Video Article

Functional Mapping with Simultaneous MEG and EEG

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Abstract

We use magnetoencephalography (MEG) and electroencephalography (EEG) to locate and determine the temporal evolution in brain areas involved in the processing of simple sensory stimuli. We will use somatosensory stimuli to locate the hand somatosensory areas, auditory stimuli to locate the auditory cortices, visual stimuli in four quadrants of the visual field to locate the early visual areas. These type of experiments are used for functional mapping in epileptic and brain tumor patients to locate eloquent cortices. In basic neuroscience similar experimental protocols are used to study the orchestration of cortical activity. The acquisition protocol includes quality assurance procedures, subject preparation for the combined MEG/EEG study, and acquisition of evoked-response data with somatosensory, auditory, and visual stimuli. We also demonstrate analysis of the data using the equivalent current dipole model and cortically-constrained minimum-norm estimates. Anatomical MRI data are employed in the analysis for visualization and for deriving boundaries of tissue boundaries for forward modeling and cortical location and orientation constraints for the minimum-norm estimates.

Protocol

1. Check system tuning and data quality

1. Check the tuning of the MEG system. Use the tuning and noise measurement software provided with the MEG system to check that all channels are properly tuned and that the average noise level is below 3 fT/cm or 3 fT on planar gradiometer and magnetometer MEG channels, respectively.
2. Collect a segment of empty room data. Acquire data with the shielded room void of subject for 5 minutes for quality assurance and noise estimation.

2. Set up the stimuli and data acquisition parameters.

1. Set up the somatosensory, auditory, and visual stimuli using a stimulus computer, projector installed outside the shield room, and a somatosensory electric stimulator (Grass Model S88).

3. Subject preparation

1. Before an MEG/EEG study, each subject must fill out several forms regarding safety and consent.
2. Check that subject is free of magnetic materials. Bring the subject into the shielded room and start MEG data acquisition to check that the data does not contain signs of magnetic artifacts. If necessary, use a degausser to reduce artifacts from magnetic objects in the body such as dental work.
3. Put on EEG cap, inject conducting gel, and check the impedances. The impedances should be below 10 kOhms.
4. Put on EOG electrodes and the reference electrode.
5. Put on head-position indicator (HPI) coils. Position the four HPI coils so that they will be under the area covered by the MEG sensor array and far away from each other.
6. Digitize fiducial landmarks, HPI coils, EEG electrodes, and head shape.
7. Move the subject into the scanner.

4. Data acquisition for each sensory modality

1. Set up stimulation protocols on the stimulus computer. For the somatosensory median-nerve stimulation, attach the electrodes on the left and right wrists and gradually increase the stimulus intensity so that the stimulus level exceeds the motor threshold. For the auditory stimulation, insert the earphones and check that the stimulus level is appropriate. For the visual stimulation, position the back-projection screen in front of the subject and check that the stimulus is correctly presented.
2. Start data acquisition and check data quality. On the raw data display, check that all channels are functioning properly and do not contain any artifacts.
3. Measure the head position. Invoke the head position measurement from the acquisition console and check that the results meet the specifications imposed by the software.
4. Start saving of raw data and on-line averaging.
5. Start stimulus delivery
6. Once all stimuli have been presented, save raw data and on-line averages.

5. Data analysis

In the data analysis, we will use anatomical MRI data for visualization of the results, for determining the shapes of tissue compartments for forward modeling, and for constraining the MEG/EEG data to the cortical surface. We use both the current dipole model and a distributed cortically constrained minimum-norm solution in the analysis. The workflow of the distributed source analysis is shown in Figure 1.

Figure 1. Overall workflow for analyzing MEG/EEG using cortically-constrained minimum-norm estimates.

Discussion

Magnetoencephalography (MEG) and electroencephalography (EEG) are the only non-invasive methods to record brain activity with a fine temporal resolution. MEG is especially well suited for studying cortical activity. This article demonstrates combined MEG/EEG data acquisition and analysis to determine brain activity associated with the processing of simple sensory stimuli. These type of experiments are used both in basic neuroscience and clinical studies. If the brain activation is focal, the current dipole model applies and the location of the activity can be determined with an accuracy of about 5 mm. In more complex situations, cortically-constrained source estimates can be employed to reveal the spatiotemporal patterns of activation. These models employ anatomical MRI data for visualization, determining the geometry of tissue compartments for forward modeling, and for cortical location and orientation constraints.

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