

Maps, Plasticity and Tracts in Visual Cortex

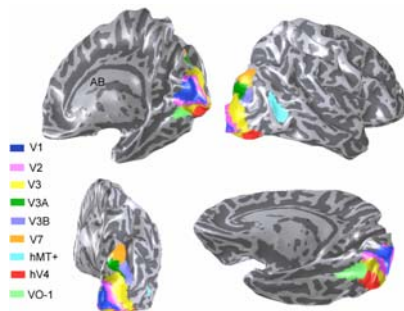
*Brian Wandell
Stanford University*

Collaborators

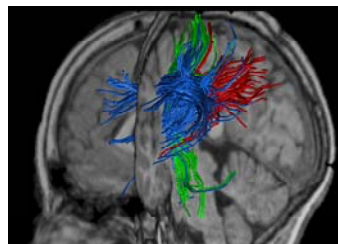
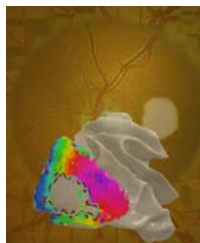
*Robert Dougherty, Alyssa Brewer, Michal Ben-Shachar,
Serge Dumoulin, Anthony Sherbondy*



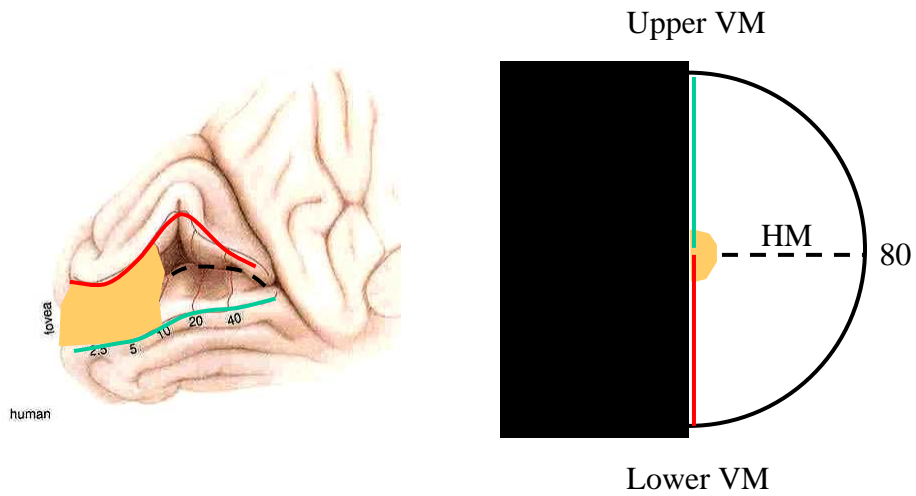
Overview



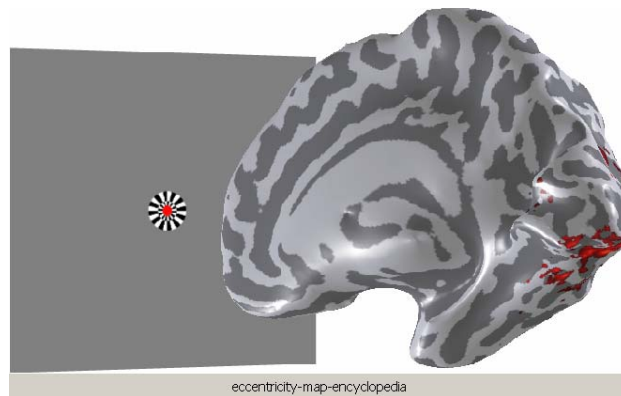
- Visual field maps and clusters
- Cortical plasticity
- Reading development (DTI-FT)



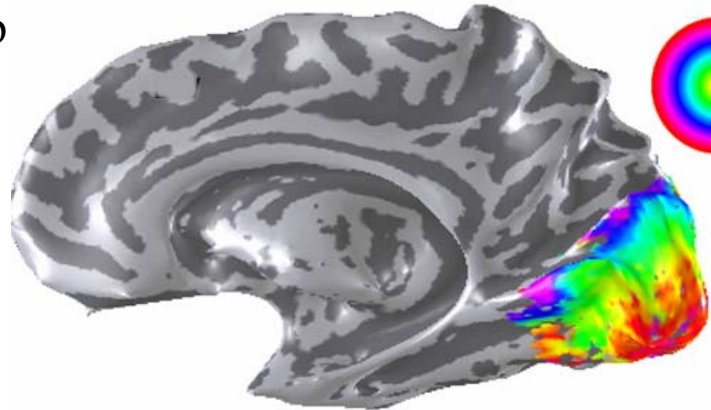
Primary visual cortex (V1) contains a visual field map



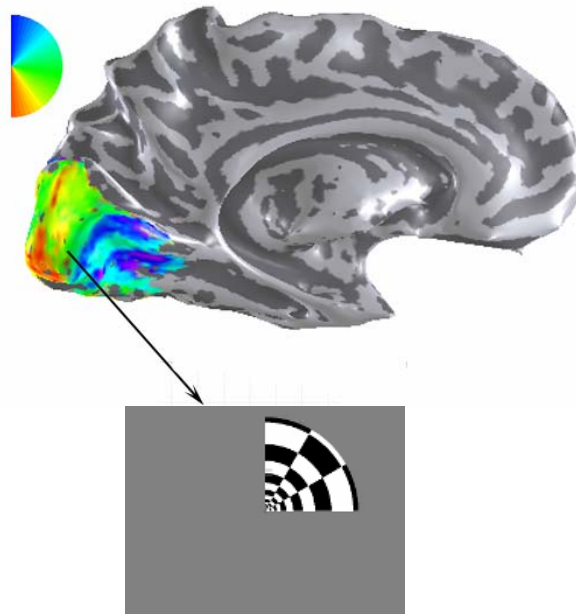
Human eccentricity mapping (Engel et al., 1994,1997; Sereno; DeYoe; Others)



Pseudo-color
representation
of visual field
map

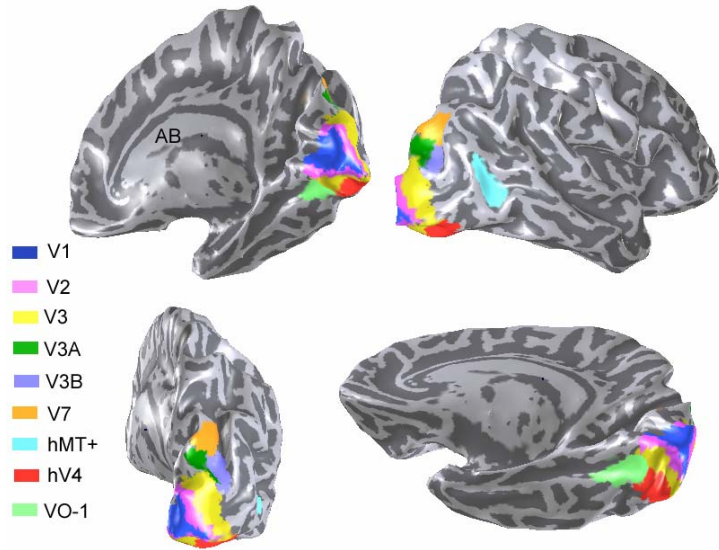


Angular
measurements
sharply
delineate
visual field
map
boundaries



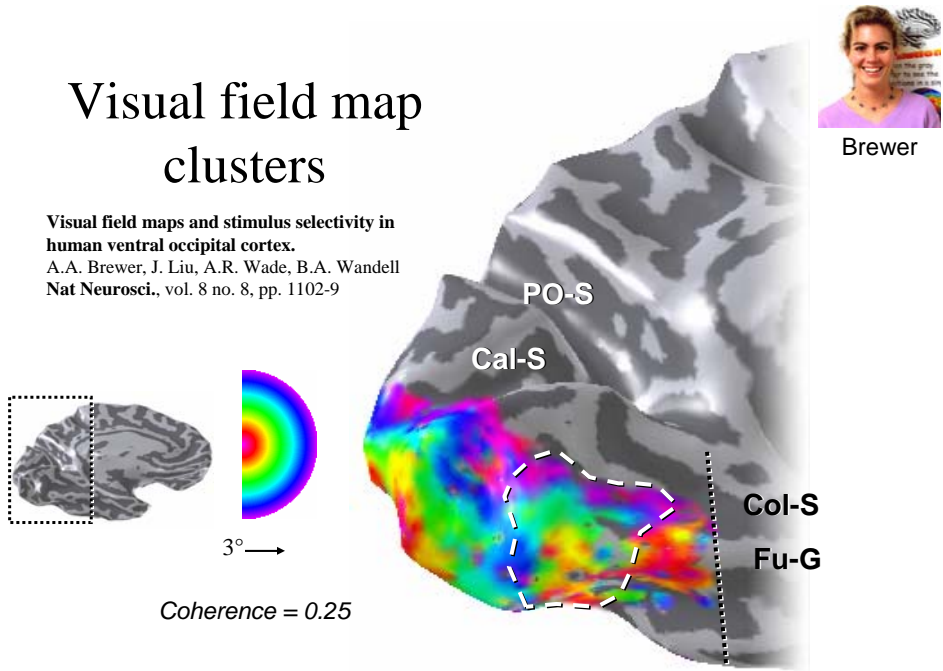
More than nine visual field maps

Wandell et al. (2005) Phil Trans Royal Society



Visual field map clusters

Visual field maps and stimulus selectivity in human ventral occipital cortex.
 A.A. Brewer, J. Liu, A.R. Wade, B.A. Wandell
 Nat Neurosci., vol. 8 no. 8, pp. 1102-9

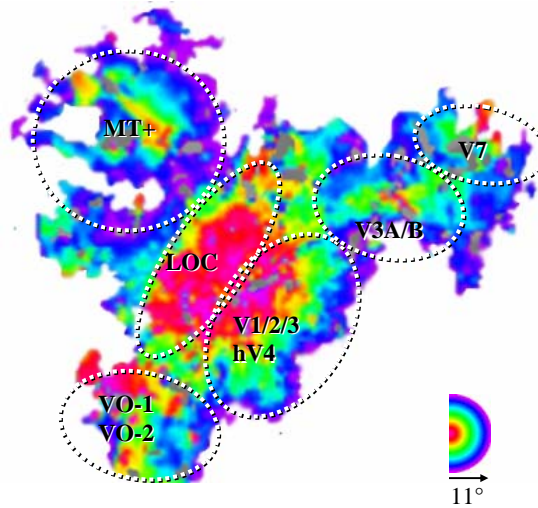


Visual field map clusters

(Wandell et al., 2005, Phil Trans Roy Soc)

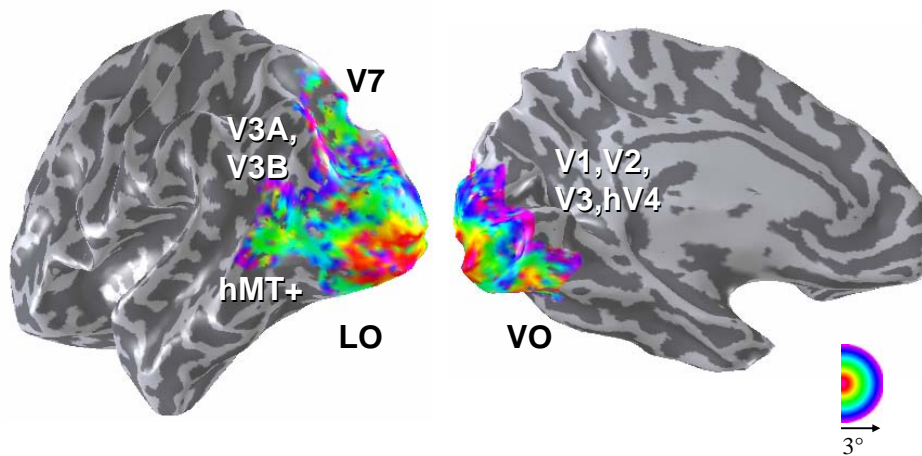
Clusters

- share a common circular or semi-circular eccentricity map.
- contain multiple angle maps within the eccentricity representation.
- may share similar computational resources.



Visual field map clusters

(Wandell et al., 2005, Phil Trans Roy Soc)

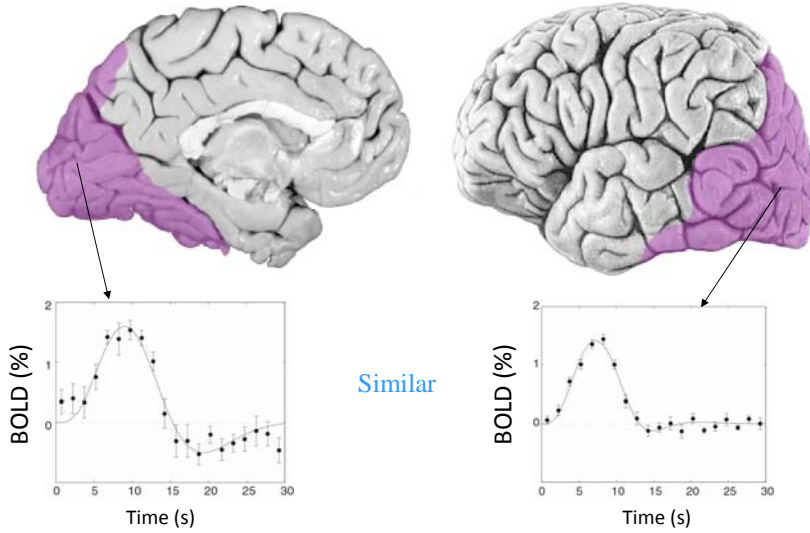


Coherence = 0.20

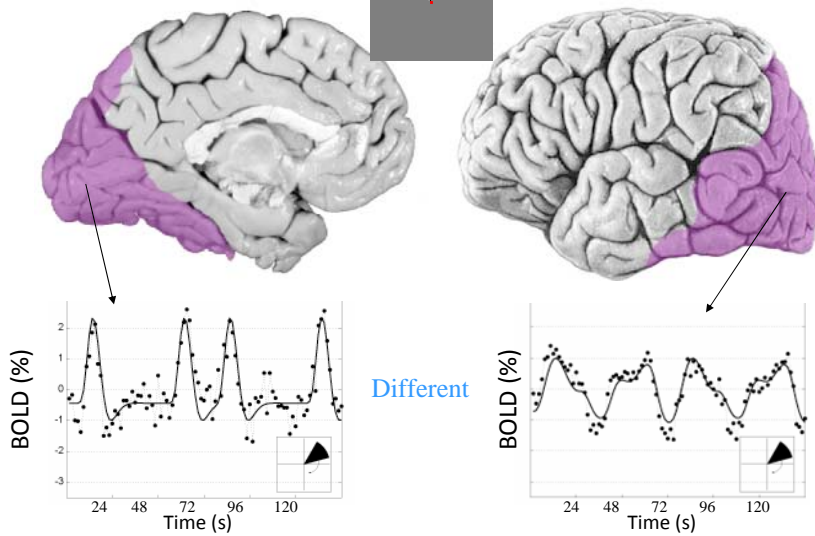
Visually responsive cortex (HRF)



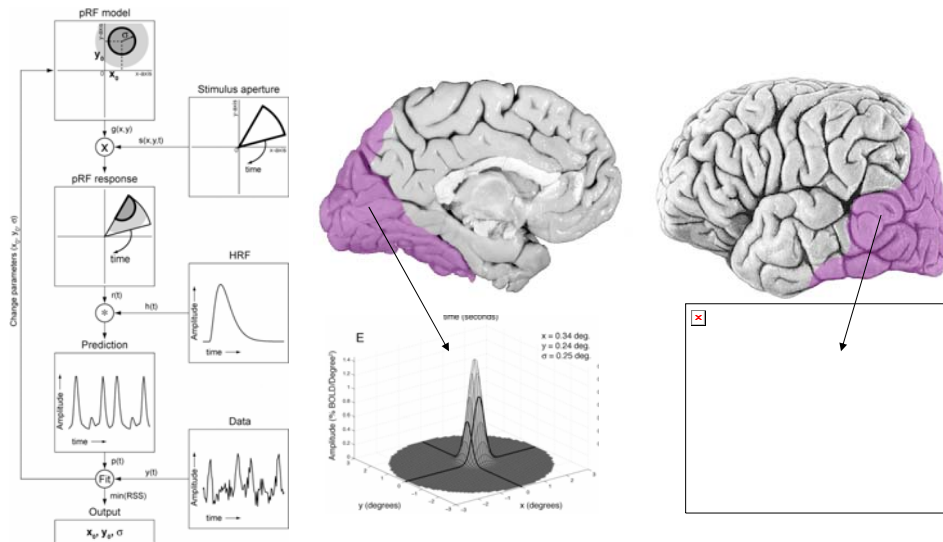
Dumoulin



Visually responsive cortex

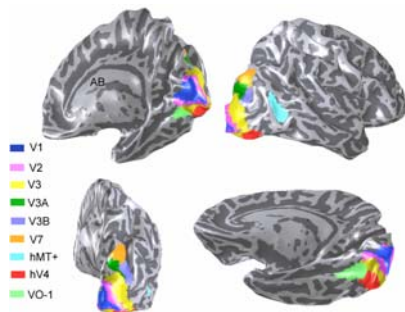


Population receptive field models



Conclusions Part I

Visual cortex can be sub-divided into a multiplicity of visual field maps. Eleven are confirmed. More maps will be reported



Beyond V1/V2, homology between the human maps and those in other species is uncertain.

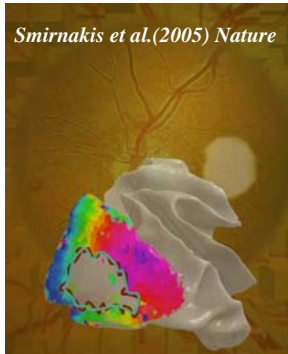
Maps are organized into distinct clusters that share a common eccentricity map but can be distinguished based on their angle maps.

Cortical Plasticity



Fine et al. (2004) Nat. Neuro

- **Recovered sight**



Smirnakis et al.(2005) Nature

- **Retinal lesions**

Recovered sight

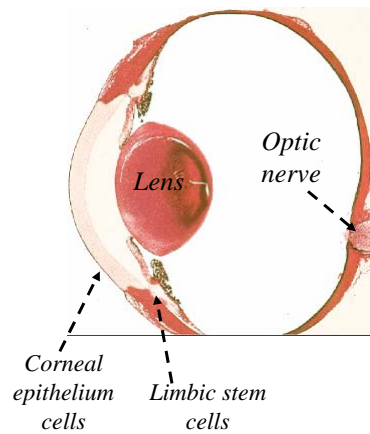
(Fine, Brewer, Wade, MacLeod, Wandell, Nature Neuroscience, 2002)



Ione Fine



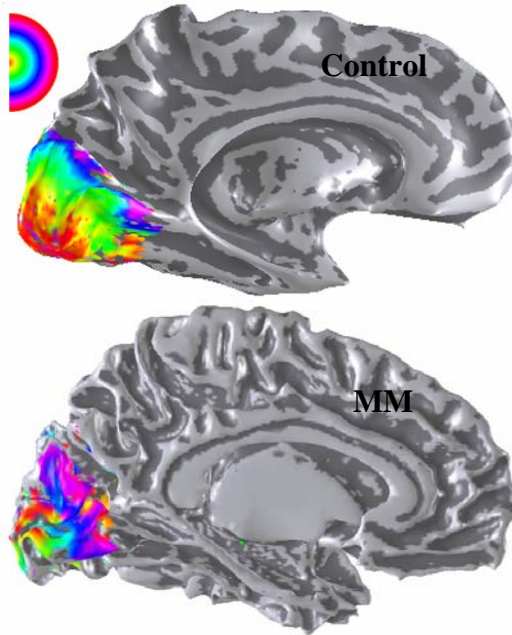
- Chemical accident at 3 yrs
- One eye lost; other cornea destroyed
- Blind from age 3 through 46
- Stem cell replacement in right eye for both epithelium and stem cells



MM's visual field maps differ from normal controls

(May 1, 2001)

- *Smaller area*
- *Portions of visual cortex fail to respond*
- *Ask me about macular degeneration*



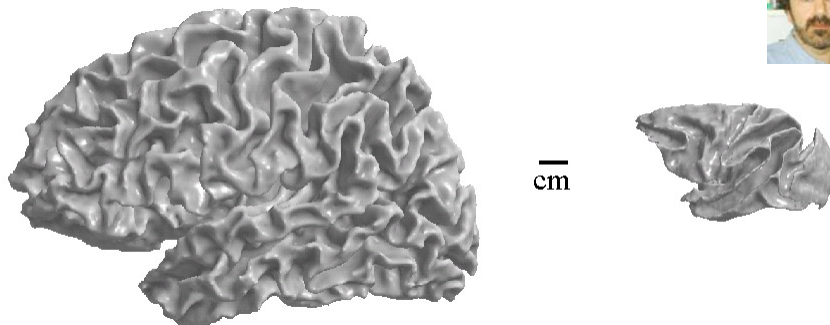
Macaque measurements (Logothetis Lab)

Potential for molecular and pharmacological studies of cortical plasticity

Smirnakis



Logothetis



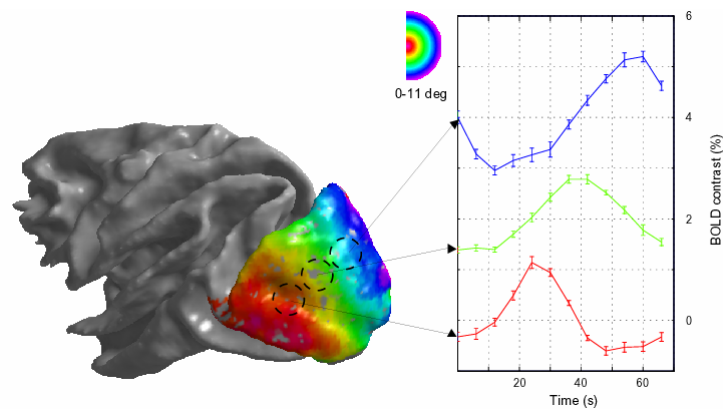
Logothetis rig for monkey fMRI (4.7T)

*Applications of visual
field mapping to
retinal dystrophies*

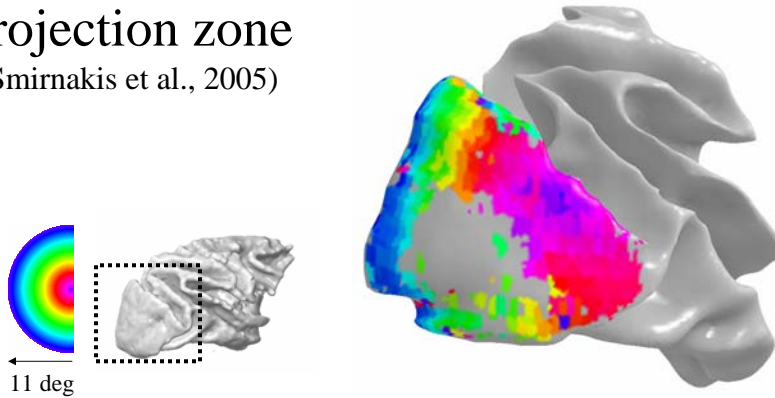
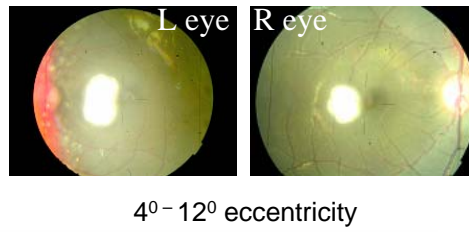


Visual field mapping in macaque

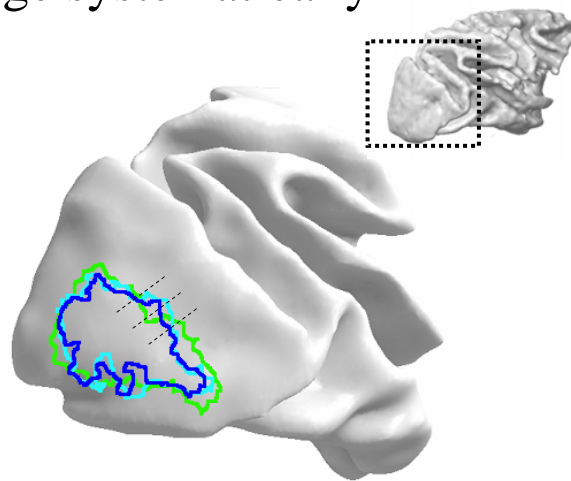
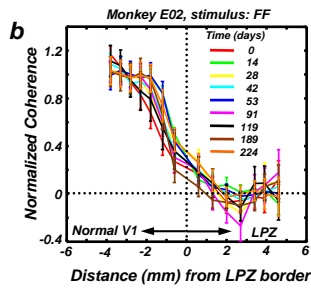
(Brewer et al., 2002, J. Neuroscience)



Retinal lesions
eliminate
activity in the
projection zone
(Smirnakis et al., 2005)

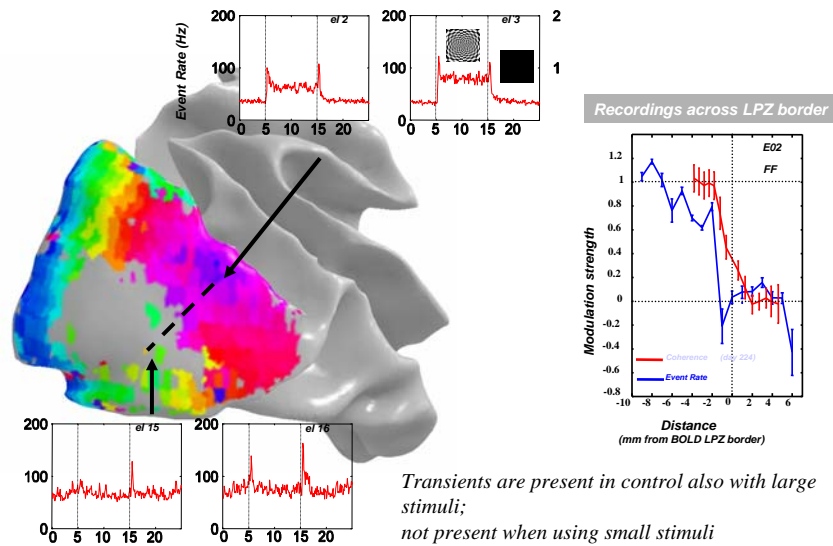


The margins of the scotoma did not
change systematically

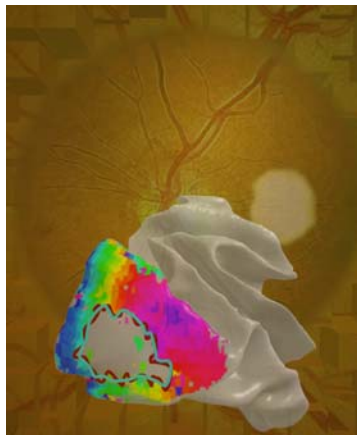


- Scotoma at 0 days
- Scotoma at 2 wks
- Scotoma at 4 months

Single-Unit recordings confirm



Conclusions Part II

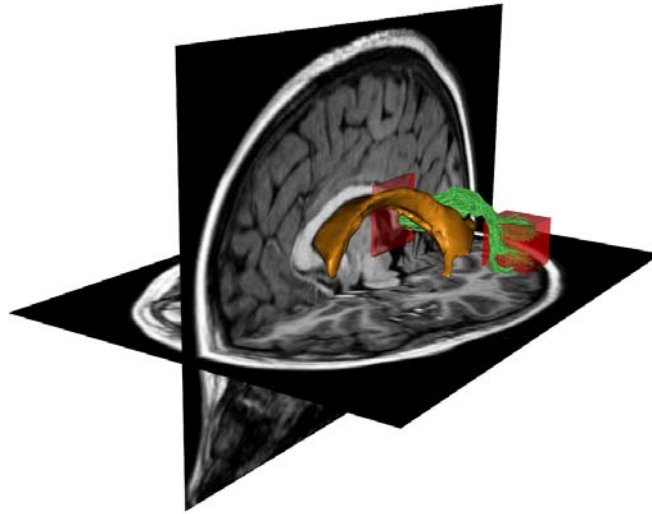


(Smirnakis et al., 2005)

- Plasticity exists in some cases (MM) but not all.
- “Over a period of 4-7 months, we observed no significant change in the position of the BOLD-defined LPZ border. Abnormal BOLD responses in the LPZ were confirmed by electrophysiological measurements of multi unit action potentials. Together, these experiments suggest that little long-term reorganization occurs in the LPZ, and that neuronal responses in the LPZ do not recover to anything approaching their normal state.”

Stelios M. Smirnakis^{1,2}, Alyssa A. Brewer^{3*}, Michael C. Schmid^{1*},
Andreas S. Tolias¹, Almut Schütz¹, Mark Augath¹, Werner Inhoffen⁴, Brian
A. Wandell³ & Nikos K. Logothetis¹.

Diffusion tensor imaging and fiber tractography of human brain pathways



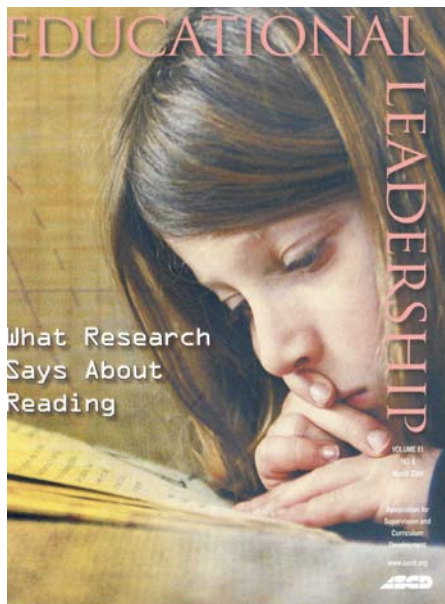
Dougherty



Ben-Shachar



Sherbondy



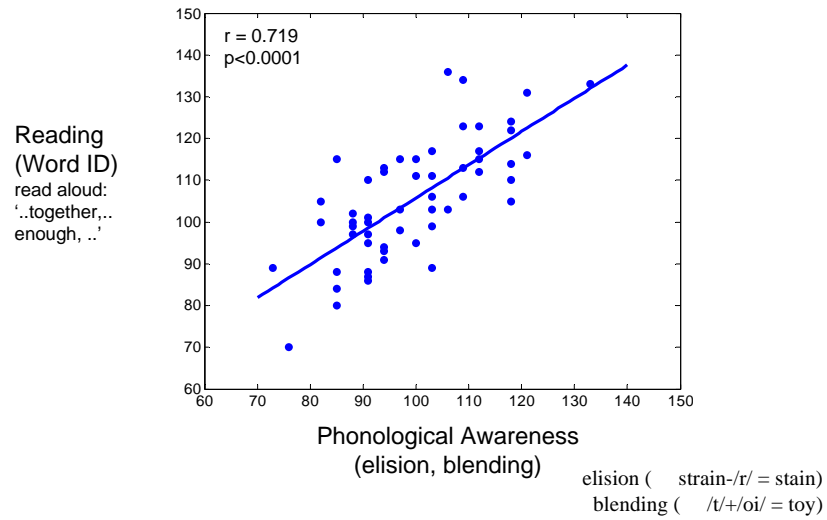
March 2004 • Volume 61 • Number 6

What Research Says About Reading

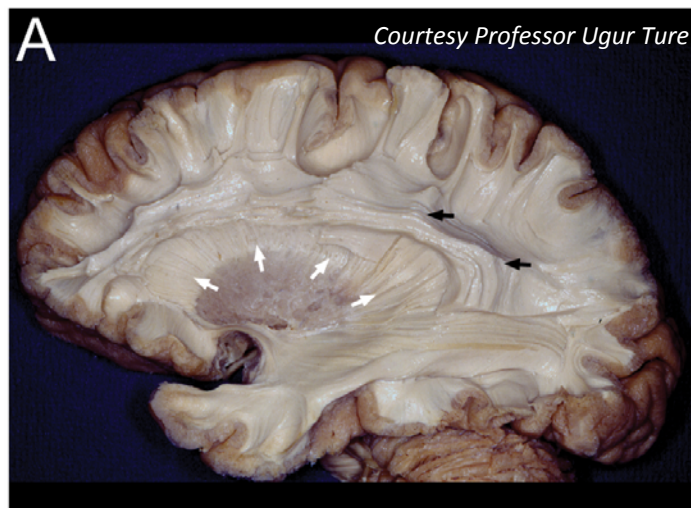
<p>6 Reading Disability and the Brain Sally E. Shaywitz and Bennett A. Shaywitz <i>Neurological research suggests that systematic phonics instruction can help many individuals overcome dyslexia.</i></p> <p>12 The Science of Reading Research G. Reid Lyon and Vicki Chhabra <i>The authors assert the primacy of peer-reviewed, quantitative research in judging "what works" in reading.</i></p> <p>18 False Claims About Literacy Development Stephen Krashen <i>The National Reading Panel has made research mistakes of its own.</i></p> <p>22 Setting the Record Straight Richard L. Allington <i>The research-supported reading intervention for at-risk students is learning-to-read exposure progression, the author asserts.</i></p>	<p>26 Research on Reading: A Cautionary Tale Gregory Camilli and Paula Smith <i>A close look at the research reveals that having and direct and differential instruction are an ideal in reading success as is systematic phonics.</i></p> <p>30 Making Words Stick Connie Just and Rebecca Duffin <i>Instruction that encourages students to actively analyze word meaning is far more effective than simply looking about word meaning in the context of reading.</i></p> <p>35 Phonics Instruction for Older Students? Just Say No Kay Iry and Marianne L. Baker <i>Intensive phonics training for older students wastes instructional time that could be used to help students make sense of real texts.</i></p> <p>40 The Case for Informational Text Neil K. Duke <i>Why nonfiction should take a more prominent place in the primary reading program.</i></p> <p>46 Creating Fluent Readers Teresa Beckett <i>The author describes how to track and improve automatic reading.</i></p> <p>52 How Do English Language Learners Learn to Read? Robert E. Slavin and Alan Chung <i>Stronger instruction emphasizing systematic phonics is the most effective approach.</i></p>
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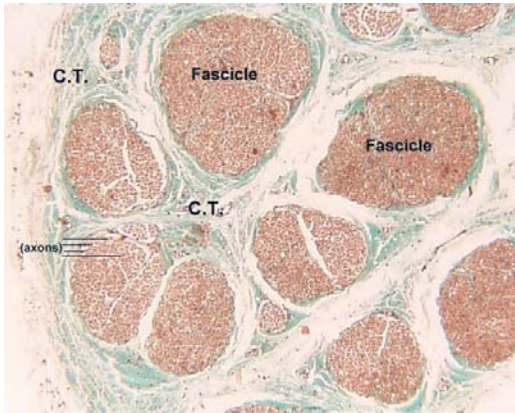
Word reading correlates with phonological awareness (Ben-Shachar, Deutsch, Dougherty, Wandell)



Human fiber tracts



Human fiber tracts

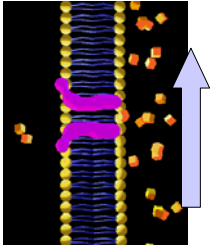


Taken from course notes at UCLA, Neurobiology 104
http://neuromedia.neurobio.ucla.edu/campbell/nervous/wp_images/182_TS_LP.gif

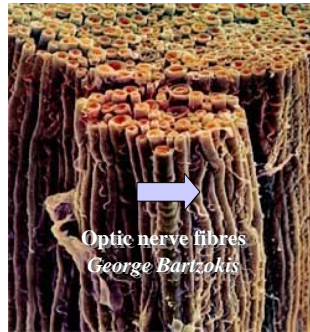
H₂O
diffusion
probes
membrane
properties in
the brain



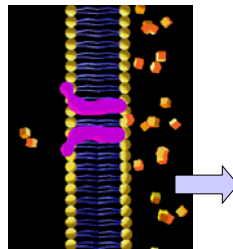
Along the axon, within the cytoskeleton, there is a large Apparent Diffusion Coefficient (ADC)



H₂O
diffusion
probes
membrane
properties in
the brain

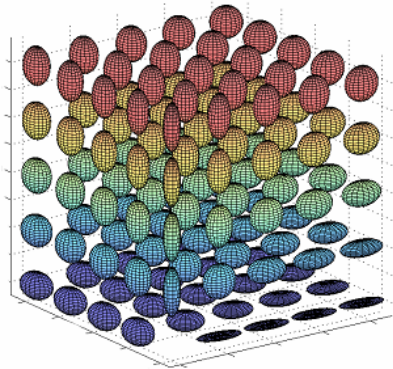


*Bi-lipid cell membranes
limit diffusion.
Hence, perpendicular to
the length the ADC is
smaller*



DTI data sets are volumes
of diffusion surfaces

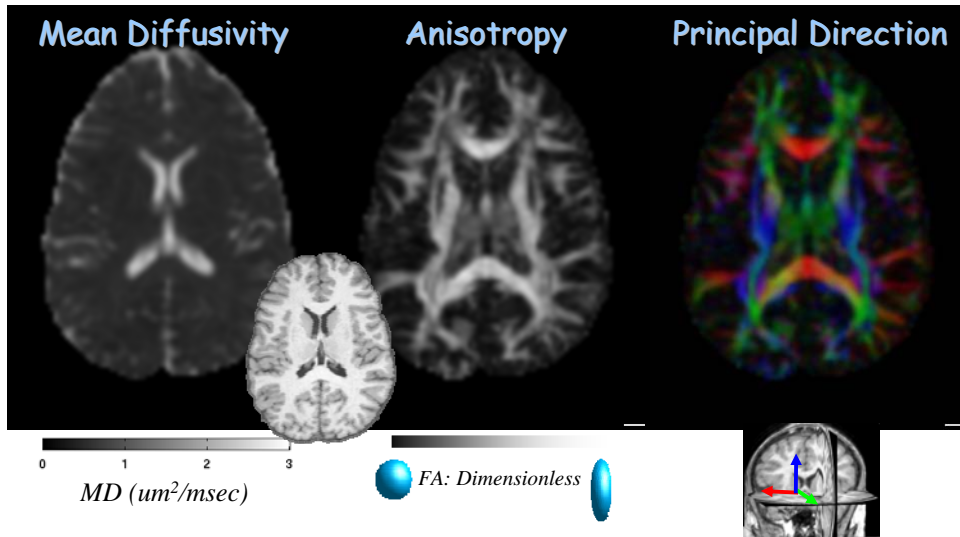
Diffusion data are surfaces



*Conventional MR volumes
are real-valued*

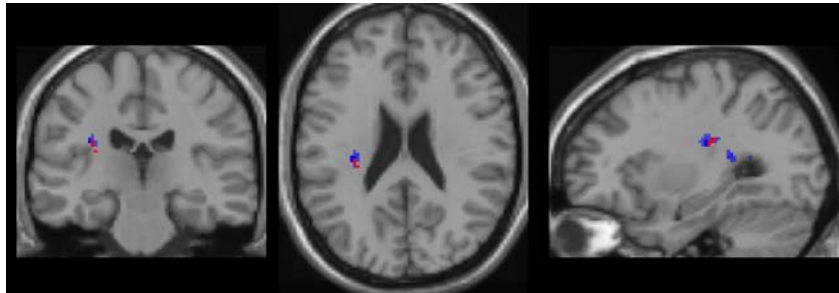


DTI Analyzes White Matter Structure

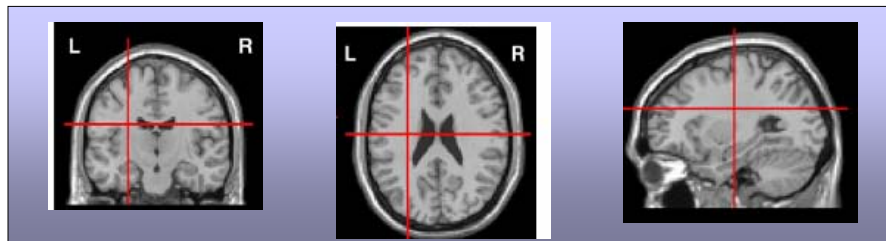


In children FA correlates with reading skill

Deutsch, Dougherty, Bammer, Siok, Gabrieli, Wandell (2005)

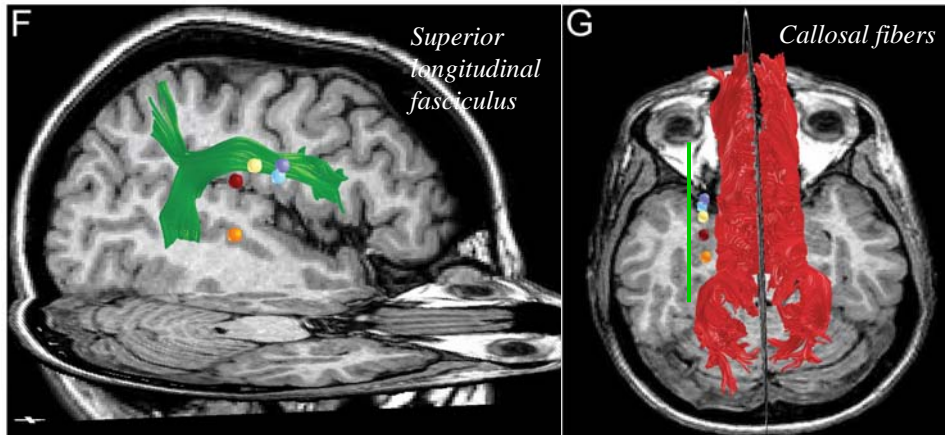


Beaulieu C, Plewes C, Paulson LA, Roy D, Snook L, Concha L, Phillips L. (2005).

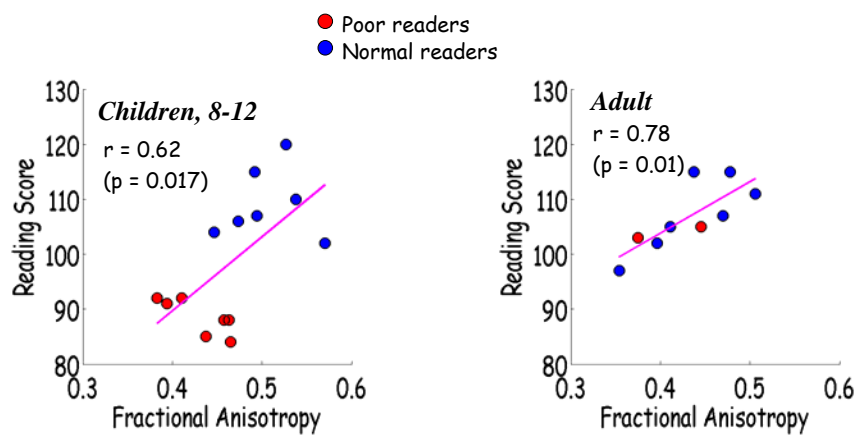


Location of FA difference with respect to major bundles

(Ben-Shachar et al., 2007)



A correlation is present in children and adults



There is a directional difference in anterior cortex (N=14)

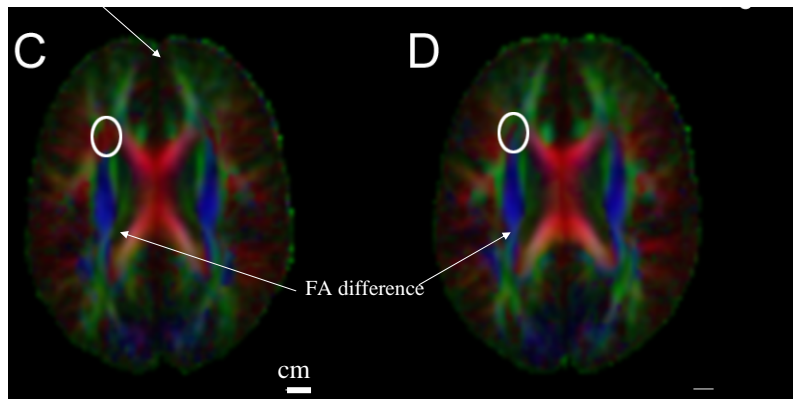
(Ben-Shachar et al., 2007)



Dougherty

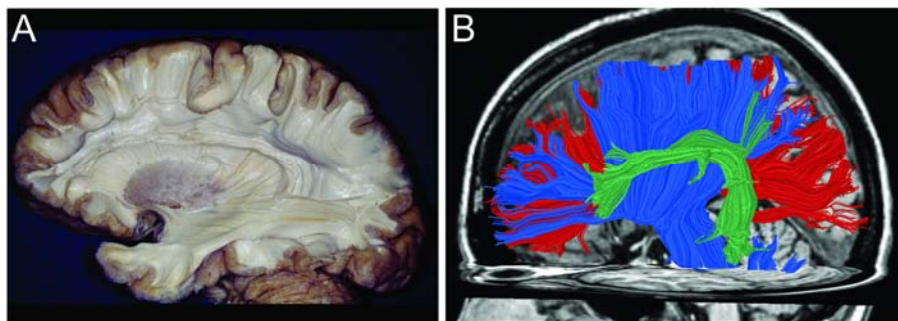
Good Readers

Poor Readers

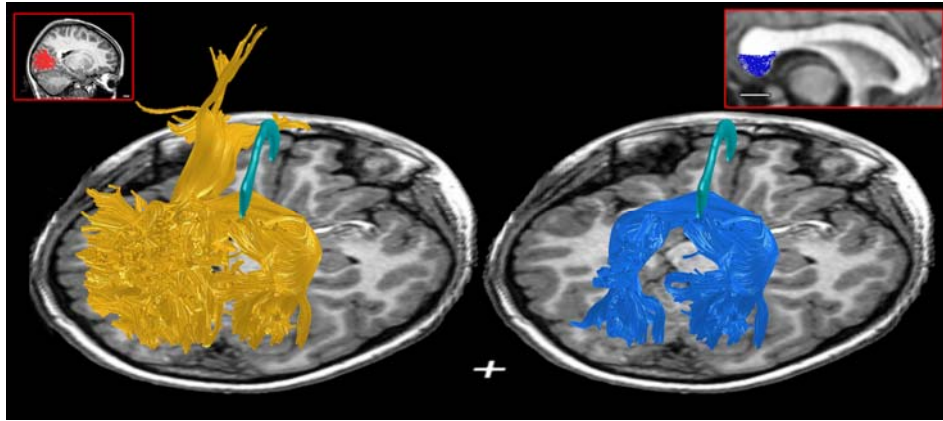


Relating diffusion imaging to white matter tracts

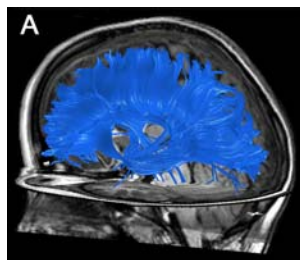
(Ben-Shachar et al., 2007, Current Opinions Biology)



DTI-FT Limitations

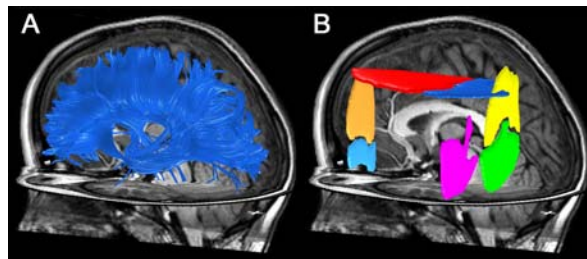


Segmentation of the callosum based on projection zones



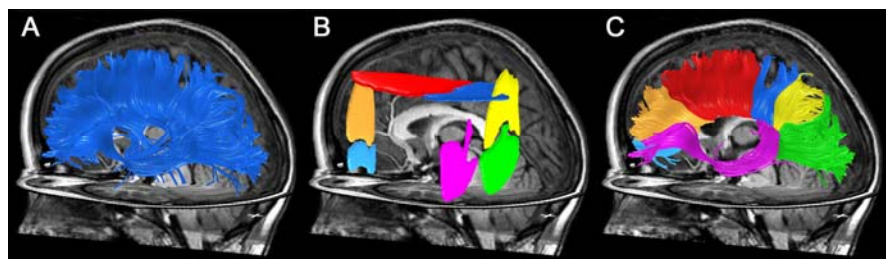
All callosal fibers

Segmentation of the callosum based on projection zones



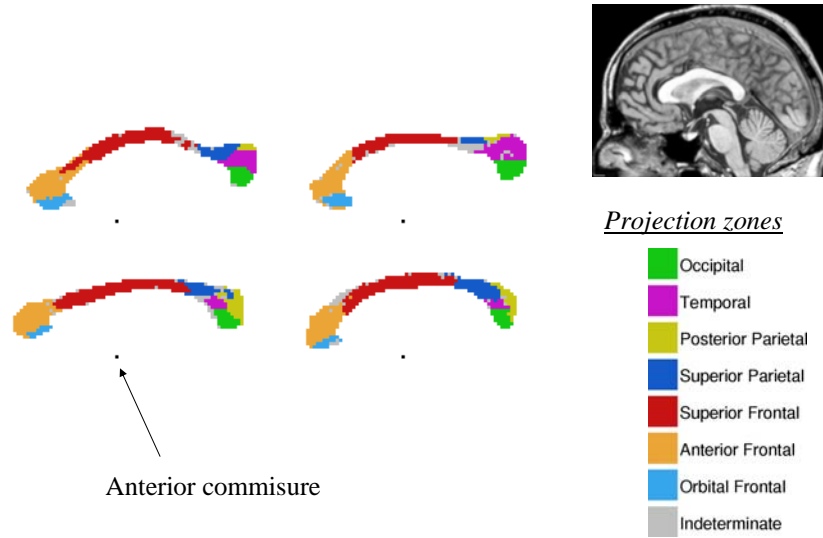
All callosal fibers → Regions of interest

Segmentation of the callosum based on projection zones

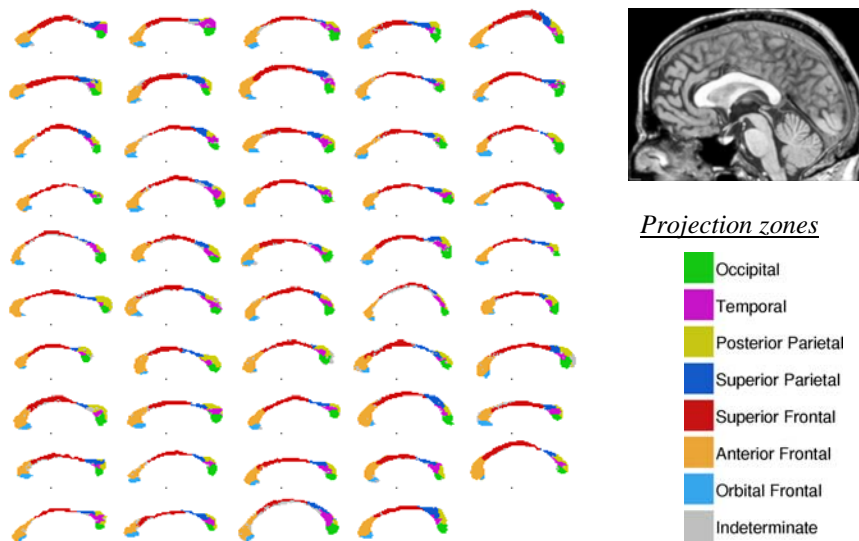


All callosal fibers → Regions of interest → Segmented fibers

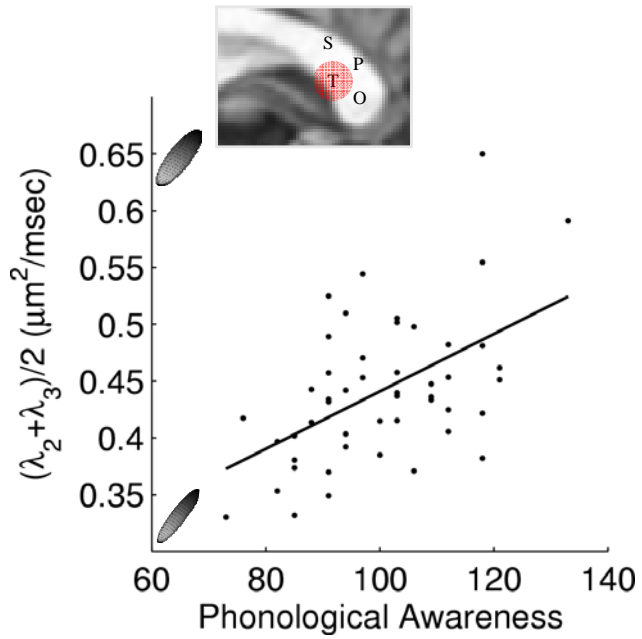
Segmentation of the callosum



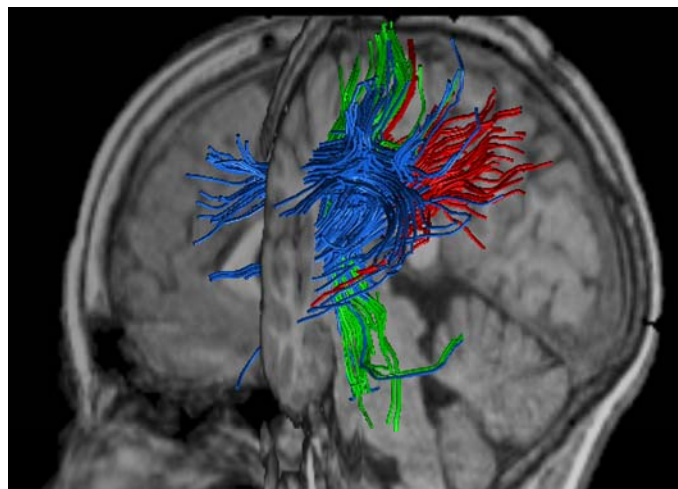
Shapes differ, segmentation is possible,
N=49 children



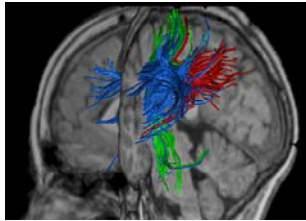
Radial
diffusivity in
callosum that
projects to
temporal lobes
correlates with
phonological
awareness
(Dougherty et al.,
PNAS, 2007)



Exuberant Growth -Pathway Shift Hypothesis (interactive demo)



Conclusions, Part III



Diffusion tensor imaging can be used in a variety of ways, ranging from FA maps, direction maps, and fiber tracts

There is excellent agreement that certain white matter differences correlate with reading skill.

Interpreting these differences, by describing the data with respect to the natural brain structures (fiber bundle positions and properties) is underway, but still in its infancy.

The DTI method has great promise. Must get back to work.

Collaborators

Alyssa Brewer



Robert Dougherty



Michal Ben-Shachar



Serge Dumoulin



Anthony Sherbondy

