

## Glossary

### Language

**Agrammatism** Form of aphasia identifying patients who after brain lesion produce sentences in in telegraphic style and leave out function words from the message. It can also affect the comprehension of grammatically complex constructions whose comprehension depends on function words or inflectional morphology, for example in passive sentences, such as *The boy was pushed by the girl*, which are misinterpreted when content words are processed (*boy pushed girl*)

**Animacy** Semantic feature of a noun, which qualifies it as being sentient/alive. It is strongly linked to the role of the actor of an action in a sentence, as most actors are animate (except for robots doing an action)

**Angular gyrus (AG)** Posterior to the supramarginal gyrus, located in the parietal lobe, along the superior edge of the temporal lobe and bordered ventrally by the superior temporal sulcus (BA 39)

**Anterior Insula (aINS)** Anterior section of the insular cortex, which is a portion folded deep within the lateral sulcus.

**Anterior superior temporal gyrus (aSTG)** Located in the anterior section of the superior temporal gyrus. Medially, it is bound by the circular sulcus of the insula and extends laterally from the anterior limit of the superior temporal sulcus to the anterior limit of Heschl's sulcus.

**Aphasia** Any language impairment due to a dysfunction in a specific language-related area, generally caused by strokes, head traumas, or cortical atrophy.

**Arcuate fasciculus (AF)** Neural pathway connecting the prefrontal cortex to the posterior superior temporal gyrus dorsally. It partly runs closely in parallel with the superior longitudinal fasciculus from prefrontal to parietal regions, but not in its posterior portion curving into the posterior temporal cortex.

**Artificial grammar learning (AGL)** Class of experimental paradigms used in cognitive psychology and neuroscience, which consist of made-up rules generating meaningless artificial languages. In neurolinguistics, such grammars are used to investigate those areas selectively involved in syntactic processing and implicit/explicit learning, when semantic information is stripped away from the sequence.

**Associative learning** A process of learning based on an association between two separate stimuli that occur together.

**Attention** A process of selecting and concentrating on specific aspects of a stimulus, while ignoring other aspects.

**Axon** Connection of the nerve cells via which it forward signals to other neurons. The axons come into contact with other neurons via synapses at which the transmission of the signals is realized by neurotransmitters.

**Basal ganglia** Set of subcortical nuclei situated at the base of the forebrain. These include: dorsal striatum, ventral striatum, globus pallidus, ventral pallidum, substantia nigra, and subthalamic nucleus.

**Brain lesion** Damage to neural tissues through injury or disease.

**Broca's area** Region of the cerebral cortex in the inferior part of the frontal lobe of the brain. It consists of two cytoarchitectonically separable parts, an anterior part called pars triangularis (Brodmann area 45) and a posterior part called pars opercularis (Brodmann area 44).

**Brodman area (BA)** A region of the cerebral cortex that is defined based on its cytoarchitectonics, or organization of cells, according to the classification proposed by Brodmann (1909).

**Case marking** Morphological property of language expressing the grammatical function of nouns, pronouns, determiners, and modifiers in a phrase or sentence. In many languages, case information of a specific word is overtly marked by morphological inflections, which are usually attached to the end of the word. Typical grammatical cases are: nominative, accusative, genitive, and dative. They are closely related to the thematic roles in a sentence.

**Center-embedded sentences** A sentence (*the boy is my son*) having another sentence embedded within it (*the boy (who is running) is my son*).

**Central sulcus** Fold in the cerebral cortex of brains in vertebrates. Prominent landmark of the brain, separating the parietal lobe from the frontal lobe and the primary motor cortex from the primary somatosensory cortex.

**Cerebellum** Region of the brain located underneath the cerebrum in the metencephalon, behind the fourth ventricle, the pons, and the medulla.

**Cloze probability** Probability of a word to complete a sentences frame. The cloze probability of a word depends on the congruency that the word has with respect to the prior sentential context, the higher the more congruent.

**Conduction aphasia** Rare form of fluent aphasia showing intact comprehension and spared production, but poor capacity for repeating words and sentences. Frequent errors during spontaneous speech include phoneme transposing and substitutions.

**Content words** Words that primarily carry lexical-semantic information, have descriptive content and referential weight, and are context-independent. They refer to events (either states or actions) and entities participating in them. Content words typically include nouns, adjectives, verbs, and adverbs.

**Corpus callosum** Largest white matter structure of the brain connecting left and right hemispheres along the bottom of the medial longitudinal fissure.

**Dendrite** Connection of the nerve cells receiving signals from other neurons.

**Derivational morphology** Elements by which words can be changed into others, by adding morphological affixes carrying semantic meaning (*drink* vs. *drinkable*). They can change both the category of a word and the meaning of its stem.

**Dysarthria** Neurological deficit in the motor-speech system with poor phoneme articulation.

**Embedding** Possibility for a linguistic unit to have another linguistic unit included within it.

**Emotional prosody** Emotional information that is conveyed in addition to what is uttered, by prosodic parameters of speech, such as intensity and pitch, but also lengthening of speech elements and pausing between these. Emotional prosody carries meaning (e.g., happy and sad, or fear and anger). In speech, this information is encoded in the auditory signal.

**Fiber bundles** Nerve cell projections of the white matter connecting various gray matter areas across the brain.

**Frontal lobe** One of the four cortical lobes of humans and other mammals, located at the front of each cerebral hemisphere, and positioned anterior to (in front of) the parietal lobe and superior and anterior to the temporal lobes.

**Frontal operculum (FOP)** Brain region in the inferior frontal cortex covering the insula and positioned ventromedial next to the classical language-related brain region called Broca's area.

**Function words** Elements that primarily carry syntactic information that allows structural assignment by anchoring, linking, or sequencing other items. Function words typically include prepositions, pronouns, determiners, conjunctions, auxiliary verbs, participles, and inflectional morphology.

**Fusiform gyrus (FG)** Part of the temporal lobe bordered medially by the parahippocampal gyrus, laterally by the inferior temporal gyrus, and caudally by the lingual gyrus. (BA 37).

**Grammar** The set of rules expressing how words can be combined together in a given language.

**Grammatical encoding** The process of producing well-formed syntactic structures in which all grammatical relations are consistently expressed.

**Gray matter** The 2–3mm outer covering over gyri and sulci of the cerebral cortex, containing numerous cell bodies organized along different cortical layers.

**Heschl's gyrus** The transverse temporal gyrus in the temporal cortex, buried within the lateral sulcus and extending medially till the circular sulcus of the insular cortex.

**Hierarchical structure** In syntax, the fundamental structural organization of linguistic constituents, expressing the dominance relation between elements within a phrase and within a sentence.

**Hippocampus** Major component of the brains of humans and other mammals. In humans and other primates, the hippocampus is located inside the medial temporal lobe, beneath the cortical surface. Like the cerebral cortex, with which it is closely associated, it is a paired structure, with mirror-image halves in the left and right sides of the brain.

**Inflectional morphology** Elements determining the grammatical relations between constituents, by adding to the words morphological affixes carrying morphosyntactic information (e.g., *run* vs. *runs*). Prototypical inflectional categories include number, tense, person, case, and gender.

**Inferior frontal gyrus (IFG)** Gyrus of the frontal lobe of the human brain. Its superior border is the inferior frontal sulcus, its inferior border is the lateral fissure, and its posterior border is the inferior precentral sulcus. Above it is the middle frontal gyrus, behind it the precentral gyrus.

**Inferior frontal sulcus (IFS)** Sulcus located between the middle frontal gyrus and the inferior frontal gyrus.

**Inferior-fronto-occipital fasciculus (IFOF)** Ventral pathway connecting BA 45 and BA 47 with the posterior STG/MTG, and the occipital cortex, also called Extreme Capsule Fiber System (ECFS)

**Intonation** The aspect of prosodic information relative to the accentuation of the thematic focus of a sentence. Intonation serves to indicate the emotions and intentions of the speaker by differentiating, for example, between questions and statements.

**Language faculty** The mental predisposition to learn, produce, and understand language.

**Layers** Structural levels of cell organization of the gray matter. The cerebral cortex mostly consist of six layers, which can be distinguished according to the type of density of nerve cells.

**Lexical selection** In production, the process of retrieving and selecting a specific word from the mental lexicon.

**Merge** In human language, the computational mechanism that constructs new syntactic objects Z (e.g., *ate the apples*) from already-constructed syntactic objects X (*ate*) and Y (*the apples*).

**Middle temporal gyrus (MTG)** Gyrus in the temporal lobe located between the superior and the inferior temporal sulcus (BA 21).

**Mirror neuron** A neuron that fires both when observing an action and when performing it.

**Morphemes** The smallest linguistic unit carrying a meaning (in the word *books*, e.g., two morphemes, *book* and *-s*). Morphemes can be free (any individual word) or bound (affixes). They can also be distinguished into inflectional (*-s* in *he runs*) and derivational (*-hood* in *childhood*) morphology.

**Morphology** The study of the internal structures of words from more fundamental linguistic units (morphemes).

**Motor cortex** Area of the frontal lobe located along the dorsal precentral gyrus anteriorly to the central sulcus. It comprises the primary motor cortex (BA 4), the premotor cortex (BA 6) and the supplementary motor area (SMA).

**Movement** In some theories of syntax, the operation that generates non-canonical sentences from more basic ones. It displaces an element from its original position (where it leaves a silent, but active, copy for interpretation, called the gap) to a new position along the sentence (the filler).

**Myelin** Fatty white substance that surrounds the axon of nerve cells and works as insulating layer for electrically transmission.

**Myelination** The growth of myelin during development.

**Neuron** Electrically excitable cell of nervous system.

**Neurotransmitters** Chemical messengers enabling neurotransmission from one neuron to another.

**Non-canonical** A sentence in a human language in which the order of the elements diverges from the basic word order of that specific language.

**Occipital lobe** One of the four cortical lobes of humans and other mammals, located in the rearmost portion of the brain, behind the parietal lobe and the temporal lobe.

**Ontogeny** The course of development of an individual organism.

**Ordering** The process of linking the arguments of sentence (subject, direct object, and indirect object) to the argument structure imposed by the verb. Ordering is especially demanding for the processing of non-canonical structures.

**Paragrammatism** Speech disturbance leading to the production of utterances in which constituents are incorrectly crossed or unfinished.

**Parietal lobe** One of the four cortical lobes of humans and other mammals, located above the occipital lobe and behind the frontal lobe and the central sulcus.

**Pars opercularis** Opercular part of the inferior frontal gyrus in the posterior section of Broca's area (BA 44).

**Pars orbitalis** Orbital part of the inferior frontal gyrus located anterior-ventral to Broca's area (BA 47).

**Pars triangularis** Triangular part of the inferior frontal gyrus in the anterior section of Broca's area (BA 45).

**Phoneme** The abstract mental representations of a sound unit, which distinguish words from another in a given language (e.g., *hat* vs. *cat*).

**Phonology** The study of sounds as discrete, abstract elements in the speaker's mind that distinguish meaning.

**Phrase** A group of words, or a single word, forming a constituent in the syntactic structure of a sentence. Phrases are named according to the syntactic category of the main element within it (noun phrase, determiner phrase, adjectival phrase, etc.).

**Phylogeny** The evolutionary course of a kind of organism.

**Pitch** The perceptual correlate of the fundamental frequency (the frequency at which the vocal folds vibrate to produce a sound).

**Pragmatics** The study of the contextual knowledge during communication.

**Precentral gyrus** Gyrus lying between the central sulcus and the postcentral gyrus in the frontal lobe.

**Precentral sulcus** Sulcus located parallel to, and in front of, the central sulcus. It divides the inferior, middle, and superior frontal gyri from the precentral gyrus. In the majority of brains, the precentral sulcus is divided into two parts: the inferior precentral sulcus and the superior precentral sulcus. However, the precentral sulcus may also be divided into three parts or form one continuous sulcus.

**Primary auditory cortex (PAC)** Located on the superior surface of the temporal lobe bilaterally in the so-called Heschl's gyrus, also called primary auditory cortex (BA 41). In addition three regions can be identified adjacent to Heschl's gyrus: a region located posteriorly (the planum temporale), a region anterolateral to Heschl's gyrus (the planum polare), and a region at the lateral convexity of the cortex in the superior temporal gyrus extending inferiorly to the superior temporal sulcus.

**Progressive non-fluent aphasia** Type of aphasia following cortical atrophy in prefrontal regions bilaterally and peri-sylvian regions in the left hemisphere, and causing both production difficulties and optimal understanding of grammatically complex sentences.

**Prosody** The set of speech properties describing language at suprasegmental level (syllable, prosodic words, intonational phrases). These properties include intonation, tone, stress, and rhythm.

**Receptorarchitecture** Description of the cortex of the regional and laminar distribution of neurotransmitter receptors in different cortical regions.

**Receptors** Protein molecule receiving chemical signals (neurotransmitters) from outside the cell.

**Scrambling** Common term for word orders that differ from the basic order. In the Chomskyan tradition, every language is assumed to have a basic word order fundamental to its sentence structure, so languages that exhibit a wide variety of different orders are said to have "scrambled" them from their "normal" word order.

**Segmental** Any segment of speech that can be identified in the speech stream.

**Semantics** The study of the meaning of individual words and the meaning of words clustered together into phrases and sentences.

**Speech errors** In language production, any misspeaking deviating from the target form of an utterance. Speech errors can be classified according to the linguistic unit being modified (phoneme, morpheme, word) and the level of representation (phonological, semantic).

**Subject-verb agreement** Grammatical matching in gender, number, and case via morphological inflection between the subject and the verb of a sentence.

**Superior longitudinal fasciculus (SLF)** Neural pathway connecting the inferior parietal lobe to the premotor and frontal cortex.

**Superior temporal gyrus (STG)** One of three gyri of the temporal lobe of the human brain, bounded by the lateral sulcus above and the superior temporal sulcus below. It includes BA 41 and 42 (primary auditory cortex) and Wernicke's area posterior (BA 22).

**Superior temporal sulcus (STS)** Sulcus separating the superior temporal gyrus from the middle temporal gyrus in the temporal cortex.

**Suprasegmental** The features of a sound or sequence of sounds beyond a single speech sound, such as stress or pitch.

**Syllable** Group of sounds consisting of an optional onset (typically, consonants), a nucleus (generally, vowel) and an optional coda.

**Syntax** The rules for arranging items (words, word parts, and phrases) into their possible permissible combinations in a language.

**Temporal lobe** One of the four cortical lobes of humans and other mammals, located beneath the Sylvian fissure on both cerebral hemispheres.

**Temporal pole** The most anterior tip of the temporal lobe, located anterior to the anterior limit of the superior temporal sulcus (BA 38).

**Temporo-parietal junction (TPJ)** Region located between the temporal and the parietal lobes, toward the posterior end of the Lateral Sulcus (BA 39).

**Thalamus** Subcortical midline symmetrical structure of two halves located between the cerebral cortex and the midbrain.

**Thematic relations** Semantic descriptions expressing the relation between the function denoted by a noun and the meaning of the action expressed by the verb.

**Thematic roles** The type of function that a noun plays with respect to the verb of a sentence. The two major thematic roles are agent (i.e., actor) and patient. Actor: The person or thing performing the act described by the verb of the sentence. Patient: The person or thing undergoing the act described by the verb of the sentence.

**Thematic role assignment** The assignment of a function to a noun by the verb of a sentence.

**Uncinate fasciculus (UF)** Ventral pathway connecting the frontal operculum to the anterior temporal cortex.

**Wernicke's aphasia** Form of aphasia identifying patients with spared linguistic production, but with severe comprehension impairment, generally due to the incapacity to grasp the meaning of spoken words and sentences.

**Wernicke's area** Region of the cerebral cortex in the temporal lobe of the brain, located in the posterior section of the superior temporal gyrus (BA 22p).

**White matter** Brain structure is mainly composed of fiber bundles that in mature state are surrounded by myelin, enabling the rapid propagation of an electrical signal.

**Working memory (WM)** Ability to actively hold information in the mind needed to do complex tasks such as reasoning, comprehension, and learning. Working memory is a theoretical concept central both to cognitive psychology and neuroscience.

**Word category** Grammatical class to which a word belongs (noun, verb, preposition, adjective, etc.).

**Word order** The way words are linearly organized in the sentences of a specific language.

**Word substitutions** Speech errors in which two words in a sentence are substituted with each other.

**World knowledge** Extra-linguistic knowledge driving conceptual-semantic interpretation.

## Methods

**Blood-oxygen-level dependent (BOLD)** A measure of neural activity changes, based on the effect of neuro-vascular coupling, in response to external stimulation or to intrinsic fluctuations at rest.

**Closure Positive Shift (CPS)** ERP component reflected in a centro-parietally distributed positive shift to be taken as a marker for processing intonational phrase boundary. CPS appears to correlate with prosodic boundary both when realized openly in the speech stream and when realized covertly in written sentences (sometimes indicated by a comma).

**Connectivity-based parcellation** A technique that permits the division of brain regions into distinct subregions, based on the similarity of the axonal connectivity profiles.

**Coordinate system** Three-dimensional coordinate system of the brain, used to map the location of brain structures along the  $x$ ,  $y$ , and  $z$  axes. The most common of such space systems are the Talairach space (created by the neurosurgeon Jean Talairach) and the MNI space (originated at the Montreal Neurological Institute).

**Diffusion tensor imaging (DTI)** A technique providing information on the internal fibrous structure based on the measure of water diffusion. Since water will diffuse more rapidly in the direction aligned with the internal structure, the principal direction of the diffusion tensor can be used to infer white matter connectivity in the brain. It can be used to identify the different fiber tracts in the human brain.

**Dynamic Causal Modeling (DCM)** A technique designed to investigate the influence between brain areas using time series from fMRI or EEG/MEG, by which various models are fit to the time series data and by using Bayesian model comparison to select the winning model.

**Early left anterior negativity (ELAN)** ERP component showing a negativity (N) deflection between 120 and 200 ms with a maximum over the left anterior scalp, which reflects initial structure building processes.

**Effective connectivity** A paradigm of analysis to determine the information flow between defined regions in the neural language network. The term *effective connectivity* refers to statistical-mathematical approaches to assess the direction of the data flow from one region to another in the neural network.

**Electroencephalography (EEG)** A technique that records at the scalp electrical activity as neural oscillations reflected in different frequency bands.

**Event-related Potentials (ERP)** Quantification of electrical activity in the cortex in response to a particular type of stimulus event with high temporal resolution in the order of milliseconds. Averages of electrocortical activity over events of similar types appear as waveforms in which so-called ERP components, which have either positive or negative polarity relative to baseline, a certain temporal latency in milliseconds after stimulus onset, and a characteristic but poorly resolved spatial distribution over the scalp. Both the polarity and the time point at which the maximum ERP component occurs, as well as partly its distribution, are the basis for the names of the different ERP components

**Fractional anisotropy (FA)** Scalar value describing the degree of anisotropy (the property of being directional dependent) of water diffusion in axonal bundles. FA is a measure often used in diffusion imaging to quantify the diffusion process. It is taken to reflect fiber density, axonal diameter, and myelination in white matter.

**Frequency bands** Delta wave: frequency range of brain activity between 1–4 Hz; theta wave: frequency range of brain activity between 4–8 Hz; alpha wave: frequency range of brain activity between 8–13 Hz; beta wave: frequency range of brain activity between 13–30 Hz; gamma wave: frequency range of brain activity between 30–100 Hz.

**Functional connectivity** A paradigm of analysis to assess brain dynamics. Methods that assess functional connectivity quantify the synchronicity of neuronal charge/discharge alternations in local and remote brain networks, using direct (EEG/MEG) and indirect (fMRI) data sources. The term *functional connectivity* refers to maps of synchronic brain oscillations of brain regions. These maps indicate which brain regions work together without providing information about the direction of the data flow between the regions.

**Functional magnetic resonance imaging (fMRI)** A technique to localize brain activity related to particular functions in the brain. It has replaced the partly invasive positron emission tomography by a non-invasive, state-of-the-art method for functional-anatomical reconstruction of the language network in the order of submillimeters. However, the temporal resolution of magnetic resonance imaging is limited, as it measures the hemodynamics of brain activity taking place in the order of seconds. Functional magnetic resonance imaging reveals precise information about the location and the magnitude of neural activity changes in response to

external stimulation but also about intrinsic fluctuations at rest, that is, in the absence of external stimulation. These neural activity changes are reflected in blood-oxygen-level dependent (BOLD) signal changes based on the effect of neurovascular coupling.

**Intracranial recordings** An invasive technique that records brain activity by placing electrodes directly on the exposed surface of the brain. It is also known as electrocorticography (ECoG).

**Left anterior negativity (LAN)** ERP component showing negativity (N) deflection between 300 and 500 ms with a maximum over the left anterior scalp, which reflects morphosyntactic processes.

**Magnetoencephalography (MEG)** A technique that records magnetic fields induced by electrocortical activity. Magnetoencephalography provides information about the amplitude, latency, and topography of language-related magnetic components with a temporal resolution comparable to ERPs but with an improved spatial resolution.

**Mismatch Negativity paradigm** Experimental paradigm, in which a rarely occurring (deviant) stimulus is presented within a sequence of standard stimuli. Deviant and standard stimuli usually differ in one crucial feature. In adults, the discrimination of these two stimulus types is reflected in a negative deflection with a peak latency of 100–200 ms following change onset. This negative deflection is labeled Mismatch Negativity (MMN).

**Near infrared spectroscopy (NIRS)** A technique that allows more flexible recording of the BOLD response, since the registration system is mounted directly on the participant's head, which means that the participant does not have to lie still, as is the case during fMRI. This advantage made it an important method for language acquisition research in infants and young children. However, the spatial resolution of NIRS is much lower than that of fMRI, whereas its temporal resolution is just as poor. For this reason this technique is mainly used with very young participants, who find it difficult to lie still for a longer period.

**N100** ERP component showing a negativity (N) deflection at around 100 ms after stimulus onset. It has been associated with acoustic processes.

**N400** ERP component showing a negativity (N) deflection around 400 milliseconds with a centro-parietal distribution, which reflects lexical-semantic processes.

**Oscillation** The rhythmic or repetitive firing of a population of neurons in the central nervous system. The number of firings per second represents the frequency of the oscillation. Depending on the number of firings, different frequency bands can be isolated.

**P600** ERP component showing a positivity after 600 ms with a centro-parietal distribution, which is associated with late syntactic integration.

**Resting-state functional magnetic resonance (rfMRI)** A technique that measures fMRI data when participants are “at rest,” that is to say, not involved in a task. This contrasts with task-related fMRI, for example from language studies, separating out the condition-related activation and only using the remaining data for analysis. Both approaches when combined with behavioral language data can provide valuable data concerning the functional connectivity between different brain regions in the language network.

**Structural magnetic resonance imaging (sMRI)** A technique that provides detailed morphometric and geometric features of the brain's gray and white matter such as its volume, density, thickness, and surface area.





This is a section of [doi:10.7551/mitpress/11173.001.0001](https://doi.org/10.7551/mitpress/11173.001.0001)

# Language in Our Brain

## The Origins of a Uniquely Human Capacity

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### Citation:

*Language in Our Brain: The Origins of a Uniquely Human Capacity*

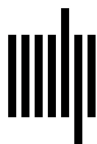
By: Angela D. Friederici

DOI: 10.7551/mitpress/11173.001.0001

ISBN (electronic): 9780262342964

Publisher: The MIT Press

Published: 2017



The MIT Press

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This book was set in Syntax LT Std and Times New Roman by Toppan Best-set Premedia Limited. Printed and bound in the United States of America.

The cover displays the white matter fiber tracts of the human brain for the left and the right hemispheres provided by Alfred Anwander, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany.

Library of Congress Cataloging-in-Publication Data

Names: Friederici, Angela D., author.

Title: Language in our brain : the origins of a uniquely human capacity / Angela D. Friederici ; foreword by Noam Chomsky.

Description: Cambridge, MA : The MIT Press, [2017] | Includes bibliographical references and index.

Identifiers: LCCN 2017014254 | ISBN 9780262036924 (hardcover : alk. paper)

Subjects: LCSH: Cognitive grammar. | Cognitive learning. | Cognitive science. | Brain--Localization of functions. | Brain--Language. | Brain--Physiology. | Brain--Locations of functionality. | Psycholinguistics.

Classification: LCC P165 .F64 2017 | DDC 401/.9--dc23 LC record available at <https://lccn.loc.gov/2017014254>

10 9 8 7 6 5 4 3 2 1