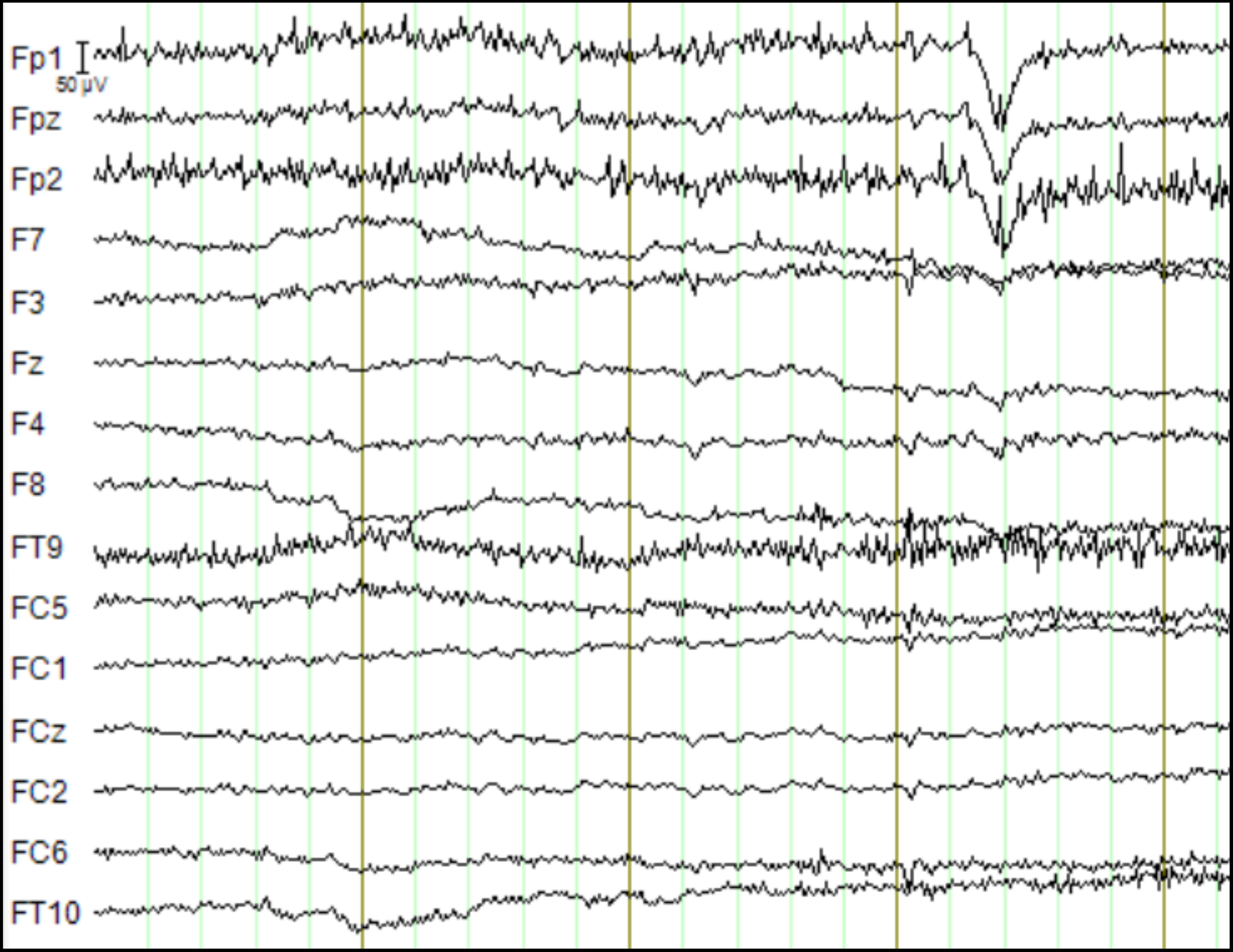
Session 3
Data Preprocessing I

Our Goal

In this sessions we will do a full ERP analysis of the data for a single subject.

Loading Data

What is in an EEGLAB Data Structure?

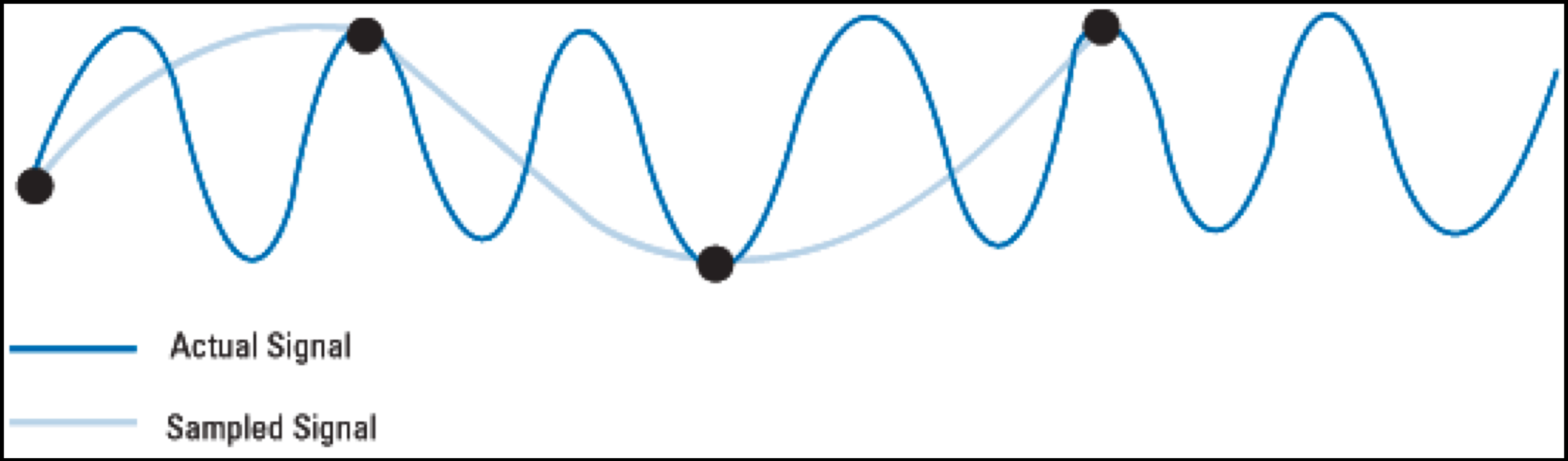


The Tree (EEG)

1. **Downsample**
2. **Remove Channels**
3. **New Reference**
4. **Filtering**
5. **Segmentation**
6. **DC Detrend (optional)**
7. **Ocular Correction (optional)**
8. **Topographic Interpolation**
9. **Resegmentation?**
10. **Baseline Correction**
11. **Artifact Rejection**
12. **Resegmentation (into conditions)**
13. **Average**
14. **Difference Computation**
15. **Stats**

Downsampling

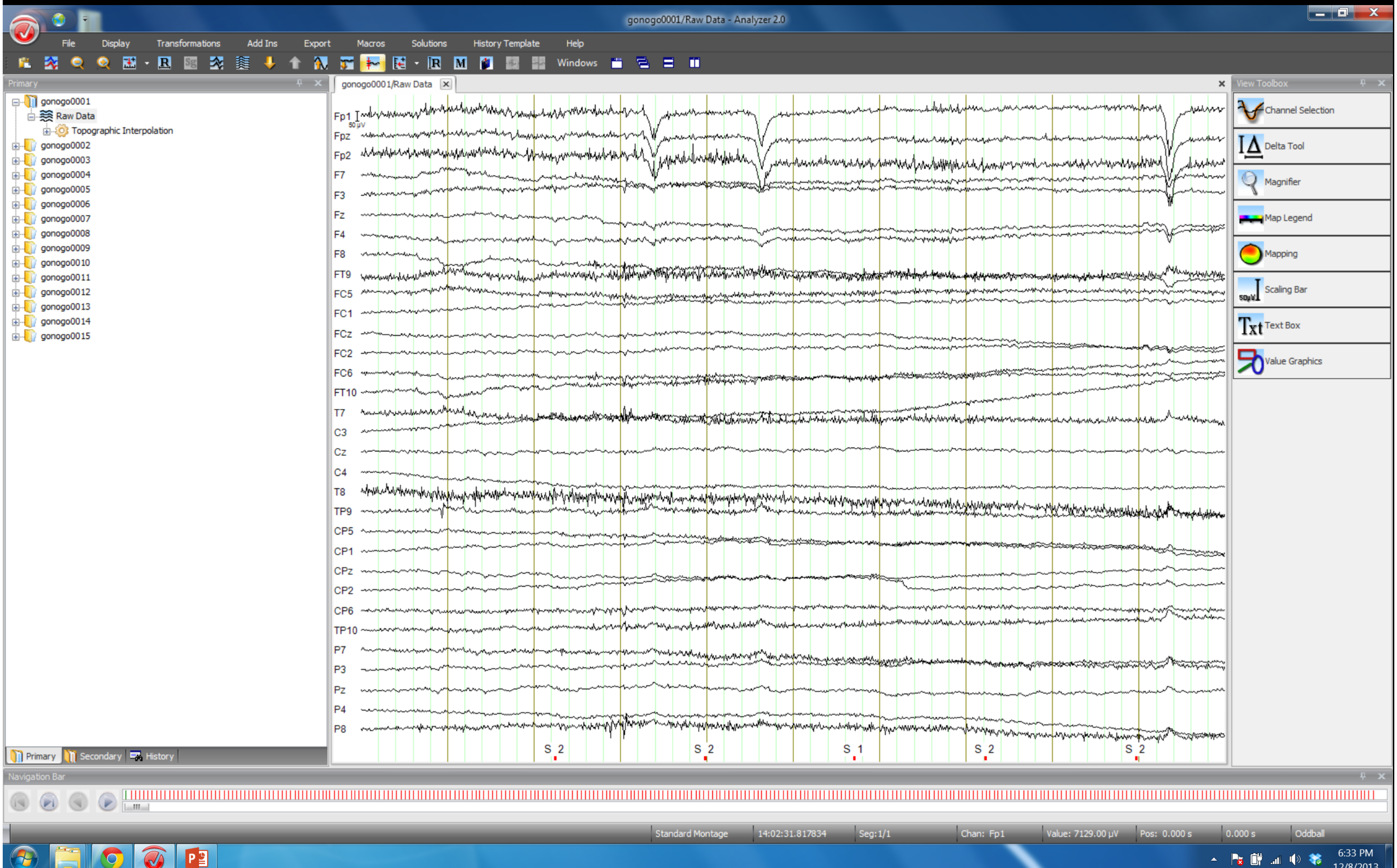
Downsampling



Downsampling Demos

Raw Data Inspection

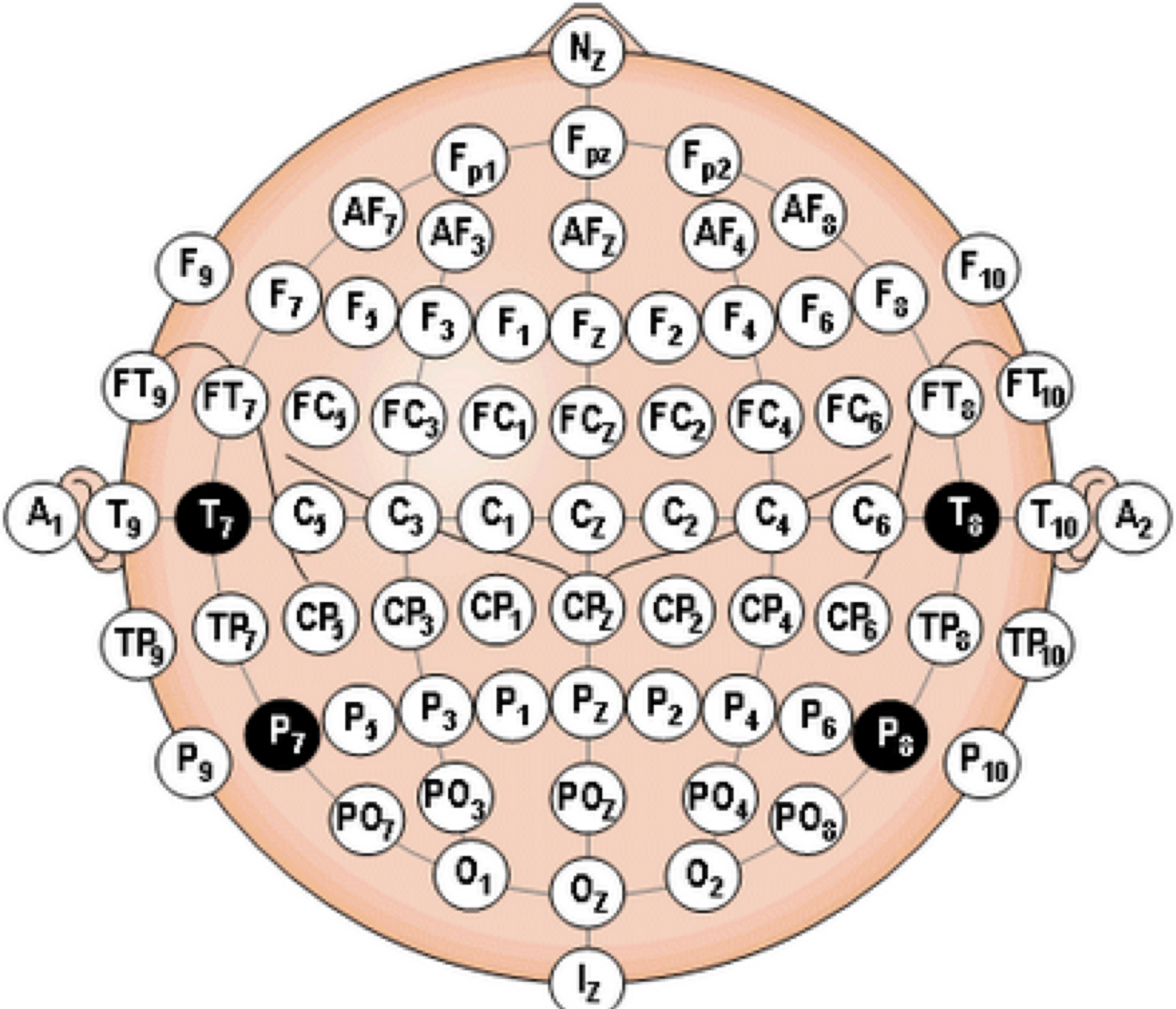
Remove Channels


gonogo0001/Raw Data - Analyzer 2.0
File
Display
Transformations
Add Ins
Export
Macros
Solutions
History Template
Help
Windows
Primary
gonogo0001
Raw Data
Topographic Interpolation
gonogo0002
gonogo0003
gonogo0004
gonogo0005
gonogo0006
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
gonogo0013
gonogo0014
gonogo0015
Primary
Secondary
History
gonogo0001/Raw Data
Fp1
Fpz
Fp2
F7
F3
Fz
F4
F8
FT9
FC5
FC1
FCz
FC2
FC6
FT10
T7
C3
Cz
C4
T8
TP9
CP5
CP1
CPz
CP2
CP6
TP10
P7
P3
Pz
P4
P8
S 2
S 2
S 1
S 2
S 2
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
14:02:31.817834
Seg: 1/1
Chan: Fp1
Value: 7129.00 µV
Pos: 0.000 s
0.000 s
Oddball
6:33 PM
12/8/2013

Issues with Removing Channels

1. Too many? (not needed = filtering)
2. Too few? (ICA)
3. We frequently ”redo” the analysis an modify this.

Rereferencing


N_Z
F_{p1} F_{pz} F_{p2}
AF_7 AF_3 AF_Z AF_4 AF_8
F_9 F_7 F_5 F_3 F_1 F_Z F_2 F_4 F_6 F_8 F_{10}
FT_9 FT_7 FC_5 FC_3 FC_1 FC_Z FC_2 FC_4 FC_6 FT_8 FT_{10}
A_1 T_9 T_7 C_5 C_3 C_1 C_Z C_2 C_4 C_6 T_8 T_{10} A_2
TP_9 TP_7 CP_5 CP_3 CP_1 CP_Z CP_2 CP_4 CP_6 TP_8 TP_{10}
P_9 P_7 P_5 P_3 P_1 P_Z P_2 P_4 P_6 P_8 P_{10}
PO_7 PO_3 PO_Z PO_4 PO_8
O_1 O_Z O_2
I_Z

The Notion…

First of all, recall that a voltage reference needs to be supplied at the time of data recording.

Why, because a voltage is the potential difference between two points.

However, offline we may wish to re-reference the data again.

The Important Point

Any voltage you see is the difference between an electrode site and another point…

THUS…

The choice of reference impacts the voltages you are observing

But Why?

Because you cannot record a voltage at a single electrode site, by definition!

Thus, you need to have a reference, but that reference may not be good from an analysis perspective.

So, we re-reference typically during data analysis.

The Answer?

The most common reference sites are the EARS and the MASTOIDS.

We use two, one on each side, to avoid a hemisphere bias.

Why not record with these? May not be best for actual recording but it is good for analysis.

Average References

Not as ideal as one might think

- electrodes not covering the entire surface of the head
- differences in polarities – an average reference can make one site positive and another negative
- reduced effects

Reference Demos

Data Filtering

Filtering is a Complex Business

Why do we do it?

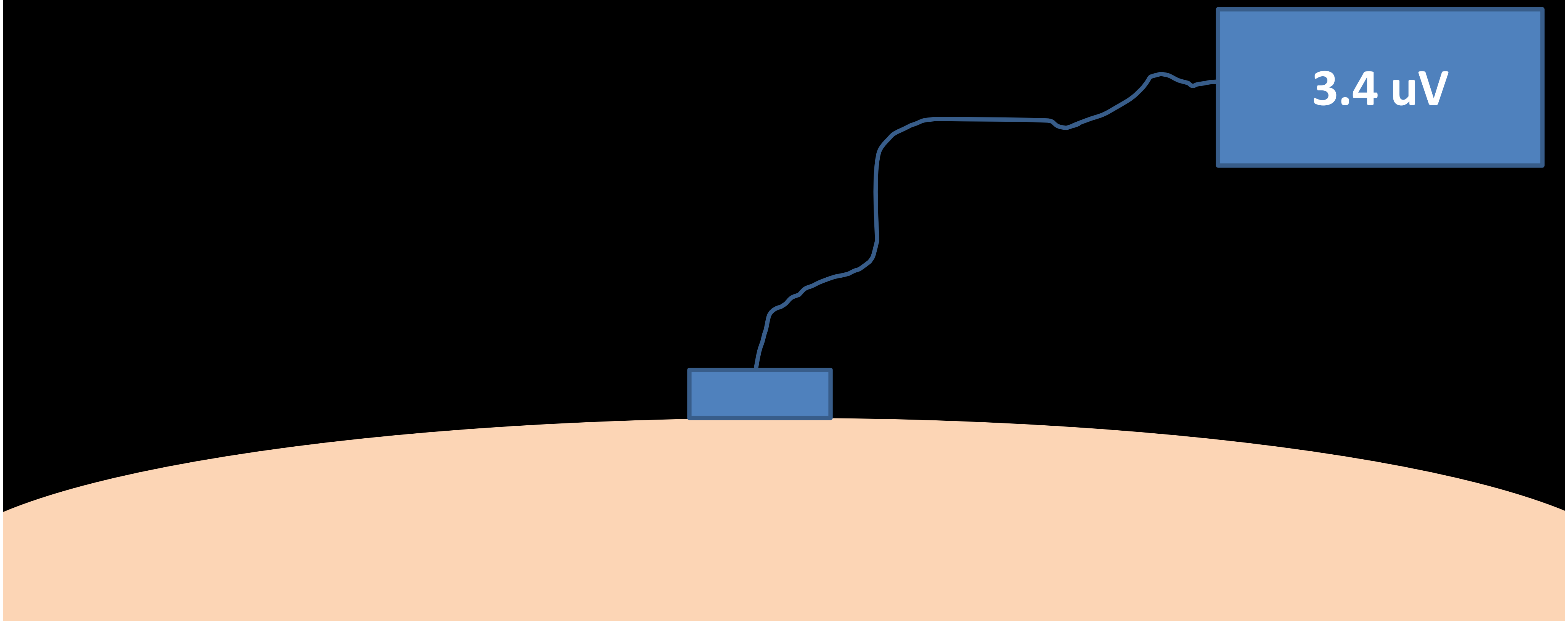
- reduce noise in the data
- prevent distortion in the data

The Problem

- filters can substantially distort your data

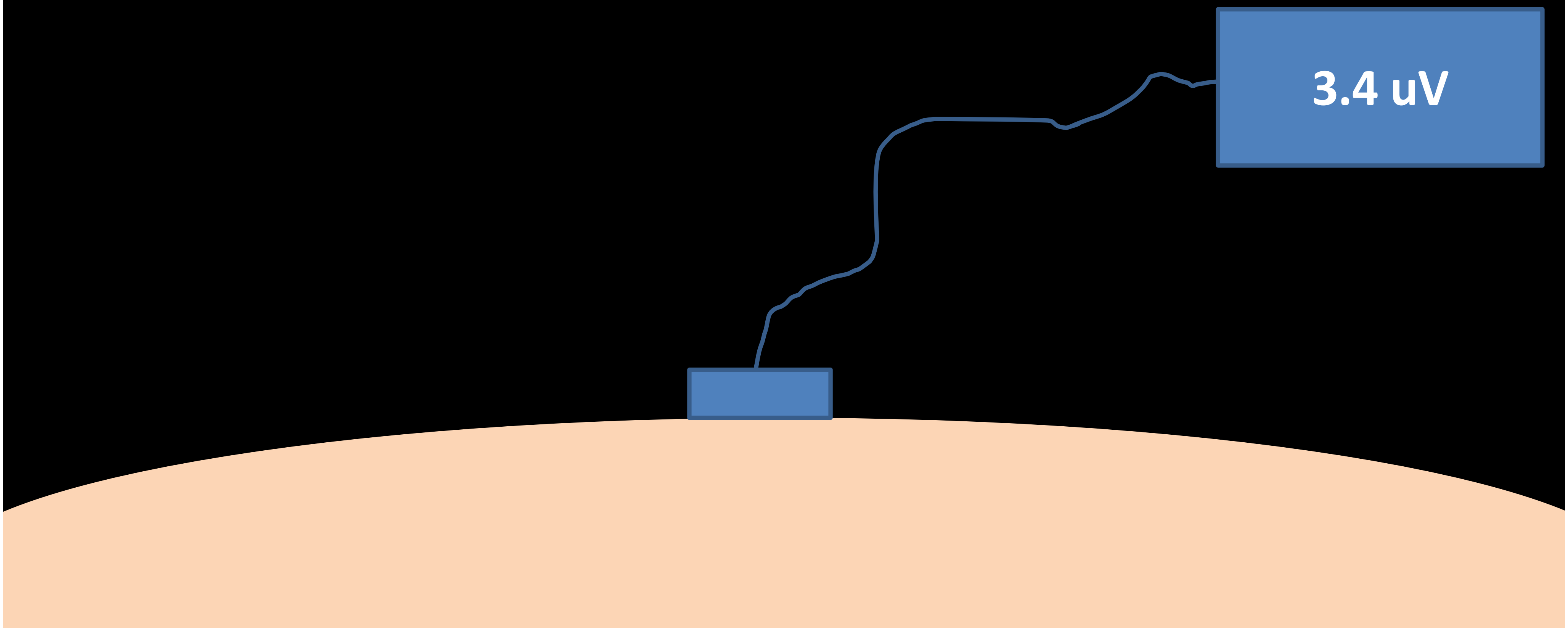
Voltage as a Waveform

At any given point in time, an electrode is measuring a voltage, or potential difference, that is the net result of the underlying neural activity.



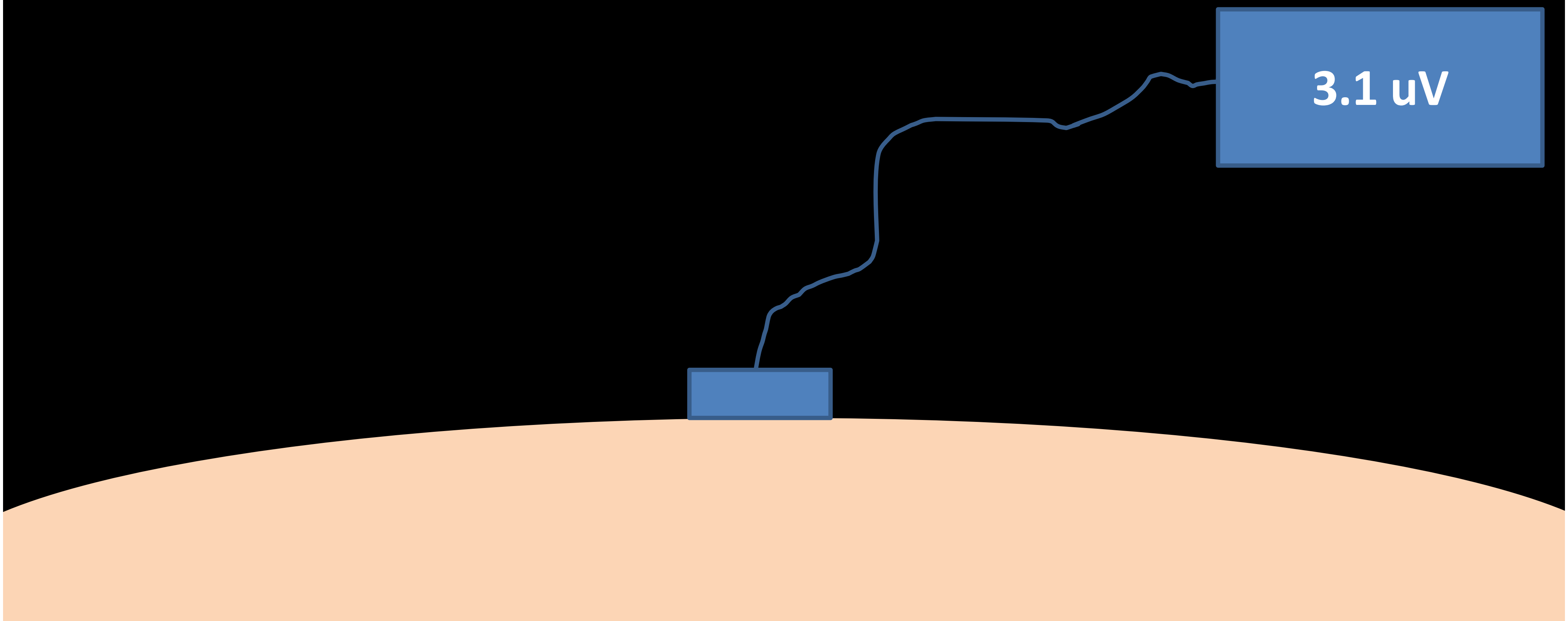
Voltage as a Waveform

However, if you take sequential measurements you will have a series of voltages from the sensor.



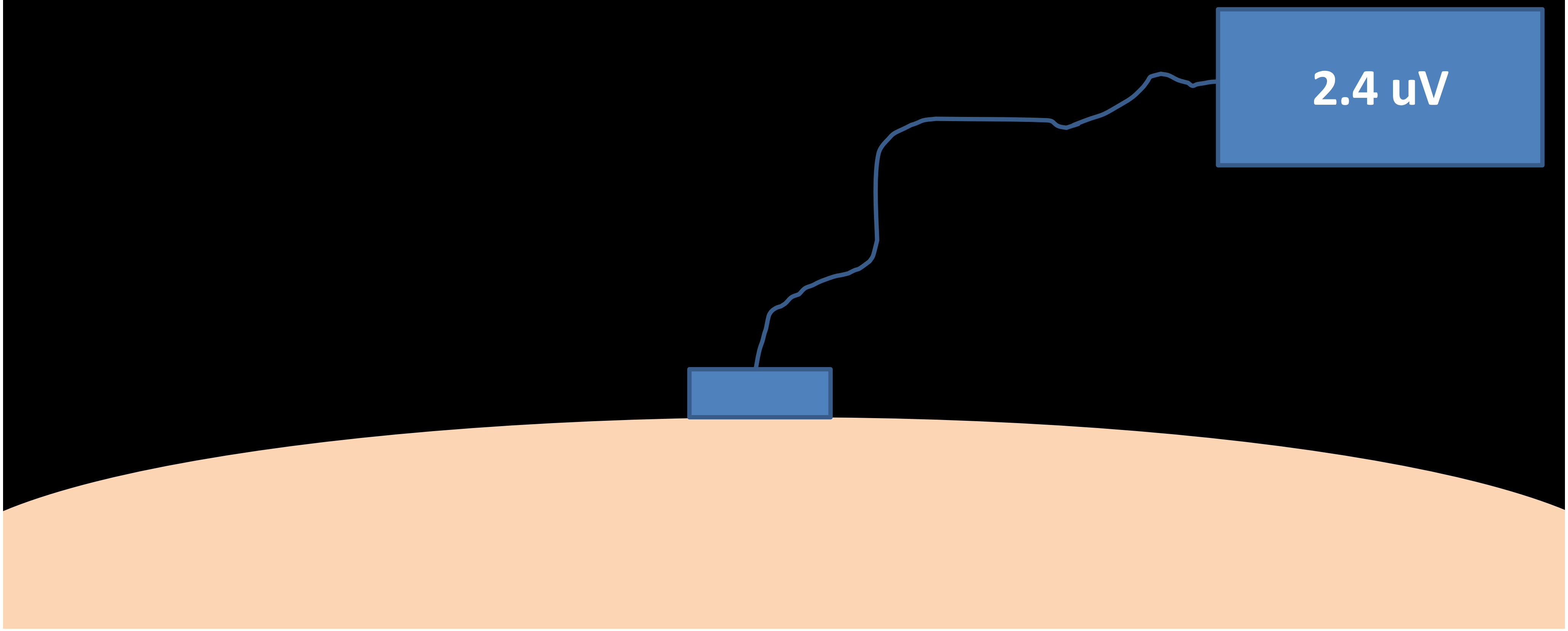
Voltage as a Waveform

However, if you take sequential measurements you will have a series of voltages from the sensor.



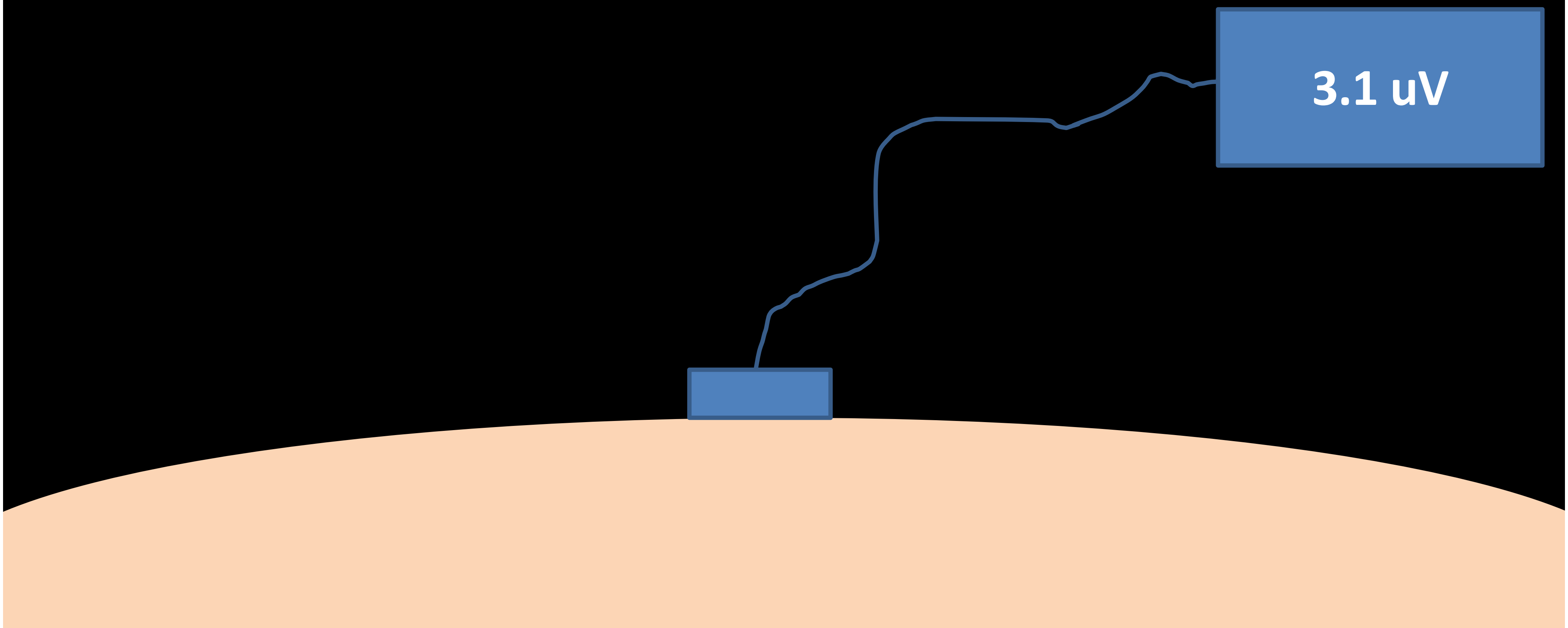
Voltage as a Waveform

However, if you take sequential measurements you will have a series of voltages from the sensor.



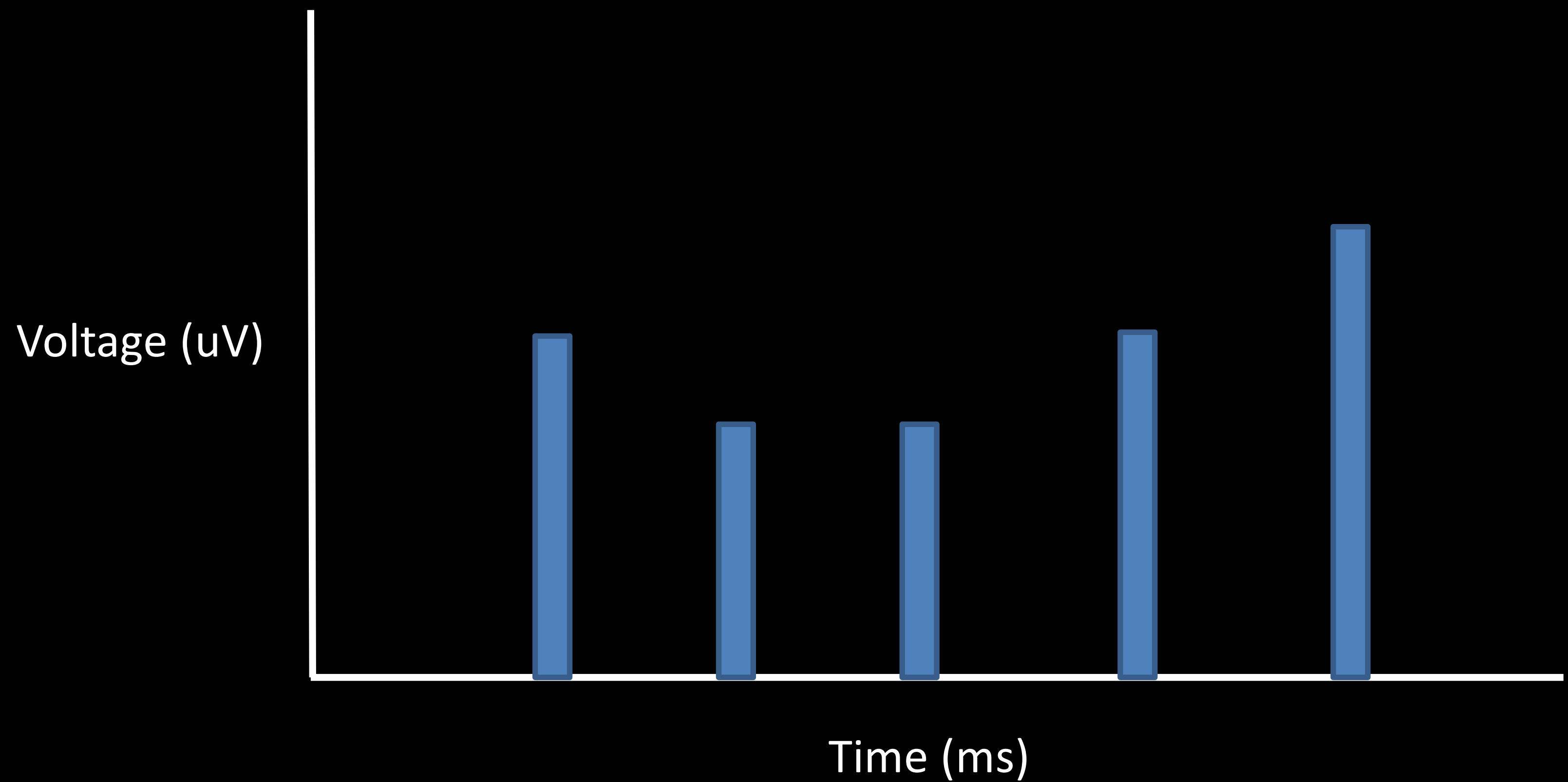
Voltage as a Waveform

However, if you take sequential measurements you will have a series of voltages from the sensor.



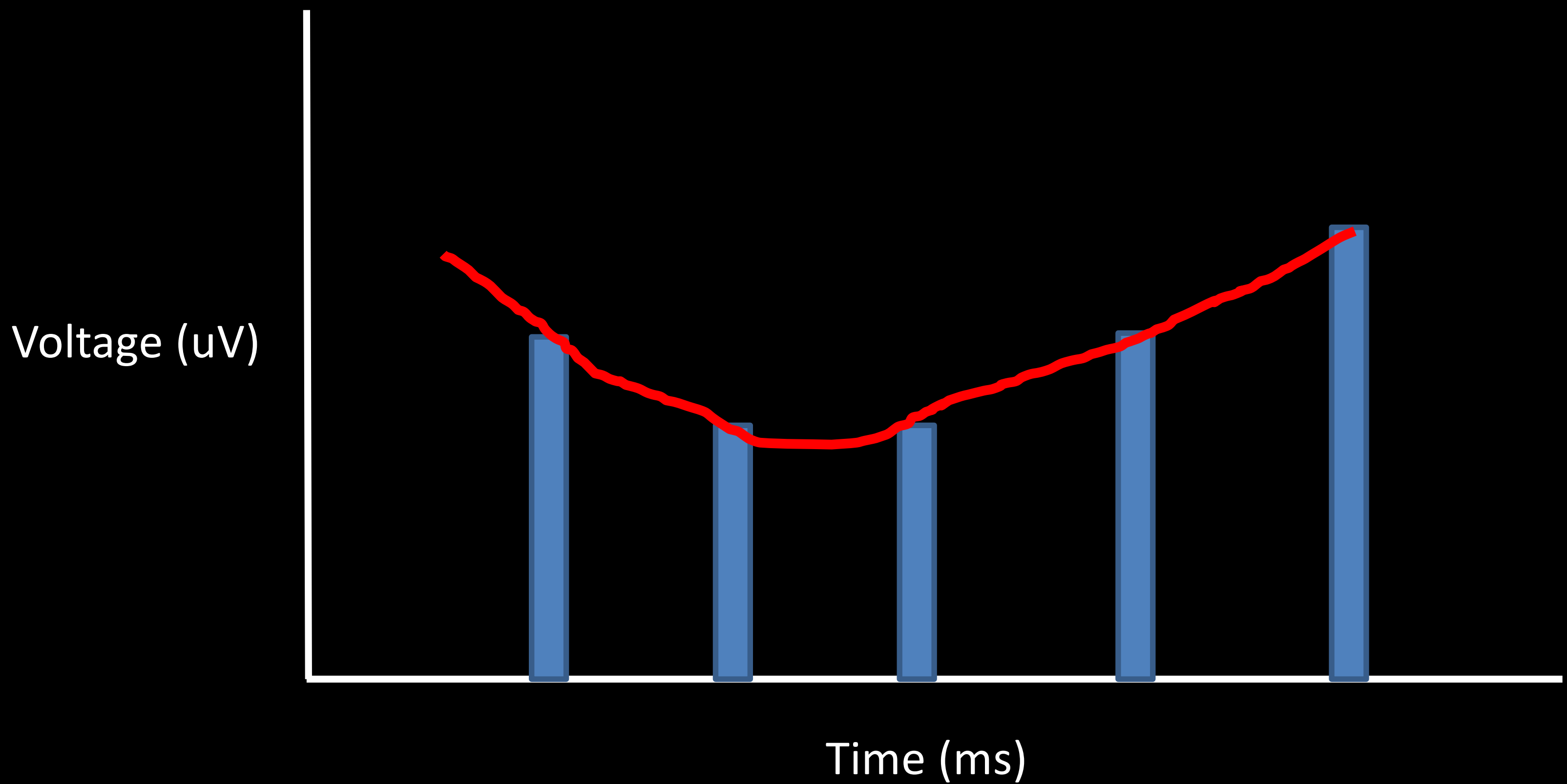
Voltage as a Waveform

However, if you take sequential measurements you will have a series of voltages from the sensor.



Voltage as a Waveform

However, if you take sequential measurements you will have a series of voltages from the sensor.



A quick note on sampling theory…

The Nyquist Theorem

Recall what we said yesterday.

To capture your EEG signal you need to have a sampling rate such that its at least twice the highest frequency of the signal.

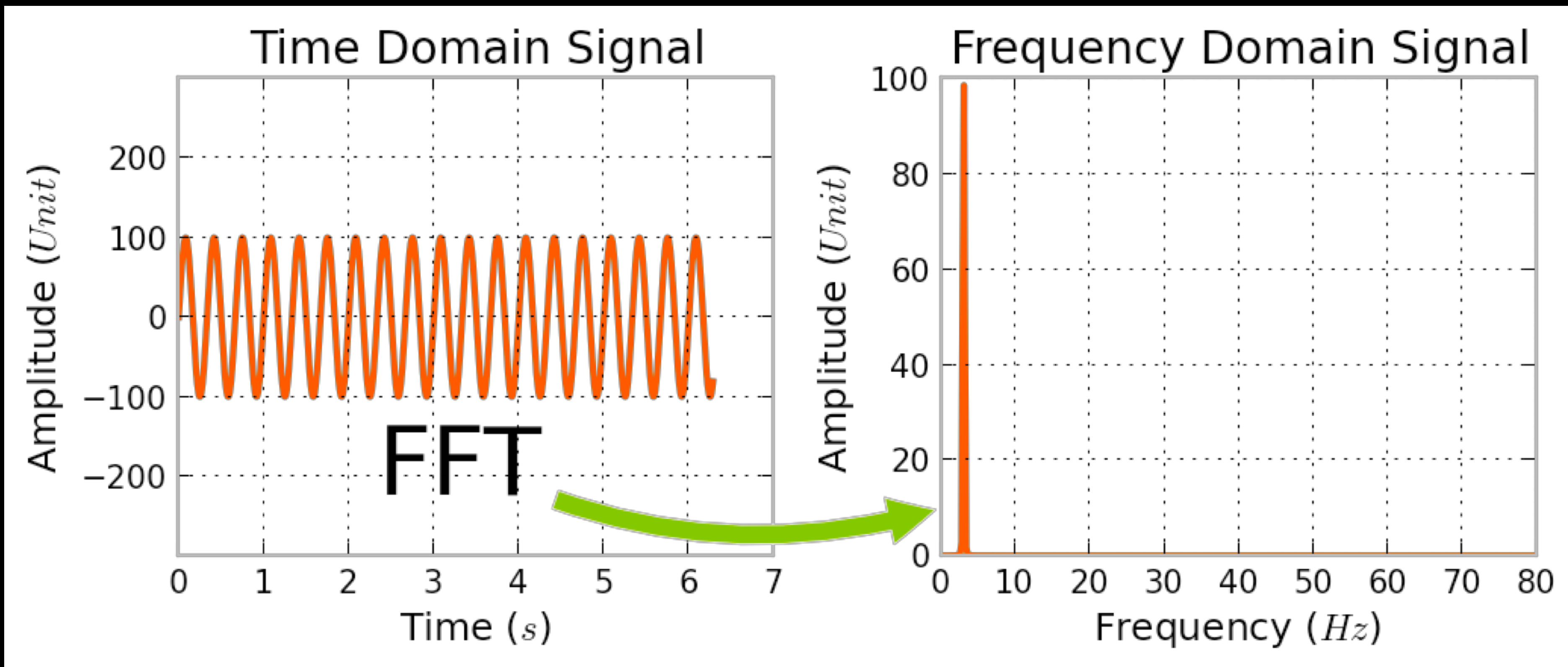
Typically, the signals we want to look at are not greater than 100 Hz (for ERPs 40 Hz).

So you can think of a series of voltages as a waveform, so what?

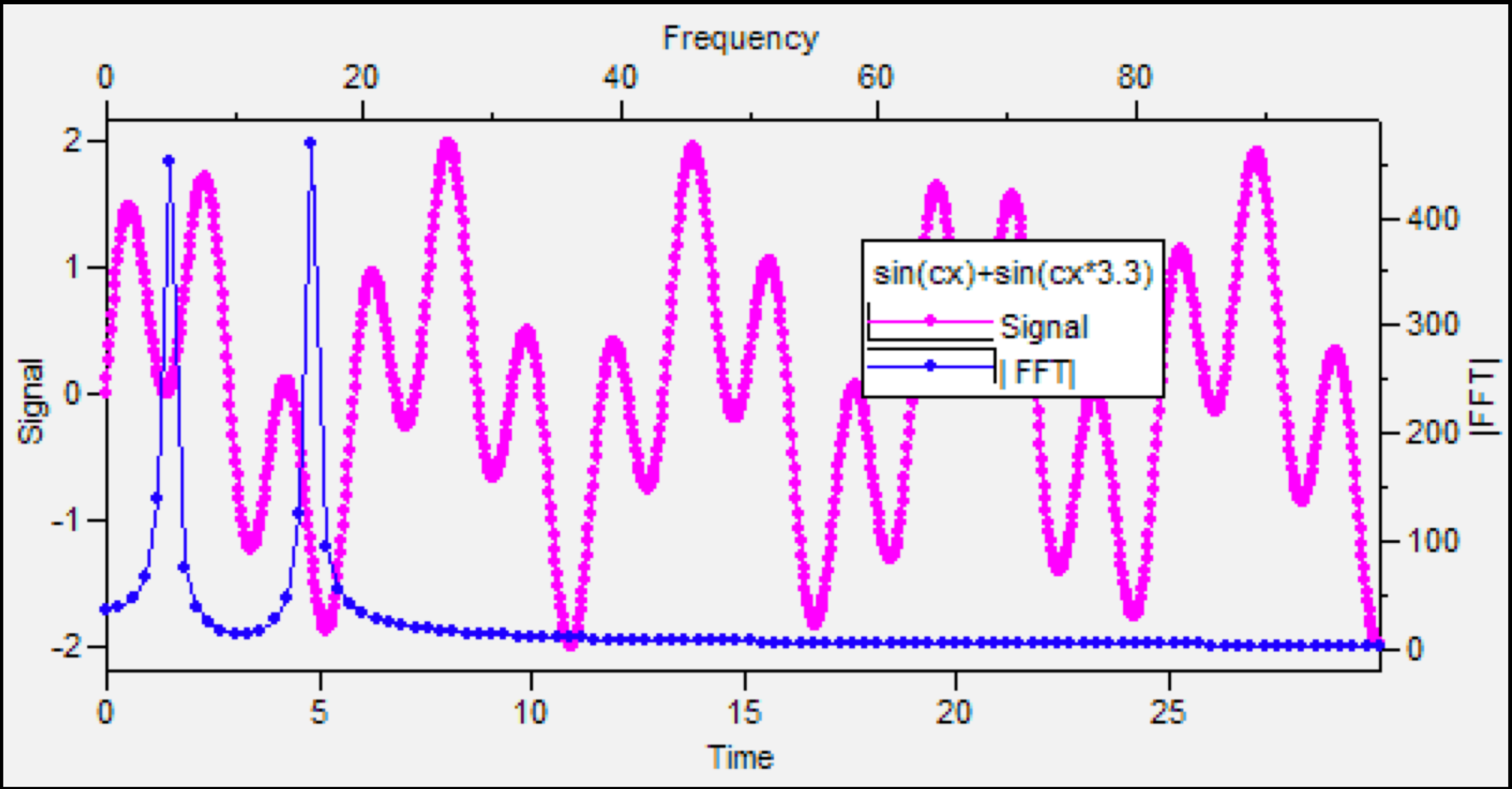
The Fourier Theorem

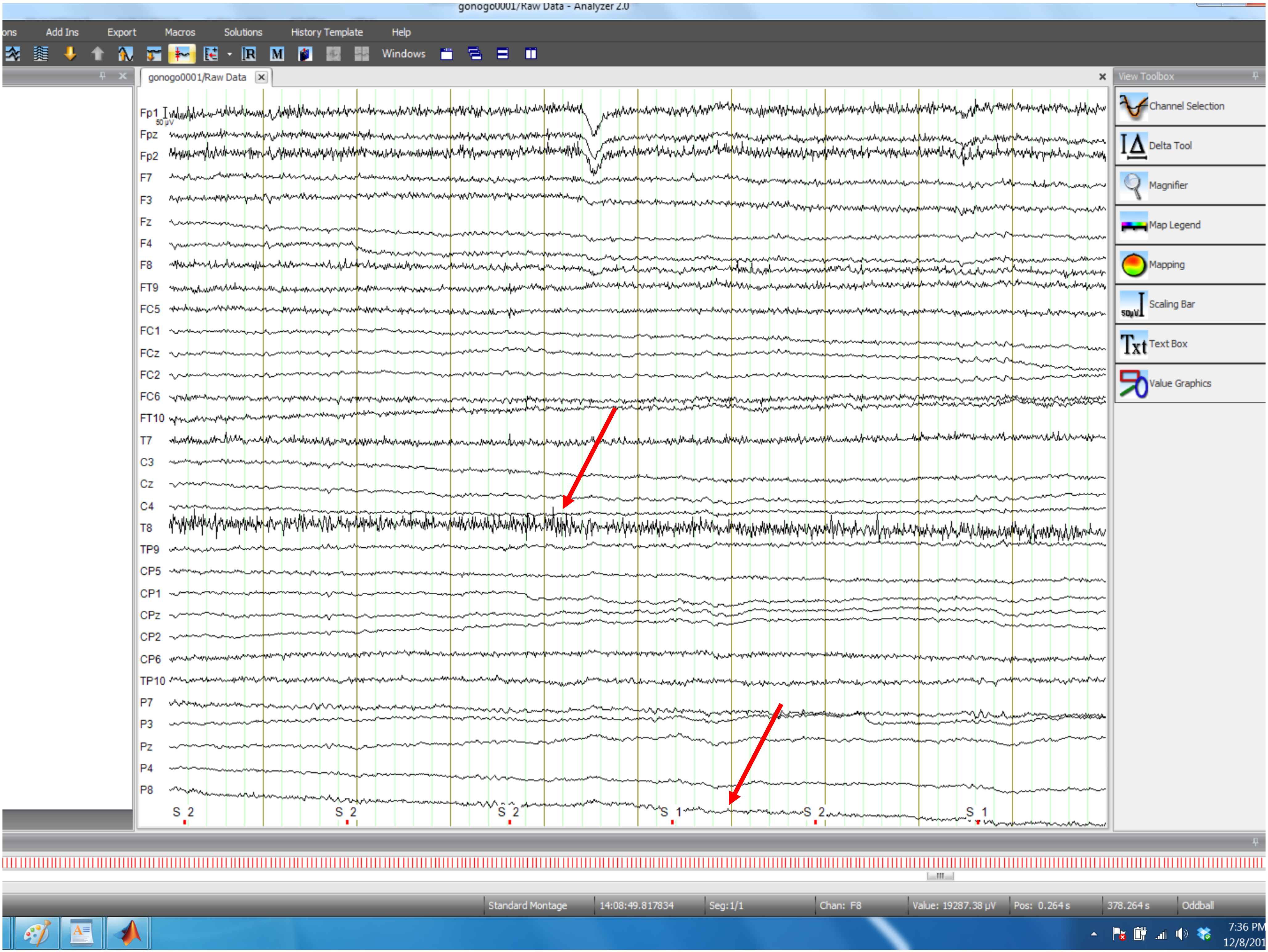
Simply put, any complex waveform can be decomposed into a series of sine waves, that when added back together, reconstruct the original waveform.

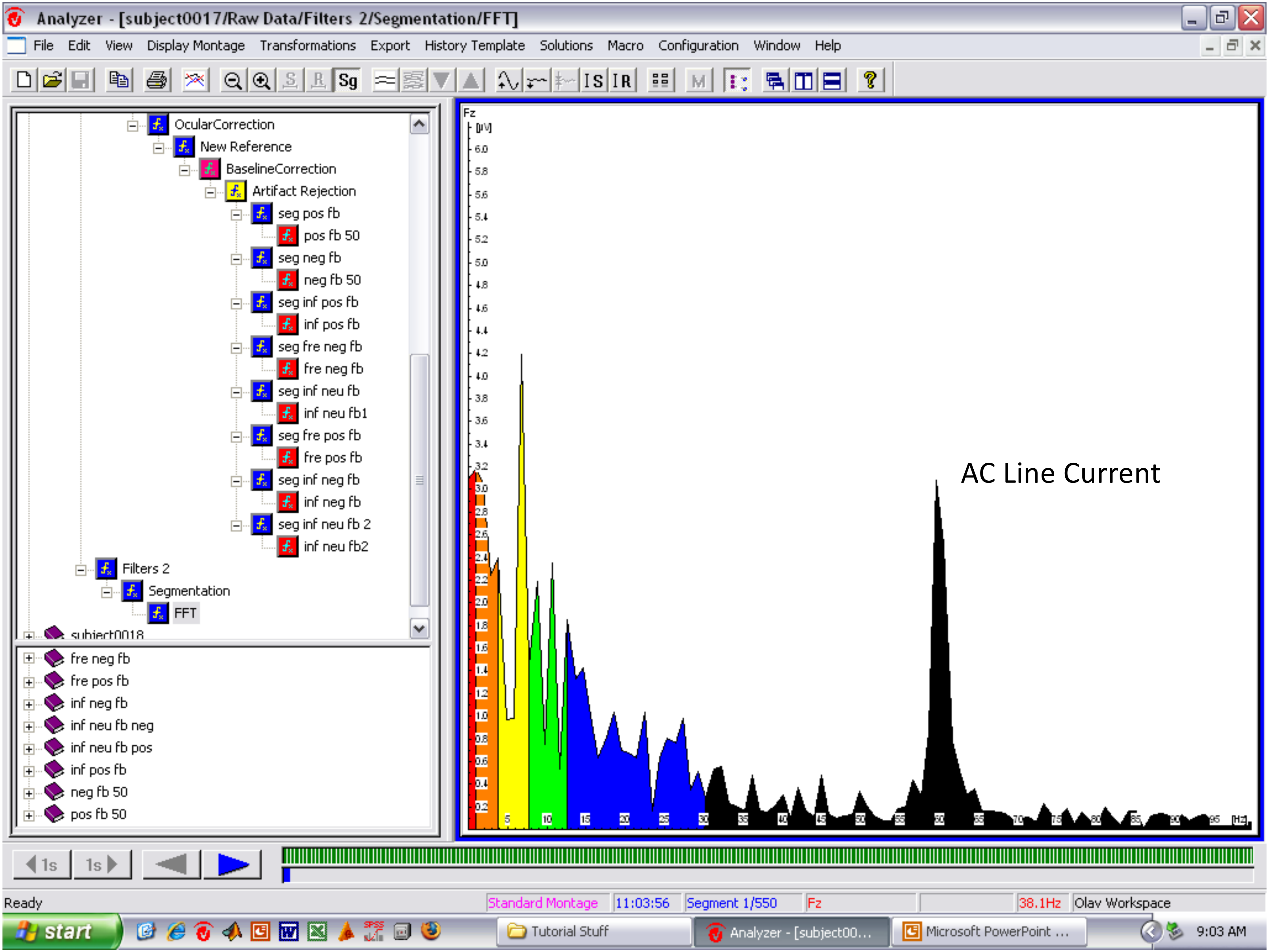
This process can be used to subtract out unwanted frequencies of data.



Time Domain Signal
Amplitude (Unit)
200
100
0
−100
−200
0
1
2
3
4
5
6
7
Time (s)
FFT
Frequency Domain Signal
Amplitude (Unit)
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Frequency (Hz)

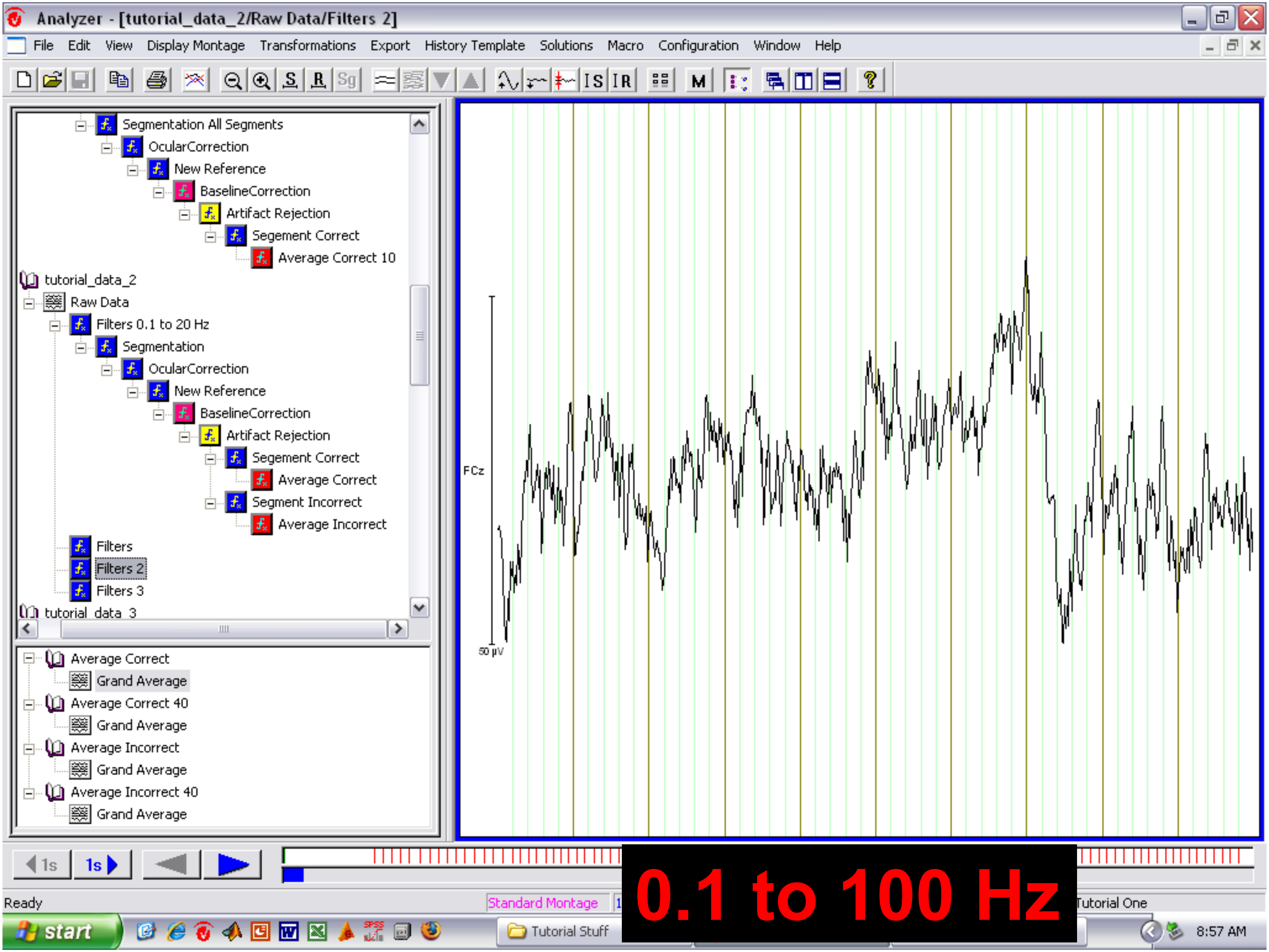

Frequency
0
20
40
60
80
2
1
0
-1
-2
Signal
400
300
200
100
0
|FFT|
sin(cx)+sin(cx*3.3)
Signal
| FFT|
0
5
10
15
20
25
Time

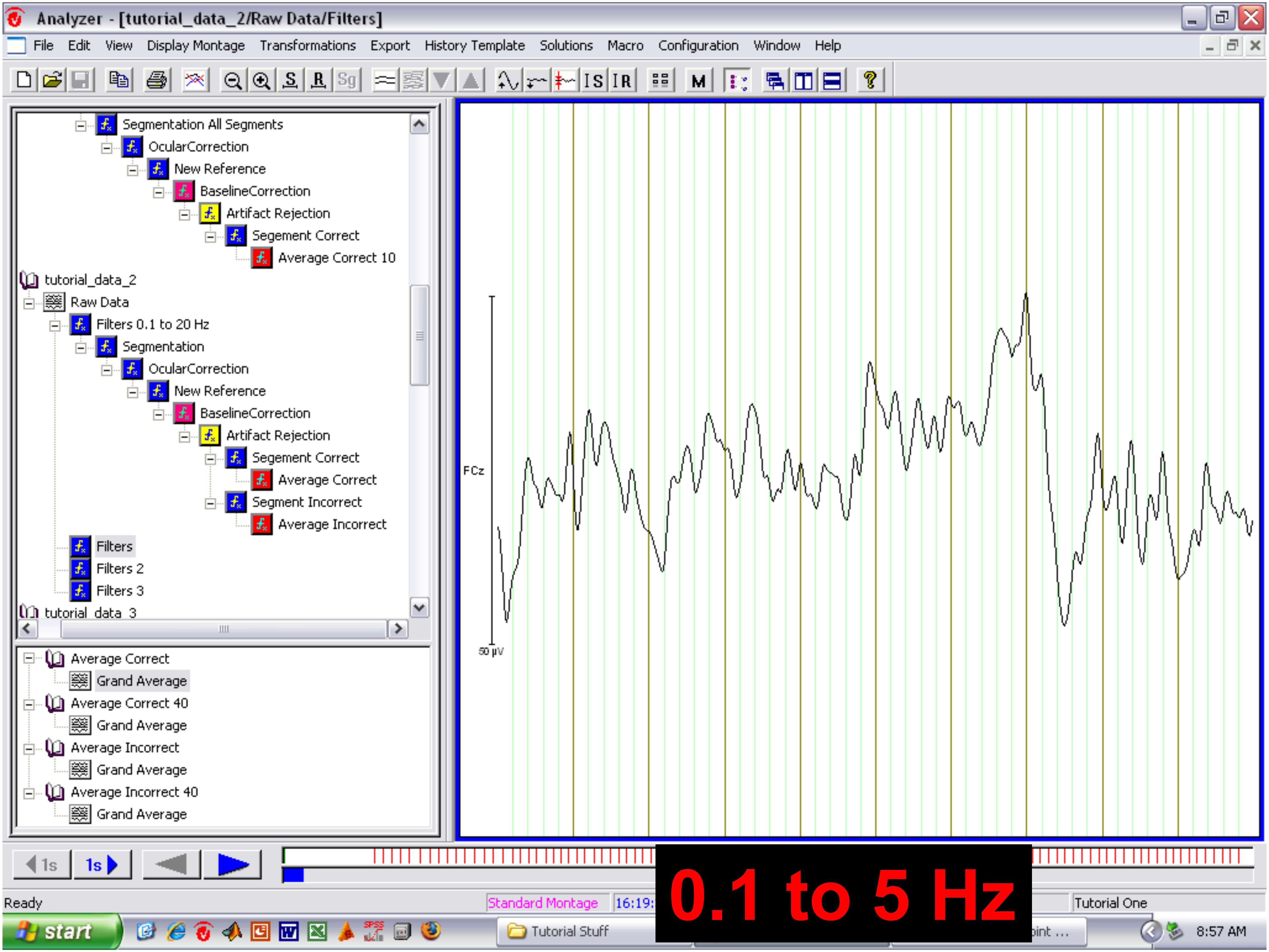

gonogo0001/Raw Data - Analyzer 2.0
ons
Add Ins
Export
Macros
Solutions
History Template
Help
Windows
gonogo0001/Raw Data
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Fp1
Fpz
Fp2
F7
F3
Fz
F4
F8
FT9
FC5
FC1
FCz
FC2
FC6
FT10
T7
C3
Cz
C4
T8
TP9
CP5
CP1
CPz
CP2
CP6
TP10
P7
P3
Pz
P4
P8
S 2
S 2
S 2
S 1
S 2
S 1
Standard Montage
14:08:49.817834
Seg: 1/1
Chan: F8
Value: 19287.38 µV
Pos: 0.264 s
378.264 s
Oddball
7:36 PM

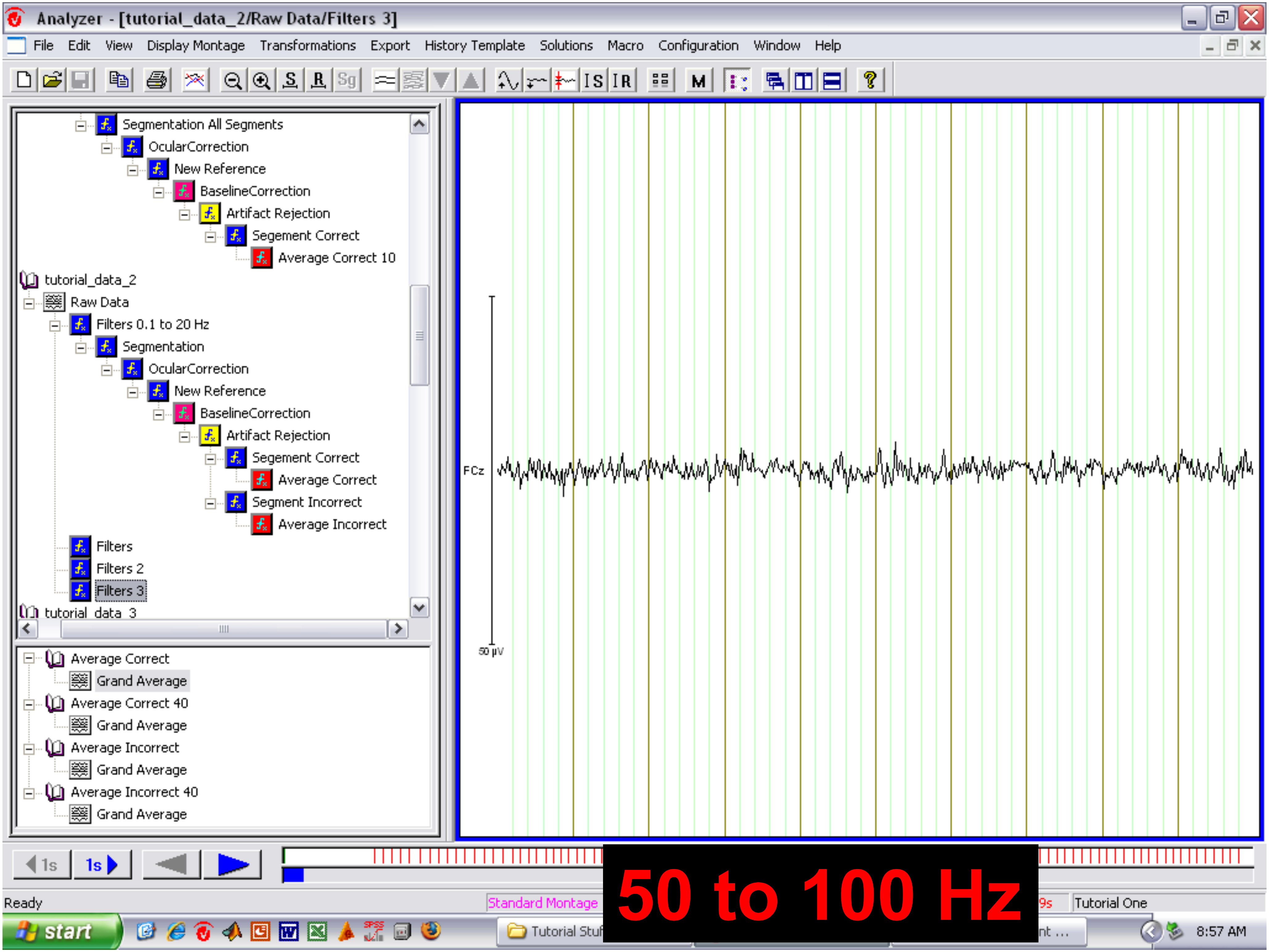

Analyzer - [subject0017/Raw Data/Filters 2/Segmentation/FFT]
File Edit View Display Montage Transformations Export History Template Solutions Macro Configuration Window Help
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
seg pos fb
pos fb 50
seg neg fb
neg fb 50
seg inf pos fb
inf pos fb
seg fre neg fb
fre neg fb
seg inf neu fb
inf neu fb1
seg fre pos fb
fre pos fb
seg inf neg fb
inf neg fb
seg inf neu fb 2
inf neu fb2
Filters 2
Segmentation
FFT
subject0018
fre neg fb
fre pos fb
inf neg fb
inf neu fb neg
inf neu fb pos
inf pos fb
neg fb 50
pos fb 50
Fz
[µV]
AC Line Current
Ready
Standard Montage
11:03:56
Segment 1/550
Fz
38.1Hz
Olav Workspace
start
Tutorial Stuff
Analyzer - [subject00...
Microsoft PowerPoint ...
9:03 AM

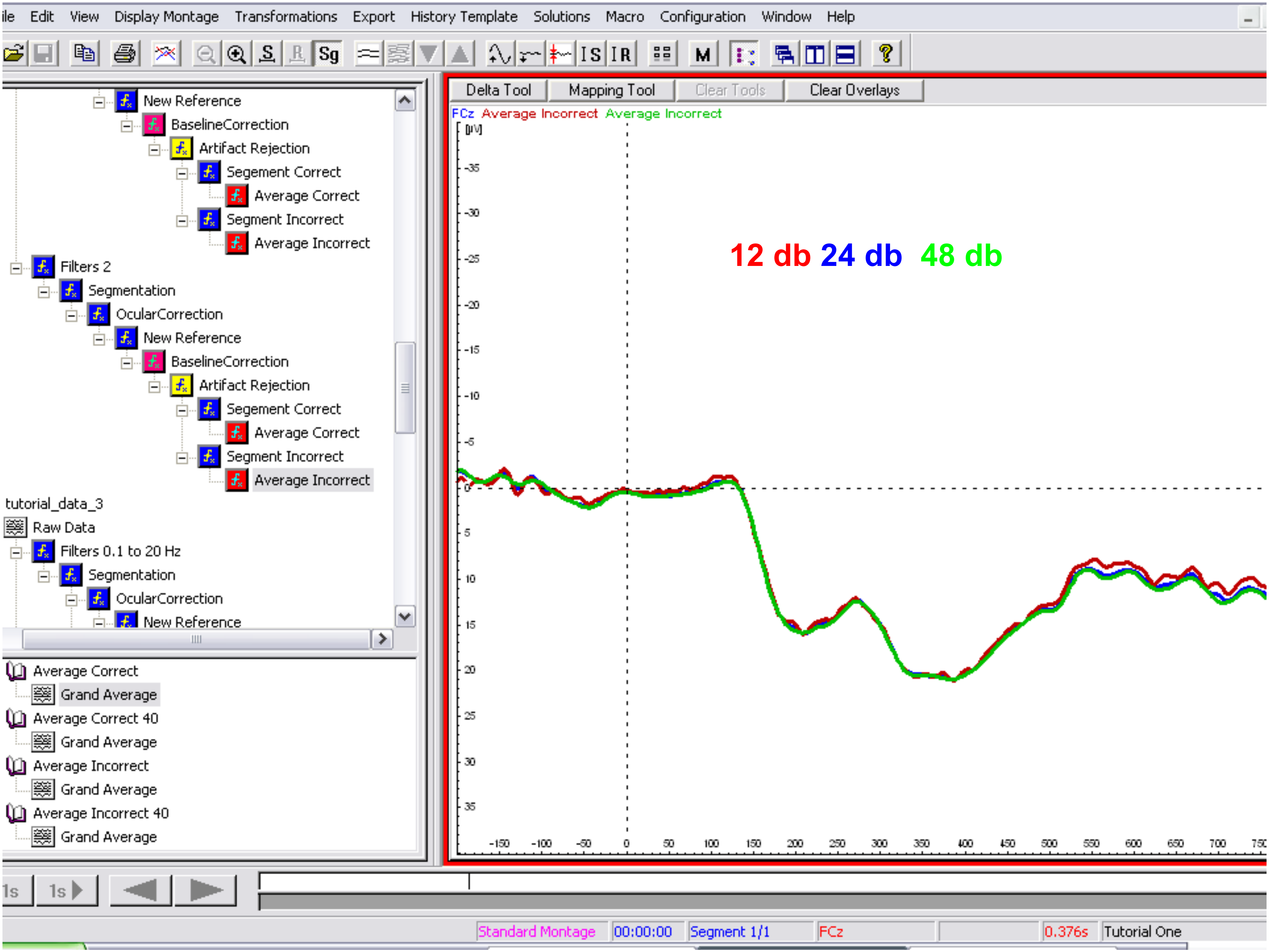
Types of Filters

1. Low Pass (30 Hz – removes above this)
2. High Pass (0.1 Hz – removes below this)
3. Bandpass (0.1 to 30 Hz – removes below and above)
4. Notch Filters (remove a specific frequency)

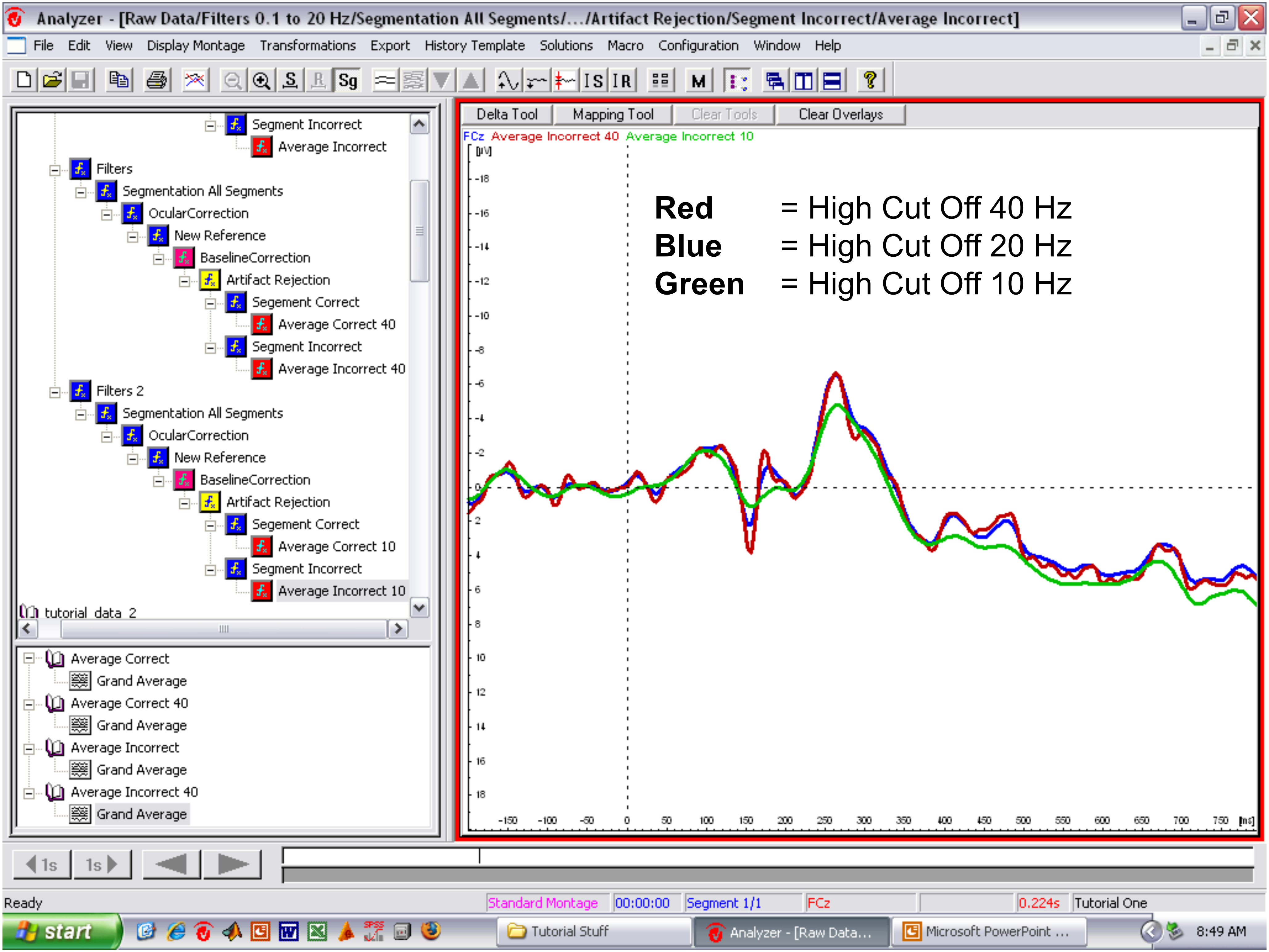

Analyzer - [tutorial_data_2/Raw Data/Filters 2]
File Edit View Display Montage Transformations Export History Template Solutions Macro Configuration Window Help
Segmentation All Segments
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct 10
tutorial_data_2
Raw Data
Filters 0.1 to 20 Hz
Segmentation
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct
Segment Incorrect
Average Incorrect
Filters
Filters 2
Filters 3
tutorial_data_3
Average Correct
Grand Average
Average Correct 40
Grand Average
Average Incorrect
Grand Average
Average Incorrect 40
Grand Average
FCz
50 µV
1s
1s
Ready
Standard Montage
Tutorial One
start
Tutorial Stuff
8:57 AM
0.1 to 100 Hz


Analyzer - [tutorial_data_2/Raw Data/Filters]
File Edit View Display Montage Transformations Export History Template Solutions Macro Configuration Window Help
Segmentation All Segments
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct 10
tutorial_data_2
Raw Data
Filters 0.1 to 20 Hz
Segmentation
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct
Segment Incorrect
Average Incorrect
Filters
Filters 2
Filters 3
tutorial_data_3
Average Correct
Grand Average
Average Correct 40
Grand Average
Average Incorrect
Grand Average
Average Incorrect 40
Grand Average
FCz
50 µV
1s
1s
Ready
Standard Montage
Tutorial One
start
Tutorial Stuff
8:57 AM
0.1 to 5 Hz


Analyzer - [tutorial_data_2/Raw Data/Filters 3]
File Edit View Display Montage Transformations Export History Template Solutions Macro Configuration Window Help
Segmentation All Segments
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct 10
tutorial_data_2
Raw Data
Filters 0.1 to 20 Hz
Segmentation
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct
Segment Incorrect
Average Incorrect
Filters
Filters 2
Filters 3
tutorial_data_3
Average Correct
Grand Average
Average Correct 40
Grand Average
Average Incorrect
Grand Average
Average Incorrect 40
Grand Average
FCz
50 µV
1s
Ready
Standard Montage
Tutorial One
start
8:57 AM
50 to 100 Hz



File Edit View Display Montage Transformations Export History Template Solutions Macro Configuration Window Help
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct
Segment Incorrect
Average Incorrect
Filters 2
Segmentation
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct
Segment Incorrect
Average Incorrect
tutorial_data_3
Raw Data
Filters 0.1 to 20 Hz
Segmentation
OcularCorrection
New Reference
Average Correct
Grand Average
Average Correct 40
Grand Average
Average Incorrect
Grand Average
Average Incorrect 40
Grand Average
Delta Tool
Mapping Tool
Clear Tools
Clear Overlays
FCz Average Incorrect Average Incorrect
[µV]
12 db 24 db 48 db
-35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35
-150 -100 -50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750
Standard Montage
00:00:00
Segment 1/1
FCz
0.376s
Tutorial One



Analyzer - [Raw Data/Filters 0.1 to 20 Hz/Segmentation All Segments/.../Artifact Rejection/Segment Incorrect/Average Incorrect]
File Edit View Display Montage Transformations Export History Template Solutions Macro Configuration Window Help
Segment Incorrect
Average Incorrect
Filters
Segmentation All Segments
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct 40
Segment Incorrect
Average Incorrect 40
Filters 2
Segmentation All Segments
OcularCorrection
New Reference
BaselineCorrection
Artifact Rejection
Segement Correct
Average Correct 10
Segment Incorrect
Average Incorrect 10
tutorial_data_2
Average Correct
Grand Average
Average Correct 40
Grand Average
Average Incorrect
Grand Average
Average Incorrect 40
Grand Average
Delta Tool
Mapping Tool
Clear Tools
Clear Overlays
FCz Average Incorrect 40 Average Incorrect 10
[µV]
Red = High Cut Off 40 Hz
Blue = High Cut Off 20 Hz
Green = High Cut Off 10 Hz
-18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18
-150 -100 -50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 [ms]
Ready
Standard Montage
00:00:00
Segment 1/1
FCz
0.224s
Tutorial One
start
Tutorial Stuff
Analyzer - [Raw Data...
Microsoft PowerPoint ...
8:49 AM

Filter Distortion

Filters can distort the AMPLITUDE and LATENCY of components.

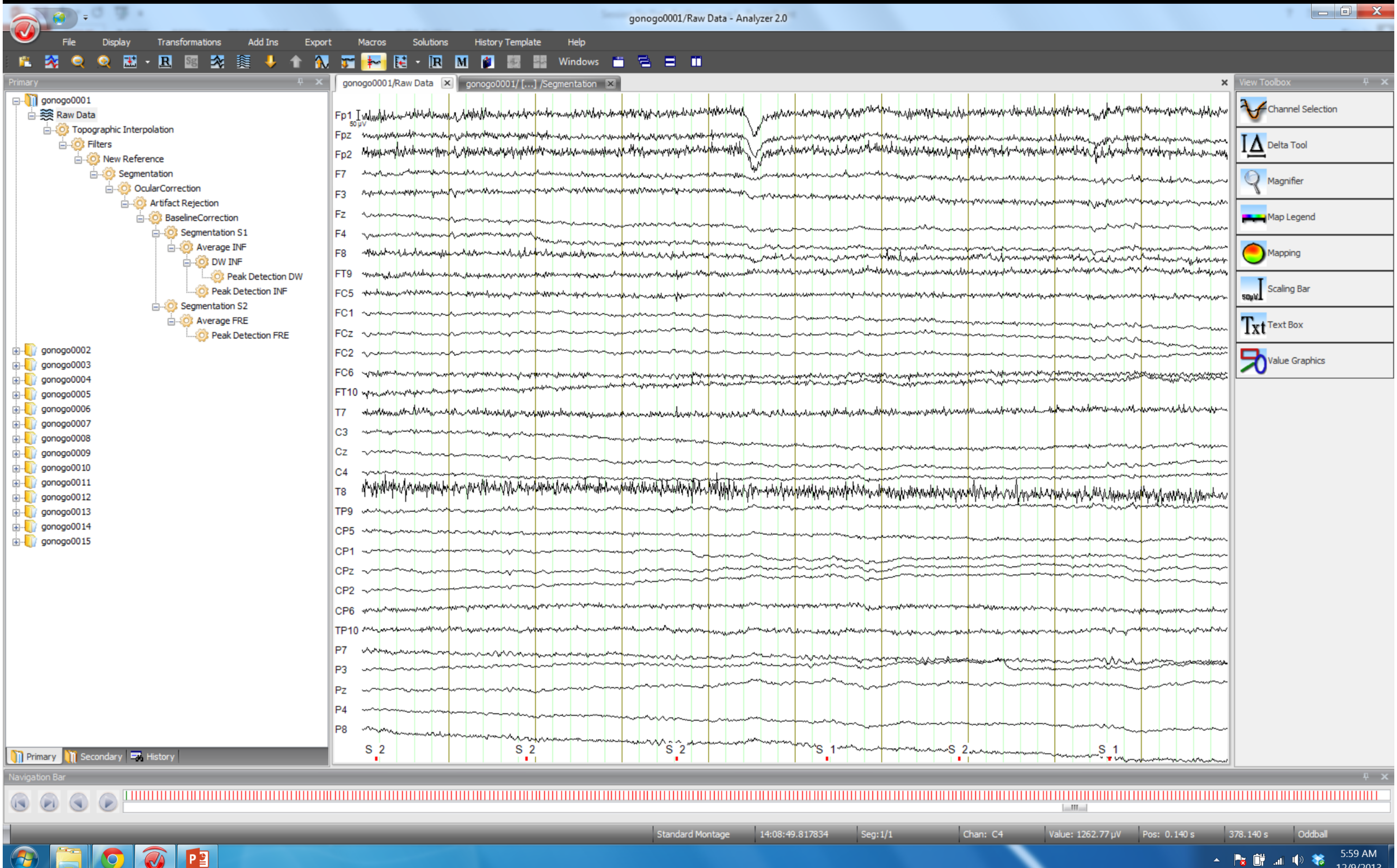
Use sensible filters – 0.1 to 30 Hz

Use sensible slopes – 24 dB

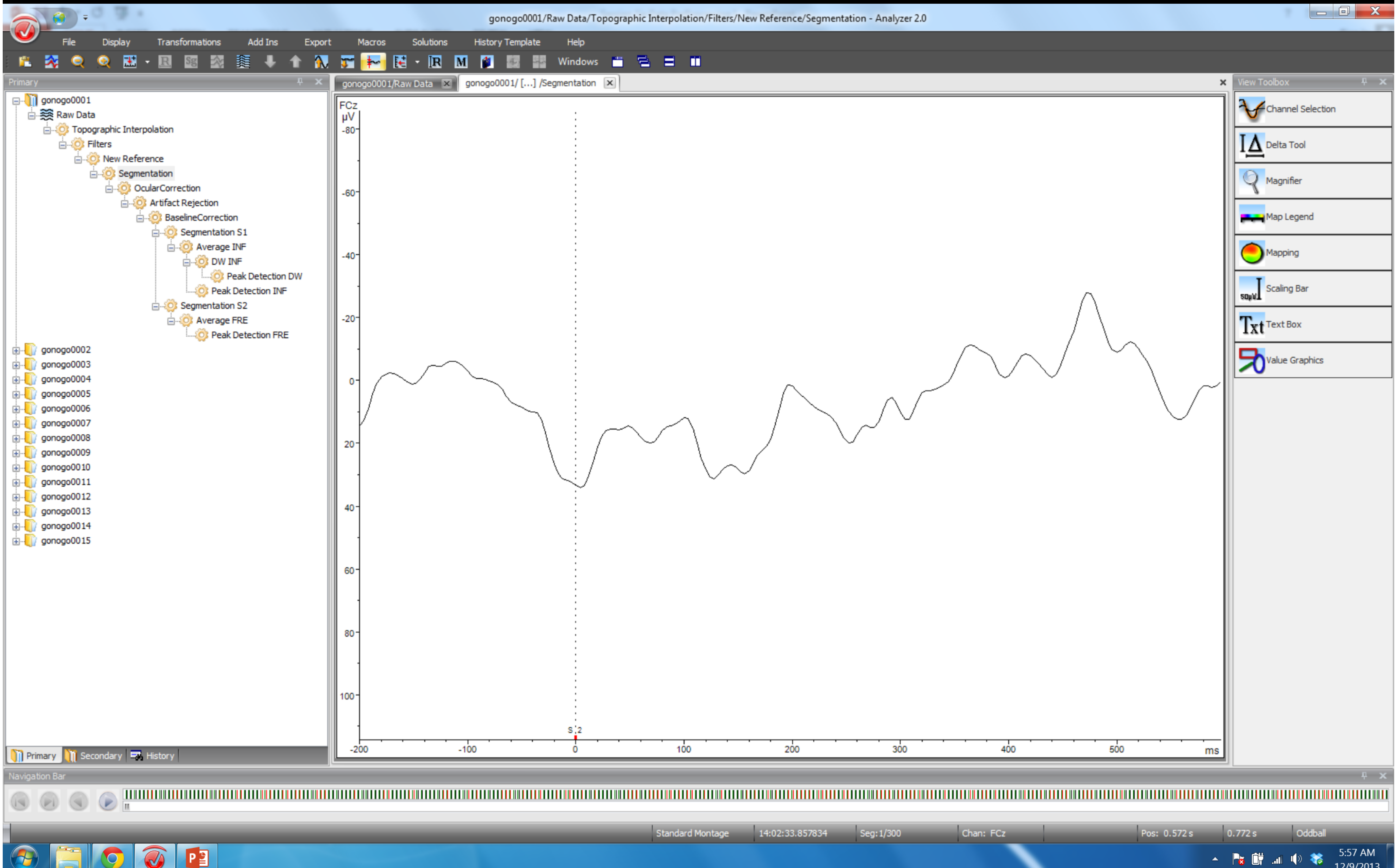
See Luck, 2014, for considerably more detail.

Fourier Demonstrations

Segmentation (Epoching)



Continuous Data



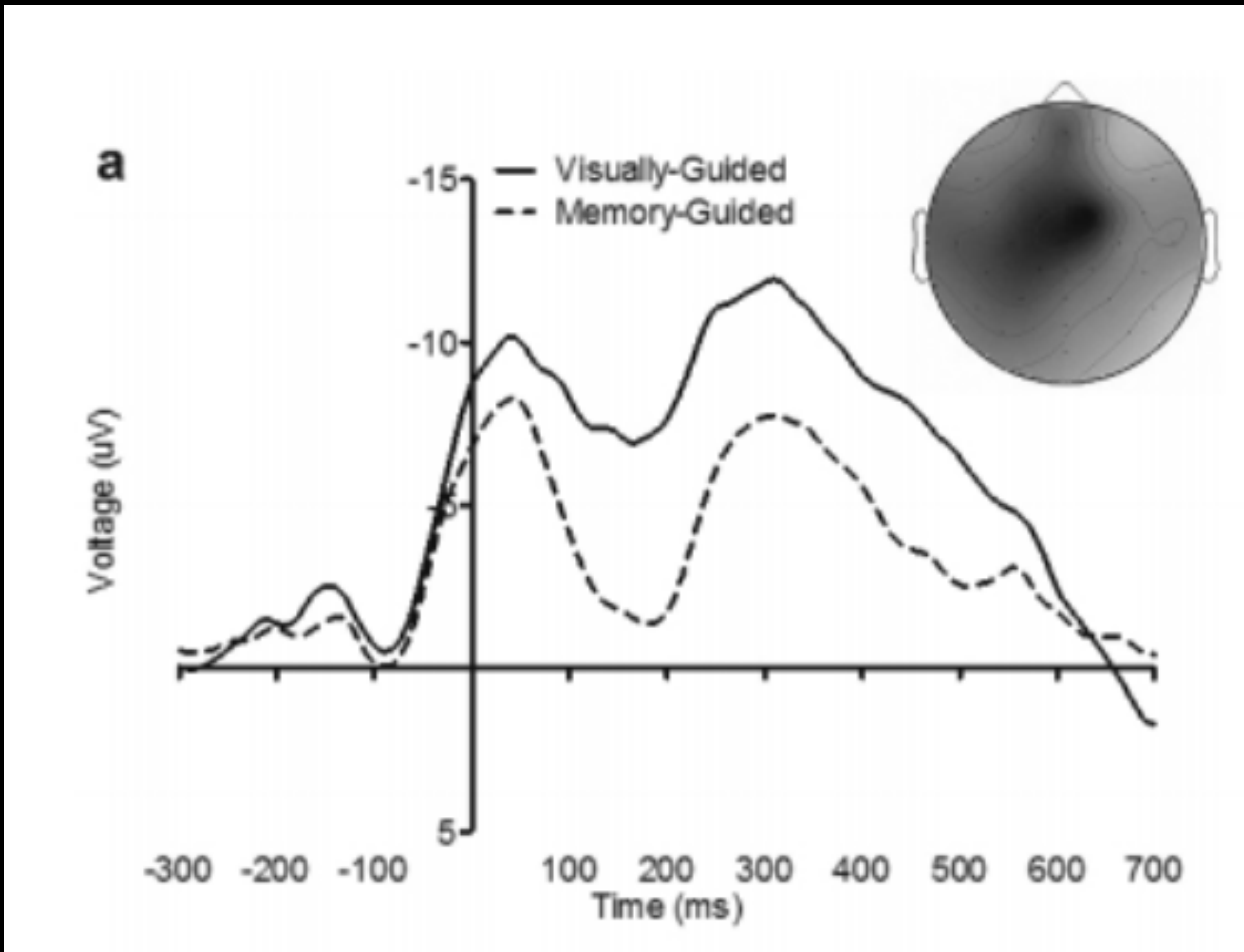
Segmented Data

Segmentation (Epochs)

Essentially, identifying a window of a given trial length

Considerations

- is the baseline common
- how large of a baseline
- how long of a window (ideally as short as possible but depends on ICA and or FFT analysis)
- other considerations



a
Visually-Guided
Memory-Guided
-15
-10
-5
5
Voltage (uV)
-300
-200
-100
100
200
300
400
500
600
700
Time (ms)

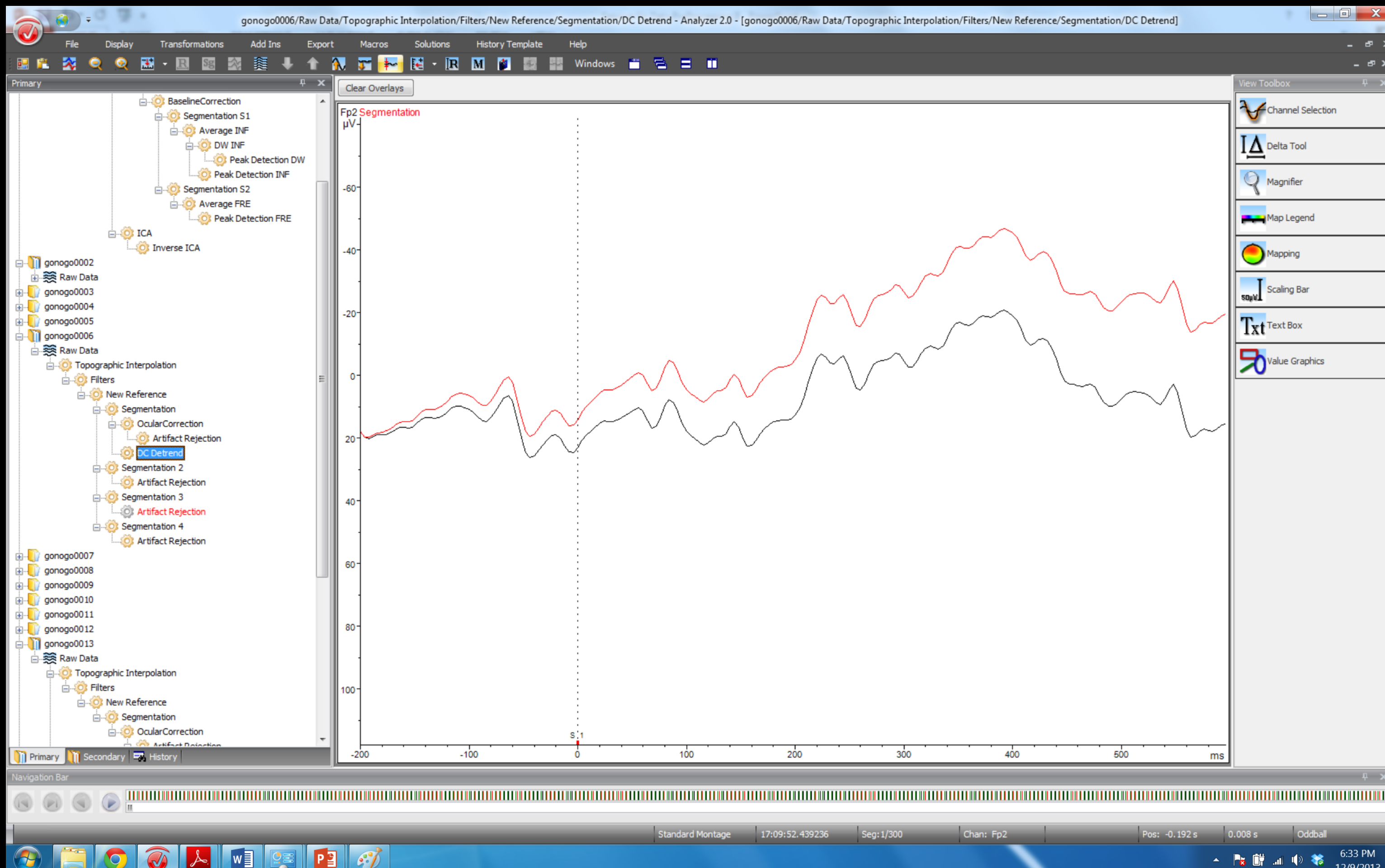
Segmentation Demos

DC Detrend (optional)

DC Detrend

Removes a continuous DC slope from each segment.

Note, this step, if used, should be done before ocular correction.



gonogo0006/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/DC Detrend - Analyzer 2.0 - [gonogo0006/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/DC Detrend]
File
Display
Transformations
Add Ins
Export
Macros
Solutions
History Template
Help
Windows
Primary
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
Raw Data
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
DC Detrend
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
gonogo0013
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Primary
Secondary
History
Clear Overlays
Fp2 Segmentation
µV
-60
-40
-20
0
20
40
60
80
100
-200
-100
0
100
200
300
400
500
ms
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
17:09:52.439236
Seg: 1/300
Chan: Fp2
Pos: -0.192 s
0.008 s
Oddball
6:33 PM
12/9/2013

DC Detrend Demo

Ocular Correction
(Tomorrow)

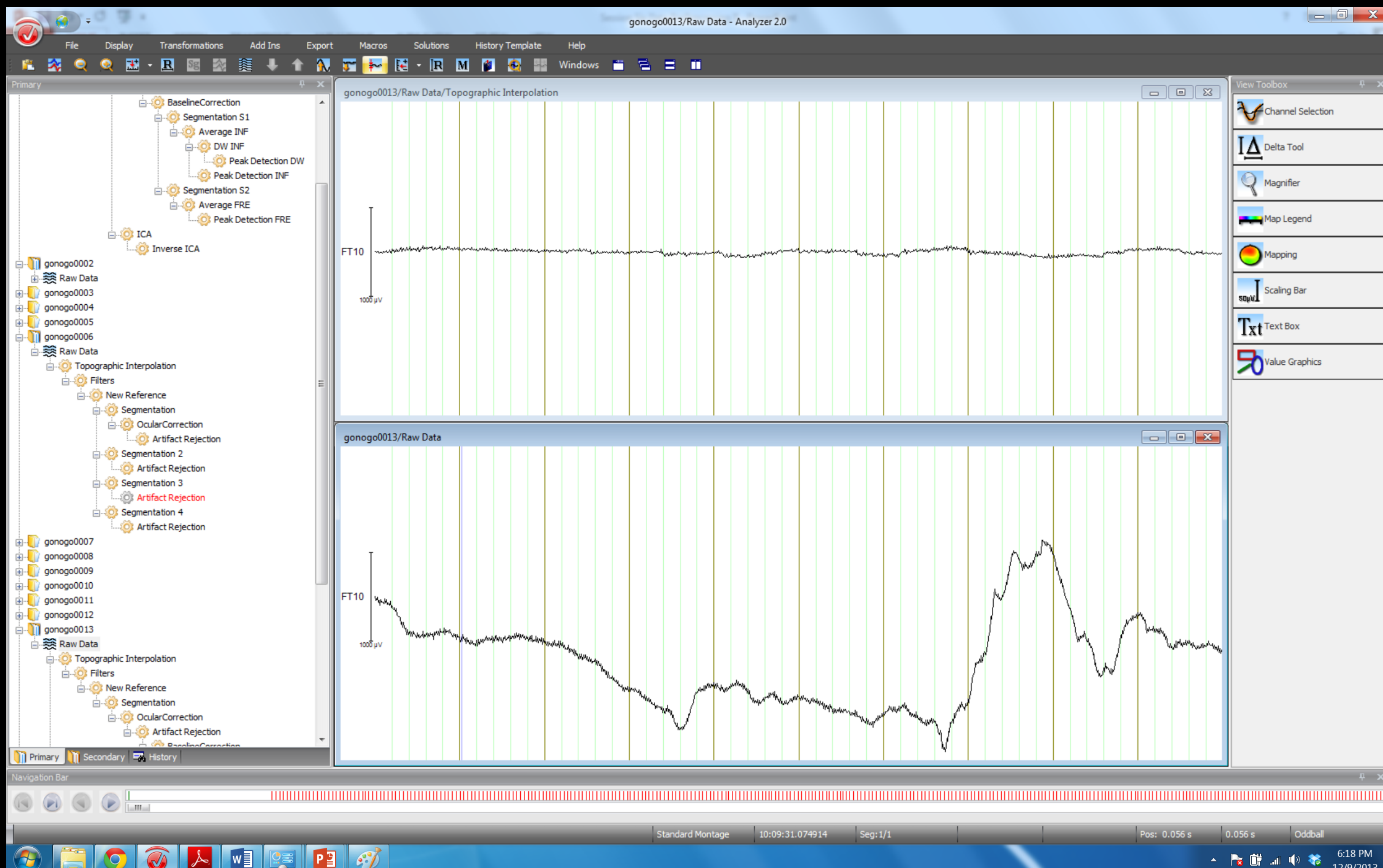
Channel Interpolation

Channel Interpolation

Essentially, you replace a channel with data from the surrounding channels.

Given the propagation of the EEG signal this is not a bad idea in principle.

Can be done via a variety of methods – most typically as an average of the surrounding channels or using a method based on spherical splines.


gonogo0013/Raw Data - Analyzer 2.0
File
Display
Transformations
Add Ins
Export
Macros
Solutions
History Template
Help
Windows
Primary
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
Raw Data
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
gonogo0013
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
Primary
Secondary
History
gonogo0013/Raw Data/Topographic Interpolation
FT10
gonogo0013/Raw Data
FT10
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
10:09:31.074914
Seg: 1/1
Pos: 0.056 s
0.056 s
Oddball
6:18 PM
12/9/2013

Channel Interpolation

Never interpolate:

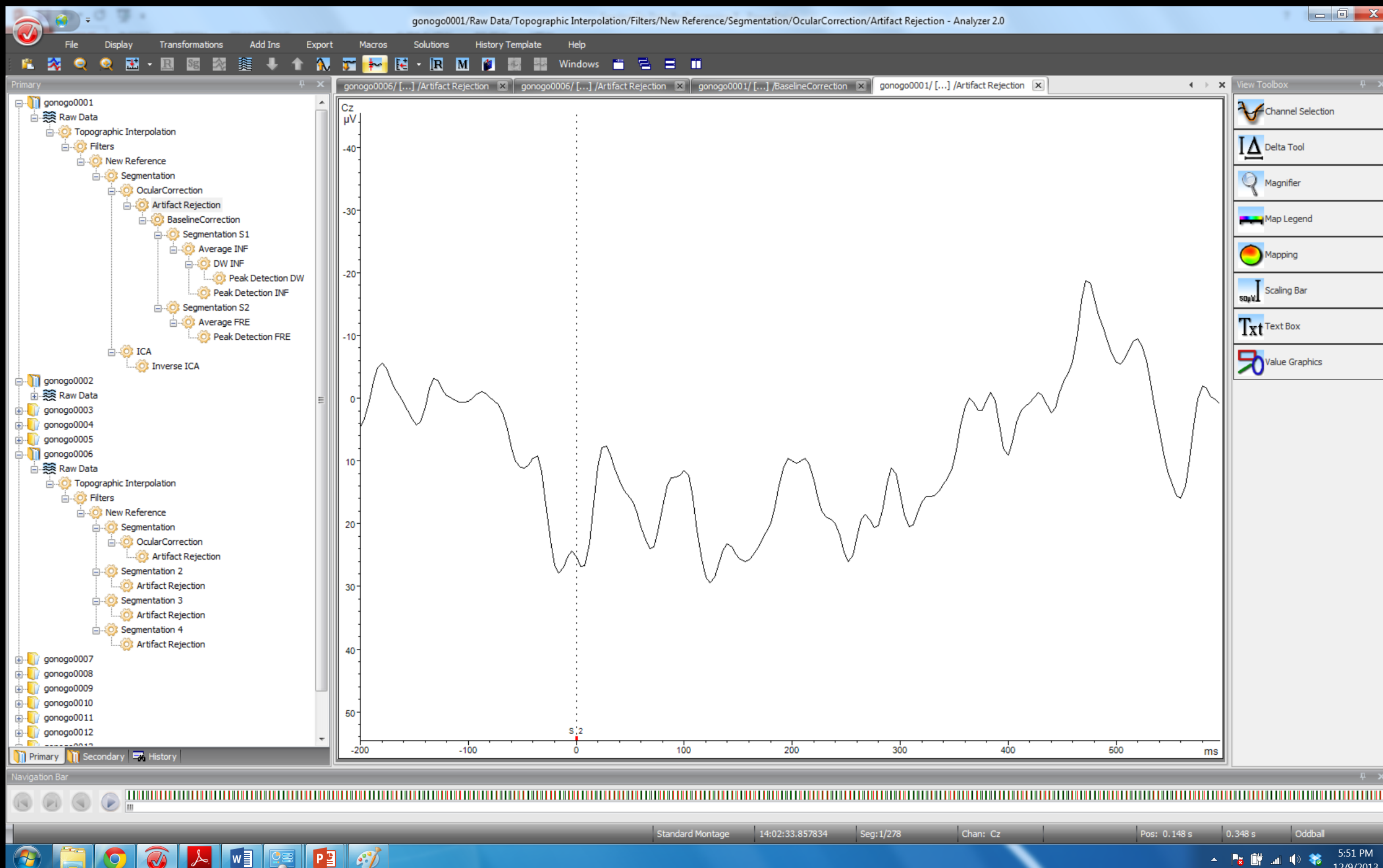
1. Your channel of interest(s)
2. Reference channels
3. EOG channels
4. Too many channels

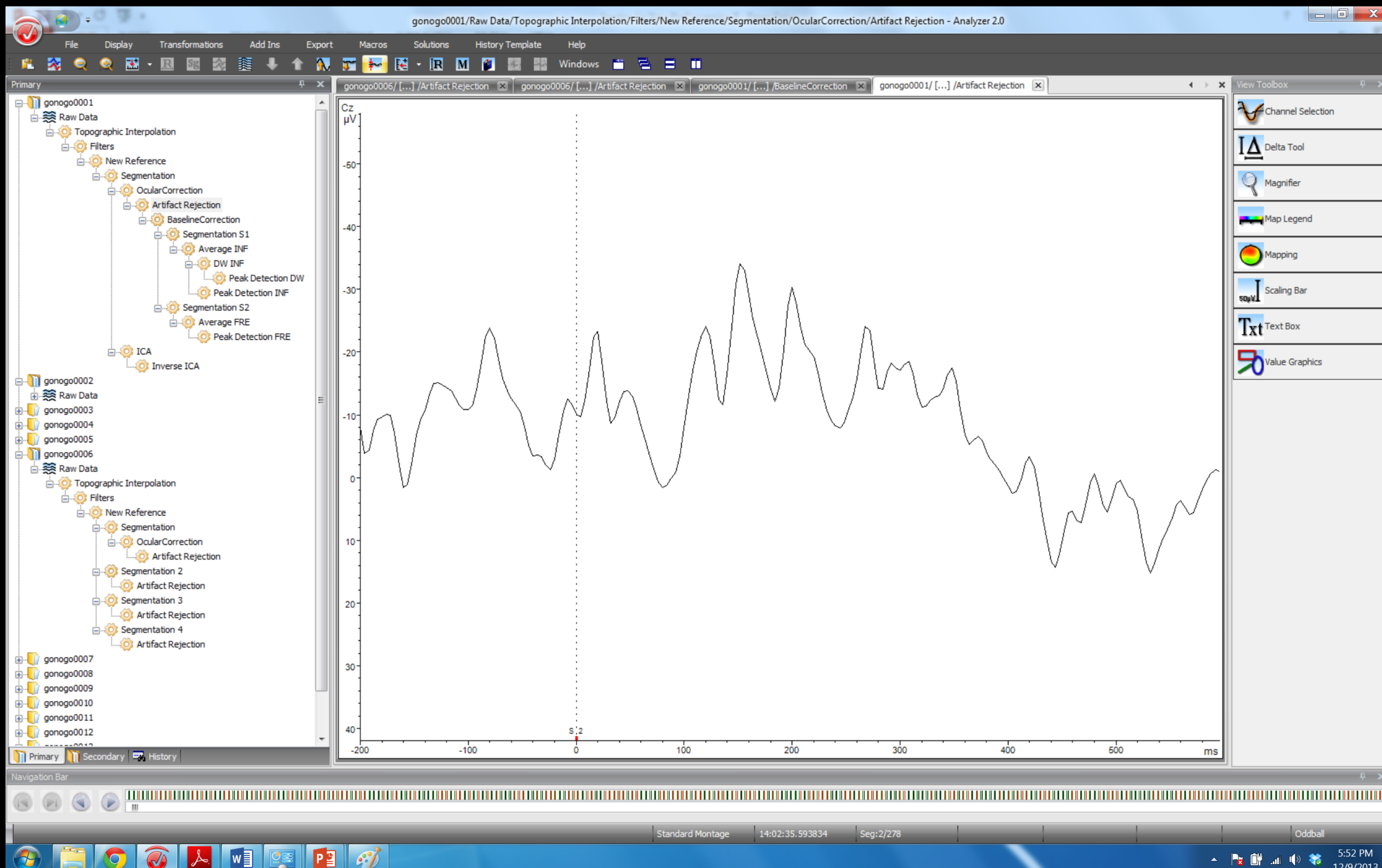
Always visually verify the interpolation looks reasonable.

Do not be afraid to throw out bad data!

Channel Interpolation
Demos

Baseline Correction


gonogo0001/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/OcularCorrection/Artifact Rejection - Analyzer 2.0
File
Display
Transformations
Add Ins
Export
Macros
Solutions
History Template
Help
Windows
Primary
gonogo0001
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
Raw Data
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
Primary
Secondary
History
gonogo0006/ [...] /Artifact Rejection
gonogo0006/ [...] /Artifact Rejection
gonogo0001/ [...] /BaselineCorrection
gonogo0001/ [...] /Artifact Rejection
Cz
µV
-40
-30
-20
-10
0
10
20
30
40
50
S 2
-200
-100
0
100
200
300
400
500
ms
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
14:02:33.857834
Seg: 1/278
Chan: Cz
Pos: 0.148 s
0.348 s
Oddball
5:51 PM
12/9/2013


gonogo0001/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/OcularCorrection/Artifact Rejection - Analyzer 2.0
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Transformations
Add Ins
Export
Macros
Solutions
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gonogo0001
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New Reference
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
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Inverse ICA
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Raw Data
Topographic Interpolation
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OcularCorrection
Artifact Rejection
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
gonogo0007
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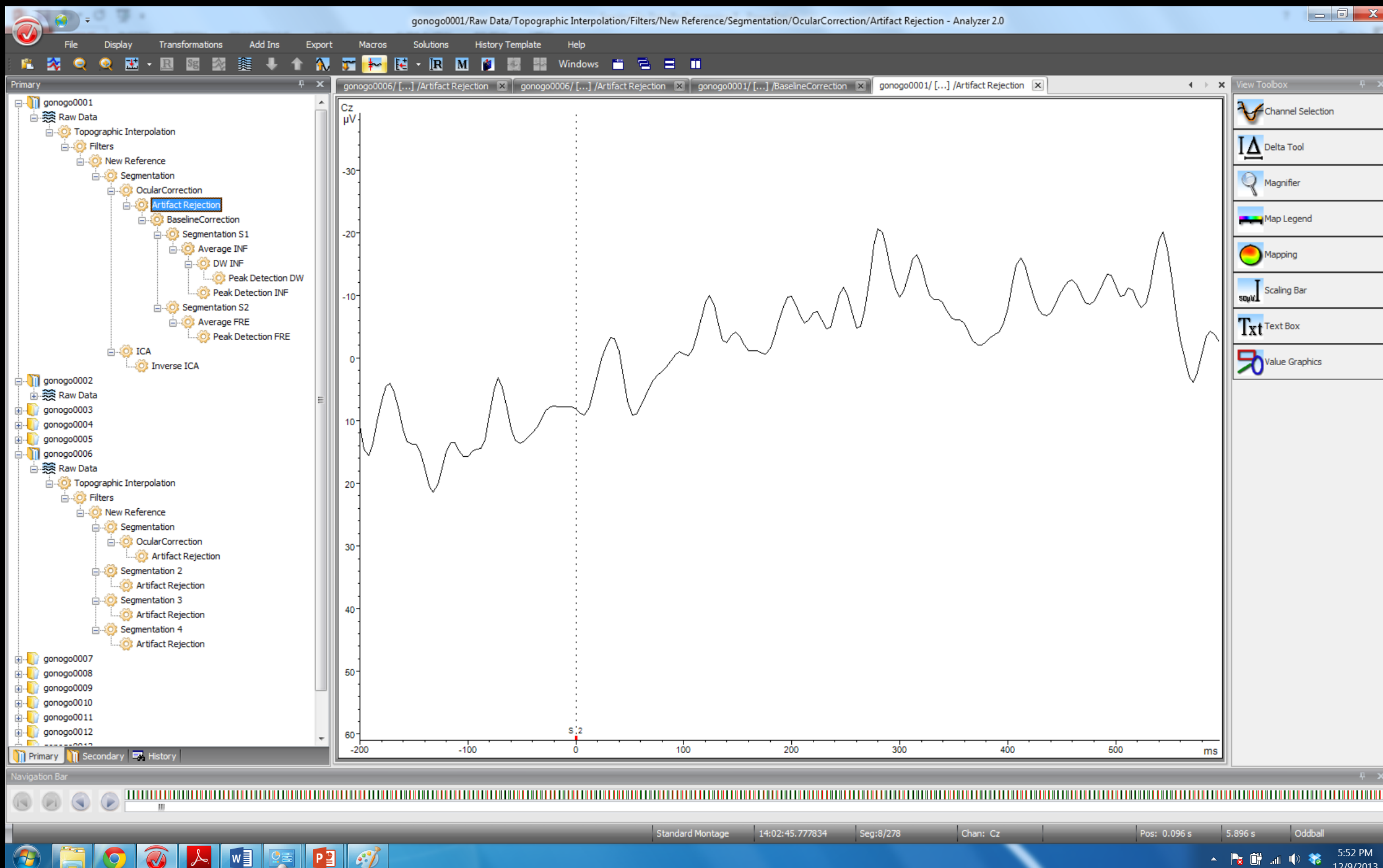
gonogo0012
Primary
Secondary
History
gonogo0006/ [...] /Artifact Rejection
gonogo0006/ [...] /Artifact Rejection
gonogo0001/ [...] /BaselineCorrection
gonogo0001/ [...] /Artifact Rejection
Cz
µV
-50
-40
-30
-20
-10
0
10
20
30
40
S 2
-200
-100
0
100
200
300
400
500
ms
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
14:02:35.593834
Seg:2/278
Oddball
5:52 PM
12/9/2013


gonogo0001/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/OcularCorrection/Artifact Rejection - Analyzer 2.0
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BaselineCorrection
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DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
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Inverse ICA
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gonogo0005
gonogo0006
Raw Data
Topographic Interpolation
Filters
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Segmentation
OcularCorrection
Artifact Rejection
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
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Secondary
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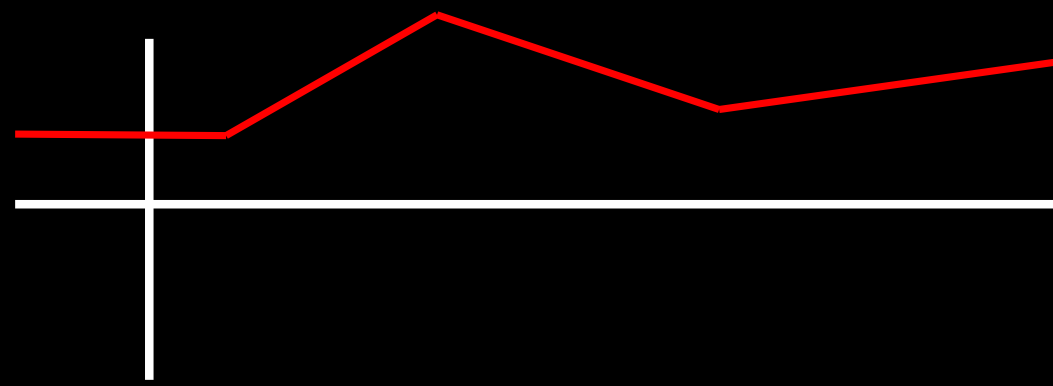
gonogo0006/ [...] /Artifact Rejection
gonogo0006/ [...] /Artifact Rejection
gonogo0001/ [...] /BaselineCorrection
gonogo0001/ [...] /Artifact Rejection
Cz
µV
-30
-20
-10
0
10
20
30
40
50
60
S 2
-200
-100
0
100
200
300
400
500
ms
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
14:02:45.777834
Seg:8/278
Chan: Cz
Pos: 0.096 s
5.896 s
Oddball
5:52 PM
12/9/2013

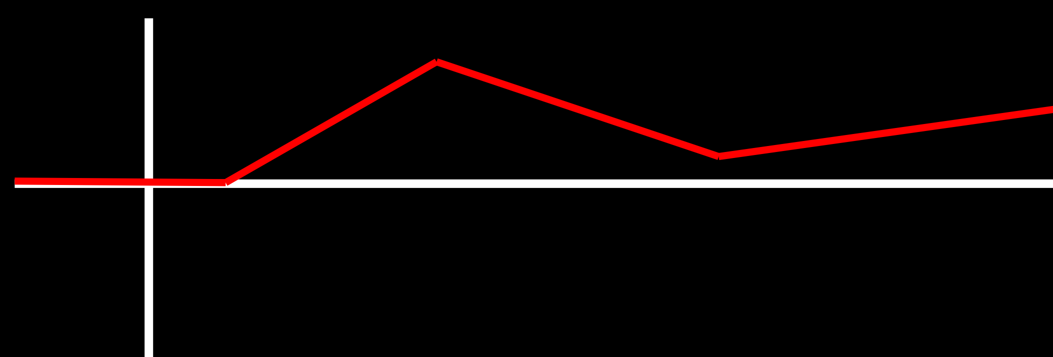
Baseline Correction

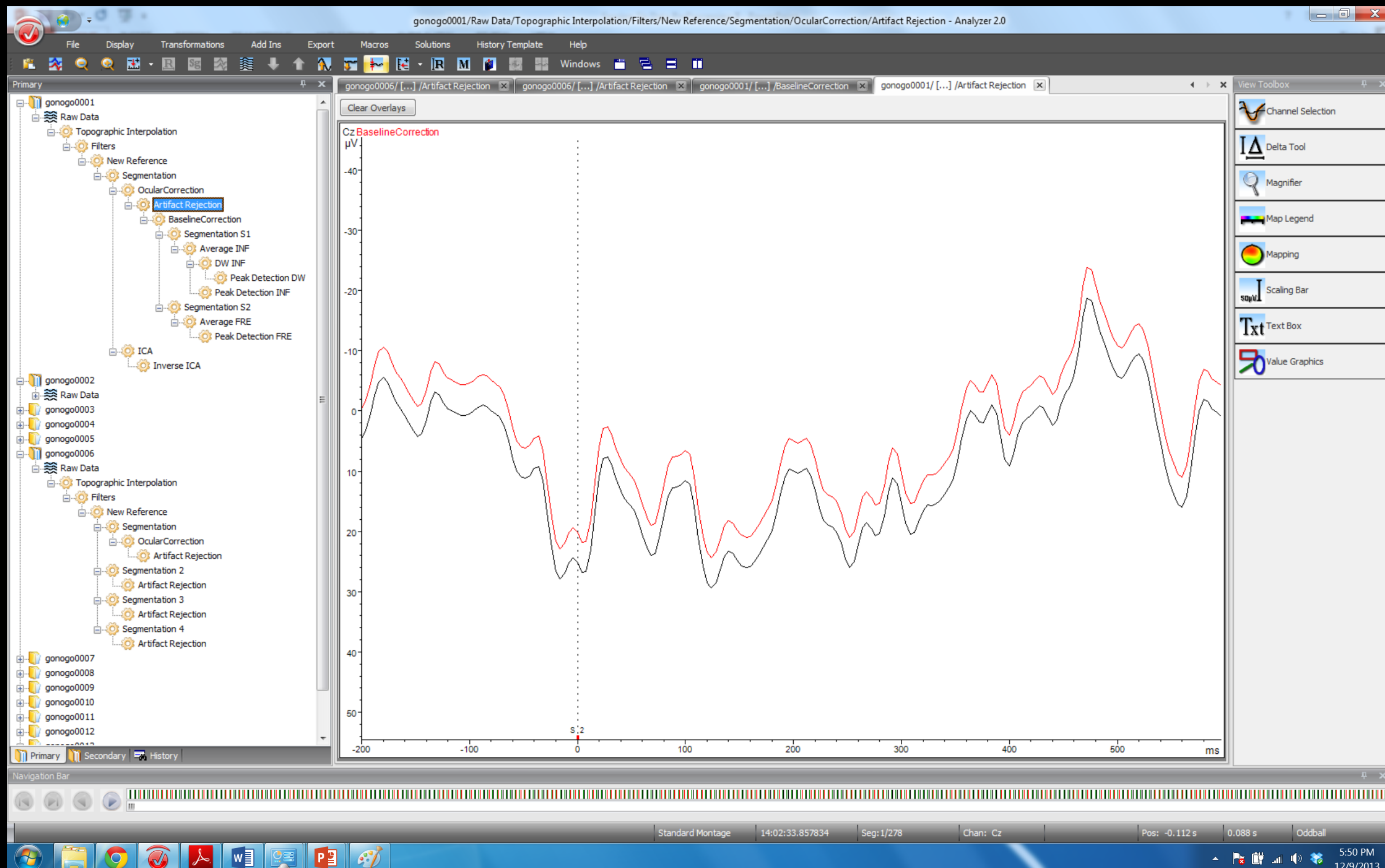
Perhaps the easiest step to understand mathematically.

For each segment, the mean voltage is taken for the baseline period (e.g., -200 to 0 ms) and that is subtracted from every time point.

This is done separately for each segment for each channel.






gonogo0001/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/OcularCorrection/Artifact Rejection - Analyzer 2.0
File
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Add Ins
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Macros
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gonogo0001
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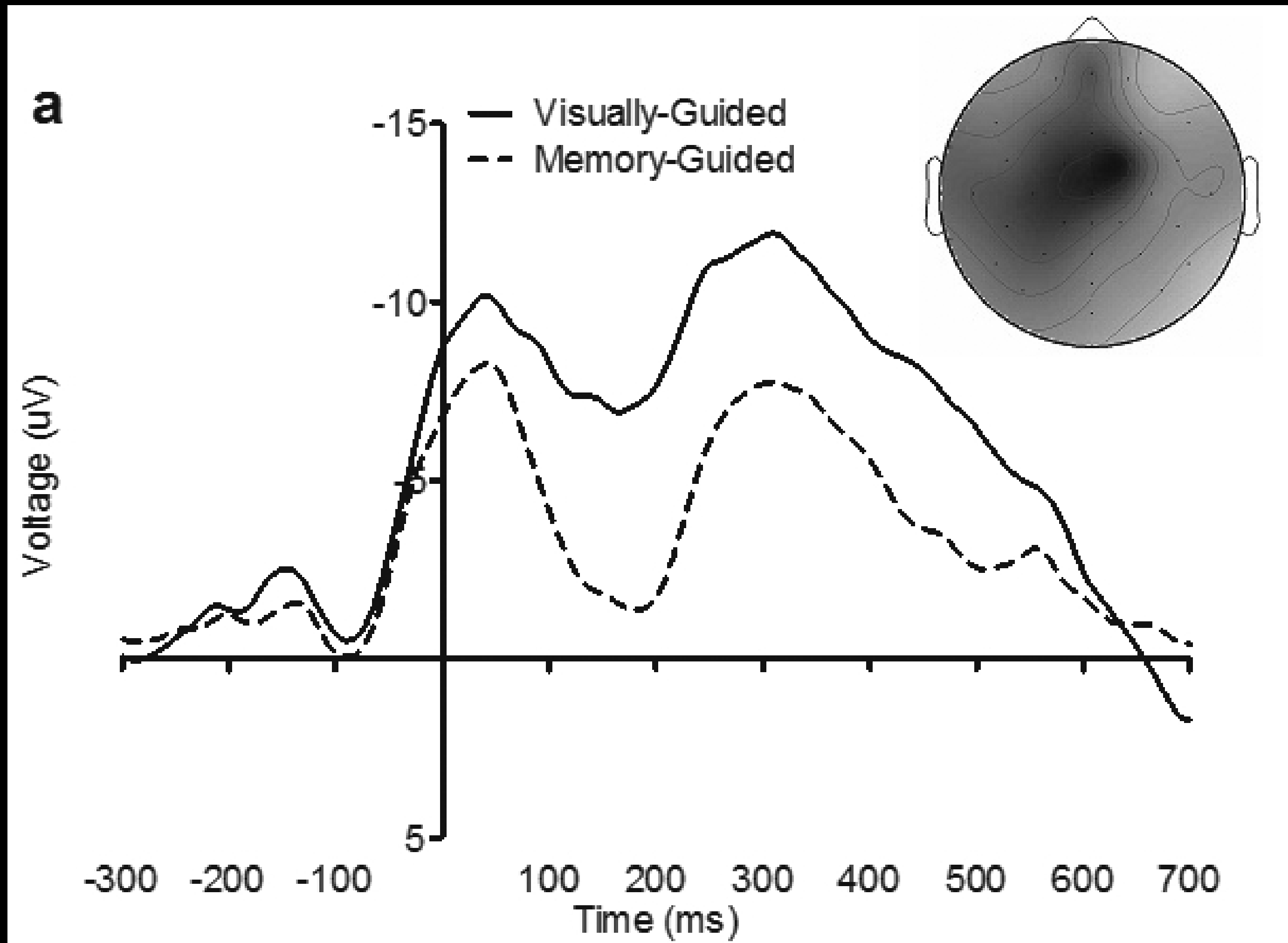
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
Raw Data
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
Primary
Secondary
History
gonogo0006/ [...] /Artifact Rejection
gonogo0006/ [...] /Artifact Rejection
gonogo0001/ [...] /BaselineCorrection
gonogo0001/ [...] /Artifact Rejection
Clear Overlays
Cz BaselineCorrection
µV
-40
-30
-20
-10
0
10
20
30
40
50
-200
-100
0
100
200
300
400
500
ms
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
14:02:33.857834
Seg: 1/278
Chan: Cz
Pos: -0.112 s
0.088 s
Oddball
5:50 PM
12/9/2013



a
Visually-Guided
Memory-Guided
-15
-10
-5
5
Voltage (uV)
-300
-200
-100
100
200
300
400
500
600
700
Time (ms)

Baseline Correction Demos

Artifact Rejection

Artifact Rejection

The idea in principle is very simple… use some form of criteria to identify artifacts and then remove those trials from a data set.

You can mark artifacts manually or automatically. I would recommend automatically to avoid introducing bias.

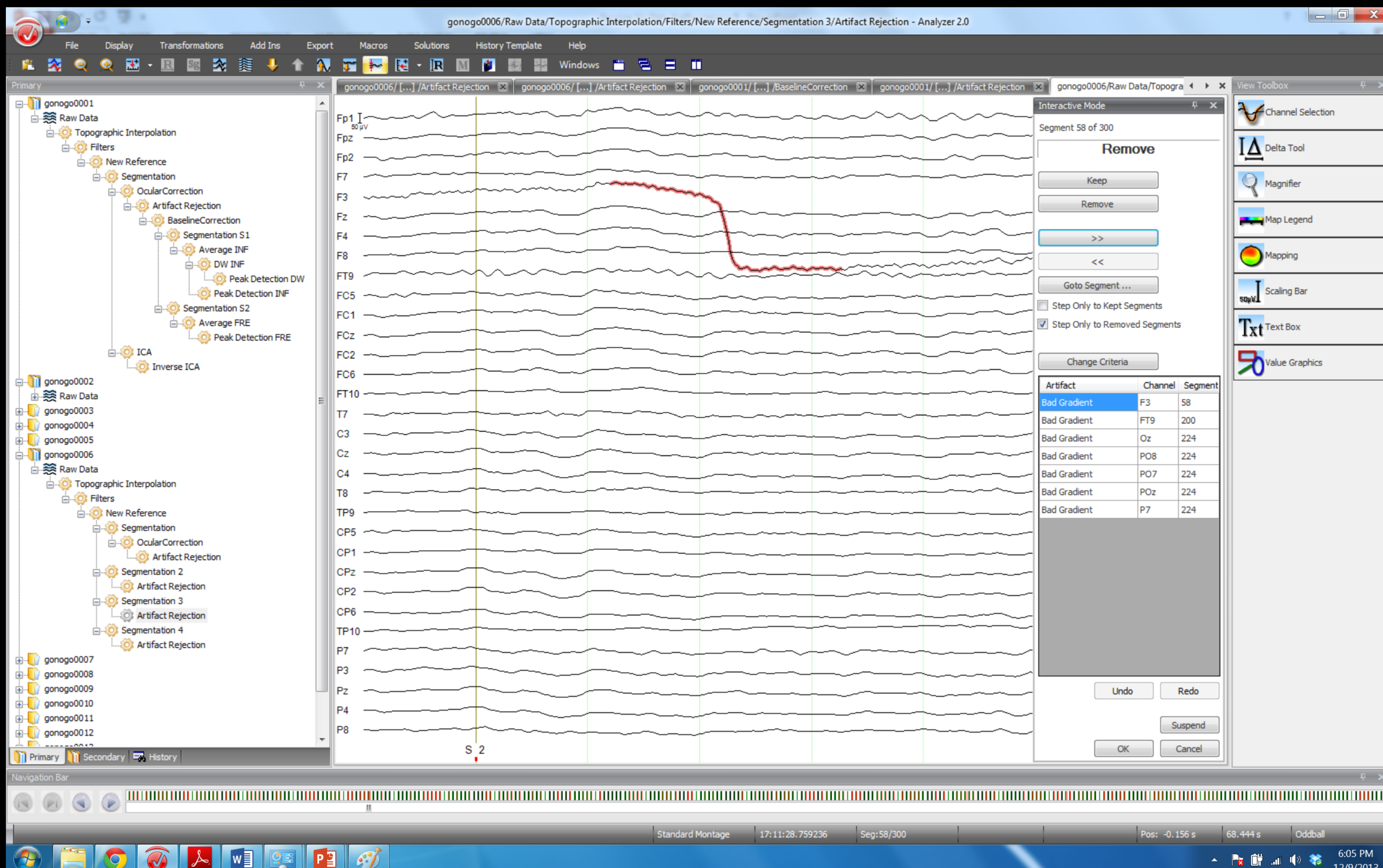
With that said, in some instances gross artifacts should be marked manually (for ICA).

Artifact Rejection

Criterion 1: Gradient

Essentially, the difference between any two sequential points in time.

Typically, a value of 10 uV/ms is enough to catch “bad data” and not lose any “good data”.


gonogo0006/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation 3/Artifact Rejection - Analyzer 2.0
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Solutions
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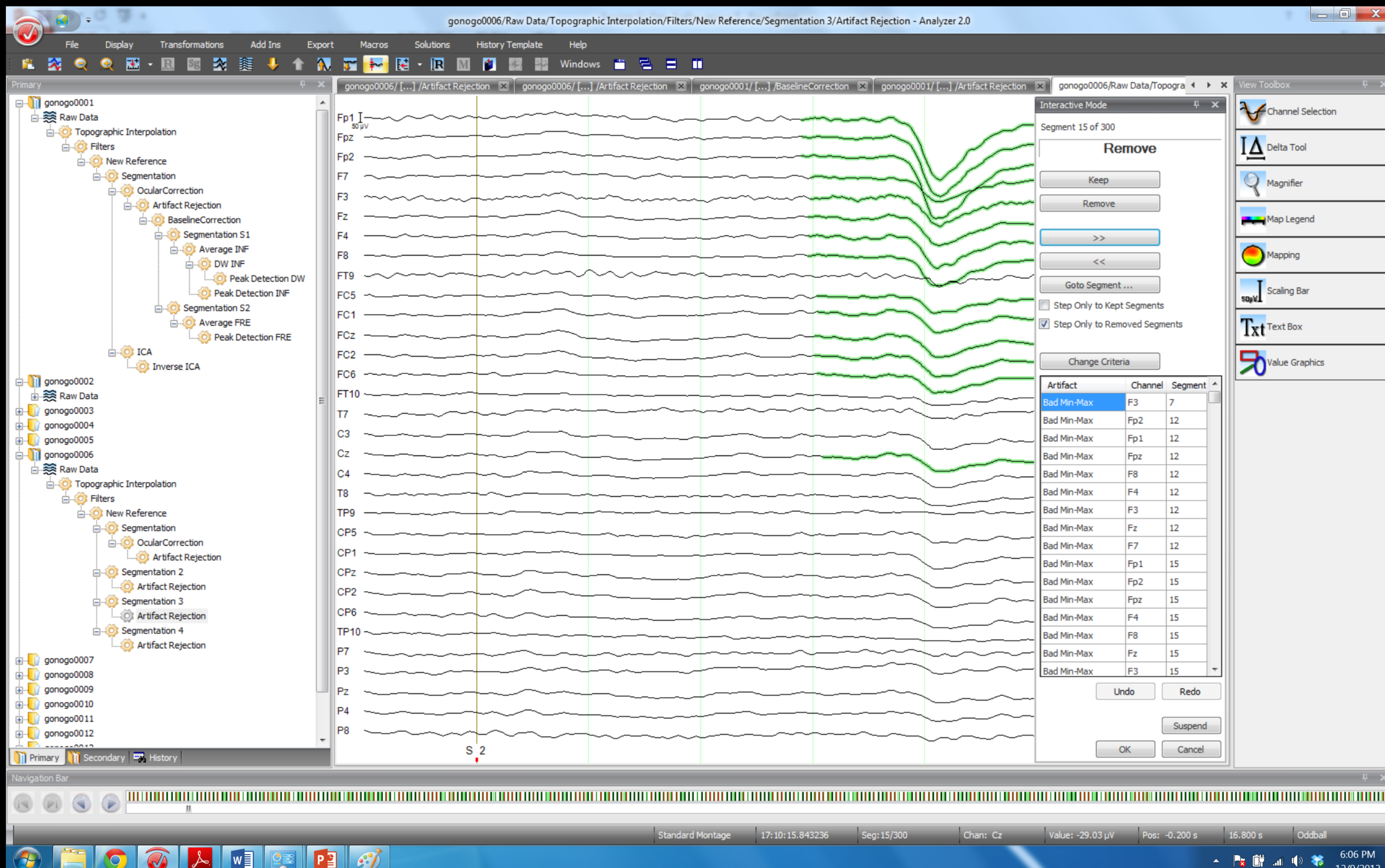
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Segmentation 2
Segmentation 3
Segmentation 4
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
Primary
Secondary
History
Fp1
Fpz
Fp2
F7
F3
Fz
F4
F8
FT9
FC5
FC1
FCz
FC2
FC6
FT10
T7
C3
Cz
C4
T8
TP9
CP5
CP1
CPz
CP2
CP6
TP10
P7
P3
Pz
P4
P8
S 2
Interactive Mode
Segment 58 of 300
Remove
Keep
Remove
>>
<<
Goto Segment ...
Step Only to Kept Segments
Step Only to Removed Segments
Change Criteria
Artifact
Channel
Segment
Bad Gradient
F3
58
Bad Gradient
FT9
200
Bad Gradient
Oz
224
Bad Gradient
PO8
224
Bad Gradient
PO7
224
Bad Gradient
POz
224
Bad Gradient
P7
224
Undo
Redo
Suspend
OK
Cancel
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
17:11:28.759236
Seg:58/300
Pos: -0.156 s
68.444 s
Oddball
6:05 PM
12/9/2013

Artifact Rejection

Criterion 2: Max Min

Essentially, the difference between the maximum and minimum voltage in a segment,

Typically, a value of 100 uV/ms is enough to catch "bad data" and not lose any "good data".


gonogo0006/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation 3/Artifact Rejection - Analyzer 2.0
File
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Transformations
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Macros
Solutions
History Template
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Primary
gonogo0001
Raw Data
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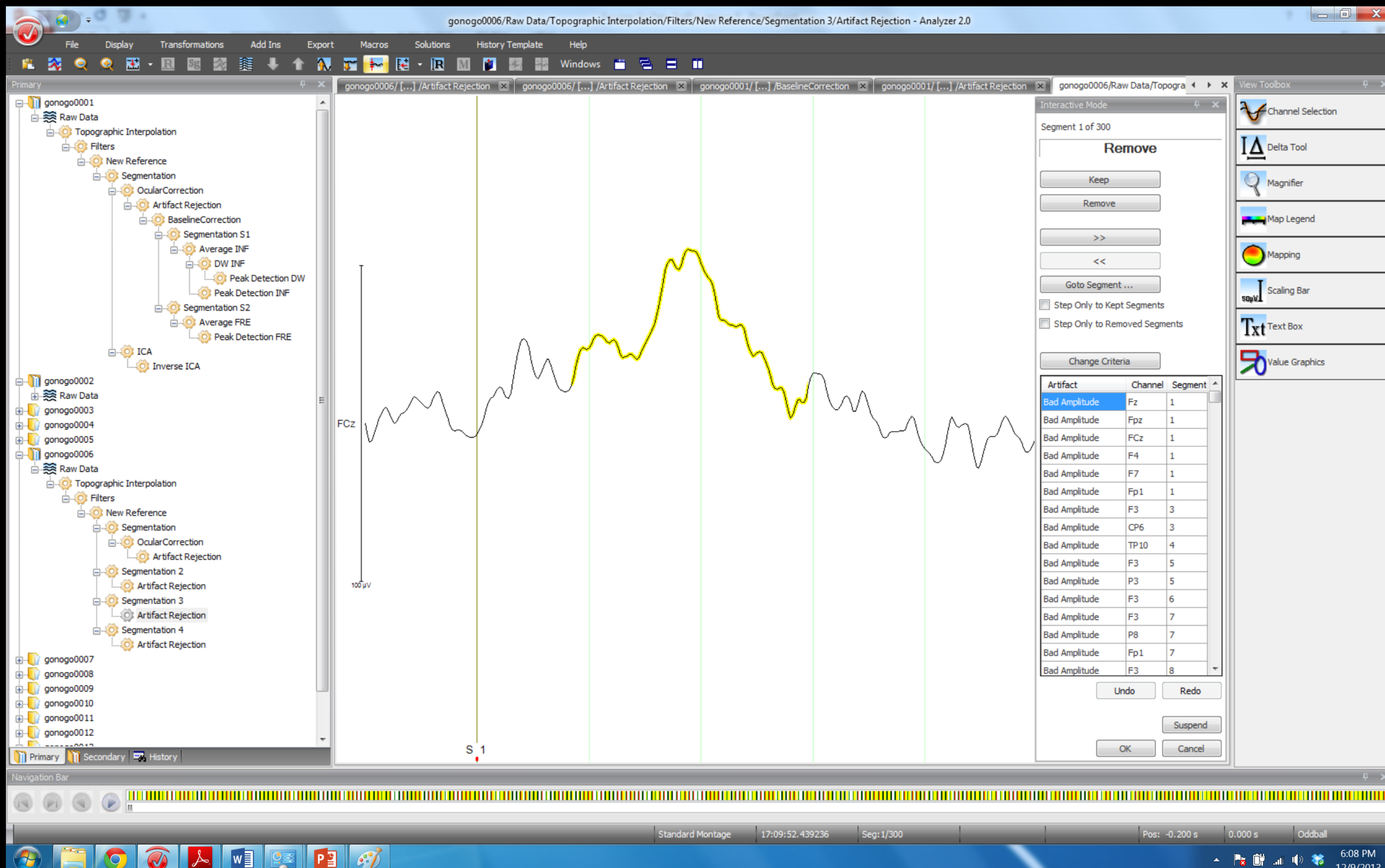
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
Raw Data
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
Segmentation 2
Artifact Rejection
Segmentation 3
Artifact Rejection
Segmentation 4
Artifact Rejection
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
Primary
Secondary
History
gonogo0006/ [...] /Artifact Rejection
gonogo0006/ [...] /Artifact Rejection
gonogo0001/ [...] /BaselineCorrection
gonogo0001/ [...] /Artifact Rejection
gonogo0006/Raw Data/Topogra
Fp1
Fpz
Fp2
F7
F3
Fz
F4
F8
FT9
FC5
FC1
FCz
FC2
FC6
FT10
T7
C3
Cz
C4
T8
TP9
CP5
CP1
CPz
CP2
CP6
TP10
P7
P3
Pz
P4
P8
S 2
Interactive Mode
Segment 15 of 300
Remove
Keep
Remove
>>
<<
Goto Segment ...
Step Only to Kept Segments
Step Only to Removed Segments
Change Criteria
Artifact
Channel
Segment
Bad Min-Max F3 7
Bad Min-Max Fp2 12
Bad Min-Max Fp1 12
Bad Min-Max Fpz 12
Bad Min-Max F8 12
Bad Min-Max F4 12
Bad Min-Max F3 12
Bad Min-Max Fz 12
Bad Min-Max F7 12
Bad Min-Max Fp1 15
Bad Min-Max Fp2 15
Bad Min-Max Fpz 15
Bad Min-Max F4 15
Bad Min-Max F8 15
Bad Min-Max Fz 15
Bad Min-Max F3 15
Undo
Redo
Suspend
OK
Cancel
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
17:10:15.843236
Seg: 15/300
Chan: Cz
Value: -29.03 µV
Pos: -0.200 s
16.800 s
Oddball
6:06 PM
12/9/2013

Artifact Rejection

Criterion 3: Amplitude

Essentially, the absolute maximum or minimum voltage that is acceptable

There is no need to use this if you use max min and gradient criteria.


gonogo0006/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation 3/Artifact Rejection - Analyzer 2.0
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Solutions
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New Reference
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection DW
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection FRE
ICA
Inverse ICA
gonogo0002
gonogo0003
gonogo0004
gonogo0005
gonogo0006
Segmentation 2
Segmentation 3
Segmentation 4
gonogo0007
gonogo0008
gonogo0009
gonogo0010
gonogo0011
gonogo0012
Primary
Secondary
History
FCz
S 1
Interactive Mode
Segment 1 of 300
Remove
Keep
Remove
>>
<<
Goto Segment ...
Step Only to Kept Segments
Step Only to Removed Segments
Change Criteria
Artifact
Channel
Segment
Bad Amplitude
Undo
Redo
Suspend
OK
Cancel
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage
17:09:52.439236
Seg: 1/300
Pos: -0.200 s
0.000 s
Oddball
6:08 PM
12/9/2013

Artifact Rejection

Criterion 4: Low Activity

Essentially this looks for segments where the deviation in voltage is below a certain range, say 0.5 uV over 800 ms.

This is essentially a check for a flat channel.

Re-referencing will distort flat channels so this is effectively useless.

Artifact Rejection

Some thoughts…

1. It is important to keep track of the number of artifacts by condition to look for systematic differences.

2. Make sure you eyeball what is being thrown away.

3. Use the most conservative artifact criteria as possible.

And this finally, might be the information needed to remove channels and interpolate them. So... Back to the start if you need to...

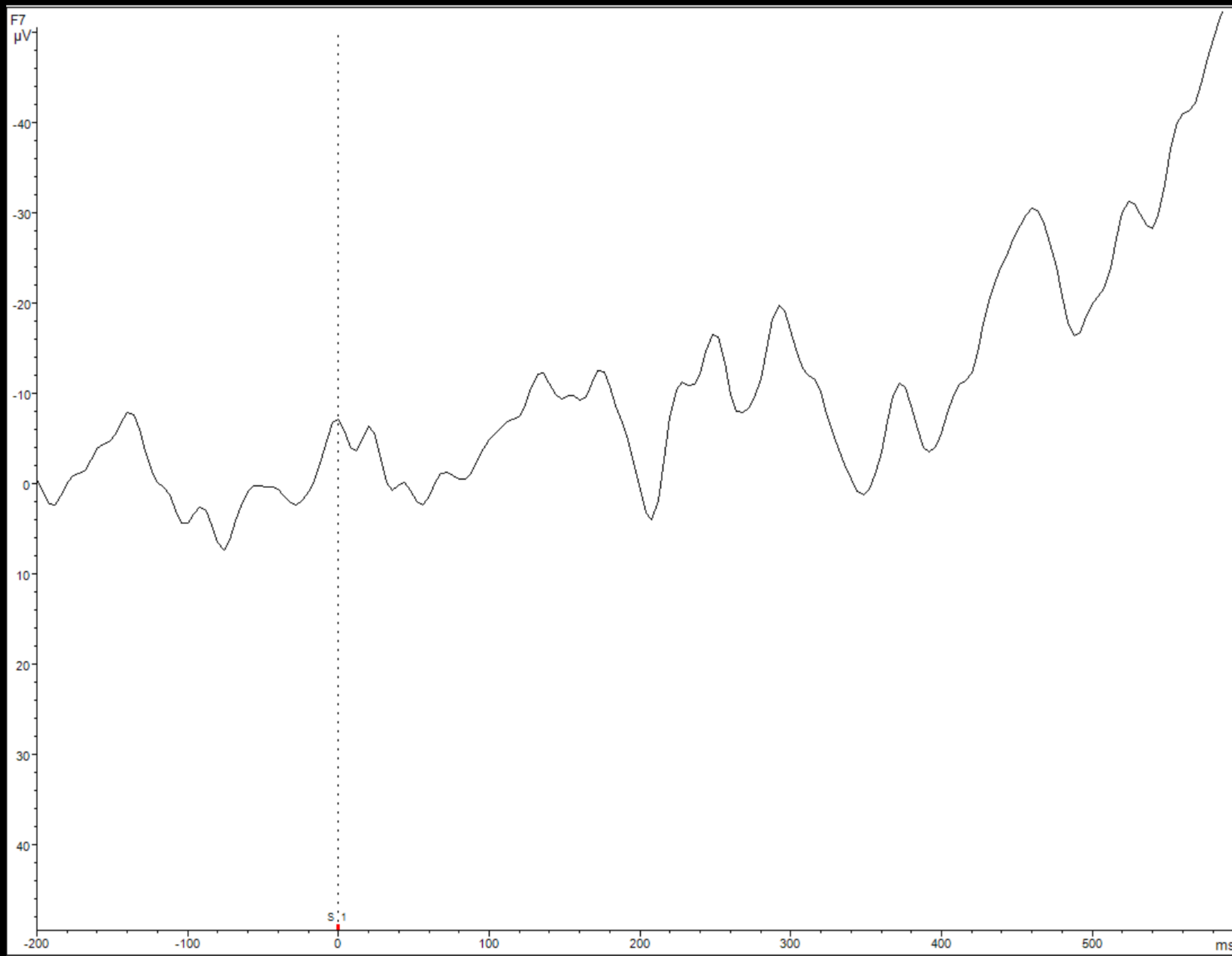
Artifact Rejection Demos

Participant Averages

Participant Averages

A lot of the analysis we have done has been automated, or at least has the potential to be automated.

Before you generate a participant average you should always take a visual inspection of the segments going into the average for anything “weird” and potential remove these segments from analysis.



F7
µV
-40
-30
-20
-10
0
10
20
30
40
S 1
-200
-100
0
100
200
300
400
500
ms

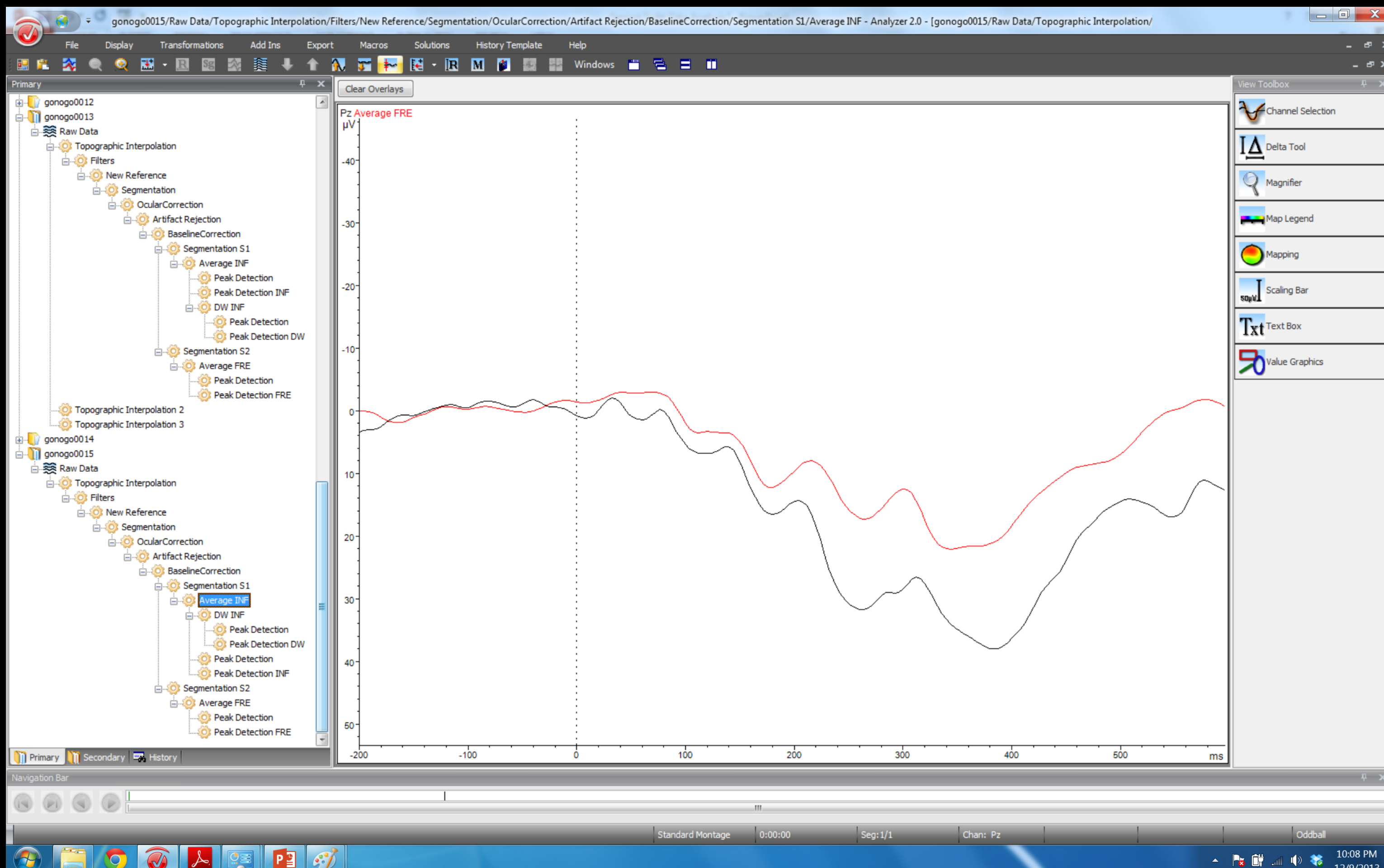
Participant Averages

A lot of the analysis we have done has been automated, or at least has the potential to be automated.

Before you generate a participant average you should always take a visual inspection of the segments going into the average for anything “weird” and potential remove these segments from analysis.

When done however…

You will have an average waveform, or ERP, for each participant for each experimental condition.



gonogo0015/Raw Data/Topographic Interpolation/Filters/New Reference/Segmentation/OcularCorrection/Artifact Rejection/BaselineCorrection/Segmentation S1/Average INF - Analyzer 2.0 - [gonogo0015/Raw Data/Topographic Interpolation/]
File Display Transformations Add Ins Export Macros Solutions History Template Help
Windows
Primary
gonogo0012
gonogo0013
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
Peak Detection
Peak Detection INF
DW INF
Peak Detection
Peak Detection DW
Segmentation S2
Average FRE
Peak Detection
Peak Detection FRE
Topographic Interpolation 2
Topographic Interpolation 3
gonogo0014
gonogo0015
Raw Data
Topographic Interpolation
Filters
New Reference
Segmentation
OcularCorrection
Artifact Rejection
BaselineCorrection
Segmentation S1
Average INF
DW INF
Peak Detection
Peak Detection DW
Peak Detection
Peak Detection INF
Segmentation S2
Average FRE
Peak Detection
Peak Detection FRE
Primary Secondary History
Clear Overlays
Pz Average FRE
µV
-40
-30
-20
-10
0
10
20
30
40
50
-200 -100 0 100 200 300 400 500 ms
View Toolbox
Channel Selection
Delta Tool
Magnifier
Map Legend
Mapping
Scaling Bar
Text Box
Value Graphics
Navigation Bar
Standard Montage 0:00:00 Seg: 1/1 Chan: Pz Oddball
10:08 PM
12/9/2013

Participant Average Demos

Order of Operations

Most of these steps are linear – they can be interchanged.

For instance, if you are using gradient and max-min criteria for artifact rejection then it does not matter if it comes before or after baseline correction.

There are some exceptions…

Order of Operations

Rereference

Always reference on continuous data as soon as possible.

Order of Operations

Filtering

Always filter continuous data to avoid edge artifacts.

Order of Operations

DC Detrend

Must be done before ocular correction.

Order of Operations

Ocular Correction

Should be done as early as possible after segmentation and before artifact rejection.

Order of Operations

Channel Interpolation

Always interpolate bad channels after ocular correction but before artifact rejection.

Difference Waveforms