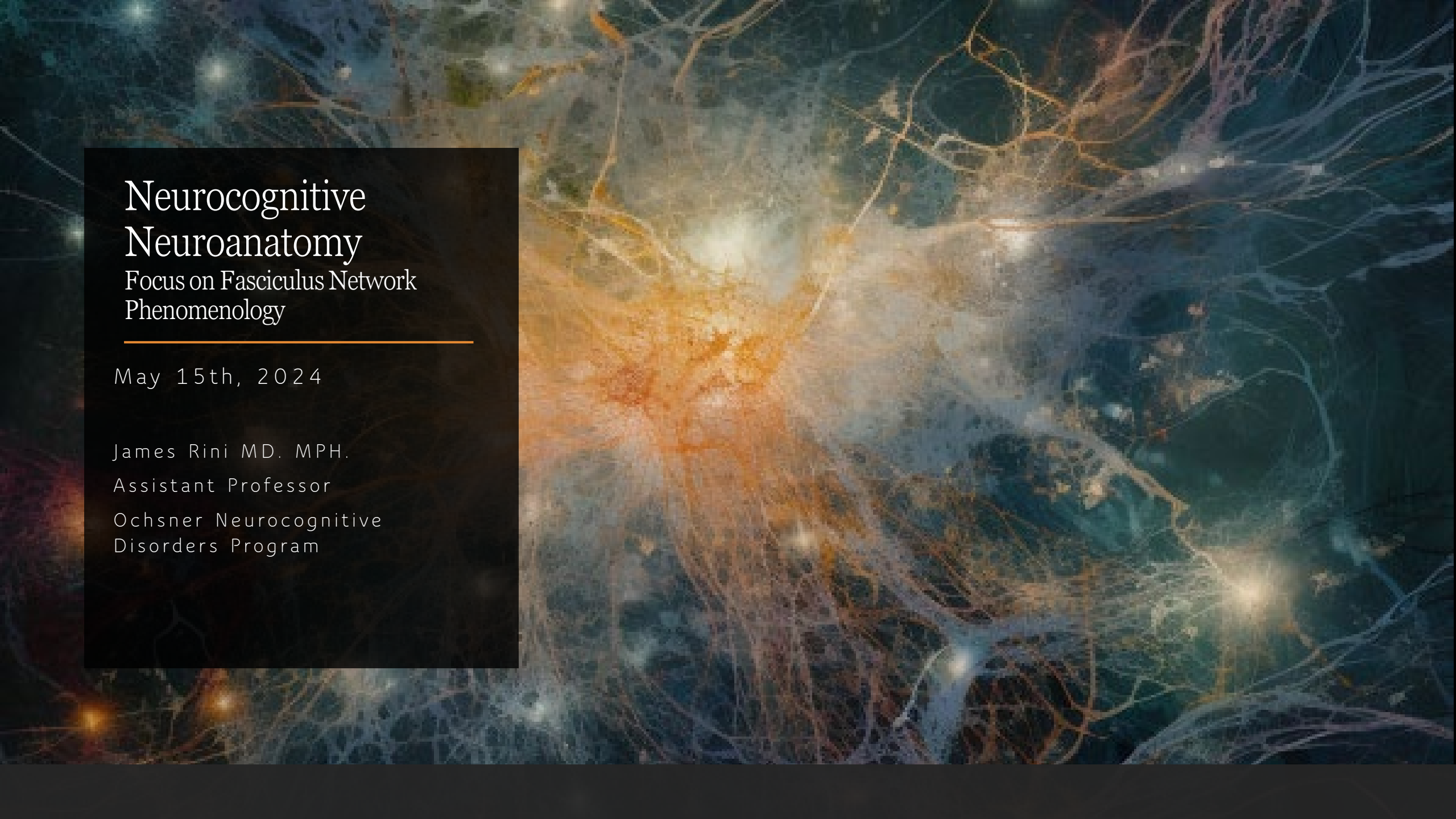

Neurocognitive Neuroanatomy

Focus on Fasciculus Network Phenomenology

May 15th, 2024

James Rini MD. MPH.

Assistant Professor

Ochsner Neurocognitive Disorders Program

Presenter Disclosure

Faculty: James Fraser Rini

I have no current or past relationships with commercial entities.

Potential for conflict(s) of interest: None

Commercial Support Disclosure

To the presenter knowledge, this program has received no financial or in-kind support from any commercial or other organization.

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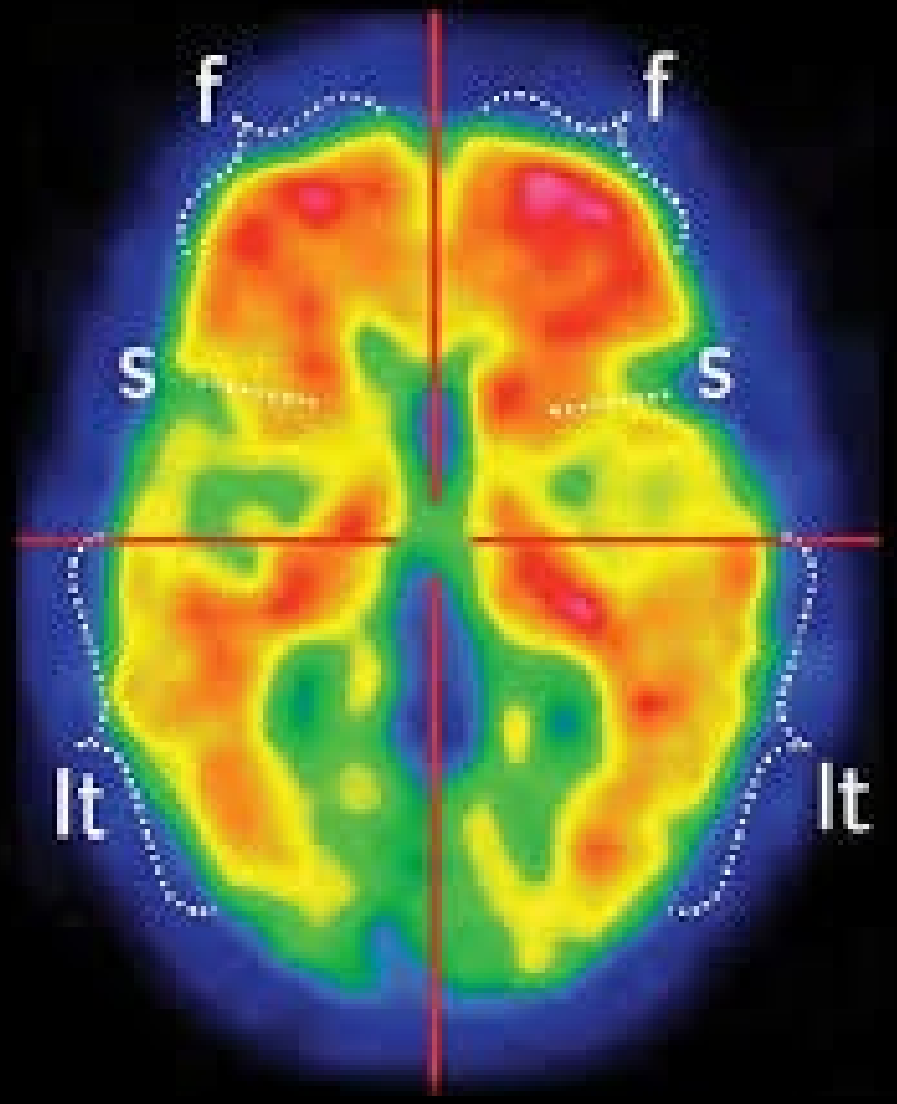

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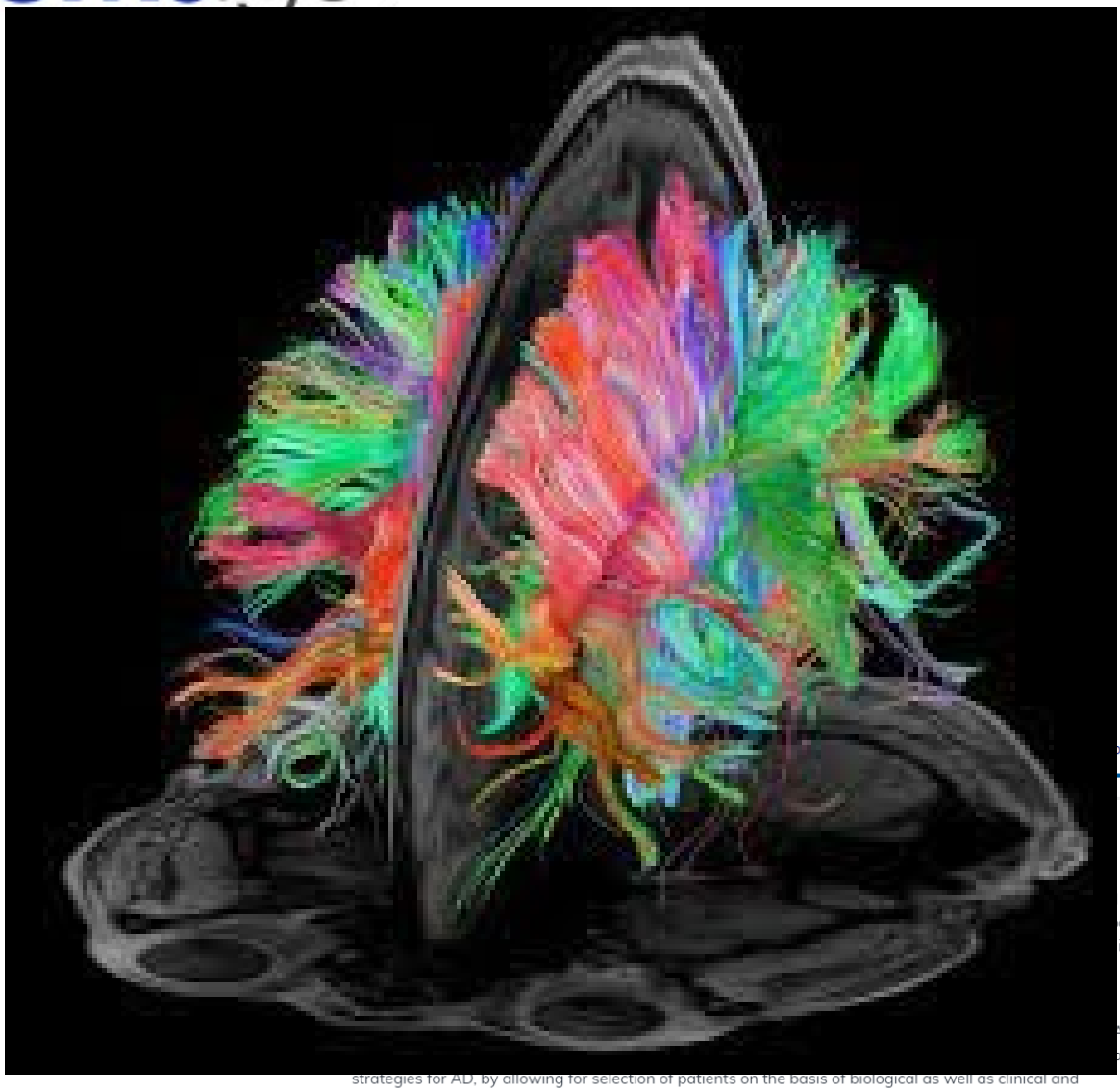


strategies for AD, by allowing for selection of patients on the basis of biological as well as clinical and epidemiological factors.

A Rose By Any Other Name

Linguistic relativity: Language Impacts How We See

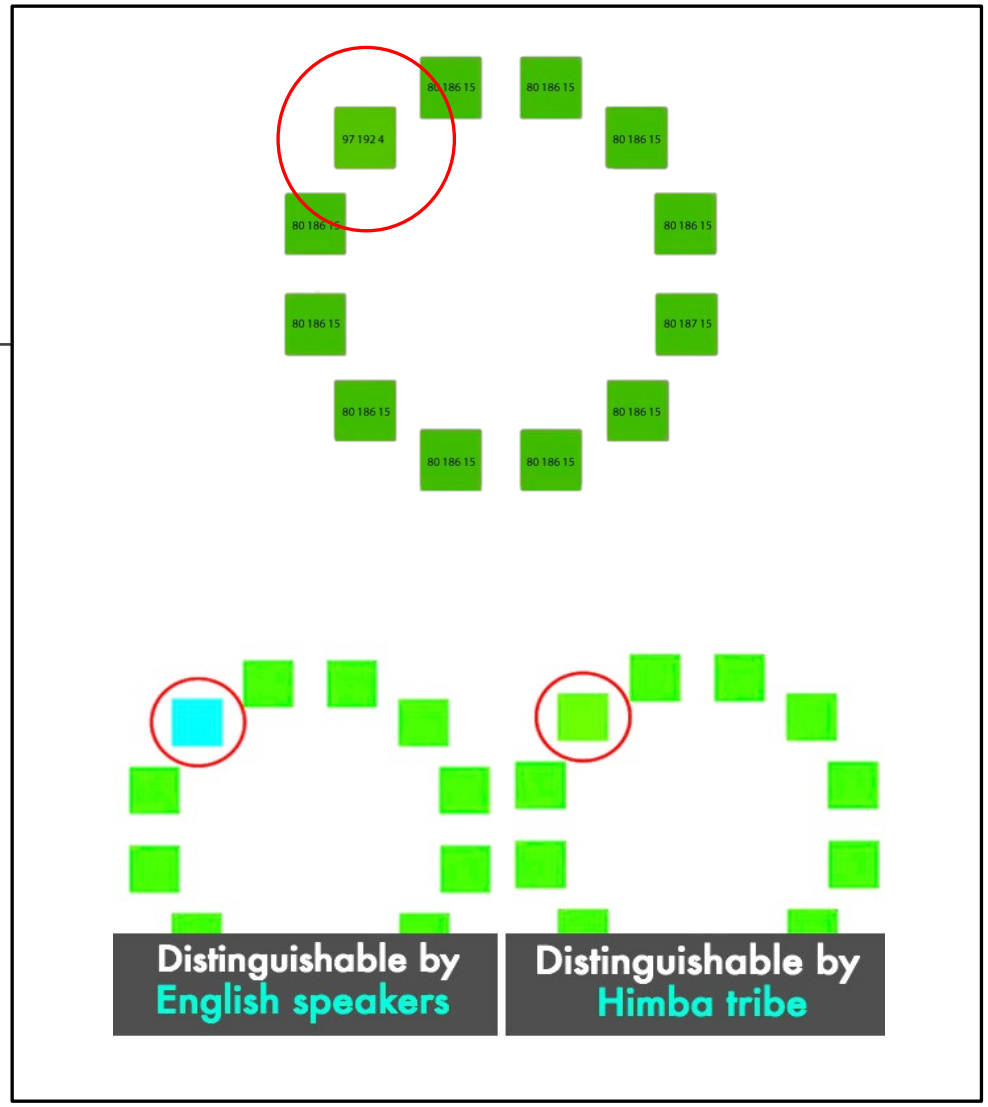
Perceptual Knowledge is **strongly** influenced by learnt distinctions

Sapir-Whorf hypothesis c.1929

- Structure of a language determines a native speaker's perception and categorization of experience.

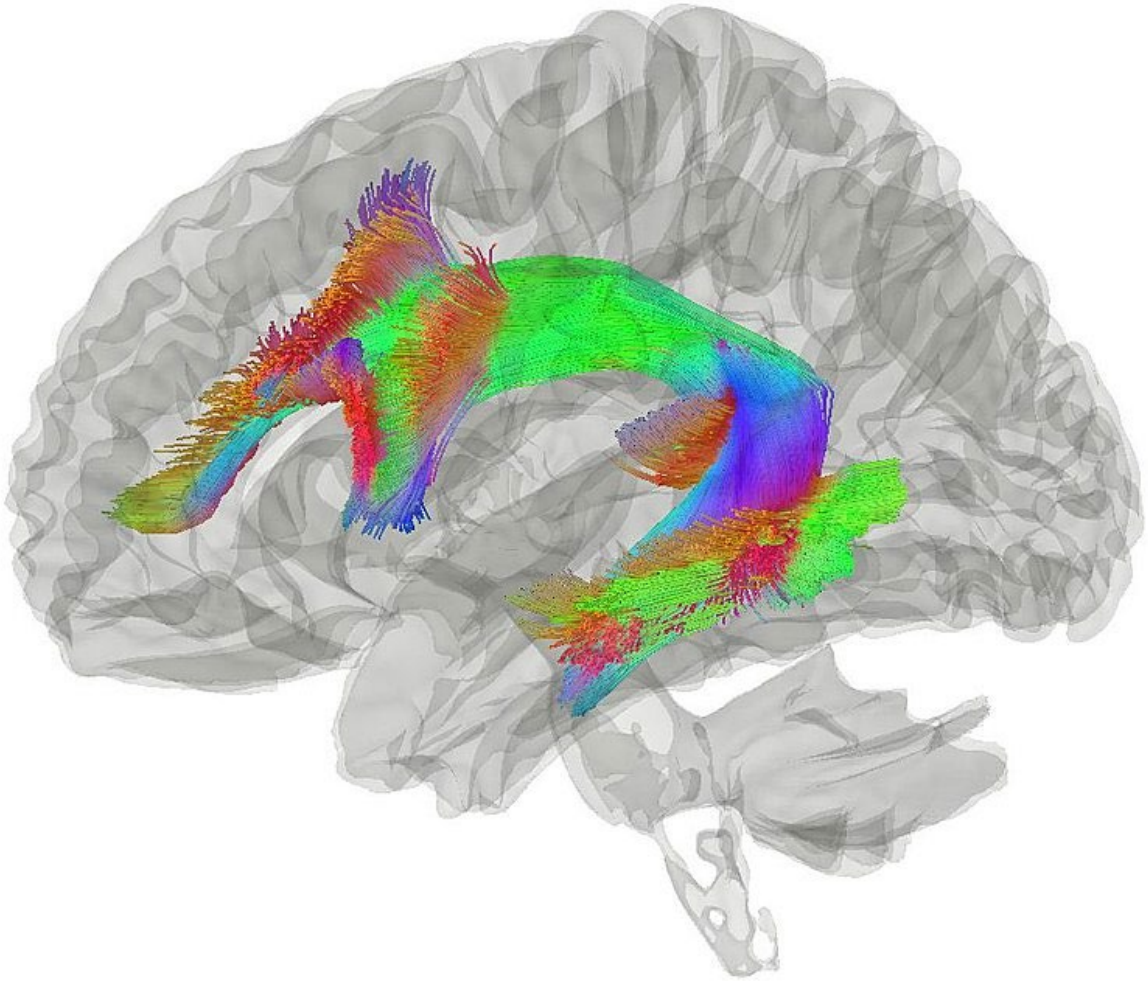
Himba tribe of northern Namibia

- *Serandu*: red, orange and pink
- *Zoozu*: black and dark shades of red, blue, green and purple
- *Vapa*: white and some yellow
- *Borou*: greens and blues (lacking the blue-green distinction)
- *Dumbu*: other greens, red and brown



Lesson: *You don't see what you haven't been taught to distinguish*

Roberson et al., 2000; Roberson et al., 2004



WHY DOES
IT MATTER?

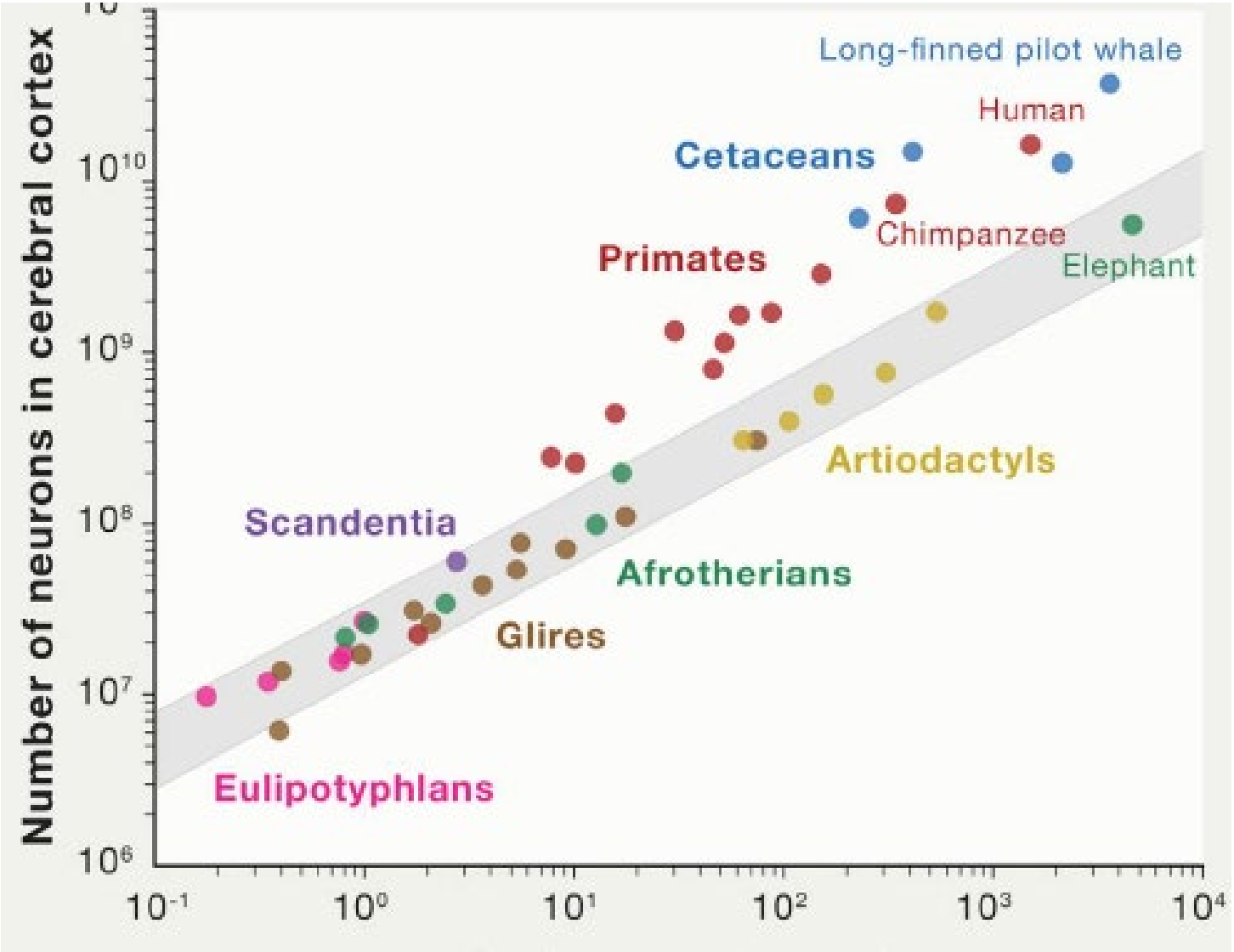
Its not the size that matters

Size of CNS generally correlates with general intelligence

BUT relationship is neither robust nor mechanistically understood.

- Several large mammals have substantially larger brains than humans
- *So, did Neanderthal*

Structural and functional differences appear to be the root of functional connectivity and higher levels of consciousness



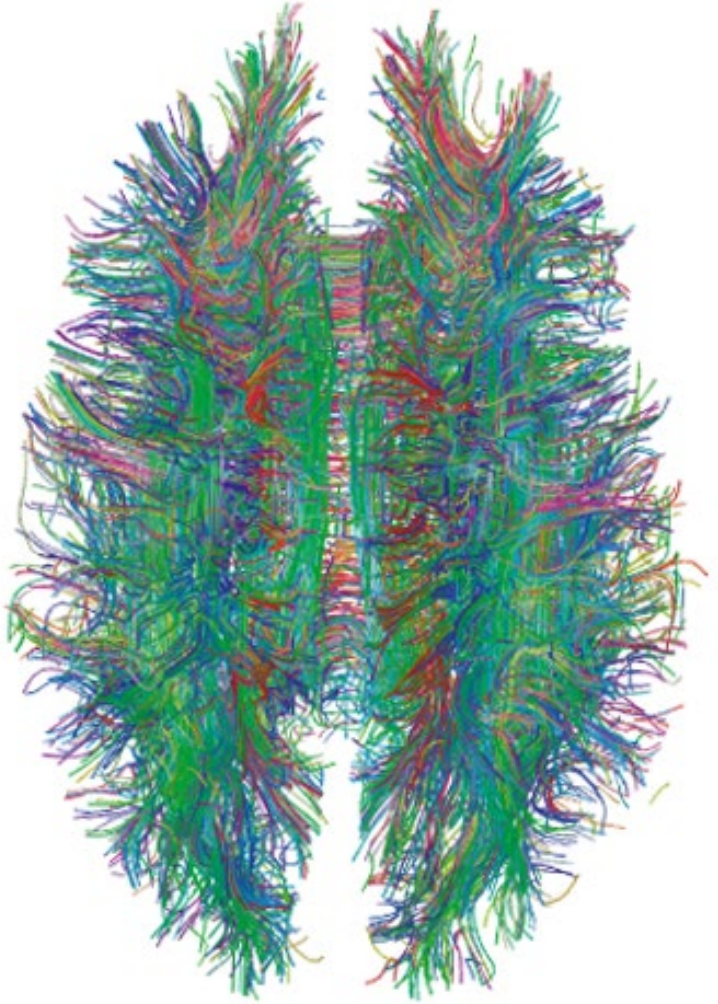
Sousa et al., 2017; Takemura et al., 2019

Connectome

Cognition and behavior are a function dynamic network connectivity i.e. connectome

Human connectome appears to be unique

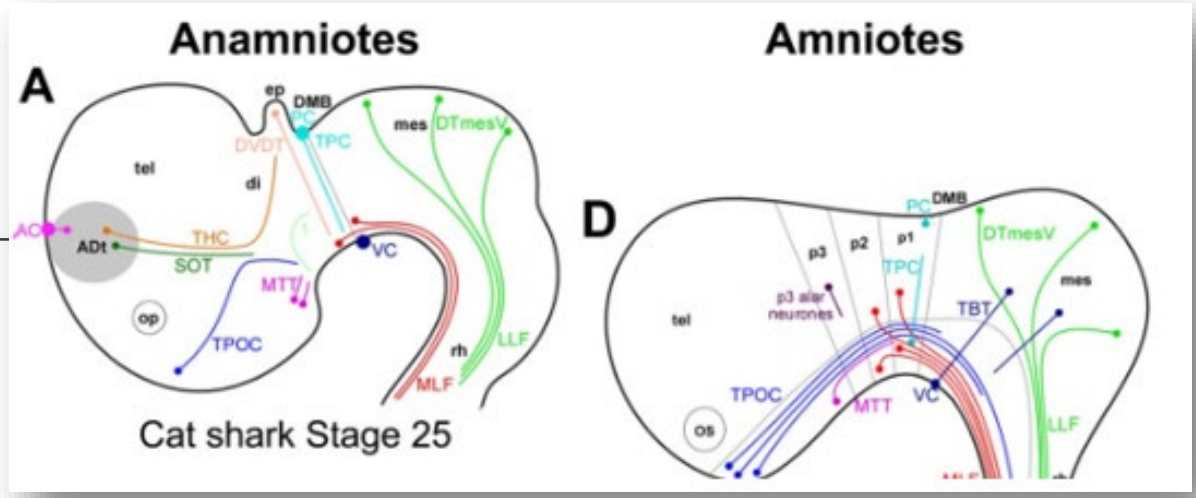
- Many species-specific differences in the organization
- Short-range projections in association areas are less myelinated
- Long-range projections in prefrontal/temporal are more numerous



Understanding how these multilayered bidirectional tract/bundles are involved in processing and modulating decisions and behaviors is crucial for understanding cognition and higher levels of consciousness

Sousa et al., 2017; Takemura et al., 2019

The First Fasciculi



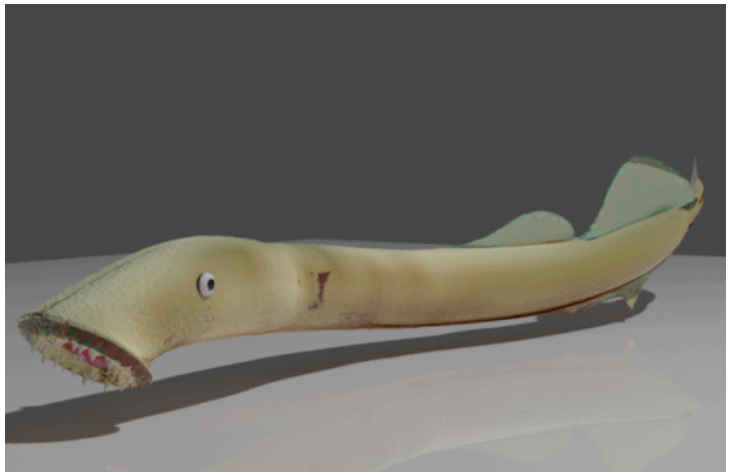
400 million years ago vertebrates evolved early axon scaffolding (i.e. bundles and myelin)

First and most conserved tract **is ventral longitudinal tract (VLT)**

- medial longitudinal fascicle (MLF)
- postoptic commissure (TPOC)

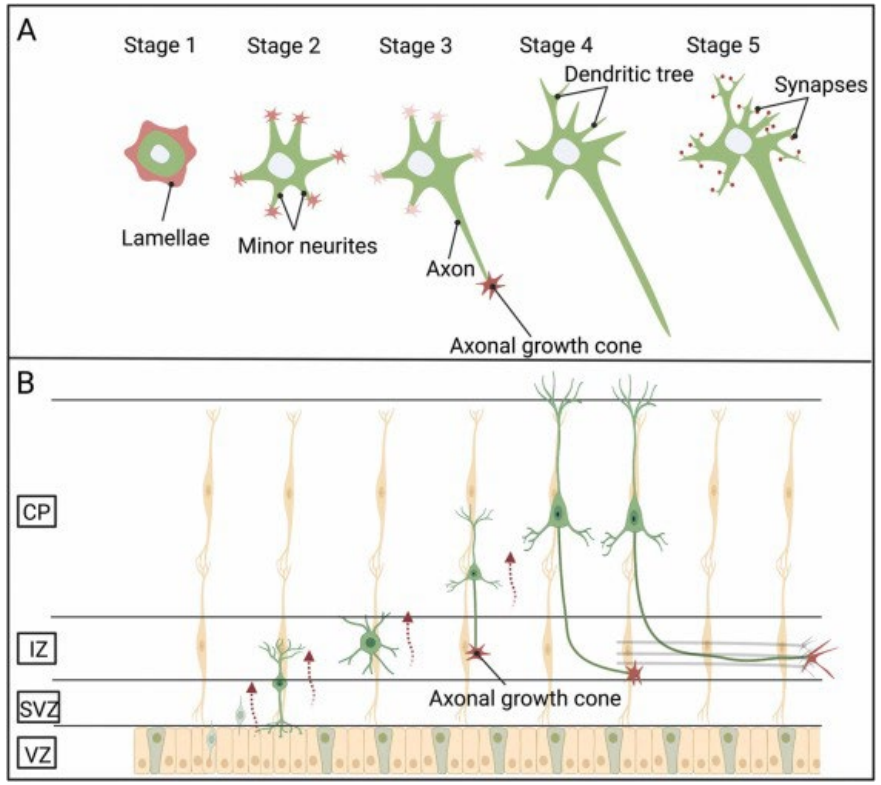
Fasciculi structures evolved for coordinate efficient and effective motor responses to cephalic sensory stimuli

- Vestibulo-ocular (VOR) reflex
- Optokinetic (OKR) reflex
- Phototaxis
- Jaw movement



Ware et al., 2015; Barandela et al., 2023

400 million years later
…things are a complicated



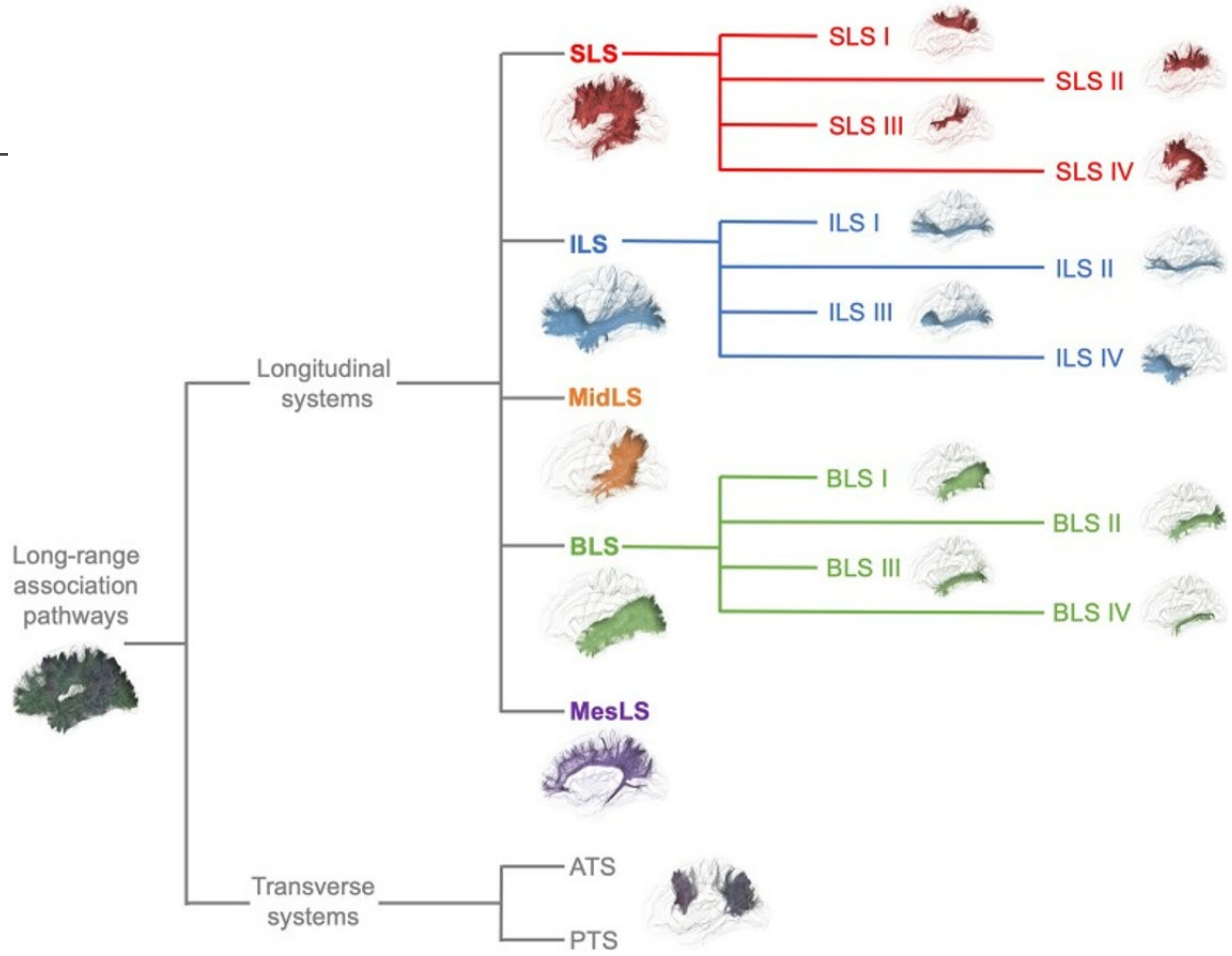
- Cuneate Fasciculus
- Gracile Fasciculus
- Spinothalamic Tract
- Spinocerebellar Tract
- Dorsal Spinocerebellar Tract
- Ventral Spinocerebellar Tract
- Dorsal Column-Medial Lemniscus Pathway
- Dorsal Longitudinal Fasciculus
- Ventral Longitudinal Fasciculus
- Medial Lemniscus
- Central Tegmental Tract
- Cerebellothalamic Tract
- Fasciculus Cinguli (Cingulum)
- Optic Radiation
- Fasciculus Solitarius (Solitary Tract)
- Medial Forebrain Bundle
- Reticulospinal Tract
- Vestibulospinal Tract
- Lateral Spinothalamic Tract
- Ventrolateral Spinothalamic Tract
- Ventral Trigeminothalamic Tract
- Dorsal Trigeminothalamic Tract
- Anterolateral System
- Dorsal Premammillary Nucleus
- Lateral Olfactory Tract
- Superior Longitudinal Fasciculus (SLF)
- Arcuate Fasciculus
- Uncinate Fasciculus
- Inferior Longitudinal Fasciculus
- Corpus Callosum
- Anterior Commissure
- Fornix
- Inferior Fronto-Occipital Fasciculus
- Fronto-occipital Fasciculus
- Superior Occipitofrontal Fasciculus
- Mammillothalamic Tract
- Anterior Thalamic Radiation
- Perforant Path
- Commissural Fibers of the Hippocampus
- Thalamic Radiations
- Corticopontine Tract

From Chaos …Comes Order

Unclear nomenclature for Association Pathways

Proposal of seven white matter *systems* defined by anatomical corridors

- Superior longitudinal system (SLS)
- Inferior longitudinal system (ILS)
- Middle longitudinal system (MidLS)
- Basal longitudinal system (BLS)
- Mesial longitudinal system (MesLS)
- Anterior transverse system (ATS)
- Posterior transverse system (PTS)

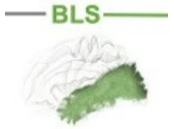


Mandonnet et al., 2018; Mandonnet et al., 2019;

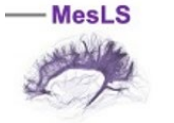
- Longitudinal system
  - Superior (SLS) — *Spatial Awareness/Attention*

  - Inferior (ILS) — *Object Awareness/Attention*

  - Middle (MidLS) — *Comprehensive Sound*



  - Basal (BLS) — *Comprehensive Vision*



  - Mesial (MesLS) — *Comprehensive eMotivation*
- Transverse system
  - Anterior (ATS) — *Articulated Language*

  - Posterior (PTS) — *Visual Language*

SLS

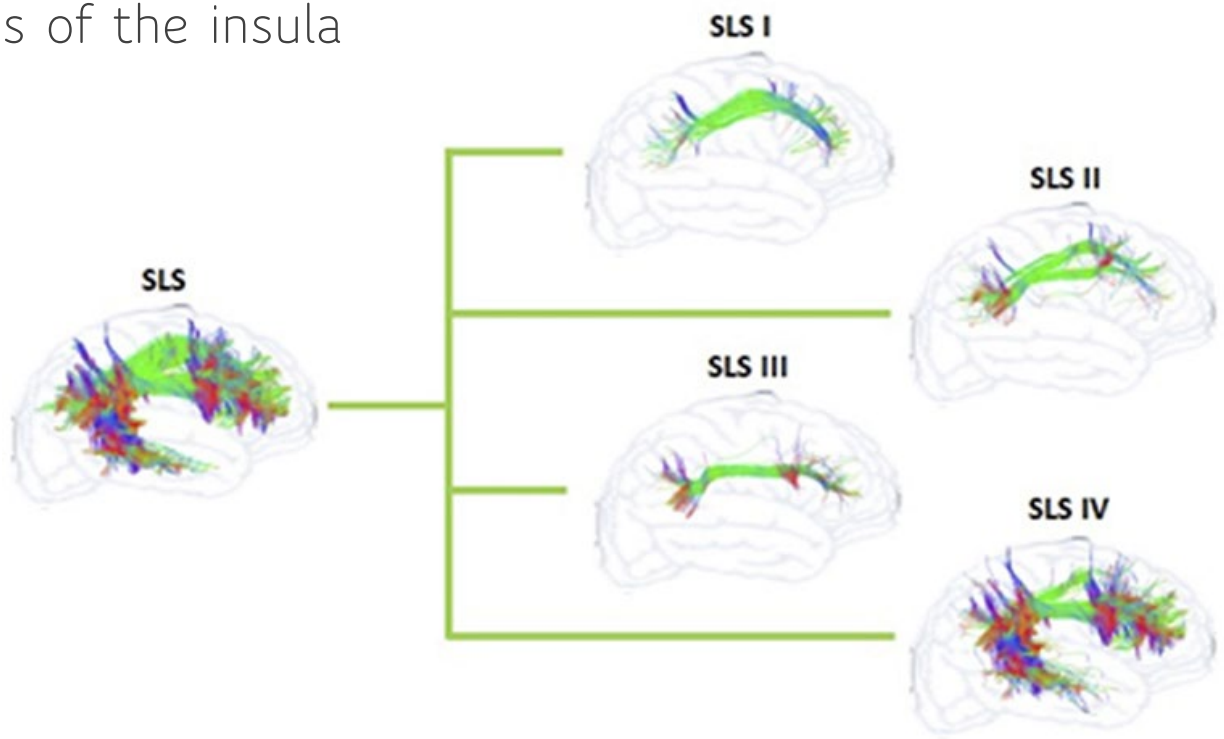
i.e. Superior Longitudinal Fasciculus (SLF) and Arcuate Fasciculus (AF)

Connects frontal lobe to parietal, occipital and temporal lobes

- Travels with corona radiata above sulcus of the insula

Can be divided into four subsystems

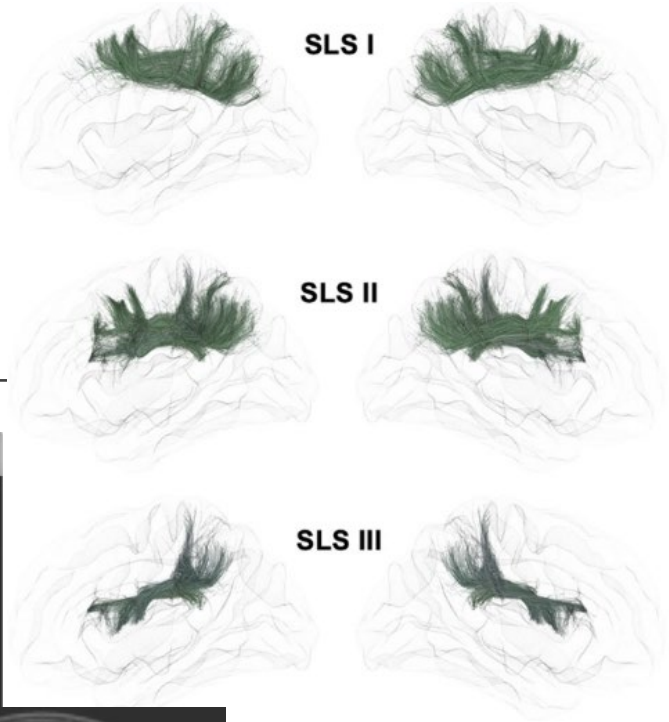
- SLS-I i.e. superior SLF
- SLS-II i.e. middle SLF
- SLS-III i.e. inferior SLF
- SLS-IV i.e. AF



Mandonnet et al., 2018; Balezeau et al., 2020; Janelle et al., 2022

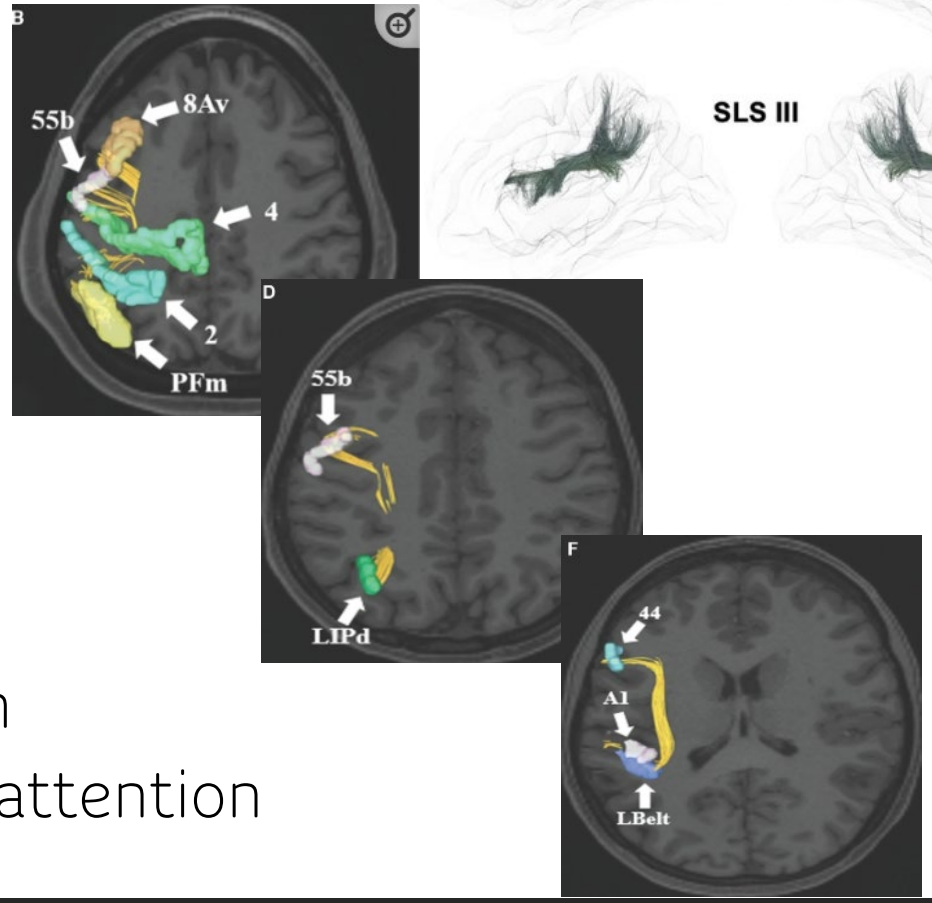
SLS I-III

i.e. Superior Longitudinal Fasciculus



Connecting the frontal lobe to the parietal lobe

- SLF I - Connect ***superior*** frontal to ***superior*** parietal lobe
- SLF II - Connect ***middle*** frontal with ***middle*** parietal lobe
  - angular [BA39] and **posterior** supramarginal gyrus [BA40]
- SLF III - Connect **inferior** frontal and ***middle*** parietal lobe
  - **anterior** supramarginal gyrus [BA40]



Dorsal Stream of Information i.e. WHERE?

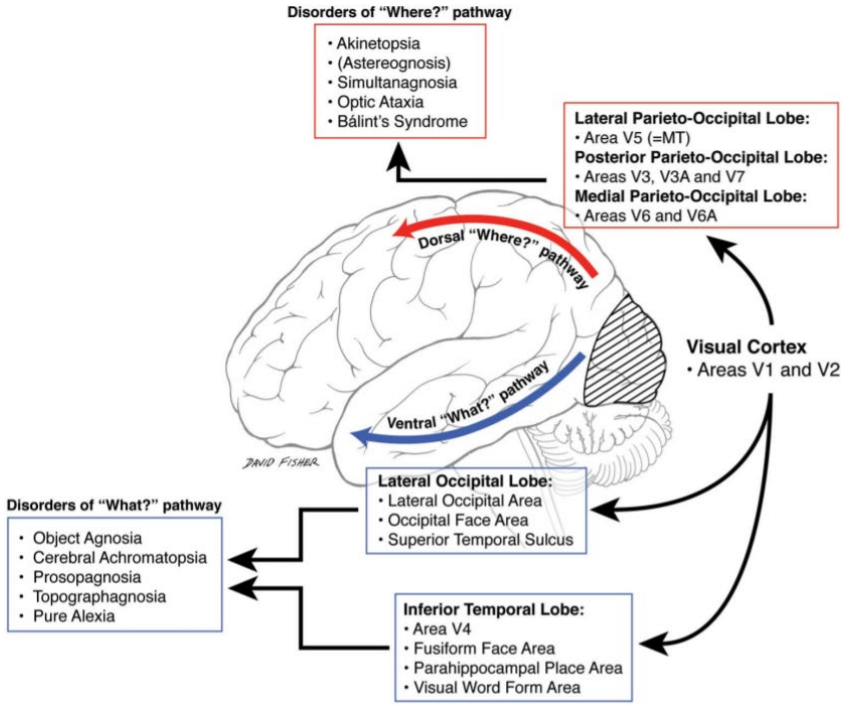
Dominant – Language awareness/attention

Non-Dominant - Visuospatial awareness/attention

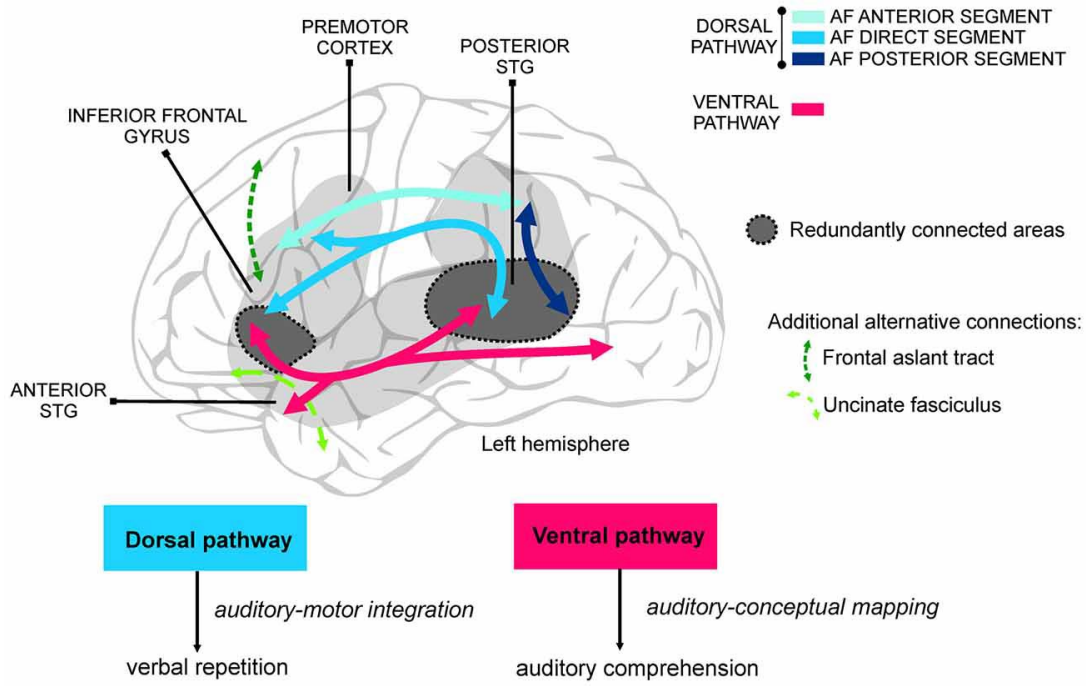
Mandonnet et al., 2018; Conner et al., 2018; Savard etal ., 2022

SLS I-III

Dorsal Stream – WHERE?



Visuospatial Circuit – *Where to look at?*

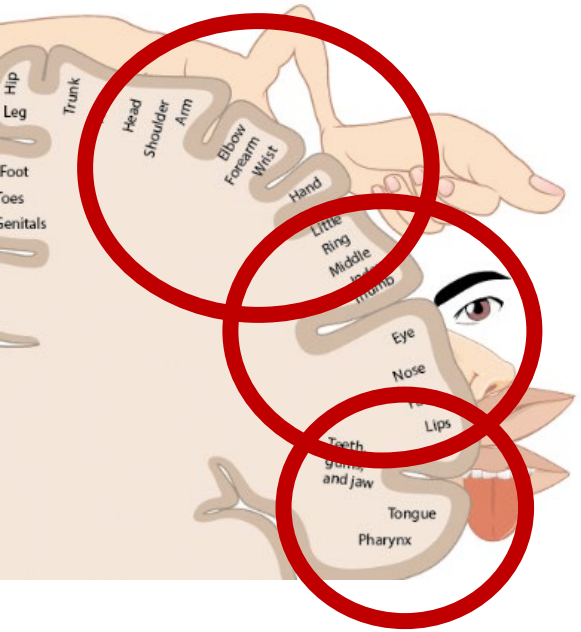


Language Circuit – *Where to move my mouth/conversation?*

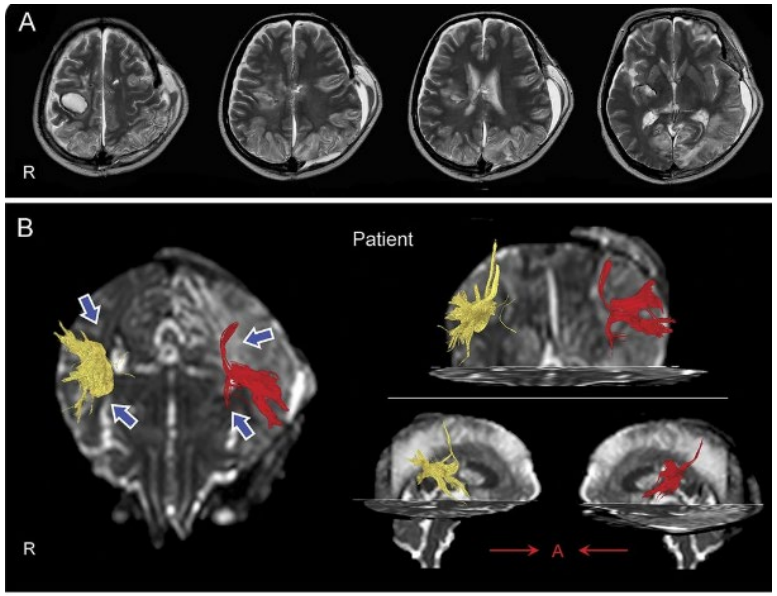
López-Barroso et al., 2017; Mandonnet et al., 2018; Conner et al., 2018; Herbert et al 2018; Janelle et al., 2022

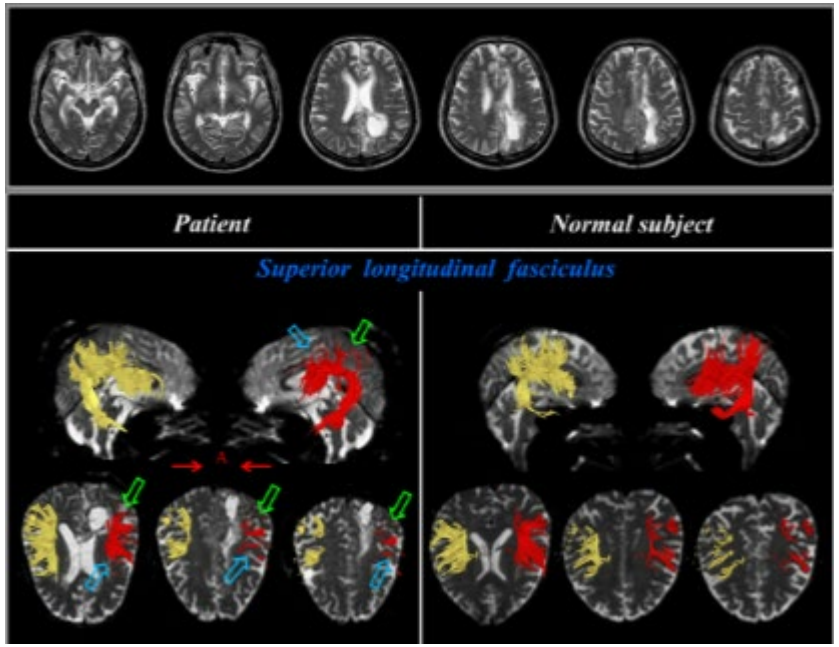
SLS I-III

Dorsal Stream – WHERE?



51-year-old s/p hemorrhage right putamen with IVH s/p EVD and craniectomy developed Balint syndrome 2/2 b/l SLP dysfunction



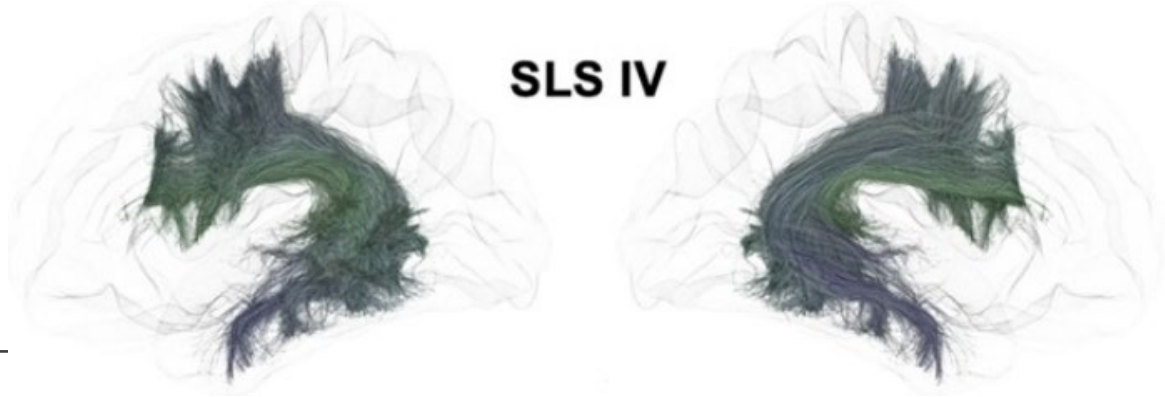


60-year-old s/p left fronto-parietal lobe meningioma resection with IVH developed ideomotor apraxia

Jang et al., 2016; Jang et al., 2018; Mandonnet et al., 2018; Conner et al., 2018;

SLS IV

i.e. Arcuate Fasciculus

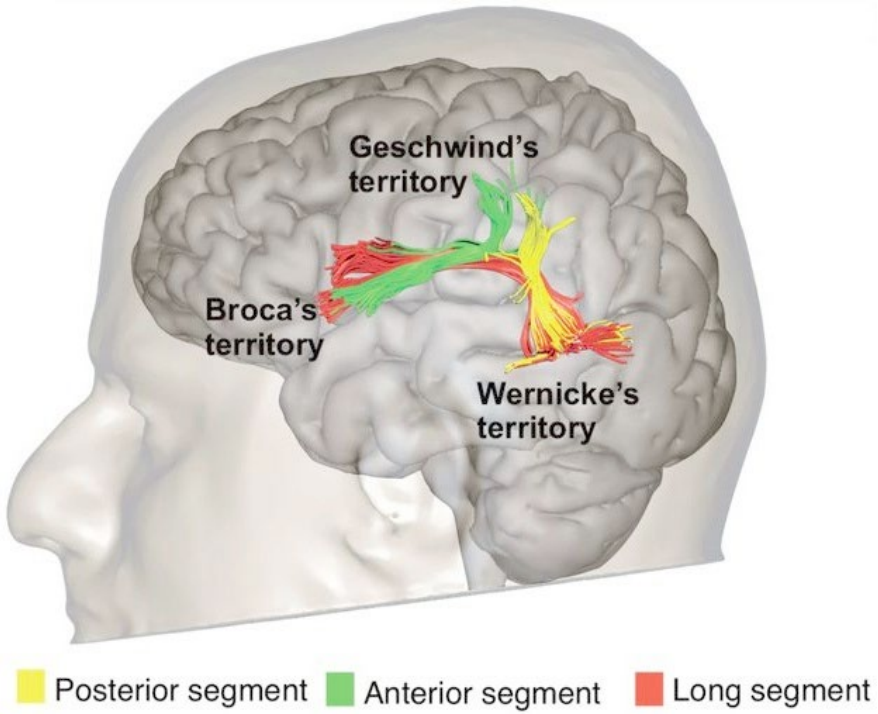


Connecting the inferior frontal to the superior temporal lobe
- i.e. Wernicke's connects with Broca

Direct/Long Segment = Repetition
- Sensory-motor mapping

Anterior Segment - Fluency
- Lexical-Semantic Processing - Basic comprehension ie words in context

Posterior Segment = Comprehension
- Lexical-Semantic Retrieval - Complex comprehension ie sentence



Mandonnet et al., 2018; Conner et al., 2018; Ivanova et al., 2021

SLS IV

i.e. Arcuate Fasciculus

Neurodivergent structural anomalies in the left arcuate fasciculus in adults with **developmental dyslexia**

- left arcuate fasciculus = grapheme-phoneme decoding
- left inferior fronto-occipital fasciculus = direct word access

Brain. 2012 Mar;135(Pt 3):935-48. doi: 10.1093/brain/awr363. Epub 2012 Feb 10.

A tractography study in dyslexia: neuroanatomic correlates of orthographic, phonological and speech processing

Maaike Vandermosten [1], Bart Boets, Hanne Poelmans, Stefan Sunaert, Jan Wouters, Pol Ghesquière

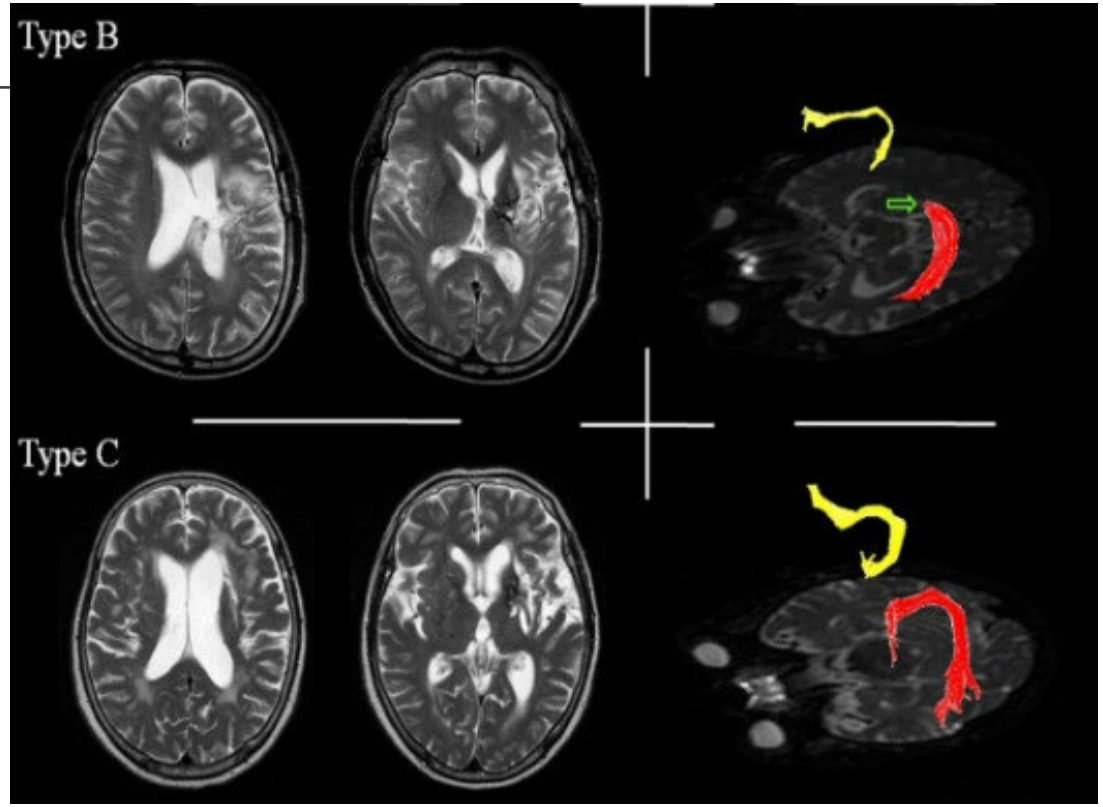
Affiliations + expand

PMID: 22327793 DOI: 10.1093/brain/awr363

RESEARCH ARTICLE Open Access

Relation between aphasia and arcuate fasciculus in chronic stroke patients

Hyung Jun Tak and Sung Ho Jang*

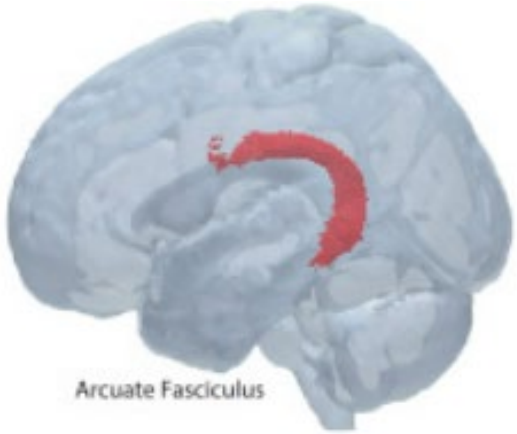


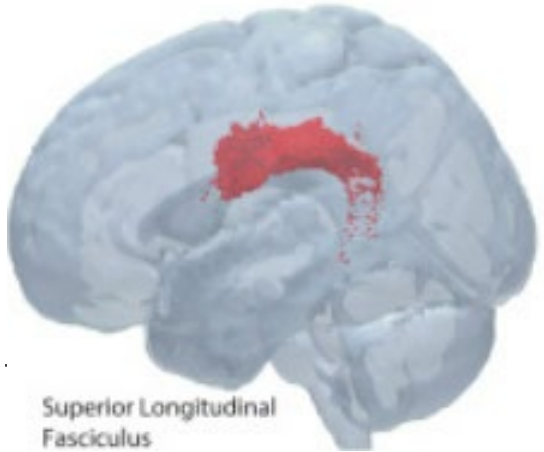
Dominant AF most commonly effected in conduction aphasia i.e. fluent paraphasic repetition/spelling/writing impaired.

Vandermosten et al., 2012; Tak et al., 2014; Mandonnet et al., 2018; Conner et al., 2018; Ivanova et al., 2021

SLS I-IV

Non-Fluent Aphasia Agrammatic > Logopenic



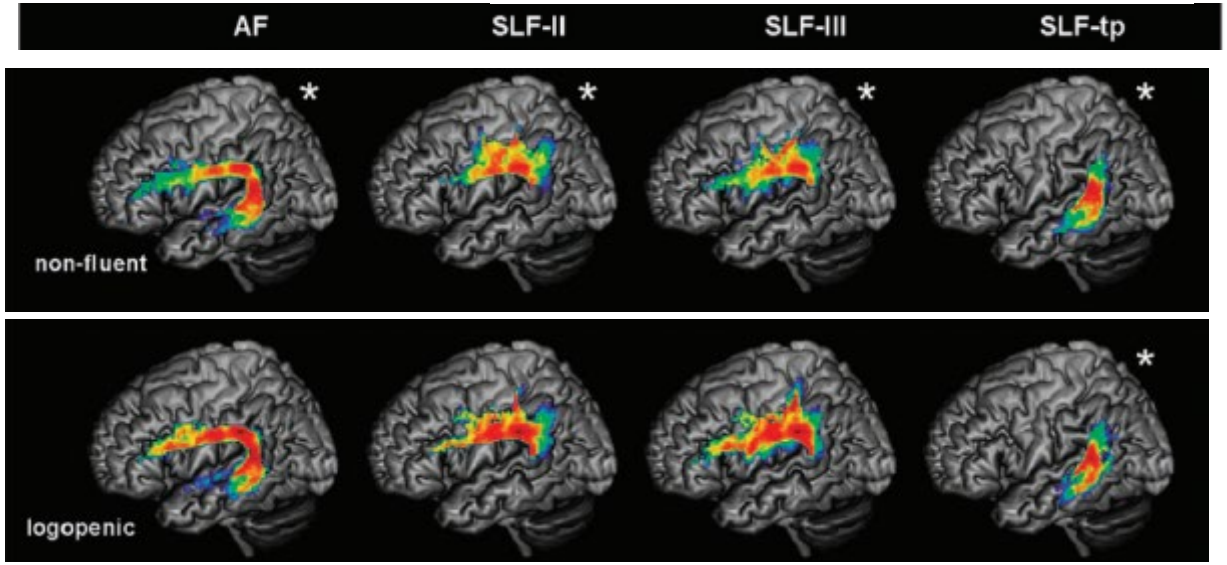


[redacted]

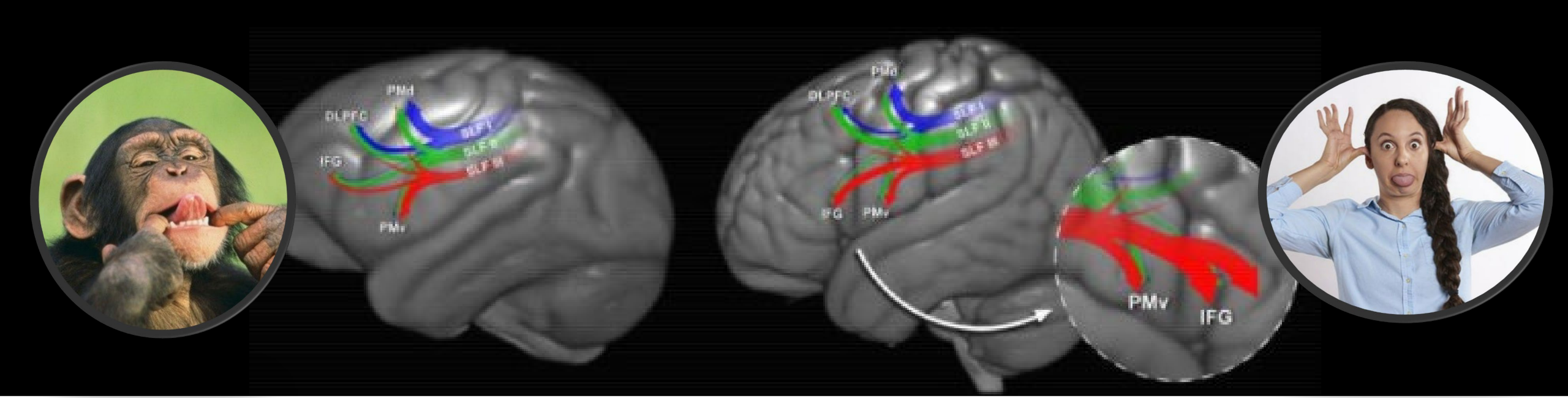
BRAIN
A JOURNAL OF NEUROLOGY

White matter damage in primary progressive aphasias: a diffusion tensor tractography study

Sebastiano Galantucci,[1,2] Maria Carmela Tartaglia,[1] Stephen M. Wilson,[1,3] Maya L. Henry,[1] Massimo Filippi,[2] Federica Agosta,[2] Nina F. Dronkers,[4,5] Roland G. Henry,[6] Jennifer M. Ogar,[1] Bruce L. Miller[1] and Maria Luisa Gorno-Tempini[1,7]



Galantucci etal., 2011; López-Barroso et al., 2017; Mandonnet et al., 2018; Conner et al., 2018; Janelle et al., 2022



- SLF II no significant asymmetry
  - SLF II more dorsal>ventral connectivity in PFC
- SLF III **Non-Dominant** lateralization
  - SLF III more ventral>dorsal connectivity in PFC
  - improved fine control of complex actions through space and time? Social cognition?
- Arcuate Fasciculus **Dominant** Lateralization
  - improved fine sensory-speech mimicry

Virtual dissection and comparative connectivity of the superior longitudinal fasciculus in chimpanzees and humans

Erin E. Hecht,[1,2] David A. Gutman,[3] Bruce A. Bradley,[4] Todd M. Preuss,[5] and Dietrich Stout[6]

Hecht et al 2015

ILS

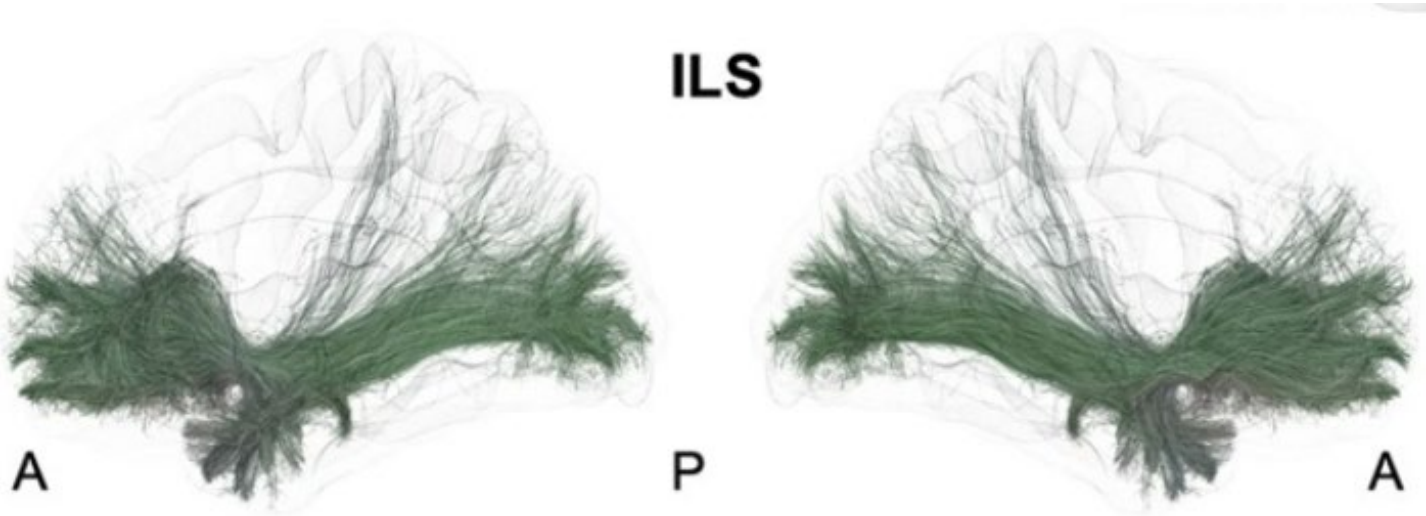
i.e. uncinate fasciculus (UC) and Inferior Fronto-occipital fasciculus (IFOF)

connects temporal/parietal/occipital lobes to frontal lobe

- pass below inferior limiting **sulcus** of the insula

Can be divided into four subsys

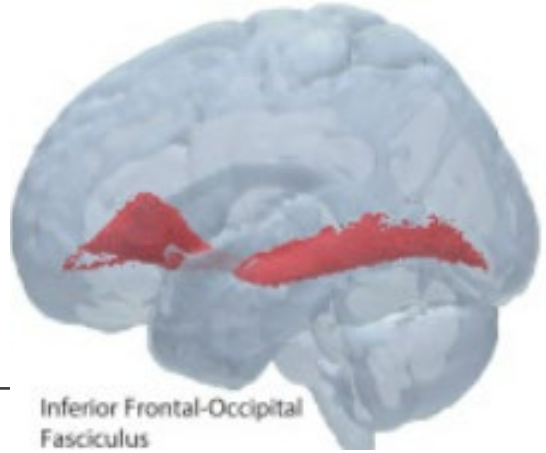
- ILS-I i.e. IFOF
- ILS-II i.e. IFOF
- ILS-III i.e. IFOF
- ILS-IV i.e. UC



Mandonnet et al., 2018; Conner et al., 2018;

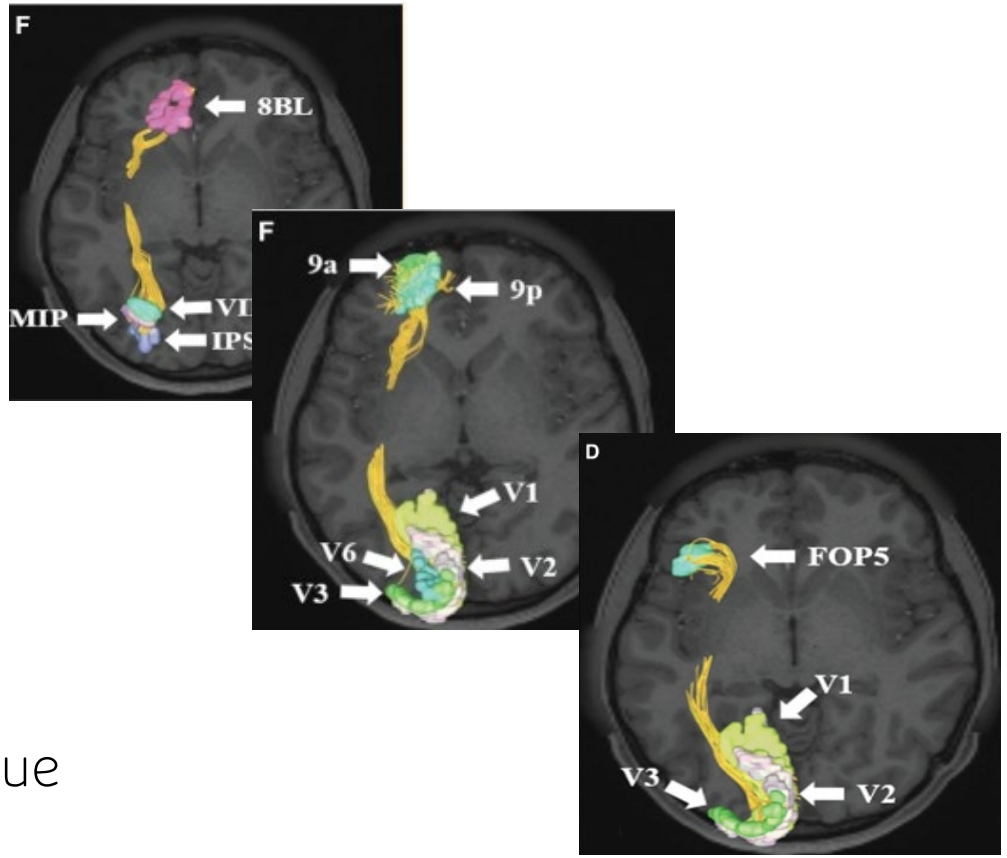
ILS I-III

i.e. Inferior Fronto-occipital fasciculus (IFOF)



connects temporal/parietal/occipital lobes to frontal lobe

- ILS I – terminates medial PFC
- ILS II – terminates middle PFC
- ILS III - terminates lateral PFC



Ventral Stream of Information – WHAT?

ILS I dlPFC/pre-FOF = visual switching tasks

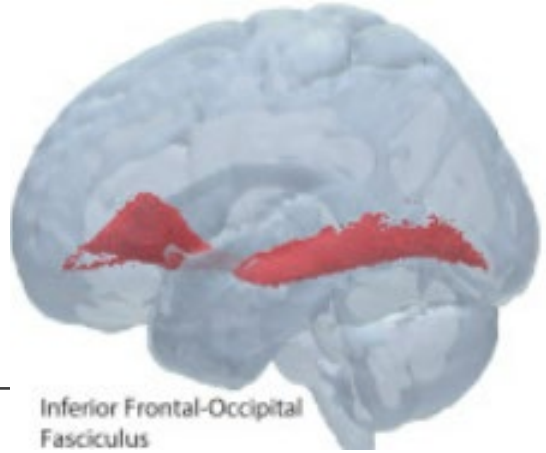
ILS II – vmPFC = goal-oriented behavior

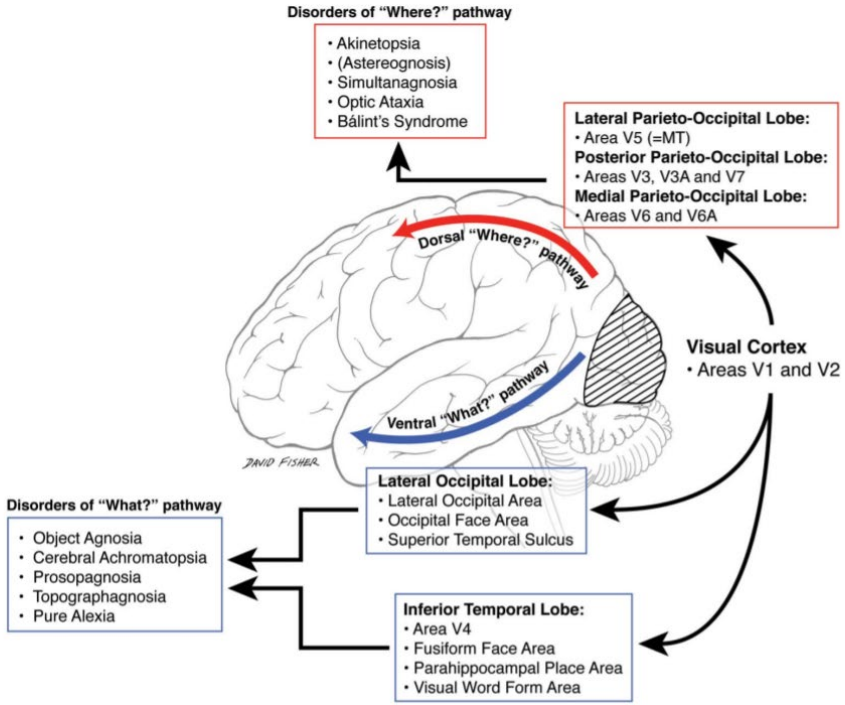
ILS III – vlPFC = semantic processing i.e. object value

Mandonnet et al., 2018; Conner et al., 2018; Janelle et al., 2022

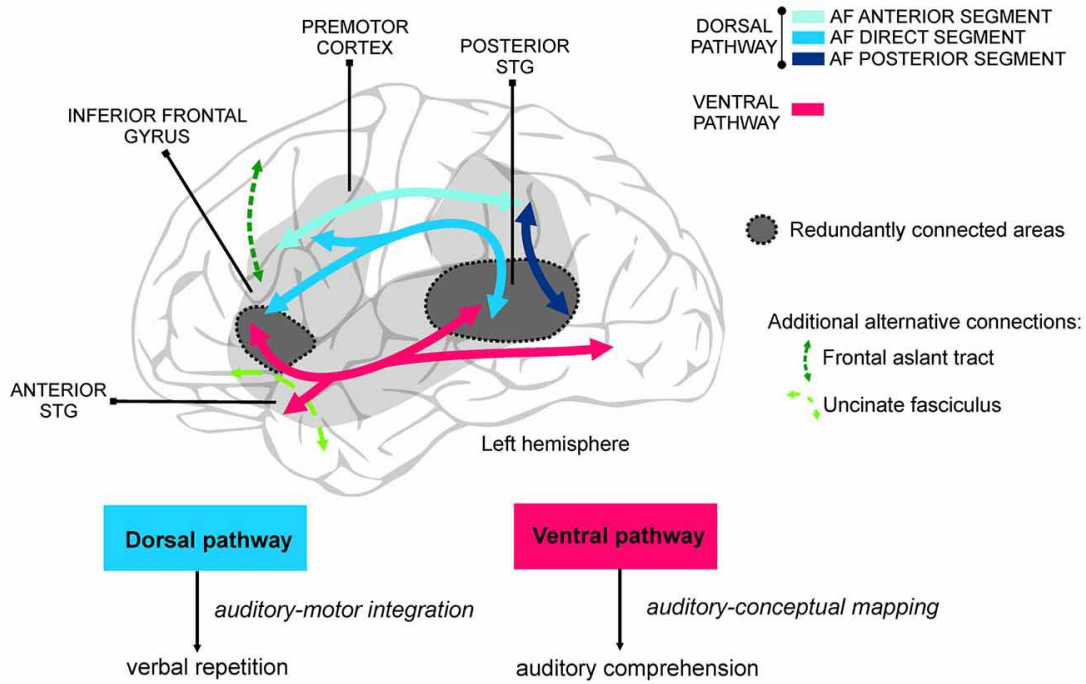
ILS I-III

Ventral Stream – WHAT?





Visuospatial Circuit – *What to look at?*

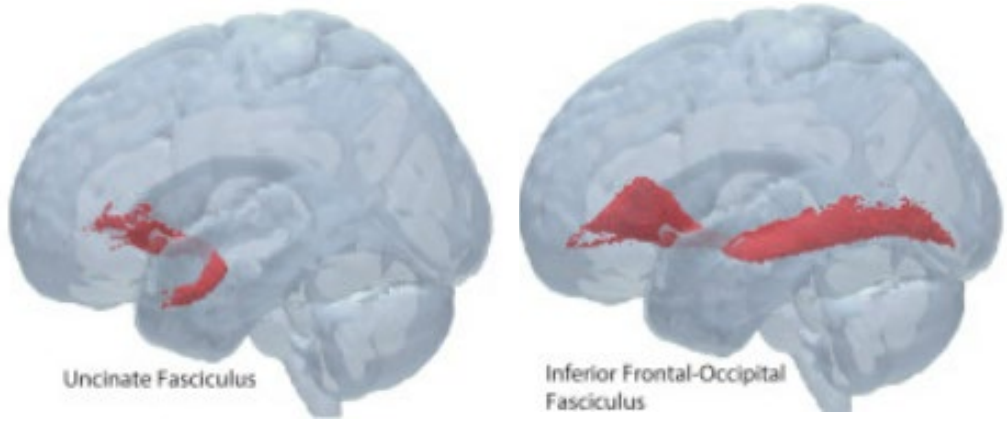


Language Circuit – *What am I looking at?*

López-Barroso et al., 2017; Mandonnet et al., 2018; Conner et al., 2018; Herbert et al 2018; Janelle et al., 2022

ILS I-IV

Semantic Dementia/Lewy Body Dementia



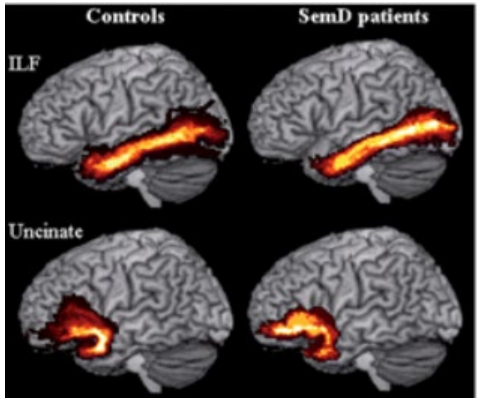
JOURNAL ARTICLE

Language networks in semantic dementia

Federica Agosta, Roland G. Henry, Raffaella Migliaccio, John Neuhaus, Bruce L. Miller, Nina F. Dronkers, Simona M. Brambati, Massimo Filippi, Jennifer M. Ogar, Stephen M. Wilson ... Show more

Brain, Volume 133, Issue 1, January 2010, Pages 286–299, https://doi.org/10.1093/brain/awp233

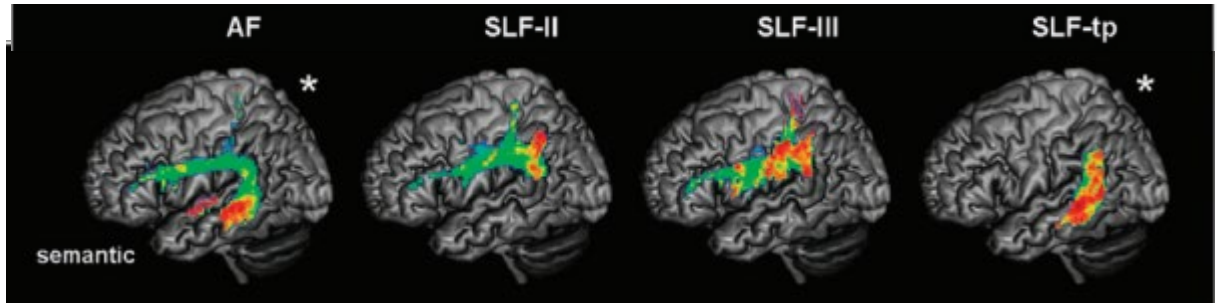
Published: 16 September 2009 **Article history**



BRAIN
A JOURNAL OF NEUROLOGY

White matter damage in primary progressive aphasias: a diffusion tensor tractography study

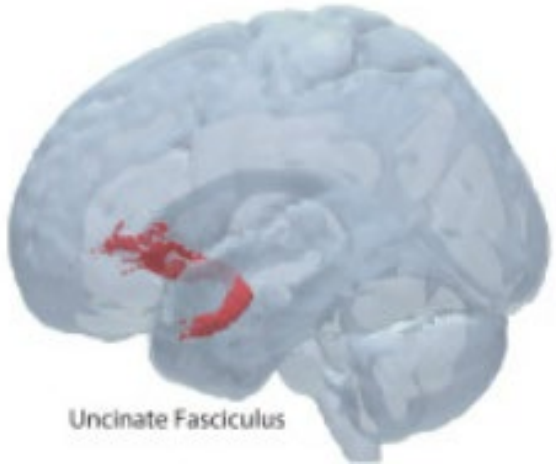
Sebastiano Galantucci,[1,2] Maria Carmela Tartaglia,[1] Stephen M. Wilson,[1,3] Maya L. Henry,[1] Massimo Filippi,[2] Federica Agosta,[2] Nina F. Dronkers,[4,5] Roland G. Henry,[6] Jennifer M. Ogar,[1] Bruce L. Miller[1] and Maria Luisa Gorno-Tempini[1,7]



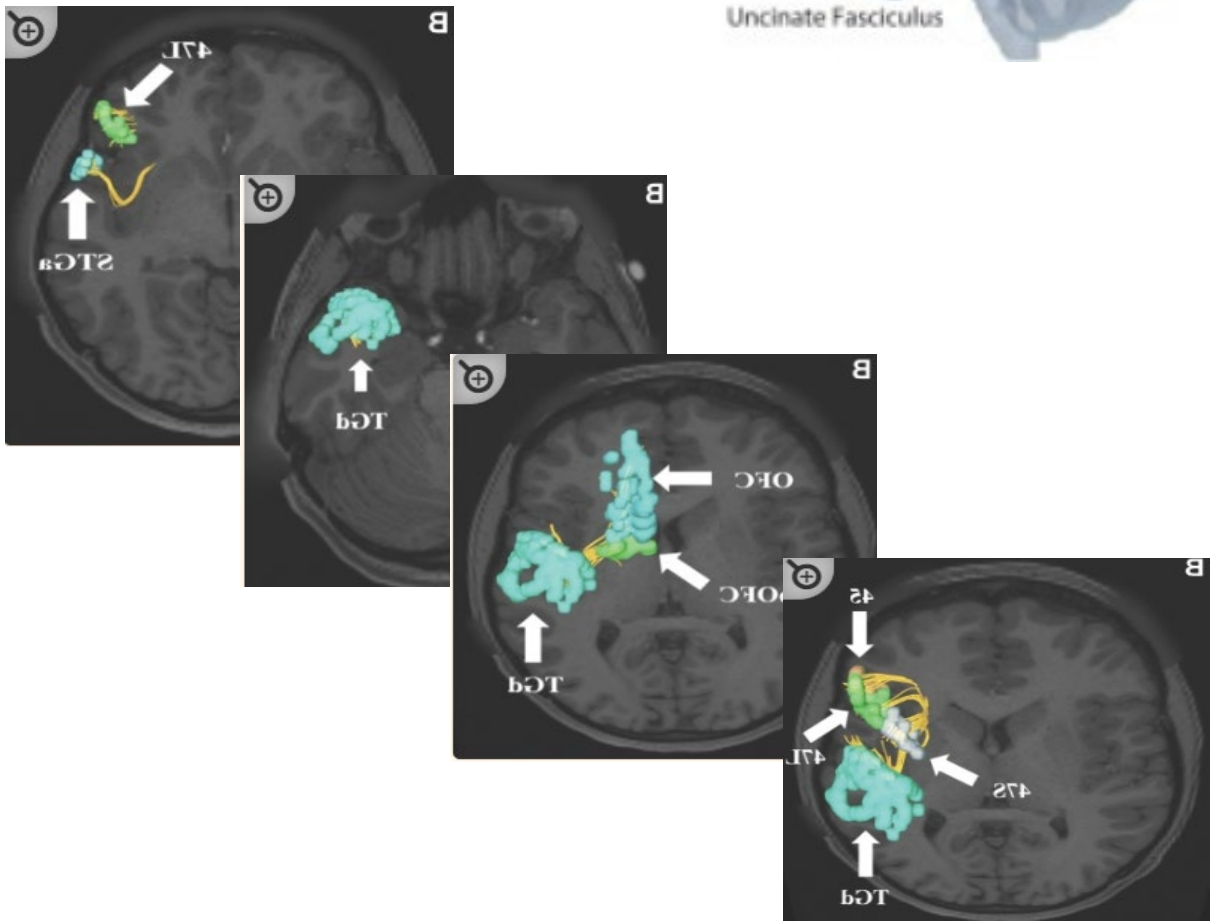
Galantucci etal., 2011; López-Barroso et al., 2017; Mandonnet et al., 2018; Conner et al., 2018; Janelle et al., 2022

ILS IV

i.e. Uncinate Fasciculus (UC)



connects orbitofrontal/inferior frontal with the anterior temporal lobe



Mnemonic associations (e.g. name + face + voice = human) to modify behavior/biasing of decisions

- Dominant - Language processing
- Non-Dominant Emotional understanding and empathy

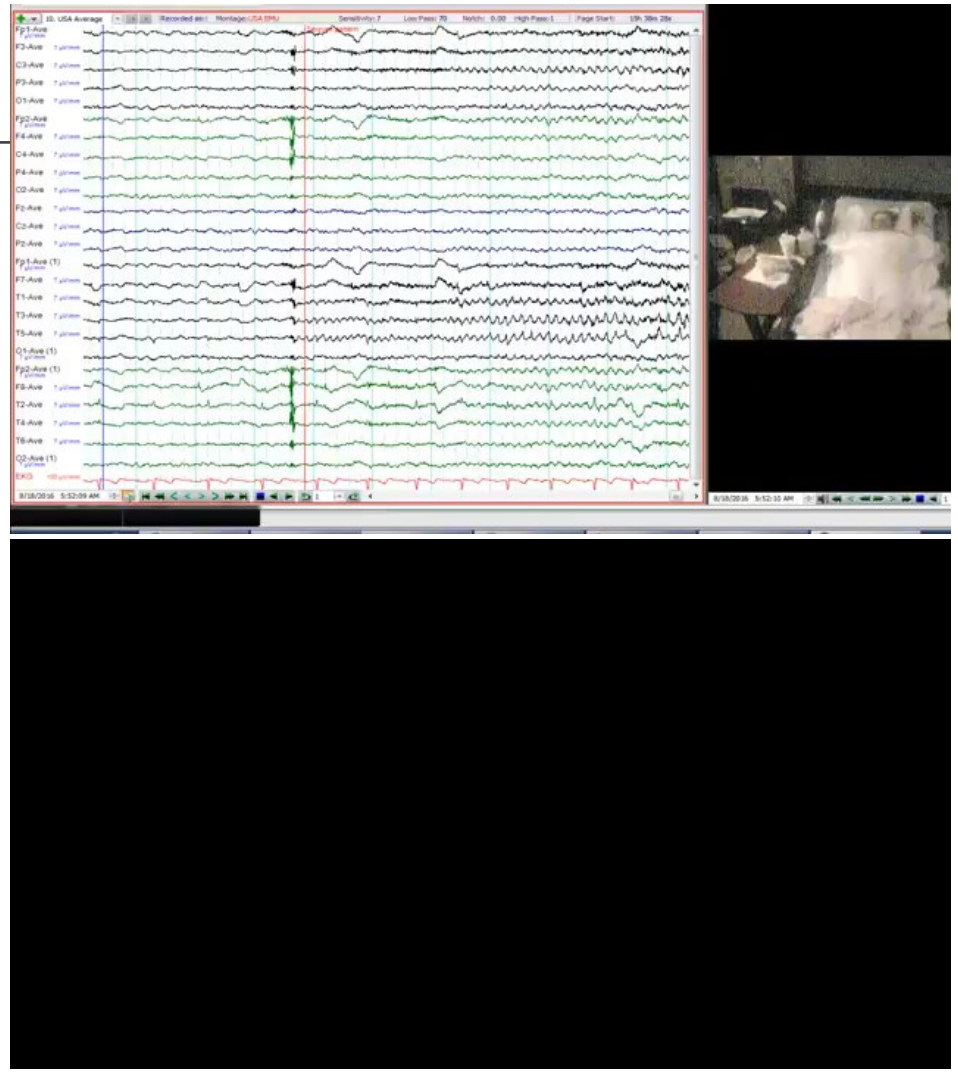
Von Der Heide et al., 2013; Mandonnet et al., 2018; Briggs et al., 2018

ILS IV

Epilepsy/bvFTD Dementia

Uncinate seizures/Uncinate Fits

- Olfactory/GustatoryHallucinations
- “Dreaming state”
- Orophargenal Automatism



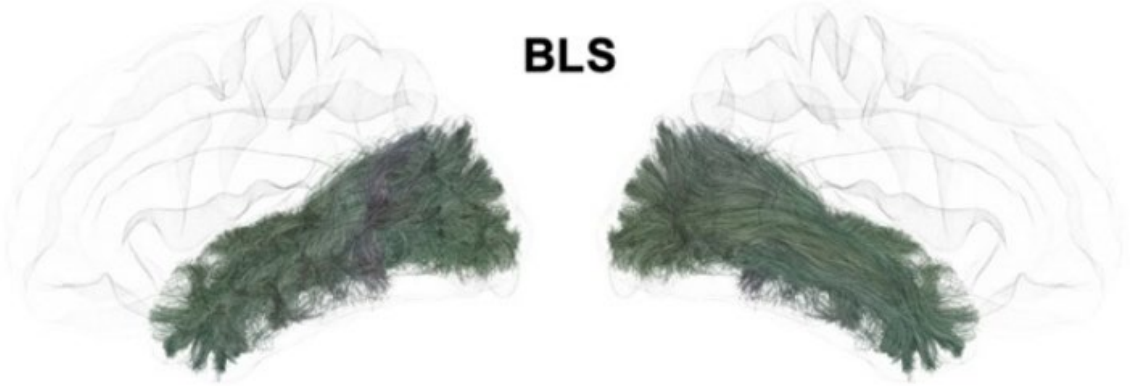
FTLD; behavior and semantic subtypes

- Loss of empathy/sympathy/social inter-relatedness
- Oropharyngeal fixation

Von Der Heide et al., 2013; López-Barroso et al., 2017; Mandonnet et al., 2018; Conner et al., 2018; Janelle et al., 2022

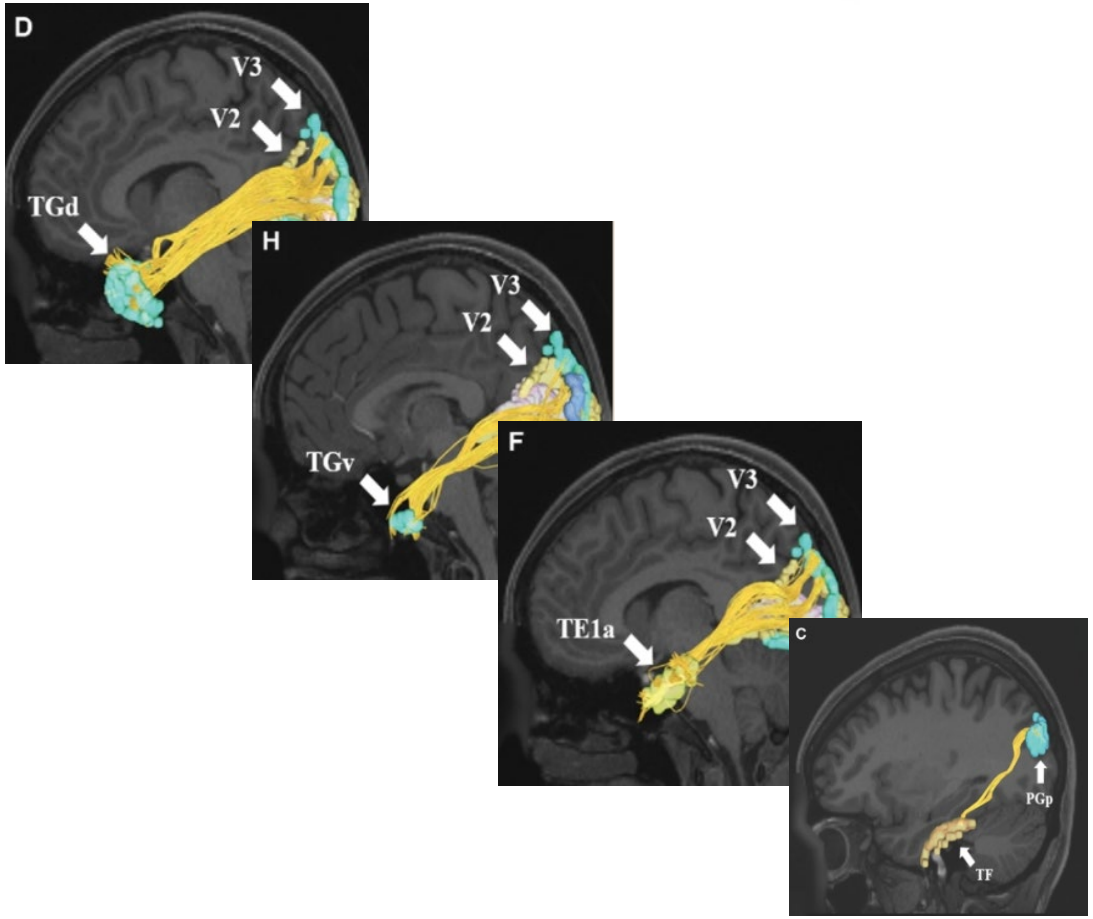
BLS

i.e. Inferior longitudinal fasciculus (ILF)



connects ventral temporal and occipital lobes

- pass below the inferior limiting sulcus of the insula
- consists of successive series of U-fibers



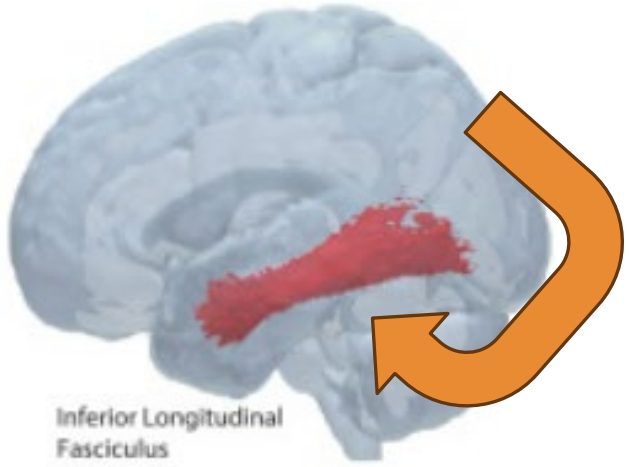
Can be divided into four subsystems

- BLS I - temporal cortex to lateral occipital (lateral)
- BLS II - temporal cortex to cuneus (medial)
- BLS III - temporal cortex to lingual gyrus (medioventral)
- BLS IV - temporal cortex to fusiform gyrus (ventral)

Von Der Heide et al., 2013; Mandonnet et al., 2018; Briggs et al., 2018

BLS

i.e. Inferior longitudinal fasciculus (ILF)



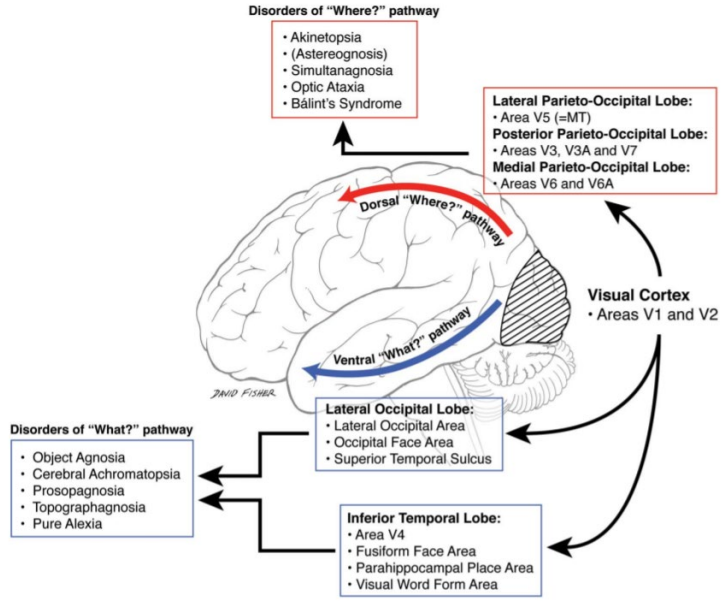
1
2
3
4

Hierarchy of Visuospatial Object Processing/ Comprehension

- Basic visual processing via BLS II
- Distance and depth perception, color determination via BLS I
- Letters and logical conditions (i.e., logical order) *via BLS III*
- face perception, object recognition, and reading via BLS IV

Clinical Implications

- Parkinson Disease/Lewy Body Disease Dementia
- Posterior Cortical Atrophy/Anton Syndrome



Visuospatial Ventral Stream
What is this?

Von Der Heide et al., 2013; Mandonnet et al., 2018; Briggs et al., 2018; Shin et al., 2019

BLS

Lewy Body Dementia

Brain Behav. 2020 Dec; 10(12): e01883.
Published online 2020 Oct 20. doi: 10.1002/brb3.1883
PMCID: PMC7749587
PMID: 33078912

Visual hallucinations and inferior longitudinal fasciculus in Parkinson's disease

Natsuko Yuki,[1,2] Akira Yoshioka,[2,3] Ryo Mizuhara,[1] and Tadashi Kimura[1]

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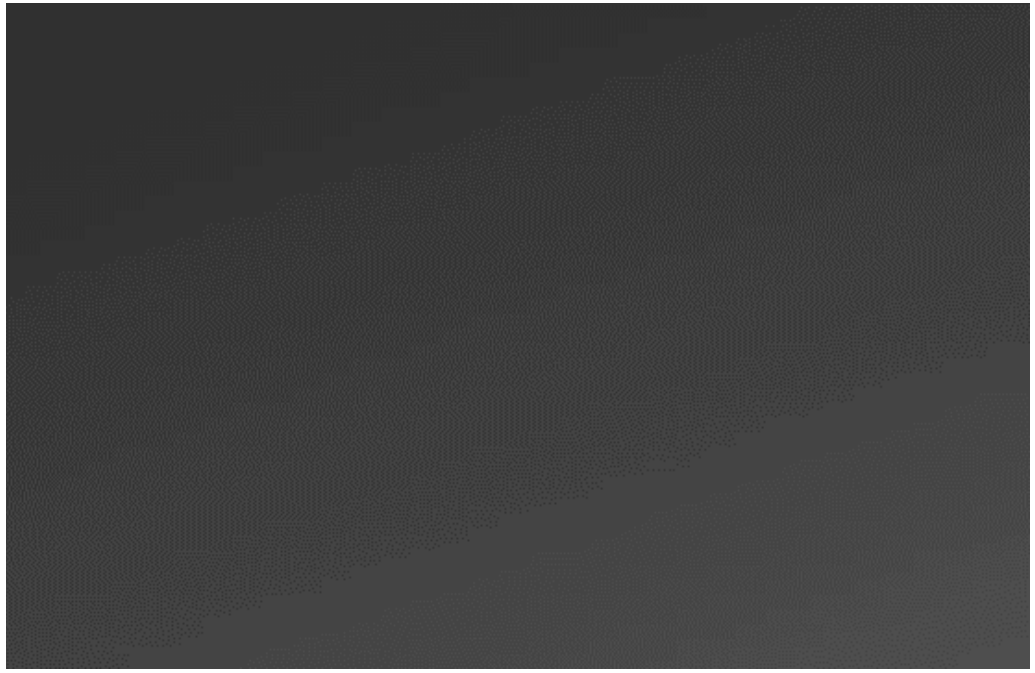
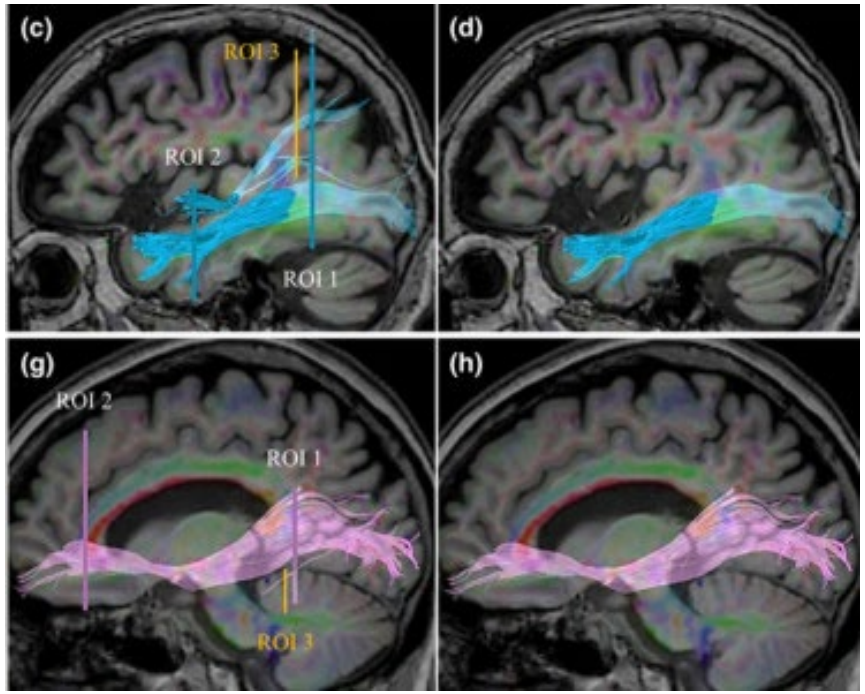
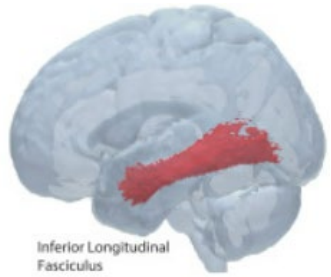






Mandonnet et al., 2018; Conner et al., 2018; Yuki et al. 2020

MesLS

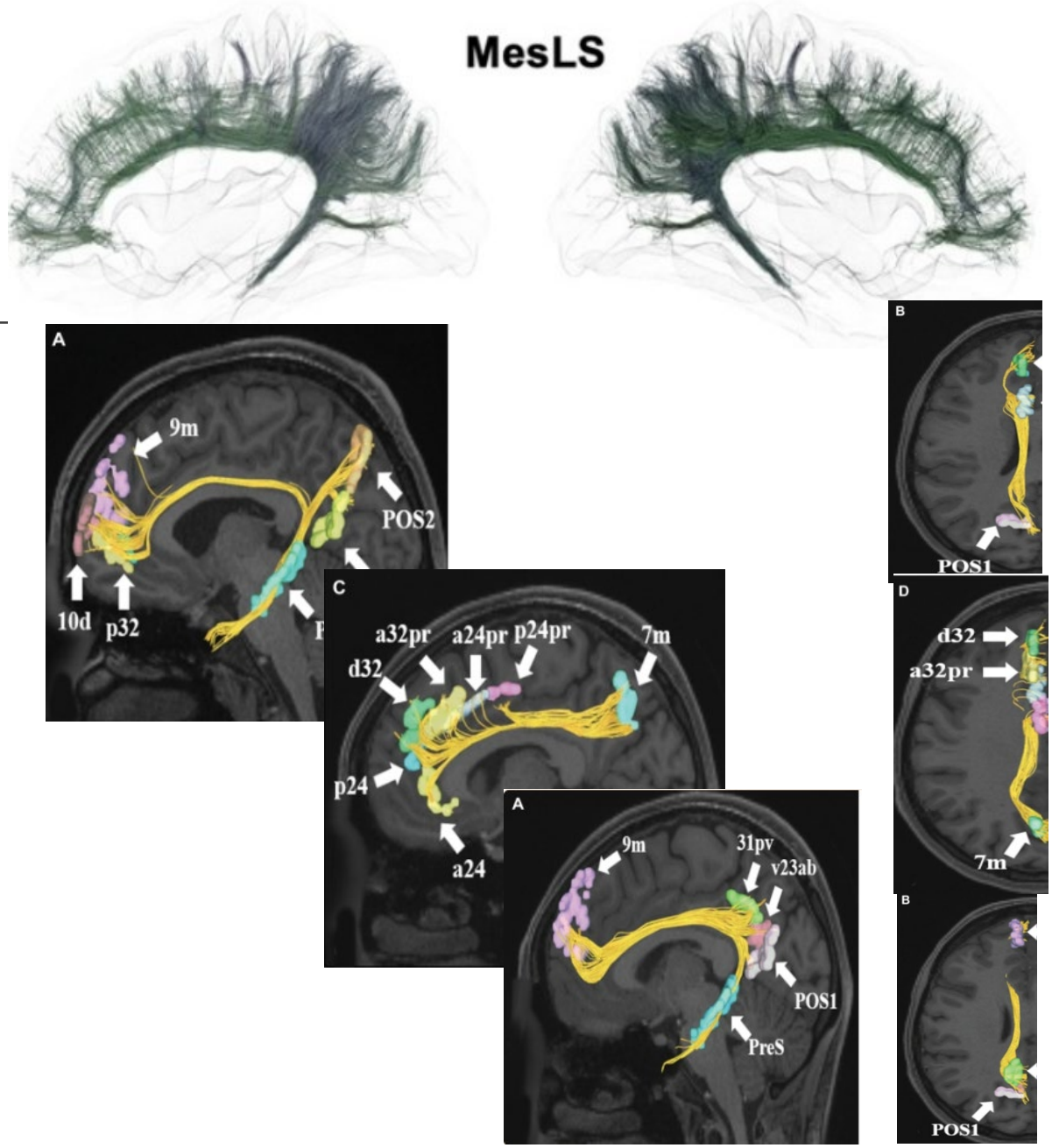
i.e. Cingulum

connects prefrontal cortex and cingulate gyrus to hippocampus

- medial surface of the hemisphere
- arching from the frontal pole up to the amygdala area.

Can be divided into two subsystems

- MesLS I or “inner cingulum”
- MesLS II or “outer cingulum” or supracingulate



Mandonnet et al., 2018; Briggs et al., 2018; Janelle et al., 2022

MesLS

i.e. Cingulum

Multimodal self-referential data relay

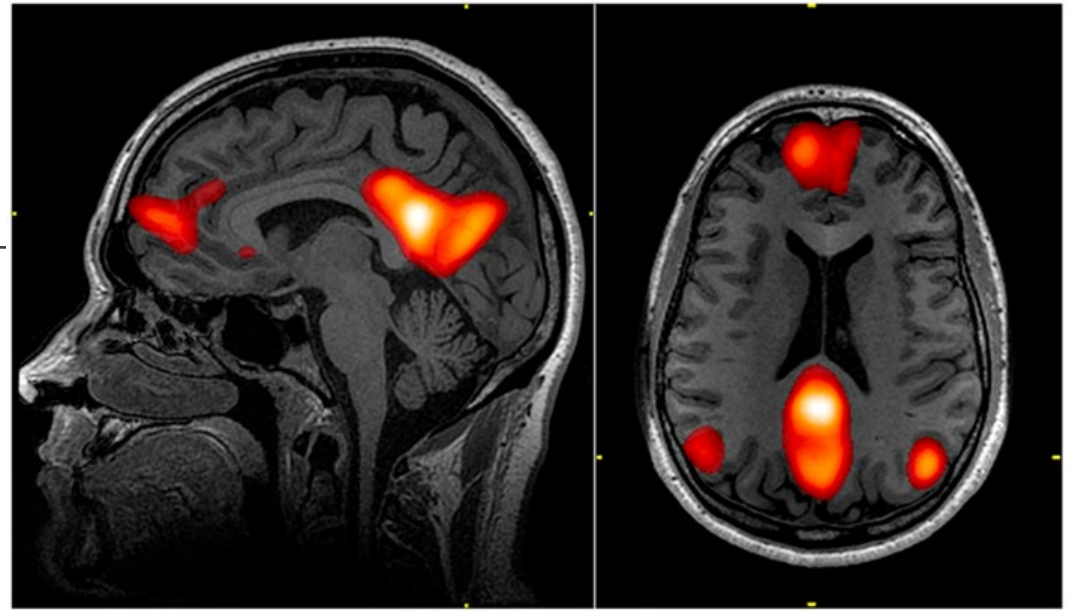
- **Anterior**; emotional response regulation, reward expectation, error monitoring
- **Posterior**: memory retrieval and spatial navigation
- **Lateral**: attention, decision making, language processing, and number processing

Clinical Significance

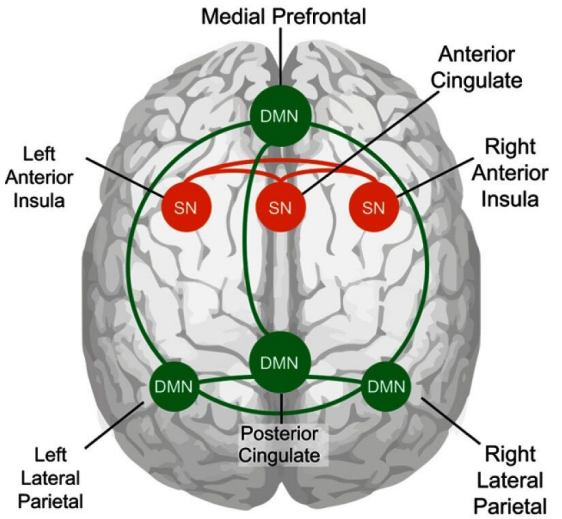
- Dementia NOS; AD, FTLD, PD
- Psych NOS; ADHD/Schizophrenia/PTSD/OCD/ASD/BD

So it effects everything?

Default Mode Network (DMN)



Most commonly defined as resting state data involved in self-awareness, introspection, and planning



van den Heuvel et al., 2008; Naumann et al., 2015; Bubb et al., 2018; Sandhu et al., 2021

MesLS

i.e. Cingulum

Brain. 2016 Dec; 139(12): 3137–3150.
Published online 2016 Oct 22. doi: 10.1093/brain/aww241
PMCID: PMC5382939
PMID: 27797805

Disconnection between the default mode network and medial temporal lobes in post-traumatic amnesia

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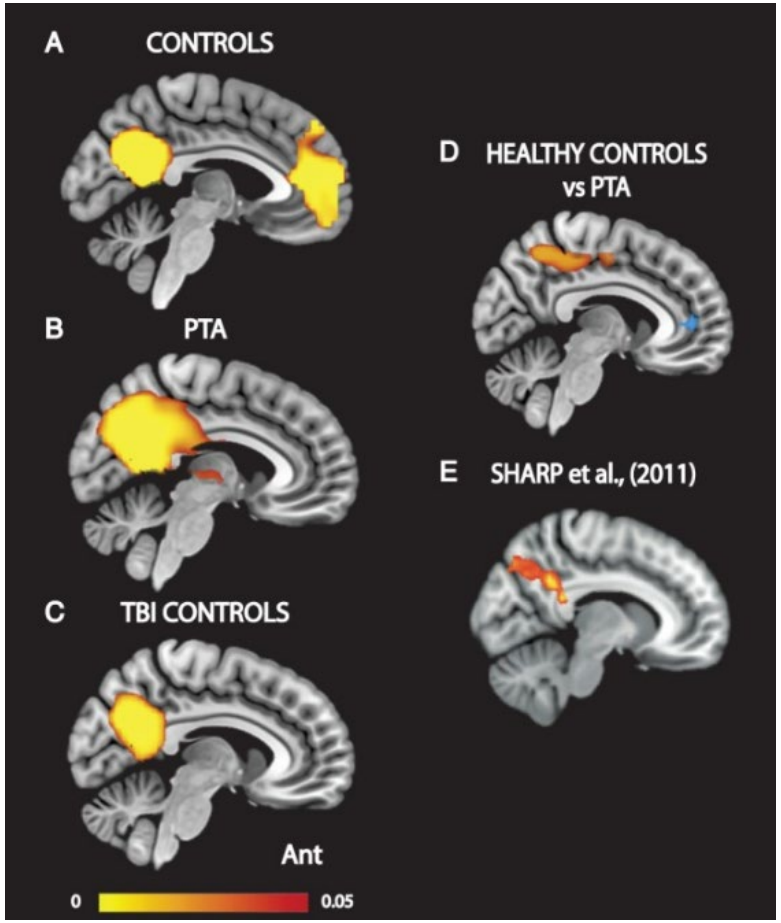
Post-traumatic amnesia (PTA) and traumatic brain injury (TBI) seem to be linked to transient/chronic disruptions in Default Mode Network

- connectivity with the parahippocampus
- connectivity between posterior (PCC, precuneus, lateral parietal) cortex and ventromedial prefrontal cortex (vmPFC).



van den Heuvel et al., 2008; Naumann et al., 2015; Bubb et al., 2018; Sandhu et al., 2021

MidLS

i.e. middle longitudinal fasciculus

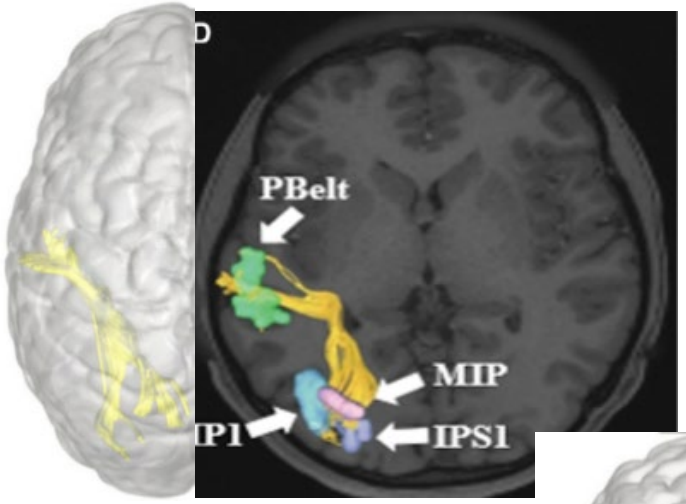
Connects anterior temporal to inferior parietal lobe/Extrastriate area

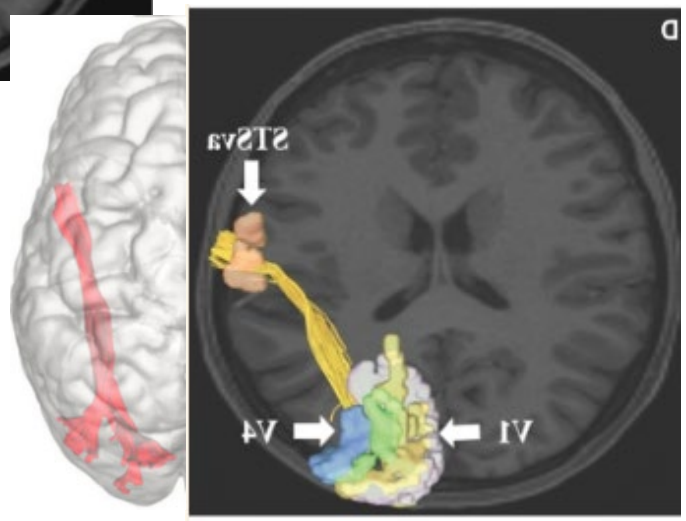
- Posterior-dorsal segment; i.e. posterior STG
- Antero-ventral segment; i.e. anterior STG

Function

- Inconsistent evidence
- Attention biases?
- Motion detection?
- Sublexical representations?
- Repetition-phonological network?
- Naming?

Clinical Significance unclear but implicated in PPAs

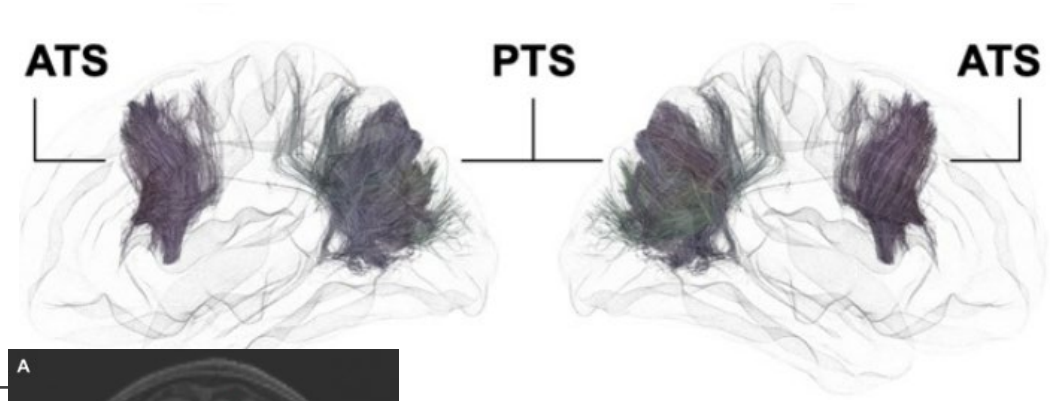




Mandonnet et al., 2018; Conner et al., 2018; Latini et al. 2020

ATS

i.e. Frontal Aslant Tract



Connects the superior to inferior prefrontal lobes

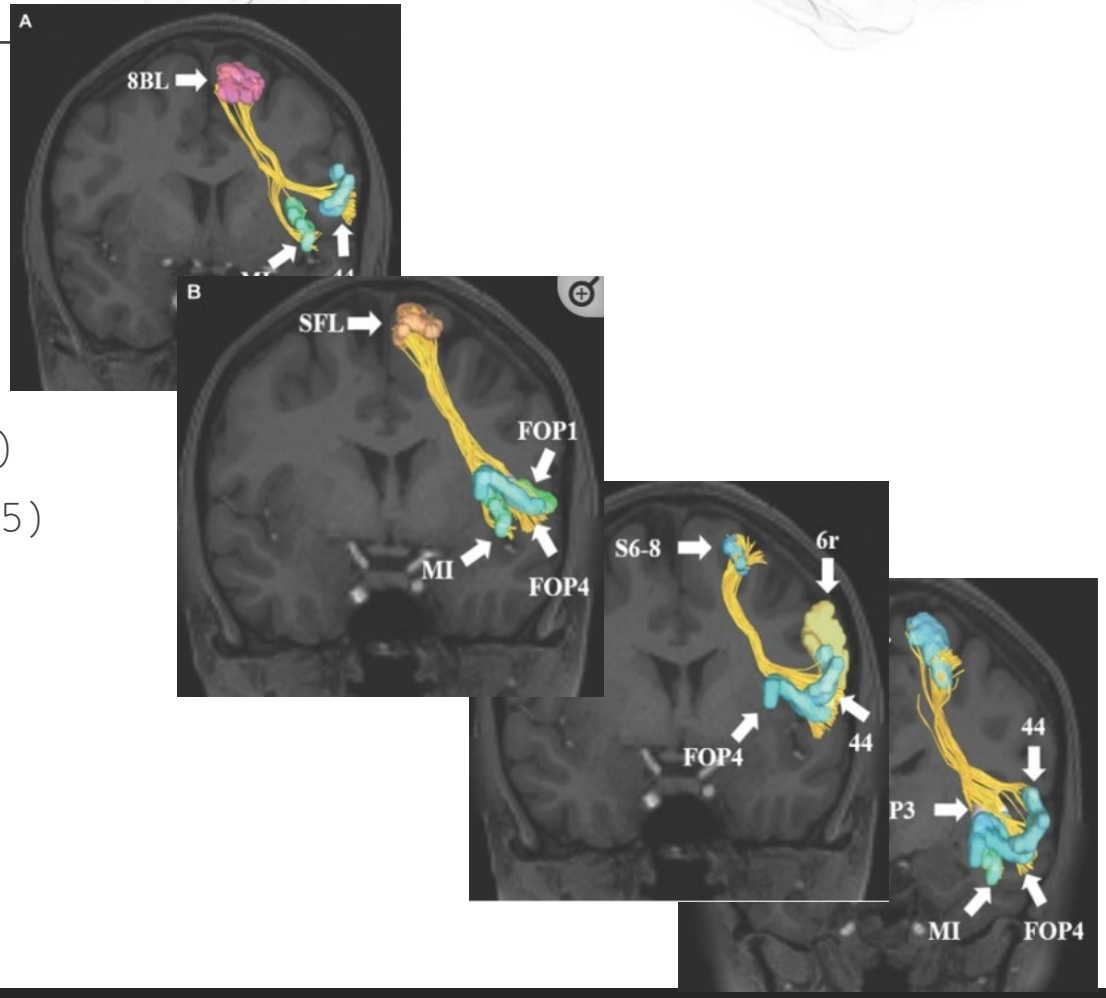
- Medial/superior frontal cortex (SMA/preSMA)
- Inferior frontal gyrus (Broca; pars triangularis/opercularis)

Can be divided into four subsystems

- ATS I - frontal area to anterior pars triangularis (Brodman 47)
- ATS II - frontal area to posterior pars triangularis (Brodman 45)
- ATS III - pre-SMA to pars opercularis (Brodman 44)
- ATS IV - SMA to precentral gyrus

Function

- Language; expressive aphasia/speech apraxia/syntax



Mandonnet et al., 2018; Briggs et al., 2018; Janelle et al., 2022

ATS

i.e. Frontal Aslant Tract

Functions

- Language order and syntax via ATS I
- translate from secondary or tertiary language via ATS II
- Inflectional morpheme via ATS III
- Nocireception via ATS III
- Articulation via ATS IV

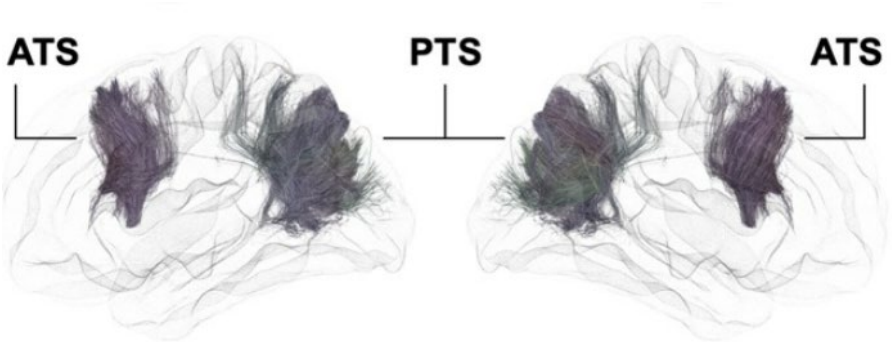
Clinical Implications

- Expressive Aphasia
- nfPPA/lvPPA

Mandonnet et al., 2018; Briggs et al., 2018; Janelle et al., 2022

PTS

i.e. vertical temporo-parietal and occipital fasciculus



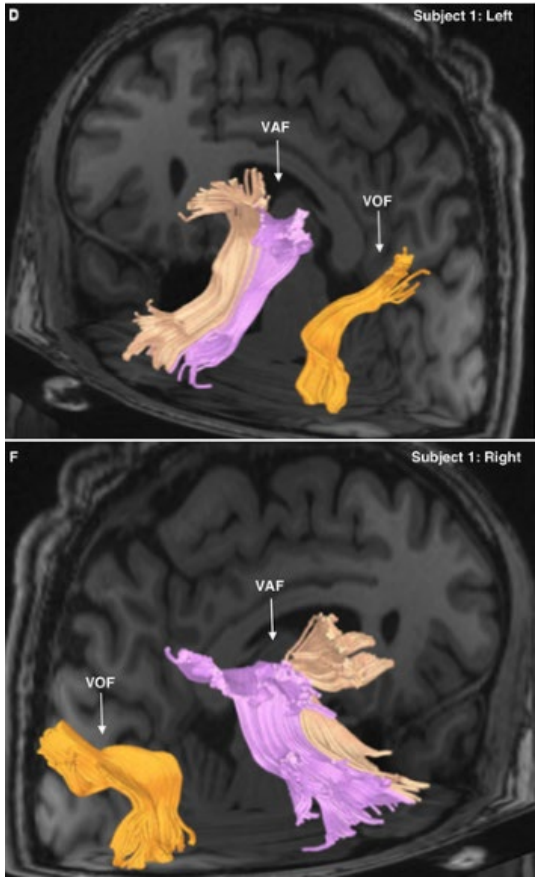
connects parietal occipital and posterior temporo-occipital

Can be divided into two subsystems

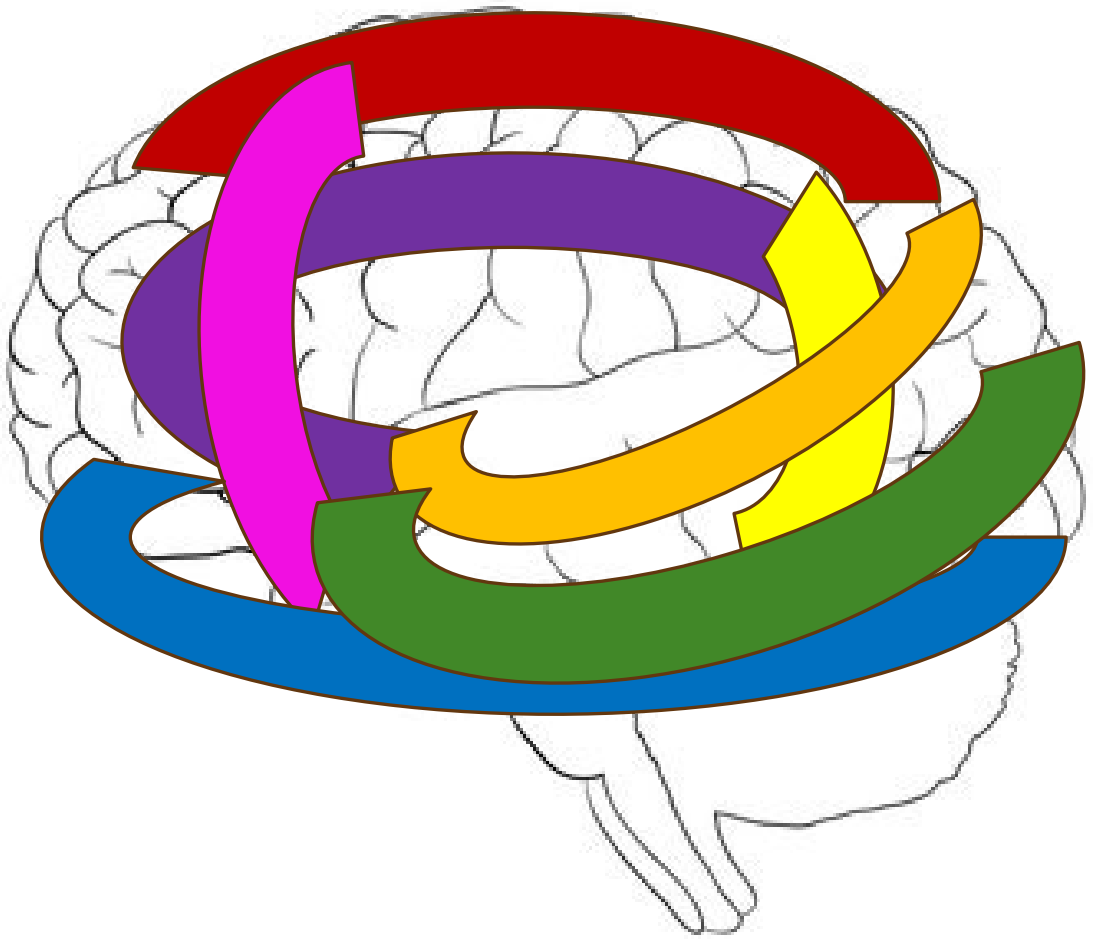
- PTS I i.e. temporo-parietal aslant tract
  - middle temporal gyrus to supramarginal/angular
- PTS II i.e. vertical occipital fasciculus
  - ventral transverse/temporo-occipital to intraparietal sulcus

Primary link between the dual visual processing streams

- VOF – Reading?
  - Pure word blindness, also known as pure alexia
- VTPF - visual word and language comprehension?



Mandonnet et al., 2018; Briggs et al., 2018; Panesar et al., 2018; Mahdy et al. 2021



Spatial Awareness/Attention

Object Awareness/Attention

Comprehensive Sound

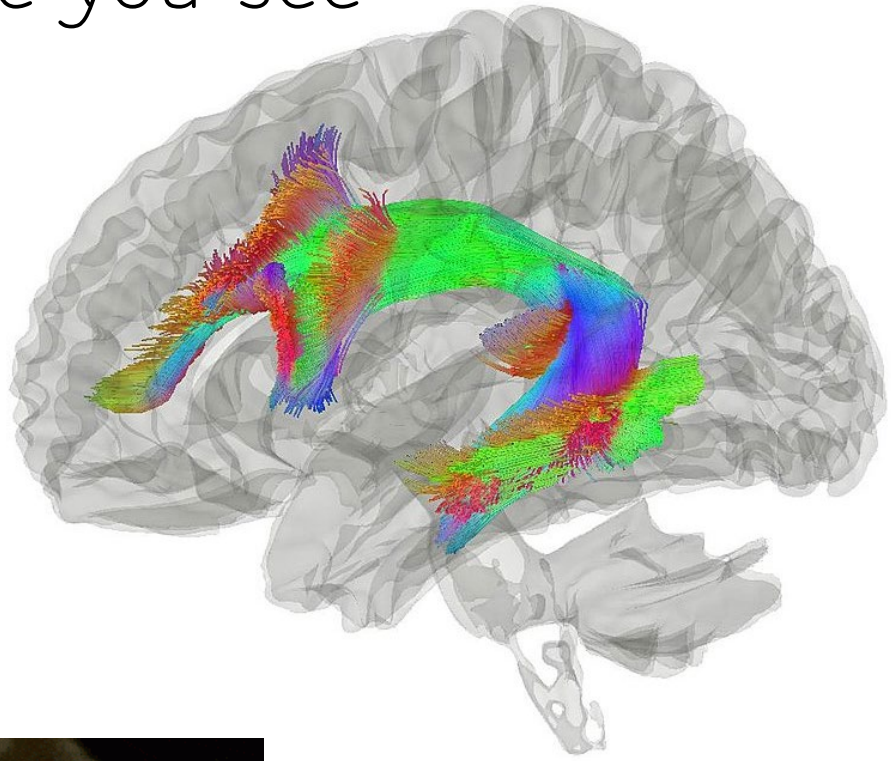
Comprehensive Vision

Comprehensive eMotivation

Articulated Language

Visual Language

Next time you see



Don’t roll your eyes

Think

Less Focal-Symptomatology

And

More Disconnection-Phenomenology

Walenski et al., 2019

Ochsner Health

Special Thanks to the Ochsner Neurocognitive Team

References