

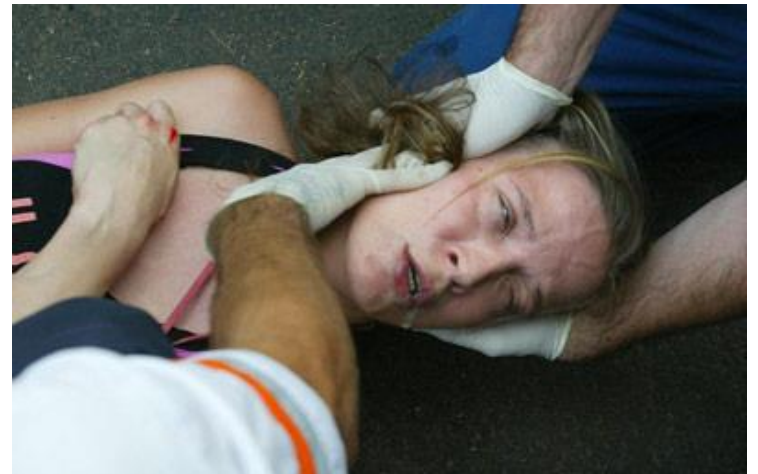


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• **Surgical Decision Making in
Temporal Lobe Epilepsy by
Heterogeneous Classifier
Ensembles**

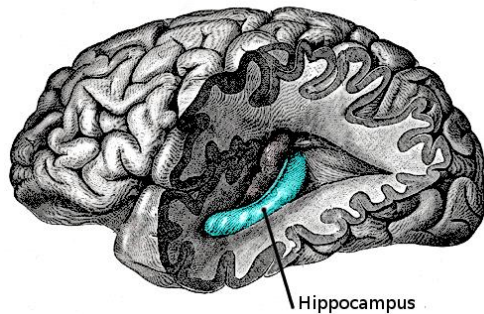
➔ Epilepsy

- Epilepsy is a brain disorder involving repeated, spontaneous seizures of any type.
- Seizures are episodes of disturbed brain function that cause changes in attention or behavior.



➔ Temporal Lobe Epilepsy (TLE)

- Localization-related epilepsies account for about 60% of all adult epilepsy cases, and **temporal lobe epilepsy (TLE)** is the **most common** and **most operated** form.



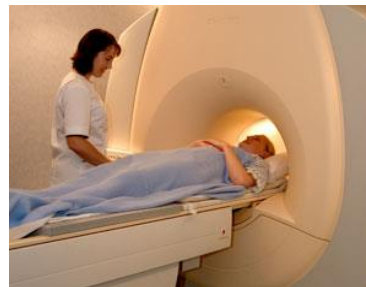
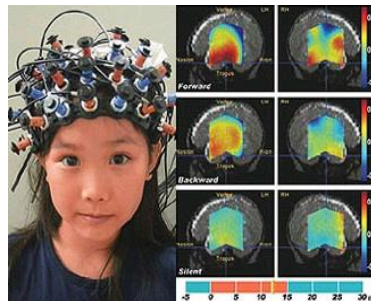
→ Treatment

- With no significant response to medication, epilepsy **surgery** will be considered.
- Focal point of the seizure will be **resected** via neurosurgery.



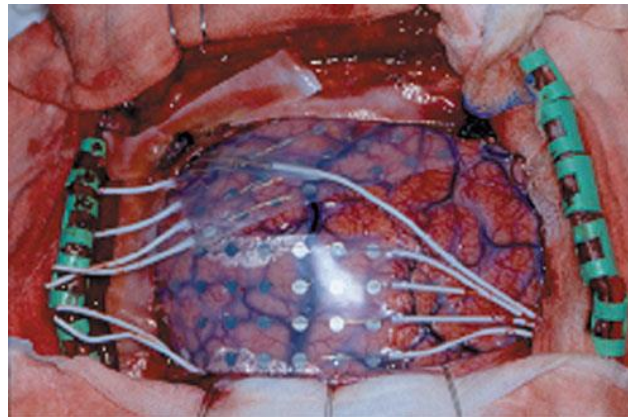
➔ Lateralization

- Finding which temporal lobe contains the focal points of the seizure. (Left or Right)
- Several **noninvasive** clinical attributes are investigated, including:
- **Imaging features** such as MRI FLAIR and SPECT
- **Neuropsychology features** like CVLT and BNT
- **WADA**
- **EEG**
- ...



➔ Extraoperative electrocorticography (eECoG)

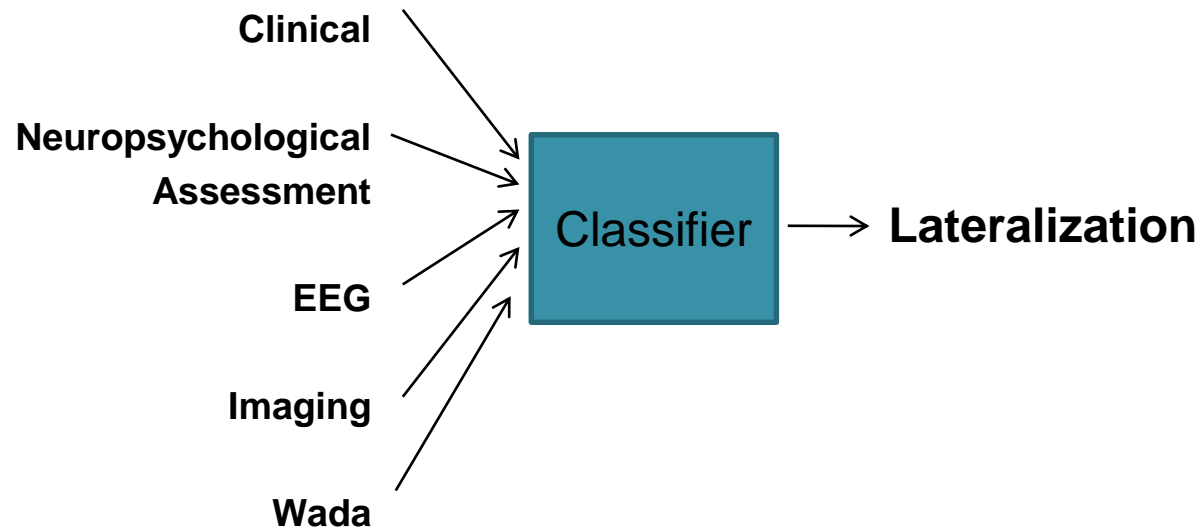
- When noninvasive clinical features are not decisive
- Electrodes are placed directly on the exposed surface of the brain to record electrical activities from the cerebral cortex.
- Such patients are sometimes referred to as Phase II patients



- Adds financial burden and further distress

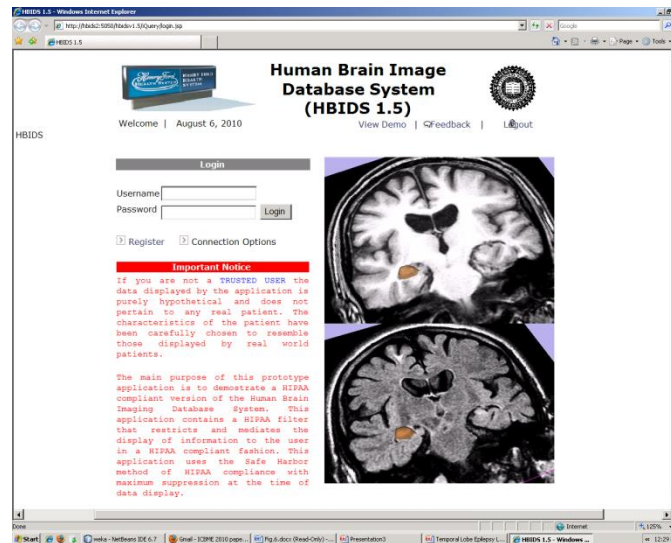
➔ Extraoperative electrocorticography (eECoG)

- Our first goal is to reduce this requirement using data mining techniques.



➔ HBIDS

- Human Brain Image Database System (HBIDS)
- Henry Ford Health System, Michigan
- 197 Features of about 170 patients

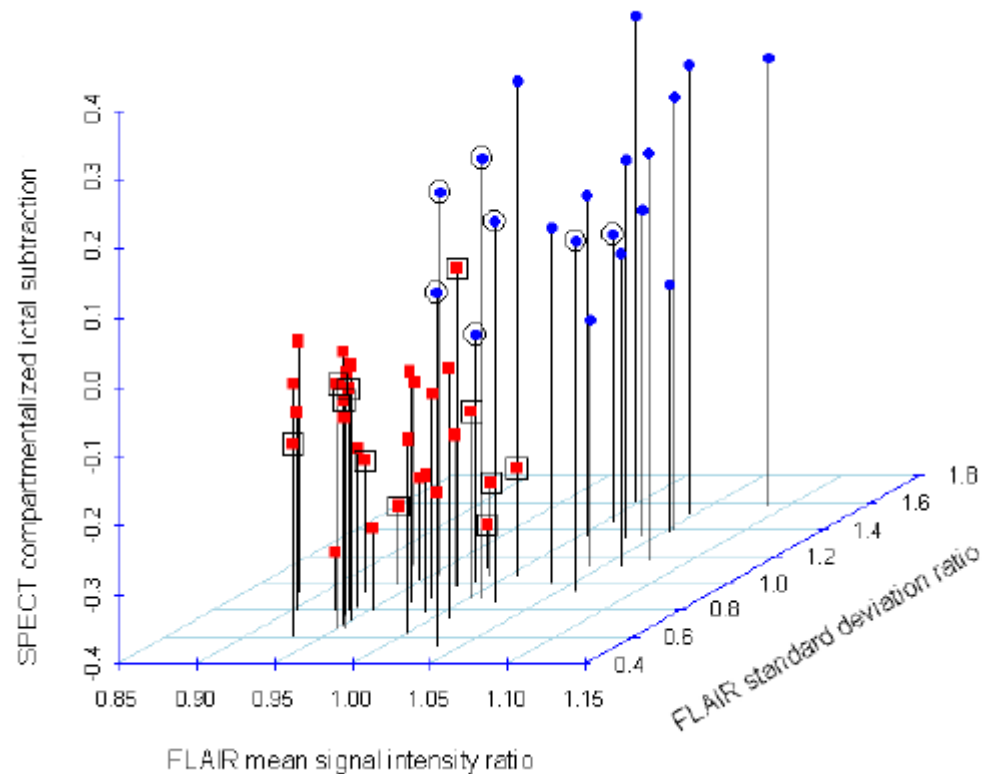




→ Some of The Features Included in HBIDS

- Semiology
- Neuropsychological profiles
- Pathology
- EEG Data (including interictal waveforms, their location and predominance as well as ictal onset location.)
- Magnetic resonance (MR) imaging
- Single photon emission computed tomography (SPECT)
- MRI fluid-attenuated inversion recovery (FLAIR) mean signal and standard deviation
- Texture analysis
- WADA test
- Location of surgery
- Outcome according to the Engel classification.

→ Patients Cohort



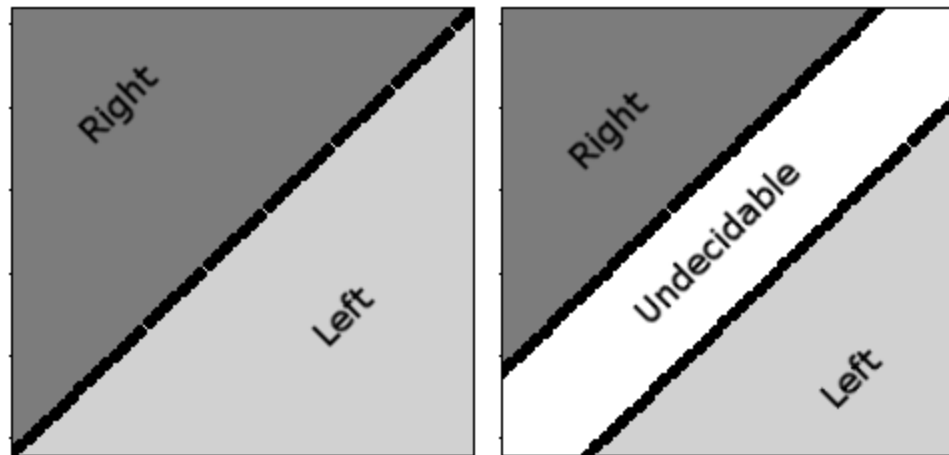
FLAIR standard deviation ratio,
FLAIR mean signal intensity ratio
SPECT compartmentalized ictal subtraction.
right side are shown with blue circles
left side abnormality with red squares.

Phase II patients are outlined.

Cases with a missing value in either of the attributes are removed.

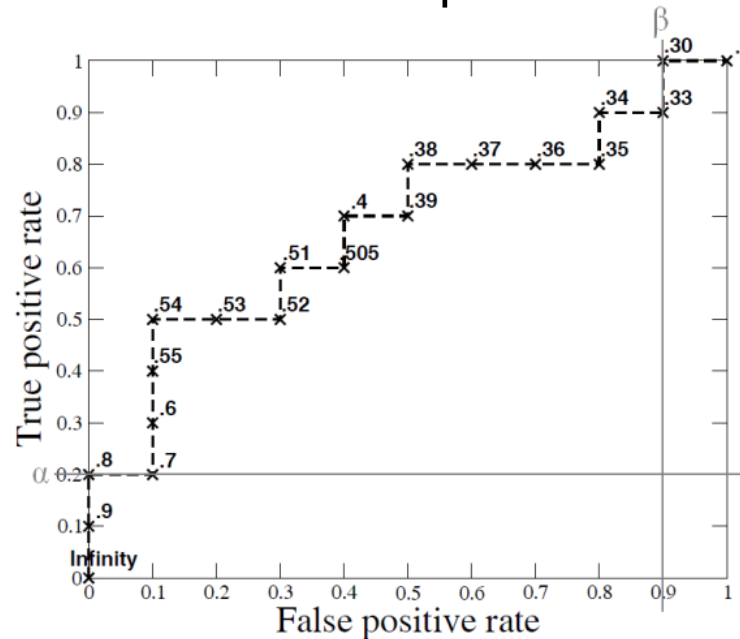
➔ Confidence in Prediction

- The domain has very low tolerance for invalid predictions.
- A confidence-based classification system would only provide predictions for cases with **achievable decision confidence** above a certain threshold.
- Other cases would be considered **not decidable**.



➔ Confident Prediction Rate (CPR)

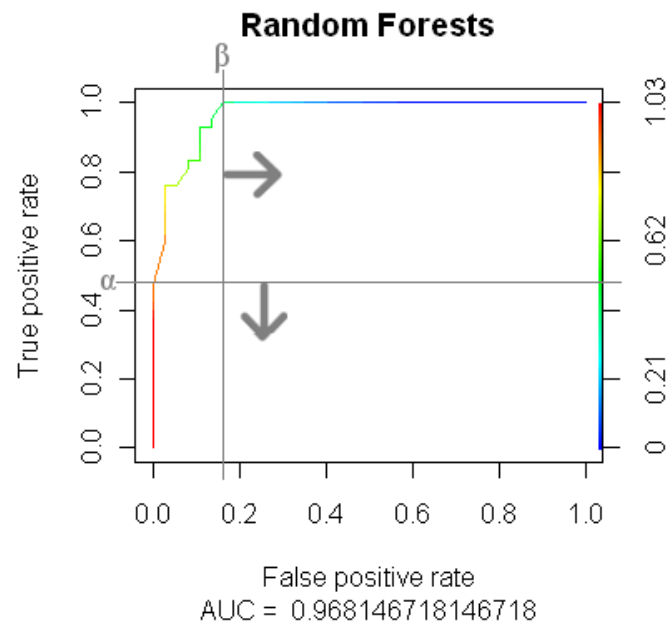
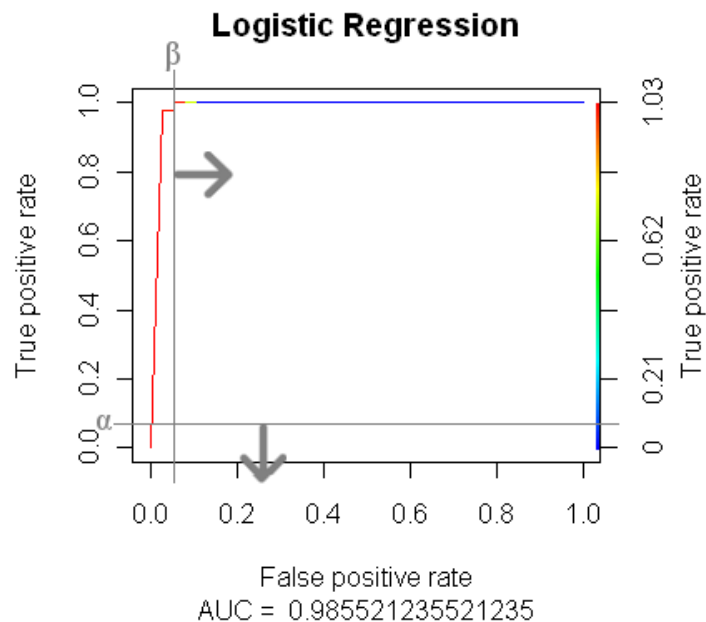
- A performance evaluation metric is needed to compare classifiers based on confidence predictions.



- The α and β limit are the upper bounds for confident prediction rate” (CPR).
- They could be set at desired confidence levels. e.g. 95%, 99.5%, 100%

$$CPR = \frac{(\#samples \mid score > \alpha) + (\#samples \mid score < \beta)}{\text{Total number of samples}} * 100$$

➔ AUC vs. CPR



LR -> AUC = 0.986, CPR = 44.3%

RF -> AUC = 0.968, CPR = 64.6%.

In a medical domain such as this case, RF should be preferred over LR despite the AUCs suggesting otherwise.

➔ Heterogeneous Classifier Ensemble

- Ensemble of classifiers with independent errors improve the overall accuracy of the classifiers:
 - Lowering the chance of getting stuck in local optima,
 - Reducing the risk of choosing the wrong classifier,
 - Expanding the space of representable functions

➔ Heterogeneous Classifier Ensemble

- With the proposed measure of prediction confidence (CPR)
- We show that a heterogeneous ensemble of classifiers improves prediction confidence.

➔ Heterogeneous Classifier Ensemble

- Naïve Bayes (NB),
- Support vector machine (SVM),
- 3-nearest neighbors (3NN),
- Multilayer perceptron (MLP),
- Logistic regression (LR),
- Random forests (RF).

➔ Performance Improvement

- “optimistic ensemble (OE)” takes a more risky approach:
 - most extreme probability toward 0 or 1
- “pessimistic ensemble (PE)” generates a conservative prediction.
 - probability which is closest to 0.5

$$OE = \{P_R(c, s) \mid |P_R(c, s) - 0.5| = \max(|P_R(\forall c, s) - 0.5|)\}$$

$$PE = \{P_R(c, s) \mid |P_R(c, s) - 0.5| = \min(|P_R(\forall c, s) - 0.5|)\}$$

Classifier	AUC	CPR
Naïve Bayes	0.993	84.8%
Support Vector Machines	0.959	36.7%
Multi Layer Perceptron	0.978	72.2%
3-Nearest Neighbors	0.964	43.0%
Logistic Regression	0.986	44.3%
Random Forests	0.968	64.6%

Ensemble Function	AUC	CPR
Mean	0.985	78.5%
Median	0.993	88.6%
Maximum	0.959	44.3%
Minimum	0.981	72.2%
Geometric Mean	0.985	78.5%
Pessimistic Ensemble	0.974	69.6%
Optimistic Ensemble	0.973	45.6%

➔ Outcome (Engel Classification)

- **About 30%** of the surgeries will not result in the improvement of the patients condition.
- Patients would be classified into four group based on successiveness of the surgery.
- **Class I** being the most cured and **Class IV** being the worst.

➔ Outcome Prediction

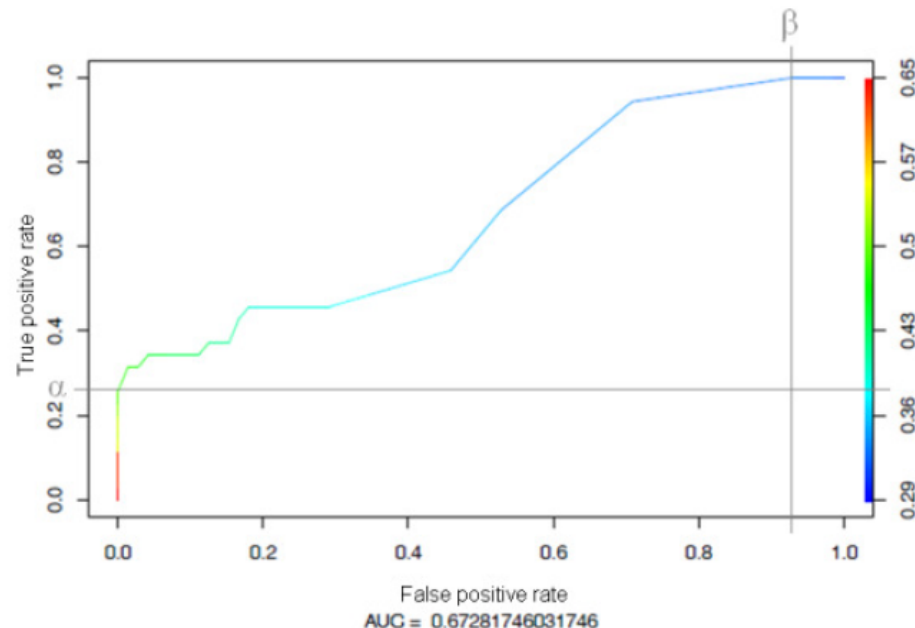
- It is not always possible for human experts to identify such unsuccessful cases prior to surgery.
- Use data mining techniques in prediction of undesirable outcome for a portion of such cases.

➔ Outcome Prediction

- Most clinical attributes had no significant discriminative power for outcome prediction.
- We found three indicators:
 - Asymmetry in the hippocampus volume of the patients: 13.9% CPR
 - Variance of the lateralization predictions by six different classifiers: 8.4% CPR
 - Average distance of the lateralization predictions from 0.5: 7.5% CPR

➔ Outcome Prediction

- Each instance was scored based on average scores of the three.



AUC is 0.67, CPR is 23.2%.

32.4% of the post-operative **seizure-bearing** patients lay inside the confident prediction region.

Near **one-third** of the patients who did not improve significantly after the surgery could be identified by this system.

➔ Discussion and Conclusion

- **Measures of confidence are needed in domains such a medicine.**
- **High AUCs is not enough.**
- **Confident prediction rate (CPR) based on ROC is one way.**
- **Ensemble classification method was applied to lateralization and surgical outcome prediction in temporal lobe epilepsy.**

➔ Discussion and Conclusion

- **Power of Data Mining in Medicine:**
 - Potentially we could lateralize **88.4%** of the patients with high confidence
 - While only **58.2%** of patients were lateralized by domain experts using noninvasive methods.
 - It is potentially possible to lateralized **81.8%** of the phase II patients.
 - While only **6.5%** of the phase I patients will not be lateralized.
 - About **one third** of the patients who would not benefit from the surgery could be flagged with a recommender system.

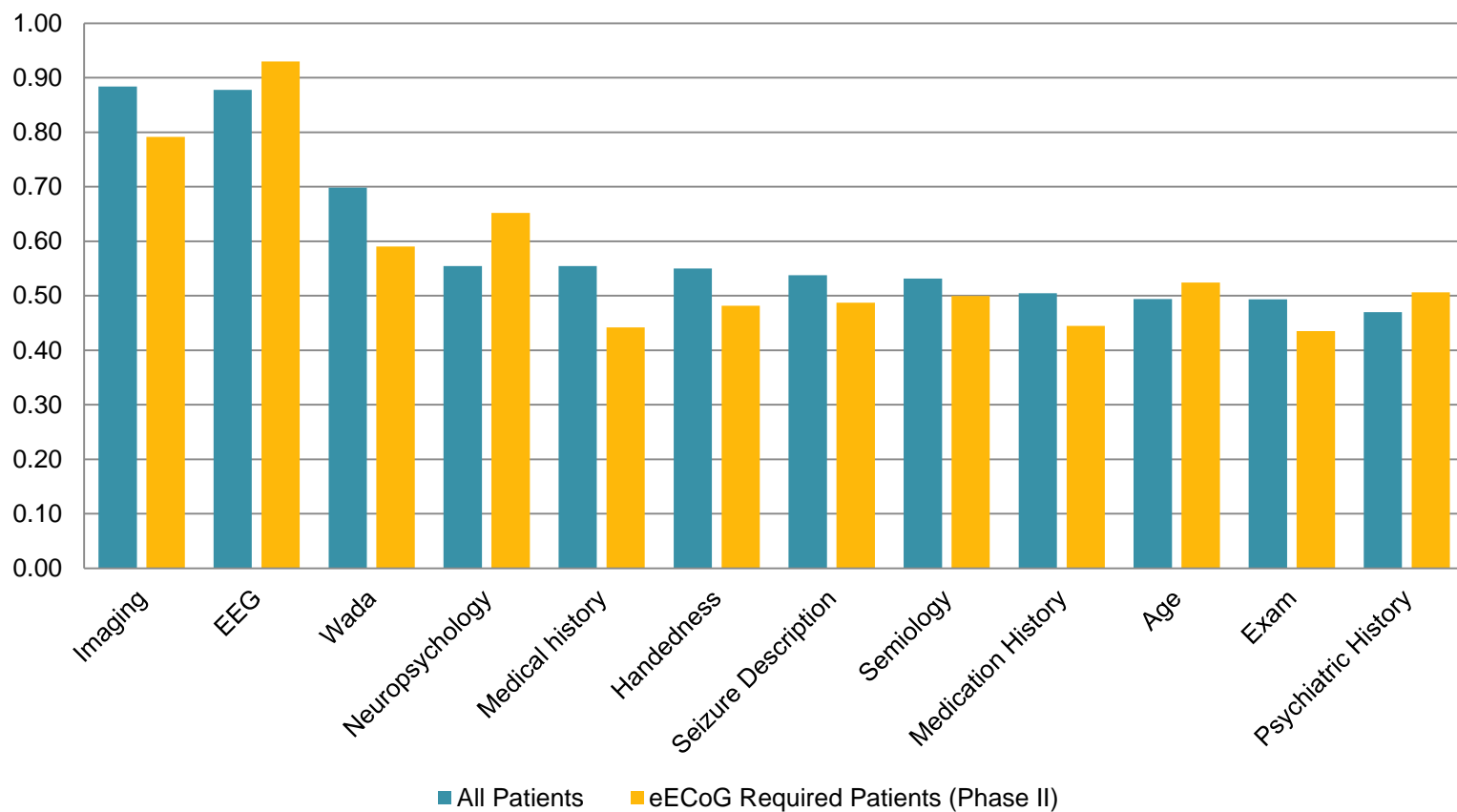


• **Thank you**

If you are interested to get more details about this research
please contact

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→ Feature Ranking



■ All Patients

■ eECoG Required Patients (Phase II)

➔ Classifier Comparison

(a) AUC of the classifiers using different feature subsets

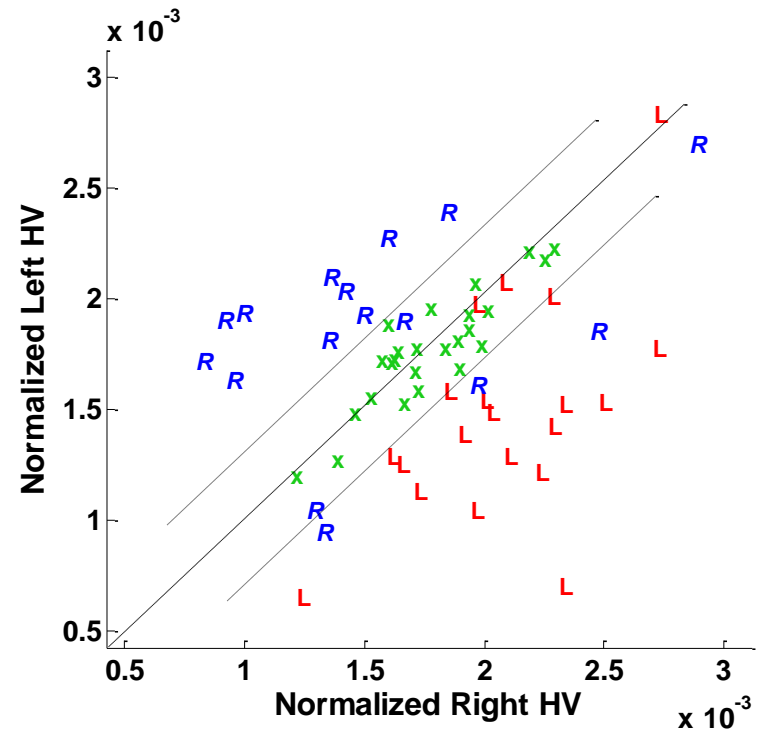
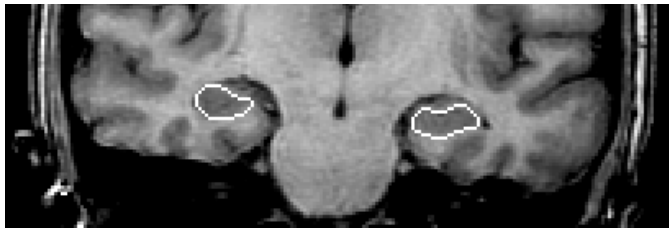
Features	NB	SVM	MLP	3NN	LR	RF
All 9	0.993	0.959	0.978	0.964	0.986	0.968
Top 4	0.973	0.970	0.974	0.952	0.966	0.957
Imaging	0.982	0.981	0.957	0.929	0.975	0.916
EEG	0.951	0.951	0.943	0.964	0.925	0.958
Wada	0.609	0.660	0.599	0.596	0.660	0.689

(b) Confident prediction rate (CPR) of the classifiers using different feature subsets

Features	NB	SVM	MLP	3NN	LR	RF
All 9	84.8%	36.7%	72.2%	43.0%	44.3%	64.6%
Top4	65.8%	72.2%	54.4%	38.0%	41.8%	36.7%
Imaging	81.0%	75.9%	59.5%	0.0%	72.2%	0.0%
EEG	53.2%	65.8%	45.6%	73.4%	30.4%	62.0%
Wada	10.1%	13.9%	12.7%	22.8%	13.9%	12.7%

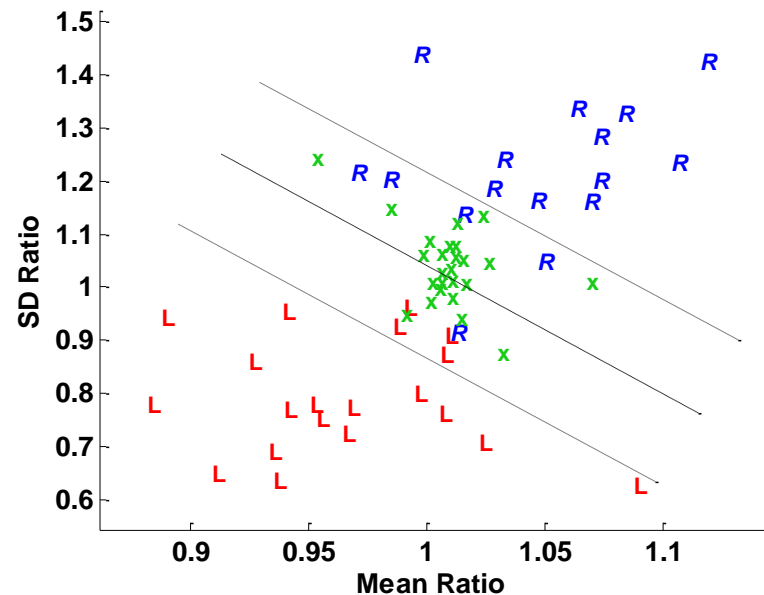
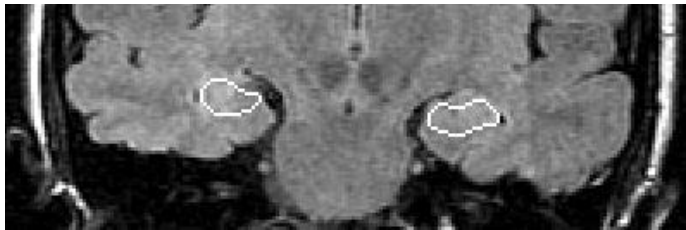
→ Experiments

- Hippocampal volume
- Normalized to intracranial volume



→ Experiments

- Hippocampal FLAIR mean and StD
- Right/Left ratios



→ Experiments

- Hippocampal SPECT
- Normalized to whole brain SPECT mean

