جامعة نيويورك أبوظبي NYU ABU DHABI	STANDARD OPERATING PROCEDURE FOR BRAIN PRODUCTS BRAINAMP MR PLUS EEG SYSTEM WITH SIMULTANEOUS MRI ACQUISITION INSTRUCTIONS	CTP_MRI_001	
		PO#:	Issue: [0.1]
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		Location: [A2, GF, 014]	

SCOPE OF DOCUMENT: Basic Operating Procedures for the Siemens 3T Prisma MRI Scanner located in A2 Building

Table of Contents

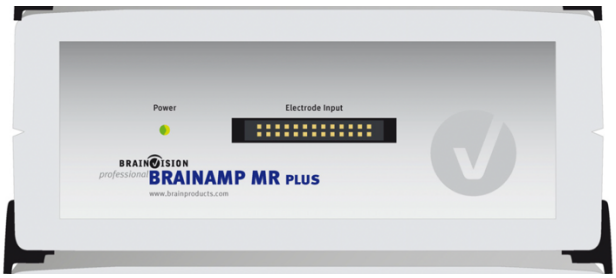
1. *Emergency Contacts*

In the event of an emergency relating to the MRI space, the following personnel should be contacted:
MRI Physicist: Osama Abdullah: 056-6793378 (mobile), email: oa22@nyu.edu
MRI Technologist: Haidee Paterson: 050-8218598 (mobile), email: hp42@nyu.edu
MEG Scientist: Hadi Zaatiti: 056-2754921 (mobile), email: hz3752@nyu.edu
Facilities Management: via EFS Helpdesk 02-628-8888 option 3 or contact the Security Desk located in the building lobby

2. *Components of the Brain Products Brain Amp MR Plus System inside MRI scanner room*

2.1 Amplifiers

2 x BrainAmp MR plus (32 channels each)



Front view

Rear view

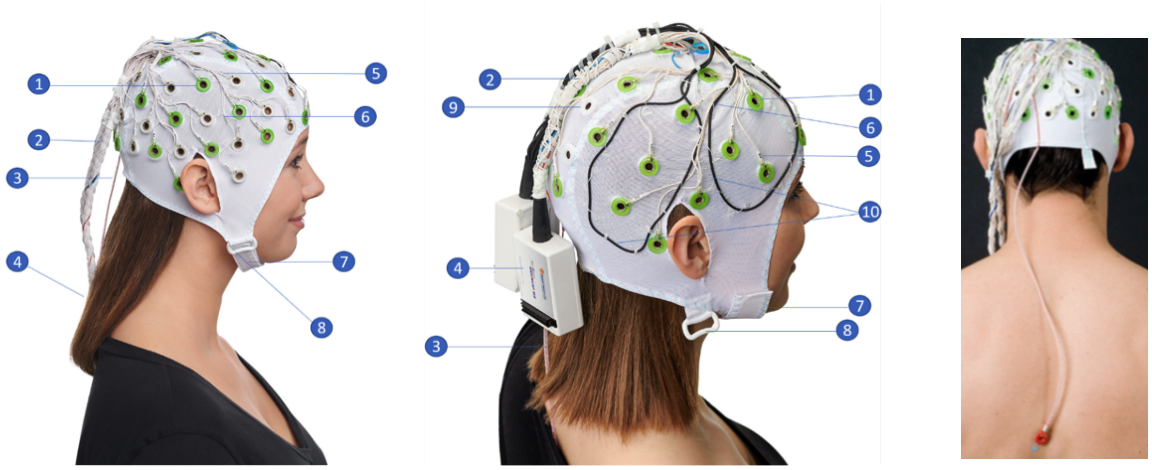
2.2 PowerPack

Front view

Rear view

2.3 Electrodes and Cap

2 x BrainCap with ECG electrode (56cm and 58cm)



1 Multitrodes for MR
- Sintered Ag/AgCl sensors

2 Cable tree
- All lead wires are bundled tight together as they leave the cap.

3 ECG electrode
- Covered with a plastic sheath to prevent the cable touching the skin.

4 Connector box
- Includes current limiting resistors

5 Name labels on every electrode for easy recognition

6 Electrode cables are routed on the outside of the cap and secured to avoid loops and cable movement

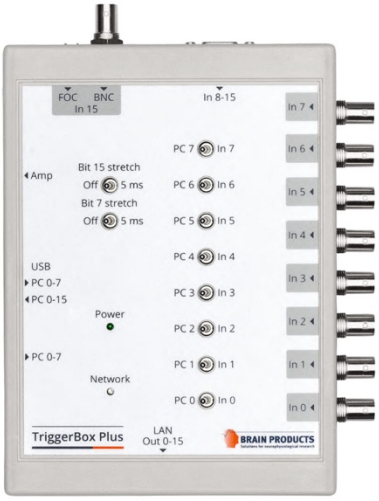
7 Chin strap

8 Loop for chest belt (chest belt not shown)

3. Components of the Brain Products Brain Amp MR Plus System outside MRI scanner room

3.1 Syncbox – extension box for phase sync recordings

3.2 Triggerbox Plus



The TriggerBox Plus helps to handle and merge triggers arriving from different sources

3.3 USB 2 Adapter BUA

The USB 2 Adapter (also known as BUA) serves as a USB interface to connect any BrainAmp amplifier with the recording computer

4. Safety considerations when performing simultaneous acquisition of EEG and fMRI

4.1 System Users

- All simultaneous acquisition of EEG and fMRI is performed within the MRI environment in the presence of a powerful magnetic field (3 Tesla)
- All MR safety rules prescribed by the MRI radiographers/physicist must be observed at all times
- All people involved in using the BrainAmp MR plus in an MR environment must an MR authorized person or MR operator or be supervised by the aforementioned

4.2 Product labeling

- All components of the MR series of amplifiers carry a label related to their safety properties in the MR environment
- Equipment that is labeled as **MR unsafe** must not enter the MR scanner room
- Only use **MR conditional** or **MR safe** equipment in the MR scanner room
- All the EEG equipment in the MR lab has been labelled appropriately and must be **strictly adhered to**

MRI Safety Symbols Table

Symbol	Term	Definition
	MRI safe	An item that poses no known hazards in all MRI environments. "MRI safe" items include non-conducting, non-metallic, and non-magnetic items.
	MRI conditional	An item that has been demonstrated to pose no known hazards in a specified MRI environment with specified conditions of use. Field conditions that define the MRI environment include static magnetic field strength, spatial gradient, dB/dt (time-varying magnetic fields), RF fields, and specific absorption rate (SAR).
	MRI unsafe	An item that is known to pose hazards in all MRI environments.

4.3 Head coil for combined EEG-fMRI with cable duct

The Siemens Head/Neck 64ch coil is the coil of choice for fMRI/EEG experiments as this coil makes it possible to route the connecting cables between the EEG cap and the amplifier in a straight line, thus preventing any loops or curves.

4.4 Protecting the amplifier from damage

Even though the primary goal is to protect the participant from electrode or cable heating, care must be taken to protect the EEG equipment from damage due to gradient field-related eddy currents and RF-heating.

The system components that are particularly sensitive to eddy current induced heating include:

- Conductive surfaces inside amplifier housing
- Conductive components inside PowerPack

The mechanism of eddy current induced heating include:

- MR sequences using parameters outside of our guidelines for simultaneous EEG-fMRI
- Incorrect amplifier placement, e.g., off-center placement

The system components that are particularly sensitive to RF-heating include:

- EEG electrode protection resistors
- Protection resistors in the cap connecting box
- The protection circuits at the amplifier input stage

The mechanisms of RF overload include:

- MR sequences using parameters outside of our guidelines for simultaneous EEG-fMRI
- Incorrect setup geometry, e.g. off center or orthogonal cable routing, cable loops
- Electrically unterminated channels

4.5 Permitted sequences: specification of sequence conditions

The EEG system is intended for simultaneous acquisition of EEG and BOLD fMRI. Imaging sequences such as DTI, ASL, and FLAIR are not permitted with our system. Imaging sequences with RF inversion pulse, such as spin echo sequences, are also not permitted.
We recommend a maximum B1+rms (B1+rms is a metric used to quantify the amount of radio frequency (RF) magnetic field that is generated by the RF transmit coil for a specific pulse sequence and is expressed in units of µT) for MRI sequences used for simultaneous EEG-fMRI measurements. The B1+rms parameter is related to minimizing the risk of RF-field related heating of electrode lead wires and cables.

Maximum allowed B1+rms values for 3 T and different caps	
Former standard BrainCap MR (prior to revision 3)	Max. B1+rms = 1 µT
Standard BrainCap MR (revision 3)*	Max. B1+rms = 1.5 µT
R-Net MR	Max. B1+rms = 1.5 µT

4.6 Gradient field parameter specifications

The formation of eddy currents within the EEG system can be minimized by:

- Reducing the surface area that the gradient field forces act upon. There are two types of spatial gradients: the phase encoding gradient and the frequency encoding gradient. The frequency encoding gradient pulses are stronger and more frequent than the phase encoding gradient pulses. The frequency encoding direction is perpendicular to the phase encoding direction. To reduce the surface area that the frequency encoding gradients act on, only left-right frequency encoding direction and anterior-posterior phase encoding direction is permitted
- Proper placement of amplifiers and PowerPacks. We recommend placing the components of the EEG system in the z-isoline of the scanner bore where the gradient magnetic fields are the most homogenous. Magnetic inhomogeneities near the scanner bore walls leads to change in magnetic fields, which contribute to the induction of eddy currents in the amplifiers
- Minimize the strength of the gradient switches. Do not run high performance or fast gradient modes

4.7 Cap and electrode preparation

- Minimize the impedance at **all** electrodes, there should be no electrodes that are not connected to the participant, this is for safety reasons. An impedance of < 100 kOhm indicates that the channel is not open
- Make sure there are no loops in connection cables or electrode leads.
- Caps and electrode nets must be used in the exact configuration in which they were supplied

5. Capping

5.1 Impedance

In the context of EEG (electroencephalography), impedance refers to the opposition to the flow of electrical current between an electrode and the scalp. It is measured in Ohms (Ω) and is a critical parameter that reflects the quality of the electrical connection between the electrodes and the skin.

5.2 Preparation of the BrainCap MR

This should be done outside of the scanner room. It is only necessary to go into the scanner room once you are ready to begin your simultaneous EEG-fMRI measurements. Make sure you have everything that you need to be able to do the BrainCap MR preparation and impedance check outside of the scanner room:

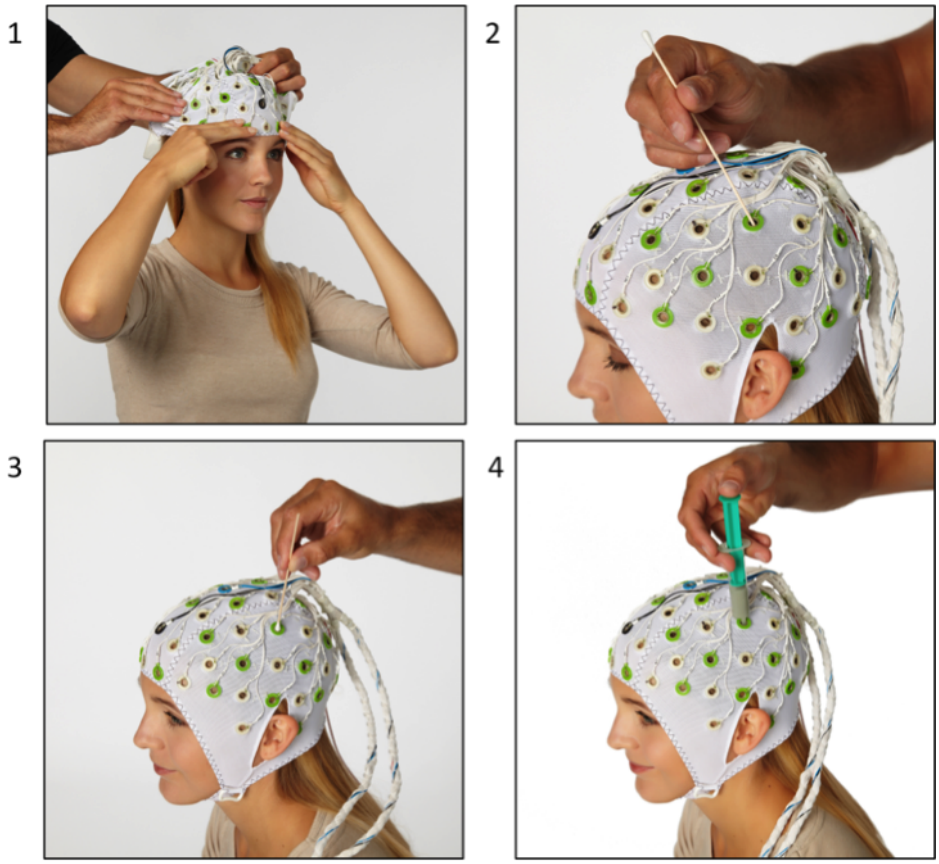
- BrainCap MR
- BrainAmp system (including USB2 Adapter, but the SyncBox is not necessary)
- Laptop with Recorder installed and a workspace for your cap loaded
- Preparation materials – as below

a. Abralyt HiCl abrasive electrode gel
b. Cotton swabs
c. Toothbrush
d. Measuring tape
e. Adhesive 8mm washers
f. Applicators
g. Syringes

The BrainCap MR system is delivered with short fibre optic cables in addition to the long (20 m) ones that you will need to use between the scanner room and the control room. These extra fibre optic cables allow you to do your impedance measurements outside of the scanner room while leaving the long fibre optics cables permanently installed in the scanner room. Furthermore, longer (100 cm) ribbon cables are provided to allow you to connect the BrainCap MR to the BrainAmp MR more comfortably for the impedance check. Note that these longer ribbon cables should only be used for preparation of the BrainCap MR and not in the scanner room, only the short (10 cm or 30 cm) cables should be used for EEG-fMRI measurements.

5.2 Positioning the cap

- First, measure the circumference of your participant's head and if you have multiple caps available, choose the cap size closest to the measurement
- To place the cap on the participant's head, start from the forehead and gently pull the cap backwards over the head. The participant may assist you by holding the front of the cap in place
- Measure the distance from nasion to inion and adjust the electrode position Cz so that it is halfway between nasion and inion
- The frontopolar and occipital electrode positions should now be in the correct place. When measured correctly, the frontopolar electrodes (e.g. Fp1/Fp2) should lie directly above the eyebrows. If they do not, choose another cap size if you have one available
- Then make sure that Cz is right-left-centred, and that lateral electrode positions are symmetrical
- The ears should be pulled out of the slits completely to allow the cap to fit snugly onto the skin behind the ears
- The cap can be fixed with the chin strap or with a chest belt. With both methods only minimal tension is necessary

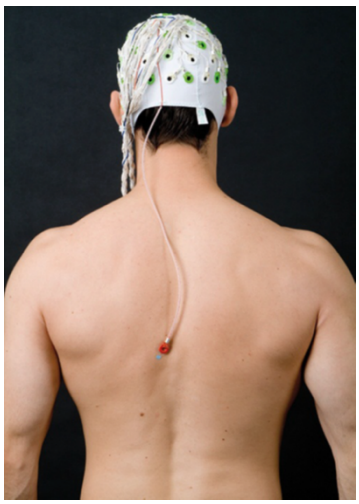


(**1**) Place the cap on the participant's head by starting from the forehead and gently pulling the cap backwards over the head. The participant may assist you by holding the front of the cap in place.
(**2**) Move the hair aside using the wooden end of the cotton swab.
(**3**) Dip the cotton end of the swab in Abralyt gel and gently twirl the stick between your finger and thumb abrade the skin.
(**4**) Fill the space between the skin and the electrode with Abralyt gel using the syringe.

- With the wooden end of the cotton swab push the hair aside until the skin is clearly visible (Figure 2 part 2)
- Dip the cotton swab into alcohol and degrease the scalp through the electrode opening by twirling the swab between thumb and index finger (Figure 2 part 3)
- Dip a second swab into the Abralyt gel and twirl on the skin. Apply only very low pressure with the swab to avoid damaging the skin.
- Using the syringe, completely fill the space from skin to electrode with the Abralyt gel (Figure 2 part 4). Draw the syringe back (from skin to electrode) as you fill the space to prevent electrolyte from spreading underneath the adaptor rim and forming a bridge to adjacent electrodes. This is particularly important when electrodes are close together.
- Fill all electrodes with gel before checking impedances using the impedance mode in the Recorder software. Make sure that the ground and reference electrode have very good impedances. This will significantly facilitate good impedance at the remaining electrodes.
- If the impedance values are not at the required level when you first check them, you can use the cotton end of the swab to gently abrade the skin a little more.
- Add more gel if necessary, but be careful not to overfill
- If you have difficulty reducing the impedance to the required level, wait for a few minutes before continuing to abrade with the cotton swab. Impedance can improve over time as the electrolyte soaks through the hair and makes a better connection between the skin and electrode.

5.3 Positioning the ECG electrode

- Before attaching the ECG electrode degrease the skin using alcohol.
- Use an adhesive washer to attach the ECG electrode holder to the participant's skin.
- The ECG electrode leaves the cap at the occipital pole and should be attached to the back of the participant along the paravertebral line. It should be positioned as far down as permitted by the lead length (see Figure 3).
- The lead wire should not be taut, it should allow the participant to move their head a little to ensure that the ECG lead is not pulled and dislodged by any movements that might be made by the participant e.g. when they move from the preparation room to the scanner room.
- Once the ECG electrode is in place you can abrade the skin using a cotton swab and Abralyt and then fill with gel in the same way as described for the EEG electrodes.



The ECG lead exits the cap at the occipital pole (**1**) and should be attached to the back of the participant as far down as permitted by the lead length along the paravertebral line (**2**). The lead wire should not be taut (**3**), it should allow the participant to move their head a little to ensure that the ECG lead is not pulled and dislodged by any movements that might be made by the participant.

Connecting to the BrainAmp MR

The front panel of the BrainAmp family of amplifiers has a socket marked 'Electrode Input' for connecting elec- trode caps using the supplied connection cables. For the impedance check during preparation use the long (100 cm) ribbon cable and for recordings in the scanner use the short bundled (10 cm) cable. The plugs on the con- nection cables are fitted with clamps and are self-locking.

a. Ensure that the clamps are open before you insert the plug (see Figure 4 part 1). As soon as you push the plug into the socket, the clamps automatically engage to prevent the plug from becoming disconnected inad- vertently, e.g. if the cable is pulled.
b. Always ensure that the plug is pushed home fully; the clamps must be engaged and point outwards (see Fig- ure 4 part 2).
c. Furthermore, the connectors on the ribbon cables feature arrows indicating the orientation in which the con- nector must be plugged into the socket. Ensure that the arrow on the plug is aligned with the arrow on the 'Electrode Input' socket (see Figure 5).
d. To remove the plug from the socket, press both clamps at the same time. The plug is released automatically.

The other end of the connection cable should be connected to the connector box on the BrainCap MR. If you are measuring with more than one amplifier, make sure that the connector boxes are connected to the amplifiers in the correct order. For example, for a 64 channel EEG recording channels 1-32 should be connected to amplifier 1 and channels 33-64 should be connected to amplifier 2. If you are using CWLs the connector for the CWLs must be connected to the BrainAmp ExG MR.

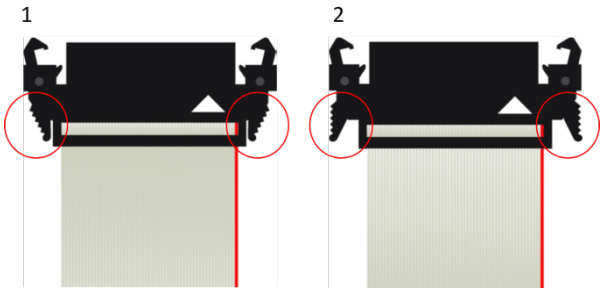


Figure 4: Plugs on the BrainAmp connection cables:

e. (**1**) the clamps are open and the plug is ready to be inserted into the socket on the BrainAmp MR front panel or the BrainCap MR connector box.
f. (**2**) the clamps are engaged, indicating that the plug is properly connected.

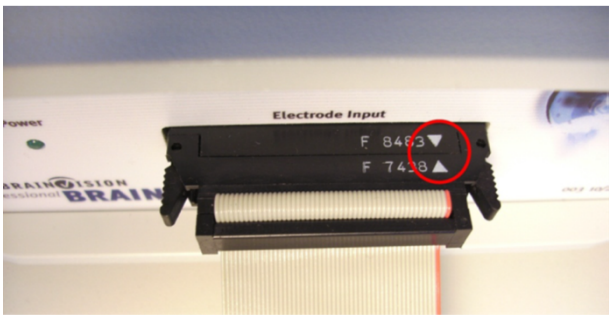


Figure 5: Arrows on the plugs of the connection cables and on the amplifier socket indicating the orientation in which the two should be connected.

Positioning the participant in the head coil

We recommend that a head coil with a space specifically for the EEG cable is used (Figure 6). Further details regarding our recommendations for head coils that are appropriate for EEG-fMRI can be found in the document 'Performing simultaneous EEG-fMRI measurements - Conditions for the safe use of BrainAmp MR amplifiers and accessories in the MR environment', available for download on the Brain Products website at https://www.brainproducts.com/downloads.php?kid=5#dlukat_84.

Once the participant is comfortably positioned in the head coil make sure that the cable tree runs straight and taught as it leaves the head coil (Figure 6). If there is space, padding can be used around the participant's head for comfort and to minimise movement. Be careful not to trap the EEG cables between the top and bottom parts of the head coil when putting the top part of the head coil in place.

Figure 6: The Brain Cap MR positioned appropriately in a head coil.

g. (**1**) cable duct specifically designed for the EEG cables. The head coil in the image is the Siemens Head/Neck 64 channel coil.

h. (**2**) the cable tree should be straight and taught as it leaves the head coil.

Cleaning and rinsing the BrainCap MR

i. Fill a plastic bowl with lukewarm water. Do not use hot or boiling water. Do not use a metal bowl as this can cause damage to the sensitive electrodes.

j. Place the BrainCap MR in the water bath and let it soak for approx. 10 minutes.

k. Gently clean the electrodes with a toothbrush to remove any residue. If the electrodes are particularly dirty, you can use a mild cleaning agent. However, note that many dishwashing agents can leave a film on the elec- trodes. Baby shampoo is the most suitable product.

l. Turn the BrainCap MR inside out and repeat step 3.

m. Cover the connector box(es) with a towel, then remove BrainCap MR from the bowl.

n. Rinse the BrainCap MR by filling the bowl with clean, lukewarm water and submerge the electrode cap for about one minute. Repeat as necessary to remove any residue left by the cleaning agent. You may also run the cap under a gently running tap to remove any residual cleaning agent.

o. Remove the BrainCap MR from the bowl and put it onto a clean, dry towel, and gently pat to remove excess water.

p. Turn the BrainCap MR inside out and repeat step 7.

q. If necessary, you can wipe the electrode cables and splitter box using a damp cloth.

10. Hang the BrainCap MR to dry on a drying rack or place it on a dummy head.