Electroencephalogram (EEG)

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EEG (Electroencephalogram)

- The electroencephalogram (EEG) measures the activity of large numbers (populations) of neurons.
- First recorded by Hans Berger in 1929.
- EEG recordings are noninvasive, painless, do not interfere much with a human subject's ability to move or perceive stimuli, are relatively low-cost.
- Electrodes measure voltage-differences at the scalp in the microvolt (μV) range.
- Voltage-traces are recorded with millisecond resolution – great advantage over brain imaging (fMRI or PET).

EEG (Electroencephalogram)

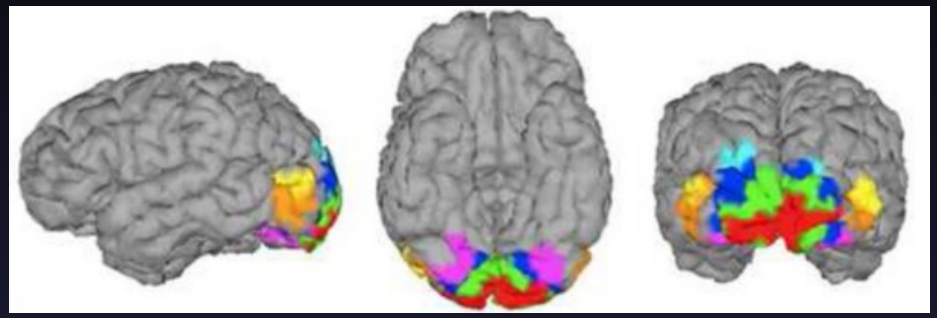
- Used to measure Electrical activity of the brain
- Detects activity of large groups of neurons that are active at the same time
- Primarily measures postsynaptic potentials (not action potentials)

EEG vs fMRI

- Spatial and temporal resolution
  - If you want to study the sequence of events from 0-500 ms poststimulus
- Cost
  - $10/hour
- Tolerability
  - Infants and children, obese people, anxious people

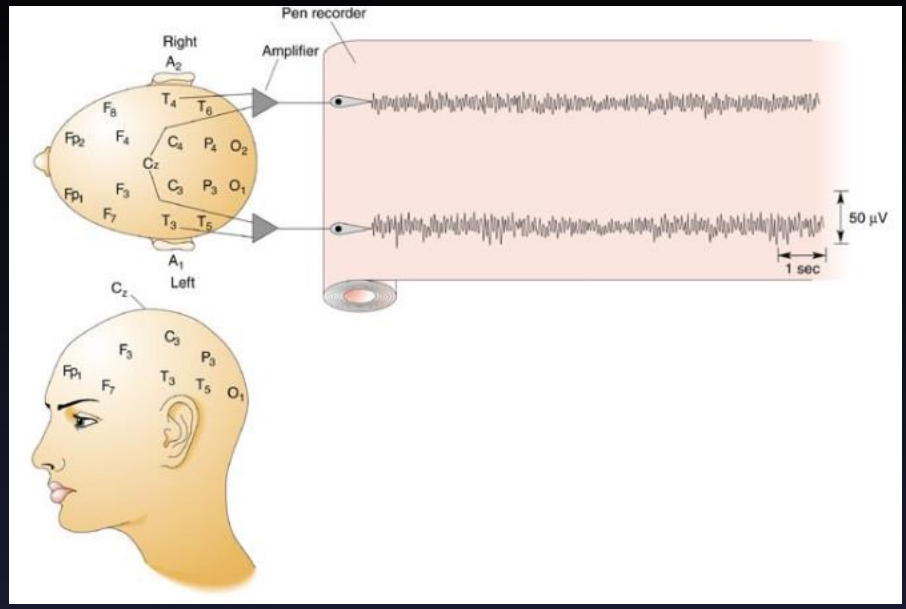
EEG vs fMRI

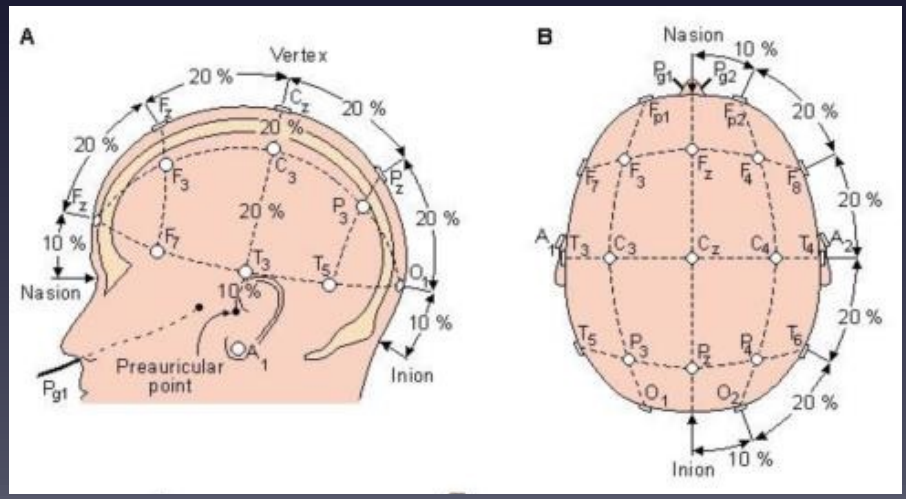
- Spatial and temporal resolution
  - If you want to differentiate V2 from V4 (defined areas in brain)
- Cost
  - $500/hour
- Tolerability
  - Infants and children, obese people, anxious people



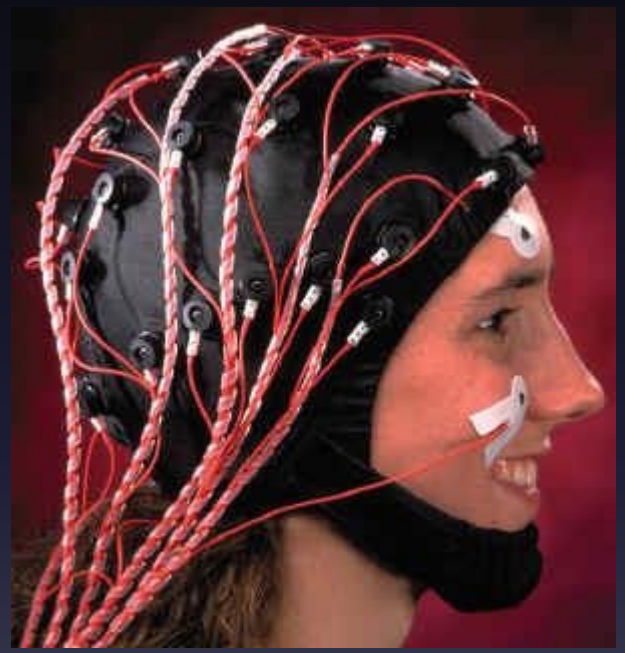
10-20 system

- Standard placements of electrodes on the human scalp:
  - A, auricle; C, central; F, frontal; Fp, frontal pole; O, occipital; P, parietal; T, temporal.
  - Even number : right side of head
  - odd number : left side of head





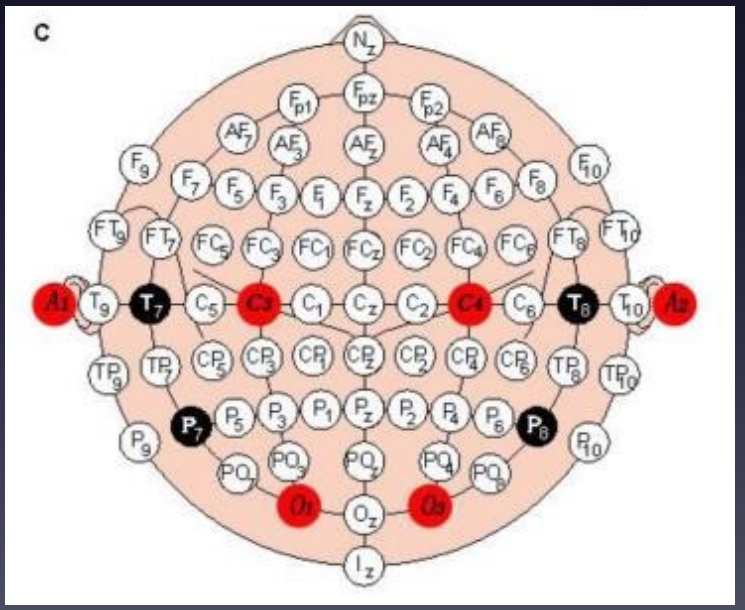
EEG



From a slide by Tom Busey at Indiana University

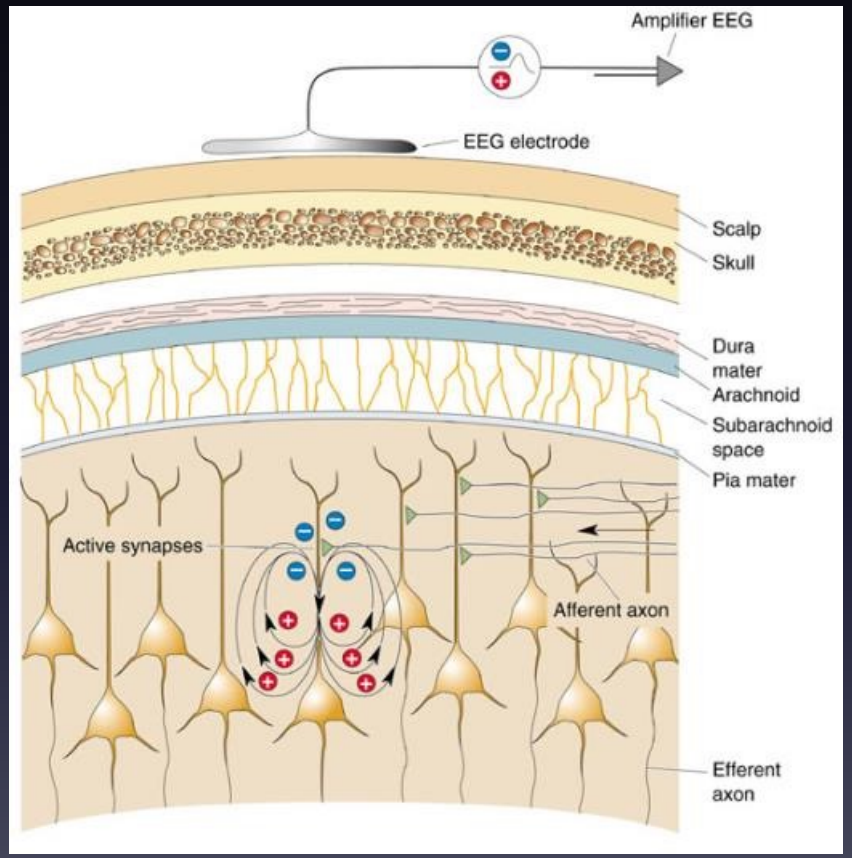
Modified Combinational Nomenclature

- Higher-resolution systems
  - extra electrodes are added using the 10% division, which fills in intermediate sites halfway between those of the existing 10–20 system
- New Letter codes
  - AF – between Fp and F
  - FC – between F and C
  - FT – between F and T
  - CP – between C and P
  - TP – between T and P
  - PO – between P and O
- Renames four electrodes of the 10–20 system
  - T3 is now T7
  - T4 is now T8
  - T5 is now P7
  - T6 is now P8



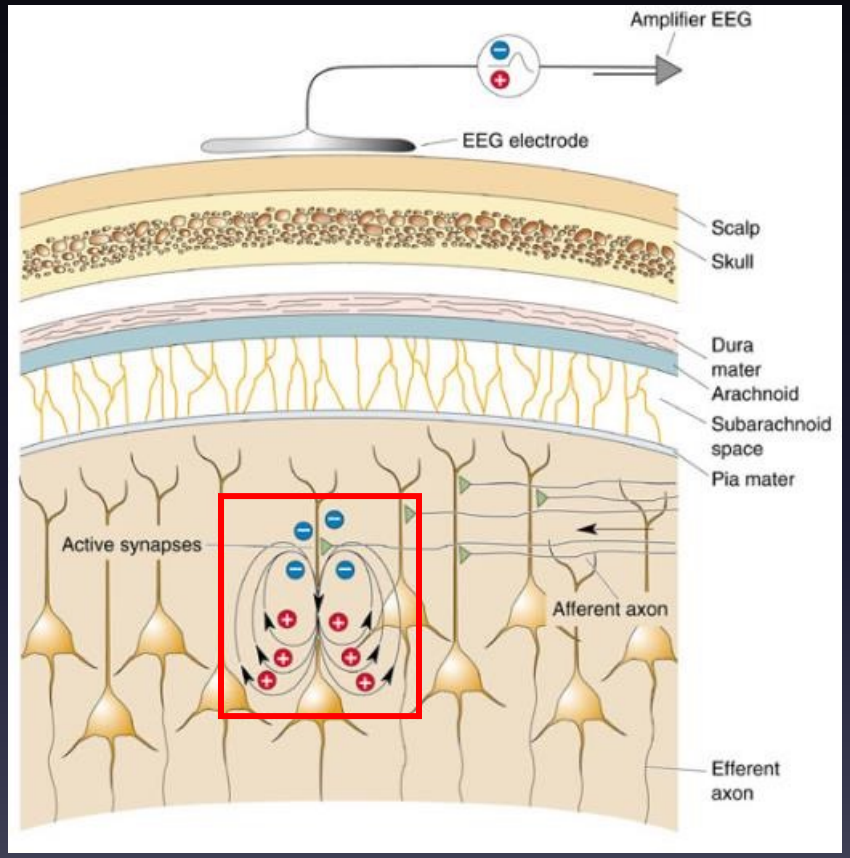
EEG

- Can be used to measure brain activity that occurs during an event, or to measure spontaneous brain activity
- activity that occurs in association with an event is sometimes called the event-related potential

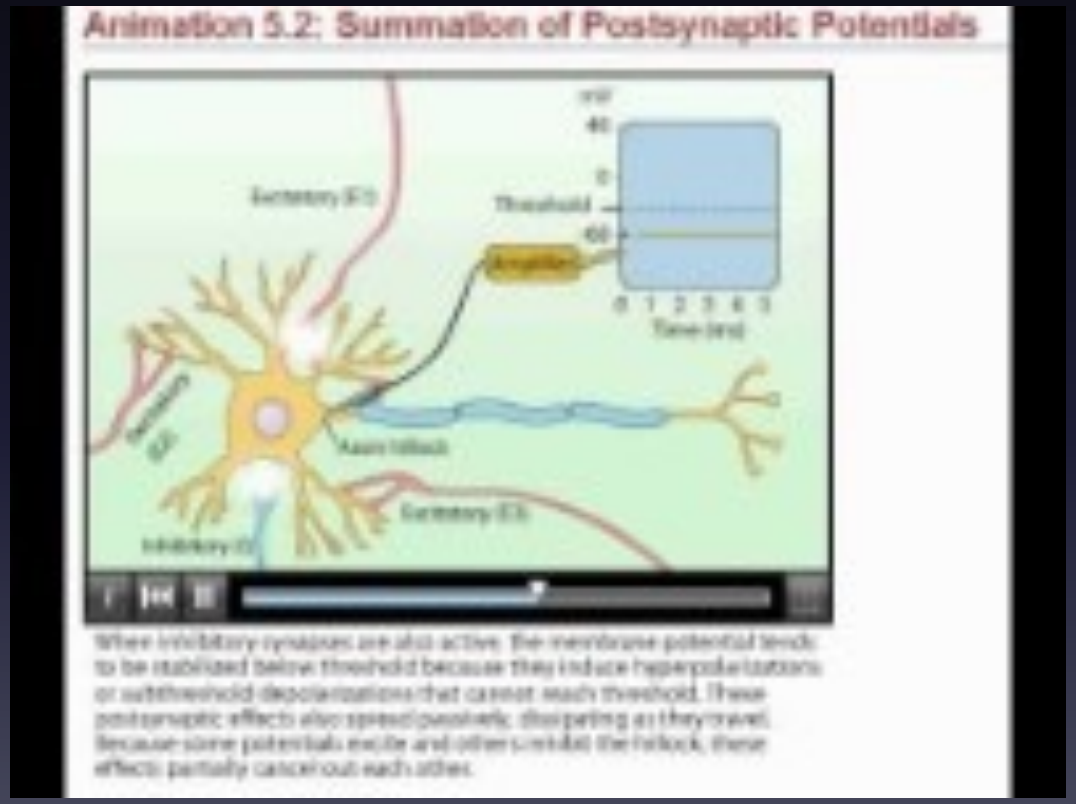


EEG

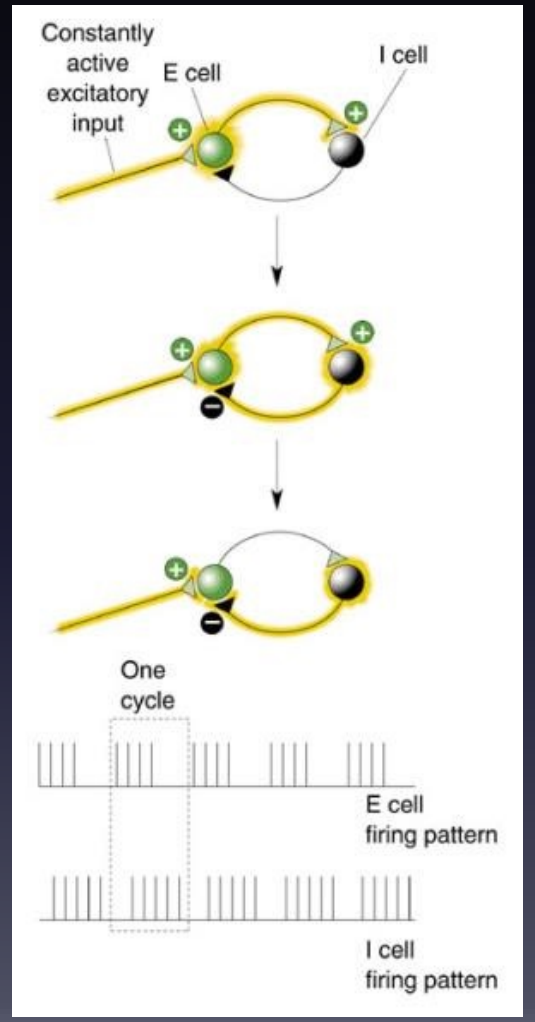
- The way of EEG works
  - Check the electrical activity that occurs in neurotransmission (Synapse)
    - The movement of positive and negative charge
  - Many neurons need to sum their activity in order to be detected by EEG electrodes



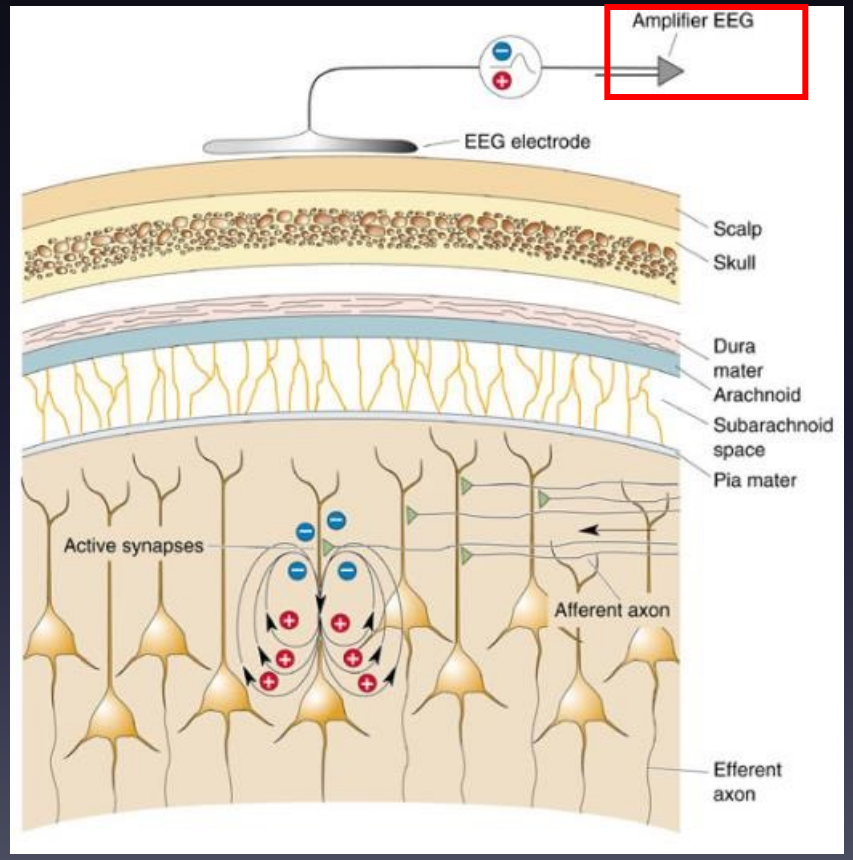
A simple circuit



http://youtu.be/v5_ynMBgt88



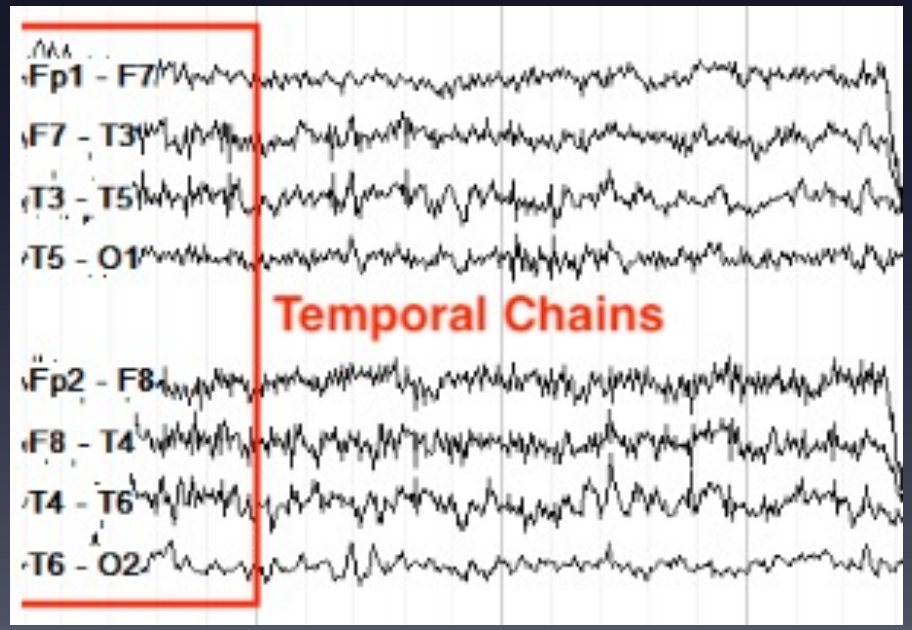
EEG



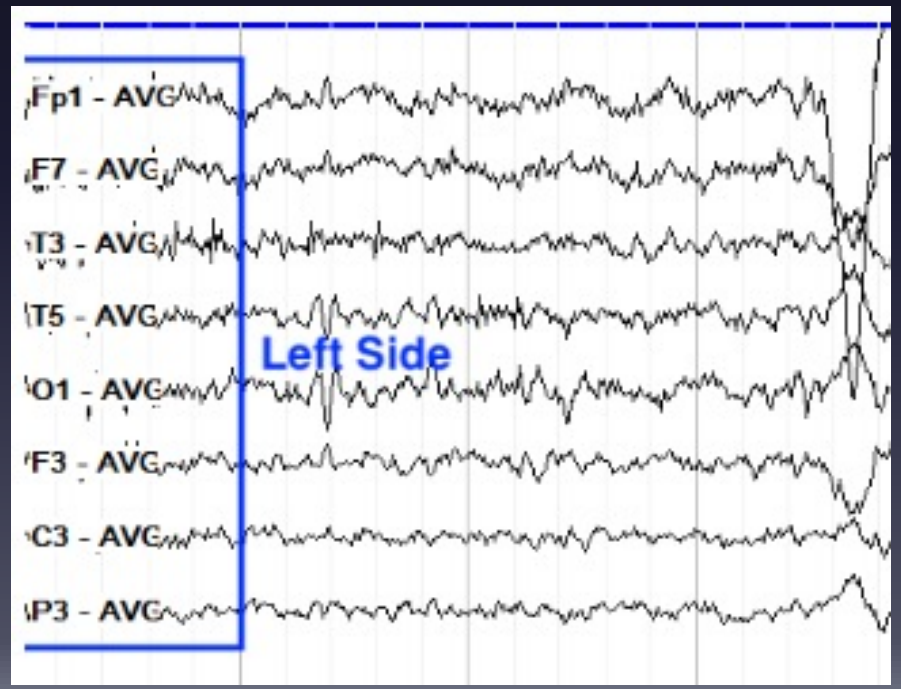
- Use differential amplifier kind of machinery

EEG

- Normal double banana montage

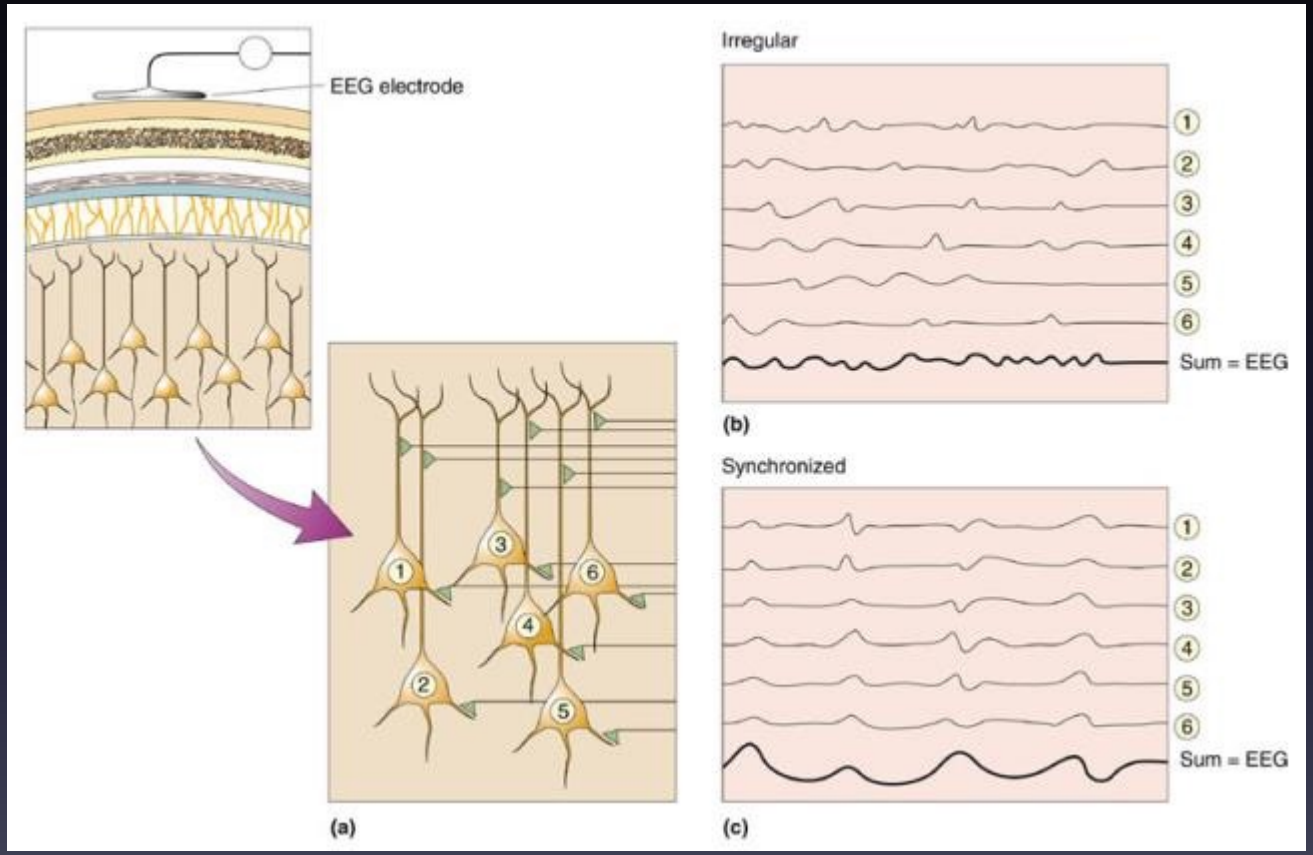


- Normal Average Referential Montage



EEG

- Many neurons need to sum their activity in order to be detected by EEG electrodes.
- The timing of their activity is crucial.
- Synchronized neural activity produces larger signals.



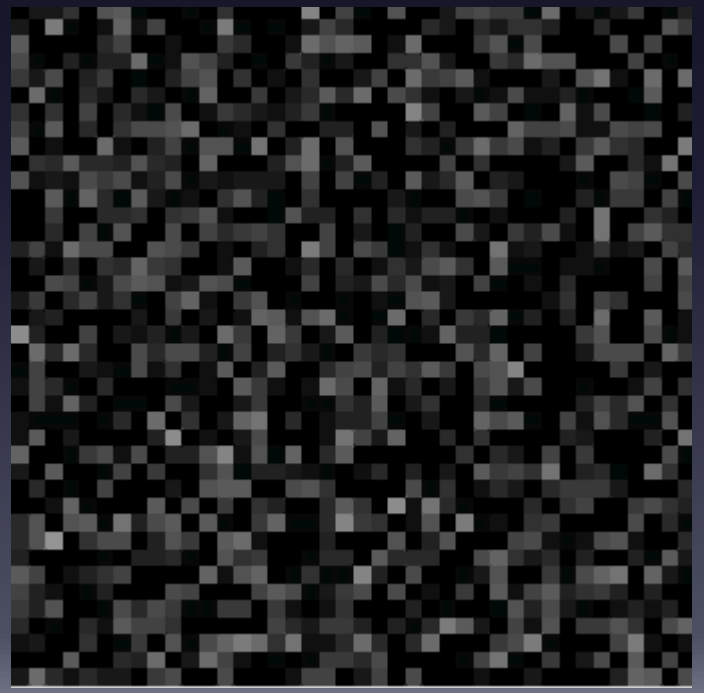
From a slide by Tom Busey at Indiana University

Synchronicity of Neuron

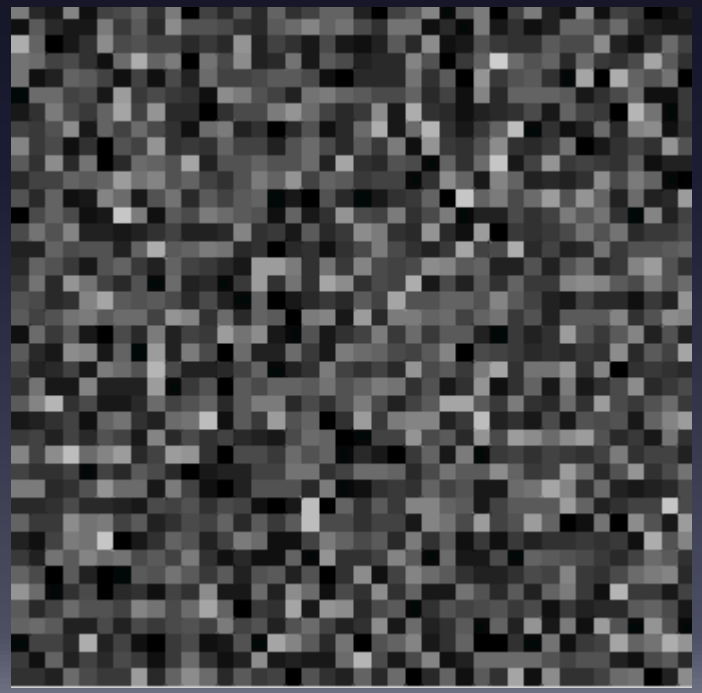
- **Two ways of generating synchronicity:**
  a) pacemaker; b) mutual coordination

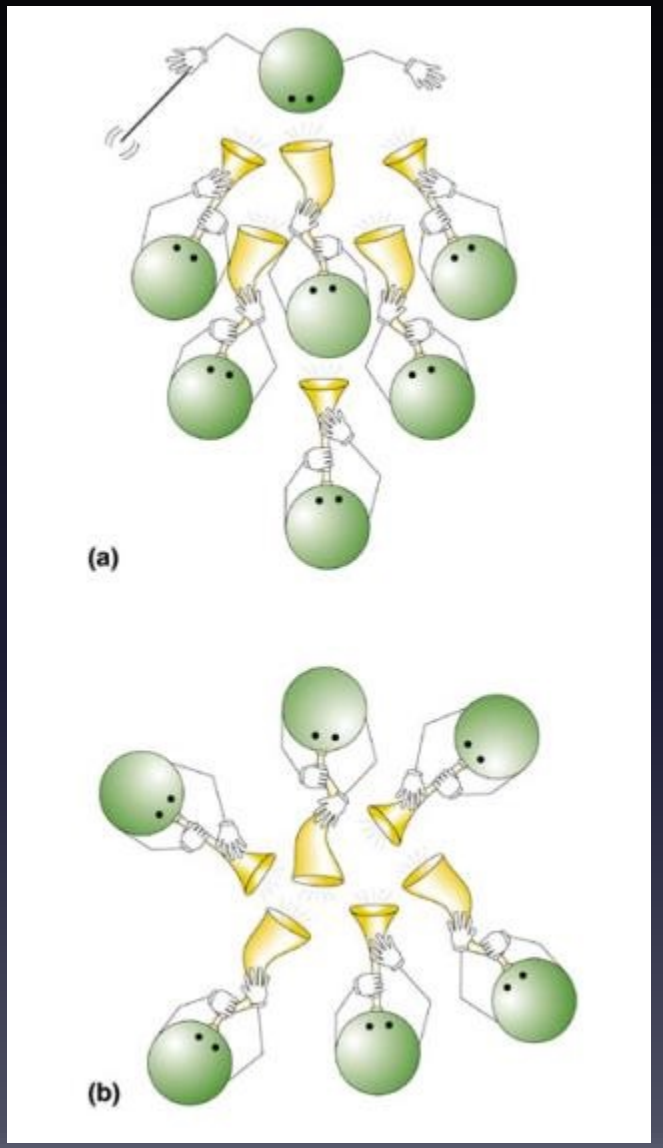
1600 oscillators (excitatory cells)

un-coordinated



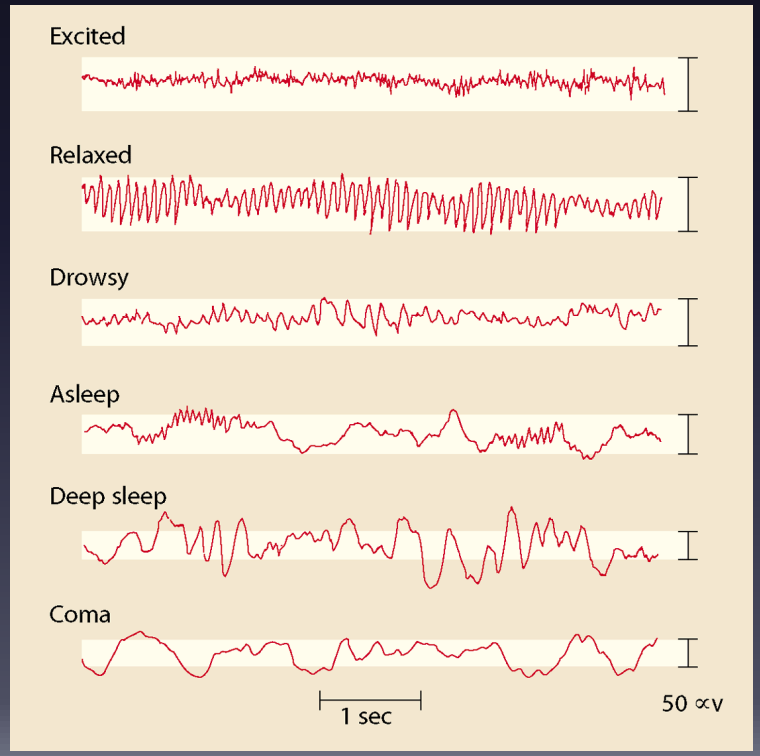
coordinated





EEG

- EEG potentials are good indicators of global brain state.
- They often display rhythmic patterns at characteristic frequencies

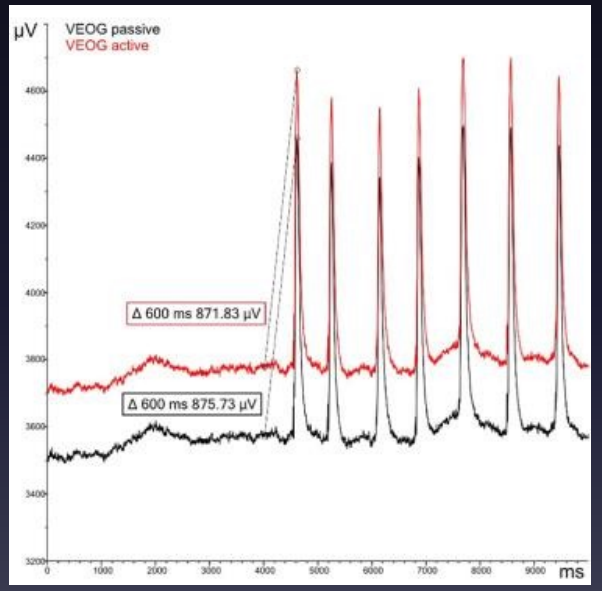


EEG

- EEG rhythms correlate with patterns of behavior (level of attentiveness, sleeping, waking, seizures, coma).
- Rhythms occur in distinct frequency ranges:
  - Gamma: 20-60 Hz ("cognitive" frequency band)
  - Beta: 14-20 Hz (activated cortex)
  - Alpha: 8-13 Hz (quiet waking)
  - Theta: 4-7 Hz (sleep stages)
  - Delta: less than 4 Hz (sleep stages, especially "deep sleep")
- Higher frequencies: active processing, relatively de-synchronized activity (alert wakefulness, dream sleep).
- Lower frequencies: strongly synchronized activity (nondreaming sleep, coma).

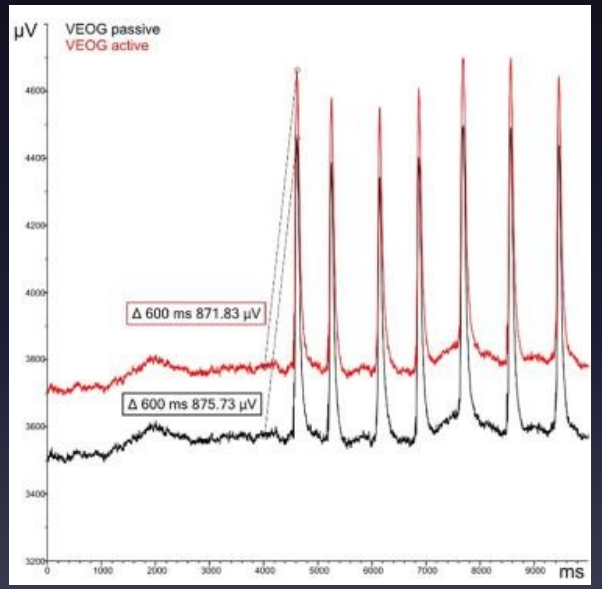
Artifact

- Ocular artifact
  - caused by a potential difference between the cornea and the retina.
  - Most of the eye blinking or vertical eyelid movement causes a large potential difference between the upper and lower safety channels of the eye.



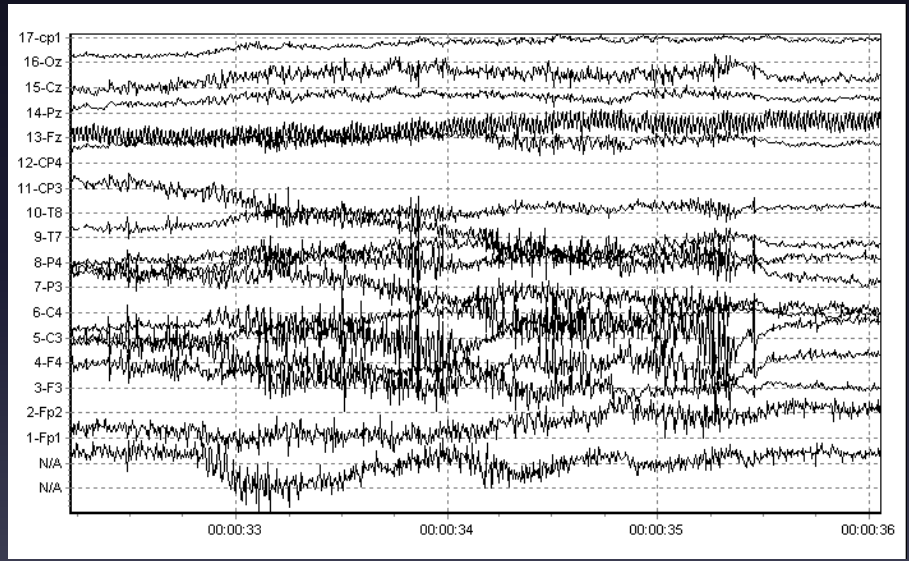
Artifact

- Ocular artifact
  - From an EEG point of view, it is noise and appears in the theta (4-7 Hz) or alpha (7-14 Hz) range.
  - Use Artifact Filtering Method
    - ex) Adaptive lattice Filter



Artifact

- Muscle artifact
  - Occurs in the muscles around the skull
  - Since it appears in a different band than the EEG signal, it can be removed through frequency filtering.

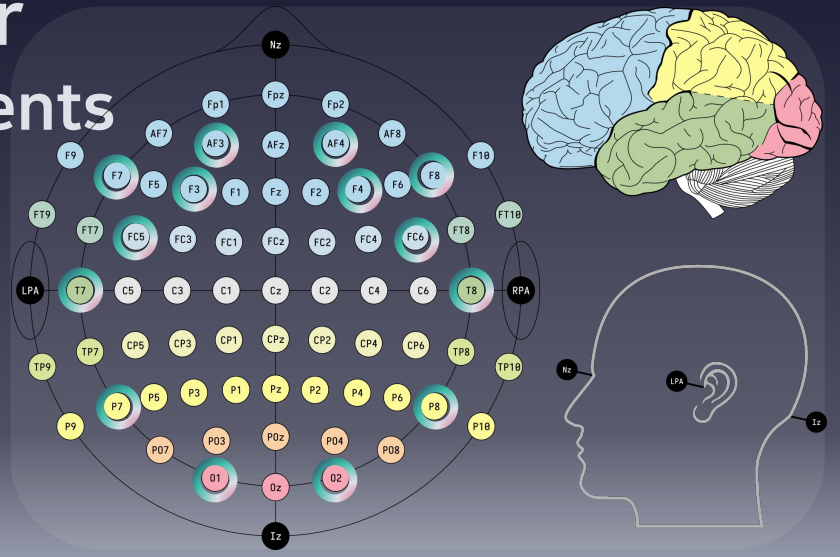


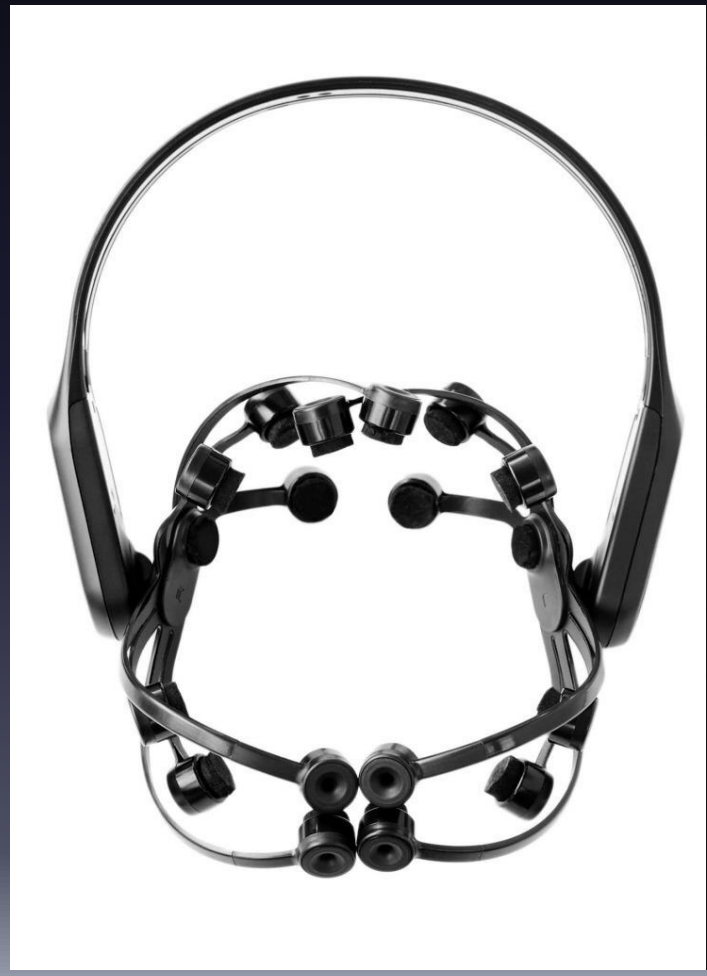
Wearable EEG device & usage of EEG

- Wearable EEG device example
  - EMOTIV device
  - Experiment on using EMOTIV device
  - Various devices
- EEG & sleep
- EEG & dementia
- Conclusion

EMOTIV EPOC X

- 14 channel EEG for whole brain sensing
- Saline Based Electrodes
  - Easy to hydrate
- Bluetooth Wireless
- 9-axis motion sensor
  - Detect head movements





Youtube Video : experimented with using EMOTIV's EPOC X

- Controlling Electronics with my Mind! | EEG Brain Computer Interface

Various wearable EEG devices

- There are more various wearable EEG devices like image
- Each of them has there own characteristics like for gaming, medical, fitness, .etc

EMOTIV INSIGHT

WORN ON THE HEAD AND USED FOR MEDICAL & GAMING APPLICATIONS.

The Emotiv Insight is a wearable EEG headset that can transmit meaningful brainwave data wirelessly to a smartphone or computer in high...

INTERAXON MUSE

WORN ON THE HEAD AND USED FOR LIFESTYLE & MEDICAL APPLICATIONS.

The InteraXon Muse is a mental activity tracking device that helps reduce stress and settle the mind. The wearable device uses 7 sensors...

MINDWAVE

WORN ON THE HEAD AND USED FOR LIFESTYLE APPLICATIONS.

The NeuroSky MindWave is a wearable headset developed by NeuroSky Inc to measure brainwave signals and monitor attention levels of the...

MINDSET

WORN ON THE HEAD AND USED FOR LIFESTYLE APPLICATIONS.

Mindset is a wearable EEG system that monitors your brain waves and alerts you when your concentration drops. Over time, the wearable...

NEUROON

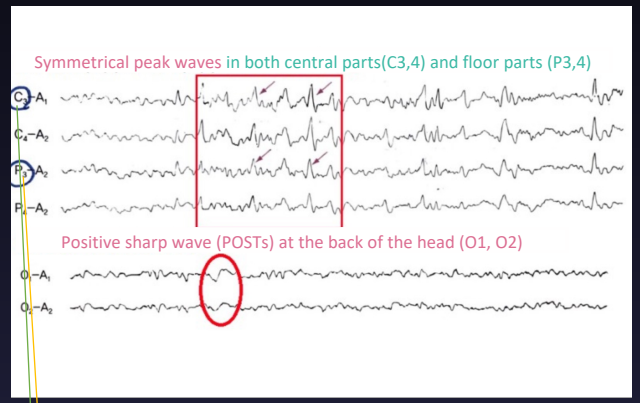
WORN ON THE HEAD AND USED FOR LIFESTYLE APPLICATIONS.

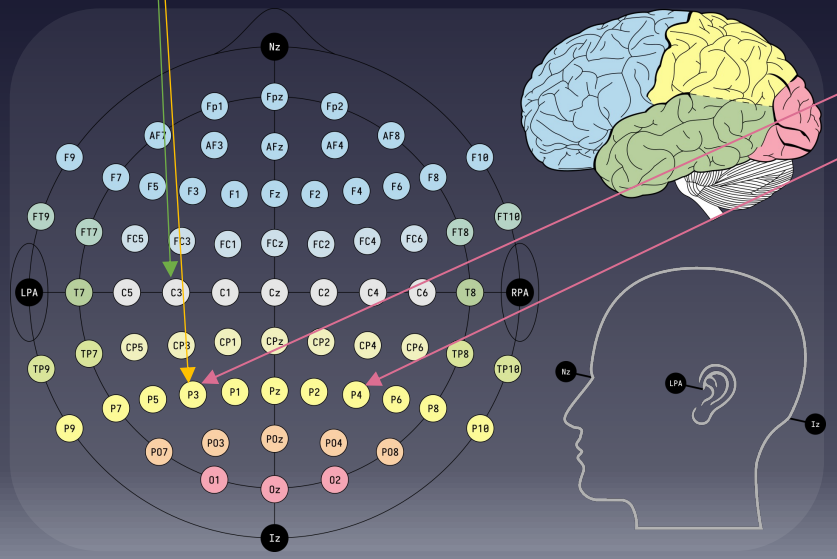
The Neuroon is a wearable technology sleep mask that allows you to switch from mono-phasic to polyphasic sleep. This technology combines...

EEG & sleep

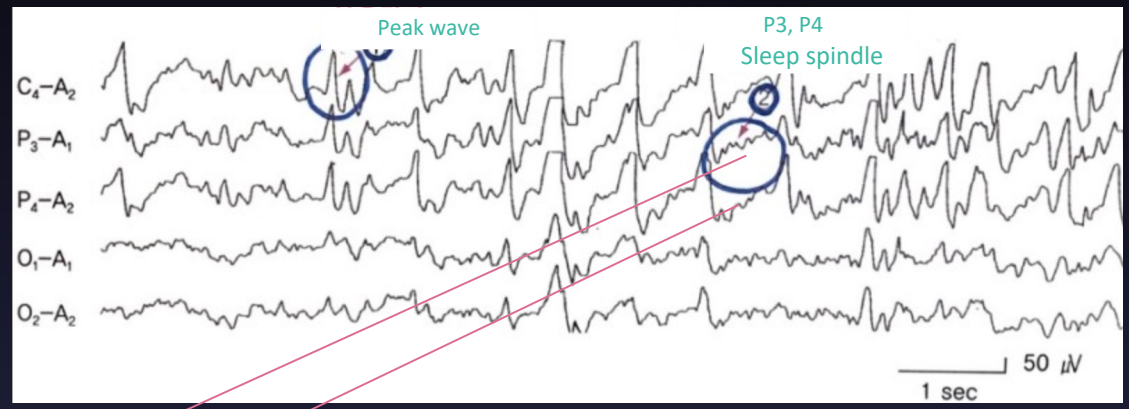
EEG & sleep

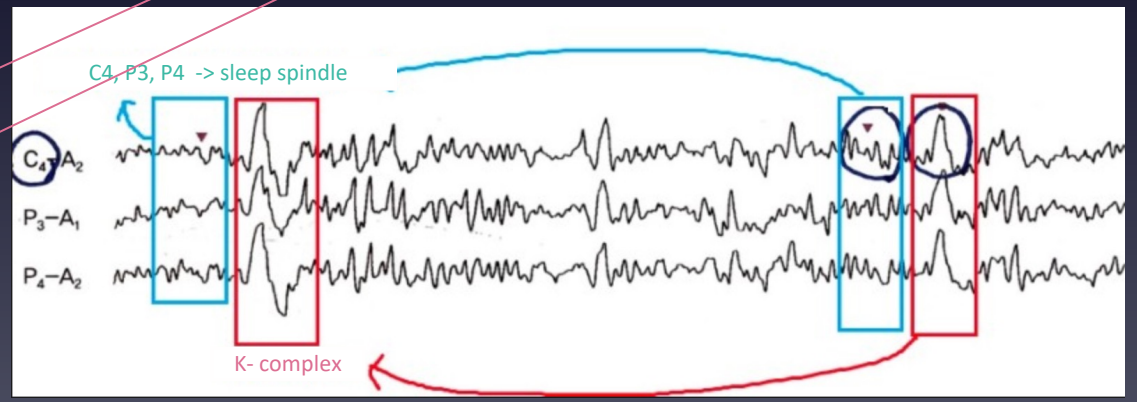
Drowsiness and Stage 1 - Non-REM





Shallow Sleep phase (Stage 2) - Non-REM





Sleep spindle : 12~14Hz

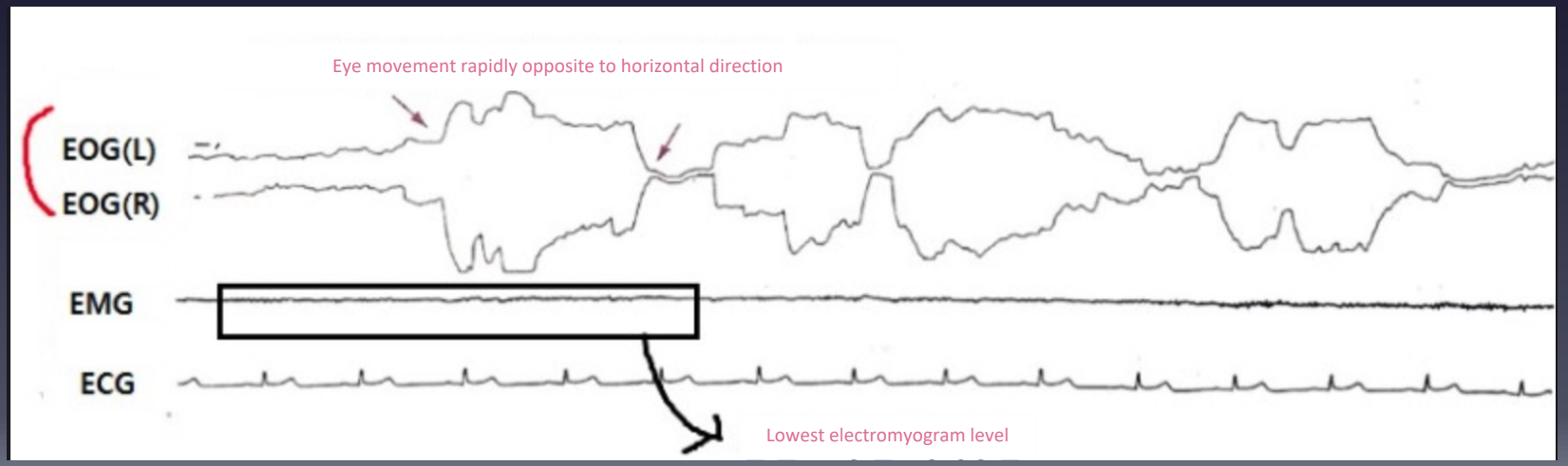
K-complex : High amplitude slow wave

EEG & sleep

Stage4 - REM

Delta waves mainly appear at the forehead and are seen at the electrodes of the forehead, Fp1, 2.

REM



EEG & sleep summary

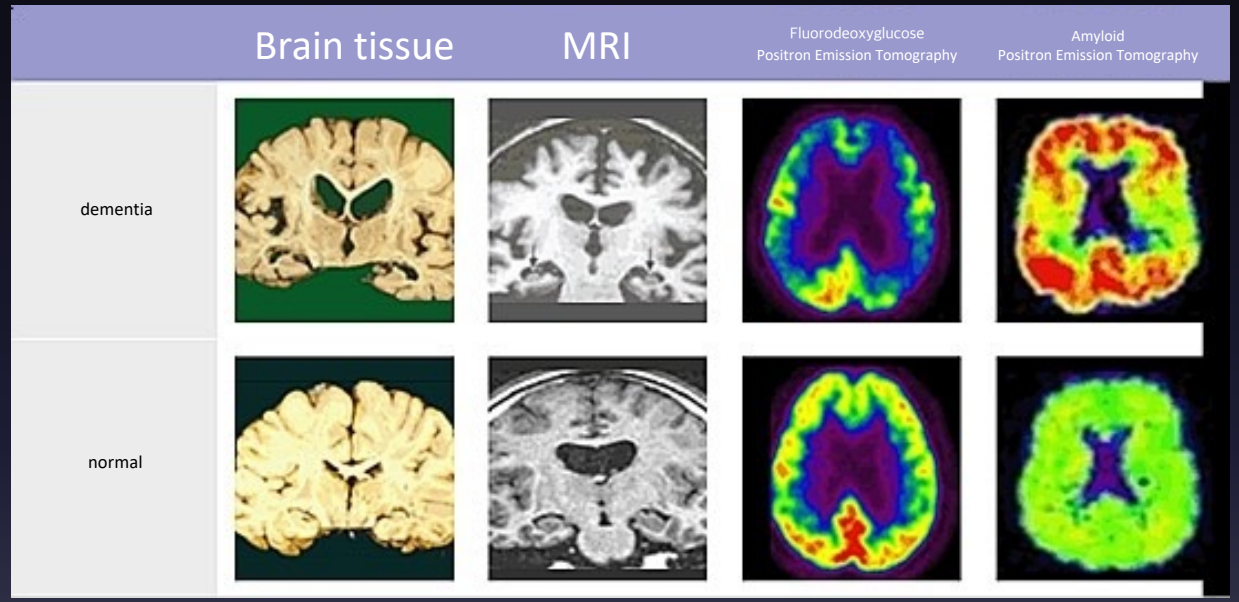
stage	Stage explanation	Frequency Features	Other features
Awakening Awakening period	Awakening Awakening period	Alpha wave (8~13Hz)	Noise caused by movement and heartbeat
Stage 1	Early light sleep phase	Mixed wave (2~7Hz) dominance, alpha wave 50% or less	No K-complex and sleep spindle
Stage 2	Shallow sleep phase	Slow wave (0~2Hz) is less than 20%	K-complex and sleep spindle wave measured
Stage 3	Severe sleep phase	Slow wave measured at 20% to 50%	
Stage 4	Deep sleep phase	Slow wave measured greater than 50%	
REM	REM Sleeper	Mixed wave dominance	Noise caused by eye movement

LUUNA : sleep assistant

- Eeg sensors to monitor & collect brainwave information
- Basically, luuna analyze brain waves for a good night's sleep
- It naturally induces sleep with quiet music
- If you set a time, when it's appropriate, luuna wake you up with an alarm
- It also stabilizes brain waves by playing sounds suitable for brain wave stabilization

EEG & Dementia

Diagnosis of dementia through biological signals (brain waves) 1



- Recently, a technology that can identify dementia early through EEG measurement and analysis technology is being developed

- Originally, when dementia occurred, for example, MRI or amyloid PET tests had to be performed to determine whether it was Alzheimer's dementia, which took about two hours as of 2019, and the diagnosis cost was also high.

Diagnosis of dementia through biological signals (brain waves) 2

- However, now, a new method is being developed to check dementia by looking at brain waves without high-cost tests such as amyloid PET tests

- Testing using brain waves has the advantage of being able to find high-risk groups non-invasive and at low cost

Uncertainty of diagnosis through brain waves 1

- However, it is not yet clear whether it is dementia or not through EEG analysis
  - A domestic company called Megnosis showed 95% accuracy as a result of clinical trials at Seoul National University Hospital
- In general, brain waves appear slowly and gently in tired or sleeping situations, and fast and dense brain waves appear in anxious or excessive tension
- When the brain undergoes degenerative changes or trauma damage, such as Alzheimer's, Parkinson's, or stroke, brain cells are crushed and synapses that act as networking between brain cells are destroyed
- And when the synapses break like this, a locally gentle, wide waveform appears

Uncertainty of diagnosis through brain waves 2

- As previously mentioned, it is too early to diagnose 100% dementia only by looking at a certain pattern of brain waves because brain waves may appear slowly depending on various physical situations

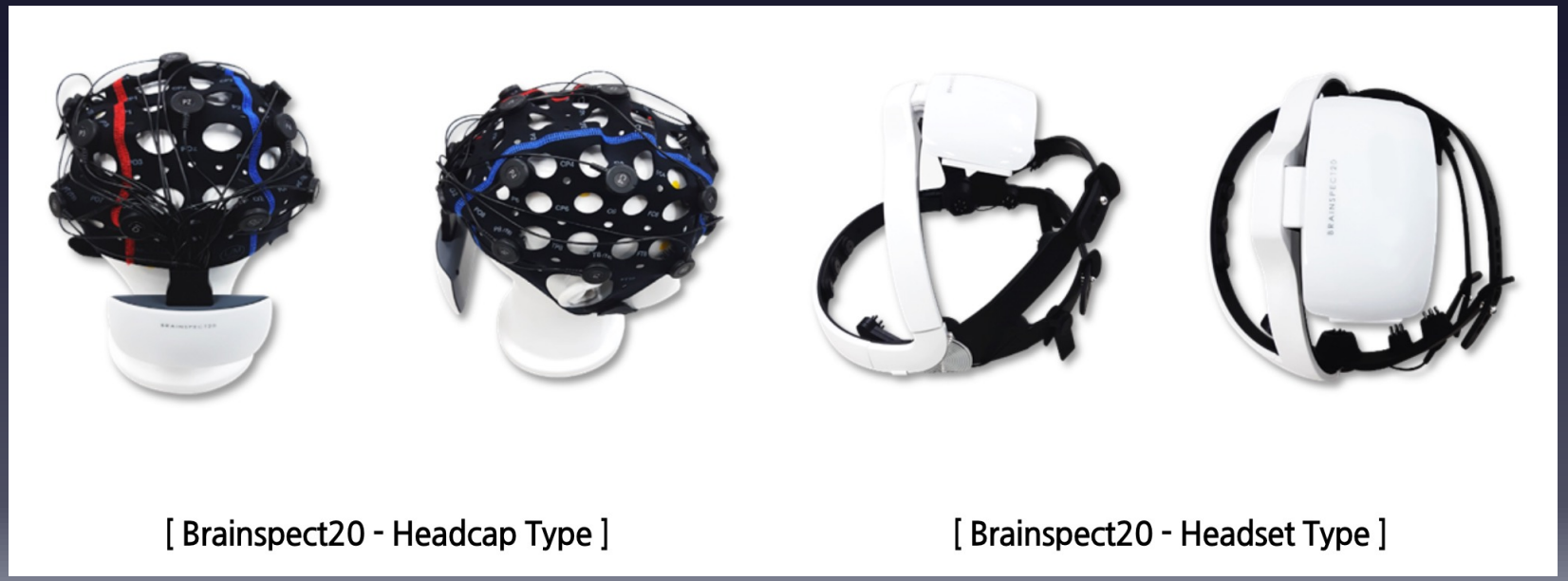
- More data will need to be accumulated, analyzed, and learned with artificial intelligence in the future to ensure accurate diagnosis

EEG and home dementia diagnostic devices

- EEG + VR : LUCY
  - As mentioned earlier, the best way to respond to dementia is to diagnose it early and slow down the progression.
  - It is important to check and train cognitive function status periodically in everyday life
  - Looxidlabs - LUCY collects information on the response speed, brain waves, eye movements, etc. of users playing VR games -> Classify dementia by analyzing them using 6channel EEG measurement
  - 61% accuracy

EEG and home dementia diagnostic devices

- Interview video
  - Megnosis – KIMES 2023 – Bluetooth Wireless EEG Measurement Device – 10 min of rest -> Mild Cognitive Disorder Identification
  - 95% accuracy using 20 channel EEG measurement



[Brainspect20 - Headcap Type]

[Brainspect20 - Headset Type]