



MRC Cognition
and Brain
Sciences Unit



UNIVERSITY OF
CAMBRIDGE

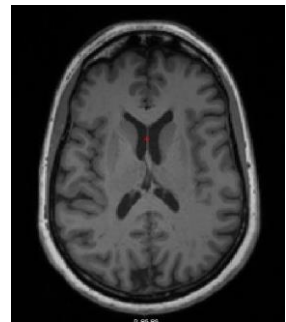
Cortical Thickness analysis using FreeSurfer

Marta M. Correia

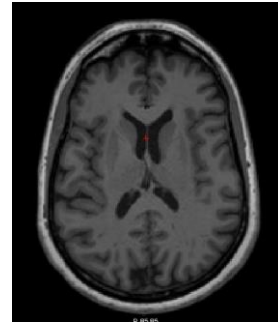
MRC Cognition and Brain Sciences Unit

Overview of FreeSurfer output

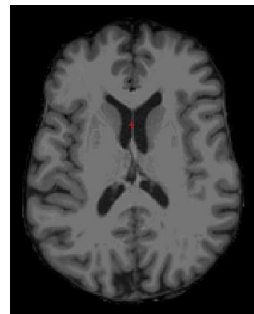
- Fully automated: `recon-all -i file.dcm -subject subj001 -all`



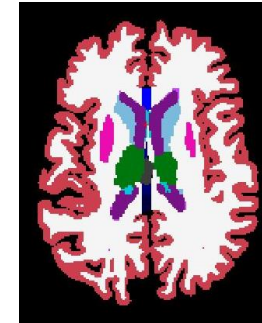
T1 Weighted
Input



Intensity Bias
correction



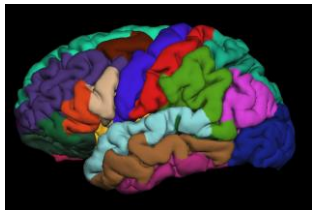
Skull Stripping



Volumetric Labeling



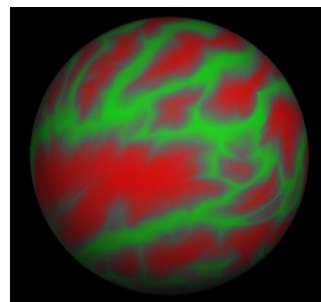
White Matter
Segmentation



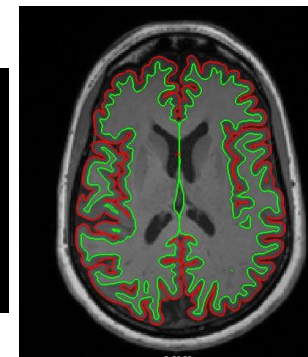
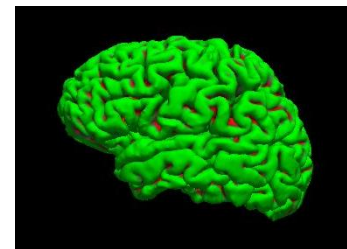
MRC Cognition and Brain Sciences Unit



Gyral Labeling



Surface Atlas
Registration

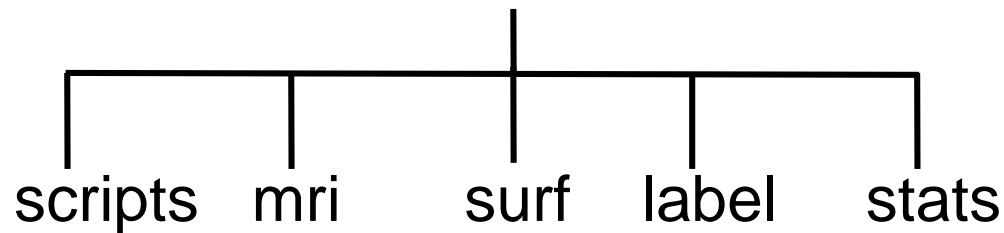


Surface Extraction

Overview of FreeSurfer output

- Fully automated: recon-all -i file.dcm -subject subj001 -all

\$SUBJECTS_DIR/subj001

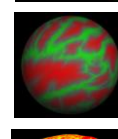
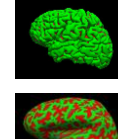
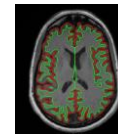
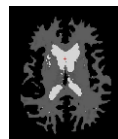
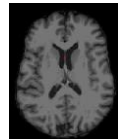
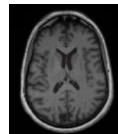


```

Thu Aug 11 11:14:17 BST 2022
/imaging/correia/users/mc04/COGNESTIC/CorticalThickness/LiveDemo/FS_SUBJECTS_DIR/CBU130685
/imaging/local/software/freesurfer/6.0.0/x86_64/bin/recon-all
-i CBU130685/1.3.12.2.1107.5.2.32.35119.2013072015333799476362342.dcm -subject CBU130685 -all
subjId CBU130685
setenv SUBJECTS_DIR /imaging/correia/users/mc04/COGNESTIC/CorticalThickness/LiveDemo/FS_SUBJECTS_DIR
FREESURFER_HOME /imaging/local/software/freesurfer/6.0.0/x86_64
Actual FREESURFER_HOME /imaging/local/software/freesurfer/6.0.0/x86_64
build-stamp.txt: freesurfer-linux-centos6_x86_64-stable-pub-v6.0.0-2beb96c
Linux login-j04 3.10.0-1160.el7.x86_64 #1 SMP Mon Oct 19 16:18:59 UTC 2020 x86_64 x86_64 x86_64 GNU/Linux
cputime unlimited
filesize unlimited
datasize unlimited
stacksize 8192 kbytes
coredumpsize 0 kbytes
memoryuse unlimited
vmemoryuse unlimited
descriptors 1024
memorylocked 64 kbytes
maxproc 4096
maxlocks unlimited
maxsignal 1029366
maxmessage 819200
maxnice 0
maxrtprio 0
maxrttime unlimited

          total      used      free      shared  buff/cache   available
Mem:    263627716  148613912  65447392  10677352  49566412   103452264
Swap:   268435452   52460308   215975144

#####
program versions used
$Id: recon-all,v 1.580.2.16 2017/01/18 14:11:24 zkaufman Exp $
$Id: mri_motion_correct.fsl,v 1.15 2016/02/16 17:17:20 zkaufman Exp $
  
```



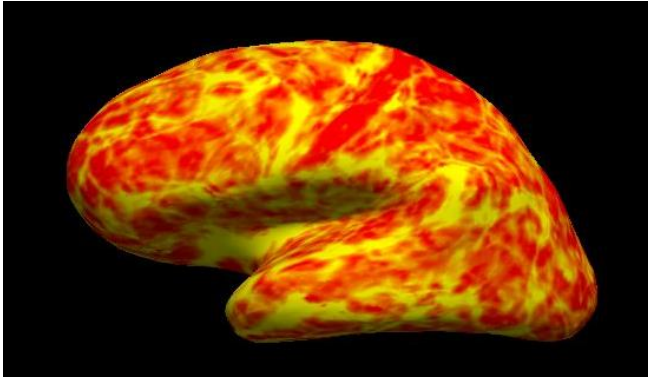
```

# Table of FreeSurfer cortical parcellation anatomical statistics
#
# CreationTime 2017/01/20-02:14:03-GMT
# generating_program mris_anatomical_stats
# cvs_version $Id: mris_anatomical_stats.c,v 1.79 2016/03/14 15:15:34 greve Exp $
# mrisurf.c-cvs_version $Id: mrisurf.c,v 1.781.2.6 2016/12/27 16:47:14 zkaufman Exp $
# cmdline mris_anatomical_stats -th3 -mgz -cortex ../Label/Lh.cortex.label -f ../stats/Lh.aparc.stats -b -a ../Label/Lh.aparc.annot -
c ../Label/aparc.annot.ctab 004 lh white
# syname Linux
# hostname compute-0-39
# machine x86_64
# user zkaufman
#
# SUBJECTS_DIR /autofs/cluster/freesurfer/subjects/test/buckner_data/stable6
# anatomy_type surface
# subjectname 004
# hemi lh
# AnnotationFile ../Label/Lh.aparc.annot
# AnnotationFileTimeStamp 2017/01/19 20:15:12
# Measure Cortex, NumVert, Number of Vertices, 143669, unitless
# Measure Cortex, WhiteSurfArea, White Surface Total Area, 97596.1, mm^2
# Measure Cortex, MeanThickness, Mean Thickness, 2.34308, mm
# Measure BrainSeg, BrainSegVol, Brain Segmentation Volume, 1262276.000000, mm^3
# Measure BrainSegNotVent, BrainSegVolNotVent, Brain Segmentation Volume Without Ventricles, 1187271.000000, mm^3
# Measure BrainSegNotVentSurf, BrainSegVolNotVentSurf, Brain Segmentation Volume Without Ventricles from Surf, 1186951.705907, mm^3
# Measure Cortex, CortexVol Total cortical gray matter volume, 517934.617407, mm^3
# Measure Supratentorial, SupratentorialVol, Supratentorial volume, 1131346.705907, mm^3
# Measure SupratentorialNotVent, SupratentorialVolNotVent, Supratentorial volume, 1062303.705907, mm^3
# Measure EstimatedTotalIntraCranialVol, eTIV, Estimated Total Intracranial Volume, 1798722.304401, mm^3
# NtableCols 10
# TableCol 1 ColHeader StructName
# TableCol 1 FieldName Structure Name
# TableCol 1 Units NA
# TableCol 2 ColHeader NumVert
# TableCol 2 FieldName Number of Vertices
  
```

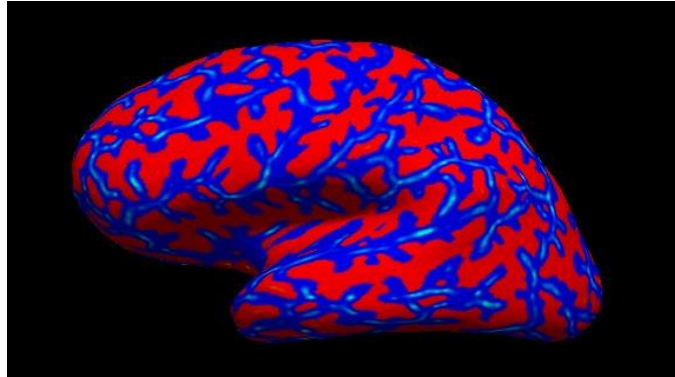
Group analysis in FreeSurfer

- Create the design matrix: set up FSGD file
- Select the metric to be analyzed: thickness, curvature, area, volume

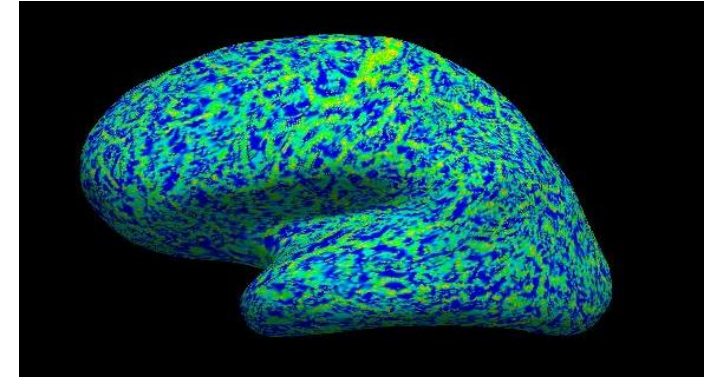
thickness



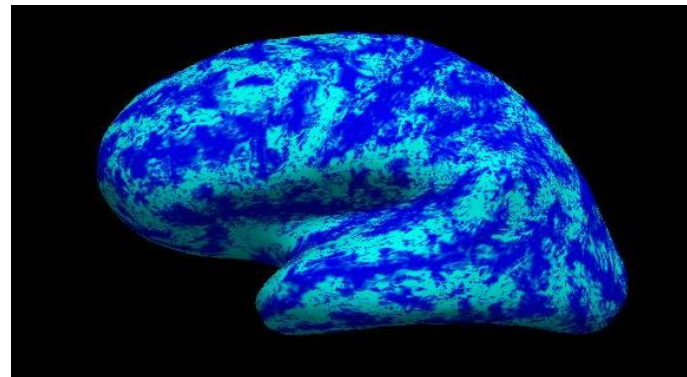
curvature



area

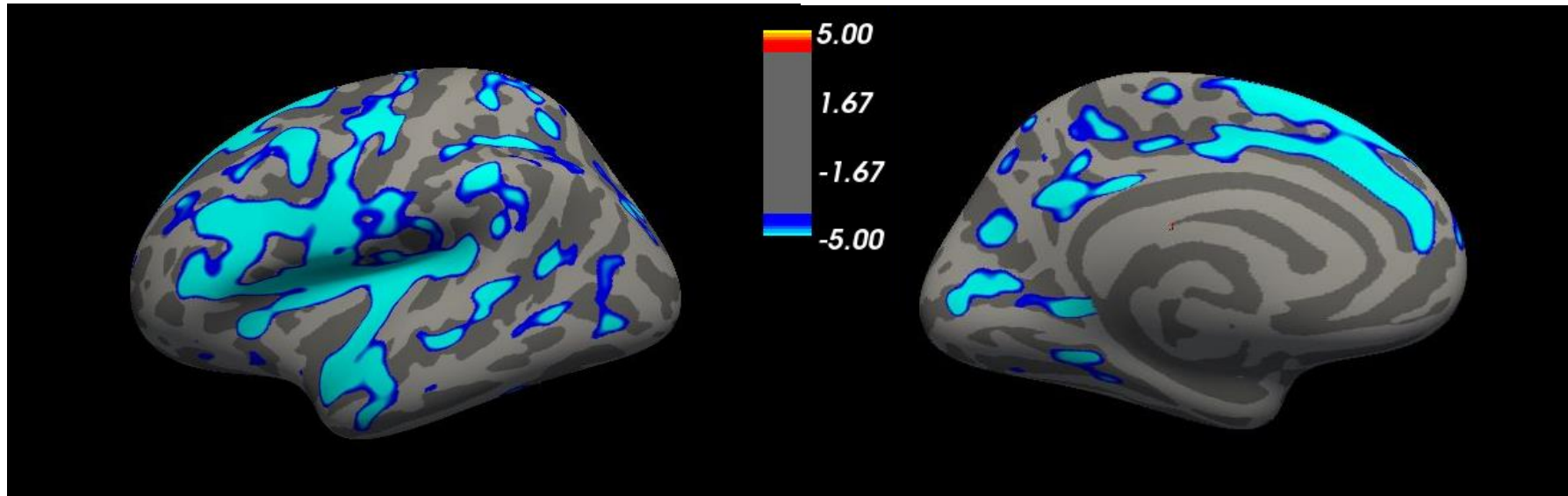


volume



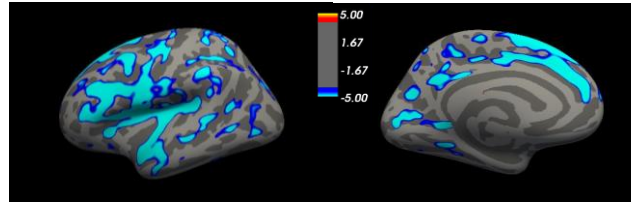
Group analysis in FreeSurfer

- Create the design matrix: set up FSGD file
- Select the metric to be analyzed: thickness, curvature, area
- Use `mri_glmfit` to fit linear model

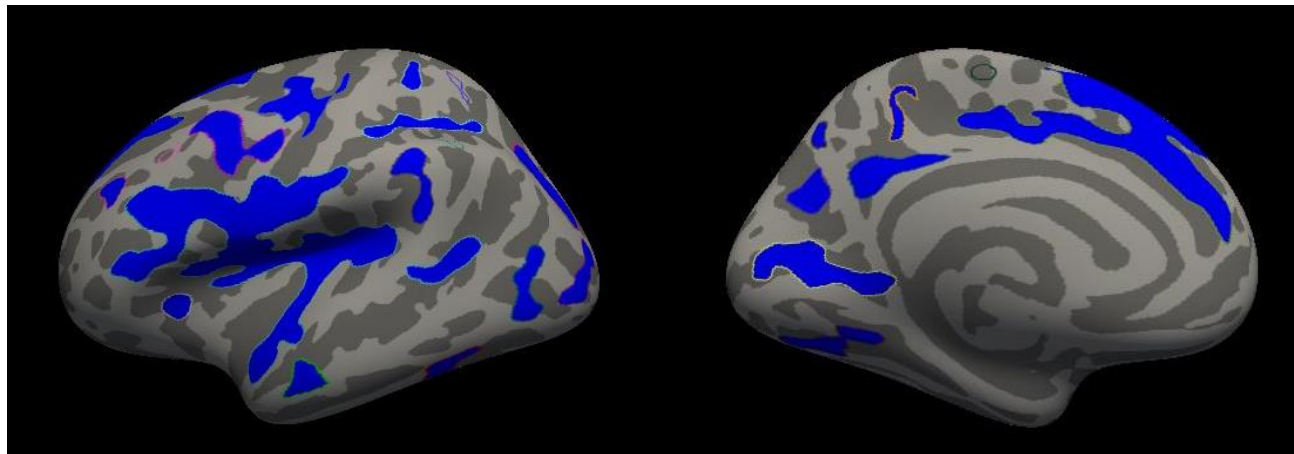


Group analysis in FreeSurfer

- Create the design matrix: set up FSGD file
- Select the metric to be analyzed: thickness, curvature, area
- Use `mri_glmfit` to fit linear model



- Run permutation analysis to correct for multiple comparisons (`mri_glmfit-sim`)

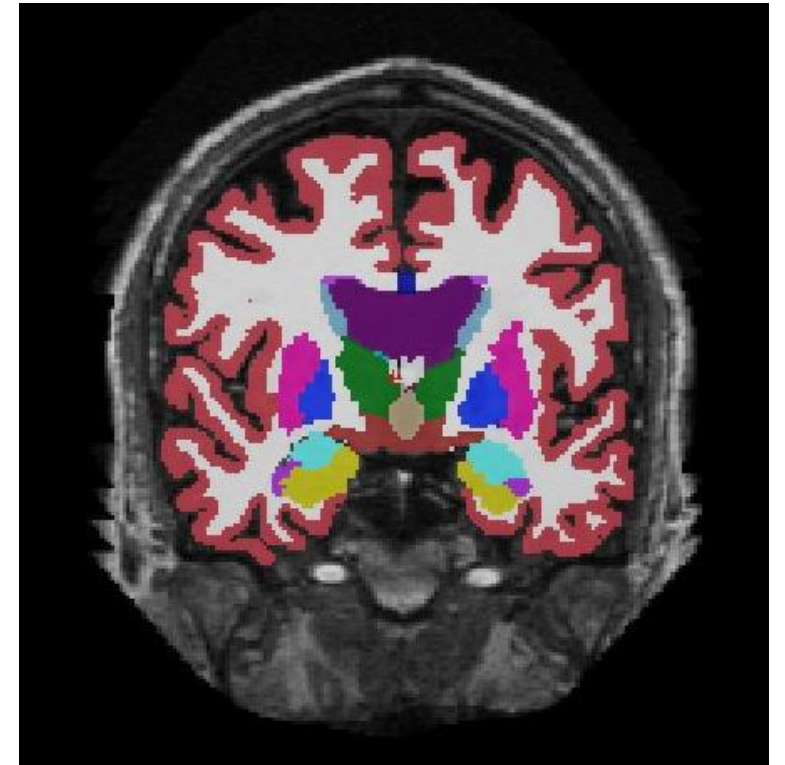


FreeSurfer vs VBM

- VBM can be performed with a number of different packages, e.g., FSL, SPM.
- Fast compared to freesurfer surface based analyses.
- VBM allows for subcortical analysis.
- Thickness estimates do not require modulation.
- False positive rates higher in VBM because of modulation (Greve and Fischl, 2017).
- VBM harder to interpret: GM density depends on thickness, surface area, gyrification, image registration, smoothing, etc.

ROI analysis in FreeSurfer

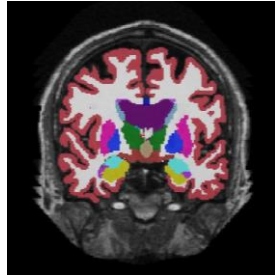
- FreeSurfer automatically computes three brain segmentations/parcellations:
 - Subcortical segmentation



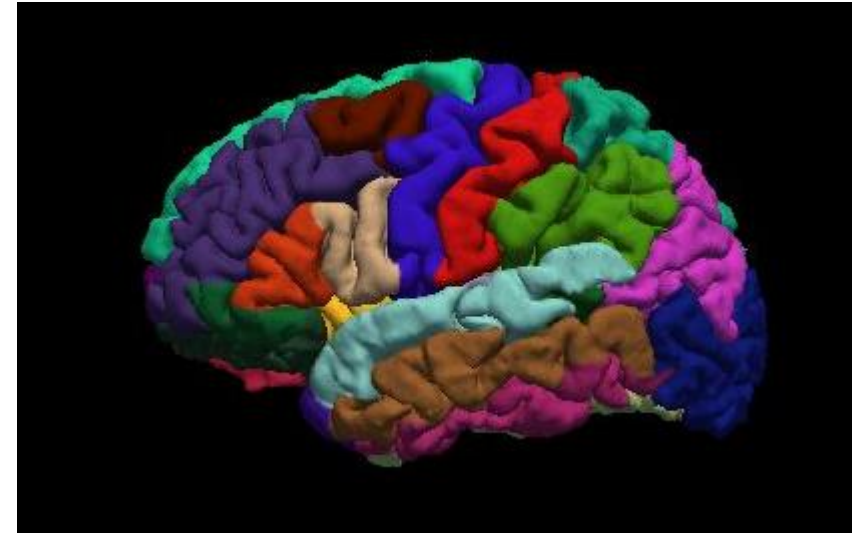
ROI analysis in FreeSurfer

- FreeSurfer automatically computes three brain segmentations/parcellations:

- Subcortical segmentation



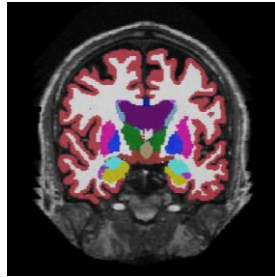
- Cortical parcellation with Desikan/Killian atlas



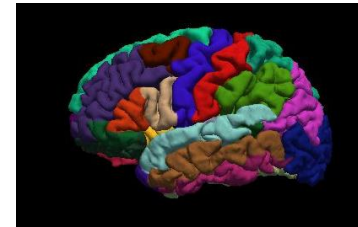
ROI analysis in FreeSurfer

- FreeSurfer automatically computes three brain segmentations/parcellations:

- Subcortical segmentation



- Cortical parcellation with Desikan/Killian atlas



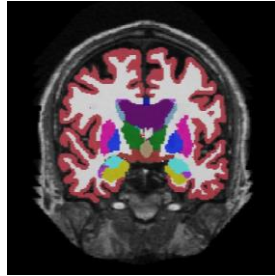
- Cortical parcellation with Destrieux atlas



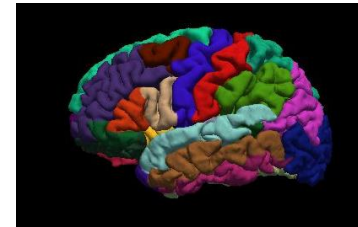
ROI analysis in FreeSurfer

- FreeSurfer automatically computes three brain segmentations/parcellations:

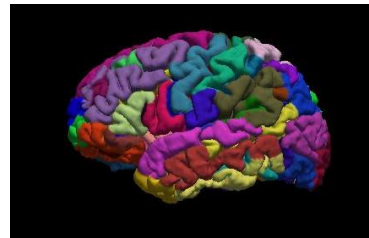
- Subcortical segmentation



- Cortical parcellation with Desikan/Killian atlas



- Cortical parcellation with Destrieux atlas



ROI analysis in FreeSurfer

- Freesurfer also computes summary statistics for these segmentations/parcellations:

#	ColHeaders	Index	SegId	NVoxels	Volume_mm3	StructName	normMean	normStdDev	normMin	normMax	normRange								
1	4	33163	33215.1	Left-Lateral-Ventricle	12.6416	10.9375	0.0000	77.0000	77.0000										
2	5	1200	1221.1	Left-Inf-Lat-Vent	26.6925	14.4286	0.0000	75.0000	75.0000										
3	7	12677	13179.5	Left-Cerebellum-White-Matter	76.4266	8.8658	13.0000	106.0000	93.0000										
4	8	51530	51612.4	Left-Cerebellum-Cortex	49.6198	11.7537	0.0000	100.0000	100.0000										
5	10	7568	7259.4	Left-Thalamus-Proper	74.9564	13.4454	2.0000	126.0000	124.0000										
6	11	5505	5379.5	Left-Caudate	64.2171	11.3418	30.0000	106.0000	76.0000										
7	12	7815	7535.4	Left-Putamen	68.3104	10.7348	11.0000	104.0000	93.0000										
8	13	2616	2576.1	Left-Pallidum	85.0787	13.5870													
9	14	2275	2297.2	3rd-Ventricle	21.7191	12.8521													
10	15	1434	1534.9	4th-Ventricle	21.0363	12.7915													
11	16	21696	21993.1	Brain-Stem	73.6558	11.9974													
12	17	4126	3917.1	Left-Hippocampus	54.9409	10.8158													
13	18	1386	1316.9	Left-Amygdala	55.4646	9.1757													
14	24	2258	2106.2	CSF	23.0097	17.2776													
15	26	645	616.8	Left-Accumbens-area	59.9147	8.0432													
16	28	3845	3686.6	Left-VentralDC	83.4960	13.4968													
17	30	18	23.6	Left-vessel	51.1111	11.2923													
18	31	902	825.1	Left-choroid-plexus	40.3836	13.0726													
19	43	32566	32846.8	Right-Lateral-Ventricle	11.8840	10.7854													
20	44	661	705.6	Right-Inf-Lat-Vent	30.2859	12.7477													
21	46	11865	12269.2	Right-Cerebellum-White-Matter	77.9968	8.7382													
22	47	49947	50175.6	Right-Cerebellum-Cortex	51.1124	11.6507													
23	49	7340	7072.8	Right-Thalamus-Proper	74.7386	12.5178													
24	50	5019	4881.1	Right-Caudate	65.2138	11.3494													
25	51	7209	6948.5	Right-Putamen	70.2717	10.7974													
26	52	2525	2415.1	Right-Pallidum	83.0780	13.4857													
27	53	4731	4554.2	Right-Hippocampus	55.0108	10.7083													
28	54	2034	1943.9	Right-Amygdala	55.7724	8.3993													
29	58	671	613.1	Right-Accumbens-area	64.5693	7.8387													
30	60	3921	3714.4	Right-VentralDC	83.0329	14.3419													
31	62	14	19.3	Right-vessel	53.5714	5.5430													
32	63	711	614.9	Right-choroid-plexus	42.3136	12.6514													

ROI analysis in FreeSurfer

- Freesurfer commands to combine summary statistics into a table:
 - asegstats2table
 - aparcstats2table
- Use your favorite tool to run statistical analyses (R, SPSS, matlab, python,...)

Quality control in FreeSurfer

- recon-all is fully automated but can sometimes fail
 - Hard fail: check logs for errors
 - Soft fail: check surfaces and edit manually

Online tutorial:

<https://surfer.nmr.mgh.harvard.edu/fswiki/FsTutorial/TroubleshootingDataV6.0>

QA video:

<https://www.youtube.com/watch?v=gf0BC0xs0tM>



MRC Cognition
and Brain
Sciences Unit



UNIVERSITY OF
CAMBRIDGE

Thank you