Fundamentals of EEG Technology

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Objectives

The learner will:

- Review the basic principles of the 10/20 System and differential amplification
- Gain an understanding of the acquisition of digital EEG waveforms
- Understand the process and utility of digital calibration
- Appreciate the optimal use of instrument controls (sensitivity and filters)
- Acquire an awareness of safety issues

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Program: 42nd Congress of the Canadian Neurological Sciences Federation

Title of Presentation: Fundamentals of EEG Technology, with an emphasis on digital techniques

Presenter's Name: Susan R. Rahey

I have/had a financial interest/arrangement or affiliation with one or more organizations that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.

Affiliation/Financial interest	**Name of organization(s)**
Grant/Research support	N/A
Consultant	N/A
Speaker's Bureau	N/A
Major stock shareholder	N/A
Other financial/material support	N/A

“Electroencephalography is like a beautiful park with a sign posted at the entrance:

For Persons With Total Commitment Only”

Ernst Niedermeyer, MD; AJET Vol.24, #2, June 1984, p.72

“The Ten Twenty Electrode System of the International Federation”

Who?

- Dr. Herbert Jasper, Montreal Neurological Institute
  - The National Hospital, Queen Square
  - Dr. F. Gibbs and colleagues in Boston and Chicago
  - Drs. Schwab and Abbott, Massachusetts General Hospital, Boston

“The Ten Twenty Electrode System of the International Federation”

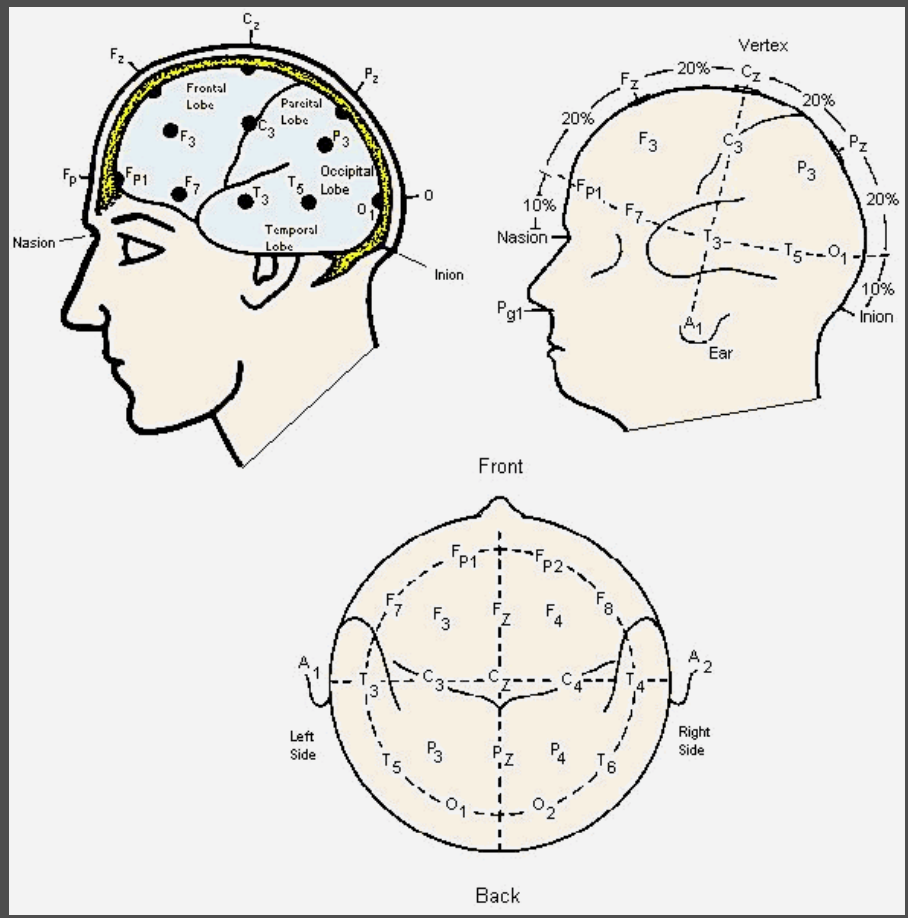
Why?

- “Make more comparable the results obtained in various laboratories
- Facilitate the communication between laboratories, in the literature, and with referring physicians who become familiar with the localization of EEG abnormalities in terms of these standard landmarks”

“The Ten Twenty Electrode System of the International Federation”

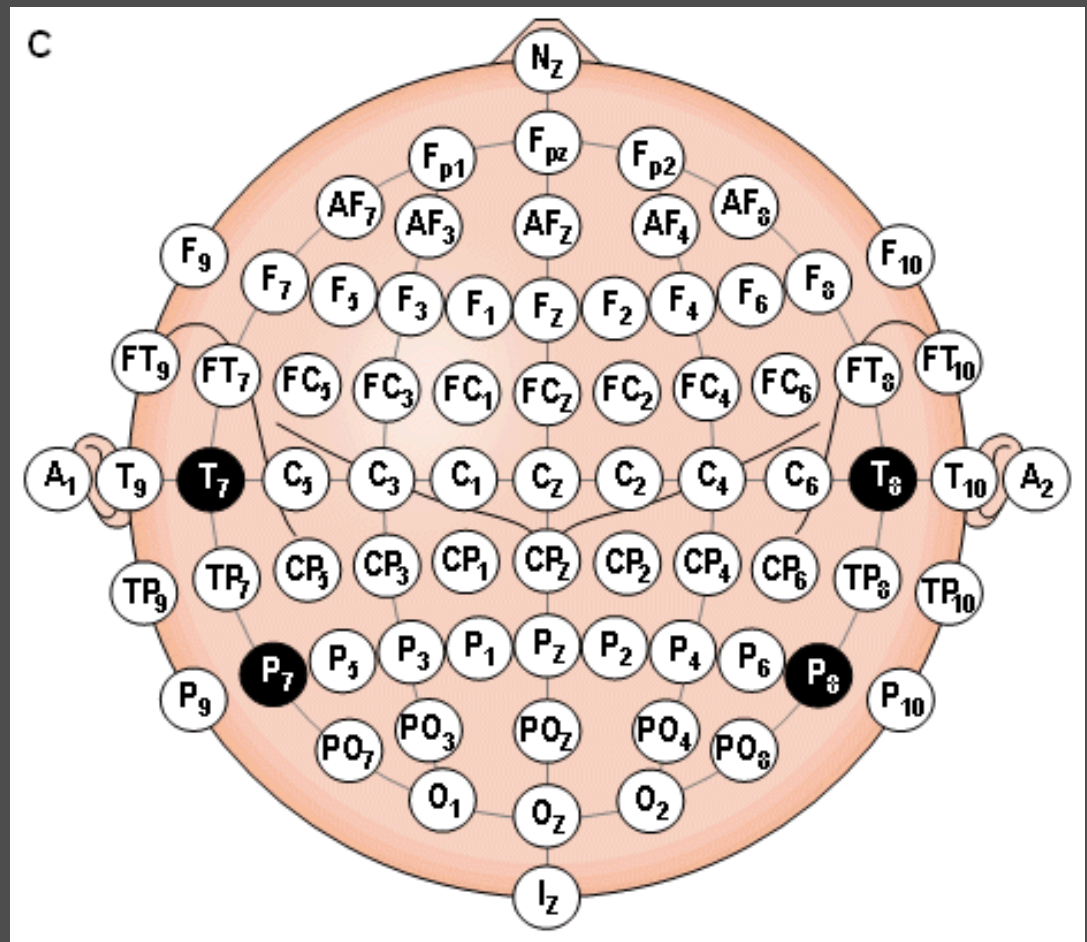
How?

- Measured location
- Common nomenclature
- Sequenced measurements



“The Ten Twenty Electrode System of the International Federation”

“ Additional electrodes may be placed between any of these principal standard positions for especially refined localization studies”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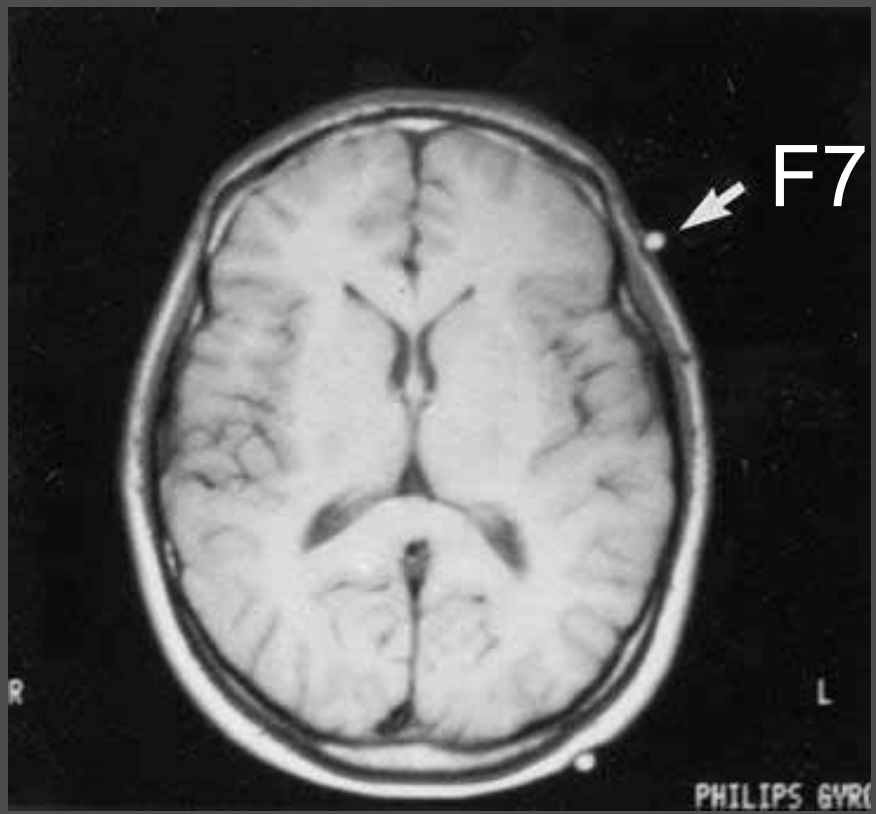
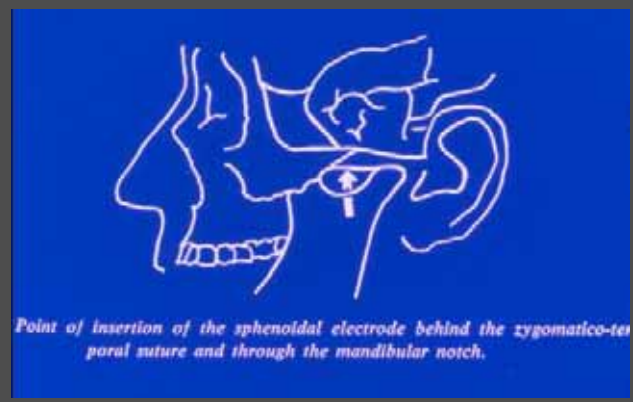
Additional Localizing Electrodes?



Additional Localizing Electrodes

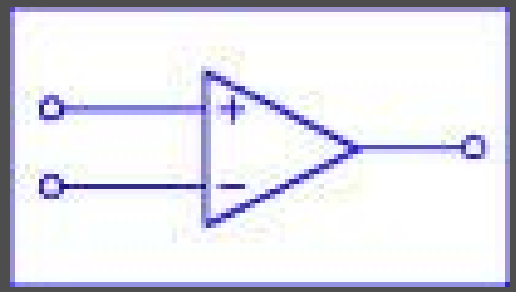
- T1/T2 (Silverman)
- Mandibular Notch
- Sphenoidal
- Nasopharyngeal



Teaching Points

- Use correct nomenclature
- Understand when additional electrodes are required and where to place them
- Recognize the importance of accurate head measurement and electrode placement

Differential Amplifiers
Analog ***and*** Digital



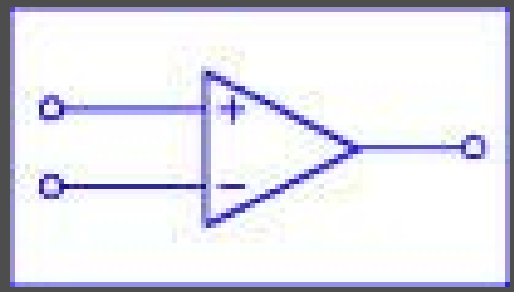
- The voltage displayed is the ***difference*** between the two channel inputs
- When there is a voltage difference between inputs, one electrode will be more negative or more positive than the other

Differential Amplification: Digital EEG

The voltage of the displayed waveform is the algebraic sum of the difference between input one, minus the reference, and input two, minus the reference

Input 1		Input 2
(F3 – FCZ)	-	(C3 – FCZ)
	↓	
F3 – FCZ	-	C3 – FCZ
	↓	
F3	-	C3

Differential Amplification



For ALL EEG instruments:

- when input 1 is more negative than input 2, the deflection of the waveform is **UP**
- when input 2 is more negative than input 1, the deflection of the waveform is **DOWN**

Differential Amplification

Teaching Points:

- Voltage displayed is the difference between two active electrodes
- In digital EEG, the system reference does not contribute to the waveforms displayed in reformatted montages
- Not every upward wave is generated by a surface negative potential

Digital EEG Acquisition

- Analog or “paper” recording
  - Filters and amplifiers process EEG signals which drive ink-writing pens
  - Electrical signal is continuous and uninterrupted
- Digital EEG Recording
  - “Source” signal sampled in time at a rate required to resolve a particular signal, or waveform, as determined by engineering theory
  - The digital signal is discontinuous

Digital EEG Acquisition

Analog to Digital Converter

ADC transforms the analog signal to a series of discrete, discontinuous data points separated by equal intervals of time.

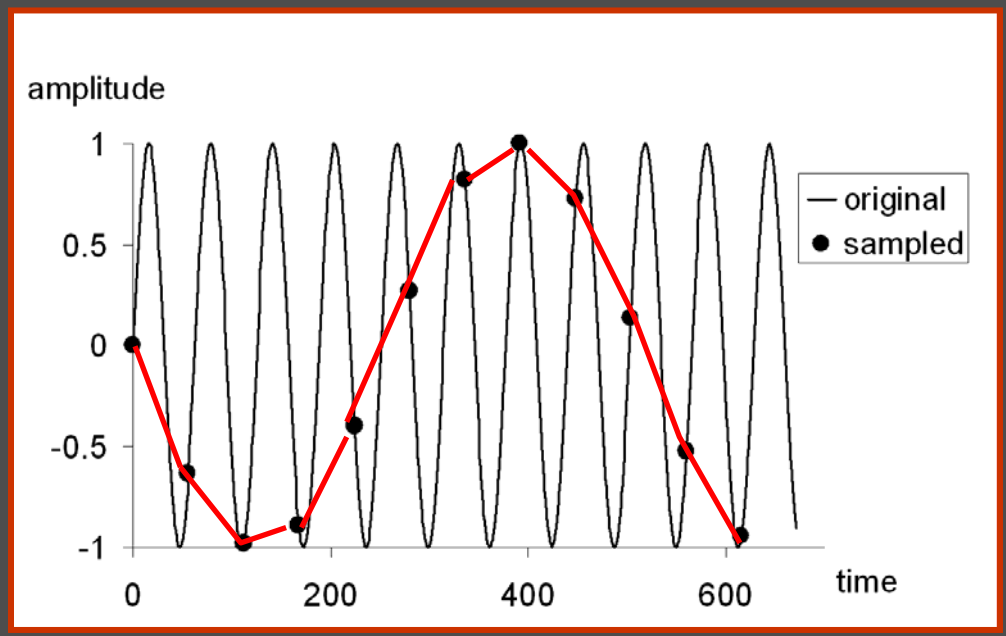
- Key concepts:
  - Sampling rate
  - The number of amplitude levels that can be resolved (bits)

Sampling Rate

- The rate at which the waveform is sampled in order to convert it into a numerical format
  - must be at least twice the highest frequency in the EEG waveforms to be recorded (Nyquist Theorem).
  - ***Aliasing*** occurs when a signal is undersampled.

Aliasing

- Aliasing occurs when a signal is sampled too slowly to resolve its frequency content
- The resulting samples form a signal whose frequency is lower than that of the original signal



Amplitude Resolution

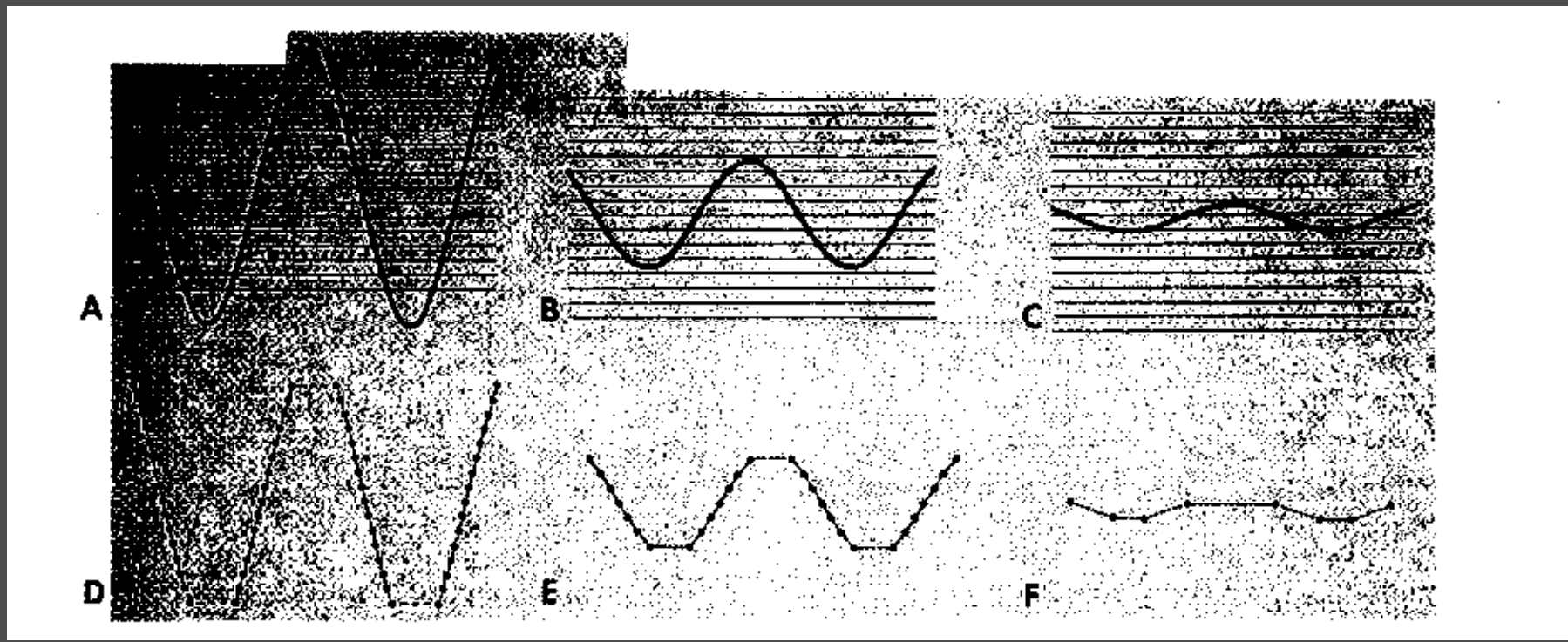
- The number of amplitude levels is expressed in terms of “bits”
- A measure of how finely the voltage can be subdivided when measured.

Amplitude Resolution

- Too few bits make it more likely that that relatively large changes can go undetected and very small amplitude changes can be overrepresented.

- Minimal Standard in Canada = 12 bits, ie 2^{12} , (or greater) with the ability to resolve voltage to 0.5μV

Amplitude Resolution



Monitor Resolution

- The number of pixels in each direction that can be used to fill in points on the EEG signal
- Insufficient pixels will have the effect of mimicking a reduced sampling rate and displaying incomplete data

Canadian guidelines require 1024 X 768, recommend 1280 X 1024

Teaching Points

Understand the effects on waveform ***display*** of:

- The features of ADC, including sampling rate and vertical resolution
- Monitor choice (size AND resolution)

Calibration

Analog

- A known voltage applied simultaneously to all inputs, each with identical sensitivity and filter settings, to detect instrument faults or setting errors
  - Electrical and mechanical baselines
  - Sensitivity
  - Filters
  - Time axis alignment
  - Pen spacing
  - Pen damping
  - Noise level
  - Paper speed
  - Performed before and after each recording

Digital

- A known voltage applied across all inputs to permit accurate amplitude measurement and display of recorded signals. May be manual or automatic
- May be performed daily or weekly or at longer intervals, dependent on lab and/or national standards
- Preexisting calibration file is attached to each individual recording

Advantages of Digital EEG

- Montage reformatting
- Editing channels
- Lots of channels!!
- Off-line manipulation of montages, filters, sensitivity and time display (“paper speed”)

Montage Reformatting

- A single common reference (“system reference”) is used as the second input (“G2”) in the differential amplifier for each channel

- To reformat: the value of the reference is subtracted from each electrode

Montage Reformatting

- Activity recorded at the reference is thus “cancelled out” and cannot contaminate the activity displayed using the various reformatting montages

Input 1		Input 2
(F3 – FCZ)	-	(C3 – FCZ)
	↓	
F3 – FCZ	-	C3 – FCZ
	↓	
F3	-	C3

- Virtually limitless options!

Montage Reformatting

Data in all channels may be compromised if the system reference is disrupted or is of high impedance

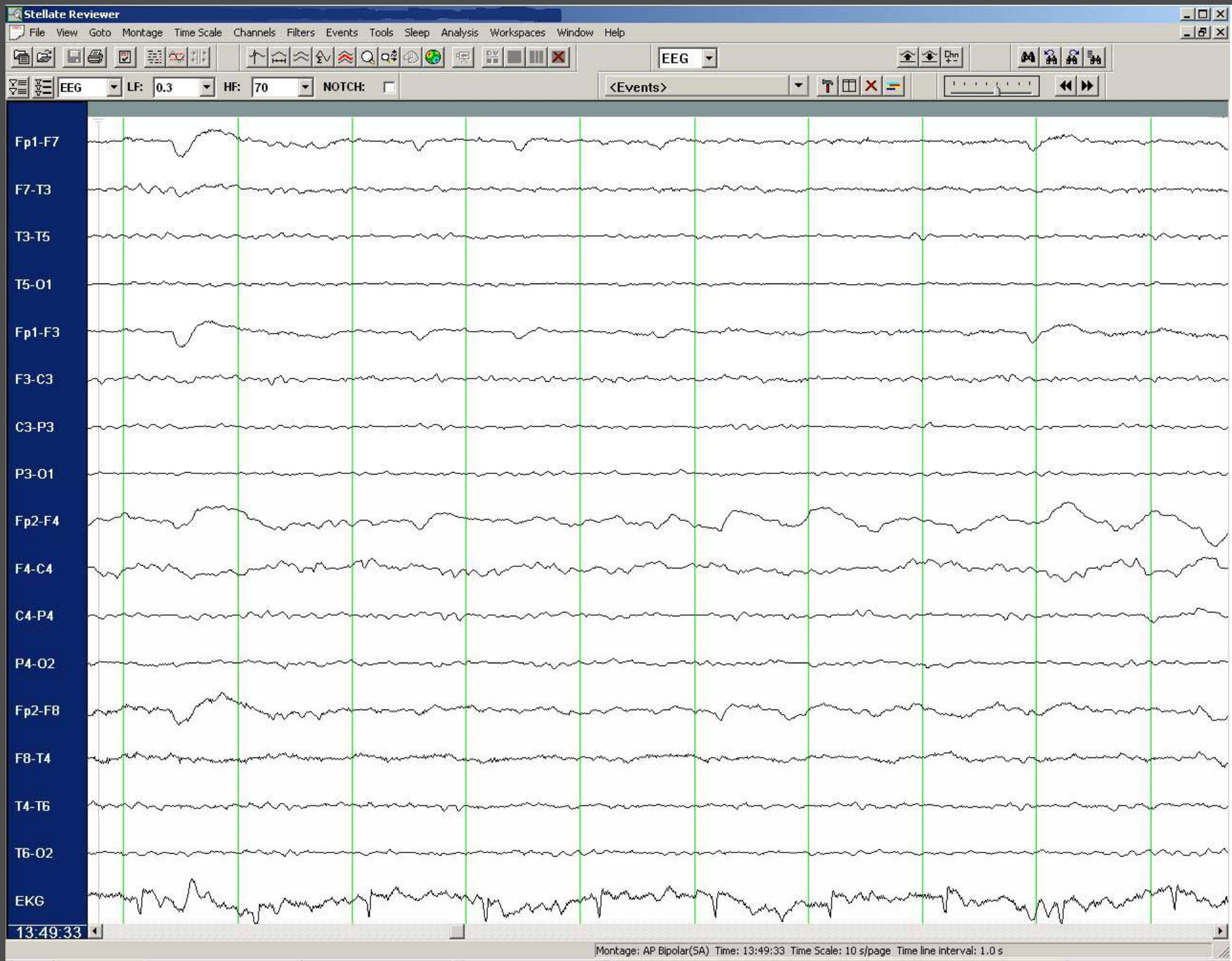
Note: Organisation of Societies for Electrophysiological Technology and Canadian Association of Electroneurophysiology Technologists Guidelines for Digital EEG Recording

Digital EEG Instrumentation: Sensitivity

- Ratio of input voltage to the signal deflection produced
- Setting with a higher numerical value means lower amplification
- Can be adjusted on and off-line as required for clarity

Digital EEG Instrumentation: Sensitivity

The sensitivity setting on a Digital EEG is recorded automatically and is not annotated and may not be displayed. Failure to confirm the display sensitivity may lead to inaccurate interpretation of results, for example…..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F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T4
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T6-O2
EKG
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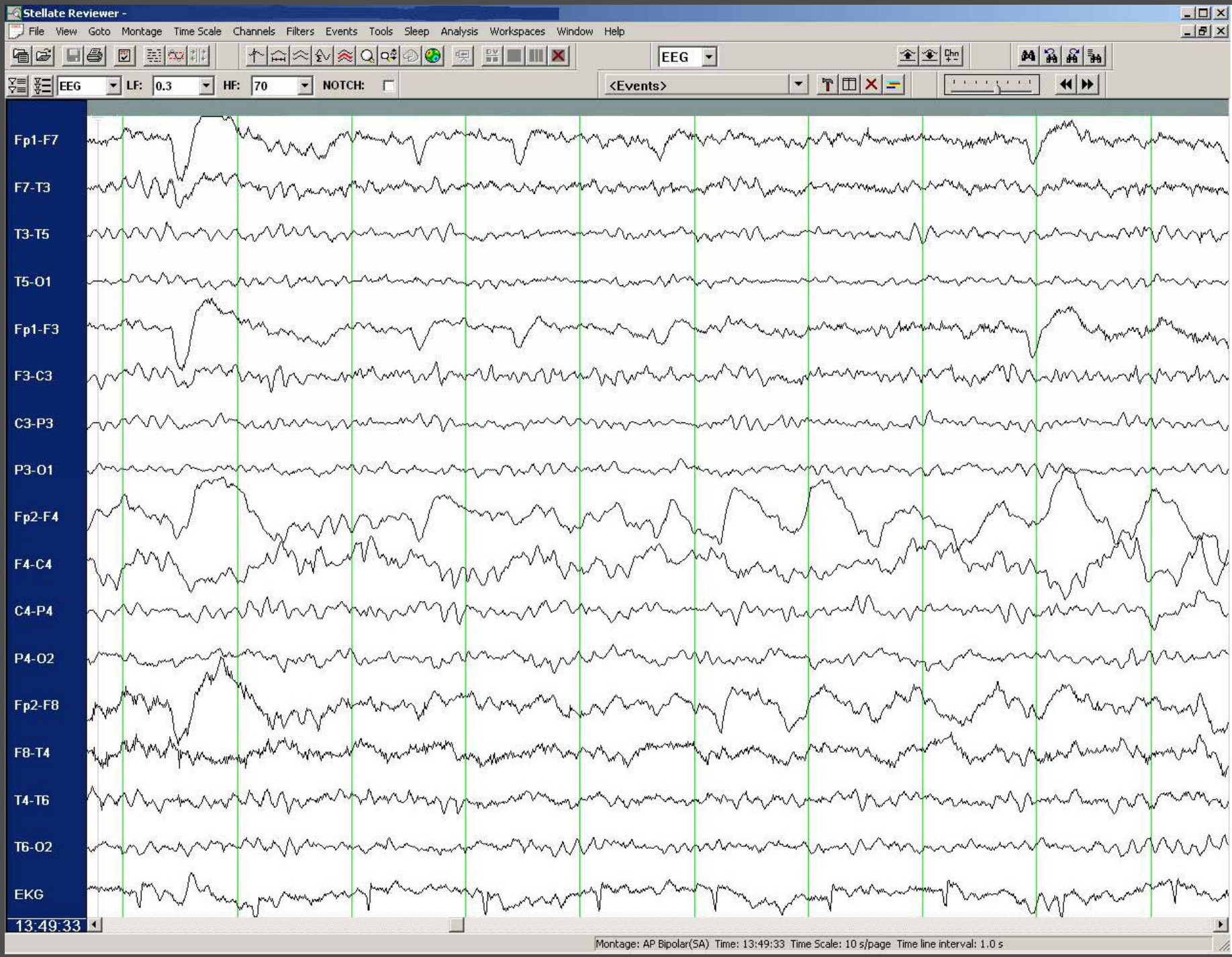
Montage: AP Bipolar(SA) Time: 13:49:33 Time Scale: 10 s/page Time line interval: 1.0 s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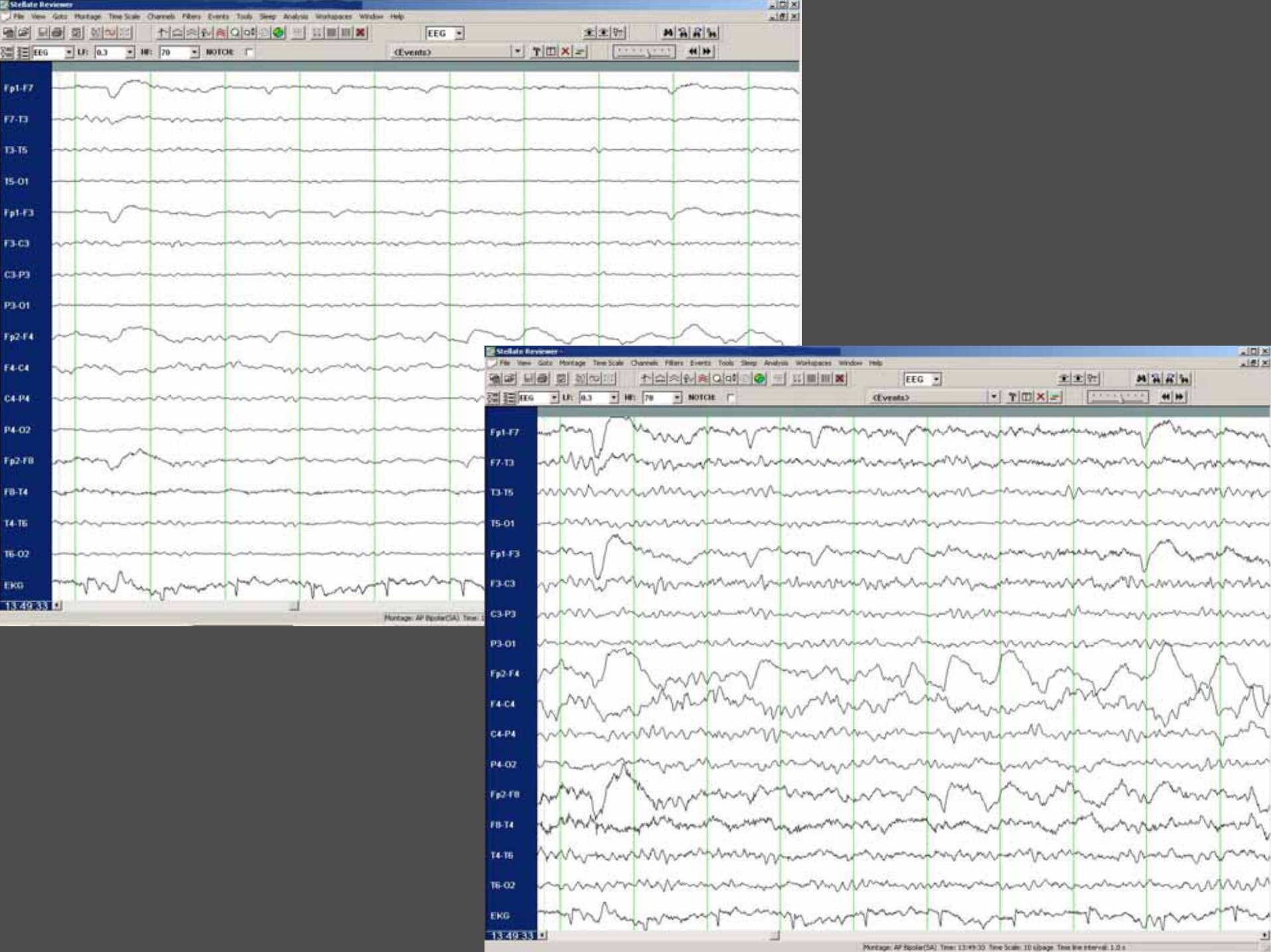
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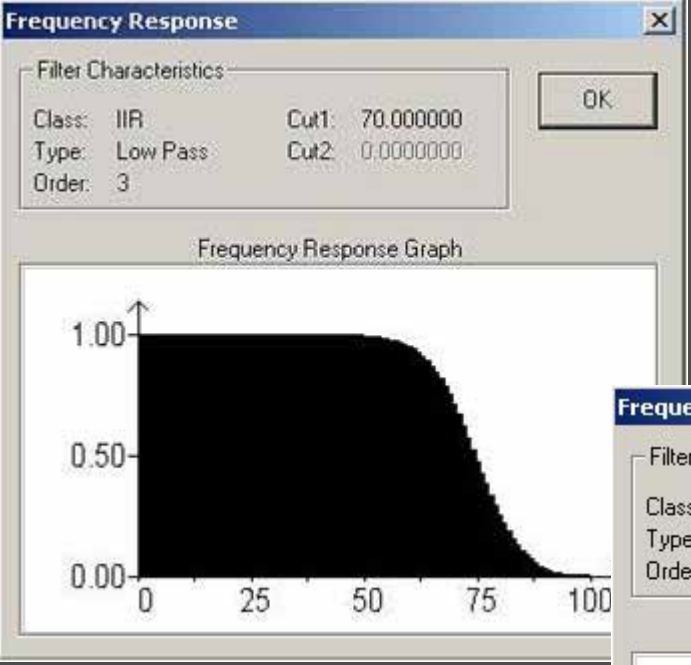
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T4
T4-T6
T6-O2
EKG
13:49:33

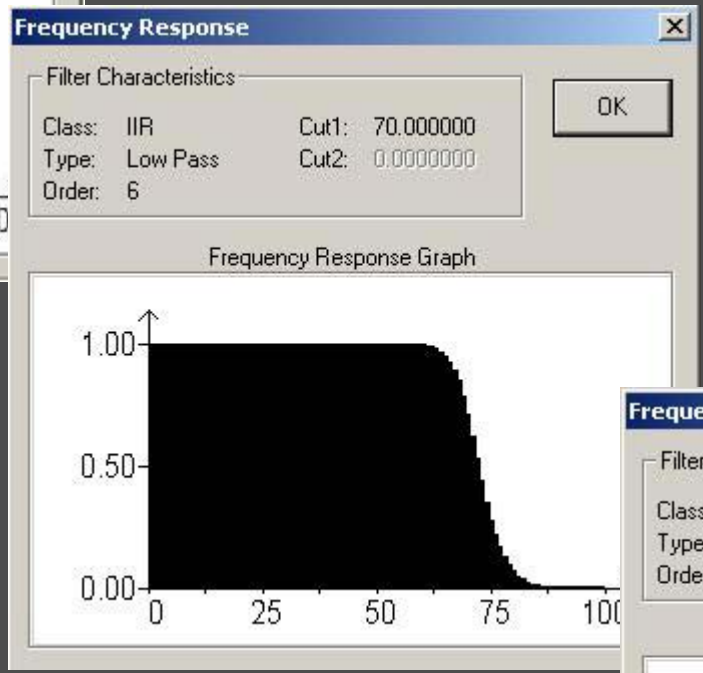
Digital EEG Instrumentation: Filters

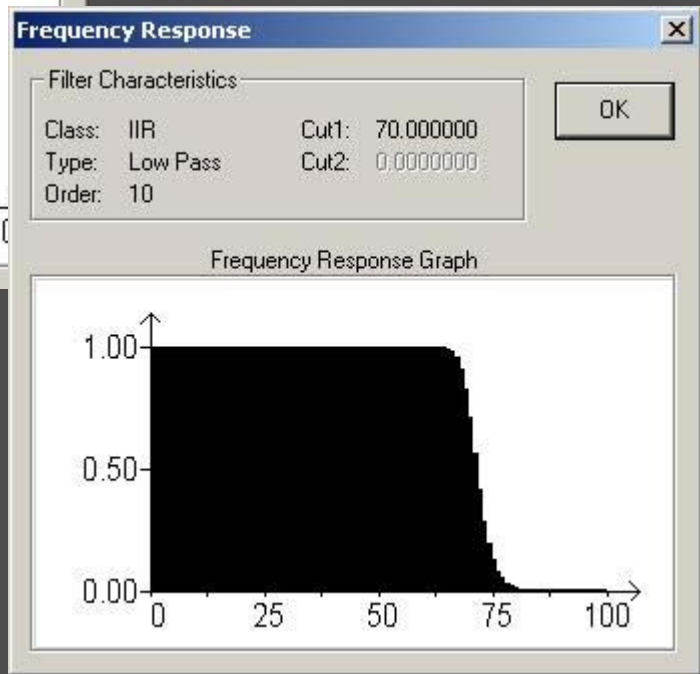
- Digital and Analog filters establish the bandwidth of the recording. Digital filters have no effect on the source data.
- There are three common approaches to digital filtering:
  - FIR (finite impulse response)
  - IIR (infinite impulse response)*
  - Frequency domain filtering

Digital EEG Instrumentation: Filters

- The roll off of a digital filter is determined by the “order” . Order refers to the number of points that are averaged by the filter at any one time
- Do not assume that all filters have the same order or that the frequency response curve of a digital EEG filter is identical to that of an analog filter of the same magnitude, for example….







higher number = steeper roll-off

Digital EEG: Weakness/ Shortcomings

- Compatibility issues
- Physician as technologist
- Blind faith in technology
- Cost!

Compatibility

- Software is proprietary
- Conversion programs cost money
- Not everyone has access to the same quality of computer hardware

Physician as Technologist

The role of the EEGer has changed from that of passive recipient of data to active manipulation of raw data

- choosing montages
- applying filters
- adjusting sensitivity settings

Blind Faith in Technology

- Not all software programs are equal
- Know ***your*** system
- “Turnkey” systems and “traces as observed” may be good but may not always be good for you – or the patient
- Computers crash

Cost

- Storage is cheap

BUT

- Upgrades can cost big money!

Hint: Buy the software warranty and maybe even the hardware warranty if it’s offered!

Safety

Electrical Safety:

- Ensure that a proper maintenance schedule is established and adhered to
- Discuss safety issues with staff
- NEVER ignore the presence of 60 Hz contamination

Infection Control:

- Review laboratory infection control policies in light of institutional policies
- Never assume that patients are not at risk in your laboratory

Other potential liability issues:

- HV and photic stimulation in pregnancy
- Driving after sleep deprived EEG

References/ Suggested Readings

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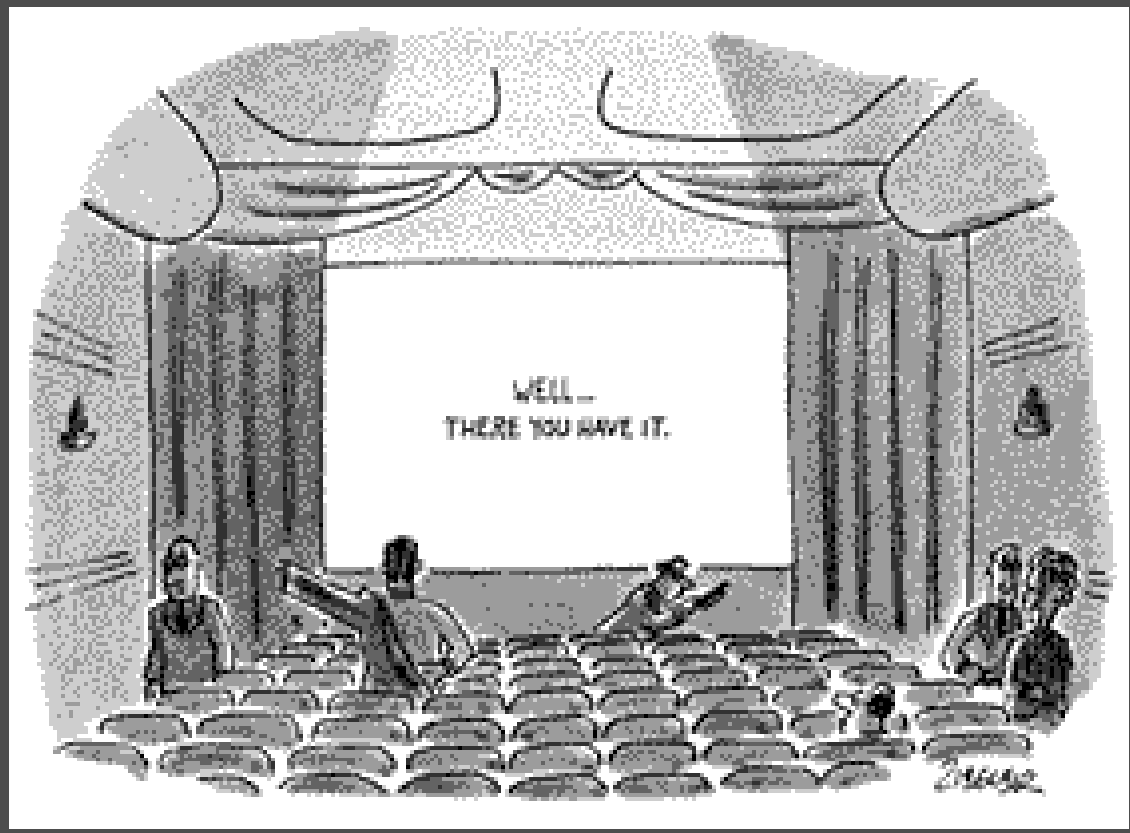
WELL...
THERE YOU HAVE IT.