511-2017-10-25-cognition

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Today's Topics

- Cognition

The emergence of behavior

Cambrian Explosion

What caused the Cambrian explosion? | The Economist

What sparked the explosion? (Fox, 2016)

- Behavior requires energy
- Behavior requires perception at a distance
- Behavior requires action
- Actions require
  - Problem solving, (sequence) planning
  - Current + stored information (memory)

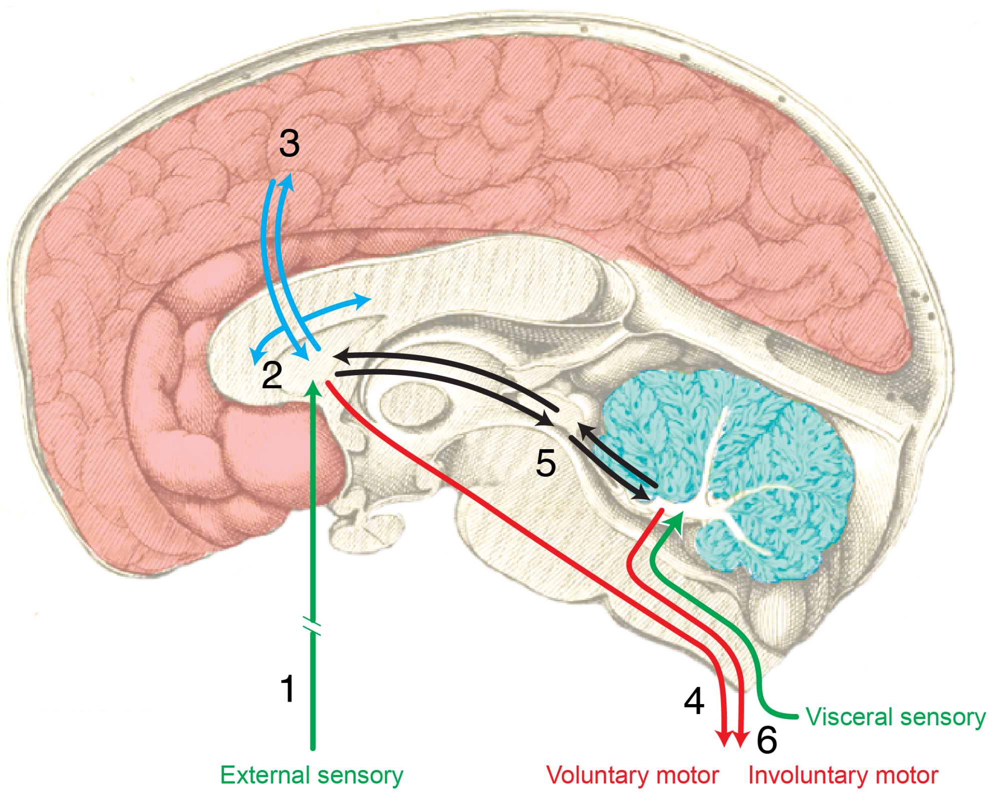
What behaviors are essential for animals to perform?

- Ingestion
- Defense
- Reproduction

What behaviors are essential for animals to perform

- Perception at a distance
- Locomotion
- Object manipulation/consumption
- Signaling/communication

How is the nervous system organized to contribute to these behaviors?



Cajal

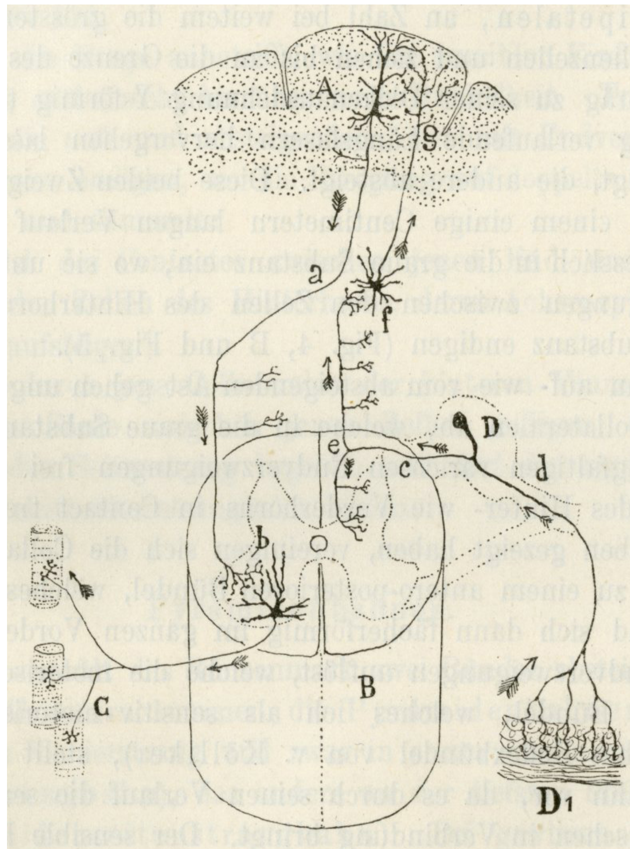
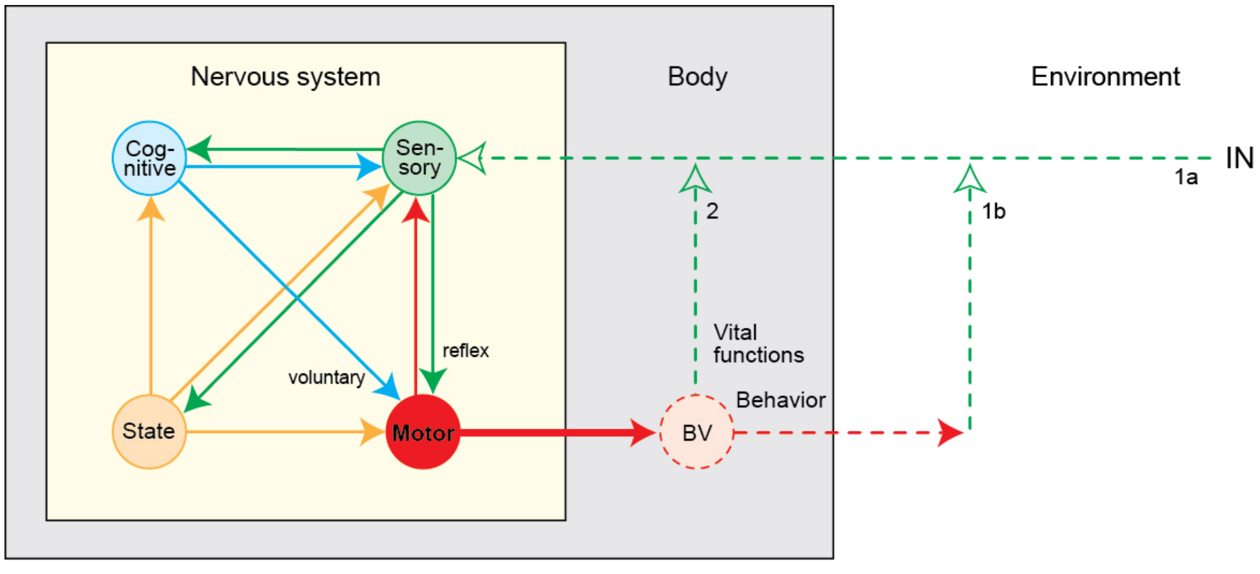


Fig. 6.

Swanson/Cajal four systems



Hierarchy of control

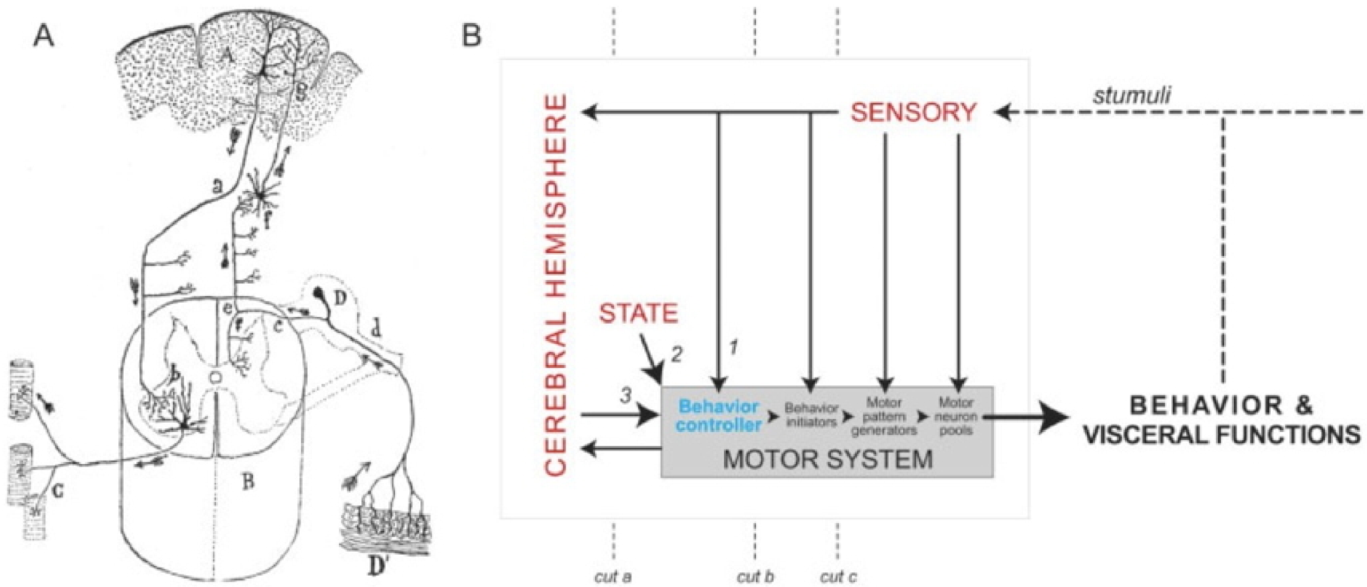


Fig. 1. **A:** Perhaps the first diagram illustrating the cellular organization of a vertebrate spinal reflex, based on the neuron doctrine and law of functional polarity, published by Cajal in 1890 (see Cajal, 1894). Note that he emphasized two interconnected sources of motor neuron (b) control: dorsal root ganglion cells (D) and cerebral cortical pyramidal (or psychomotor) neurons (A). For clarity, he showed sensory input to the right side of the spinal cord, and motor output from the left side. **B:** A modern version of the basic plan of nervous system organization, adding behavioral state inputs (2) to sensory or voluntary (1) and cerebral hemisphere/cognitive or voluntary (3) inputs to the motor system hierarchy; see text for details (adapted from Swanson, 2000a).

(Swanson, 2005)

Functional segregation

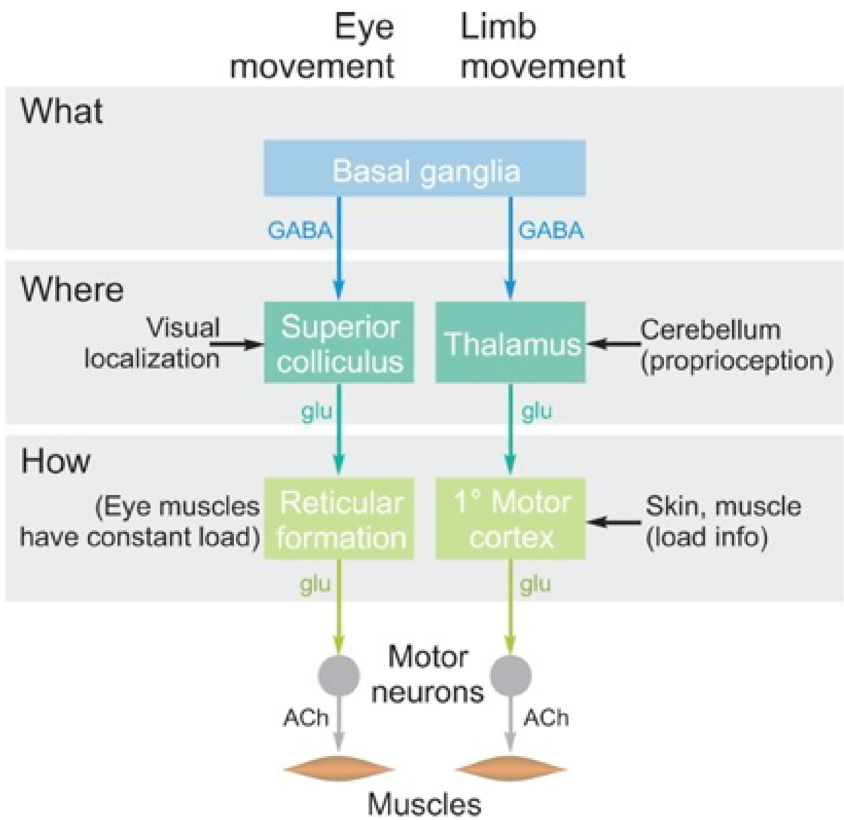
Cortico-striatopallidal differentiations for:

- Motivated behaviors
- Locomotion and posture
- Orienting movements (eyes, head)
- Reaching, grasping, manipulating
- Orofaciopharyngeal movements
  - facial expression
  - vocalization
  - licking, chewing, swallowing
- Breathing
- Autonomic responses
- Neuroendocrine responses

Fig. 8. Hypothesized differentiations of the cerebral cortico-nuclear system (cortico-striatopallidal system) for all major classes of motor responses or behavior (adapted from Swanson, 2003a).

(Swanson, 2005)

Do what, where, how?



(Swanson, 2012)

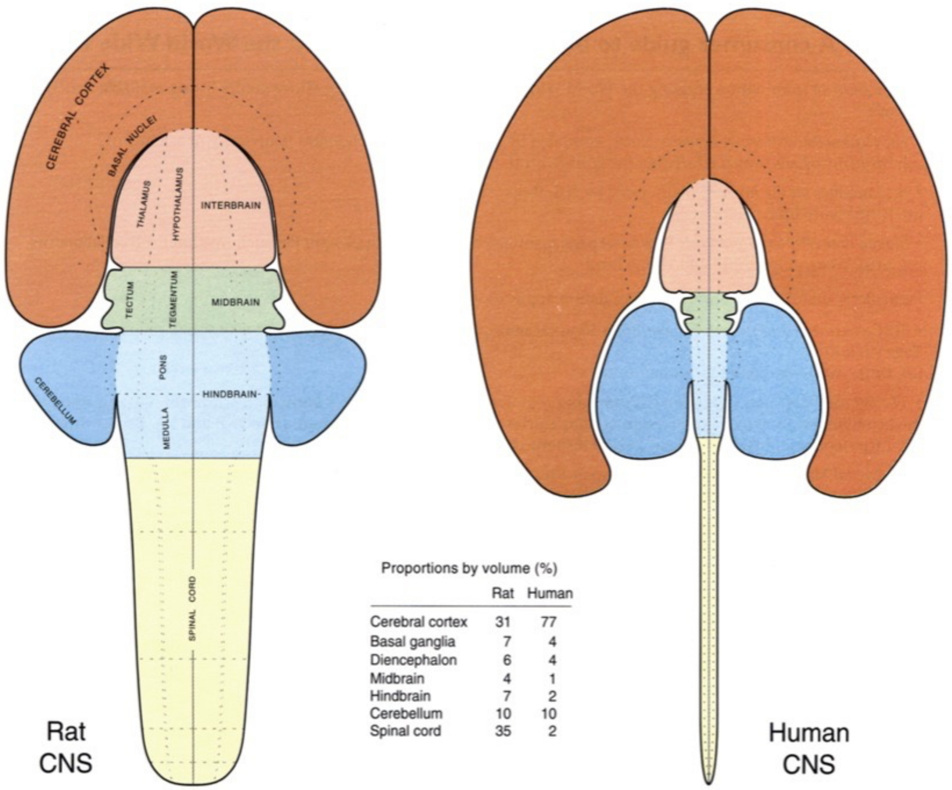
Facets of cognition

- Perception
- Attention
- Imagery

Facets of cognition

- Learning and conditioning
- Memory
  - Episodic
  - Semantic
  - Procedural
- Language
- Problem-solving

Cognition and the cerebral cortex



	Rat	Human
Cerebral cortex	31	77
Basal ganglia	7	4
Diencephalon	6	4
Midbrain	4	1
Hindbrain	7	2
Cerebellum	10	10
Spinal cord	35	2

(Swanson, 2012)

Cortical schema

- Areas
  - Unimodal sensory
  - Polymodal association
  - Motor
- Connections
  - Association
  - Commissural

Cortical areas

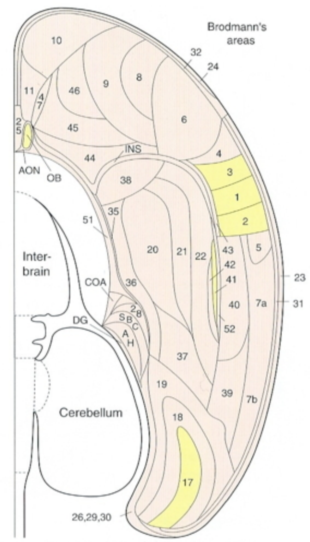


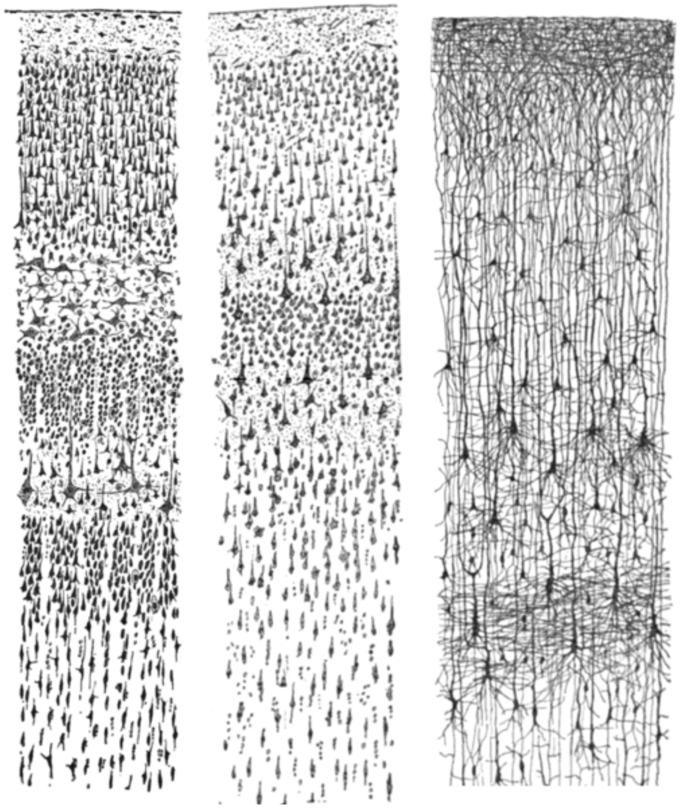
Figure 10.5 A topological representation of Brodmann's regionalization of the cerebral cortex (light red) into areas is shown on this flatmap of the human brain (see Figs. 10.3 and 10.4). Primary sensory cortical areas are indicated in yellow. Compare with Figures 6.7 and 10.1. Key: 1-3, somatic sensory; 17, visual; 41, auditory; AH, Ammon's horn; AON, anterior olfactory area, COA, cortical amygdalar area; DG, dentate gyrus; INS, insular area; OB, olfactory bulb; SBC, subicular complex. Adapted with permission from L.W. Swanson, Mapping the human brain: past, present, and future, *Trends Neurosci.* 1995, vol. 18, poster accompanying p. 471.

(Swanson, 2012)

Cortical schema

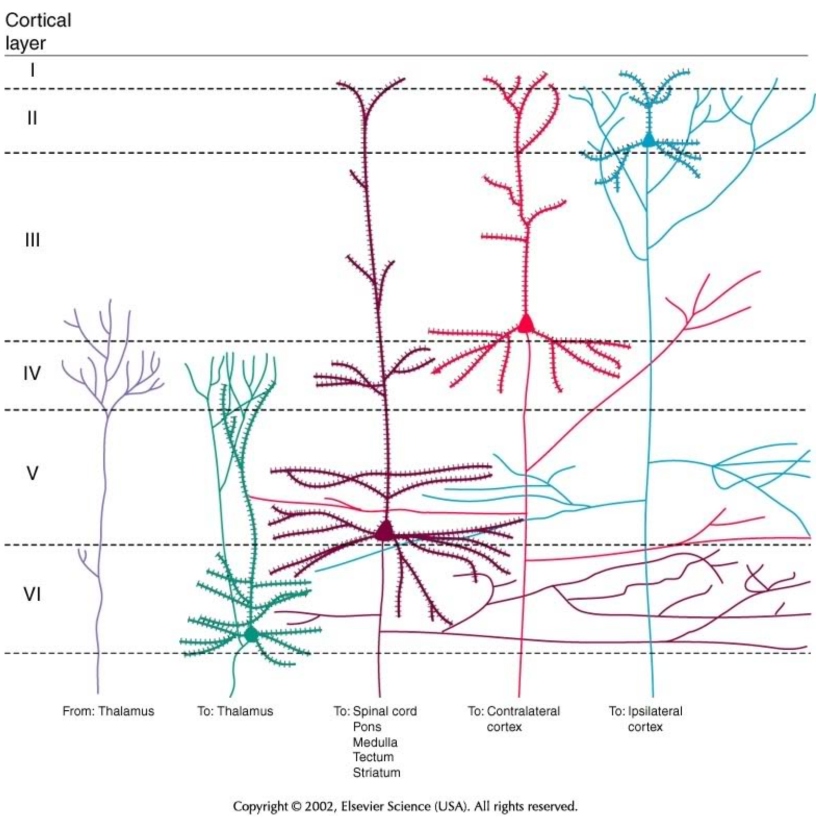
- Columnar structure
- Cytoarchitectonic differerences (e.g. Brodmann)

Cortical columns



https://upload.wikimedia.org/wikipedia/commons/thumb/5/5b/Cajal_cortex_drawings.png/518px-Cajal_cortex_drawings.png

Cortical layers



http://s27.photobucket.com/user/caiomaximino/media/layerscortex.jpg.html

Cortical connections by layer

Layer	Connection type	Comments
I		Few cell bodies
II	Efferent	Ipsilateral association via large pyramidal cells
III	Efferent	Contralateral commissural
IV	Afferent	from thalamus; small stellate & granual cells; V1 has sublayers
V	Efferent	Superficial -> Basal ganglia; Deep -> brainstem, spinal cord; pyramidal cells
VI	Efferent	Thalamus

Cortical circuit schematic

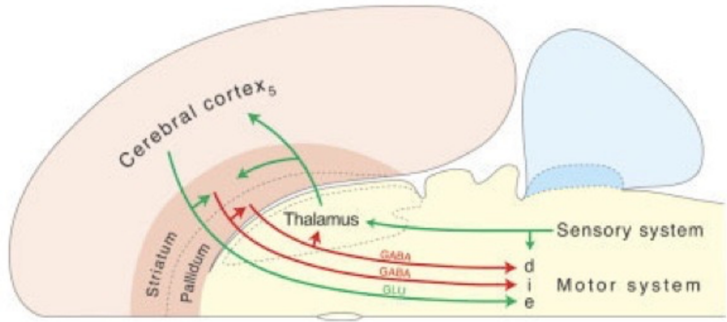


Fig. 2. A model of the elementary or minimal circuit element characteristic of almost all parts of the cerebral hemispheres (pink). It consists of a triple descending projection to the motor system of the brainstem and spinal cord (see Fig. 1B), with feedback to cerebral hemisphere via thalamus. The model predicts that the cerebral hemisphere provides a direct excitatory input (e) to motor system via glutamatergic (GLU), layer 5 (for isocortex), cortical pyramidal neurons that generate a collateral in the striatum (lateral cerebral nuclei), which sends an inhibitory input (i) to motor system via GABAergic (GABA) medium spiny stellate neurons providing a collateral to pallidum (medial cerebral nuclei). The latter then sends a disinhibitory (d), GABAergic projection to motor system, with collaterals to dorsal thalamus, which then projects back to cortex via glutamatergic neurons (and of course receives various classes of sensory input). Many thalamic nuclei also project to striatum (Smith et al., 2004). This minimal circuit element is topographically organized and differentially elaborated regionally.

(Swanson, 2012)

Behavioral control column

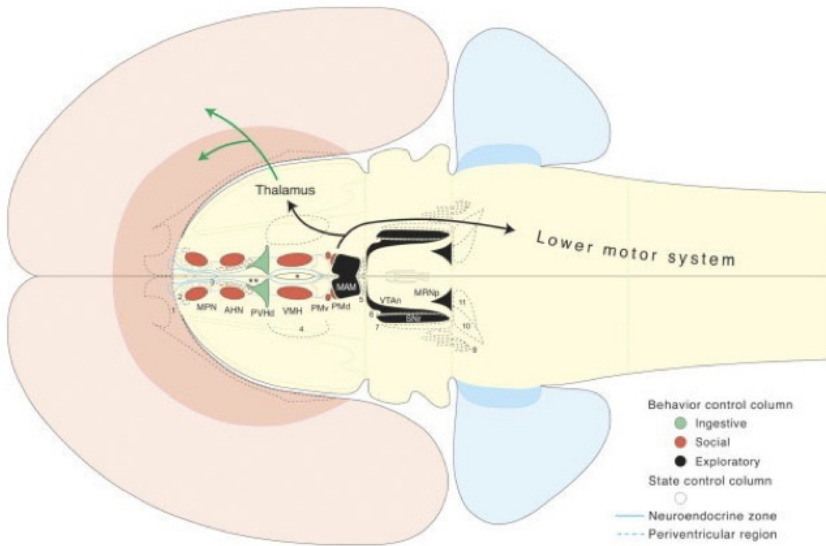
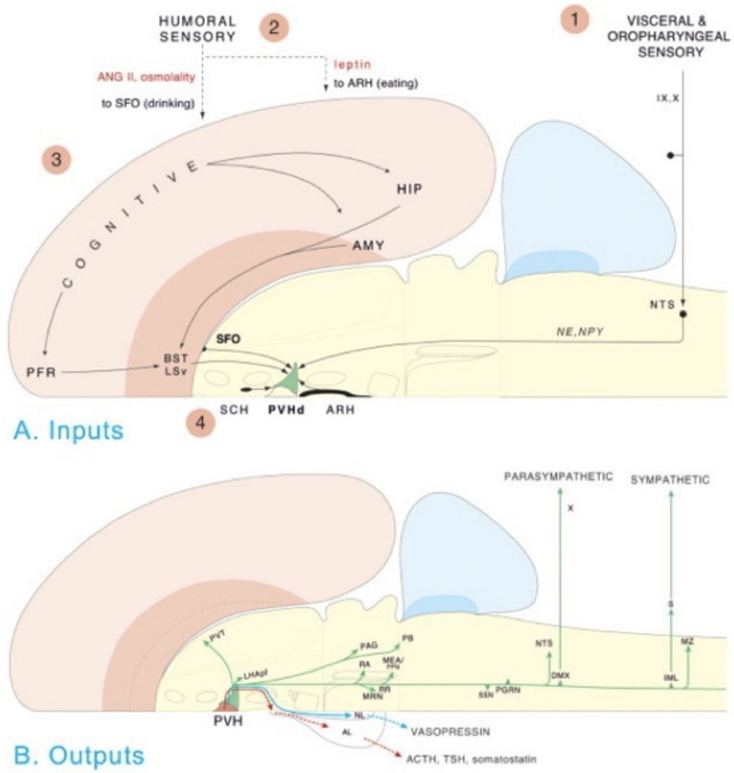


Fig. 3. Basic topography of the behavior control column (BCC) in ventromedial regions of the upper brainstem as viewed on a flatmap of the rat central nervous system. Each component minimally generates a dual projection to the lower motor system (primarily motor pattern generator networks and motoneuron pools) and dorsal thalamus. Where analyzed experimentally (dorsal premammillary nucleus, PMd; mammillary body, MAM; and reticular substantia nigra, SNr), the thalamic projection is a collateral of the descending projection to motor system. This dual projection may be either glutamatergic (e.g., MAM) or GABAergic (e.g., SNr). The BCC caudal segment contains MAM, nondopaminergic ventral tegmental area (VTAn), SNr, and parvicellular midbrain reticular nucleus (MRNp). The BCC rostral segment contains medial preoptic nucleus (MPN), anterior hypothalamic nucleus (AHN), ventromedial nucleus (VMH), ventral premammillary nucleus (PMv), and PMd. Two critical functional regions lie between the BCC rostral segment and third ventricle (midline): the median eminence (*, asterisk) and surrounding neuroendocrine motor zone (solid blue line), and the periventricular region (dashed blue line and **, double asterisks), which contains visceromotor pattern generator and circadian rhythm generator networks. The behavioral state control column, running parallel to the BCC, is indicated by dashed outlines (see text for more information).

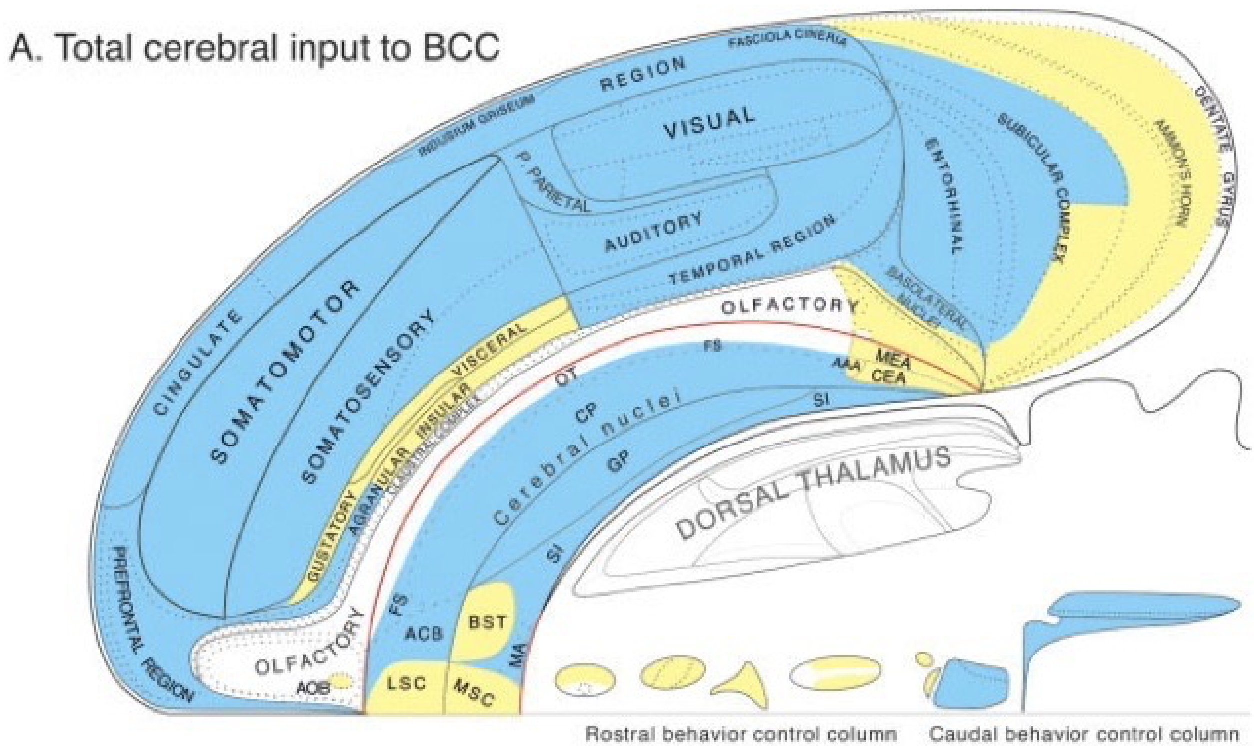
(Swanson, 2005)

Behavioral control column



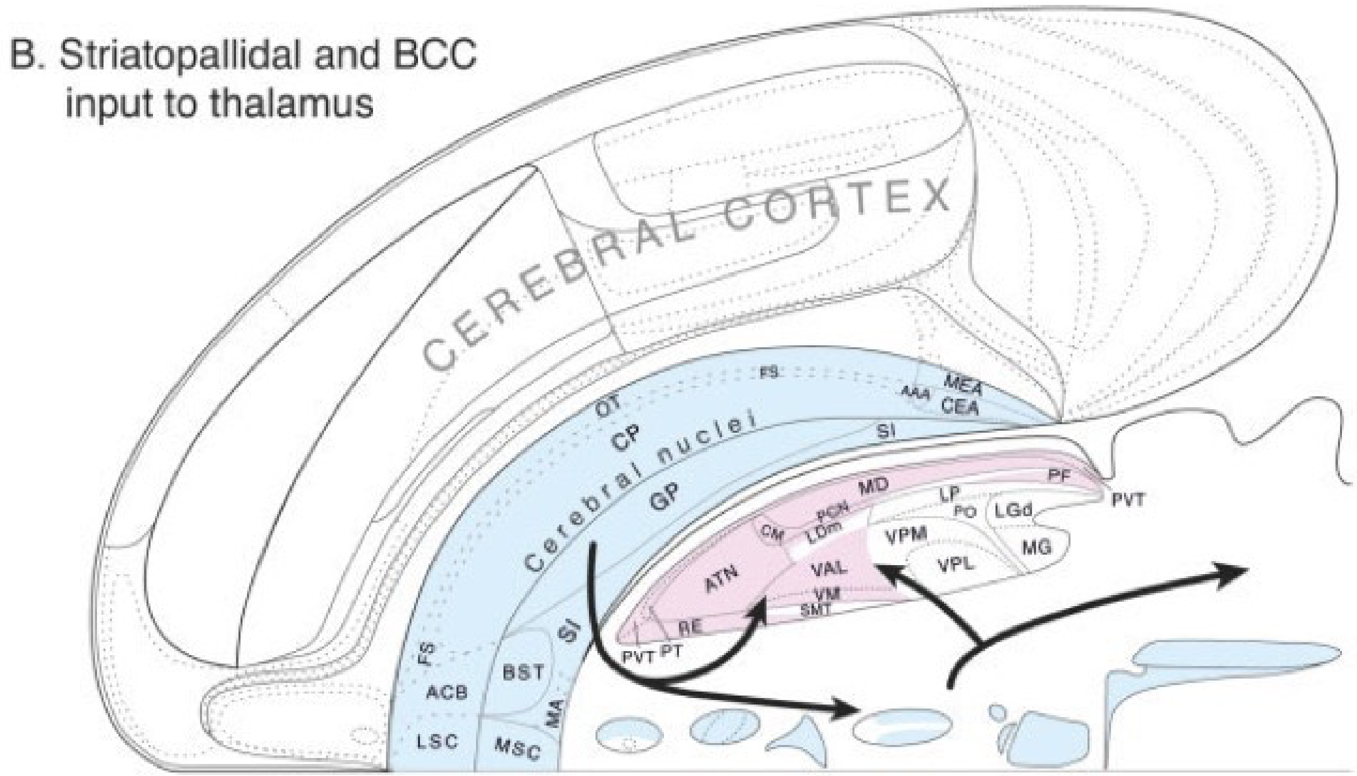
(Swanson, 2005)

Behavioral control column



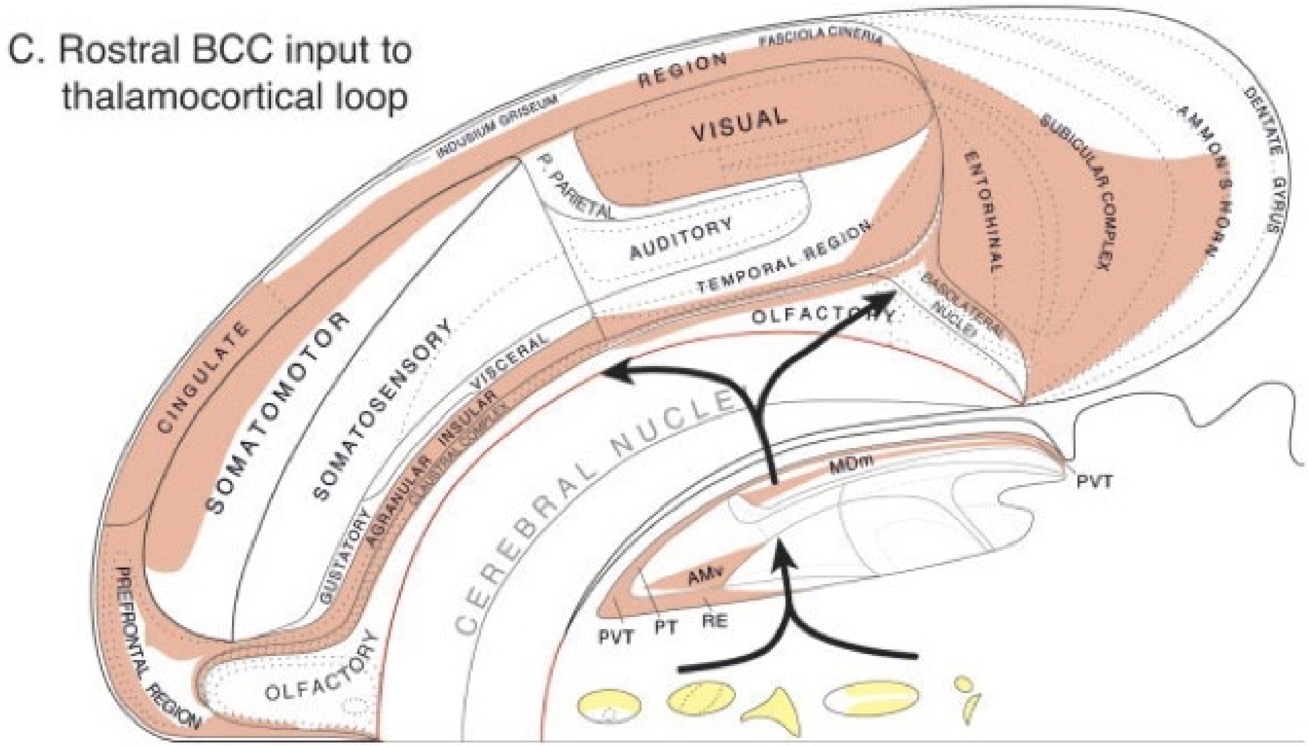
(Swanson, 2005)

Behavioral control column



(Swanson, 2005)

Behavioral control column



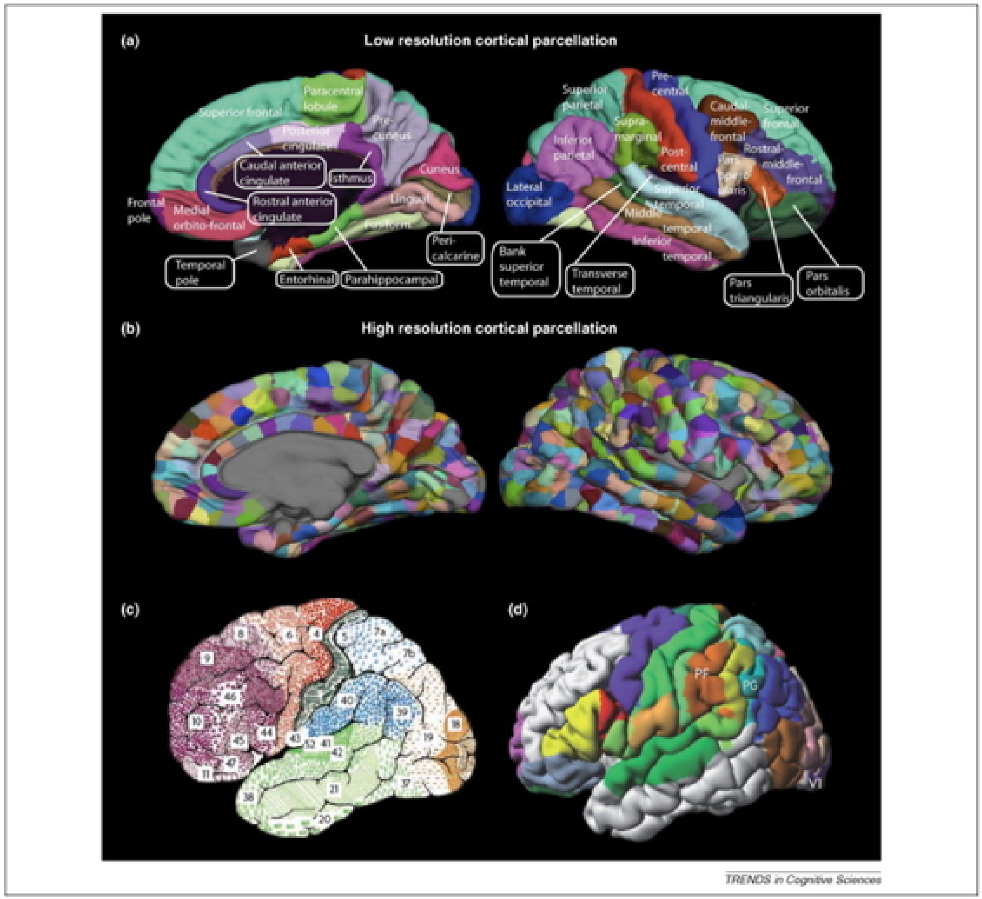
(Swanson, 2005)

Processing networks

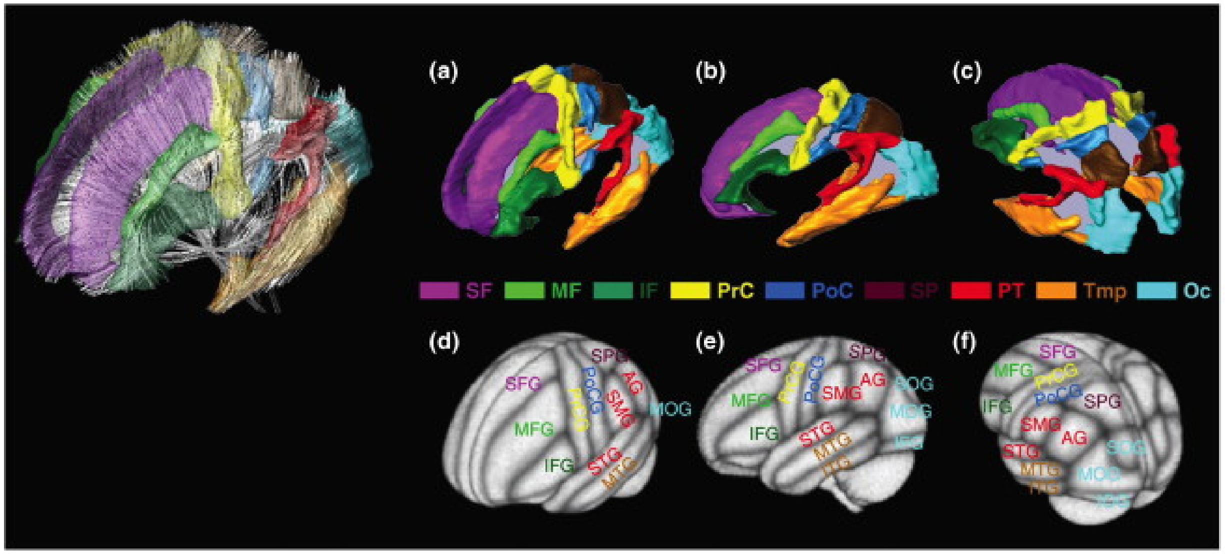
"*Although it has long been assumed that cognitive functions are attributable to the isolated operations of single brain areas, we demonstrate that the weight of evidence has now shifted in support of the view that cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks….*"

(Bressler & Menon, 2010)

(Bressler & Menon, 2010)

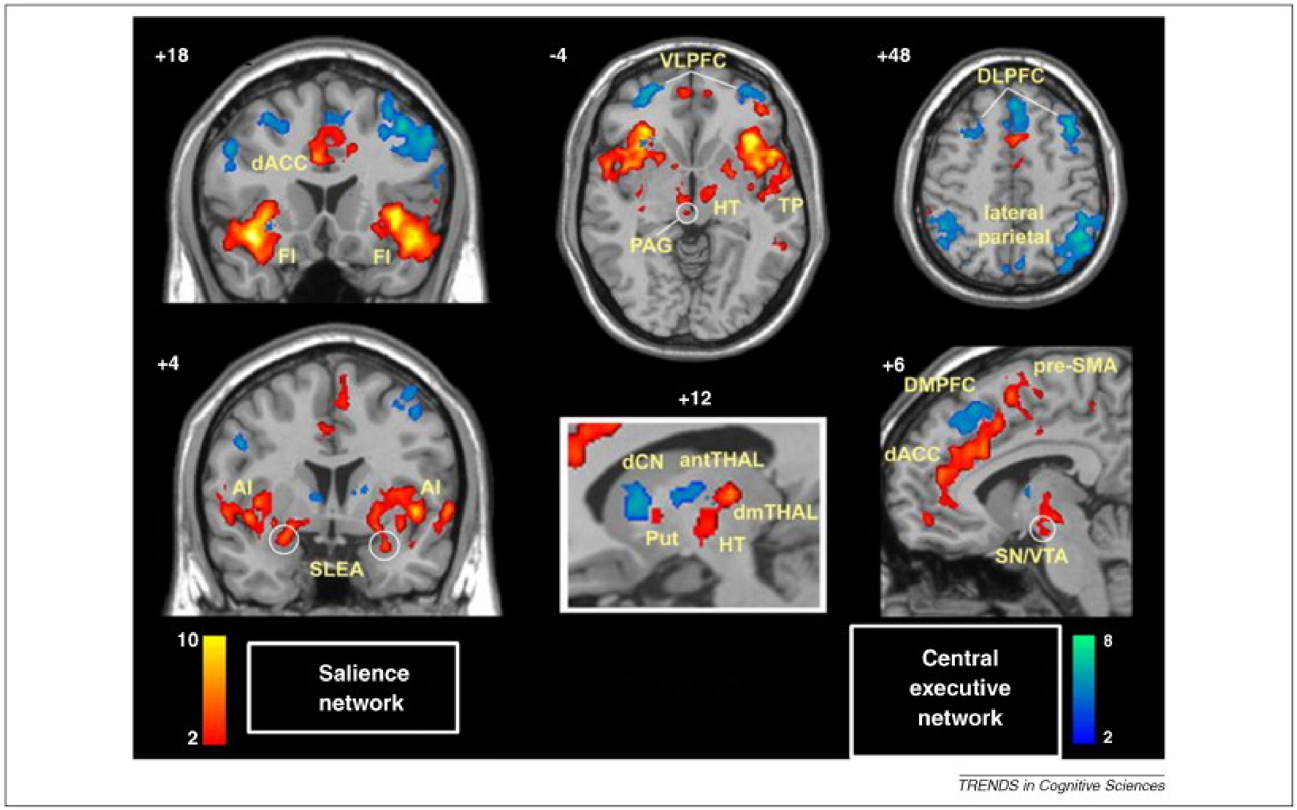


(Bressler & Menon, 2010)

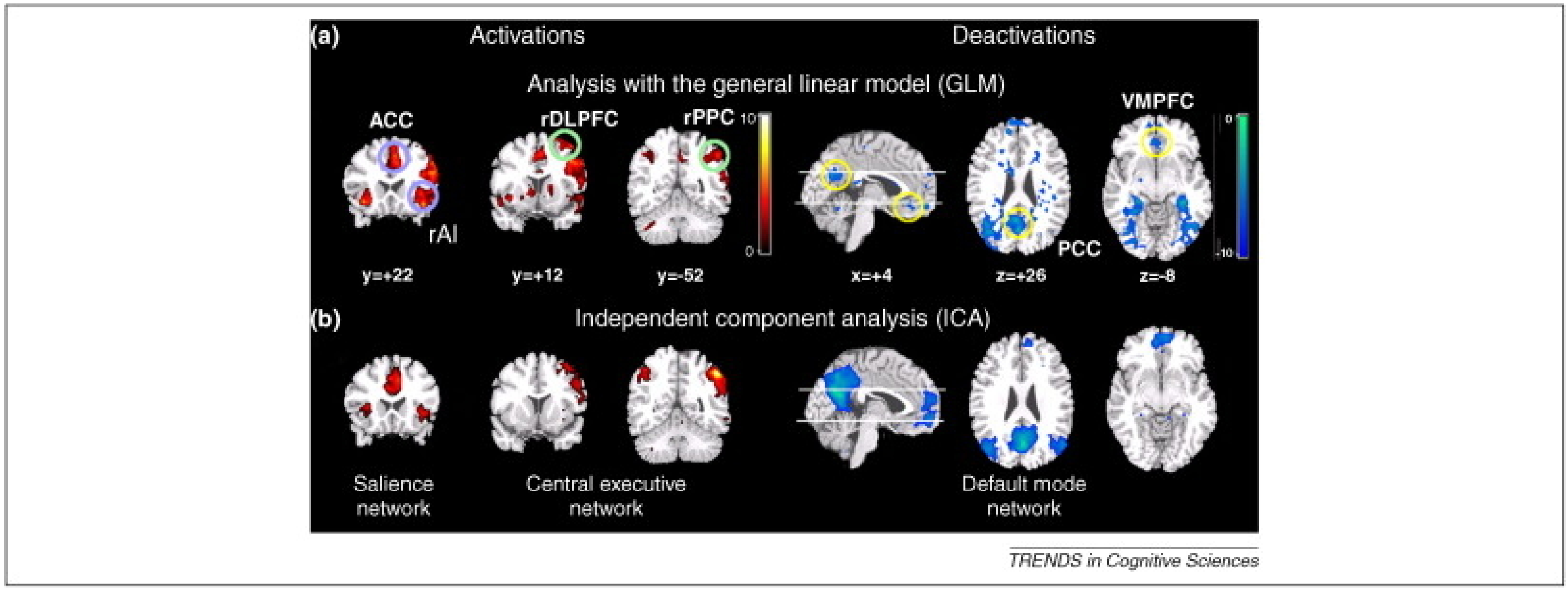


TRENDS in Cognitive Sciences

(Bressler & Menon, 2010)



(Bressler & Menon, 2010)



Summary

- Cognition
  - Do what, where, when, and how
- The "cognitive" cortex
- Processing networks
  - Functional specialization
  - Dynamic interaction

Language and the brain

Language behavior

World's fastest talking man sings Michael Jackson's BAD in 20 seconds

Language behavior

- Productive
  - Speaking (2-5 words/s), modulate prosody, often combined with gesture
  - Writing, typing (.5-1.5 words/s)
- Receptive
  - Listening, responding (facial expressions, gestures, laughter, etc.)
  - Reading (3-5 words/s)
- How so fast? Time for feedback?

Hierarchical structure of language information

- Phonetic
  - |Ber| |wiTH| |mē|
- Syntactic
- Semantic


"Bear with me" requests patience.
"Bare with me" requests that you get naked with me.
Good to know.
your ecards
someecards.com

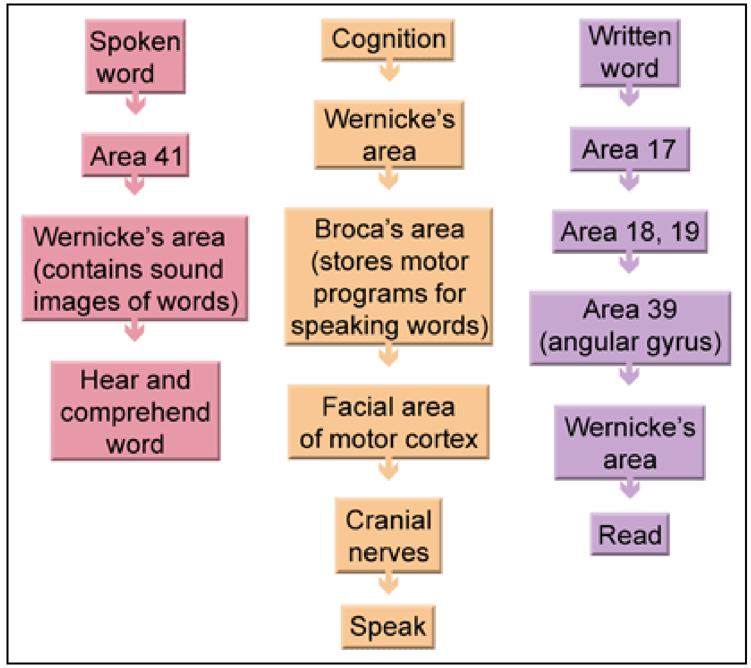

BEAR WITH ME
grammarly

Hierarchical structure of language information

- Pragmatic
  - "I beg your pardon?!"
  - "Sure thing."
  - "Aaaaaa!!!"

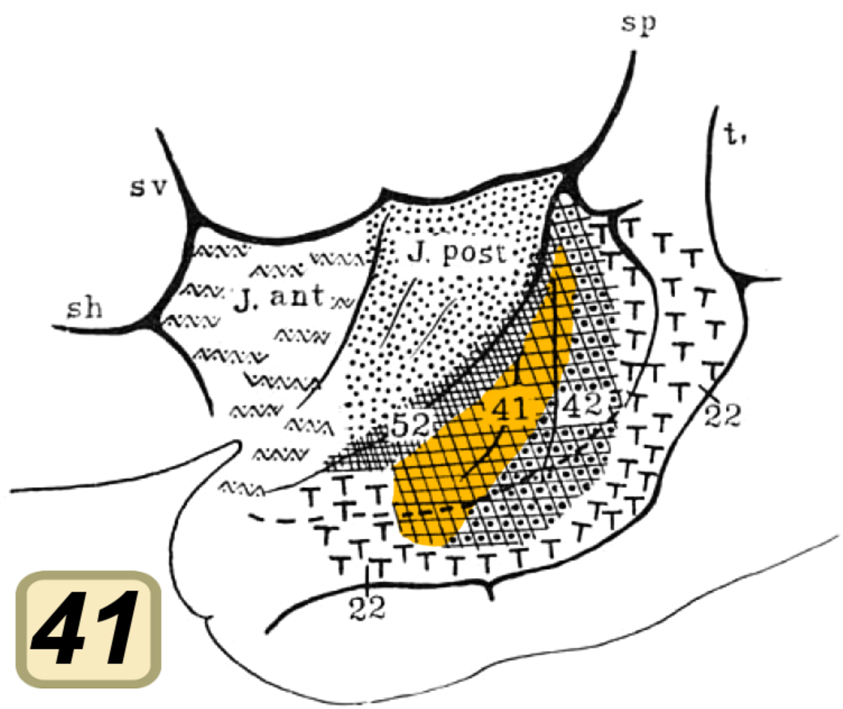
Wernicke-Geschwind model

- Perception ≠ production

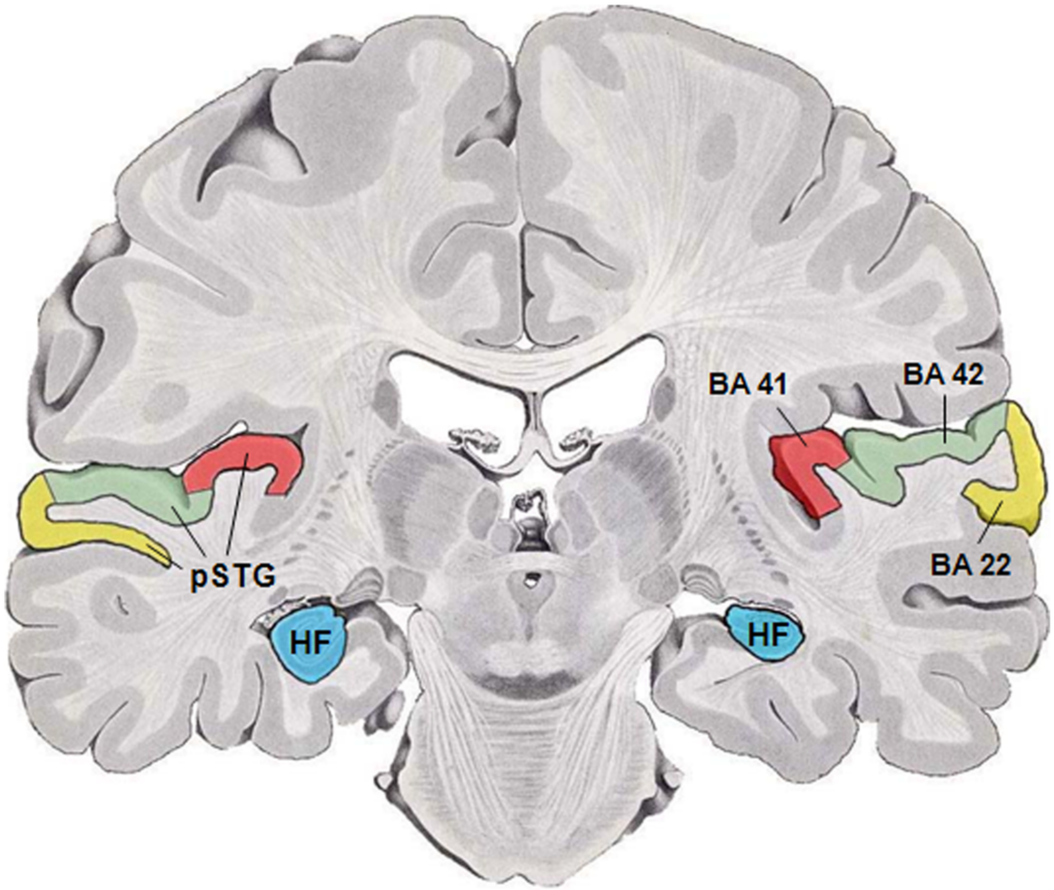

Spoken word
Area 41
Wernicke's area (contains sound images of words)
Hear and comprehend word
Cognition
Wernicke's area
Broca's area (stores motor programs for speaking words)
Facial area of motor cortex
Cranial nerves
Speak
Written word
Area 17
Area 18, 19
Area 39 (angular gyrus)
Wernicke's area
Read

Wernicke-Geschwind model

- Wernicke's area
  - Perception
  - Adjacent to primary auditory cortex (A1; Heschl's gyrus; BA 41)
  - Wernicke's area (BA 42)



41


BA 41
BA 42
pSTG
BA 22
HF
HF

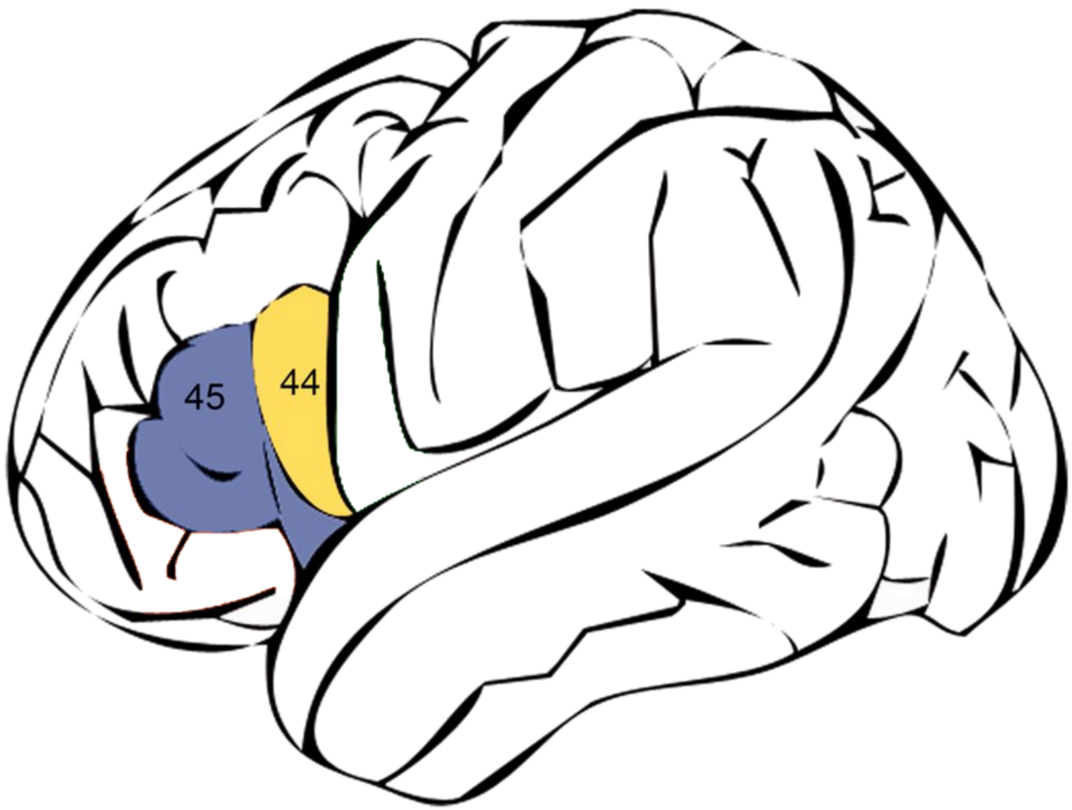
Wernicke-Geschwind model

- Wernicke's area
  - Perception
  - Adjacent to primary auditory cortex (A1; Heschl's gyrus; BA 41)
  - Wernicke's area (BA 42)
  - Receptive or fluent aphasia

Wernicke's aphasia

Wernicke-Geschwind model

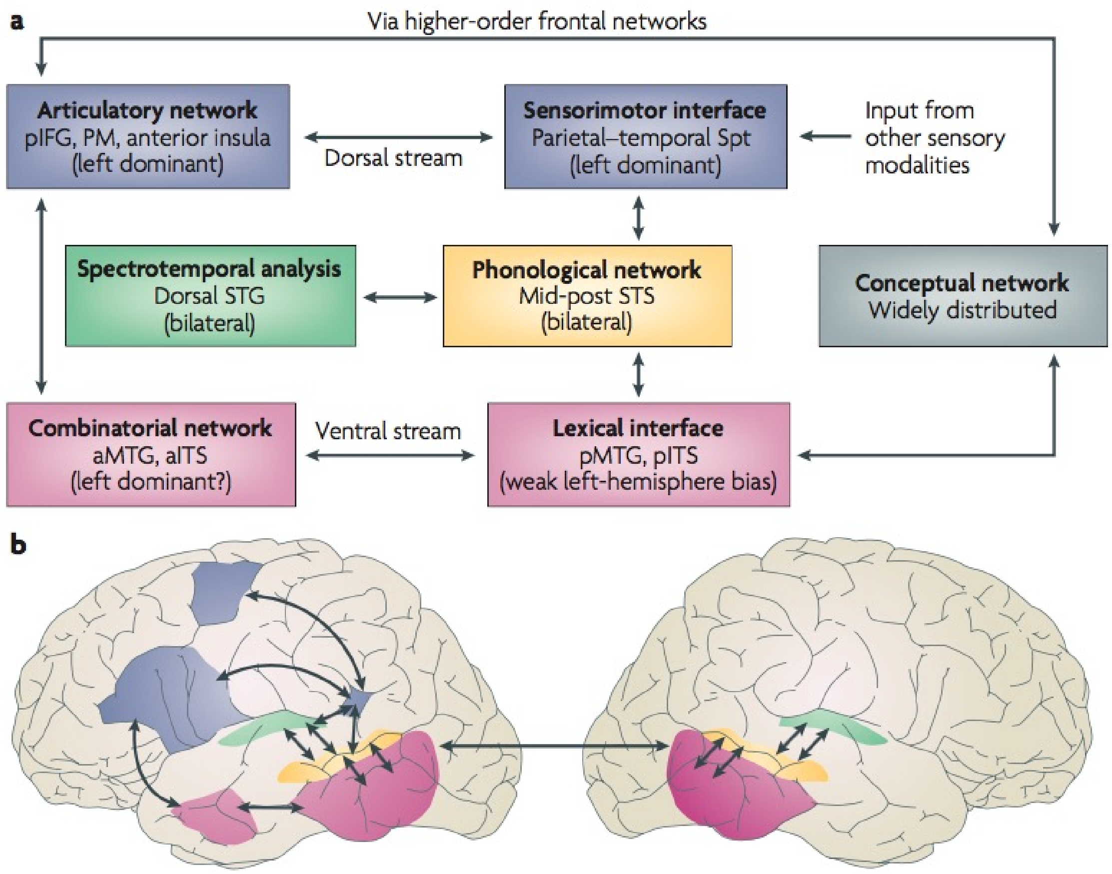
- Broca's area
    - Production
    - Inferior frontal gyrus, pars opercularis (BA 44) & pars angularis (BA 45) - Expressive aphasia


45
44

Broca's Aphasia

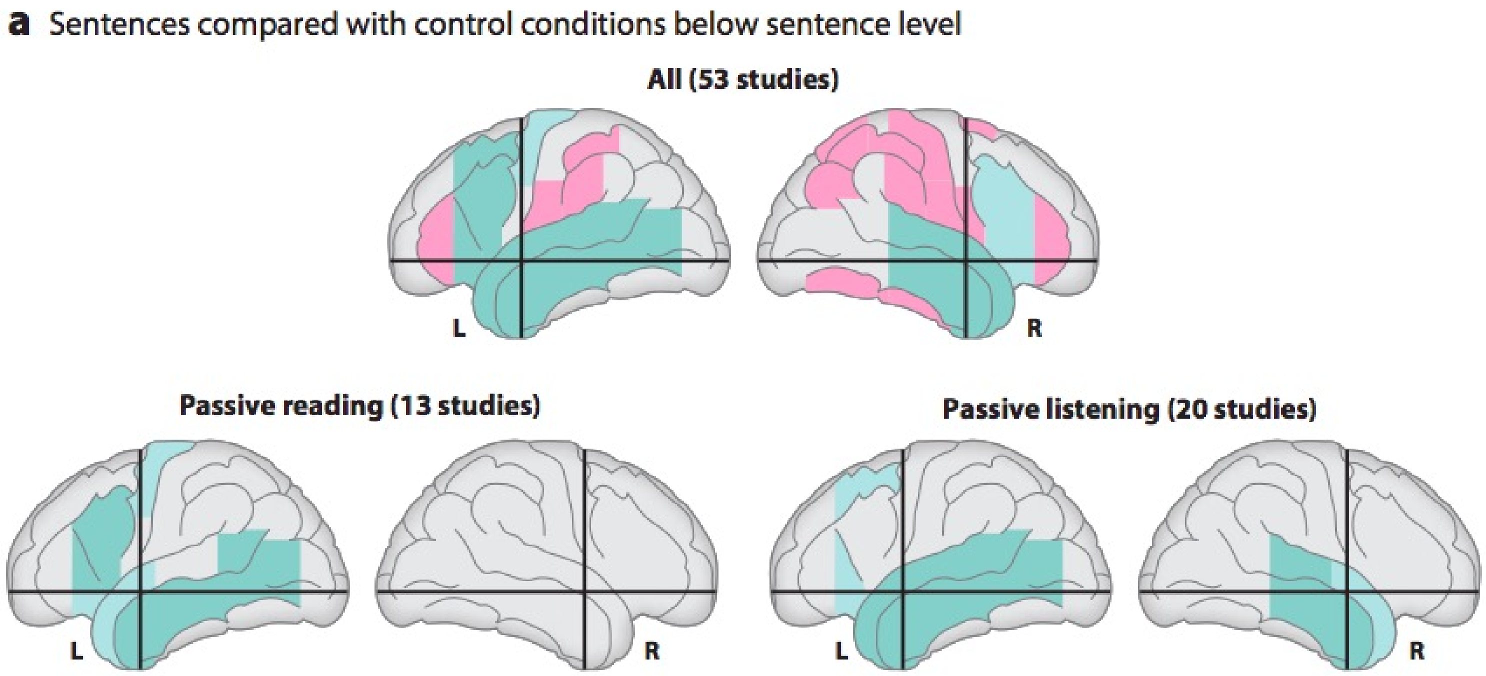
(Hickok & Poeppel, 2007)

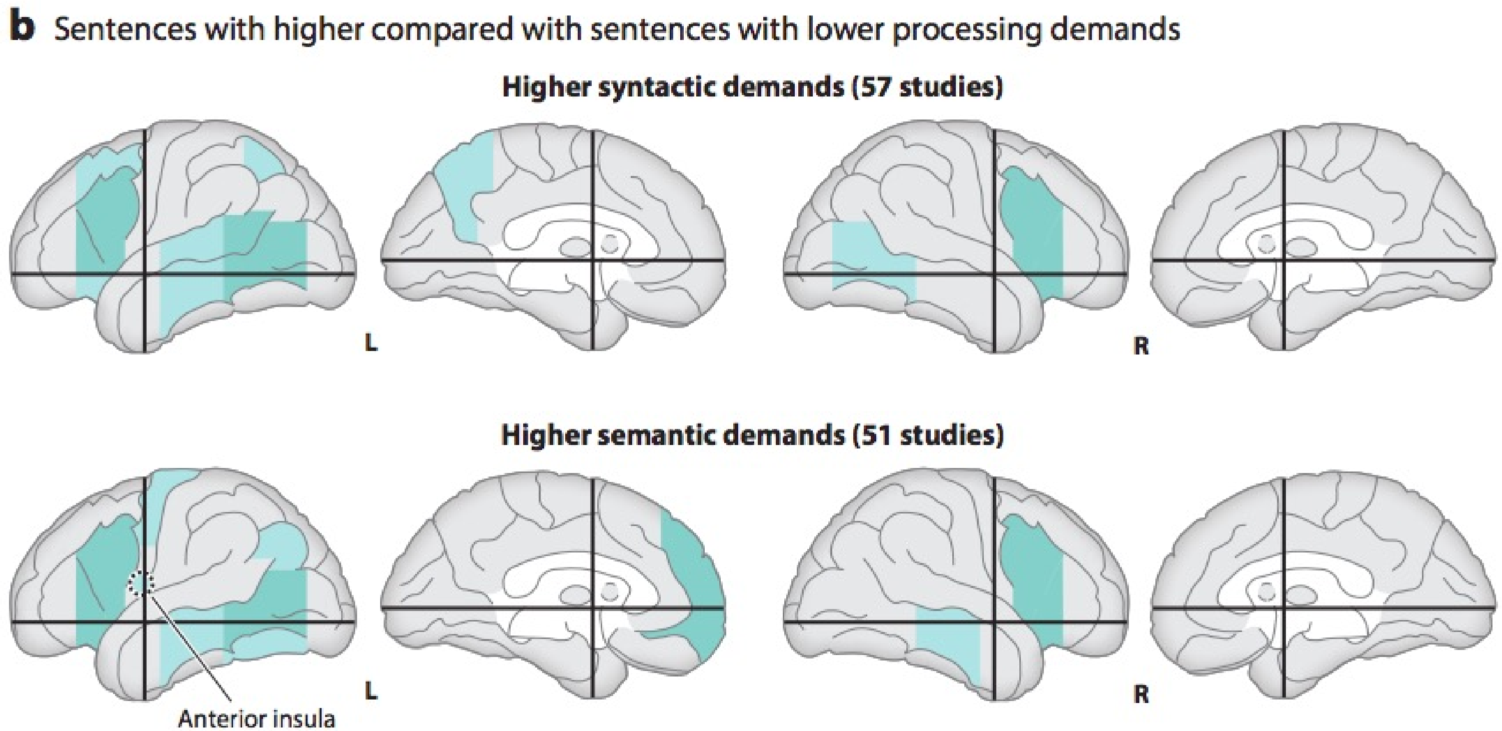
- Dual streams
  - Ventral (speech signals -> semantics)
  - Dorsal (speech signal acoustics -> articulatory networks in frontal lobe)



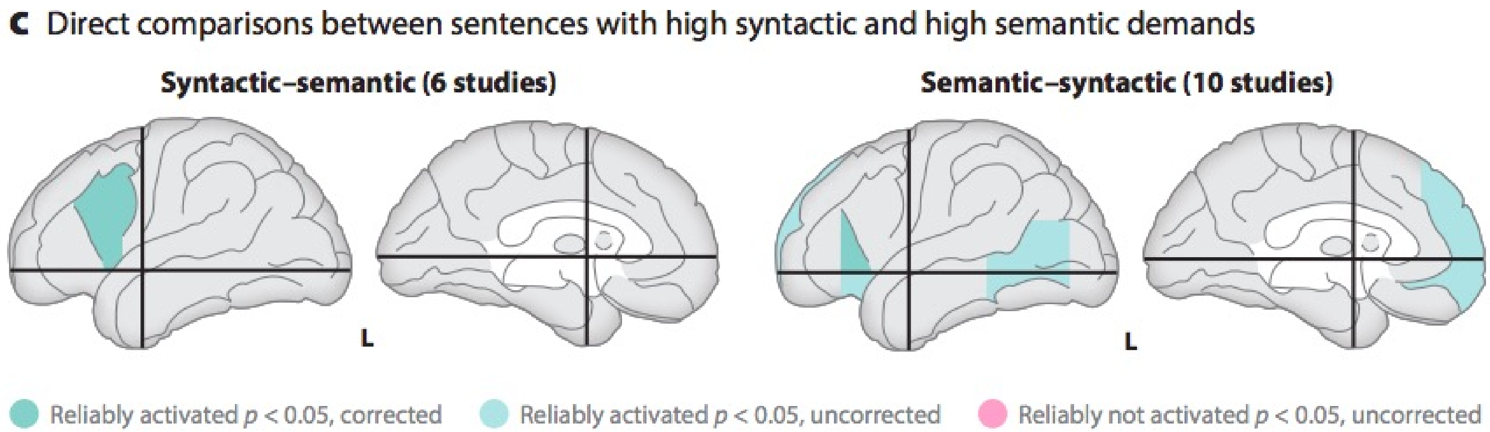
(Hickok & Poeppel, 2007)

(Hagoort & Indefrey, 2014)





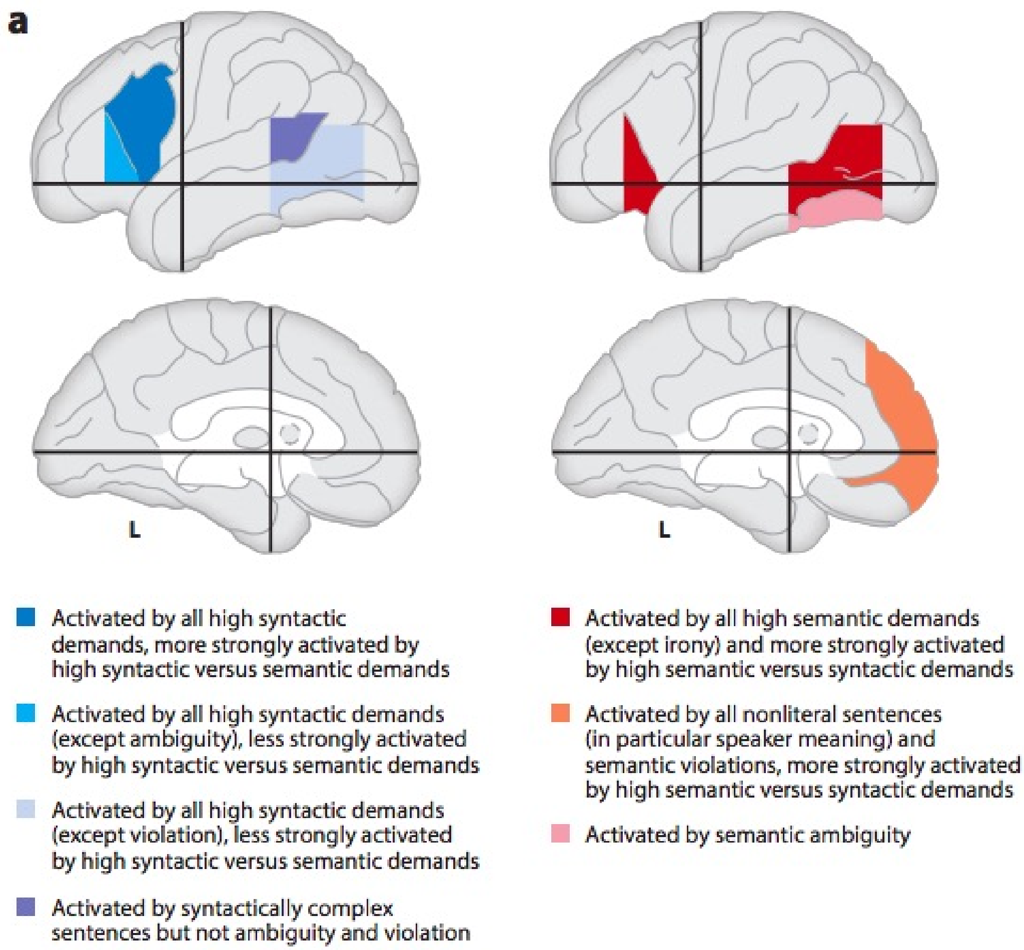
(Hagoort & Indefrey, 2014)



(Hagoort & Indefrey, 2014)

Summing up

- WG model incomplete, simplistic
- Rapid, fluent comprehension and production of language relies on
  - Distributed temporal/frontal networks
  - Efficient bottom-up and top-down processing
  - Syntactic vs. semantic/articulatory processing



(Hagoort & Indefrey, 2014)

Next time…

- Learning and memory
    - Distributed systems
    - Associative learning, NMDA receptors, and the hippocampus

References

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