Measurement of Human Visual Areas Across Individuals

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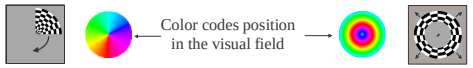
Robert F. Dougherty - Alyssa A. Brewer - Alex A. Wade - Brian A. Wandell
Psychology Department, Stanford University, California, USA

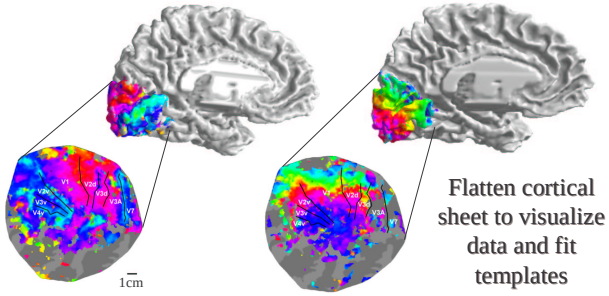
Purpose

Characterize the position and size of human visual areas V1, V2 and V3.

Background

- We measure activity in visual cortex with functional MR
- By stimulating different regions of the visual field in sequence, we create traveling waves of activity across cortex
- Retinotopic maps are derived from the phases of the traveling waves, which code position in the visual field





Flatten cortical sheet to visualize data and fit templates

Methodological Issues

- All brains have been carefully hand-segmented following an initial automatic segmentation.
- All measurements are made on the 3d cortical surface to avoid the distortions induced by flattening.
- Talairach coordinates are computed based on hand-defined landmarks (AC, PC, mid-sagittal plane, and cerebral boundaries)

Contact: bobd@stanford.edu

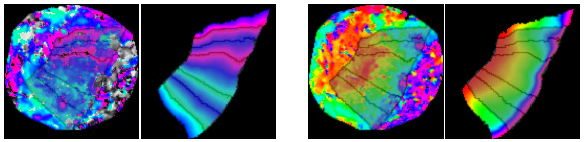
Data Processing

Visual areas are defined by fitting templates of the expected patterns of activity to the data. The templates are jointly deformed to fit the data by an affine transform followed by an elastic deformation that minimizes the differences between the templates and the data (*Error*), as well as the *Strain Energy* of the deformation field (u,v):

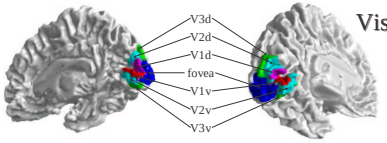
$$Error(u,v) = T1(x+u, y+v) - R1 + T2(x+u, y+v) - R2$$

$$Strain\ Energy(u,v) = \int \frac{\lambda}{2}(u_x + v_y)^2 + \mu\left(u_x^2 + v_y^2 + \frac{1}{2}(u_y + v_x)^2\right) d(x,y)$$

(Where λ and μ are constants which determine the elasticity properties.)

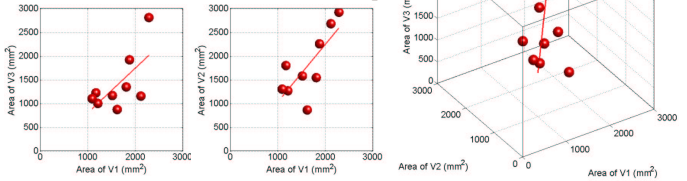


Results



Visual Areas

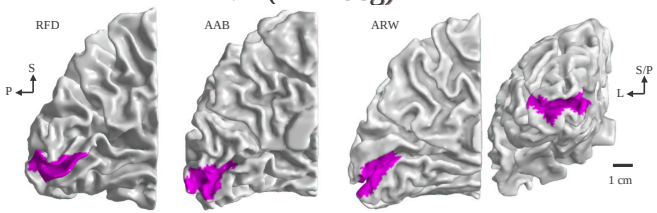
V1/V2/V3 Surface Area Relationship



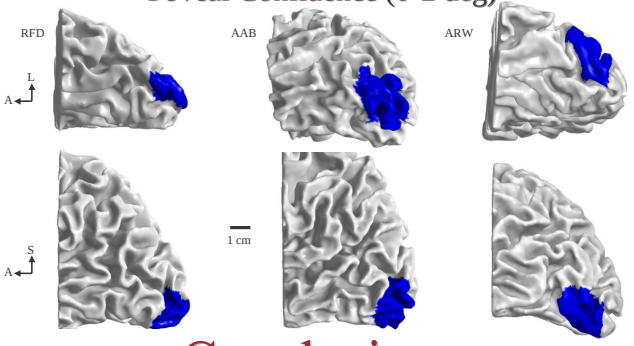
Data Summary

				Area (mm2)							Talairach coordinates (LR,AP,SI)			
				Foveal (0-2deg)	2-12 deg eccentric						Center of	Horizontal Meridian at 12deg eccentric		
Subject	Age	Sex	Hemisphere	Confluence	V1	V2v	V2d	V3v	V3d		Foveal Conf.	V1	Dorsal V2-V3	Ventral V2-V3
AAB	29	F	Right	2249	1171	898	859	611	534		(23,-96,-16)	(16,-82,2)	(7,-85,13)	(8,-78,-7)
RFD	32	M	Right	1818	1809	771	538	673	516		(20,-96,-18)	(11,-81,-4)	(13,-94,8)	(8,-75,-16)
PN	28	M	Right	3024	2117	1337	1250	577	655		(30,-90,-17)	(8,-71,0)	(14,-87,5)	(16,-66,-9)
JR	32	M	Right	3084	1091	650	1016	550	509		(22,-90,-3)	(11,-77,8)	(11,-85,15)	(4,-66,-2)
AAB	29	F	Left	2541	1877	1126	1234	958	1093		(-23,-94,-11)	(-18,-78,2)	(-12,-93,17)	(-2,-68,-6)
RFD	32	M	Left	1762	1212	633	644	500	594		(-22,-93,-25)	(-6,-79,-12)	(-12,-72,-13)	(-4,-91,-9)
PN	28	M	Left	2705	1517	788	1108	583	601		(-31,-92,-16)	(-13,-81,-6)	(-13,-97,6)	(-21,-71,-7)
JR	32	M	Left	3006	1619	431	742	436	572		(-30,-92,-10)	(-16,-71,7)	(-13,-82,7)	(-14,-66,-3)
ARW	29	M	Left	3175	2285	1457	1537	1402	1047		(-37,-82,-11)	(-21,-75,4)	(-15,-86,13)	(-13,-66,-4)
			mean:	2598	1633	899	992	699	680	mean distance:	12.8	12.5	15.5	15.6
			stdev:	539	425	342	325	302	226	stdev:	5	5.3	9.4	7.3
			range:	1782-3175	1091-2285	431-1457	538-1537	436-1402	509-1093	range:	3.6-23.3	4.7-22.9	4.5-36.6	1.4-27.4

V1 (2-12 deg)



Foveal Confluence (0-2 deg)



Conclusions

- Our measurements of the size and individual variance of V1 agree with recent post-mortem measurements (Andrews et al, 1997)
- V2 & V3 surface area is correlated with V1 area across individuals (V1 explains 66% of V2 and 44% of V3 variance)
- Sulcal landmarks are more predictive than Talairach coordinates for V1/2/3 location

References

- Andrews, Halpern & Purves (1997) **Correlated Size Variations in Human Visual Cortex, Lateral Geniculate Nucleus, and Optic Tract.** *J. Neurosci, 17*; 2859-2868.
- Fischer & Modersitzki (1999) **Fast Inversion of Matrices Arising in Image Processing.** *Numerical Algorithms, 22*; 1-11.
- Wandell, Chial, & Backus (2000) **Visualization and Measurement of the Cortical Surface.** *J. Cog. Neurosci., 12 (5)*; 739-52.
- Wandell (1999) **Computational Neuroimaging of Human Visual Cortex.** *Annual Rev. Neurosci, 10 (22)*.