MRC Cognition and Brain Sciences Unit

UNIVERSITY OF CAMBRIDGE

Cortical Thickness analysis using FreeSurfer

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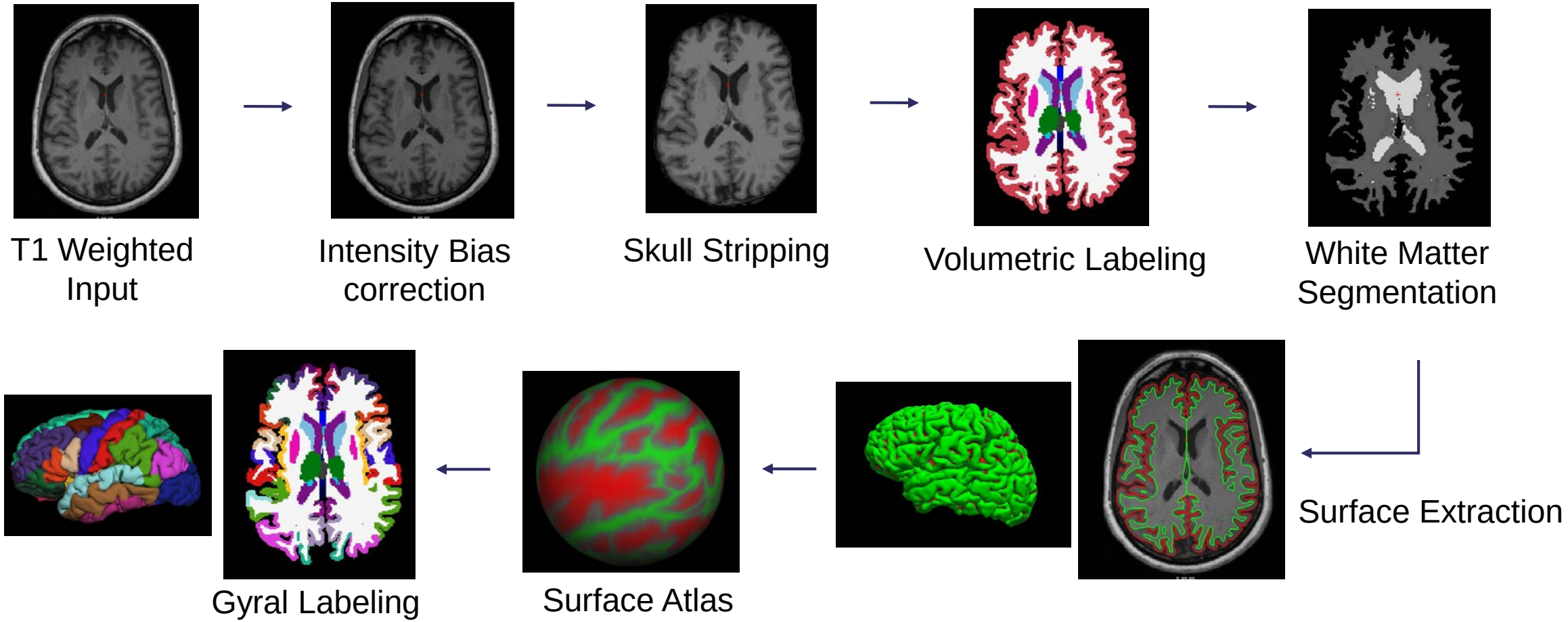
MRC Cognition and Brain Sciences Unit

Overview of FreeSurfer output

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

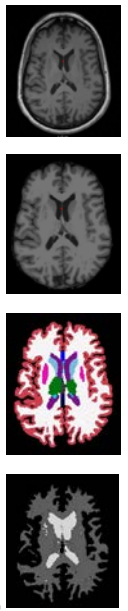


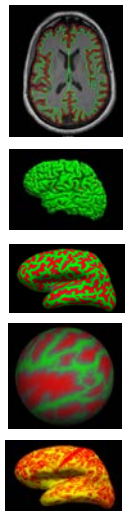
Overview of FreeSurfer output

- Fully automated: recon-all –i file.nii –subject subj001 –all

$SUBJECTS_DIR/subj001

scripts mri surf label stats





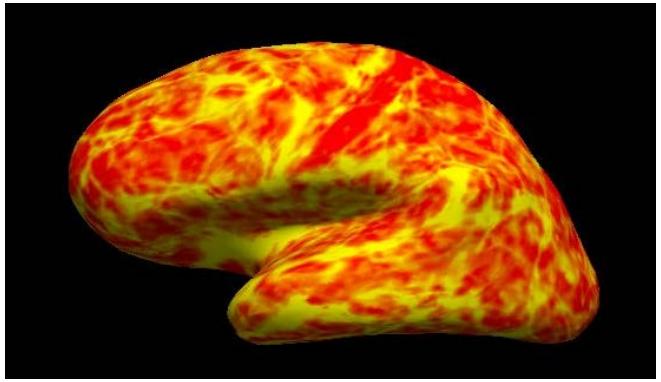
```
Thu Aug 11 11:14:17 BST 2022
/imaging/correia/users/mc04/COGNESTIC/CorticalThickness/LiveDemo/FS_SUBJECTS_DIR/CBU130685
/imaging/local/software/freesurfer/6.0.0/x86_64/bin/recon-all
-i CBU130685/1.3.12.2.1107.5.2.32.35119.2013072015333799476362342.dcm -subject CBU130685 -all
subjid CBU130685
setenv 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
# sysname  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
```

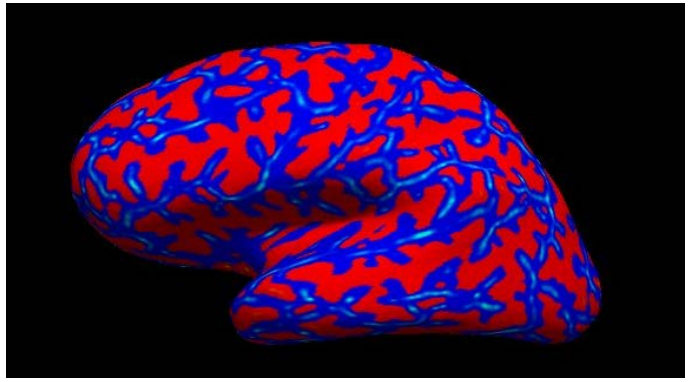
Group analysis in FreeSurfer

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

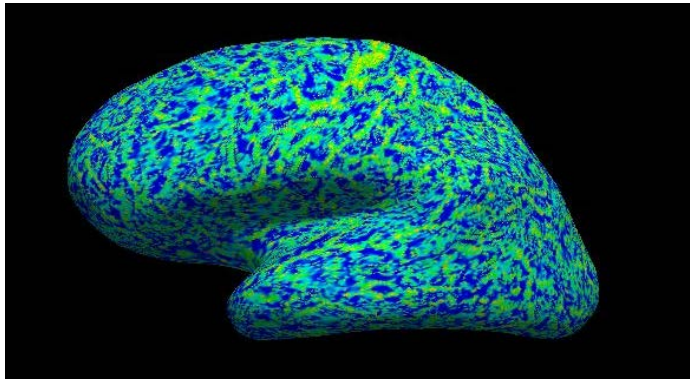
thickness



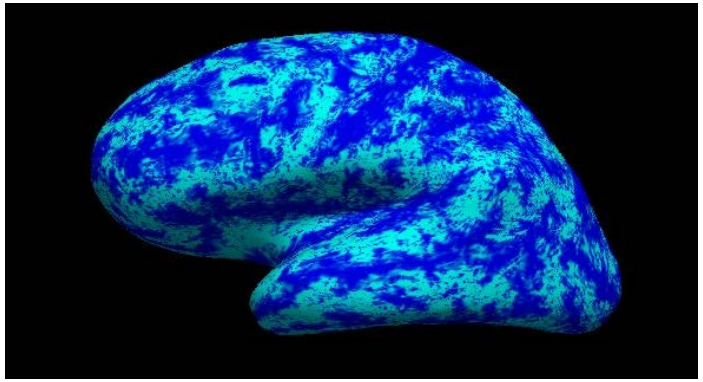
curvature



area

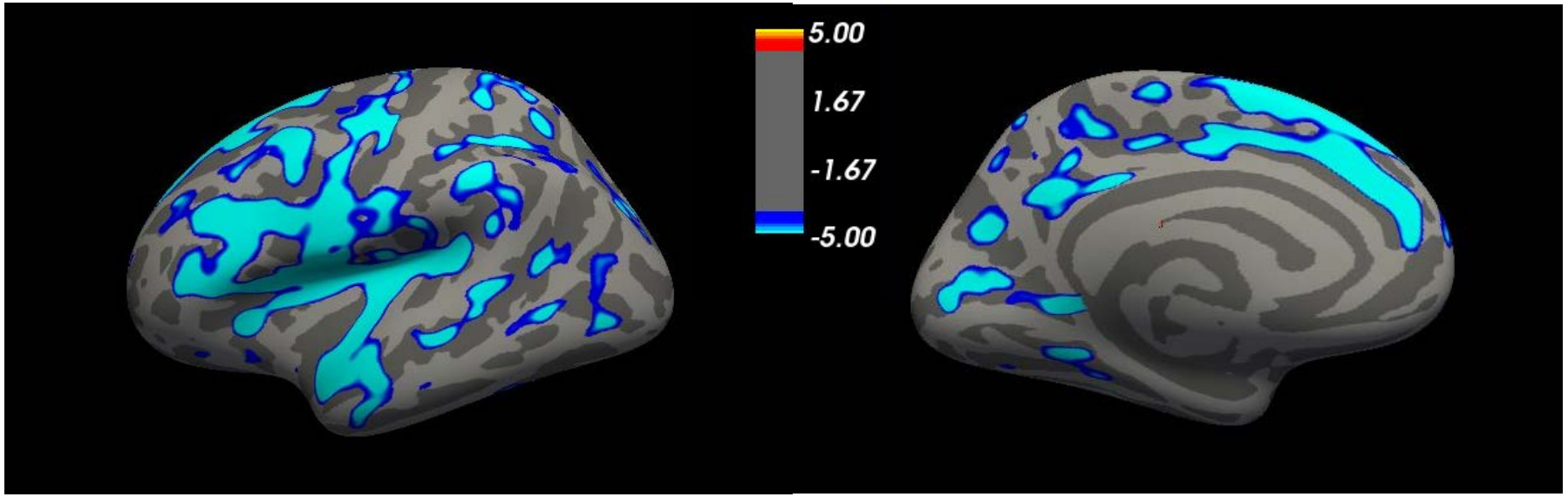


volume



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



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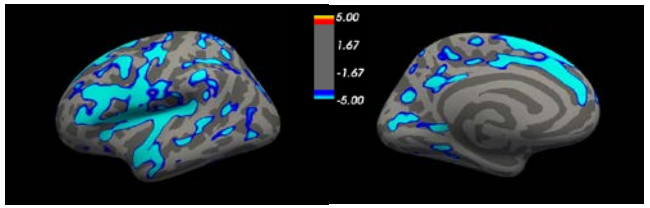
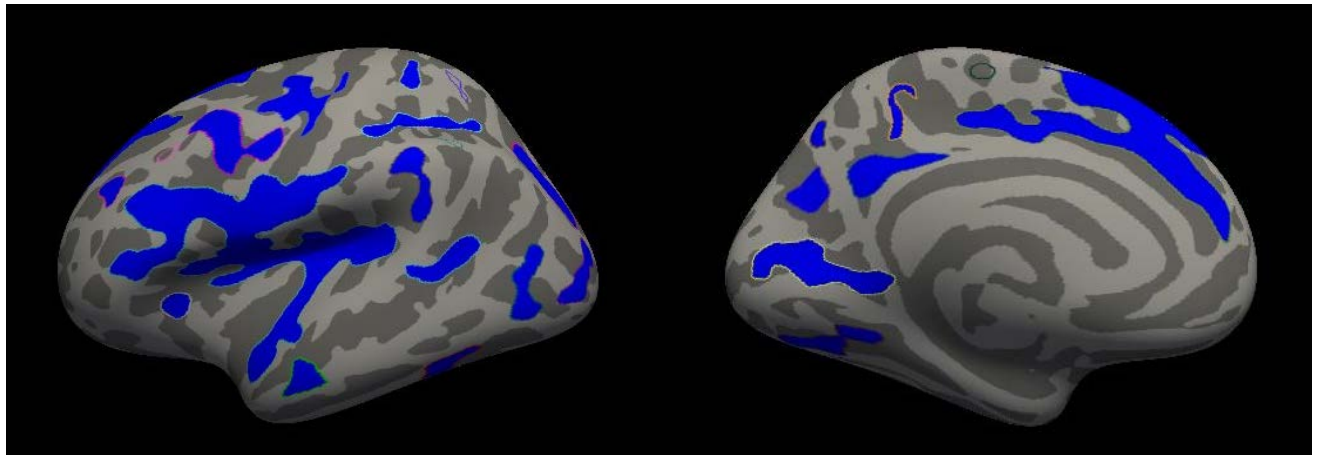


- Run permutation analysis to correct for multiple comparisons (**mri_glmfit-sim**)

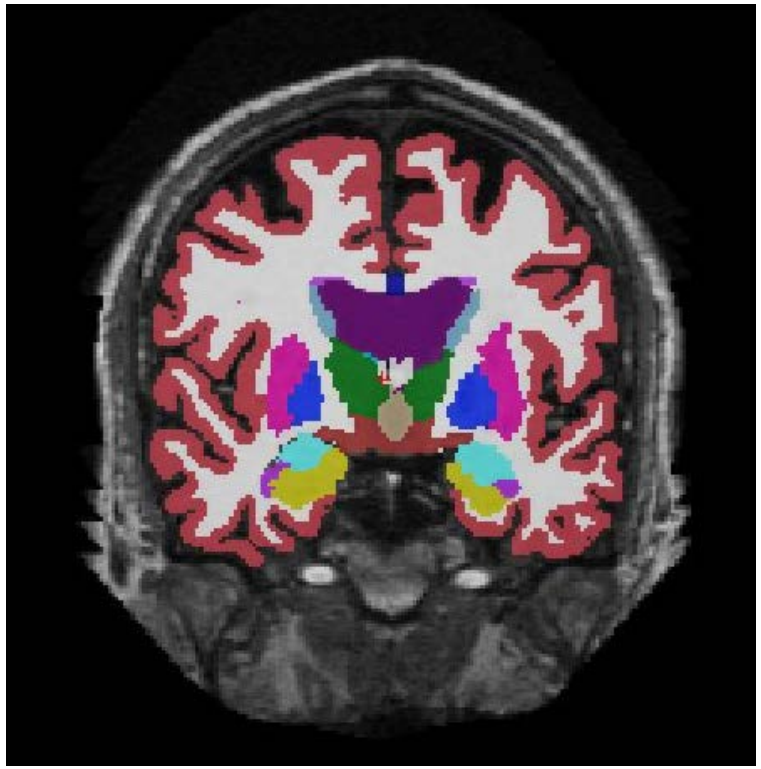


FreeSurfer vs VBM

- 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



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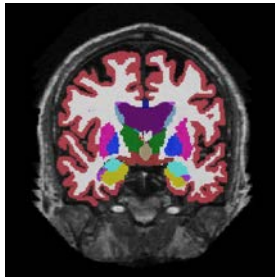
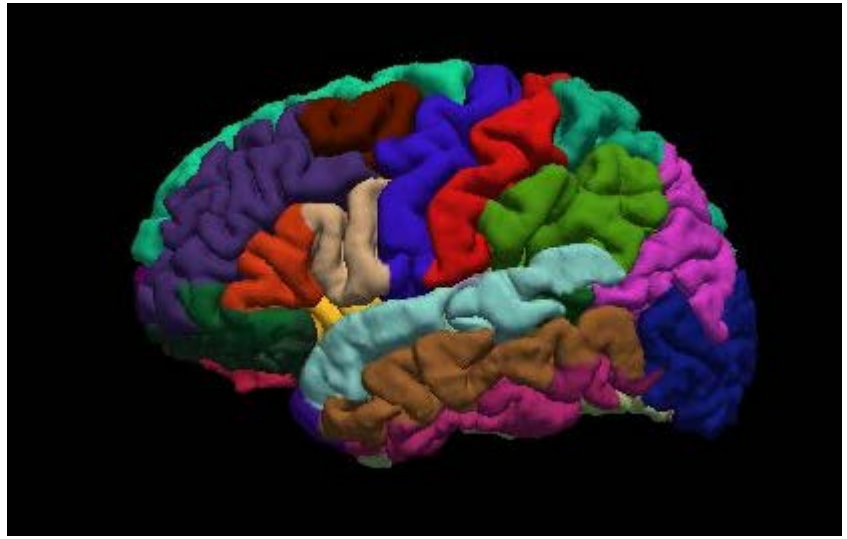


  - Cortical parcellation with Desikan/Killian atlas



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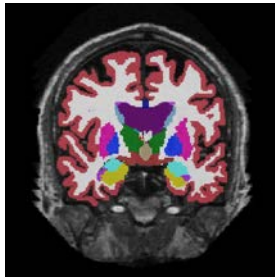
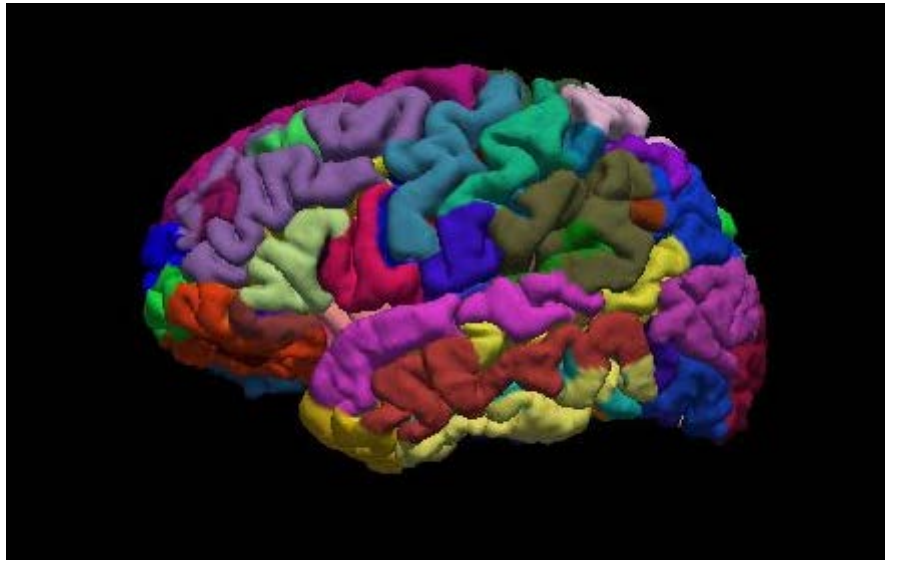


  - Cortical parcellation with Desikan/Killian atlas

  - Cortical parcellation with Destrieux atlas



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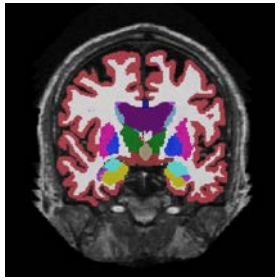

  - Cortical parcellation with Desikan/Killian atlas

  - 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
```

```
# ColHeaders StructName NumVert SurfArea GrayVol ThickAvg ThickStd MeanCurv GausCurv FoldInd CurvInd
bankssts                        1549   1071   2450  2.312 0.392     0.117     0.027       15     1.7
caudalanteriorcingulate         1313    872   2385  2.418 0.765     0.138     0.034       28     1.6
caudalmiddlefrontal             3199   2130   5942  2.510 0.511     0.123     0.031       36     4.1
cuneus                          2562   1649   3157  1.821 0.381     0.144     0.039       40     3.8
entorhinal                       563    426   1731  3.091 0.584     0.121     0.034        5     0.7
fusiform                        5047   3596  10285  2.434 0.620     0.133     0.035       70     7.3
inferiorparietal                8042   5545  13455  2.215 0.455     0.132     0.032      110    10.7
inferiortemporal                5102   3673  11404  2.493 0.650     0.144     0.040       94     8.6
isthmuscingulate                1907   1224   3105  2.256 0.724     0.119     0.035       25     2.2
lateraloccipital                9205   6257  14885  2.136 0.472     0.147     0.039      137    14.9
lateralorbitofrontal            4222   2946   8332  2.471 0.591     0.155     0.046       70     7.8
lingual                         5486   3753   8138  1.959 0.510     0.141     0.037       85     8.2
medialorbitofrontal             3093   2128   5805  2.319 0.709     0.112     0.030       36     3.4
middletemporal                  4376   3078  10128  2.614 0.584     0.142     0.039       74     6.7
parahippocampal                 1032    702   1844  2.259 0.592     0.089     0.018        5     0.7
paracentral                     2307   1446   3756  2.345 0.569     0.110     0.027       20     2.5
parsopercularis                 2650   1792   5514  2.576 0.543     0.121     0.030       30     3.1
parsorbitalis                   1057    727   2286  2.532 0.657     0.143     0.038       16     1.6
parstriangularis                2141   1459   3940  2.356 0.500     0.127     0.032       27     2.7
pericalcarine                   2548   1712   2721  1.691 0.391     0.130     0.033       30     3.2
postcentral                     6544   4316   9705  2.032 0.557     0.119     0.029       75     7.4
posteriorcingulate              2226   1523   3741  2.217 0.636     0.136     0.027       34     2.3
precentral                      8389   5216  14323  2.494 0.559     0.112     0.033       93    10.9
precuneus                       6696   4580  11104  2.280 0.484     0.135     0.034       91     9.3
rostralanteriorcingulate        1561   1039   3180  2.637 0.768     0.139     0.046       32     2.8
rostralmiddlefrontal            9595   6816  18338  2.347 0.549     0.144     0.040      156    15.6
superiorfrontal                11421   7851  23492  2.576 0.597     0.123     0.031      130    14.4
superiorparietal                9669   6435  15365  2.145 0.455     0.131     0.031      122    12.2
superiortemporal                6366   4317  12330  2.537 0.584     0.115     0.027       67     7.0
supramarginal                   7067   4902  13057  2.359 0.519     0.137     0.036      105    10.0
```

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

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Questions?