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BRAIN AND FOREIGN LANGUAGE LEARNING: A NEUROPEDAGOGICAL PERSPECTIVE

This study investigates the neurobiological correlates of foreign language (FL) learning/acquisition, specifically examining the interplay between the brain structure, its functions, and FL acquisition. In particular, the study posits that a comprehensive understanding of neurological foundations of language perception and procession is essential for optimizing language learning outcomes.

The primary objective of this article is to syntesize current research on the neurobiological underpinnings of FL acquisition, with a focus on the contributions of the cognitive and affective factors to FL acquisition.

Methods. This research employs a systematic review, theoretical positioning, analysis and synthesis of findings from neuroscience, psychology, and linguistics to elucidate the neural mechanisms underlying FL learning.

Results. The conducted analysis reveals that FL acquisition induces neuroplastic changes across diverse brain regions, including all cerebral lobes, and enhances white matter connectivity within language processing networks. While the left hemisphere demonstrates dominance in verbal processing, the right hemisphere plays a significant role in early language learning stages. The arcuate fasciculus, a critical neural tract connecting the Broca and the Wernicke areas, is essential for effective language processing. Furthermore, affective factors exert a profound influence on FL learning outcomes. Specifically, positive emotions, such as enjoyment and motivation, foster engagement, whereas negative emotions, such as anxiety, can impede learning. Emotional intelligence, facilitating self-regulation, positive social interactions, and enhanced communication skills, is crucial for successful FLL. Content- and process-related, as well as collaborative learning emotions also significantly modulate the language learning experience.

Scientific Novelty. This study contributes novel insights to FL Pedagogy by integrating neurological and affective perspectives on FL learning, exposing the interconnectedness of cognitive and affective processes in language acquisition.

Conclusions. FL learning is a complex activity arising from the dynamic interaction of neuro-anatomical structures and cognitive functions of the human brain. Successful FL acquisition is contingent upon multiple factors, including the brain's structural and functional adaptability, and the recognition of affective and neurological influences on learning. Therefore, pedagogical strategies should extend beyond purely cognitive language instruction to incorporate affective factors and cultivate supportive learning environments.

Implications for Further Research. The study reveals implications for further research in the field of FL Neuropedagogy. Particularly, future research is deemed to delve into identifying notable pedagogical interventions to enhance neural plasticity for effective FL learning with a special focus on the impact of diverse teaching methodologies on neural adaptation in this process.

Keywords: *brain anatomy; foreign language acquisition; white matter; gray matter; cerebral hemispheres; arcuate fasciculus; synaptic connectivity; neural pathways; neuroplasticity; cognitive functions; emotional regulation; positive learning environment.*

The axis around which this research unfolds is the relationship between the brain structure, its functions and foreign language (FL) learning/acquisition.

Introduction. Biologically considered, the body's most complex organ, *the brain,* is central to the governance of motor activity, cognition, and emotion (Quatieri, et al., 2020, p. 60). Functionally, it mediates thought processes, muscle coordination, and sensory information processing (Akram, Sfera, 2024, p. 1232), memory, touch, vision, breathing, temperature, hunger and every process that regulates the human body (Ferro, 2022, p. 1). This extensive functional breadth is fundamentally underpinned by a vast network comprised of approximately 86 billion neurons inter-connected through a vast synaptic archi-tecture (Akram, Sfera, 2024, p. 1232).

The major goal of this article is to reveal the complex structure and functions of the human brain and expose its role in FL acquisition.

Methods. Employing a systematic review, theoretical positioning, analysis and synthesis, this paper attempts to lay the foundation of the Neuropedagogical framework for FL instruction from a twofold perspective – cognitive and affective.

Results. In terms of anatomical structure, the brain is characterized by three fundamental *sections*: the cerebrum, the cerebellum, and the brainstem (Quatieri, et al., 2020, p. 60). *The cerebrum* is the largest section that occupies about two-thirds of the brain (Quatieri, et al., 2020, p. 60). It is located in the front section of the skull and accounts up to 85 percent of the brain's weight (Ferro, 2022, p. 1). *The limbic system,* anatomically situated within the brain's cerebrum, is recognized as a principal neural network underpinning emotional experience and processing. Its involvement extends to domains of memory and learning. Moreover, it assumes a critical role in the development of cognitive and decision-making processes (Wróbel, 2018, p. 44).

More specifically, the cerebrum is composed of two large halves, or *hemispheres* (Peate, 2017, p. 539), which are referred to as the left brain and the right brain (Quatieri, et al., 2020, p. 61). Each hemisphere presents as a soft, whitish anatomical structure, deeply fissured and folded into formations known as gyri and sulci. In terms of hemispheric specialization, the frontal lobe of the right brain mediates motor control of the contralateral (left) side of the body, and the left brain correspondingly mediates control of the right side (Peate, 2017, p. 539). Some of these grooves are short and others are very deep and long, dividing each hemisphere into distinct lobes. The cerebrum further exhibits a constricted frontal pole, situated anteriorly at the brow and a posterior region extending caudally towards the occiput. In their superior aspect, the two hemispheres are delineated by a prominent interhemispheric cleft, referred to as the longitudinal fissure (Shannon, 1962, p. 522).

To provide a visual foundation for understanding the general structure of the human brain, Figure 1 illustrates key anatomical features.

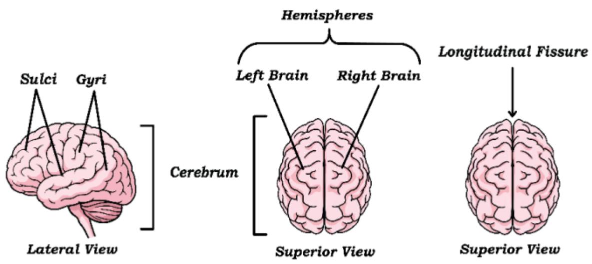

Figure 1. Key Anatomical Features of the Brain

Beyond the bilateral cerebral hemispheres, the structural composition of the cerebrum further includes *an outer layer* (Sari, Erbas, 2022, p. 134) (the topical layer (Quatieri, et al., 2020, p. 61)) and *an inner layer* (containing deeper structures, such as the hypothalamus, the olfactory bulbs, the basal ganglia etc. (Quatieri, et al., 2020, p. 61)), which are *gray and white matter*, respectively (Sari, Erbas, 2022, p. 134) that make up the central nervous system's interior (Massoud, 2022, p. 1).

The grey matter is also called the *cerebral cortex* (Sari, Erbas, 2022, p. 134). About 86 billion nerve cells (neurons) make up the grey matter in the human brain (Ferro, 2022, p. 1), that are embedded in *neuroglia* (Massoud, 2022, p. 1). Externally, the cerebral cortex is encased by the hemis-pheres and comprises several layers of neurons with diverse shapes (Wróbel, 2018, p. 39–40). Moreover, the cerebral architecture is organized in a multi-layered pattern that has regional varieties. Predominantly, it presents as a six-layered neocortex, further divisible into distinct areas or fields according to cytoarchitecture, that reveals variations in cell shape, size, and density, which are utili?-ed to delineate cortical areas (Forstmann, Keuken, Alkemade, 2015, p. 76). The mature adult cerebral cortex, chara-cterized by an exten-sively convoluted surface (Quatieri, et al., 2020, p. 62), exhibits a surface area approximating 1600–4000 cm² and a thickness ranging from 2–5 mm (Nunez, Cutillo, 1995; Srinivasan, 2023, p. 29). The inner layer of the hemispheres consists of white matter, which is constituted by associative, commissural, and projection nerve fibers (Wróbel, 2018, p. 39). The albescent appearance of white matter is attributable to *the myelin sheaths*, a fatty substance that enwrap a significant proportion of its nerve fibers hidden in neuroglia, their characteristic white appearance (Massoud, 2022, p. 1).

Scholarly research robustly and consistently supports the assertion that *the left cerebral hemisphere* is demonstrably dominant for manual dexterity and language functions in approximately 92 percent of individuals (Ferro, 2022, p. 1). Its functional specialization importantly encompasses verbal information processing, core linguistic competence, factual memorization (including specific dates, proper names, and accurate orthography), analytical and logical reasoning skills, clear speech articulation, comprehensive comprehension, arithmetic calculation, and precise writing abilities (Furman, et al., 2020, p. 355). Cognitive processing within the left hemisphere is hypothesized to be analytical and predominantly sequential, emphasizing the perception of discrete and successive informational units; whereas the effective systematization of complex data is critically and fundamentally reliant upon temporal duration (Wróbel, 2018, p. 40).

Conversely, *the right hemisphere* is implicated in the regulation of creative aptitude, spatial cognition, cultural understanding, and musical competence (Ferro, 2022, p. 1). The information is processed holistically, with all attributes of the stimulus being perceived compr-ehensively and simultaneously, regardless of temporal considerations (Wróbel, 2018, p. 40).

In their turn, each cerebral hemisphere (Wróbel, 2018, p. 39) is anatomically organized into lobes, distinguished by fissures and the longitudinal fissure. *The corpus callosum*, a substantial white matter structure mediating hemispheric integration, is located at the base of the longitudinal fissure that serves to connect the two hemispheres and mediate interhemispheric transfer of infor-mation (Wróbel, 2018, p. 40; Ferro, 2022, p. 1). The principal *lobes*, namely frontal, parietal, temporal, and occipital (Jawabri, Sharma, 2023, p. 1), are generally characterized by a notably high neuronal density and a highly convoluted structure and are primarily located within the extensive cerebral cortex (Sari, Erbas, 2022, p. 134).

To illustrate the brain's internal organ-ization, Figure 2 presents two cross-sectional views: a coronal section (top) detailing the arrangement of grey matter, white matter, sulci and gyri within the cerebral cortex, and a sagittal section (bottom) highlighting significant subcortical structures.

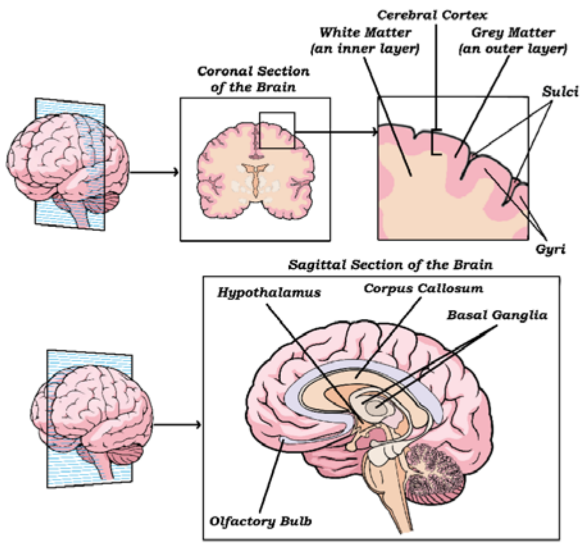

Figure 2. Brain Sections: Coronal and Sagittal Views

In particular, *the frontal lobe* is the higher cognitive center of the brain, responsible for important complex activities (Quatieri, et al., 2020, p. 62) and cognitive skills (Peate, 2017, p. 538), such as problem solving, abstract reasoning, moral judgment (Quatieri, et al., 2020, p. 62), emotional expression, language, sexual behavior (Peate, 2017, p. 538), memory and impulse control. It is located at the front of the brain behind the forehead (Javaid, Roheen, Afzal, 2020, p. 20296). Relative to other organisms, the frontal lobe in humans is characterized by its larger dimensions and advanced development (Peate, 2017, p. 539). It is often conce-ptualized as the "control panel" governing personality and communicative abilities. Furthermore, this lobe importantly subserves primary motor function, specifically, the fundamental ability to move muscles consciously, and also encompasses two key areas critically essential for speech. These key speech areas incorporate the specialized part commonly called *the Broca area*, which is directly associated with speech production and clear articulation (Peate, 2017, p. 538).

The parietal lobe is located near the center of the brain, behind the frontal lobe, in front of the occipital lobe and above the temporal lobe. Within the parietal lobe is situated the primary sensory area (Peate, 2017, p. 539), responsible for integrating sensory input across modalities (Ferro, 2022, p. 1). This includes somatosensory information, such as warmth, cold, pain, and touch (Peate, 2017, p. 539), alongside essential functions related to reading and understanding symbolic, abstract, and geometric language and concepts (Quatieri, et al., 2020, p. 62). Additionally, it is also particularly crucial for spatial orientation and navigation (Ferro, 2022, p. 1), as well as complex movement coordination (Quatieri, et al., 2020, p. 62).

The temporal lobe, situated inferior to the frontal and parietal lobes and ventral to each cerebral hemisphere, is responsible for the reception and interpretation of auditory stimuli originating from the ear (Peate, 2017, p. 539). It assumes a pivotal role in auditory perception, and contributes significantly to mnemonic processes (Quatieri, et al., 2020, p. 62), information organization, speech comprehension (Javaid, Roheen, Afzal, 2020, p. 20296), and the generation of memories and affective responses (Ferro, 2022, p. 1). It is thought to be associated with long-term memory, such as remembering autob-iographical information, dates and places. Crucially, the temporal lobe encompasses *the Wernicke area*, a significant region facilitating speech recognition and the interpretation of linguistic meaning (Peate, 2017, p. 539).

Figure 3 highlights the approximate loca-ions of the Broca area, primarily associated with speech production, and the Wernicke area, generally linked to language comprehension, both pivotal regions for language processing in the cerebral cortex.

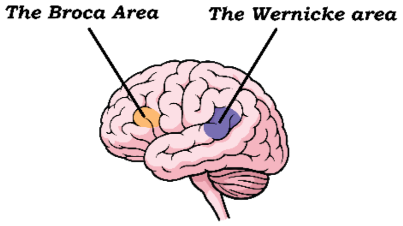

Figure 3. The Broca and the Wernicke Areas

The occipital lobe is located at the posterior cranium, positioned caudal to the parietal and temporal lobes. A key component of this lobe is the primary visual cortex, a cerebral region that receives retinal input. The occipital lobe contains different areas relating to visual communication. One area is where visual images of language are received (the visual receiving area) and another is where it is interpreted (visual association area). It is within this crucial lobe where the mind actively engages to interpret color perception and other fundamentally important aspects of vision (Peate, 2017, p. 539).

To provide a comprehensive under-standing of the brain's major subdivisions, Figure 4 illustrates the four principal lobes – frontal, parietal, temporal, and occipital – from lateral, superior, posterior, and inferior perspectives.

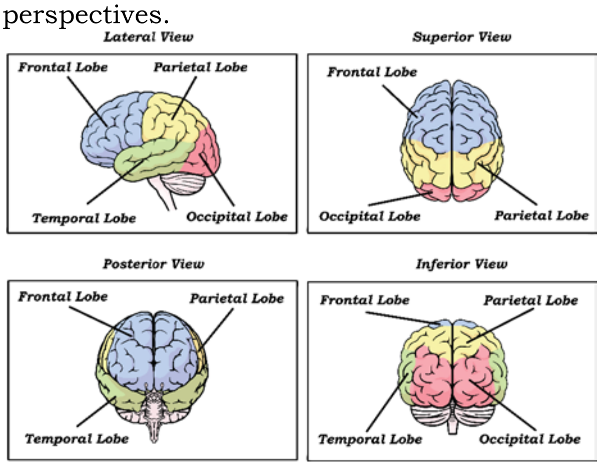

Figure 4. Anatomical Views of the Cerebral Lobes

The second major part of the brain is *the cerebellum*, or "little brain" (Forstmann, Keuken, Alkemade, 2015, p. 78); it sits on top and to the back of the brainstem (Srinivasan, 2023, p. 29) and is located below the occipital lobe and behind the brainstem (Forstmann, Keuken, Alkemade, 2015, p. 78). The cerebellum has long been associated with the fine control of muscle movements (Srinivasan, 2023, p. 29), from maintaining balance, coordination of half automatic movements to *cognitive functions* such as attention, language, working memory (Forstmann, Keuken, Alkemade, 2015, p. 78), and overall learning (Srinivasan, 2023, p. 29). Analogously to the cerebrum, the cerebellum is organized into two hemis-pheres, interconnected via the vermis.

The anatomical organization of the cerebellum from an inferior perspective is depicted in Figure 5.

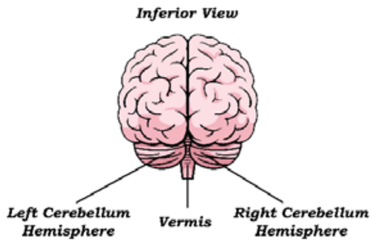

Figure 5. Inferior View of the Cerebellum

Each hemisphere consists of anterior, posterior, and flocculonodular lobes.

Figure 6 depicts the three main lobes of the cerebellum as visualized in a sagittal section of the human brain.

The cerebellum is connected to the brainstem through cerebellar peduncles, namely the superior, middle, and inferior peduncles. Although it represents only about 10% of total brain volume, the cerebellum houses a neuronal count exceeding that of the remainder of the brain (Forstmann, Keuken, Alkemade, 2015, p. 78).

The cerebellar peduncles which serve as crucial pathways connecting the cerebellum to the brainstem, are illustrated in Figure 7.

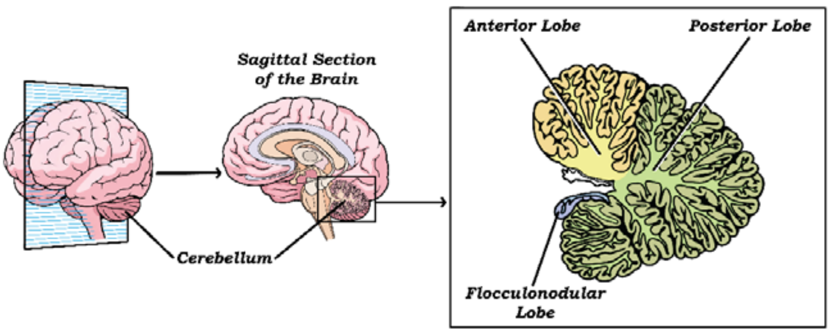

Figure 6. Lobes of the Cerebellum: Sagittal Section

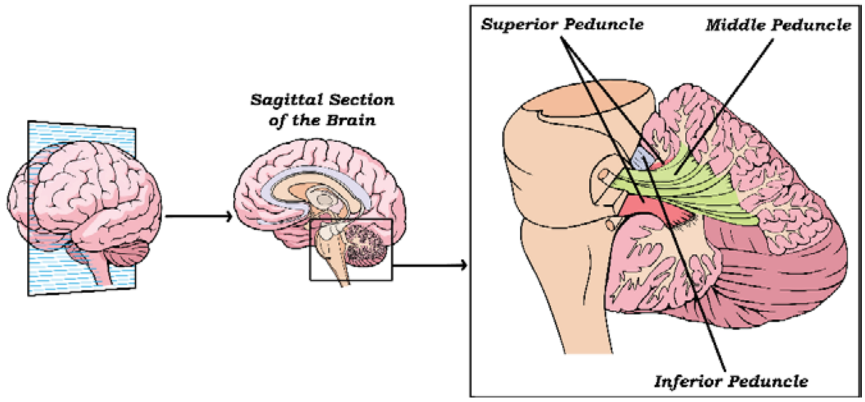

Figure 7. The Cerebellar Peduncles

The brainstem or the brain's stalk, is the brain's third major division (Srinivasan, 2023, p. 29), which is located at the basal region of the brain, linking it to the spinal cord and the diencephalon of the cerebrum (Massoud, 2022, p. 1). It effectively serves as the primary pathway for nerve fibers to seamlessly transmit signals (action poten-?ials) bidirectionally between the spinal cord and higher brain regions of the cerebrum (Srinivasan, 2023, p. 29). *The brainstem primary functions* involve crucial information relay between the brain and body, efficient delivery of key nerve signals to the face and head, and fundamental control of essential physiological processes (Ferro, 2022, p. 1).

These processes include cardiac regulation, respiration, sleep-wake cycles, blood pressure, certain reflexes, and bodily responses during the "fight-or-flight" reaction (Peate, 2017, p. 539).

Figure 8 illustrates the location of the brainstem within the human brain, presenting a sagittal section where this vital structure is clearly identified and highlighted.

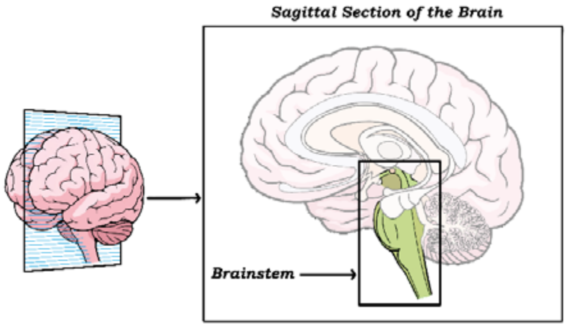

Figure 8. Sagittal View of the Brainstem

Furthermore, comprehension of the brain's cellular constitution is crucial for a refined understanding of its architecture and functional mechanisms. It is posited that the brain is constituted by billions of cells (Martin, Rubin, 1997, p. 33). The central nervous system is composed of numerous excitable nerve cells (Massoud, 2022, p. 1) heterogeneously shaped (Squire, et al., 2008, p. 4), known as *neurons*. Consequently, *neuroglia* is a specialized tissue that maintains these neurons and their processes. Additionally, *axons,* also named *nerve fibers*, are the long extensions of a neuron cell (Massoud, 2022, p. 1).

Neurons are categorized based on function (sensory, motor, interneuron), location (cortical, spinal), neurotransmitter (glutamatergic, cholinergic), and shape (pyramidal, granule, mitral), particularly regarding the number of cell body extensions. Most neurons have one (often branched) axon for signal transmission. Additionally, *dendrites* receive synaptic contacts. Dendrites are capable of complex branching and often bear *dendritic spines*. Consistent with active secretory cell function, neurons display large nuclei and copious smooth and rough endoplasmic reticulum and Golgi apparatus. Microtubules are abundant within neurons and their extensions, supporting axonal and dendritic structures while facilitating macromolecule and organelle transport (Squire, et al., 2008, p. 4). Beyond neurons, *glial cells*, also numbering in the billions, represent a substantial cellular component of the nervous system. These glial cells are also engaged in responses to injury and disease and are integral to the production and maintenance of myelin (Martin, Rubin, 1997, p. 33).

Figure 9 provides a detailed illustration of the primary cellular components of the nervous system, showcasing the key anatomical features of a neuron alongside the various types of supporting neuroglial cells.

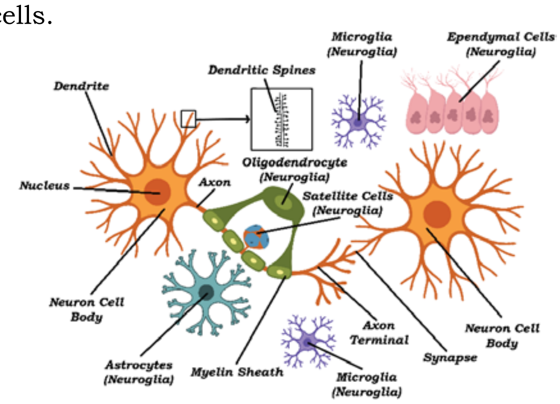

Figure 9. Neurons and Neuroglia

A specialized barrier, *the Blood-Brain Barrier*, ensheathes the inner lining of cerebral blood vessels. It is a critical component for the functional integrity of the nervous system and the brain itself. This "barrier" functions as a filter, selectively allowing passage of beneficial compounds while blocking detrimental substances. This endothelium, composed of specialized cells lining cerebral blood vessels, regulates the movement of chemical molecules into and out of the brain (Akram, Sfera, 2024, p. 4), which is important for transmitting signals between neurons.

To demonstrate the specialized nature of cerebral microvasculature, Figure 10 provides a visual progression from a sagittal section of the brain showing major blood vessels to an enlarged view of a brain capillary that contribute to the blood-brain barrier.

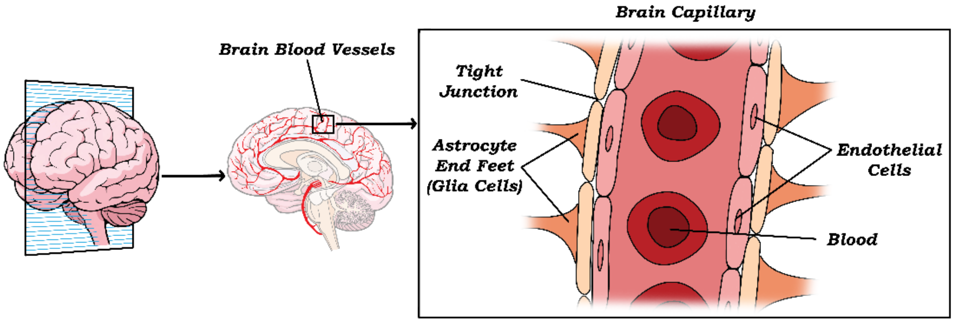

Figure 10. Cellular Components of the Blood-Brain Barrier in a Brain Capillary

The structure that mediates signal transmission between a neuron and another neuron or effector cell is *a synapse*. Synapses are fundamental to neuronal communication (Peate, 2017, p. 538). Trillions of synapses are estimated to connect the brain's billions of neurons to neurons throughout the body, including the spinal cord and peripheral nervous system (Massoud, 2022, p. 1). While the human brain encompasses diverse varieties of synapses, these structures are broadly classifiable into electrical and chemical synapses. Despite representing a numerical minority, *electrical synapses* are ubiquitously present throughout nervous systems and facilitate the direct, passive flux of electrical current between neurons (Purves, et al., 2004, p. 93). Conversely, *chemical synapses* employ neurotransmitters for signal transmission. This mechanism entails neurotransmitter synthesis, storage, release, receptor binding, and termination of activity (Squire, et al., 2008, p. 135).

Additionally, it is widely posited that alterations in the strength and number of the synaptic connections are the common fundamental basis of information storage within the cerebral cortices (Purves, et al., 2004, p. 753). Upon neurotransmitter binding, either directly or indirectly, ion channels in the postsynaptic membrane open or close. Typically, the resulting ionic fluxes modify the postsynaptic cell's membrane potential. That mediates information transfer across the synapse (Purves, et al., 2004, p. 116). At synapses, neurotransmitters are released to enable the transmission of impulses between neurons. Neuro-transmission is a physiologically vital process (Akram, Sfera, 2024, p. 1238).

Historically, scientists have identified in excess of 100 distinct neurotransmitters, which are categorized into *two primary classes*: small-molecule neurotransmitters and neuropeptides. The multiplicity of neurotransmitters enhances the physiological repertoire of synapses (Purves, et al., 2004, p. 98). Neurons can release multiple neurotransmitters (Purves, et al., 2004, p. 96), which can produce different types of responses on individual postsynaptic cells (Purves, et al., 2004, p. 98).

Furthermore, *the neural pathways*, which are constituted by white matter tracts, serve as connections between distinct brain regions. These tracts comprise neuronal axons that form synapses and provide neurotransmission in remote areas. Specifically, within the brainstem white matter tracts include axons that connects the cerebrum, cerebellum and spinal cord. Additionally, neural pathways are generally classifiable into distinct categories: brainstem tracts (afferent and efferent), projection tracts (cortico-subcortical), association tracts (intercortical), and commissural tracts (interhemispheric) (Forstmann, Keuken, Alkemade, 2015, p. 78). Notably, all cerebellar neural connections with other brain regions are mediated via *the cerebellar peduncles* (Vachha, Massoud, Huang, 2022, p. 471). These peduncles connect the cerebellum to the brainstem: the superior to the midbrain, the middle to the pons and the inferior to the medulla oblongata and spinal cord (Forstmann, Keuken, Alkemade, 2015, p. 78; Vachha, Massoud, Huang, 2022, p. 471).

The primary divisions of the brainstem are illustrated in a sagittal view of the brain in Figure 11.

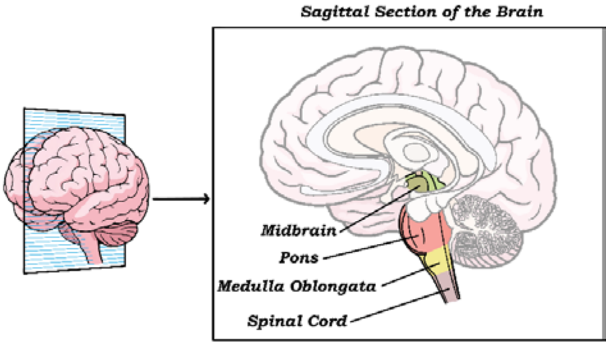

Figure 11. Anatomy of the Brainstem

Besides, white matter plays a crucial role in bodily information processing. It impacts cognitive abilities, including focus, learning, problem-solving, and balance during walking by connecting signal-sending and receiving regions. The brainstem consists of such major *white matter tracts* as arcuate fasciculus, superior longitudinal fasciculus, inferior fronto-occipital fasciculus, uncinate fasciculus, inferior longitudinal fasciculus, the frontal aslant tract, the cingulum, the fornix (Stanford Medicine, 2018).

Figure 12 illustrates the general anatomical locations and trajectories of several key white matter fasciculi and tracts within the human brain.

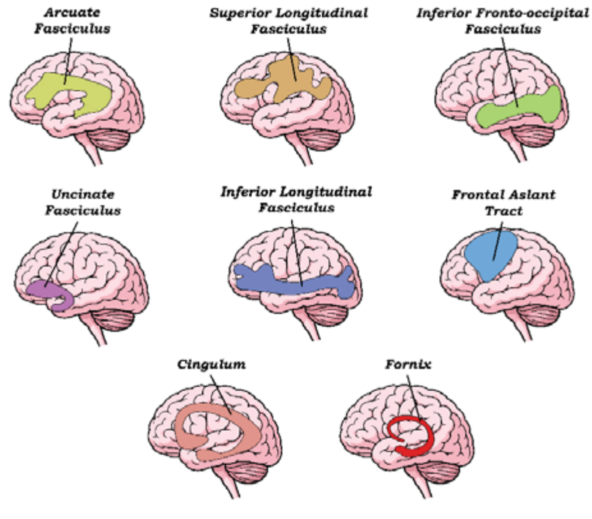

Figure 12. Key White Matter Fasciculi and Tracts of the Human Brain

The posterior superior temporal gyrus is connected to the frontal lobe via *the arcuate fasciculus*, a white matter tract. It links distinct brain regions through axon bundles that transmit signals, and facilitates neural communication. The arcuate fasciculus is sometimes referred to as the superior longitudinal fasciculus. Without it, gray matter structures would be functionally unable to communicate across brain regions (Kamiya, Reed, 2023). Basically, the arcuate fasciculus connects the Broca and the Wernicke areas, which are important for language functions (Eichert, et al., 2019, p. 107–108). Indeed, word learning performance strongly correlates with microstructural properties and functional connectivity strength between these areas. The human word learning ability depends on efficient communication between temporal and frontal areas, which is structurally supported by the arcuate fasciculus (López-Barroso, et al., 2013, p. 13168). This connection is crucial for language processing and production (Eichert, et al., 2019, p. 108; Klibi, 2020, p. 4).

The arcuate fasciculus also plays a significant role in reading skill development (Yeatman, et al., 2011, p. 3304), and reading acquisition enhances its structural properties (Schotten, et al., 2014, p. 989). Effective phoneme discernment is fundamental to reading ability and the integrity or volume of the left arcuate fasciculus demonstrates a correlation with phonological awareness skills (Saygin, et al., 2013, p. 13253). Phonological awareness tasks may enhance reading, strengthen arcuate fasciculus structure, and potentially facilitate new word learning (Klibi, 2020, p. 10). The anatomy of the posterior arcuate fasciculus correlates with vocabulary comprehension and reading performance (Robertsson, et al., 2016, p. 1). Auditory and motor areas also communicate via the arcuate fasciculus (López-Barroso, et al., 2013, p. 13168), potentially crucial for language development as a substrate for auditory-motor integration (López-Barroso, et al., 2013, p. 13171). Strengthening the arcuate fasciculus enhances connectivity between auditory and motor cortices, and consequently between temporal and frontal areas active during reading aloud (Klibi, 2020, p. 10).

Figure 13 illustrates the crucial anatomical connection between the Broca Area and the Wernicke Area, facilitated by the Arcuate Fasciculus, forming a key component of the brain's language network.

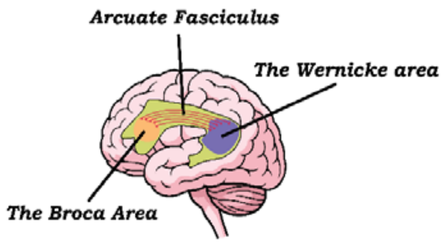

Figure 13. The Arcuate Fasciculus Connecting the Broca and the Wernicke Areas

For a better understanding, the ideas discussed above are synthesized in Figure 14.

Subsequently, the operations of the brain can be partitioned into various subsystems, study of which constitutes study of the brain functions. Some of the functions realized by the brain can be considered as *lower order processes*, such as regulation of breathing and temperature, motor coordination, basic emotional responses, etc., whereas *higher order processes* represent such cognitive functions as perception, attention, memory, language (Hatfield, 2000, p. 397), thinking, reasoning, self-awareness, and emotional intelligence (Patten, 2008, p. 65) and more. Since they are essential for FLA, they require cursory specification.

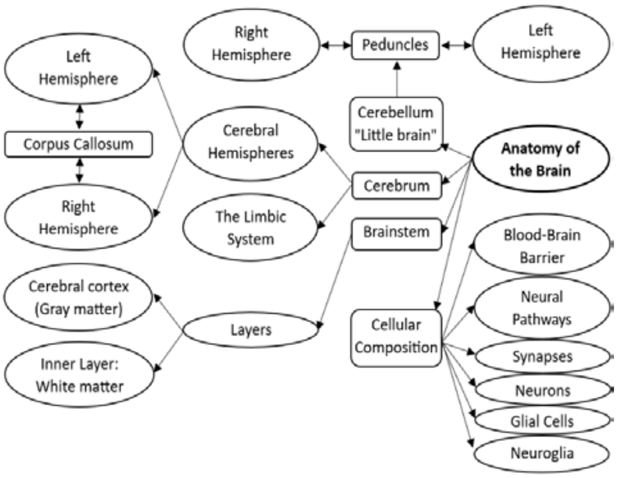

Figure 14. Anatomy of the Brain

The human body by itself is considered to be a totally sensory organ, however it is evidence-based that *the seven senses* being the checkpoints of the body are: sight, sound, smell, touch, taste, movement, and position in space (Naegele, 2015). Due to the cognitive process of categorization, the brain transforms sensory stimulation into information (Barrett, 2009, p. 326). More specifically, *categorization* is the process of sorting and organizing things, objects and experiences into group, class, or category. Respectively, being capable of categorizing things makes a human able to promptly respond to environmental stimuli (Creary, Airth, 2023). Accordingly, to categorize something means to make it meaningful.

One of the higher order cognitive functions of the brain is perception. *Perception* is the name for psychological processes by which *individuals register and evaluate information* detected from the internal or external environment with a focus on understanding what externally driven sensations refer to in the world (Barrett, 2009, p. 330). Perceptual organization in the brain occurs when the elements of a visual pattern are grouped into larger perceptual units or perceptual wholes (Kimchi, et al., 2005, p. 282) or when objects from a common class are grouped into a category representation (Hampton, Estes, Simmons, 2005, p. 1460; Quinn, Schyns, Goldstone, 2006, p. 119). Perceptual categorization is fundamental to the brain's ability to process voluminous amounts of sensory information and efficiently recognize objects including speech. In fact, perceptual categorization is the neural bridge between lower-level sensory and higher-level language processing (Bernstein, Liebenthal, 2014, p. 26–27).

Attention – another higher order cognitive function – is the main indicator of the efficiency of the human brain, since if attention is reduced, a person will hardly be able to concentrate (Esanova, Akabirova, Yakubova, 2023, p. 254). It is conceivable that a matrix comprising various sources of attention, operationally defined as any influence on neuronal firing rate, underlies attentional mechanisms (Barrett, 2009, p. 331). Generally, attentional mechanisms are posited to augment the signal-to-noise ratio of neurons which represents attended stimuli. Nevertheless, they may also modulate inter-areal communication. Consequently, the effect of attention on neural synchrony is important (Lindsay, 2020, p. 5). Attention is frequently classified into *four major types*: selective, divided, sustained, and executive attention (Mazarin, Skidmore, 2023).

Attention is closely related to *memory*. This bidirectional relationship implies that goals, episodic context, and stored knowledge shape attentional selection and vigilance. These reciprocal influences manifest across different memory modalities and their underlying neural systems. Firstly, the finite capacity of memory necessitates attentional gating for encoding. Secondly, the division of attention during encoding prevents shaping conscious memories, although the role of attention in this process is more complex. It is considered that attention and memory cannot operate without each other (Chun, Turk-Browne, 2007, p. 177). Memory, alongside sensations from the world, sensations from the body, and prior experience, forms three fundamental aspects of the whole mental life, continually available. Different combinations and weights of these three aspects produce myriads of mental events that constitute the mind. Depending on the focus of attention this stream of brain activity is parsed into discrete psychological moments that may be differently named: feeling, thinking, remembering, or even seeing (Barrett, 2009, p. 330).

The brain generates mental states and actions by integrating exteroceptive sensory stimulation (sensory stimuli available *by* and captured *from* the external world), somat-

?visceral stimulation (sensory signals from within the body), and prior experience (memory) (Barrett, 2009, p. 330). Through their synergistic operation, this neural circuitry may ascribe meaning to incoming sensory input based on prior experience, facilitating sensory prediction and response formulation (Barrett, 2009, p. 333). Cognition focuses on how prior experiences are reinstated. Remembering is called *memory*. When not consciously recalled, it is called *thinking*. Referring to the future, it is called *imagining*. This activity provides a sense of self through time. Cognition research examines how prior sensory stimulation is encoded, associatively recombined, or reinstated (Barrett, 2009, p. 331). Memory assumes a pivotal role in language learning and retention. It underpins the encoding and storage of linguistic information, which encompasses vocabulary, grammar, and syntactic structures. Through sustained repetition, memory mechanisms facilitate the comprehension and retention of these linguistic features (Shichida at Home, 2023).

Language acquisition and language learning abilities are significantly affected by specific characteristics of the neural activities of the left and right brain hemispheres, particularly in relation to individual psychological abilities. Specifically, like it has been mentioned above, *the left hemisphere of the brain* focuses on verbal information processing, language skills, memorization of factual information, analysis, logic, and recognition (Furman, et al., 2020, p. 355). Consequently, language functions are predominantly lateralized to the left hemisphere, with speech sound-meaning mappings in the left temporal cortex and motor commands for speech production in the left frontal cortex (Purves, et al., 2004, p. 637).

On the other hand, the *right hemisphere of the brain* is more focused on non-verbal information, processing information through images and symbols, imagination, artistic and musical abilities, a holistic view of understanding (Furman, et al., 2020, p. 355), and emotional speech content. Studies involving congenitally deaf individuals indicate that the neural substrates for sign language correspond to those for spoken and heard communication. This suggests that language regions are dedicated to symbolic representation and communication, rather than being exclusively limited to spoken or auditory language (Purves, et al., 2004, p. 637).

The most recognized language-related brain regions are the Broca area, situated in the left frontal lobe, and the Wernicke area, located in the left superior temporal lobe between the primary auditory cortex and angular gyrus (Hong, et al., 2017, p. 10). Functionally, the Broca area relates to language production, while the Wernicke area correlates with language comprehension. However, there exists a significant, equally important network of neural connections between these regions, contributing to overall language function (Klibi, 2020, p. 6).

It is worth mentioning that the French physician and anatomist, Pierre Paul Broca discovered the most crucial part when he identified a common region in the brain in two of his speech-impaired patients; this came to be known as *the Broca area***.** Located within the posterior inferior frontal gyrus of the dominant hemisphere, the Broca area, corresponding to Brodmann areas 44 (pars opercularis) and 45 (pars triangularis), is essential for language function (Keller, et al., 2009, p. 32). More recent research has included other areas of the frontal lobe along with the Broca area (Hagoort, 2014, p. 137; Stinnett, Reddy, Zabel, 2023).

The primary functions of the Broca area are both language production and comprehension (Stinnett, Reddy, Zabel, 2023). While the exact role in the production is still unclear, many believe that it directly impacts the motor movements to allow for speech (Flinker, et al., 2015, p. 2871). Despite its traditional association with speech production alone, the Broca area lesions are occasionally linked to impairments in language comprehension. Different regions of the Broca area specialize in various aspects of comprehension. The anterior portion helps with semantics, while the posterior is associated with phonology (Skipper, et al., 2007, p. 263). The Broca area is also necessary for language repetition, gesture production, sentence grammar and fluidity, and the interpretation of others' actions (Flinker, et al., 2015, p. 2871; Brown, Yuan, 2018, p. 1214; Stinnett, Reddy, Zabel, 2023).

On the other hand, Carl Wernicke, a German neurologist, first described *the Wernicke area* in 1874. This discovery highlighted it as one of two cortical regions crucial for speech processing. The Wernicke area is anatomically localized to Brodmann area 22, within the posterior aspect of the superior temporal gyrus in the dominant hemisphere (DeWitt, Rauschecker, 2013, p. 185). Given the left hemisphere dominance in most people, the Wernicke area is usually left-sided. This area encompasses the auditory cortex on the lateral sulcus (DeWitt, Rauschecker, 2013, p. 181; Chang, Raygor, & Berger, 2015, p. 251).

Because the Wernicke area is responsible for the comprehension of written and spoken language, damage to this area commonly results in a fluent but receptive aphasia.

Receptive aphasia impairs language comprehension, not expression. Wernicke aphasia presents with fluent but meaningless speech. Auditory incomprehension further characterizes Wernicke aphasia, which prevents the understanding of spoken language. Besides, patients with Wernicke aphasia are unaware of their comprehension deficits (Javed, et al., 2023).

Aphasia's clinical presentation varies in severity. Verbal output can range down to single-word sentences, reflecting a disso?iation between understanding and expressive ability – awareness of message without articulation. Repetition is typically impaired, and requires the Broca and the Wernicke areas, as well as arcuate fasciculus integration (Stinnett, Reddy, Zabel, 2023).

It is clear therefore that language is deeply rooted in the human brain and is genuinely affected by the principle of *neuroplasticity*. It may be beneficial for language learners to identify tasks with a potential of intensifying the neural synapses in language-related regions (Klibi, 2020, p. 6). In general, FL learning induces gray matter changes in frontal, parietal, and temporal lobes, particularly for vocabulary (Wei, et al., 2023, p. 2). Right prefrontal connections, increasing with FL learning, may support working memory for vocabulary. Furthermore, adult FL learners necessitate broader neural adaptation beyond typical language network, involving the right hemisphere early on (Wei, et al., 2023, p. 5).

Neurofunctional studies reveal that in contrast to high-proficiency FL learners, low-proficiency FL learners exhibit reduced brain activation overlap between first language (L1) and second language (L2) processing, and consequently, therefore recruit additional right hemisphere areas, potentially and tentatively supporting word retrieval. The lexical-semantic brain activation primarily depends on learner performance, whereas grammatical domain differences depend on the stage of FL acquisition (Wei, et al., 2023, p. 1).

Beyond the differences in brain activation and in the ability to process language, emotions are at the core of how learners view and react to internal and external stimuli, making them an integral part of a comprehensive understanding of FL learning and acquisition (Shao, et al., 2020, p. 2).

Emotions are crucial for successful FL acquisition. Emotions involve psychological perceptions interpreting internal bodily sensations. Emotion researchers study how sensory information and prior emotion concepts contextualize these sensations. This integration creates emotion-labeled mental states used by the brain for self and body regulation, directly or through action (Barrett, 2009, p. 331). Emotions can vary in type and intensity – from articulation thrill to critical FL interaction anxiety (Plonsky, Sudina, Teimouri, 2022, p. 346).

In particular, emotions such as enjoyment, love (Plonsky, Sudina, Teimouri, 2022, p. 347), anger, hope, pride and boredom, can each impact on students' actions and learning in a variety of ways. These emotions can be affected by classroom factors such as curriculum content, environment, or individual differences between students like genetic factors, general tendencies, and external factors as social interactions, home environment (Andrienko, Chumak, Genin, 2020, p. 67).

Specifically, in the Control-Value Theory (CVT), *achievement emotions* are viewed as feelings directly associated with outcomes or actions contributing to achievements (Pekrun, et al., 2007, p. 14). Within the framework of the CVT's taxonomy of achievement emotions, wherein enjoyment is classified as an activating positive affect, the construct of foreign language enjoyment is presented (Pekrun, et al., 2007, p. 15; MacIntyre, Gregersen, 2012, p. 208–209). Enjoyable FL learning experiences foster resource development and active engagement in learners (Jin, Zhang, 2019, p. 1027; Ning, 2022, p. 1099). Higher FL learning enjoyment fosters increased learner interaction with peers and instructors, which strengthens classroom interpersonal relationships (Simon, 1967, p. 30; Albert, E., Robert, 1977; Berscheid, 1987), which raises their enthusiasm for FL acquisition (Fredrickson, 2006, p. 88). The emotion of enjoyment can also influence students' FL proficiency by mediating their cognitive processes (Fredrickson, 2013, p. 815). FL learning enjoyment fosters the utilization of diverse learning strategies and cognitive expansion which greatly enhances learning efficacy (Ning, 2022, p. 1099).

Another emotion that causes enjoyment is *motivation* – a driving force behind persi?tence in FL learning as it helps achieve better learning results (Magnano, Craparo, Paolillo, 2016, p. 9; Arias, Soto-Carballo, Pino-Juste, 2022, p. 3). Motivation may be enhanced through encouragement and emotional support, which foster resilience and contribute to improved FL instruction outcomes (Romano, et al., 2020, p. 4774; Thao, et al., 2023, p. 2). Motivation has been persistently acknowledged as a pivotal constituent in the domain of FL acquisition (Magnano, Craparo, Paolillo, 2016, p. 10; Arias, Soto-Carballo, Pino-Juste, 2022, p. 2; Thao, et al., 2023, p. 6). Motivation prompts learners to surmount linguistic challenges. It intensifies active participation in FL self-study and native speaker interaction and directs learners to define clear FL learning objectives. Motivation is thus crucial for L1/L2 learning. It compels learners to commit time and effort to language profi-?iency for socio-economic advancement (Thao, et al., 2023, p. 6). The inclusion into the learning process of content-related emotions gives the growth of student interest and involvement in the discussions, their positive motivation and better learning student experiences (Andrienko, Chumak, Genin, 2020, p. 72).

In addition, *self-awareness* is also critical for FL learning, since it allows individuals to accurately discern their emotions profoundly influencing their communication (Killian, 2012, p. 503; Kanesan, Fauzan, 2019, p. 2; Thao, et al., 2023, p. 6). Complementing self-awareness is *self-confidence*, a quality that leverages personal strengths to encourage assertive and positive communication (Partido, Stafford, 2018, p. 974; Upadhyay, et al., 2020, p. 120). Learners with high self-confidence are more likely to engage in risk-taking activities and surmount challenges (Thao, et al., 2023, p. 6). Integral to this framework is *self-regulation*, which presides over an individual's communicative behavior and response to various emotional contexts (Laborde, et al., 2014, p. 44; Zhoc, Chung, King, 2018, p. 987; Thao, et al., 2023, p. 6).

Another significant emotional factor in FL learning is *language anxiety*. Anxiety is considered to have an impact on human cognitive activity (Lu, 2022, p. 697). Specifically, T. Scovel's (Scovel, 1978) review examined its role based on accumulated evidence (Plonsky, Sudina, Teimouri, 2022, p. 346). The concept *anxiety*, originating from psychology, refers to "an unpleasant state of mind that is characterized by individual perceived feelings like nervous, fear, and worry, and is activated by the autonomic nervousness system" (Spielberger, 1972, p. 482; MacIntyre, Gardner, 1991, p. 107; Yu, 2022, p. 2). It is related to FL acquisition as humans experience the feeling of tension and apprehension specifically associated with a L2 context (Yu, 2022, p. 2).

Language anxiety is believed to be essentially situation-specific: for instance, apprehension and fear about communication, negative social evaluation, poor test or academic performance, and a measurable individual variable that "interfere[s] with the acquisition, retention, and production of the new language" (MacIntyre, Gardner, 1991, p. 86). Thus, quantitative approaches are principally adopted by researchers to determine causality between variables and language proficiency or achievement. Consequently, various measurement instruments, informed by these conceptions have emerged, exemplified by scales (Imai, 2010, p. 279) like the French Class Anxiety Scale (Gardner, Smythe, 1975, p. 221) and Foreign Language Classroom Anxiety Scale (Horwitz, Horwitz, Cope, 1986, p. 129).

Extending the foregoing, some scholars have classified anxiety into facilitating and hindering anxiety based on its effects on FL learning. *Facilitative anxiety* motivates students to overcome learning challenges and increases effort, whereas *hindering anxiety* prompts task avoidance and negative psychological experiences like nervousness and apprehension, and diminished confidence (Lu, 2022, p. 697).

The context shift in FL learning is believed to predispose learners to anxiety. Consequently, FL classroom anxiety stems from the fear of evaluation and negative feedback. High anxiety hinders language output, causing information loss, poor performance, and negative psychological reactions (Lu, 2022, p. 697). For instance, such negative emotions as frustration (Yu, 2022, p. 2), boredom, shame, guilt (Plonsky, Sudina, Teimouri, 2022, p. 347) can decrease learners' motivation and interest in FL learning and even weaken the language learning competence (Yu, 2022, p. 2).

However, scholarly opinions as to the impacts of positive and negative emotions on FL learning differ (Andrienko, Chumak, Genin, 2020, p. 71). Some researchers prove that happiness has a positive effect on learning, memory and social behaviour (Hernik, Jaworska, 2018, p. 508). Conversely, "negative emotions are held to be detrimental to the pursuit of achievement goals, investment of effort, cognitive processes (such as attention and memory), motivation, self-regulation and self-efficacy" (Rowe, Fitness, 2018, p. 28; Andrienko, Chumak, Genin, 2020, p. 71). From the other perspective, negative emotions can intensify development, depending on how learners interpret and engage with these emotions during interactions (Imai, 2010, p. 288). Based on his research, M. Swain asserts that negative emotions and embarrassment can enhance students' FL learning, since students might be reluctant to abash themselves in front of their peers (Swain, 2013, p. 198; Ning, 2022, p. 1100). On balance, a negative emotional state can both facilitate and/or impair learning and memory, depending on its intensity and duration (Vogel, Schwabe, 2016, p. 1; Tyng, et al., 2017, p. 2; Andrienko, Chumak, Genin, 2020, p. 71).

More specifically, a mild and acute stress (Cahill, McGaugh, 1996, p. 238) can *expedite* learning and cognitive performance, while an excessive and chronic stress definitely impedes learning and is detrimental to memory performance (Tyng, et al., 2017, p. 3). Emotions are key to encoding emotionally charged input. Its components enhance attention to salient new information by improving detection, evaluation, and extraction for memorization (Tyng, et al., 2017, p. 4; Andrienko, Chumak, Genin, 2020, p. 71; Uno, et al., 1989, p. 1705). Respectively, emotion drives attention (Sylwester, 1995, p. 22) and engages meaning, predicting learning (Jensen, 2005, p. 93; Smilkstein, 2011). Thus, emotions affect cognitive performance (Goleman, 1995) and emotional engagement is linked to attention (Patten, 2008, p. 73; Sapolsky, 1992; Larrison, 2013, p. 46).

The conventional views of emotions hindering learning are shifting to emotion-cognition interdependence via neural mechanisms. This integration, termed "emotional thought", encompasses key cognitive processes: learning, memory, decision-making, and creativity (Immordino-Yang, Damasio, 2007, p. 3). Emotions regulate and often underlie most essentially cognitive activities, since "it is literally neurobiologically impossible to build memories, engage complex thoughts, or make meaningful decisions without emotions" (Immordino-Yang, 2015; 4, p. 71).

Hence, the ability to remain calm under pressure may help individuals in many ways to navigate language learning difficulties with resilience (Mohzan, Hassan, Halil, 2013, p. 306; Thao, et al., 2023, p. 3). Thereupon, *emotional openness* allows students to adapt and make progress in their language learning journey, with positivity fostering a conducive learning atmosphere (Mayer, Geher, 1996, p. 101; Iliane, et al., 2018, p. 370; Thao, et al., 2023, p. 3). *Awareness of privacy* also contributes to a respectful learning environment (Iqbal, et al., 2022), while a positive ambiance boosts motivation and enjoyment in language learning (Alipour, et al., 2021, p. 876; Thao, et al., 2023, p. 3). *Constructive reminders* promote positive communication and accountability (Epstein, 1998; Vela, 2003; Thao, et al., 2023, p. 3). *Impulse control* supports effective language learning by fostering thoughtful and intentional communication (Schutte, et al., 1998, p. 169; Fox, et al., 2011, p. 151; Thao, et al., 2023, p. 3). Lastly, *sensitivity development* (Goleman, Boyatzis, McKee, 2013; Killgore, et al., 2016, p. 24), self-reflection (Beauvais, Özbaş, Wheeler, 2019, p. 104), and discomfort expressions (McCloughen, Foster, 2017, p. 2713; López-Martínez, et al., 2019, p. 149) play significant parts in promoting empathy, understanding, and continuous improvement, thereby creating a supportive language learning environment (Thao, et al., 2023, p. 3). *A sense of belief* is essential, notably in impactful situations. Strong positive belief counteracts negative emotions like anxiety (Lu, 2022, p. 698). Moreover, *positive emotions* in FL instruction enhance student motivation and engagement, leading to better FL learning outcomes than *negative or neutral* emotional experiences (Shukurova, 2024, p. 862).

Furthermore, *content-related emotions* aroused by the content of education, can amplify students' learning experience, motivation, and oral communication skills (Andrienko, Chumak, Genin, 2020, p. 67). *Process-related emotions*, which are a part of the learning process and social environment, should be studied separately from content-related emotions (Andrienko, Chumak, Genin, 2020, p. 67).

Emotions associated with *collaborative learning*, which involves social interaction where learners work together to accomplish set objectives, are expected to emerge in the goal achievement process (Imai, 2010, p. 283). Some emotion researchers argue that whereas emotions are aroused in people's adaptation and survival, they are most likely, if not exclusively, aroused in *interpersonal relationships* (Simon, 1967; Albert, E., Robert, 1977; Berscheid, 1987) and in sharing emotion-laden experiences with others (Rime, Corsini, Herbette, 2002, p. 186; Imai, 2010, p. 280). Positive interactions with peers and educators, as well as future work associates, can also enrich the learning experience. All these constituents make up emotional intelligence of an individual.

Emotional intelligence (EI) defined as skills for appraising, expressing, and regulating emotion, is crucial for motivation, planning, and action (Patten, 2008, p. 65; Salovey, Mayer, 1990, p. 185). It also plays a key role in FL/L2 learning as it fosters better understanding of language nuances, enhances motivation, and improves communication skills, leading to a more effective learning experience (Thao, et al., 2023, p. 1). In other words, it is the ability to perceive and generate emotions aiming at assisting thought, to understand emotions and emotional knowledge, and to reflectively regulate emotions so as to promote emotional and intellectual growth (Mayer, Salovey, 1997, p. 5; Andrienko, Chumak, Genin, 2020, p. 67). EI arguably makes individuals "more fully human" (Goleman, 1995); and self-awareness as "the sense of an ongoing attention to one's internal states" is also pivotal (Patten, 2008, p. 65). EI improvement can bolster resilience, motivation, and capacity for positive interactions with peers, educators, and future associates (Kant, 2019, p. 441; Sekaryanti, et al., 2022, p. 150; Thao, et al., 2023, p. 2). Thus, English-majoring students who possess a higher level of EI are likely to experience better outcomes in their language learning journey (Thao, et al., 2023, p. 6).

Besides, it is thought that students with high EI can better regulate stress and emotions fostering positive peer relationships, self-awareness, resilience, and social skills, thus creating conducive learning environments (Kant, 2019, p. 441; Sekaryanti, et al., 2022, p. 151; Thao, et al., 2023, p. 1). EI also enables learners to empathize, comprehend cultural subtleties, and establish profound connections with native speakers of the target language (Pence, Vickery, 2012, p. 160; Estévez, Jiménez, Segura, 2019, p. 488; Smith, Heaven, Ciarrochi, 2008, p. 1323). In addition, EI fosters self-awareness and introspection permitting learners to track their progress, establish feasible objectives, and utilize effective learning strategies (Killian, 2012, p. 503; Laborde, et al., 2014, p. 44; Zhoc, Chung, King, 2018, p. 985; Kanesan, Fauzan, 2019, p. 2; Thao, et al., 2023, p. 4). Respectively, the teacher awareness of emotional factors impacting learning is pivotal in a FL course. Focusing on perceiving speaker emotions, correlating them with cognitive information, and generating emotional responses can enhance learner emotional and social competence (Andrienko, Chumak, Genin, 2020, p. 70).

However, it should be generally acknowledged that teachers often pay attention primarily and predominantly to the cognitive factors inherent in FL acquisition, frequently ignoring diverse emotional dimensions of the learning process (Lu, 2022, p. 696). Teachers can effectively shift student expectations, actively stimulate motivation, and strategically facilitate self-attribution in order to bolster self-confidence and successfully overcome anxiety (Lu, 2022, p. 698) by incorporating multiple language instruction strategies to evoke positive emotions, such as *humor, games, or storytelling*, potentially yielding greater FL proficiency gains over conventional methods (Shukurova, 2024, p. 862). Empathy and a positive, stress-free atmosphere can also aid enjoyable FL learning (Liu, 2017, p. 264).

To extend the foregoing, attractive environments stimulate the release of "happiness hormone", prompting learning (Salimpoor, et al., 2013, p. 216). Therefore, the essential harmony between a conducive educational environment and authentically positive emotions must be considered a compulsory element in the thoughtful organization of quality education specifically preparing a learner to readily accept feedback. In the course of shaping this mechanism, neurons produce the reducing neuromediator, which participates in shaping a sense of habit, when rewards are decreasingly making effect (Schultz, 2010, p. 1). Therefore, it is advisable to consider non-standard forms of assessment, which might expand the range of possible encouragement for the brain (Levy, Glimcher, 2011, p. 14705).

Noteworthy, the dopamine system responsively reacts to stimuli in two distinct ways: readily activating in response to positive news, and demonstrably reducing its activity after receiving negative one. The expected reward, however, does not alter dopamine. However, unexpected encouragement all of a sudden increases neuromediator production, enhancing pleasure (Schultz, 2010, p. 1). Thus, when organizing an educational process, the elements of non-conventional encouragements may stimulate motivation for learning by maintaining a high level of dopamine, boosting a desire to learn (Barabanova, Kazlauskiene, 2020, p. 114).

With positive emotions and attitudes, students may readily demonstrate enthusiasm, overall passion, and positivity about FL learning (Shukurova, 2024, p. 862). With that specific view in mind, teachers are supposed to model a robust growth mindset, notable resilience, and a clear willingness to take risks with language use in the classroom (Shukurova, 2024, p. 862). Evidence of the significant influence of emotion on human functioning and its remarkable ability to override the purely rational mind must strongly prompt educators to carefully consider what contemporary neuroscience and neuropsychology can definitively reveal about the most effective ways to better inform teaching and learning practices (Patten, 2008, p. 67).

The foregoing concepts are generalized and symbolized in Figure 15.

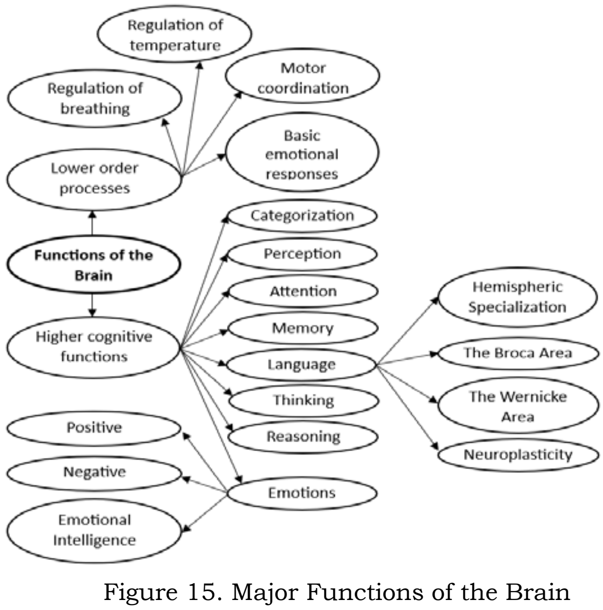

Figure 15. Major Functions of the Brain

To systematize the information presented in this study, Table 1 synthesizes the most critical neuroanatomical constituents conducive to FL learning/acquisition.

Table 1

Neuroanatomical Constituents of the Human Brain

Anatomy	Cerebrum	Cerebral Hemispheres	Left Hemisphere	Frontal Lobe	The Broca area	speech production
						speech articulation
					Higher cognitive center	problem-solving
						abstract reasoning
						moral judgment
						emotional expression
						sexual behavior
						memory
						impulse control
				Parietal Lobe	Spatial orientation and navigation	
					Sensory input	warmth
						pain
						touch
				Temporal Lobe	The Wernicke area	speech recognition
						speech meaning
					auditory input	
					long-term memory	
				Occipital Lobe	visual input	
			Connected by the corpus callosum			
			Separated by the longitudinal fissure			
			Right Hemisphere			
		The Limbic System	Thalamus			
			Hypothalamus			
			Olfactory bulb			
			Basal ganglia			
		Layers	Outer Layer: Cerebral cortex (Gray matter)			
			Inner Layer: White matter		associative nerve fibers	
					commissive nerve fibers	
					projective nerve fibers	
	Cerebellum "Little brain"	Cerebellum Hemispheres	Left Hemisphere	Anterior lobe		
				Posterior lobe		
				Flocculonodular lobe		
			Connected by the vermis			
			Right Hemisphere			
		Connected to the Brainstem via Peduncles	Superior cerebellar			
			Middle cerebellar			
			Inferior cerebellar			
	Brainstem	Functions	Relaying information between the brain and the body			
			Supplying nerve signals to the face and the head			
			Controlling heart rate, breathing, wake and sleep cycles, blood pressure			
	Cellular Composition	Blood-Brain Barrier				
		Neural Pathways	Brainstem tracts	Afferent	carry information to the brain	
				Efferent	carry information from the brain	
			White Matter Tracts	Arcuate fasciculus	Connects Broca's and Wernicke's areas	
				Superior longitudinal fasciculus		
				Associations	connect two cortical areas	
				Commissural	connect the brain's hemispheres	
				Projections	connect cortical and subcortical gray matter	
		Synapses	Electrical synapses			
			Chemical synapses		Neurotransmitters	Small-molecule
						Neuropeptides
		Neurons	Axons			
			Dendrites			
			Dendritic spines			
		Neuroglia				
		Glial Cells				

Conclusions. To summarize, the scientific corroborations seem to be strong that FL learning is a complex relationship between the brain structure and its functions. As evidenced by the systematic review of current neurolinguistic research, FL learning induces significant neuroplastic changes across multiple cerebral regions. Particularly pronounced effects are observed in the temporal, parietal and frontal lobes of the brain. These structural adaptations are complemented by enhanced white matter connectivity, specifically within the arcuate fasciculus, a neural tract fundamentally supporting efficient language processing.

The analysis of the brain's functions presented in the article demonstrates that the left hemisphere exhibits dominance in verbal processing and established linguistic competencies, whereas the right hemisphere assumes a crucial supportive role, especially during early and intermediate stages of FL acquisition. Overall, this hemispheric collaboration represents a neurological adaptation employed for adult language learning.

Besides, the article exposes the profound influence of affective factors on language learning outcomes. The neurobiological evidence confirms that emotions are not merely incidental to learning; they constitute integral components of cognitive processing. Positive emotional states, such as enjoyment and motivation, may significantly enhance neuroplasticity and cognitive engagement, while negative emotional states like anxiety can either facilitate or impede language acquisition depending on their intensity and duration. Moreover, emotional intelligence emerges as a critical mediator in this process that enables learners to regulate affective responses, develop resilience as well as establish meaningful communicative relationships.

Consequently, the theoretical and empirical insights derived from the conducted analysis yield important implications for FL Neuropedagogy. Effective FL teaching must transcend conventional cognitive-focused methodologies to incurporate the affective dimension that create learning environments to optimize neuroplasticity and emotional engagement. Such environments should strategically balance cognitive challenges with emotional support to provide structured opportunities for communication while mitigating debilitating anxiety.

To supplement the obtained insights, **future research** may focus on several prospective areas: developing targeted pedagogical interventions designed to enhance neural plasticity for FL learning; investigating the longitudinal effects of affective factors on language learning outcomes; examining differential impacts of various instructional methodologies on neural adaptation patterns; designing emotion-aware teaching strategies to capitalize on the mutualism of cognition and affect.

The functional constituents of the brain, summarized in Table 2, illustrate how cognitive and affective processes interact synergistically to ensure effective FL learning. In conclusion, FL acquisition is a multifaceted process characterized by neuroplastic changes across different brain regions that are influenced by various cognitive processes and emotional states. By conceptualizing FL acquisition through such neurobiological lenses, educators and researchers can develop more effective, evidence-based approaches that align with the brain's natural learning mechanisms that ultimately enhance FL learning outcomes.

Table 2

Functional Constituents of the Human Brain

Functions	Lower order processes	Regulation of breathing				
		Regulation of temperature				
		Motor coordination				
		Basic emotional responses				
		Other				
	Higher cognitive functions	Categorization	Sorting and organizing information			
		Perception	Understanding external sensations			
		Attention	Focus and concentration			
			Selective attention			
			Divided attention			
			Sustained attention			
			Executive attention			
		Memory	Encoding			
			Storing			
			Recalling			
		Language	Hemispheric Specialization	Left Hemisphere	Verbal information	
					Language skills	
					Logic	
				Right Hemisphere	Nonverbal information	
					Images	
					Artistic abilities	
			Brain Areas for Language	The Broca Area	Language production and comprehension	
					Left frontal lobe	
				The Wernicke Area	Spoken and written language comprehension	
					Superior temporal lobe	
			Neuroplasticity	Changes in gray matter		
				Connectivity changes		
		Thinking				
		Reasoning				
		Emotions	Positive	Enjoyment		
				Motivation		
				Love		
				Hope		
				Pride		
			Negative	Anxiety		
				Frustration		
				Boredom		
				Shame		
				Guilt		
				Stress	Mild and acute	Facilitates cognitive performance
					Excess and chronic	Impairs learning
						Detrimental to memory performance
			Emotional Intelligence	Self-awareness		
				Self-confidence		
				Self-regulation		
			Teacher's Role	Acknowledge emotional factors		
				Create a positive learning environment		

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МОЗОК ТА ОПАНУВАННЯ ІНОЗЕМНОЇ МОВИ: НЕЙРОПЕДАГОГІЧНІ ЗАСАДИ

Анотація. *У статті досліджується взаємозв'язок між структурою будови людського мозку, його когнітивними та афективними функціями та оволодінням іноземної мови (ІМ). Особливу увагу приділено ролі різних ділянок мозку в процесі опрацювання мовної інформації. Розуміння цих нейрофізіологічних підвалин є надзвичайно важливим для успішного опанування ІМ.*

Метою статті є аналіз та узагальнення сучасних досліджень нейробіологічних засад опанування ІМ, з особливим акцентом на роль структури мозку, когнітивних процесів та емоційних чинників оволодіння ІМ.

Методи. У статті використано теоретичний аналіз, синтез та узагальнення результатів наукових досліджень нейронауки, психології та лінгвістики з метою глибшого розуміння функціонування мозку для поліпшенням результативності вивчення ІМ.

Результати. У статті обґрунтовано особливості нейрофізіологічних механізмів, які є важливим підґрунтям оволодіння ІМ. Відповідно, цей процес спричиняє нейропластичні зміни в різних ділянках мозку, охоплюючи всі лобові частки, а також сприяє поліпшенню взаємозв'язків білої речовини в нейромережах. Ліва півкуля є домінантною для логічного та раціонального опрацювання вербальної інформації, в той час як права півкуля є промінантною під час креативного й емоційного процесування вхідної інформації. Крім того, з'ясовано, що фасцикулярний аркуатус ("вигнута пучка") з'єднує зони Брока і Верніке, що є ключовим чинником впливу на мовленнєву діяльність індивіда.

Особливу роль у статті відведено ролі емоціям в опануванні ІМ. Підкреслено, що значення емоцій у процесі навчання є беззаперечним, оскільки вони здійснюють значний вплив на навчальні результати. Зокрема, позитивні емоції, такі як задоволення та мотивація, сприяють активному залученню студентів до навчального процесу. Водночас, негативні емоції, такі як переживання та підвищена тривожність, можуть ускладнювати засвоєння мовного матеріалу. Тому емоційний інтелект відіграє ключову роль у формуванні здатності до саморегуляції, розвитку позитивних соціальних взаємодій, набутті та вдосконаленні комунікативних навичок і вмінь, що є надзвичайно важливими для ефективного вивчення ІМ. Крім того, емоції, пов'язані зі змістом навчання, його процесом, а також із взаємодією в груповому навчанні, можуть істотно впливати на загальний досвід вивчення ІМ.

Наукова новизна результатів дослідження. Дослідження пропонує нейропедагогічний погляд на нейрофізіологічні та емоційні аспекти вивчення ІМ, акцентуючи увагу на тісному взаємозв'язку когнітивних і афективних процесів.

Висновки. Опанування ІМ є складним явищем, зумовленим взаємодією нейрофізіологічних структур і когнітивних процесів людського мозку. Успішне оволодіння ІМ залежить від низки чинників, зокрема від структурної та функціональної пластичності мозку, а також від усвідомлення емоційних і нейрофізіологічних аспектів навчання. Тому педагогічні стратегії навчання мають виходити за межі суто когнітивного підходу, зважаючи також і на емоційні чинники та створюючи сприятливе освітнє середовище.

Перспективи подальших досліджень. Майбутні дослідження можуть бути зосередженими на визначенні конкретних педагогічних завдань, спрямованих на стимулювання нейропластичності для успішного вивчення ІМ. Важливим напрямом є також дослідження довготривалого впливу емоційних чинників на процес навчання ІМ та аналіз того, як різні методики викладання сприяють нейронній адаптації у цьому процесі. Крім того, необхідно розробити стратегії навчання, які враховують емоційний компонент, з метою підвищення ефективності результатів оволодіння ІМ.

Ключові слова: *анатомія мозку; оволодіння іноземною мовою; біла речовина; сіра речовина; ліва і права півкуля мозку; фасцикулярний аркуатус; синаптичні з'єднання; нейронні шляхи; нейропластичність; когнітивні функції; пам'ять; увага; сприйняття; мотивація; усвідомленість; емоційний інтелект; емоційна регуляція; сприятливе навчальне середовище.*

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