

Chapter 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

This chapter presents the theoretical background of language processing in the brain and a comprehensive literature review of the work presented in the thesis. Language acquisition is the process that facilitates individuals (human beings) to perceive and comprehend any language through employing words and sentences as the most effective communication tool. This chapter includes all the significant perspectives associated with language acquisition and comprehension, dealing with the language acquisition process, types of language acquisition, and skill acquisition. In language comprehension, both native language comprehension and bilingual comprehension have been discussed, and it can be said that language comprehension involves different regions of the brain for different types of sentences. Different experimentation techniques involved in the neuro-linguistic study have been discussed in brief, along with the analysis of brain regions (activated regions in language acquisition), which are also given in detail. This chapter also includes all the exciting findings on language acquisition and comprehension processes based on fMRI/EEG techniques and comprises different computational tools dedicated to neuro-linguistic study. Multiple research works have been done on language acquisition, comprehension, and

production in the last few decades. The evolution of safe and non-invasive functional measuring techniques has proven feasible to be used with infants and adults for neural data acquisition. Hence, it is now possible to systematically document neural activity and its impact on phonetics, brain responses to phonic level stimuli, progression in linguistic development, etc. showing high precision

2.1 LANGUAGE ACQUISITIONS

Language acquisition can be defined as a process that facilitates humans to perceive and comprehend any language by employing words and sentences as the most effective communication tools. Language acquisition is a term that is generally used to describe first language acquisition, which emphasises the attainment of the native or primary language in infants [2]. This differs from second language acquisition, where studies are dedicated to additional language acquisition in adults and children. Language acquisition is one of the central human characteristics where the brain plays a pivotal structural and functional role. As the top centre for the attainment of languages, the brain stores linguistic data and becomes accustomed to the regularities (grammatical) present in the language. Moreover, the current developments in functional neuroimaging have played a significant role in the systems-level investigations in progress in the brain [46]. According to Eric Lenneberg (1967),[47] humanoid language acquisition was an example of biologically constrained erudition, which usually occurs through a critical period starting from early life and finishing by adolescence. Though it appears to be natural and instinctual, second language acquisition involves certain deliberate practices and processes associated with language learning. The critical period [48] mentioned by Lenneberg is the growth time during which certain quintessential practices have their eventualities on improvement and learning of language in accordance with the specific atmosphere in which the being has been socialised. Suppose there is no proper socialisation during this critical learning period. In that case, it can negatively impact the language learning

process, and in extreme cases, there will be no learning if the exposure is absent., J. R. Hurford [49] describes the existence of this critical period or sensitive period, which is crucial for human language acquisition in his evolutionary model. First language acquisition is an enigmatic experience in human life that cannot be elucidated [50]. It is natural and astounding, since it takes place without any deliberate effort and with ostensible speed and precision. Children acquire their first language without any conscious effort, suggesting that language learning as a natural process is both straightforward and simple. But it does not hold as kids/children pass through different learning phases for the first language acquisition. The various steps in language learning in children include cooing, holophrastic stage, babbling, normal speech, and telegraphic speech. Infants start experimenting with phonemes from all languages of the world at the age of cooing up to 9 months. After nine months, children begin to utter particular phonemes, this is called babbling, from their native language. They start speaking single words by the age of 1-year. Around 1.5 years to 2 years in the holophrastic stage, their capacity to combine words develops substantially. At 2.5 years on the telegraphic stage, they set themselves to utter a structured phrase. Along with physical growth, children's linguistic ability also undergoes progressive development. They learn to employ composite structures in language by accumulating words and phrases from their immediate environment. By the age of 5, children usually start uttering everyday speech. The most numerous theories associated with language acquisition are- behaviourist theory, interactionist theory, and innatist theory. The behaviourist theory [51] links learning of language to verbal behaviour in which stimuli are given to children, and their response is recorded with reinforced conditioning. The Innatist theorists [52] assume that children have an innate ability in the brain solely responsible for their linguistic competence, called a language acquisition device (LAD). According to them, language acquisition is an inborn ability, and the human brain, which contains all the linguistic information, gets triggered when speech is heard. The Interactionists [53] believe that language is acquired through the physical interaction of children with their surroundings, and

that no distinct segment exists in the brain which is responsible for linguistic abilities. Children naturally learn the first language, commonly known as the native language. Alternatively, learners of the second language should acquire a minimum of one native language before learning another. The knowledge of the first language helps them learn an additional language. Second language learners also have cognitive adulthood/maturity and meta-linguistics cognizance to help solve problems while engaging in arguments using a second language [54]. Mainly, sign languages are employed for communication by people born deaf, and the acquisition of language begins in the later stages of life. Our brain needs to get programmed through some special training or practice to acquire expertise in any skill, whether language or technical skills.

2.1.1 FIRST LANGUAGE ACQUISITION

The language expertise acquired during initial babyhood is important in determining future reading attainment as well as academic and professional accomplishments [55], [56]. Neuroimaging studies have revealed an association between the white matter structural design of the brain and language expertise. Recent studies have shown that language expertise among children is directly rooted in the prevalent network in the brain for language processing that develops over time in life [57].

Studies [58] which are based upon functional Near-Infrared Imaging (fNIRS), propose that the moderate musical modulations in the linguistic stream (<8 Hz) can speck word and syllable borders in a nonstop linguistic stream, serving children in mastering the structures and words of the language they use. Sensitivity of children toward sluggish regular modulations, which are intrinsic in the linguistic stream, enables language attainment during infancy (early stages) and the development from linguistic in dialogue to language in print throughout the initial years of attainment of reading [59], [60]. Studies based on neuroimaging additionally propose that the

neural networks present in an adult brain, upon hearing language, pass into a synchronised communication amid the various frequency modulations of the linguistic stream and the endogenic recurring oscillations of neural movement. Rates of neural firing are usually wavering at diverse frequency groups, together with Delta (1-3 Hz), Gamma (30-80 Hz), and Theta (4-8 Hz). The slower frequencies correspond to word and syllabic borders (Delta-Theta), whereas the frequencies which are faster correspond to individual phonemes [61], [62]. Conclusions suggest that the brain's right hemisphere might have an all-inclusive better capability for processing rhythmic sensitivity than the brain's left hemisphere, which only has selective sensitivity for a favoured range of sluggish rhythmic modulations [63].

SLA (Spatial Language Acquisition) is the acquisition of FoR (frame of reference) [64] by people in their native language (north/south, left/right), which varies greatly in terms of both frequency and availability of FoR terms [65],[66],[67][68]. For example, the English language favours egocentric words ("left," "front") for describing limited table-top arrangements, whereas other languages prefer geocentric words (like "north," "uphill"). Moreover, numerous research have revealed the association between the available FoR illustrations in non-verbal intellectual tasks of members of that community and the dominant FoR in a specific language community [69], [70]. After performing several experiments among children, researchers have found the influence of pre-existing language circuits in acquiring new word forms from native phonemics, which further explains how children learn new words after a few repetitions [71]. Scholars have [72] done an fMRI experiment and obtained that the suspension in the attainment of a first language could be related to differences in the concentration of tissue inside the occipital cortex near the areas which have been acquired for determining practical employment throughout the processing of language in individuals with a later acquisition age. The results have proposed that the deficiency of previous language understanding influences the functional characteristics and the structural association of the brain [73].

Scholars have [74] further stated that the input nature could vastly impact the heart of the system that novices use to learn words' characteristics in a natural language. Furthermore, a statistical agenda of learning concluded that learners could track the distributional info in their surroundings, which could also be used to pull out the principles and structures of corporeal input that they take.

2.1.2 SECOND LANGUAGE ACQUISITION

A rudimentary part of new language learning is the attainment of its vocabulary. In the study of language and its structure, morphology is the study of words, the origin and historical development of words, their meanings, and their associations with different terms (same language). Studies that [75] examine the initial stage of learning based on the morphological rules of a new language (L2) in grownups have recommended that, regardless of limited experience, adult linguistic learners can attain both the words along with the morphological rules of a new language.

Studies in multilingualism/bilingualism have documented the behaviours wherein neural illustration of an L2, i.e. the second language, varies with respect to an individual's L1 (first language) [76]. There are significant variances in the course of activation amid first and second languages, both in range and degree. L2s tend to exhibit more activity inside conventional left hemisphere language zones and stimulate different zones to separate the traditional language network. The two main theories propose a method by which the neural signs of L2 vary from L1. The first rudimentary variance is compact neuroplasticity throughout the learning of L2, which happens at an older age than the learning of L1. Incidentally, L2 learning needs more neural possessions primarily because of maturational variations of neural plasticity inside areas and paths backing learning of L1 (first language) [77]. A substitute theory proposes that elements somewhat govern the neural variances in L2 vs. L1, and that a learner's L2 is generally lesser in expertise concerning their L1. In this regard, L2's processing typically includes improved processing

demands and hence extra neural possessions [78]. The investigational outcomes propose that expertise can enlighten the functional and structural systems distinctly in the bilingual brain, which recommends a distinct type of plasticity for age-reliant effects against experience and proficiency.

Scholars have [79] acquired that the organisational variations in brain areas are known to assist language functions throughout foreign language gain. The outcomes of their research demonstrate that development in hippocampus volume and cortical thickness for the left middle frontal gyrus, superior temporal gyrus, and inferior frontal gyrus for interpreters' comparative to controls. Furthermore, the right hippocampus and the left superior temporal gyrus were more flexible for transcribers in obtaining sophisticated expertise in a foreign language [80].

Studies have [81] inspected how the acquisition age of L2 influences the brain assemblies in bilingual individuals. Additionally, it is also exposed that AoA, language expertise, and present level of experience are likewise vital in rationalising structural variances. The structural aberrations linked with multilingualism and bilingualism have been stated where bilinguals tend to have additional density/volume of grey matter in the left caudate [82], Heschl's gyrus [83], and left inferior parietal region [84].

Scholars [85] have also examined the links between attitude towards language learning and expertise in ISLA (instructed second language acquisition) and obtained a strong link between the point of view towards language learning and expertise in L2, a second language. A study based on language learning achievements in dizygotic and monozygotic twins [86] proposed the opinion that a positive point of view towards the understanding of language and the linguistic class could be strictly associated with just how well an individual does ISLA regardless of inborn skills for language, tutor's skills, and relationships of L1-L2.

In [87], the authors studied the neural substrata of fresh grammar learning in a set of healthy grownups/adults and completed an experiment based on fMRI in respect of functional connectivity that determined that the assignation of the brain's network in the case of grammar attainment is connected with one's language learning skills.

For babies who are naturally deaf and cannot listen to the speech spoken around them, the visual signal of dialogue informs inadequate phonic facts to support impulsive language attainment. Language attainment begins only after acquaintance with and involvement in sign language, which corresponds to ages well past infancy for these children. It is verified that, for the start of language learning, the discrepancies in age influence dealing with language in the grown-up/adult brain [88], [89]. The fMRI analysis of deaf innate signers has also stated that active areas for classic language zones are in the left hemisphere LH, with an alteration in the direction of bilateral activation in the frontal and temporal lobes. These outcomes have been obtained for different sign languages containing American, British, and Japanese using several errands and stimuli [90],[91],[92]. Language attainment age is linearly and inversely related to activation levels in the anterior language segments and related to levels of activation in posterior visual regions for language tasks through sentences in American Sign Language (ASL), grammatical ruling, and phonemic hand ruling [93].

Authors have [93] obtained that the sign of neuroplasticity relies on the age after which learning starts in many realms of ability/skills attainment. However, the accomplishment known late in childhood or maturity/adulthood has been confirmed to be a constraint in studies intended to decide the connection amid brain plasticity and age of acquisition. As stated by [94], in the early years of life, while the brain is in an active, influential stage, early corporeal experiences have the capability to toughen the neural system. Neuroimaging analysis of language development focuses mainly on the alteration in brain assembly and function amid simultaneous and consecutive bilinguals where multilingualism/bilingualism is attained later. It also

explores the best phase in language growth and acquires a relationship amid final skill performance and age of acquisition [95].

The Nobel laureate Santiago Ramon Y Cajal suggested that mental action might bring structural variations in the assembly of the human brain in 1894. Authors [96] have realised that the mass of the human brain enlarges and becomes renormalized through the course of skill attainment. This is called the expansion-renormalization model, on the basis of which the learning-associated neural developments frequently follow a series of expansion, selection, and renormalization [97]. The model imagines an initial rush of grey matter structure, probably reflecting the progress of neural resources such as neurons, synapses, and glial cells, which are surveyed by a selection procedure working on this novel tissue. The changes in brain assembly have been conveyed during various periods, for instance, some months of juggling exercises, preparing for a medical exam, three-dimensional direction-finding training, foreign language attainment, etc.

A learner's age plays an essential role during the language acquisition process, as the language learned at an early age expands the possibility of being professional in a language. In the acquisition of the first language, the social surrounding of the baby/child/infant also plays a significant role. Furthermore, the nature of input language, learning age, and teaching strategies are likewise pivotal. Acquisition of a second language turns out to be comparatively hassle-free if it is acquired at a premature age (before puberty), since the brain has extra plasticity during this period, on top of a clear awareness of learning language received throughout the learning process, the first language. Developing vocabulary and grammar in a second language turns out to be relaxed if done concurrently or consecutively with L1 in early childhood. Alternatively, the attainment of sign language can be completed in later years of life because deaf-born children typically acquire it. Furthermore, the age aspect is concluded by the expertise in the attainment of sign language.

Moreover, skill growth, in addition to proficiency in learning, is as well dependent on age.

2.2 LANGUAGE COMPREHENSION

Language processing includes the orderly use of words intended to communicate emotions and thoughts among individuals. The essential purpose of this analysis is to inspect the language processing task by the brain, i.e., how the brain works and realises communication. Major language processing tasks are concentrated in the cerebral cortex.[97]

Different language tasks are managed in numerous areas of the brain; nevertheless, the two utmost prominent zones of the brain dedicated to language processing are Wernicke's area and Broca's area. The nerve fibres that attach the Broca's and Wernicke's areas are called arcuate fasciculus, that works as a changeover centre for speech and communication amongst the two parts.[99] In sentence comprehension, the main goal is to find the particular function of noun phrases (i.e., who is doing what?).

Studies [100] built on fMRI have done an affirmative factor study that authenticated a grammar-relevant and a verbal memory-relevant factor fundamental to the calculated performance. A voxel-based morphometric analysis of grey matter has exposed that while children's capability to assign specific roles is linked with grey matter probability (GMP) in the left inferior frontal gyrus and the left inferior temporal gyrus, the verbal employment of memory-related presentation is related to GMP in the left parietal operculum, encompassing into the posterior superior temporal gyrus. The morphometric analysis of grey matter based on voxels revealed that the children's capability to deploy thematic roles is linked with grey matter probability (GMP) in the left inferior temporal gyrus and the left inferior frontal

gyrus. The verbally employed memory performances are constantly associated with GMP in the left parietal operculum encompassing the posterior superior temporal gyrus. These areas are known to be involved differently in the composite procedure of sentence creation. The results of the research have recommended a direct correspondence amid GMP in language-related brain areas and differential intellectual abilities that lead to the course of sentence understanding.

EEG mu rhythms recognized at frontocentral electrodes are the leading cause of human motor cortical actions. They are controlled when aspirants achieve an act, or when they notice another's an accomplishment, or when they visualise acting an act. Time-frequency (TF) modulation of mu rhythms has also been observed in studies [101] while contributors read the notional language, perceptual language, and action language. The closing results have exposed that mu displacement at front-central locations is associated with action language rather than sensitive and abstract language. It also reveals that the beginning process occurs online primarily based on semantic mixing amongst several words in the sentence.

There is a nonstop and systemic upsurge in the action of brain areas together with the left superior temporal sulcus, inferior frontal gyrus, and left basal ganglia as a function of actual size in sentence comprehension, which additionally implies its connection with the calculation of semantic and syntactic composition. Experiments [102] on non-spoken sign language for deaf individuals demonstrate a similar network of language zones. The reading and sign language processing procedures produced similar effects on language assembly in the basal ganglia. Additionally, the influence remained stronger in all cortical language zones for written language than for sign language.

Assembled on neuroimaging information, literature [103] has acknowledged widespread overlay and language-specific cortical instigation between sign language grasp and signed action observation. Intersections in cortical activation are frequently found in the superior/ inferior parietal lobe and fusiform gyrus. Researchers in [104] have

additionally recognized that the left inferior frontal gyrus (IFG) and middle superior temporal gyrus (STG) in deaf inborn signers were further eagerly triggered by American Sign Language (ASL) rather than the indication asserting almost the same subject matter. At this point, Graph Theoretical Analysis (GTA) has been used as a supplementary viewpoint on analysis of activation on neuronal-based cognition analysis.

A study in [105] examines both the semantic and syntactic processing of innate as well as foreign-accented speech. A closer inspection of auditors who did not appropriately differentiate the foreign accent discloses ERP responses for grammatical and semantic mistakes. However, listeners who did not distinguish the foreign accent displayed any ERP outcomes for grammatical errors but expressed late negativity for the semantic errors. A study in [106] suggests that working the right hemisphere in the brain is vital in deciding the activation of incident knowledge elements that disrupt the linguistic framework. Throughout language grasp, the brain stimulates the fundamentals of event information that is semantically inconsistent in context.

In [107], the authors suggest that the overall prosodic info accessible during language understanding supports the creation of online estimation for forthcoming words and that, in any case for quantifier sentences, the understanding of spoken language might advance more incrementally than the comprehension through serial visual presentation (SVP) reading. The study establishes that the understanding of spoken sentences runs incrementally. The influence of truth-values over optimistic and negative quantifier sentences is similar. It also means that people use spoken language more efficiently to create online calculations about forthcoming words than written SVP input. The development of language understanding usually proceeds incrementally in the case of listening to natural speech rather than during the SVP reading ERP experiment along with N400 effects.

Authors in [108] discover that the cortical illustration of language understanding arises out to be extra-focused inside the superior and middle temporal areas in late

childhood and prior adolescence. Language skills and expertise are typically related to right hemispheric participation, mainly when listening to stories. The procedure of language understanding is represented further bilaterally than language creation, and a hemispheric detachment with left-hemispheric language construction is not unusual, even in healthy right-handed individuals.

In [109], the authors completed an experiment and discovered that the medial parietal lobe is associated with referential language processing. A detailed study of the fMRI-based investigation was conducted using a pairwise t-test of the entire cluster activation. This corroborated that every referential sub-condition was linked with further activation than the non-referential state.

The brain's cortical areas orthodoxly connected with language understanding are Wernicke's area and Broca's area. Eleven subjects of the Curtiss- Yamada Comprehensive Language Evaluation Receptive (CYCLE-R) have been reserved to achieve voxel-based lesion-symptom mapping (VLSM) based study of functional neuroimaging data that showed that lesions to five left hemisphere brain areas affected execution on the CYCLE-R, together with the posterior middle temporal gyrus and white matter underlying, the superior temporal sulcus, the anterior superior temporal gyrus and angular gyrus, mid frontal cortex in BA 46 and BA 47 of the inferior frontal gyrus. This study also projected that the middle temporal gyrus has a different domineering role in understanding at the word level. However, other areas play a more significant role at the level of the sentence.

2.3 BILINGUALISM:

A considerable share of the world population is multilingual/bilingual and uses more than one language smoothly. A bilingual individual can simply generate and use sentences that fit into two or more languages without any type of trouble. Henceforth, the capability to recognize and grasp two different language codes present in

one brain with slight conflict is a case of great theoretical and practical interest. There is an ongoing discussion on whether an early and continued acquaintance with one language makes differences in the shape of brain action throughout language processing.

Authors in [110] have experimented by including highly skilful Spanish/Catalan multilingual/bilinguals and Spanish monolinguals to make grammatical and semantic decisions in Spanish. Grammatical verdicts have displayed amplified activation in IFG (BA 45), occipital lobe (BA 18), fusiform gyrus (BA37), and in the superior parietal lobe (SPL, BA 7). For monolingual individuals, the cortical instigations were found in IFG (BA 45/46/9), SFG (BA 6), BA 8/32 and BA 18/23/37). This analysis proposes that bilinguals use added brain areas. Though, the effective working of these zones relies on the age of attainment, usage of language, task circumstances, kind of stimuli, cognitive/linguistics demands, and the close resemblance between the languages the bilinguals use.

Throughout the reading, listening, and speaking of bilingual languages, competencies in both languages remain active concurrently; however, only one language is straightforwardly needed. This equivalent activation enables the procedure of code swapping and code shifting through the course of language expressions. Research has stated that while bilinguals use visual words, they encounter language co-activation that forces them to engage in repressive control to limit race from the non-target language. Authors in [111] suggest that the level of language co-activation in bilingual oral word conception is primarily controlled by the total number of daily acquaintances with the non-target language. Furthermore, bilinguals who are slightly predisposed to cross-language instigation can show greater competence in overpowering intrusion via a non-linguistic task.

Conclusions in [112] propose that language function must be treated as an outcome of the association of a network of brain areas in place of considering only limited brain zones to be mixed up in that. The fMRI experiments and analysis suggested that

activation of BA 44 and BA45 was primarily left-lateralized in three tasks (receptive semantic expressive paradigm), representing functions in language, phonemes, and semantics. Though their right homolog zones were as well active, that could be because of their engagement in an administrative function, attention, or memory handling. In contrast, there was a superiority in the stimulation of BA 22 on the right. The authors argue that the effect of right BA22 on language processing is typical of a larger chain that includes the left IFG, inferior parietal lobule, and bilateral STG. Some explorers stated the right hemisphere as a phonological and semantic processing bench.

In [113], EEG-based experiments were used to complete two tasks: the semantic decision job and the reading job. The diverse wave maps of test 1 proposed that the variance between literal and novel metaphorical sentences had frontal dissemination. Late positive complex (LPC) amplitudes for novel metaphorical sentences become compact in both tests. However, this consequence was left-lateralized in experiment 2; it effectively offered a broader parietal dispersion in test 1.

In [114], authors planned an experiment based on repeated transcranial magnetic stimulation (rTMS) boosting lexical conclusion versus concreteness judgement responsibilities. The results give the sign of an initial motor cortex- TMS interfering protocol that creates a left-lateralized task and meaning explicit variation in response latencies, slowing up the dealing out of action-associated words related to faster intangible word responses. The outcomes powerfully suggest the causal participation of modality explicit circuits in language conception that offers a sophisticated order cognitive phenomenon that is based on elementary biological mechanisms.

In [115], the authors conducted an experiment grounded in near-infrared spectroscopy (NIRS) and used the job of hearing English sentences through six unlike speeches. The outcomes indicated that the Japanese subjects understood the speeches and some of the speech features, while amplitudes in specific frequency

ranges were amplified. The NIRS measurements additionally proposed that the advancement of amplitudes in high frequency ranges from 7000 to 8500 Hz positively increased the Oxy-Hb accumulation in most of the language areas (BA 45/44/22).

A study [116] confirms the harmony in the neural illustration of sentences between two languages. They recommended a model which successfully predicted Portuguese sentences by using brain positions and weightiness applied to neutrally plausible semantic features (NPSF) from a mapping established in English. The mapping between the neural instigation patterns and NPSF can be found from any set of participants in either language, which can successfully estimate the activation progress of new sentences made up of new words.

Consistent with the meta-linguistic sentence estimation model, if the mapping between semantics and brain instigation has harmony across languages, then a prognostic model should be used to acquire a mapping between the semantic characterization and activation outlines in one language and guess the activation outline in another language. A study built on the EEG experiment in [117] proposes a robust mapping between gamma-band fluctuations and semantic amalgamations; nevertheless, beta-band oscillations have a solid mapping with syntactical blending.

Authors in [118] present a functional and structural connectivity union to examine the topographic network anatomy sub-serving an intellectual function of attention. In this system pattern, direct communication between system nodes has been found by investigating the functional MRI time series with a multivariate technique of directed partial correlation (DPC). For an unswervingly affecting pair of nodes, an area-to-area probabilistic fibre trail based on diffusion tensor imaging information is directed to realise the maximum likely anatomical white matter fibre zone that facilitates the functional interactions. This mutual approach is helpful at two stages of acoustic conception: lower-level speech acuity and higher-level speech acknowledgment.

The learning in [119] proposed that the scope of findings concerning oscillating neural dynamics in the beta and gamma frequency scopes to sentence-level language understanding can be assumed to have a united description under the prognostic coding context. They anticipated that the beta action imitates the active care of the current Neurocognitive network (NCN) accountable for creating and illustrating a sentence-level connotation and the top-down spread of estimates grounded on that sense to lower stages of the processing ladder.

The learning in [120] exposed the route of progress in frontotemporal inactive state connectivity from 5-year-old children to grown-ups (adults) by investigating its association with the basic low-frequency BOLD fluctuations in language-associated areas. The conclusions of an inter-hemispheric connection of left and right IFG amid 5-year-old children along with the long-range connectivity from IFG to pSTS inside the left hemisphere of grown-ups/adults are reliable with the prior low-frequency fluctuation (LFF) study of fMRI data. It is shown that robust long-range connectivity in a grown person is directly linked to the developing trajectory of an appropriate discerning left-hemispheric language system. The outcome supports the notion that frontotemporal functional association inside the language system in the left hemisphere is important for dealing with syntactically composite sentences.

TABLE 2.1: Recent Research on Language Acquisition

Author	Task	Computation Method	Data Acquisition Method	Result
P. K. Kuhl et al., 2010 [98]	Prior-reading and language in the second, 3rd, fifth year of life	Alpha, beta, and gamma rhythms analysis.	EEG /E-MEG /fMRI /NIRS	Primary grasp of phonic components of a language needs learning in the societal background
R. I. Mayberry et.al.2011 [73]	Phonemic hand judgement, grammatical judgement, and American Sign Language	t-statistics	fMRI data	Activations left-lateralized outline was detected
I. Kovelman et al., 2012 [58]	Language task and Rhythm Task	t-test analysis	fNIRS (functional Near Infrared) imaging	The right hemisphere displayed a total of larger activation to the sluggish rhythmic stimuli, and the left hemisphere showed larger activation in relation to frequencies which are slower and faster
J. Martenson et al., 2012 [79]	Intense foreign language studies for three months	t-test on cortical thickness	MRI	Changes that are structural in the brain areas recognized for serving language functions throughout Attainment of foreign language

E. Partanen et al., 2017 [71]	Attainment of word form, linked with the development of reading	Event-related field (ERF) waveform analysis.	MEG	Children's brains appear more flexible than grownups in attaining new forms of a word. Correspondingly, the developing brain uses a network of left-lateralized perisylvian to achieve new word forms.
O. Kepinska et al., 2017 [87]	Grammar-learning task	Threshold-free cluster enhancement approach (TFCE), size of the cluster, z-value	fMRI	For functional connectivity, the appointment of networks of the brain throughout attainment of grammar is attached with an individual's learning capabilities for language
V. Havas et al., 2017 [75]	Primary structural learning in adults for a new language	Analysis of Variance (ANOVA) on reaction times (RTs)	EEG	Mature learners of language attain both new structural rules and new words
M. Walton et al., 2018 [55]	Valuations of Speeded Naming and Phonological Processing in children	TBSS (Tract Based Spatial Statistics).	DTI	Relationships detected in the left ventral paths. As well, young kids depend on an extensive network for processing of language

TABLE 2.2: Review of Language comprehension in the brain

Author	Task	Computation Method	Data Acquisition Method
N.F. Dronkers [121]	English sentence comprehension	t-test	fMRI/MRI
K. Lidzba [108]	Language comprehension (Beep Stories) and language production (Vowel Identification) tasks	Statistical analysis (t-tests).	fMRI
A. Fenger [100]	Normalised sentence understanding test to obtain participant's grammatical expertise	Morphometry analysis (cluster size, z-score) based on voxel.	MRI
A. G. Lewis [117]	understanding tasks of other languages and Semantic consistency in a brief tale.	beta and gamma oscillatory activity	EEG/MEG
P. Roman [110]	Semantic violation, grammatical violation and control condition	t-score	fMRI
I. Moreno [101]	Reading action language	TF (Time-frequency) analysis and ERP (Event-related potential) analysis	EEG
R. Metusalem [106]	Anticipated, Event-Unrelated, Event-Related words and conception question and answers are used	Numerous statistical studies were led on mean measures of ERP voltage	EEG
N.F. Dronkers [121]	English sentence comprehension	t-test	fMRI/MRI
Y. Yang [116]	English and Portuguese language reading	BOLD activation analysis	fMRI
S. Grey [105]	Foreign-accented and native-accented speech	Mean ERP amplitudes	EEG/ERP
L. Liu [122]	the observation of sign language by non-signers vs understanding of sign language by signers	Graph theoretical analysis (GTA)	fMRI
C. Brodbeck [109]	Visuo-spatial referential Areas 36	t-tests	EEG/MEG
P. Chen [111]	Pairs of words containing an Korean-English inter-linguistic homophone	ANOVAs with relatedness	Event-related potential (ERP)

N. Vukovic [114]	Action words, abstract words and pseudo words	ANOVA, along with the self-determining aspects of Job	repetitive transcranial magnetic stimulation (rTMS)
K. Inada [115]	English speech task	Enhanced amplitudes	Near-infrared spectroscopy system (NIRS)
A. Moreno [102]	Sign language paradigm and written French stimuli	Z-score	MRI/fMRI
R. Alemi [112]	ARN (Auditory Responsive Naming) paradigm, WP (Word Production) task, VSD (Visual Semantic Decision) paradigm	Group ICA	fMRI
K. Rataj [113]	Semantic decision and a reading task	t-test	EEG

2.4 DATA ACQUISITION AND ANALYSIS TECHNIQUES

The former decade has perceived swift expansions in non-intrusive methods that spot language processing in the human brain. They comprise of Magnetoencephalography (MEG), Electroencephalography (EEG)/ Event-related Potentials (ERPs), functional Magnetic Resonance Imaging (fMRI), structural/resting-state Magnetic Resonance Imaging (rsMRI), Near-Infrared Spectroscopy (NIRS), Positron emission tomography (PET), Diffusion Tensor Imaging (DTI), etc.

MAGNETIC RESONANCE IMAGING (MRI) can be merged with MEG and/or EEG, thus delivering static structural/anatomical pictures of the brain. Structural MRIs display the structural variances in brain sections across the lifespan and have presently been used to speculate the second language phonic learning

among adults [123]. Structural MRI readings of young children can be used to classify the scope of different brain shapes, and these readings are associated with language skills later in childhood [124]. If the structural MRI images are overlaid on the physiological action noticed by MEG or EEG, these procedures' spatial localization of brain actions can be enhanced.

FUNCTIONAL MAGNETIC RESONANCE IMAGING (fMRI) is an extensive neuroimaging method in adults, bringing high spatial-resolution plots of neuronal action across the whole brain [125]. fMRI finds variations in blood oxygenation in response to neural activation. However, neural activities occur in milliseconds; the blood oxygenation fluctuations caused by them can show an effect over quite a few seconds, and hence limit the temporal resolution of fMRI. fMRI analysis helps us to determine the exact localization of brain activity. Some necessary fMRI studies have positively recognized remarkable resemblances in the structures receptive to language among children/infants and adults [126], [127].

ELECTROENCEPHALOGRAPHY (EEG) is an electrophysiological monitoring technique used to find the brain's electrical response. It is classically non-intrusive with the electrodes (conductors) positioned along the scalp, though intrusive electrodes are infrequently used, e.g., in electrocorticography. EEG computes the voltage disparities which are the result of ionic current inside the neurons of the brain. In a clinical context, EEG [128] is referred to as the copy of the brain's usual electrical movement from numerous electrodes positioned on the scalp during a certain period of time.

EVENT-RELATED POTENTIALS (ERPs) are widely used for the deep study of speech and linguistic processing among babies and young kids [129][130][99]. ERPs are a portion of EEG which manages the electrical activity that is time-sealed in the exhibition course of an explicit sensory stimulus (such as syllables or words) or an intellectual process (acknowledgment of a semantic heresy in a sentence or a phrase). By introducing sensors on a child's scalp, the movement of neural network

shooting in a harmonised fashion can be found, and variations of the voltage taking place as a function of cortical neural activity can be spotted.

MAGNETOENCEPHALOGRAPHY (MEG) is also a vital brain imaging technology that tracks human brain action through temporal resolutions. The SQUID (superconducting quantum interference device) sensors inside the MEG helmet evaluate the small magnetic fields associated with electrical currents formed by the brain while carrying out sensory, motor, and cognitive errands. MEG allows the precise localization of the neural currents responsible for creating the magnetic fields [131], [132] used in new head tracking approaches and MEG to prompt phonic insight in new-borns and infants in the early years of life.

NEAR-INFRARED SPECTROSCOPY (NIRS) is a technique that can also be used to find cerebral hemodynamic reactions concerning neural movement. It efficiently uses light absorption that is sensitive to the accumulation of haemoglobin to precisely calculate the procedure of brain activation [133]. It computes the modifications in blood oxy- and deoxy-haemoglobin accumulation in the brain with the entire blood volume disparities in several areas of the cerebral cortex using near-infrared light. By using the NIRS technique, the brain activity in explicit brain areas can be efficiently measured by nonstop keeping an eye on the blood haemoglobin level.

DIFFUSION TENSOR IMAGING (DTI) is an MRI-based neuroimaging technique that evaluates the position, alignment, and anisotropy of the brain's white matter zones [134].

POSITRON EMISSION TOMOGRAPHY (PET) computes the secretions from metabolically agitated radioactive chemicals inserted into the blood [135]. The computer processes the information released to produce multi-dimensional pictures of the chemicals dispersed all over the brain.

2.5 DATA ANALYSIS

Functional magnetic resonance imaging (fMRI) is a safe and non-intrusive technique to measure brain activity by using the signal discrepancies related to brain activity. This method has been developed as a pervasive technique in rudimentary clinical and intellectual neuroscience. This is a clever technique to measure the differences in metabolism that happen in the active areas of the brain. The fMRI info can be efficiently treated to classify the areas of the brain included in the operations and to conclude the variations that happen in brain actions due to a brain lesion.

2.5.1 STATISTICAL ANALYSIS METHODS

Pre-processing steps can enhance the excellence of fMRI imaginings. Once the pre-processing is done, the statistical analytic technique can finish the deduction of active voxels by stimuli. fMRI studies primarily deal with the interrelation of hemodynamic response function and stimulation. The local potency discrepancies in the images are called activation. These approaches are distinguished into two wide-ranging types: the univariate methods (hypothesis testing methods) and the multivariate methods (exploratory methods).

2.5.1.1 THE UNIVARIATE METHODS

The simplest of all data analysis models, the univariate analysis considers only one variable in calculation. It defines which voxels can be considered activated by analysing the signal models. This permits the parameterization of the reaction and the approximation of the model parameters. The approach comprises the Generalised Linear Model (GLM) [136].

2.5.1.2 MULTIVARIATE METHODS

Multivariate analysis takes a whole host of variables into consideration. This makes it a complicated as well as essential tool. The greatest virtue of such a model is that it considers as many factors into consideration as possible. This has been functional in fMRI readings where information is acquired from a data set possessing former facts of experiential circumstances. Some of the organisational properties, like resemblance measures, independence, decorrelation, etc., are the basis to differentiate between vital features existing in the dataset. Contrasting to the univariate approaches that convey voxel-wise statistical analysis, the multivariate methods suggest statistical interpretations of the brain to designate the brain reactions in terms of spatial patterns [137]. The multivariate approach covers Principal Component Analysis (PCA), Independent Component Analysis (ICA), and Multi-Voxel Pattern Analysis (MVPA). In MVPA, feature selection is done through approaches that choose the voxels that consume different mental jobs. There are different approaches for the feature selection, and these are the t-test, f-score, ANOVA, the recursive feature evaluation methods (RFE), Voxel activation criteria, and SVM (support vector machines) [138].

2.6 NEUROIMAGING SOFTWARE TOOLS

Software means are typically used in the study and visualisation of neuroimages to study the assembly and working of the brain. Some of the widespread neuroimaging software means are Brain Suite [139], AFNI (Analysis of Functional Neuro-Images), EEGLAB, Free Surfer, CONN (Functional Connectivity Toolbox), FSL, and SPM (Statistical parametric mapping), etc.

TABLE 2.3: Tools for Neuro-data analysis

Tool Name	Availability	Input Data	Results
Slicer (3D Slicer) [140]	Open source and free software	Image	Image computing and Scientific visualisation
AFNI (Analysis of Functional Neuro- Images) [141]	Open-source Environment	functional MRI data	Mapping the activity of the human brain
CONN [142]	MATLAB based cross-platform imaging software	Resting-state MRI data and fMRI	Computation, analysis, and display
EEGNET [143]	Data from MEG, EEG, and some signals (electrophysiological)	frequency /time analysis, ICA,	artefact rejection in addition to numerous data visualisation methods.
Free Surfer [144]	Brain imaging software package	MRI scan data	Enables imagining of functional areas of the exceedingly pleated cerebral cortex; Functional mapping of brain
SPM (Statistical parametric mapping) [145]	Toolbox based on MATLAB	PET or fMRI	Statistical study
FSL (FMRIB Software Library) [146]	software library (available freely)	structural, functional, and diffusion MRI brain imaging data	Statistical study and Image
NITRC (Neuroimaging Informatics Tools and Resources Clearinghouse) [147]	Computational neuroscience resources and tools	PET/SPECT, MR, EEG/MEG, CT, optical imaging	Enabling connections among developers and researchers

2.7 READING AND WRITING IN THE BRAIN

Reading is translating some group of carved symbols with a predefined meaning (for communication). The capability to recognize, create, and use written text is

very significant for daily life in this modern society. The ability to read is not an inborn feature, but language, particularly communicating ability (by singing or speech/dialog), is a natural feature. [148][149]. David Olson (1996) states the possessions of literateness in various diverse features of perception and linguistic routine to prove that learning to read is instantaneous with the detection of well-organised language assemblies. Learning to read correspondingly allows the apparatuses to criticise grammaticality grounded on inscribed signs instead of denoting acoustic understanding, refining syntactic decision responsibilities. [149],[150]. A model regarding reading development shows data from studies of offspring. It suggests that they have to go through wide-ranging progressive phases for the sake of progress. Although not the only probable model for the development of reading, and possibly inept in the case of bilingualism, the key stages of learning give a suitable and significant outline for discerning reading progress and will continue to be hand-me-down as an origin for more research. She suggests that while learning an alphabetic language, children start as logographic readers, then move on to beginner and mature alphabetic reading, and finally improve to orthographically fluent reading. [151][152][153][154][155]. Even though each stage of this progressive development is more persuasive, logogrammatic reading includes acknowledging textual content and letters as significant essentials and mapping explicit sounds with accurate signs. For labelling words in semantic reminiscence, logographic reading is accomplished via distinguishing relevant words' features such as logo colours, letter forms, and different random pictorial indicators. Due to the fact that word identity is dependent on these symbols, the section is called visual-cue reading at this stage [156]. Alphabetic readers identify those words, which are complete pictorial signs and are made up of fundamental letters resembling specific sounds. This stage may be separated into two subphases of progress: first -> beginner and second -> mature reading. Beginner alphabetic readers depend upon reading based on phonetic features and termed phonetic-cue reading [156][157], wherein firm relevant words' phonetic features are cast-off as memory cues. The word's preliminary and/or very last letters and their equivalent phonemes are frequently used, as an instance, 'm' and 'k' in 'milk'. Thus,

letters are immediately associated with the reader's mental lexicons' pronunciation. Alphabetic readers, who are considered to be mature, start practising phonological recoding for the sake of recognizing words: they use implied instructions for inducing reliable associations among oral phonemes and written letters and merge those elements into a complete word, a manner referred to as cipher reading [158]. The aptitude turns progressively extra smooth with exercise, ever-converting from gradual, verbal "sounding-out" to the fast, internal merger of phonemes [159]. Tactics to decipher similar development with greater exposure for printing: readers start with chronological deciphering, wherein single graphemes indicate that there is a single morpheme, and are eventually capable of enforcing hierarchical deciphering, wherein graphemes tag following or preceding phonemes (inclusive of the 'i' within the "city" and the 'e' in "cell", each marking the previous 'c' as an 's') [160]. Phonological recoding, finally, is used for launching words in an individual's memory and permitting them to distinguish words by sight. Orthographic readers bear to apply sight-word techniques. However, their recoding capabilities experience "progressive lexicalization" [151]. Readers learn merging [155] grapheme-phoneme forms which happen among different words, aiding them to interpret words built on bigger elements than earlier, which include morphemes and letter clusters. Practice through reading and gradually automating the phonemic recoding of these shared letterforms upsurges recoding productivity.

Key predictors of reading accomplishments are Phonological Awareness and Linguistic Consistency. PA (Phonological awareness) is the awareness of and skill to govern sounds inside words[?]. PA (Phonological awareness) comprises both phonological blend and analysis, that is, the capability of blending different phonemes into consistent words and also breaking words into integral fragments, respectively. However, these two skills are involute with each other [161]. It has been shown that reading progress can be predicted by PA development. Studies illustrate that pre-literate phonological education progresses, i.e. reading performance and analysing disabilities, are linked together with phonological issues [162]. Limited PA ability hinders

later attainment of word recognition expertise and grapheme-phoneme correspondence rules [163]. Overall reading performance inside the initial years of gaining knowledge is linked with phonological skills; nonetheless, this connotation drops in the later elementary school grades. A researcher in his studies discovered that variations in reading attainment amongst Dutch students later on the completion of grade 1 may be defined through distinctive reading talents in place of phonological capability. Though, phonological impact on reading attainment in American children becomes more extended, until grade four. That is probable because of the variance in grapheme-phoneme uniformity between Dutch and English: Dutch has a far steadier, or obvious, orthography than English, which is relatively unbalanced [164]. Consequently, it is discovered that by the completion of grade 1, German and Dutch kids displayed eighty five percent precision in analysing nonwords - and Swedish youngsters 90 percent precision - even as English readers were slow pointedly behindhand at 50 percent precision and did not catch up until grade four [165].

Many studies have been based on the cognitive approaches underlying reading talent as well as understanding, and various theories have been proposed. Even though there are multiple models in the literature, and each of these models has a somewhat different preference to conceptual context (top-down) and to visual input (bottom-up). The most famous models are the DRC (dual-route cascaded) and connectionist models. There have been special versions on connectionist models since it became evolved. However, the original model was put forward in 1989; that is, based on visual word recognition and pronunciation [166]. The model is created upon the principle of PDP (parallel distributed processing). In PDP, the processing is dispersed throughout a community of working elements and is led in parallel instead of chronologically. It suggests a 3-layer model which includes orthographic and phonological units and an intermingled stage of "hidden" elements that work simplest as mediators and do no longer receive exogenic input provided or produce output. In this model, lexical selection tasks (dividing stimuli into words and nonwords) are

achieved with the aid of studying activation designs: real phrases have greater identifiable orthographic and phonological designs than nonwords. This version is limited to monosyllabic words (nonetheless, this has recently been stretched to polysyllabic words [167]) and mightn't calculate syllabic strain nor record the results of semantic priming or context. The DRC (dual-route cascaded model) is a computational version that plays two duties: reading aloud and word recognition (lexical decision) [168][169]. Though the version is restricted only to words that are monosyllabic, it has no approach for computing lexical strain, and its functioning at the lexical selection assignment is straightforward at its finest [168].

While reading a written word/letter/sentence/symbol, eye movements are considered vital indicators of intellectual processing. While reading text or looking at objects, we scan a field of view, and our eyes flutter to and fro in swift actions known as saccades. The fluctuations have an inactiveness of 150 to 175 ms. Cognitive processing concentrates upon the pictorial info occupied during the 200-300ms fixation amid saccades (as the speed of eye motion could be very fast for any sort of visual info to be engaged in for the duration of a saccade itself) [170]. In studies, it has been found that overall average fixations are much longer while we read aloud or comply with alongside an audio track in comparison to whilst we read silently. This happens because as eyes flow faster than the voice, so there may be a need for regular pauses so that it is able to permit the voice to catch up [171]. Fixations also depend on the type of word that is being read. Content phrases are fixated approx. eighty five percent of the time, whilst function words (together with 'the' and 'and') are most effectively fixed approx. thirty five percent of the time. [172], [173]. It has been shown that word length also affects fixation probability (words having 2 to 3 letters are fixated approx. 25 percent of the period, while words containing 8 or more than 8 letters are approximately at all times fixated upon). Subsequently, those words which occur more frequently have more likelihood to be left out, as are words whose viable denotations are controlled by way of the context of the sentence. [174]. It has been stated that commonly improved complication of

text consequences in longer fixation instances, shorter onward saccades, and extra recurrent regressions. [173].

For efficient reading, perceptual span is also an important and standard factor. Perceptual span is defined as the total size of the visual field that acquires information at a glance. Readers who study or use alphabetic languages study from left-to-right order, and they display a perceptual span with limitations of three to four letters to the left from the current word and fourteen to fifteen letters to the right from the current word. [175]. The start of the current word defines the left boundary [175], whereas the right boundary is properly described more via the overall number of letters present. [176]. This irregularity is overturned in languages wherein readers read in right-to-left order, as in, for an instance, Hebrew. The perceptual span isn't much like the vicinity wherein words may be truly diagnosed; nevertheless, it can be shown as, in alphabetical languages, the word identity span is only seven to eight letters from the fixation point within the track of analysis, not the entire 15-letter span of general belief. [176], [177]. The most beneficial area for fixation has been recognized, and it's near the middle of a word. The most suitable viewing position is the site of nominal identification delay; the further from this vicinity fixation happens, the much more likely a re-fixation may be. [178].

In language processing, the left hemisphere is active. The left frontal cortex contains the brain's busiest part that shows activation during the reading process. The frontal operculum and the posterior superior, middle temporal, and inferior temporal gyri are the most activated areas. [179]. In various sub-methods of reading, many cortical areas are concerned. Nevertheless, the visual word form area and the frontal operculum are the most familiar localization and function.

The frontal operculum is placed within Broca's vicinity at the ventral surface of Brodmann's 44 and 45 within the left inferior frontal gyrus and it is engaged particularly in reading courses. It shows unwavering, more prominent activation while

reading pronounceable nonwords aloud concerning actual words, and hence this suggests that it has a role in phonological processing. While dealing with words with little grapheme-phoneme consistency and low-frequency, it is active. [179]. Additionally, lesioned patients struggle to reply to low-frequency words with lower spelling-sound consistency than high-consistency, low-frequency words unswerving with primary outcomes. [179].

The visible word form area (VWFA) displays activation in reply to visible word stimuli and may be identified in nearly any literate individual. It's a left-lateralized inferotemporal vicinity of the fusiform cortex. Its activation is not dependent upon spatial (3-D) position, size, font, or case of offered words and is explicit to linguistic input. [180]. Activation also doesn't vary; relying on stimulus presentation to the left or right field of vision: visual word form info is engaged in each instance to the VWFA. [181]. The visible word form area (VWFA) presents a reduced amount of activation with visually alike consonant strings comprising unlawful letter groupings. But interestingly, it is likewise activated by actual words and through readable pseudowords. Its reaction outline, is for that reason, inhibited through the orthographic guidelines of the reader's local language. [180]. The VWFA is likewise the anticipated basis of a regarded ERP (event-related potential) component. An ERP is a pointy negative electric spike over left inferior temporal electrodes at one hundred eighty to two hundred ms after the appearance of a word stimulus. [181].

Reading and writing are quite new human signs of progress that were initiated numerous thousand years back. [182]. These skills (reading and writing) needed to be made upon an already existing neural system, as the human brain did not change to back these abilities [183]. In the neuroscience literature, these structures' particular nature and position have been the basis of debate. [184],[185]. The scope to which overlapping intellectual and neural processes mediate reading and writing has been a specific issue in this discussion. [186],[187]. Both (reading and writing) are complicated communication abilities that involve the specific organisation

of several componential methods. Given their deeply entangled content, progress, and usage, instinctively, one could expect that a few centre facets of those abilities could overlap. [188]. Initial studies by Dejerine and many other researchers emphasised the significance of the left posterior cortex in each writing as well as reading. Dejerine (1891)[189] stated that for both reading and writing, the left angular gyrus is an important word, and this was concluded in his study of Mr. C's case. Mr. C. had, first of all, a loss in reading without aphasia (i.e., pure alexia) tailed off 5 years later with the aid of an unexpected beginning of a loss in writing (agraphia) [183],[189],[190],[191]. Based on the study of the case, it was concluded that lesions linked with alexia without agraphia (i.e., pure alexia) are normally localised to the left posterior inferior temporal cortex.[183]. In comparison, lesion spots linked with agraphia said within the literature had been quite diverse [192],[188] and comprise of left inferior parieto-occipital cortex [193],[194], left posterior parietal cortex [195], left posterior parieto-temporal cortex [196],[197], left posterior middle frontal cortex [198],[199], as well as subcortical regions [200],[201]. Up-to-date, imaging has empowered further precise evaluation of lesions linked with specific writing and reading impairments, at the side of the structures lively in people in good health in the course of the implementation of those abilities. [183],[202],[203],[204],[205],[181]. In the case of reading, numerous functional neuroimaging and lesion research has indicated the crucial significance of part of the left ventral temporal occipital cortex acknowledged as the VWFA (visible word form area). [183], [184],[206],[207]. This zone forms a fundamental part of a bigger reading system proposed to include the occipital cortex for processing of written/printed features, the posterior parietal cortex for serial reading and top-down attention, the left inferior frontal insular regions for oral reading, and the anterior left temporal cortex for processing meaning. [88],[208],[7],[209]. Extra areas have additionally been implicated, together with the superior temporal sulcus (bilaterally), left posterior superior temporal gyrus, right superior frontal gyrus, precentral gyrus (bilaterally), and the cerebellum. [209],[205].

In the modern age, very little devotion has been dedicated to figuring out the brain

networks related to writing (mentioned as the spelling within the literature, relying on the assignment). [186],[188], [210],[211],[212]. A current meta-study of eleven functional imaging research stated that the most regular areas linked with writing have been the inferior frontal cortex, left inferior temporal cortex, the posterior intraparietal sulcus, and fusiform gyrus, (however not the angular gyrus, which has been frequently involved in lesion research).[213]. One more meta-study by Planton stated that the left intraparietal sulcus was a dependable location linked with writing. However, the right cerebellum and left middle frontal gyrus have been additionally determined to be concerned.[214]. As in step with the reading literature, it isn't always clear with functional neuroimaging research which of those areas inside the reading system (community) are mostly needed to the method of writing and which of those are simply engaged as a part of the complete action.

Mostly associated with present-day studies, a handful of researchers have attempted to recognize neural sources of both writing and reading in a person. In a study of a person having a brain tumour who underwent surgical resection of the anterior left and middle fusiform gyrus and adjoining areas of the inferior temporal gyrus [215], he eventually showed shortfalls in orthographic processing via reading (usually with reduced pace) and spelling (mistakes like writing 'tipe' as opposed to 'type'). Philipose, in 2007, analysed perfusion- and diffusion-based MRI of a big cluster of acute strokes in four patients for classifying mind areas perilous for written spelling and (oral) reading of pseudo-words and words (which may be pronounceable). [216]. It was determined that losses in writing and studying were highly linked with infarctions and/or hypoperfusion inside the posterior superior temporal cortex, left posterior temporal cortex (Brodmann's vicinity (BA) 37), and inferior parietal cortex (normally BA 40, however, as well as BA 39 extra weakly). The mentioned areas have been involved in the writing and reading of each pseudo-words and words.

The most crucial area for reading is the left occipitotemporal cortex, situated at the boundary of the fusiform and lingual gyri. Different ultimately considerable

voxels for reading comprise adjoining white matter (the optic radiations) and a handful of voxels inside the inferior parietal cortex [217]. The most difficult zones used for writing are mainly positioned inside the left inferior parietal cortex, that is, the supramarginal gyrus. There are also essential voxels within the superior temporal cortex consisting of the angular gyrus, Heschel's gyrus, the mid frontal cortex, underlying white matter, and the sensorimotor cortex [217].

Functional imaging analysis in healthy individuals has proposed some overlay inside the neural connections of writing and reading. Rapp Dufor and Lipka stated that the left inferior frontal gyrus becomes triggered further to the left mid-fusiform gyrus in healthy individuals throughout writing and reading [210],[218]. In the case of reading for single-word, substantial voxels are situated mainly inside the left temporal occipital cortex and white matter underlying, along with little extension in the lateral temporal, left posterior, and inferior parietal cortex. Sentence-level reading is similarly linked with the lateral temporal cortex and the left temporo-occipital cortex. However there is an additional anterior extension that includes substantial voxels within the more advanced part of the temporal pole, posterior and inferior, and the white matter next to insula.[217].

Most important voxels for mutually sentence-level and single-word writing are positioned mostly inside the left supramarginal gyrus and white matter underlying this. In the case of single-word writing, most of the crucial voxels are situated inside the left supramarginal gyrus together with a few extensions within the Heschel's gyrus, postcentral gyrus, and angular gyrus.[217]. The zones linked with sentence-level writing is just like single-word writing, together with a vast overlapping zone mainly within the left supramarginal gyrus, in addition to voxels inside the Heschel's gyrus and postcentral gyrus, nevertheless exclusively are involved white matter areas consistent with the corona radiata, posterior limb of the internal capsule, and external capsule. A small percent of essential voxels additionally exist inside the underlying

white matter of the parietal cortex, consistent with the region of the dorsal posterior part of the superior longitudinal fasciculus.[217].

Purcell, Eden, and Napoli Ello concluded that both reading and writing depend on shared lexical illustrations in the left occipitotemporal cortex. [219]. That study found that writing words (via typing the word) exclusively triggered the supra-marginal gyrus, inferior frontal gyrus, superior parietal lobe, fusiform gyrus, and middle superior frontal gyrus. A coexisting study of writing and reading uncovered an intersection in the occipitotemporal cortex and left inferior frontal gyrus, organised with an area in the occipitotemporal cortex lateral and superior to the visual word form area (VWFA) exclusively linked with writing.

2.8 PERFORMANCE METRICS

CONFUSION MATRIX: A confusion matrix is a valuable tool for analysing how well your classifier can recognize images of different classes

TABLE 2.4: Performance Measure

	Predicted Class		
	Positive	Negative	Total
Positive	TP	FN	P
Negative	FP	TN	N

The performance of the classifiers is measured by the quantity of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). Where TP (True Positive) is the number of positive instances that are classified as positive, FP (False Positive) is the number of negative instances that are classified as positive, TN (True Negative) is the number of negative instances that are classified as negative, and FN (False Negative) is the number of positive instances that are classified as negative. By using these quantities, standard accuracy, sensitivity, specificity, precision, MCC, and ROC area performance measures are defined as:

PRECISION: Precision is defined as the proportion of instances classified as positive that are really positive.

$$Precision = \frac{TP}{(TP + FP)} \quad (2.1)$$

RECALL: Recall is defined as the proportion of positive instances that are correctly classified as positive.

$$Recall(Classifier) = \frac{TP}{(TP + FN)} \quad (2.2)$$

ACCURACY: Accuracy is defined as the proportion of correctly classified instances.

$$Accuracy = \frac{(TP + TN)}{(TP + FN + FP + TN)} \quad (2.3)$$

FP RATE: It is the probability that a classifier produces erroneous results as positive results for negative instances.

$$FPRate = \frac{FP}{(FP + TN)} \quad (2.4)$$

F-MEASURE: This measure is approximately the average of the two when they are close. The two measures are sometimes used together in the F1 Score (or f-measure) to provide a single measurement for a system.

$$F - Measure = \frac{2(Precision \times Recall)}{(Precision + Recall)} \quad (2.5)$$

MATTHEW’S CORRELATION COEFFICIENT (MCC): The MCC is a balanced measure that considers both true and false positives and negatives. The MCC can be obtained as

$$MCC = \frac{((TP)(TN) - (FP)(FN))}{\sqrt{([TP + FP][TP + FN][TN + FP][TN + FN])}} \quad (2.6)$$

RECEIVER OPERATING CHARACTERISTICS (ROC): The ROC is a graph that shows the performance of a classifier by plotting the TP rate versus FP rate at various threshold settings. The area under the ROC curve (AUC) of a classifier is the probability that the classifier ranks a randomly chosen positive instance higher than a randomly chosen negative instance.

2.9 CONCLUSIONS

In this chapter, the theoretical backgrounds related to language processing in the brain and literature review are presented. At first, a brief overview of language acquisition and language comprehension was presented. Also, reading and writing in the brain are discussed in subsequent sections of these chapters. Further, in this chapter, a literature survey of prominent approaches for language acquisition, comprehension, tools, and techniques used in neurolinguistics is also conducted.