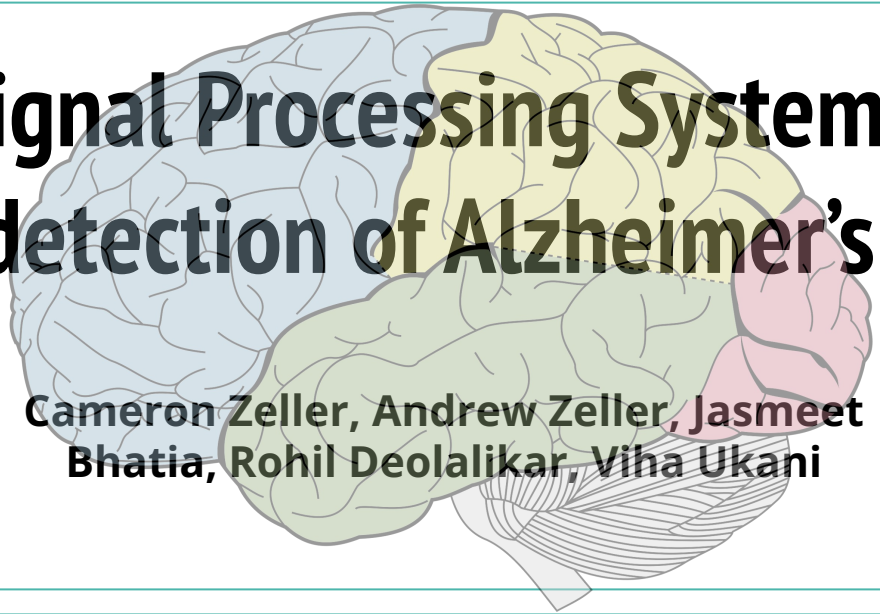
EEG Signal Processing System for the early detection of Alzheimer's Disease



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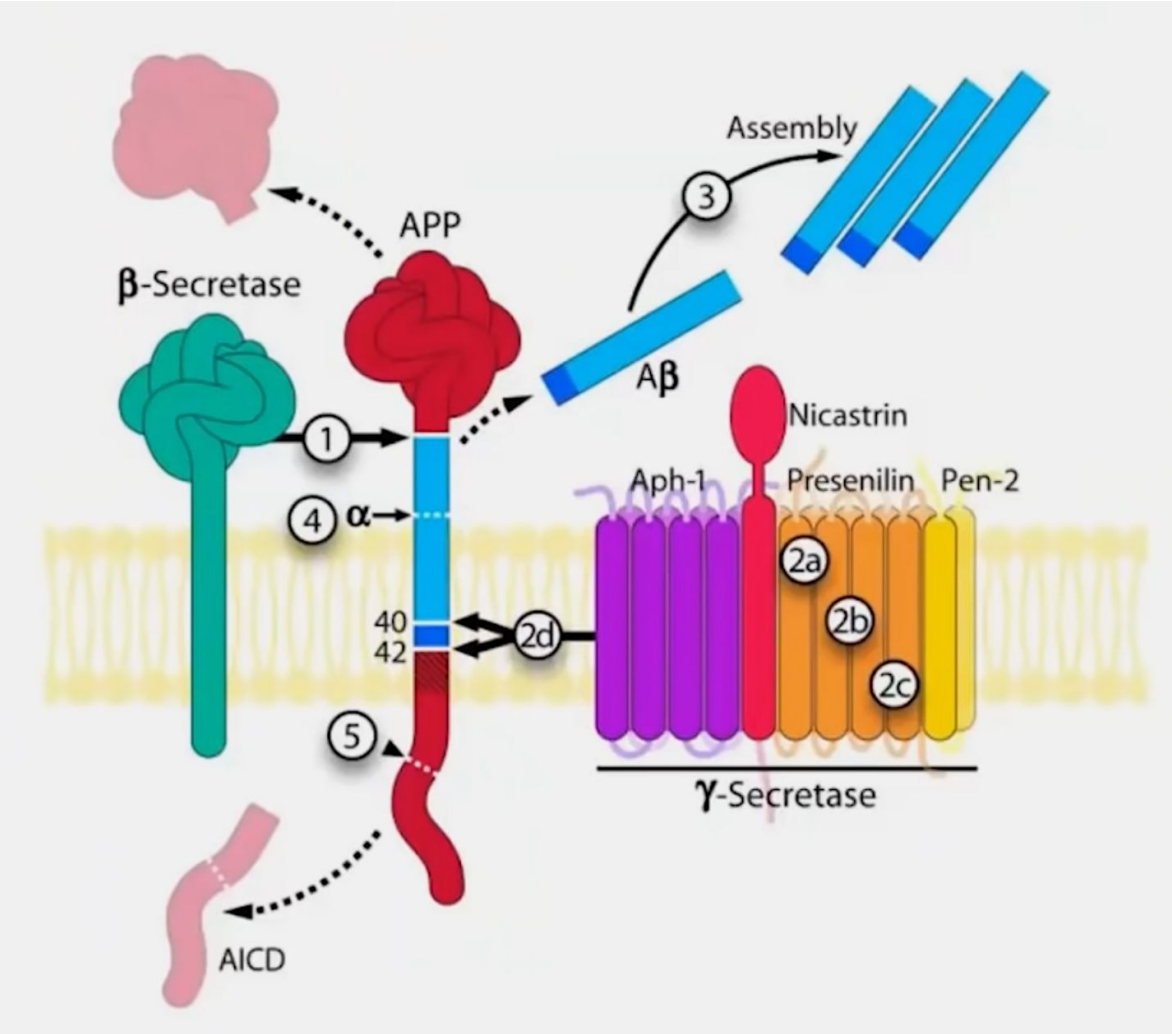
What is Alzheimer's?

- Alzheimer's disease (AD) is a progressive irreversible neurological disorder.
- Symptoms of AD include memory loss, confusion, disorientation, difficulty in problem-solving and decision-making, personality changes, and behavioral problems.
- According to the Alzheimer's Association, approximately 1 in 9 people over the age of 65 have AD, and nearly 1 in 3 people over the age of 85 have the disease.
- Currently, there is no cure for AD, but early detection and treatment can help to slow its progression and improve the quality of life for those affected.

The Amyloid Cascade


Assembly
3
APP
β-Secretase
Aβ
Nicastrin
1
Aph-1
Presenilin
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4
α
2a
2b
40
42
2d
2c
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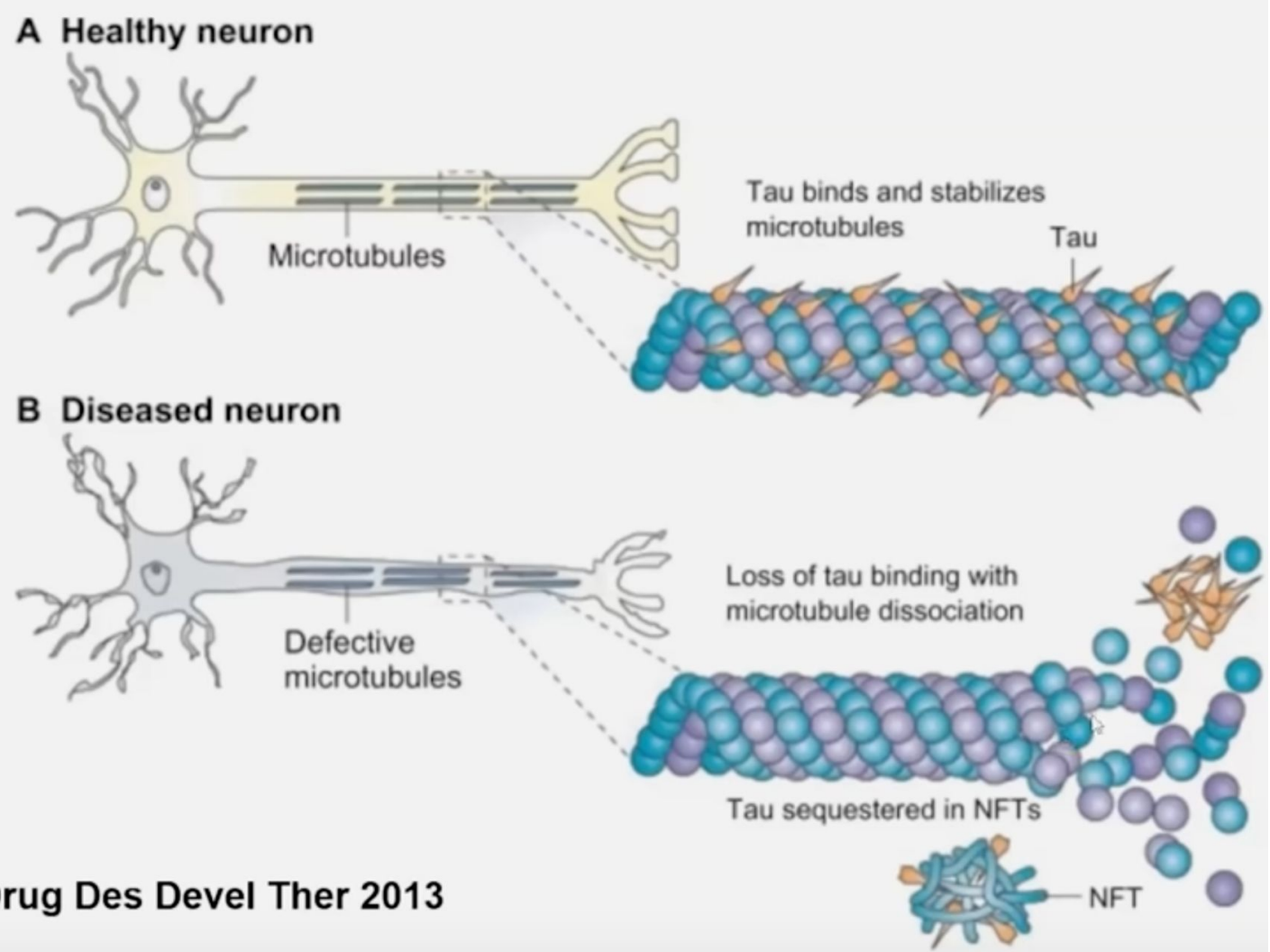
γ-Secretase
AICD



Chen et al, Drug Des Devel Ther 2013

EEG as a Diagnostic Tool for AD

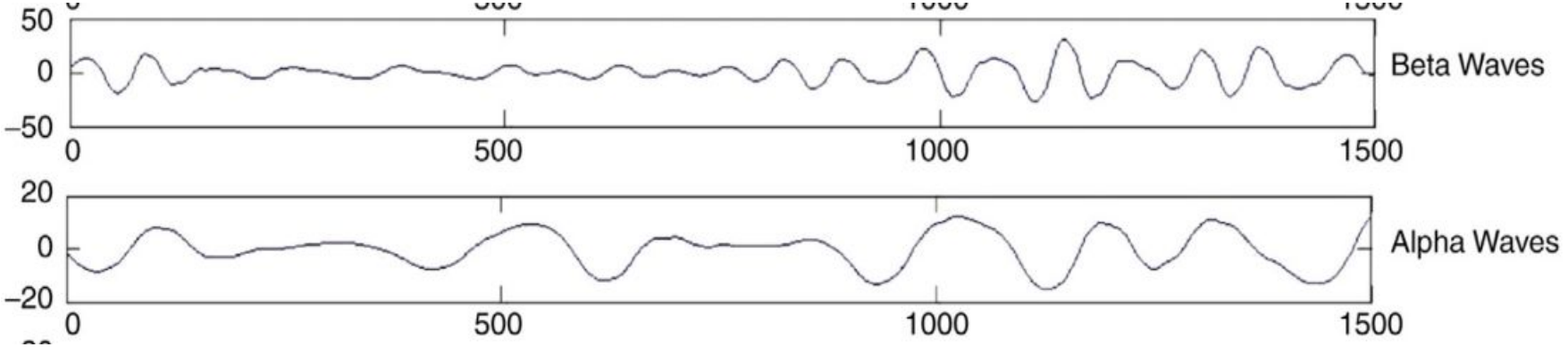
- Electroencephalography (EEG) is a non-invasive technique that measures and records the electrical activity of the brain using electrodes placed on the scalp.
- It provides valuable information about brain function and abnormalities.
- It can be useful for diagnosing brain damage, brain tumor, stroke, sleep and neurodegenerative disorders.
- EEG has been used for decades in the diagnosis and monitoring AD.

EEG Process

EEG Signal Recording	Signal Processing	Analog-to-Digital Conversion
- EEG records the electrical activity generated by the use of different micro-dipoles in the surface of cortex regions. - EEG is recorded though different sensors (electrodes) placed on the scalp - Most common placement - International 10-20 System	- The recorded signals are transmitted from EEG scalp electrodes to the next stage - a bio-signal amplifier. - The amplitude of the acquired neural signals is raised. - Noise is cancelled from the input signals.	- Processed signals are passed to the analog-to-digital converter that transforms neural responses from analog-to-digital domain. - Digitized brain signals are transmitted to interfaced computer.

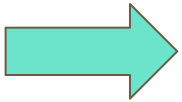
What is different in the EEG of an AD Patient?

- Slowing down of alpha and beta waves in the EEG can be an early indicator of AD - increased power in low frequencies
- Alpha Waves (8-12 Hz) - associated with relax states
- Beta Waves (12-30 Hz) - low amplitude waves associated with active thinking, attention, focus, problem-solving.



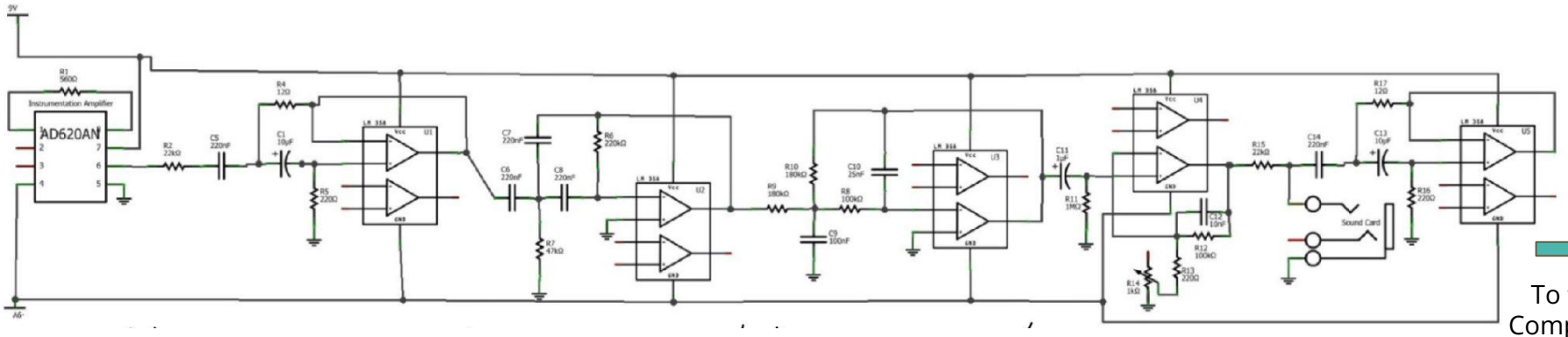
Role of our Circuit in this Process

- Take in raw EEG signals from the electrodes (leads) on a patient
- Filter unwanted noise from the signal
- Amplify the signal to a usable amplitude (μV to V)
- Send a processed signal to a computer for processing and analysis



Step 2 of the process discussed before - Signal Processing

Six-stage EEG Circuit



Instrumentation Amplifier

60 Hz Notch Filter

7 Hz High-Pass Filter

31 Hz Low-Pass Filter

Variable Gain Op-Amp

60 Hz Notch Filter

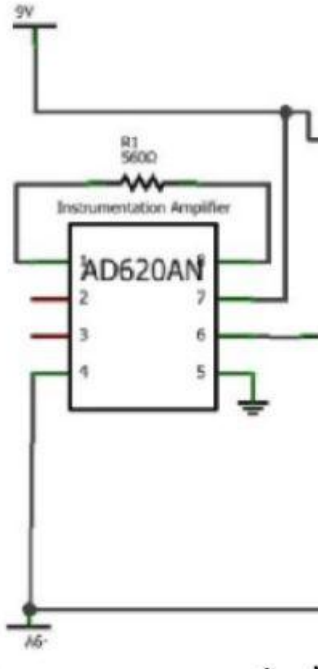
Note: driven right leg grounding could have been used instead of notch filters to get rid of power line interference

Instrumentation Amplifier

G = 1 + 49400/Rg

Resistor Rg can be chosen by user

Rg of 560 ohms → G = 1 + 49400/560 = 89.2



Op-amp

G = 1 + R12/(R13+R14)

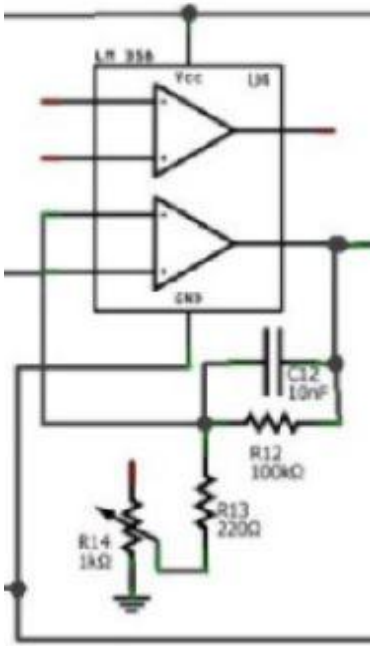
R14 is potentiometer so gain can be controlled manually

With 1k ohm potentiometer:

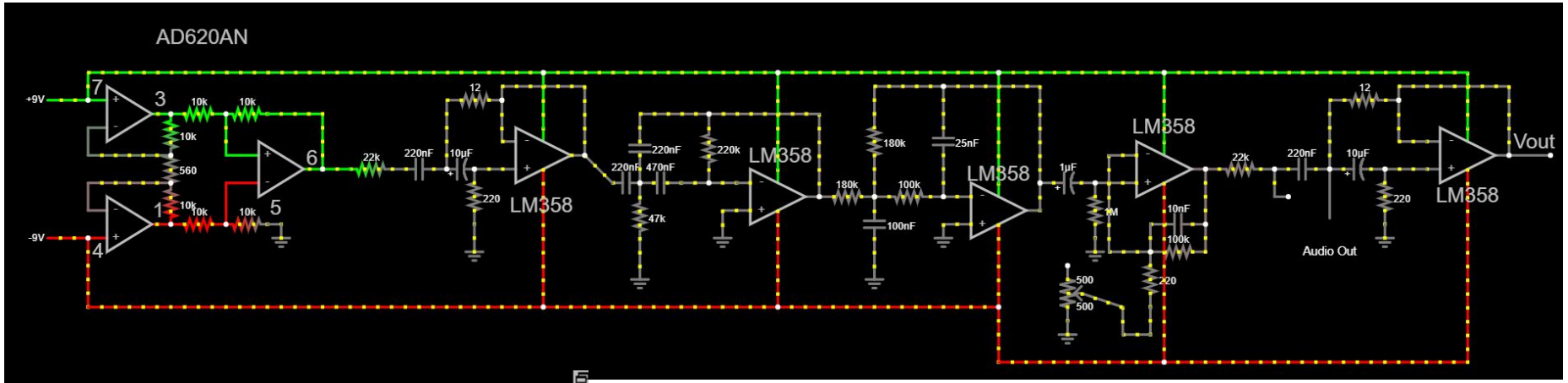
When R = 1000, G = 1 + 100k/(220+1k) = 83

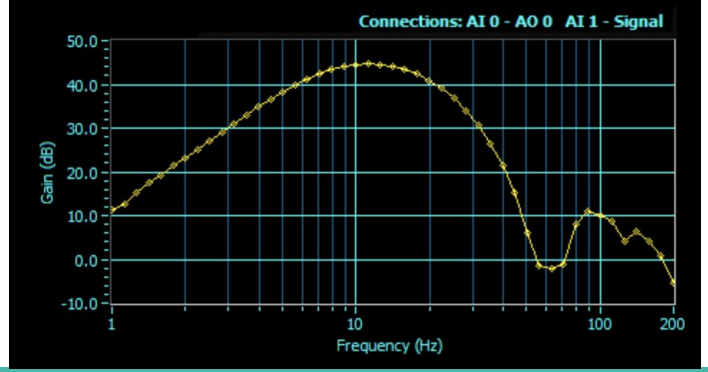
When R = 1000, G = 1 + 100k/(220+0) = 456

Wide range of gain values to account for any differences in EEG signal amplitudes



Simulation





- Simulation of circuit in Falstad
- Frequency response of circuit

EEG Analysis

- FIR and IIR filtering
- Choosing Artifact-free signal
- AD analysis techniques
  - Power Spectra → Spectral Analysis
  - Slowing → Left Shifting
  - Reduction in Complexity → Entropy Measures
  - Less Synchronization → Statistical
  - Amplitude Envelope → Statistical

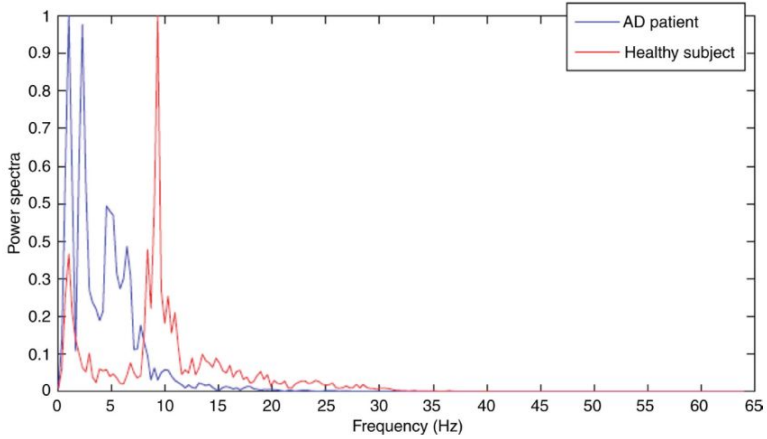
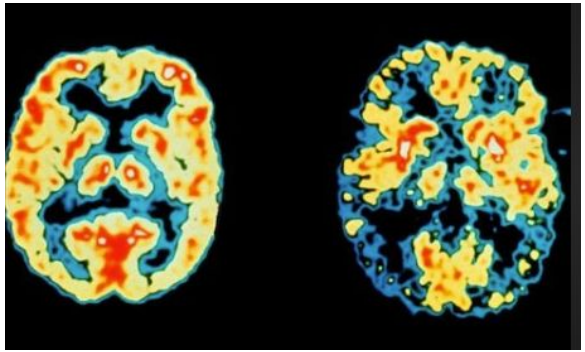


Figure 2.4 ***Comparison between a mild AD patient and a healthy subject using power spectrum.*** The graph is presented for Fz electrode [12].

NDA as a way to identify AD

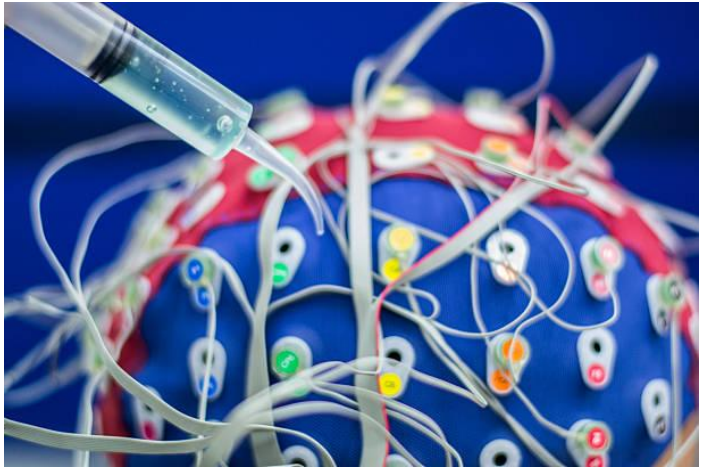
- Nonlinear Dynamical Analysis of EEG data has shown decreased complexity of EEG
- Regular but less complex patterns from less intact neuron systems.
- Interconnected neurons exhibit local nonlinear interactions -> NDA
- AD patients have lower correlation dimensions (D2) values



Electrode type

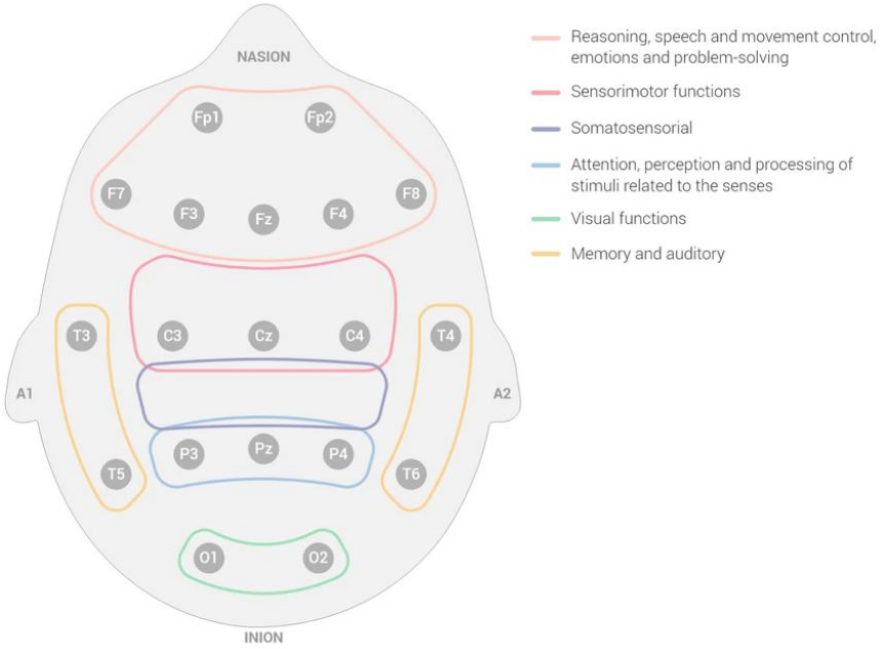
Types of EEG electrodes: disposable gel, reusable disc, headband/electrode caps, saline based electrodes and needle electrodes

- Aiming for accuracy and severity of disease in patients…(Gel)
- **Advantages for Gel electrodes**:
- High density recording availability for better resolution
- High signal quality that is less susceptible to movement and interference
- Increased stability of measurements for longer time periods
- Compatible with alternative measuring methods: ring electrodes
- Integratable with other research equipment such as NFIRS & TMS
- **Disadvantages with Gel Electrodes**
- Scratch skin to improve impedance
- Time consuming to clean and set up…patients can not have greasy hair
- Gel drys out after 5hrs…procedure takes 20-40mins



Limitations

- 2 methods for getting EEG signals; Wired and Wireless
- Electrodes of the BCI type with conducting gels, have shown to have a 30% higher maximum information rate
- Wires restrict movement and are time consuming
- Other factors that may affect results of signal include hypoglycemia, intense bright lights, medications, caffeine, and oily hair on the scalp
- Hard to gain access to EEG data; not as publicly available
- Difficult to access systematic methods and practices for diagnosing AD
- Does not incorporate biophysical knowledge; numbers do not describe what is actually happening physiologically
- EEG alone is not a good diagnosis. Better when paired with MRI, SPECT, or TMS
- Memory loss and EEG abnormalities correlation is not well studied.
- Positive side: EEG can be done when patient is (i) at rest (ii)performing memory tasks (iii) stimulated with visual, tactile, or auditory stimulations.



Significance and Potential Impacts

1. Early detection and intervention of Alzheimer’s Disease using this circuit can:
   - can improve patient outcomes
   - delay the progression of the disease
   - reduce the economic and social burden of Alzheimer's on individuals, and their families.
2. An accurate and reliable EEG signal processing system can have vast impacts on Brain-Computer Interfacing (BCI)
3. It can also be used as an effective diagnostic tool for the detection of various other neurodegenerative diseases that include Mild Cognitive Impairment (MCI).

Thank you!

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