Cognitive Science 279: Electrophysiology of Cognition

Spring Quarter 2013

Tu/Th 11-12:20 – CSB 180

Prof. Marta Kutas
Office: 155 CSB; CSB 105 (lab)
phone: 534-7450
Course website: http://kutaslab.ucsd.edu/people/kutas/279
Username/password needed to access website
email: kutas@cogsci.ucsd.edu

Counterterrorism | Criminal Justice | Medical | Advertising | Security Testing

A scientific test that taps brain records so accurately it caught a serial killer, may prove to be the first objective, empirical measurement of memory loss and drug efficacy in Alzheimer's and other brain disorders.

***Marina Murphy* reports**

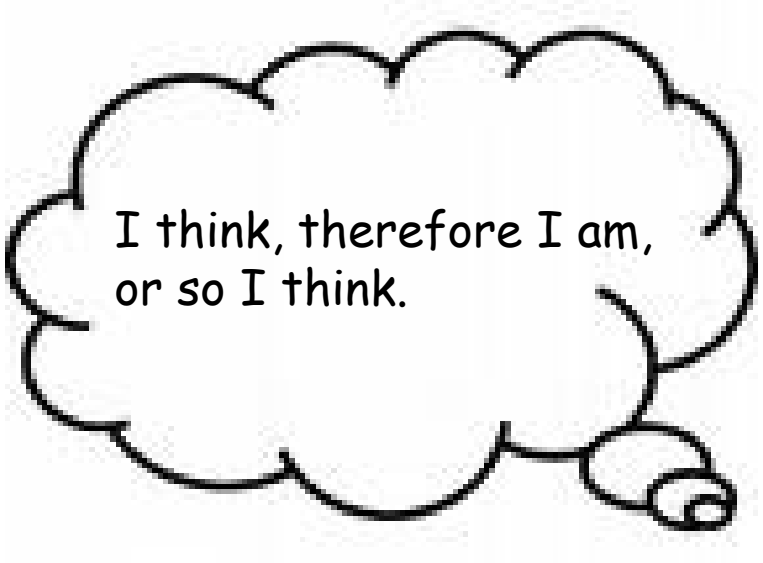
from Brain Finger Printing Laboratories

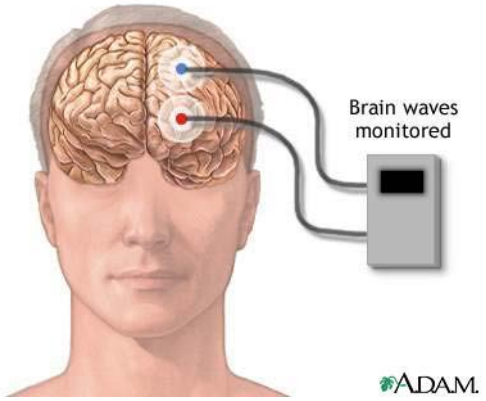
See also Emotiv, Mattel Mindflex, NeuroFocus

Journal of Experimental Psychology
Memory and Language
Language and Cognitive Processes
Brain and Language
Cognitive Brain Research
Cognition
J. Neuroscience
Psychological Science
Psychophysiology
Biological Psychology
Cerebral Cortex
Nature
Science
etc.

Mental processes are not observables; they must be inferred!

from Wordpress, photo by Gutter

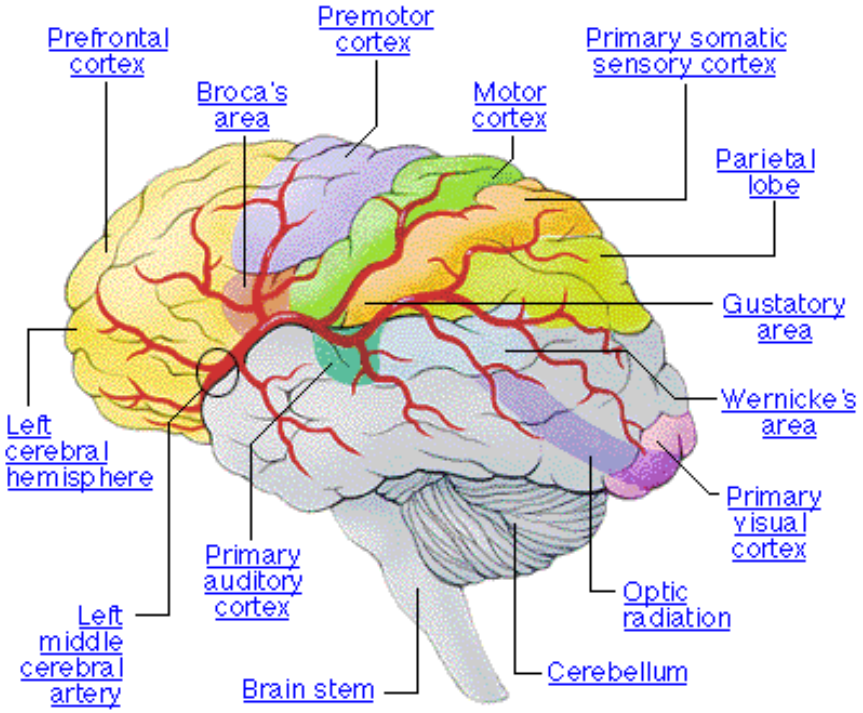




Sensation/Perception
Cognition
Memory
Emotion/Feeling/Mood
Action

Nature and time course of Processing

Representations, operations, mechanisms, and timing



EEG does NOT make brain an open book, but

The EEG can be measured during behaviorally mute epochs – between stimulation and before a response (if there is any at all) becomes visible as behavior. It makes for a great dependent variable of mental activity.

EEG bears various relationships to psychological constructs – expectation, subjective probability, selective attention, movement preparation. To explain patterns, we must take psychological context – subjective and objective – into account.

Moreover, temporal resolution of ERPs is on same order of magnitude as postulated for cognitive processes….milliseconds, seconds. Thus, ***EEG is direct manifestation of covert mental processes, and direct reflection of instantaneous neural activity.***

Relatively non-invasive and cheap and easy to record (compared to e.g., PET, fMRI).

adapted from Roesler, 2005

Greenough: "*EEG is waste matter of the mind*", but if you are interested in mind-brain interactions in HUMANS go work with

Emanuel Donchin – he runs a lab where they record electrical activity on the human scalp to make inferences about information processing. (1971)

“Has ERPolgy (brain wave recording) been cost effective, or will it go down in the history of science as a costly strategic blunder that has used up vast resources and consumed the careers of many brilliant investigators?” *Patrick Rabbitt (psychologist works in cognitive gerontology; uses reaction time as main dependent measure. Age and Cognitive Performance Research Centre, University of Manchester, England, BBS, 1988*

A little history ..

Caton (1875) discovers brain electrical activity

Berger (1929-1938) publishes about presence of electrical activity on scalp of healthy human (Elektrenkephalogramm), recorded with sensitive radio amplifiers

Adrian and Matthews (~1930): “It was difficult to think of the human brain displaying such simple uniform activity when the subject was conscious: even though his attention was not fully engaged it was difficult to suppose that most of the cortical neurons would be free to join in such uniform and regular pulsation.”

W.T. Greenough (1971): “*EEG is the waste matter of the brain*”

EEG discovered 1928

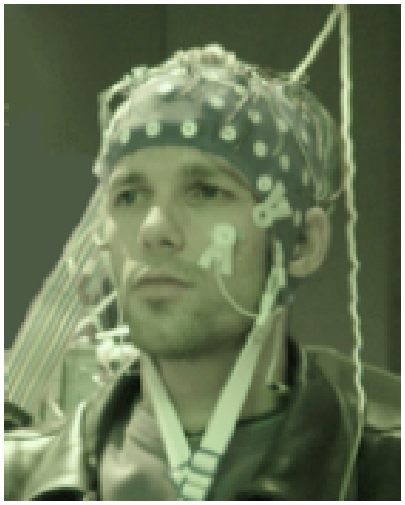
Hans Berger

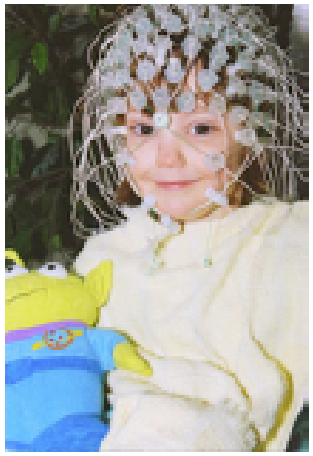
Early recording set-up

Human Subject

Modern EEG collection

(with wet electrodes)





A baseball cap that reads your mind

May 16th, 2008 By Lisa Zyga

The brain-computer interface consists of a baseball with six electrodes (one under the left ear) that detect the wearer's EEG signals. In the current prototype, the system can detect brain activity that corresponds with a person's drowsiness level. Credit: Chin-Teng Lin, et al. ©2008 IEEE.

Similar technology could also allow you to control home electronics such as TVs, computers, and air conditioners, all by just thinking about them.

Dry electrodes for monitoring of vital signs in functional textiles

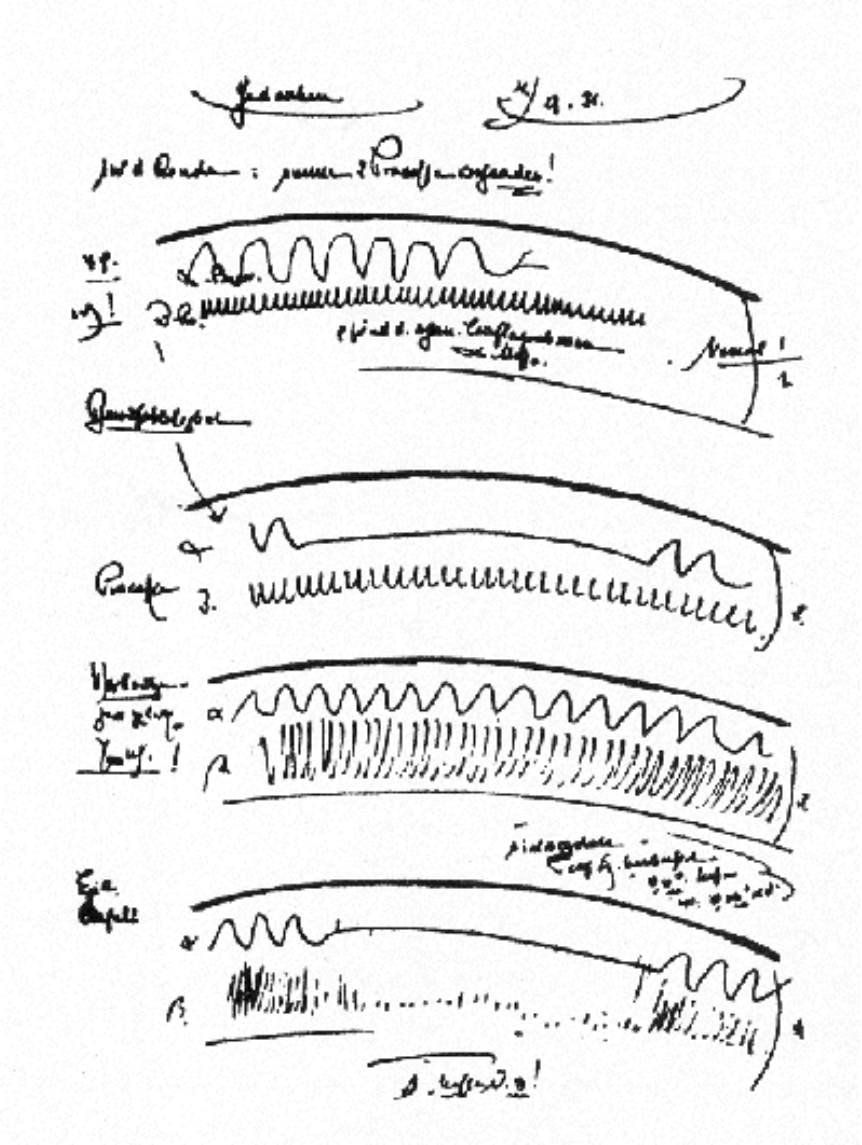
Jens Mühlsteff, Olaf Such

Abstract---**Wearable electronics may become a key element in the future to measure a patient's physiological parameters not only in a clinical environment. This paper describes dry electrodes based on conductive rubber, which can be integrated into clothing for monitoring purposes. Characteristic electrical properties like warm up time, skin electrode impedance and motion artefacts will be discussed.**

Fig. 1. Dry electrode made of conductive rubber and integrated into a garment with shielded cable

EMOTIV EEG recording device

Berger's Notebook



…one of Berger's recordings…

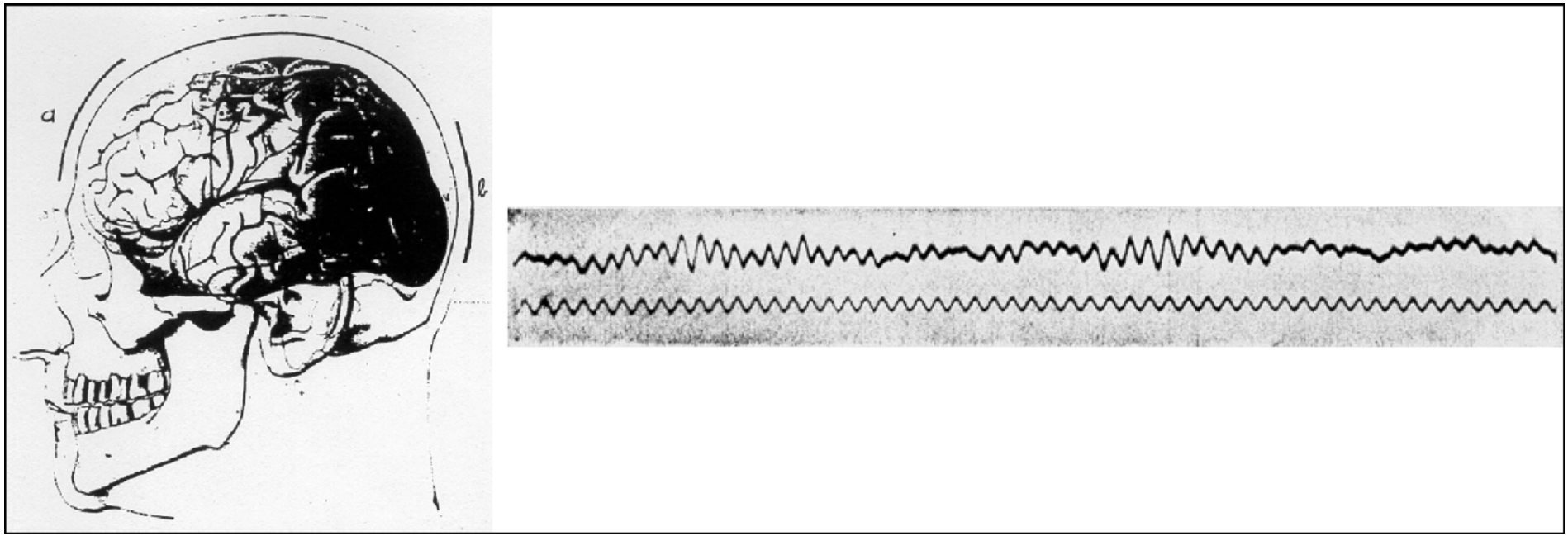


Figure 1. One of the first recordings of an electroencephalogram (EEG). Left panel: schematic illustration of the localization of lead plate electrodes: Right panel, upper trace: EEG of Hans Berger's son Klaus (15 years). Right panel, lower trace: time marker, sine wave 10 Hz. From "U¨ ber das Elektrenkephalogramm des Menschen, 1. Mitteilung," by H. Berger, 1929, *Archiv fur Psychiatrie*, *87*, p. 553.

When I eventually started to study medicine, I was primarily attracted by the diseases of the brain and the psychiatric illnesses, because I believed that the question I was most interested in could be pursued in this field at best. It was the discipline of psychophysiology, the border area where physiology and psychology meet, which should become my research area — the science which tries to delineate the relationships between brain processes and psychic events.]

(Berger, 1938, p. 173; translation by Frank Roesler)

Bands of Activity

Delta 0.5-4 Hz

Theta 4-8 Hz

Alpha 8-13 Hz

Beta 13-30 Hz

Gamma 30-50 Hz

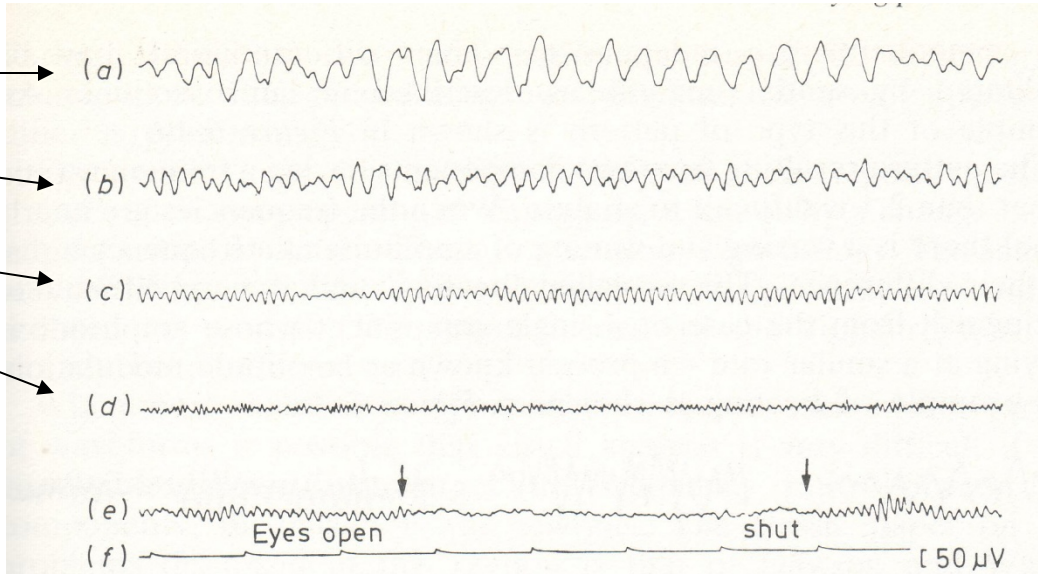
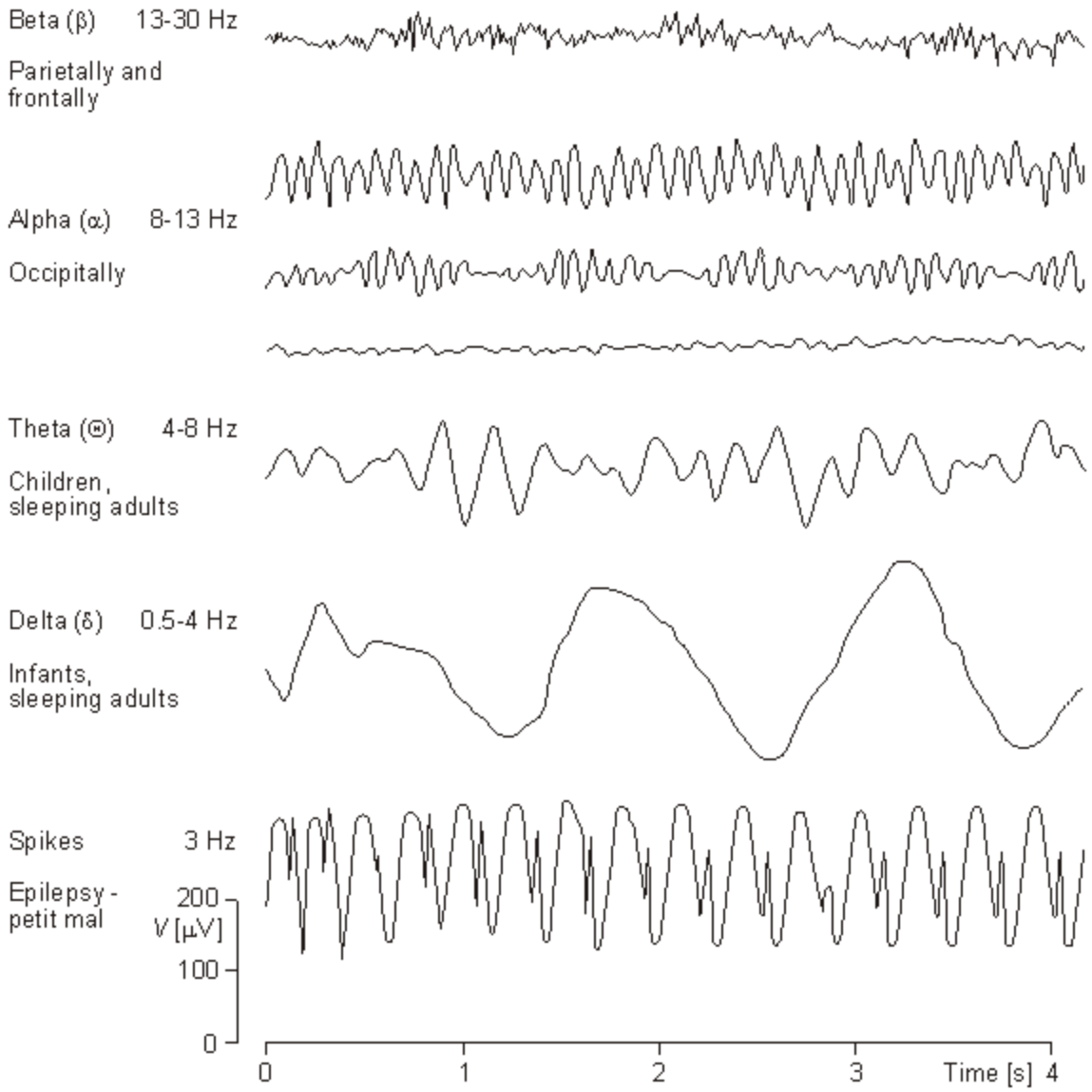


Figure 6.3 Examples of (a) delta, (b) theta, (c) alpha and (d) beta activity. (e) Blocking of the alpha rhythm by eye opening. (f) 1 s time marker



…general states of activation…alpha=rest; beta=mental activity

A little history ..

Caton (1875) discovers brain electrical activity

Berger (1929-1938) publishes about presence of electrical activity on scalp of healthy human (Elektrenkephalogramm), recorded with sensitive radio amplifiers

Adrian and Matthews (~1930): “It was difficult to think of the human brain displaying such simple uniform activity when the subject was conscious: even though his attention was not fully engaged it was difficult to suppose that most of the cortical neurons would be free to join in such uniform and regular pulsation.”

W.T. Greenough (1971): “EEG is the waste matter of the mind”

1950's-1970's

Parametrization/Measurement of a complex signal is always a problem…

…in early days of EEG, most objective method: count 0 crossings per unit time

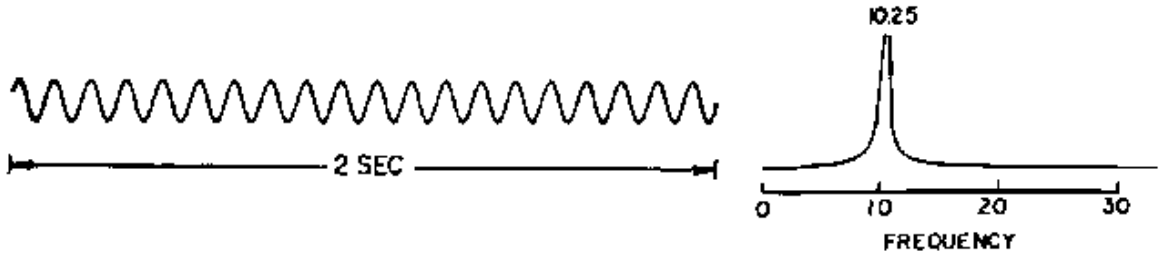
Conclusion: EEG is related to different states of vigilance

Key constructs: arousal and activation

Research topics:

1. Functional relations between EEG and *mental states* (physiologically or psychologically defined (e.g., sleep, calculation)
2. Relation between EEG and *personality traits (intraversion, IQ)*
3. Relation between EEG and *mental health status (psychiatric, neurologic)*

Major analytic advance … **spectral analysis** (objective measurement of frequency content of signal): EEG viewed as sum of set of elementary sine and cosine waves of different frequencies



a

Sine wave

b

9.75 Hz wave with noise added

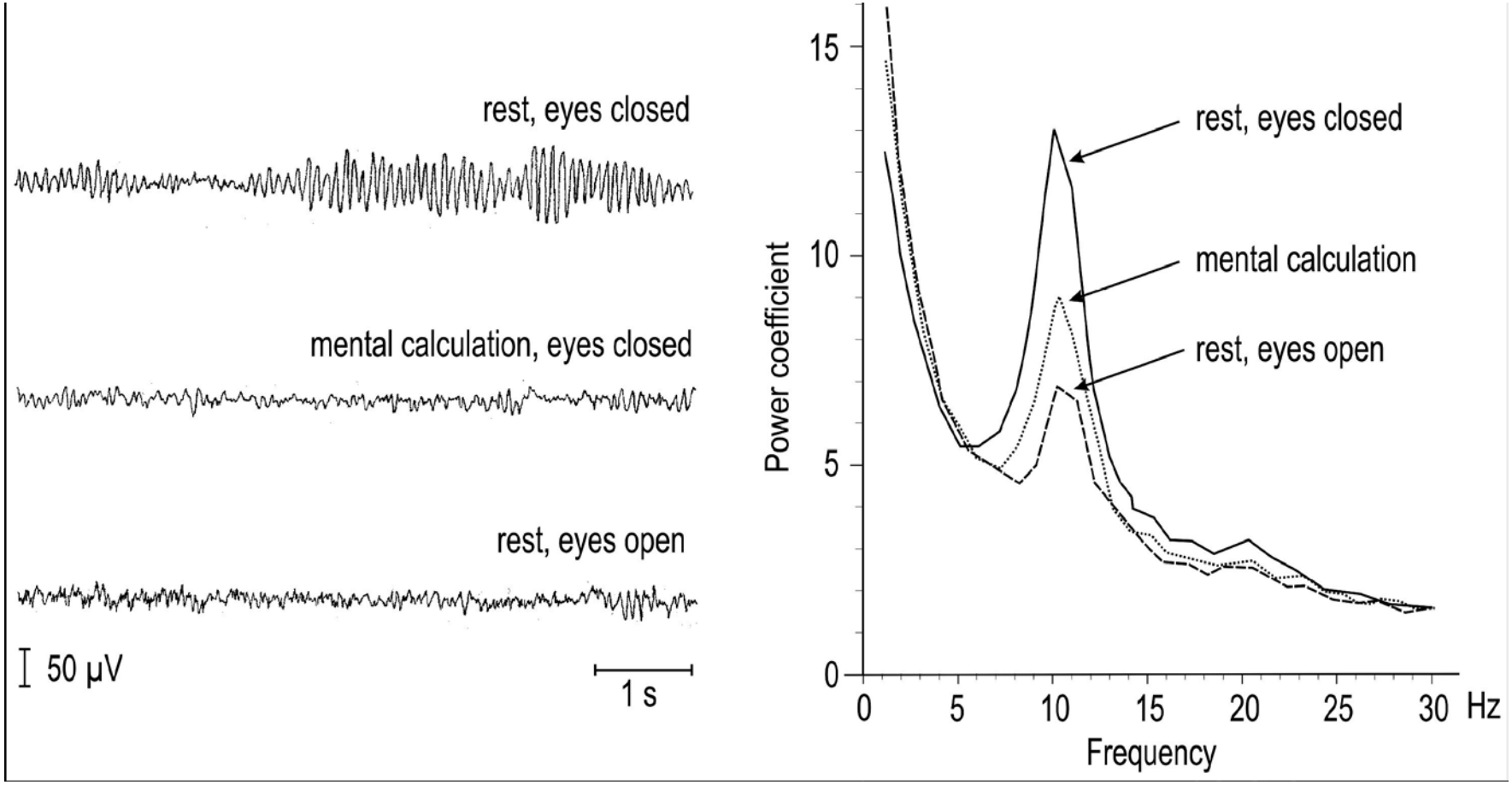
c

Noise only < 20 Hz

d

Mix of 3 waveforms

Major analytic advance … **spectral analysis** (objective measurement of frequency content of signal: EEG viewed as sum of set of elementary sine and cosine waves of different frequencies



EEG was function of situational demands and personality traits; i.e., EEG depends on psychological differences not defined by physical variables.

LIMITATIONS of EEG STUDIES

- only small (<20)% variance of EEG signal explained
- only states of long duration, not brief epochs

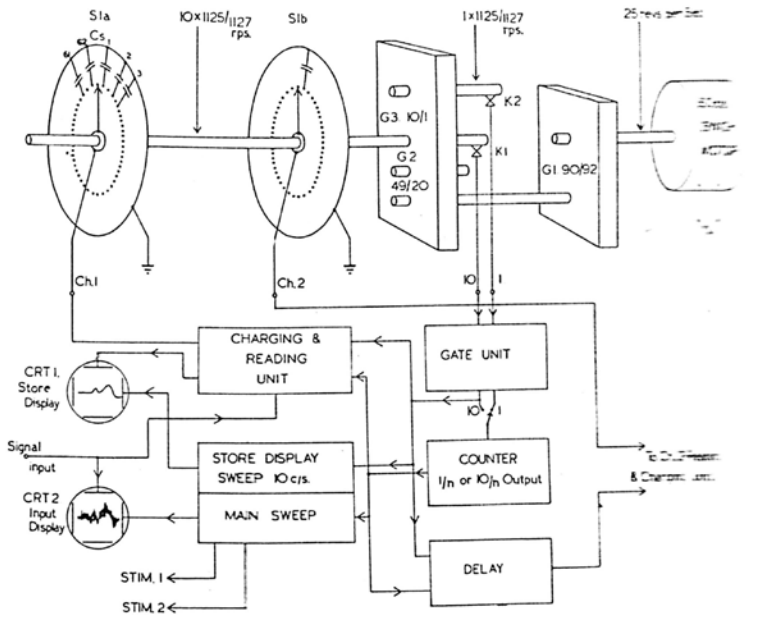
  – rest, vigilance, mental calculation, etc. but not brief epochs
- coarse states mapped onto broad psychological constructs (e.g., vigilance, arousal)

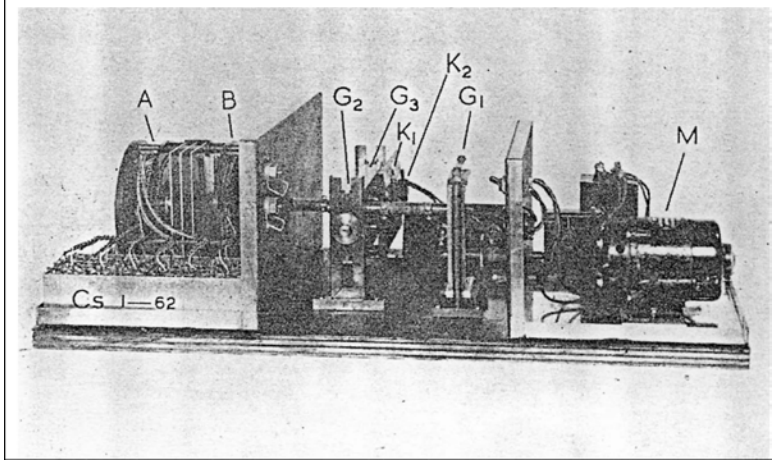
Dawson (1947)

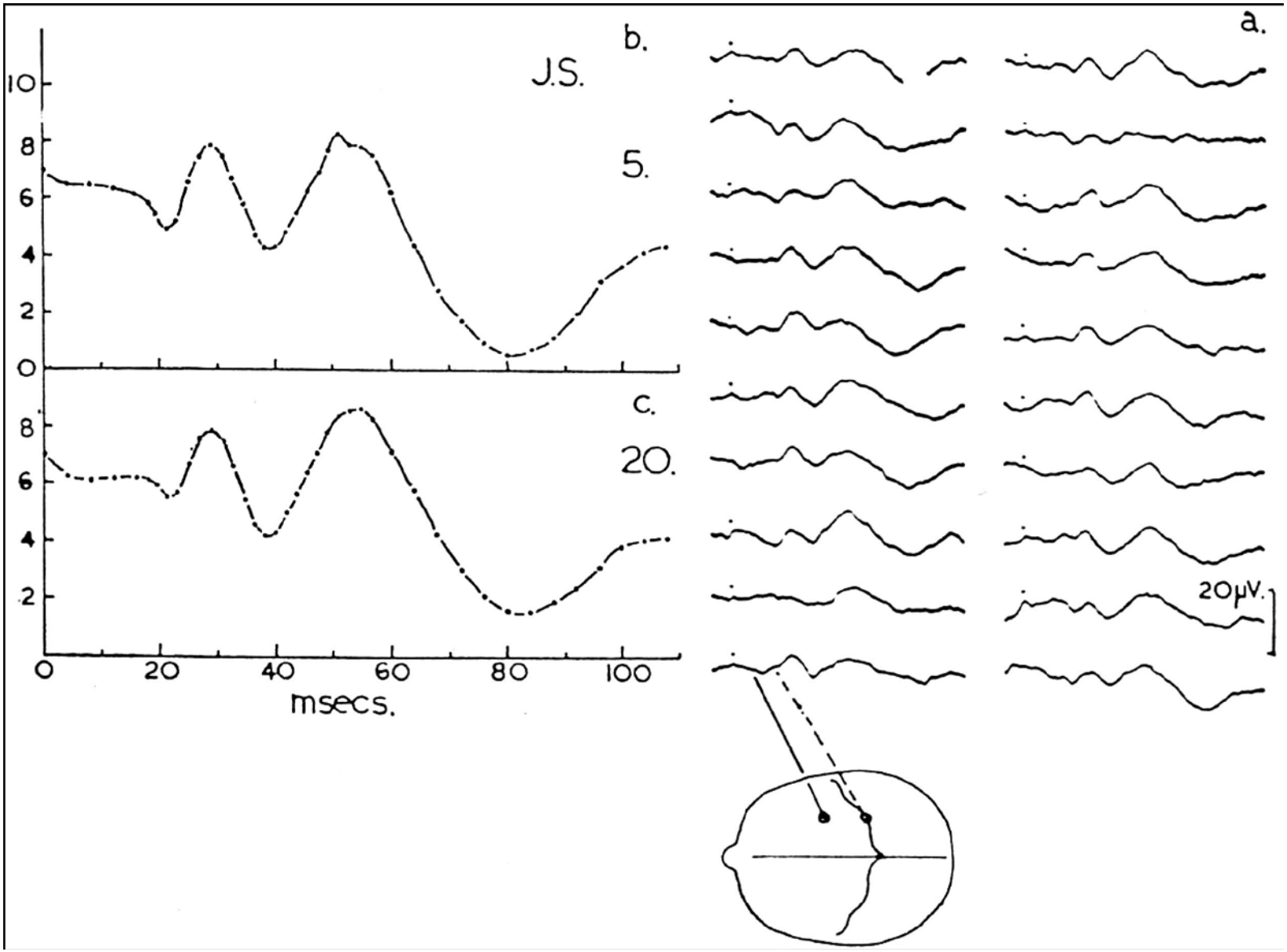
Introduced evoked potential (EP)/event-related brain potential (ERP) paradigm: believed ***there should be a systematic response of brain to an event*** – a signal buried in background EEG activity.

How to get it out?
-- overlap time-locked responses on storage oscilloscope
-- later, averaging with electro-mechanical machine using capacitors (next slide),then mainframes, and now computerized averaging algorithms

This is a controversial assumption to this day (see e.g., Kotchoubey, 2006).


S1a
Cs1
10×1125/1127 rps.
S1b
1×1125/1127 rps.
G3 10/1
G2 49/20
K2
K1
G1 90/92
Ch.1
Ch.2
10
1
CHARGING & READING UNIT
GATE UNIT
CRT 1. Store Display
Signal input
STORE DISPLAY SWEEP 10 c/s.
COUNTER 1/n or 10/n Output
CRT 2 Input Display
MAIN SWEEP
DELAY
STIM. 1
STIM. 2


A
B
G2
G3
K2
K1
G1
M
Cs 1—62



The first somatosensory EPs …(a) single trials, (b&c) averages from Dawson, 1954); averaging certainly improved signal to noise ratio!

Evoked Potentials….wow!!

The brain responds to external stimuli …and this can be recorded at the human scalp, and tracked in time.

Voltage waveforms in time with features (amplitude, latency) that are influenced by stimulus features (loudness, pitch, brightness, color, contrast, etc.)

Objective measurement of normal and abnormal sensory processing … in every sensory modality

We can record electrical activity at the human scalp and it reflects brain activity; it's not just electrical phrenology, it is systematic.

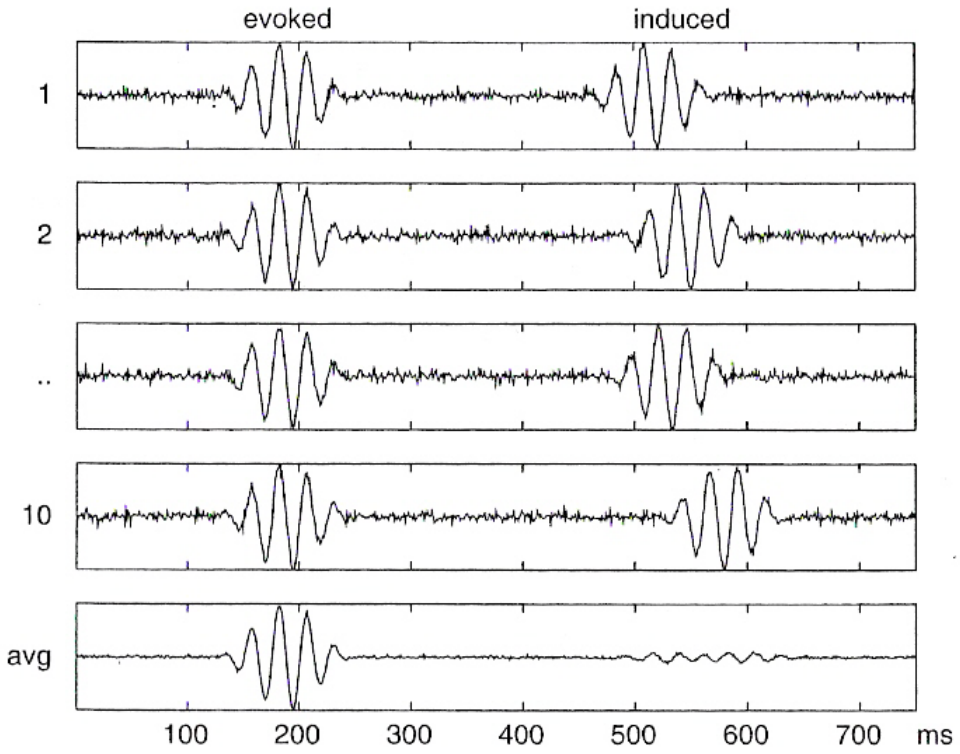


Figure 1-5 An idealized illustration of the difference between evoked and induced activity. Evoked activity (left) is precisely phase-locked to the stimulus onset and therefore is wholly retained in the average waveform (bottom). However, induced activity (left) which has a small jitter in phase will be averaged out across many trials (*From: Herrmann et al.* **[year]).**

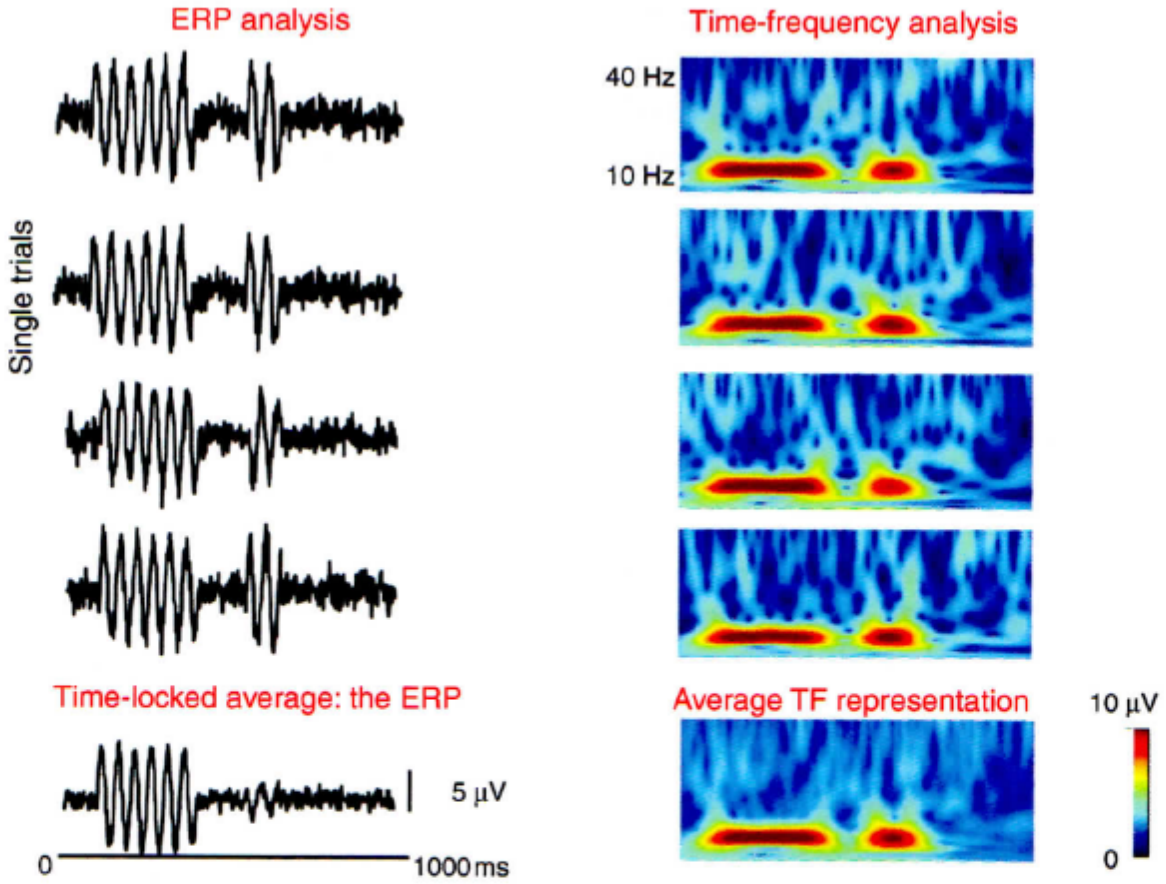


Fig. 2.1. Simulated EEG data illustrating the difference between phase-locked (evoked) activity and non-phase-locked (induced) activity. The left-hand side of the figure presents single-trial EEG time courses that show two consecutive event-related responses (an amplitude increase at 10 Hz). The first response is phase-locked with respect to the reference time point ($t = 0$), and as a result, this evoked response is adequately represented in the average ERP. The second response is time-locked, but not phase-locked to $t = 0$, and as a result, this induced response is largely lost in the average ERP. The right-hand side of the figure shows time-frequency (TF) representations of each single trial, with red colors coding for the amplitude increase at 10 Hz. Crucially, the average TF representation contains both the phase-locked and the non-phase-locked responses.

Bastiaansen, Mazaheri, Jensen, 2012

What is an evoked potential?

***Additive model or amplitude modulation theory*: discrete voltage deflection elicited by a stimulus or event**

***Phase-resetting view*: ERP or an ERP component is the consequence of phase-resetting, not a specific discrete response. A stimulus perturbs the phase of ongoing oscillation, causing the phase to become consistent across trials during the period immediately after the stimulus.**

Shared generator hypothesis