Origins of Language

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JANUARY 2025

CJV Intention: Origins of Human Language

- Review of Evelina Fedorenko MIT lab: Language and thought in the human brain
- How Language Began: The Story of Humanity's Greatest Invention by Daniel Everett, 2017
- Human Lineage: Matt Cartmill and Fred H. Smith, 2018 (Neandertals & Language)
- A Critical Introduction to Language Evolution: Current Controversies and Future Prospects: Ljiljana Progovac, 2019
- Review of Neanderthal Language: Demystifying the Linguistic Powers of our Extinct Cousins by Rudolf Botha, 2020
- Review The Language Puzzle by Steven Mithen, 2024

CJV on the evolution of language

- I have reviewed the books in prior slide and a bunch of other sources.
- The evolution of language is an incredibly complex area of study.
- Language does not fossilize.
- Fundamental to the evolution of language are cultural and biological evolution. Not all linguistic theories adhere to the latter.
- There are a multiplicity of theories and hypotheses within this field.
- None yet holds a scientific majority view, except for gradualism.
- I attempt to summarize the major views and most interesting theories.
- Of the primates only later hominins had language. It is unclear whether cetaceans do.
- There appears to be a correlation of language to brain size.

Words

- Words are always entirely learned and culturally specific.
- Words can be combined; grammar = rules by which we combine words

- There were likely proto-languages (giving meaning to sounds) for a million years; then merging of words into phrases and sentences; gaining meaning thru a shared understanding of sounds
- Eventually gained the ability to share non-present events (references to past and future), things you can't just point to.
- Role of music and gestures in evolution of language is debated.

Offline brain systems

- Offline brain systems: neurons that fire without a coexisting stimulus (not sensory neurons, but neurons in multi-modal association areas)

- Our ability to think of something without a present stimulus = escape from immediate present (can talk about time; alternative worlds) abstraction; talking about what is not present

Types of words

- Lexical = mean things: dog, comb, bicycle
  - Abstract = can’t see, may not exist = justice
  - Concrete = can see = a dog
  - Iconic = words that have a perceived resemblance between their form and their meaning, look like or sound like their referent; easy to learn their meaning: i.e. "quack”, “plop”, "peep" "crash" mimic the sounds they denote, and "wiggle" and "zigzag" mimic motion. Also include onomatopoeia like "clunk", "oomph", and "purr". Kids learn these first; easiest words to grasp; H. erectus probably used these
  - Arbitrary = different word for same thing in different languages
- Grammatical = and, if, this

Language and speech

- Unique vocal tract evolved ability to produce more complex sounds: e, ou, ah
- Speech is separate from language; it is vehicle for communication with others; language does not have to be spoken
- Hearing ability for certain frequencies up to 5 kilohertz: MHs, Ns, SH
- Voluntary control of breathing during speech: 10% inhale, 90% exhale
- Dating of origin of capacities: expanded thoracic vertebral canal compared with australopithecines and Homo ergaster to control breathing = dated to at least 500 Ka (1.6 Ma-100 Ka) = LCA of MHs and Ns; but not in H. erectus (short, unmodulated speech)

Language and speech

- Breath control during bipedal movement and running in H. erectus may have contributed to rhythm and breath control in speech
- Origin of languages: in Africa; probably in 1 individual; with isolation, increased number of languages; i.e. 4 Ka = proto-Indo-European languages = today 400 languages

Sociality and Language

- Social need for complex interactions (Acheulean tool making learning, hunting, crossing bodies of water) imply need for language
- Crucial to language development was its social context: enable social communication and bonding; note Dunbar’s concept of sociality and brain size evolution; language is inherently designed for social group communication; basis for social innovation
- Tool making learning: learning from observation in social setting, a crucial prerequisite for development of language; exaptation of hierarchical motor sequences
- Co-ordinated scavenging and hunting: language is major advantage
- Language increases collective thinking and innovation

What were the first words?

- Original mother tongue: The evidence for this is that all human languages, unlike other forms of animal communication, string together words into sentences that have subjects, verbs and objects ("*I kicked the ball*"), and anyone can learn any language.
- Comparative linguists search for sounds that come up again and again in languages from all over the world. They argue that if any relics of a mother tongue still exist today, they will be in those sounds. Merritt Ruhlen, for example, argues that sounds like *tok*, *tik*, *dik*, and *tak* are repeatedly used in different languages to signify a toe, a digit or the number one. Although studies by Ruhlen and others are contentious, the list of words they say are globally shared because they sound almost the same also includes *who*, *what*, *two* and *water*.

Earliest words

- Another approach is to look at words that change very slowly over long periods of time. Use of such statistical studies to show that words for the numbers 1 to 5 are some of the slowest evolving. Also on this list are words involved in social communication, like *who*, *what*, *where*, *why*, *when*, *I*, *you*, *she*, *he* and *it*. This list fits with the expectation that language evolved because of its social role
- More broadly, we can say with some confidence that the first words probably fitted into just a few categories. The first ones may have been simple names, like those used by some of our primate relatives.
- Vervet monkeys give distinct alarm calls for leopards, eagles and pythons, and young vervets must learn these. In humans, *mama* is a strong candidate for a very early noun, given how naturally the sound appears in babbling and how dependent babies are on their mothers. The sound "*m*" is also present in nearly all the world's languages. Finally, simple social words like you, me and I, yes and no, were probably part of our early vocab.

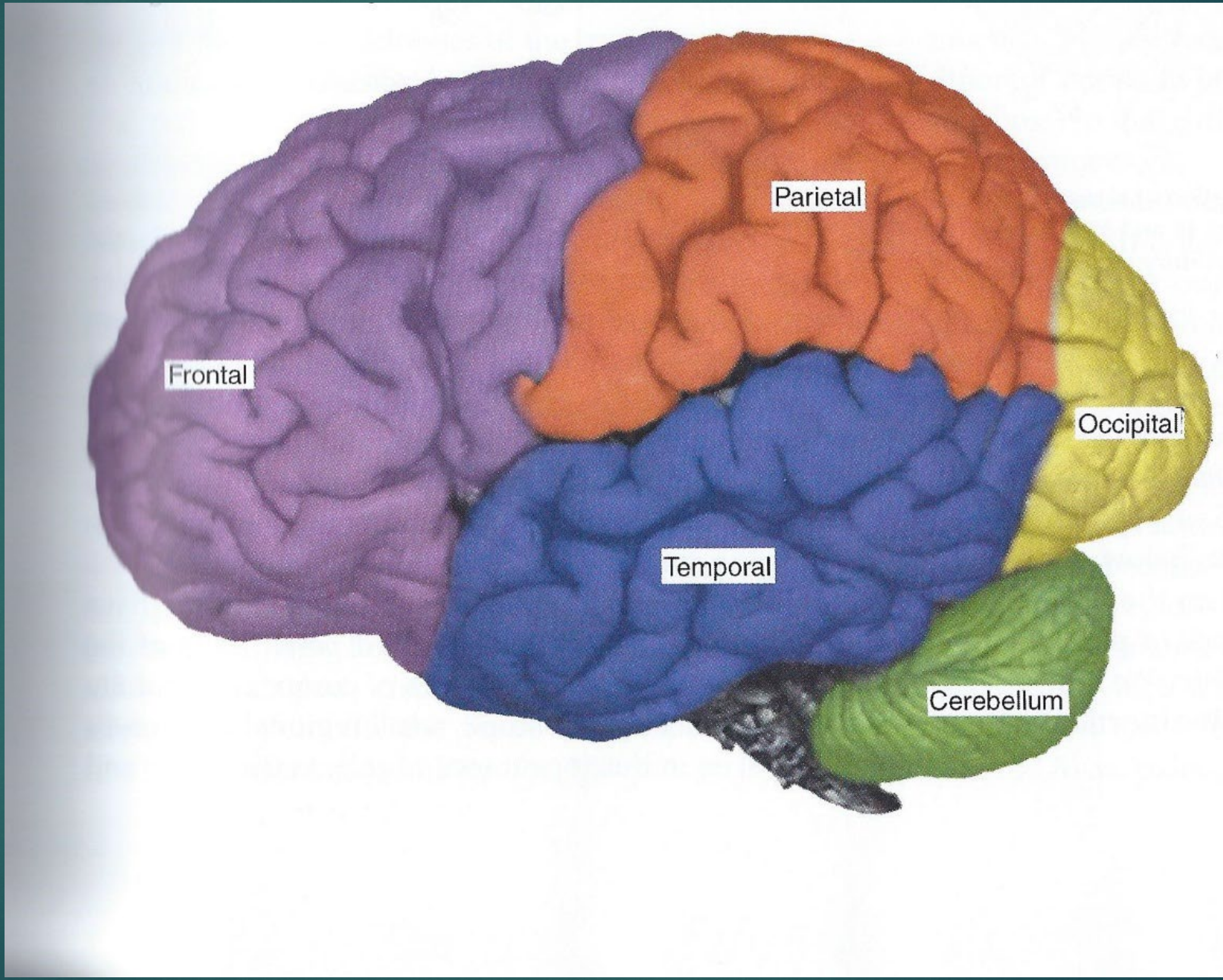
Is "Huh?" a Universal Word? Conversational Infrastructure and the Convergent Evolution of Linguistic Items -- Mark Dingemanse, et al. 2013

- A recent study suggested that huh is universal.

- Huh, used as a 'repair initiator' when, for example, one has not clearly heard what someone just said, is a universal word.

- Presented evidence and arguments that huh?, or more precisely a short questioning interjection with the function of other-initiation of repair, is a universal word likely to be attested in similar form in all natural spoken languages. The similarity of this interjection across languages is unlikely to be specified in our genetic makeup and we argue that it is the result of convergent cultural evolution:

Brain’s 4 lobes



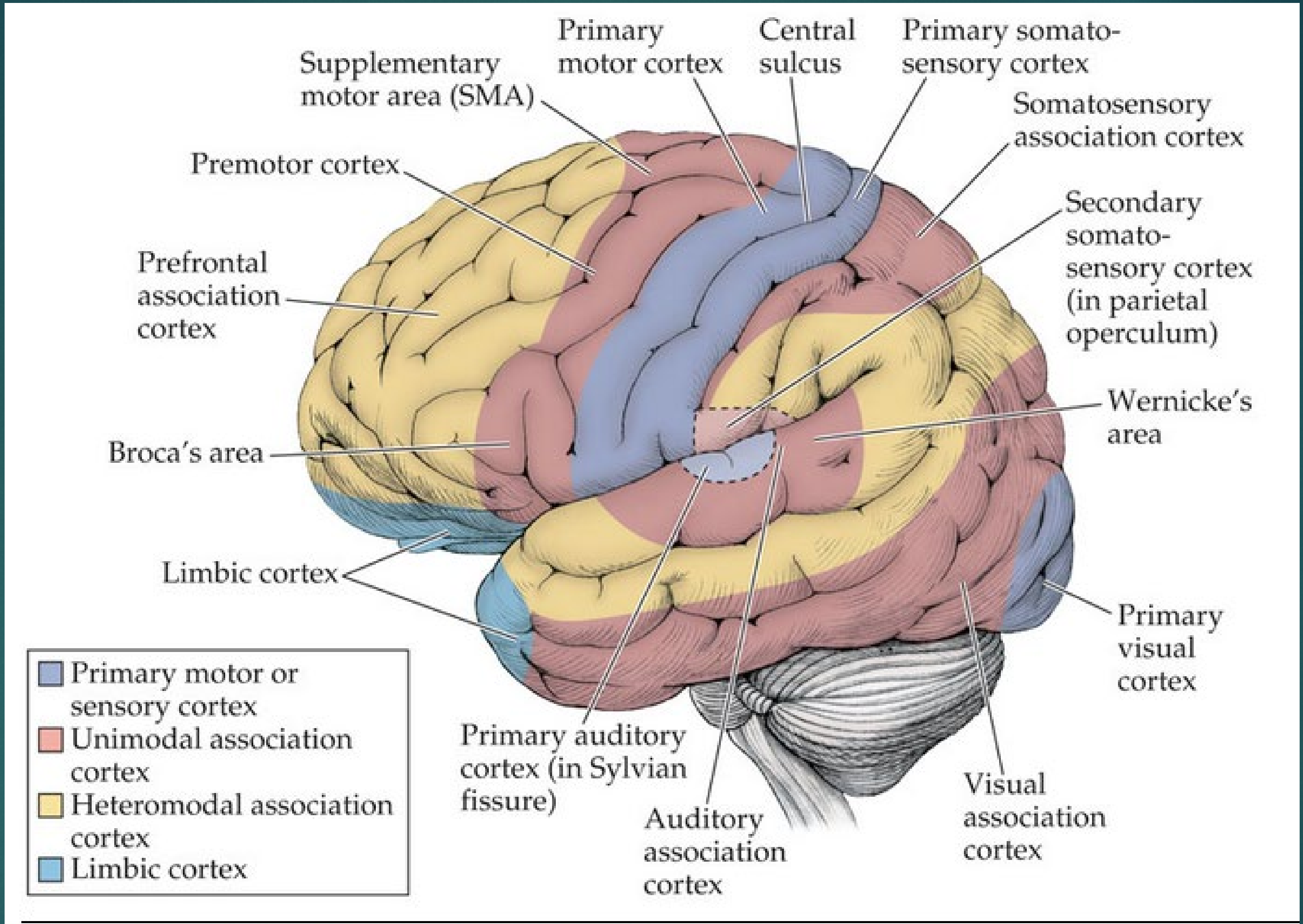
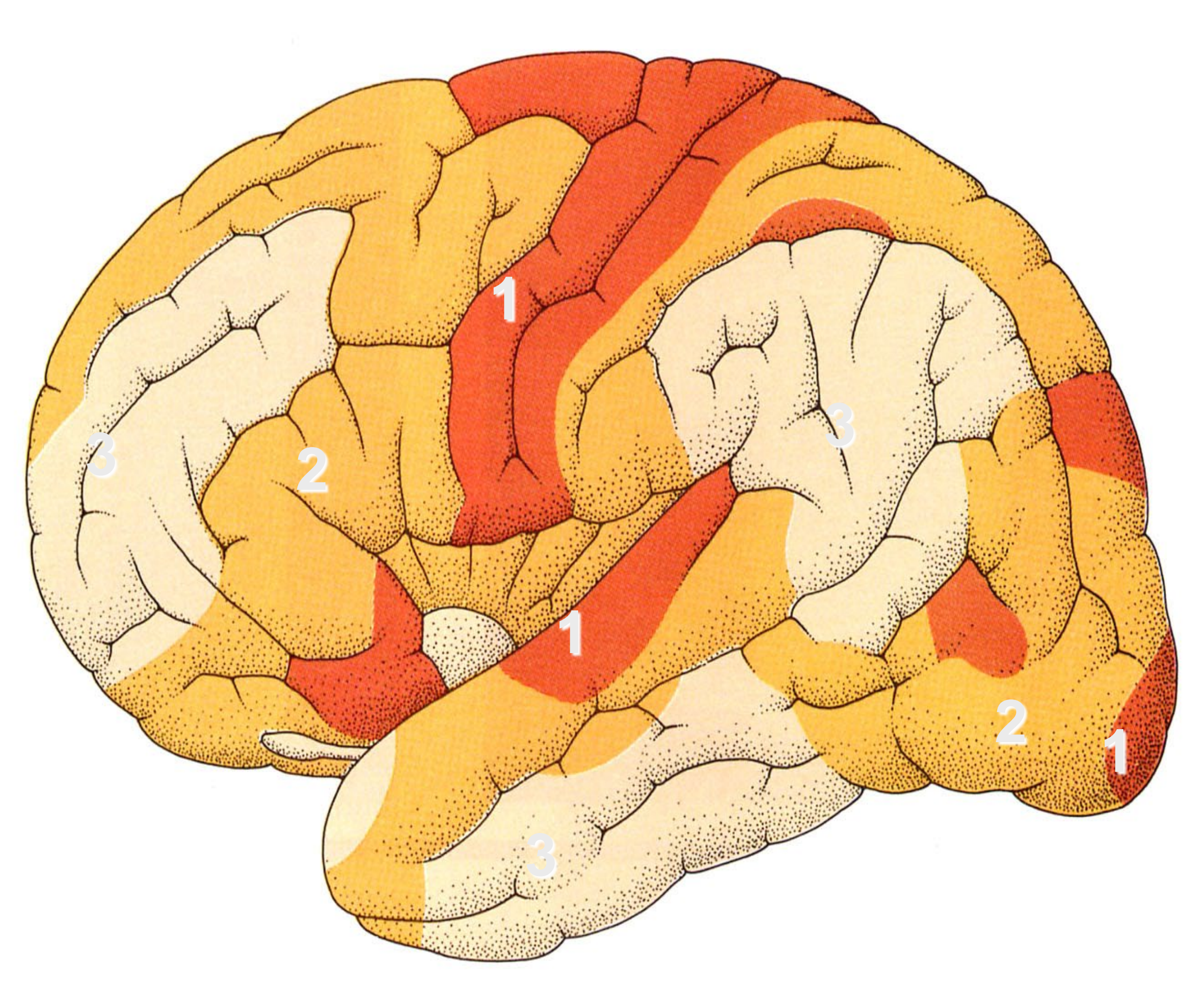


Figure 2.25 Association Cortex Lateral view of left hemisphere showing main areas of primary sensory and motor cortex,

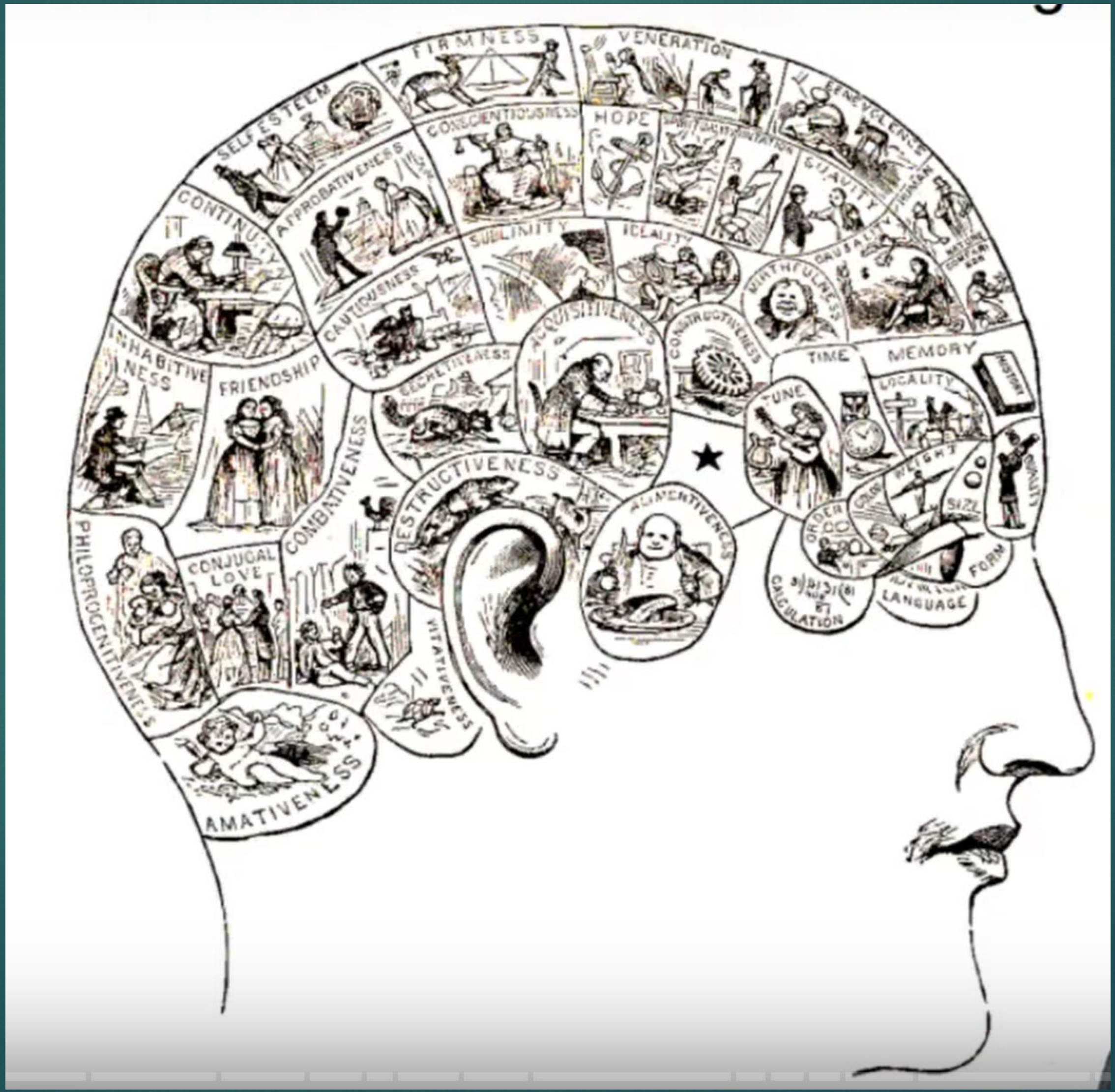
Primary = direct perception; Unimodal Association = single perceptual processing
Heteromodal association = multisensory, multimodal, higher cognitive processing

Order of Cortical Maturation

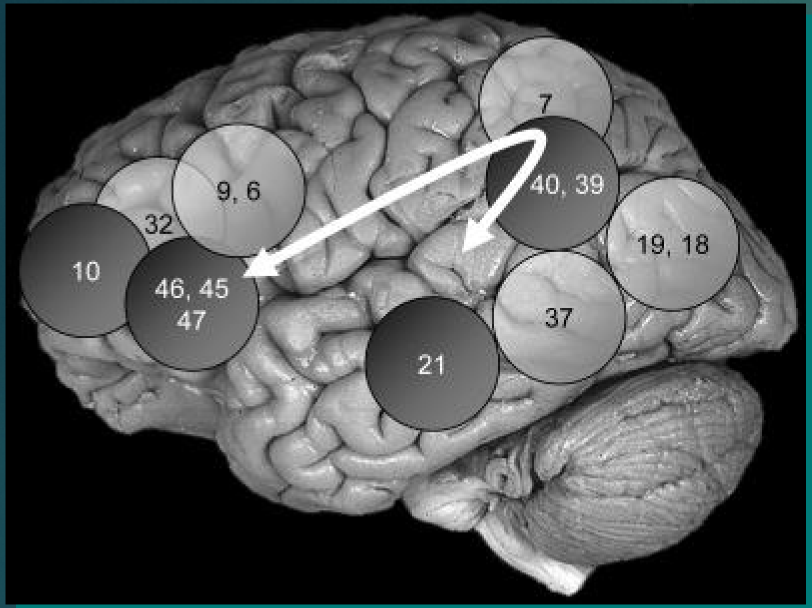


1 – Sensorimotor & primary areas; 2 – secondary areas; 3 – Association areas

Phrenology chart, 1883: bump analysis = good idea (functional localization), poor technology



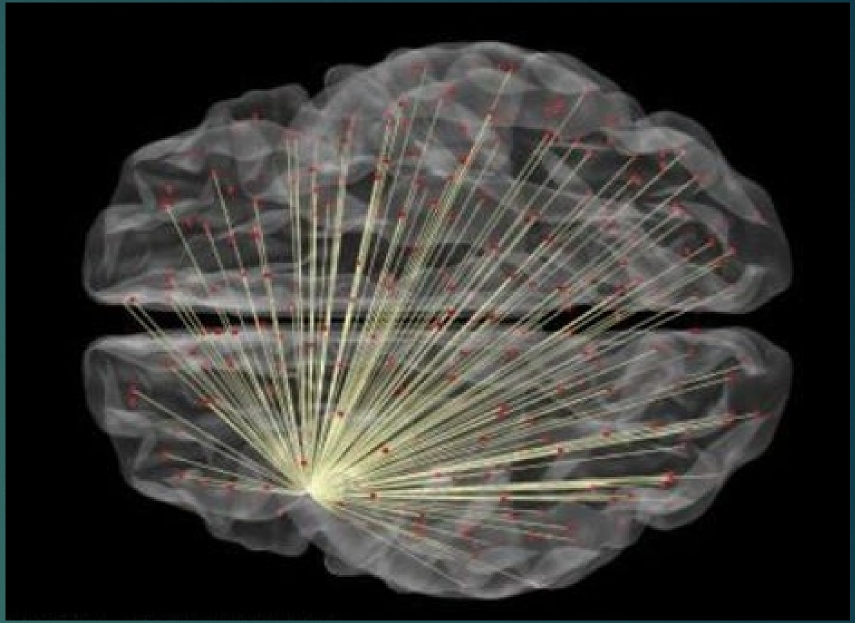
P-FIT: Parieto-Frontal Integration Theory: Biological basis of IQ



Dark Grey: Left Hem

Light Grey: Right Hem

Arcuate Fasiculus: connector



Parieto-Frontal Integration Theory (P-FIT) identifies a brain network related to intelligence, one that primarily involves areas in the frontal and the parietal lobes:

High intelligence probably requires *undisrupted information transfer among the involved brain regions along white matter fibers*

10% of Fluid IQ: Connectivity to Left DLPFC: goal monitoring

Brain as Swiss army knife: Domain Specific Areas of the Brain

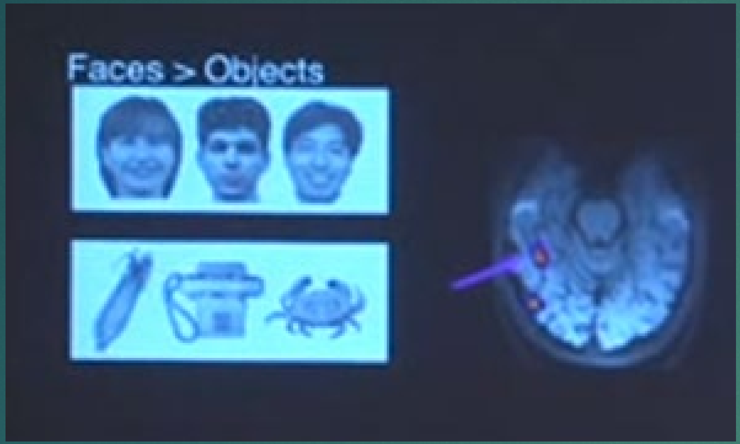
Special purpose, domain specific processors (localized functional areas):

- Classic: Vision, Touch, Motor Control, anger & fear (Amygdala) areas
- Faces
- Color
- Regions of space
- Visual motion
- Body parts (but not faces)
- Hearing sounds with pitch
- Hearing sounds without pitch
- Speech
- Understanding the meaning of a sentence
- Understanding mental states of others
- Voice recognition

141 functions: $1400

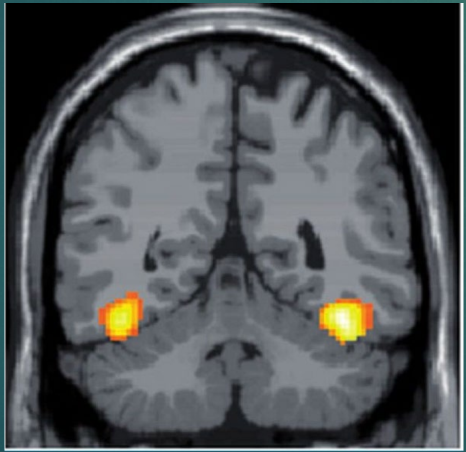
Fusiform Face Area (FFA): Face Recognition

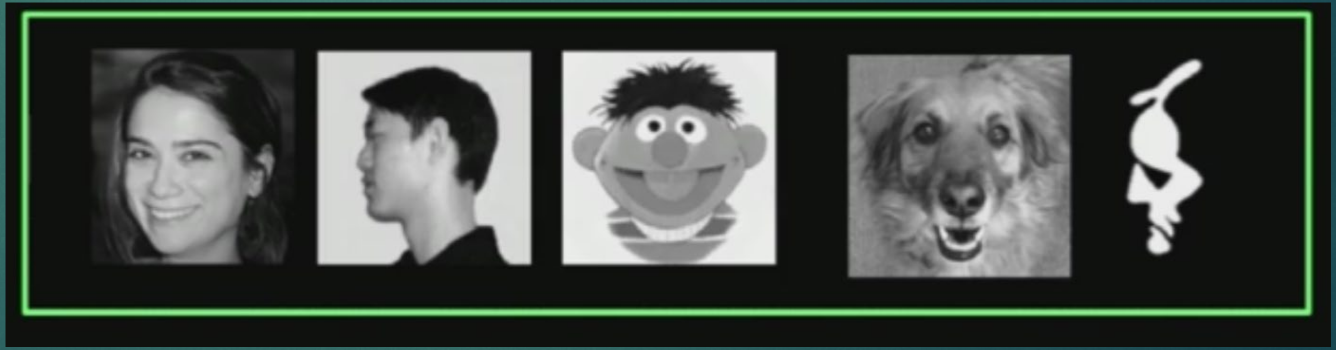
Brain regions for face vs. object recognition



<u>Genetic</u>: Face perceptual abilities are inherited

No correlation between IQ & face recognition





Confirmed in epileptic pt with 2 electrodes on FFA

Nancy Kanwisher at MIT

FFA: Face recognition

But also visual processing in experts: chess boards in expert chess players

Amygdala beats FFA

- Amygdala has faster face processing than the FFA; faster than blink of an eye (33ms)
- Flashes of faces result in a response from the amygdala, initiating an emotional response, sometimes without even activating the FFA at all.

Visual Word Area: Reading is experience dependent

FFA

VWFA
Left ventral occipitotemporal cortex

PPA

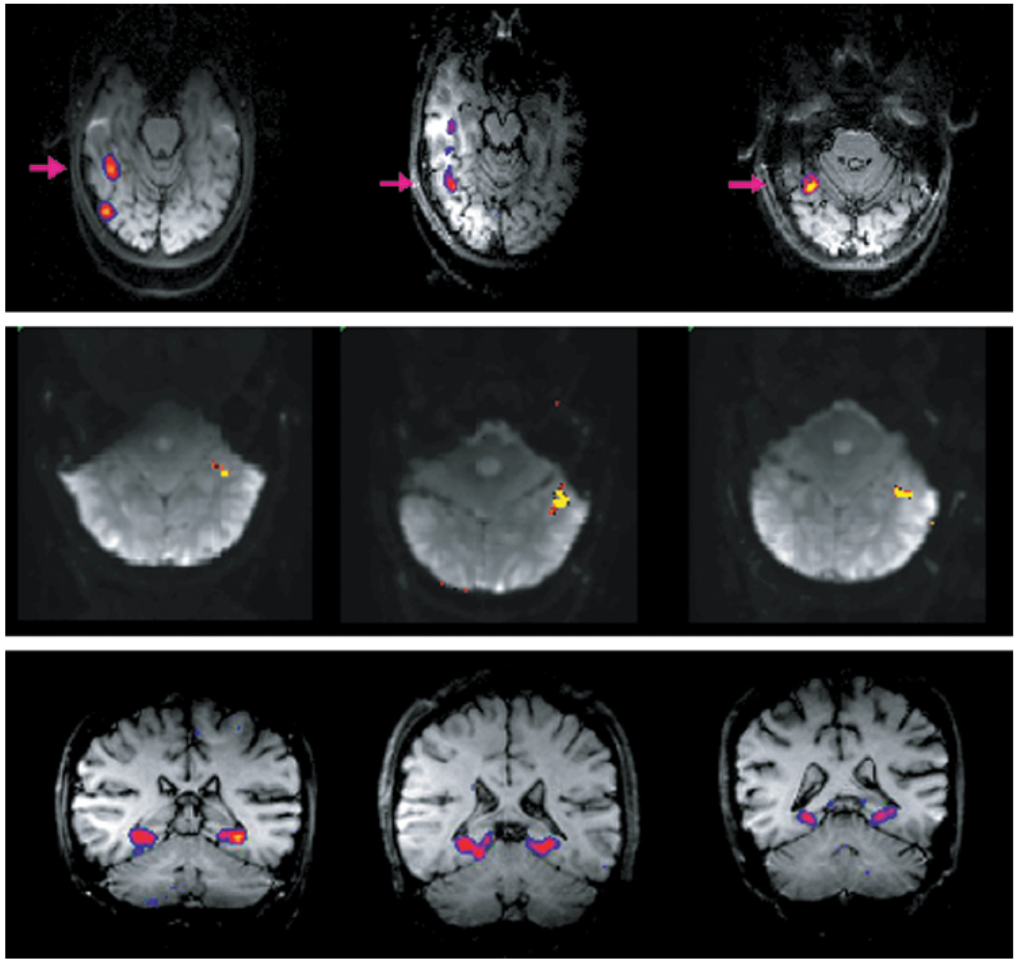


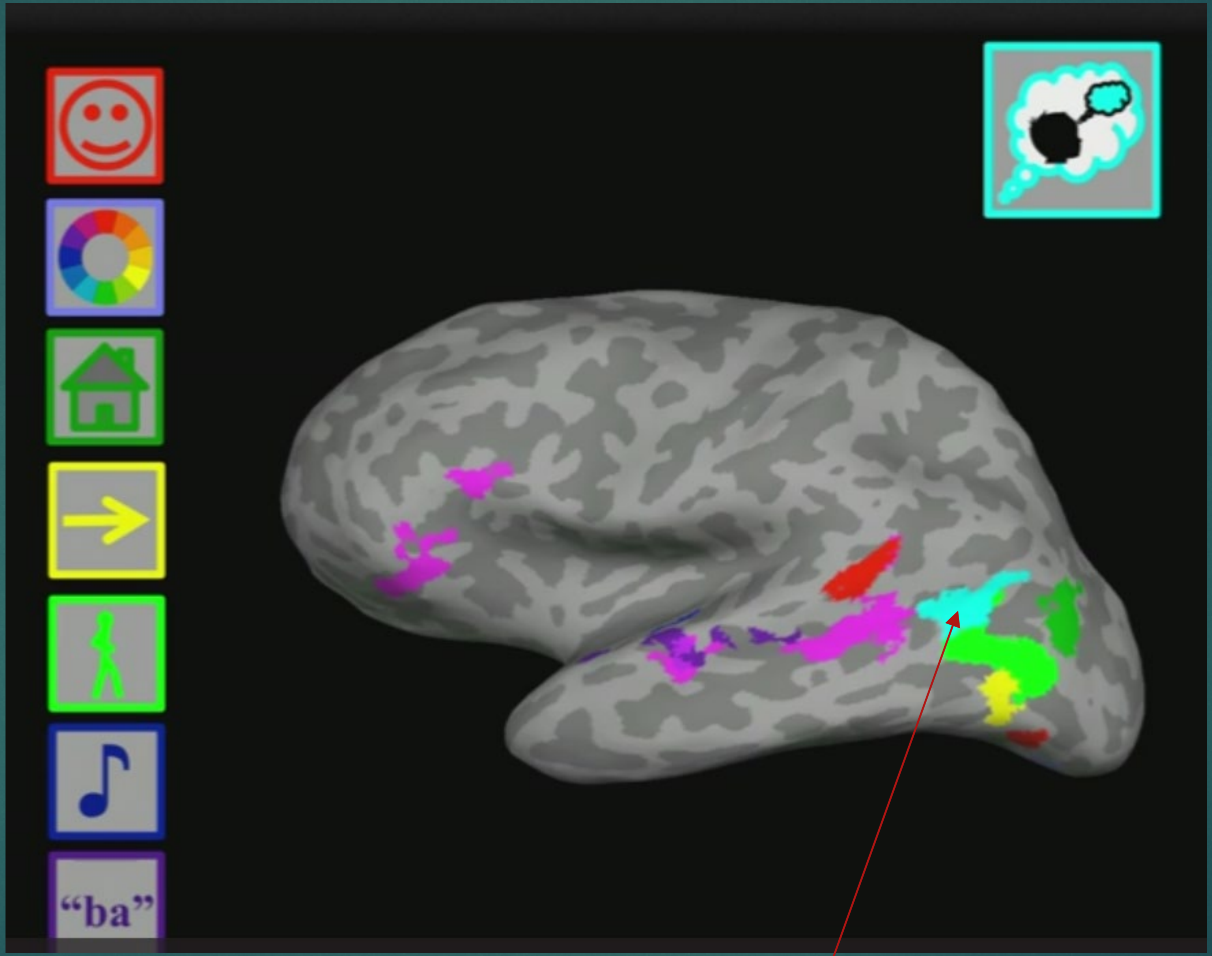
Fig. 6. Three of the functionally specific regions that have been discovered using the individual-subjects functional ROI approach. Top panel: the fusiform face area (FFA), which is defined by a higher response to faces than objects shown in three individual subjects (data from Kanwisher et al. 1997). Middle panel: a word and letter-string selective region, which is defined by its higher response to visually presented words than line drawings of objects shown in three individual subjects (data from Baker et al. 2007). Lower panel: the parahippocampal place area (PPA) which is defined by a higher response to scenes than objects shown in three individual subjects (data from Epstein et al. 1999).

Faces

Visual Words based on experience: literacy changes the brain

Scenes

Thinking about thoughts of others

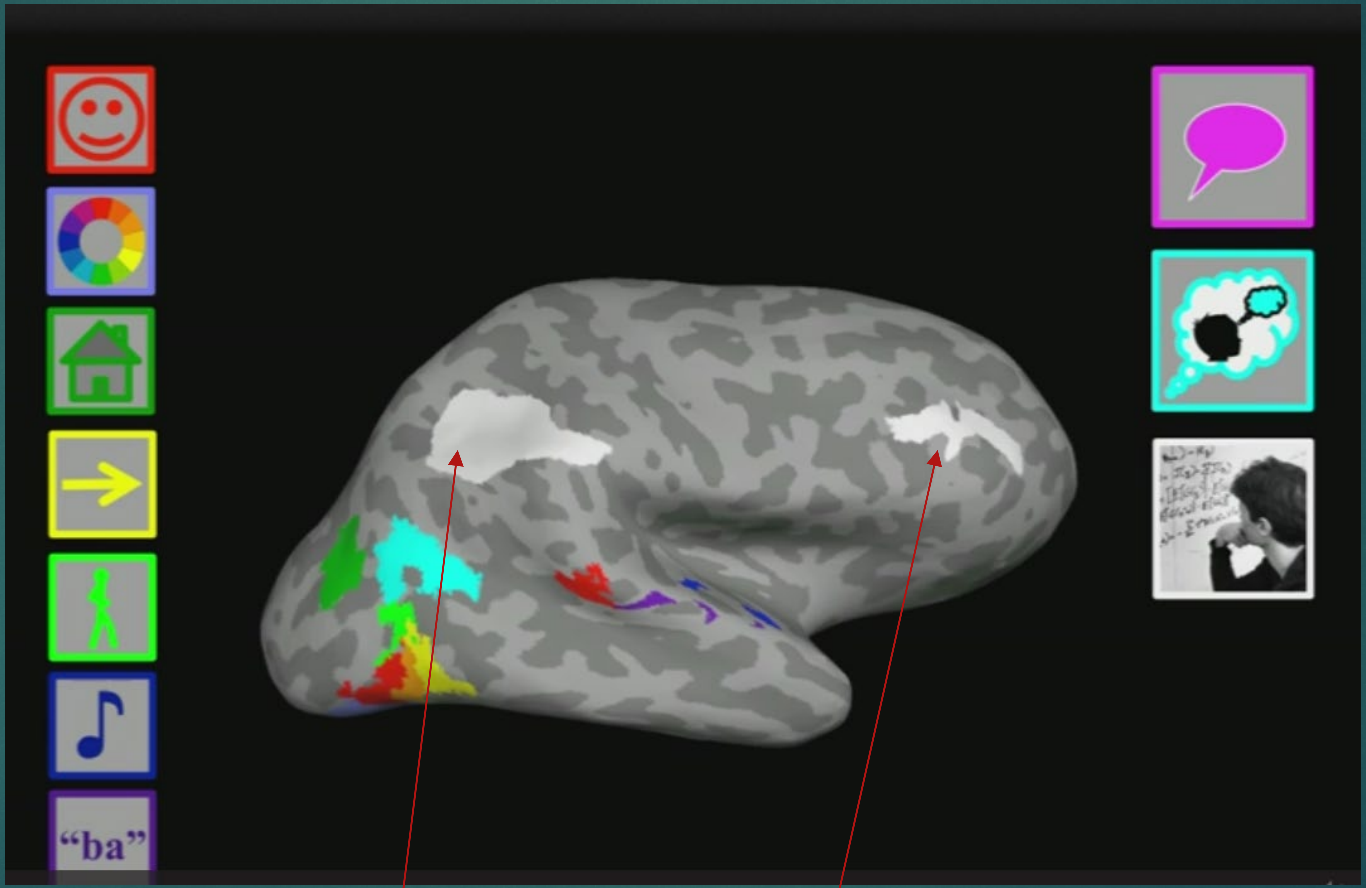


Other's Thoughts

Modular/specialized brain areas

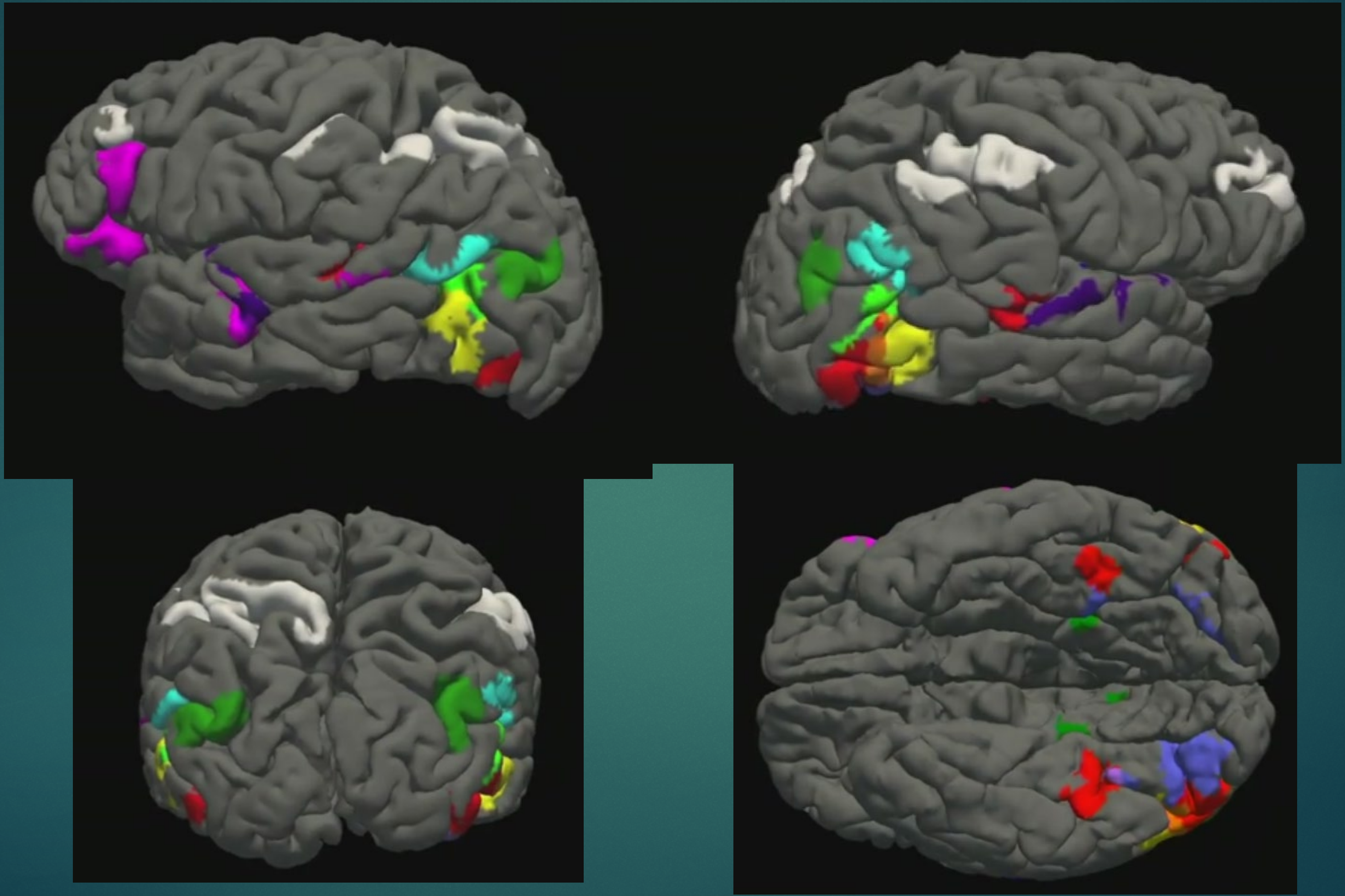
- There are domain-specific regions (i.e. sensory motor areas).
- Tailored to solve particular problems of longstanding importance to our species
- Proof of functional specialties of these areas:
  - activation on fMRI for normal function and
  - lesion studies for pathology

General Purpose Processors = multiple demand



Respond to any difficult mental task

Same places in everyone: genetic



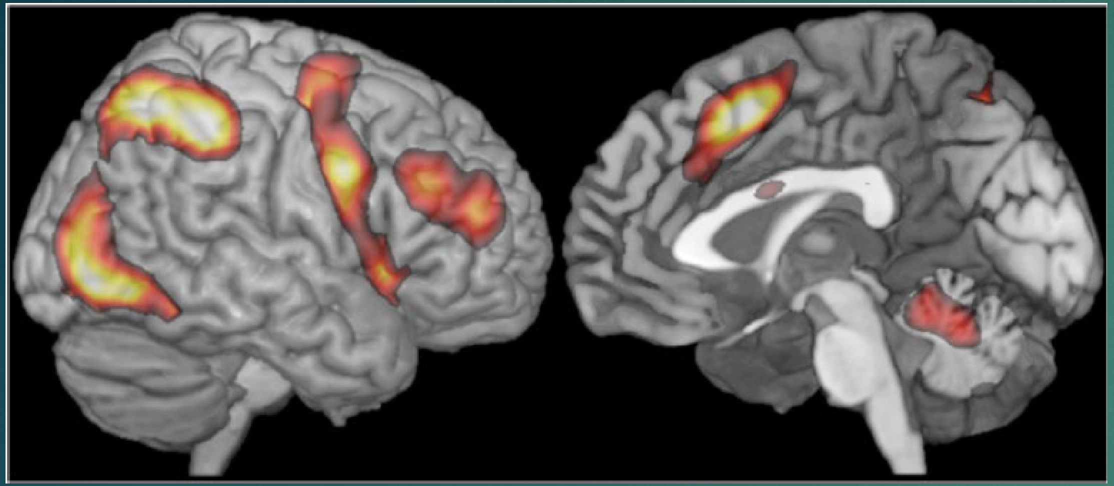
Multiple-demand (MD) system: Functionally general regions

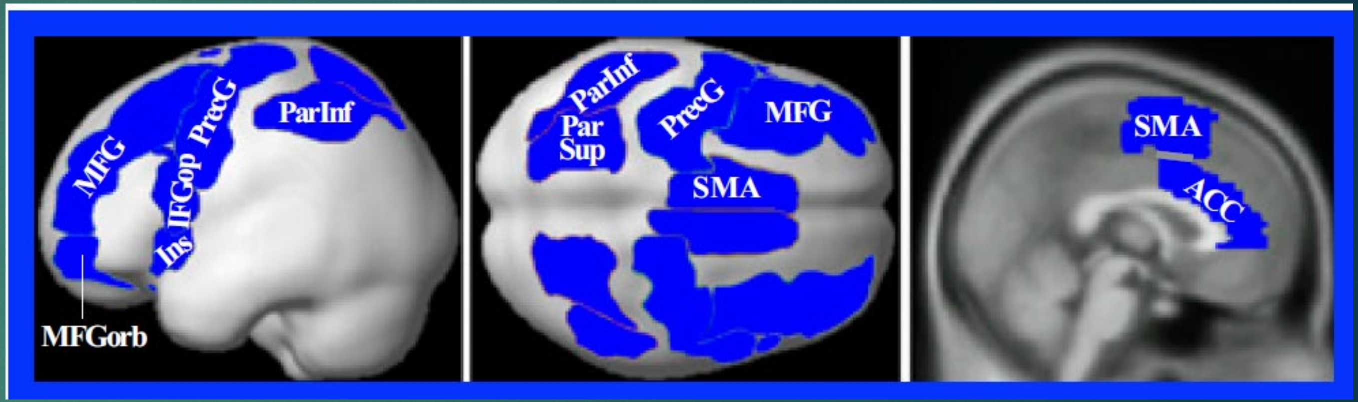
- There are also a set of functionally general regions that endow us with the cognitive flexibility necessary to solve novel problems.

- Study: Seven diverse demanding cognitive tasks produced overlapping activation at the individual-subject level in a number of frontal and parietal brain regions

Evelina Fedorenko, et al., 2013

Multiple Demand Processors: 7 prefrontal/parietal areas





- Problems used: Localization, math, multisource interference tasks, spatial and verbal WM, Stroop
- Opposite of Default Mode Network (DMN) areas: medial temporal lobe, parts of the medial prefrontal cortex, the posterior cingulate cortex, and the precuneus

20 years of imaging brain connectivity

Hae-Jeong Park & Karl Friston 2013

Michel Thiebaut de Schotten & Stephanie Forkel, 2022

Distributed & Parallel Processing Networks: Connectivity networks

- Ways brain is neuroanatomical organized into networks:
  - Extensive neuron to neuron connections
  - Neurotransmitter systems
  - Functional areas organized via heteromodal connections
  - White matter fiber tracts – short to distant
  - Multiple processing networks: i.e. semantic memory, language, attention, etc.
  - Hub regions, i.e. expressive, receptive
  - Connectivity networks

Dynamic networks model

- Brain isn't just functionally modular. While certain regions are specialized to process certain types of information and are active during certain tasks, they are all part of distributed functional networks.

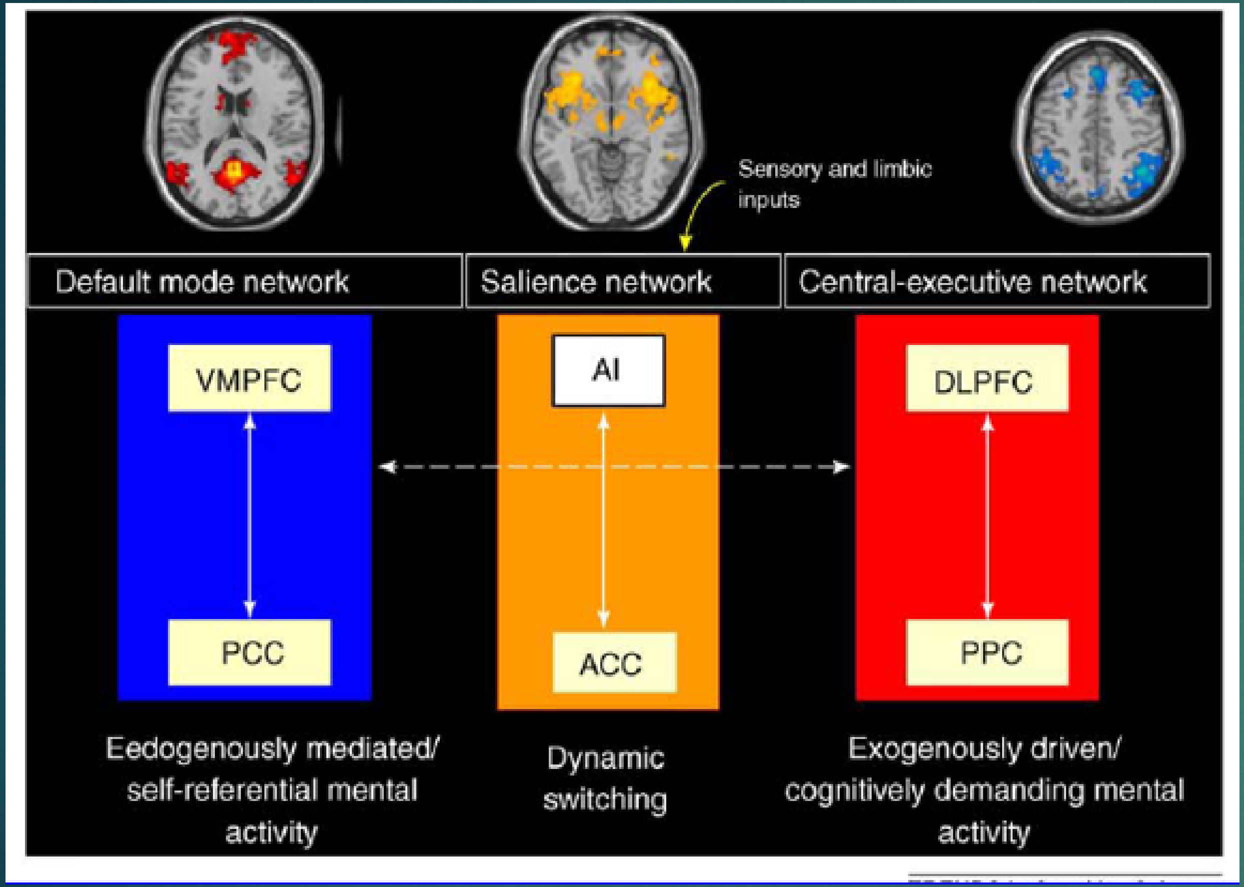
- The CNS is an integrated, wide, dynamic network made up of cortical functional epicenters connected by both short-local and large-scale white matter fibers.

- Brain function results from parallel streams of information dynamically modulated within an interactive, multimodal, and widely distributed circuit.

Major Modules

- The frontoparietal control module spans the frontal, parietal and temporal lobes. It developed relatively recently on the timescale of evolution. It is analogous to an orchestra conductor; heavily involved in what is called executive function, intelligence, problem solving, decision making
- Another highly interconnected module is the salience module, which hooks up to the frontoparietal control module and contributes to a range of behaviors related to attention and responding to novel stimuli
- Default mode module spans the same lobes as the frontoparietal control network. It contains many hubs and is linked to a variety of cognitive tasks, including passive thoughts not focused on a particular task, introspective thought, learning, memory retrieval, emotional processing, inference of the mental state of others and even gambling. Oppositional (1 on, 1 off & vice versa) to Salience module

Major Connectivity Networks



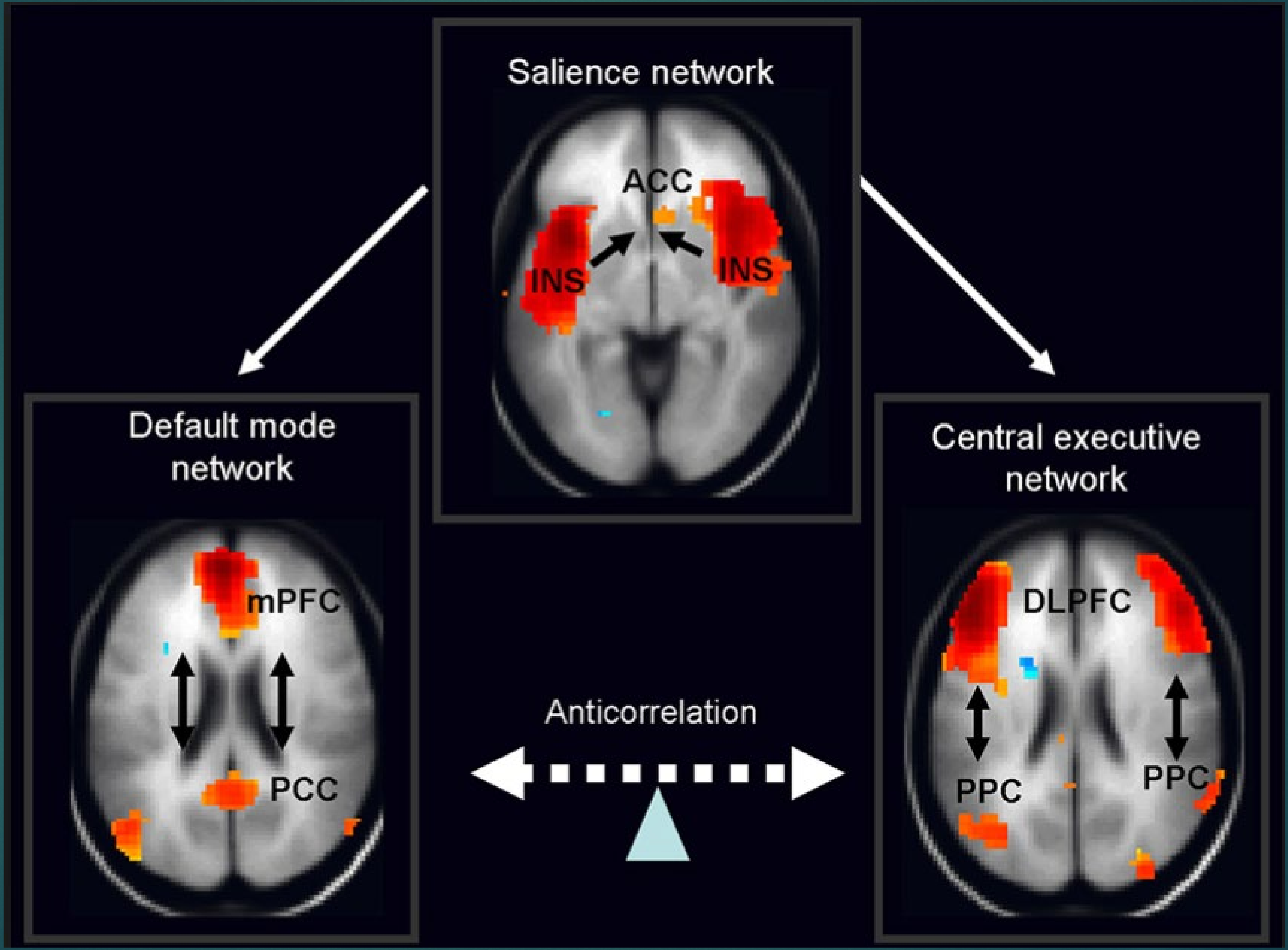
3 major networks:

DMN: day dreaming, self reference

Salience: earliest cortical signal of behaviorally salient events, such as errors. Interoceptive awareness, emotional responses, & empathic processes.

Central Executive: higher-order cognitive and attentional control

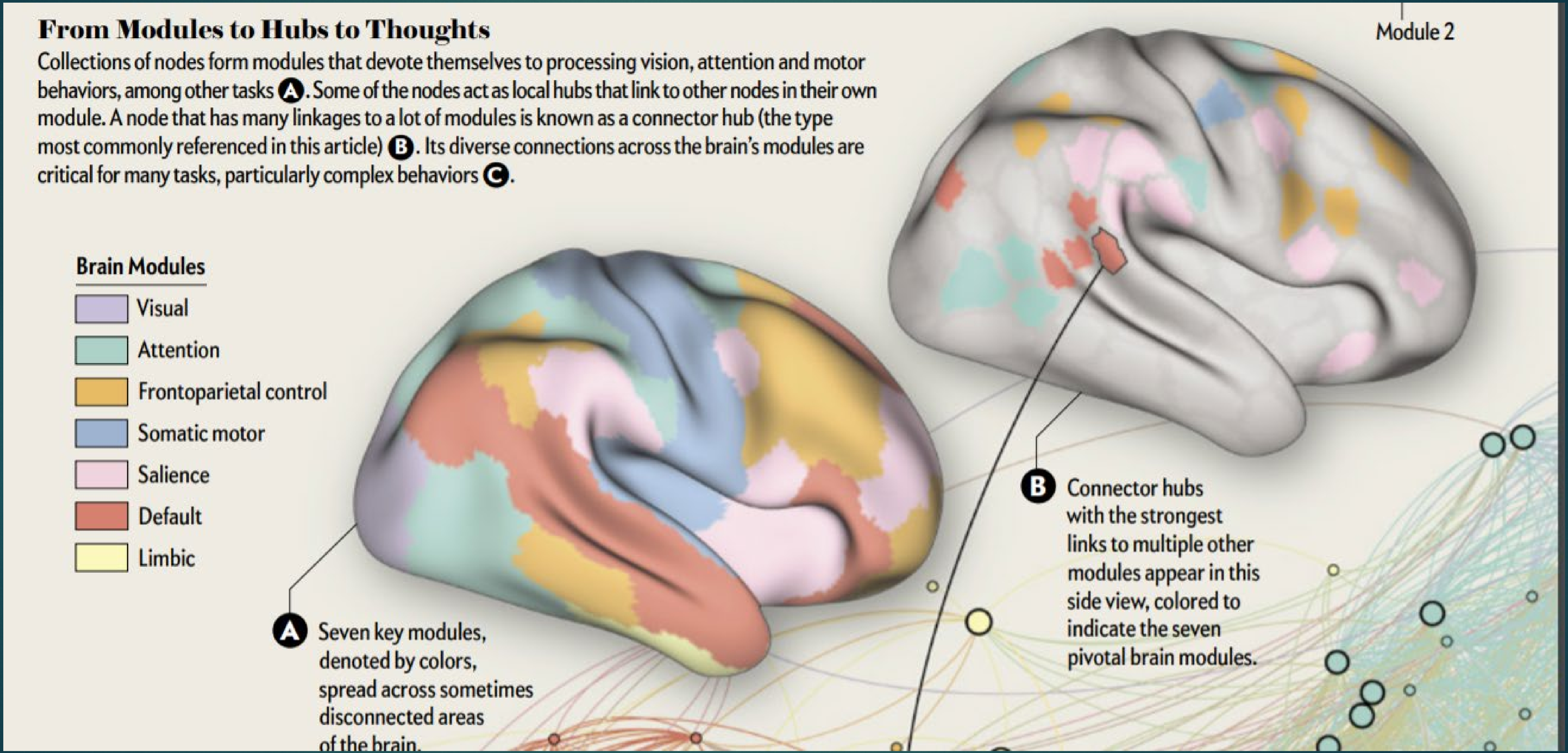
3 Major Networks



Brain connectivity

- Brain-connectivity patterns establish a “fingerprint” that distinguishes each individual.
- People with strong functional connections among certain regions have an extensive vocabulary and exhibit higher fluid intelligence—helpful for solving novel problems—and are able to delay gratification. They tend to have more education and life satisfaction and better memory and attention.
- Others with weaker functional connections among those same brain areas have lower fluid intelligence, histories of substance abuse, poor sleep and a decreased capacity for concentration
- Aberrant connectivity patterns accompany depression, schizophrenia, Alzheimer’s, Parkinson’s, autism spectrum disorder, attention deficit disorder, dementia and epilepsy.

Modules and Hubs



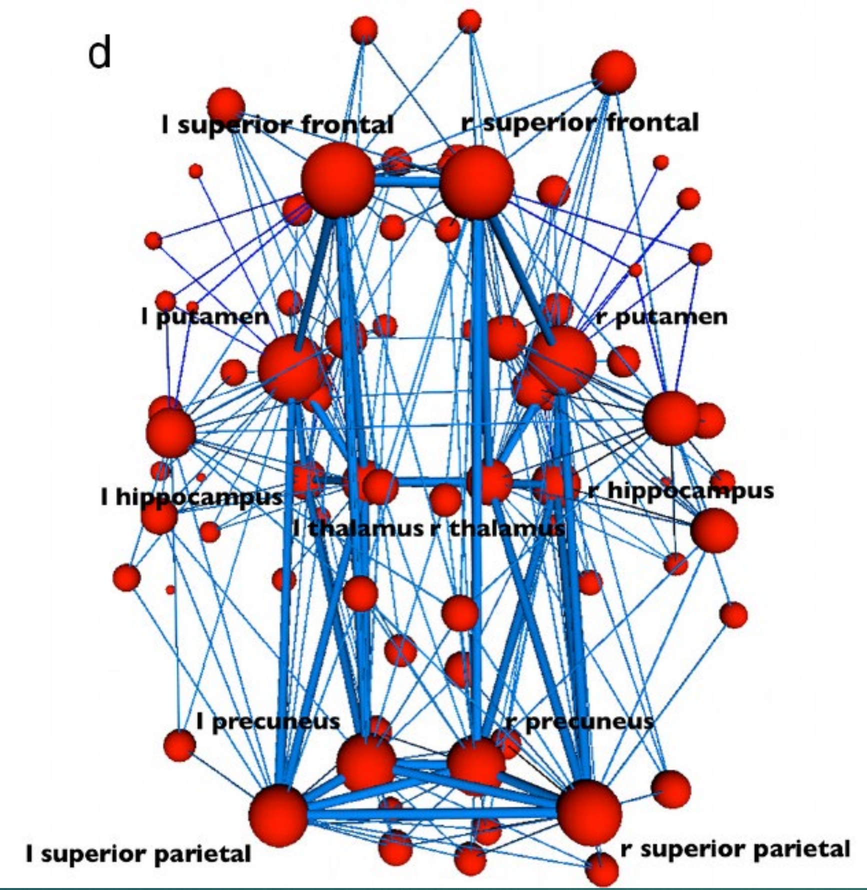
Rich World Organization

- Brain Hubs: Some regions have a high degree, low clustering, short path length, high centrality and participation in multiple communities across the network,

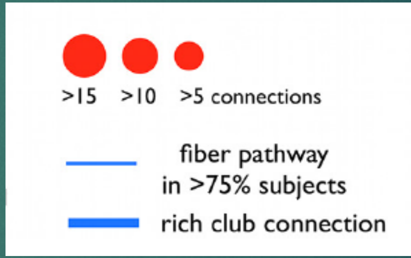
- Brain hubs form a "rich club," characterized by a tendency for high-degree nodes to be more densely connected among themselves than to nodes of a lower degree.

- There is a group of 12 strongly interconnected bihemispheric hub regions, comprising the precuneus, superior frontal, superior parietal cortex, subcortical hippocampus, putamen, and thalamus.

12 Rich World Hubs: central areas and freeways



Bilateral frontoparietal regions, including precuneus, superior frontal and parietal cortex, hippocampus, thalamus, and putamen are individually central & also densely interconnected, together forming a rich club.



Connections between rich-club regions (dark blue) and connections from rich-club nodes to the other regions of the brain network (light blue). The figure shows that <u>almost all regions of the brain have at least one link directly to the rich club. Brain lesions that damage one of the rich club hubs will have more serious behavioral effects (3x more) than damage to non-hub area.</u>

Disease Conditions = Impaired Functional Connectivity

- Alzheimer’s: decreased connectivity
- Autism: altered connectivity
- Depression: abnormal connectivity
- Schizophrenia: disrupted networks
- ADHD: Altered "small networks" and Thalamus changes
- Aging brain: disruption of brain systems and motor network
- Epilepsy: disruption and decrease/increase in connectivity
- Parkinson's disease: altered connectivity
- Obsessive Compulsive Disorder: increase/decrease in connectivity
- Pain Disorder: altered connectivity

White Matter commonality of all psychiatric disorders

- Metaanalysis: major depressive disorder, bipolar disorder, social anxiety disorder, obsessive-compulsive disorder, or posttraumatic stress disorder, as well as healthy control

- Most common behavior = negative thinking

- The most common difference in white matter structure that — present in every emotional disorder — was disruption in a region of the brain that connects different parts of the "default-mode network," which is responsible for passive thoughts not focused on a particular task.

DMN

- That area is the left superior longitudinal fasciculus. The superior longitudinal fasciculus, or SLF, also connects the default-mode network and the cognitive control network, which is important in task-based thinking and planning and tends to work in alternation with the default-mode network.

- The constant negative thoughts or ruminations associated with most emotional disorders appear to be due to a hyperactive default-mode network

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