How to get quality ABR and ASSR recordings

Problem: Signal vs. Noise

An evoked potential is an electrical potential recorded from the nervous system of a human or animal following presentation of a stimulus.

Examples of evoked potential responses to auditory stimulus: ABR (Auditory Brainstem Response), ASSR (Auditory Steady-State Response).

When we record evoked potentials using surface electrodes, we also record a lot of noise along with the signal. In ABR and ASSR tests response (signal) is very weak, usually measured in nV (nanovolts). At the same time, noise in the recording is measured in tens and hundreds of µV (microvolts). Finding the signal in all this noise is like finding the proverbial needle in a haystack. So, how do we find that signal?

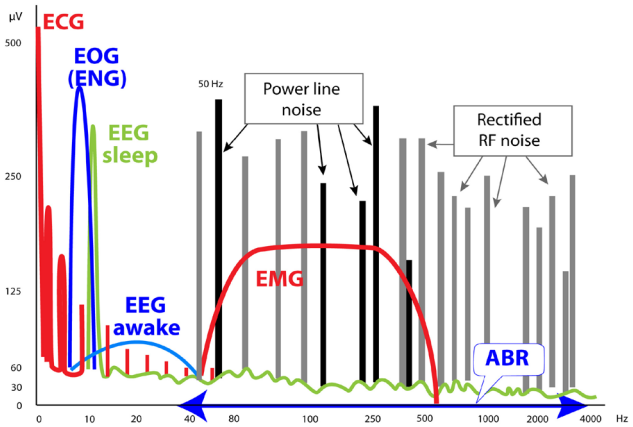

Fig.1. Possible sources of noise for ABR, by amplitude and frequency

Types of noise

- Physiological
  - EEG
  - ECG
  - EOG (ENG)
  - EMG
- Electromagnetic
  - Power line noise: 50/60 Hz and their harmonics
  - Electric field noise
  - Magnetic field noise
  - Radio-frequency (RF) interferences

Solutions

Preparing the environment

- Proper grounding of the test facility (to reduce the initial level of interference), or, ideally, using an electromagnetic shielded room
- Turning off strong sources of electromagnetic and RF interference (magnetic induction loops for hearing aids, radios, mobile phones, TVs)
- Placing device as far away as possible from the sources of electrical interference (unshielded fluorescent tubes, lamps, cables carrying power, other electronic devices)
- Reducing the ambient acoustic noise level (especially for threshold search and PTA), or, ideally, using a soundproof room; as an alternative, using TDH-39 acoustically shielded headphones or insert phones
- Using the battery-powered notebook (disconnected from the power source)

Neuro-Audio hardware features

- Low level of amplifier noise
- High common-mode rejection ratio
- High amplifier impedance
- Good galvanic isolation

Neuro-Audio software features

- Digital filtering (in the frequency range of the signal)
- Notch filter (eliminates power line noise)
- Coherent averaging (cancels out all noise not time-locked to stimuli)
- Weighted averaging (saves time, reduces the influence of artifacts on results)
- “Minimize Interference” algorithm (works for stimulation rate below 30 Hz)
- Using advanced stimulus (chirp) to increase response amplitude

What can the doctor do?

- Preparing the patient (should be asleep, or relaxed and calm, with eyes closed, preferably lying down on a comfortable bed)
- Achieving recommended electrode impedance values (below 2 kOhm)
- Reducing loop area (keeping the electrode wires together)

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- Loosely “braiding” the electrode wires together
- Not moving the electrode wires during the recording
- Using odd stimulation rate: i.e., 11 Hz instead of 10 Hz
- Using lower stimulation rate (10-21 Hz) produces better response morphology
- Don’t talk or otherwise distract the patient during the test

Electrode placement

Types of electrodes:

- Reusable (cup) – more difficult to apply
- Disposable – easier to apply, single use only

Applying an electrode to the skin:

1. Clean electrode skin sites with an alcohol wipe (alcohol prep pads).
2. Abrade skin with a mild abrasive solution (NuPrep, for example). Wipe off any excess solution.
3. Apply some conductive electrode paste or gel (Ten20, for example) to reusable electrodes. Disposable electrodes are ready to apply on prepared skin (pre-gelled).
4. Apply the electrodes to the skin. Tape can be used to secure the reusable electrodes in place on the skin.

After an appropriate preparation the skin may become a little red, and you should get very low impedances (0.5-2 kOhm).

Be careful not to damage the skin!

Neonates. Observe and comply with any local protocol that may limit the agents and techniques used in preparing electrode sites in neonates. Some clinicians use only the alcohol pads to prepare skin on neonates (age 0-3 months).

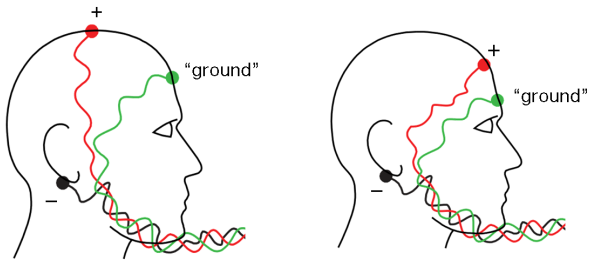

Fig. 2. Electrode placement for ABR and ASSR (left: Cz-M; right: Fpz-M)

Inverting (–): mastoid (M) or earlobe.

Non-inverting (+): vertex (Cz) or high forehead (Fpz)

Ground: forehead.

Usually, 2 channels are used for ABR and ASSR recording. In this case, 4 electrodes are used: non-inverting (+) is connected by pup-jack linker (Y-adapter) to both + inputs on the **Neuro-Audio**.

With two-channel placement, it’s important to connect left mastoid to 1st channel and right mastoid to 2nd channel. This way, the software will correctly differentiate ipsilateral and contralateral traces.

Post-auricular muscle (PAM) reflex

The PAM contracts in response to moderately loud sounds. The PAM artifact usually occurs at 10-14 ms and has a large amplitude. It can easily be avoided by routinely using earlobe electrode placement instead of mastoid one. Also, since it is caused by muscular tension of the neck or the jaw, it is a good idea to use a pillow for comfort. If the room is cold, offer a blanket at the beginning of the test, since in a cold environment you have a tendency to tense up. Patient comfort is key to keeping PAM artifact to a minimum.

New adaptive notch filter

Usually notch filter is not recommended to use during recording, only to find out if the source of interference is really the power line. Often higher harmonics of the mains frequency also contaminate the recording. **Neurosoft** software uses new adaptive notch filter by default. It has really useful features:

- No signal distortion (safe to use during recording)
- Dynamic tracking of mains frequency (50/60 Hz)
- High harmonic filter (100/120 Hz and higher)

Harmonics of main power supply frequency:

- 60 Hz AC: 60, 120, 180, 240, 300, 360, 420 Hz …
- 50 Hz AC: 50, 100, 150, 200, 250, 300, 350 Hz …

Radio-frequency (RF) noises

Even though RF signals have much higher frequencies than ABR – in the Megahertz (MHz) and Gigahertz (GHz) ranges – they are introduced in the differential amplifier due to its non-linearity through a phenomenon called rectification. Common-mode rejection is ineffective above 20 kHz and does not protect against RF interferences. Moreover, if RF interferences rectify into the ABR frequency range, they can’t be filtered out by the bandpass filter and will contaminate ABR response.

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Mains electricity by country

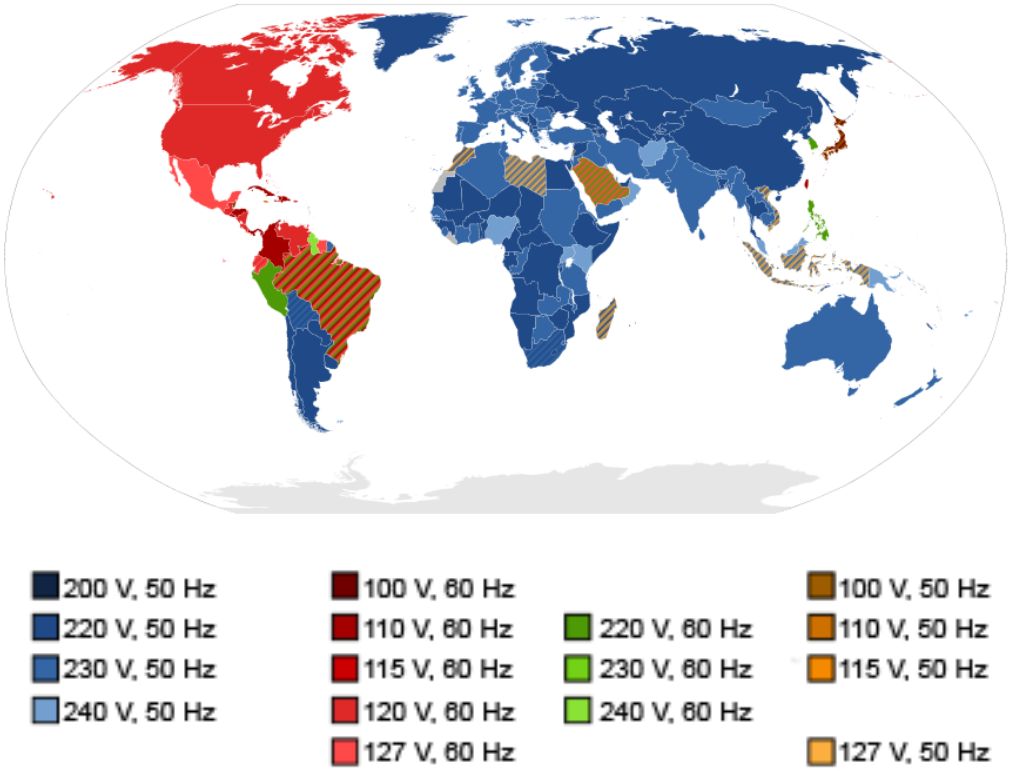

Fig. 3. Mains electricity voltage and frequency (World map); from Wikipedia

It is important to set correct mains frequency for your country in the software settings (menu Setup|Change..., Hardware page, Mains supply frequency (Hz))

Abbreviations

ABR – Auditory Brainstem Response
AC – Alternating current
ASSR – Auditory Steady-State Response
ECG – Electrocardiography
EEG – Electroencephalography
EMG – Electromyography
ENG – Electronystagmography
EOG – Electrooculography
PAM – Post-auricular muscle
PTA – Pure-tone audiometry
RF – Radio-frequency