

# PROBABILISTIC HUMAN BRAIN ATLAS FOR FUNCTIONAL IMAGING: COMPARISON TO SINGLE BRAIN ATLASES

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## Introduction

Quantitative region-based analysis is important in functional imaging. Manual delineation of volumes of interest (VOIs) for the comparisons is often too time intensive to be practical for clinical applications. Applying a predefined brain atlas from a single brain would not be ideal for region-based analysis due to anatomical variability.

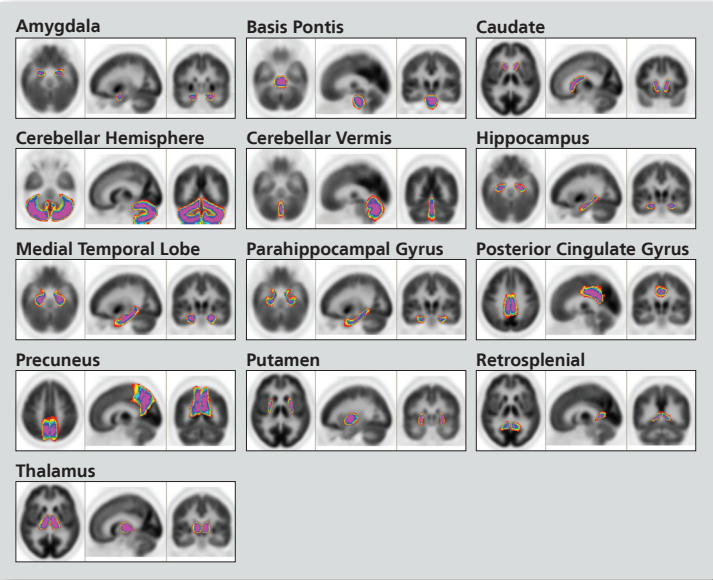
## Objectives

Our goal to help overcome these limitations was to create and validate a probabilistic human brain atlas that would allow for more precise and flexible automated region-based comparisons.

## Methods

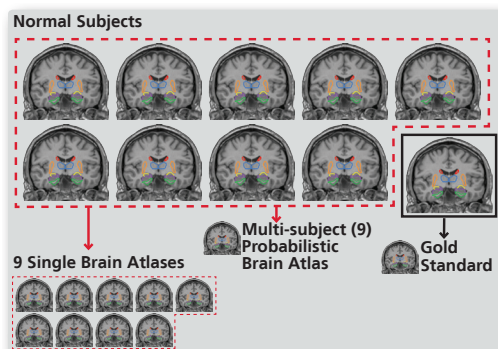
- T1-weighted MRI scans were obtained for 10 subjects. Four subjects also received 11C-DTBZ PET scans and six received FDG-PET scans. Thirteen VOIs were manually defined on each MRI scan as the consensus opinion of three physicians.
- The segmented MRIs were co-registered to the PET scan for each patient. Each PET scan was registered to a template volume using MIMneuro deformable registration (see poster 1694). After registration, the VOIs from each patient were transformed into template space. (see Figure 1)
- A leave-one-out scheme was used for validation (see Figure 2)
  - One subject from the 10 was selected to be used as the gold standard.
  - Comparisons were made to the gold standard for each of the 13 VOIs from the 9 single brain atlases and the multi-subject probabilistic (made from the 9 subjects) brain atlas.
  - Comparisons using the probabilistic brain atlas used each of the levels in the probabilistic atlas.
  - Probabilistic atlas levels ranged from 1/9 (VOI comprised of all of the voxels that at least 1 out of 9 VOIs had in common) to 9/9 (VOI comprised of all voxels that 9 out of 9 VOIs had in common).
  - Sensitivity, specificity and degree of overlap for each atlas VOI were averaged across the 10 leave-one-out validation trials. (see Figure 3)

**Figure 1**  
**Multi-subject Probabilistic Atlas**



Multi-subject probabilistic atlas comprised of all 10 subjects showing each VOI defined. Each color of the 10 step color scale represents a different probabilistic level ranging from 1/10 (red) where the VOI is comprised of all of the voxels that at least 1 out of 10 subjects had in common to 10/10 (purple) where the VOI is made of all of the voxels that 10 out of 10 subjects had in common.

**Figure 2**  
**Leave One Out Scheme**



One subject is used as the gold standard for comparison to each of the remaining nine single brain atlases and the probabilistic atlas comprised of the same nine remaining subjects

**Figure 3**  
**Equations**

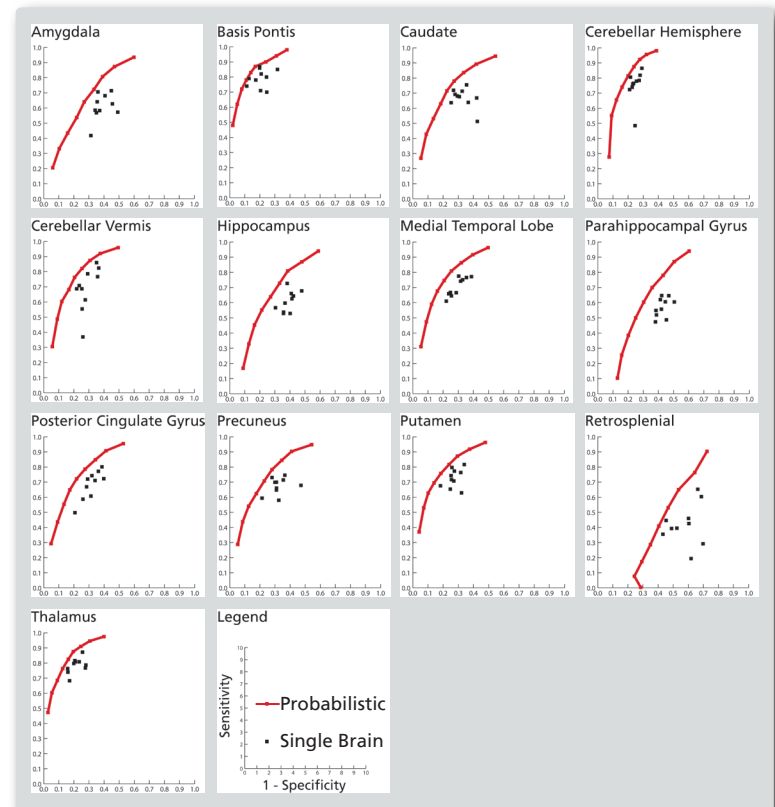
$$\text{Sensitivity} = \frac{A \cap B}{A} \quad \text{Specificity} = \frac{A \cap B}{B} \quad \text{Overlap (Accuracy)} = \frac{A \cap B}{A \cup B}$$

Where A = Voxels in the Gold Standard VOI and B = voxels in the tested VOI

## Results

- The average sensitivity and specificity of Single Brain Atlas VOIs fell under the corresponding average ROC curve for the 10 Probabilistic Brain Atlas VOIs (see Figure 4)
- 3.69 +/- 0.75 levels of the Probabilistic Brain Atlases averaged better sensitivity than the most sensitive Single Brain Atlas VOI.
- 4.69 +/- 0.63 levels of the Probabilistic Brain Atlas averaged better specificity than the most specific Single Brain Atlas VOI.
- 3.31 +/- 0.85 levels of the Probabilistic Brain Atlas had higher overlap metrics than the best Single Brain Atlas VOI.
- If the overall most representative Single Brain Atlas was used rather than the best VOI for each structure then the Probabilistic Brain Atlas shows even greater advantage with better overlap metrics for 5 of the probabilistic atlas levels.

**Figure 4**  
**ROC Curves**



ROC curves for each VOI comparing the average ROC curves from the 10 probabilistic atlases (red) to the 10 single brain atlases (black).

## Conclusions

- The probabilistic atlas is able to obtain more precise results than a single brain atlas by accounting for anatomic variability which can hinder accurate comparisons between subjects.
- By providing adjustable levels within the probabilistic atlas, the user is able to place emphasis on anatomic accuracy, specificity, or sensitivity for quantitative comparisons.
- The probabilistic atlas allows for a robust and customizable solution for automatic region-based analysis.