

A few questions on the content of the
previous lecture

slido



Anterograde amnesia affects the ... the accident/lesion, while retrograde amnesia impacts the ... the accident/lesion.

ⓘ Start presenting to display the poll results on this slide.

slido



The Simon effect is an example of ...

ⓘ Start presenting to display the poll results on this slide.

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The fact that Henry Molaison (Patient H.M.) could not ... memories, but could learn new skills (e.g., mirror star tracing), reflects the fact that his ... memory was intact.

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Language processing

Dr. Lavinia Carmen Uscătescu

April 8th , 2024

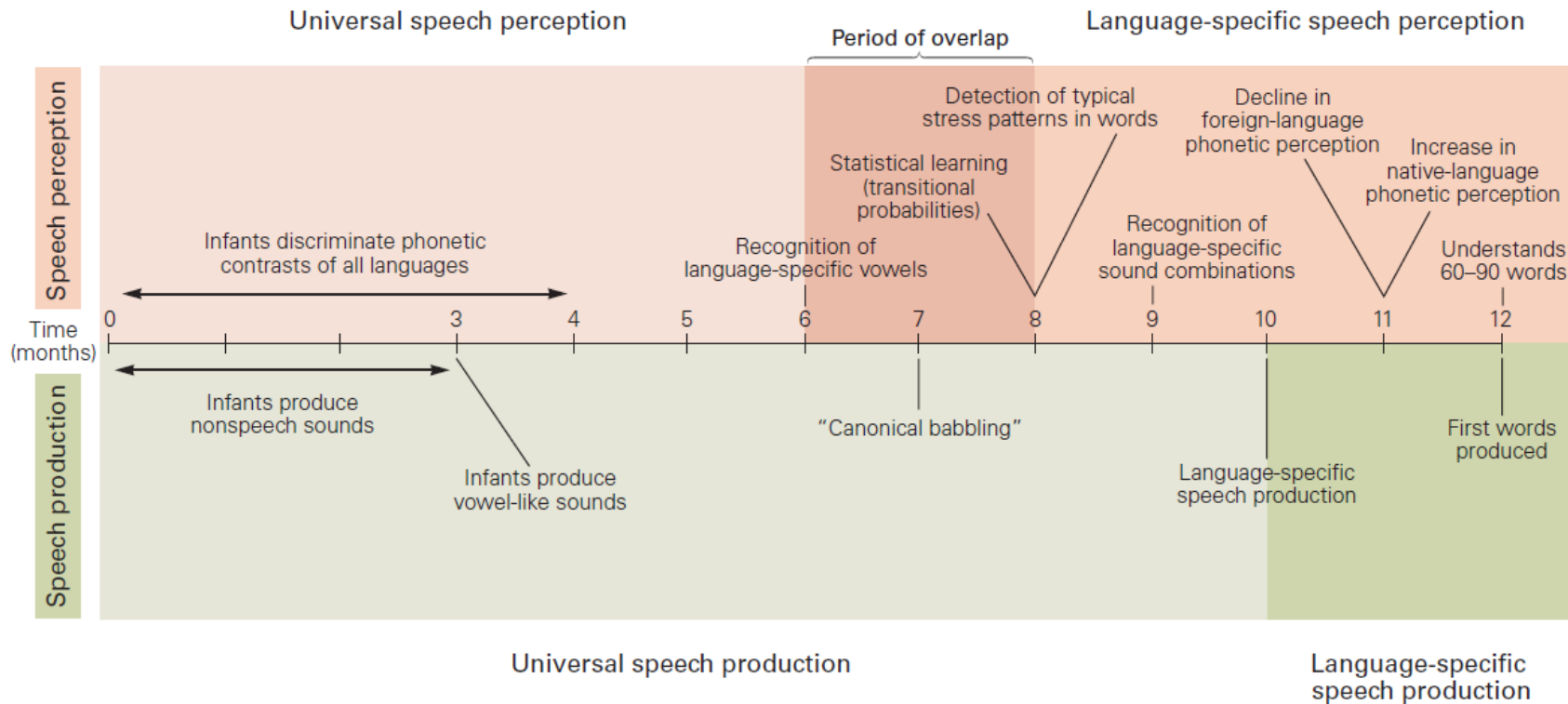
Outline

1. Language development
2. Neural mechanisms of language processing

Language development

Regardless of culture and which language they hear, **all children** initially exhibit **universal** patterns of **speech perception** and **production**.

By the age of **3 years**, children know approximately 1,000 words (by adulthood 70,000), **create long adult-like sentences** and can **carry on a conversation**.



Between 3 and 4 years of age, children respond to the **differences between grammatical and ungrammatical sentences** in an adult-like way, although tests using the most complex sentences indicate that the intricacies of grammar are **not mastered until late childhood**, between 7 and 10 years of age.

Figure 55-2 Language development progresses through a standard sequence in all children. Speech perception and production in children in various cultures initially follow a **language-universal pattern**. By the end of the first

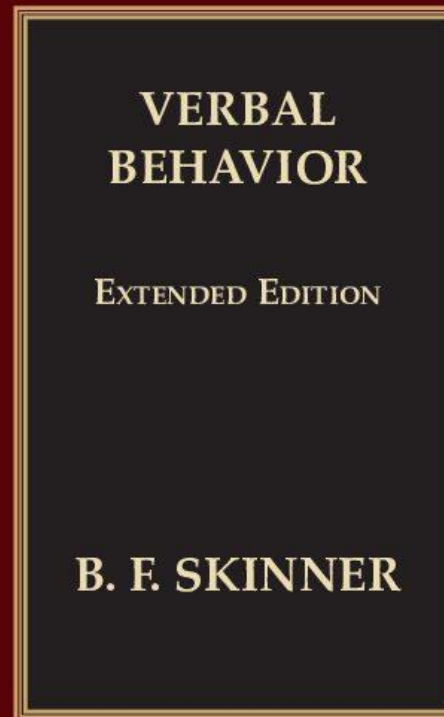
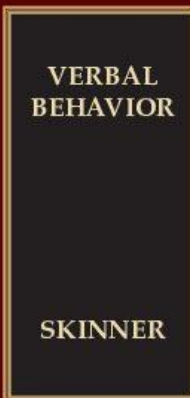
year of life, **language-specific patterns emerge**. Speech perception becomes language-specific before speech production. (Adapted, with permission, from Doupe and Kuhl 1999.)



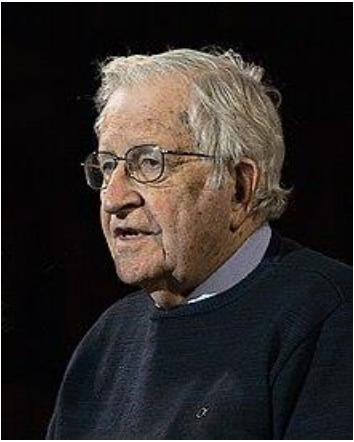
BURRHUS FREDERIC SKINNER
AT THE TIME OF PUBLICATION OF *VERBAL BEHAVIOR*

Skinner called *Verbal Behavior* his most important book. It took him over twenty years to complete it. The book extends his laboratory-based research on selection-by-consequences to the behavior of talking, writing, gesturing, and even thinking. These verbal actions differ from other behavior, he explains, because they do not operate on the environment directly, but rather through the behavior of a verbal community. Skinner illustrates his analysis with examples from literature, the arts, and the sciences, as well as from his own verbal behavior and that of his colleagues and children. Today, teachers and parents who work with children or adults lacking verbal skills will find Skinner's analysis key to teaching others to communicate effectively.

This Extended Edition includes three of Skinner's articles published after his 1957 original book: "A Lecture on Having a Poem" (1971), "The Evolution of Verbal Behavior" (1986), and "The Behavior of the Listener" (1988). They address creativity, how verbal behavior arose, and the role that listeners play in his analysis.



Skinner argued that language, like all animal behavior, was a learned behavior that developed in children as a function of external reinforcement and careful parental shaping.



Noam Chomsky

*Chomsky argued that **traditional reinforcement learning has little to do with the ability of humans to acquire language. Instead, he proposed that every individual has an innate “language faculty” (“nativism”) that includes a “universal grammar” and a universal phonetics; exposure to a specific language triggers a “selection” process for one language.***

A Review of B. F. Skinner's *Verbal Behavior*

Noam Chomsky

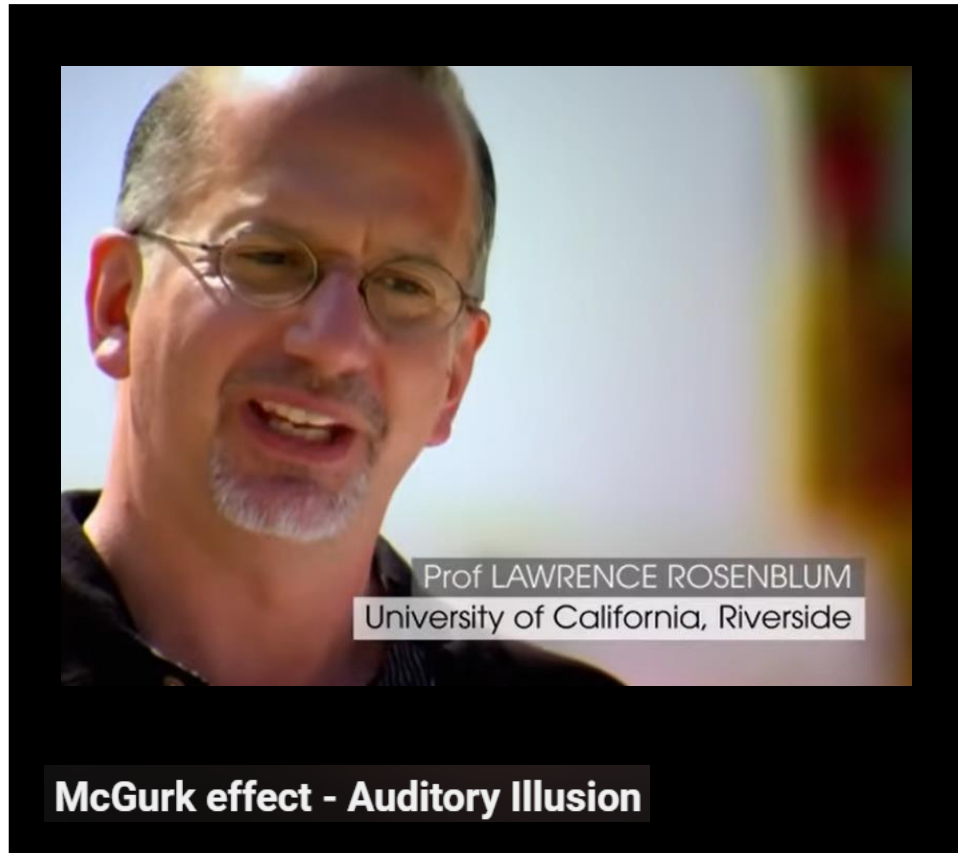
In Leon A. Jakobovits and Murray S. Miron (eds.), *Readings in the Psychology of Language*, Prentice-Hall, 1967, pp. 142-143

Skinner's thesis is that external factors consisting of present stimulation and the history of reinforcement (in particular, the frequency, arrangement, and withholding of reinforcing stimuli) are of overwhelming importance, and that the general principles revealed in laboratory studies of these phenomena provide the basis for understanding the complexities of verbal behavior. He confidently and repeatedly voices his claim to have demonstrated that the contribution of the speaker is quite trivial and elementary, and that precise prediction of verbal behavior involves only specification of the few external factors that he has isolated experimentally with lower organisms.

The fact that all normal children acquire essentially comparable grammars of great complexity with remarkable rapidity suggests that human beings are somehow specially designed to do this, with data-handling or “hypothesis-formulating” ability of unknown character and complexity.⁴⁸ The study of linguistic structure may ultimately lead to some significant insights into this matter.

<https://chomsky.info/1967/>

Vision plays a role in speech perception



<https://www.youtube.com/watch?v=2k8fHR9jKVM>

Deaf individuals communicate through a **visual-manual channel**.

Deaf infants “**babble**” with their hands at approximately the same time in development as hearing infants babble orally. Other

developmental milestones, such as **first words and two-word combinations**,

also occur on the developmental timetable of hearing infants.

[Curr Biol](#). 2018 May 7; 28(9): 1453–1459.e3.

doi: [10.1016/j.cub.2018.03.044](https://doi.org/10.1016/j.cub.2018.03.044)

A Visual Cortical Network for Deriving Phonological Information from Intelligible Lip Movements

[Anne Hauswald](#)^{1,2,4,5,*} [Chrysa Lithari](#)^{1,2,4} [Olivier Collignon](#)^{2,3} [Elisa Leonardelli](#)² and [Nathan Weisz](#)^{1,2,**}

Summary

Successful lip-reading requires a mapping from visual to phonological information [1]. Recently, visual and motor cortices have been implicated in tracking lip movements (e.g., [2]). It remains unclear, however, whether visuo-phonological mapping occurs already at the level of the visual cortex—that is, whether this structure tracks the acoustic signal in a functionally relevant manner. To elucidate this, we investigated how the cortex tracks (i.e., entrains to) absent acoustic speech signals carried by silent lip movements. Crucially, we contrasted the entrainment to unheard forward (intelligible) and backward (unintelligible) acoustic speech. We observed that the visual cortex exhibited stronger entrainment to the unheard forward acoustic speech envelope compared to the unheard backward acoustic speech envelope. Supporting the notion of a visuo-phonological mapping process, this forward-backward difference of occipital entrainment was not present for actually observed lip movements. Importantly, the respective occipital region received more top-down input, especially from left premotor, primary motor, and somatosensory regions and, to a lesser extent, also from posterior temporal cortex. Strikingly, across participants, the extent of top-down modulation of the visual cortex stemming from these regions partially correlated with the strength of entrainment to absent acoustic forward speech envelope, but not to present forward lip movements. Our findings demonstrate that a distributed cortical network, including key dorsal stream auditory regions [3, 4, 5], influences how the visual cortex shows sensitivity to the intelligibility of speech while tracking silent lip movements.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5956463/>

The critical period for language learning: the case of Genie Wiley



<https://www.youtube.com/watch?v=VjZolHCrC8E>



Brain and Mind 3: 79–100, 2002.

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Childhood Experience and the Expression of Genetic Potential: What Childhood Neglect Tells Us About Nature and Nurture

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(Received: 15 April 2002; in final form: 23 April 2002)

Abstract. Studies of childhood abuse and neglect have important lessons for considerations of nature and nurture. While each child has unique genetic potentials, both human and animal studies point to important needs that every child has, and severe long-term consequences for brain function if those needs are not met. The effects of the childhood environment, favorable or unfavorable, interact with all the processes of neurodevelopment (neurogenesis, migration, differentiation, apoptosis, arborization, synaptogenesis, synaptic sculpting, and myelination). The time courses of all these neural processes are reviewed here along with statements of core principles for both genetic and environmental influences on all of these processes. Evidence is presented that development of synaptic pathways tends to be a “use it or lose it” proposition. Abuse studies from the author’s laboratory, studies of children in orphanages who lacked emotional contact, and a large number of animal deprivation and enrichment studies point to the need for children and young nonhuman mammals to have both stable emotional attachments with and touch from primary adult caregivers, and spontaneous interactions with peers. If these connections are lacking, brain development both of caring behavior and cognitive capacities is damaged in a lasting fashion. These effects of experience on the brain imply that effects of modern technology can be positive but need to be monitored. While technology has raised opportunities for children to become economically secure and literate, more recent inadvertent impacts of technology have spawned declines in extended families, family meals, and spontaneous peer interactions. The latter changes have deprived many children of experiences that promote positive growth of the cognitive and caring potentials of their developing brains.

<https://psycnet.apa.org/record/2002-15753-003>

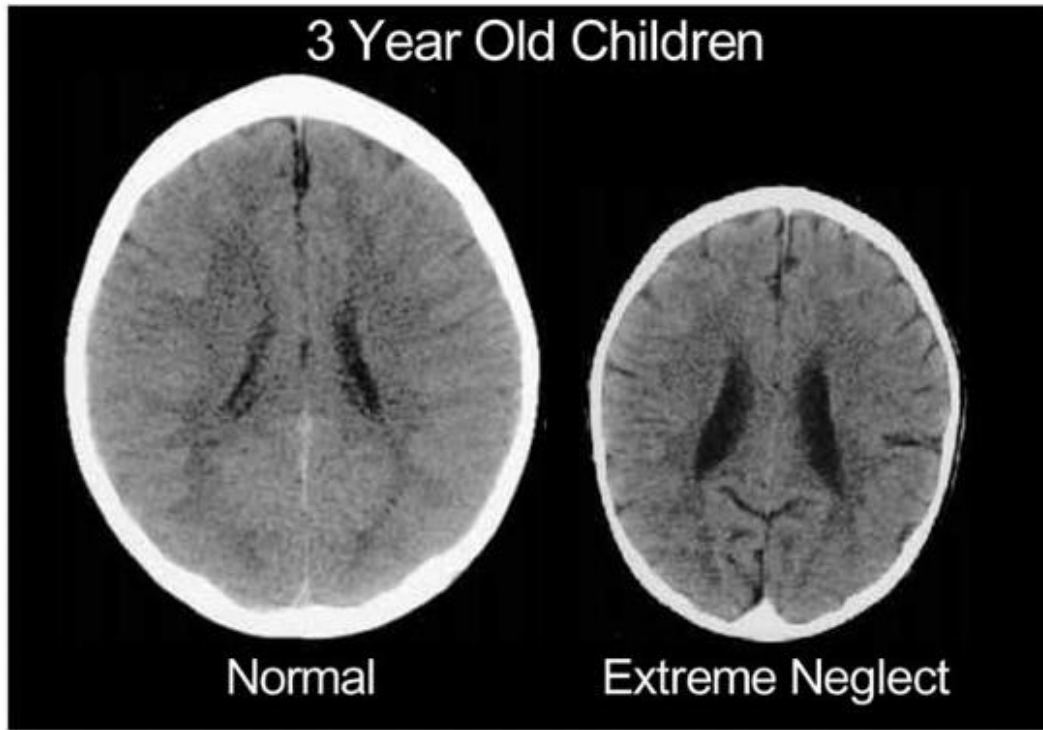


Figure 1. Abnormal brain development following sensory neglect in early childhood. These images illustrate the negative impact of neglect on the developing brain. In the CT scan on the left is an image from a healthy three year old with an average head size (50th percentile). The image on the right is from a three year old child suffering from severe sensory-deprivation neglect. This child's brain is significantly smaller than average (3rd percentile) and has enlarged ventricles and cortical atrophy.

Perry, (2002)

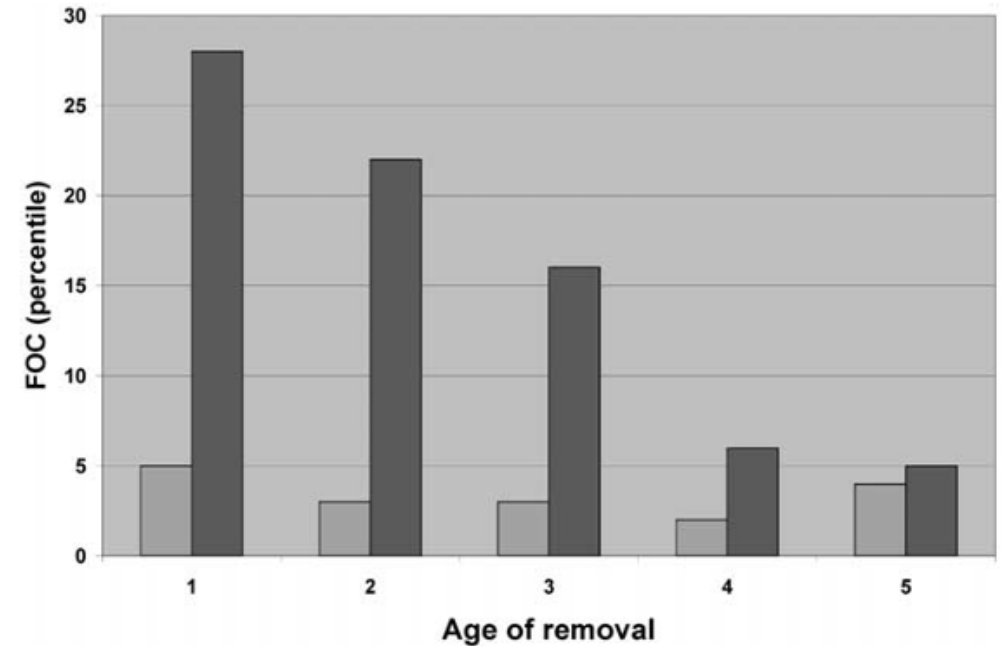


Figure 2. Sensory deprivation neglect: effects of early removal on recovery. Children were removed from neglectful environments at different ages (ages 8 months to 5.7 years). Their frontal-occipital circumference was measured and compared to same-aged norms (blue bars). Children were placed in foster care and one year later re-evaluated. FOC was measured (maroon bars) and in each group increased although with increasing age, the improvement after a year of foster placement started to decrease such that children removed after four years in the neglectful setting had no statistically-significant improvement one year later. Data are from 112 children with some form of severe neglect in the first five years of life (modified from Perry and Pollard, 1997).

Neural mechanisms of language processing

The N400

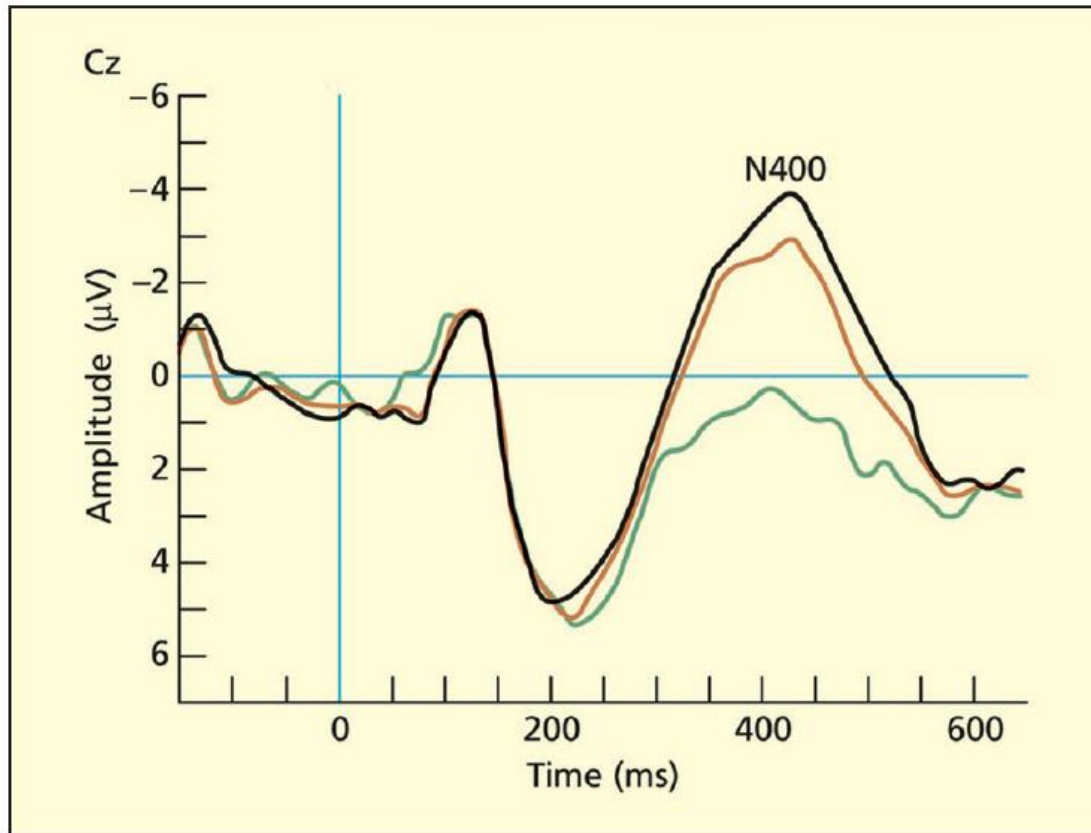


FIGURE 12.6: The N400 response to the critical word in three types of sentence: **semantically coherent and correct** (“the Dutch trains are *yellow*”; green line), **semantically coherent but incorrect** (“the Dutch trains are *white*”; brown line), **semantically incoherent** (“the Dutch trains are *sour*”; black line).

From Hagoort et al., 2004. Reprinted with permission from AAAS.

Ward, (2020), p. 306

- The N400 is found either when a word is **semantically anomalous**, as in “the Dutch trains are sour” (trains cannot be tasted), or **conflicts with known facts** about the world, as in “the Dutch trains are white” (Dutch people know they are yellow).
- Words **need not be presented in sentence** form for the N400 to be elicited.
- An N400 is elicited for the third word in triplets such as “river–bank–money,” but not “finance–bank–money” => the N400 reflects **global context** (operating over all three words) and not local context, given that the last two words are identical in both triplets.
- The N400 tends to emerge **earlier for spoken words** than written words.

Broca's aphasia/ expressive aphasia



Pierre Paul Broca
(1824 – 1880)

A few months later, Broca encountered a second patient, Lelong, who also exhibited reduced productive speech as the result of a stroke 1 year before. This 84-year-old patient could say only five words, 'oui' ('yes'), 'non' ('no'), 'tois' (a mispronunciation of 'trois' ('three') which he used to represent any number), 'toujours' ('always') and 'Lelo' (a mispronunciation of his own name).

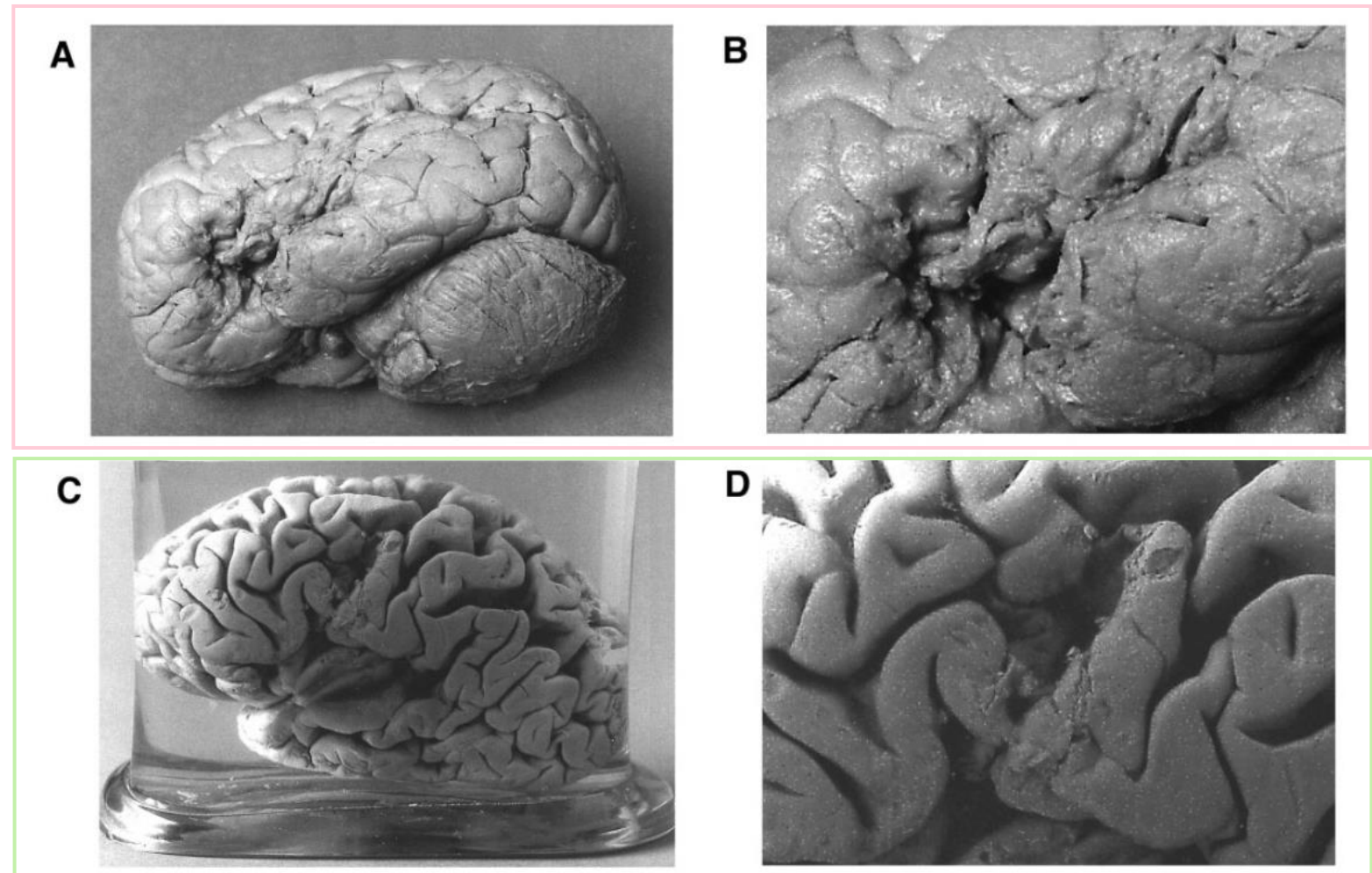


Fig. 3 Photographs of the brains of Leborgne and Lelong, Paul Broca's first two aphasic patients. (A) Lateral view of the brain of the first patient, Leborgne. The external lesion is clearly visible in the inferior frontal lobe. The softening in the area superior and posterior to the lesion suggests further cortical and subcortical involvement. (B) Close-up of the visible lesion in Leborgne's brain. (C) Lateral view of Broca's second patient, Lelong. The frontal, temporal and parietal lobes have retracted due to severe atrophy, exposing the insula. (D) Close-up of the visible lesion in Lelong's brain. Note that only the most posterior part of what is currently called Broca's area is infarcted; the anterior portion is completely spared.

Dronkers et al., (2007)

Paul Broca's historic cases: high resolution MR imaging of the brains of Leborgne and Lelong

N F Dronkers¹, O Plaisant, M T Iba-Zizen, E A Cabanis

In 1861, the French surgeon, Pierre Paul Broca, described two patients who had lost the ability to speak after injury to the posterior inferior frontal gyrus of the brain. Since that time, an infinite number of clinical and functional imaging studies have relied on this brain-behaviour relationship as their anchor for the localization of speech functions. Clinical studies of Broca's aphasia often assume that the deficits in these patients are due entirely to dysfunction in Broca's area, thereby attributing all aspects of the disorder to this one brain region. Moreover, functional imaging studies often rely on activation in Broca's area as verification that tasks have successfully tapped speech centres. Despite these strong assumptions, the range of locations ascribed to Broca's area varies broadly across studies. In addition, recent findings with language-impaired patients have suggested that other regions also play a role in speech production, some of which are medial to the area originally described by Broca on the lateral surface of the brain. Given the historical significance of Broca's original patients and the increasing reliance on Broca's area as a major speech centre, we thought it important to re-inspect these brains to determine the precise location of their lesions as well as other possible areas of damage. Here we describe the results of high resolution magnetic resonance imaging of the preserved brains of Broca's two historic patients. We found that both patients' lesions extended significantly into medial regions of the brain, in addition to the surface lesions observed by Broca. Results also indicate inconsistencies between the area originally identified by Broca and what is now called Broca's area, a finding with significant ramifications for both lesion and functional neuroimaging studies of this well-known brain area.

<https://pubmed.ncbi.nlm.nih.gov/17405763/>

Wernicke's aphasia/ fluent aphasia/ receptive aphasia

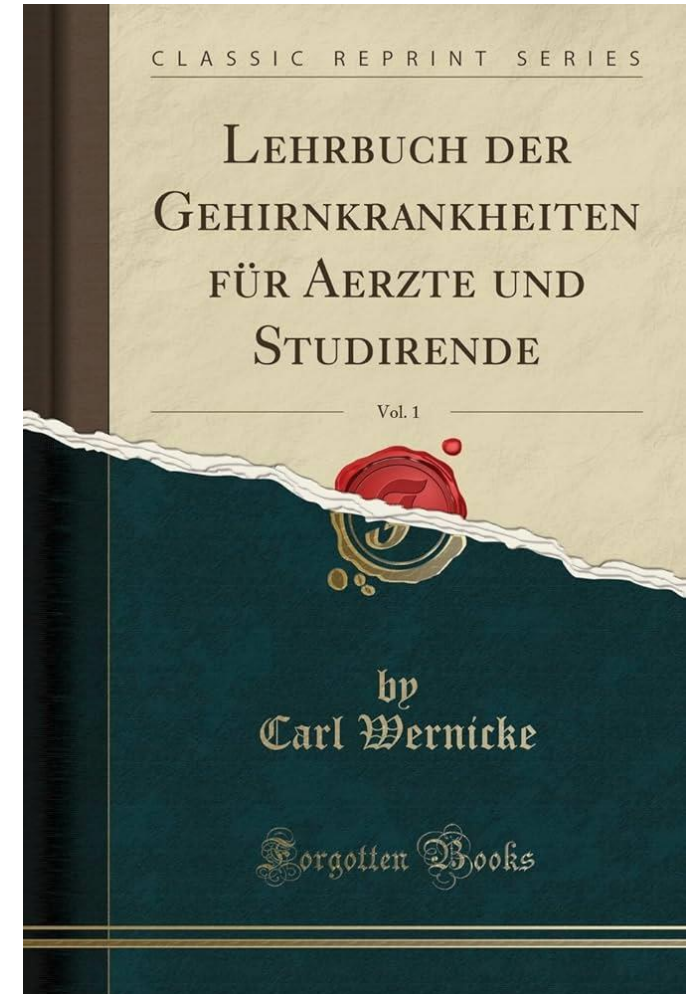


Carl Wernicke
(1848 – 1905)

Wernicke examined a patient who had suffered a **stroke** and was **capable of speech** but was **not able to understand** either **spoken** or **written** language.

On examining his brain **after death**, Wernicke found a **lesion** in the **left hemisphere** but in the **rear parietal/temporal** region.

He published his results in 1874 and named the condition *sensory aphasia*, but it is now also known as Wernicke's aphasia.

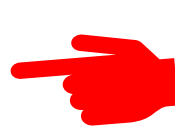
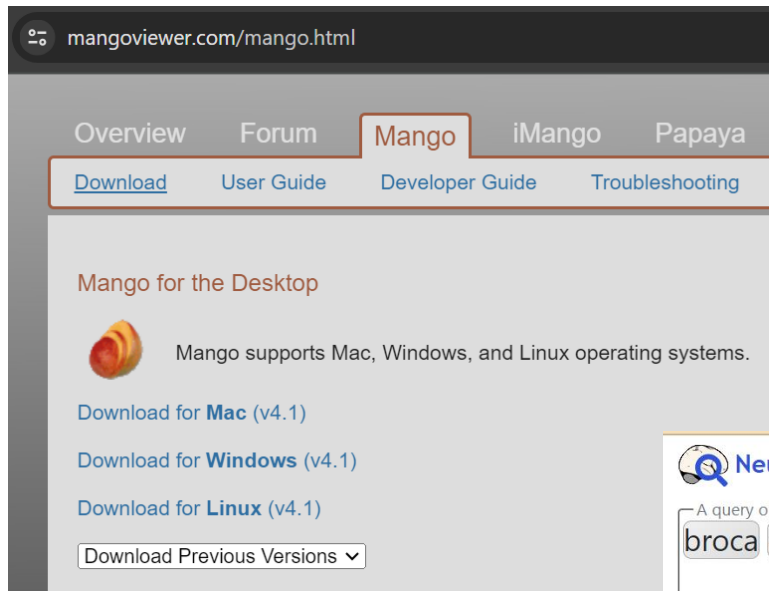


The Wernicke conundrum and the anatomy of language comprehension in primary progressive aphasia

M.-Marsel Mesulam,^{1,2,3} Cynthia K. Thompson,^{1,4} Sandra Weintraub^{1,5} and Emily J. Rogalski¹

Wernicke's aphasia is characterized by severe word and sentence comprehension impairments. The location of the underlying lesion site, known as Wernicke's area, remains controversial. Questions related to this controversy were addressed in 72 patients with primary progressive aphasia who collectively displayed a wide spectrum of cortical atrophy sites and language impairment patterns. Clinico-anatomical correlations were explored at the individual and group levels. These analyses showed that neuronal loss in temporoparietal areas, traditionally included within Wernicke's area, leave single word comprehension intact and cause inconsistent impairments of sentence comprehension. The most severe sentence comprehension impairments were associated with a heterogeneous set of cortical atrophy sites variably encompassing temporoparietal components of Wernicke's area, Broca's area, and dorsal premotor cortex. Severe comprehension impairments for single words, on the other hand, were invariably associated with peak atrophy sites in the left temporal pole and adjacent anterior temporal cortex, a pattern of atrophy that left sentence comprehension intact. These results show that the neural substrates of word and sentence comprehension are dissociable and that a circumscribed cortical area equally critical for word and sentence comprehension is unlikely to exist anywhere in the cerebral cortex. Reports of combined word and sentence comprehension impairments in Wernicke's aphasia come almost exclusively from patients with cerebrovascular accidents where brain damage extends into subcortical white matter. The syndrome of Wernicke's aphasia is thus likely to reflect damage not only to the cerebral cortex but also to underlying axonal pathways, leading to strategic cortico-cortical disconnections within the language network. The results of this investigation further reinforce the conclusion that the left anterior temporal lobe, a region ignored by classic aphasiology, needs to be inserted into the language network with a critical role in the multisynaptic hierarchy underlying word comprehension and object naming.

<https://pubmed.ncbi.nlm.nih.gov/26112340/>

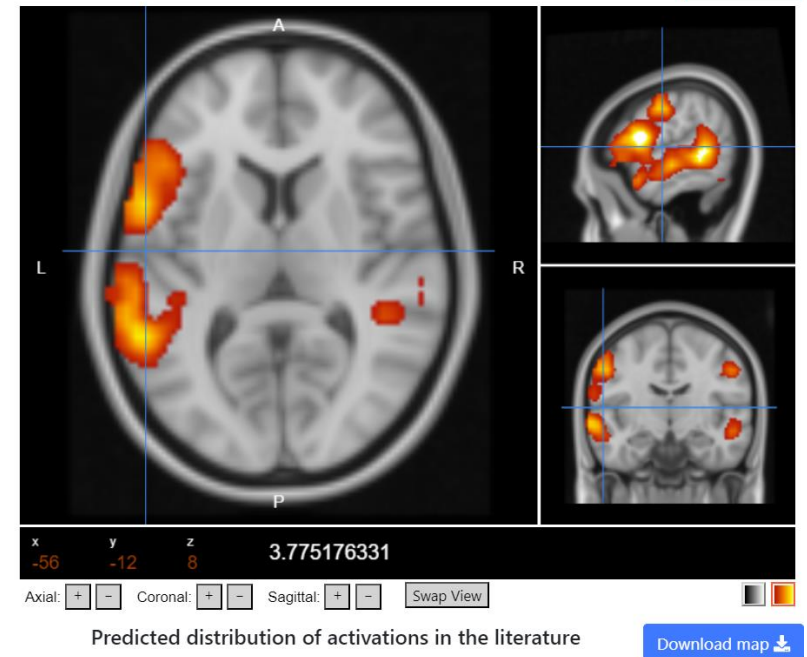


Use this open-source software to load neuroimaging files for visualization

<https://neuroquery.org/>

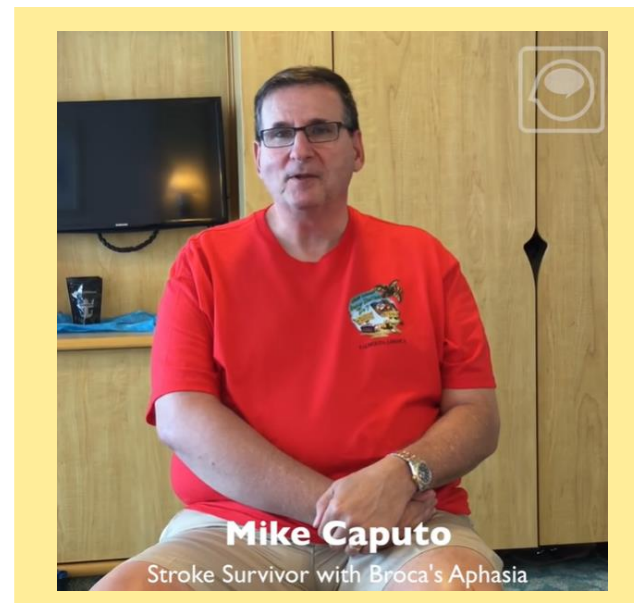
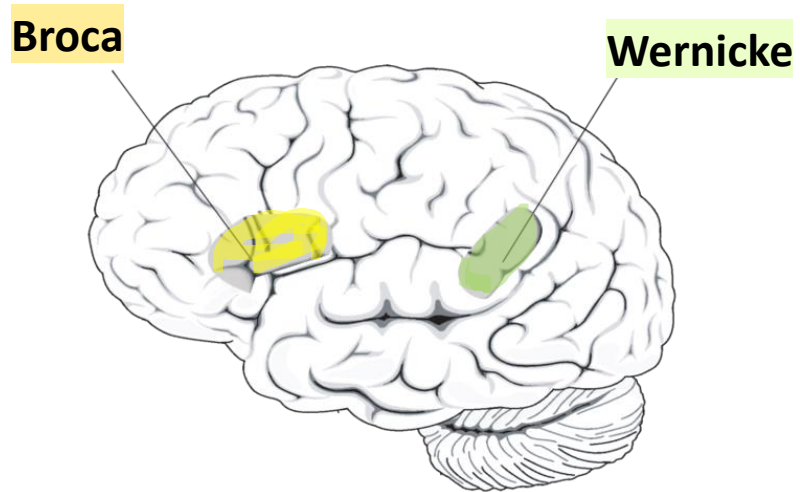
	Term	Similarity	Weight in brain map	N
In query	aphasia			494
	broca			1083
In expansion	speech			2192
	language			4019
	left			12782
	motor			7928
	frontal			11471
	m1			722
	temporal			11897
	inferior			10215
	auditory			4009
	visual			10448

Use this website to see and download activation maps (in .nii.gz format; nii = Neuroimaging Informatics Technology; gz = compressed using Gnu Zip (gzip) software)



Type of aphasia	Speech	Comprehension	Capacity for repetition	Other signs	Region affected
Broca	Nonfluent, effortful	Largely preserved for single words and grammatically simple sentences	Impaired	Right hemiparesis (arm > leg); patient aware of defect and can be depressed	Left posterior frontal cortex and underlying structures
Wernicke	Fluent, abundant, well articulated, melodic	Impaired	Impaired	No motor signs; patient can be anxious, agitated, euphoric, or paranoid	Left posterior superior and middle temporal cortex

Kandel et al., (2021), p. 1379



<https://www.youtube.com/watch?v=JWC-cVQmEmY>



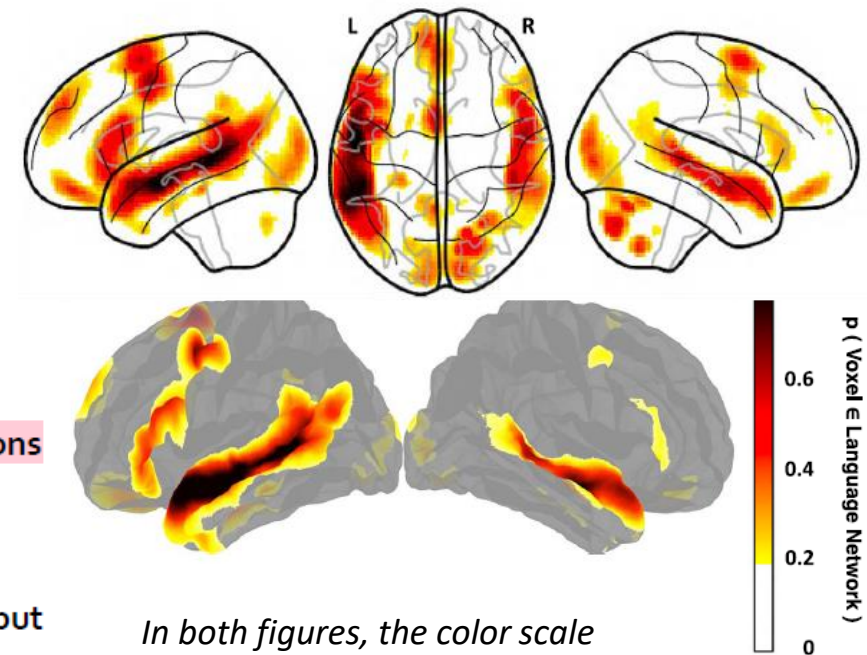
<https://www.youtube.com/watch?v=3oef68YabD0>

Probabilistic atlas for the language network based on precision fMRI data from >800 individuals

Benjamin Lipkin ^{1 2}, Greta Tuckute ^{3 4}, Josef Affourtit ^{3 4}, Hannah Small ⁵, Zachary Mineroff ⁶, Hope Kean ^{# 3 4}, Olessia Jouravlev ^{# 7}, Lara Rakocevic ^{# 3 4}, Brianna Pritchett ^{# 3 4}, Matthew Siegelman ^{# 8}, Caitlyn Hoeflin ^{# 9}, Alvincé Pongos ^{# 10}, Idan A Blank ^{# 11}, Melissa Kline Struhl ^{# 3}, Anna Ivanova ^{# 3 4}, Steven Shannon ⁴, Aalok Sathe ^{3 4}, Malte Hoffmann ¹², Alfonso Nieto-Castañón ^{4 13}, Evelina Fedorenko ^{14 15 16}

Two analytic traditions characterize fMRI language research. One relies on averaging activations across individuals. This approach has limitations: because of inter-individual variability in the locations of language areas, any given voxel/vertex in a common brain space is part of the language network in some individuals but in others, may belong to a distinct network. An alternative approach relies on identifying language areas in each individual using a functional 'localizer'. Because of its greater sensitivity, functional resolution, and interpretability, functional localization is gaining popularity, but it is not always feasible, and cannot be applied retroactively to past studies. To bridge these disjoint approaches, we created a probabilistic functional atlas using fMRI data for an extensively validated language localizer in 806 individuals. This atlas enables estimating the probability that any given location in a common space belongs to the language network, and thus can help interpret group-level activation peaks and lesion locations, or select voxels/electrodes for analysis. More meaningful comparisons of findings across studies should increase robustness and replicability in language research.

<https://pubmed.ncbi.nlm.nih.gov/36038572/>



In both figures, the color scale reflects the proportion of participants for whom that voxel/vertex belongs to the top 10% of language > control voxels/vertices.

▼ Download - parcels

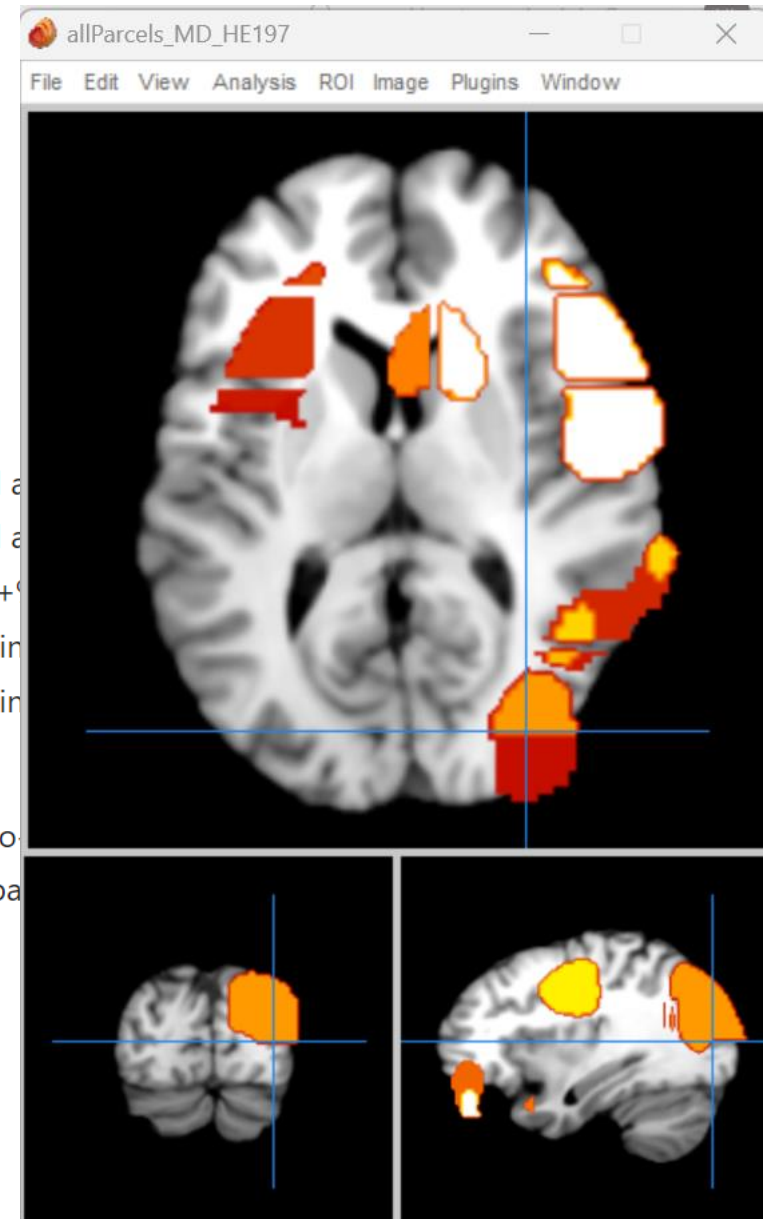
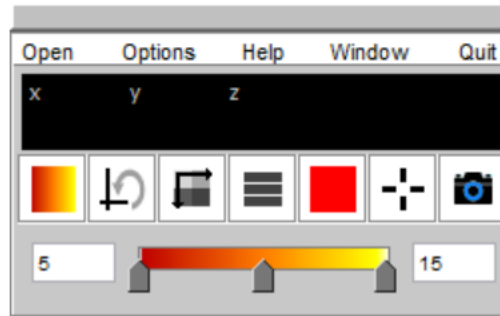
Language Parcels - [Download Current Parcels](#) - ROI Indices

- ▶ A subset of the original parcels from [Fedorenko et al. \(2010\)](#) which include the 8 parcels in the frontal a
- ▶ A subset of the original parcels from Fedorenko et al. (2010) which include the 8 parcels in the frontal a
- ▶ The original parcels from Fedorenko et al. (2010), where 60-79% of individuals showed activity (cf. 80+%)
- ▶ The updated parcels created from a probabilistic overlap map from 220 participants (currently in use in
- ▶ The updated parcels created from a probabilistic overlap map from 220 participants (currently in use in

MD Parcels - [Download Current Parcels](#) - ROI Indices

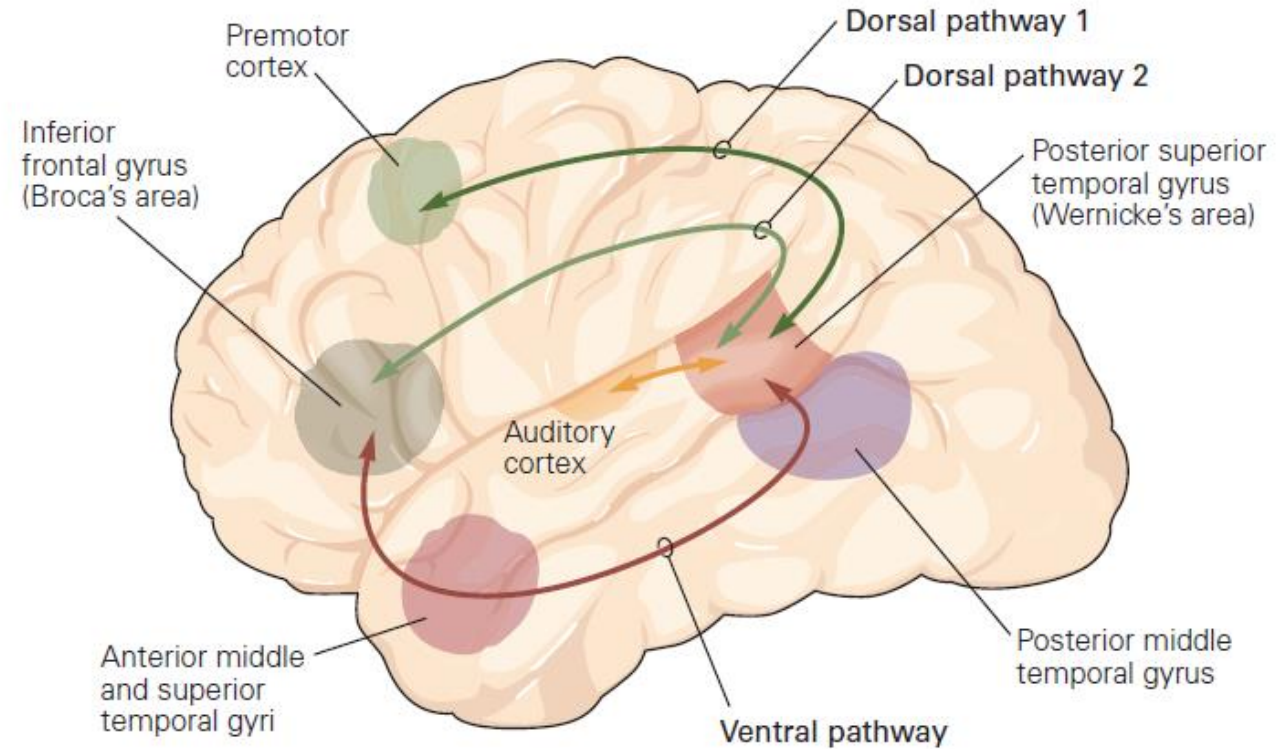
- ▶ The original anatomical parcels used in [Fedorenko et al. \(2013\)](#), created based on the aal atlas (Tzourio
- ▶ The functional parcels, created (by Idan Blank) based on a probabilistic overlap map from 197 participa

<https://evlab.mit.edu/funcloc/index.html>



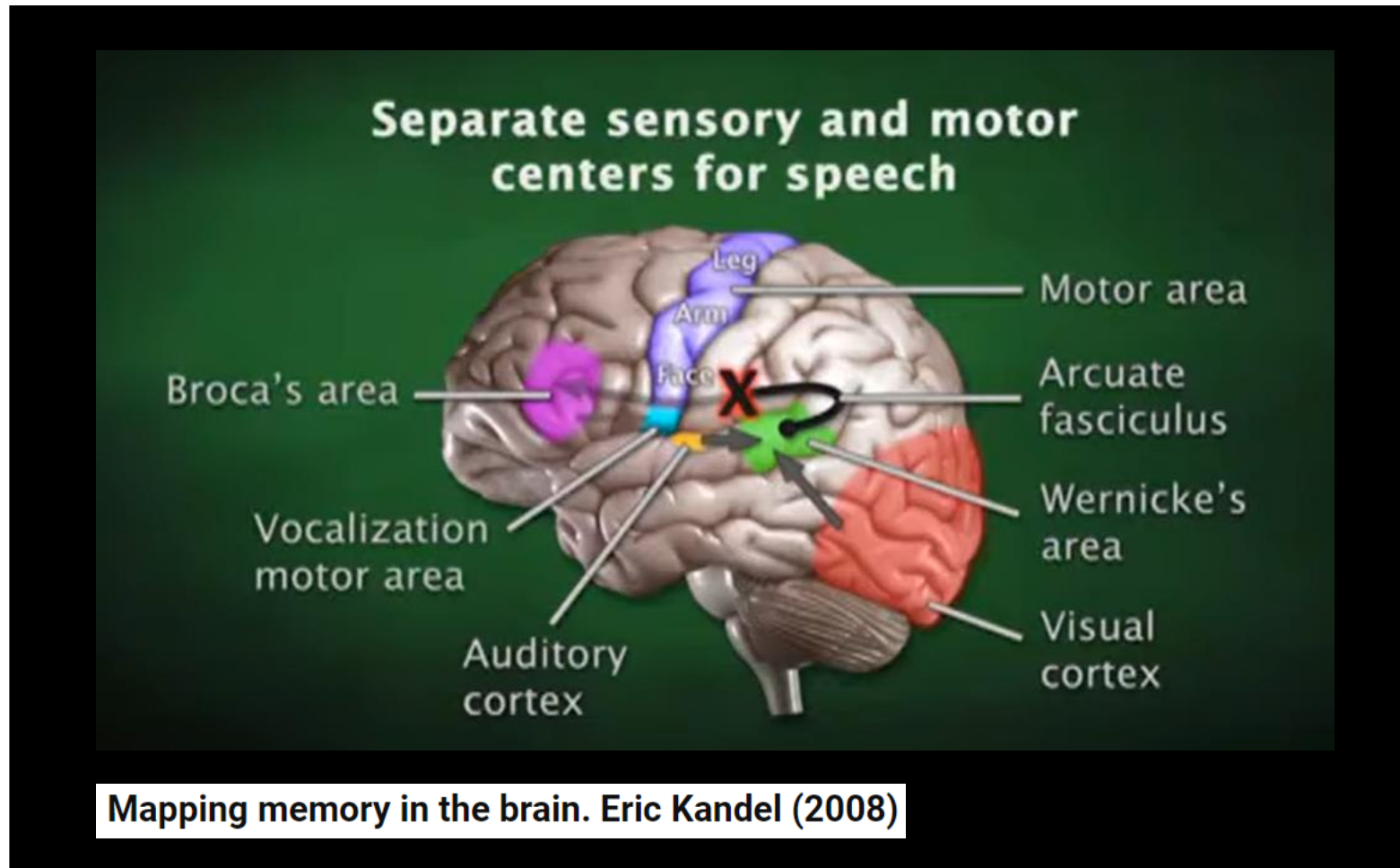
Dual-stream model of language processing

Figure 55–4 Dual-stream model of language processing. Temporal and spectral analyses of speech signals occur bilaterally in the auditory cortex followed by phonological analysis in the posterior superior temporal gyri (yellow arrow). Processing then diverges into two separate pathways: a dorsal stream that maps speech sounds to motor programs and a ventral stream that maps speech sounds to meaning. The dorsal pathway is strongly left hemisphere dominant and has segments that extend to the premotor cortex (dorsal pathway 1) and to the posterior inferior frontal cortex (dorsal pathway 2). The ventral pathway occurs bilaterally and extends to the anterior temporal lobe and the posterior inferior frontal cortex. (Adapted, with permission, from Hickok and Poeppel 2007, and Skeide and Friederici 2016.)



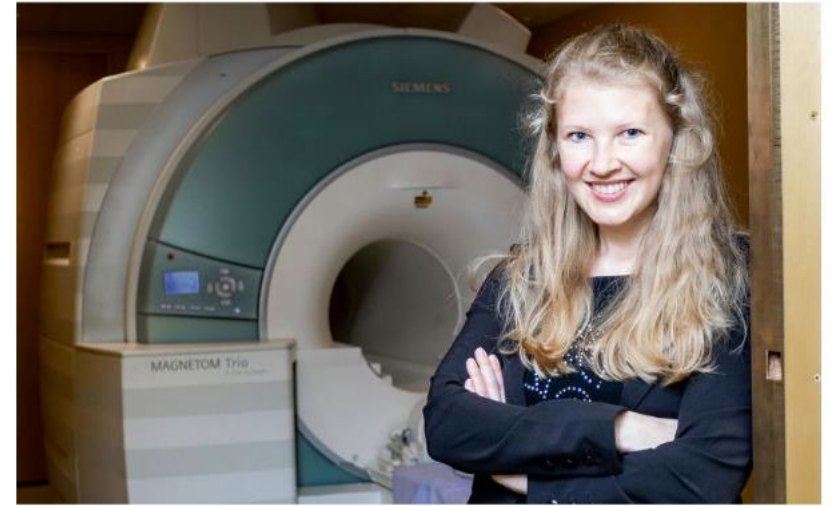
Kandel et al., (2021), p. 1380

The arcuate fasciculus and conduction aphasia



<https://www.youtube.com/watch?v=eJzO5t9xis> from 26:05 to 27:30

Further resources



Evelina (Ev, as in 'ever', not Eve) Fedorenko

► Key discoveries

- 1. Language-processing brain regions are functionally specialized for language
- 2. The language network is ubiquitously sensitive to both word-level meanings and combinatorial (syntactic/semantic) processing
- 3. Composition is the core driver of the language network.
- 4. The multiple demand (MD) network is highly domain-general and supports fluid intelligence.
- 5. The domain-general multiple demand (MD) network does not support language comprehension.

<https://evlab.mit.edu/research/>