BIOSYNTHESIS OF NEUROTRANSMITTERS IN THE ACTIVATION OF SPEECH CENTERS

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Annotation: *This scientific study investigates the biosynthesis of neurotransmitters during the activation of speech centers and the molecular-biochemical mechanisms of their role in inter-neuronal information transmission. Special attention is given to the synthesis rate, release, receptor interactions, and synaptic involvement of major neurotransmitters such as dopamine, acetylcholine, GABA, and glutamate in the Broca and Wernicke areas. The functions of each neurotransmitter in the initiation, continuation, and semantic processing of speech are analyzed based on the dynamics of electrochemical signal transmission. Furthermore, the activity of enzymes regulating neurotransmitter biosynthesis — particularly tyrosine hydroxylase, choline acetyltransferase, and GABA transaminase — is explained in relation to factors such as age, stress, and physiological conditions. The research aims to provide a biochemical interpretation of the pathogenesis of speech disorders, including aphasia and logoneurosis, as well as to explore possibilities for neurobiochemical diagnostics and pharmacological rehabilitation. This work holds significant scientific relevance for the fields of neuropsychology, medical biochemistry, and neurological therapy.*

Keywords: *speech centers, neurotransmitters, dopamine, acetylcholine, GABA, glutamate, Broca's area, Wernicke's area, electrochemical signal transmission, synaptic cleft, biosynthetic enzymes, tyrosine hydroxylase, neurobiochemistry, aphasia, logoneurosis.*

The human brain contains highly specialized regions responsible for speech production and comprehension, primarily located in the left hemisphere for most individuals. Two of the most significant centers are Broca's area and Wernicke's area, each playing a distinct yet interdependent role in the neurobiological process of language [1]. Broca's area, situated in the posterior part of the left inferior frontal gyrus (Brodmann areas 44 and 45), is primarily associated with motor planning and articulation of speech. It regulates the coordination of muscles involved in phonation, such as the tongue, lips, and larynx, translating linguistic concepts into motor commands. Beyond articulation, recent research suggests Broca's role extends to syntax processing, grammatical structuring, and speech fluency. Damage to this region results in Broca's aphasia, characterized by slow, effortful, and grammatically simplified speech, although comprehension often remains largely intact [2]. Wernicke's area, located in the posterior section of the superior temporal gyrus (Brodmann area 22), is crucial for decoding and semantic understanding of language. It processes auditory input, enabling recognition of words, meaning extraction, and linguistic association. Individuals with damage to this area typically exhibit Wernicke's aphasia, producing fluent but nonsensical speech with severe impairment in comprehension and semantic accuracy [3]. Broca's and Wernicke's areas are interconnected via the arcuate fasciculus, a bundle of neural fibers enabling bidirectional communication between speech planning and comprehension centers. This dynamic network ensures real-time feedback during speech, allowing humans to monitor and self-correct verbal output. Thus, speech is not a localized but rather a distributed process relying on precise coordination of cortical and subcortical regions. Understanding the anatomical and functional synergy between these centers is fundamental to modern neurolinguistics, cognitive neuroscience, and clinical speech rehabilitation. Neurotransmitters play a fundamental role in the regulation of speech by enabling rapid communication between neurons within the brain's language network [4]. They act as chemical messengers that transmit signals across synaptic clefts, directly influencing neural excitation, inhibition, and synchronization required for the initiation, planning, and execution of speech. The coordinated activity of multiple neurotransmitter systems ensures the integration of cognitive, motor, emotional, and auditory processes essential for verbal communication. Neurotransmitters involved in speech can be broadly classified into excitatory, inhibitory, and modulatory categories. Glutamate is the primary excitatory neurotransmitter, responsible for enhancing neuronal activity and facilitating signal propagation, particularly in the Wernicke's area during language comprehension [5]. GABA (gamma-aminobutyric acid) functions as the main inhibitory neurotransmitter, maintaining speech rhythm and preventing excessive neuronal firing. Dopamine serves a modulatory function, supporting motivation, speech initiation, and reward-based verbal behavior, particularly in the basal ganglia and Broca's area. Acetylcholine, another key modulator, enhances attention and working memory, optimizing the processing of semantic and phonological information. These neurotransmitters work in a highly synchronized manner to regulate lexical retrieval, syntactic organization, phonological encoding, and articulation [6]. Dysregulation of any of these systems may result in speech disorders such as aphasia, stuttering, or logoneurosis. Dopamine is one of the most important neuromodulatory neurotransmitters in the human brain, playing a central role not only in motor control and reward processing but also in speech motivation, verbal initiative, linguistic creativity, and cognitive flexibility. Its biosynthesis begins in dopaminergic neurons, primarily within the substantia nigra pars compacta and ventral tegmental area (VTA), and follows a highly regulated biochemical pathway [7]. The process starts with the amino acid L-tyrosine, which is transported into the neuron and converted into L-DOPA by the rate-limiting enzyme tyrosine hydroxylase. This step requires tetrahydrobiopterin (BH4) as a cofactor. L-DOPA is then rapidly decarboxylated to dopamine by aromatic L-amino acid decarboxylase (AADC). Once synthesized, dopamine is stored in vesicles via the vesicular monoamine transporter (VMAT2) and released into the synaptic cleft upon neuronal activation [8]. In the context of speech, dopamine exerts its influence through the mesocorticolimbic and nigrostriatal pathways, modulating activity in brain regions such as the Broca's area, prefrontal cortex, basal ganglia, and cingulate cortex. Within these regions, dopamine acts primarily on D1-like (D1, D5) and D2-like (D2, D3, D4) receptors, which regulate synaptic plasticity, working memory, mental energy, and selection of motor or linguistic responses. Broca's area, responsible for speech planning and articulatory programming, relies heavily on dopaminergic input to initiate vocal output. A deficit in dopamine often results in hypophonia, verbal bradykinesia, or even mutism, as seen in Parkinson's disease, where nigrostriatal dopamine depletion severely restricts speech fluency and spontaneity. From a motivational perspective, dopamine is strongly associated with anticipatory reward and goal-directed behavior [9]. Speech is not merely a motor act but a motivationally driven communicative behavior. Dopamine enhances speech initiation, social engagement, and verbal assertiveness by amplifying the expected reward value of communication. This is why individuals with higher dopamine activity tend to display greater eloquence, charisma, and persuasive speech, whereas dopamine deficiency may result in social withdrawal, reduced verbal initiative, and monotone speech. Dopamine also plays a crucial role in verbal creativity, particularly in semantic expansion, divergent thinking, and metaphor generation. The prefrontal cortex, one of the major targets of mesocortical dopamine projections, governs associative thinking, idea integration, and flexible cognitive switching — the foundations of creativity. Elevated dopaminergic tone enhances lexical fluency, poetic improvisation, idea flow, and narrative imagination, which explains why many highly creative individuals show elevated dopamine sensitivity. Conversely, excessive dopamine may lead to disorganized speech or hyper-associative thought patterns, as observed in certain stages of schizophrenia. Furthermore, dopamine is deeply involved in self-monitoring and adaptive feedback during speech. Via its influence on the anterior cingulate cortex (ACC), dopamine enables real-time evaluation of linguistic choices, correction of errors, and adjustment of tone or vocabulary based on social context. This contributes to emotional expressiveness and conversational intelligence — features essential for effective oratory and public speaking. In conclusion, dopamine is not merely a biochemical agent of pleasure or movement — it is a driving force behind speech motivation, communicative initiative, and creative linguistic expression. Its balanced activity ensures that speech is not only produced but is purposeful, emotionally resonant, socially adaptive, and intellectually original [10].

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