Journal of Engineering and Applied Sciences 7 (6): 395-398, 2012
ISSN: 1816-949X

Electroencephalogram Technology Synopsis

Wichian Sittiprapaporn
Faculty of Medicine, Mahasarakham University, Thailand

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 (SER) 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). Electrode 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). 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).

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 def lection) (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 R/O 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 electro-caps 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 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. This system is based on external skull landmarks (nasion, inion<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 (α/numeric) electrode identifier, specifying lobe and specific scalp (brain) area, with <L> and <R> lateralization based on odd and even numbers, respectively (zero being midline); 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, <2>electrodes over<L>ones; in the USA, most labs change rule (2) to<L>over<R>monitoring electrodes used for: EOG, EKG, EMG, environment, respiration (Epstein and Brickley, 1985; Remond and Offner, 1952; Remond and Torres, 1964; Spehlmann, 1981).

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) (Clenney 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 can 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 (dart and dome to >3 sec^{-1} wave and spike to >3 sec^{-1} spike and wave and flat-topped waves to >RMTDs)
- Clinical significance/correlation of certain EEG patterns (14 and 6 sec^{-1} positive spikes, B-Mitterns, small sharp spikes [BETS] and 6 sec phantom spike/wave) (Hjorth, 1982; Remond and Offner, 1952; Spehlmann, 1981)

EVOKED POTENTIALS

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 ERPs) which increases with increasing latency; ERPs 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 Aranibar, 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

EEG: Eyes-closed:
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

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: 70.0 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, Plat: 40 m sec)

Instruction to subjects: You will be hearing 2 different tones one high-pitched (Beep) and one low (Boop). I want you to completely ignore the low-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 those 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---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: 10 m sec, Plat: 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 tune into them 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 (Grass P/S)
Artifact Rejection: On

REFERENCES

Buchsbaum, M.S., A.C. King, J. Cappelletti, R. Coppolla and D.P. van Kammen, 1982. Visual evoked potential topography in patients with schizophrenia and normal controls. Adv. Biol. Psychiatry, 9: 50-56.

Celesia, G.G., 1985. Visual Evoked Responses. In: Evoked Potential Testing, Owen, J.H. and H. Davis (Eds.). Grune and Stratton Inc, Orlando, FL.USA.

Clenney, S.L. and S.M. Johnson, 1983. Back to Basics: A Handbook of EEG Technology. Beckman Instrument Co., USA.

Epstein, C.M. and G.P. Brickley, 1985. Interlectrode distance and amplitude of the scalp EEG. Electroencephal. Clin. Neurophysiol., 60: 287-292.

Federico, P.A., 1984. Evoked-Related Potential (ERP) correlates of cognitive styles, abilities and aptitudes. Personality Individual Differences, 5: 575-585.

Frances, M.D., 1989. The EEG Handbook. Little Brown and Company, Boston.

Goff, W.R., 1974. Human Average Evoked Potentials: Procedures for Stimulating and Recording. In: Bioelectric Recording Techniques, Petterson, R.F.T. (Ed.). Academic Press, New York, USA.

Halliday, A.M., G. Barrett, E. Halliday and W.F. Michel, 1977. The Topography of the Pattern-Evoked Potential. In: Visual Evoked Potentials in Man: New Developments, Desmedt, J.E. (Ed.). Clarendon Press, Oxford, UK.

Hjorth, B., 1982. An adaptive EEG derivation technique. Electroencephal. Clin. Neurophysiol., 54: 654-661.

Lehmann, D. and W. Skrandies, 1984. Spatial analysis of evoked potentials in man-A review. Prog. Neurobiol., 23: 227-250.

Owen, J.H. and H. Davis, 1985. Evoked Potential Testing: Clinical Applications. Grune and Stratton Inc., Orlando, FL, USA.

Persson, A. and B. Hjorth, 1983. EEG topogram-an aid in describing EEG to the clinician. Electroencephalogr. Clin. Neurophysiol., 56: 399-405.

Pfurtscheller, G. and A. Aranibar, 1977. Event-related cortical desynchronization detcted by power measurements of scalp EEG. Electroencephalogr. Clin. Neurophysiol., 42: 817-826.

Remond, A. and F. Offner, 1952. A new method for EEG display. Electroenceph. Clin. Neurophys., 7: 453-460.

Remond, A. and F. Torres, 1964. A method of electrode placement with a view to topographical research. Electroencephalogr. Clin. Neurophys., 17: 577-578.

Sato, K., H. Kitajima, K. Mimura, H. Hirota, Y. Tagawa and N. Ochi, 1971. Cerebral visual evoked potential in relation to EEG. Electroenceph. Clin. Neurophys., 30: 123-138.

Spehlmann, R., 1981. EEG Primer. Elsevier Biomedical Press, Amsterdam, The Netherlands.

Spehlmann, R., 1985. Evoked Potentials Primer. Butterworth Publishers, Stoneham, MA. USA., ISBN: 9780409900057, Pages: 400.

Tyner, F.S., J.R. Knott and W.B. Jr. Mayer, 1983. Fundamentals of EEG Technology. 1st Edn., Vol. 1, Raven Press, New York, USA.