Chapter 5: Basic Principles of ERP Recording Part 2

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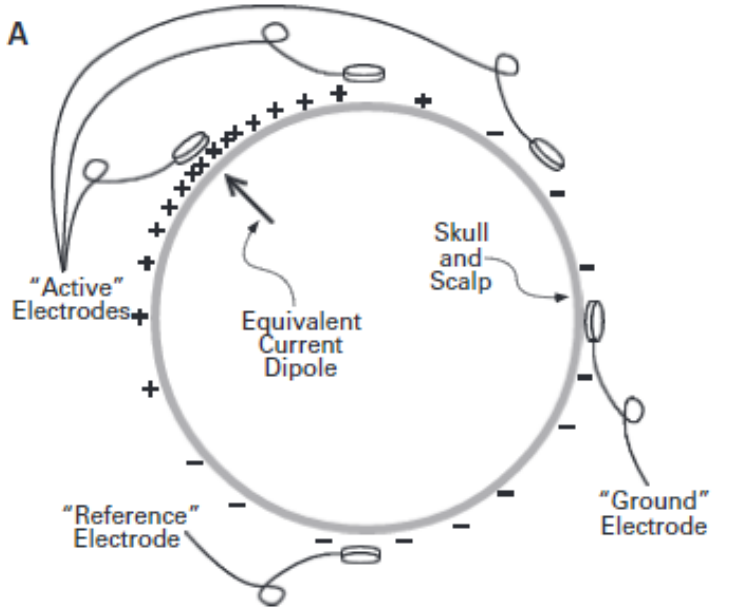
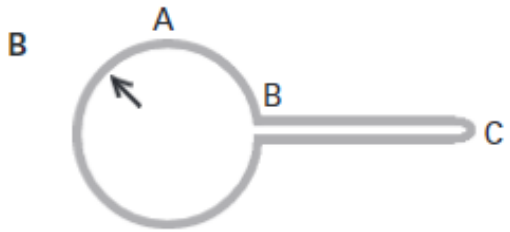
The Reference Electrode





- Differential amplifiers
  - A-G
  - R-G
  - [A-G] – [R-G] = A-R
- Common mode voltage
  - The electrical potential between the subject's body and the amplifier's ground circuit
- Common mode rejection
  - The ability of an amplifier to subtract away the common mode voltage accurately
  - Good amplifer = at leat 70dB

The Reference Electrode

- *The no-Switzerland principle* There is no electrically neutral site on the head or body. An ERP waveform therefore reflects the differ ence in voltage between two sites that both contain neural activity

Re-referencing Your Data Offline

- You can easily re-reference offline
- A-B = (A-R) – (B-R)
- Re-referencing process (Lm as initial reference)
  - a = A – Lm (original waveform for channel A)
  - r = Rm – Lm (Rm recorded)
  - a’ = A – ([Lm+Rm]/2) (what we are trying to compute)
  - = A – (Lm/2) – (Rm/2)

    = A – (Lm – [Lm/2]) – (Rm/2)

    = (A – Lm) – ([Rm – Lm]/2) = a – (r/2)
- Monopolar recordings vs. Bipolar recordings

The Average Reference

- *Average Reference* Re-referencing data to the average of all of scalp sites

$$a1 = (A1 - Lm)$$

$$a2 = (A2 - Lm)$$

$$a3 = (A3 - Lm)$$

$$\begin{aligned} avg(a1, a2, a3) &= (a1 + a2 + a3) \div 3 \\ &= [(A1 - Lm) + (A2 - Lm) + (A2 - Lm)] \div 3 \\ &= [(A1 + A2 + A3) - 3Lm] \div 3 \\ &= avg(A1, A2, A3) - Lm \end{aligned}$$

$$\begin{aligned} a1 - avg(a1, a2, a3) &= (A1 - Lm) - (avg[A1, A2, A3] - Lm) \\ &= A1 - avg(A1, A2, A3) \end{aligned}$$

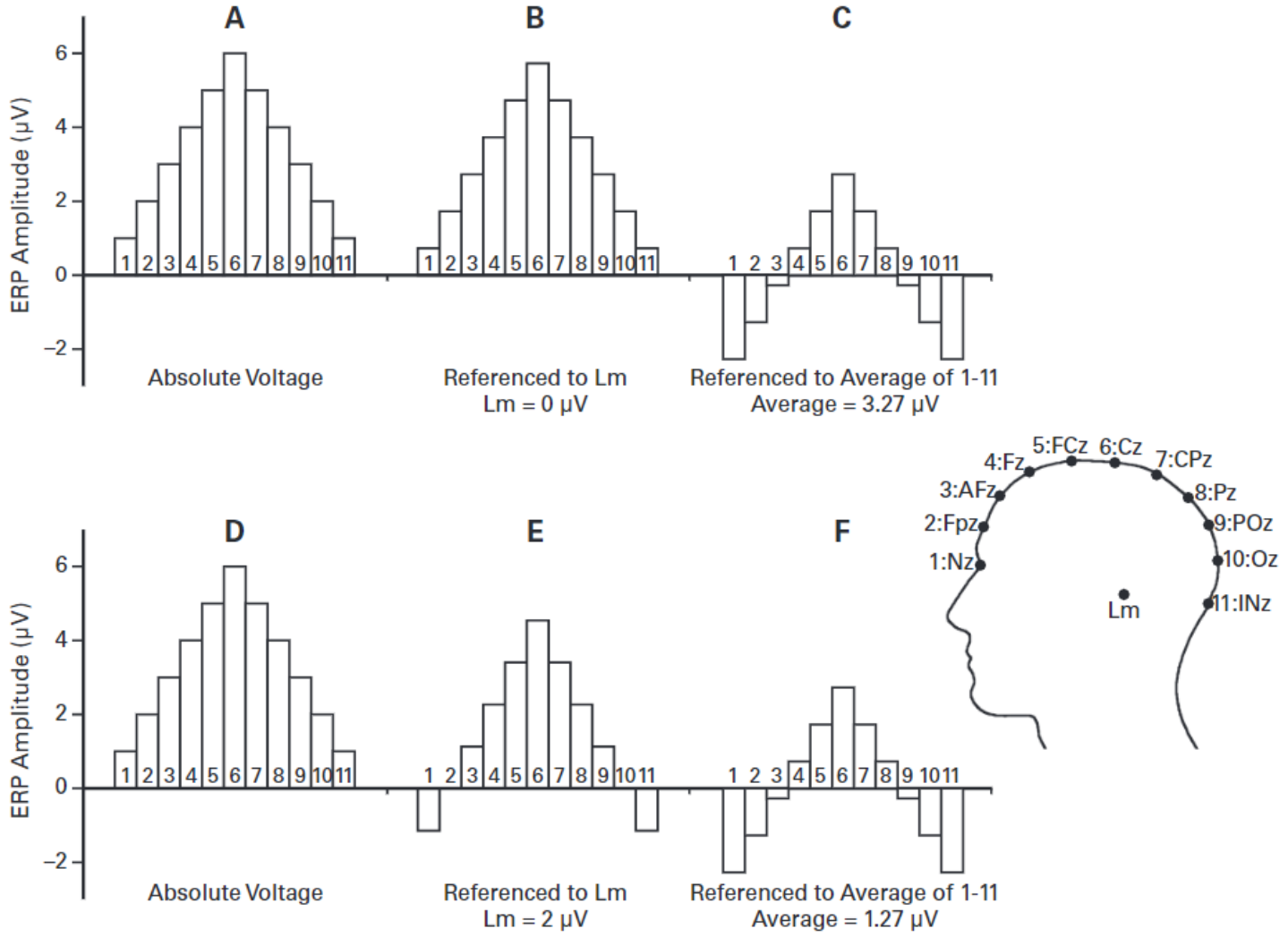
$$a2 - avg(a1, a2, a3) = A2 - avg(A1, A2, A3)$$

$$a3 - avg(a1, a2, a3) = A3 - avg(A1, A2, A3)$$

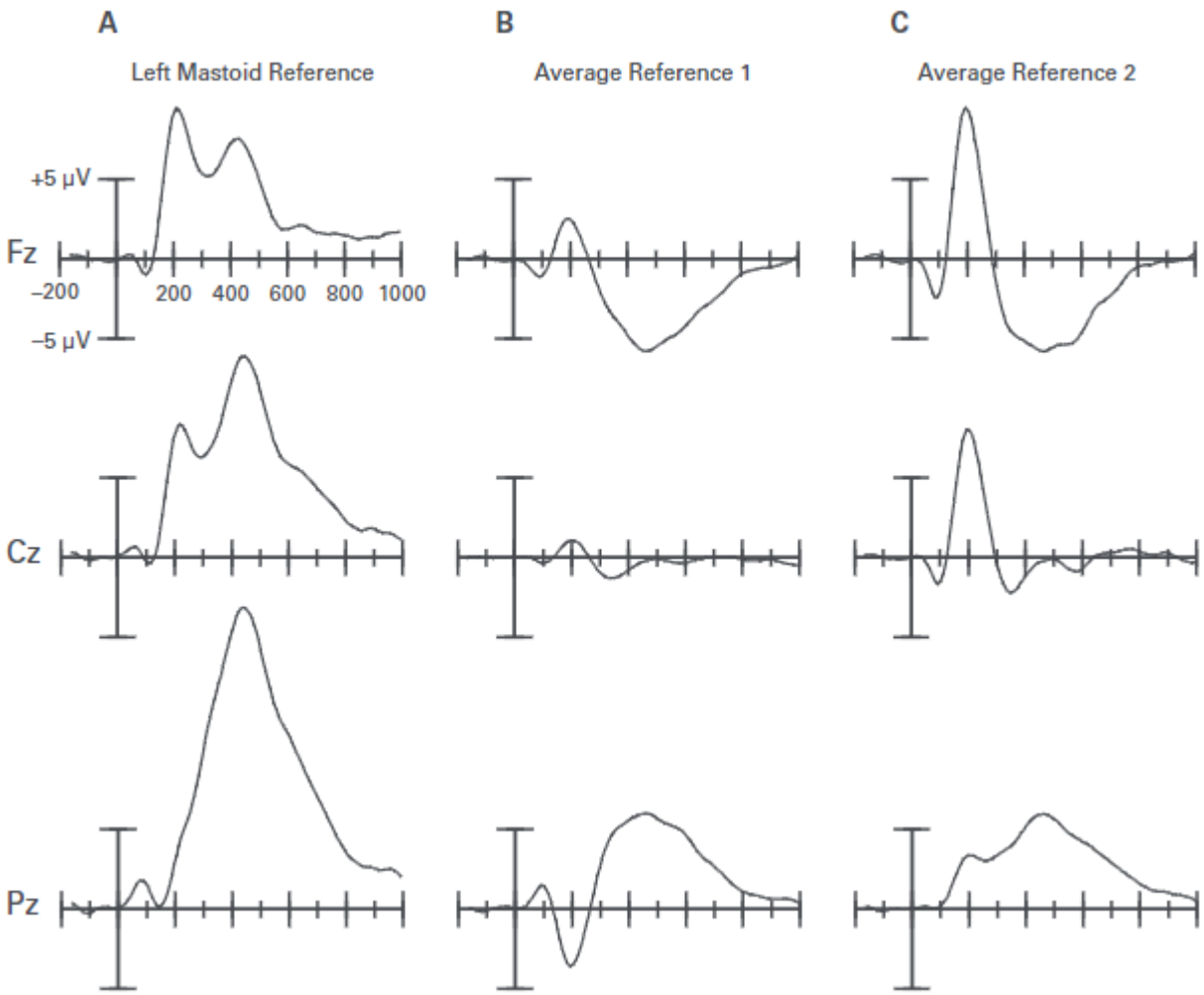
The Average Reference

- Advantage
  - Convenient
  - Not biased toward a particular hemisphere
  - Minimize noise
  - Unlikely that the average reference will subtract away most of the voltage for a given component
- Side effects
  - Imperfect approximation of absolute voltage
  - Average reference will change depending on what electrode sites you happened to record from
  - The voltage will always sum to zero across all of the electrode sites at every point in time
  - Difficult to compare waveforms and scalp distributions across studies

The Average Reference



The Average Reference



- A: Lm as reference
- B: average of Fz, Cz, Pz
- C: average of Fz, Cz, Pz + 5 occipital&temporal sites

Choosing a Reference Site

1. Choose a site that is convenient and comfortable
2. Avoid sites that is biased toward one hemisphere
3. Avoid using a reference that introduces a lot of noise into data
4. Avoid using a reference that is near the place on the scalp where the effect of interest will be largest
5. Use a site that is commonly used by other investigators in your area of research

- There is no single best site

Choosing a Reference Site

1. Look at your data with multiple different references
2. Concentrate on the pattern of differences in voltage among electrodes, not on the specific voltage at each site
3. Most common practice will be the average mastoids or average earlobes
4. Might use something else if some other reference is standard in your area of research
5. If the data look noisy with a mastoid/earlobe, you may gain some statistical power by using average reference
6. If you use average reference, use large number of evenly spaced electrodes that cover more than 50% of the head and report all electrodes

Current Density

- Completely avoid the reference problem by transforming data from voltage into current density
- *Current density (Scalp current density[SCD] or current source density[CSD]):* The flow of current out of the scalp at each point on the scalp
- *Surface Laplacian:* Taking the second derivative of the distribution of voltage over the scalp
- Use interpolation algorithm
  - Less accurate near the edge of electrode array
- Has the advantage of “sharpening” the scalp distributions of ERP components
- Minimizes activity from dipoles that are deep in the brain and emphasizes superficial sources