Decision Support System for Epilepsy

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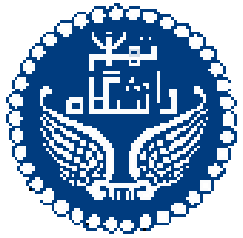
Chairman, IEEE Iran Section, Iran



Decision Support System (DSS)

Goal: Enhance decision making

Issues: Foundations, functionality, interfaces, implementation, impacts, and evaluations

Fields: Decision theory, statistics, computer supported cooperative work, database management, management science, mathematical modeling, operations management, cognitive science, psychology, user-interface management, …

Journal Publications

- Decision Support Systems (by Elsevier)
- International Journal of Decision Support Systems (by Inderscience)
- Journal of Decision Systems (by Taylor & Francis)
- International Journal of Decision Support System Technology (by IGI Global)
- Journal of Soft Computing and Decision Support Systems (by Penerbit UTM Press)

Medical DSS & E-Health E's

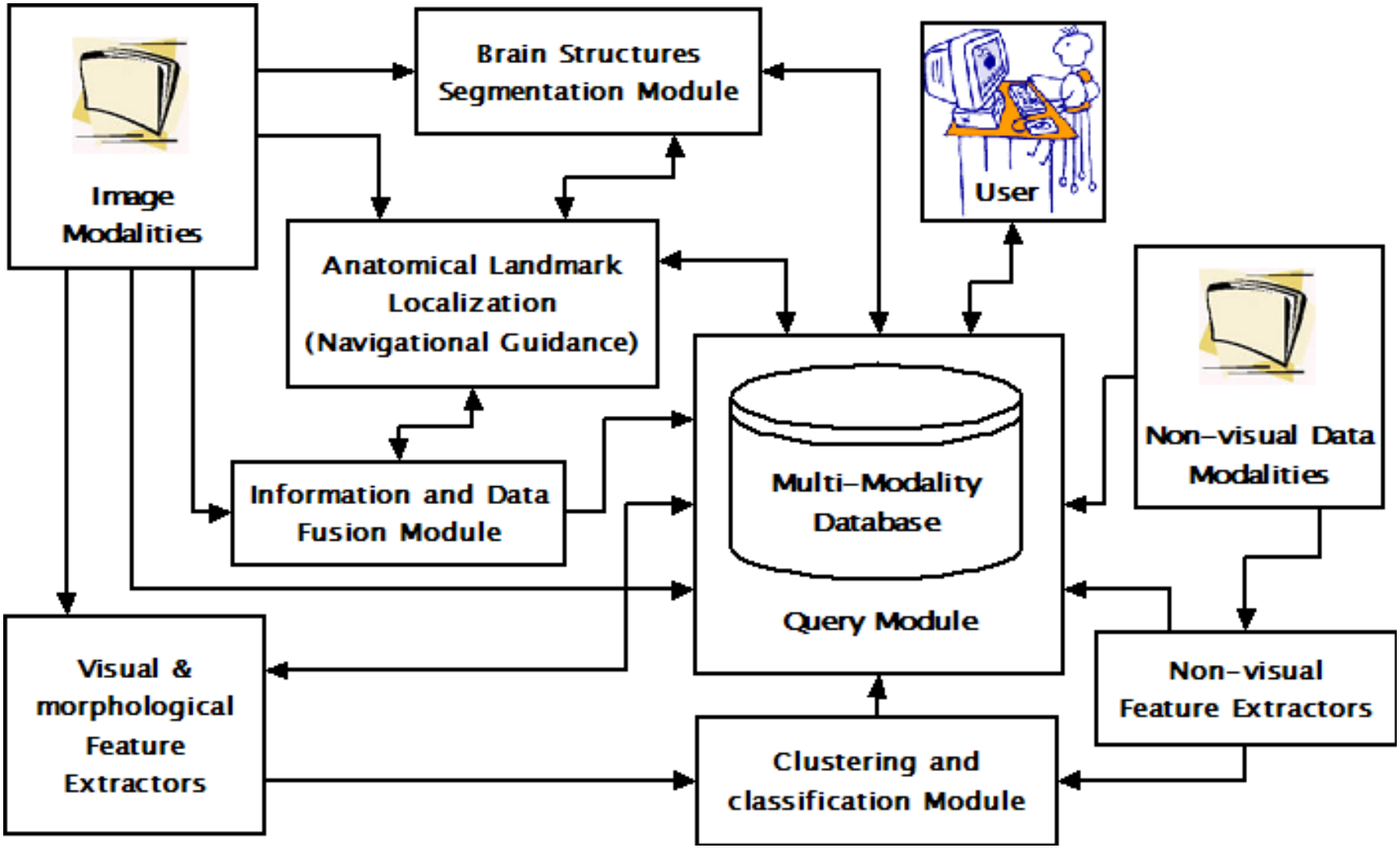
1. Efficiency, decreasing cost
2. Enhancing quality of care
3. Evidence based
4. Empowerment of physicians and patients
5. Encouragement of a new relationship between patients and health professionals
6. Education of physicians and patients
7. Enabling information exchange in a standardized way
8. Extending the scope of health care beyond its conventional boundaries
9. Ethics
10. Equity

- **Easy-to-use**
- **Entertaining**
- **Exciting**

Epilepsy & Treatment Challenges

- About 1% of population (~ 50 Million individuals) suffer from epilepsy.
- About 35% of epilepsy patients are drug-resistant.
- Surgery is a treatment for drug-resistant epilepsy patients.
- Localization of the seizure focus is a pre-requisite for surgery.
- About 30% of surgically treated patients don’t become seizure-free.

Proposed Decision Support System



Medical Imaging

Noninvasive characterization of tissues, structures, physiological processes, functions, ….

- Magnetic Resonance Imaging (MRI)
- Functional Magnetic Resonance Imaging (fMRI)
- Single Photon Emission Computed Tomography (SPECT)
- Positron Emission Tomography (PET)

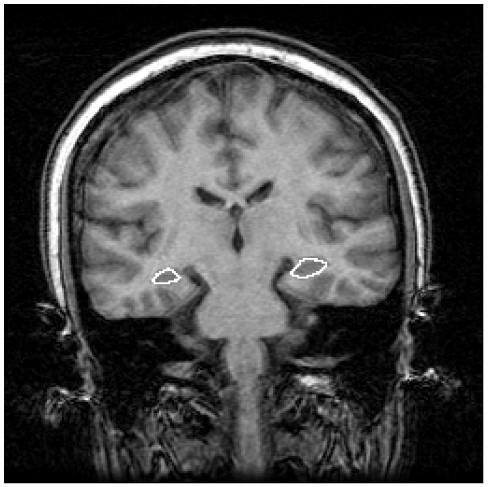
Medical Image Analysis Research

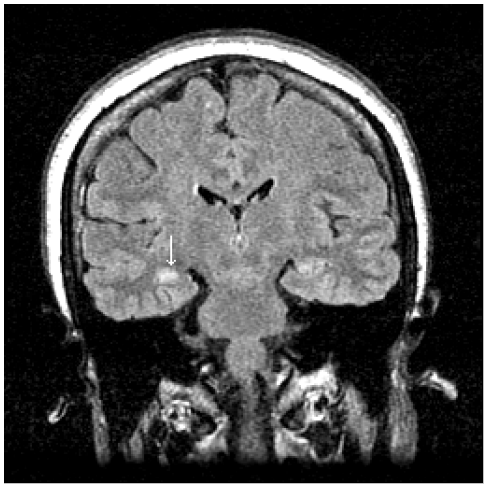
- Improve quality of medical images
- Extract quantitative information for diagnosis, prognosis, and treatment evaluation
  - Segmentation
  - Feature extraction
  - Clustering/classification
  - Database construction
  - ……..

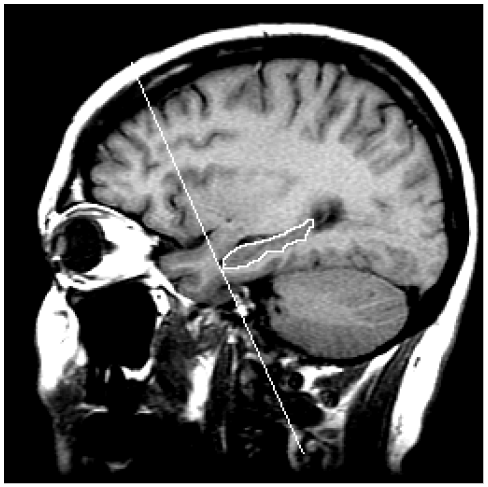
Benefits of DSS for Epilepsy

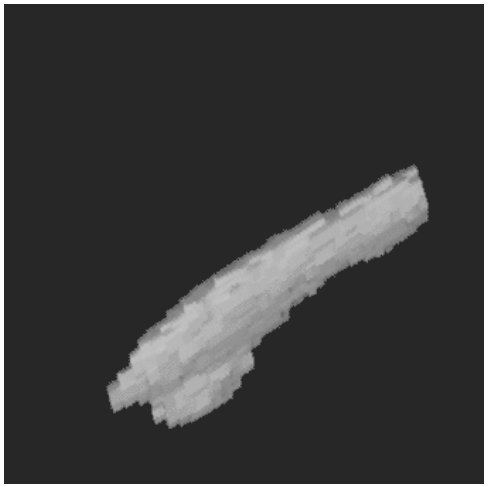
- Temporal Lobe Epilepsy
  - Avoid Phase II Studies
    - Lateralize Focal TLE
    - Suggest Non-Temporal Lobe Epilepsy
  - Predict Surgery Outcome (Likelihood of Seizure Free)
- Non-Temporal Lobe Epilepsy
    - Identify Insular Epilepsy
    - Lateralize Insular Epilepsy
    - Suggest Non-Focal Epilepsy
    - Predict Surgery Outcome (Likelihood of Seizure Free)

Segmentation and Characterization of Hippocampus





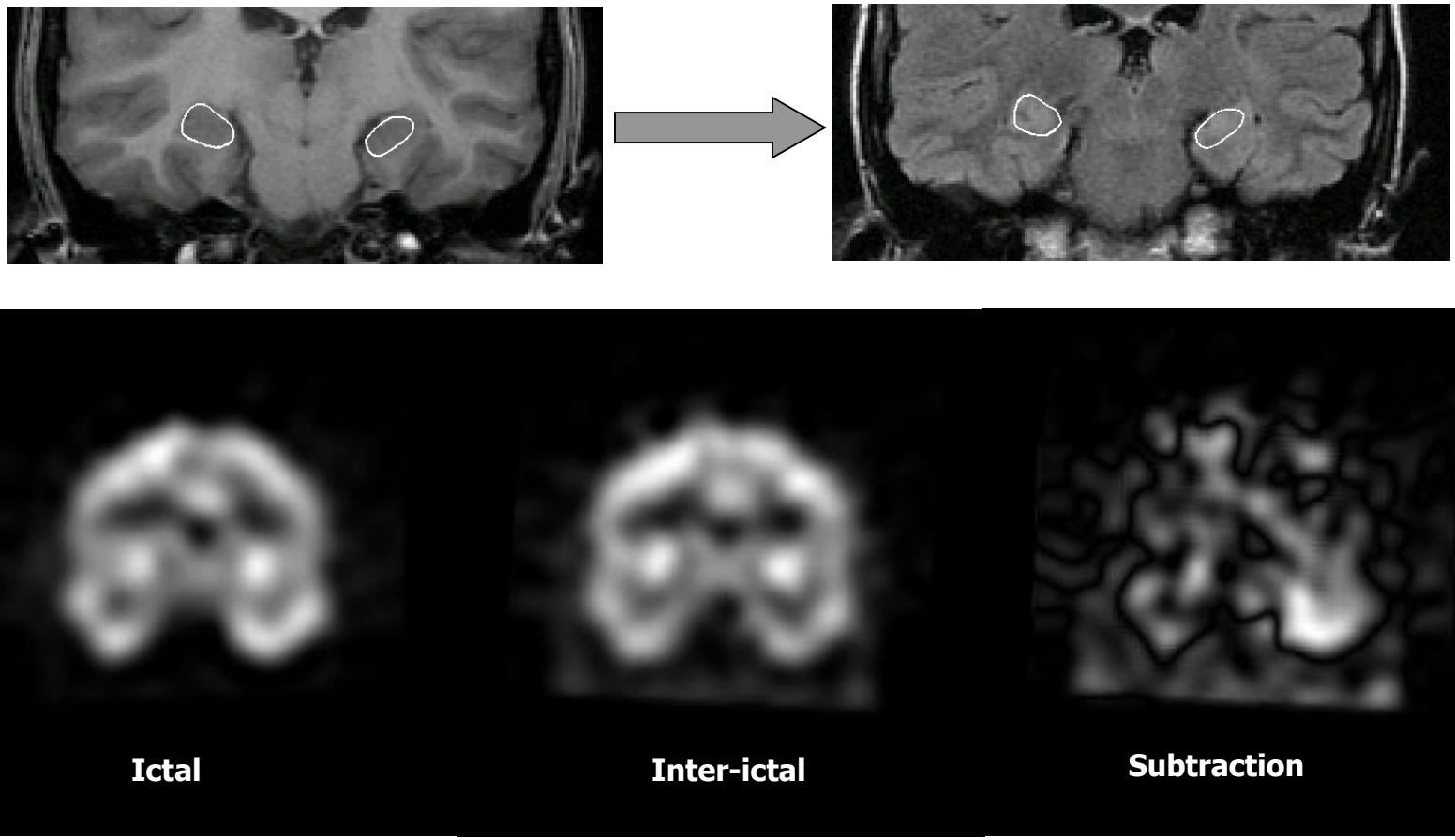




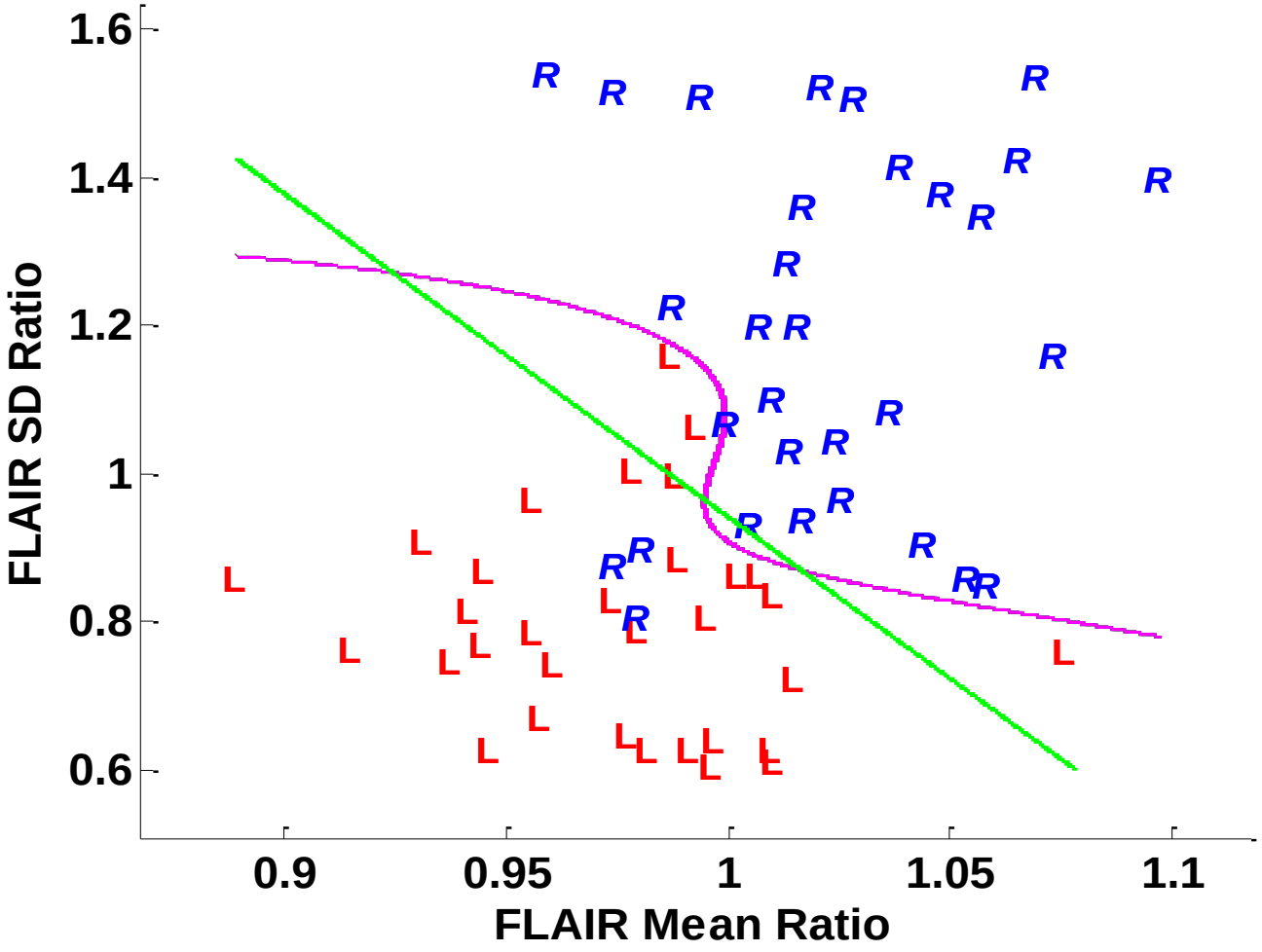
Lateralization of TLE

- Volume of Hippocampus
  - Left vs. Right
  - Lateralization Accuracy < 85%
- Intensity Characteristics of Hippocampus and Other Brain Structures
  - FLAIR
  - SPECT
  - Multi-Modality
  - Multi-Structure

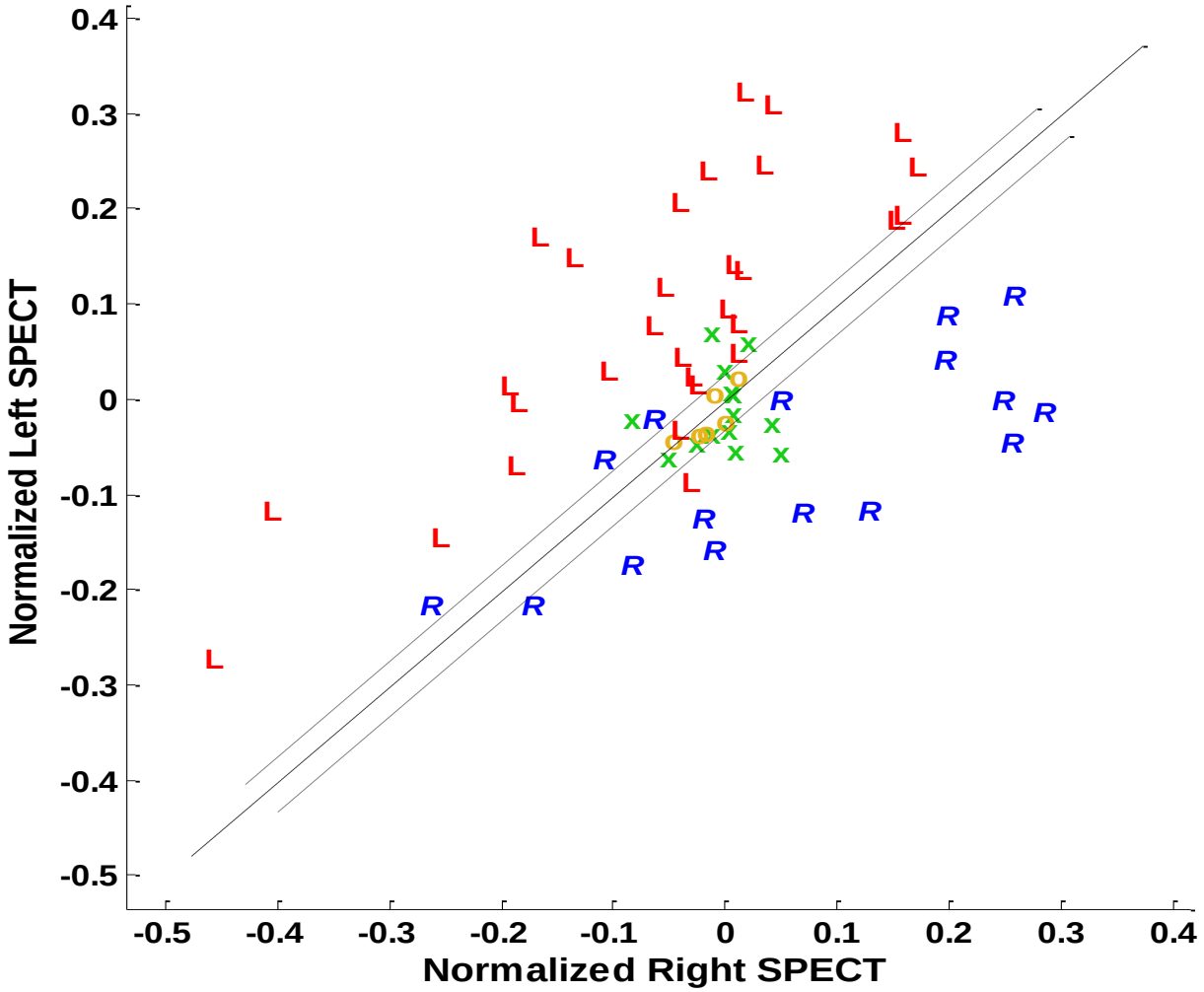
Quantitative Analysis of FLAIR and SPECT using T1 MRI



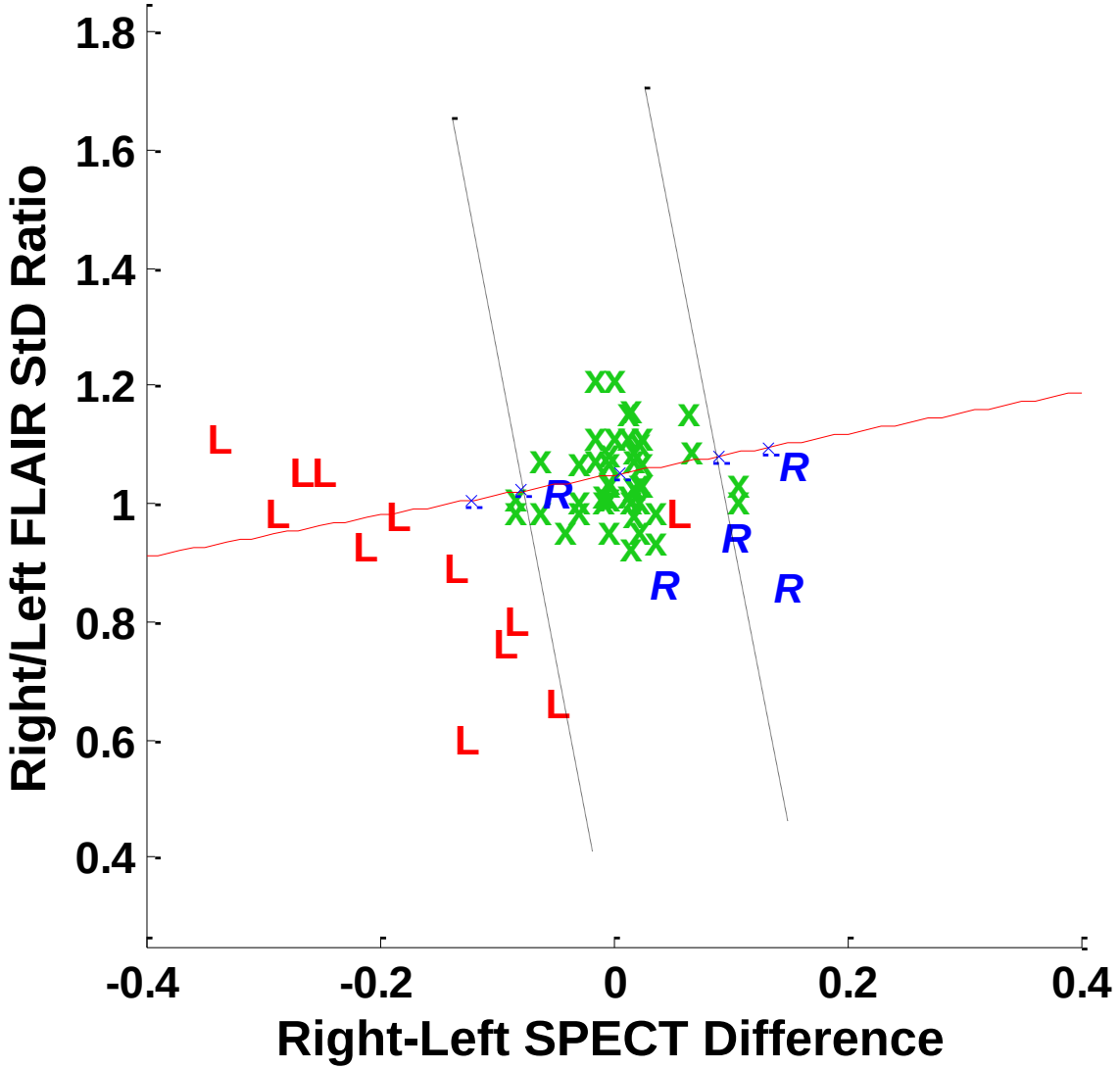
FLAIR Signal in Hippocampus



SPECT Signal in Hippocampus



FLAIR + SPECT


Right/Left FLAIR StD Ratio
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
-0.4
-0.2
0
0.2
0.4
Right-Left SPECT Difference
L
LL
L
L
L
L
L
L
L
L
R
R
R
R
R

FLAIR Signal in Multiple Structures

Table 3. Comparison of lateralization accuracy (LA) of mTLE patients based on the FLAIR features of multiple brain structures (extracted using 2 segmentation methods) and 2 classifiers (linear and nonlinear).

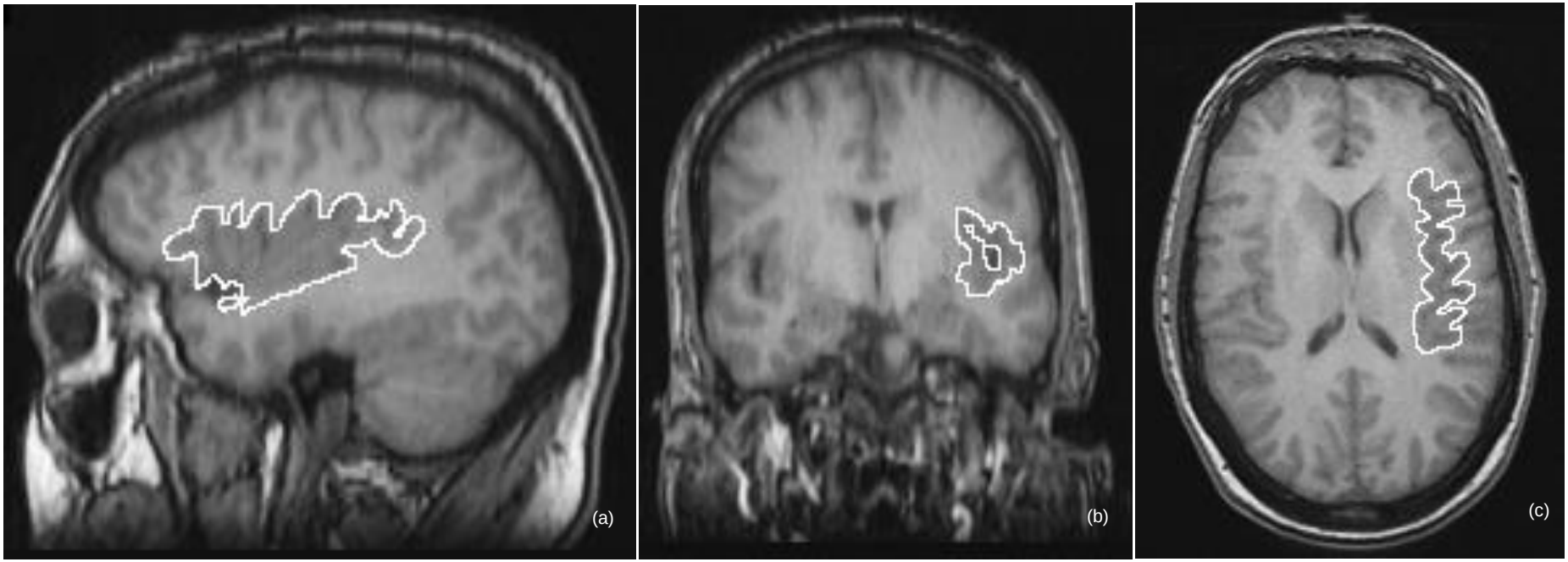
Segmentation Method	HAMMER		FreeSurfer	
Structures / **Classifier**	**Linear**	**Nonlinear**	**Linear**	**Nonlinear**
Hippocampus	76%	87%	87%	89%
Hippocampus, Amygdala	83%	93%	84%	94%
Hippocampus, Amygdala, Entorhinal Cortex	80%	100%		

Outcome Prediction

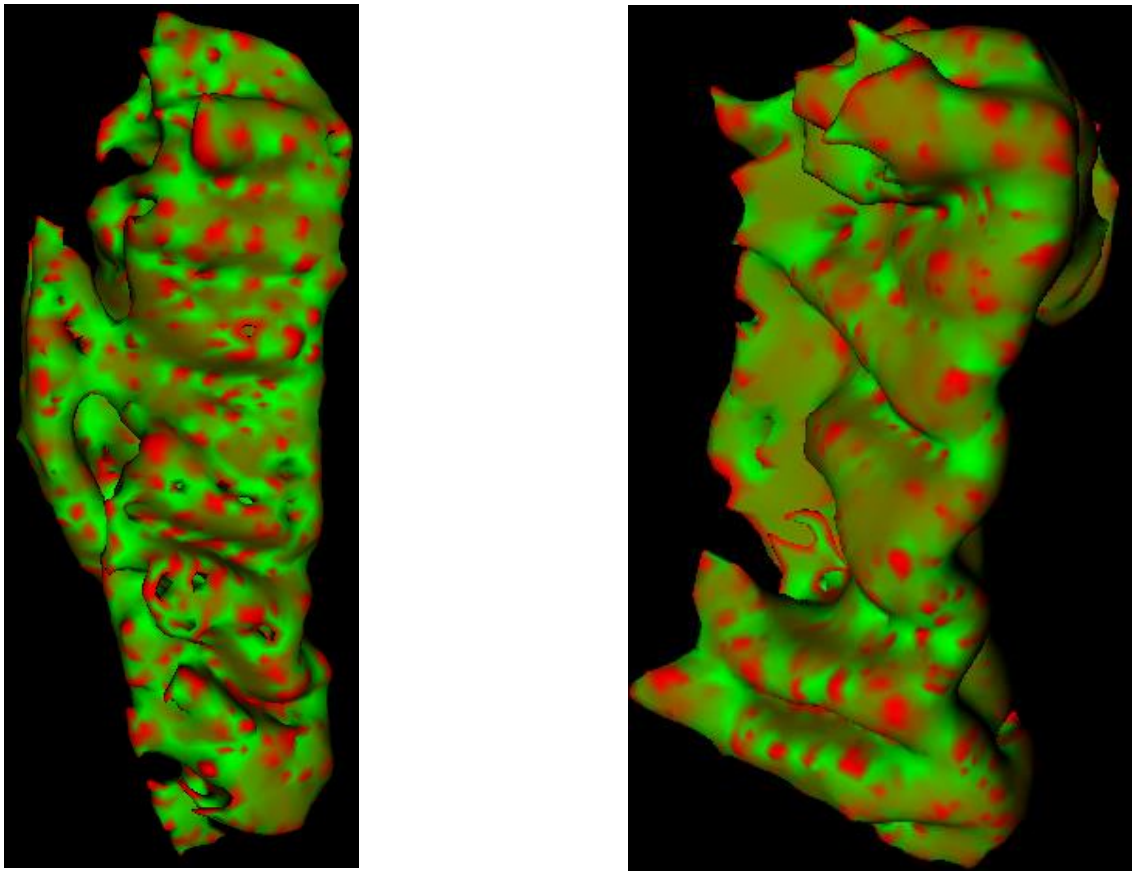
Table 4. The p-values for correlation between the **hippocampal volume asymmetry** and the **surgical outcome** for a variety of two-class classifications of favorable outcome vs. unfavorable outcome.

The two classes defined for classification	Engel Class I (n=78) vs. Non-Class I (n=23)	Engel Class Ia (n=69) vs. Non-Class Ia (n=32)	Engel Classes Ia-Ib (n=73) vs. other Engel Classes (n=28)
p-value	0.003	0.004	0.001

Curvature Analysis of Gray-White Matter Interface in Perisylvian Area

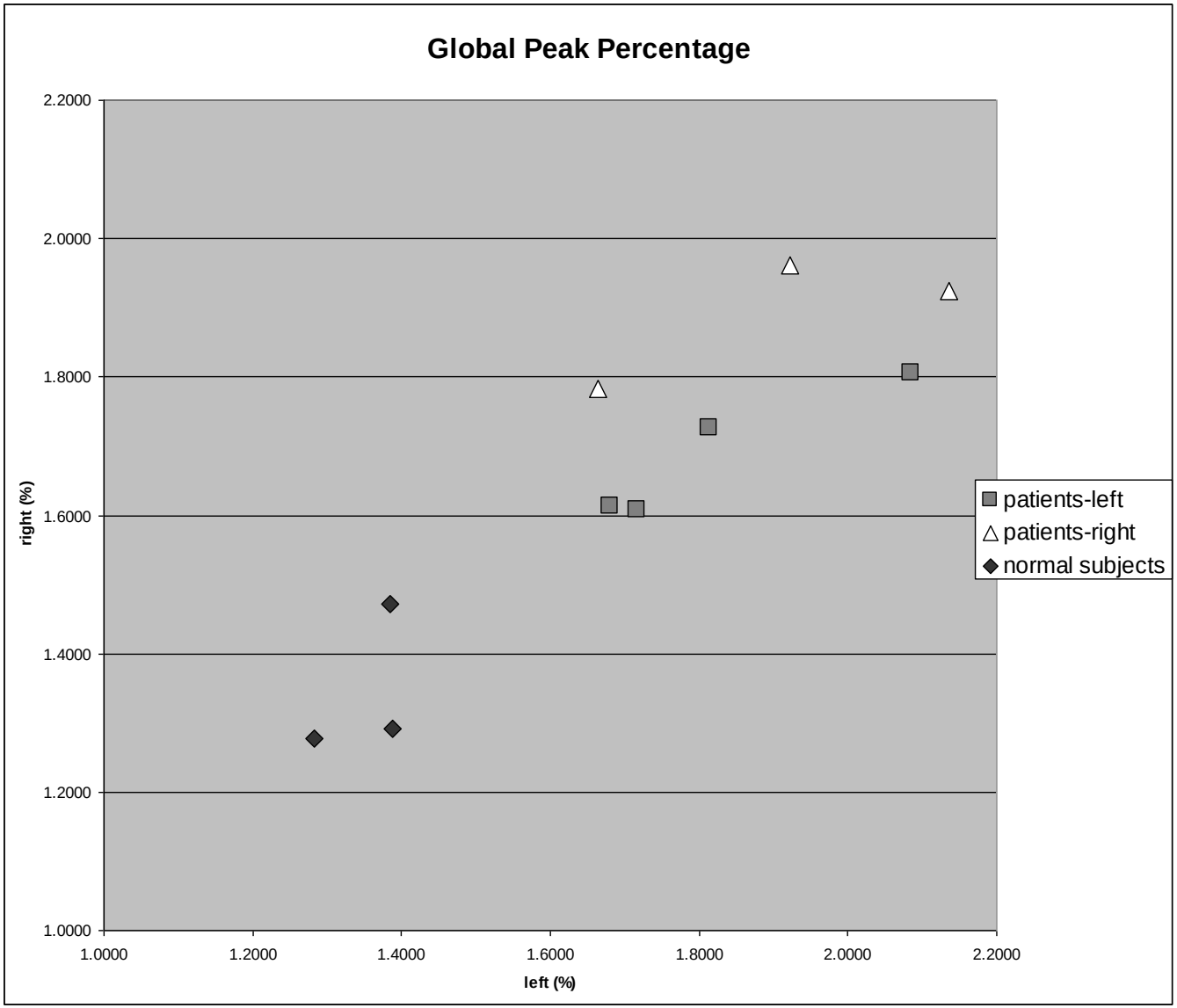


Curvature Measures

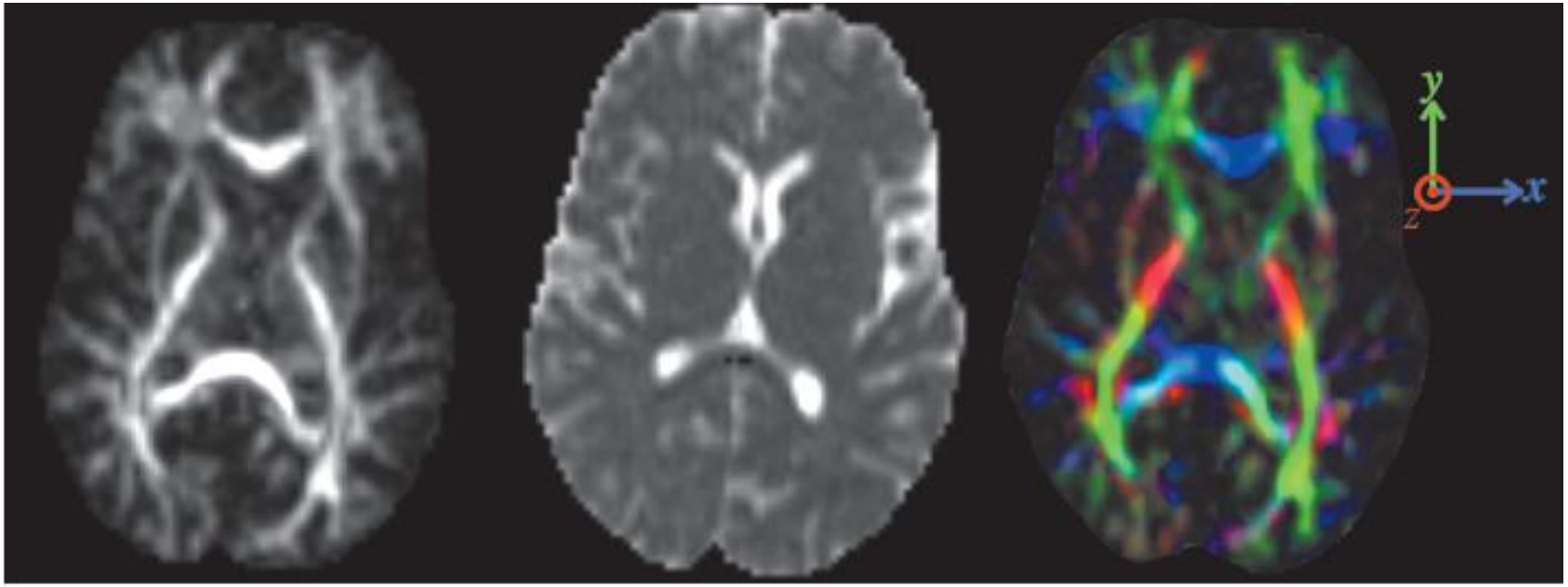


Color-coded surface of the gray-white matter interface of an epileptogenic deep perisylvian area (left) and that of a subject without epilepsy (right).

Peak Percentages for Subjects with and without DPS Epilepsy

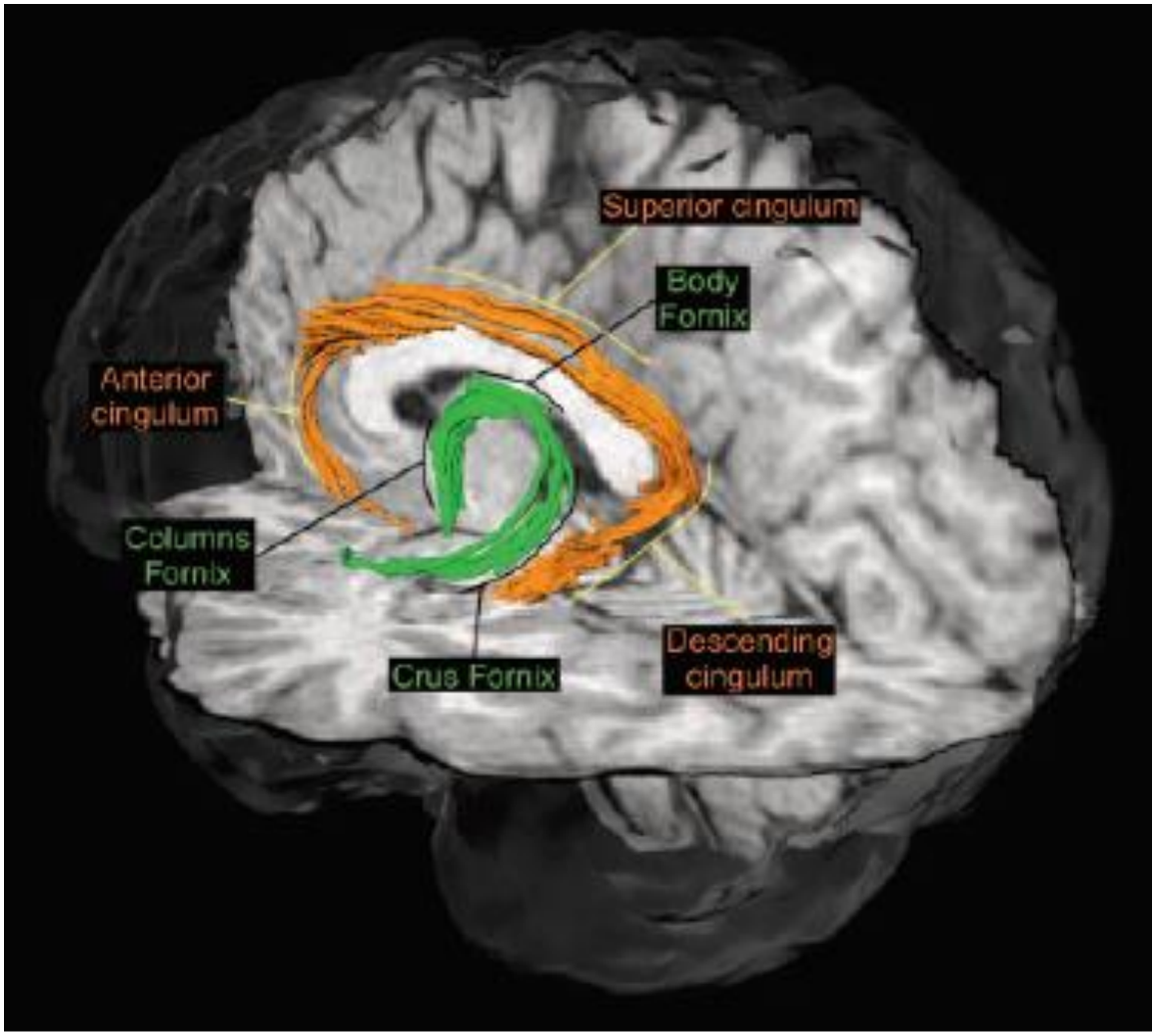


Diffusion Tensor Imaging (DTI)



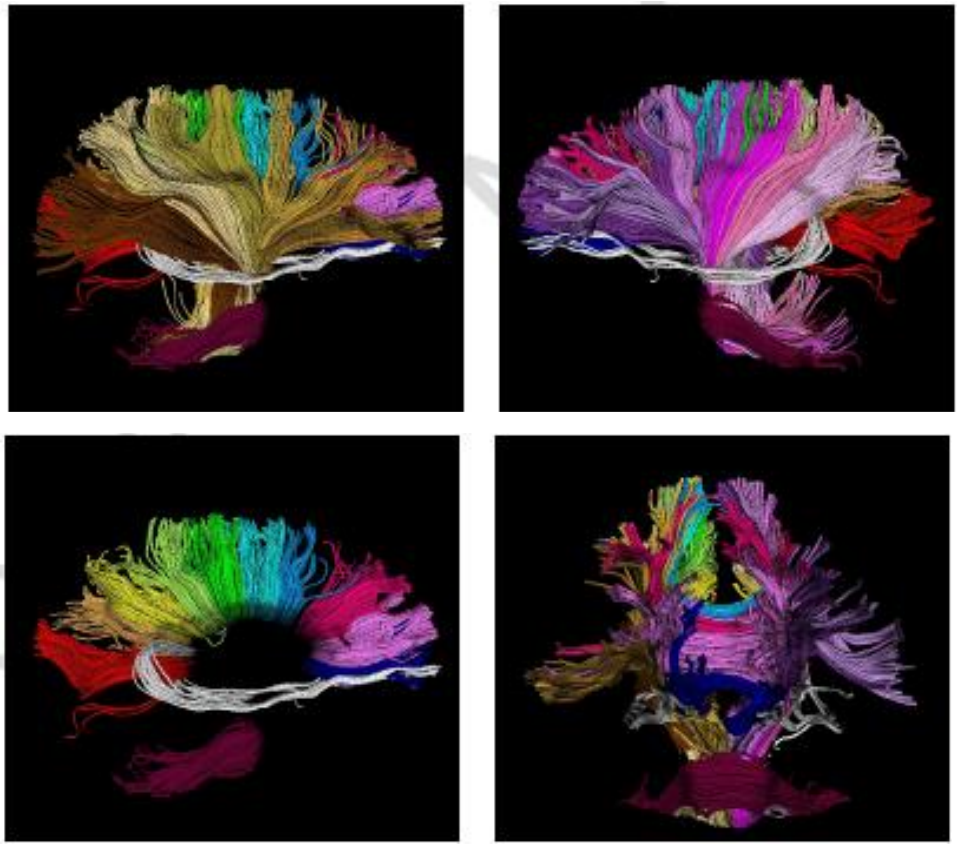
Relative anisotropy (RA), Apparent diffusion Coefficient (ADC), major diffusion vector images.

DTI Tractography



AJNR Am J Neuroradiol 26:2267–2274, October 2005

DTI Tractography

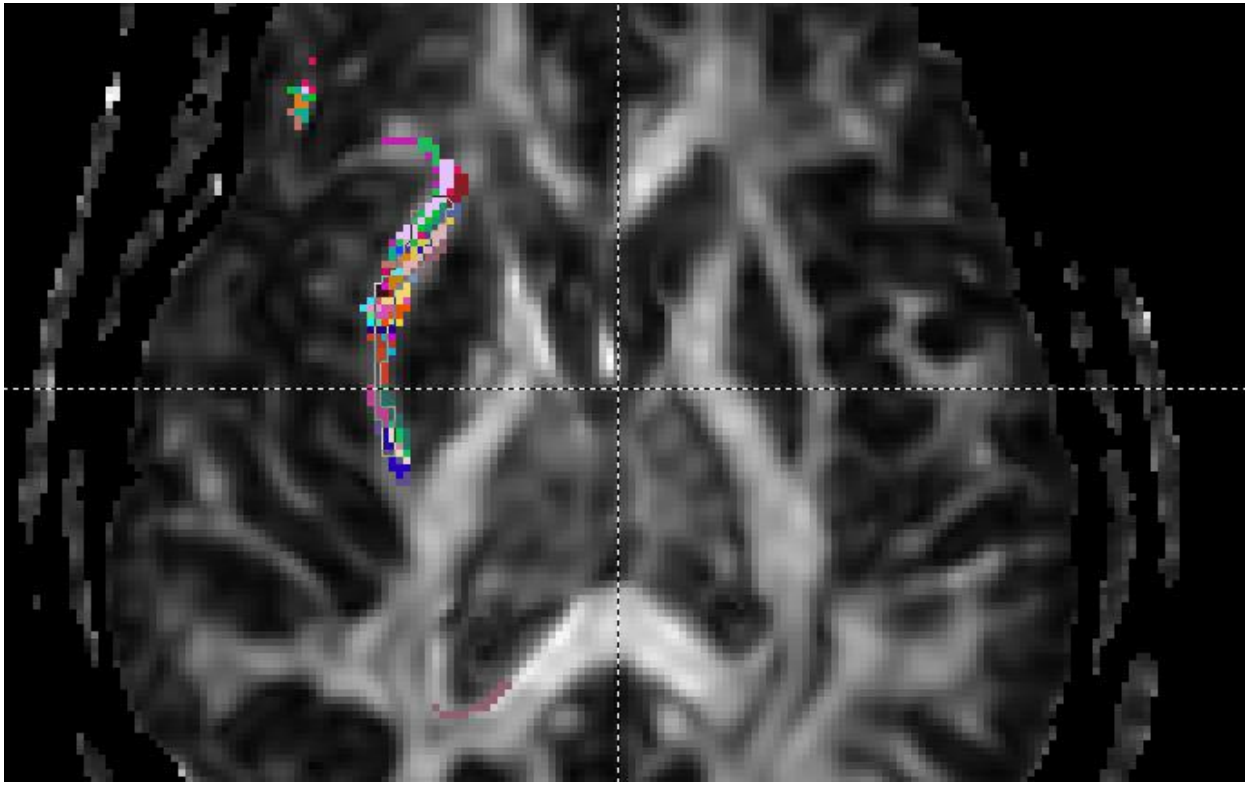


About 3000 fiber trajectories clustered to 25 user-initialized bundles.

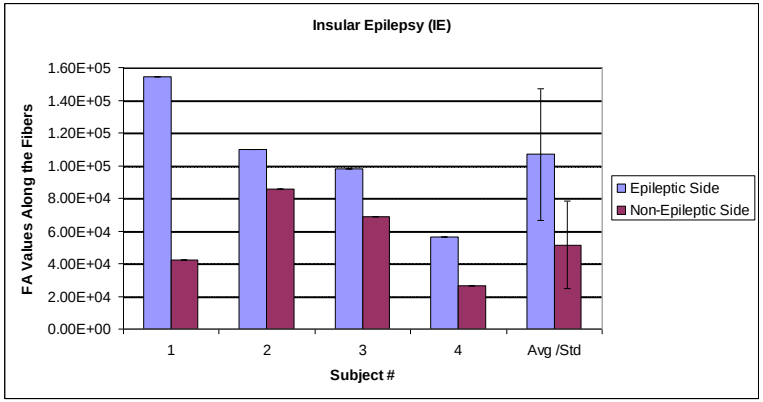
Maddah, et al, Medical Image Analysis, 2007

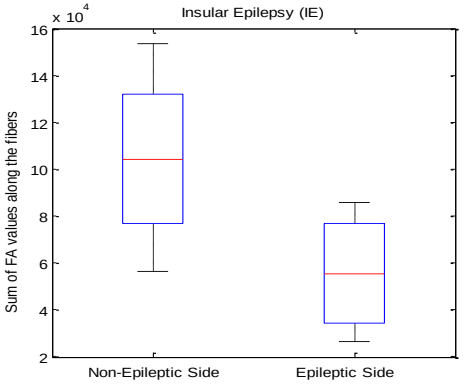
DTI in Perisylvian Epilepsy

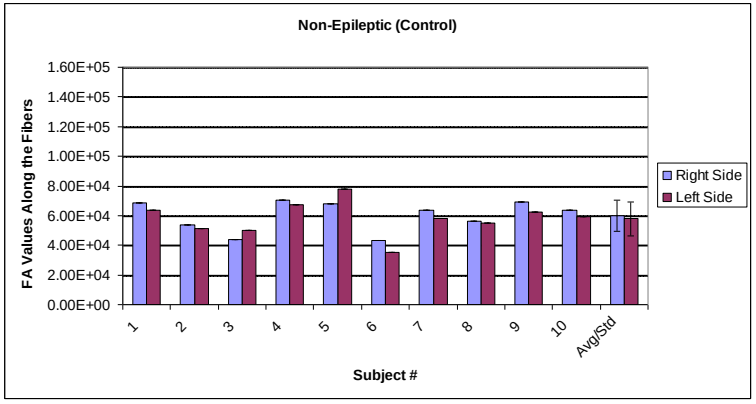
Insula

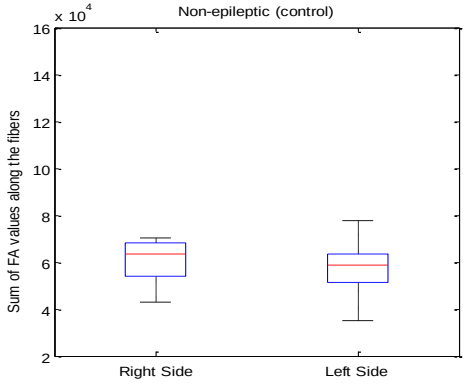


DTI Tractography: Insular Epilepsy vs Control



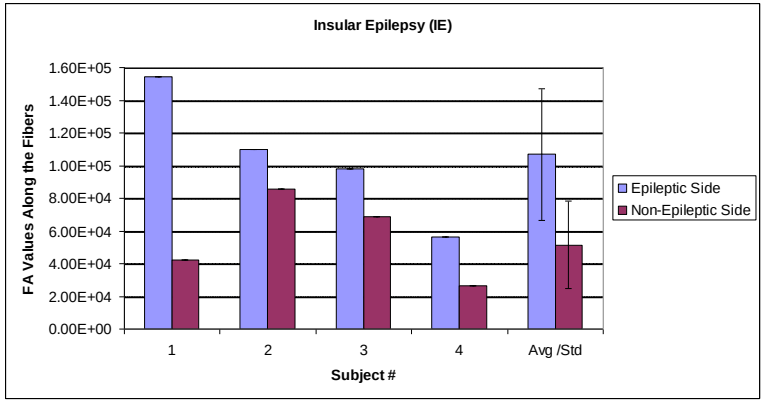


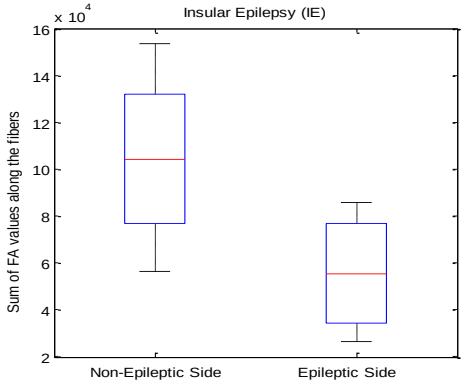


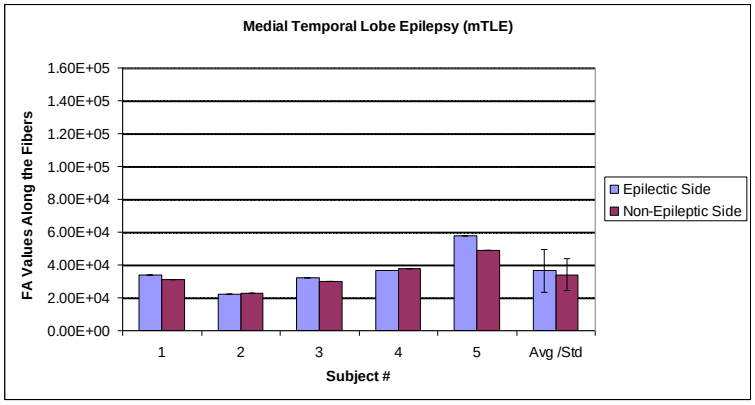


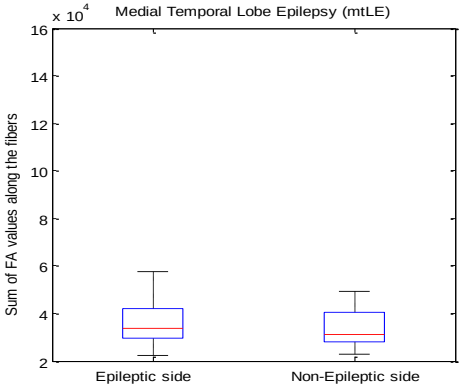
DTI Tractography:

Insular Epilepsy vs. Temporal Lobe Epilepsy

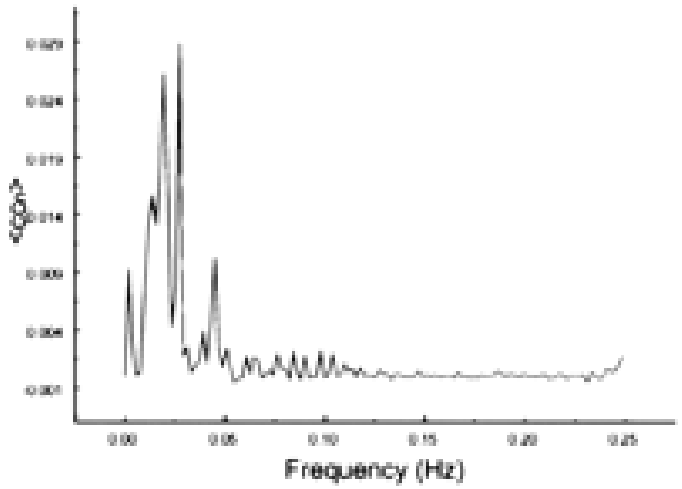




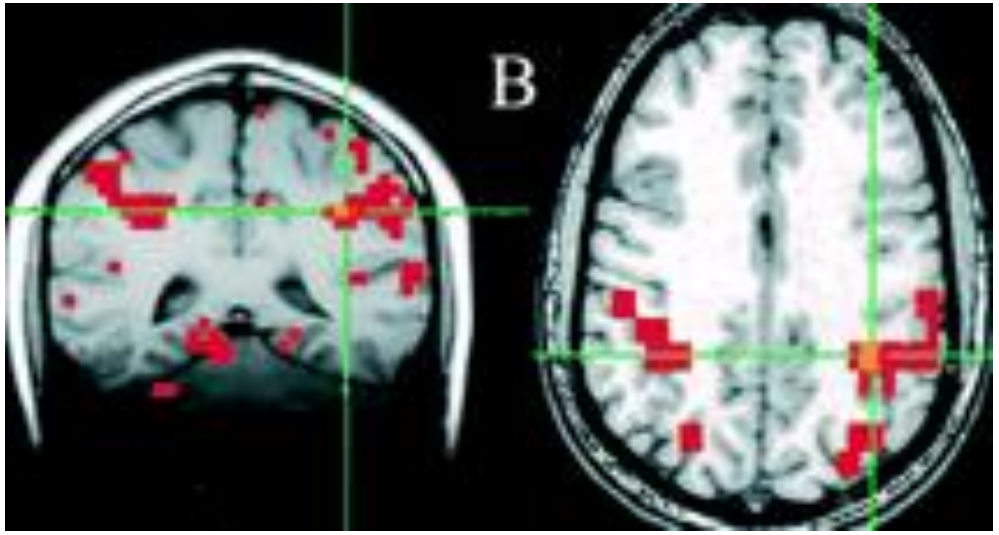




Resting State Low Frequency Fluctuations in fMRI



Resting fMRI time series from cortical regions show strong positive inter-regional correlations subtended by low frequencies.



A “seed voxel” is correlated with all others and thresholded.

Preprocessing of Resting State fMRI

1. Remove the first few (e.g.,10) time points
2. Correct for differences in image acquisition times of slices
3. Correct head motion
4. Normalize to MNI atlas
5. Smooth spatially
6. Remove linear tread
7. Filter frequency range 0.01–0.08 Hz
8. Select top 5% of voxels with largest energy and do the following:
    - Correlation
    - Connectivity
    - Connected component

Resting State fMRI Data

5 control subjects

7 epileptic patients:

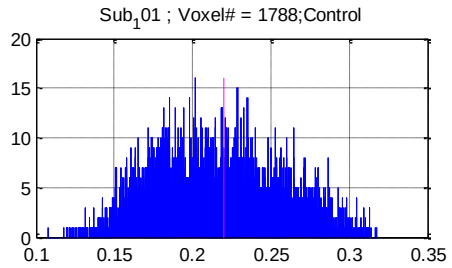
- One patient is seizure-free
- Two patients are not seizure-free
- Four patients are not resected

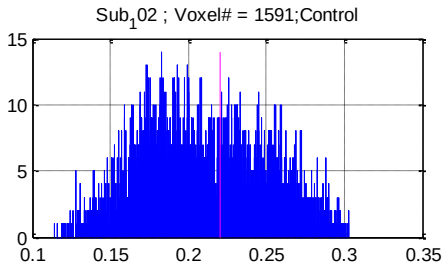
5 minutes rs-fMRI were acquired using an EPI sequence:

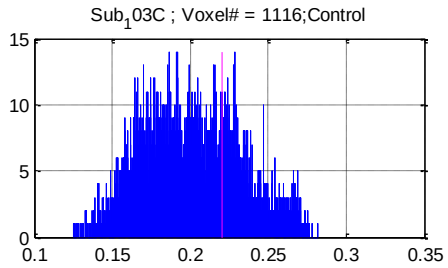
- 34 axial slices, thickness = 3.5 mm
- In-plane resolution = 64 × 64 ; 3.5 mm x 3.5 mm
- TR = 2000 ms, TE = 30 ms, flip angle = 90°

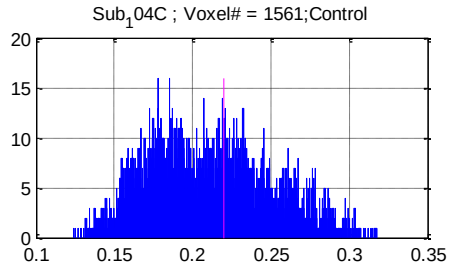
Correlation Analysis

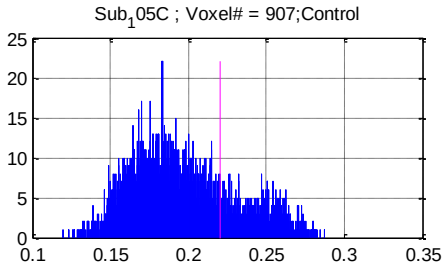
Blue=Control, Cyan=Undetermined, Black=Not Seizure-free, Red=Seizure free

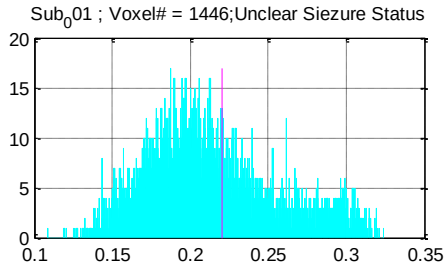


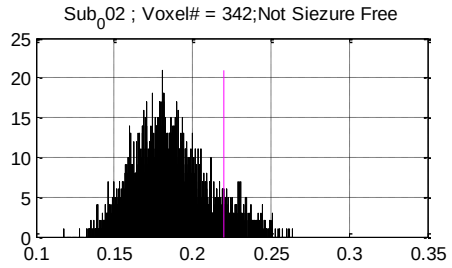


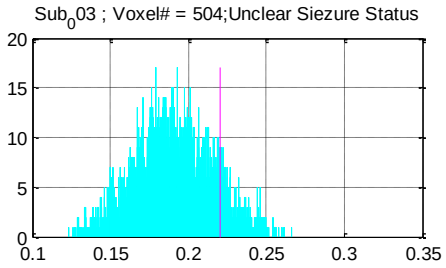


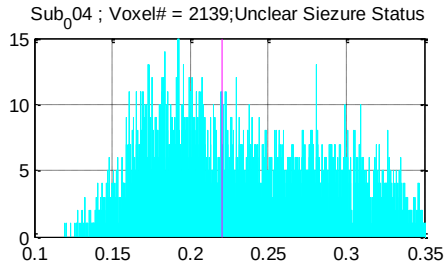


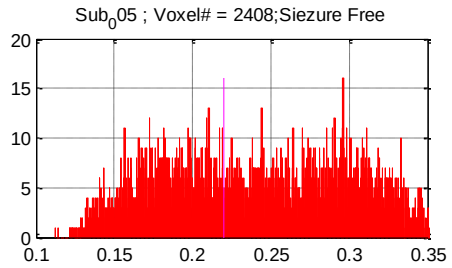


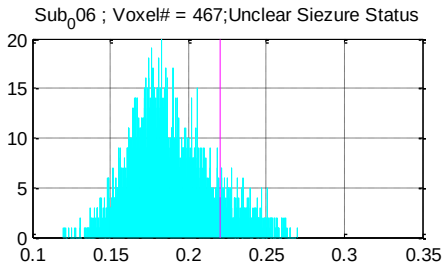


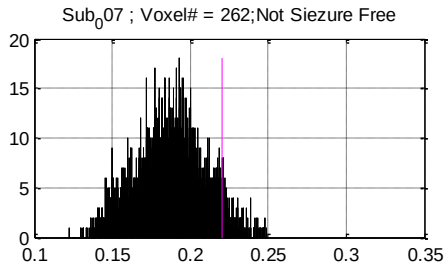






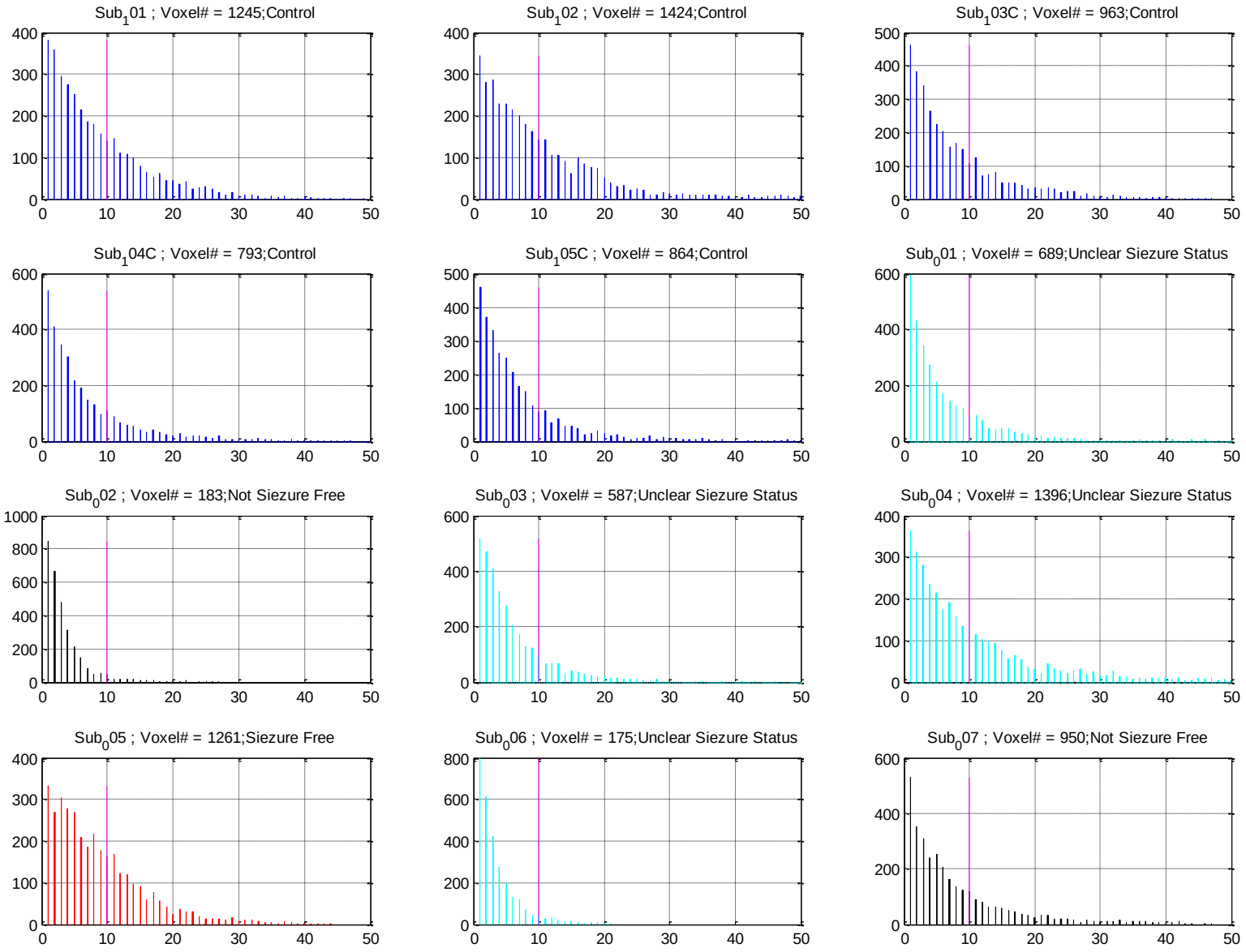




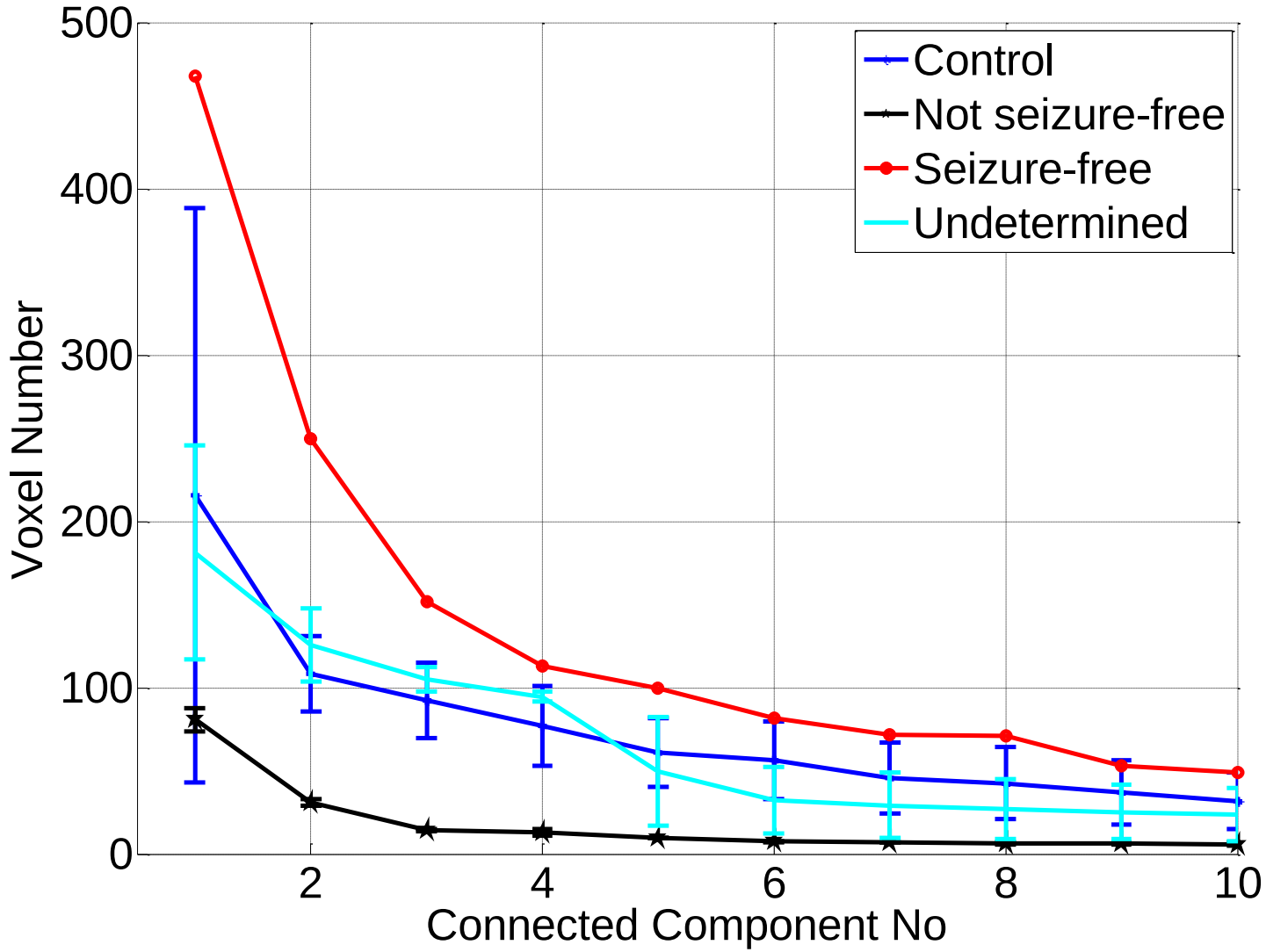


Connectivity Analysis

Blue=Control, Cyan=Undetermined, Black=Not Seizure-free, Red=Seizure free



Connected Component Analysis



Conclusion

- Decision Support Systems are useful in various applications in health and disease.
- 50 million people suffer from epilepsy.
- Epilepsy is a hard to treat disease.
- A DSS may be developed and then used to improve diagnosis, treatment planning, and prognosis of epilepsy.
- Medical image analysis is a fundamental part of an epilepsy DSS.

Conclusion

- Quantitative analysis of medical images allows non-invasive characterization of brain structures.
- Results of quantitative analysis may be used for lateralization of temporal lobe epilepsy.
- They may also provide indications for ideal outcome after surgery.
- Lots of works have been done but not all used for patient care.
- DSS and e-health technology will allow healthcare to benefit from image analysis results.

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- Mr. Payam Bahman-Bijari, UT, Iran
- Mrs. Ladan Amini, UT, Iran
- …….

Thank you!