

Neurobiology of Language Development: An Update

Vikas Kumar¹, Joydeep Das², Madhumita Bhattacharya³

¹Clinical Psychologist, Sri Sri University, Cuttack, Odisha.

²PhD. Scholar, Dept. of Clinical Psychology, Central Institute of Psychiatry, Kanke, Ranchi, Jharkhand.

³Assistant Professor, Dept. of Clinical Psychology, Central Institute of Psychiatry, Kanke, Ranchi, Jharkhand.

Corresponding Author: Vikas Kumar

ABSTRACT

Language is a human's ability to use an extremely rich set of symbols, plus rule for combining them to communicate information. The concept of the emerging field of neurobiology of language is that foremost study of the human brain, i.e., it is a subfield of neuroscience and particular in human neuroscience. By saying this, we mean to distinguish this from this related field psychology and linguistics, in which the emphases of investigation are certainly to understanding the brain but are not *ispo facto* focused on the understanding of neural mechanism. The human brain has multiple anatomical specializations that may be relevant to explaining our capacity for language. First, human brains have wider cortical minicolumns in both Broca's and Wernicke's areas compared with great apes. Second, human brains exhibit leftward asymmetries in Broca's area volume and in the width of planum temporal minicolumns that are not found in great apes. Third, the projections of the human arcuate fasciculus reach beyond Wernicke's area to a region of expanded association cortex in the middle and inferior temporal cortex that appears to be involved in processing word meaning.

Keywords: *Language Development, Neurobiology of Language, Broca's areas, Wernicke's areas, and psychiatric disorders.*

INTRODUCTION

What is language: Language is human's ability to use an extremely rich set of symbols, plus rule for combining them to communicate information. The human ability to use language far exceeds that any other organism on earth. As Bhartrihari, an Indian thinker observed 'Everything is cognized through language'. Indeed, language changes the world of experience in critical ways. Language is a unique power bestowed human to represent and share unbounded thoughts is critical to all human societies and has significantly played a pivotal role in the rise of human as species in the last million years from peripheral and a minor member of the sub-Saharan African ecological community to the dominant species on the earth today.

The language evolution of human being is thus one of the most interesting and significant evolutionary events that which has occurred in the last 5–10 million years, and indeed during the entire history of life on Earth. Given its central role in human behavior, and in human culture, it is unsurprising that the origin of language has been a topic of myth and speculation since before the beginning of history. From the dawn of modern evolutionary theory, of Darwin questions about the evolution of language have generated a rapidly growing scientific literature. Since the 1960s, an increasing number of scholars with backgrounds in genetics, anthropology, speech science linguistics, neuroscience, and evolutionary biology and devoted

themselves to understand various aspects of language evolution and language sciences.

Language from Apes to Humans:

Mutation of the FOXP2 gene need not have been the only factor in the switch. Until the emergence of *Homo sapiens*, the anatomical requirements for fully articulate speech were probably not complete. For example, the hypoglossal canal is much larger in humans than in great apes, suggesting that the hypoglossal nerve, which innervates the tongue, is also much larger in humans, perhaps reflecting the importance of tongued gestures in speech (Corballis, M. C., 2009). The evidence suggests that the size of the hypoglossal canal in early australopithecines, and perhaps in *Homo habilis*, was within the range of that in modern great apes, while that of the Neandertal and early *Homo sapiens* skulls was contained well within the modern human range. A further clue comes from the finding that the thoracic region of the spinal cord is relatively larger in humans than in nonhuman primates, probably because breathing during speech involves extra muscles of the thorax and abdomen (Corballis, 2009).

Animals models for language:

Human beings are unique in that they communicate through a system of language. Non-human animals have a system of communication but lack language. Thus, a nonhuman animal might be able to signal food or danger or make sexual advances to another animal but is not able to produce language akin to ours. However, many species share with us mechanisms for sound production. Zebra finches share many features with human beings pertaining to communication and sound production. Both have critical periods during development during which they must hear the sounds of their respective communication or language they are to produce, and both have specific temporal periods during which they must hear as well as practice these sounds (Helekar et. al., 2003).

Bierens de Haan, one of the earliest reviews of animal language parallels,

described six characteristics of language: The signals used are 1) vocal; 2) articulate, that is complex sounds are constructed from phonetic units; 3) have a conventional meaning (to the speaker and recipient); 4) the sounds are indicative (or represent objects or events in the environment); 5) they are produced with the intention of communicating to someone else; and 6) they are joined together to form new combinations. Bierens de Haan concluded that although animals meet the first five criteria: “real creative language, the faculty of combining words into phrases, is beyond the faculties of the animal mind. It is only the human mind that possesses the full faculty of combining words into phrases and phrases into conversations, of constantly creating new means to express and communicate feelings and thought (Snowdon, C. T., 1990).

The accomplishments of apes, monkeys, and birds do not approach those of a human child. However, it would be naive to expect an ape to match totally the linguistic competence of a human child. Bonobos, chimpanzees, and humans are distinct species, each of which has evolved its own communicative and cognitive adaptations. Among the defining characteristics of our own species are our linguistic and cognitive skills. If we were to find a Kanzi that imitated all human cognitive and linguistic abilities, we would probably be asking ourselves what sort of genetic disorder led him to be so short and hairy. The finding of some rudiments of language-like phenomena in natural communication, such as simple grammars, rudimentary symbolization, similar perceptual systems, along with the potential exhibited by some of the great apes, indicates that many of the components of linguistic ability have appeared at different times in evolution; but it is only with human beings that all of the components that define our linguistic abilities have come together in one species.

Prenatal language learning:

Prenatal language learning is an important aspect of human development. During the third trimester of gestation, a baby in the womb can hear the mother's voice clearly and makes use of this ability by learning the rhythms, tones, and sequences of whatever languages the mother speaks. These phonological patterns do not stand apart from context but instead, are experienced as integral parts of the mother's moods and activities. By building up neural patterns in the brain, the baby gets a head start on the phonological contours, grammars, and uses of the mother's languages (Childs, M. R., 1998).

Babies begin learning the language in the womb. An early discovery using acoustic spectrography revealed that the first cry of a 900-gram baby already contained intonations, rhythms, and other speech features that could be matched with the mother's voice spectrograph. This proved that by about 26 weeks of gestation, this baby had already acquired certain features of its mother tongue (Sherr, L., 1995).

Communication in the antenatal period:

- Unborn babies can recognize their mum's voice from 16 weeks and dad's from 20 weeks
- Unborn babies respond to singing and being read to from 24 weeks. They may move about to show that
- They are listening, babies develop preferences for music while in the womb and they can move in rhythm to music and their heart rate increases
- Babies are able to remember from the first trimester and babies communicate through movement all the way through pregnancy
- It is really important to communicate and stimulate a baby right from the start.

Structure of Language / The rule system of Language:

- **Phonology** is the sound system of the language, including the sounds that are used and how they may be combined (Stoel-Gammonand Menn, 2009).

Phonology provides a basis for constructing a large and expandable set of words out of two or three dozen phonemes. A *phoneme* is the basic unit of sound in a language; it is the smallest unit of sound that affects meaning.

- **Morphology** refers to the units of meaning involved in word formation. A *morpheme* is a minimal unit of meaning; it is a word or a part of a word that cannot be broken into smaller meaningful parts.
- **Syntax** involves the way words are combined to form acceptable phrases and sentences.
- **Semantics** refers to the meaning of words and sentences. Every word has a set of semantic features, which are required attributes related to meaning. Words have semantic restrictions on how they can be used in sentences.
- **Pragmatics** system of using appropriate conversation and knowledge of how to effectively use language in context.

Neurobiological origins of language:

Language has a long evolutionary history and is closely related to the brain, but what makes the human brain uniquely adapted to language is unclear. The regions of the brain that are involved in language in humans have similar analogues in apes and monkeys, and yet they do not use language. There may also be a genetic component; mutations in the FOXP2 gene in humans, the gene that prevents from constructing complete sentences (Arbib, M. A., 2005).

Neurobiology of language development:

The study of the relation of brain to language functioning is called neurolinguistics. Lenneberg (1967) hypothesized that the two hemispheres are equipotential for language until approximately two years of age, at which time Left Hemisphere dominance begins to develop and continues until puberty. This neural basis is stable across languages like Chinese, English, Hindi and many sign languages, i.e. the left-lateralized network of the brain is dominant (Mac Sweeney, et. al.,

2008). The newer studies suggest, for example, that there is not one unified language area in the brain where linguistic signals are processed. Different brain systems sub serves different aspects of language processing, and the language processing areas of the brain include many more regions than the classical Broca's and Wernicke's areas (Zatorre et. al., 1992). There is evidence that the language system is more flexible during development than later in life. For example, damage to classic left hemisphere language regions, especially the Broca's area (speech production) and Wernicke's area (speech comprehension) during development have much less pronounced effects on language abilities than damage to the same brain regions in adulthood (Bates, 1999). The gene responsible for language impairments is localized to the long arm of chromosome 7 in the 7q31 region and subsequently identified as the FOXP2 gene. The significant linkage has been reported to 13q21 (using various language phenotypes), 16q (using a phonologic memory phenotype), and 19q (again, with various phenotypes) (Feldman, 2007).

The Neurobiology of Language Processing:

Language processing subdivides functions such as reading, speaking, auditory comprehension, and writing into many different, semi-independent components, which are sometimes called modules or processors. These components can be further divided into variable numbers of highly specialized operations, such as those involved in mapping features of the acoustic signal onto phonemes or in constructing syntactic structures from words. Each operation accepts only particular types of representations as input and produces only specific types of representations as output (Temple, C., 2014).

The perisylvian cortex organized to support these functions has been the subject of much investigation. Two general classes of theories of the relationship of parts of the

perisylvian association cortex to components of the language processing system have been developed. One is based on holist or distributed views of neural function and one on localizationist principles. The basic tenet of holist/distributed theories is that linguistic representations are distributed widely and that language processing components rely on broad areas of the association cortex. Localizationist theories maintain that language processing components are localized in specific parts of the cortex (Ojemann, 1991).

Neurobiological adaptations for language:

Broca's and Wernicke's areas:

These regions are where language is located in the brain everything from speech to reading and writing. The language itself is based on symbols used to represent concepts in the world and this system appears to be housed in these areas. The language regions in human brains highly resemble similar regions in other primates, even though humans are the only species that use language.

The brain structures of chimpanzees are very similar to those of humans. Both contain Broca's and Wernicke's homologues that are involved in communication. Broca's area is largely used for *planning* and *producing vocalizations* in both chimpanzees and humans. Wernicke's area appears to be where *linguistic representations* and *symbols* are mapped to specific concepts. This functionality is present in both chimps and humans; the chimp Wernicke's area is much more similar to its human counterpart that is the Broca's area, suggesting that Wernicke's is more evolutionarily ancient than Broca's (Tagliatela, et. al., 2008).

Connections between Wernicke's and Broca's areas:

Beyond these human specializations within human Broca's and Wernicke's areas, there are differences between humans and non-human primates in the white-matter

connections that link these two regions. Anterograde and retrograde tracer techniques have been used to describe the connections of Wernicke's and Broca's areas homologues in macaque monkeys. Direct connections between the two regions have been identified, but the pathway is weak and its function unknown. In fact, the dominant frontal connection of Wernicke's homologue (area Tpt) is not within the process; it is displaced from nearby extrastriate visual cortex (Rilling, J. K. 2014). For example, visual motion area MT lies within the superior temporal sulcus (STS) in chimpanzees and rhesus macaques. However, in humans, it lies considerably posterior to STS, and STS instead appears to contain association cortex. The posterior limit of the temporal-lobe arcuate fasciculus terminations in the human brain coincides very closely with the anterior limit of visual motion area MT, consistent with a displacement of MT by the highly expanded arcuate pathway.

Motor neurons:

In order to speak, the breathing system must be voluntarily repurposed to produce vocal sounds, which allows the breathing mechanisms to be temporarily deactivated in prefer of song or speech production. The human vocal tract has evolved to be more suited to speaking, with a lower larynx, 90° turn in the windpipe, and large, round tongue. Motor neurons in birds and humans bypass the unconscious systems in the brainstem to give direct control of the larynx to the brain.

Gestural origin:

The earliest language was strictly vocal, reading and writing came later. Some new research (Arbib, M. A., Liebal, K., and Pika, S. 2008) suggests that the combination of gestures and vocalizations may have moderated to the development of more complicated language in protohumans. Chimps that produce attention-getting sounds show activation in areas of the brain that are highly similar to Broca's area in humans. Even hand and mouth movements with no vocalizations cause very similar

activation patterns in the Broca's area of both humans and monkeys. When monkeys view other monkeys gesturing, mirror neurons in the Broca's homologue activate. Groups of mirror neurons are specialized to respond only to one kind of viewed action, and it is currently believed that these may be an evolutionary origin to the neurons that are adapted for speech processing and production.

Other regions involved in language:

Cortical areas in the vicinity of Broca's and Wernicke's regions, other brain areas participate in language processing as well, for example, the motor cortex. Their role in speech function such as articulation has been demonstrated in electrophysiological studies of Foerster and the Vogts at the beginning of the twentieth century. The involvement of the premotor cortex in language processing has been elucidated by recent functional imaging techniques, but also intraoperative mapping in patients during neurosurgery. It has been hypothesized, that the premotor cortex plays a role in the planning but also in semantic processes and categorization.

The *dorsolateral prefrontal cortex*, frontal operculum, and the insula participate in different aspects of language processing, and so forth. A complete list of cortical areas involved in language would encompass areas of even more cortical regions. Subcortical nuclei, for example, the basal ganglia and the thalamus, participate in language processing as well. Finally, an important aspect of speech control is the neuromuscular control of tongue, lips, larynx, pharynx, the vocal cords and the muscles necessary for breath and so forth, which are controlled, in addition to cortical motor and somatosensory areas, by the cerebellum and cranial nerves and their nuclei (Binder et. al., 1997).

The *cerebellum* also has increased its rCBF in some activation studies involving both language and other cognitive functions. This may be a result of the role of this part of the brain in processes involved in timing and temporal ordering of events,

or in its being directly involved in language and other cognitive functions (Andreasen et al., 1998).

Development of language and plasticity:

Evidence for the plasticity of language in the human brain should not be surprising in light of all that has been learned in the last few decades about developmental plasticity of isocortex in other species (Bates, E., 1999).

Children with left or right focal brain injuries should yield the strongest evidence for plasticity because these children acquire their lesions before language development has gotten underway. At the same time, this is the period of development in which inherent regional specialization should be most apparent because the child has not yet had the time or occasion to develop alternative forms of brain organization (Bates et al., 1997).

Thus, a focal lesion within the left hemisphere may result in an initial delay in the first stages of linguistic development, in comparison with normal children and in children with early right hemisphere damage. Subsequently, however, the neural and behavioral plasticity of the developing brain may permit undamaged cerebral areas to solve the linguistic task, resulting in performance that is well within the normal range.

An enduring issue in the neurobiology of language concerns the origins of the specialized role of language areas within the left hemisphere and whether they arise from a specialization specifically for the processing of linguistic information, or whether they are linked to more general aspects of processing, such as the sensory and motor information important in speech perception and production (Gazzaniga, 2000).

Word processing:

Human interaction and thought crucially depend on words, which can take either auditory or visual form. During initial word processing stages, the acoustic signal or letter string are analyzed in their respective sensory modalities, followed by

mapping of letter symbols or phonemes onto a word lexicon and, finally, semantic access and integration. The fact that the same semantic knowledge can be accessed by symbols in two different modalities allows exploration of the brain substrate that underlies retrieval of supramodal meaning (Marinkovic et al., 2003).

Evidence from functional brain imaging suggests that language comprehension is subserved by modality-specific distributed networks (Cabeza and Nyberg, 2000). Spoken language, as well as complex non speech stimuli, evoke bilateral activation in the superior temporal cortices (Binder et al. 1997, and Zatorre et al. 1992). Leftward speech-related asymmetry has been observed in temporal and left inferior prefrontal cortex (Friederici et al. 2000, Price et al. 1997). Neuroimaging studies of reading, however, suggest a more clearly left lateralized activity in ventral temporal and inferior prefrontal regions (Gabrieli et al. 1998). The available neuroimaging evidence suggests that the prefrontal and temporal regions contribute to semantic and mnemonic processing of words presented in both spoken and written and may represent the neural basis of supramodal processing.

Hickok and Poeppel (2007) have suggested that language is represented by two processing streams:

(1) a bilaterally organized ventral stream, which is involved in mapping sound onto meaning and includes structures in the superior and middle portions of the temporal lobe; and

(2) a left dominant dorsal stream, which translates acoustic speech signals into motor representations of speech and includes the posterior frontal lobe and the dorsal-most aspect of the temporal lobe as well as the parietal operculum.

Focusing on the ventral stream, Hickok and Poeppel propose a model which suggests that cortical speech processing first involves the spectrotemporal analysis of the acoustic signal by auditory cortices in the dorsal superior temporal gyrus (STG) and

phonological level processing involves the middle to posterior portions of the superior temporal sulcus (STS). Subsequently, the system diverges in parallel into the ventral and dorsal streams. The ventral stream projects toward the posterior middle and inferior portions of the temporal lobes, a region believed to link phonological and semantic information. These authors argue that the more anterior regions of the middle and inferior portions of the middle temporal gyrus (MTG) are involved in a combinatorial network of speech processing.

Sentence processing:

Listening to connected speech is a task that humans perform effortlessly each day. This is surprising given the short time that the processing system has to deal with different types of information. Segmental phonemes and suprasegmental phonological information (prosody or pitch), as well as syntactic and semantic information, must be accessed and coordinated within milliseconds.

The functional neuroanatomy of speech perception prior to syntactic and semantic processes has been described in detail recently by Hickok and Poeppel (2007). Studies on the functional neuroanatomy of semantic processes at the sentence level are rare. Rather, most imaging studies of semantic processes are conducted at the word level. Such studies indicate that the left middle temporal gyrus (MTG), the angular gyrus and the left inferior frontal gyrus (IFG) support semantic processes. It is proposed that the frontal cortex is responsible for the strategic and executive aspects of semantic processing. Friederici (2002) studies investigating semantic processes at the sentence level report a variety of activation loci, including the left IFG (Brodmann area, BA 45/47), the right superior temporal gyrus (STG) and the left MTG, as well as the left posterior temporal region. Anterior and posterior temporal activation has been reported during sentence processing.

Discourse processing & pragmatics:

Language comprehension involves processes at multiple levels of analysis including lexical, syntactic, semantic, and pragmatic & discourse. Research on individuals with brain damage has led to the realization that both cerebral hemispheres are involved in language comprehension, albeit to varying degrees with regard to these different levels of linguistic analysis (Caplan, 1992). Discourse processes as they are an integral part of our daily communications, subsuming, but also going beyond, the processes engaged in recognizing words, syntactic parsing and comprehending isolated sentences (Gernsbacher, 1994).

A person with right hemisphere damage is often described as experiencing difficulties at the level of discourse. They tend not to elaborate on details of a discourse, producing fewer propositions and fewer complex propositions, although their basic knowledge of scripts or event schema appears to be intact. Right hemisphere damage patients are frequently unable to maintain the theme of a conversation, missing the main point altogether (Brownell and Martino, 1998). Right hemisphere damage patients have been found to have difficulties drawing certain types of inferences (Beeman, 1993) or revising them when new information comes up in a discourse (Bihrlé et al., 1986).

Conceptual semantic knowledge:

The semantic system necessarily involves impairment in comprehension and production of spoken and written words. Currently, the internal organization of the semantic system has been a subject of much debate; a widely accepted opinion is that meaning is represented as a set of semantic features and that the semantic information associated with an object can be accessed from both pictures and words. This has an important consequence for rehabilitation since to address the semantic system language is not required. Pictures, compared to words, have a privileged access to the semantic system because they represent directly some of the semantic features of the

corresponding concept whereas the relationship between a word and its meaning is arbitrary.

The way in which we interact with the world is determined by our network of accumulated knowledge concerning the objects, animals, and people that comprise it. The organization of this conceptual database, typically termed semantic memory, remains a much-debated issue. Neuropsychological studies of brain-damaged individuals with disrupted semantic memory, and more recently, functional imaging investigations in healthy control subjects, have been critical in shaping current theories regarding the cognitive and neural architecture of this system (Thompson et. al., 2004).

The neural basis of general semantic memory has been extensively investigated, and it is generally accepted that regions within the left temporal lobe are critically involved in the representation of knowledge for objects and animals (Wiggs et. al., 1999). The literature related to personal knowledge, however, reveals a major discrepancy between brain regions implicated by neuropsychological case reports and regions suggested by functional imaging studies. The majority of cases who have presented with impairments in person-specific semantics have had right temporal lobe damage.

A person with semantic dementia, a neurodegenerative condition which affects anterior and infero-lateral regions of the temporal lobe, provide a unique opportunity to investigate the psychological and neural basis of conceptual knowledge. Despite a profound loss of semantic knowledge with anomia and impaired comprehension, many other cognitive processes including phonological and syntactic aspects of language, working memory, non-verbal problem solving, visuospatial and frontal executive function are preserved, at least in the early stages of the disease.

Memory for language:

Working memory according to Baddeley (1986) is a multicomponent,

capacity limited system that comprises a controlling *central executive* and that includes an articulatory loop system. The central executive, the component that is not well understood, is thought to regulate information flow within working memory, retrieval of information from other memory systems, and the processing and storage of information. The articulatory loop, the better-understood component, includes a capacity limited phonological short-term store and an articulatory control process (verbal rehearsal) that acts to refresh and maintain speech material in the store for a brief period. The articulatory loop's function is to store verbal input temporarily, especially novel phonological input, while other cognitive tasks such as auditory comprehension take place. The ability to temporarily store novel material also allows the listener the opportunity to create long-term phonological representations of that material (Baddeley et. al., 1998), this view of working memory will hereafter be referred to as phonological working memory (PWM).

Universal grammar:

The language bioprogram hypothesis proposes that humans have an innate, cognitive grammatical structure allowing them to develop and understand language. According to this theory, this system is embedded in human genetics and underpins the basic grammar of all languages. Some evidence suggests that at least some of our linguistic capacities may be genetically controlled. Mutations in the FOXP2 gene prevent people from combining words and phrases into sentences. However, these genes are present in the heart, lungs, and brain, and their role is not entirely clear (Locke, J. L., and Bogin, B. 2006).

Brain areas associated with language during different stages of Development:

In most of the adults, the left hemisphere of the brain is dominant for language that is language function is lateralized. When it comes to language, the left hemisphere is primarily characterized by a capacity to analyze and sequence

linguistic information, while the right hemisphere is known for its holistic perception. Right-hemispheric damage often results in problems with social communication, also referred to as pragmatics. Locke argued, in his theory of language development, that the right hemisphere sub-serves language development during the first two phases, when the child is oriented towards interaction with the caregiver and the collecting of whole utterances (Locke, 1997). The left hemisphere gradually takes command, as the child starts to analyze the different elements of language and the rules for their combinations. In this way, language lateralization develops. The fMRI studies suggest that early language processing is predominantly bilateral (Dick et. al., 2008). The occurrence of lateralization is taken about one year earlier in girls than in boys, which corresponds with the earlier onset of puberty in girls. In children with brain damage, cognitive functions can be shifted to other brain regions, as for language, to the non-dominant and most often the right hemisphere. The possibility of brain repair, called plasticity, is more likely to occur before lateralization is completed (Carlsson, 1994).

The areas of the brain mainly involved in language processing for receptive language are Wernicke's area located in the posterior part of the temporal lobe and adjoining parts of the parietal lobe, adjacent to the auditory cortex, and for expressive language are Broca's area located in the lower posterior part of the frontal lobe. The structures those which are integrated into a network and form a language implementary system. In childhood, these areas gradually increase in thickness, corresponding to increased grey matter (Dick et. al., 2008). This results in an asymmetry between the hemispheres, where the left hemisphere is larger than the right, particularly in the area of the planum temporal. Reversed or absent asymmetry has been seen in studies of children with

language disorder (Dick et. al., 2008). The area of Rolando, located in the precentral gyrus at the Rolandic fissure, which is the primary motor area involved in the motor control of the speech act, while the secondary motor area for initiating speech motor activity adjacent to it overlaps partly with Broca's area. The phonological encoding is considered to be localized in the perisylvian region, near the Sylvian fissure, of the dominant hemisphere, while articulatory retrieval is located in Broca's area (Baddeley et. al., 1998). Hickok and Poeppel proposed a dual-stream model of speech processing involving auditory fields of the superior temporal gyrus bilaterally (Hickok and Poeppel, 2007). A ventral stream processes speech signals for comprehension projects towards the inferior posterior temporal cortex and is largely bilateral.

The dorsal stream maps sound onto articulatory-based representations involves a region in the posterior Sylvian fissure at the parietal-temporal boundary and ultimately projects to the frontal regions. It is strongly left-hemisphere dominant. A memory network within the limbic system, including the hippocampus, interacts with speech and language, as the left hippocampus is particularly important for memory for language. Moreover, associative areas within several regions in the temporal, frontal and parietal lobes interact with the main language system (Mesulam, 1990). The cerebellum is associated primarily with the balance and coordination of movements, but it has lately also been associated with language functions, particularly with the modulation of linguistic and other cognitive abilities and with motor speech planning.

Cerebral asymmetry of language: The language function shows functional laterality towards the left side of the brain. This function of language largely depends on the posterior area of superior temporal gyrus. Damage to this area is associated with a defect in comprehension of spoken language. It is considered that the specific area is responsible for language function

and it is named as Wernicke's area. Split-brain patients were capable of naming objects when presented to the left hemisphere but failed to do the same task when presented to the right hemisphere, proving a major left hemisphere involvement in language function.

Neurobiology of language development in different disorders:

Aphasia: Primary progressive aphasia (PPA), normally resulting from a neurodegenerative disease such as frontotemporal dementia or Pick Complex or Alzheimer's disease and it is heterogeneous clinical condition indicating by a progressive loss of specific language functions with giving initial caution of other cognitive domains.

Neuroimaging in aphasia: Neuro-imaging studies reveal that majority of PPA patients represent with structural and metabolic changes limited to their dominant language hemisphere, especially in the area of the left Sylvian fissure (Caselli and Jack 1992; Gorno-Tempini et. al. 2004, 2008; Mesulam 2003; Mesulam et. al., 2008). The specific, abnormalities in the left posterior frontoinsula region, i.e. inferior frontal gyrus (Broca area), insula, premotor and supplementary motor areas have been usually detected in patients with apraxia of speech and agrammatism (Hu et al. 2010; Nestor et al. 2003; 2008; Rohrer et al. 2008; Whitwell et al. 2010). Nonetheless, some individuals with this variant have been shown to have more generalized atrophy (Cappa et. al., 1996), and there is a subset of cases with unremarkable imaging (Mesulam et. al. 2008).

Dementia:

Dementia is caused when the brain is damaged by diseases, such as a series of strokes or Alzheimer's disease. The disease of Alzheimer's is the most common cause of dementia but not all dementia is due to Alzheimer's. The specific symptoms that someone with dementia experiences will depend on the specific location of the brain which is damaged and the disease that is causing dementia.

Alzheimer's disease: The left hemispheric damage is linked to problems with semantic memory and language, so someone may struggle to find the right word for something. Recent studies of persons with neurological impairment implicate a right hemisphere-subcortical circuit in the production of formulaic expressions (Van Lancker Sidtis, 2012). In AD clinical observations point strongly to preserved production of formulaic expressions which, when unrecognized, may mask veridical cognitive and language deficiencies.

Autism: Autism Spectrum Disorder marked abnormalities involve in the acquisition and pragmatic language skills among 25-50% of individuals with the diagnosis (Rapin and Dunn, 2003) and rest of the 50-75% have a failure to develop language skills at any level. As the severity of the disorder varies, language abilities in children with ASD range anywhere from nearly normal to profoundly impaired. Individuals of Nonverbal with ASD are a distinct minority in research reports, as because an understanding of communicative impairments is hoped to lead to an understanding of failed communicative skills.

Brain imaging studies of language in ASD:

Several studies have been done to investigate language processing in ASD using functional brain imaging. In one study of fMRI of adults with ASD, an abnormal language-related responses found in Broca's area (left inferior prefrontal cortex, BA45) and left middle temporal gyrus (BA21) during "deep" (semantic) vs. "shallow" (perceptual) processing of visually presented words (Harris, et. al., 2006). The subjects of ASD also showed diminished activation to concrete versus abstract words. A consistent Data with the possibility that participants with ASD were performing more semantic and phonological processing during perceptual tasks, and were thus less able to suppress this processing. In a related semantic category task, a small sample of adults with autism was compared to

matched controls on the ability to categorize a set of words as tools, colors, or feelings (Gaffrey, M. S., et. al., 2007). The group of autism had less activation of left inferior frontal gyrus (Broca's area) than controls, but more activation in visual areas (extrastriate visual cortex bilaterally), suggesting an important role of perceptual components (possibly visual imagery) during semantic decision. In language-related activity in Lateralization (which hemisphere of the brain) of language functioning in ASD has been shown to be aberrant in multiple studies.

Schizophrenia: In Schizophrenia deficit in verbal functioning showing various abnormalities in aspects of verbal production and an extensive literature exist, comprehension and cerebral lateralization for language (DeLisi L. E., 2001). Some epidemiological and clinical reports indicate that language abnormality in people with schizophrenia may predate the illness and have their origins in early brain development, as evidenced by noted delays in language acquisition and reading abilities (DeLisi L. E., et. al., 1991., Henriksson KM, McNeil TF., 2004).

Functional studies of language processing in Schizophrenia:

Several fMRI studies using language paradigms also show abnormal processing on verbal fluency tasks and loss of left hemisphere lateralization in the temporal and frontal lobes of patients with chronic schizophrenia (Sommer I.E.C., Ramsey NE, Kahn RS., 2001; Kubicki M, McCarley RW, and Nestor PG, et. al., 2003).

Recent fMRI studies provoke activation with various language paradigms in patients who already have the diagnosis of schizophrenia and provide evidence for disturbances in the representation and processing of meaning of words, text, discourse and verbal self-monitoring (Boksman K, et. al., 2005; Weiss E.M, et. al., 2006; Yurgelun-Todd D. A., et. al., 1996; Fu C. H., et. al., 2006; Kircher, et. al. 2002) showed that the number of complex sentences produced was correlated

with activation in the right posterior middle temporal lobe (left Brodmann's area 22) and left superior frontal gyrus (left Brodmann's area 10) in controls but not in people with schizophrenia and postulated that this might contribute to their simpler speech patterns.

CONCLUSION

The evolution of human language is suggested that "it the hardest problem in science" (Christiansen and Kirby, 2003) and some of the skeptics have credibly concluded that scientists might spend their time more constructively on more tractable topics (Lewontin, 1998). Language has not been fossilizing, and we lack time machines, so all of our data are indirect, and often several steps removed from the direct, conclusive evidence we might desire. But this is true of many problems in science that are considered legitimate pursuits, from the Big Bang to the origin of life, so this difficulty is not insuperable. A biological understanding of language would surely entail a full understanding of how brains generate, represent, and manipulate concepts, and such a broad understanding of cognitive neuroscience remains a distant hope today to understand the neurobiology of language & language development (some pessimistically suggest it is forever beyond the reach of the human mind).

REFERENCES

- Andreasen, N. C., Paradiso, S., & O'leary, D. S. (1998). "Cognitive dysmetria" as an integrative theory of schizophrenia: a dysfunction in cortical-subcortical-cerebellar circuitry? *Schizophrenia Bulletin*, 24(2), 203-218.
- Arbib, M. A. (2005). From monkey-like action recognition to human language: An evolutionary framework for neurolinguistics. *Behavioral and brain sciences*, 28(02), 105-124.
- Arbib, M. A., Liebal, K., & Pika, S. (2008). Primate vocalization, gesture, and the evolution of human language. *Current Anthropology*, 49(6), 1053-1076.
- Baddeley, A. (1986). Working memory and comprehension. In D. Broadbent, J.

- McGaugh, M. Kosslyn, N. Mackintosh, E. Tulving, & L. Weiskrantz (Eds.), *working memory* (pp. 75–107). New York: Oxford University Press.
- Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review*, 105(1), 158.
 - Bates, E. (1999). Plasticity, localization and language development. *The changing nervous system: Neurobehavioural consequences of early brain disorders*, 214-253.
 - Bates, E., Thal, D., Trauner, D., Fenson, J., Aram, D., Eisele, J., & Nass, R. (1997). From first words to grammar in children with focal brain injury. *Developmental Neuropsychology*, 13(3), 275-343.
 - Beeman, M. (1993). Semantic processing in the right hemisphere may contribute to drawing inferences from discourse. *Brain and language*, 44(1), 80-120.
 - Bihle, A. M., Brownell, H. H., Potter, H. H., & Gardner, H. (1986). Inference deficits in right brain-damaged patients. *Brain and language*, 27(2), 310-321.
 - Binder, J. R., Frost, J. A., Hammeke, T. A., Cox, R. W., Rao, S. M., & Prieto, T. (1997). Human brain language areas identified by functional magnetic resonance imaging. *The Journal of Neuroscience*, 17(1), 353-362.
 - Boksmann, K., Théberge, J., Williamson, P., Drost, D. J., Malla, A., Densmore, M., & Neufeld, R. W. (2005). A 4.0-T fMRI study of brain connectivity during word fluency in first-episode schizophrenia. *Schizophrenia Research*, 75(2), 247-263.
 - Brownell, H., & Martino, G. (1998). Deficits in Inference and Social Cognition: The Effects of Right Hemisphere Brain Damage. *Right hemisphere language comprehension: Perspectives from cognitive neuroscience*, 309.
 - Cabeza, R., & Nyberg, L. (2000). Imaging cognition II: An empirical review of 275 PET and fMRI studies. *Journal of cognitive neuroscience*, 12(1), 1-47.
 - Caplan, D. (1992). *Language: Structure, processing, and disorders*. The MIT Press.
 - Cappa, S. F., Perani, D., Messa, C., Miozzo, A., & Fazio, F. (1996). Varieties of Progressive Non-fluent Aphasia. *Annals of the New York Academy of Sciences*, 777(1), 243-248.
 - Carlsson, G., Uvebrant, P., Hugdahl, K., Arvidsson, J., Wiklund, L. M., & Wendt, L. (1994). The verbal and non-verbal function of children with right-versus left-hemiplegic cerebral palsy of pre-and perinatal origin. *Developmental Medicine & Child Neurology*, 36(6), 503-512.
 - Caselli, R. J., & Jack, C. R. (1992). Asymmetric cortical degeneration syndromes: a proposed clinical classification. *Archives of Neurology*, 49(7), 770-780.
 - Childs, M. R. (1998). Prenatal language learning. *Journal of Prenatal & Perinatal Psychology & Health*, 13(2), 99.
 - Corballis, M. C. (2009). The evolution of language. *Annals of the New York Academy of Sciences*, 1156(1), 19-43.
 - DeLisi, L. E. (2001). A speech disorder in schizophrenia: Review of the literature and exploration of its relation to the uniquely human capacity for language. *Schizophrenia Bulletin*, 27(3), 481.
 - DeLisi, L. E., Boccio, A. M., Riordan, H., Hoff, A. L., Dorfman, A., McClelland, J., & Oden, N. (1991). Familial thyroid disease and delayed language development in first-admission patients with schizophrenia. *Psychiatry research*, 38(1), 39-50.
 - Dick, J. E. (2008). Stem cell concepts renew cancer research. *Blood*, 112(13), 4793-4807.
 - Feldman, L. B. et al., (2007). Monolingual and bilingual recognition of regular and irregular English verbs: Sensitivity to form similarity varies with first language experience. *Journal of Memory and Language*, 57(1), 65-80.
 - Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in cognitive sciences*, 6(2), 78-84.
 - Fu, C. H., Vythelingum, G. N., Brammer, M. J., Williams, S. C., Amaro, E., Andrew, C. M., & McGuire, P. K. (2006). A fMRI study of verbal self-monitoring: neural correlates of auditory verbal feedback. *Cerebral Cortex*, 16(7), 969-977.
 - Gabrieli, J. D., Poldrack, R. A., & Desmond, J. E. (1998). The role of left prefrontal cortex in language and memory. *Proceedings of the National Academy of Sciences*, 95(3), 906-913.
 - Gaffrey, M. S., Kleinhans, N. M., Haist, F., Akshoomoff, N., Campbell, A., Courchesne,

- E., & Müller, R. A. (2007). A typical participation of visual cortex during word processing in autism: An fMRI study of the semantic decision. *Neuropsychologia*, 45(8), 1672-1684.
- Gazzaniga, M. S. (2000). Cerebral specialization and interhemispheric communication. *Brain*, 123(7), 1293-1326.
 - Gernsbacher, M. A., & Foertsch, J. (1994). In search of complete comprehension: Getting “minimalists” to work. *Discourse Processes*, 18(3), 271-296.
 - Gorno-Tempini, M. L., Brambati, S. M., Ginex, V., Ogar, J., Dronkers, N. F., Marcone, A., & Miller, B. L. (2008). The logopenic/phonological variant of primary progressive aphasia. *Neurology*, 71(16), 1227-1234.
 - Harris, G. J., Chabris, C. F., Clark, J., Urban, T., Aharon, I., Steele, S., & Tager-Flusberg, H. (2006). Brain activation during semantic processing in autism spectrum disorders via functional magnetic resonance imaging. *Brain and Cognition*, 61(1), 54-68.
 - Helekar, S. A., Espino, G. G., Botas, A., & Rosenfield, D. B. (2003). Development and adult phase plasticity of syllable repetitions in the birdsong of captive zebra finches (*Taeniopygia guttata*). *Behavioral neuroscience*, 117(5), 939.
 - Henriksson, K. M., & McNeil, T. F. (2004). Health and development in the first 4 years of life in offspring of women with schizophrenia and affective psychoses: Well-Baby Clinic information. *Schizophrenia Research*, 70(1), 39-48.
 - Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience*, 8(5), 393-402.
 - Hu, S., & Wang, L. V. (2010). Neurovascular photoacoustic tomography. *Front. Neuroenergetics*, 2(10).
 - Kircher, T. T., Oh, T. M., Brammer, M. J., & McGuire, P. K. (2002). Neural correlates of syntax production in schizophrenia. *The British Journal of Psychiatry*, 186(3), 209-214.
 - Kubicki, M., McCarley, R. W., Nestor, P. G., Huh, T., Kikinis, R., Shenton, M. E., & Wible, C. G. (2003). A fMRI study of semantic processing in men with schizophrenia. *Neuroimage*, 20(4), 1923-1933.
 - Lenneberg, E. H., Chomsky, N., & Marx, O. (1967). *Biological foundations of language* (Vol. 68). New York: Wiley.
 - Locke, J. L. (1997). A theory of neurolinguistic development. *Brain and language*, 58(2), 265-326.
 - Locke, J. L., & Bogin, B. (2006). Language and life history: A new perspective on the development and evolution of human language. *Behavioral and Brain Sciences*, 29(03), 259-280.
 - MacSweeney, M., Capek, C. M., Campbell, R., & Woll, B. (2008). The signing brain: the neurobiology of sign language. *Trends in cognitive sciences*, 12(11), 432-440.
 - Marinkovic, K., Dhond, R. P., Dale, A. M., Glessner, M., Carr, V., & Halgren, E. (2003). Spatiotemporal dynamics of modality-specific and supramodal word processing. *Neuron*, 38(3), 487-497.
 - Mesulam, M. (1990). Large-scale neurocognitive networks and distributed processing for attention, language, and memory. *Annals of Neurology*, 28(5), 597-613.
 - Mesulam, M. M. (2003). Primary progressive aphasia- language-based dementia. *New England Journal of Medicine*, 349(16), 1535-1542.
 - Nestor, P. J., Graham, N. L., Fryer, T. D., Williams, G. B., Patterson, K., & Hodges, J. R. (2003). Progressive non-fluent aphasia is associated with hypometabolism centered on the left anterior insula. *Brain*, 126(11), 2406-2418.
 - Ojemann, G. A. (1991). Cortical organization of language. *The Journal of Neuroscience*, 11(8), 2281-2287.
 - Price, C.J. et al. (1997) Segregating semantic from phonological processes during reading. *J. Cogn. Neurosci.* 9, 727-733.
 - Rapin, I., & Dunn, M. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain and development*, 25(3), 166-172.
 - Rilling, J. K. (2014). Comparative primate neurobiology and the evolution of brain language systems. *Current opinion in neurobiology*, 28, 10-14.
 - Rohrer, J. D., Warren, J. D., Barnes, J., Mead, S., Beck, J., Pepple, T., & Warrington, E. K. (2008). Mapping the progression of progranulin-associated

- frontotemporal lobar degeneration. *Nature Clinical Practice Neurology*, 4(8), 455-460.
- Sherr, L. (1995). *The psychology of pregnancy and childbirth*. Blackwell Science Inc.
 - Snowdon, C. T. (1990). Language capacities of nonhuman animals. *American Journal of Physical Anthropology*, 33(S11), 215-243.
 - Sommer, I. E. C., Ramsey, N. F., & Kahn, R. S. (2001). Language lateralization in schizophrenia, a fMRI study. *Schizophrenia Research*, 52(1), 57-67.
 - Stoel-Gammon, C. (2011). Relationships between lexical and phonological development in young children. *Journal of child language*, 38(01), 1-34.
 - Tagliatela, J. P., Russell, J. L., Schaeffer, J. A., & Hopkins, W. D. (2008). Communicative signaling activates 'Broca's' Homolog in chimpanzees. *Current Biology*, 18(5), 343-348.
 - Temple, C. (2014). *Developmental cognitive neuropsychology*. Psychology Press.
 - Thompson, S. A., Graham, K. S., Williams, G., Patterson, K., Kapur, N., & Hodges, J. R. (2004). Dissociating person-specific from general semantic knowledge: roles of the left and right temporal lobes. *Neuropsychologia*, 42(3), 359-370.
 - Van LanckerSiddis, D., Cameron, K., & Siddis, J. J. (2012). Dramatic effects of speech task on the motor and linguistic planning in severely dysfluent parkinsonian speech. *Clinical linguistics & Phonetics*, 26(8), 695-711.
 - Weiss, E. M., Hofer, A., Golaszewski, S., Siedentopf, C., Felber, S., & Fleischhacker, W. W. (2006). Language lateralization in unmedicated patients during an acute episode of schizophrenia: a functional MRI study. *Psychiatry Research: Neuroimaging*, 146(2), 185-190.
 - Whitwell, J. L., Avula, R., Senjem, M. L., Kantarci, K., Weigand, S. D., Samikoglu, A., & Petersen, R. C. (2010). Gray and white matter water diffusion in the syndromic variants of frontotemporal dementia. *Neurology*, 74(16), 1279-1287.
 - Wiggs, C. L., Weisberg, J., & Martin, A. (1998). Neural correlates of semantic and episodic memory retrieval. *Neuropsychologia*, 37(1), 103-118.
 - Yurgelun-Todd, D. A., Renshaw, P. F., Gruber, S. A., Waternaux, C., & Cohen, B. M. (1996). Proton magnetic resonance spectroscopy of the temporal lobes in schizophrenics and normal controls. *Schizophrenia Research*, 19(1), 55-59.
 - Zatorre, R. J., & Evans, A. C. (1992). Lateralization of phonetic and pitch discrimination in speech processing. *Science*, 256(5058), 846.

How to cite this article: Kumar V, Das J, Bhattacharya M. Neurobiology of language development: an update. *Int J Health Sci Res*. 2019; 9(1):256-269.
