EE 791 Lecture 6B

EEG Recording

Feb 23, 2015

EEG Hardware

- High impedance (20 MΩ) AC-coupled differential amplifier/filter per channel
- Standard gold or silver cup electrodes with chloride paste
- Recording and display/storage system
- First analog chart recorder (limited bandwidth)
- Now PC based running under windows showing typically 30 sec epochs
- Sampling rate 200 Hz, 500 to 1 kHz for event related potentials

EEG Recording

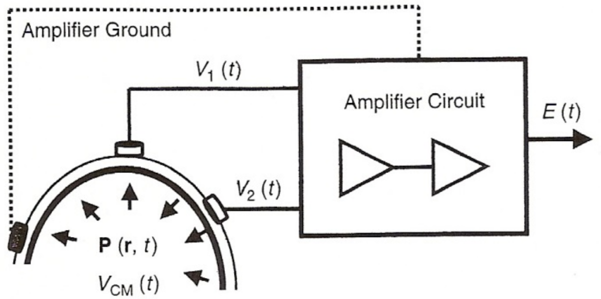


Figure 7-2 Brain mesosources $\mathbf{P}(\mathbf{r}, t)$ generate scalp potential differences $V_2(t) - V_1(t)$. The potentials at scalp locations 1 and 2 are $V_1(t) + V_{CM}(t)$ and $V_2(t) + V_{CM}(t)$, respectively, where the common-mode potential $V_{CM}(t)$ is typically due mostly to capacitive coupling with power line fields. The amplifier circuit may contain several amplifier stages plus external circuit elements. The EEG system is designed to reject the common-mode potential $V_{CM}(t)$ and amplify the potential difference between pairs of scalp locations such that the output voltage is proportional to scalp potential differences, that is, $E(t) \cong A[V_2(t) - V_1(t)]$, where A is the total system *gain*. The amplifier system makes no distinction between recording electrodes and the so-called EEG "reference electrode." By contrast, the (internal) ground electrode placed on the scalp, nose, or neck provides a reference voltage to the amplifier to prevent amplifier drift and to facilitate better common mode rejection.

The Amplified Signal

$$E(t) \cong A[V_2(t) - V_1(t)]$$

$$E(t) = \left(1 - \frac{Z_1 + Z_2}{2Z_{\mathrm{IN}}}\right)[V_2(t) - V_1(t)] + \left(\frac{Z_1 - Z_2}{Z_{\mathrm{IN}}}\right)V_{\mathrm{CM}}(t) + \vartheta\left(\frac{1}{Z_{\mathrm{IN}}^2}\right)$$

The EEG System

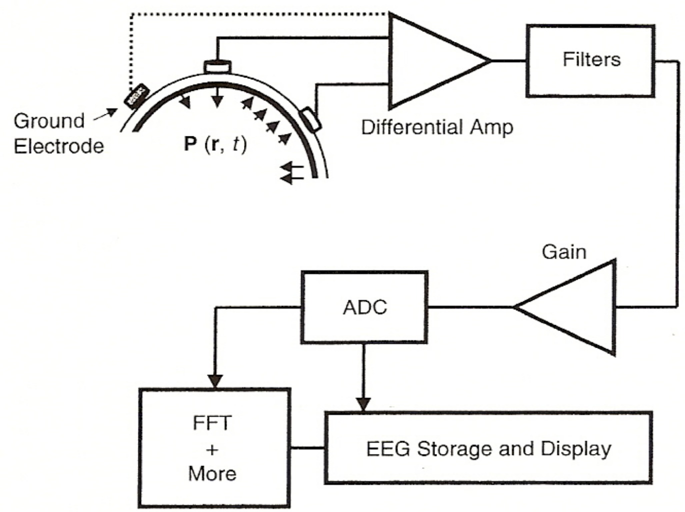
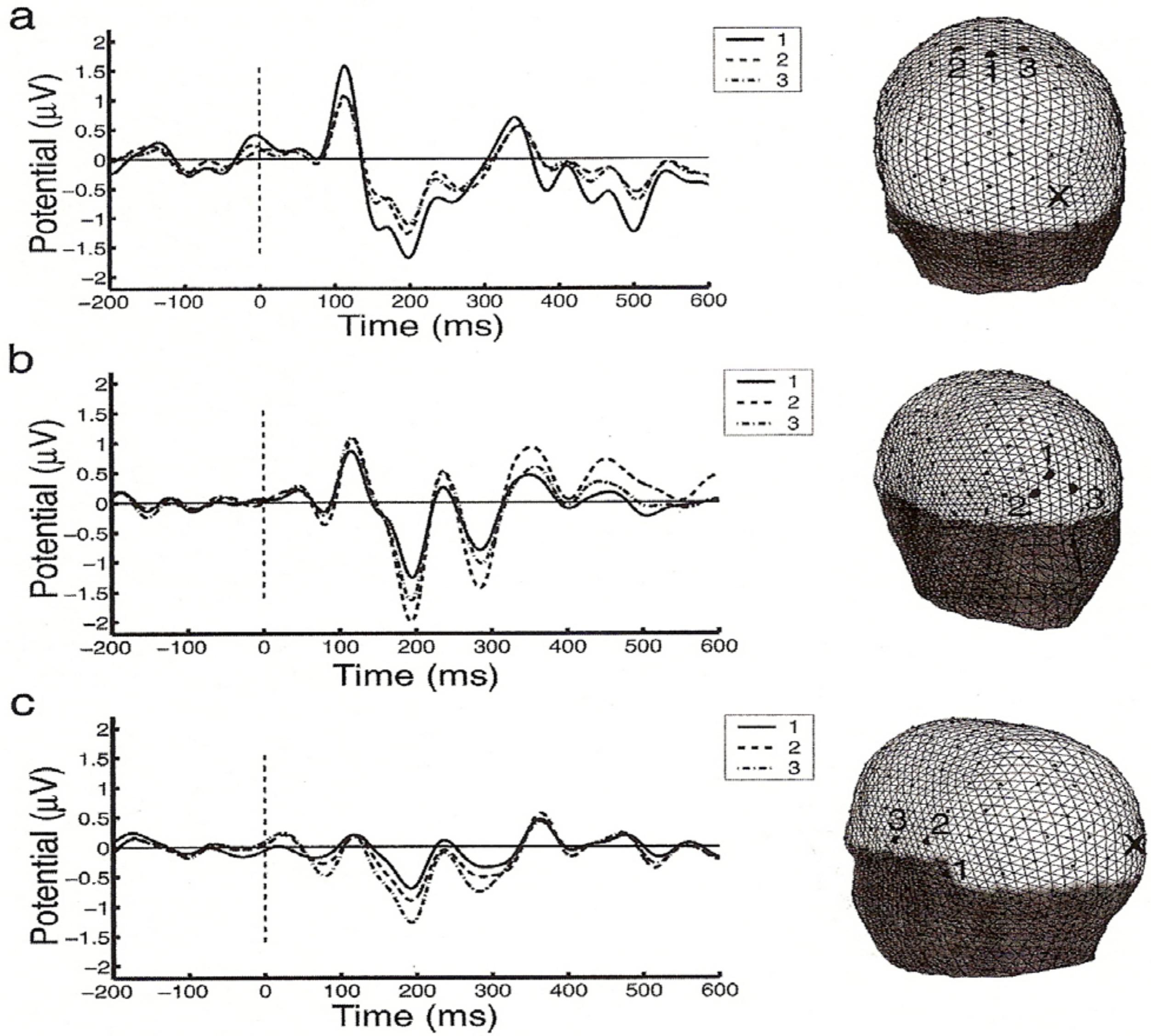


Figure 7-3 The major components of a typical EEG recording system. Electrodes record scalp signals due to brain current sources (arrows) that are passed through differential amplifiers sensitive to potential differences between electrode pairs and insensitive to the (generally much larger) spatially constant potentials over the scalp (common modes). Modern EEG systems record simultaneously from about 32 to 131 scalp locations. Analog filters low pass the input signal, typically removing substantial EEG power above about 50 to 100 Hz. High-pass analog EEG filters typically remove substantial power below about 0.5 Hz, depending on application and filter roll-off characteristics. A notch filter may or may not be used to remove power line frequencies (60 Hz in the US). The scalp potential difference signal is substantially boosted by amplifier gains. In modern EEG systems, the analog signals are sampled and numbers assigned to each part of the waveforms (ADC, analog to digital conversion). This step requires measuring ADC output produced by a calibration signal. EEG waveforms may then be displayed on a paper chart or computer screen and stored for additional processing, typically starting with application of fast Fourier transforms (FFT) to each data channel. Adapted from Cadwell and Villarreal (1999) and Fisch (1999).

Quest for an Ideal Reference

- No such thing as a monopolar recording (assumes reference has 0 EEG)
- Most common references are opposite ear, linked ear or mastoid placements, as well as the common average
- Can change reference to another location after recording by simple transformation
- Next figure shows VEP recorded at O2 with reference varying

The Ideal Reference



Distant Reference

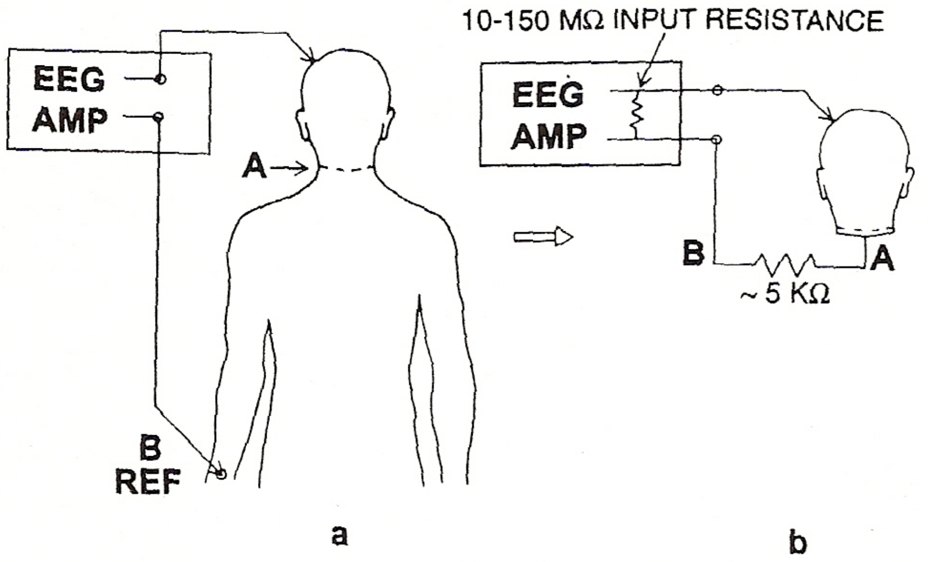
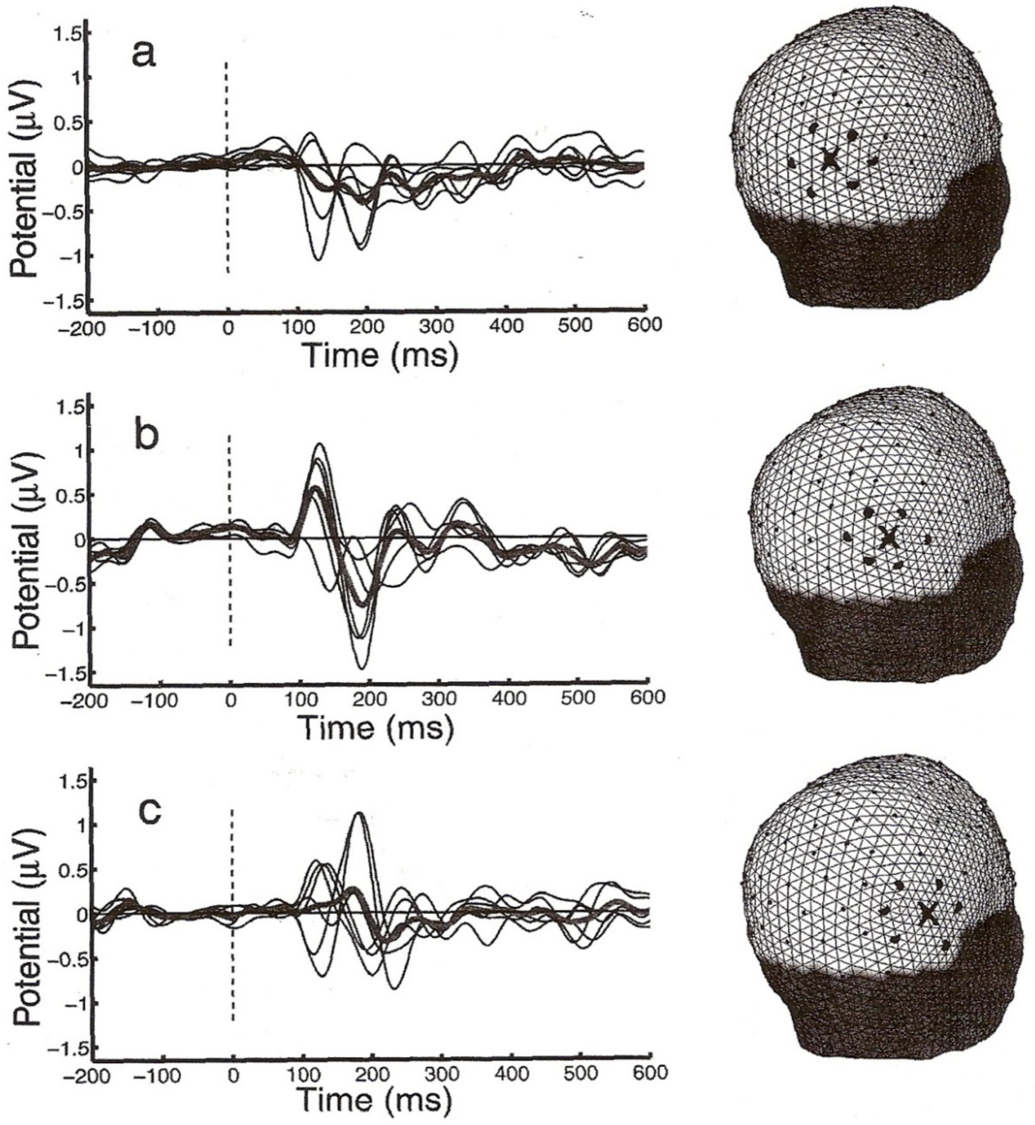
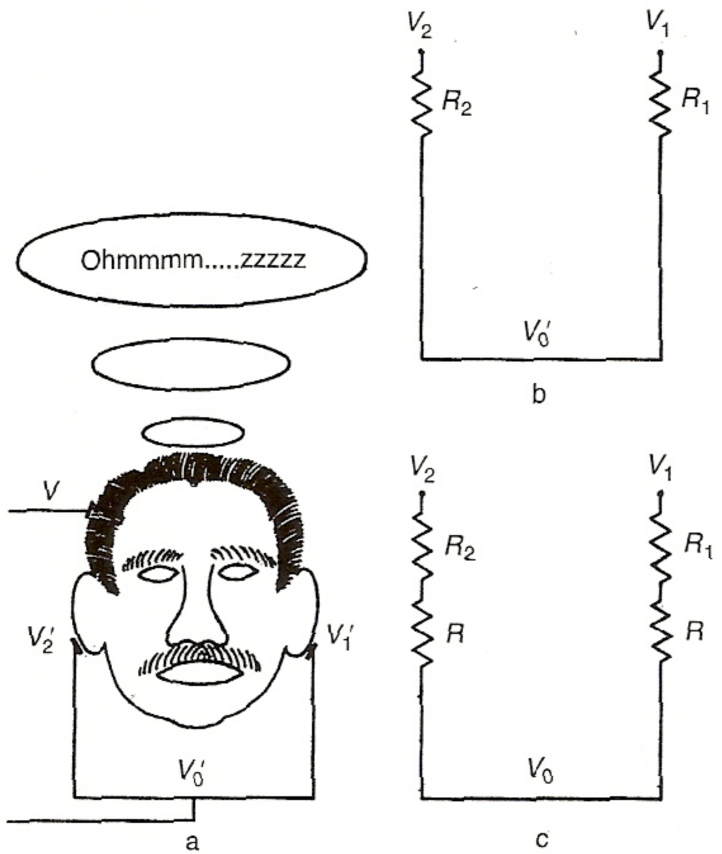


Figure 7-5 This figure addresses the general question—Can a "distant" reference for scalp EEG be found? (a) The physically distant reference at the hand (B) is electrically equivalent to a reference at the neck (A) with respect to sources in the head. The hand reference can be expected to pick up more EKG and other artifact. (b) The circuit equivalent to (a), but ignoring non-brain sources. Reproduced with permission from Katznelson (1981).

Bipolar Recording Effects



Linked Ear Reference



Common Average Reference

$$V_n = \Phi(\mathbf{r}_n) - \Phi(\mathbf{r}_R)$$

$$\frac{1}{N}\sum_{n=1}^{N} V_n = -\Phi(\mathbf{r}_R) + \frac{1}{N}\sum_{n=1}^{N}\Phi(\mathbf{r}_n)$$

$$\Phi(\mathbf{r}_R) = \frac{1}{N}\sum_{n=1}^{N}\Phi(\mathbf{r}_n) - \frac{1}{N}\sum_{n=1}^{N} V_n$$

Various References

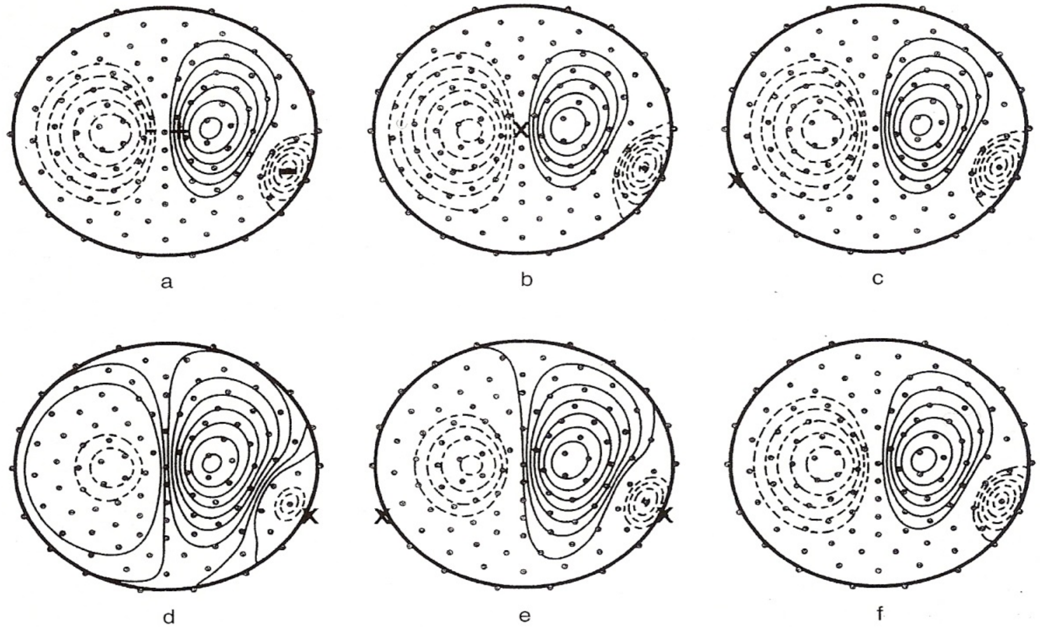


Figure 7-9 Potential maps on the surface of the 4-sphere head model due to two dipole sources – one radial at lower right and one tangential in the center. The tangential source is located 3.2 cm below the scalp; it has twice the strength of the radial dipole located 1.4 cm below the scalp. The four concentric spheres model parameters are given in fig. 6-5. Potentials were calculated at 111 surface sites, with nearest-neighbour separation of about 2.7 cm and subtending an angle of 109 degrees from vertex. The simulated electrode positions are indicated by small gray circles. Topographic maps of the potential distribution were obtained from a spline interpolation as discussed in chapter 8. (a) Potential map with respect to infinity. (b) Potential map with reference indicated by an X located at the vertex. (c) Potential map with reference X at the left mastoid. (d) Potential map with reference to a right mastoid electrode. (e) Potential map with respect to the mathematically linked (averaged) mastoids. (f) Average reference potential map obtained by first calculating the potentials at 110 electrode sites with respect to the vertex and then calculating the average reference using (7.10) with the first sum set to zero.

Spatial Sampling