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Lecture Title: EEG PART 1.

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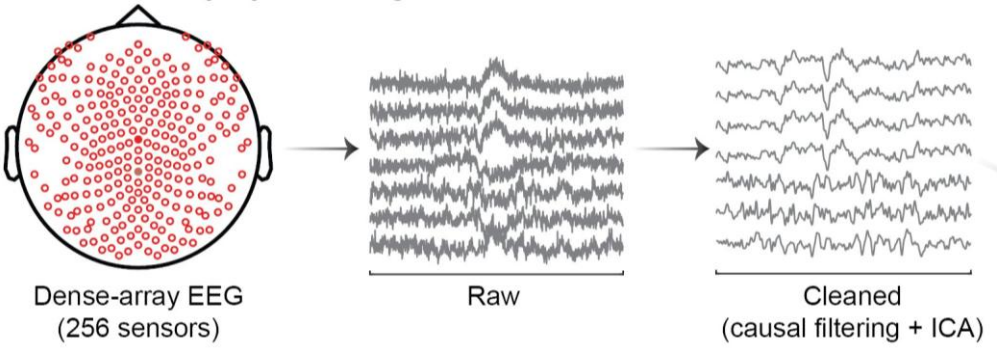
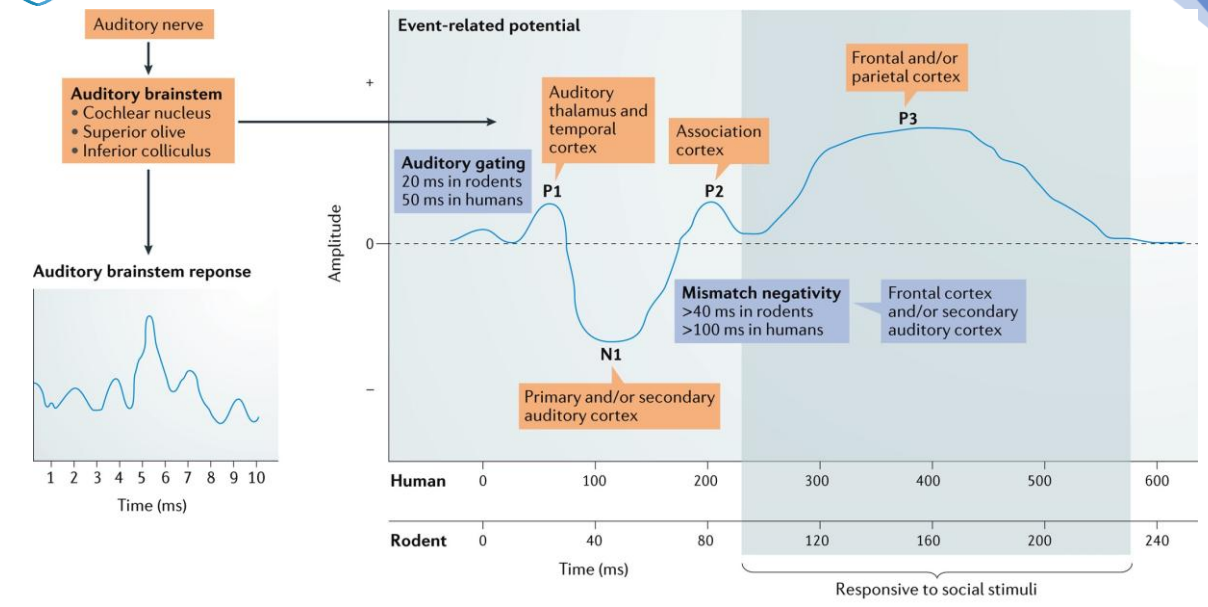
EEG

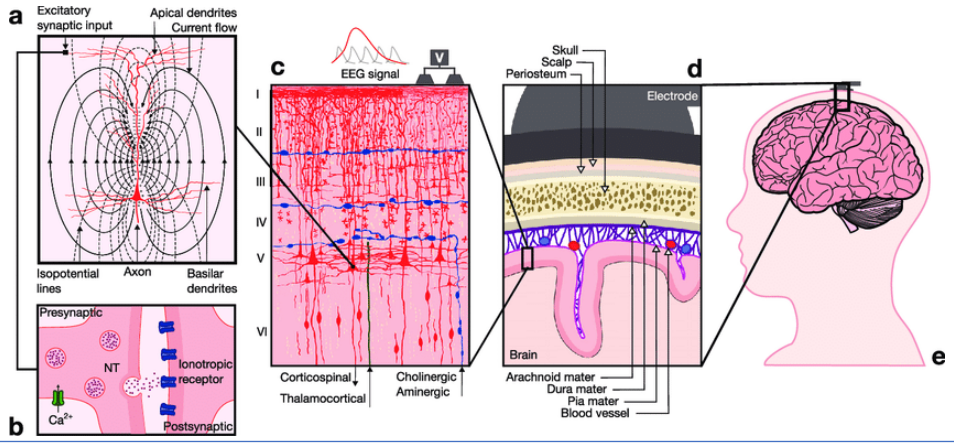
- The EEG is an electrophysiological technique for recording electrical activity arising from the human brain. EEG has superb temporal sensitivity.
- EEG is used mainly in the evaluation of dynamic cerebral functioning.



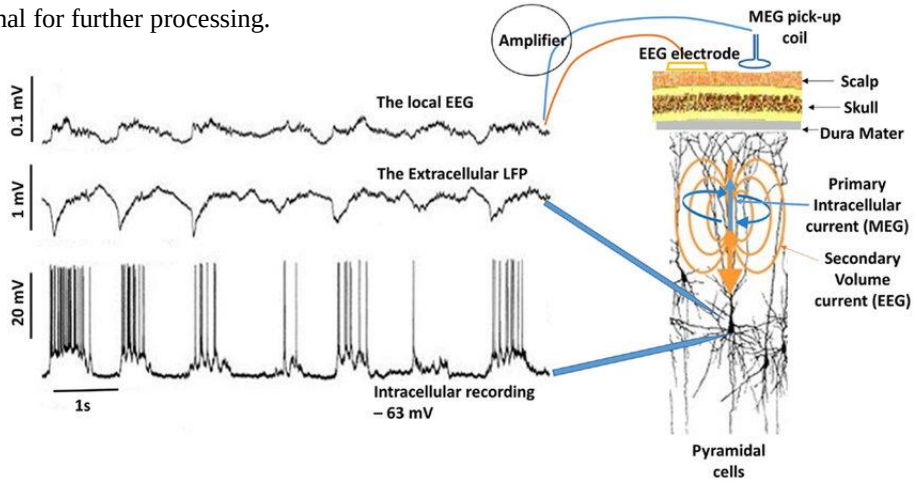
- For clinical indications: depth of anaesthesia during surgical procedures; monitoring potential complications in ischemia or infarction.
- EEG waveforms may also be averaged, giving rise to evoked potentials (EPs) and event-related potentials (ERPs), potentials that represent neural activity of interest that is temporally related to a specific stimulus.



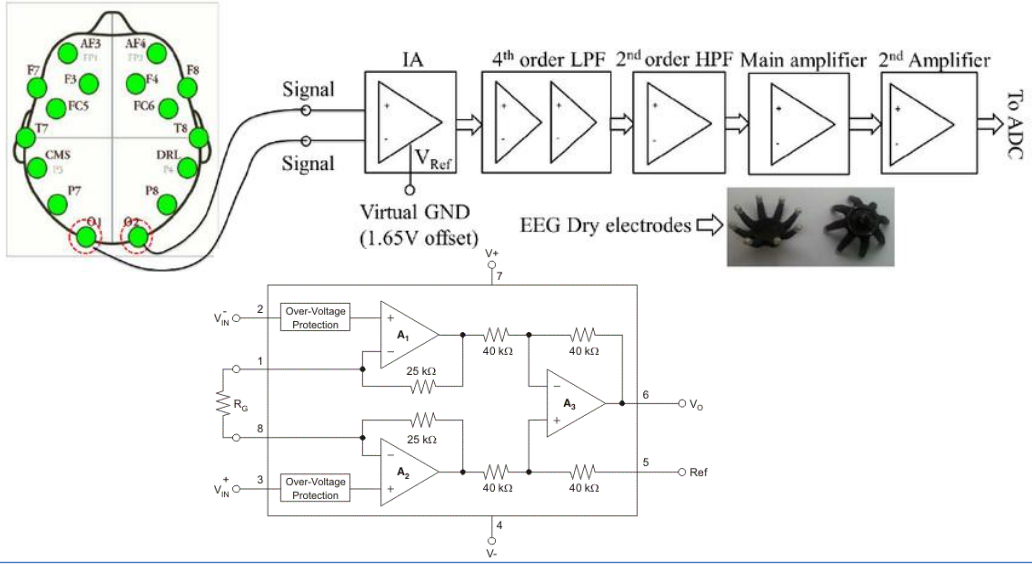
- The EEG is primarily generated by cortical pyramidal neurons in the cerebral cortex that are oriented perpendicularly to the brain's surface.
- The neural activity detectable by the EEG is the summation of the excitatory and inhibitory postsynaptic potentials of relatively large groups of neurons firing synchronously.



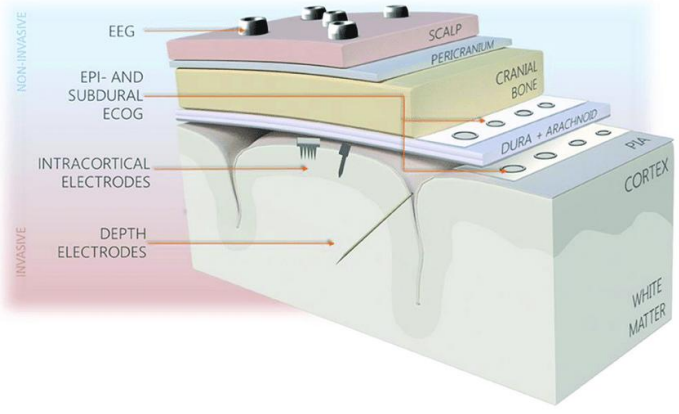
- The EEG signal comprises electrical rhythms and transient discharges distinguished by location, frequency, amplitude, form, periodicity and functional properties.
- The EEG signals from the brain are recorded, then amplified and converted to a digital signal for further processing.



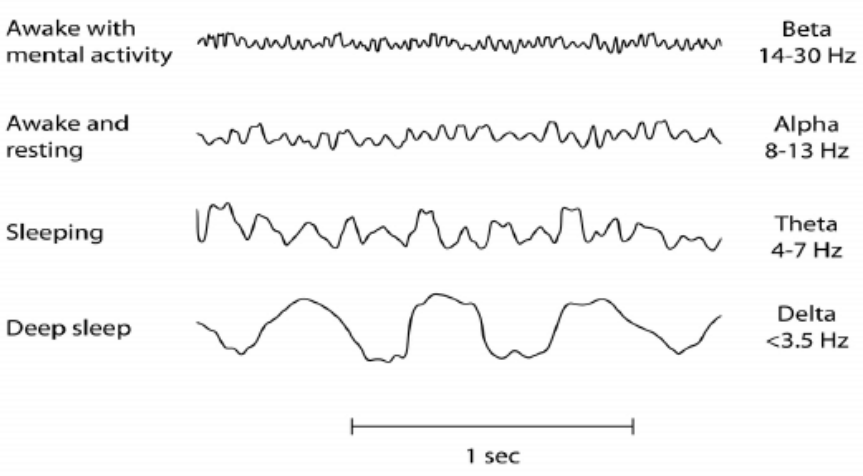
- The EEG signal voltage amplitudes ranges 1 to 100µv peak to peak at low frequencies (1 to 50 Hz) at the surface of scalp.



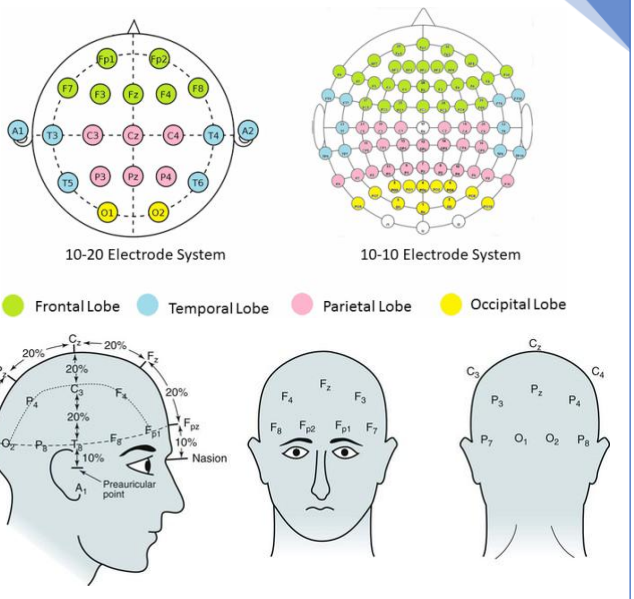
- EEG is a cerebral activity that may be overwhelmed by other electrical activity generated by the body or environment.
- Cerebrally generated EEG voltages must first pass through multiple biological filters (the brain, CSF, meninges, the skull, and skin) that reduce the signal amplitude and spread the EEG activity out more widely than its original source vector.



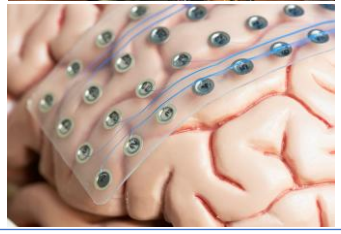
- EEG waves: generally, there are four wave groups (alpha, beta, theta, and delta).
- The EEG rhythm and waveforms are varied by ***the position of electrode placements*** on ***certain parts of the brain***.

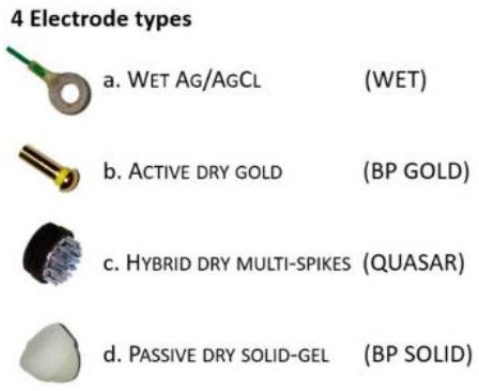


- The 10-20 System of Electrode Placement: is a method used to describe the location of scalp electrodes used to record the EEG using a machine called an electroencephalograph.



- EEG electrodes transfer ionic currents from cerebral tissue into electrical currents used in EEG preamplifiers.
- The electrical characteristics are determined primarily by the type of metal used. The traditional wet electrodes consisted in Ag/AgCl ring-shaped electrodes.

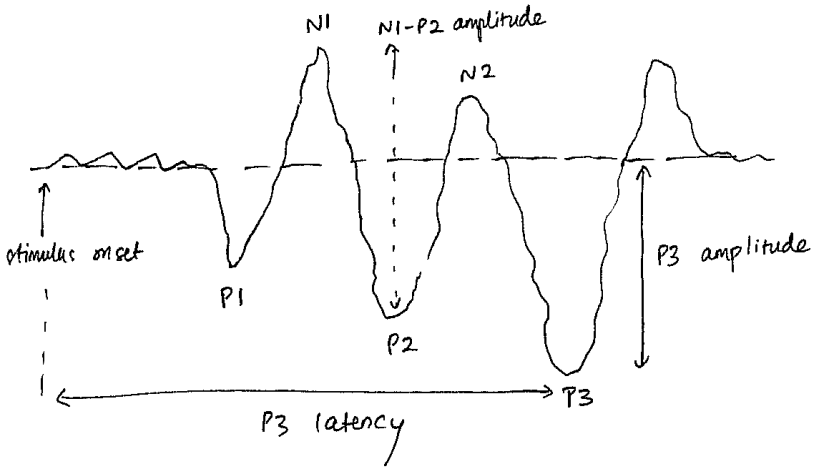




Evoked potentials (EP)

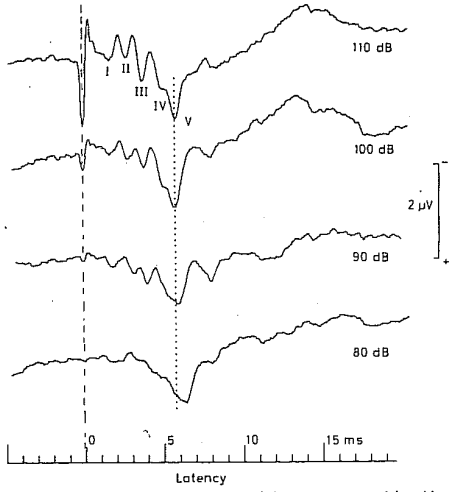
- Evoked potential/event related potential is EEG in response to some stimulus like visual, audio, somasensory, etc.
- The EP is evoked with the brain still active doing other things, so we have EP plus ongoing EEG, which is much higher than EP. So, we need to use ensemble averaging, median filtering, PCA, etc. to reduce ongoing EEG.
- EP are normally analysed in time domain
- Peaks
  - There are distinguishable peaks in EP (after reducing ongoing EEG, say through averaging)
  - The peaks are identified as P1,P2,P3,….N1,N2,N3
  - Sometimes, the peaks are identified using the latency, for example, it is know that the third positive component, P3 has latency about 300 ms, so it is also know as P300
- Latency and amplitude
  - Each peak will have a latency and amplitude
  - Latency is the time delay (in ms) from the stimulus onset
  - Amplitude is the amplitude of the peak in microVolts
  - Sometimes, we also use peak-peak amplitudes, like N1-P2 amplitude.

Evoked potential



Types of EPs –Brain stem auditory

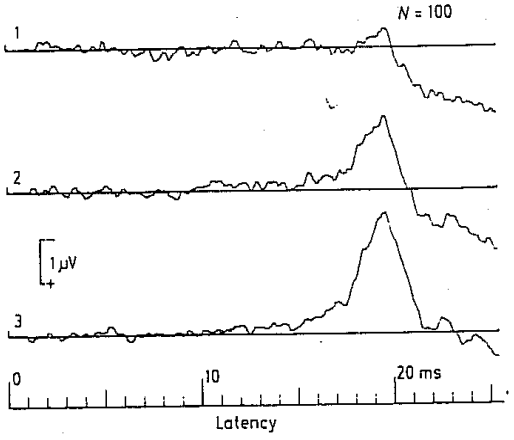
- Small amplitude EP, with short latencies
- Evoked when the stimulus is brief auditory stimuli (clicks or narrow tone bursts)
- Consist of about 6 waves in the first 10 ms after the sound
- The frequency range is about 100 – 2000 Hz



Change of auditory evoked brain stem potentials with decreasing intensity. The upper trace shows the potentials evoked by a binaural click stimulus of 110 dB presented 5 ms after start of epoch. Each trace is the average of 2000 trials. The various waves can be seen with V being the largest (5.6 ms latency). The early components disappear as the intensity is reduced and the latency of wave V is slightly increased at the lowest intensity. Electrodes C_z – left mastoid

Types of EPs –Somatosensory

- Tactile stimulation
- By electrical stimulation of the median nerve at the wrist or tibial and peroneal nerves at the leg
- Total duration is about 400 ms but only the first 20 ms are important
- The responses are localised on the scalp over the hand area of the sensorimotor cortex contralateral to the stimulated wrist
- EP spectral content from 100 to 2000 Hz



Somatosensory evoked potentials to left median nerve stimulation. Electrode 1 was 5 cm to the right of C_z, electrodes 2 and 3 were 2 cm and 4 cm posterior to electrode 1. Latency is about 20 ms

Types of EPs –Visual Evoked Potential

- VEP is important in many disease diagnoses and psychological studies
- Evoked when subjects perceive some visual stimulus
- Amplitude higher than AEP or SEP, ranging up to 20 microVolt
- The frequency ranges vary for different components from 1 to 300 Hz
- Example: Checkerboard pattern reversal
  - Pattern reversal must be less than 10 ms
  - Can detect problems with the visual system – increase in the latency

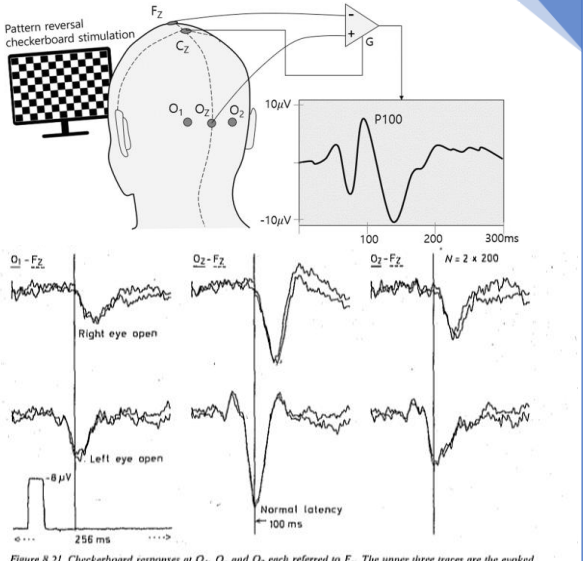
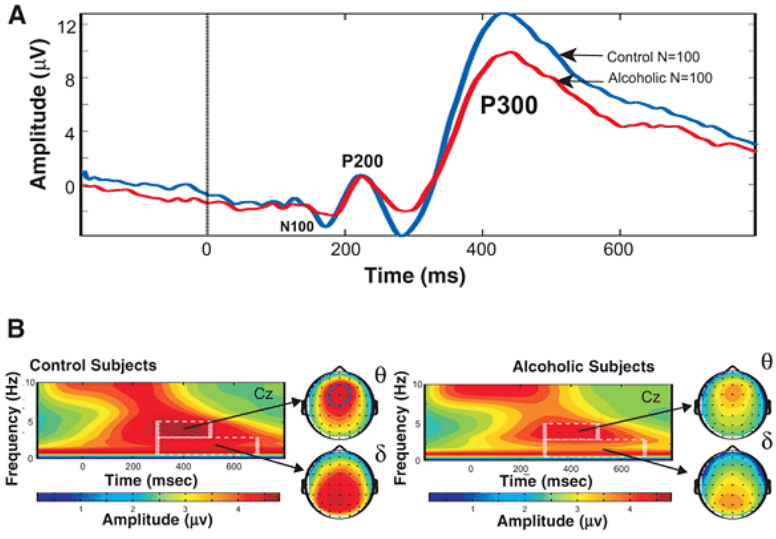


Figure 8.21 Checkerboard responses at O_1, O_z and O_2 each referred to F_z. The upper three traces are the evoked potentials when using only the right eye; the lower three when using the left eye. Pattern reversal occurs at start of epoch. Epoch length 256 ms. Vertical lines mark normal latency of 100 ms. Latency when using right eye is abnormally long (136 ms) due to retrobulbar neuritis

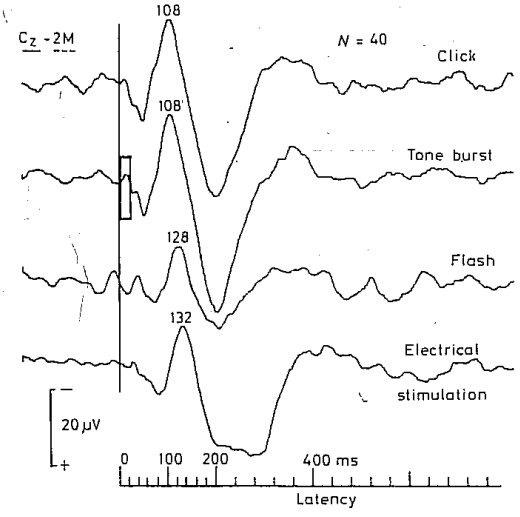
EP components

- Many components can be evoked each with a different experimental paradigm
- Some of these components
  - N100
  - P300
  - N400
  - ERD/ERS



EP components – N100

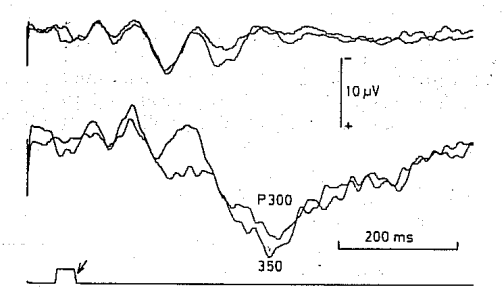
- N100 can be evoked easily by auditory, visual and tactile stimuli
- For example, clapping a hand, showing a flash of light
- It is believed to be the response to stimulus perception, i.e. when the brain recognises that a stimulus has been presented
- Normally, N100 is less than 20 Hz, so a LPF of 20 Hz should be used
- So, apply a LPF before/after doing averaging
- In the figure, why is the flash N100 latency longer than the click N100 latency?



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

EP components – P300

- P300 is the third positive component evoked with a 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

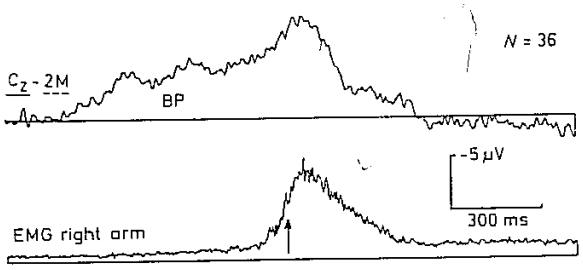


EP components – N400

- 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

EP components –ERS/ERD

- In recent years, it has been that ERD/ERS is evoked in the contralateral/ipsilateral motor cortex preceding voluntary movement
- In contralateral motor cortex
  - ERD occurs just before movement in the 10-12 Hz (also known as mu band)
  - ERS after movement
  - Other bands like 14-18 Hz and 36-40 Hz are also used
- Useful for Brain-computer interface



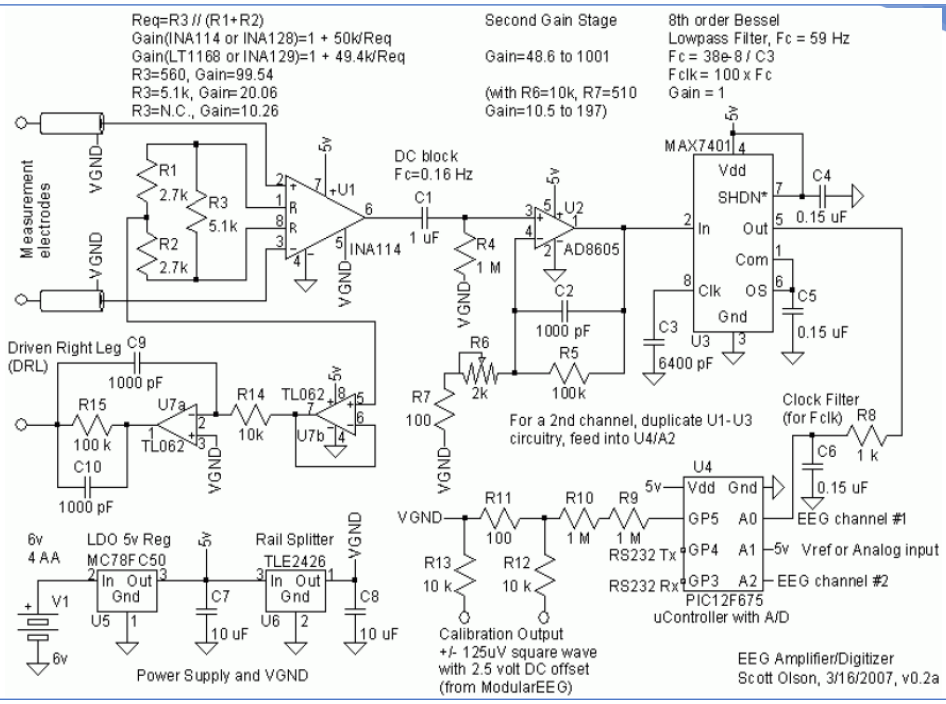
The increase in negative potential at the vertex (referred to common mastoid) preceding motor movement (Bereitschaftspotential, BP). The lower trace shows the rectified EMG of the operant muscles. The arrow shows the time at which the computer was triggered. The calibration is for the EEG

EEG Features

- Features are some values computed from the signals
- Features should be
  - Representative of the signal
  - Reproducible
- Other criteria of the features will depend on the application
  - Smaller dimension than the signal
  - Inter-class variance high/intra-class variance low
  - Robust/enhanced representation of the signal (invariant to changes in noise, scale factors, etc.)

Simple features

- Simple features are like
  - Mean (but not very useful as we usually set it to zero)
  - Standard deviation
  - Energy (which can be computed by using variance after setting mean to zero)
- Very often, we measure the energy in different spectral bands like delta, theta, alpha, beta and gamma and use them as features
- To do this, we filter the EEG signal in the specific bands and then compute the energy



THANK YOU