# Delineating the Superior Temporal Gyrus using Dynamic Programming in Schizophrenia and Bipolar Disorder

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## Introduction

The superior temporal gyrus (STG) has been implicated in neurological disorders that disrupt its normal function in, for example, schizophrenia (SCZ) and bipolar disorder (BPD) [1,2]. However, several neuroimaging and post-mortem studies have discovered conflicting differences in the morphometry of the STG in SCZ and BPD [3,4,5,6]. These differences arise from the consideration that the volume of the gray matter of the STG is considered an entity. The highly folded cortical structure of the STG as well as anatomical definitions of its boundaries may confound quantification of morphometric measures. Dynamic Programming (DP) allows for two critical components of cortical analysis: namely, a 3D representation of the grey-white matter surface and a cortical representation that shows the position, variation, and density of the neocortical cells which are currently viewed as gray matter on MRI [7]. DP has been used to analyze such morphometric properties as volume, surface area, and thickness of the planum temporale [8]. In this study, we use DP to delineate the structure of the STG and to test differences in the STG due to gender, laterality, and diagnosis.

## Labeled Cortical Distance Maps (LCDM)

The flow chart below describes the pipeline for generating LCDMs [8,9]. Following Miller et al. [9], LCDMs are generated, which are histograms of labeled tissue compartments of GM, WM, and cerebrospinal fluid computed as a function of distance from the GM/WM isosurface.

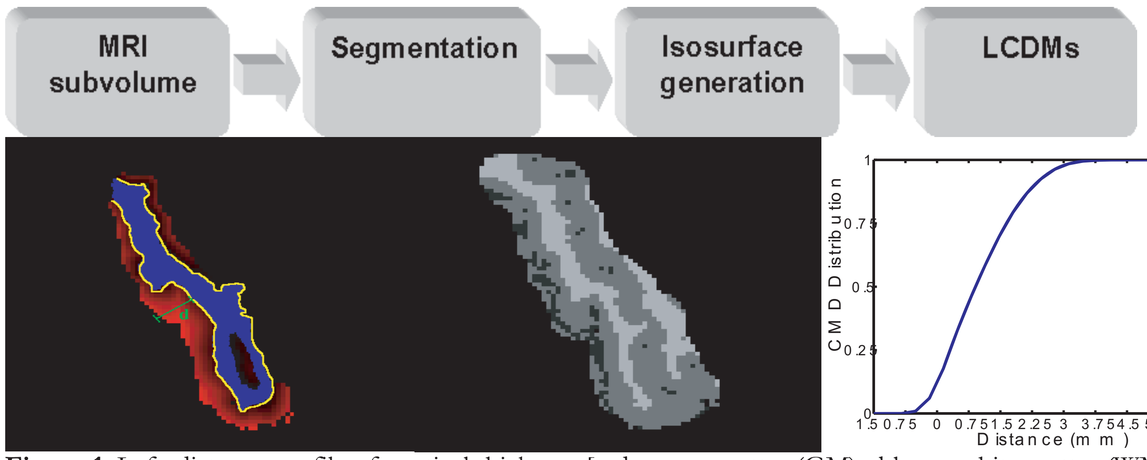


**Figure 1**: Left: distance profile of cortical thickness [red = gray matter (GM) , blue = white matter (WM), yellow = gray/white isosurface, green line = distance of laminar layer]. Middle: segmentation of gray and white matter. Right: corresponding LCDM.

## Methods

MPRAGE scans of 1mm$^3$ resolution from 60 subjects were included in our study, of which 20 were controls (10 males and 10 females, age: 36.5±11.2, mean±SD), 20 were SCZ patients (10 males and 10 females, age: 36.5±7.82), and 20 were BPD patients (10 males and 10 females, age: 40±9.43) were selected.

DP delineation of the STG was initiated with several landmarks. The posterior landmark of the STG boundary begins at the intersection of the angular gyrus (AG) and the STG at the most posterior extent of the lateral fissure (LF) [Figs. 2B, C; Figs. 3B, D]. The anterior landmark of the STG boundary is located at the superior portion of the temporal pole at the ascending ramus of the LF [Figs. 2B, C; Fig. 3A]. The inferior extent of the STG boundary follows from the posterior landmark along the superior temporal sulcus (STS) all the way to the anterior landmark [Fig. 2B; Fig. 3B, D]. The superior extent of the STG boundary follows from the anterior landmark along the LF to the posterior landmark [Fig. 2B; Fig. 3A, C].

Surface area (SA) was determined from the triangulated manifold while volume (V) and cortical thickness (T) were respectively derived from the total number of voxels and the 95th percentile distance from the LCDM histogram respectively. To account for the large size of the STG, thickness and volume data were retrieved at censored distances of 4 mm, 4.5 mm, 5 mm, 5.5 mm, 6 mm.

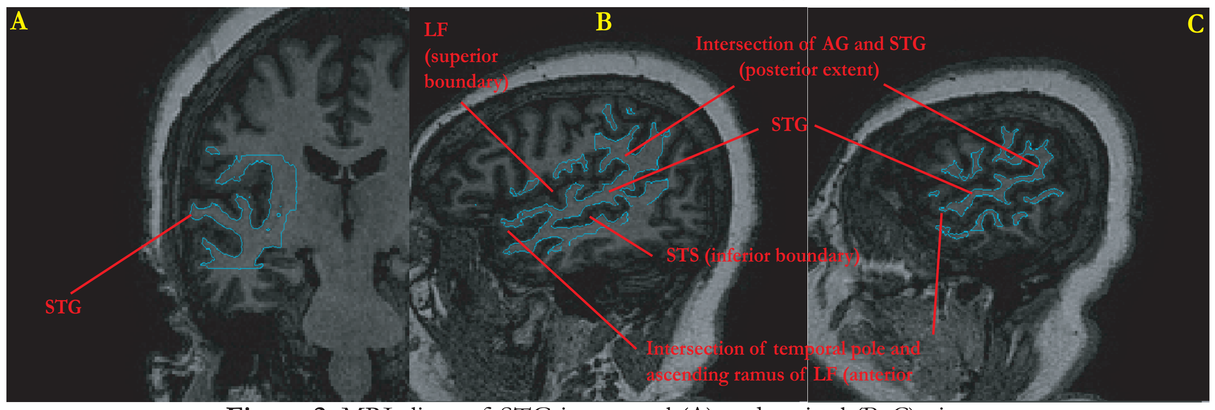


**Figure 2:** MRI slices of STG in coronal (A) and sagittal (B, C) views.

**References**:

[1] Kasai, K., Shenton, M.E. et al. Progressive decrease of left superior temporal gyrus gray matter volume in patients with first-episode schizophrenia. Arch Gen Psychiatry, 60(8), 766-775, 2003.

[2] Frazier, J.A., Breeze, J.L. et al. Cortical gray matter differences identified by structural magnetic resonance imaging in pediatric bipolar disorder. Bipolar Disord, 7(6), 555-569, 2005.

[3] Hirayasu, Y., McCarley, R.W. et al. Planum temporale and Heschl gyrus volume reduction in schizophrenia: a magnetic resonance imaging study of first-episode patients. Arch Gen Psychiatry, 57(7), 692-699, 2000.

[4] Kasai, K., Shenton, M.E. et al. Progressive decrease of left superior temporal gyrus gray matter volume in patients with first-episode schizophrenia. Am J Psychiatry, 160(1), 156-164, 2003.

[5] Bruno, S.D., Papadopoulou, K. et al. Structural brain correlates of IQ changes in bipolar disorder. Psychol Med, 36(5), 609-618, 2006.

[6] Nugent, A.C., Milham, M.P. et al. Cortical abnormalities in bipolar disorder investigated with MRI and voxel-based morphometry. Neuroimage, 30(2), 485-497, 2006.

[7] Khaneja, N., Miller, M.I. et al. Dynamic Programming generation of curves on brain surfaces. IEEE Trans Pattern Anal Mach Intell, 20(11), 1260-1265, 1998.

[8] Ratnanather, J.T., Honeycutt, N.A. et al. Dynamic Programming generation of boundaries of local coordinatize submanifolds in the neocortex: application to the Planum Temporale. NeuroImage, 20, 359-377, 2003.

[9] Miller, M.I., Hosakere, M. et al. Labelled Cortical Mantle Distance Maps in the Cingulate Quantify Differences Between Dementia of the Alzheimer Type and Healthy Aging. Proc. Nat. Acad. Sci. 100:15172-7, 2003.

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## Results

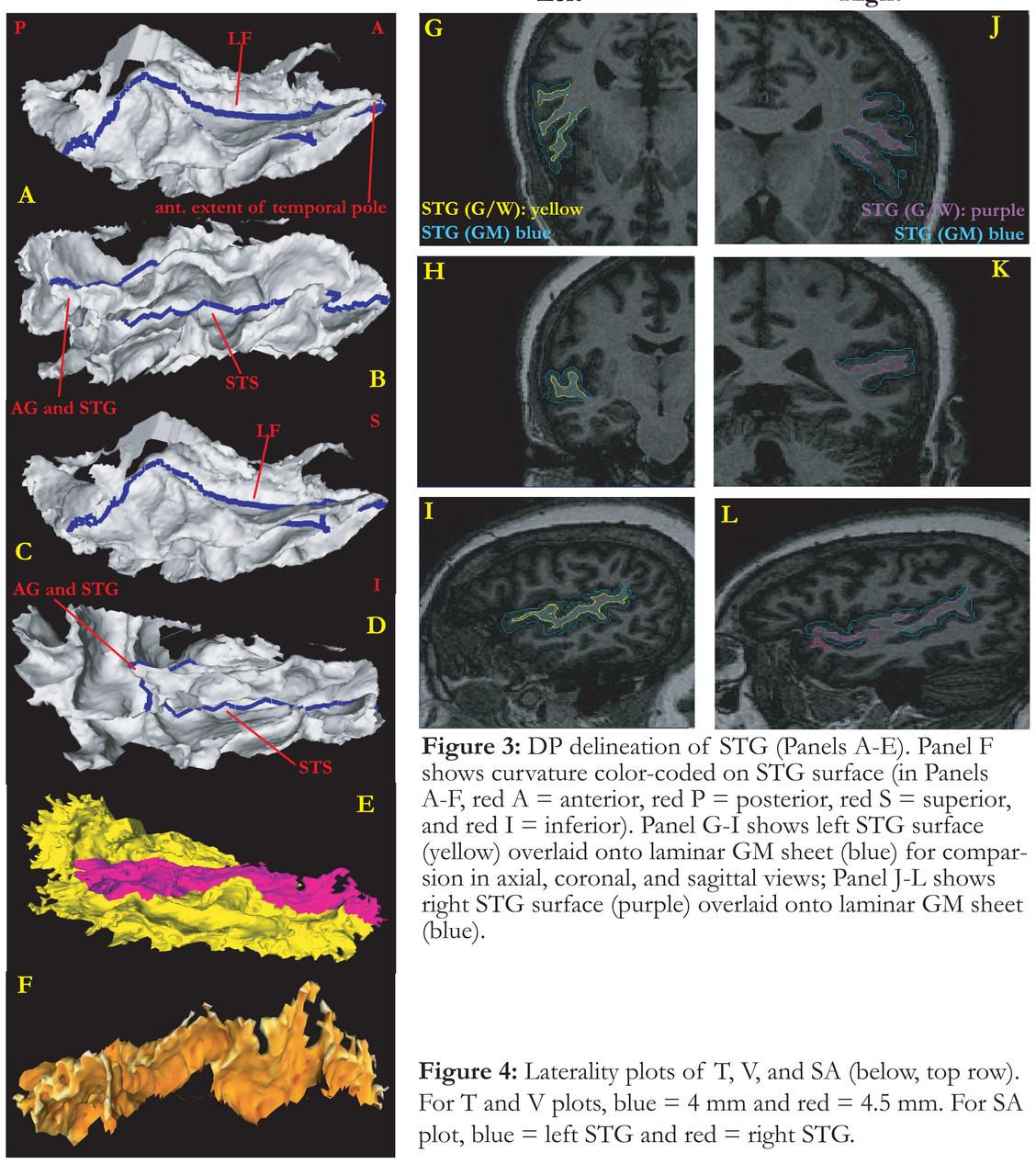


**Figure 3:** DP delineation of STG (Panels A-E). Panel F shows curvature color-coded on STG surface (in Panels A-F, red A = anterior, red P = posterior, red S = superior, and red I = inferior). Panel G-I shows left STG surface (yellow) overlaid onto laminar GM sheet (blue) for comparsion in axial, coronal, and sagittal views; Panel J-L shows right STG surface (purple) overlaid onto laminar GM sheet (blue).

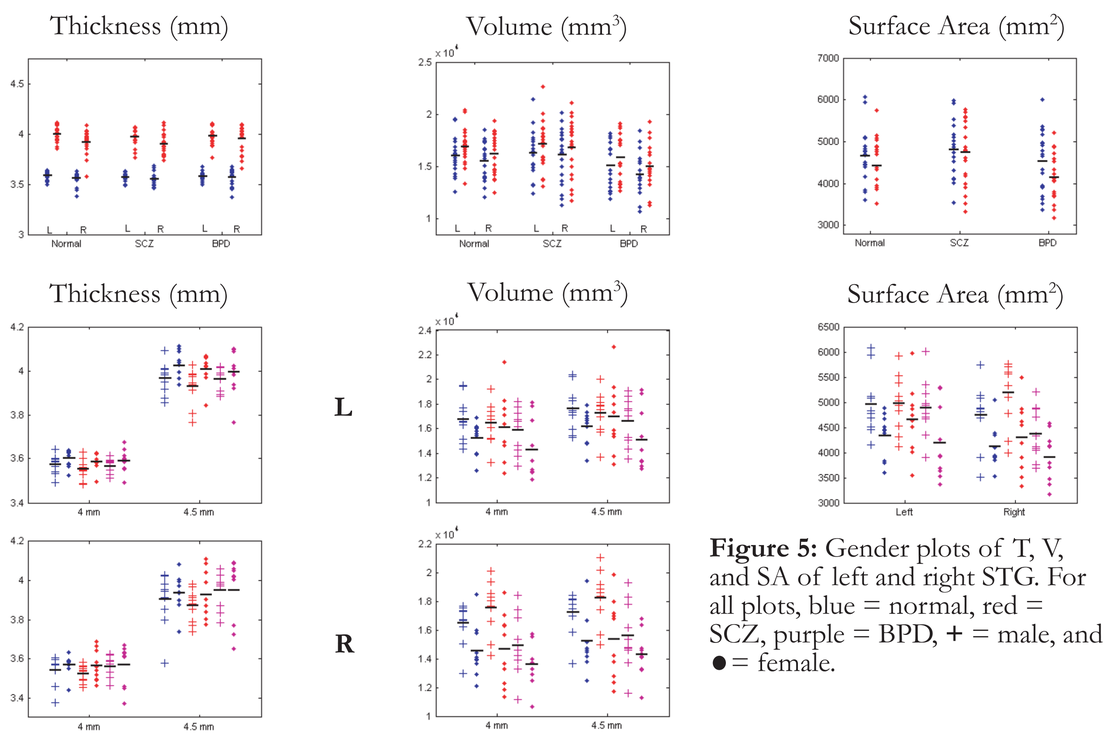


**Figure 4:** Laterality plots of T, V, and SA (below, top row). For T and V plots, blue = 4 mm and red = 4.5 mm. For SA plot, blue = left STG and red = right STG.

**Figure 5:** Gender plots of T, V, and SA of left and right STG. For all plots, blue = normal, red = SCZ, purple = BPD, + = male, and ● = female.

Thickness

| | | | | | |
|---|---|---|---|---|---|
| **Gender** | $p < 0.05$ | $p < 0.05$ | $p = 0.06$ | $p = 0.0862$ | $p = 0.1486$ |
| **Laterality** | $p < 0.005$ | $p < 0.0001$ | $p < 0.0005$ | $p < 0.001$ | $p < 0.0121$ |
| **Diagnosis** | $p = 0.559$ | $p = 0.558$ | $p = 0.4958$ | $p = 0.4472$ | $p = 0.5234$ |

Volume

| | | | | | |
|---|---|---|---|---|---|
| **Gender** | $p < 0.0005$ | $p < 0.001$ | $p < 0.001$ | $p < 0.005$ | $p < 0.005$ |
| **Laterality** | $p < 0.05$ | $p < 0.05$ | $p < 0.05$ | $p < 0.05$ | $p < 0.01$ |
| **Diagnosis** | $p < 0.01$ | $p < 0.01$ | $p < 0.05$ | $p < 0.05$ | $p < 0.05$ |

Surface Area

| | |
|---|---|
| **Gender** | $p < 0.0001$ |
| **Laterality** | $p < 0.001$ |
| **Diagnosis** | $p < 0.05$ |

**Table:** p-values of gender, laterality, and diagnosis.

## Discussion

-data was most sensitive at 4 and 4.5 mm (i.e. more voxels is less significant)
-between subjects, laterality, gender, and diagnosis play a significant role in SA of STG; diagnosis and gender play a role in V of STG; and gender has a marginally significant difference in T
-within subjects, laterality is significantly different for SA, V, and T
-SCZ has larger V than normals, and BPD has smaller V than normals
-SCZ has larger SA than normals, and BPD has smaller SA than normals
-left STG is always larger than right STG; females have thicker STG than males
-LCDM and laminar approximation (LA) are closely similar as validated by surface overlays in Figure 3; future progress will compare both LCDM and LA and validate LCDM

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