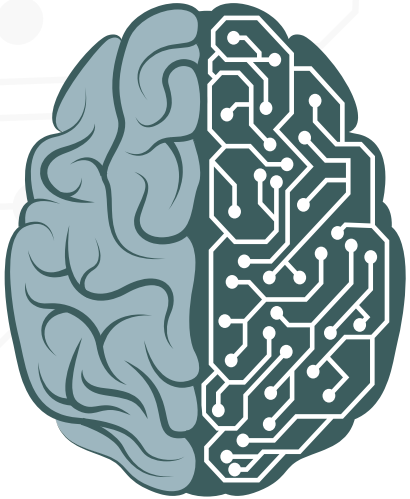

Paroxysmal slow wave events as predictive markers for epilepsy

based on Zelig et al. research

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Background & Need

- **Epilepsy** is one of the most common neurological disorders in children and adults, characterized by the occurrence of spontaneous seizures. (Miller et al. 2014)

- **The need:** 1. Prediction - Predicting epilepsy early may improve outcomes
  2. Diagnosis - Diagnosing epilepsy is challenging

PSWE

Paroxysmal slow wave events (PSWEs) are defined as slow transient events, in which the network switches from apparently normal activity to brief periods of low-frequency activity.

MPF = median power frequency

In rats : MPF < 5 [Hz] for at least 10 consecutive seconds

In humans : MPF < 6 [Hz] for at least 5 consecutive seconds

- At least two electrodes

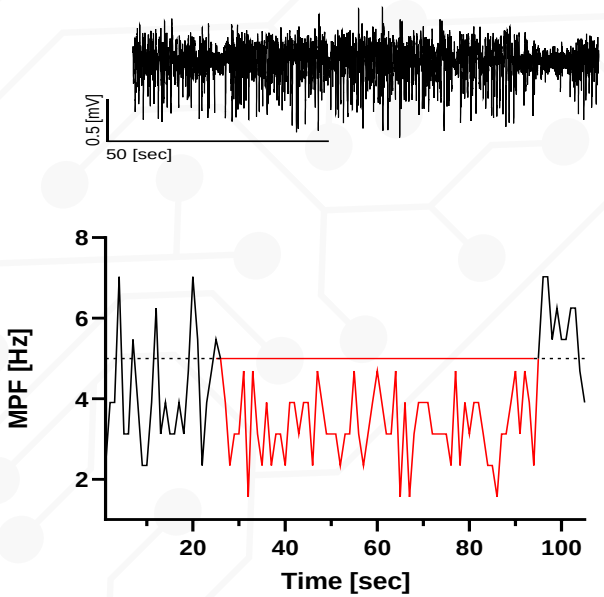


Figure 1: ECoG signal and MPF per sec respectively**.** PSWE can be seen in the middle of the graph (in red) – when the MPF is less than 5 [Hz] for at least 10 [sec] (rats definition of PSWE).

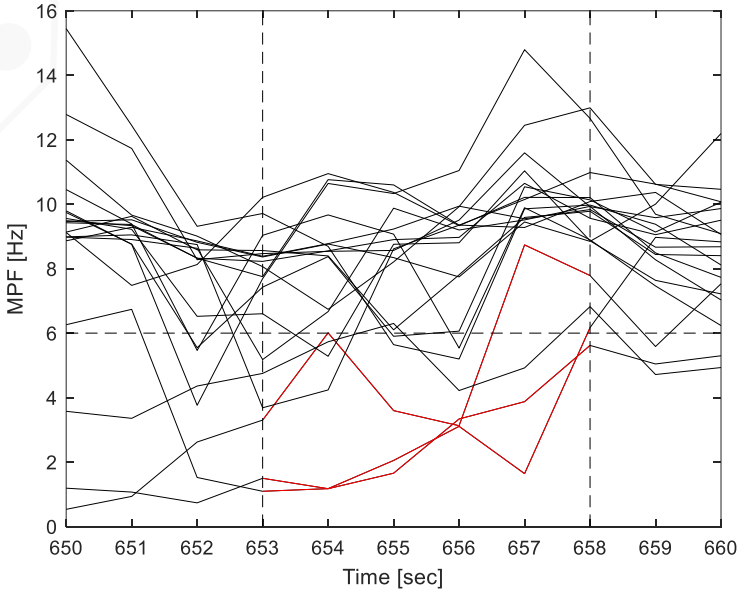


Figure 2: MPF per sec respectively**.** PSWE can be seen in the middle of the graph (in red) – when the MPF is less than 6 [Hz] for at least 5 [sec] (humans definition of PSWE).

Previous studies:

- Occurrence per minute of PSWE is correlated to cognitive impairment (MMSE score)
- Occurrence per minute of PSWE was higher in Alzheimer's disease compares to controls in the same age
- PSWE more frequent and longer duration in epilepsy patient compared to controls

[1] Paroxysmal slow cortical activity in Alzheimer's disease and epilepsy is associated with blood-brain barrier dysfunction

- The occurrence of PSWE in early EEG from patients who later reported spontaneous seizures was significantly higher compared to seizures free patients and healthy controls
- Occurrence of PSWE predict epilepsy with AUC=0.72
- 72 hours after first seizure PSWEs have a high predictive value for epilepsy (0.82)

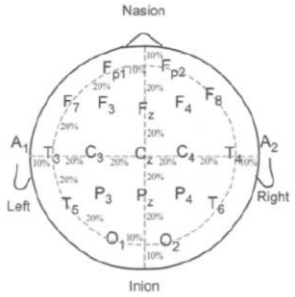
[2] Paroxysmal slow wave events predict epilepsy following a first seizure

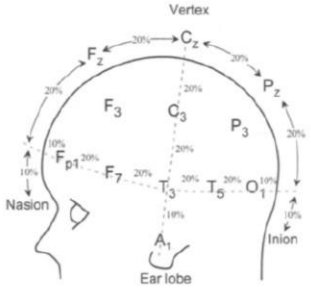
Goals

The study aimed to confirm prior research suggesting certain PSWE features could forecast epilepsy, employing a logistic regression model capable of distinguishing between epilepsy and non-epilepsy.

Methods

- 184 Epilepsy + 154 non-epilepsy patients.
- Each patient had EEG data recorded using the conventional 10-20 method with 19 electrodes, with a minimum recording duration of 20 minutes.
- Fs : 250 Hz





- Pre-processing: Based on previous research

1. DC removal
2. BPF : 1-45 Hz
3. Reference to average

The features:

Based on the article:

1. Occurrence per minute
2. Mean MPF
3. Mean duration
4. Mean number of channels that pick up PSWEs

Additional features:

5. Energy: $E = \frac{1}{N}\sum_{n=1}^{N} \mathrm{x}_\mathrm{n}^2$ (assessment of signal strength)

6. Zero crossing: $ZC = \sum_{n=2}^{N}(x_n \cdot x_{n-1} \leq 0)$ (estimation of instantaneous frequency)

7. Delta 0.5-3
8. Theta 3-8 Hz
9. Alpha 8-12 Hz
10. Beta 12-20 Hz

$$FT = \sum_{\text{all freq}} f_j \; ; \; \theta = \frac{1}{FT} \cdot \sum_{j=3}^{8} f_j$$

* **Normalization**

Classification model- logistic regression

80% train (separate to 80% train and 20% validation) and 20% test.

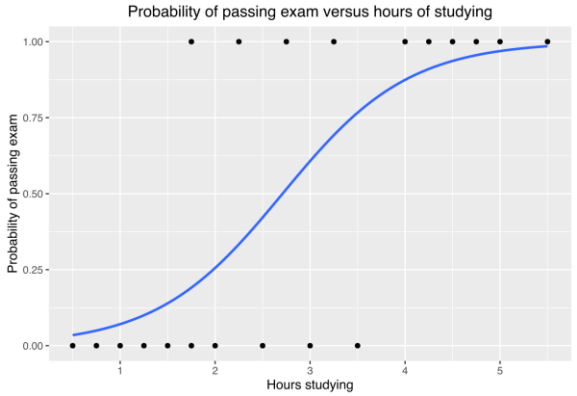
$$Y_j(\ 1\ for\ epilepsy\ and\ 0\ for\ non-epilepsy)$$

$$X_j = (x_{1j}, \dots x_{Mj}) - when\ M\ is\ the\ number\ of\ features$$

$$if\ \pi(X_j) = P(Y_j = 1\ |X_j) : \log\left(\frac{\pi(X_j)}{1-\pi(X_j)}\right) = \beta_0 + \beta_1 x_{1j} + \cdots + \beta_M x_{Mj}$$

$$\log P(\beta|Y,X) = \sum_{j=1}^{N} Y_j \cdot \log \pi(X_j) + (1-Y_j) \cdot \log\left(1-\pi(X_j)\right)$$

$$\hat{\beta} = \arg\max \log P(\beta|Y,X)$$



Forward features selection algorithm

$$number\ of\ calculation = \frac{1}{2}m(2d - m + 1)$$

Optimal criterion : AUC

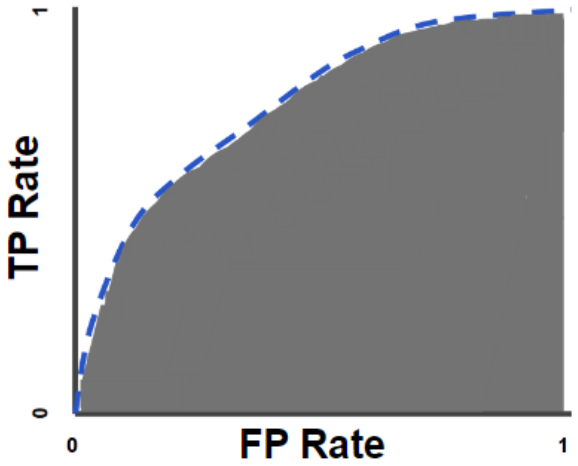
True positive rate = sensitivity

$$TPR = \frac{N_{TP}}{N_{TP} + N_{FN}}$$

False positive rate = (1- specificity)

$$FPR = \frac{N_{FP}}{N_{FP} + N_{TN}}$$

J optimal – maximum of the AUC



https://developers.google.com/machine-learning

Results

The features that selected are: ' mean_MPF', ' mean_delta', 'mean_beta',' Mean_duration'.

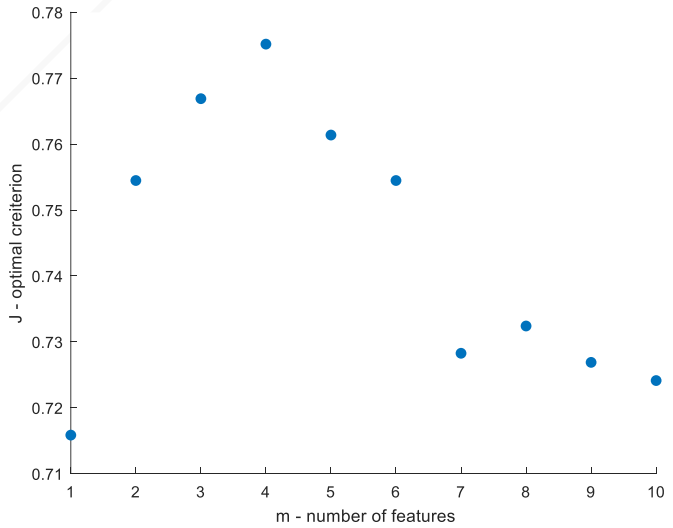


Figure 3: The AUC as function of the number of chosen features.

Results

Youden's J statistic : max (J) ; J =sensitivity + specificity – 1

Sensitivity = 0.8378 , Specificity=0.667, AUC=0.7621

- 31 / 37 epileptic patients identified has epileptic.
- 21 / 31 non-epileptic patients identified has non-epileptic.

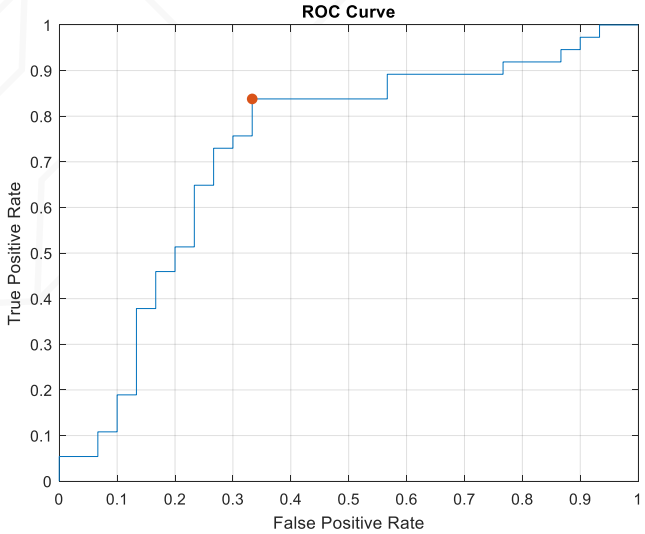


Figure 5: The ROC of the chosen model on the test data.

In red- the threshold that chosen using Youden J statistic.

Replicate the article model

Sensitivity = 0.7838 , Specificity=0.5806, AUC=0.6459

- 29 / 37 epileptic patients identified has epileptic.
- 18 / 31 non-epileptic patients identified has non-epileptic.

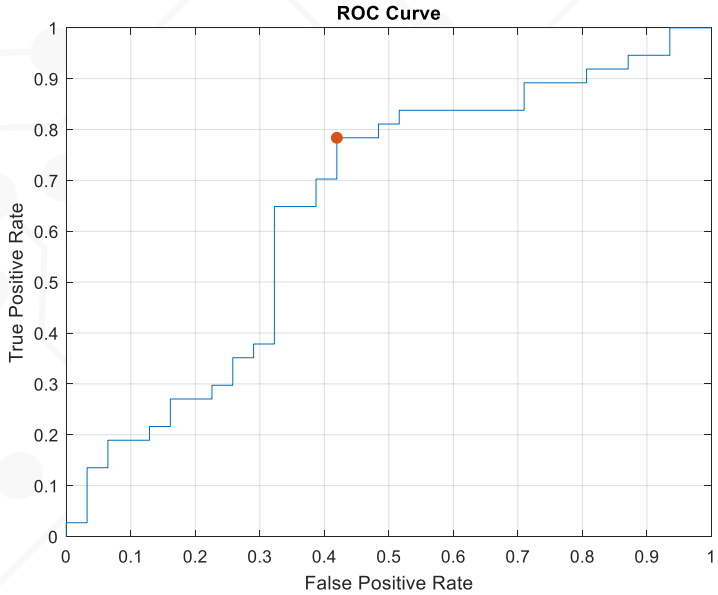


Figure 6: The ROC of the chosen model on the test data.

In red- the threshold that chosen using Youden J statistic.

Discussions

Article model	New model With 10 features and FFS
Sensitivity= 0.7838	Sensitivity=0.8378
Specificity=0.5806	Specificity=0.667
AUC=0.6459	AUC=0.7621
ODD ratio=8.79	ODD ratio=30.993

- Differences in results from multiple runs

Conclusions and summary

- FFS identified four key features contributing to optimal model performance.
- Evaluation on validation data showed the model's effectiveness in distinguishing epilepsy from non-epilepsy cases.
- Model incorporating FFS demonstrated superior accuracy, sensitivity, and specificity.

- Model performance susceptible to data fluctuations or experimental conditions.
- Future studies include increasing dataset size or exploring alternative modeling approaches to enhance reliability.

Literature

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