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American Sign Language (ASL): Linguistically and Cognitively - Why Deaf People Should Learn ASL & Learn it Early

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American Sign Language (ASL): Linguistically and Cognitively
Why Deaf people should learn ASL & learn it early

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Abstract

This thesis presents data supporting the value of including American Sign Language (ASL) in the education of Deaf people. Historically, Deaf education has not fully included or has excluded ASL in an effort to focus on English due to a belief that ASL hinders learning English. ASL must fit within the definition of language with unique linguistic features for its inclusion in language education. Plasticity of the brain lends itself to the ability for language processing networks to form based on language experience. Deaf people can fully access visual language versus auditory language. Therefore, acquiring ASL early in life, during the critical period, allows Deaf people to establish a strong language foundation, upon which they could also learn English. Late language learning alters neural networking, which can lessen one's ability to process language and use other cognitive processes. Despite differing modalities, ASL and English engage similar neural networks, called language regions. Consequently, ASL follows similar cognitive processes to English, which supports the value of ASL as a language fully accessible for Deaf people to acquire and use. Learning ASL prepares Deaf people for success in communication, learning English, and other endeavors in life because of effective neural networking.

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Introduction to Language

History of American Sign Language (ASL)

The history of American Sign Language (ASL) in the United States of America began in 1817 with the establishment of the first American school for the Deaf (Leigh et al., 2016a). In some literature, the use of d/Deaf includes people who have clinical deafness (deaf) and those who also identify with the Deaf community (Deaf). For the purpose of this thesis, the use of the word Deaf includes both groups. Some teachers of the Deaf followed the philosophy of "[using] signing to bridge to English, and their efforts [were] the precursors to ASL/English bilingualism" (Leigh et al., 2016a, p. 92). Many people, however, viewed signing as a type of mime serving as a lesser substitute for spoken language (Chamot, 2003).

In 1880, the International Congress of Milan, banned the use of sign language in Deaf education. During this time, educators employed the "oralist" method by requiring Deaf students to lipread and speak, and any student who signed received a physical punishment (Chamot, 2003). Alexander Graham Bell (AGB), the famous inventor of the telephone, advocated to eradicate Deaf culture and deafness. AGB's idea of eugenics led him to present a *Memoir upon the Formation of a Deaf Variety of the Human Race*, in which he proposed a law to prevent marriage between two deaf people (Van Cleve & Crouch, 1989).

The United States recognized the ban on ASL in Deaf education until the 1950s-1960s. Considering the hostility against Deaf people, even with the release of the ban, the curriculum for Deaf students still emphasized spoken and written English. Educators prohibited younger students from using ASL before learning English (Leigh et al., 2016a). Around this time, an American linguist, William Stokoe, worked as an English professor at Gallaudet University, the famous Deaf university in Washington, D.C. While there, the

National Science Foundation offered Stokoe a grant for research to discover if ASL had linguistic features (Chamot, 2003). New research and the reimplementation of ASL in Deaf students' curriculum led to the proposal of an important question regarding ASL's classification as a real language.

Defining Language

According to Dan Jurafsky, a professor of linguistics at Stanford University, "understanding why and how languages differ tells about the range of what is human" (Shashkevich, 2019). Shashkevich (2019) defines language as "the primary tool for expression and communication" including semantics, syntax, phonetics, as well as social and psychological aspects. Professor Jurafsky added that the importance of studying languages other than one's own helps one understand the foundation of humans' unique way of communicating with one another.

According to a statement from the anthropology department at Palomar College, language means more than communication alone; language "influences [one's] culture and even [one's] thought process" (Moore, 2021), meaning language shapes how a person lives in, experiences, and perceives the world. Oxford Languages (2023) defines language as follows: the principal method of human communication, consisting of words used in a structured and conventional way and conveyed by speech, writing, or gesture. This definition includes the modes of spoken (speech), written, and signed (gesture) language.

Linguists analyze the structure and science behind language, called linguistics, by studying the phonological, morphological, syntactic, semantic, and pragmatic aspects of language. These aspects cover the details associated with the form, meaning, and use of a

language by the users of that language. Each language has its own established parameters which govern its grammatical features and production.

Explanation of Linguistics

Language must consist of a governed set of symbols. Symbols have a kind, either spoken, written, signed, or drawn, and a form, either arbitrary or iconic. A language produces infinite possibilities for the number of sentences within a domain unrestricted by time, which allows introduction of new information. Sentences have relationships, and one sentence could have more than one meaning. For example, “I’m going to the store” can simply state that one plans to go to the store or can be a request to another to join the one going to the store.

Language changes over time while the users monitor their use of the language and learn from other users to self-correct and expand their language use. Variations in language also occur within certain regional dialects. Connected to the understanding of these basics of language, the field of linguistics has various major subfields, including but not limited to phonology, morphology, syntax, semantics, neurolinguistics, and sociolinguistics. In order for a language to rightfully receive the title of a language, it must have all features that make a language a unique communication system. The following linguistic concepts come from the lectures of professor Robert (Bob) Moore (2022), using information from Valli et al. (2011), with original analysis and examples.

Linguists define phonology as the study of the smallest contrastive units of language. In spoken language, phoneticists study the structure and organization of sounds. In American Sign Language (ASL), the study focuses on the structure and organization of signs (the

contrastive units). Signs have five (5) parameters: handshape, orientation, location, movement, and nonmanual markers/signals (NMM/NMS). Unmarked handshapes account for the most common in American Sign Language (ASL) compared to the more difficult and thus less common marked handshape formation.

Figure 1.1: Unmarked Handshapes: B, O, C, A, S, 1, 5 (Conlin-Luippold, 2015)

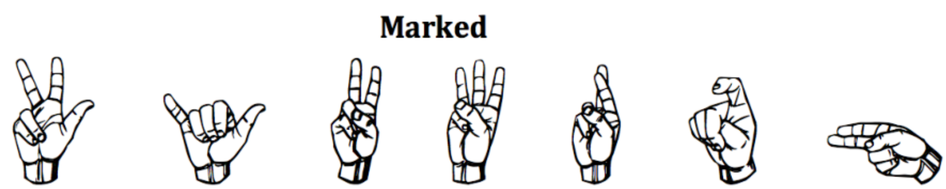


Figure 1.2: Marked Handshapes: 3, Y, 2/V, W, R, X, H (Conlin-Luippold, 2015)

As shown in Figures 1.1 & 1.2, the seven unmarked handshapes (B, O, C, A, S, 1, 5) do not require the variety of bending the joints of the fingers nor the variety in wrist placement, also known as the orientation parameter of the sign (i.e. X and H versus the other handshapes shown). More marked handshapes exist, but the seven unmarked handshapes form the basis of most signs. Most handshapes come from the handshapes of letters or numbers (as shown above); therefore, the labels for those handshapes match the letters or numbers. Location of the sign includes the place of articulation or point of contact, such as

on/at the head, torso, hand, arm, or in space. Some signs occur in space and some contact other parts of the body.

Movement of the sign includes considerations of local, palm, and arm movements, proximity, path movement, and handedness. Local, palm, and arm movements relate to handshape and orientation. Proximity deals with whether the sign physically contacts the body in some way or only has close proximity without contact. Path movement shows how a sign can move from one distinct location to another, adding modifying movements (i.e. circle, twist, etc.). Handedness refers to the use of one's dominant versus nondominant hand. Certain signs use two hands in which the two hands will have differing parameters to create one sign.

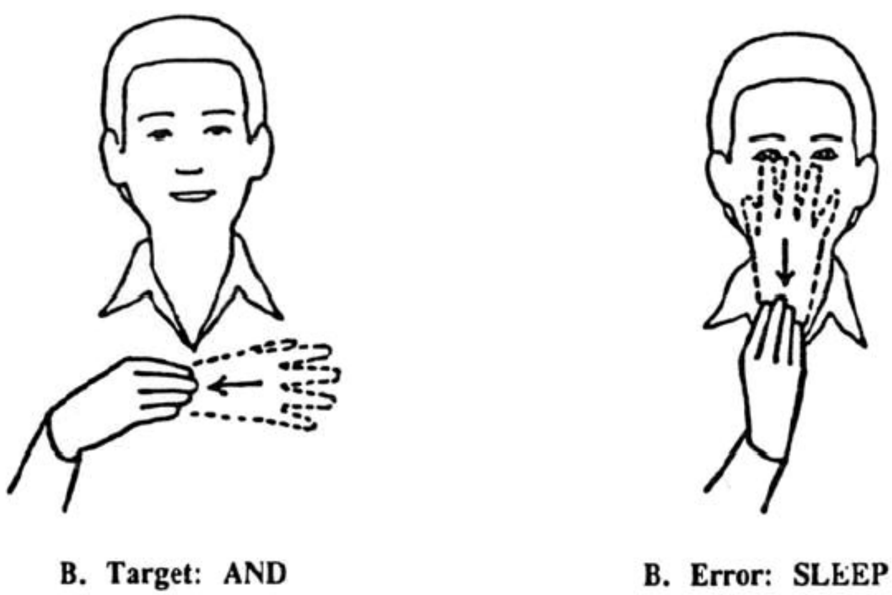


Figure 1.3: Example of Signs for Parameter Importance

(https://www.researchgate.net/figure/Example-of-a-phonological-substitution-error-produced-when-a-signer-was-shadowing-the_fig1_237552712)

As shown in Figure 1.3, while the signs of AND and SLEEP share handshape and movement, the orientation and location differ, resulting in different signs and different meanings and parts of speech. A nonmanual markers/signal (NMM/NMS) serves as a parameter for signs, but not all signs have a designated NMM. For example, negated signs use a head shake and question sentences have specific eyebrow markers. Wh-word questions use furrowed brows, while yes-no and rhetorical questions use raised eyebrows.

The morphology branch of linguistics includes the smallest meaningful parts of language. In ASL, morphologists study the inflectional and derivational process of sign parts. Inflection adds information to a verb by showing subject-object verb agreement or the frequency of action. Subject-object verb agreement moves from the established location of the subject to the object. Repetition of the verb shows repetition of the action and circular, continuous signing of the verb represents continuously or effortfully performing the verb. Derivation includes compounds, noun-verb pairs, number incorporation, etc. Traditionally, noun-verb pairs have the same handshape, orientation, and location, but the verb has one sign and the noun repeats that sign. Number incorporation means a number, usually one through nine, can be used as a handshape in the sign.

Figure 1.4: Number Incorporation for Day versus Three Days

(https://www.lifeprint.com/asl101/pages-signs/d/day2.htm)

As shown in Figure 1.4, the number incorporation changes the sign for day to the sign for three days, which can also happen in the signs for minute, hour, week, month, year, and more. Once the sign parts come together, construction of sentences occurs. Similar to spoken language, some ASL signs have a specific meaning attached to them. Classifier (CL) constructions in ASL, however, use specific handshapes and other sign parameters to represent something. The signer must establish the representation prior to employing the use of a classifier. Constructions include instrumental (use) (ICL), locative (LCL), semantic

(SCL), elemental (ECL), body (BCL), body part (BPCL), and descriptive (DCL) classifiers (Mikos et al., 2001). The three (3) handshape can represent a vehicle or a horse as a classifier (LCL, ICL, DCL) (Figure 1.2). The use of the five (5) handshape as an ECL can show water spilling (Figure 1.1).

Syntax analyzes the function of sentence structures. As previously mentioned, questions require the use of raised or furrowed eyebrows non-manual markers, depending on the kind of question. Further, questions in ASL differ from questions in English because the question word (i.e. what or when) comes at the end of the sentence. In general, ASL sentences follow a TPOSVR order: time (T), place (P), object (O), subject (S), verb (V), and reaction (R). A "normal" sentence in ASL has a topic comment structure, which follows the OSV order. Syntax includes expressions of time, types of verbs, parts of speech, and function of space in connection with each other to form complete ideas in a functional, communicative language.

Following the discussion of phonology, morphology, and syntax, linguistics must also assess semantics. Semantics has three branches of meaning: referential, social, and affective (Moore, 2022; Valli et al., 2011). Referential semantics have denotative meaning, such as an idea or thing represented or pictured using language. Social and affective meaning present a connotation about the social identity of the language user or the feelings, attitudes, and opinions of the language user.

Figure 1.5: Dad and Mom Signs

(https://www.lifeprint.com/asl101/pages-signs/m/momdad.htm)

Social semantics include the distinction between male and female, using the top half of the face to mean male and the bottom half to mean female in ASL signs (Figure 1.5). Again, NMMs indicate the affective meaning of language. Similar to semantics, sociolinguistics also relates meaning in use and language but more specific to social use of language. Analogous to spoken languages, specific geographic regions and people groups use language in specific, unique ways.

Finally, neurolinguistics involves the investigation of language as it functions within the neural networks of the human brain. Language uses many neural circuits, and the age one learns language and the type of language one uses influences the way in which the brain

processes language. Learning language, in educational and societal settings, impacts the ability for the brain to comprehend and configure language.

Language in the Brain

Language processing in the brain follows the language stimulus (sound or sign) to the phonological features to access the lexicon (word). Then the brain processes through the other aspects of language leading to the semantic process to find meaning and assess the more complex meaning within the context of the sentence. According to Fujii et al. (2016), phonological processing occurs in the dorsal stream and semantic processing occurs in the ventral stream.

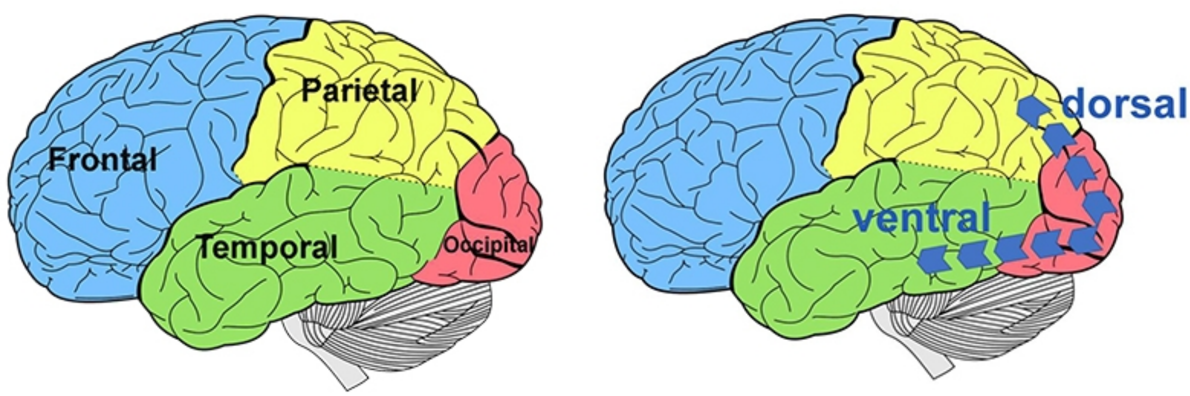


Figure 1.6: Lobes of the Brain with the Dorsal and Ventral Stream

(https://cviscotland.org/images/lessons/large/1552385610.jpg)

Figure 1.6 shows the frontal, parietal, temporal, and occipital lobes as well as the dorsal and ventral streams. The dorsal stream connects the network between the occipital and parietal lobes, while the ventral stream connects the occipital and temporal lobes. The

language processing networks from the frontal, parietal, and temporal lobes all connect at the arcuate fasciculus (AF) (Figure 1.8, shown below). The occipital lobe, also known as the visual cortex, complements language processing, such as written language, sign language, or paralinguistic features (i.e. tone of voice or body/facial expressions).

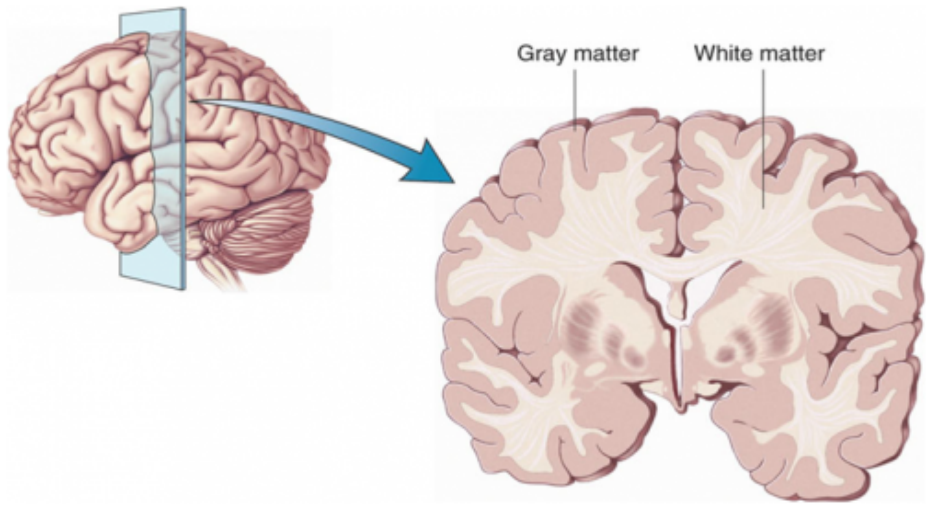


Figure 1.7: Gray and White Matter in the Brain

(https://difference.guru/wp-content/uploads/2018/02/cws_5a7ce6b673d9b.png)

Studies can compare the ventral and dorsal white matter tracts as a measure of the processing networks within the brain. White matter contains the part of the nerves, called the axon, which acts as the communication channels from one part of the brain to another (Figure 1.7). More white matter means more communication channels, which should indicate more processing.

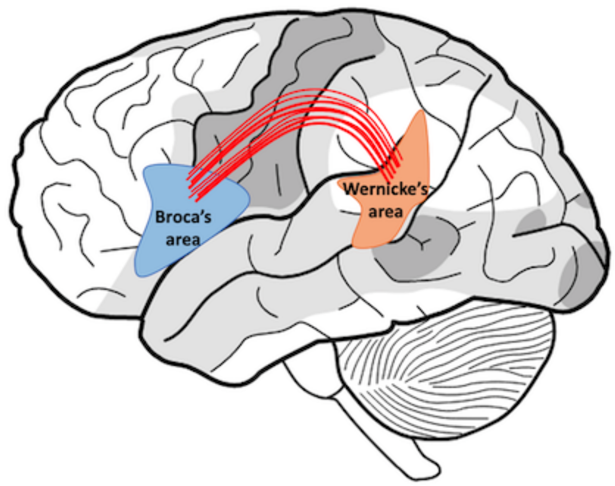


Figure 1.8: Broca's and Wernicke's Areas Connected by the Arcuate Fasciculus (AF)

(https://study.com/cimages/multimages/16/arcuatefasc434344326711636489.png)

The frontal lobe in the left hemisphere of the brain houses the Broca's area, which gives one the ability to articulate and produce language. Articulation of ideas and the correct use of language depends on the function of the Broca's area (Figure 1.8). Connected to the Broca's area by the arcuate fasciculus (AF), the Wernicke's area functions in comprehension of language, meaning it holds the role of language processing as described above. The Wernicke's area (Figure 1.8) mainly occupies the posterior superior temporal lobe (*Speech & language)*. Literature refers to these language-related parts of the brain as the perisylvian region. Language processing tends to predominantly function within the left hemisphere of the brain.

Referring to Figure 1.7, the part of the cerebral cortex labeled gray matter has a ridge, called a gyrus. A gyrus has a name dependent on the location of the ridge within a lobe as well as the positioning within the lobe (i.e. inferior, middle, or superior). Examples include the inferior frontal gyrus (IFG), middle frontal gyrus (MFG), and the middle temporal gyri.

Figure 1.9 (below) shows the areas of the brain, some of which relate to language processing, as mentioned above. Fujii et al. (2016) calls the brain a "dynamic network with plasticity" (p. 379).

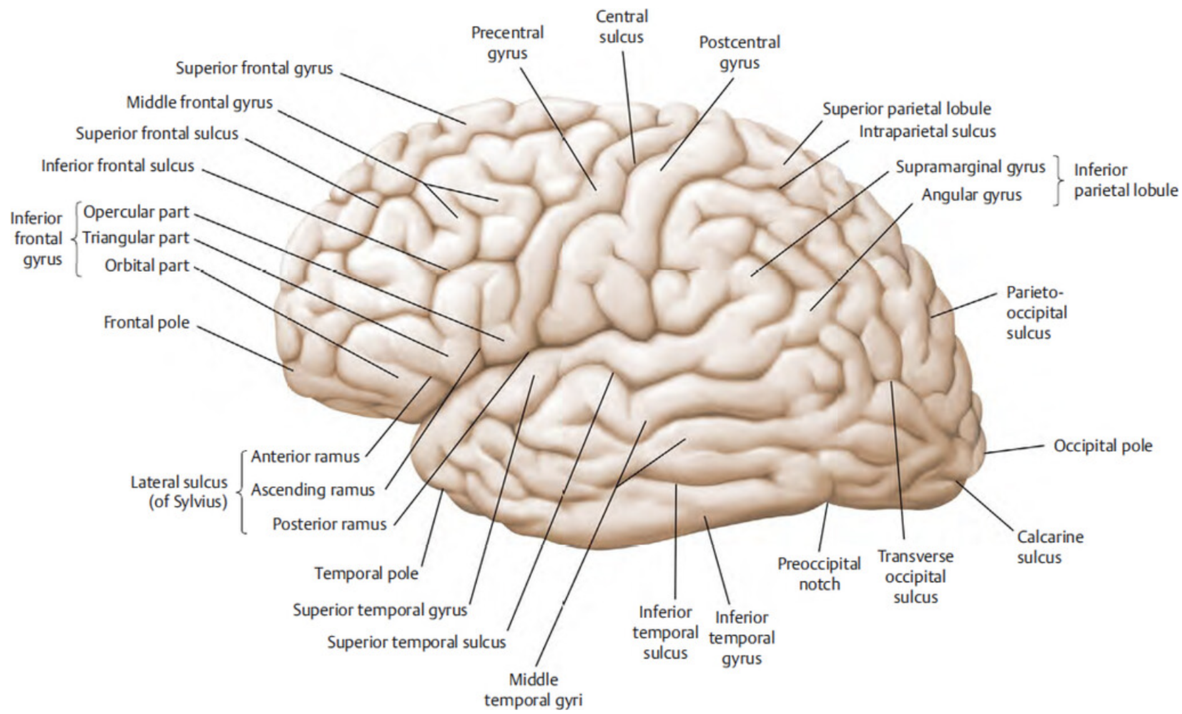


Figure 1.9: Macroscopic View of Areas of the Brain

(https://medone-education.thieme.com/24ZF2)

Measurements of Brain Activity

In response to a language stimulus, various tests or scans can measure the activation of specific language processing regions in the brain. An electroencephalogram (EEG) measures an event related brain potential (ERP). An EEG uses electrodes to detect the activation of neural networks through measuring the electricity caused by neural synapse firing. ERPs can show N400, left anterior negativity (LAN), and P600 measurements, each

of which associate with types of linguistic processing (Capek et al., 2009). Functional transcranial Doppler ultrasound (fTCD) measures the lateral indices (LIs) of the brain activation in order to determine lateralization of the hemispheres. EEG and fTCD produce plotted graphs over a unit of time.

Positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) take scans of the brain, which produce visual representations of the brain with color-highlighted regions (Figure 1.10, shown below). PET scans follow the metabolism of glucose (sugar) within the brain because the brain needs to use sugar in order to function. A person undergoing a PET scan can swallow, inject, or inhale glucose in order for the scan to trace the glucose in the brain areas (Bosquez, 2022). Similar to a PET scan, MRI scans measure metabolic changes within the body, namely within the brain for fMRI. An fMRI scan, however, can detect additional metabolic functions, in addition to glucose, such as oxygen level changes and blood flow. Metabolism functions change within the brain in response to processing a stimulus. The fMRI scan generates a cognitive map for the purpose of labeling brain areas functioning in language and visual perception (American Psychological Association, 2014).

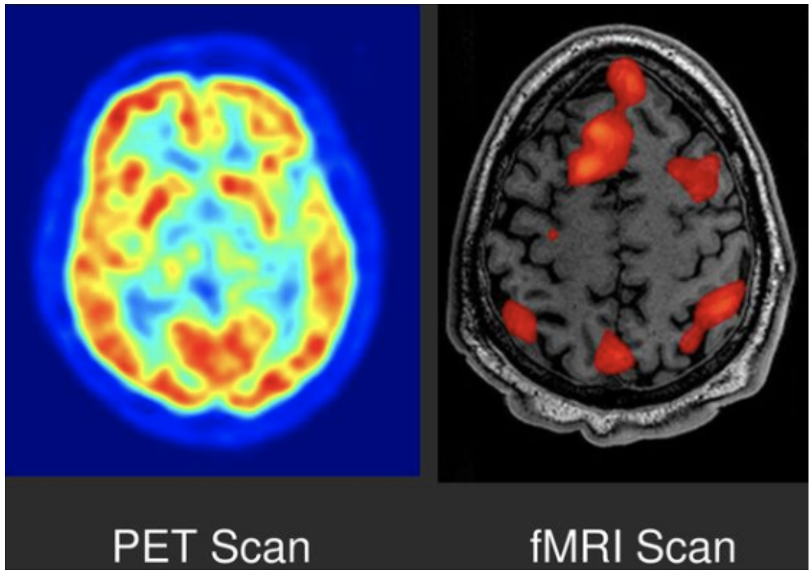


Figure 1.10: PET Scan versus fMRI Scan

(slideplayer.com/slide/12155258/71/images/3/Investigating+the+brain+with+scans.jpg)

Acquisition of Language

Critical Period

Supported by various research studies, Malloy (2003) says the "human brain is wired for language" (p.13). Malloy (2003) further proposes the most pressing issue for children with hearing loss relates to their development of language skills "at a rate comparable to that of normally hearing peers" (p.13). According to Leigh et al. (2016a), "language deprivation not only causes delays in learning academic content, but also having weak language skills can affect thinking, social, and reading skills" (p. 95).

In order to develop at a comparable rate, the children with hearing loss need comparable exposure to language. The family members of approximately 90% of children with congenital, significant hearing loss only use spoken language, which means the children do not have full access to the language mode (visual) that comes naturally to them (Malloy, 2003). When learning English or any other spoken language, a hearing child can learn the use of social language more rapidly than the use of academic language. For Deaf children, the same remains true for learning social and academic ASL because ASL serves as the *cultural* language for Deaf people. Without formal sign language exposure, deaf children tend to use a self made gesture system called homesign because humans feel the need to communicate in a way that they can fully access (Cheng et al., 2019).

According to Hall (2017), Deaf children's need for a fully accessible first language foundation, arguing that children have one time-sensitive period of high brain plasticity for language acquisition that spans from birth to about five (5) years of age. If a child misses the critical period of language development, then the child already has language deprivation. Language education for Deaf children tends to follow an "either-or" trend: ASL or English.

English education typically occurs first with the implementation of ASL education as a last resort due to the belief that ASL interferes with English acquisition; however, there exists a "long-standing lack of empirical evidence that spoken language-only approaches are more effective" (Hall, 2017, p. 961).

Furthermore, Hall (2017) describes that "brain changes associated with language deprivation may be misrepresented as sign language interfering with spoken language outcomes of cochlear implants, which leads to…preventing sign language exposure before implantation and spreading misinformation" (p. 961); however, cochlear implanted children who signed from birth had standardized language test scores comparable to hearing peers. Other studies, in the following sections, evaluate the use of sign language by congenitally Deaf people starting at birth and its effect of establishing a language foundation. Having a language foundation allows Deaf students to perform on nonverbal intelligence tests with comparable scores to their hearing peers (Leigh et al., 2016b). When children have access to a language, they "can use language to form new thoughts without having the experiences with real objects and events" (Leigh et al., 2016b, p. 128). Historically, people believed deafness to equal unintelligence; however, Deaf people can have intelligence, they just need a way to show it through language.

Cerebral Plasticity

The concept of critical period derives from scientifically quantifiable cerebral plasticity. Merriam-Webster (2023) defines the word plasticity as the capacity for continuous alteration of the neural pathways and synapses of the living brain and nervous system in response to experience or injury. According to Friedmann and Rusou (2015), the

neurotransmitter gamma-aminobutyric acid (GABA) enables the changes of neural circuits in response to sensory experience. At the closure of the critical period, the brain undergoes physical and functional changes, which decrease the "neuromodulatory systems regulating acetylcholine and serotonin, which prevent further structural changes, limit excessive circuit rewiring, and shift the neural circuit to a stable state" (Friedmann & Rusou, 2015, p. 28). The end of the critical period allows for structural stability as well as consolidation and organization of neural pathways, which has significance in long-term structure and function of the nervous system; however, the closure elevates the importance of maximizing exposure for neural development during the critical period.

According to Cheng et al. (2019), ventral and dorsal white matter tracts play a crucial role in language processing. Comparing data from deaf native signers, hearing second language (L2) signers, and deaf late signers (age of first language (L1) onset at 13, 14, or 21 years), Deaf late signers have altered microstructure of white matter in left arcuate fasciculus (AF) and other language-related pathways. Deaf native signers and hearing native speakers have similar white matter microstructure, supporting the cruciality of early language experience "for the language system to become robustly connected as observed in the canonical mature state, regardless of its sensory-motor modality" (Cheng et al., 2019).

Age of Acquisition

Defining the critical period and brain plasticity theories requires an understanding of when a person should acquire language. Friedmann and Rusou (2015) found that the "acquisition of syntax in a first language has a critical period that ends during the first year of life, and children who missed this window of opportunity later show severe syntactic

impairments" (p. 27). A study conducted by Boudreault and Mayberry (2006) supported that claim by testing the syntactic structure of thirty congenitally Deaf adults, in three groups of ten, who had full language exposure by the age of thirteen years. For the purpose of this study, the first language (L1) of each subject means American Sign Language (ASL). The subjects fit into one of three groups based upon age of acquisition (AoA): native learner (starting at birth), early L1 learner (starting at 5-7 years of age), and delayed L1 learner (starting at 8-13 years of age).

As mentioned in the Explanation of Linguistics section, Boudreault and Mayberry (2006) examined the syntactic structure of simple, negative (Neg), agreement verb (Agr Verb), question (Wh), relative clause (RC), and classifier (CL). The calculations for sensitivity scores for each ASL syntactic structure include ratios of correct and incorrect judgments of grammatical stimuli as a function of chance (Boudreault & Mayberry, 2006). The higher sensitivity scores represent higher correct judgments, or "hits", when presented with the specified grammatical stimuli.

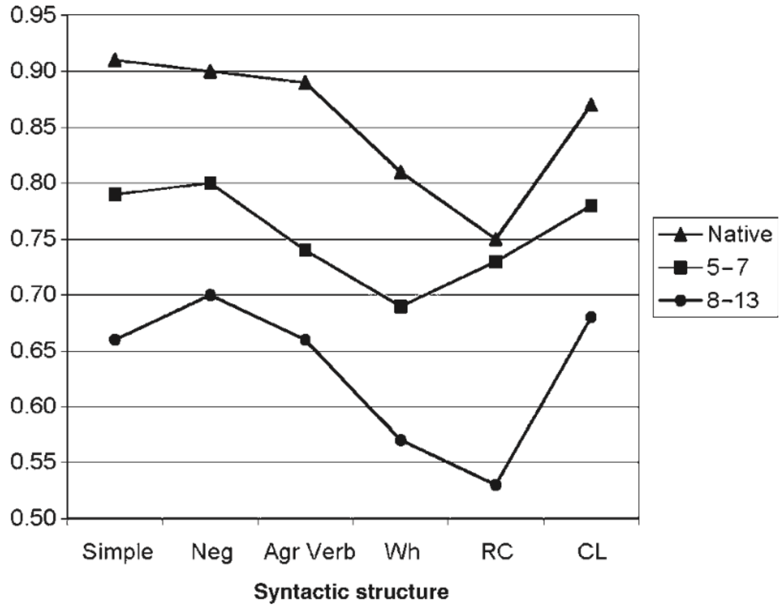


Figure 2.1: Mean sensitivity scores for ASL syntactic structure for three AoA groups (Boudreault & Mayberry, 2006, p. 623)

In Figure 2.1, the sensitivity scores for all six types of ASL syntactic structure follow a correlation of higher sensitivity with earlier learners; the order of highest to lowest sensitivity follows the order of native, early, then delayed L1 learners (Boudreault & Mayberry, 2006, p. 623). These results suggest that delay in language exposure affects language acquisition; therefore, a Deaf person's earlier exposure to first language results in higher accuracy in language, namely grammatical judgment of syntactic structures. In combination with other research findings, Boudreault and Mayberry (2006) further claimed that "these results show that delayed exposure to a first language in childhood affects all subsequent language acquisition cross-modally" (p. 633). In terms of Deaf language use and education, this claim has direct implications for the acquisition of the English language.

Given the results according to age of acquisition, the critical period must include full access to language in a modality fully accessible to the language learner. According to Friedmann and Rusou (2015), postlingual deafness, meaning after the first year of life, or children who have deafness in only one ear had *normal*, meaning on par with hearing peers, syntactic abilities because they had access to spoken language during the critical period. For a child with congenital deafness, a signed language, such as ASL, has a modality fully accessible to them. Learning language during the critical period has crucial implications for future cognitive and communicative abilities.

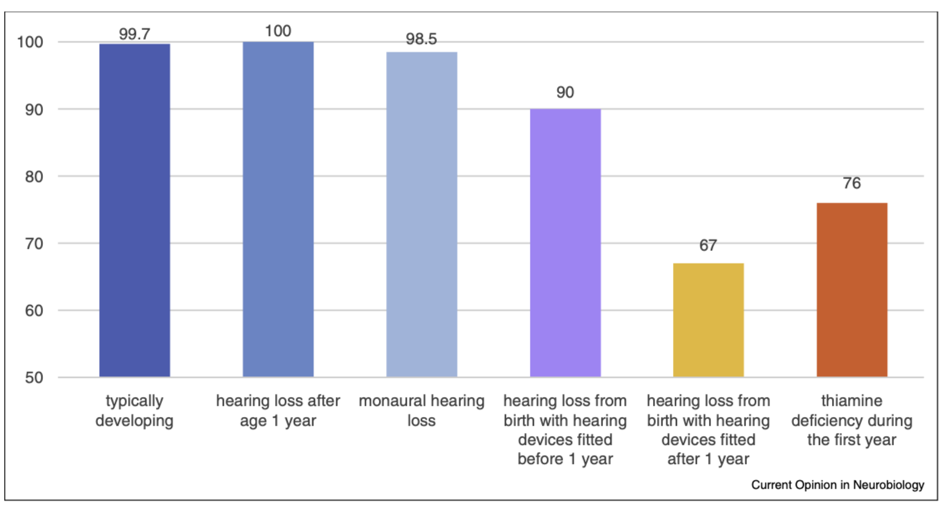
Language Foundation

If Deaf children need to acquire language within a critical period, they should learn a language they can truly acquire. Many believed, as some still do, that ASL would hinder the success of Deaf and hard-of-hearing (HOH) children to learn English. Despite the concerns, research shows that "early learning of ASL need not create concerns for future development of English structure, speech, or other cognitive skills" (Wilbur, 2000, p. 81). Furthermore, research shows ways in which ASL can contribute to English skill development. According to Wilbur (2000), "once ASL is established as a means of communication, teachers can then use it as a medium of instruction for all subjects, including English, which can be taught along with speech, speechreading, and reading" (p. 81).

Wilbur (2000) attributes the cause for Deaf students' problems in learning to read and write in English to inadequate language skills and teaching methods because of teachers' focus on modality and sentence structure over other aspects of language learning and use. The Deaf students struggle because they do not have a language model in a modality

accessible to their senses, particularly they lack access to the visual language of ASL. The lifelong struggles stemming from language deprivation exceed linguistic-related issues. In contrast to the students who have English language problems, Wilbur (2000) reported that Deaf children of Deaf parents have superior skills in some or all of English measurements as well as in general measurements of ability. This finding emphasizes the need for a strong language foundation in order to succeed in other nonlinguistic activities.

Friedmann and Rusou (2015) reports that "studies show that deaf or hearing children who acquire sign language from their deaf parents experience normal language development" (p. 29). This conclusion not only refutes the claim that ASL will negatively impact a Deaf child learning English, but it further states that hearing children of a Deaf adult (CODAs) will not have a negative impact on English learning because of learning ASL as their first language (L1).



The comprehension of structures derived by Wh-movement (object relatives, object questions, and topicalization), in a sentence–picture matching task in various groups differing on language input and brain development during the critical period for the acquisition of syntax in a first language: the first year of life.

Figure 2.2: Comparative Percentages for Comprehension of Structure by Linguistic Experience (Friedmann & Rusou, 2015, p. 31)

As shown in Figure 2.2, exposure to a first language within the first year of life makes a tremendous difference in a person's language comprehension abilities (Friedmann & Rusou, 2015, p. 31). Deaf children must have exposure to a signed language because "deafness blocks infants' language experience in a spoken form" (Mayberry et al., 2018). Language processing occurs in the perisylvian region of the left hemisphere of the brain. According to Mayberry et al. (2018), ASL follows a similar hierarchy to English because language comprehension of ASL has a similar trajectory of processing pathways, despite sensory-motor differences between the languages.

In addition to needing a language foundation, the environment promoting the building of the foundation also has importance. Matching the idea of a critical period, Garcia et al. (2019) report that research shows a dynamic acquisition of language between 18 and 20 months old with an acceleration of learning language when a child becomes two years old. In terms of the environment of a child, Garcia et al. (2019) expand on language problem association with behavior problems. Behavior problems may follow a pattern of poor parenting skills, and oppositely, better parenting skills can help lead to less behavioral problems and thus indirectly lead to more language production. The subjectivity of this study limits the quantitative variables of the study.

Garcia et al. (2019) implement a brief home-based intervention for infants between the ages of 12 and 15 months who exhibit above-average behavior problems, quantifiable by the use of a screening, called Brief Infant-Toddler Social and Emotional Assessment (BITSEA), with a score exceeding the 75th percentile. Measurements of parenting skills, using the Dyadic Parent-Child Interaction Coding System (DPICS III), and child language

production, using Child Language Data Exchange System (CHILDES), occur at baseline, post-intervention, at 3-month follow-up, and at a 6-month follow-up.

In their discussion, Garcia et al. (2019) state "parenting skills have consistently been associated with improvements in child behavior and have now been found to account for child and infant language outcomes following a behavioral intervention" (p. 556). These new results exaggerate the cruciality of parents' active involvement in the development and acquisition of their children's language. Again, subjective variables in studies like this limit the repeatability and comparability of future studies.

Brain Lateralization of Language

During the developmental phase of brain "plasticity," Berl et al. (2014) discusses the idea of less lateralization and more activation of neural networks. According to Berl et al. (2014), approximately 95% of right-handed adults show left-dominant lateralization for language representation, with right lateralization in the cerebellum. This study did not include Deaf subjects, but it measured brain lateralization by age, showing scores for left, bilateral, and right lateralization. The children of varying ages completed auditory description decision tasks, which involved auditory stimuli and word definition decision tasks. They completed baseline intelligence and language skill testing prior to experiment, and the difficulty of each experimental task corresponded to the language skills appropriate for the child's age. A pediatric neurologist conducted the collection of the measurements for the neural lateralization using functional magnetic resonance imaging (fMRI) (Berl et al., 2014).

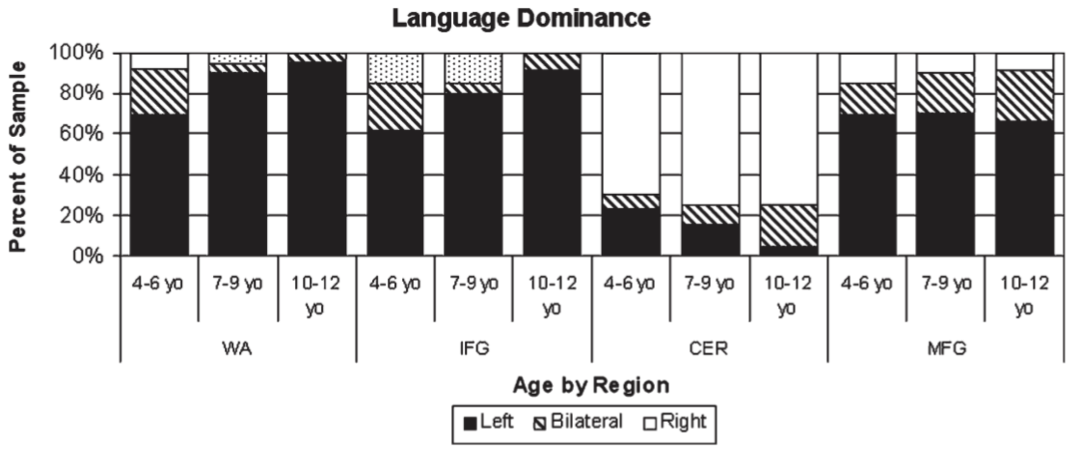


Figure 2.3: Language Dominance for Lateralization by Neural Region according to Age (Berl et al., 2014, p. 276)

In Figure 2.3, the Wernicke's Area (WA), the inferior frontal gyrus (IFG), and the middle frontal gyrus (MFG) show left lateralization for all ages four to twelve years. From this study, Berl et al. (2014) determined, by the age of four years, these children established the same language networks as adults exhibit, and, by the age of seven years, the children's left language temporal dominance matched adults. In conclusion, "the unique variance in lateralization accounted for by age may reflect the developmental timing of the underlying neuroanatomic structures" (Berl et al., 2014, p. 280).

The lateralization of those language neural pathways within the brain should have similarities between ASL and English. A study conducted by Mayberry et al. (2018) included three groups of signers: Deaf native signers, hearing second language (L2) signers, and adolescent L1 learners. One subject, by the pseudonym of Martin, did not learn any official language until the age of 23 years, but he daily uses ASL now at the age of 51 years (Mayberry et al., 2018). In order to assess development of language processing systems in a brain with initial linguistic exposure following the critical period, Mayberry et al. (2018)

compared Martin's neural activation with language stimuli to hearing L2 signers, who began learning ASL around the same age as Martin. The accuracy and response time of Martin and the L2 signers matched; however, Martin exhibited neural activation outside of the left and right perisylvian language areas, rather than typical left-dominant language areas within the perisylvian region.

This finding of differing lateralization patterns had congruence with previous studies of post-critical period brain maturation without linguistic experience. If linguistic neural pathways do not form during the critical period, those language pathways will not form normally. Some changes within the perisylvian language network can still occur through adolescence as maturation continues, but the majority of the connections form during the critical period. The right hemisphere contributes to language processing in children with bilateral processing, but its contribution decreases as the child matures and processing becomes more concentrated in the left hemisphere (Mayberry et al., 2018). These data further support critical period theory. The discussion of lateralization continues in the sections within the Processing of Language.

Delayed Acquisition and Language Organization

With a delay in language acquisition, the language in the brain can follow a different organizational pattern from those who learn language during the critical period. A study compares the age-dependent acquisition of language and the resulting neural response by measuring two groups: one consisting of early language learners and the other of late language learners (Lieberman et al., 2015). The first group's participants included eighteen native signers, sixteen of whom learned ASL from a Deaf parent as a primary language from

birth and two participants who had hearing parents but had exposure to ASL by two years of age. The second participant group included late-learning signers, meaning the participants' initial ASL exposure ranged from age 5 to 14 years and the years of ASL experience ranges from 5 to 39 years. All participants used ASL as their primary language during the time of the study. Educational background varied for the participants between not completing high school to college graduation (Lieberman et al., 2015).

The study measured eye movements to a target picture matching the semantic and/or phonological features of the sign in a sign stimulus video. The measurements fit into two average categories: (a) saccade latency, meaning the amount of time for the eyes to move to the picture after the signed stimulus and (b) fixation proportion, meaning the time eyes looked at either the target picture or the sign stimulus (Lieberman et al., 2015).

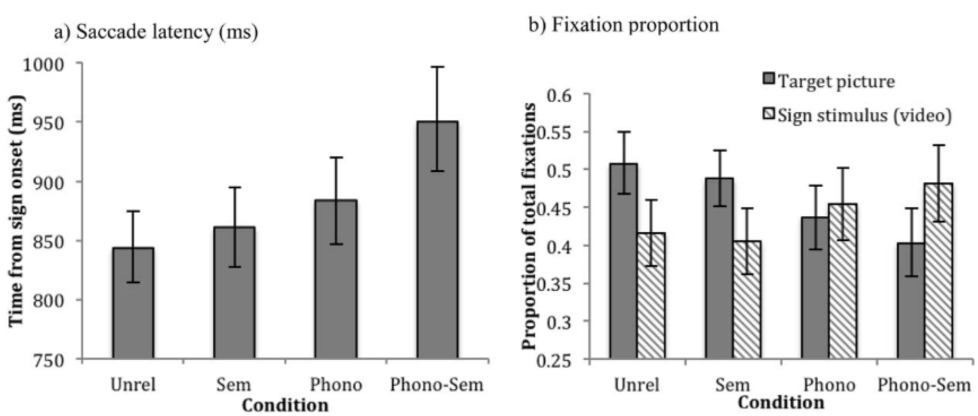


Figure 2.4: Early Language Learners' Eye Measurements by Semantic and Phonological Features (Lieberman et al., 2015, p. 1134)

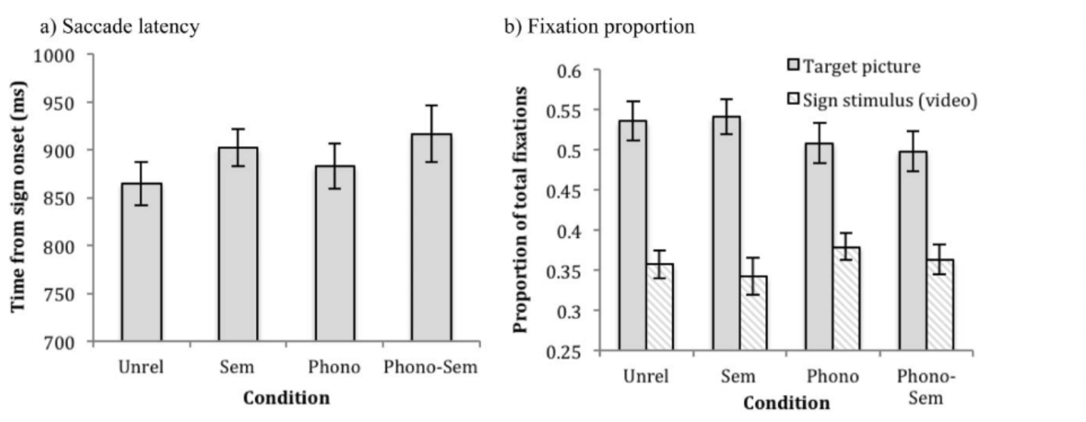


Figure 2.5: Late Language Learners' Eye Measurements by Semantic and Phonological Features (Lieberman et al., 2015, p 1136)

According to the above Figures 2.4 and 2.5, late-learners of ASL did not have real-time activation of sublexical features of signs. Native signers activated processing of semantic and phonological features during real-time processing. Furthermore, the late-learners of ASL showed less time of total fixation on the *sign* stimulus than native signers, which implies their decreased level of processing the language stimulus. The native signers relied more on the lexicon in sign than the late-learners.

According to Lieberman et al. (2015), "early language deprivation appears to affect the organization of the ASL mental lexicon in a way that yields reduced early and online activation of phonological, sublexical features" (p. 1137). Therefore, mental lexicon organization can differ in early versus delayed exposure to a primary language; late language exposure can permanently affect language organization within neural networks. A person must acquire language within the critical period in order to have neural networks for the most effective processing of language.

Processing of Language

Comparison of the Modalities

American Sign Language contains all the required linguistic components of a language; however, its mode of expression and reception differs from aural-oral languages. A different mode means a different stimulus and production, which each provoke differing neural networks. According to Lieberman et al. (2015), “sign language comprehension requires visual attention to the linguistic signal and visual attention to referents in the surrounding world, whereas these processes are divided between the auditory and visual modalities for spoken language comprehension”(p. 1130).

Utilization of an event related brain potential (ERP), measured by an electroencephalogram (EEG) can quantify the different modes. An ERP measures a posterior bilateral N400, a left anterior negativity (LAN), and P600 in response to language stimulus over time (Capek et al., 2009). The level of a N400 increases as semantic information increases, with the highest measurements for spoken language in the posterior medial sites of the brain. The LAN and P600 measurements correspond with the syntactic information. The measurements show activation within the left and right hemispheres of the frontal lobes (F7 and F8) and the parietal lobes (P3 and P4). Capek et al. (2009) hypothesize if the language-processing neural network functions independent of the mode/form of a language, then the ERPs for ASL sentences will have similarities to the ERPS for written and spoken languages.

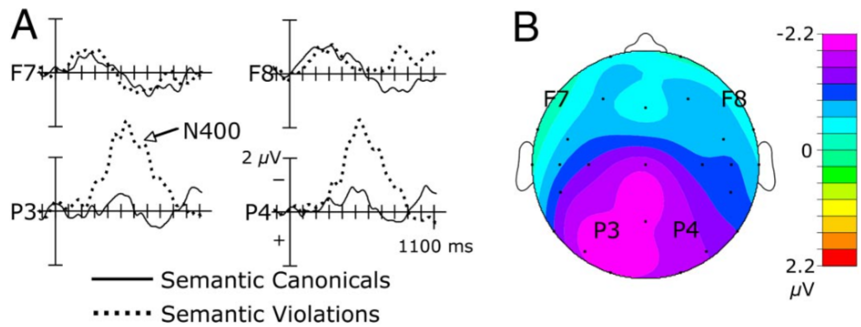


Figure 3.1: Average Event Related Brain Potential (ERP) & Voltage Map for Syntactic Input (Capek et al., 2009, p. 8786)

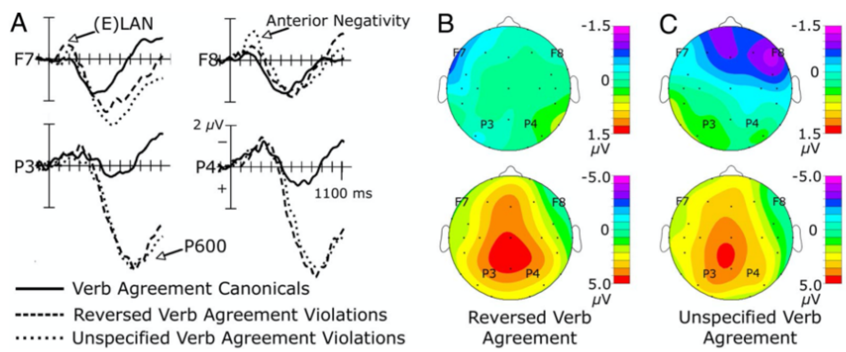


Figure 3.2: Average Event Related Brain Potential (ERP) & Voltage Map for Semantic Input (Capek et al., 2009, p. 8786)

Both the semantic and syntactic stimulations included canonical (normal/accurate) and violations (anomalies) to assess where the brain processes the information. Similar to spoken language, ASL semantic anomalies elicit N400 (Figure 3.1) significantly more in the posterior compared to the anterior and significantly more in the medial than lateral. This finding shows that ASL and spoken language use similar semantic processing centers within the brain, despite the difference in modality. Connected to the movement of signs, explained

in the Explanation of Linguistics section, verb agreement in ASL means the sign for the verb moves from the subject in the direction of the object. Spoken languages do not share this feature that only a visual language can have.

As shown in Figure 3.2, the LAN and P600 for reversed verb agreement show higher response in the left hemisphere of the brain, sharing the neural process of spoken language. Unspecified verb agreement, however, had a significant anterior negative response within the anterior right hemisphere instead of the common spoken language left lateral processing system. This finding supports the claim that spatial syntax requires a unique processing system, not used in spoken language. This right lateral processing system also appears in the processing of music structure. According to Capek et al. (2009), the right lateral syntactic processing establishes the "critical role of experience in shaping the organization of language systems of the brain" (p. 8788).

To assess the critical impact that experience has on shaping brain systems, Emmorey et al. (2005) study the responses to spatial concepts in both English and ASL. Classifier constructions, as explained in the Explanation of Linguistics section, use literal space to match the concept. With a positron emission tomography (PET) scan, Emmorey et al. (2005) measured the brain area activation of ten right-handed, hearing children of a Deaf adult (CODAs), who natively sign. The tasks include: (1) ASL classifier construction and (2) spoken English preposition for spatial relationships, then (3) ASL-named object and (4) English named object for controlled variables.

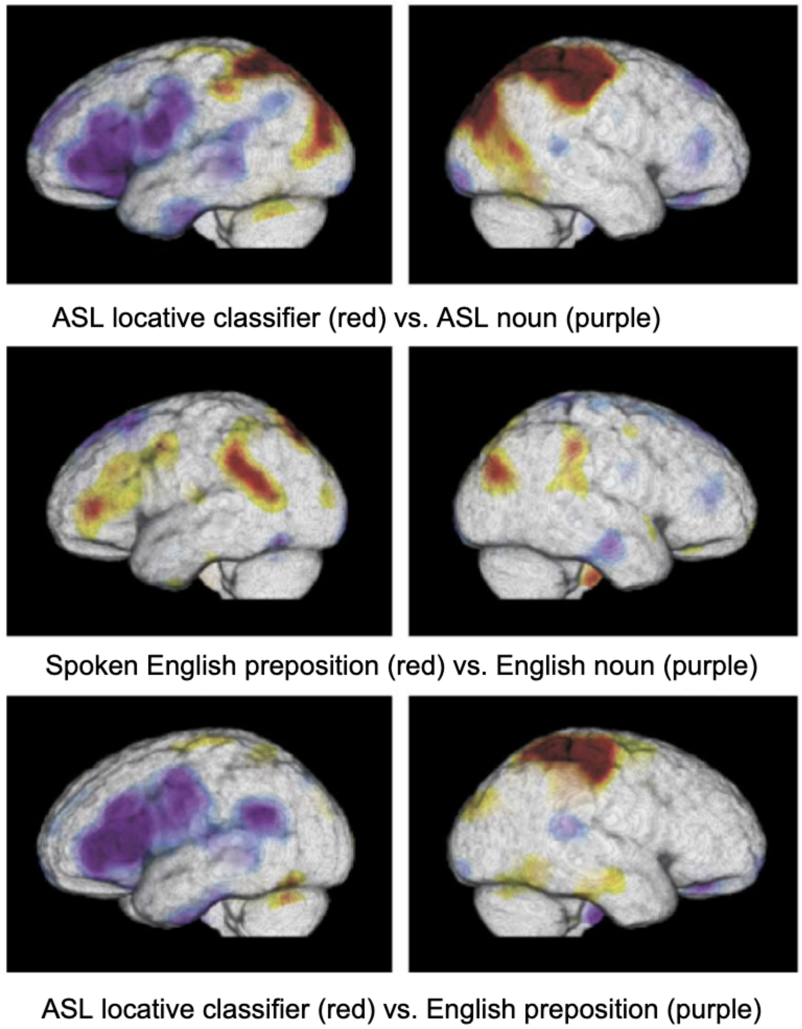


Figure 3.3: ASL Locative Classifier and English Preposition Brain Activation (Emmorey et al., 2005, p. 837)

Looking at Figure 3.3, these results determine the activation of Broca's area coordinated with the production of an ASL noun and an English preposition. Each of these tasks require the retrieval of a name. ASL classifiers do not have an attached, inherent name or meaning; therefore, Broca's area activation does not occur in response to locative classifiers ("prepositions") in ASL.

Parietal activation occurs in both ASL locative classifiers (LCL) and English prepositions. From a previous study (H. Damasio et al., 2001, NeuroImage, 13), Emmorey et al. (2005) reported that the English speakers present left parietal activation in response to spatial prepositions in English. The hearing, native-signing subjects in the current study exhibit more right hemisphere activation for English spatial prepositions. Given the understanding that ASL activates the right parietal lobe more than English, the ASL-English bilinguals in this study have a brain adapted to function more like an "ASL brain" for perceiving space. Long-term exposure to ASL in a hearing brain altered the anatomy and physiology of the brain in order to perceive space. The frontal, temporal, and occipital lobes showed no significant differences in activation between tasks (Emmorey et al., 2005).

To evaluate the activation of the Broca's area by ASL signs, Horwitz et al. (2003) also evaluated native ASL and English bilinguals, but this study compares those subjects with English monolingual subjects. Broca's area, located in the inferior frontal gyrus, has two regions: Brodmann areas (BA) 44 and 45, with a predicted correspondence to the articulations requiring oral/laryngeal or extremities' muscles and requiring language generation, respectively (Horwitz et al., 2003).

The tasks included language productions, motor controls of limbs or oral muscles, and rest as the controlled variable. Horwitz et al. (2003) use positron emission tomography (PET) scans to examine neuroimaging of BA44 and BA45 activation. Comparing the motor controls (nonlinguistic articulations) to rest, the majority of the activation occurs for motor controls within the BA44 region of the Broca's area; furthermore, the activation occurs predominantly within the left hemisphere of the brain. Language production mainly activates the BA45 region, with little or no additional activation of the BA44 region when subtracting

out the standard, nonlinguistic-related data. For the bilingual participants, the scans for the spoken English and ASL tasks show no significant difference in activation of the BA45. Similarly, the monolinguals show the same activation of the BA45 region for the spoken English tasks as for the language production tasks of the bilinguals. Again, the activation occurs mostly within the left hemisphere. In conclusion, Horwitz et al. (2003) determine that, when learned early in life, the language production of English and ASL activate the same left dominant neural region of BA45 within the Broca's area.

While certain features of ASL, such as space, may activate additional areas of the brain, such as the parietal lobe, compared to the neural activation from English, ASL still activates the language centers of the brain required in the processing of spoken language. When learned early in life, ASL and English each activate the BA45 region of the Broca's area, almost instinctively from the other language. This supports the claim that ASL does follow a similar neural process as a spoken language (namely English), which shows that ASL needs to have the place as a true, valuable language for education and use. Modality, whether spoken or signed, does not determine the legitimacy of a language. The neuroimaging from the above studies shows the legitimacy of similar neural processing of language, despite modality.

The inclusion of hearing, native signing bilinguals in these two studies rather than Deaf signers can potentially limit the application of the data to congenitally deaf, native signers.The following studies, however, include Deaf signers as subjects. These studies continue the comparison of spoken versus signed language articulation and hearing versus Deaf neural pathways related to language.

Twomey et al. (2017) consider the impact of auditory input on the functionality and lateralization of superior temporal cortices (STC). This study's Deaf participants use British Sign Language (BSL) instead of ASL; however, BSL and ASL have a shared modality. The hearing participants also know BSL. This study performs functional magnetic resonance imaging (fMRI) to quantify the neural activation in response to the tasks. The picture tasks include decisions about objects related to their (1) phonological, (2) semantical, or (3) visual/physical features. Each task includes looking at a pair of pictures and deciding whether the pair has the (1) same sign handshape or hand location, (2) same category (i.e. animals), or (3) same picture.

Table 3.1: Deaf Early (DE) and Deaf Late (DL) Participant History and Preference (Twomey et al., 2017, p. 9566)

		Language	
Participants	Use of hearing aids	Used when growing up	Preferred
DE1	Data missing	Data missing	Data missing
DE2	Rarely	BSL/SSE	BSL
DE3	Every/all day	BSL/SSE/SpE	BSL
DE4	Data missing	Data missing	Data missing
DE5	In the past	BSL/SSE/SpE	BSL
DE6	Rarely	BSL	BSL
DE7	Never	BSL	BSL
DE8	Every/all day	BSL	BSL
DE9	Never	BSL	BSL
DE10	Data missing	Data missing	Data missing
DE11	Every/all day	BSL/SpE	BSL
DL1	In the past	SpE	BSL
DL2	Rarely	SpE	BSL
DL3	Never	SpE	BSL
DL4	In the past	SpE	BSL
DL5	Every/all day	SpE	BSL
DL6	Rarely	SpE	BSL
DL7	Sometimes	SpE	BSL
DL8	Never	SpE	BSL
DL9	Data missing	Data missing	Data missing
DL10	Every/all day	SSE/SpE	BSL
DL11	Every/all day	SpE	SpE
DL12	Every/all day	SpE	BSL

Abbreviations: BSL = British Sign Language, SSE = sign supported English, SpE = spoken English.

According to Twomey et al. (2017), Deaf early (DE) means BSL learning started at birth and Deaf late (DL) means BSL learning occurred at 15 years of age or older. In Table 3.1, despite various histories of hearing aid use or BSL versus spoken English (spE) use, most of the participants prefer BSL. When given the opportunity to learn and use a language with a signed modality, the majority of the participants choose that language, even if previously using spoken English as their primary language.

Compared to hearing signers, Deaf signers had significantly higher activation of right STC. In hearing subjects, the left and right STC activates more in response to auditory stimuli than for visual tasks. In response to tasks sans auditory input (for Deaf subjects), the left STC activates for cognitive tasks, such as visuospatial processing. In consideration of these results, hearing signers' left and right STC associate with the presence of auditory input because of their auditory experience. Deaf signers' engage their right and left STC in response to visual tasks. Therefore, the lack of auditory input in the experience of a Deaf person changes the function of traditionally auditory-related brain regions to have visual-related functions (Twomey et al., 2017).

In the future, when comparing signers, a study can evaluate the influence that the level of sign language proficiency may have on the level of activation within the STC regions while processing visual information. A study of this nature may have challenges in determining the parameters of proficiency, since proficiency evaluations include subjectivity.

To determine lateralization of sign language, Gutierrez-Sigut et al. (2016) conduct a study to evaluate lateral activation in response to covert and overt phonological and semantic sign language (BSL) tasks. Functional transcranial Doppler ultrasound (fTCD) measures the lateral indices (LIs) to determine which region has the highest lateralization. The covert tasks

require the participant to generate as many signs matching the given handshape (phonological) or the given semantic category (i.e. sports or fruits). Overt tasks necessitate repetition of the given sign immediately following the stimulus. Each task includes a preparation and relaxation period before and after the stimulus and sign generation. Graphs show the LIs of each task, phonological-covert, phonological-overt, semantic-covert and semantic-overt, over a measurement of time with a highlighted period of interest (POI).

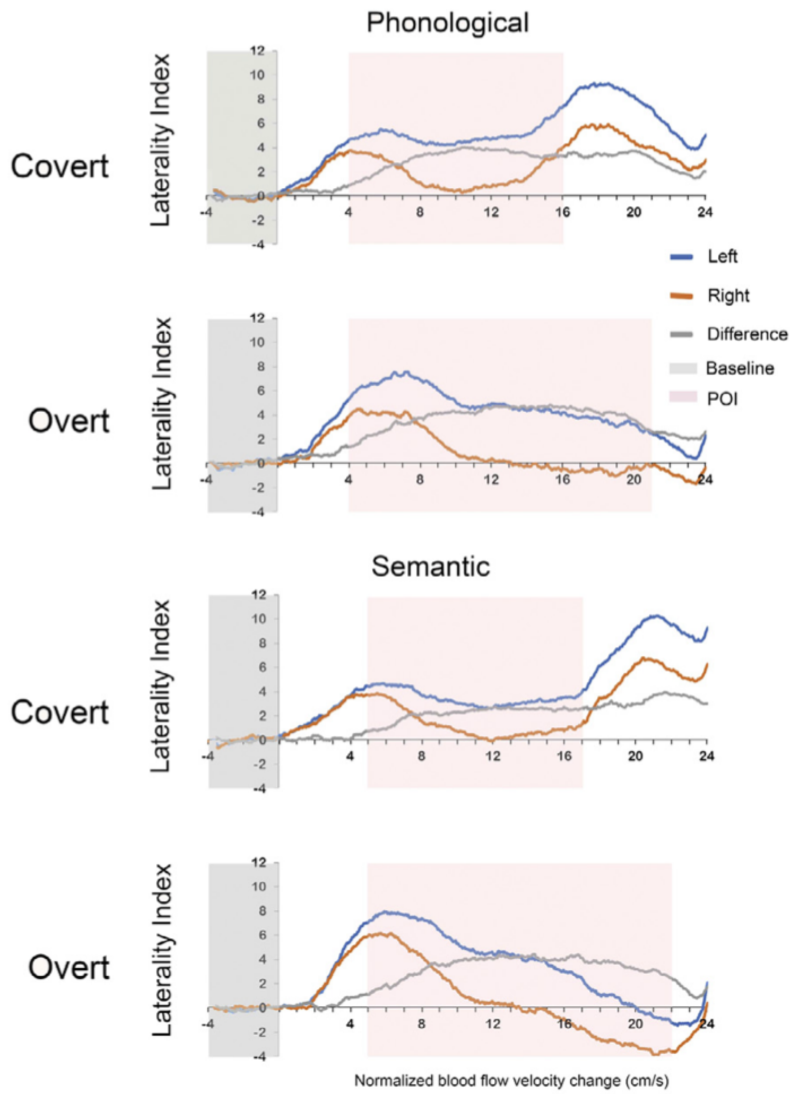


Figure 3.4: Lateral Indices for Each Overt and Covert Task (Gutierrez-Sigut et al., 2016, p. 113)

According to Figure 3.4, each of the four tasks in this study activate the left hemisphere more than the right hemisphere of the brain. These data mean that sign language (BSL) production has a predominantly left lateralization, similar to spoken language. Gutierrez-Sigut et al. (2016) claim that “specific properties of sign production such as the

increased use of self-monitoring mechanisms or the nature of phonological encoding of signs" (p. 109) may contribute to increased left lateralization.

Further studies on differing phonological encoding features, such as unmarked versus marked handshapes or one-handed versus two-handed signs, can provide more insight into the strength of left lateralization markers. For example, marked handshapes and two-handed signs may activate more lateral indices in the brain than their counterparts. Self-monitoring in sign language versus speech also presents an interesting study because self-monitoring in sign language has visual limitations while one can simultaneously, auditorily self-monitor spoken language.

Spoken language users tend to monitor their language production by listening to their voice as they speak and adjusting their production, as needed. Unlike spoken language users' ability to self-monitor their language output through listening, users of signed language do not look at their hands or their face as they produce language; therefore, signers cannot self-monitor their language as readily. Emmorey et al. (2009) examine the three-dimensional (3D) movement of target signs within a carrier phrase by using an Optotrak Certus system to measure the X dimension (horizontal), Y dimension (vertical), and Z dimension (outward/forward) in millimeters. The study recruited 13 right-handed Deaf participants who use ASL as a primary language but only uses data from nine participants due to errors in the recording of the other four.

Figure 3.5: ASL Signs for the Carrier Phrase and Targets (Emmorey et al., 2009, p. 191)

Each participant signed the target signs within the carrier phrase under five conditions: blindfolded, wearing tunnel-vision goggles, normal (citation) signing, shouting, and informal (more casual, sloppy) signing. The target signs in the carrier phrase (THINK/KNOW____YESTERDAY) have a directionality to their location and movement phonological parameters, as shown in Figure 3.5. Sign language users tend to look at the face

of the person with whom they speak, but sometimes they will use eye gaze to add meaning to directionality. Using the target signs, which accompany the use of eye gaze, the 3D measurements of the signs evaluate whether the five conditions affect the production of signs.

Table 3.2: Average X, Y, and Z Dimensions (mm) for the Five Conditions[1] (Emmorey et al., 2009, p. 195)

Measure	Normal	Blind	Tunnel	Informal	Shouting
X dimension size	64	71	74	55	93*
Y dimension size	58	63	50*	45**	67
Z dimension size	79	90	88	75	168**

1 *p<0.0125, **p<0.001

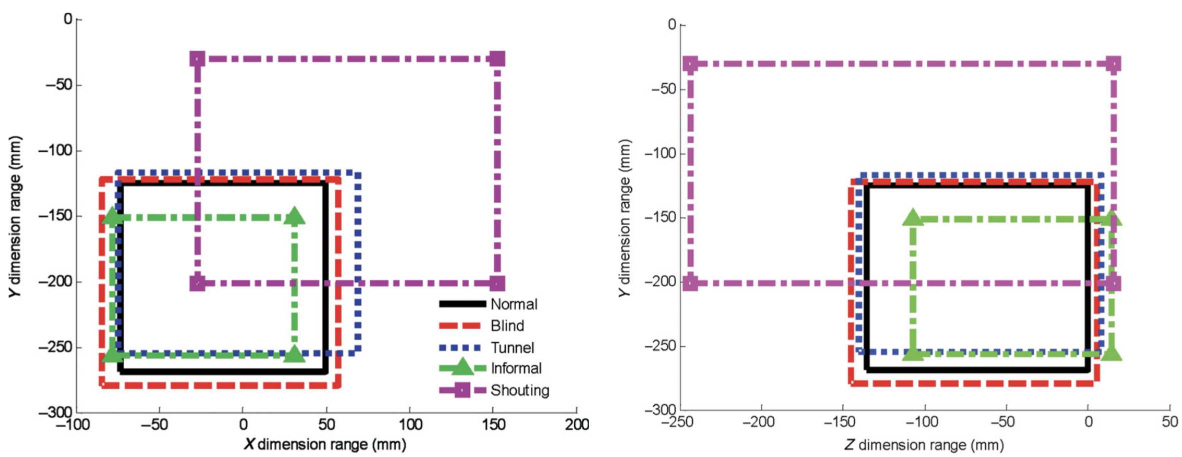


Figure 3.6: Five Conditions for the X, Y, and Z Dimensions (Emmorey et al., 2009, pp. 196-197)

Excluding the shouting condition, Table 3.2 shows that the only significant differences between the other four conditions appear in the Y dimension (vertical) of the

tunnel and informal conditions. As displayed in Figure 3.6, the normal, blind, tunnel, and informal conditions have similar X, Y, and Z dimensions overall. A smaller vertical signing space serves as a common characteristic of informal, casual signing (Table 3.2 & Figure 3.6). Tunnel vision's significant difference in the Y dimension only equates to a less than 10 mm difference from the normal condition's Y dimension.

Hearing people using spoken language tend to speak more loudly if they cannot hear themselves. This study also evaluates the condition of shouting. In theory, self-monitoring in ASL, if similar to spoken language, should mean blind signing resembles shouting signing. Blind signing, however, does not have any distinguishable differences from normal signing. Blind signing does not look like "loud" signing. Overall, visual feedback does not seem to have a significant role in the production of ASL (Emmorey et al., 2009). Similar to the proposal of Gutierrez-Sigut et al. (2016), the effort of self-monitoring sign language production sans the ability to visually perceive the production may increase language processing within the left hemisphere's language centers.

Support for English

As introduced in the Critical Period section, many arguments against ASL appear with the pretext that ASL hinders English acquisition. Some believe that Deaf people who learn ASL decrease their capacities for learning and succeeding in English. The neural networks used in language processing, however, depend on whether language learning occurs during the critical period.

In regard to early versus late language learning, the age of acquisition affects which neural networks function in language processing. For early exposure, language processing

occurs in the anterior brain; for late exposure, language processing occurs in the posterior brain. The anterior brain includes the traditional language processing networks. The posterior brain includes the traditional visual information processing networks. For a person who experiences late language exposure, language information processing functions within the visual networks, which does not process language as efficiently as the traditional language processing networks (Hall, 2017). From research presented by the American Society for Deaf Children in conjunction with Gallaudet University, test scores determine that Deaf children who experience active language learning with their parents from a young age have higher social, cognitive, and linguistic abilities than Deaf children who do not (Malloy, 2003).

In a study conducted by Emmorey et al. (2016), all participants had Deaf parents, congenital deafness, and the primary language of ASL. The methods require the subjects to either fingerspell an English word or produce the ASL sign matching the English word. The ASL sign types include one-handed signs, body-anchored signs (body as location parameter), and two-handed signs. ASL uses fingerspelling for proper names or technical terms as well as for a special sign type called loan signs. Loan signs use the handshapes for English letters in the spelling; however, loan signs each have a specific orientation, location, and movement that do not follow the regulated fingerspelling parameters.

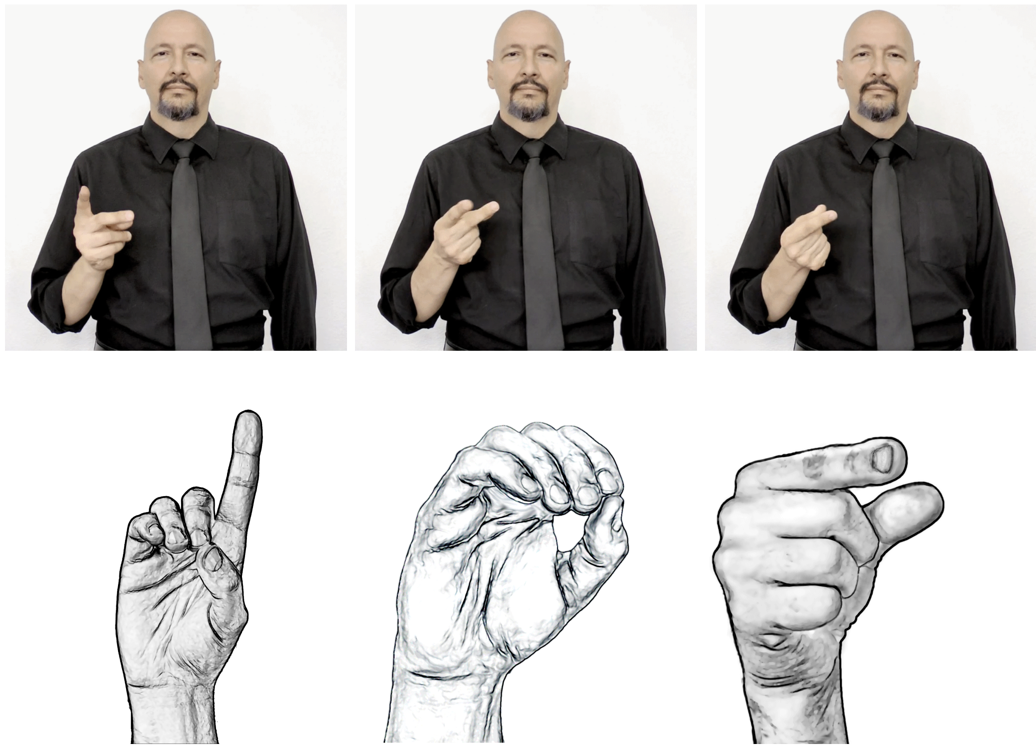


Figure 3.7: Loan Sign versus Fingerspelling for Dog

(https://www.lifeprint.com/asl101/pages-signs/d/dog.htm;

https://www.lifeprint.com/asl101/fingerspelling/abc-gifs/index.htm)

Figure 3.7 shows the difference between loan sign and normal fingerspelling parameters for dog. The letters in loan signs tend to blend together and some letters may not fully appear in the word. The signs for yes and no also fit in the loan sign category, denoted by a #YES and #NO. A baseline task asks the subject to answer yes or no to whether the English word includes a descending letter, such as j, p, q, or y, meaning the letter has a palm-down orientation. The results for the one-handed signs, body-anchored signs, and

two-handed signs use the descender baseline as the controlled variable. Emmorey et al. (2016) operates positron emission tomography (PET) scans to obtain data.

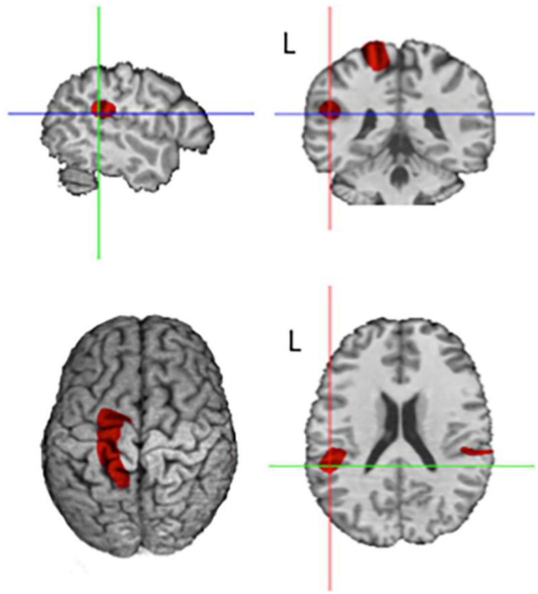


Figure 3.8: PET Scan of the Conjunction of One-handed, Body-anchored, and Two-handed Signs (Emmorey et al., 2016, p. 39)

The PET scan showing the conjunction of sign types (Figure 3.8) supports the claim that sign language processing happens in brain regions, called "language regions", with more left lateralization, similar to spoken language. According to Emmorey et al. (2016), the bilateral activation in the supramarginal gyrus bilaterally can reflect processing of phonological features. The subjects in this study all learned ASL early in life (from birth), so their brains employ language centers in the brain to process ASL. In terms of fingerspelling tasks, the PET scans show higher activation in the visual word form area (VWFA) for

fingerspelled words than for other sign types. These data promote the incorporation of ASL in the education curriculum for Deaf children in order to enhance English learning.

Continuing the analysis of fingerspelling with regard to English learning, Emmorey et al. (2015) study the "neural regions that underlie comprehension of fingerspelled words, printed words, and ASL signs in deaf ASL–English bilinguals" using functional magnetic resonance imaging (fMRI). A false font task, meaning a string of letters not creating a word, serves as the baseline. Hearing non-signers serve as the control group in this study of 28 Deaf participants, 21 of whom learned ASL from birth and seven of whom learned ASL by the age of seven years.

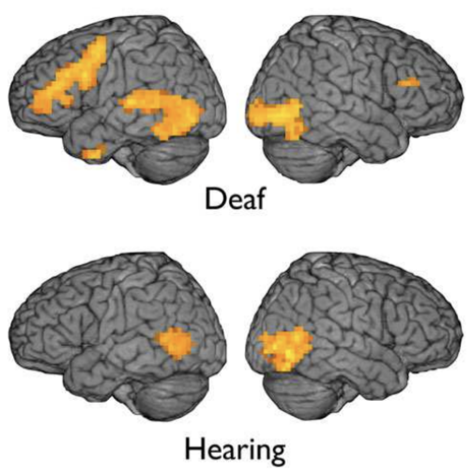


Figure 3.9: Fingerspelled Words versus Baseline (Emmorey et al., 2015, p. 756)

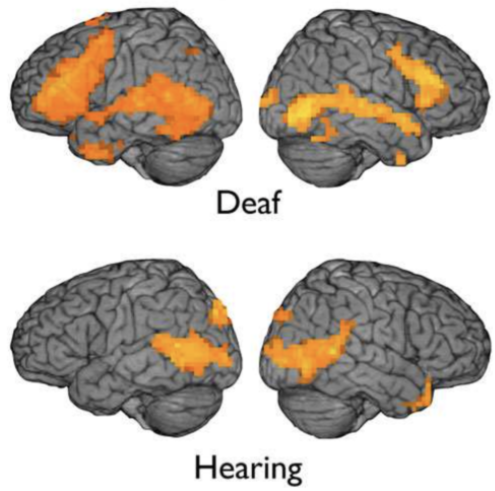


Figure 3.10: ASL Signs versus Baseline (Emmorey et al., 2015, p. 756)

As expected, fingerspelling and ASL signs activates more neural networks in someone who knows the language (Deaf) than someone who does not know the language (hearing). Some activated networks do overlap between these measures (Figures 3.9 & 3.10). In fingerspelled words, the Deaf and hearing averages show activation of the temporal cortex and the left middle temporal gyrus. For ASL signs, the Deaf and hearing average activations overlap in the temporal cortex, right temporal pole, left inferior and middle temporal gyri, and the occipital cortex. Refer back to the Language in the Brain section for an explanation of the temporal lobe (cortex), a gyrus, and the occipital lobe (cortex). The left inferior and middle temporal gyri mean the ridges in the lower and middle parts of the left temporal lobe. The right temporal pole means the front point-looking part of the right temporal lobe, see the right picture of the hearing brain in Figure 3.10. These data lead to a claim that hearing people recognize ASL as a language despite not understanding the language. The ASL stimuli activate the frontal cortex and additional regions within the temporal cortex in the Deaf participants.

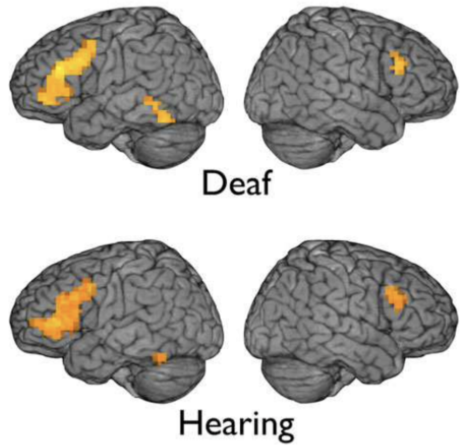


Figure 3.11: Printed Words versus False Fonts (Emmorey et al., 2015, p. 755)

In Figure 3.11, both the Deaf and hearing subjects can comprehend the stimulus of printed words. Printed words activate the same neural circuit in Deaf and hearing people alike. These data sustain the claim that ASL does not hinder English learning but rather enhances the ability for Deaf people to learn English. Learning ASL did not decrease the Deaf participants' comprehension of written English. ASL allows Deaf people to establish a language foundation accessible to their senses. Looking again at Figure 3.9, fingerspelled and printed words engage a similar neural network in Deaf signers, which advances the idea that "fingerspelling can provide a mediating link to support literacy and vocabulary acquisition in deaf readers" (Emmorey et al., 2015, p. 766).

Considering the data in this section, learning ASL at a young age supports the learning of English for Deaf people. ASL engages language-processing neural networks, similar to English. ASL also shows left lateralization of activation, like English. When a Deaf person learns ASL early, the activation in their brain for written English and fingerspelling in ASL have indistinguishable differences. Learning ASL early not only

networks the neural circuits for language, but it also paves the way to learn and comprehend English.

Conclusion

Historically, the curriculum for Deaf students either excluded or limited the use of ASL because of the belief that learning ASL hindered a Deaf student from learning English. Deaf people need a fully accessible language; ASL offers a sensory-motor modality versus an incompletely accessible modality of spoken English. A child needs to learn a language before a delay in language learning leads to language deprivation and further delays in academic and social skills.

Humans desire contemplation, expression, and connection; all of which communication can accomplish. Language plays a key role in the lives of humans by providing a means by which to communicate. Every language must have an established system of features, parameters, and rules. Symbols of the spoken, written, signed, or drawn forms can compose the set within a language. With these symbols, users of a language can produce endless possibilities of information. The language users define the language by monitoring, correcting, and expanding the language over time.

Linguistics, the study of language, characterizes the organization of a language by phonology, morphology, syntax, and semantics. Each of these categories describes specific parts of the language's structure and function. American Sign Language (ASL) fulfills the requirements of each linguistic category with its unique structure and function. From the shape of one's hand to the order of the words, ASL functions as an independent language with special linguistic rules to follow.

The brain employs many neural networks for language processing. The frontal, parietal, and temporal lobes connect at the arcuate fasciculus (AF), which also include the Broca's area and Wernicke's area. Language can activate specific areas of each lobe,

depending on the language task. The Broca's area allows articulation and production of language while the Wernicke's area functions in comprehension. Tests and scans, such as electroencephalogram (EEG), functional transcranial Doppler ultrasound (fTCD), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI) can measure the activation of a neural area by means of electrical signal or imaging of metabolism.

The critical period of language learning tends to occur between birth and the age of five years old. If a child misses language acquisition within the critical period, the child suffers from language deprivation, which can negatively impact cognitive and social function. The idea of critical period comes from the quantifiable plasticity of the brain. As the brain develops and organizes experiences, new network circuits form. Evidence from studies evaluating participants of early or late age of acquisition shows that late language learners do not have as many neural networks for language processing within the perisylvian regions. This results in more time for comprehension and/or less overall comprehension across various structures of language. These data support the importance of early language acquisition as a means of linguistic success in the future.

When Deaf people have full access to a visual language, namely ASL or their country-specific sign language, a language foundation forms. Utilizing one's language foundation, allows one to learn and understand other concepts, including another language, through cognitive processing. Full language access may also have implications for behavior of children. Humans desire to express themselves and for others to understand them. When parents and children can communicate in a language with one another, the behavior of the child can improve. Furthermore, parents taking an active role in their child's learning

experience correlates with improved behavior on behalf of the child. Schools encouraging ASL in Deaf children's education can also support parents in how to best take an active role in their child's learning.

In terms of lateralization, language processing tends to take place predominantly in the left hemisphere. Due to plasticity, younger children may show some bilaterality or right lateralization in certain brain areas. With maturation, however, the brain shows left lateralization for both English and ASL. Some features of ASL require right hemispheric processing, but most ASL processing concentrates in the left hemisphere. Left lateralization of ASL further supports the claim of ASL functioning as a full, valuable language.

If a Deaf person learns language later, some linguistic neural networks do not form and the period of brain plasticity has lessened or closed. If a Deaf person learns language early, then their language experience and success compares to English and can support English learning. ASL has a sensory-motor modality while English has an aural-oral modality. Using brian tests and scans, the activation of language regions in the brain show that both languages activate similar regions. ASL does differ in its monitoring functions since self-monitoring cannot occur through passive listening as English can. Signers do not watch their hands or facial expressions, so blocked visual perception does not notably change overall signing.

Research shows that native signers have comparable intelligence test scores to hearing peers, made possible by the language foundation of the sensory-motor modality of ASL. Even in hearing people who do not sign, some activation occurs within the language regions of the brain, meaning they recognize a language. In addition to ASL engaging language regions, printed words activate the same neural networks in native Deaf signers and

hearing non-signers. These data support that ASL does not hinder Deaf people from learning and succeeding in English.

Overall, ASL fulfills all the requirements of a true language, and its processing requires the traditional language regions of the brain. Due to the critical period of brain plasticity, Deaf children should learn sign language (ASL) at an early age of acquisition. Schools need to include ASL in the early education of Deaf students. This promotes neural networking with left lateralization to successfully and efficiently process language. With a sign language foundation, Deaf people can learn English better. Language processing lends itself to cognitive abilities in other domains, such as academics and social interaction. Therefore, Deaf people learning ASL early not only prepares them for success in language but for success in all aspects of their lives.

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