Electroencephalogram Technology Synopsis

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Abstract: Electroencephalogram (EEG) source is within the cerebral cortex, large neural populations, all synchronized together to summate at the scalp surface. EEG signal recorded is the summation of the various neuronal populations beneath it and is a composite of various frequencies, designed Δ (0-3.5 Hz), Θ (4-7 Hz), α (8-13 Hz) and β (13+ Hz). EEG is analyzed according to voltage, frequency, location, degree of symmetry and coherence between left and right hemispheres and specific waveform morphology and patterns. The International 10-20 System of Electrode Placement was introduced by Herbert Jasper in 1958 and adopted by the International Federation of EEG Societies and is currently in widespread use. Evoked Potentials (EP) are time-locked to the stimulus. Testing modalities and EP test types include: Auditory (BAER and AER), Visual (VER), Somatosensory (SBR) and Cognitive (ERP). Quantified EEG includes Topographic Brain Mapping (TBM, BEAM) and Fast Fourier Transform (FFT) to analyze both EEG and EP data.

Key words: Electroencephalogram, quantified egg, evoked potential, event-related potential, frequency, Thailand

INTRODUCTION

Electroencephalogram: Electroencephalogram (EEG) (spontaneous brain electrical activity) source is within the cerebral cortex, large neural populations, all synchronized together to summate at the scalp surface. Voltage is attached by meninges, skull and scalp tissue (mostly skull) and is measured in microvolts (µV). Electrodes placed on scalp surface are diffuse physiological electrodes and their field areas of underlying cortex overlaps (Clenney and Johnson, 1983; Frances, 1989; Spehlmann, 1981).

First EEG (rabbit in 1875) was introduced by Caton. First EEG of man by Hans Berger, a German Psychiatrist (the father of EEG) who named the field and early activities discovered, using Greek nomenclature. First published 1929 but not replicated until 1934, by Matthews and Lord Adrian in English. In 1935, EEG labs spread widely throughout the world many discoveries were made including the regionalization of Berger’s alpha rhythm to posterior scalp. Berger’s original equipment (a single-channel Einthoven String Galvanometer) was very insensitive, his electrodes were two saline-soaked pads, one anterior and one posterior scalp, using German ex-soldiers who had sustained skull defects in World War I no localization was possible. Today, multichannel recordings are made from highly sensitive equipment (Clenney and Johnson, 1983; Frances, 1989; Tyner et al., 1983). Electrodes joined together (derivation) in either a bipolar or a monopolar (Referential) method. Output of two electrodes is fed into a differential amplifier where they are compared to each other with respect to ground. The two inputs are called grid one (or input one) and grid two (or input two). Polarity convention has the pen move in the direction of the more negative electrode. Recordings thus indicate relative (not actual or absolute) polarity (Remond and Torres, 1964; Spehlmann, 1981).

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Amplifier output can be directed to writing pens, oscilloscope or digitized and written directly into a computer’s memory. Pens move up and down, recording voltage oscillations while paper moves from right to left at a standard speed (30 mm sec⁻¹) a little faster than EKG where the standard is 25 mm sec⁻¹, producing a squiggly line or brain wave pattern on the paper. Gain is ratio of output voltage to input voltage, while sensitivity refers to display (how many µV/mm⁻¹ of pen deflection) (Frances, 1989; Persson and Hjorth, 1983; Spehlmann, 1981; Tyner et al., 1983). EEG is analyzed according to voltage, frequency, location, degree of symmetry and coherence between (homologous areas in) left and right hemispheres and specific waveform morphology and patterns. Certain specific morphologies and patterns have been correlated with specific pathology such as epileptic spikes and metabolic encephalopathy triphasic waves duration is often used to describe waveforms and to estimate the frequency of non-repeating waves. Duration is reciprocal of frequency. Most EEG findings are non-specific. Clinical usefulness of EEG while greatest
in the epilepsies is still limited, e.g., normal EEG does not
RO epilepsy (Frances, 1989; Spehlmann, 1981). Electrode
types and attachment methods: stick-on and -in relative advantages and disadvantages essentials good
mechanical and electrical contact various types of
combination adhesive/electrolyte creams, pastes, bentonite, etc., best a pure electrolyte (gel) in an electrode
secured to the scalp with a pure adhesive (collodion)
called a fixed-perimeter electrode measurement of
impedance vs. resistance for electrical contact elec-
trodes are recessed electrodes fixed in a flexible
(stretchable) cap (Frances, 1989; Spehlmann, 1981;
Tyner et al., 1983). Electrode placement systems differed
in the past including the number of electrodes, their
placement, nomenclature and interconnection methods
(mono vs. bipolar montages) inhibiting inter-laboratory
communication and comparison of results and leading to
many disagreements between early workers (Spehlmann,
1981). The International l0-20 System of Electrode
Placement was introduced by Herbert Jasper in 1958 and
adopted by the International Federation of EEG Societies
and is currently in widespread use. This system is based
on external skull landmarks (nasion, union< L > and < R>
pre-auricular) involves computing percentages (10 or
20%) of measured distances between them, thus
standardizing placement for different sized (and to some
extent-shaped) skull nomenclature two-part (alpha/numeric)
electrode identifier, specifying lobe and specific scalp
(brain) area, with < L > and < R > lateralization based on odd
and even numbers, respectively (zero being median); there
is room for additional electrodes evenly-spaced between
standard ones, also for sphenoidal and nasopharyngeal
leads; system is not for use with ECoG where electrode
layout is different and usually designated by purely
numeric nomenclature system, individualized for the
particular operation/recording on a relatively small patch
of exposed brain surface. The 10-20 system montage
display rules: Anterior electrode take precedence over
posterior ones, < L >electrodes over < R > ones; in the USA,
mains change rule (2) to < L >over< R >monitoring
electrodes used for: EOG, EKG, EMG, environment,
respiration (Epstein and Brickley, 1985; Remond and

Multiple sources for artifacts (unwanted signals)
physiological (from the patient’s subject’s own body
such as eye motion, heart activity, perspiration, muscle
tension, tremor and other movements vocalization/
sobbing/crying/glossopharyngeal, respiration)
environmental (50/60 Hz mains, static electricity, movement near patient); instrumental (electrode artifact,
amplifier or other EEG equipment malfunction)
(Clemney and Johnson, 1983; Spehlmann, 1981;
Tyner et al., 1983). Drug effects are extremely variable
when they can be recognized as such they are usually
evident as an excess of fast activity (in the β range) but
result in other (slower) frequencies as well, especially
with toxic (non-therapeutic) serum drug levels the effect
is usually individual-specific, rather than being fully
determined by drug type, dose or route of administration,
although there are exceptions (IV valium universally
results in high-amplitude β, for instance); also variable:
degree of persistence of EEG effect after drug has been
discontinued (Remond and Offner, 1952). Historically,
the major controversies in the field of EEG have involved
disputes regarding:

• The methods and terminology of electrode placement
  systems (how many electrodes where they are placed
  and what they are called) and recording derivations
  (bipolar vs. referential/monopolar/unipolar)  

• The use of clinical diagnostic descriptors to name
  EEG waveforms and/or patterns (petit mal variant,
  psychomotor variant)  

• Continuous changing of EEG descriptors without
  standardization (dEast and dome to >3 sec⁻¹ wave and
  spike to >3 sec⁻¹ spike and wave and flat-topped
  waves to =RMID)  

• Clinical significance/correlation of certain EEG
  patterns (14 and 6 sec⁻¹ positive spikes, B-Mittens,
  small sharp spikes [BTS] and 6 sec phantom spike/ 
  wave) (Hjorth, 1982; Remond and Offner, 1952;
  Spehlmann, 1981)  

EVOKEPOTENTIALS

Evoked Potentials (EPs) (or responses) in contrast to
spontaneous EEG activity may have their source in any
location within the neuraxis, depending on what specific
EP component is being recorded are time-locked to the
stimulus, short-latency EPs are deterministic (stereotyped)
by possessing the same latency, amplitude, polarity and
waveform every time; longer-latency EPs are less so with
more latency jitter (especially cognitive EPs) which
increases with increasing latency; EPs are also more
subject to state (of consciousness) variations (Celesia,
1985; Goff, 1974; Spehlmann, 1985). Other technical
terminology used: trigger, A/D and D/A conversion (vert.
or voltage resolution) addresses (horiz. or time
resolution), memory bins; repeat stimulus until time-
locked signal averages-IN and spontaneous, random
noise averages-OUT; signal (of interest); (background)
noise; S/N (Signal/Noise) ratio; 2X improvement in S/N
ratio requires squaring the sampling n; need for at least 4
samples (addresses) per fastest EP component in order to
adequately resolve it related to the Nyquist frequency caveat (filters and sampling rate) to prevent aliasing; 2 different terms: ISI, dwell time; epoch/sweep/window, automatic artifact rejection (voltage gate: no guarantee of excluding all artifact) (Halliday et al., 1977; Owen and Davis, 1985; Spehlmann, 1985). Testing modalities and EP Test types include:

**Auditory**: BAER, AER.

**Visual**: VER (Pattern shift and patterned/unpatterned flash) (Full-field, half-field and quadrants).

**Somatosensory**: SER (Median, ulnar, radial, peroneal, posterior tibial).

**Cognitive**: ERP (Contingent negative variation, P300 or late positive complex, probe) (Buchsbaum et al., 1982; Celesia, 1985; Federico, 1984; Goff, 1974; Halliday et al., 1977; Pfurtscheller and Araniba, 1977; Owen and Davis, 1985; Sato et al., 1971; Spehlmann, 1985; Lehmann and Skrandies, 1984).

This is a relatively new field, NOT as yet standardized (with differing nomenclature, stimulating and recording methods, polarity convention) and a very confusing literature; how many electrodes/channels and derivations; recent recognition of the benefits of multichannel EP recording with full 10-20 electrode set, especially with brain mapping EP usefulness; both clinical (Dx and OR monitoring) and research.

**QUANTIFIED EEG**

Quantified EEG (QEEG) (computerized application, Appendix) includes the following (mostly research) areas of study:

- Topographic Brain Mapping (TBM, BEAM) of both EEG and EP data, based on multichannel data, to increase accuracy in identification of abnormalities (e.g., mapped flash VER)
- Fast Fourier Transform (FFT) or frequency spectral analysis of both EEG and EP data either mapped or stacked sequentially (CSA), to follow the course of a changing condition (e.g., intraoperatively)
- Digital filtering of data to eliminate phase shifts due to conventional hardware analog filtering
- Off-line montage re-formatting capability for viewing the data re-plotted in different montages
- Studies of coherence, global power, individual and combined frequency band ratios and comparisons, etc.

- Statistical comparison of patient/subject data to normative data banks, including those made from the subject’s own baseline condition data (before administration of a drug or other experimental charge)
- Re-referencing of patient/subject data to either the common average or Hjorth’s source (Laplacian) derivation, for detailed analysis of scalp voltage field distributions
- Equivalent dipole determinations for possible solutions to Helmholtz’s inverse problem of what unique source (within the brain) gave rise to this particular (scalp) voltage field distribution?
- Computerized recognition and (on-line) correction of various types of EEG artifacts that either obscure the recording or otherwise interfere with its interpretation
- Exert system for automated EEG analysis and interpretation to do-away with the human subjective element, inter-rater variability, over-reading and under-reading, etc.

- Single trial EPs, adaptive filters zero-crossing analysis frequency averaging, steady-state EPs (Frances, 1989; Hjorth, 1982; Persson and Hjorth, 1983; Remond and Offner, 1952)

**APPENDIX**

**COMPUTERIZED EEG/FFT/EP/ERP PARAMETERS RECORDING PROTOCOL FOR A COMPARISON OF AVERAGE VS. SUPERIOR INTELLIGENCE STUDENTS**

**EEG: Eyes open:**
- Recording duration needed: 1-2 min, 30 sec’s artifact-free data for FFT'ing
- Approximate time needed: 2 min
- Gain: 30,000
- Low pass filter: 1.0 Hz
- High pass filter: 30.0 Hz

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**Auditory P300 Event-Related Potential (ERP) [Oddball Paradigm]:**
- Number of repetitions: 125 Target repetitions/trial, 2 trials, Grand average: 250 Targets, approximately: 1500 Non-targets
- Approximate time needed: 40 min
- Gain: 30,000
- Low pass filter: 1.0 Hz
- High pass filter: 30.0 Hz
- Rate: 0.8 sec⁻¹
Epoch: 1024 m sec
Ratio: 6:1
Artifact rejection: On
Stimulus: Dual auditory (Target: 2 kHz, Non-target: 1 kHz, Level: 85 dB, R/F: 10 m sec, Flat: 40 m sec)

Instruction to subjects: You will be hearing 2 different tones one high-pitched (Beep) and one low (Boop). You want to completely ignore the high-pitched tones but listen for the high ones --- keep an ongoing mental count of those. We will do this twice and I will be asking you after each trial how many of these high-pitched Beep tones did you hear?

Auditory probe Event-Related Potential (ERP)
[Attend-Ignore paradigm]:
Number of repetitions: 375 Repetitions/trial per condition, Grand average; 1500 each, total: 4 trials for the 2 conditions
Condition order: Attend—Ignore—Attend—Ignore—Attend
Approximate time needed: 40 min
Gain: 30,000
Low pass filter: 1.0 Hz
High pass filter: 70.0 Hz
Rate: 0.8 sec⁻¹
Epoch: 512 m sec
Artifact rejection: On
Stimulus: Single Auditory (2 kHz, Level: 85 dB, R/F: 16 m sec, Flat: 40 m sec)
Instruction to subjects:
Attend: I want you to listen to the tones, you do not have to count them, just listen to them very carefully and try to hear them all.
Ignore: I want you to ignore the tones try not even hear them tune them out ignore them completely.

Unpatterned Flash Visual Evoked Potential (VEP):
Number of Repetitions: 300/trial, 2 trials, Grand Average: 600
Approximate time needed: 15 min
Gain: 30,000
Low pass filter: 1.0 Hz
High pass filter: 70.0 Hz
Rate: 0.8 sec⁻¹
Epoch: 1024 m sec
Stimulus: Single External (Graz P/S)
Artifact Rejection: On

REFERENCES


