Neural Imaging and Signal Systems
(BT 640)

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Ack: Few images are from Google

Todays Lecture

EEG to Evoked Related Potential (VEP,SEP,AEP)

↓

Intro to
Brain Computer Interfaces (BCI)

↓

Cognitive Paradigms in Brain Computer Interfaces

METHODS TO ANALYZE BCI DATA

Acknowledgement: Integrated lecture from lot of resources (Textbooks, Youtube, NPTEL, coursera)

Biomedical Instrumentation System (Heart or Brain Signal)

RECAP

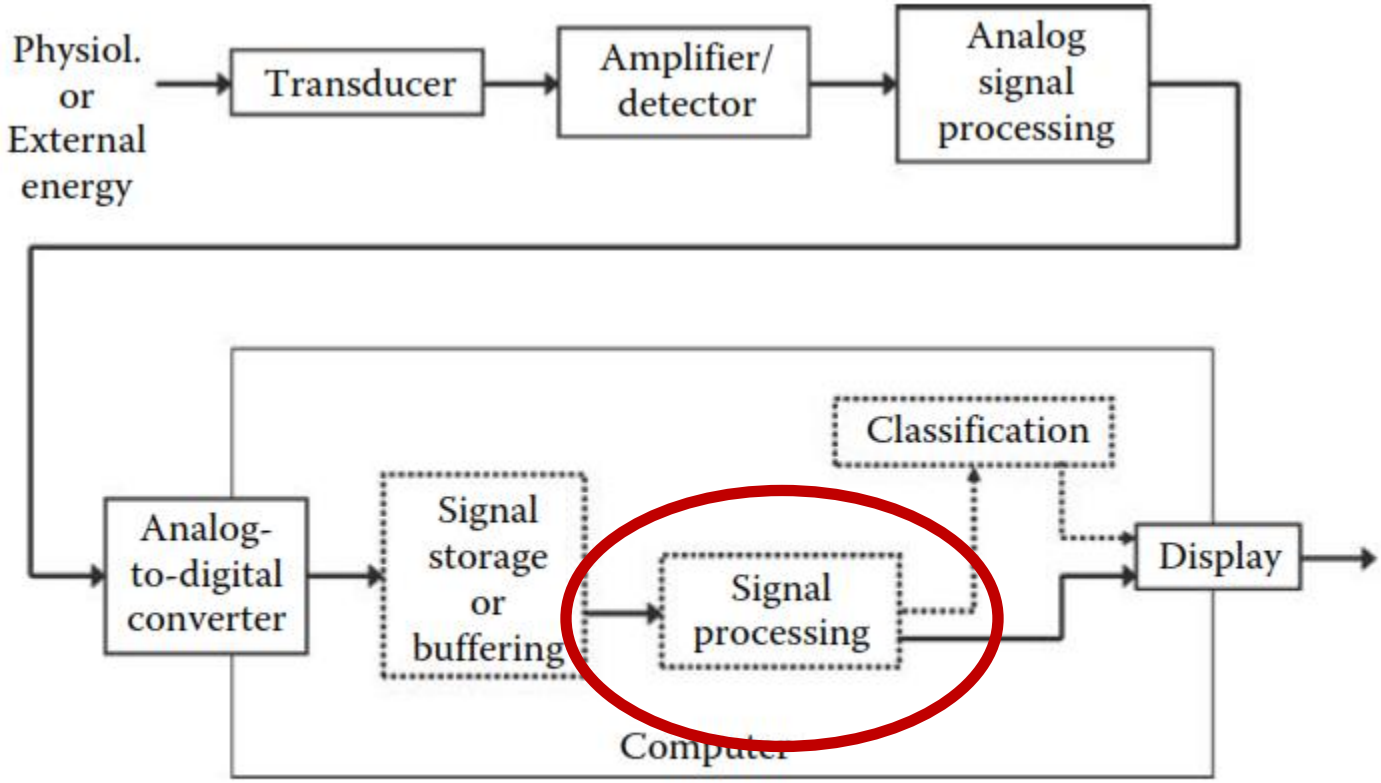
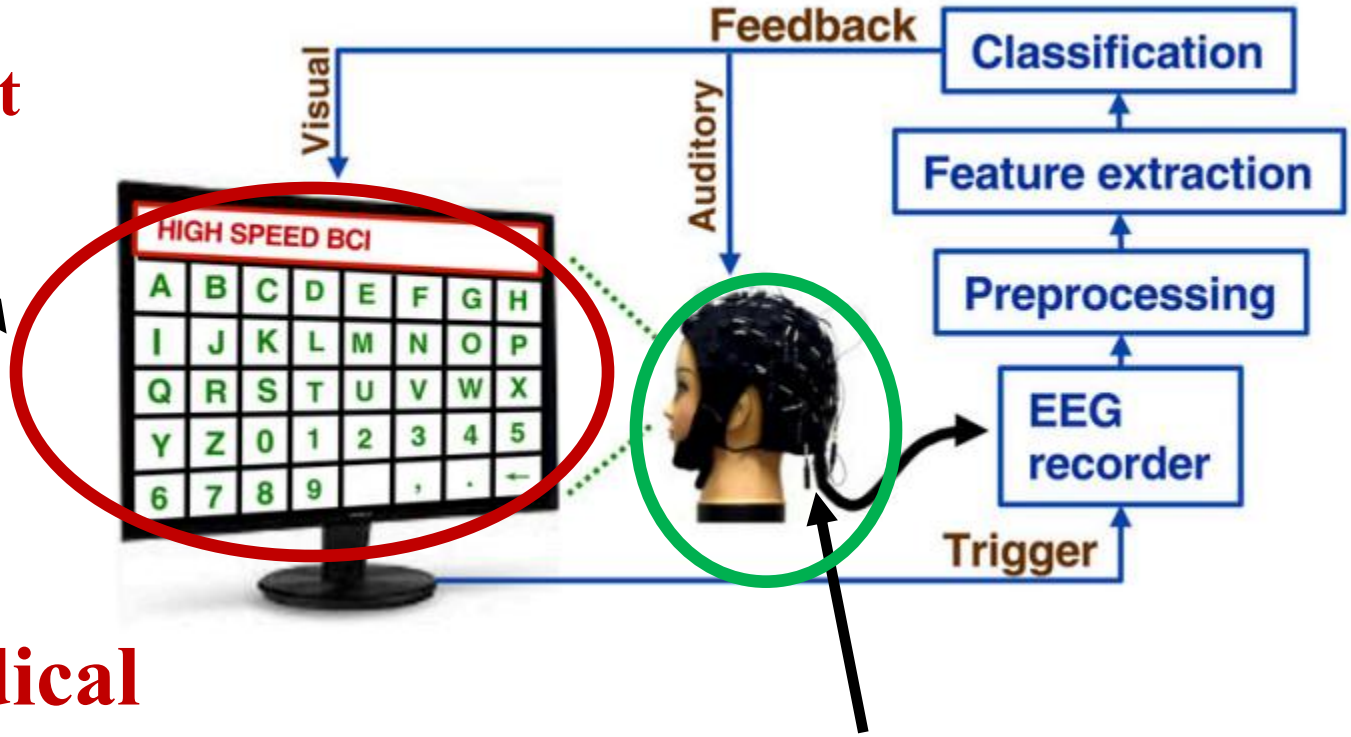


Figure 1.2 Schematic representation of a typical biomedical measurement system.

Content from Biosignal and Medical Image Processing By Semmalow

Brain Computer Interface (BCI)

Cognitive paradigm and Task is important

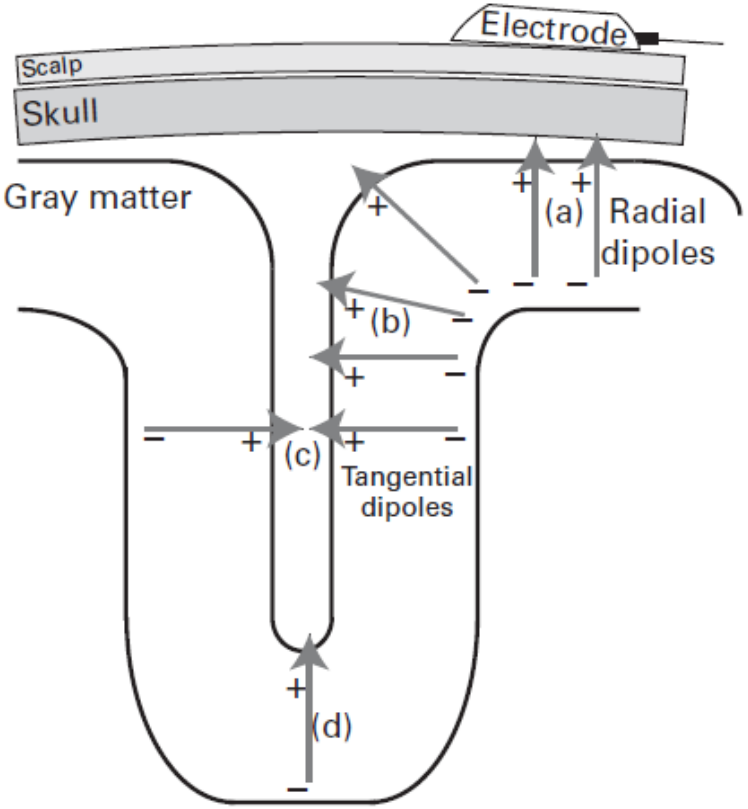


Biomedical Instrumentation System (Brain Signal)

<u>Electroencephalogram</u> is one type of Modality

Image from Google (Modified)

Already SEEN



Content from book: Mike Cohen, Analyzing Neural Time Series Data

Journey from EEG (Electroencephalogram) to Event Related Potential (ERP)

EEG cannot measure all neural events. In fact, most of the events in the brain are not measurable with EEG. If you find that assertion disappointing or disheartening, perhaps you will take some comfort in reading that the same could be said of all brain-imaging techniques, from single-unit recordings to local field potentials, from voltammetry to MR-based imaging. No single brain-imaging technique can record most of the events in the brain. Differ-

Physiological Basis of Electroencephalogram (Already Seen)

Dipole orientation around sulcus regions of brain with respect to skull

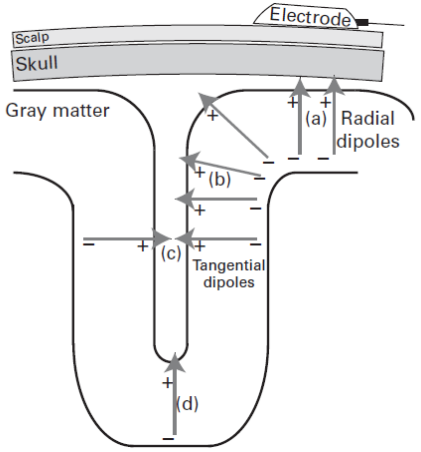


Figure 5.1

Illustration of dipoles in different orientations with respect to the skull. The dipoles illustrated in (a) will contribute the strongest signal to EEG, whereas the dipoles illustrated in (b) will contribute the strongest signal to MEG. The dipoles illustrated in (c) are unlikely to be measured because the dipoles on opposing sides of the sulcus produce electrical fields that are likely to cancel each other. The dipole illustrated in (d) will make a smaller contribution to EEG than dipole (a) because it is further away from the electrode. (This figure is inspired by figure 1 of Scherg 1990.)

Content from book: Mike Cohen, Analyzing Neural Time Series Data

Journey from EEG (Electroencephalogram) to Event Related Potential (ERP)

- EEG reflects mainly the summation of excitatory and inhibitory postsynaptic potentials at dendrites of ensemble of pyramidal neurons (Mike Cohen, Neural Time Series).

- Electrical potential generated can be modeled as dipole.

- Electrical fields generated by individual neurons sum, and the resulting field becomes powerful enough to be measured from outside the head.

Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

Event Related Potential/Evoked Potential

- Event related potentials (ERP) display stable time relationship to a definable reference event. (Vaughan et al, 1969).
- Temporal response to some stimulus like visual, audio, somatosensory, etc.
- As we know, the ERP is evoked with the brain still active doing other things.
- So we have ERP plus ongoing background EEG.

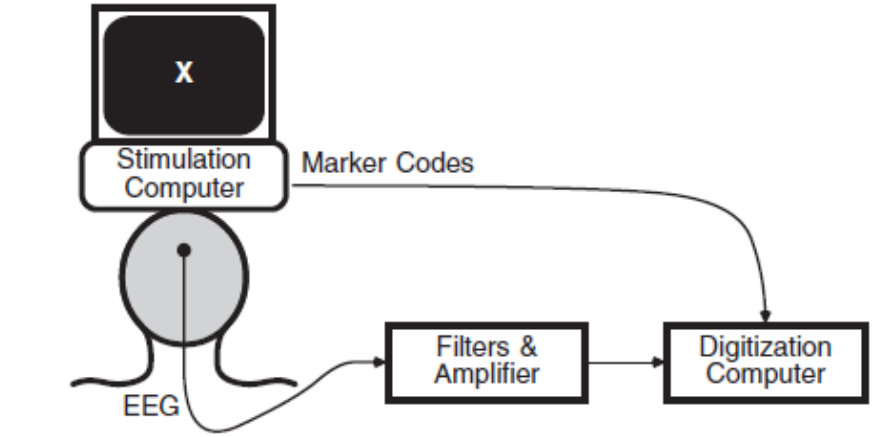
Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

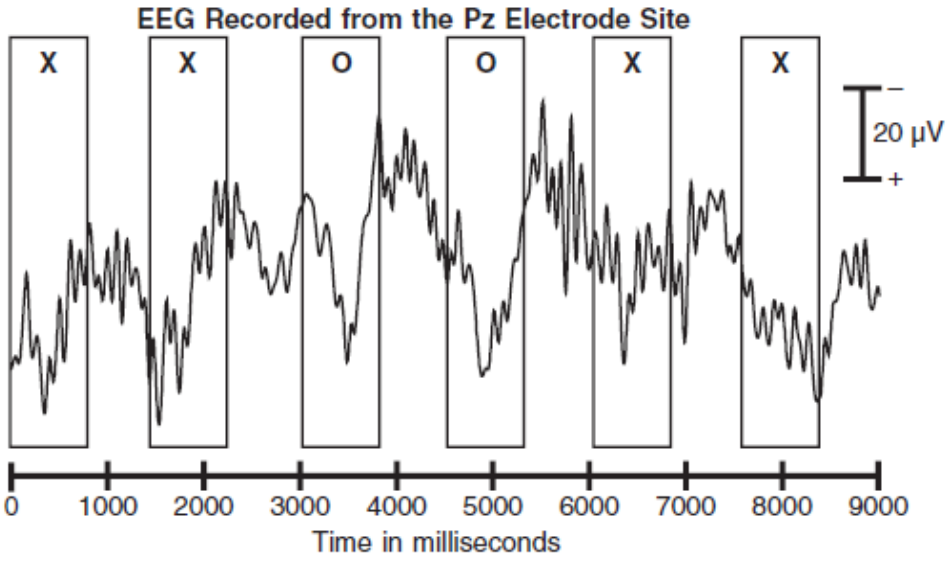
Visual Evoked Potential

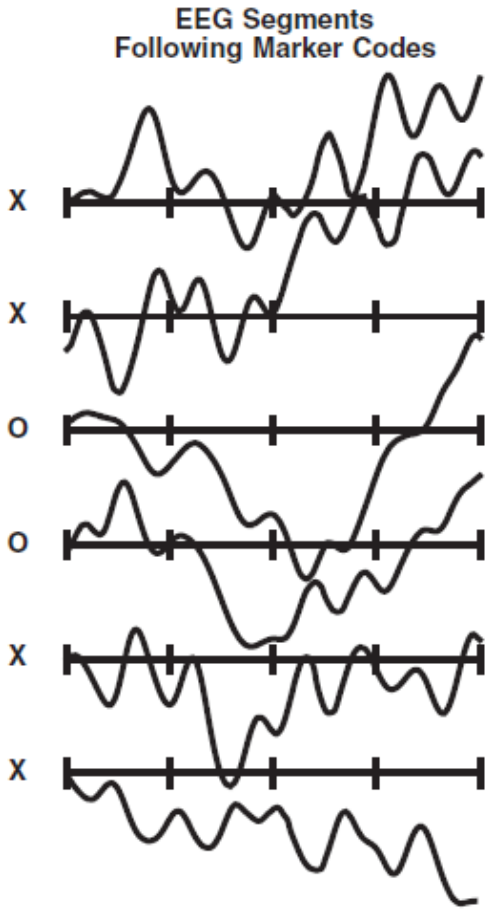
- Visual Evoked potentials (VEP) when subjects perceive visual stimulus during a task.
- Amplitude from VEP higher than AEP or SEP, and range up to 20 microVolt
- Visual Evoked Potential is studied the most using EEG.

Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

VEP experiment







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VEP experiment-ENSEMBLE AVERAGE OF "O" TRIALS

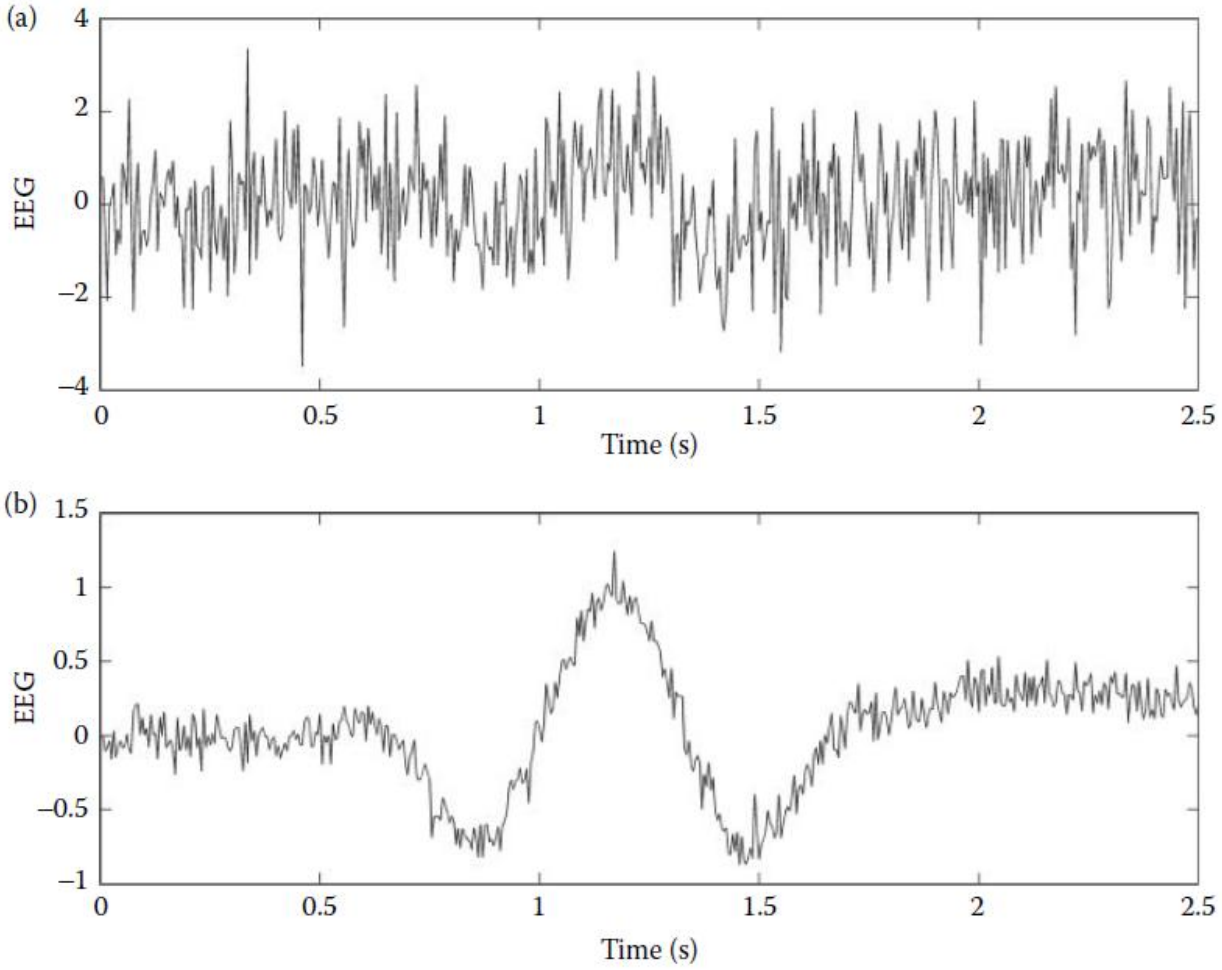


Figure 4.2 (a) The raw EEG signal showing a single response to the stimulus. (b) The ensemble average of 100 individual responses such as in graph (a) with the VER now clearly visible.

Content from Biosignal and Medical Image Processing By Semmalow

Some Strategy to Analyse Signals

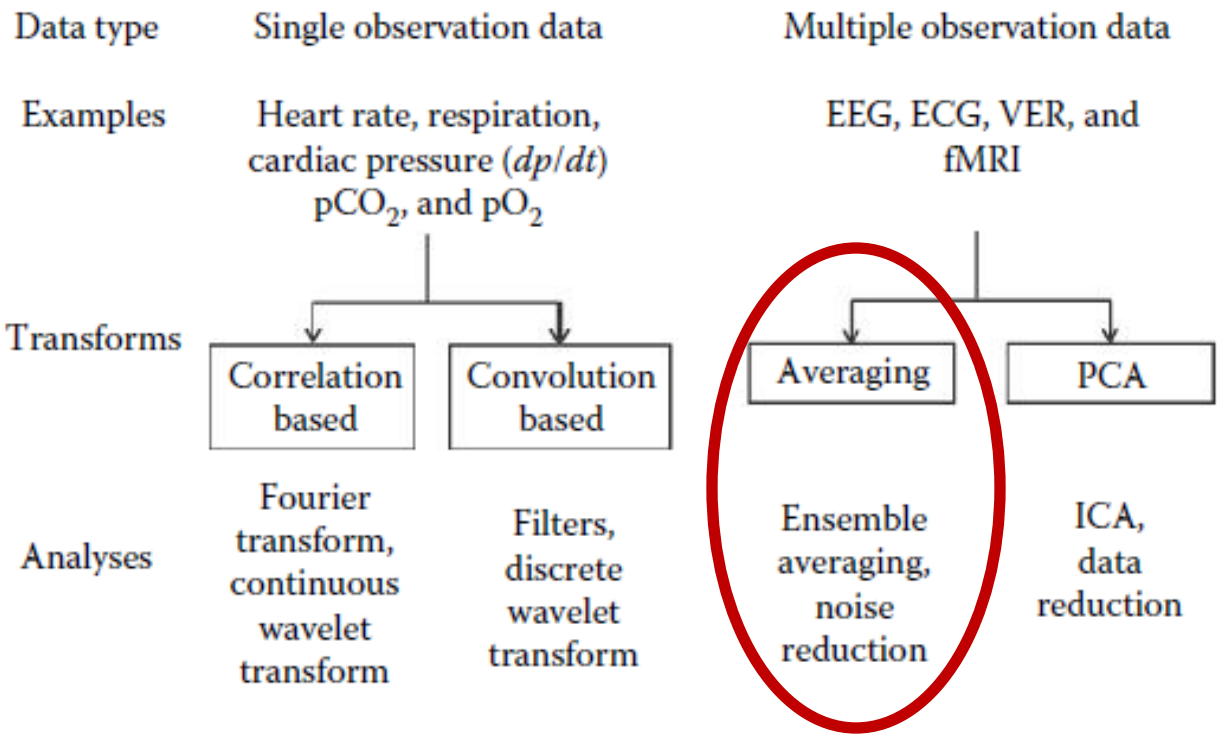
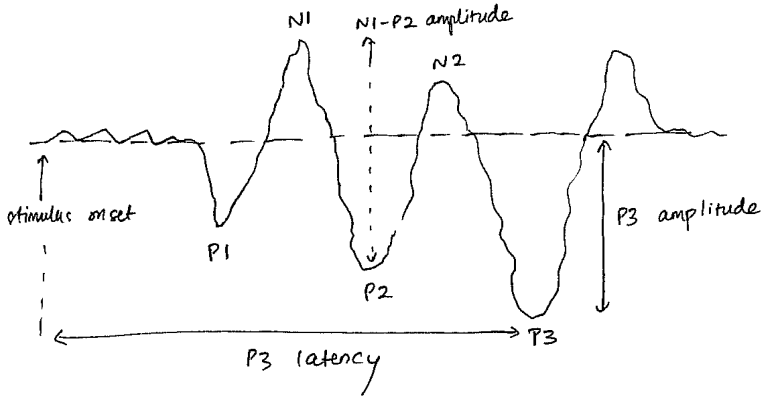
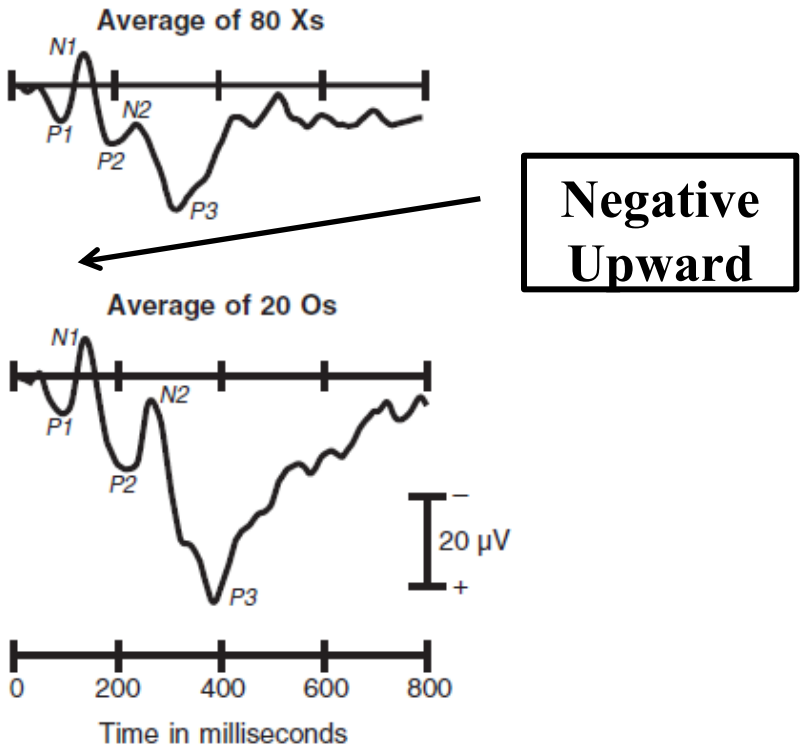


Figure 2.7 A summary of some of the analyses techniques covered in this book, the basic strategy used, and the related data type.

Content from Biosignal and Medical Image Processing By Semmalow

Results-A simple VEP experiment





Early physiologists plotted negative upward because this allows Resting/Action potential to be plotted as an upward spike

Textbooks still use both creating confusions to new comers but do mention explicitly

Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

EP components evoked across ERP studies (i.e. VEP, AEP and SEP)

Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

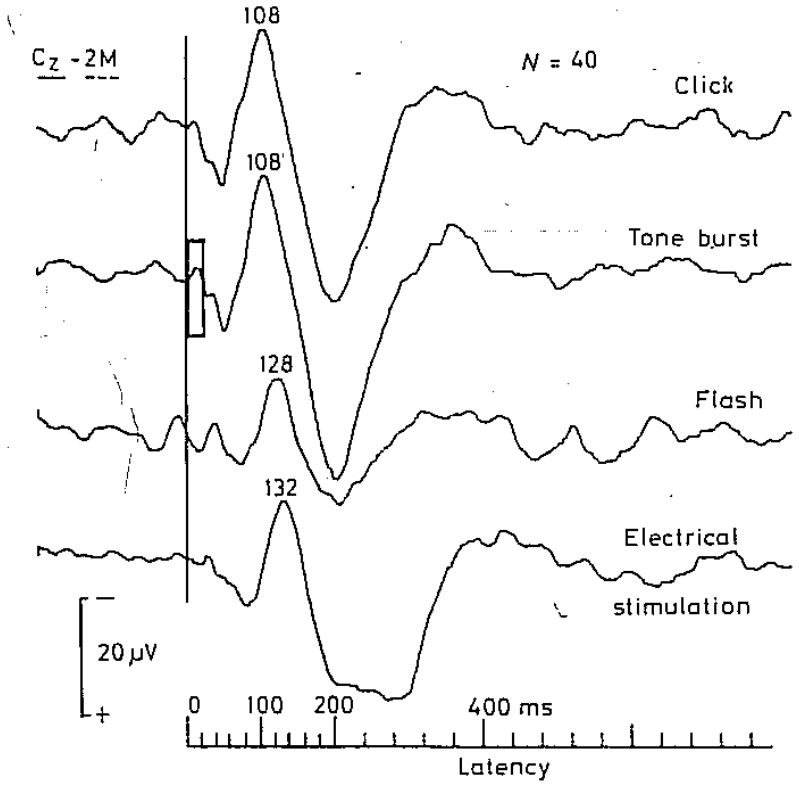
EP components evoked across all ERP studies (i.e. VEP, AEP and SEP)

- Many components can be evoked with different experimental paradigm.

- Some of these components
  - N100
  - P300
  - N400

EP components evoked across all ERP studies (i.e. VEP, AEP and SEP)

ERP component – N100



Average evoked potentials in response to various stimuli. The latency of the 'N100' is shown on the traces. The increased latencies of flash and electrical evoked potentials can be attributed to the peripheral delays. Vertex referred to common mastoids

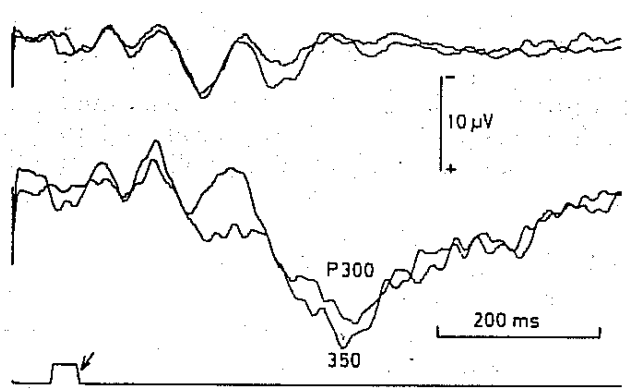
- N100 can be evoked easily by auditory, visual and tactile stimuli.
- For example, clapping a hand, showing a flash of light.
- **It is believed to be the response to stimulus perception, i.e. when the brain recognises that a stimulus has been presented.**
- Normally, N100 is less than 20 Hz, so a LPF of 20 Hz should be used.

Figure from Cooper et. al., EEG technology, 3rd ed.

P300 component

EP components evoked across all ERP studies (i.e. VEP, AEP and SEP)

ERP component – P300



P300 for non-target and target pictures

X

- P300 is the third positive component evoked with latency about 300 ms.It relates the subjects ability of attention
- P300 is commonly elicited using oddball paradigm
- Say, two pictures are presented, one with higher frequency than the other
- The subject has to responds (say by pressing a button) when the infrequent picture is seen
- This is when P300 will be evoked significantly
- Eg: 2 pictures square and X shown
- Square shown with 80% probability, subject concentrates on the occurrence of X
- When X occurs, P300 is elicited
- Normally, P300 is less than 8 Hz, so a LPF of 8 Hz should be used
- P300 is maximal is midline parietal, i.e. Pz.

Figure from Cooper et. al., EEG technology, 3rd ed.

EP components evoked across all ERP studies (i.e. VEP, AEP and SEP)

ERP components – N400

- N400 is the negative component evoked with latency about 400 ms.
- It relates the subjects ability in processing semantic information
- Normally, N400 is less than 8 Hz, so a LPF of 8 Hz should be used
- For example, word in a sentence that is an outlier will evoke N400.

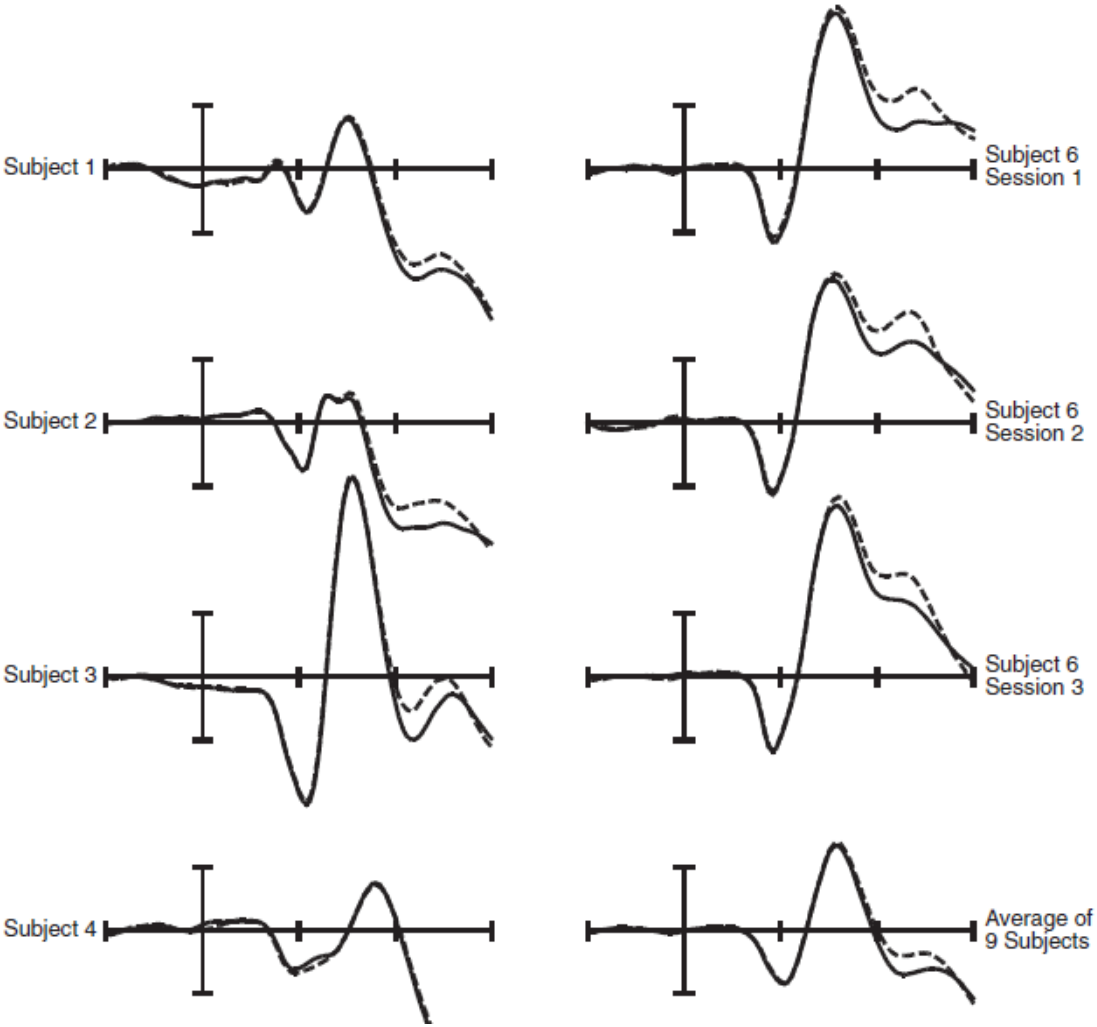
"It was nice seeing you eating a cake" may not evoke N400.

But "It was nice seeing you eating a cage" will evoke N400.

So, N400 has been used in assessing language capabilities

How reliable are ERP across subject to subject and across same experiments??

Reliability of ERP across sessions/subjects



- ERP components differ between subjects and within sessions

Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

Cons/Pros of ERP

- Compared to behavioural measures like self reports, questionnaires (there is a cognitive connect from ERPs)
- Temporal resolution is high.
- Spatial resolution is poor.
- ERP setup cost is less when compared to MRI.

Steve Luck's Book: Introduction to Event Related Potential and its Neural Origins

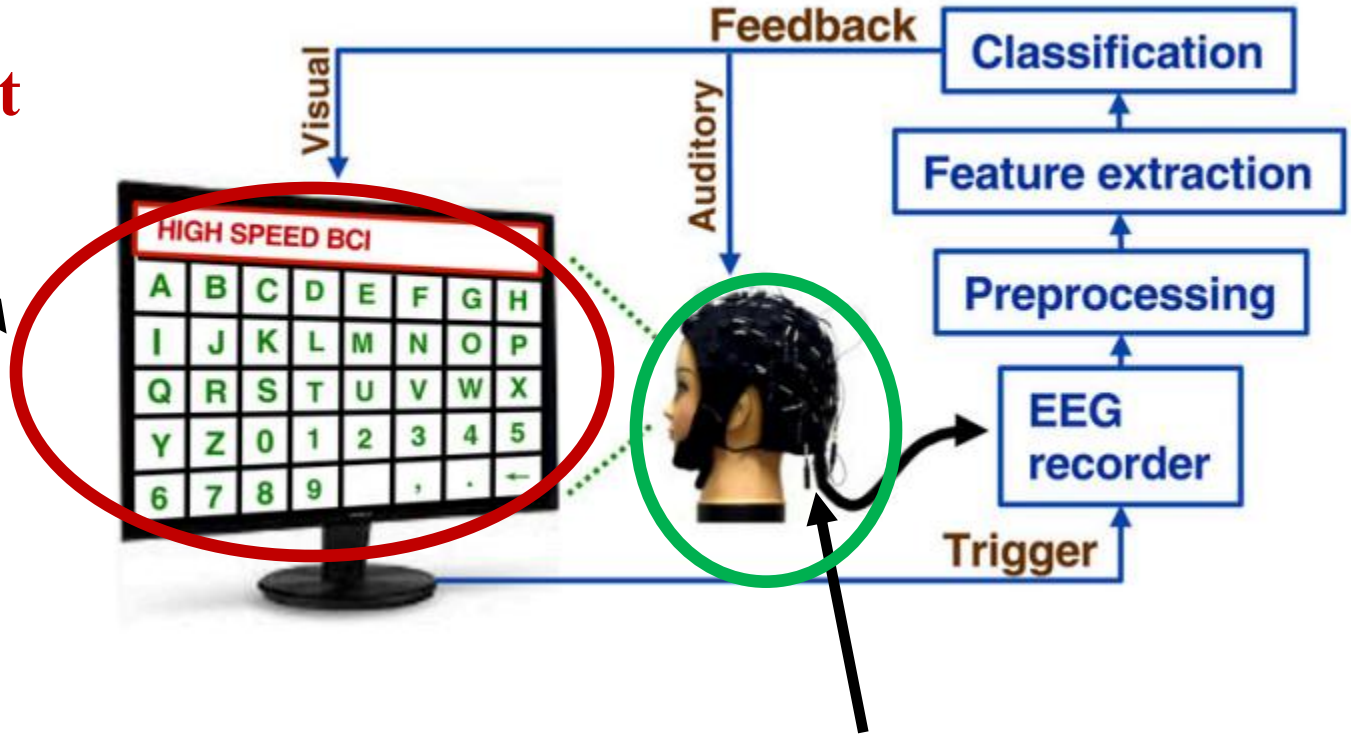
What is Brain Computer Interface(BCI) Traditionally

Traditional BCI Definition-Purists Way

- A BCI is a system that measures activity of the central nervous system (CNS) and converts it into artificial output that restores or replaces natural CNS output
- Enables brain activity to control external devices.
- Is to give severely paralyzed people (say: locked in) a way to communicate without depending on muscle control.
- BCI combines hardware for acquiring brain signals, cognitive paradigm and machine learning algorithms to enable communication.

Brain Computer Interface (BCI)

Cognitive paradigm and Task is important



<u>Electroencephalogram</u> is one type of Modality

Image from Google (Modified)

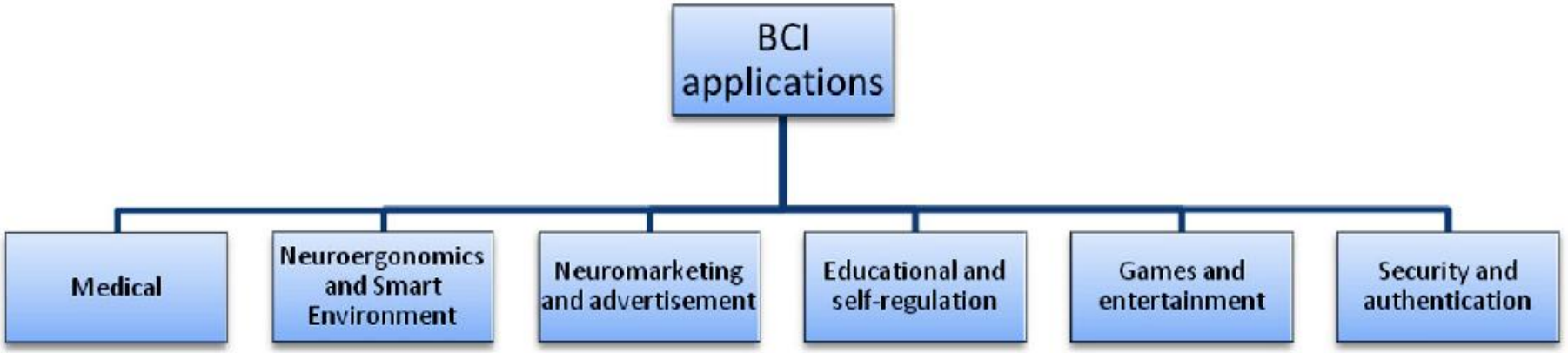
Can Brain Computer Interface(BCI) be used to find what Mr.X thinks?

Brain Computer Interface(BCI) the Modern T20 way

Modern BCI Definition-Perhaps T20 way

- A system which takes any biosignal (eyeblinks, muscle movements) and maps the intention of a person in real time

BCI applications

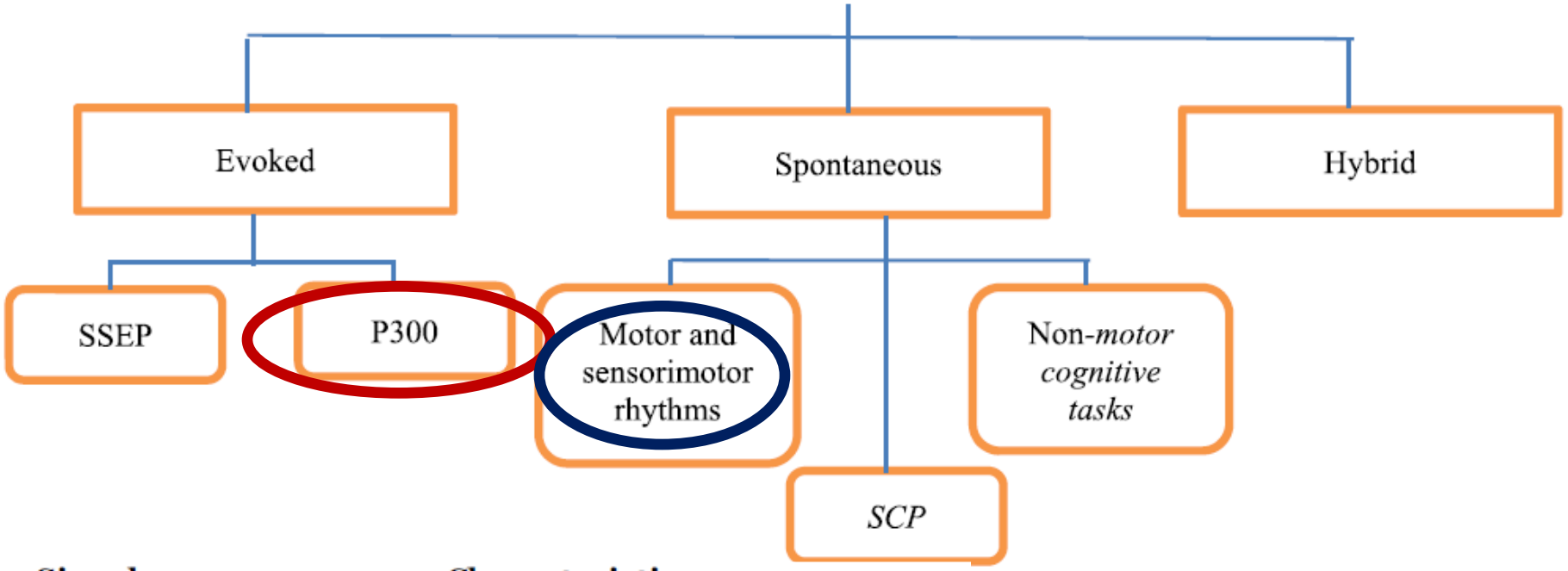


Ramadan, Rabie A., and Athanasios V. Vasilakos. "Brain computer interface: control signals review."*Neurocomputing*223 (2017): 26-44

Next lets look at

Cognitive Paradigms

Cognitive Paradigms- Control Signals



Signal	Characteristics
VEP	It is based on signal modulations in the visual cortex
P300	It is the positive peaks due to infrequent stimulus
SCP	It is the slow voltages shift in the brain signals
Sensorimotor rhythms	It is based on modulations synchronized to motor activities

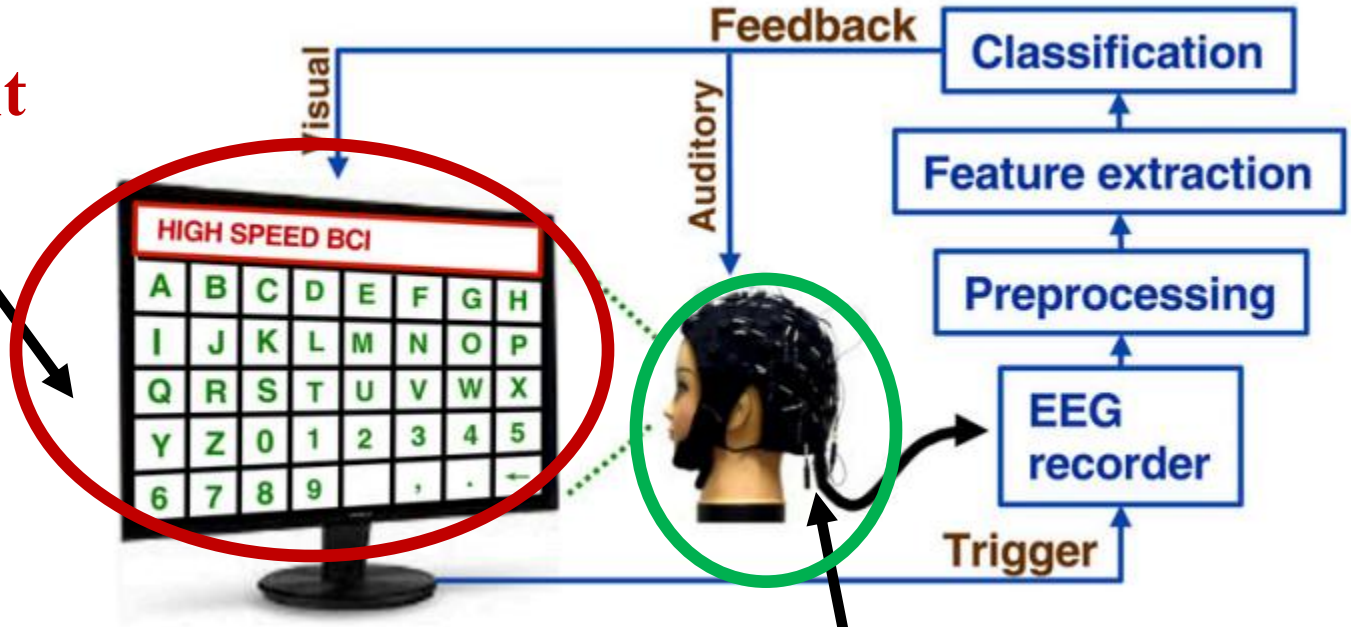
R.A.Ramadan et al, Neurocomputing, 2017

Lets Focus on EEG-BASED BCI (Paradigm-P300)

Revisiting Brain Computer Interface (BCI)

Cognitive paradigm and Task in important

We decided P300 ☺



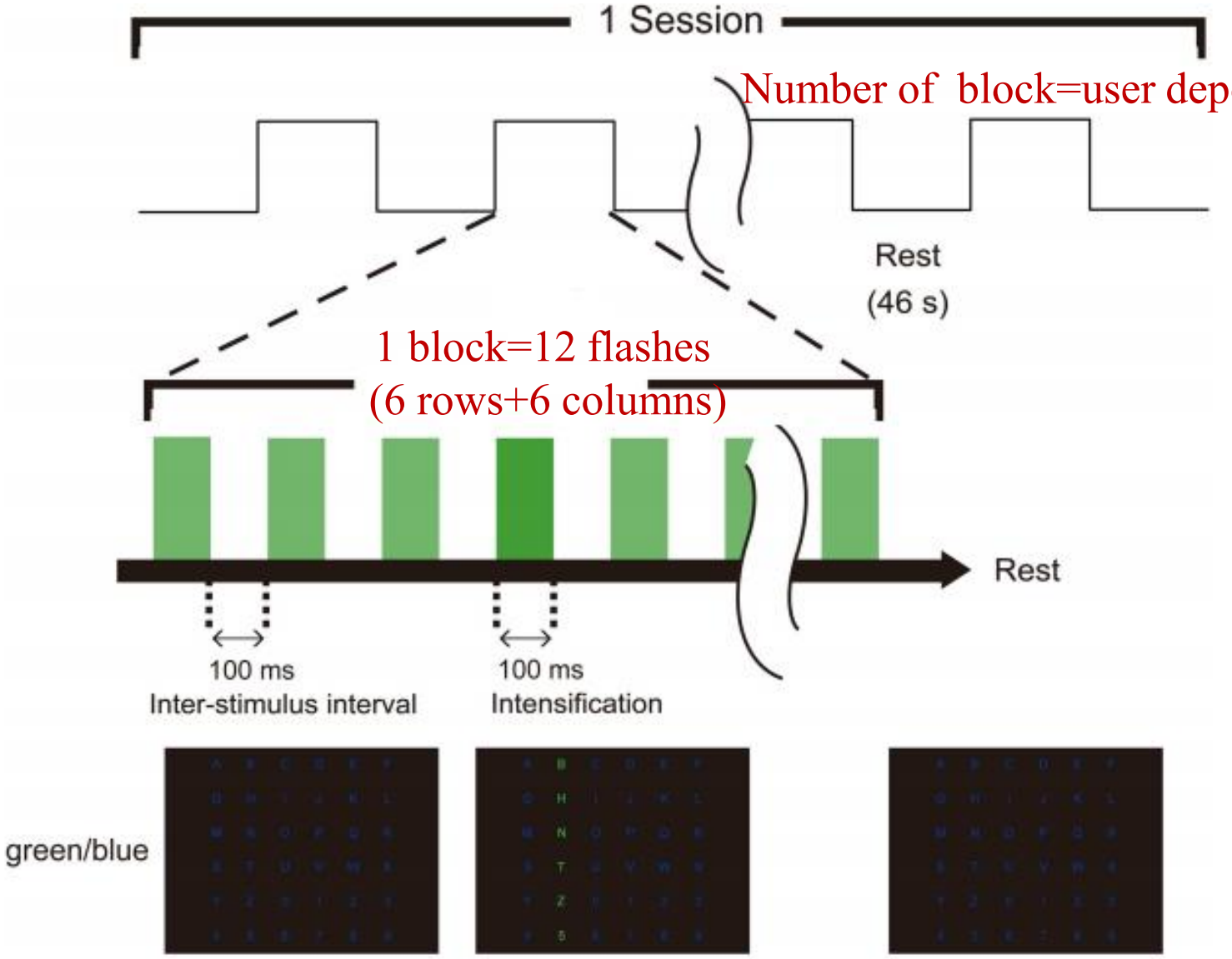
We decided EEG

Numerous ways to Acquire Data for BCI from brain

Image from Google (Modified)

Exploiting P300 ERPs for Spelling Letters

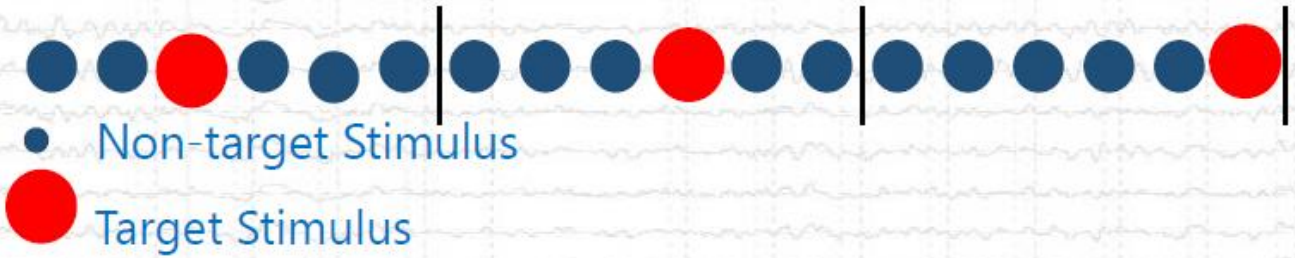
P300 Matrix Speller

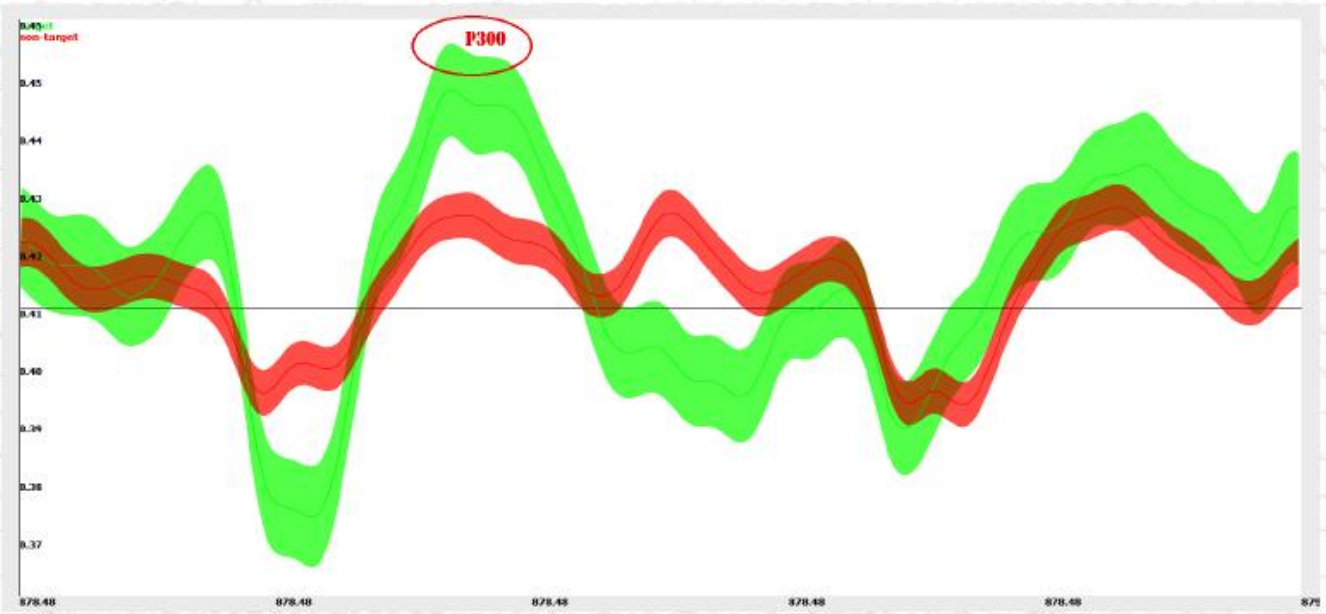


Modified from S.Ikegami et al, Frontiers in Neurology, 2012

Translation of EEG to command
(Simple Signal processing)

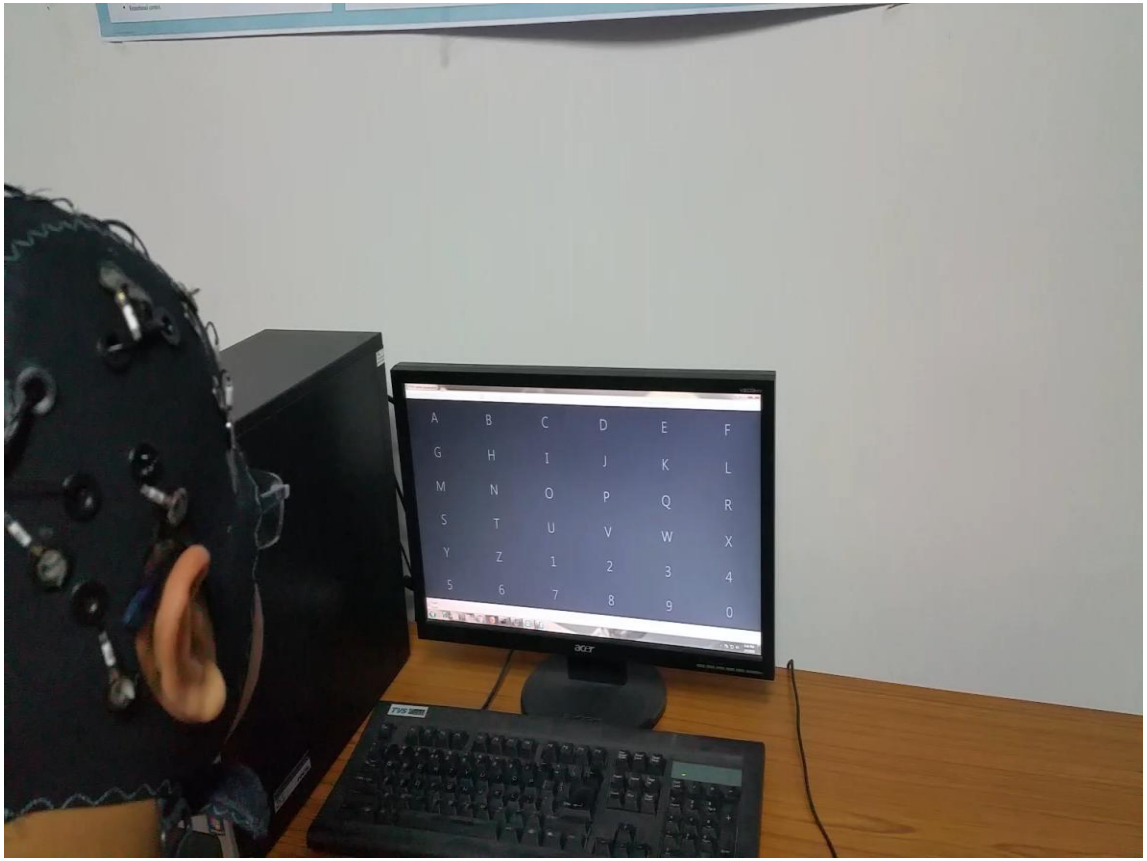
Average of epochs from target and non-target trials in Pz electrode





Acknowledgement for preparing this Figure: Mr.Bipra Chatterjee, IIT Guwahati

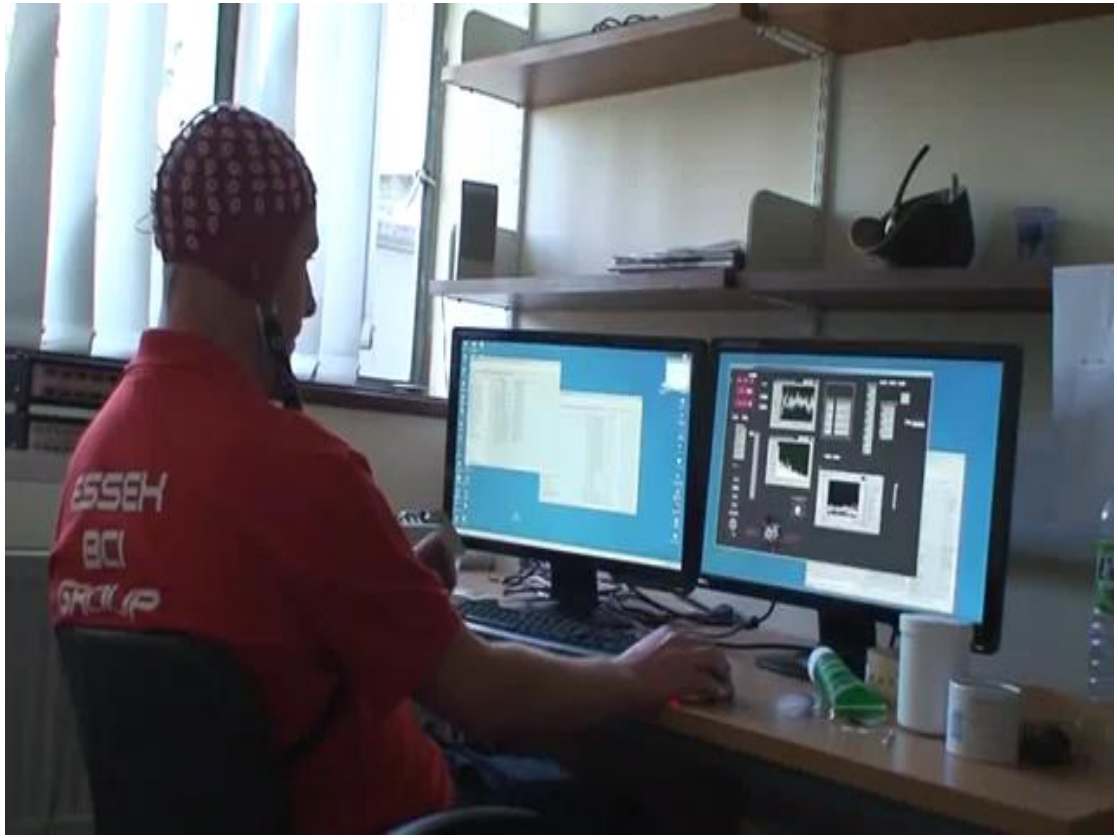
P300 Matrix Speller at IIT Guwahati



Temporal features (1-12 Hz) and a Bayesian LDA classifier.

Nearly five subjects able to spell a letter under 1.5 mins in real-time.

SSVEP system at University of Essex



Developed by Prof.Palaniappan and Dr.John Wilson

Some Strategy to Analyse Signals

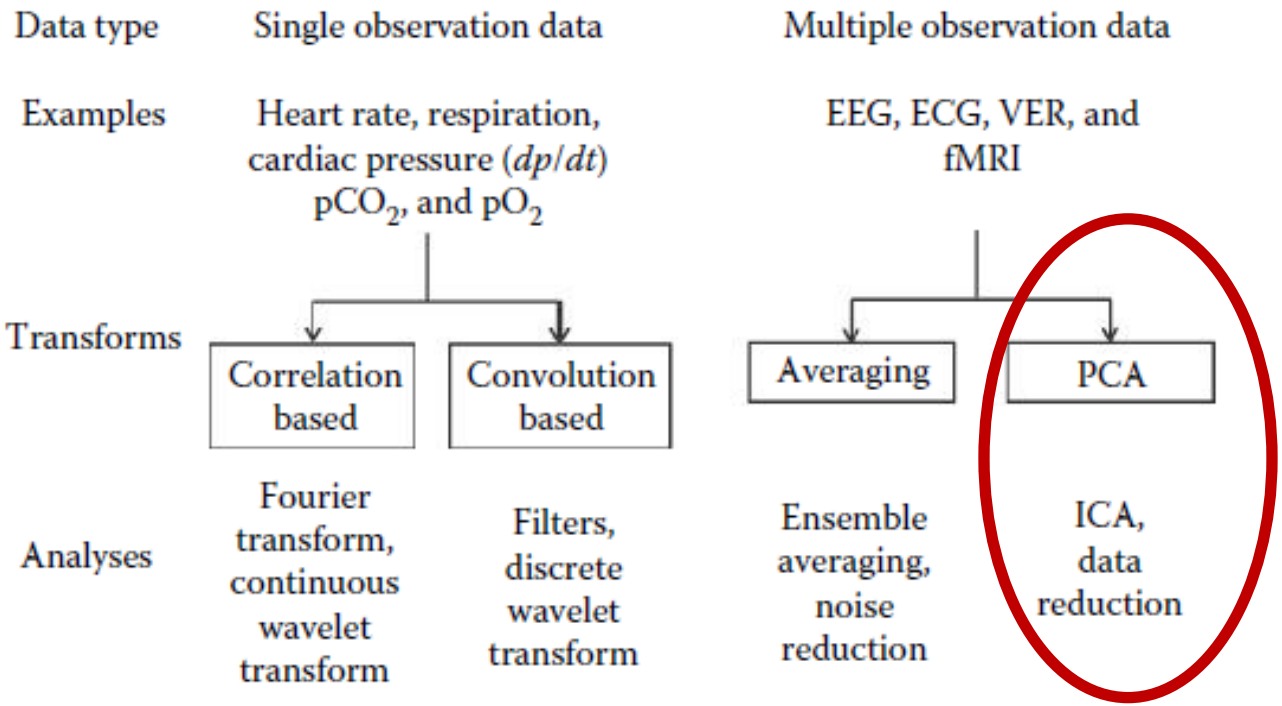


Figure 2.7 A summary of some of the analyses techniques covered in this book, the basic strategy used, and the related data type.

Content from Biosignal and Medical Image Processing By Semmalow

Any Questions?

Thanks for Coming ☺