THEORIES AND MODELS OF NEUROLINGUITICS/ LINGUITICS AHASIOLOGY

Abstract

There are several schools of thought concerning theories in connection with the human brain, its relationship with language and language disorders. The theories were postulated and came into light in early 1800 and further investigated and explored till date, by several neurologists accounting for brain, language and neurological language disorder coined as aphasia. The periods of theories were termed as preclassical, classical, and modern era. Theories once combined with time, classifies the localist, associationism/ connectionist, hierarchical and holistic theory under classical period of history whereas neoclassical and dynamic localization of function theory belongs to modern era.

Several neurologist, physicians, psychiatrist and behaviour are the contributed their conception and conclusions with respect to the human brain structures, its involvement in language perception and execution as well as to neurological language disorders such as aphasia.

Based on theories, several models were geared up by neurologists and physicians imparting immense contribution to assessment of language disorder accounted from damaged brain.

Keywords: Neurologist, Physicians, Psychiatrist, holistic theory, neurological language.

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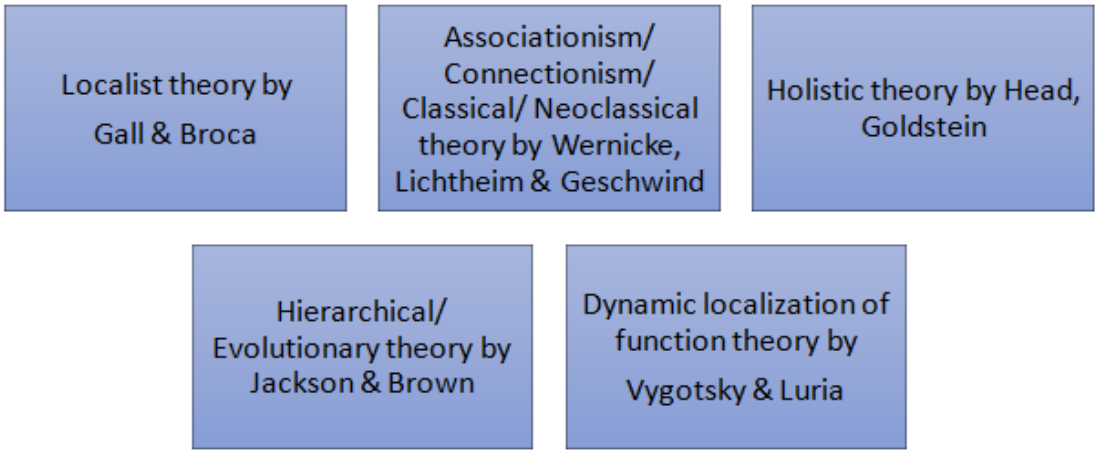
I. INTRODUCTION

There are several neurolinguistic theories, having influential impacts with connection between human brain, language and its disorders which were elaborated in the perpetuity from localist to holistic further combined with eras from preclassical to contemporary as mentioned below.

II. THEORIES ACCORDING TO THE TIME PERIOD

According to eras in historical period, conceptualisation of brain, language and aphasia has been discovered by several neurologists in different time period. These periods were coined as pre-classical period (on and/ or before 1800); 2. Classical period was considered from 1860s to early mid-19th century; 3. Modern era came into picture before the discovery of brain scanning systems like CT scan and finally the contemporary era is continuing since the development of several instrumental analysis of brain, that is since 1970s to till date.



Theories According to Localization are presented in Figure 1

Theories once combined with time period, are classified as the localist, associationism/ connectionist, hierarchical and holistic theory under classical period of history whereas theory of neoclassical and dynamic localization of function was secured to modern era.

III. CONCEPT OF BRAIN, LANGUAGE AND APHASIA - ACCORDING TO THE EPOCHS OF THE HISTORY COMBINED WITH THE LOCALIZATION THEORIES ARE:

The period of pre-classical (till 1860s) era had documented the first known references evincing the brain as the center of language and pathology of brain can lead to language disorder as appeared in Egyptian so-called Edwin Smith Papyrus, about 1,500 BC, which may be copied from an older papyrus written between 3,000 and 2,200 BC.

Around 400 BC, Greek antiquity of Hippocrates' Corpus framed the role of brain in language disorders. Hippocrates suggested that the brain was the biological structure responsible for human's intellectual capacity and any damage to this structure will lead to specifically two different types of language disturbances correlating with two major aphasic syndromes. Hippocrates was referred to the first direct forefather of contemporary aphasiology.

It was Plato's (4th century BC) proposal that the areas are in one-to-one relationship with various functions while second school of thought of Aristotle, schemed a psychological process arising from the sensory organs communicating with cognitive ability which are congruous with the motoric functions. These thoughts influenced future models, highlighting the harmony between brain and language functions.

During 17th century, in the monogram of Speech Amnesia, Johann Gesner (German Physician) postulated that speech disorders are caused by passivity in the connections between the different parts of the brain resulting in disturbances while correlating lingual symbols and signs related to various abstract thoughts, pictures, or images. Hence, he also considered speech disorder as a disorder of memory.

To add up, it can be convinced that, during 19th century, several theories and knowledge of researchers have expressed neurolanguage disorder as a disconnection between language and damaged brain areas, which are responsible for linguistic functions. It was also presumed that any insult to the structures, accountable for intelligence or memory and organization processes can be blameworthy for the detachment of "thoughts to its lingual signs. Several neurologists have coined the term 'aphasia' as neurolanguage disorder.

IV. CLASSICAL PERIOD NEUROLINGUISTIC THEORIES (1861-1945)

Localist, associationism/ connectionist, hierarchical and holistic theory are grounded under the classical period of neuroscience and neurolinguistic development.

1. **Localist aka Localism Theory:** Localist theory suggests that the cortex in the brain and other areas hold the responsibility of higher functions like linguistic, meta cognitive and meta linguistics skills, which are altogether synchronise to carryout various language function.

   Well-known localists including Gall and Broca had suggested that aphasia resulted from a lesion in such language center of brain.

2. **Anatomy of Brain Theory Postulated by Gall:** Franz Joseph Gall was the first anatomist connoting that the tissues and membranes of the brain grows and expand along with its assigned function for providing nutrition to the brain. He put forth that structurally, the cortex considered as the gray matter is a uniform and continuous layer of neural tissues and nerve cells, proposed to be the highest level of organization of the brain. He stated that both the right and left hemispheres contain different elevated ridges or convolutions called as gyri on the surface of brain, varying in every single human.

   Assumptions of Gall highlighted that the cortex size will be directly responsible for the skull growth. Cranioscopy procedure was developed imparting that it would be

"almost" possible to examine the cortex by observing the cranium, had supported the assumption. His studies disclosed that the frontal lobe of brain contains two areas for language, one for speech production and the other for storing lexiconsin memory. To sum up, Gall's opinions were localizing the structures and functions of human brain.

3. **Neurolinguistic Evolution by Broca:** Paul Broca was the founder of the field contributing to the birth of neurolinguistics, when he presented his theory at the Anthropological Society of Paris in 1861, based on a patient named Leborgne's, who had major difficulties in producing speech that he was almost mute with only utterance of 'Tan'. After death of the patient, the autopsy of his braindone by Broca, revealed the probable cause of speech disorder as a lesion in the particular areaof the brain which was later came to be known as Broca's area, located in the posterior inferior frontalgyrus of dominant hemisphere, that is mostlyin the left hemisphere.

   In 1865, Broca concluded that the left hemisphere is the dominant hemisphere in right handers, solely responsible for language and vice versa. He also suggested that a recovery from aphasia might be possible if the right hemisphere would dominantly accomplish the functions of left hemisphere. To summarise, it can be concluded that Broca's proclamations were quite localist and later given rise to the connectionist theories.

V. ASSOCIATIONISM/ CONNECTIONISM OR CONNECTIONIST THEORY

Associationism, later renamed as Connectionism or connectionist theory, was also termed as the classicalor neoclassical era theory, former based on Wernicke - Lichtheim view while the later one was based on Geschwind view. This theory assumed that the higher functions were depended on the connections between different centers in the cortex, needed for linguistic function like the association between the images and words, whereas aphasia resulted from broken connections between these centers. This theory somehow correlated with Gesner's hypothesis during 17^{th} century.

In a nutshell, the clinical study of neuroscience in nineteenth century, was dictated by the study of aphasia, established by the work of Pierce Paul Broca. The localization of linguistic capabilities in the designated areas of brain and role of cerebral dominance for language were the highlights.

1. **Wernicke, Father of Associationism/ Connectionist Theory:** During early 1870s, neurologist named Carl Wernicke, presented a theory based on his dissection of patients with language disorder and correlated it with Broca's findings. Based on his theory, Wernicke proposed a well know connectionist model represented several other language syndromes related to brain areas along with the classification of aphasia. The connectionist model represented the language processing in the brain and its relation to various aphasic syndromes.

   Postulations of Wernicke's connectionist theory is:
   - Brain has allocated areas for receiving the final connection of auditory system. These areas are juxtaposed to the cortical area in the brain.

- This area was called as anassociation area for more complex functional processing of sensory and motoric information.
- Wernicke's area in the first temporal gyrus was considered as second language center after Broca's area as first center for language. Wernicke's area became the memory store house of words perceived auditorily, due to its nearness to auditory pathway in the brain.
- He described those patients with reduced language comprehension had lesions in Wernicke's area, the posterior part of the first or superior temporal gyrus and adjacent areas (parts of the angular gyrus, the supramarginal gyrus, and the second temporal gyrus are included).
- He also postulated that there was a specific "language gyrus" ranging from Wernicke's area (responsible for receptive function) to Broca's area (responsible for expressive function) and aphasia could be caused by lesions in either of these areas (Wernicke's / Sensory aphasia or Broca's / Motor Aphasia). Later, according to Norman Geschwind, a lesion affecting the bundle of fibers called arcuate fasciculus, connecting the Wernicke's and Broca's area can be responsible for conduction aphasia.

2. **Connectionist models by Lichtheim:** Ludwig Lichtheim(1885), a German Physician set forth a proposal of elaborative aphasic syndromes based on connectionist model representing brain and language. He adopted Wernicke's views for providing a model with respect to Broca's area (M) being responsible for the motor representations required for articulatory (repetition) utterances while Wernicke's area (A) accountable for auditory input and its analysis was represented in the form of auditory word as the two major areas involved in language comprehension and expression.

Conclusively, he postulated a third language center as the "concept center" with an unspecified localization in the model of language function based on Wernicke's model. Lichtheim generated the diagram representing the complete classification of aphasia in 1.3.

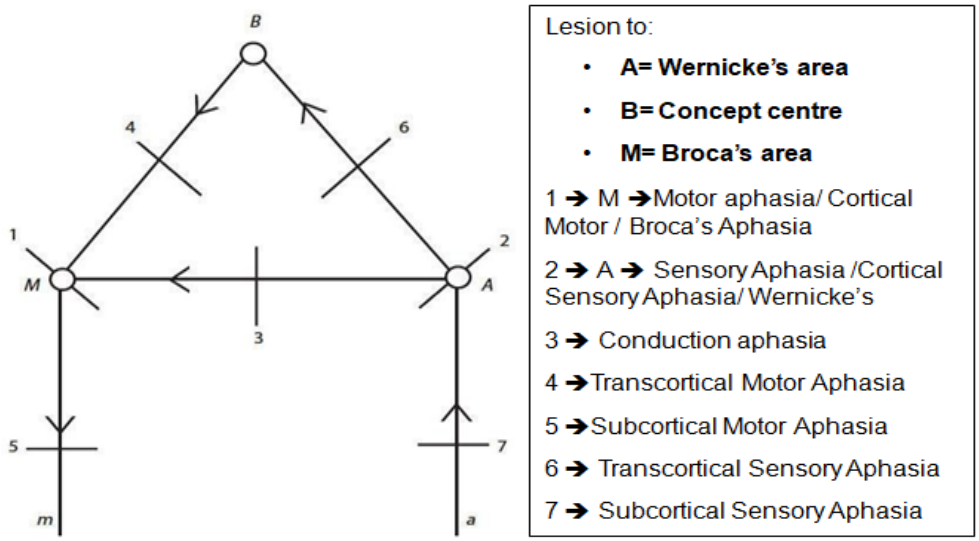


Figure 2

Source: quizelet.com

Depending upon the nature of information flowing between various components, this model would be predicting the types of aphasia. The following kinds of aphasia exist in Lichtheim's model:

- A lesion of M will cause the *classical Broca's aphasia*, in which *language comprehension* is s*pared* while *articulatory language is disturbed*.
- A disorder of A will cause *Wernicke's aphasia* with the symptoms.
- A disorder of the connecting pathway will cause the "*conduction" aphasia*, where ability of a patient to repeat would be impaired.

3. **Transcortical Motor Aphasia (4):**
   - This is due to the lesion between **M and B.** This will produce the same type of output seen in Broca's aphasia, but as in the transcortical sensory aphasia, repetition ought to be normal because the basic pathway involved in repetition is intact.

4. **Subcortical Motor Aphasia (5):**
   - This resulted in dysarthria, a motor speech disorder on account of lesion between **M and the oral musculature**.

5. **Transcortical sensory aphasia (6)**, due to a disruption in the path between **B** and **A**, it would be resulting *difficulty in comprehension.*
   - Words perceived via auditory sensation remains intact, however there is a disturbance in its connection to the concept center. As an outcome, the individual with such aphasia, can no longer comprehend the meaning of language perceived acoustically or auditorily.
   - *Although repetition is ought to be intact.*

6. **Subcortical Sensory Aphasia (7):**
   - In this type of aphasia, the memories of auditorily perceived words stored in Wernicke's area are intact and can be transmitted to the motor centers.
   - However, due to the interruption in the pathway carrying the information from the periphery to sensory area denoted by 'A', disturbs the comprehension and processing of spoken speech sounds, termed as "*pure word deafness"* where the person is unable understand any verbal spoken expression.

To conclude, the Connectionist models are one type of "faculty" models in which brain is accountable for language functions as a processing of focused task.

The Broca's area oversees the motor programming involved in the production of spoken language, also called as motor speech centre. The posterior language area holds the comprehension of verbal and expressive language in form of sound patterns of words. The notion of "center" consisting of individual skill relates to the cortex responsible for storing language components is considered to be located somewhere in the brain, emerged most clearly in this model.

Finally, the connectionist model also represents each of the language learning skills that includes hearing, speaking, reading, and writing -as a single entity. All the four

language learning skills are interconnected with each other and share interaction between them as all are interdependent.

7. **Extension of connectionist theory:**In relation to extension of connectionist theory, Joseph Jules Dejerine (during early 19th Century) located a language area around the Sylvian fissure in the dominant hemisphere.

   After his patient's autopsy, Dejerine postulated about alexia and stated that the left parietal lobe manages reading and the alphabet sounds arecoupled with their orthographic or grapheme forms.

8. **Criticism of Associationism/ Connectionist Theories and Models:** Several neurologists across the globe disparaged the analysed theory and models related to connectionism. Sigmund Freud, Henry Head were among others who had shown their disparity regarding model.

9. **Disparity by Freud:** In 1891, Sigmund Freud censured the connectionist model documented by Wernicke's and Lichtheim's by raising questions regarding the concluded logic related to neurolinguistic theory and aphasia. He also stated that basic observations made by the connectionists were incorrect.

   According to Freud, language should be mapped in the areas between the lobes of brain responsible various sensory and motoric functions. For example: frontal lobe for language production; temporal lobe for auditory perception while occipital lobe for visual perception and discrimination. He draws the inference that there were several lacunae in these models in general.

10. **Disagreement by Head:** During late 18th Century, Henry Head disagreed with the analysis of symptoms of language disorders and viewed the whole concept of model and the center as a diagram. He also challenged the locations in the brain for language functions.

    He discredited the connectionist model as it failed provide any solution to neurolanguage disorders. According to him, the model was the compilation of simple formulas based on selected assumptions where the defected language functions were portrayed through damage to the center or discontinuation of pathways. He also stated that language disorder cannot be evaluated in form of task involving language as there are individuals who can follow simple and single commands but not the complex or multidirectional commands.

    On a final note, there was a denial from Head's side regarding the neurological and psychological involvement in the connectionist model.

VI. HIERARCHICAL OR EVOLUTIONARY THEORY

1. **Theory of holism/ holistic:** During 19th century, localism and associationism were on its peak. However, holism was gaining its support in different fields. Neurologist like Henry Head and Psychiatrist like Kurt Goldstein were considered to beholistic influencers.

Holistic theory suggested that the extensive areas of the brain work together to handle many language functions, referred as "cognitivism. Holism suggested that all designated parts of brain interact and works together to achieve higher functions and skills like "meta cognitive skills or intellectual," "logical thinking", figurative ideas," or "abstract thoughts," are also being handled by the cortex. However, aphasia signifies not only loss of linguistic ability, rather in general it may be cognitive loss also. Damage to the brain results in a reduced mental process and this was acclaimed by a holistic school of neurologists and psychologists.

2. **Holistic view of Head:** Henry Head (1861 – 1940) presented an original quadruple classification of aphasia based on the functional disturbances. The types of aphasia were named after the functional difficulties like deficit in verbal expression (as verbal aphasia), grammatical, sentence structure or syntactic deficits (syntactic aphasia/agrammatism), naming difficulties (as nominal aphasia), and deficit in understanding the language meaning or semantic (semantic aphasia).

   Head's theory highlighted the following:
   - The most complex functions of brain (cognitive skills, thought and language processing) were affected first followed by all levels of activities in case of brain damage.
   - At the damaged level, negative exhibitions were noted on the site of lesion.
   - A lesion cause effects that are positive and disinhibits activities which are normally controlled by structural functions at the damaged level.
   - The sensory and motoric functions have hierarchically developed in a top down fashion or lower to higher as per the neurological mapping of the central nervous system.
   - In order to execute the activities in a best possible way, the central nervous system integrates all the functions based on the best possible physiological activities.

   During early 19th century, Head also introduced some general guidelines to carryout testing in aphasics and compelled to use empirical procedures to diagnose the type of aphasia.

3. **Holism by Goldstein:** A German psychiatrist named Kurt Goldstein, was considered with a reputation of a liberal minded neurologist working more on speech problems. In mid-19th century, he coined a term as "abstract attitude" which was an umbrella term describing the personality of an individual. For example, abstract attitude allows an individual to initiate a task, prioritise and memorise the important things out of the rest. Importantly, it indicated how a person stand alone in the external surroundings.

   According to Goldstein, these abstract attitudes are remarkably absent in individual aphasics who have naming difficulty (anomic), difficulty in producing sentence structures and grammatical correction. He combined the psychological, language efficiency and physiological factors to describe these abstract attitudes. If a person does not persist these attitudes, then a language disorder will arise.

In conclusion, Goldstein had classified the cerebral cortex into peripheral and central part, whereas the disturbances in the central part will result in deprivation of abstract attitude.

VII. HIERARCHICAL EVOLUTION/ TRANSFORMATION-BASED THEORIES

This theory propounds on answering certain questions like:

- The development of brain by piling of layers upon layers, formation of gyri, sulcus and other cortical, subcortical structures and areas.
- The role of cortical, subcortical structures and areas of language processing and production.
- The relationship between the evolution of brain and language over time in different species.
- The acquisition and development of linguistic features and language in children.
- The adult's performance on various functions of language.

All these questions were represented by Jackson and Brown in form of their own school of theories.

1. **Jackson's School of Cognition and Intellectual Ability:** John Hughlings Jackson was known for postulating the role of brain in language processing and communication. He supported the connection between cognition and language; however, he was not into the anatomy of brain. Jackson was more interested in finding the types and complexity of human reactions and responses towards various stimuli. He proposed automatic and propositional classification of language.

   The automatic part contained few rotted stereotype answers with newly formed words whereas propositional part consisted of syntactic and semantic form of linguistic. According to him, a person with aphasia won't be able to rationalise the propositional level indicating some loss of cognition followed by thoughts and language; however, speaking ability persisted based on paralinguistic and suprasegmental aspects.

   Jackson also supported the hierarchical function of brain from simpler form to complex, where information passes from lower organised structural centers to higher complexed one, fuelling the automaticity of speech and language into complex form.

2. **Theory of Jason Brown:** Brown's theory on aphasia was impacted from Jackson's, where Brown combined the evolution of brain with its functional views in relation to aphasia. He dwelled more on bonding between suprasegmental aspects, which were influenced by emotions, voluntary function, creativity and several aspects of language.

   Brown's theory on microgenesis is a classic example of hierarchical evolution where he predicted that every action of language passes through all the stages that is from depth to surface level of brain. According to Brown, neurological and psychological functions are counterpart of each other, both contributing to human language.

3. **Rediscovery of Associationism or Introduction of Neoclassical Theory by Geschwind:** Norman Geschwind aka behavioural neurologist became the influential personality to redefined associationism as "connectionism,". He expanded Wernicke's classical theory and models for the classification of aphasia while discovering the neoclassical school of neurolinguistics during 1960s.After compilation, a new model was well named as **Wernicke-Geschwind model** for processing and interpreting linguistic. This model represented language processing through 7 major anatomical areas of brain. According to him, auditory cortex and Wernicke's area are responsible for decoding and encoding of language perceived auditorily. The encoded information passes on to Broca's area via arcuate fasciculus and finally, primary motor area coordinates to produce the speech. Primary visual cortex and angular gyruscontributes to the processing of visual language in form of reading. These seven anatomical components function in an interconnected fashion in dominant hemisphere (left) of brain to yield the output of language processing.

In the western world, Geschwindmentored the clinical and theoretical analysis for neurolanguage disorder/ aphasia. He explained the cortical language disorder as disconnection syndrome or disconnected language disorder. Conduction aphasia is an excellent example of such disconnection syndrome, resulting from the lesion in arcuate fasciculus, which disconnect the pathway for transferring encoded information from Wernicke's to Broca's area. The anatomical view of such disconnection syndrome is shown in Fig. 1.4

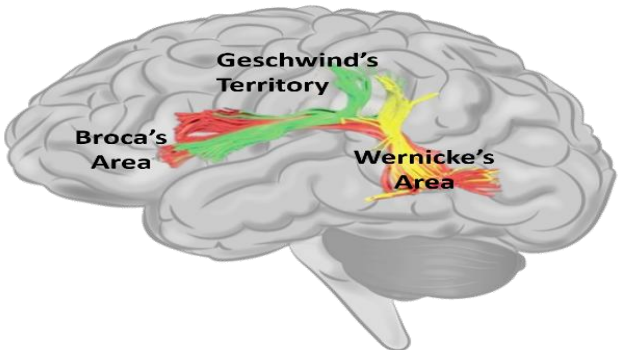


Figure 3: The image is directed towards the important source of language processing.
Source: (from www.4.4 Language in the Brain – Psychology of Language (opentextbc.ca)

VIII. THEORY ON DYNAMIC LOCALIZATION OF FUNCTION

This theory came into limelight during 20th century i.e., modern era period. According to this theory, there are several sub functions of language that are circumscribed to various dynamic parts of the brain, which are further combined to perform a prodigious function. However, the complexity rises after the brain damage at site of lesion leading to the functional disturbances of language.

In mid 1900s, a renownedpsychologistIvan Pavlov had emphasized that the linguistic complexity and behaviours were matured, as the brain considered to be the dynamic system, gets develop and mature with course of time. The dynamic system contains the interconnected anatomical structures within the centra nervous system.

Furthermore, Leg Vygotsky focused on localizing the discontinued function of language rather than the place or site of lesion of damaged brain. Based on the origin and hierarchy of development, he emphasised that disturbed linguistic functions should be considered.

According to him, various organs work in a dynamic cooperative manner to complete a task while this cooperation are handled by several neural anatomical structure located in an assorted form all over the brain. He posited a connection between language and thought.

In 20th century, this dynamic localization theory was influenced by the contribution of Alexander Luria, a famed aphasiologist and psychologist. He viewed brain as several interconnected functional structure for carrying out different complex activities requiring cooperation of each structure. He divided brain into 3 forms of blocks which are as follows:

1stblock consist of subcortex (limbic system) and brainstem; maintaining the gait, posture and regulation of emotions while any damage to this block will be resulting in loss of tonicity and balance.

2ndblock contain all the three lobes (temporal, parietal and occipital excluding frontal) of the posterior cortex in brain, that is responsible for receiving and assessing the stimulations from various sensory organs and storing the information. These structures are meant to process and organize the phonetic segments, vocabularies, meaning and smallest form to structure, varying from simple to complex form of language (semantics and syntax).

3rdblockconsist of frontal lobe, as the largest lobe (front of brain or pre cortex separated by precentral gyrus) containing motor and premotor areas. It is solely accountable for programming and controlling all the higher cognitive and linguistic activities as well asmotoric movements. It is also responsible for carrying out the verbal expression and arranging the utterances of linguistic form.

Luria classified different types of aphasia based on site of lesion of the 2nd and 3rd blocks. The classifications of aphasia were as follows:

The damage to 2nd block leads to (1) Afferent motor aphasia (2) Sensory aphasia (Acoustic-gnostic) (3) Acoustic-mnestic aphasia and (4) Semantic aphasia (Amnestic aphasia) whereas dynamic and efferent motor aphasia were resulted from damages to the 3rd block.

Luria focused on relationship between cognition, linguistics and neuropsychology. Finally, his contribution had targeted the restoration of lost functional ability of the system which became the stepwise clinical framework for assessment and management of aphasia, in current generation.

IX. SUMMARY

All through the centuries, various neurologists, physicians, psychologist and behaviourist, all over the globe has immensely contributed to the world of brain, its relationship with language processing and its functions, role of intellectual/cognition and neurological language disorder aka aphasia. The development of neurolinguistic has been

quantified by shedloads of theories and models, postulated regarding brain, language and aphasiology, creating abundant knowledge and essential details which were refurbished from generation to generation. Starting from preclassical before 18th century period (of Hippocrates) to the continuation of modern period in 20th century (by Luria), neurolinguistic theories have contributed in manifesting aphasia as the center of all neurologists and neurolinguist since last 2 centuries.

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