Simultaneous EEG-fMRI: handling scanner related artifacts in Analyzer 2

BrainVision Analyzer 2 Webinar 03 / 2017

Brain Products Teaching Material
October 2017

Scientific & Technical Support Teams
Brain Products GmbH

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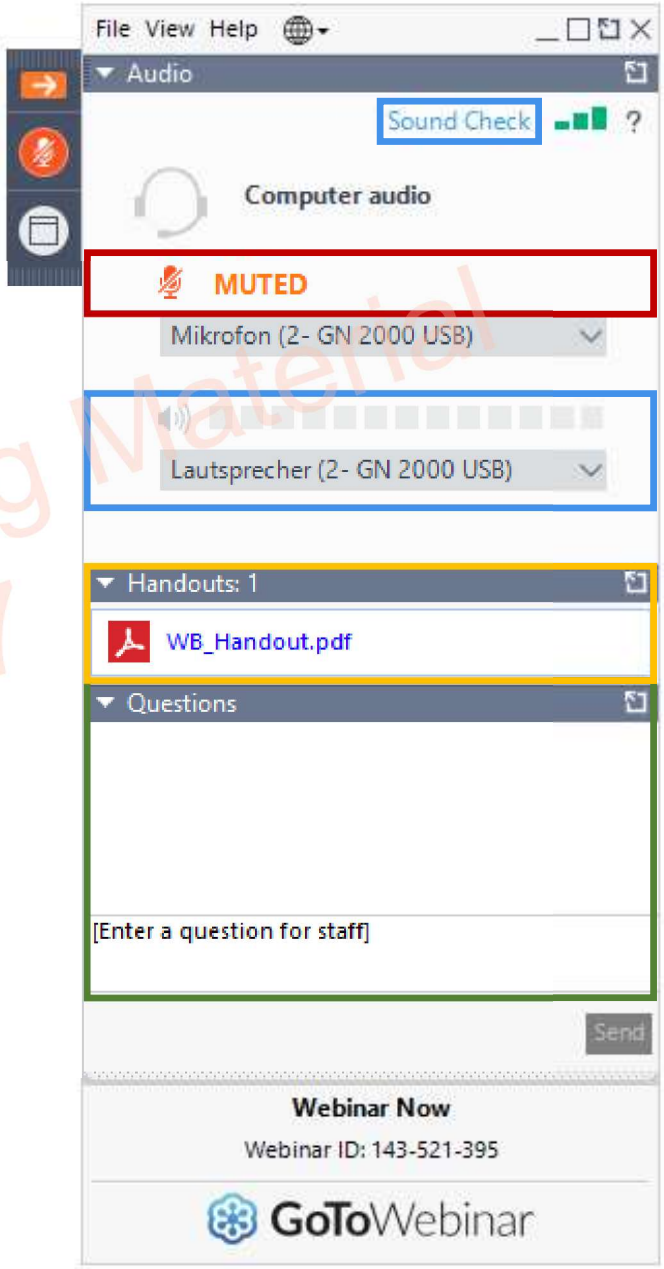
Scientific Consultant

Webinar procedure

- Please note that your microphones are **muted**. All attendees will stay in ***listen-only mode*** throughout the webinar.
- You can change your **audio output device** at any time and also perform a **sound check**.
- Please note that we only offer Computer audio (VoIP) and no audio via phone call.

- Please ask questions only via the **Questions pane**.
- Your question will be handled by the moderation team and either answered directly or compiled for the Q&A session at the end of the webinar.

- If any material is provided, please download via clicking the file in the **Handouts pane**.



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What do we want to achieve in the next 90 minutes?

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Main Goal

- To correct EEG data for scanner related artifact

We will achieve this goal by:

- Understanding the origin and nature of scanner related artifacts
- Considering how the recording environment can influence the data
- Learning how to inspect data for scanner related artifact
- Learning about the correction methods available
- Learning how to apply these methods in Analyzer 2

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Content and supplementary resources

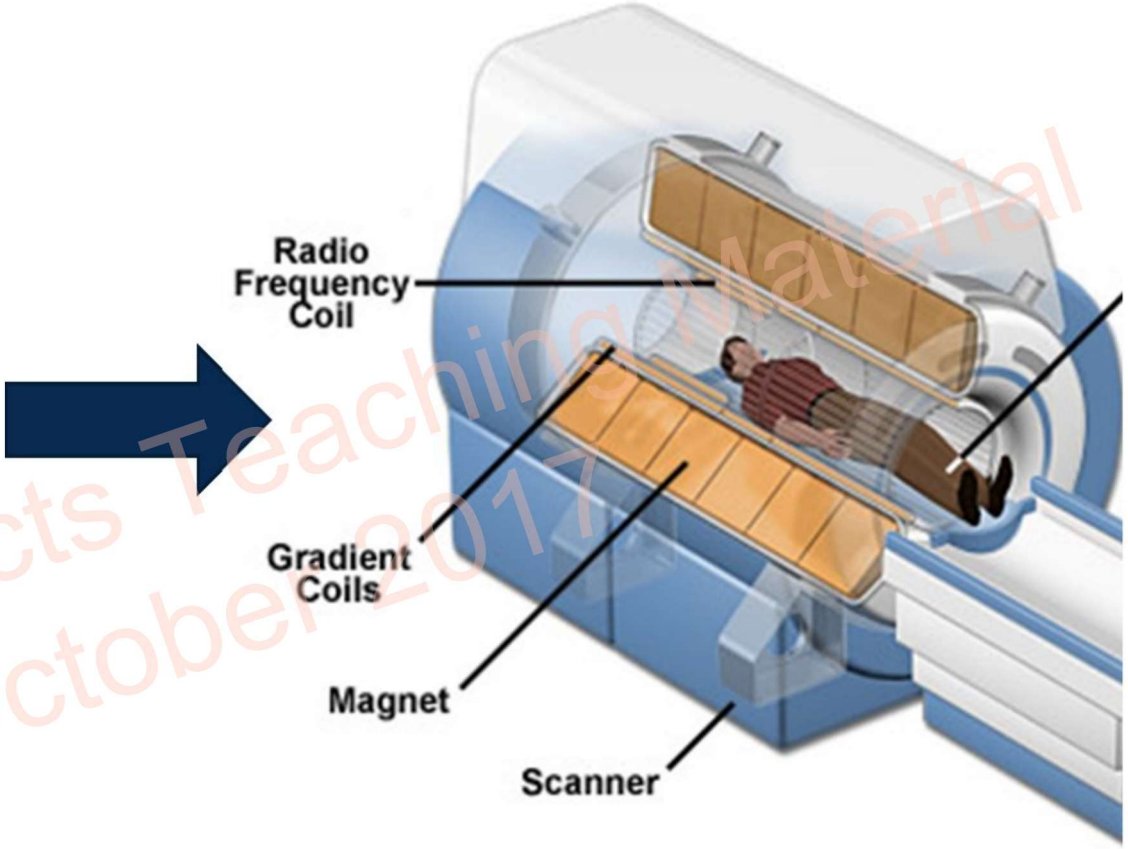
- This is not an introductory webinar about EEG-fMRI measurements.
- Participants should already be familiar with:
  - The principles of simultaneous EEG-fMRI measurement
  - Setting up an EEG-fMRI experiment.
  - Basic data processing in Analyzer 2.
- Resources
  - Video of the webinar
  - Slides available as a pdf
  - References given at the end
  - Question session

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What is special about EEG data recorded in the MR environment?

- MRI is a hostile environment for measuring electrophysiological data!





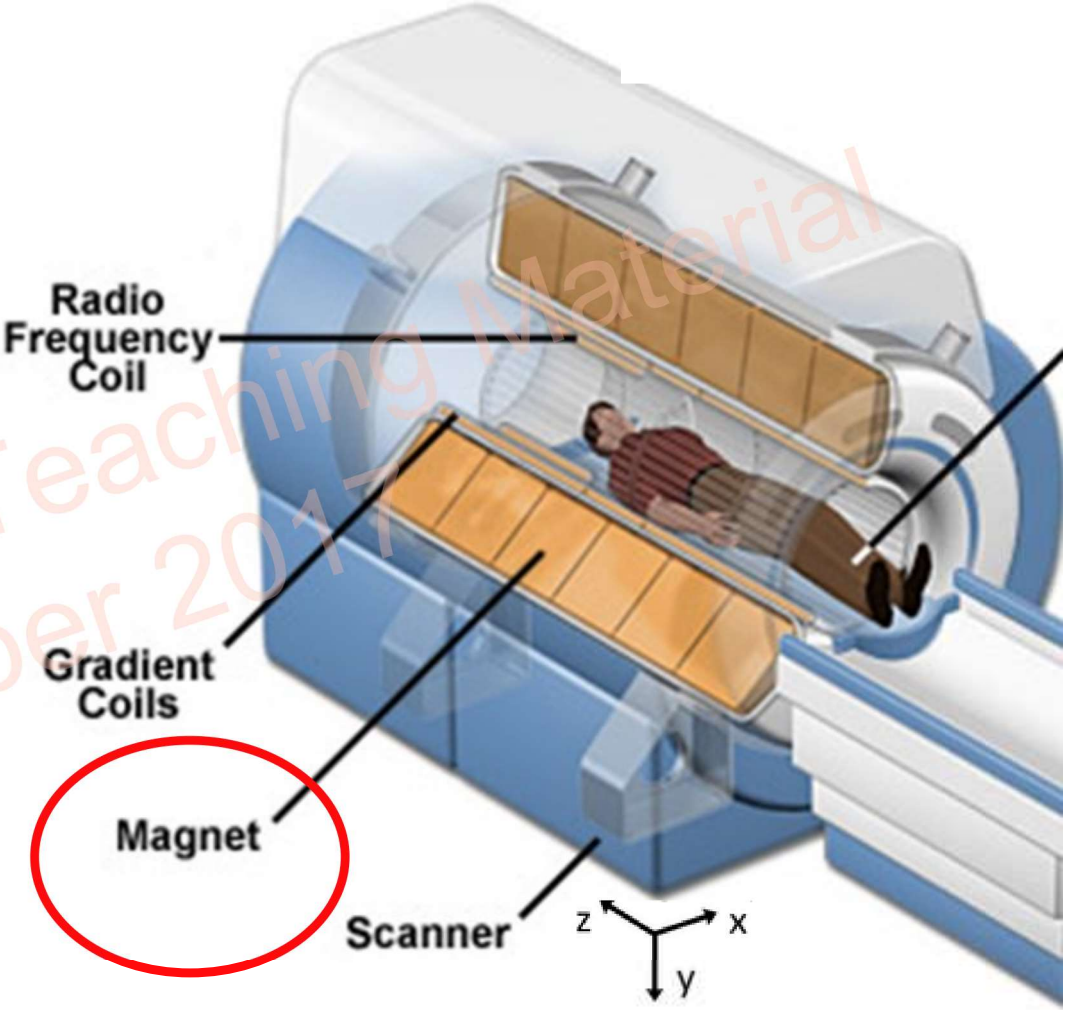
https://nationalmaglab.org/education/magnet-academy/learn-the-basics/stories/mri-a-guided-tour

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- The signal is contaminated by artifacts that we just don't see under regular laboratory conditions

So where do these artifacts come from?

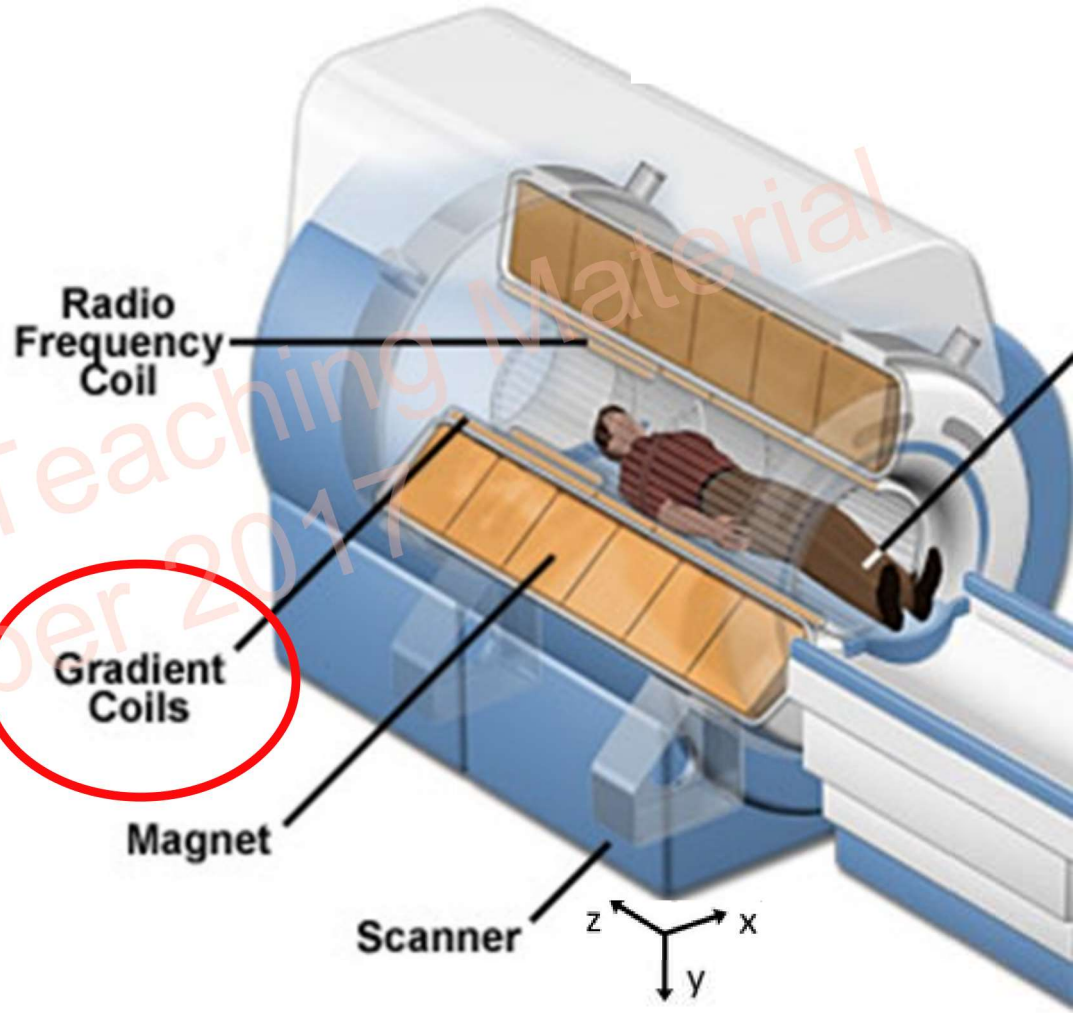
- **Static field (B0)**
  - This is the field strength of the scanner
  - Expressed in Tesla (T)
  - It's always there (even when not scanning)
  - Therefore it will always influence your data



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So where do these artifacts come from?

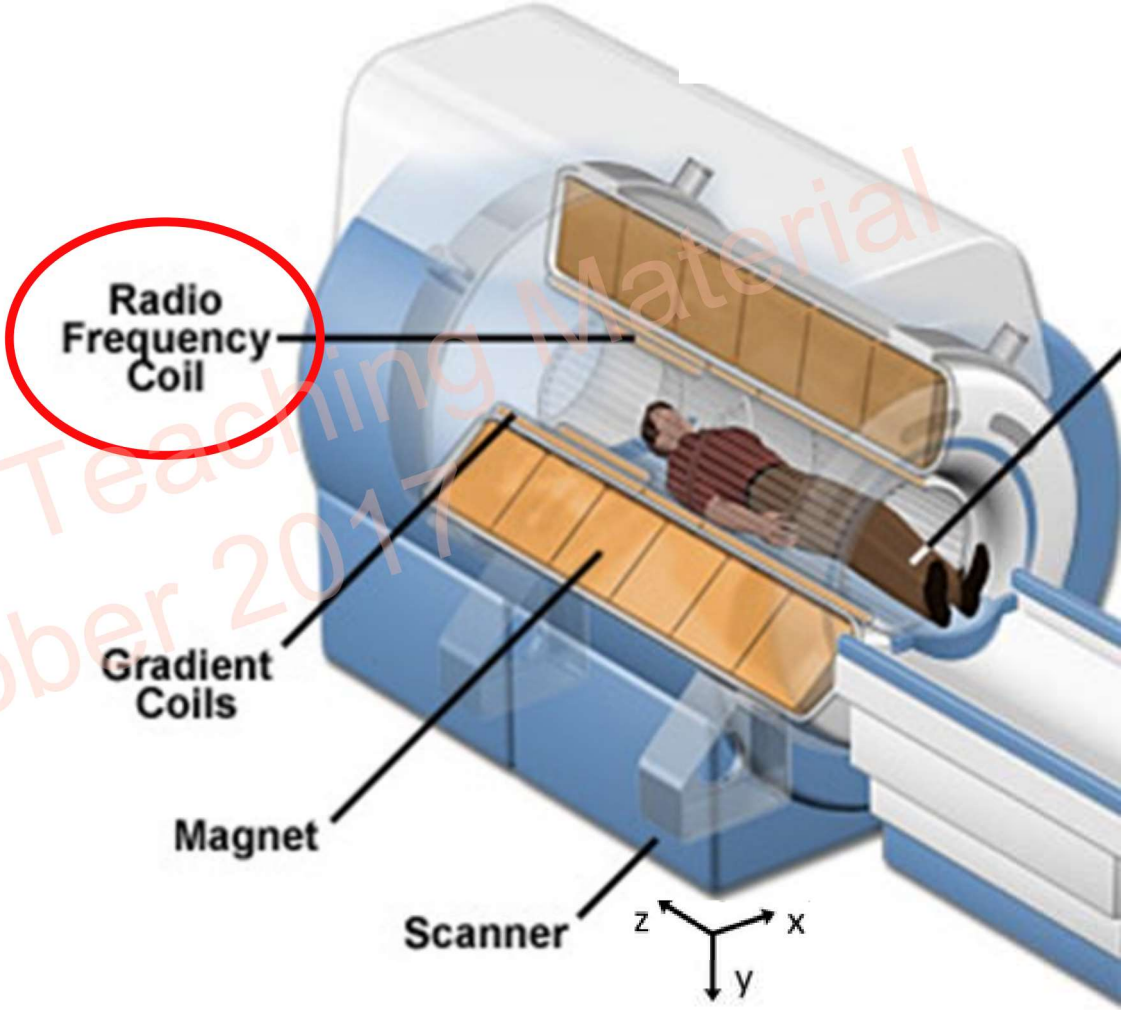
- **Rapidly changing magnetic fields (B1)**
  - Spatial gradients generated in the x, y and z direction
  - Also called ‘gradient switching’
  - This is what happens during scanning when sequences are running
  - Source of the acoustic noise that you hear during scanning



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So where do these artifacts come from?

- **Radio Frequency (E1)**
  - Pulses from the transmit coil
  - Always present during scanning



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Why are these fields important?

- Any change in the magnetic field induces current in the electrode leads (Faraday's Law)
  - Gradient switching
  - Movement

- This current flow results in the generation of voltage potentials
  - These measured along with the EEG data
  - These artifacts are much larger and faster than the EEG

- This is what makes the MR environment challenging for EEG!

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Main scanner related artifacts

- Cardioballistic artifact
  - Distortion of the EEG signal due to movement related to the cardiac cycle (static field)
- Gradient artifact
  - Massive distortions in the signal due to the gradient switching when MR sequences are running
- Radio Frequency artifact
  - Very high frequency and is usually dealt with using a low pass filter

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Other potential sources of artifact

- Movement (subject and/or electrode leads)
- Vibration of the EEG equipment
  - Ventilation system
  - Helium pump
  - Surrounding environment
- Lights in the scanner room
- Medical monitoring devices in the scanner room

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Achieving a good recording

- Practical setup (for reducing noise)
  - Position of the amplifier in relation to the z –axis of the scanner
  - Straight cables, also in line with z-axis
  - Reduce subject movement
  - Reduce vibrations: use the supplied 30cm ribbon cable, secure cables and amplifier
  - Positon the ECG electrode appropriately

- Interfaces with the scanner (for artifact handling)
  - **Master clock**: clock synchronization (SyncBox)
  - **Gradient system**: accurate triggers for gradient artifact correction

- Recorder workspace

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Safety

- There are many important safety aspects to consider for EEG-fMRI recordings

- Only factors related to data quality will be discussed today

- Please refer to our documentation for further information

- For questions and further advice: **techsup@brainproducts.com**

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Interim summary

- Recording EEG in the MR environment is clearly challenging
- But we do understand the fields involved and their potential effects on the EEG data
- We can take steps to minimize these effects by controlling our recording environment.
- Attention to detail during recording is critical to the success of the artifact handling.

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Interim summary

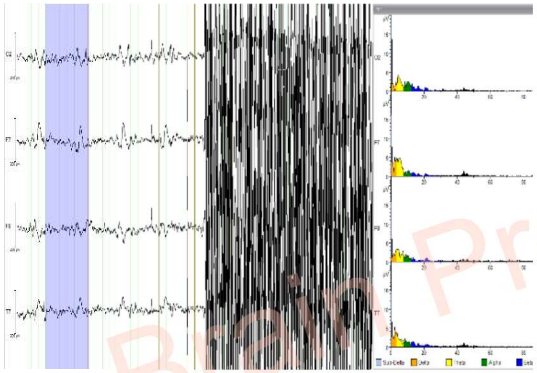
So, back to our learning goals…

- Considering how the recording environment can influence the data
- Understanding the origin and nature of scanner related artifacts
- Learning how to inspect data for scanner related artifact
- Learning about the correction methods available
- Learning how to apply these methods in Analyzer 2

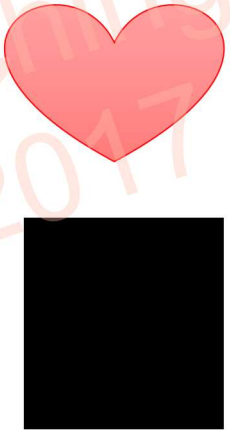
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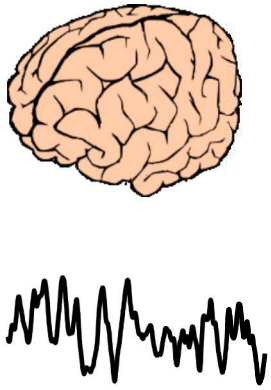
Overview of data handling process

Inspect noise in pre-scanning (static field) data	Gradient artifact correction and evaluation	Cardioballistic artifact correction and evaluation	Proceed with your regular data analysis pipeline









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Structure

- **Inspecting noise in B0** data in Analyzer
  - Identify noise in the data
  - Check prerequisites for artifact handling

- **Gradient artifact correction**
  - Describe the nature of gradient artifact
  - Describe the correction method
  - In Analyzer
    - Inspecting the gradient artifact
    - Apply the MR Correction transformation

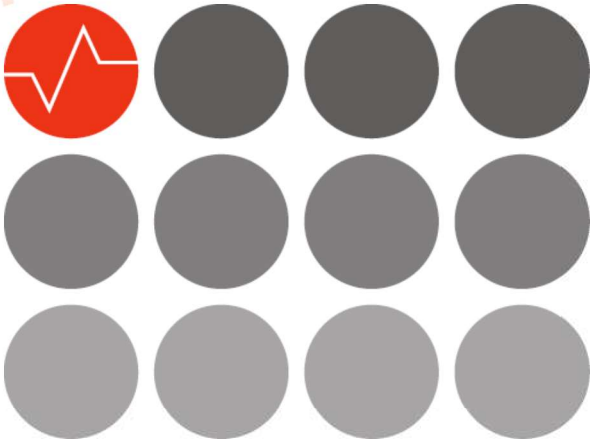
- **Cardioballistic artifact correction**
  - Describe the nature of cardioballistic artifact
  - Describe the correction method
  - In Analyzer
    - Inspecting cardioballistic artifact
    - Apply the CB Correction transformation

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Let's take a look at some data recorded in the static field

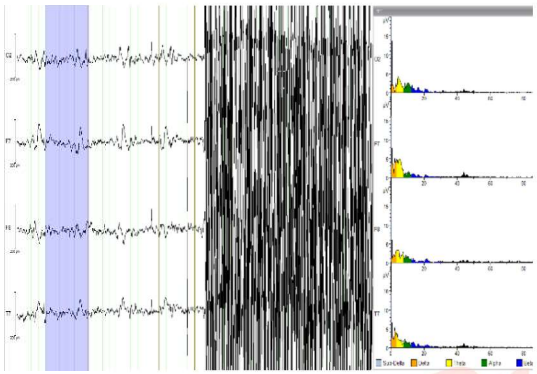
You can see this is the video recording of the webinar

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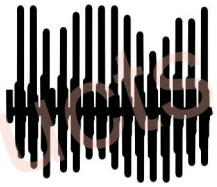


Interim Summary

Done	Next
Inspect noise in pre-scanning (static field) data	Gradient artifact correction and evaluation





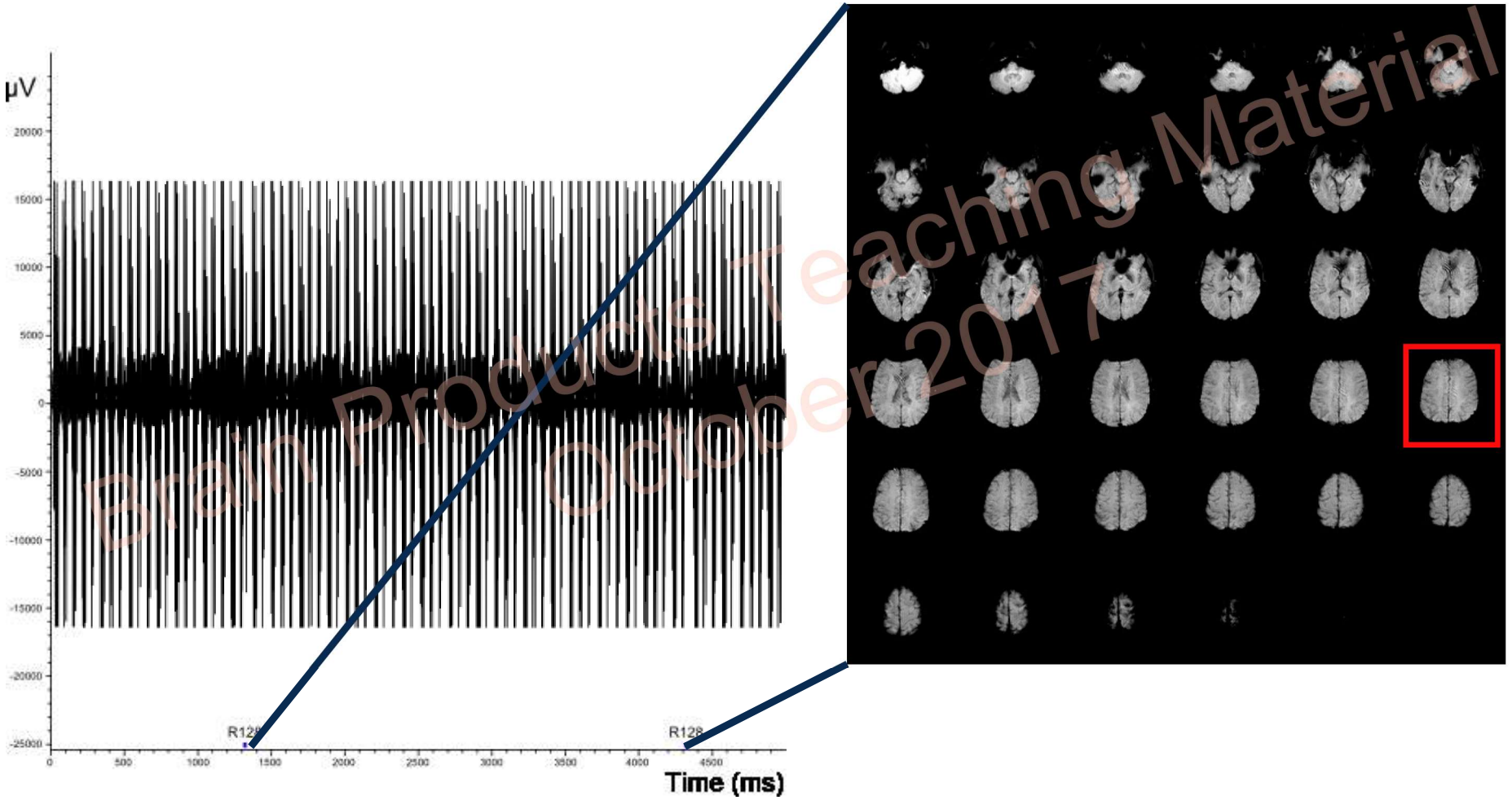


- Look at the frequency content
- Identify noise sources
- Eliminate noise during pilot testing
- Check ECG signal
- Make sure we have what we need for the artifact correction

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Gradient artifact

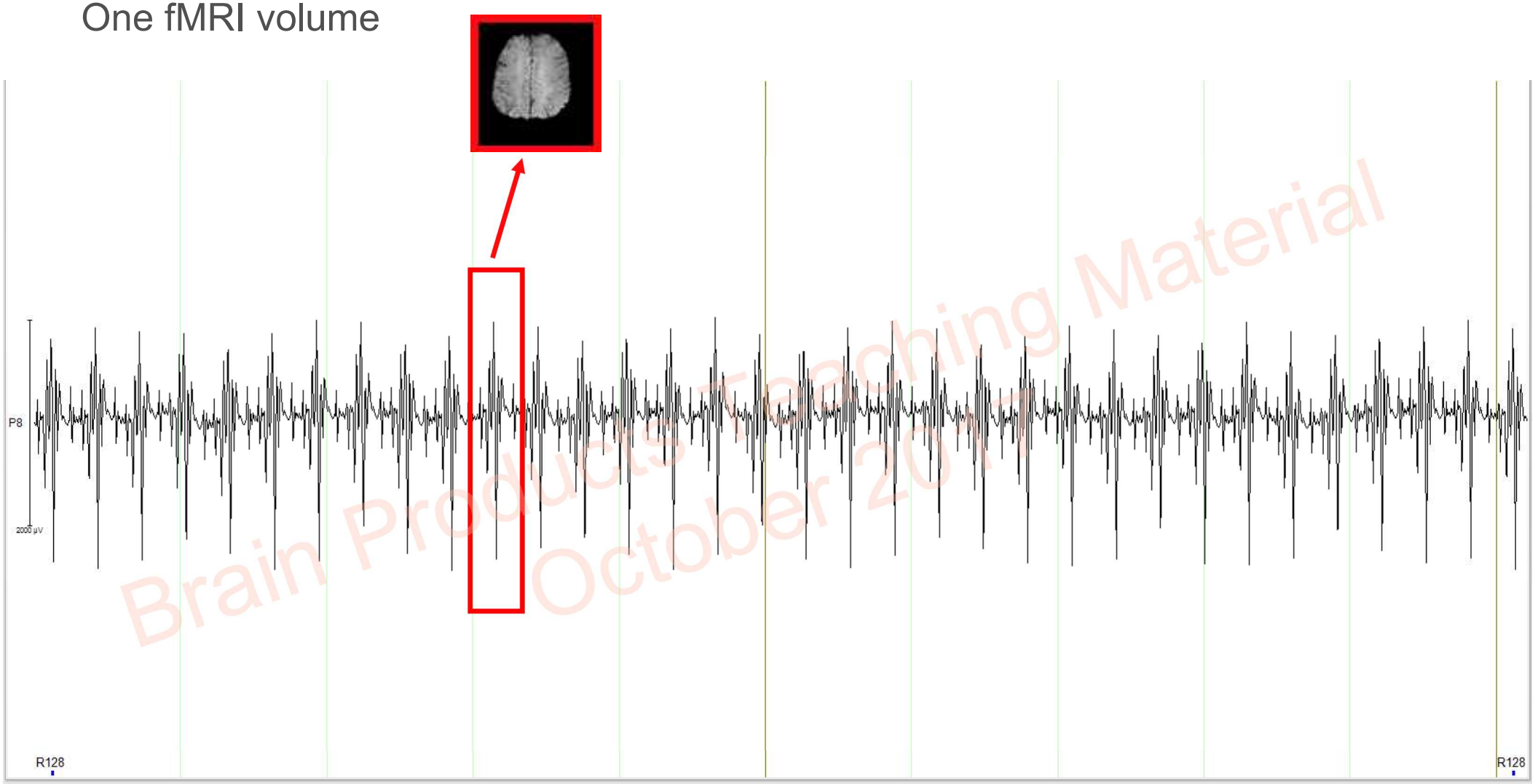
- Where does it come from?



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Gradient artifact

One fMRI volume



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Gradient artifact

Features of gradient artifact

- Technical in nature
- Repetitive
- Predictable
- Temporally stable TR (Repetition Time)

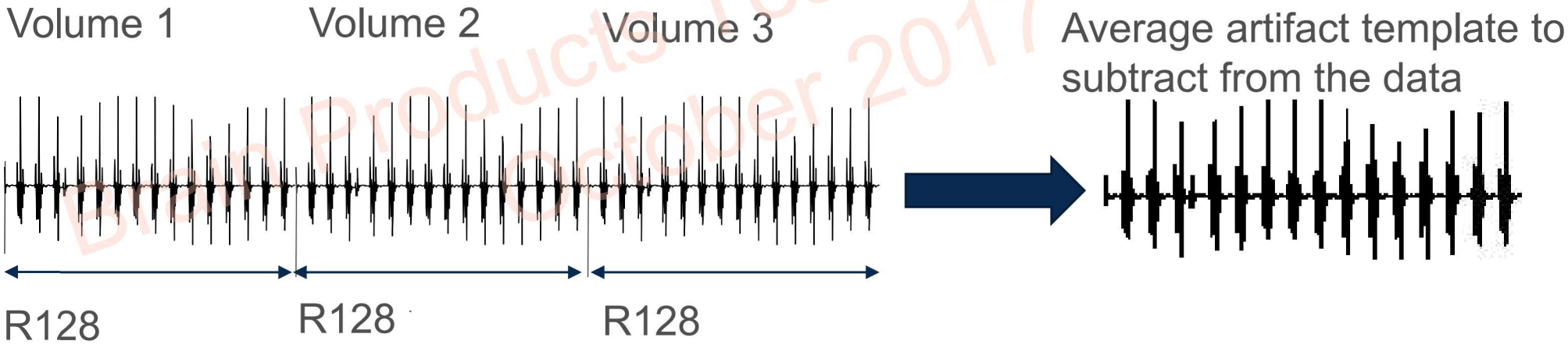
- Because of these characteristics we can use a template subtraction approach for removing the artifact.
- MR Correction transformation uses the **Average Artifact Subtraction** approach (Allen et al. 2000)

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What do we need in order to do AAS?

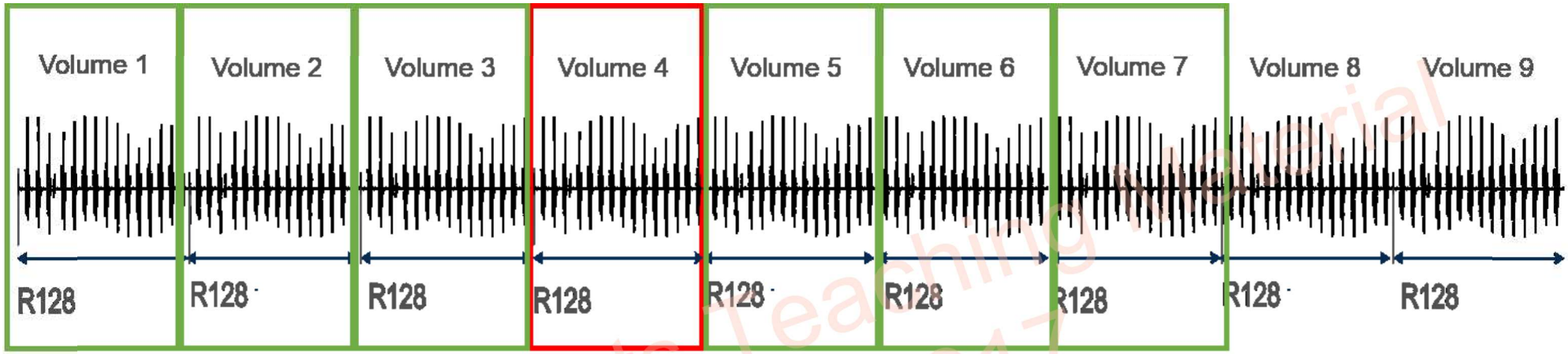
- We need the EEG acquisition to be synchronised to the scanner clock (avoid temporal jitter)

- We need accurate volume markers:



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AAS – how it works

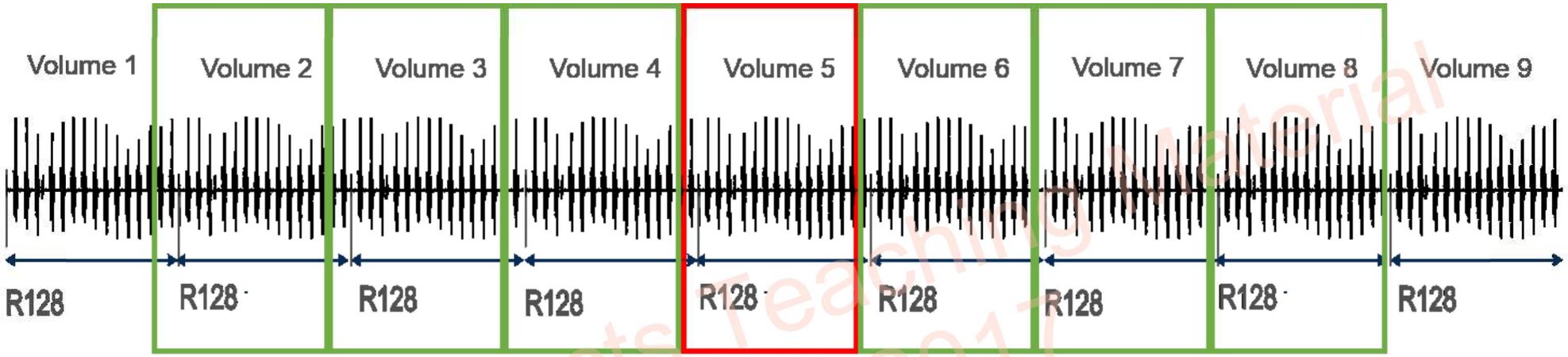


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To correct the gradient artifact in volume 4, an artifact template is created from this volume plus the three volumes before and the three volumes after

Note that three volumes are chosen for demonstration only, ten volumes each side of the volume to be corrected is recommended

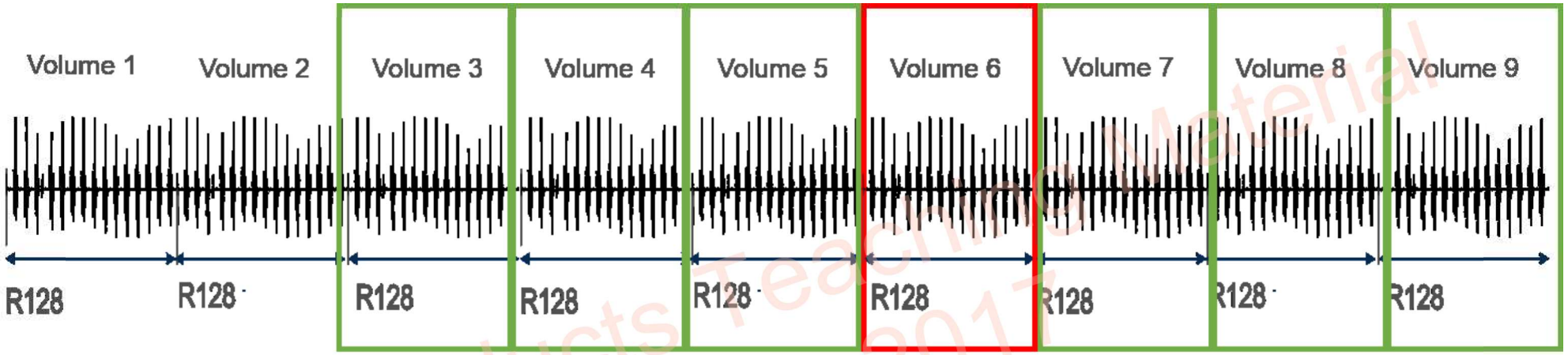
AAS – how it works



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To correct the gradient artifact in volume 5, the artifact template slides along and is created from volume 5 plus the three volumes before and the three volumes after

AAS – how it works



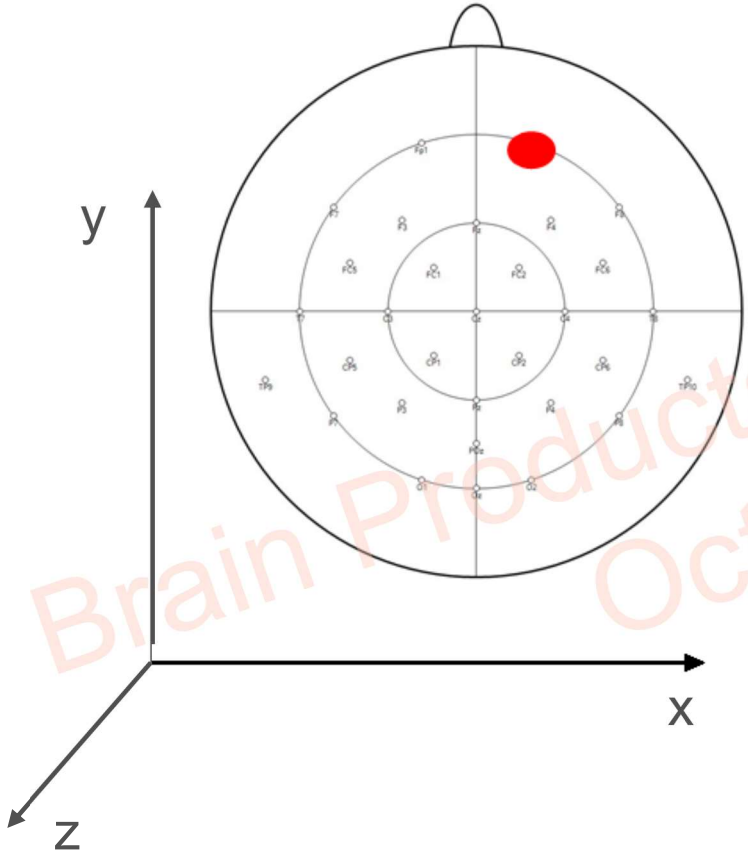
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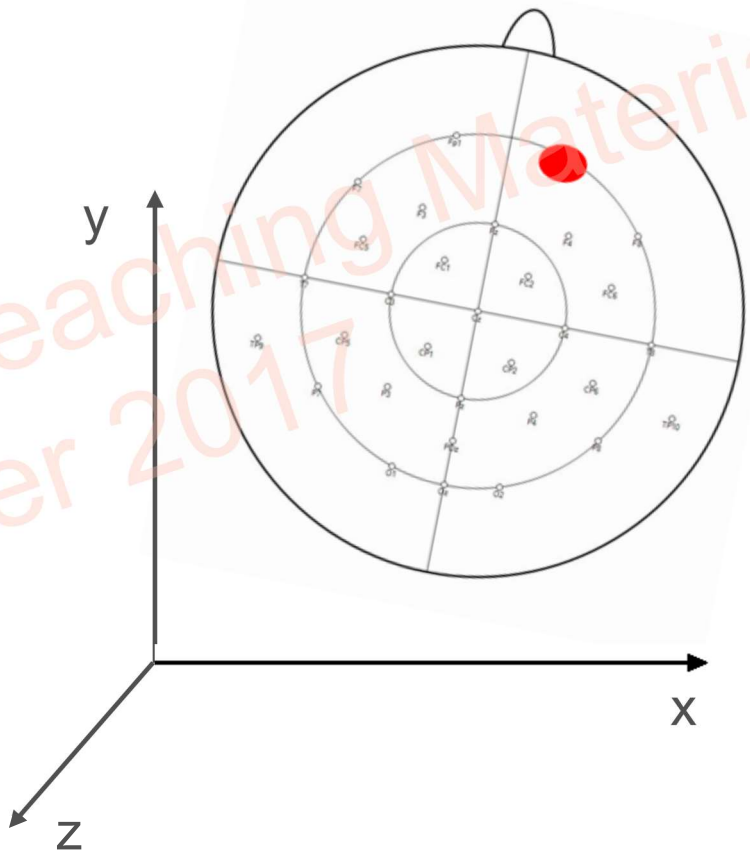
To correct the gradient artifact in volume 6, the artifact template slides along and is created from volume 6 plus the three volumes before and the three volumes after

This continues throughout the data to be corrected

AAS – further considerations

- Gradient artifact changes over time due to head movement
  - movement causes changes in the orientation of electrodes in relation to the gradient field





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- Solution: sliding average

AAS – further considerations

- Gradient artifact varies in amplitude and shape across EEG channels
  - Due to electrode and cable arrangement and their position in the gradient field
  - Solution: gradient artifact template calculation and correction is done per channel

- Risk of removing EEG data with the gradient artifact
  - Solution: make sure stimuli are not time locked to the volume start
  - Solution: make sure that the window for the sliding average is not too short

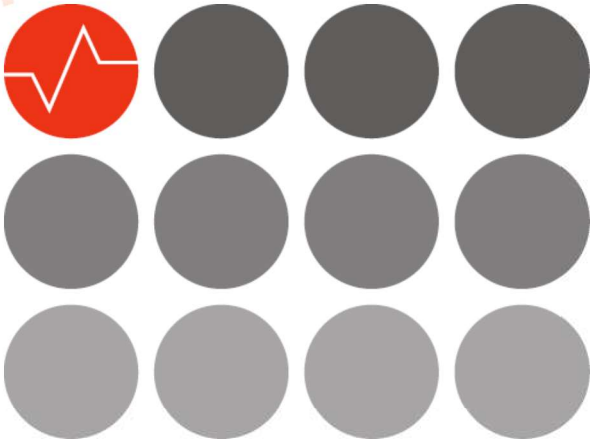
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Let’s have a look at the gradient artifact.

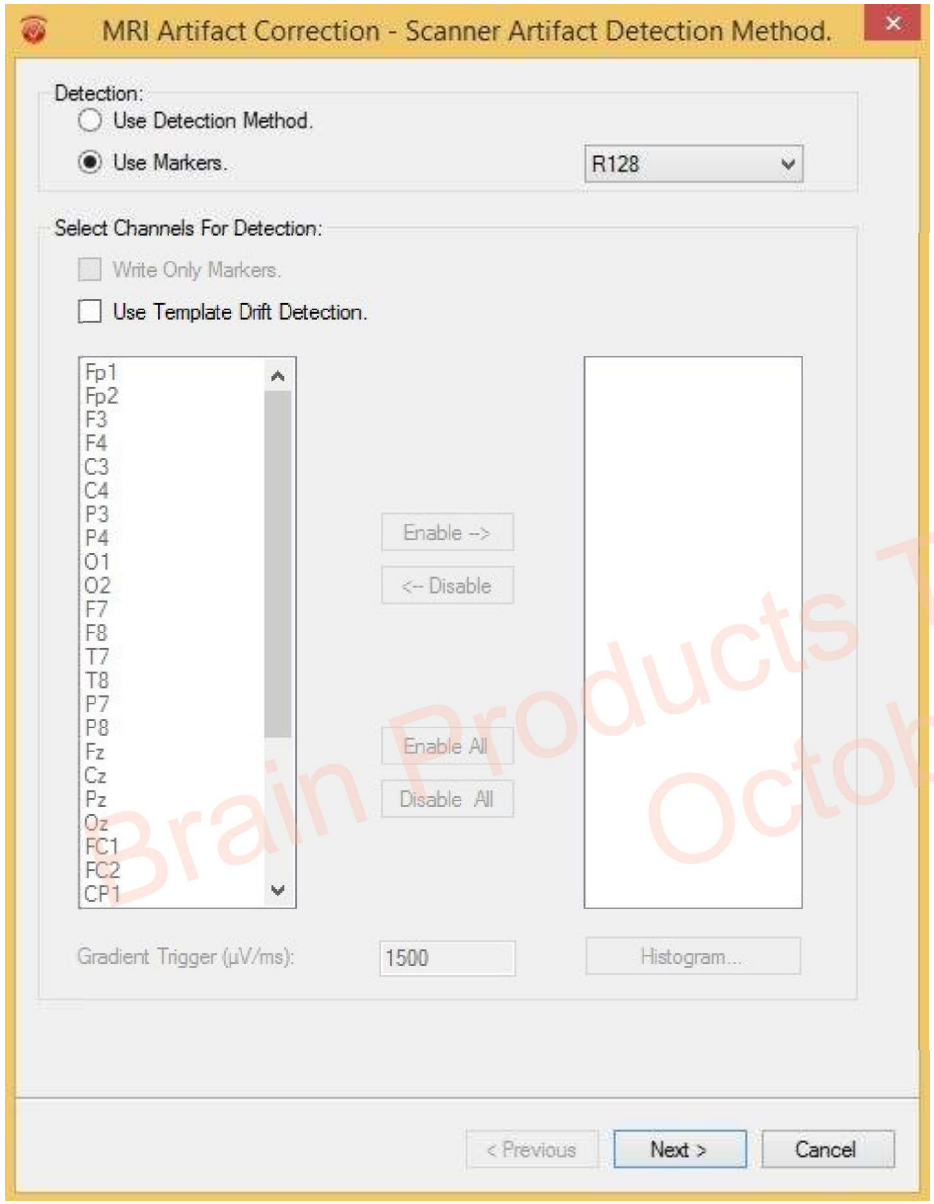
You can see this is the video recording of the webinar.

Recommended settings for the MR correction transformation are shown in the next slides.

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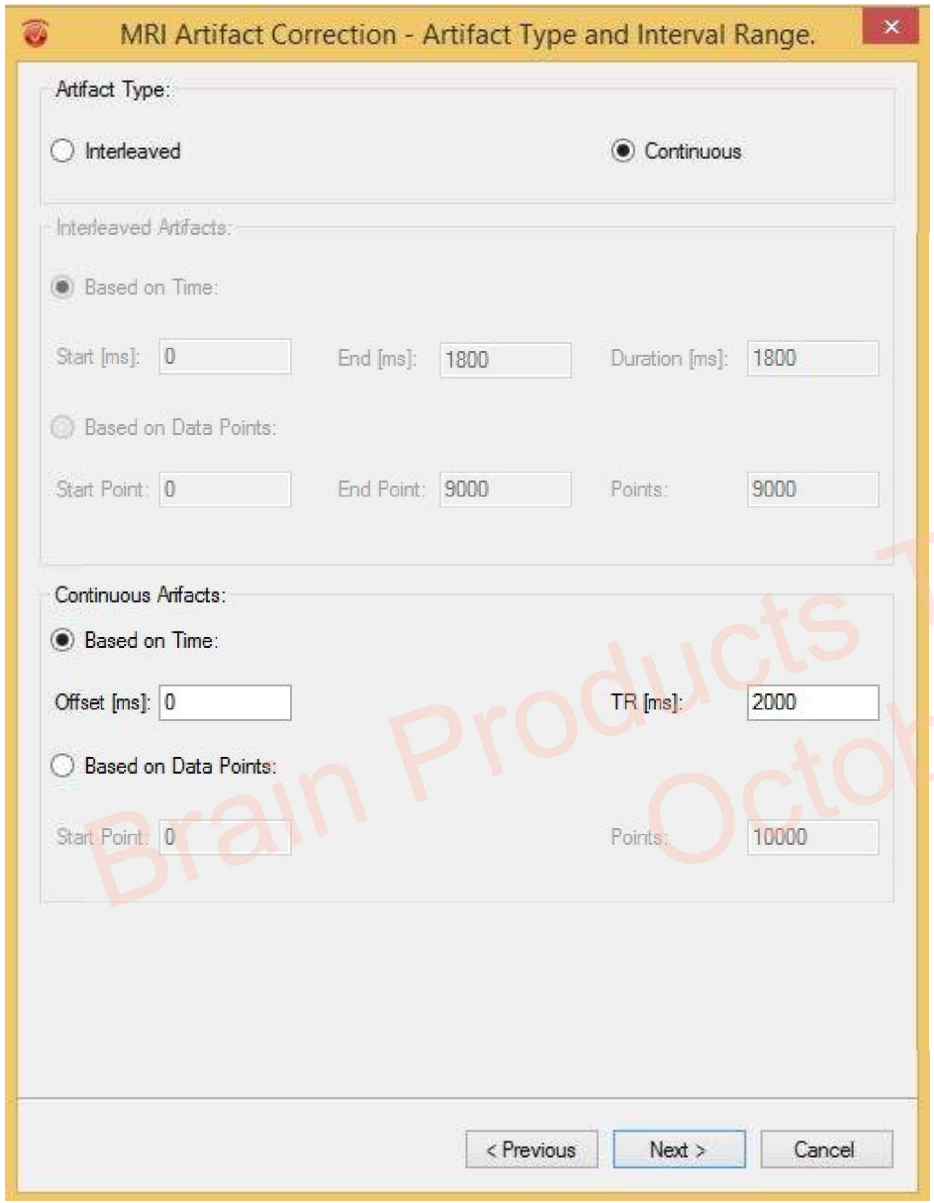
Recommended settings: MR Correction



- Select ‘Use Markers’
- Select the volume trigger from the scanner
- In this case ‘R128’

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Recommended settings: MR Correction



- The correct settings here depend on the parameters of your fMRI sequence

Artifact Type

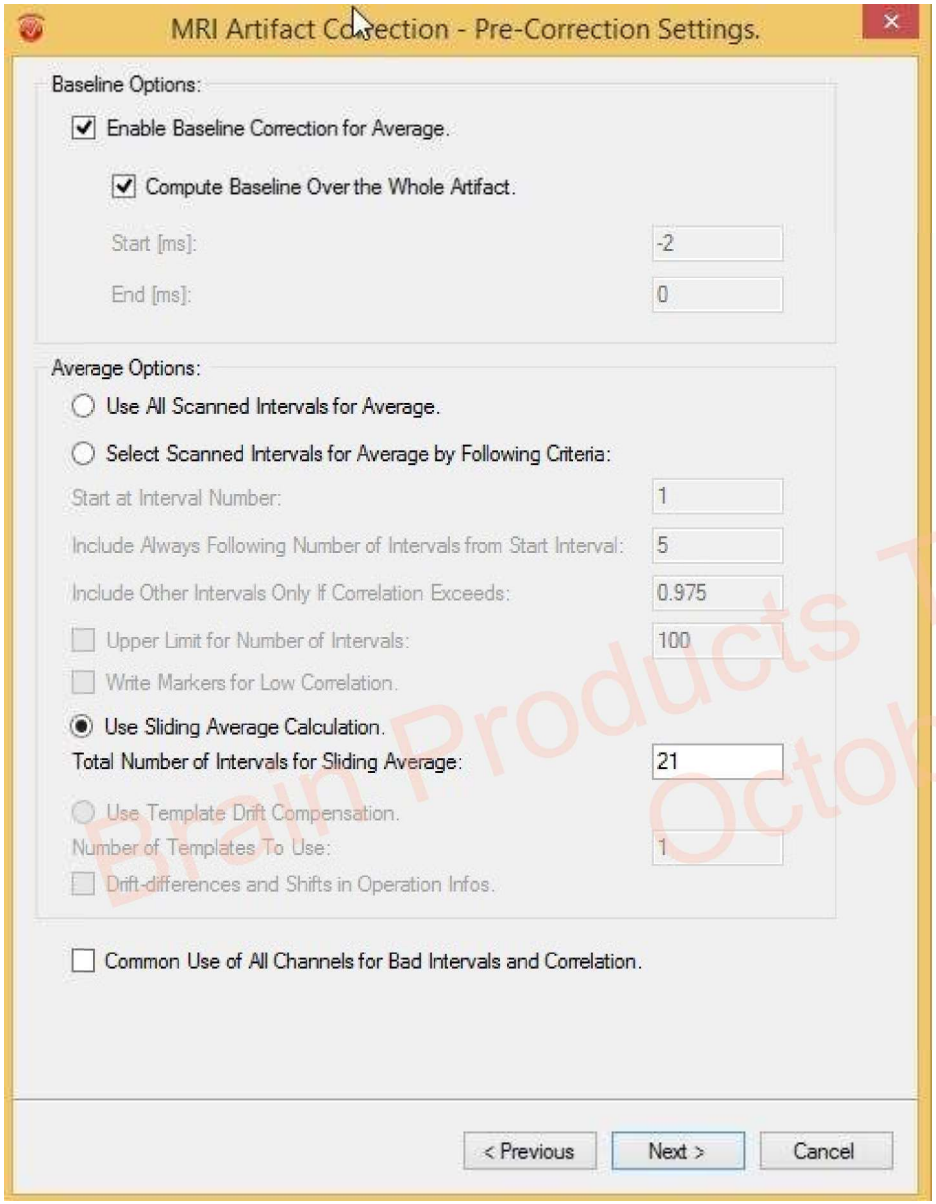
- Here we have ‘Continuous’ scanning (no gaps between volumes)

Continuous Artifacts

- Our TR is 2000ms

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Recommended settings: MR Correction



Baseline options

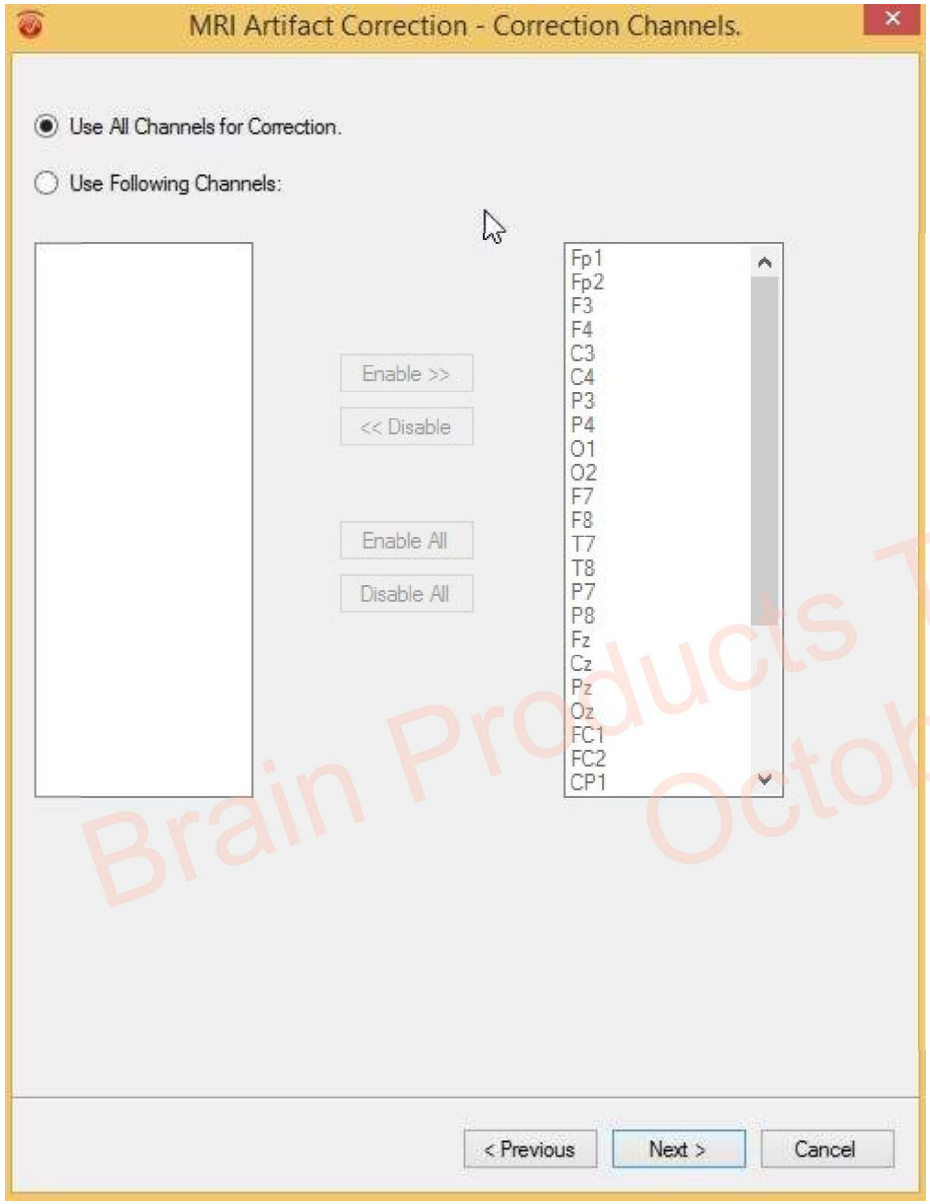
- Enable baseline correction and compute the baseline over the whole artifact
- We need to baseline correct to avoid an offset between the artifact template and the data

Average Options

- Select ‘Use Sliding Average Calculation’
- For the number of interval select 21

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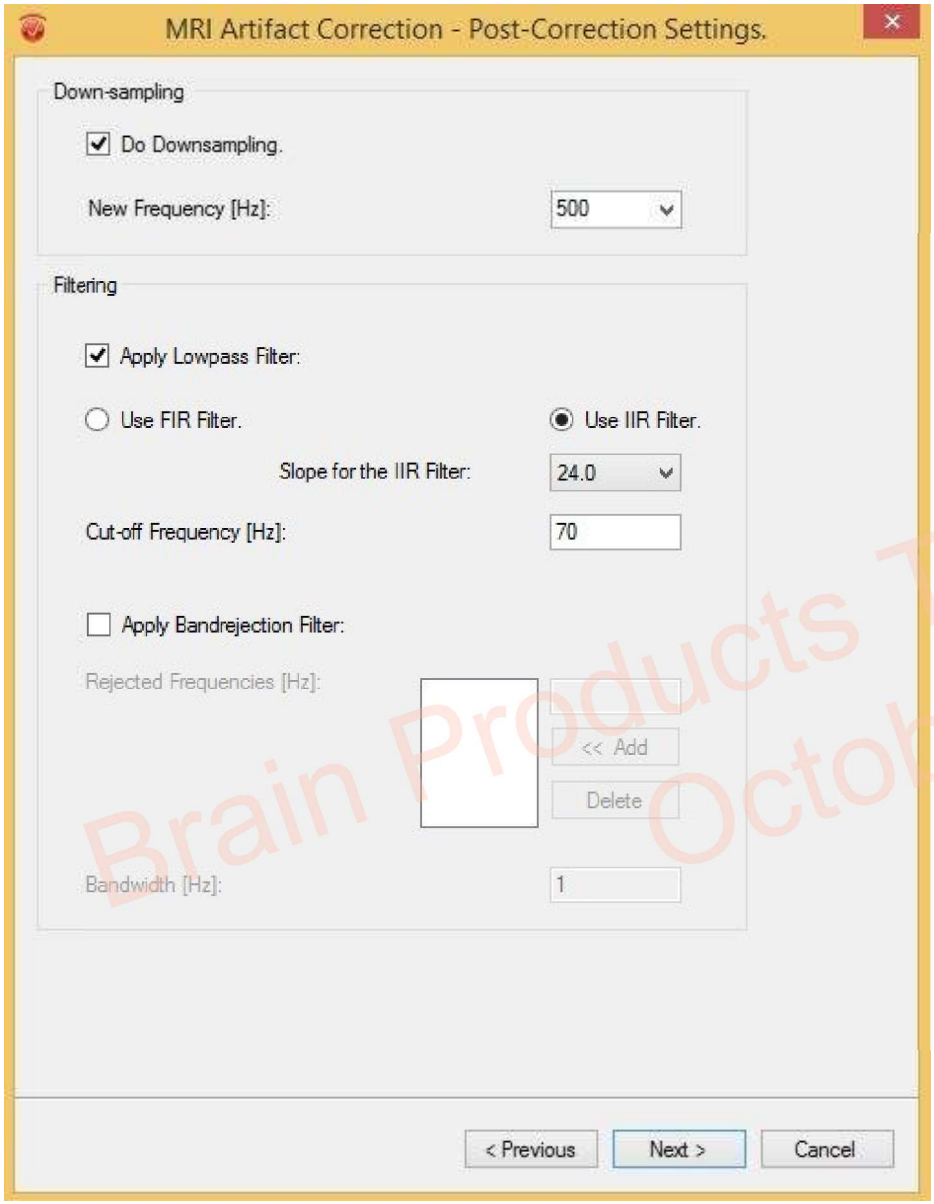
Recommended settings: MR Correction



- Use all channels for Correction

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Recommended settings: MR Correction



Down-sampling

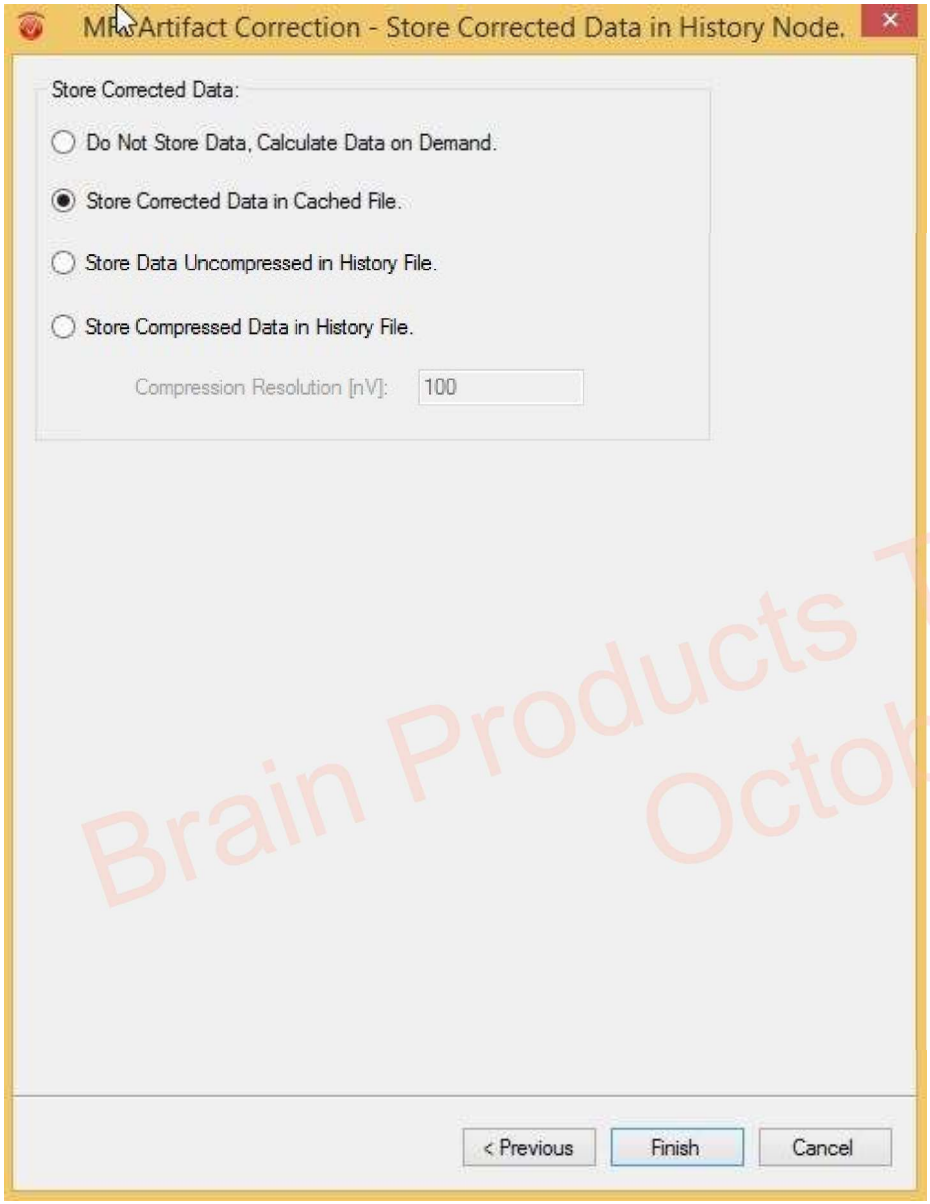
- This is optional but recommended
- A sampling rate of 5000Hz is not necessary after gradient artifact correction.
- Choose a new sampling rate that is suitable for your data processing pipeline

Filtering

- This is also optional
- You can filter now or at a later stage in your analysis

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Recommended settings: MR Correction

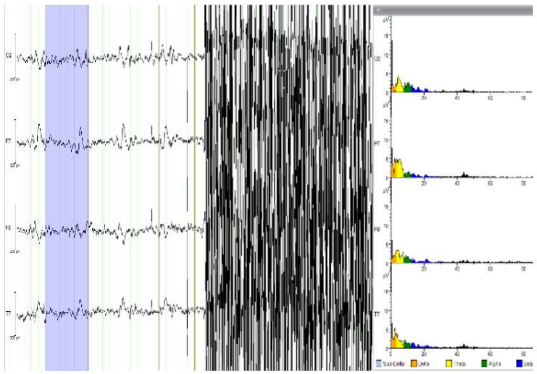


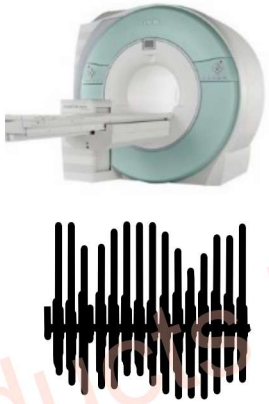
- We recommend that you select ‘Store Corrected Data in a Cached File’
- This avoids increasing the size of the history files
- It also avoids ‘on demand’ processing that can take a lot of time for such calculation intensive transformations

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Interim Summary

Done	Done	Next
Inspect noise in pre-scanning (static field) data	Gradient artifact correction and evaluation	Cardioballistic artifact correction and evaluation







- Look at the frequency content
- Identify noise sources
- Eliminate noise during pilot testing
- Check ECG signal
- Make sure we have what we need for the artifact correction

- Marker timing for volume triggers
- Check synchronisation with MR clock
- Run MR Correction transformation
- Check for residual gradient artifact

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Cardioballistic artifact explained (briefly!)

- **Physiological** rather than technical artifact

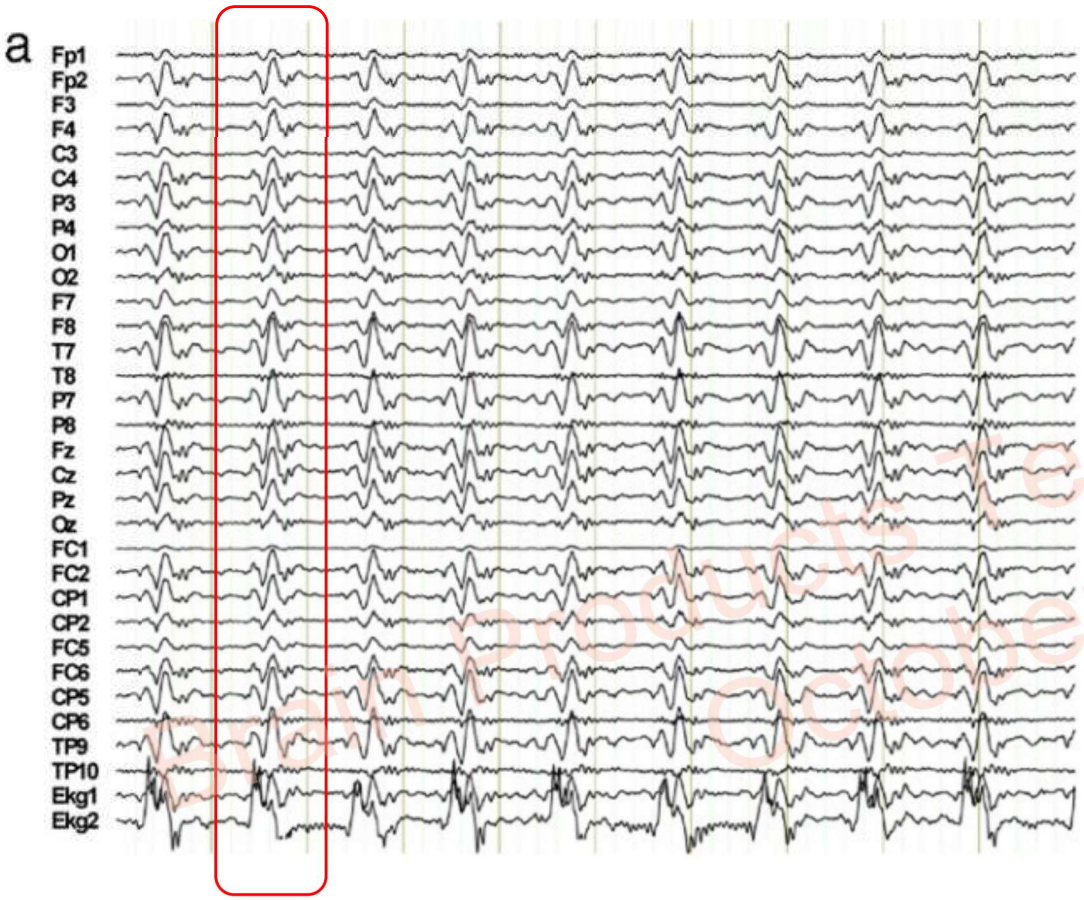
- Motion related to cardiac activity induces electromotive forces in the circuit formed by the EEG leads and the subject, this is picked up by the amplifier

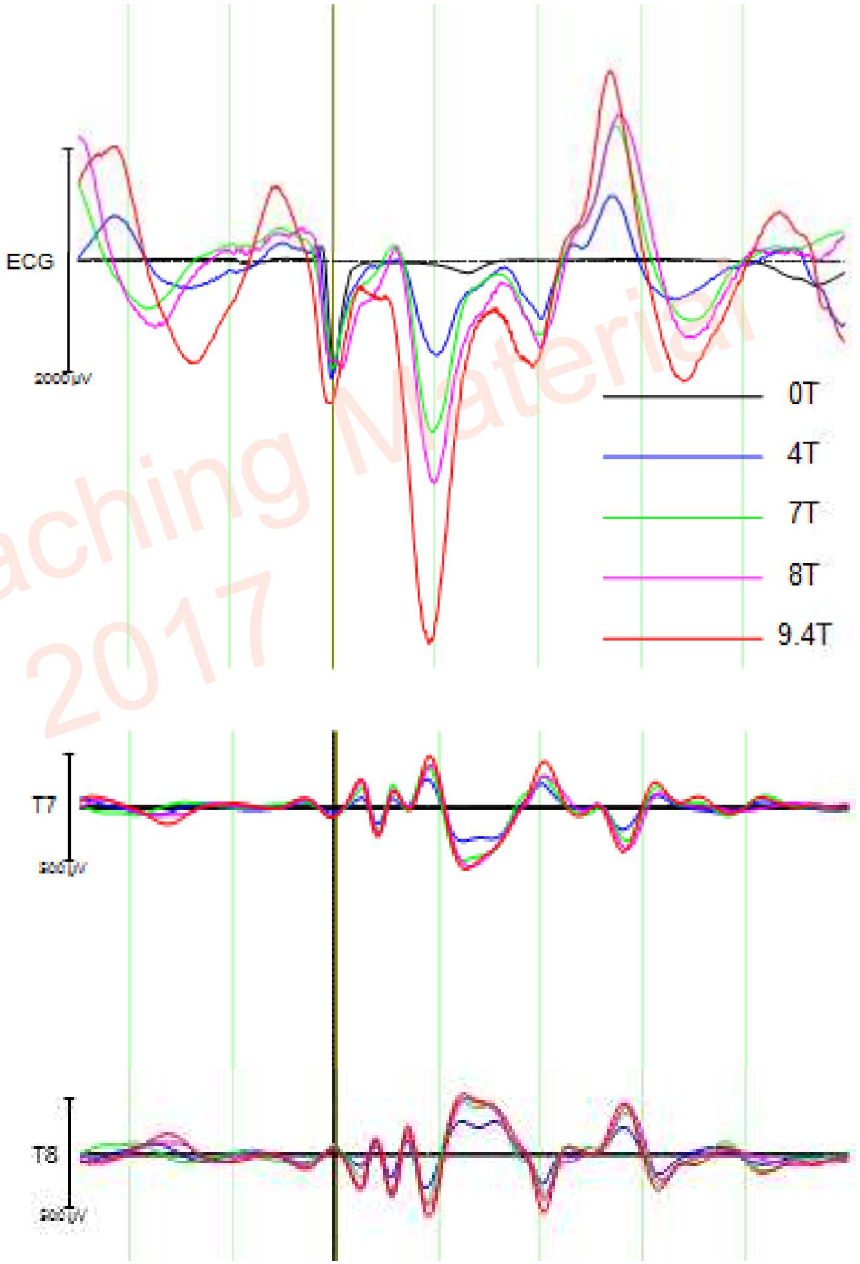
- Multiple sources:
  - Axial head rotation
  - Pulsatile properties of the blood vessels
  - Motion of the blood

- It is related to the static field (B0) so it is always present
- It is irregular both between and within participants

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Cardioballistic artifact

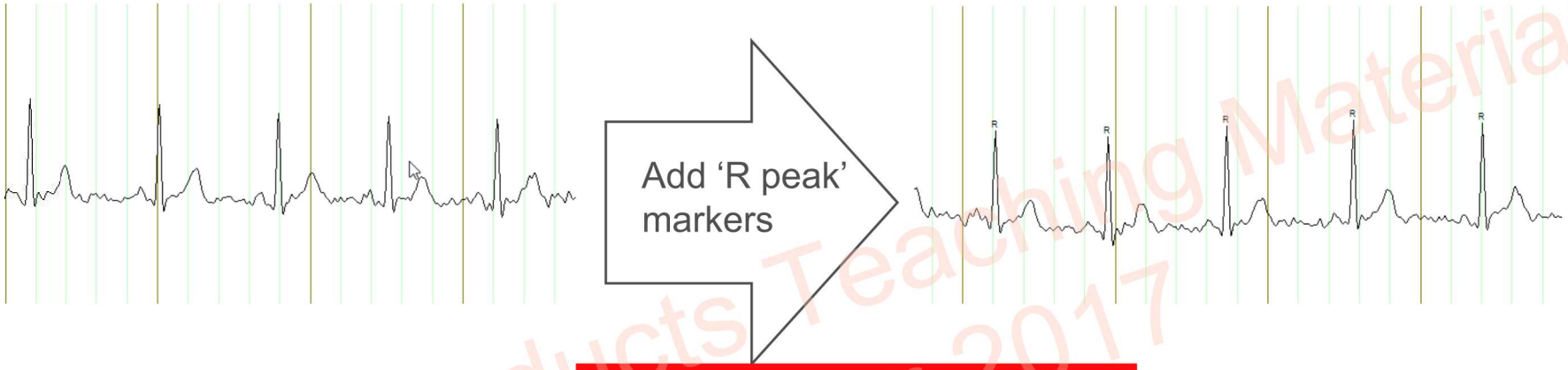




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Cardiaballistic artifact correction

- We also use a template subtraction approach for CB artifact correction
- However, we do not have markers…



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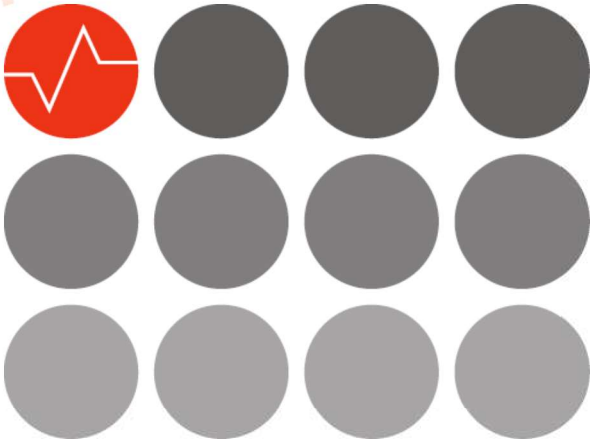
Find R peak → Verify R peak → Use R peak

Let's have a look at the cardioballistic artifact.

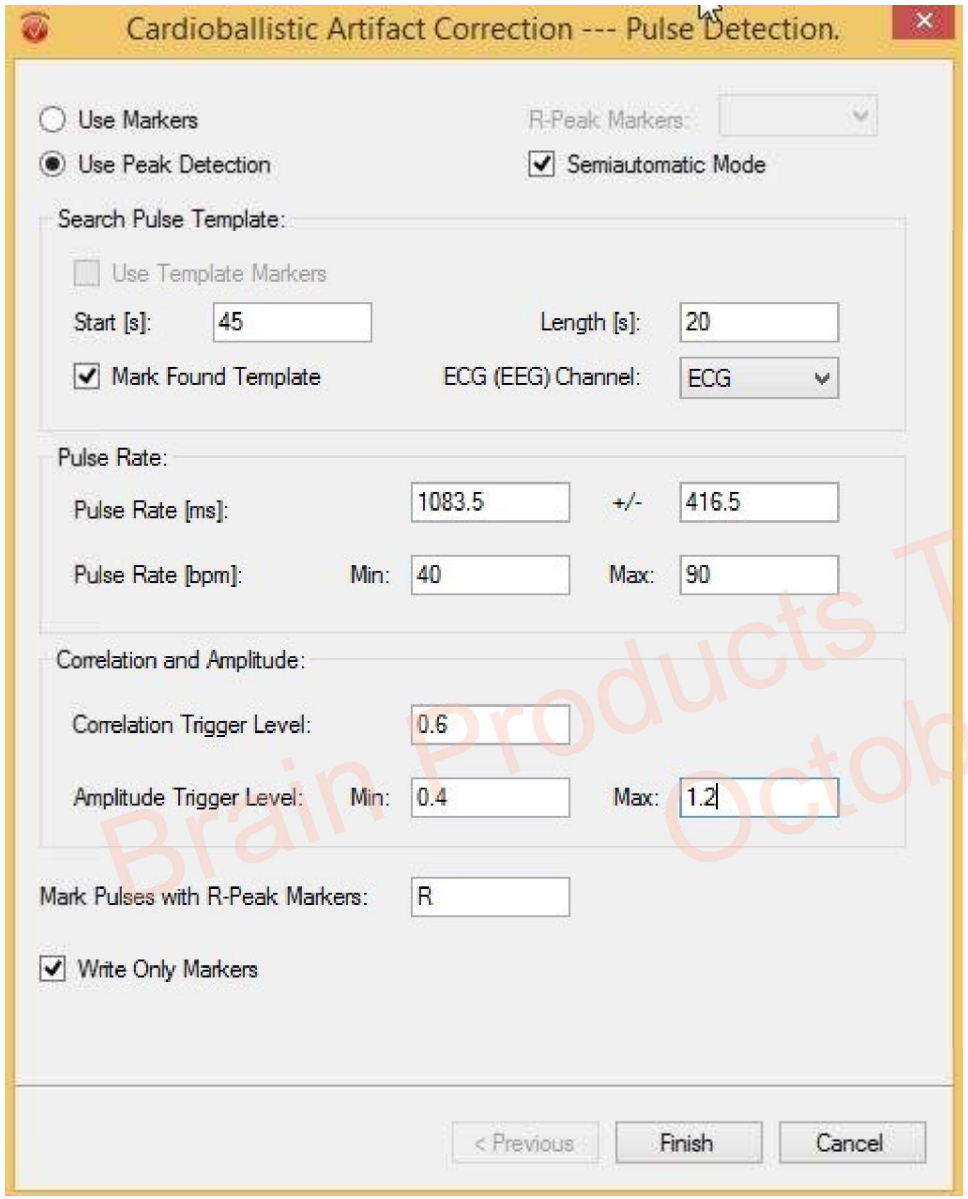
You can see this is the video recording of the webinar.

Recommended settings for the CB Correction transformation are shown in the next slides.

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Recommended settings: CB Correction



- Select ‘Use Peak Detection’
- Enable the ‘Semiautomatic Mode’ check box

Search Pulse Template

- Specific a time range for the template search
- Enable ‘Mark Found Template’
- Select the ECG channel

Pulse rate

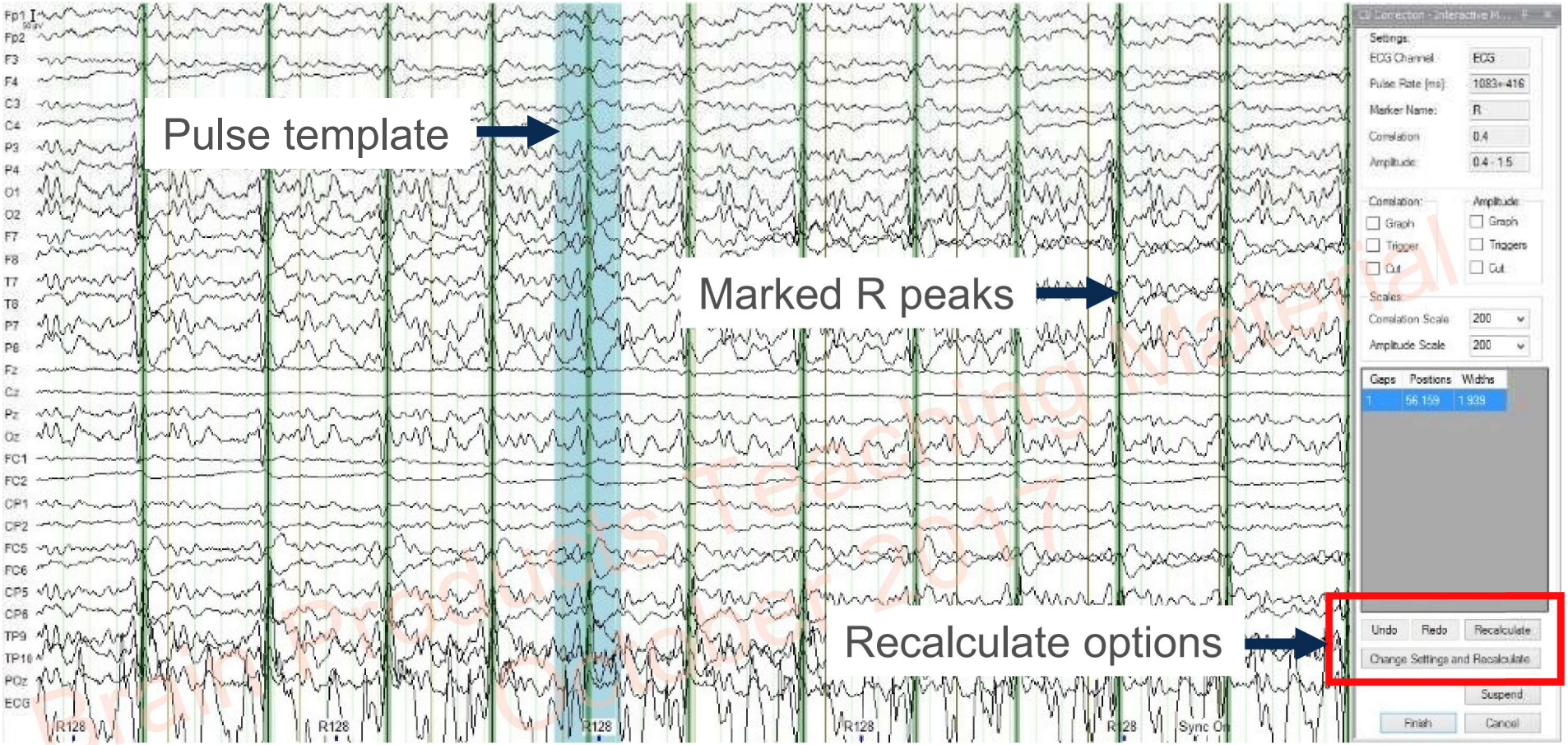
- Specify a realistic pulse rate range for your subject (check the ECG channel for heart rate if in doubt)

Correlation and amplitude

- Try the values specified here, you can change them later if necessary
- Mark pulse with ‘R’
- Enable ‘Write Only Markers’
  - This allows you to have a history node where the markers are saved, but no correction is performed. This can be useful if you wish to check your R peak markers again later and / or run the correction again.
  - This will results in a 2 step process, where the correction is done in a second step.
- After clicking on ‘Finish’ the semiautomatic mode window will open

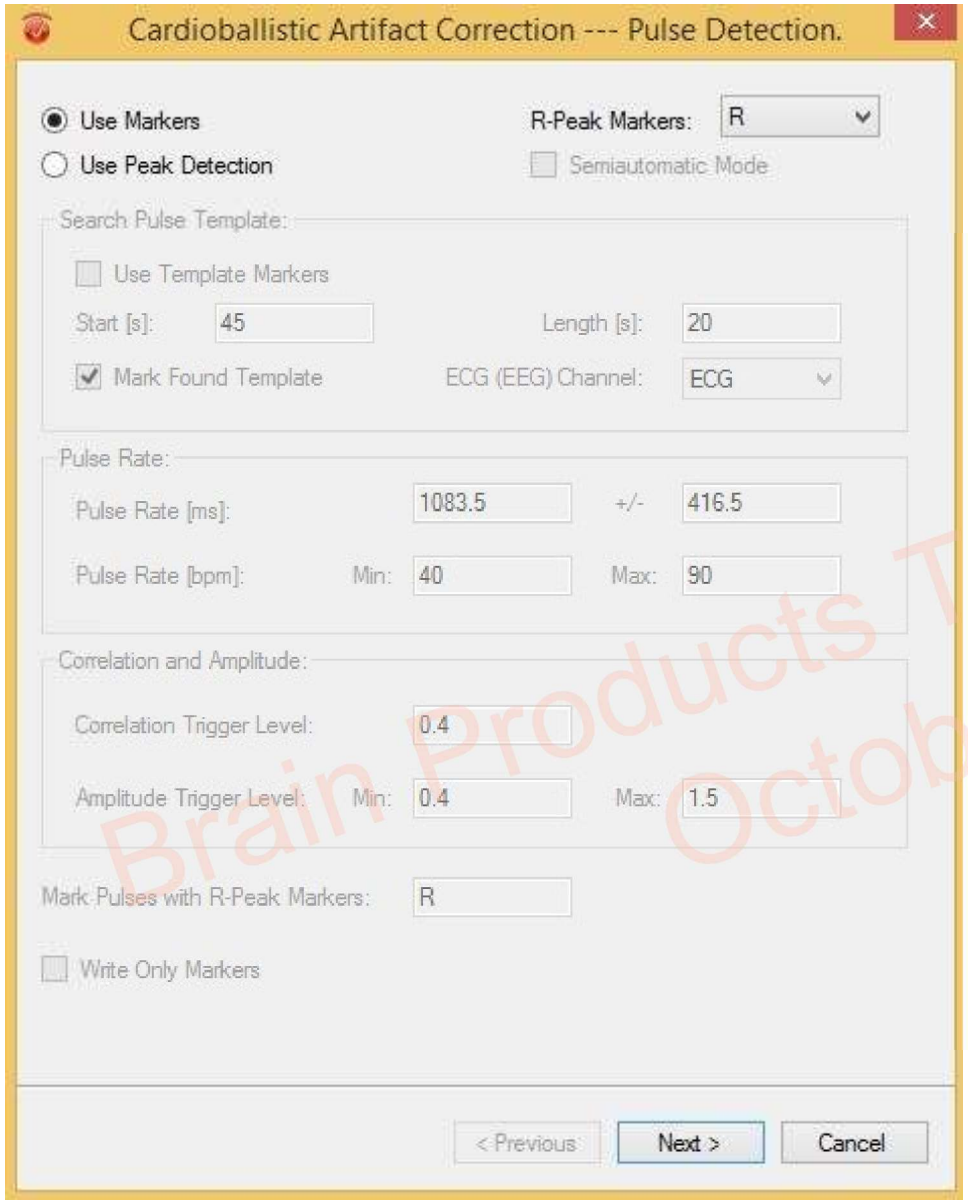
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Recommended settings: CB Correction



- The semiautomatic mode allows you to check the pulse template and verify the marked R peaks
- You can change the parameters and recalculate if necessary
- Tip: Double click on the ECG channel to display only this channel, this will make it easier to check the template and marked peaks
- When you are happy with the peak detection click on ‘Finish’, this will close the transformation and create a new history node containing the R peaks

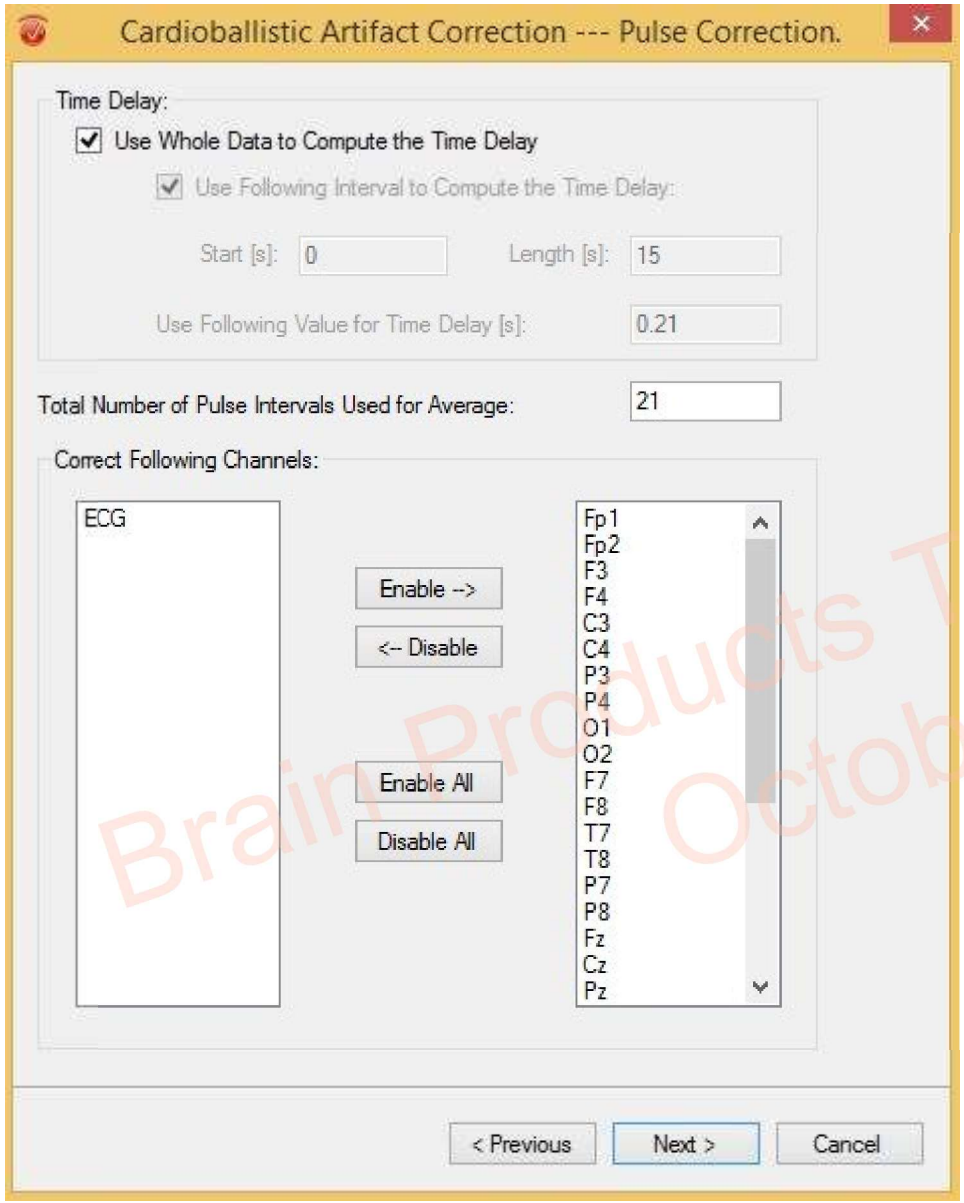
Recommended settings: CB Correction



- Select the history node containing your R peaks (created in the previous step) and then open the CB Correction transformation again
- This time select ‘Use Markers’ and select the R markers
- No further information is required this time because we already have our R peaks marked

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Recommended settings: CB Correction



Time Delay

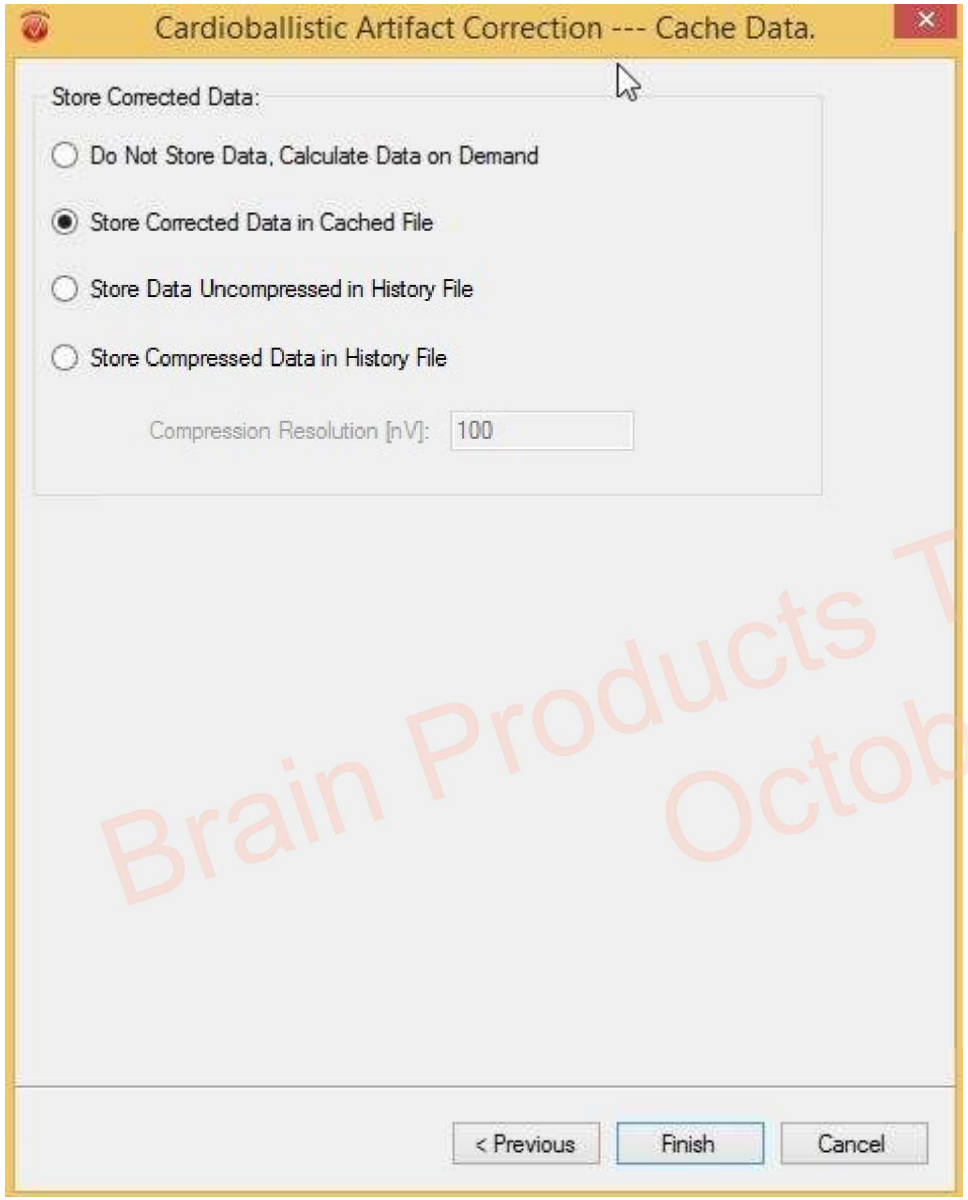
- Select ‘Use Whole Data to Compute the Time Delay’
- Specify the number of pulse interval to be used for the Average, we recommend using 21

Correct the Following Channels

- Select all channels except the ECG channel

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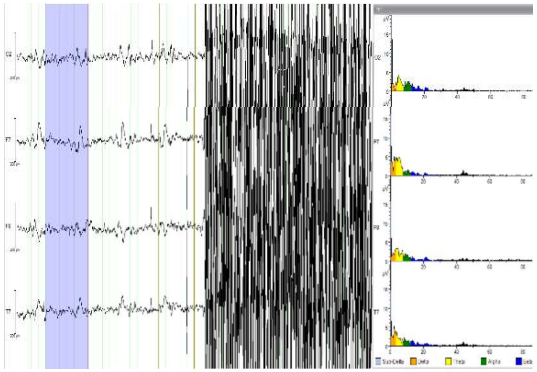
Recommended settings: CB Correction



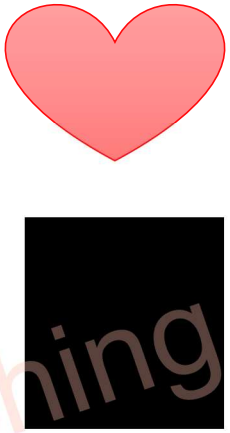
- We recommend that you select 'Store Corrected Data in a Cached File'
- This avoids increasing the size of the history files
- It also avoids 'on demand' processing that can take a lot of time for such calculation intensive transformations

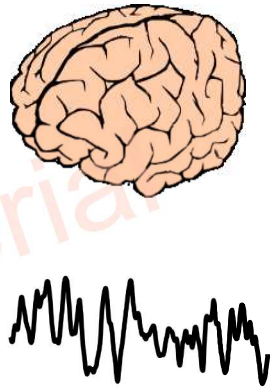
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Inspect noise in pre-scanning (static field) data	Gradient artifact Correction and evaluation	Cardioballistic artifact correction and evaluation	Proceed with your regular data analysis pipeline









- Look at the frequency content
- Identify noise sources
- Eliminate noise during pilot testing
- Check ECG signal
- Make sure we have what we need for the artifact correction

- Marker timing for volume triggers
- Check synchronisation with MR clock
- Run MR Correction transformation
- Check for residual gradient artifact

- Place R-peak markers using CB Correction in semiautomatic mode
- Run CB Correction
- Evaluate correction

- Pilot test your paradigm outside of the scanner
- Be aware of potential differences in effects due to the scanner environment

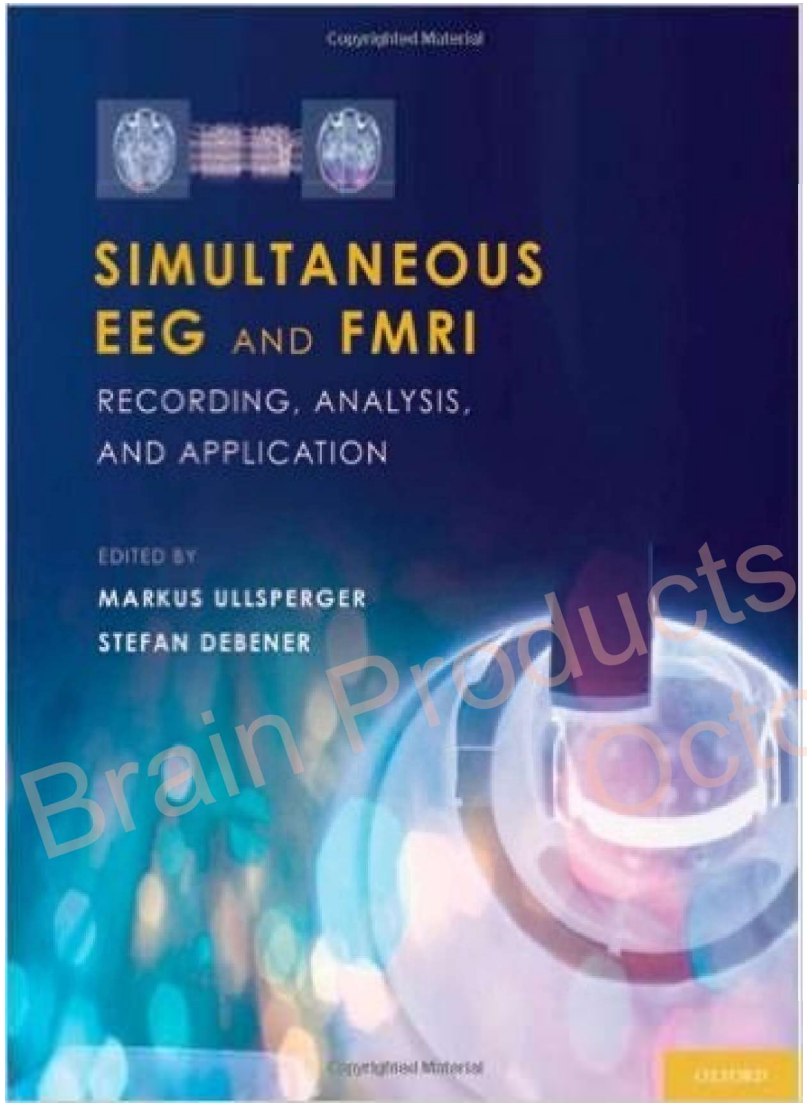
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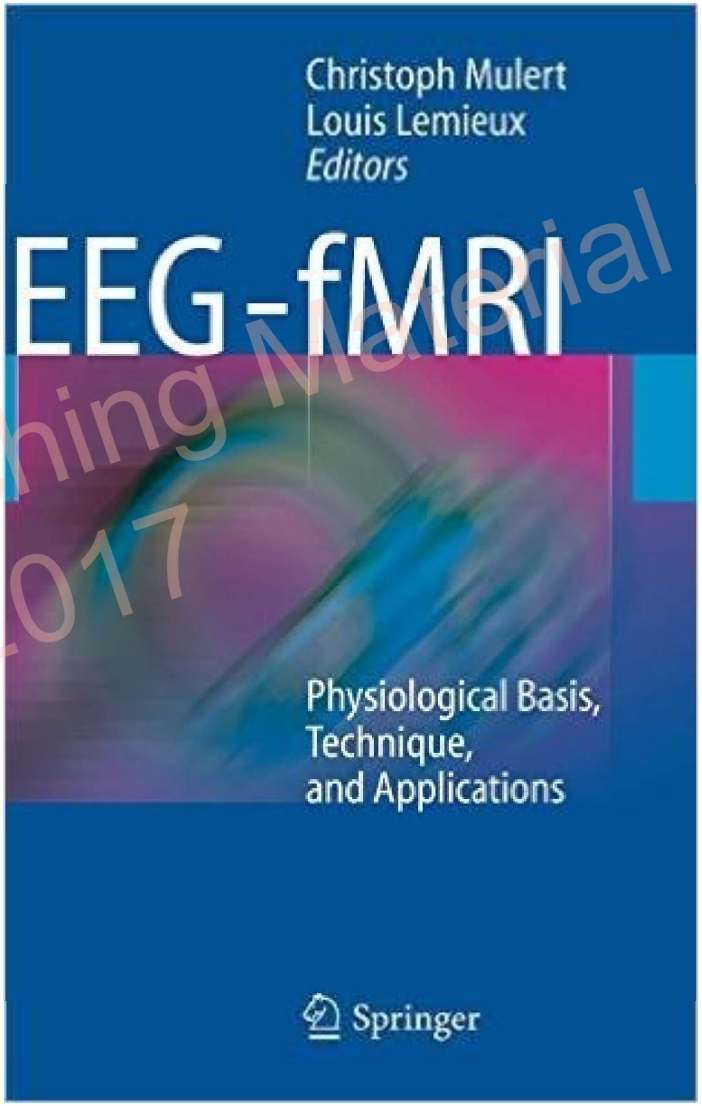
Take home messages

- Record good data!
  - Take care of the environment and recording parameters
- Check data recorded in the **static field**
  - Pilot testing
  - Short section of data before scanning starts for every subject
- Accurate timing for **gradient artifact correction**
  - Accurate volume triggers
  - Synchronisation with the scanner clock (SyncBox)
- Accurate R peak detection for **cardioballistic artifact correction**
  - Good ECG signal
  - CB correction in semiautomatic mode NEVER in automatic mode

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Recommended literature EEG/fMRI





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References

Gradient artifact

- Allen et al. (2000). A method for removing imaging artifact from continuous EEG recorded during functional MRI.

https://www.ncbi.nlm.nih.gov/pubmed/10913328

- Ritter et al. (2007). Evaluating gradient artifact correction of EEG data acquired simultaneously with fMRI.

https://www.ncbi.nlm.nih.gov/pubmed/17462844

Cardioballistic artifact

- Allen et al. (1998). Identification of EEG events in the MR scanner: the problem of pulse artifact and a method for its subtraction.

https://www.ncbi.nlm.nih.gov/pubmed/9758737

- Debener et al. (2008). Properties of the ballistocardiogram artefact as revealed by EEG recordings at 1.5, 3 and 7 T static magnetic field strength.

https://www.ncbi.nlm.nih.gov/pubmed/17683819

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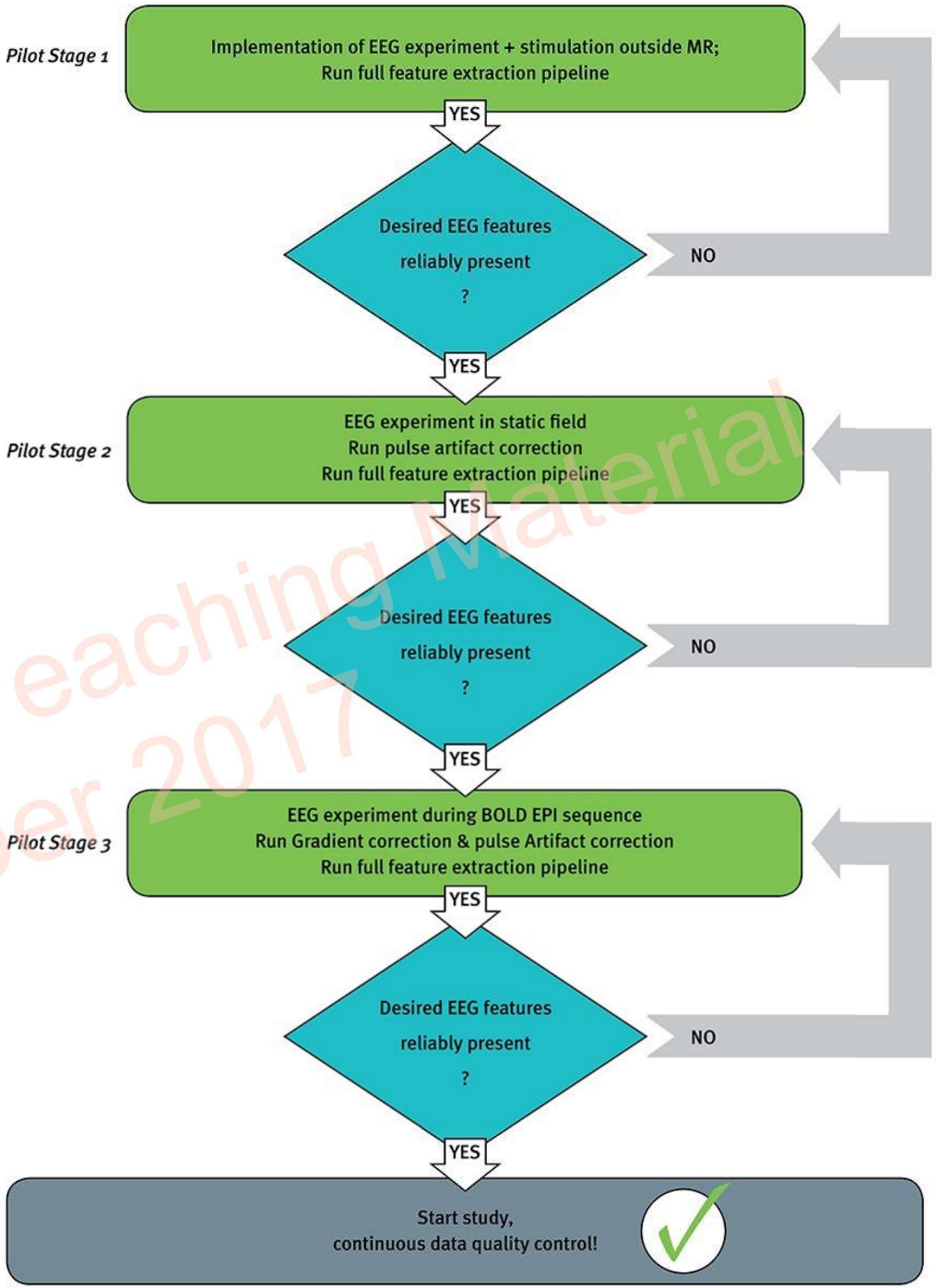
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Simultaneous EEG and BOLD fMRI: Best setup practice in a nutshell

Brain Products / March 23, 2016

by Dr. Robert Störmer, Dr. Mario Bartolo, Dr. Stefania Geraci and Dr. Tracy Warbrick (Brain Products' Technical Support Team)

http://pressrelease.brainproducts.com/eeg-fmri/



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And finally…

If you have any questions about ***EEG-fMRI data handling*** please contact us: **techsup@brainproducts.com**

If you have any questions about analyzing your data in Analyzer***, for non EEG-fMRI topics***, please contact us: **support@brainproducts.com**

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