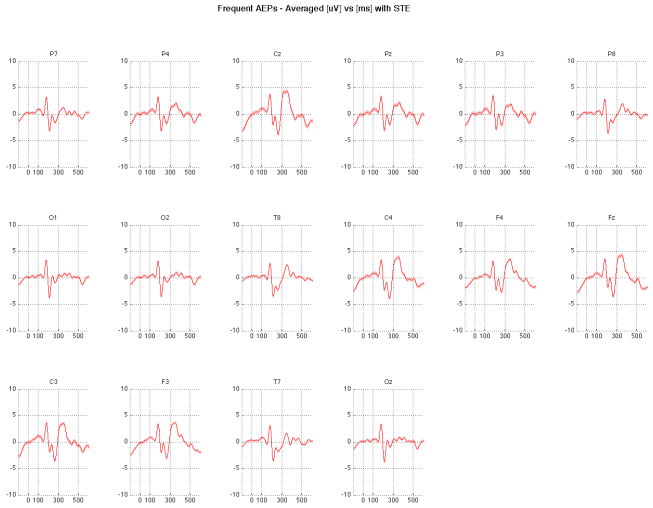

Figure 11. ERPs after averaging (with standard error) for all frequent stimuli.

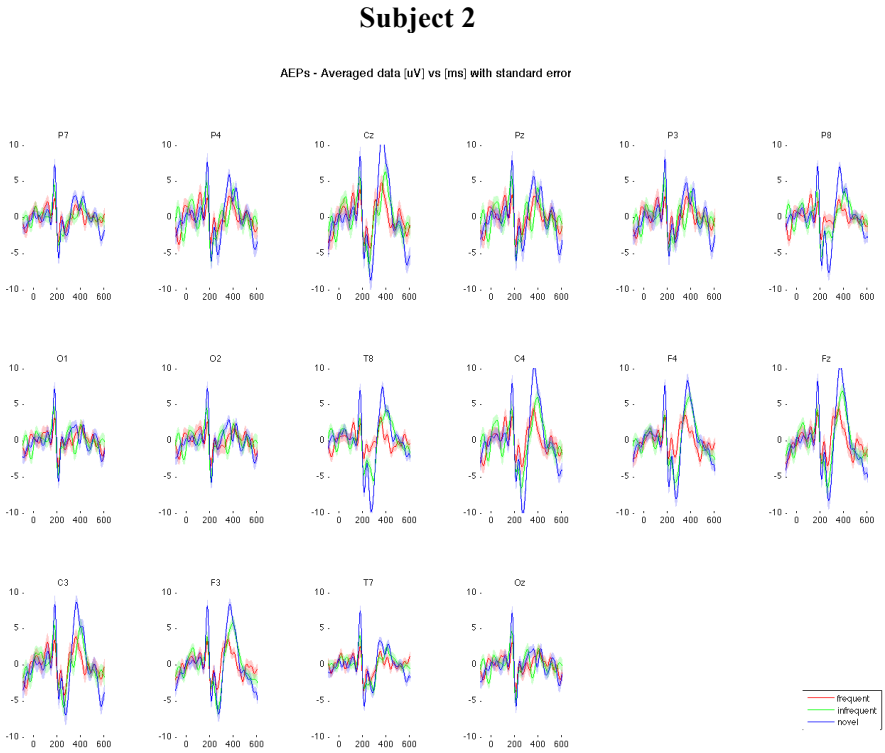

Figure 13. ERPs after averaging (with standard error) for 3 different types of stimuli.

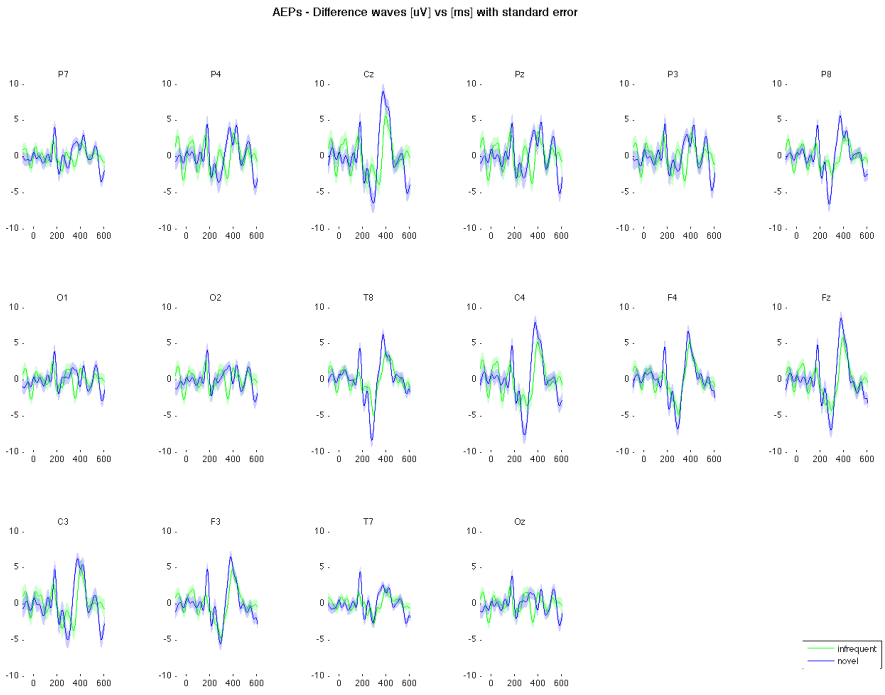

Figure 14. ERPS on difference waves (with standard error) for infrequent and novel stimuli.