

Happy Birthday to Dave!

- About the human brain
- MRI measures of brain activity
- MRI measures of brain connections
- **Diagnosing reading impairments**
- Software tools for checking and sharing



QUANTITATIVE MEASUREMENTS



COMPUTATIONAL MODELS



CHECK AND SHARE



The visual system actively interprets image data

Even simple judgments – such as lightness - depend on substantial interpretation of the image data carried out by brain circuits

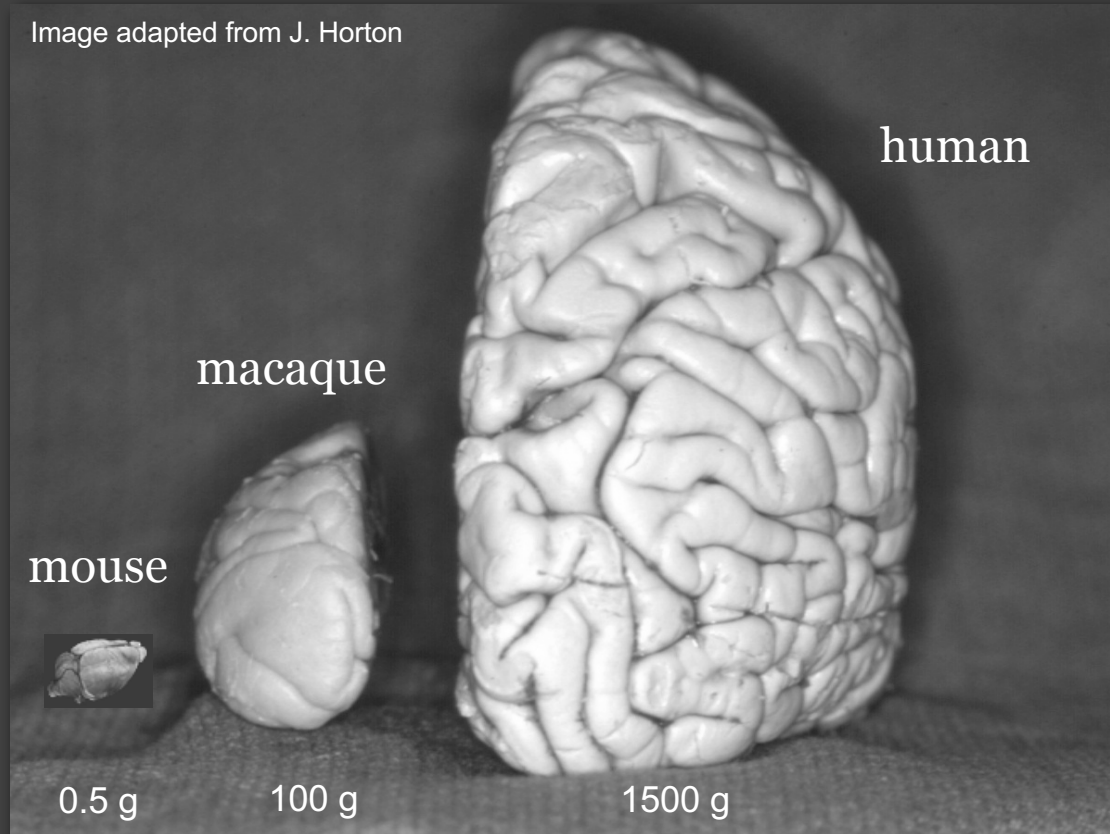
(Anderson and Winawer, Nature, 2005)



The human brain

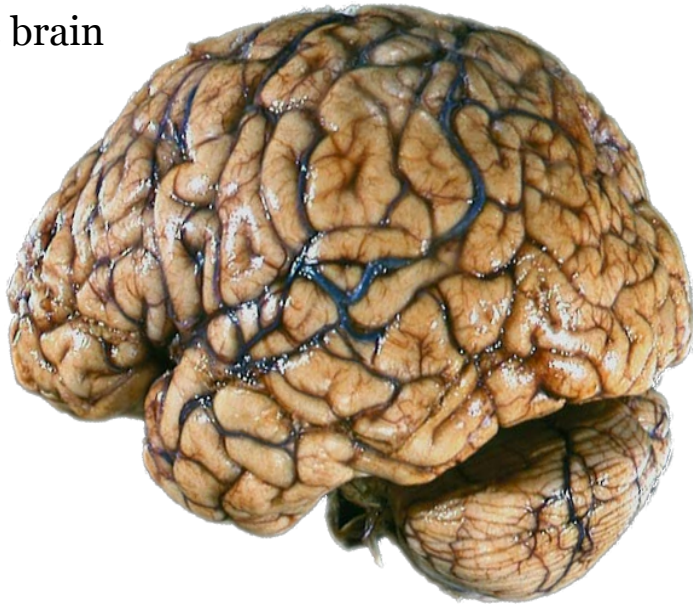
1: 15: 3000 (volume ratios)

- Brains differ
- Check which system was measured



Brain parts

Brain computations takes place in the gray matter (also called cerebral cortex), a thin (2-4 mm) sheet of neural tissue that cover the surface of the brain



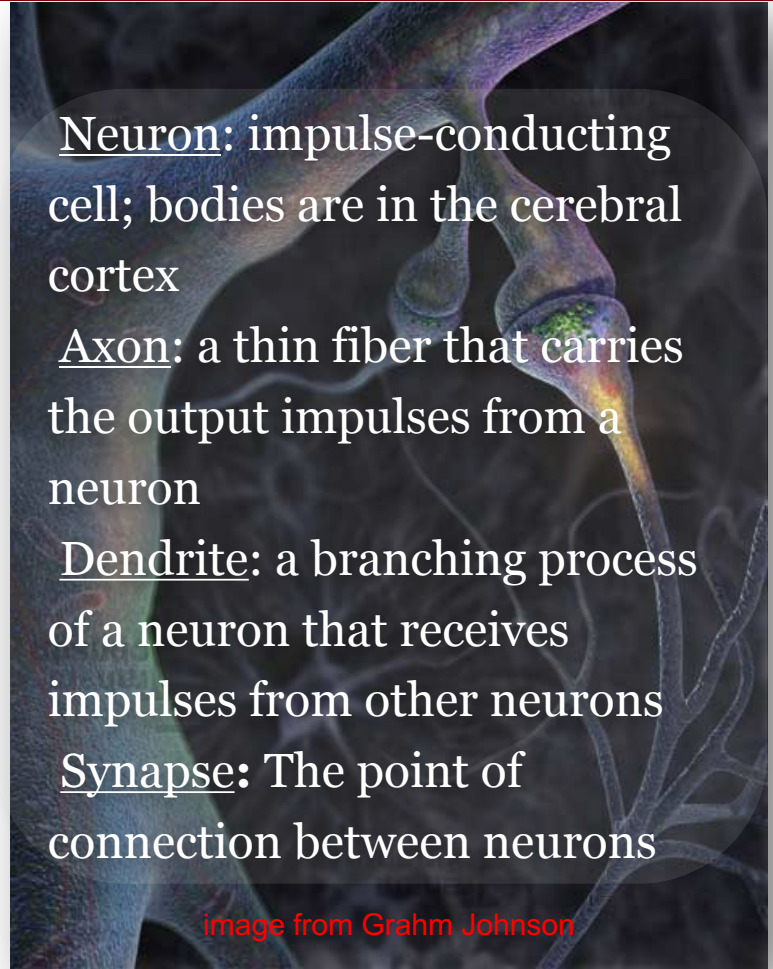
Neuron: impulse-conducting cell; bodies are in the cerebral cortex

Axon: a thin fiber that carries the output impulses from a neuron

Dendrite: a branching process of a neuron that receives impulses from other neurons

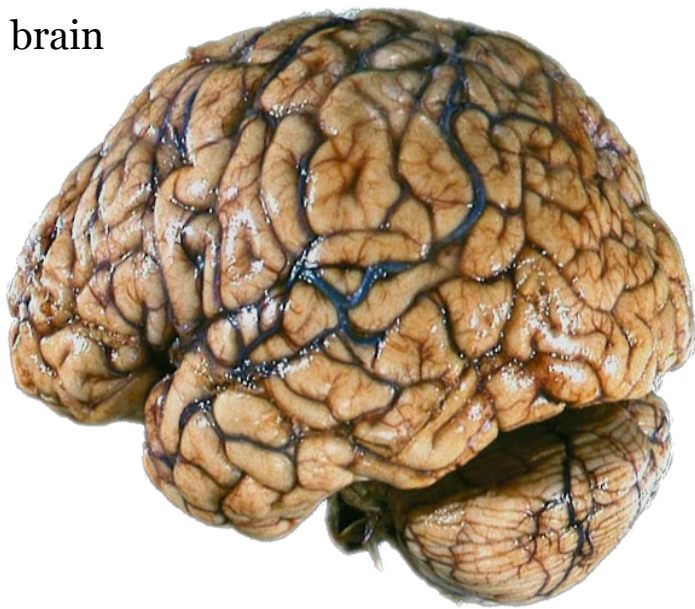
Synapse: The point of connection between neurons

image from [Grahm Johnson](#)



Brain numbers

Brain computations takes place in the gray matter (also called cerebral cortex), a thin (2-4 mm) sheet of neural tissue that cover the surface of the brain

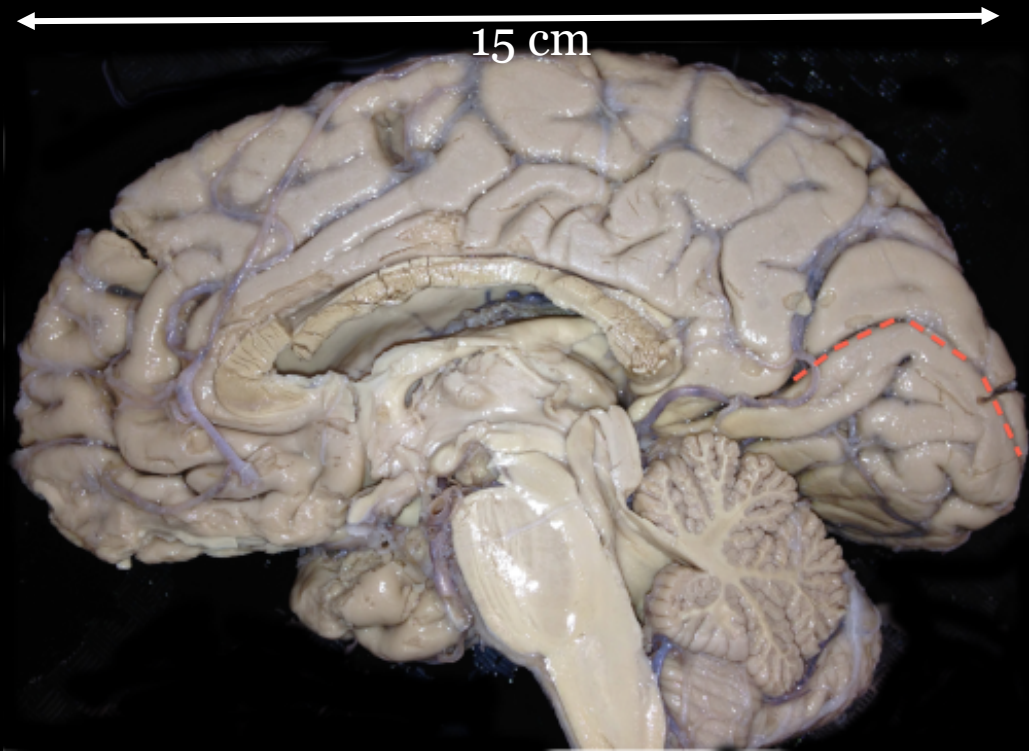


- Neurons/mm³: 10^4 - 10^6
- Total Cortical Neurons: 10^{11}
- Synapses/neuron: 10^3
- Total Cortical Synapses: 10^{14}
- Surface area of each hemisphere: $25 \times 30 \text{ cm}^2$

image from [Grahm Johnson](#)

Human fascicles (tracts)

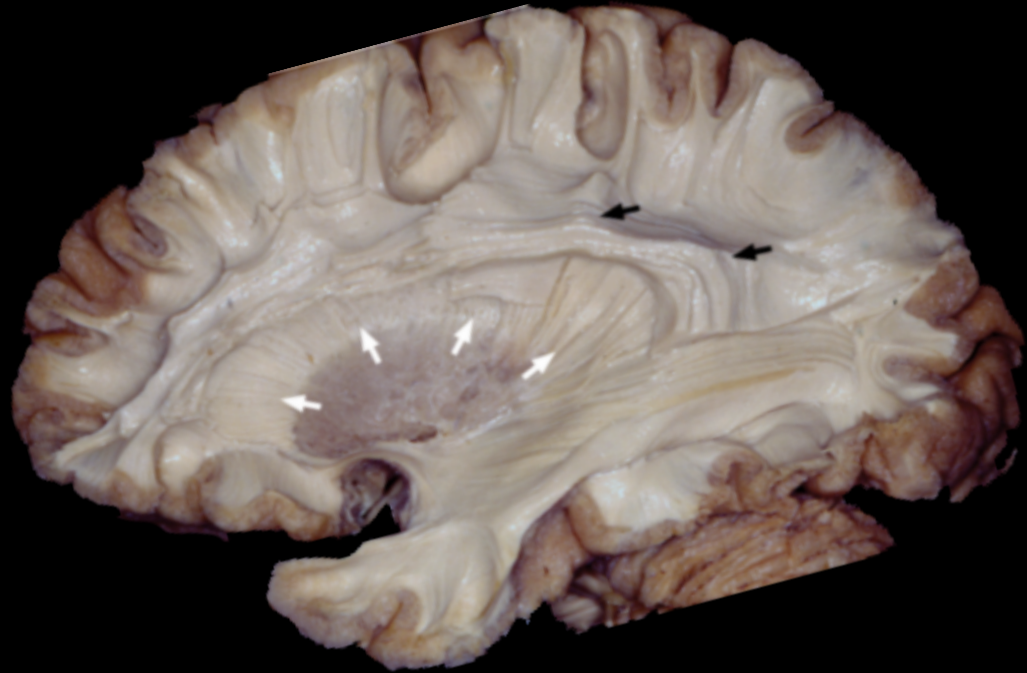
- There are many long-range connections
- These connections are not passive – they change their properties in response to use
- A system with active wires



Courtesy Professor Peggy Mason

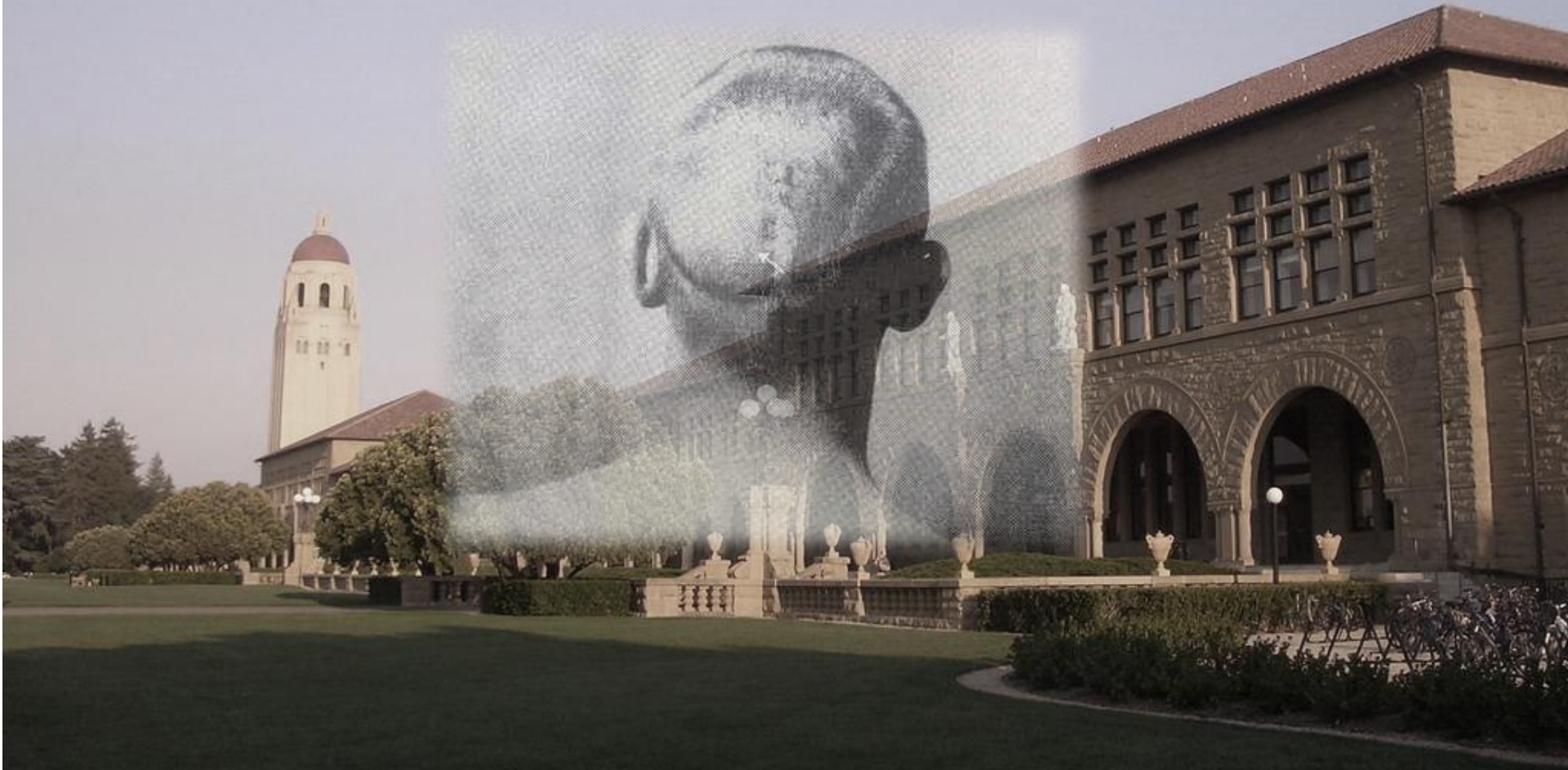
Human fascicles (tracts)

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Courtesy Professor Ugur Ture

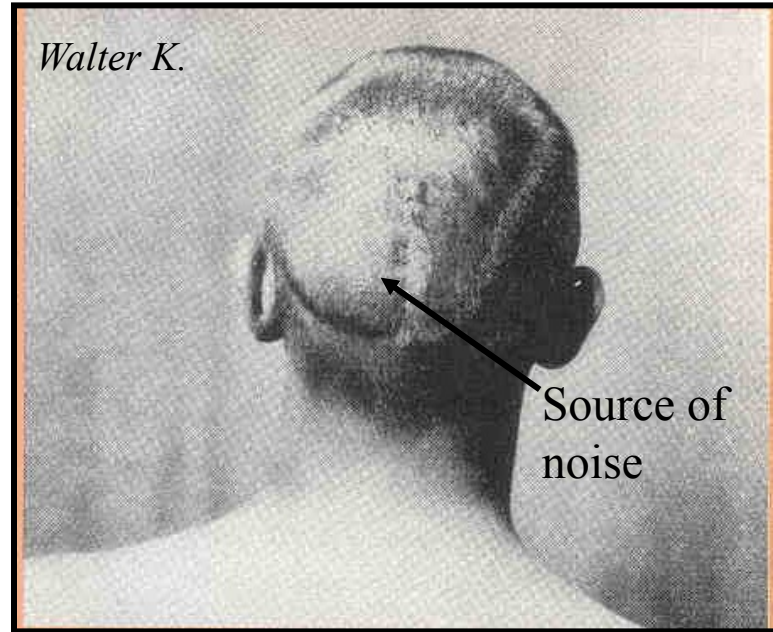
The functional MRI signal (BOLD, fMRI)



Neural and vascular activity are coupled

“On turning down a left occipital bone flap, a large angry-looking angioma arteriale racemosum of the left occ. Lobe was disclosed which extensively involved the visual cortex. The haemorrhage occasioned by the bone flap was so excessive that the operation had to be abandoned without touching the tumour. A decompression, however, was made. The patient was discharged ... with greatly improved vision.”

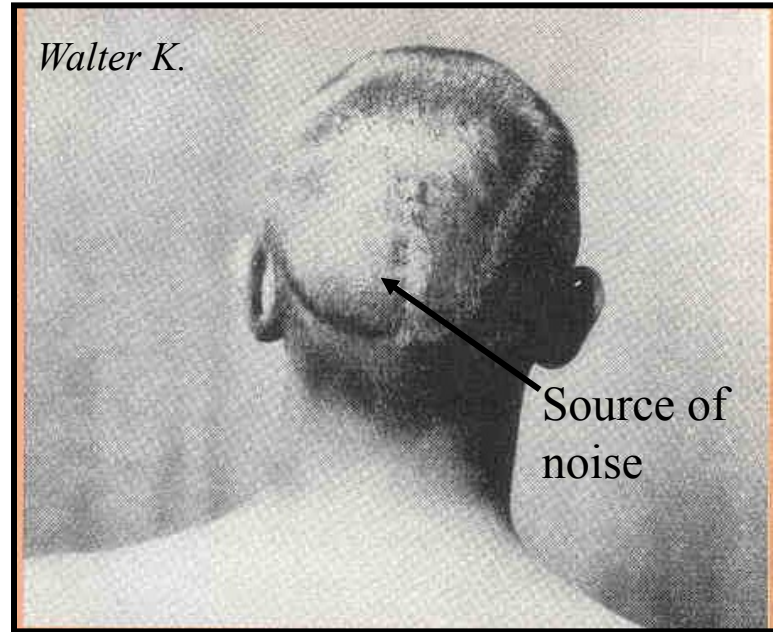
Observations Upon the Vascularity of the Human Occipital Lobe During Visual Activity
J.F. Fulton, M.D. (1928)



Neural and vascular activity are coupled

- Subject noted that ‘the noise in the back of his head increased in intensity when he was using his eyes.’
- No increase for hearing, touch or smell
- Increased more when he tried harder

Observations Upon the Vasculature of the
Human Occipital Lobe During Visual Activity
J.F. Fulton, M.D. (1928)



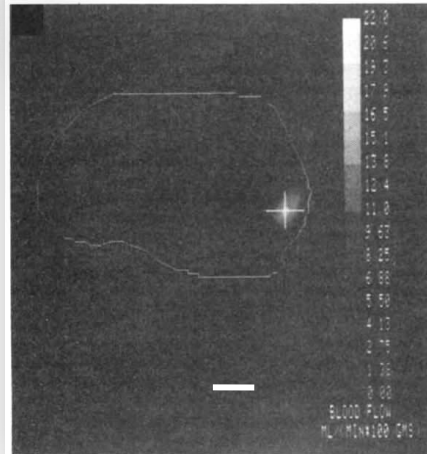
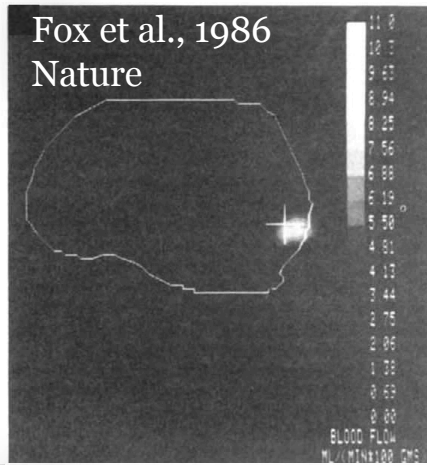
MRI scanners measure the blood oxygen level

- Around 1990, Ogawa, Tank, Ugurbil showed how to use MRI to measure changes in blood oxygenation in the living human brain
- Functional MRI (fMRI) measures a Blood Oxygen Level Dependent (BOLD) signal that is driven by neural activity
- High spatial resolution (mm), low temporal resolution (sec)

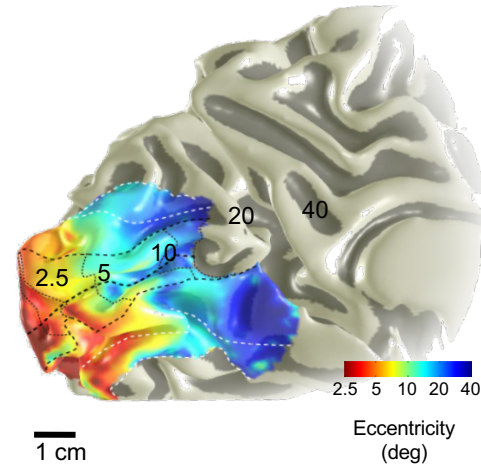
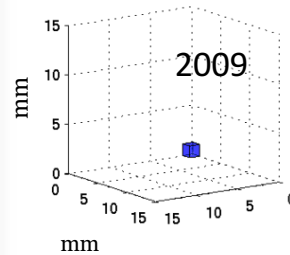
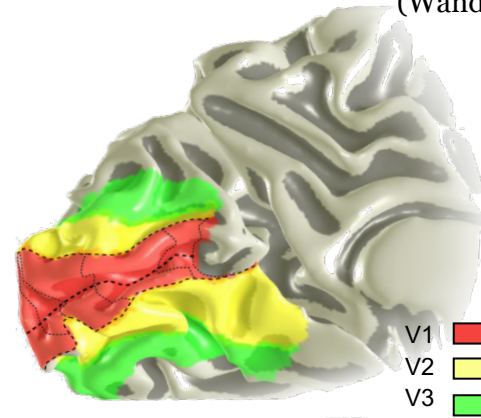
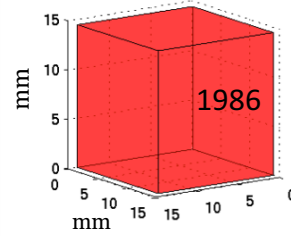


Remarkable progress in 25 years

(Wandell and Winawer, 2011)

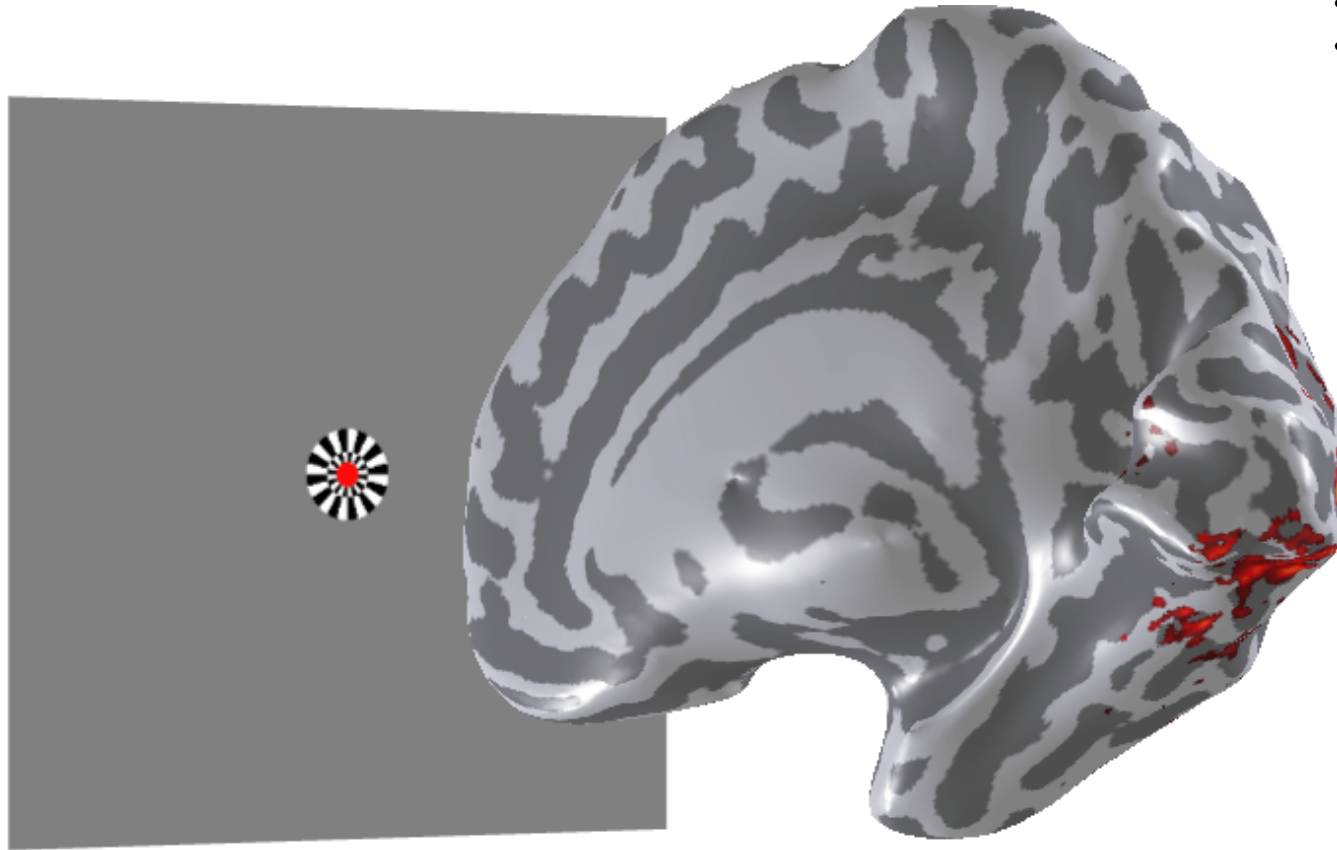


Voxel size



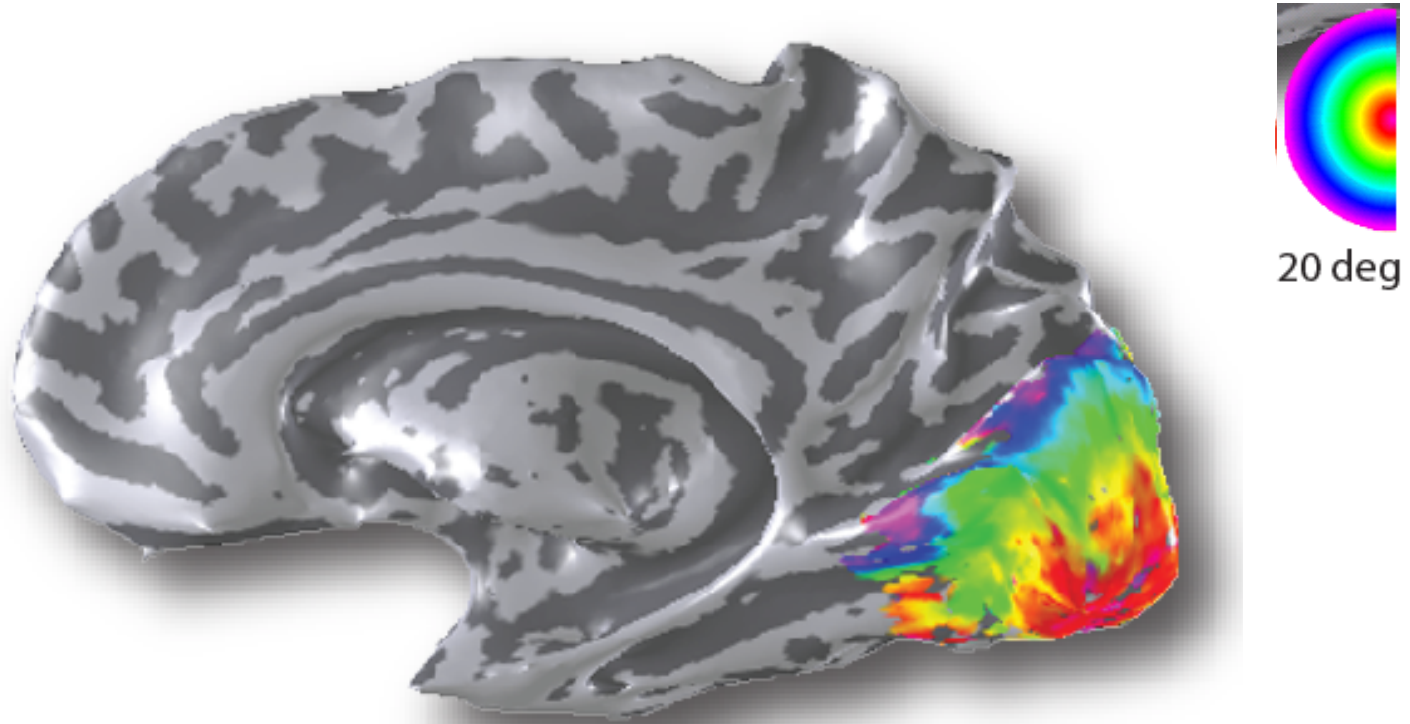
Human eccentricity mapping with fMRI

(Engel et al., 1994,1997; Sereno; Tootell, DeYoe; Others)



- Inflated brain
- Gray/white are sulci/gyri

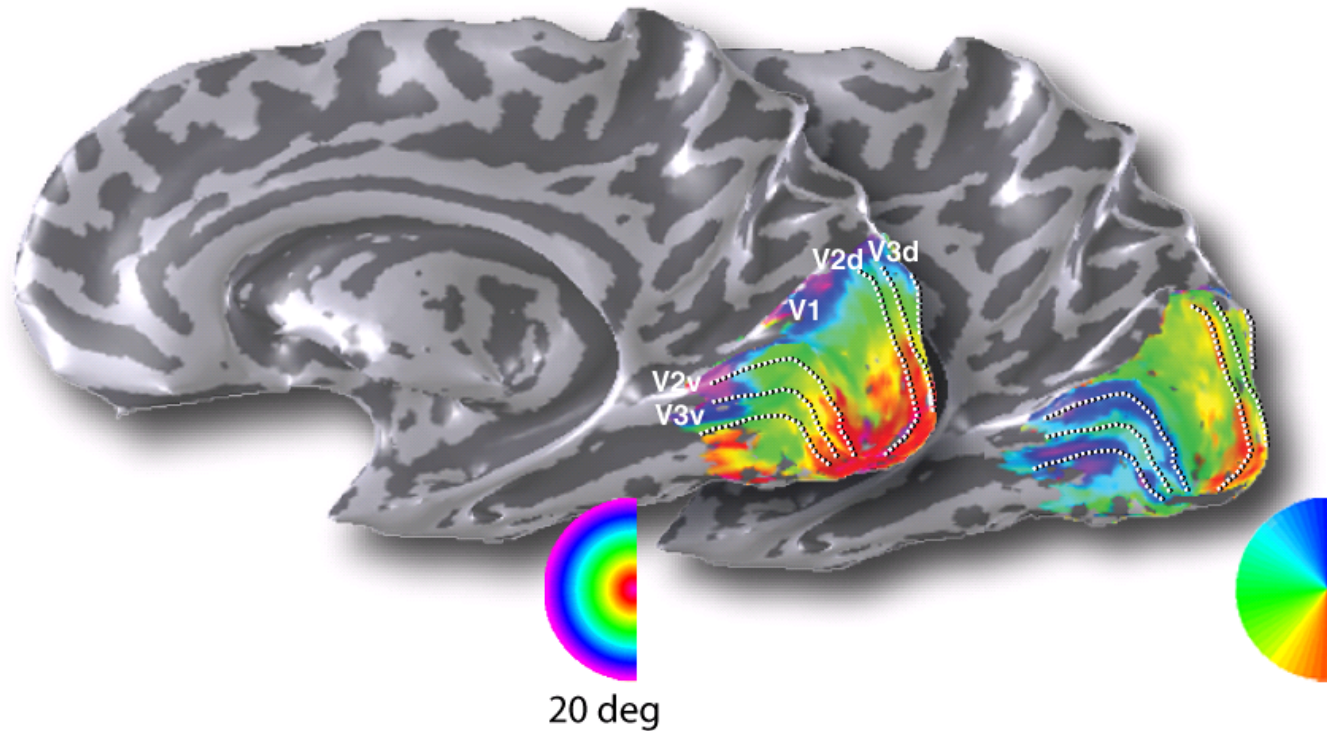
Pseudo-color representation of visual field map



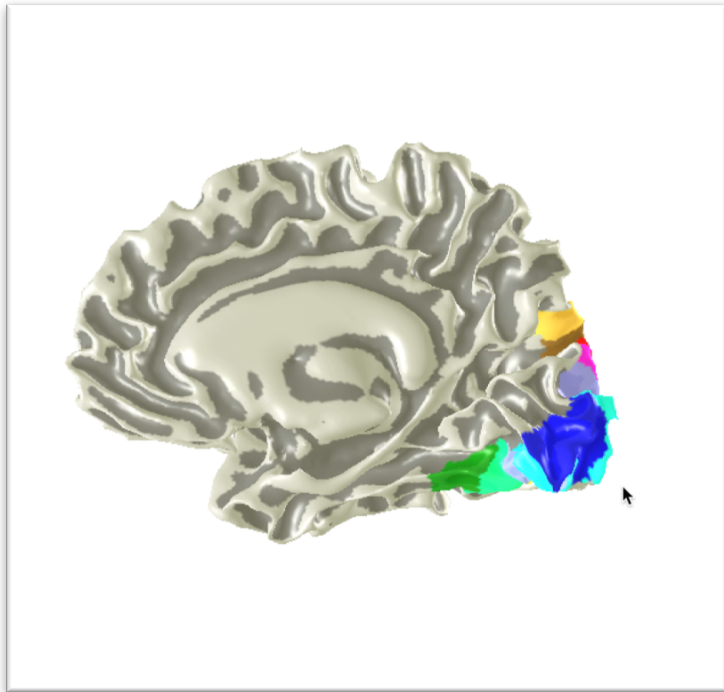
Angular measurements sharply delineate visual field map boundaries



Combining eccentricity and angle data yields maps



More than sixteen visual field maps



Wandell, Dumoulin, Brewer
(2007)
Neuron

Wandell and Winawer
(2011)
Vision Research

- Tile the entire occipital lobe
- Extend into IPS and VOT
- Response properties differ

Cell
PRESS

366 Neuron 56, October 25,
2007

Neuron
Review

Visual Field Maps in Human Cortex

Brian A. Wandell,^{1,*} Serge O. Dumoulin,¹ and Alyssa A. Brewer²
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²Department of Cognitive Sciences, University of California, Irvine, Irvine, CA 92697, USA
*Correspondence: wandell@stanford.edu
DOI 10.1016/j.neuron.2007.10.012

Much of the visual cortex is organized into visual field maps: nearby neurons have receptive fields at nearby locations in the image. Mammalian species generally have multiple visual field maps with each species having similar, but not identical, maps. The introduction of functional magnetic resonance imaging made it possible to identify visual field maps in human cortex, including several near (1) medial occipital (V1, V2, V3), (2) lateral occipital (LO-1, LO-2, hMT+), (3) ventral occipital (hV4, VO-1, VO-2), (4) dorsal occipital (V3A, V3B), and (5) posterior parietal cortex (IPS-0 to IPS-4). Evidence is accumulating for additional maps, including some in the frontal lobe. Cortical maps are arranged into clusters in which several maps have parallel eccentricity representations, while the angular representations within a cluster alternate in visual field sign. Visual field maps have been linked to functional and perceptual properties of the visual system at various spatial scales, ranging from the level of individual maps to map clusters to dorsal-ventral streams. We survey recent measurements of human visual field maps, describe hypotheses about the function and relationships between maps, and consider methods to improve map measurements and characterize the response properties of neurons comprising these maps.

Vision Research 51 (2011) 718-

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737
Vision Research
journal homepage: www.elsevier.com/locate/visres

ELSEVIER

Review

Imaging retinotopic maps in the human brain

Brian A. Wandell*, Jonathan Winawer
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ARTICLE INFO

ABSTRACT

Article history:
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A quarter-century ago visual neuroscientists had little information about the number and organization of retinotopic maps in human visual cortex. The advent of functional magnetic resonance imaging (fMRI), a non-invasive, spatially-resolved technique for measuring brain activity, provided a wealth of data about human retinotopic maps, just as there are differences amongst non-human primate maps, the human maps have their own unique properties. Many human maps can be measured reliably in individual sub-

Modeling the diffusion signal in a voxel

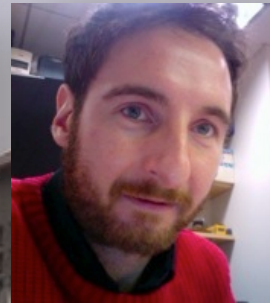
Ariel Rokem



Aviv Mezer



Franco Pestilli



Hiromasa Takemura



QUANTITATIVE MEASUREMENTS

∞

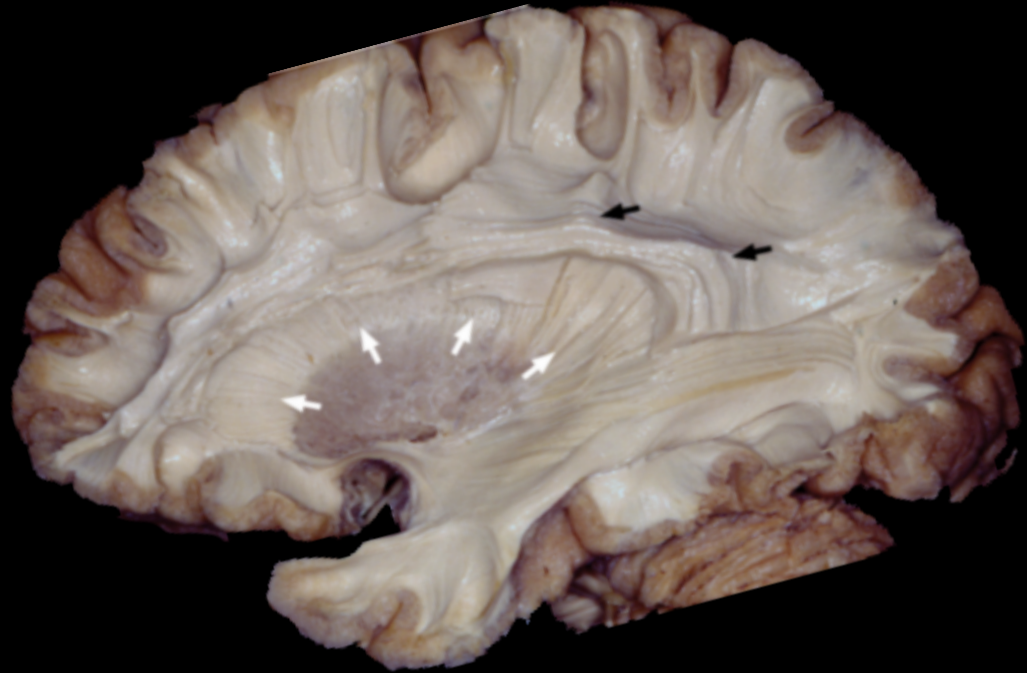
COMPUTATIONAL MODELS

∞

CHECK AND SHARE

Human fascicles (tracts)

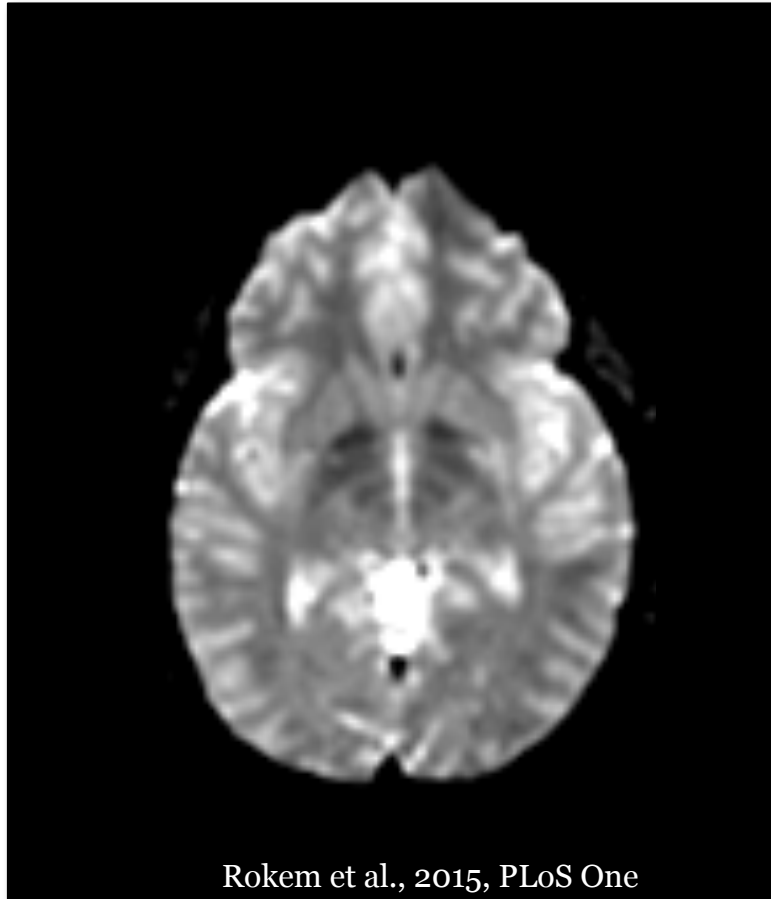
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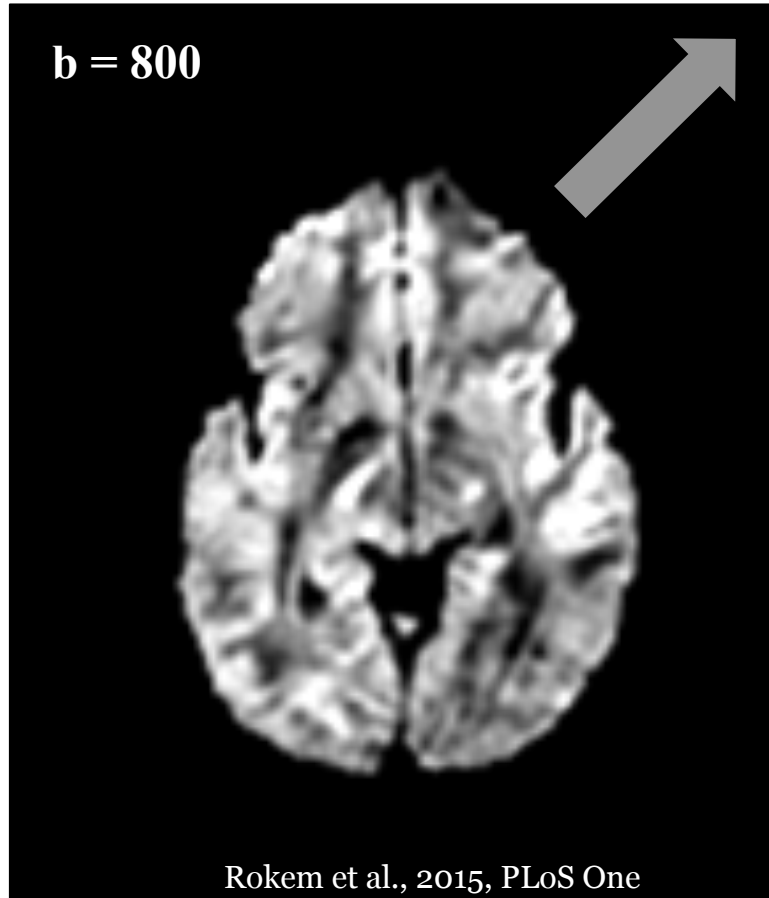
Non-diffusion MR image

Dark means large
signal attenuation
High ADC



Diffusion weighting: Directions

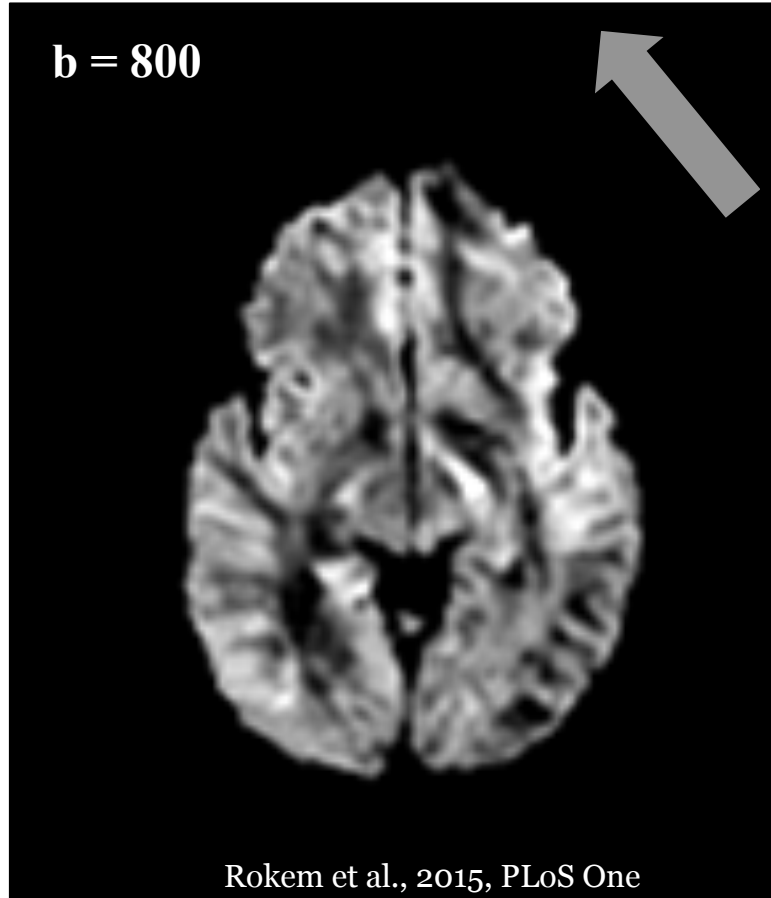
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High ADC



Rokem et al., 2015, PLoS One

Diffusion weighting: Directions

Dark means large
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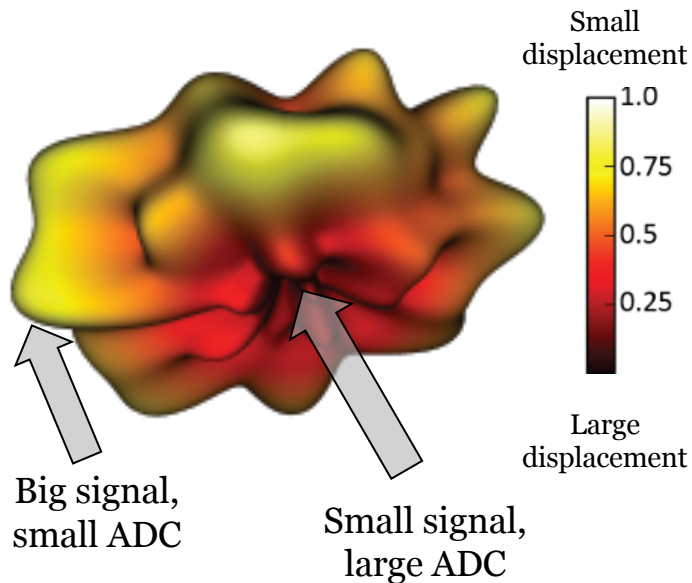
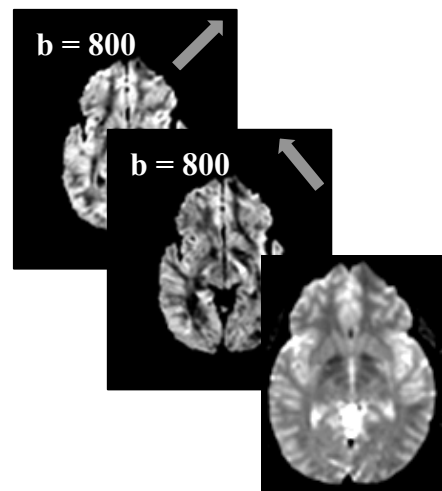
Rokem et al., 2015, PLoS One

Diffusion signals in different directions

Apparent diffusion coefficient (ADC)
Diffusion data are surfaces at every voxel

E. O. Stejskal and J. E. Tanner
(1965)

$$S(\theta) = S_0 e^{-bD(\theta)}$$



The measured diffusion signal in a direction, θ , is related to the apparent diffusion coefficient in that direction, $D(\theta)$

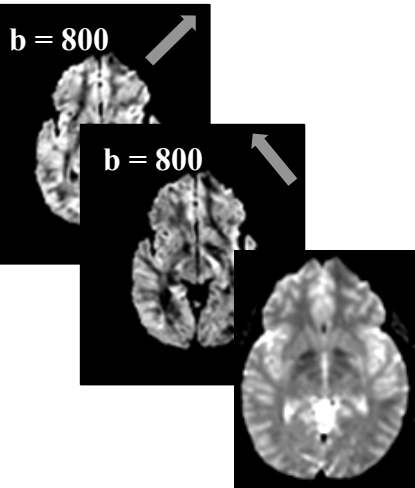
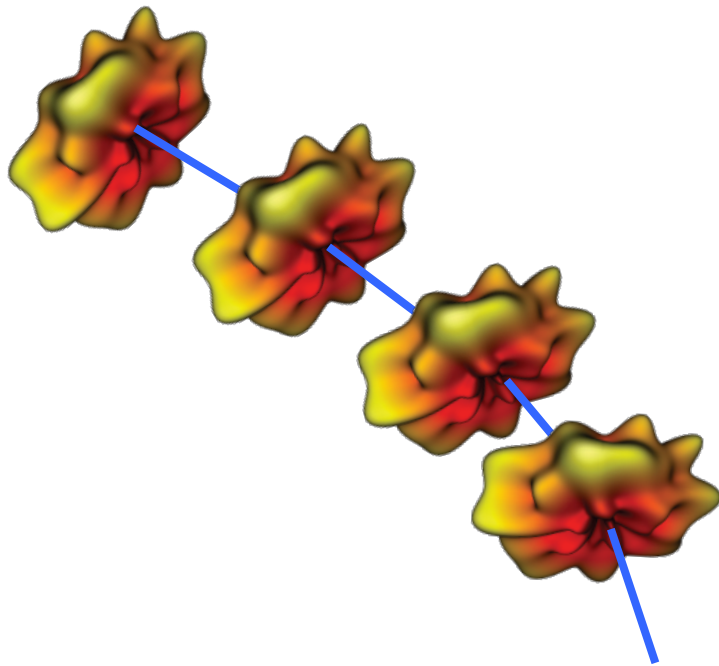
Diffusion signals in different directions

Tractography algorithms combine the local (voxel) diffusion measurements to estimate white matter tracts (streamlines)

E. O. Stejskal and J. E. Tanner
(1965)

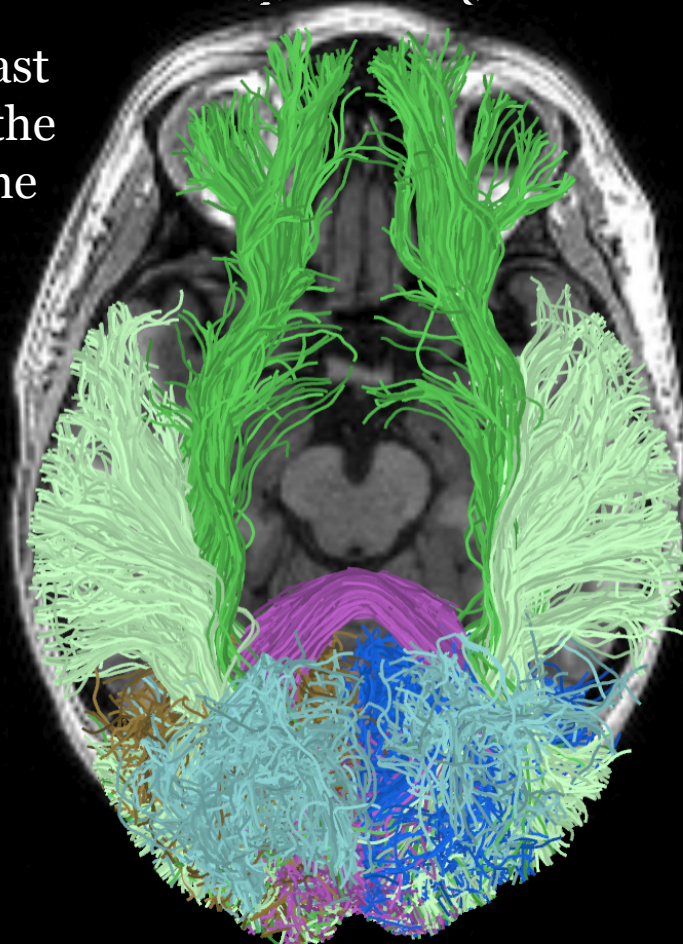
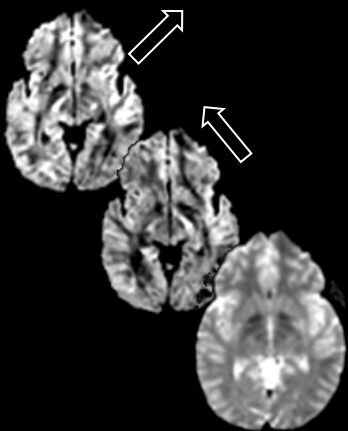
$$S(\theta) = S_0 e^{-bD(\theta)}$$

The measured diffusion signal in a direction, θ , is related to the apparent diffusion coefficient in that direction, $D(\theta)$



Tractography modeling

Tracts with at least one endpoint in the visual parts of the brain



nature **methods**
Techniques for life scientists and chemists

Home | Current issue | Comment | Research | Archive | Authors & referees | About the journal

home > archive > issue > article > abstract

NATURE METHODS | ARTICLE

Evaluation and statistical inference for human connectomes

Franco Pestilli, Jason D Yeatman, Ariel Rokem, Kendrick N Kay & Brian A Wandell

PLOS | COMPUTATIONAL BIOLOGY

OPEN ACCESS | PEER-REVIEWED

RESEARCH ARTICLE

Ensemble Tractography

Hiromasa Takemura , Cesar F. Caiafa, Brian A. Wandell, Franco Pestilli

Published: February 4, 2016 • <http://dx.doi.org/10.1371/journal.pcbi.1004692>

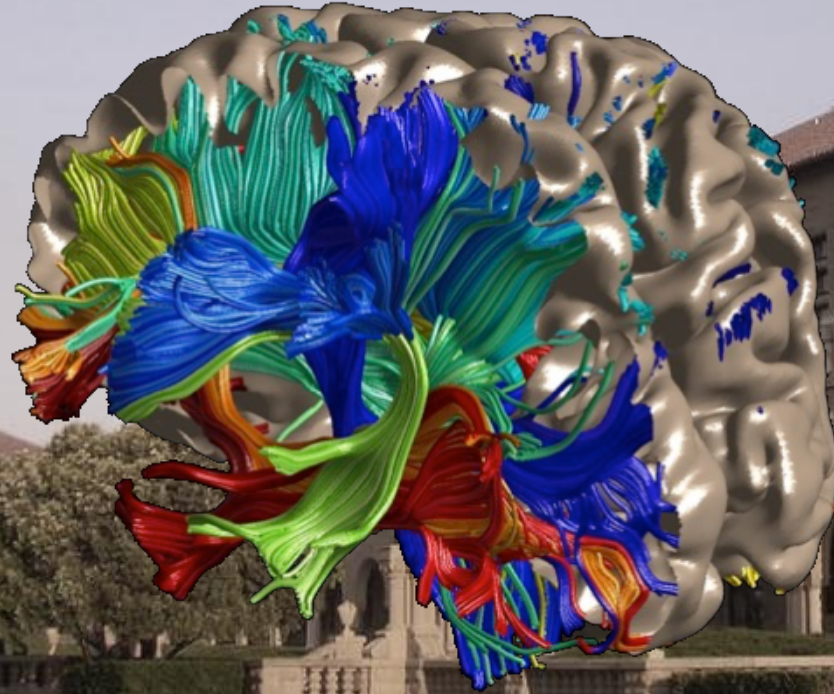
Annual Review of Neuroscience
Vol. 39: 103-128 (Volume publication date July 2016)

Clarifying Human White Matter

Brian A. Wandell

Department of Psychology and Neurosciences Institute, Stanford University, Stanford, California 94305; email: Wandell@stanford.edu

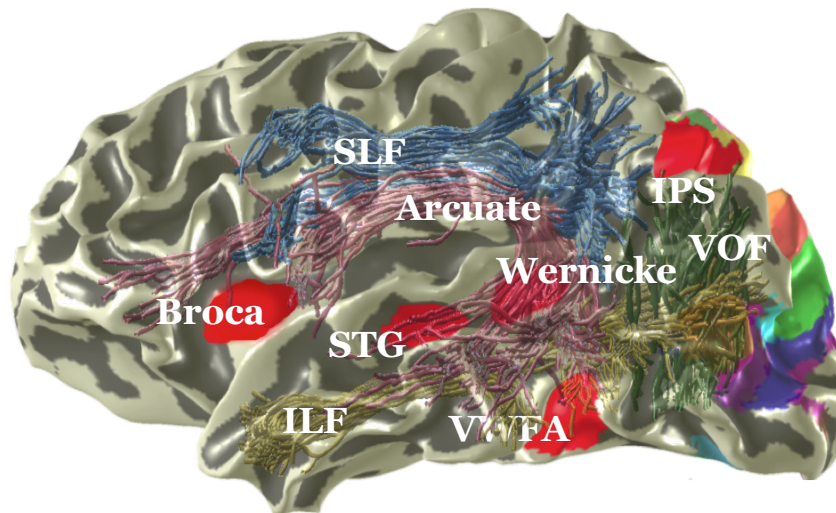
The circuit for seeing words



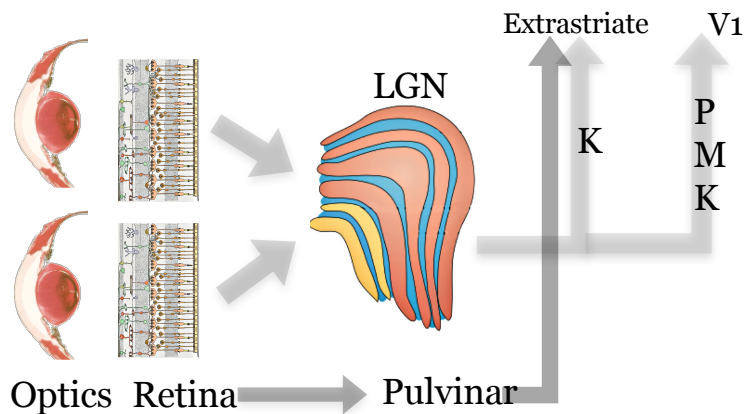
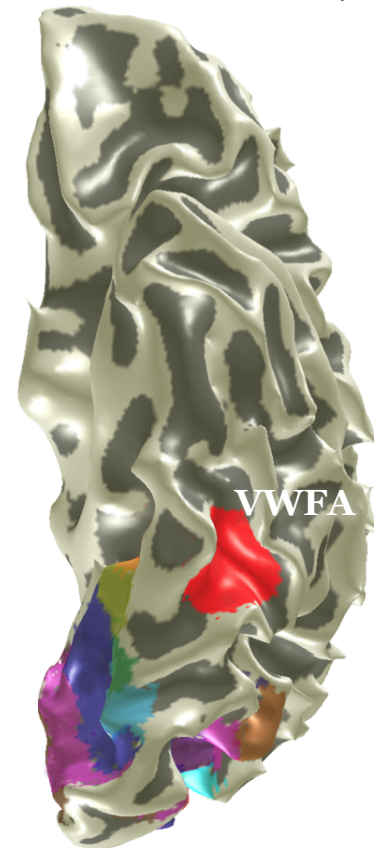
Major components of the reading pathway

The goal: Diagnosis

- Quantitative measures
- Computational modeling
- Check and share

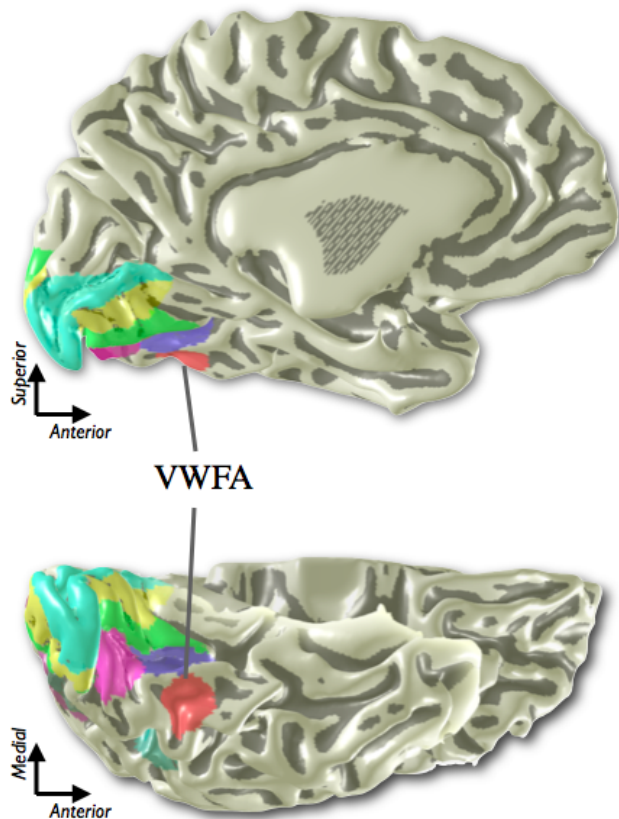


Wandell and Le (2017)

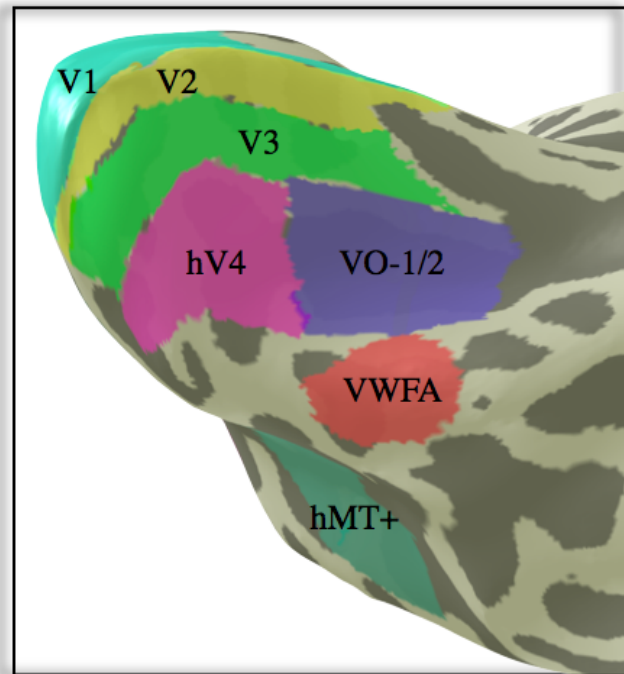


Learning to See Words
B.A. Wandell, A. Rauschecker and J.
Yeatman (2012).
Annual Review of Psychology Vol.
63, pp.31-53.

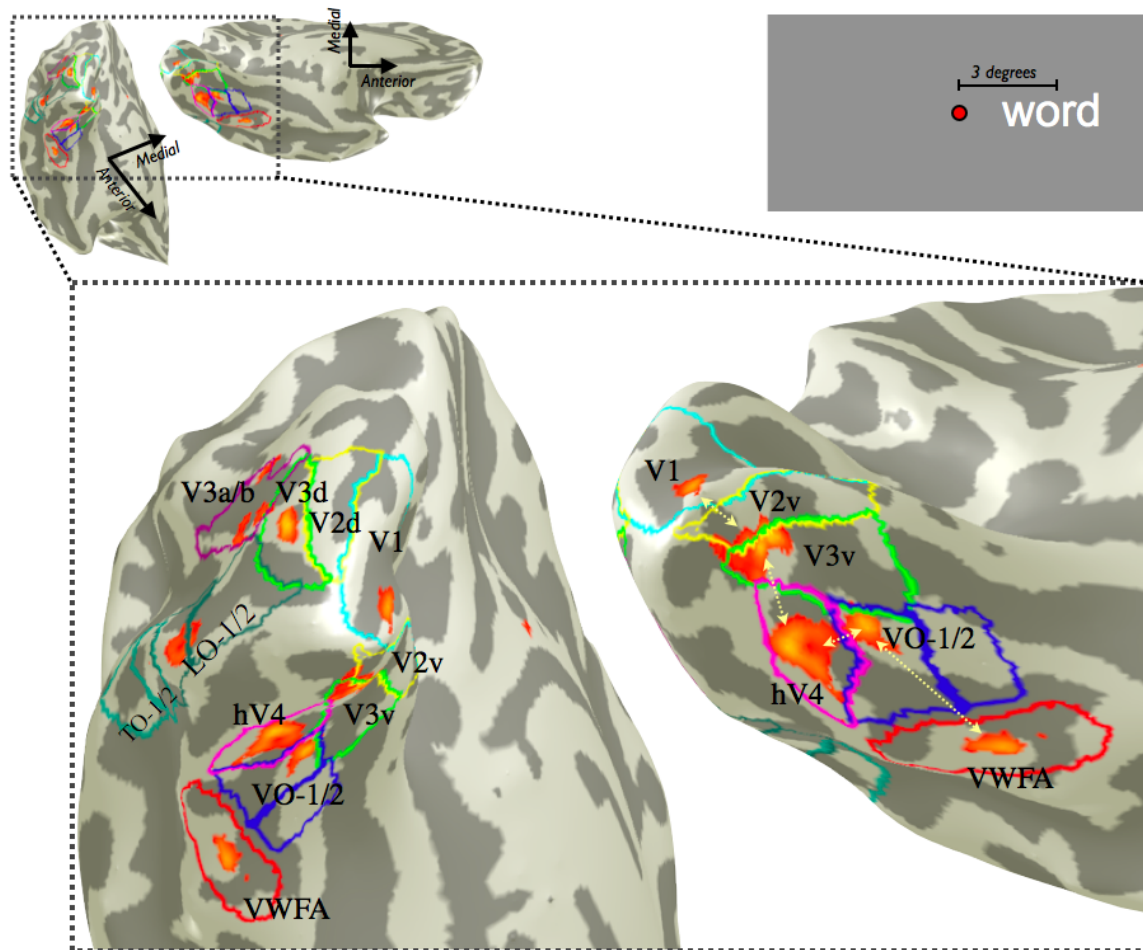
Locating reading circuits and maps



VWFA - essential for reading, but not unique to reading



Measuring the activity while reading (fMRI)

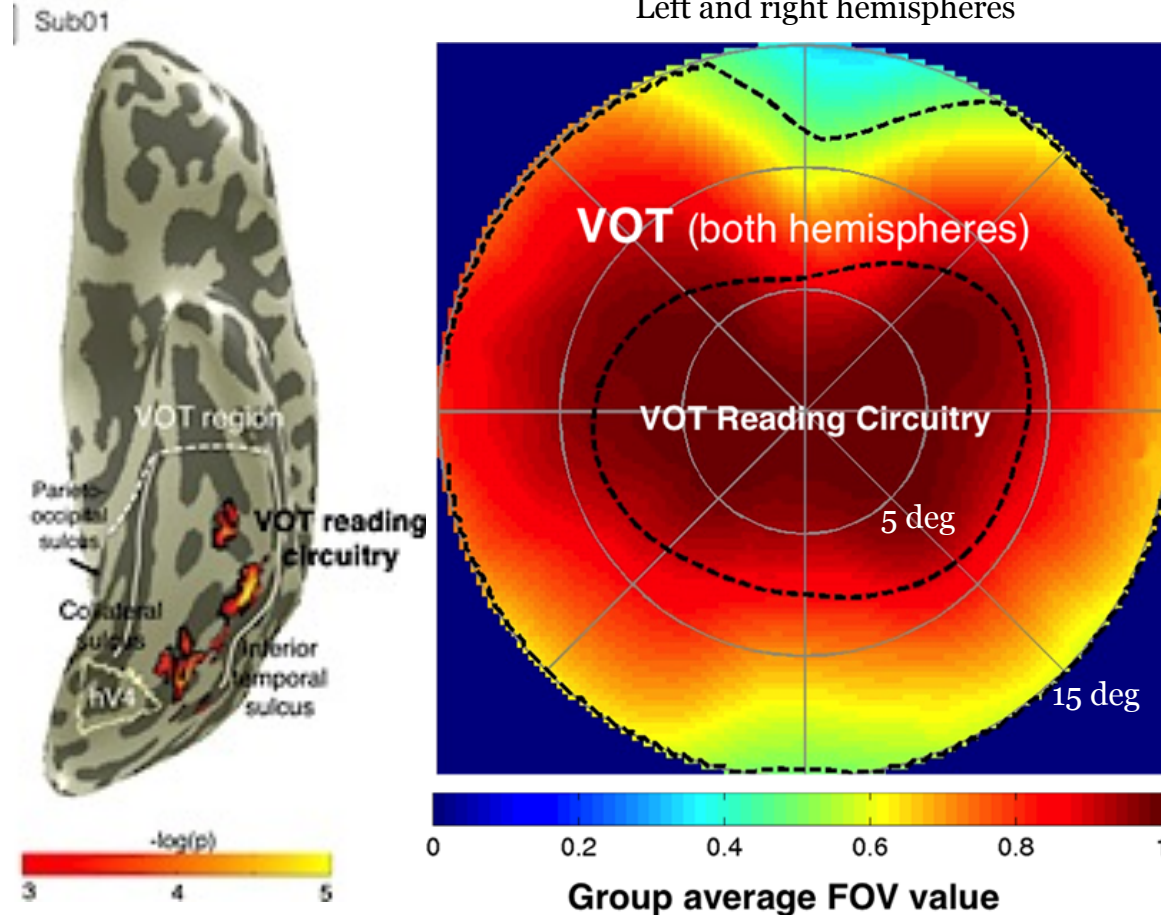


We can see the locations of the cortical activations during reading

Through the maps and on to the VWFA

Small field of view for the reading circuitry

Le et al. 2017
Journal of Vision

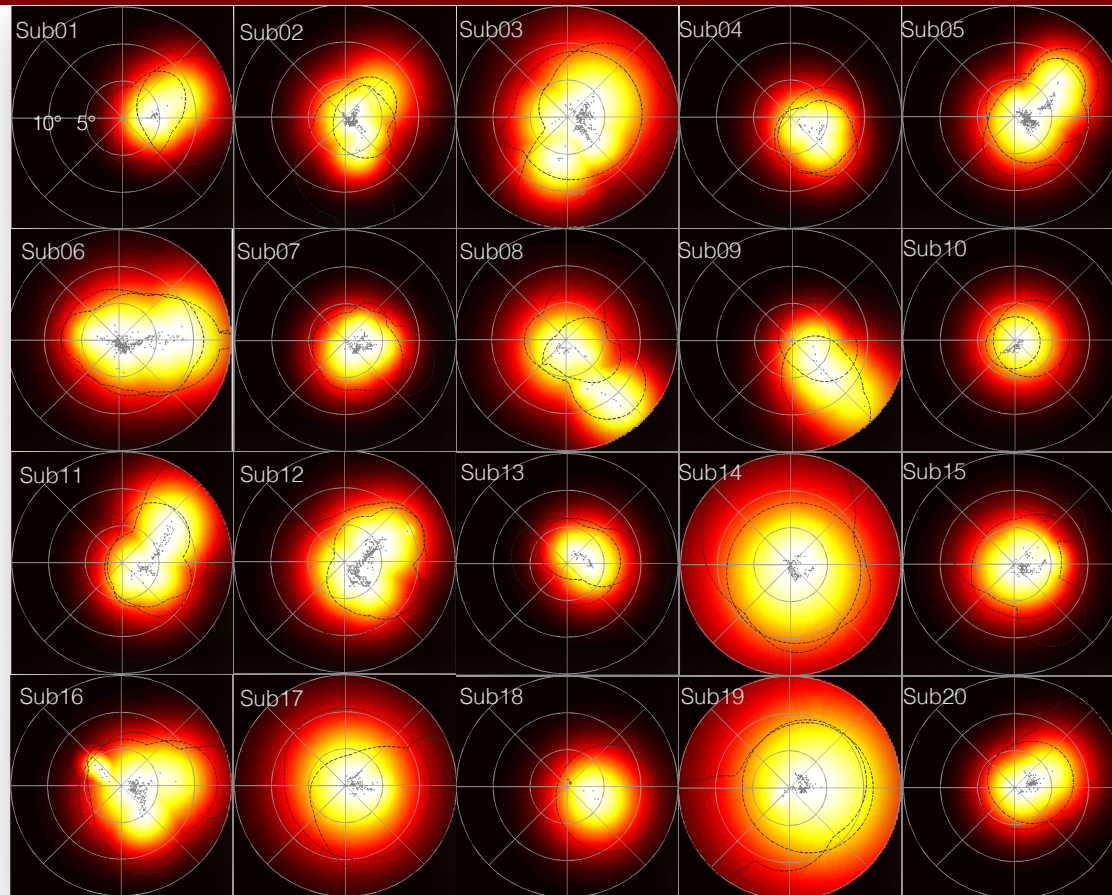


The portion of cortex engaged in reading only sees a small part of the visual field

This may be why it is very hard to read in the peripheral field

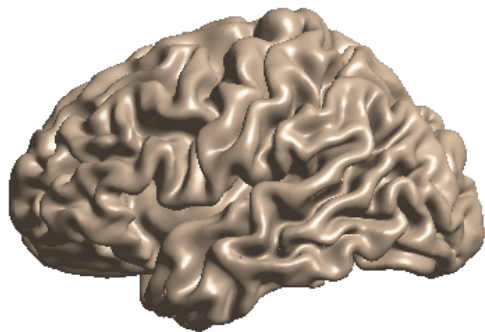
Field of view of the VOT reading reading circuitry

Left hemisphere only



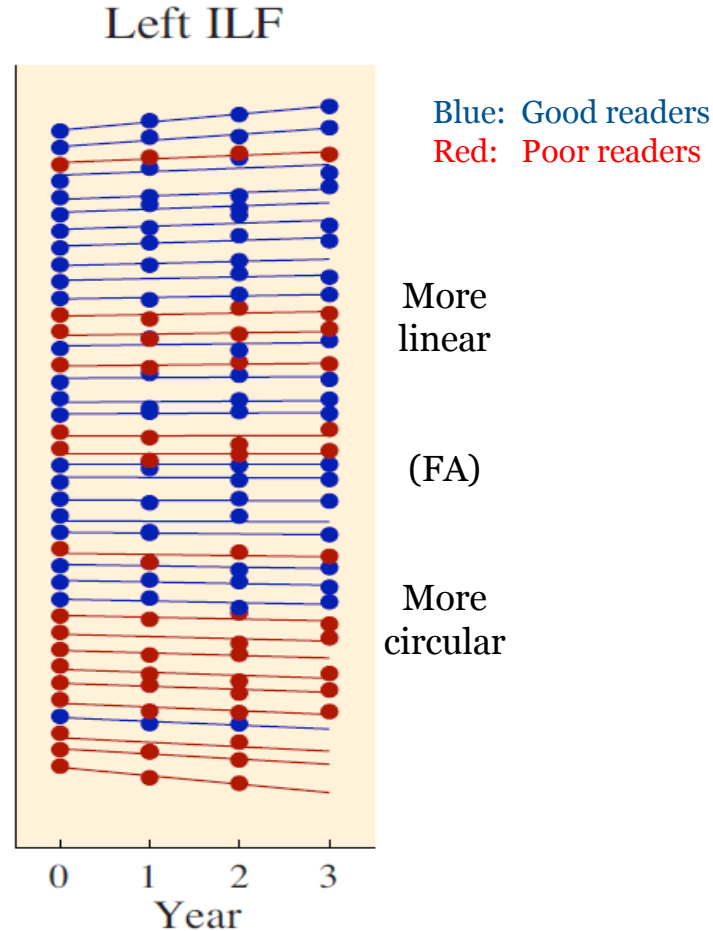
- There are significant differences between subjects
- Yes, we are correlating these differences with measures of word recognition
- FOV value: relative effectiveness in evoking a response in ROI

Diffusion (FA) changes differs between good and poor readers

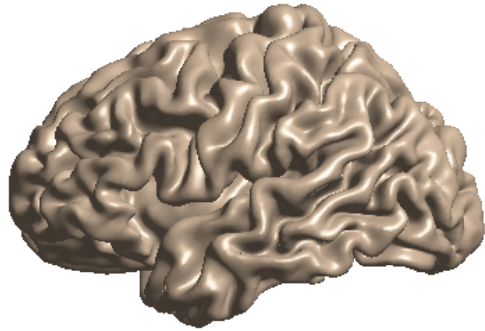


Fractional anisotropy (displaced)

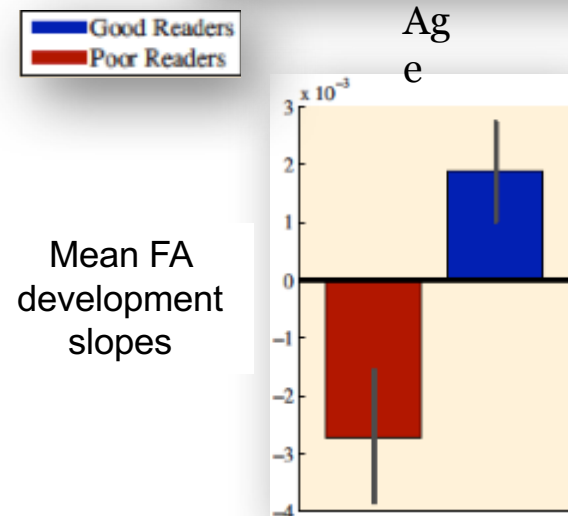
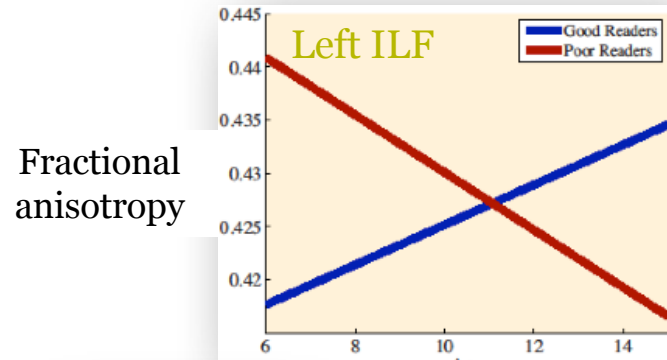
- Measured brain and behavior at 4 time points (**data management!**)
- The first measurements predict reading over the next few years
- The rate and direction of FA development differs between good and poor readers in both the Arcuate and the ILF



Diffusion (FA) changes differs between good and poor readers



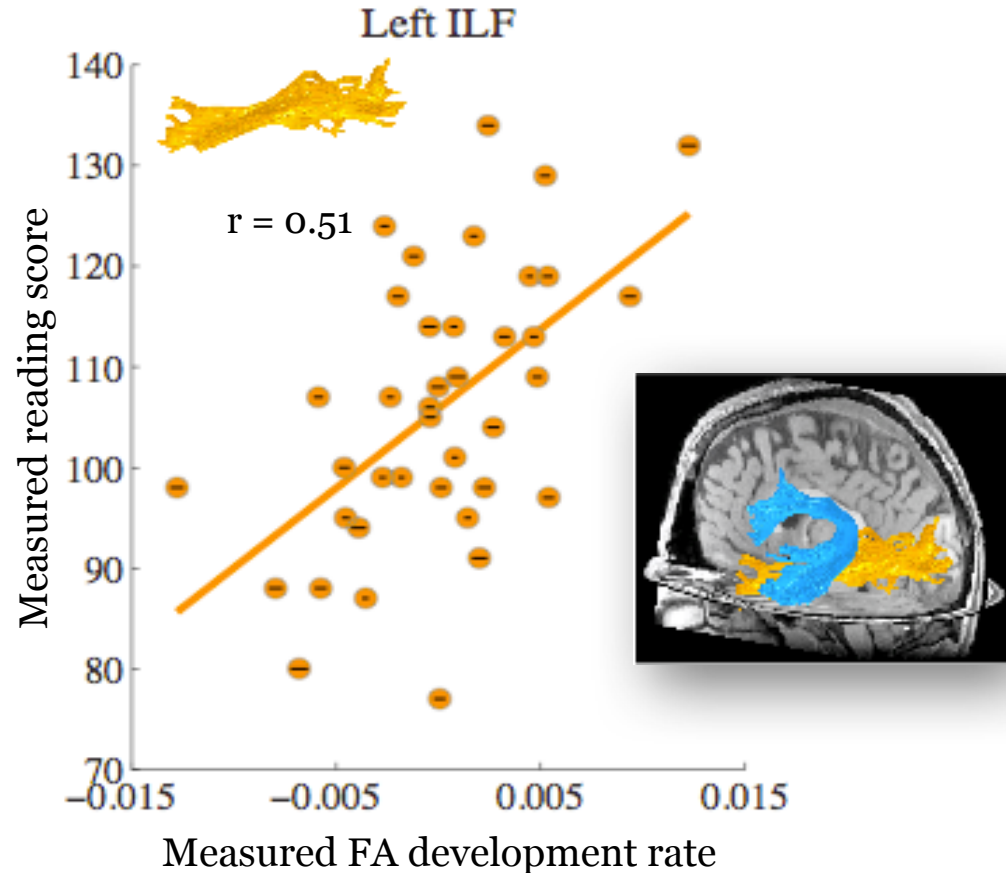
- Measured brain and behavior at 4 time points (**data management!**)
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Correlations between tract diffusion change and seeing words

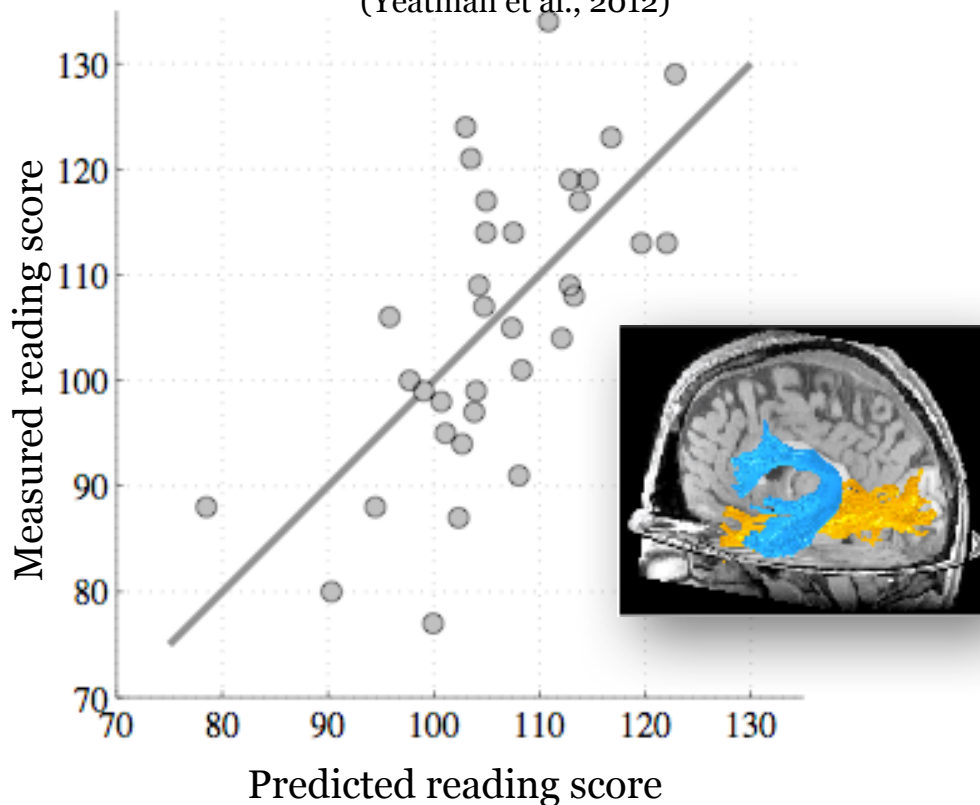
(Yeatman et al., 2012, *PNAS*)

- Development measured by dMRI in the ILF and Arcuate, but not others tracts, correlates with the ability to rapidly see words
- This is one reason we think that the wires are active, changing in response to learning and memory



Neuroprognosis

Predicting reading scores from rate of white matter development
(Yeatman et al., 2012)



- Simple models that combine tissue properties from two tracts (ILF and AF) predict measured reading skill
- The predictions are not yet useful; they are statistically reliable

Project on Scientific Transparency

11817	10970	9935	9548	8707	8290	8008	8058	7188	8078	11981	8177	8339
12288	10949	11142	10812	9498	10285	8817	7910	7180	8208	9944	9071	9088
11897	11823	11291	9469	7995	8438	8379	4482	8252	7288	7730	8490	9184
12549	10858	7881	8330	8778	8878	4848	4888	6177	7448	8888	7382	8878
11712	8763	7782	9112	7111	8838	8881	8882	8888	6111	8178	7882	7881
12848	10888	8488	10711	8881	11888	7111	8711	4888	8888	10874	8872	8288
11788	10788	8781	8881	8888	7111	8888	8411	8388	7888	1782	8888	8738
9888	8888	1078	7888	8818	10844	10824	10881	8812	8777	8321	7881	10388
8818	7848	8881	8711	8888	10888	12188	12874	12881	12877	10781	1888	10347
8878	8714	8887	8481	8884	11127	12881	18887	13888	14894	14784	11882	11882

Project on Scientific Transparency

POST

POST aims to revolutionize the way that neuroscience imaging research is done.
Click to learn more about the Project on Scientific Transparency.

Reproducible research and diagnosis

Computational reproducibility is not an afterthought—it is something that must be designed into a project from the beginning.

One does need to develop a whole set of programming and research disciplines with the end result in mind and stick with them.



Donoho

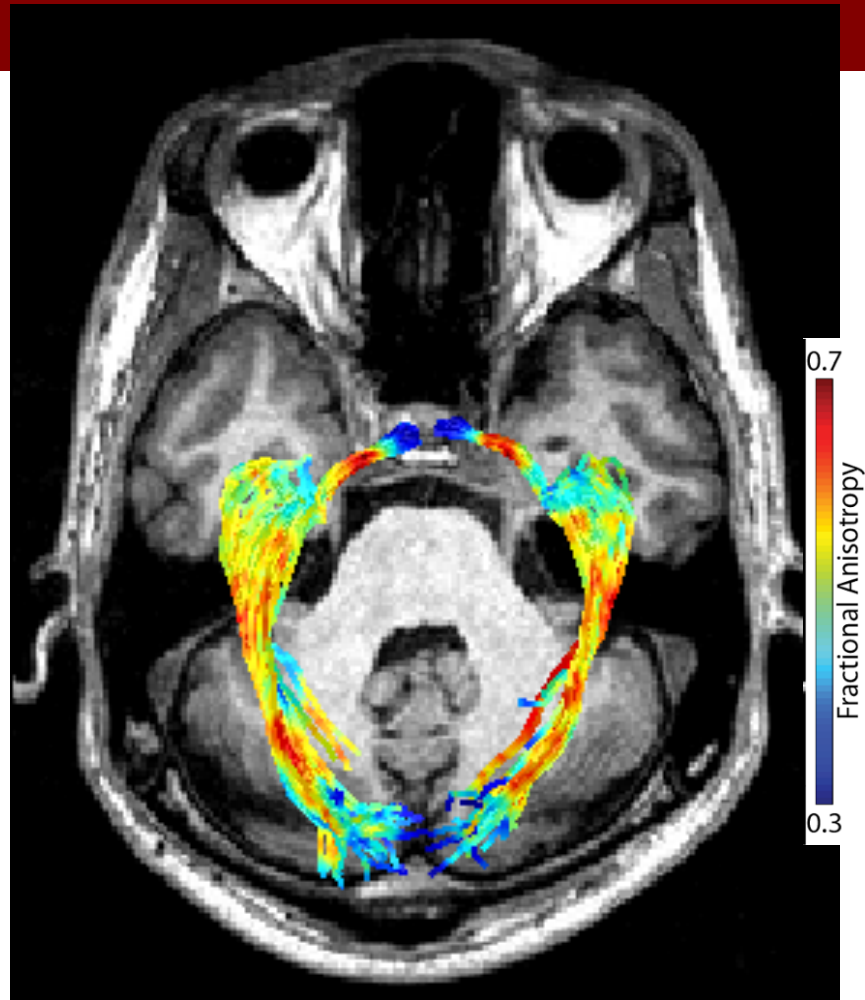
A motivating example

- A subject or patient with a retinal eye disease comes to the lab
- We want to know the consequences of retinal degeneration on cortical structures

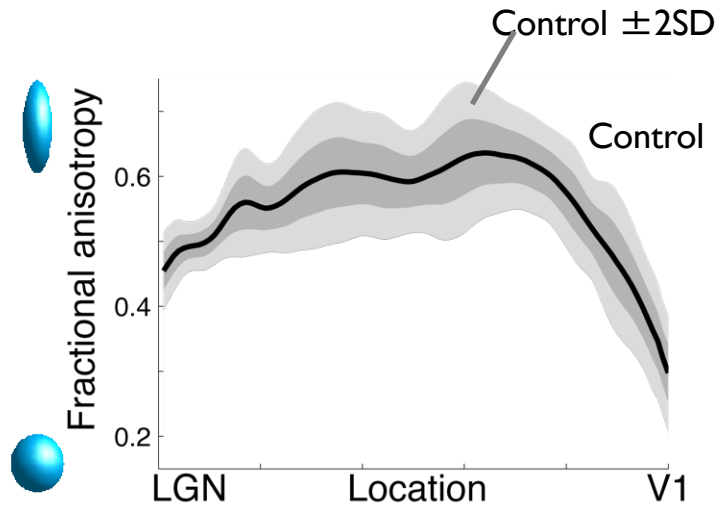


A motivating example

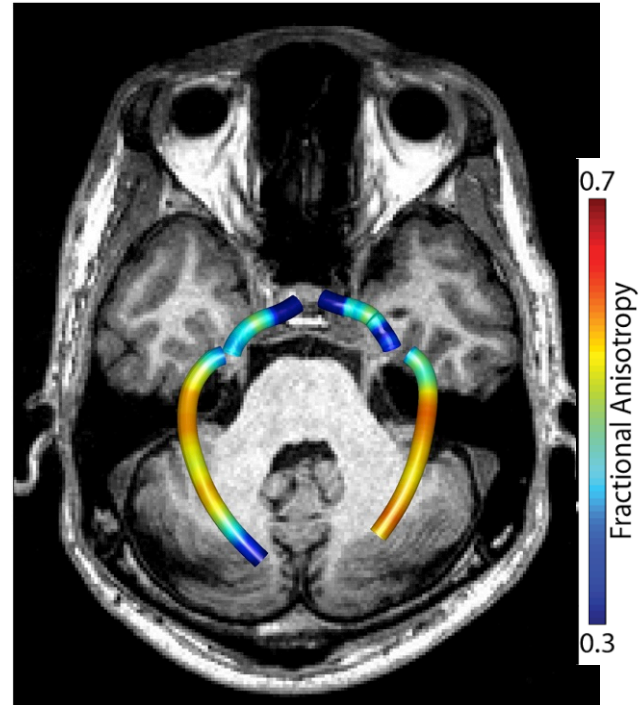
- Measure the subject's visual white matter and secure the data!
- Use validated computational tools for quality assurance
- Use open-source software for tract identification, tissue estimation and comparison with other populations



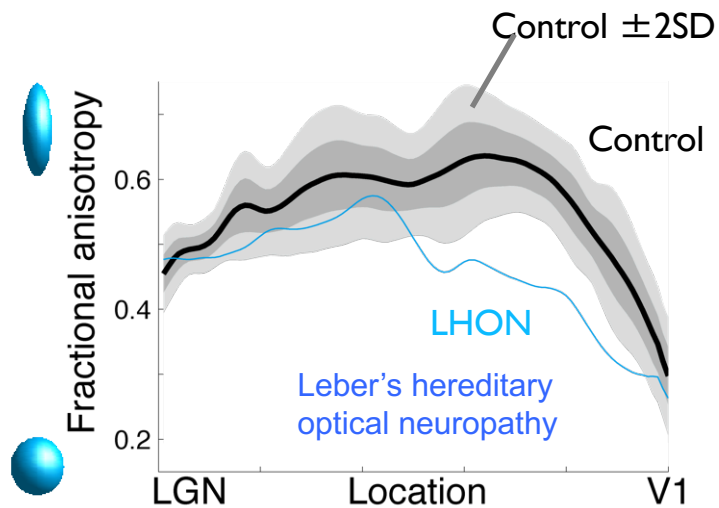
Use databases to find control data



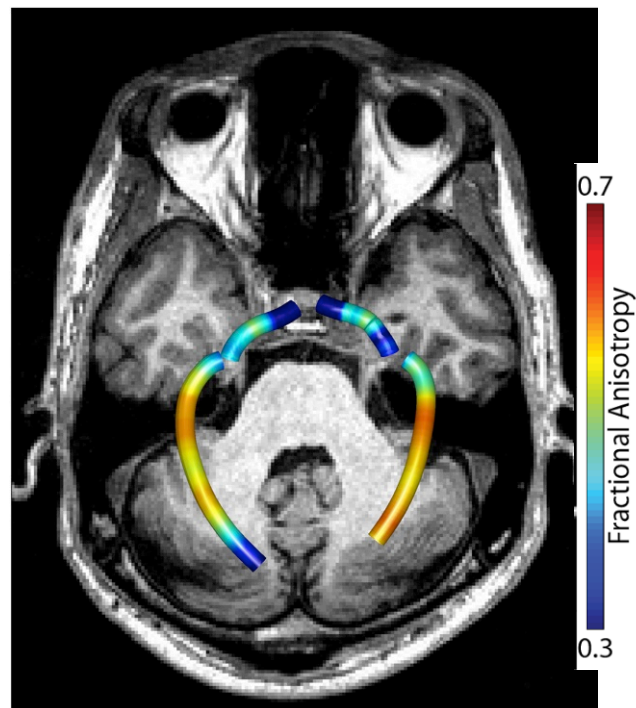
The expectation based on data
acquired and stored



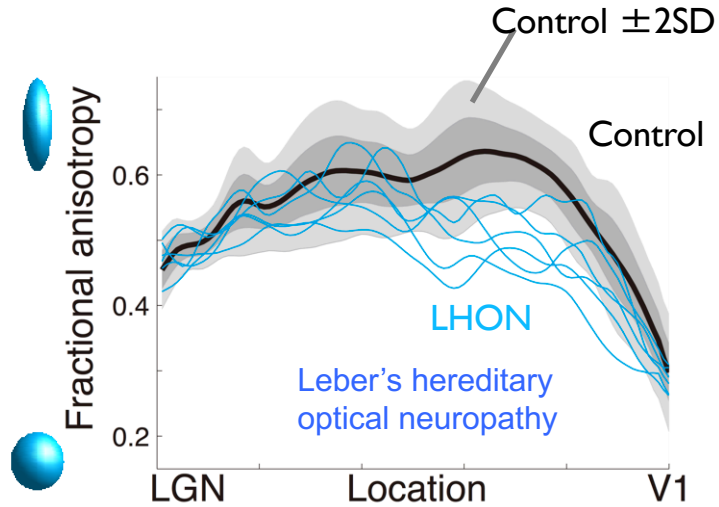
Compare your subject with the distribution and think



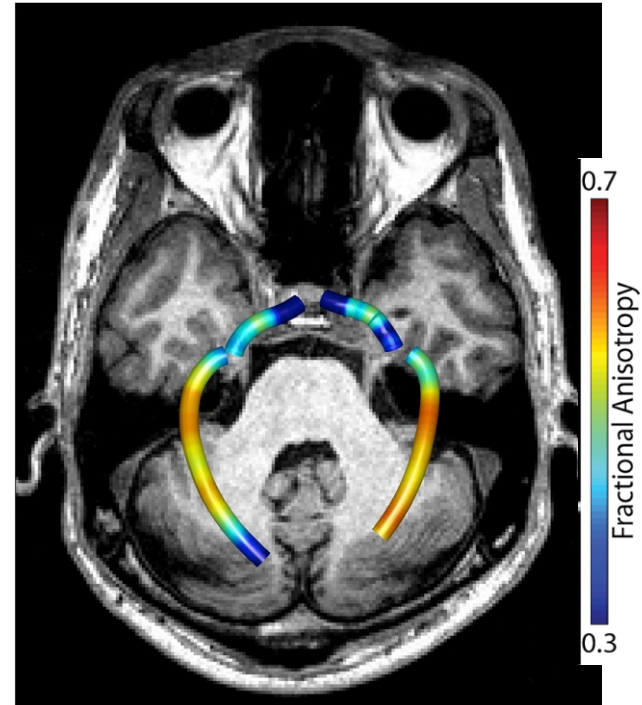
This subject compared to the expectation



Data science and statistics issues



Each subject with the disease has some variation and we would like to know, and track each one over time



Advanced analysis in the Flywheel database (AFQ)

Commercial disclosure:
I am a co-founder of
Flywheel Exchange

The screenshot displays the Flywheel database interface. On the left is a dark sidebar with navigation options: DASHBOARD (Sessions, Collections, Search, Upload), ADMIN (Projects, Collections, Site), and a Manage Site button. At the bottom of the sidebar is the user profile for Brian Wandell. The main content area is titled 'Dashboard • Collections' and shows a table of sessions. The first row is highlighted in blue. Below the table, a detailed view of the selected session is shown, including a timestamp and buttons for 'RUN UTILITY GEAR' and 'UPLOAD DATA'. A table below this view has columns for Time, Measurement, Description, Type, and Tasks.

Dashboard • Collections Displaying 4 of 4

SESSIONS TABLE:

Session Label	All Projects	Subject
20130607_1111_4...	Weston Havens	091_RD
20150803_1518	ALDIT: Stanford CNI	ex10306
2016-02-26 13:25:20	ALDIT: JHU	SNR Test 2
2016-02-24195911	ALDIT: Palo Alto VA	15058_phanto...

Session Details:

Timestamp:

RUN UTILITY GEAR **UPLOAD DATA**

Time	Measurement	Description	Type	Tasks
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Happy Birthday to Dave (with love to Miki and Dan, too)

- About the human brain
- MRI measures of brain activity
- MRI measures of brain connections
- Diagnosing reading
- Software tools for checking and sharing



Arthur Murray Millbrae Dance Studio
January 17, 2015 · 🌐

Top Couple



QUANTITATIVE MEASUREMENTS



COMPUTATIONAL MODELS



CHECK AND SHARE