Course: General Introduction to the Hearing Impairment (680)
Semester: Spring, 2022

ASSIGNMENT No. 1

Q.1 Answer these short questions.

a) What and how do you measure with an audiometer?

Hearing loss comes with age but can affect anyone. According to a study in American Family Physician, at least 25 percent of people over 50 experience hearing loss, and 50 percent of people over 80 experience it. One way to test for hearing loss is through the use of audiometry.

An audiometry exam tests how well your hearing functions. It tests both the intensity and the tone of sounds, balance issues, and other issues related to the function of the inner ear. A doctor who specializes in diagnosing and treating hearing loss called an audiologist administers the test.

The unit of measure for sound intensity is the decibel (dB). A healthy human ear can hear quiet sounds such as whispers. These are about 20 dB. A loud sound such as a jet engine is between 140 and 180 dB.

The tone of a sound is measured in cycles per second. The unit of measure for tone is Hertz (Hz). Low bass tones measure around 50 Hz. Humans can hear tones between 20-20,000 Hz. Human speech generally falls in the 500-3,000 Hz range.

An audiometry test is performed to determine how well you can hear. This may be done as part of a routine screening or in response to a noticeable loss of hearing.

The common causes of hearing loss include:

- birth defects
- chronic ear infections
- inherited conditions, such as otosclerosis, which occurs when an abnormal growth of bone prevents structures within the ear from functioning properly
- an injury to the ear
- inner ear diseases, such as Ménière's disease or an autoimmune disease that affect the inner ear
- regular exposure to loud noises
- a ruptured eardrum

Damage to the ear or exposure to loud sounds for a long period can cause hearing loss. Sounds louder than 85 dB, such as you hear at a rock concert, can cause hearing loss after only a few hours. It's good to use hearing protection, such as foam earplugs, if you're exposed to loud music or industrial noise on a regular basis.

Sensorineural hearing loss occurs when hair cells in the cochlea aren't working properly. The cochlea is the part of the ear that translates sound vibrations into nerve impulses to be sent to the brain. Sensorineural hearing loss can also occur due to damage to the nerve that carries sound information to the brain or damage to part of the brain that processes this information. This type of hearing loss is usually permanent. It can be mild, moderate, or severe.

The Risks of Audiometry

Audiometry is noninvasive and carries no risk.

How to Prepare for Audiometry

An audiometry exam requires no special preparation. All you have to do is show up to your appointment on time and follow the audiologist's instructions.

How Audiometry Is Performed

There are a few tests involved in audiometry. A pure tone test measures the quietest sound you can hear at different pitches. It involves using an audiometer, which is a machine that plays sounds via headphones. Your audiologist or an assistant will play a variety of sounds, such as tones and speech, at different intervals into one ear at a time, to determine your range of hearing. The audiologist will give you instructions for each sound. Most likely, they'll ask you to raise your hand when a sound becomes audible.

Another hearing test allows your audiologist to assess your ability to distinguish speech from background noise. A sound sample will be played for you and you'll be asked to repeat the words you hear. Word recognition can be helpful in diagnosing hearing loss.

A tuning fork may be used to determine how well you hear vibrations through your ears. Your audiologist will put this metal device against the bone behind your ear, the mastoid, or use a bone oscillator to determine how well vibrations pass through the bone to your inner ear. A bone oscillator is a mechanical device that transmits vibrations similar to a tuning fork.

This test doesn't cause any pain or discomfort and takes about an hour.

After Audiometry

After the test, your audiologist will review your results with you. Depending on how well you hear volume and tone, your doctor will tell you about any preventive measures you should take, such as wearing earplugs around loud noises, or any corrective measures you may need, such as wearing a hearing aid.

b) What and how do you measure with a sound level meter?

sound-level meter, device for measuring the intensity of noise, music, and other sounds. A typical meter consists of a microphone for picking up the sound and converting it into an electrical signal, followed by electronic circuitry for operating on this signal so that the desired characteristics can be measured. The indicating device is usually a meter calibrated to read the sound level in decibels (dB; a logarithmic unit used to measure the sound intensity). Threshold of hearing is about zero decibels for the average young listener, and threshold of pain (extremely loud sounds) is around 120 decibels, representing a power 1,000,000,000,000 (or 10^{12}) times greater than zero decibels.

The electronic circuitry can be adjusted to read the level of most frequencies in the sound being measured or the intensity of selected bands of frequencies. Because the alternating current (AC) signal received by the unit's microphone first must be converted to a direct current (DC), a time constant must be incorporated to average the signal. The constant selected depends on the purpose for which the instrument was designed or for which it is being used.

A typical sound-level meter can be switched between a scale that reads sound intensities uniformly for most frequencies—called unweighted—and a scale that introduces a frequency-dependent weighting factor, thus yielding a response more nearly like that of the human ear. A-frequency-weighting is the most commonly used standard, but B-, C-, D-, and Z-frequency-weightings also exist. The A-frequency-weighting scale is useful in describing how complex noises affect people. Thus, the scale is recognized internationally for measurements relating to prevention of deafness from excessive noise in work environments.

In the early 1970s, as concern about noise pollution increased, accurate, versatile, portable noise-measuring instruments were developed. Sound level is not a measure of loudness, as loudness is a subjective factor and depends on the characteristics of the ear of the listener.

Q.2 Describe the cochlea, its structure and function in detail.

The inner ear consists of:

- The cochlea (organ of hearing);
- The peripheral vestibular apparatus (organ of body balance).

Cochlea

The cochlea is a dense, snail-like structure of two and three-quarter turn, which lies sideways and houses the organ of Corti. Its spiral canal varies in length from 29mm to 40mm and is divided into three compartments by partitions of bone and membrane. The upper (scala tympani) and lower (scala vestibule) compartments are filled with a fluid called perilymph; the middle compartment (scala media) is filled with a fluid called endolymph.

The organ of Corti is located on the lower membrane (basilar membrane) of the scala media and consists of cells with hair-like projections, connecting with the terminal ends of the auditory nerve. Each projection responds to different sound frequencies, with high frequencies located at its base and low frequencies towards the tip of the spiral canal (Hussain, 2016).

The first turn of the canal bulges into the middle ear and is called the promontory; the outline of this can often be seen when viewing the tympanic membrane with a microscope.

Peripheral vestibular system

The peripheral vestibular system is responsible for maintaining balance, coordinating the position of the head and eye movement. The system consists of sacs filled with endolymph, with the fibres of the vestibulocochlear nerve distributed on the walls of these sacs. Two functionally different sensory receptor systems detect head movement:

- Semicircular canals detect rotational head movements;
- Utricles and saccules detect changes in the position of the head relating to gravity (linear acceleration) and head tilts on horizontal and vertical planes.

Hair cells moving at a different rate to the endolymph cause shearing forces, and these are detected and conducted by the vestibular nerve to the brain, which interprets the type of movement that has occurred.

The primary function of the middle ear is to convert air vibrations, which have been channelled down the external ear canal to the tympanic membrane, into fluid vibrations in the cochlea.

The three smallest bones in the body – the malleus, incus and stapes (Fig 1) – are located in the middle ear. These are known collectively as the ossicles and are vital to hearing.

The malleus lies high in the middle ear, suspended by a ligament, and its head articulates with the body of the incus by a synovial joint. Although the lateral process of the malleus is the most-prominent point visible on the tympanic membrane, the incus can often be seen during otoscopy. The incus articulates with the stapes, and the footplate of the stapes sits in the oval window at the base of the cochlea. The stapes measures, on average, 3mm long and 1.4mm wide; it is attached to the oval window by a ligament.

Sound waves travel along the external ear canal and cause the tympanic membrane to vibrate. The embedded lateral process of the malleus causes the vibrations to continue across the ossicles to the footplate of the stapes. The middle ear reduces the loudness of sound partly by transferring the medium of sound from air to fluid from the ossicles to the cochlea but also by the function of the ligaments. Sound waves transmitted to the ossicles disturb the endolymph in the cochlea and cause movement of the hair-like projections on the basilar membrane. This movement of the hairs generates neural impulses, which are relayed to the brain through the cochlear nerve (Tysome and Kanegaonkar, 2018).

To guard against loud sounds, muscles attached to the malleus and stapes contract, which reduces the vibrations and protects the cochlea. This is the acoustic reflex. It takes about 40 milliseconds to occur, so if there is a sudden loud sound, such as an explosion, it will not happen in time and noise-induced hearing damage can occur.

In the foetus, the auditory cortex (hearing part of the brain) is fully formed, which is why newborn screening of hearing is very effective and 98.5% of babies born in the UK are tested in the first three months after birth (Public Health England, 2019).

The importance of the ear

Problems with hearing or balance can be extremely debilitating. Hearing connects people socially and a person's ability to balance and move around safely helps maintain independence.

Although the ear is a relatively small structure, it is served by five cranial nerves:

- Trigeminal nerve (fifth cranial nerve);
- Facial nerve (seventh cranial nerve);
- Vestibulocochlear (eighth cranial nerve);
- Glossopharyngeal (ninth cranial nerve);
- Vagus (tenth cranial nerve).

During an ear examination, stimulation of the auricular branch of the vagus nerve can cause the patient to cough; this is called the Arnold's reflex

Q.3 Elaborate the physiology of the human ear. What is the frequency range of hearing of a normal human ear?

Hearing is the process by which the ear transforms sound vibrations in the external environment into nerve impulses that are conveyed to the brain, where they are interpreted as sounds. Sounds are produced when vibrating objects, such as the plucked string of a guitar, produce pressure pulses of vibrating air molecules, better known as sound waves. The ear can distinguish different subjective aspects of a sound, such as its loudness and pitch, by detecting and analyzing different physical characteristics of the waves. Pitch is the perception of the frequency of sound waves—i.e., the number of wavelengths that pass a fixed point in a unit of time. Frequency is usually measured in cycles per second, or hertz. The human ear is most sensitive to and most easily detects frequencies of 1,000 to 4,000 hertz, but at least for normal young ears the entire audible range of sounds extends from about 20 to 20,000 hertz. Sound waves of still higher frequency are referred to as ultrasonic, although they can be heard by other mammals. Loudness is the perception of the intensity of sound —i.e., the pressure exerted by sound waves on the tympanic membrane. The greater their amplitude or strength, the greater the pressure or intensity, and consequently the loudness, of the sound. The intensity of sound is measured and reported in decibels (dB), a unit that expresses the relative magnitude of a sound on a logarithmic scale. Stated in another way, the decibel is a unit for comparing the intensity of any given sound with a standard sound that is just perceptible to the normal human ear at a frequency in the range to which the ear is most sensitive. On the decibel scale, the range of human hearing extends from 0 dB, which represents a level that is all but inaudible, to about 130 dB, the level at which sound becomes painful. (For a more in-depth discussion, see sound.)

In order for a sound to be transmitted to the central nervous system, the energy of the sound undergoes three transformations. First, the air vibrations are converted to vibrations of the tympanic membrane and ossicles of the middle ear. These in turn become vibrations in the fluid within the cochlea. Finally, the fluid vibrations set up traveling waves along the basilar membrane that stimulate the hair cells of the organ of Corti. These cells convert the sound vibrations to nerve impulses in the fibres of the cochlear nerve, which transmits them to the brainstem, from which they are relayed, after extensive processing, to the primary auditory area of the cerebral cortex, the ultimate centre of the brain for hearing. Only when the nerve impulses reach this area does the listener become aware of the sound.

The outer ear directs sound waves from the external environment to the tympanic membrane. The auricle, the visible portion of the outer ear, collects sound waves and, with the concha, the cavity at the entrance to the external auditory canal, helps to funnel sound into the canal. Because of its small size and virtual immobility, the auricle in humans is less useful in sound gathering and direction finding than it is in many animals. The canal helps to enhance the amount of sound that reaches the tympanic membrane. This resonance enhancement works only for sounds of relatively short wavelength—those in the frequency range between 2,000 and 7,000 hertz—which helps to determine the frequencies to which the ear is most

sensitive, those important for distinguishing the sounds of consonants. Sounds reaching the tympanic membrane are in part reflected and in part absorbed. Only absorbed sound sets the membrane in motion. The tendency of the ear to oppose the passage of sound is called acoustic impedance. The magnitude of the impedance depends on the mass and stiffness of the membrane and the ossicular chain and on the frictional resistance they offer.

When the tympanic membrane absorbs sound waves, its central portion, the umbo, vibrates as a stiff cone, bending inward and outward. The greater the force of the sound waves, the greater the deflection of the membrane and the louder the sound. The higher the frequency of a sound, the faster the membrane vibrates and the higher the pitch of the sound is. The motion of the membrane is transferred to the handle of the malleus, the tip of which is attached at the umbo. At higher frequencies the motion of the membrane is no longer simple, and transmission to the malleus may be somewhat less effective.

The malleus and incus are suspended by small elastic ligaments and are finely balanced, with their masses evenly distributed above and below their common axis of rotation. The head of the malleus and the body of the incus are tightly bound together, with the result that they move as a unit in unison with the tympanic membrane. At moderate sound pressures, the vibrations are passed on to the stapes, and the whole ossicular chain moves as a single mass. However, there may be considerable freedom of motion and some loss of energy at the joint between the incus and the stapes because of their relatively loose coupling. The stapes does not move in and out but rocks back and forth about the lower pole of its footplate, which impinges on the membrane covering the oval window in the bony plate of the inner ear. The action of the stapes transmits the sound waves to the perilymph of the vestibule and the scala vestibuli.

Function of the ossicular chain

In order for sound to be transmitted to the inner ear, the vibrations in the air must be changed to vibrations in the cochlear fluids. There is a challenge involved in this task that has to do with difference in impedance—the resistance to the passage of sound—between air and fluid. This difference, or mismatch, of impedances reduces the transmission of sound. The tympanic membrane and the ossicles function to overcome the mismatch of impedances between air and the cochlear fluids, and thus the middle ear serves as a transformer, or impedance matching device.

Ordinarily, when airborne sound strikes the surface of a body of water, almost all of its energy is reflected; only about 0.1 percent passes into the water. In the ear this would represent a transmission loss of 30 dB, enough to seriously limit the ear's performance, were it not for the transformer action of the middle ear. The matching of impedances is accomplished in two ways: primarily by the reduction in area between the tympanic membrane and the stapes footplate and secondarily by the mechanical advantage of the lever formed by the malleus and incus. Although the total area of the tympanic membrane is about 69 square mm (0.1 square inch), the area of its central portion that is free to move has been estimated at about 43 square mm. The sound energy that causes this area of the membrane to vibrate is transmitted and concentrated in the 3.2-square-mm area of the stapes

footplate. Thus, the pressure is increased at least 13 times. The mechanical advantage of the ossicular lever (which exists because the handle of the malleus is longer than the long projection of the incus) amounts to about 1.3. The total increase in pressure at the footplate is, therefore, not less than 17-fold, depending on the area of the tympanic membrane that is actually vibrating. At frequencies in the range of 3,000 to 5,000 hertz, the increase may be even greater because of the resonant properties of the ear canal.

The ossicular chain not only concentrates sound in a small area but also applies sound preferentially to one window of the cochlea, the oval window. If the oval and round windows were exposed equally to airborne sound crossing the middle ear, the vibrations in the perilymph of the scala vestibuli would be opposed by those in the perilymph of the scala tympani, and little effective movement of the basilar membrane would result. As it is, sound is delivered selectively to the oval window, and the round window moves in reciprocal fashion, bulging outward in response to an inward movement of the stapes footplate and inward when the stapes moves away from the oval window. The passage of vibrations through the air across the middle ear from the tympanic membrane to the round window is of negligible importance.

Q.4 Describe briefly what you understand by the difference between the effect of conductive hearing loss and sensory neural deafness on children's ability for speech?

If your child is deaf or has hearing loss, it means that **your child's ears can't do all or any of the things they should be able to do**. For example, your child might:

- have muffled hearing
- not be able to hear sounds coming from some directions
- have trouble hearing certain frequencies or sounds.

Hearing loss can be mild, moderate, severe or profound. It can affect one or both ears.

Types of deafness or hearing loss

Deafness or hearing loss can be:

- **congenital** – this is deafness or hearing loss from birth or soon after birth
- **acquired** – this is deafness or hearing loss that happens later in life.

There are two main types of deafness or hearing loss – conductive and sensorineural.

Conductive hearing loss is when sounds from outside your child's ear have trouble getting through the outer or middle ear. Conductive hearing loss is usually caused by middle ear fluid from middle ear infections, and is usually temporary.

Sensorineural hearing loss is when the inner ear or the auditory nerve doesn't work properly. Sensorineural hearing loss usually lasts for life and can get worse over time.

Mixed hearing loss is when a child has both conductive and sensorineural hearing loss.

Diagnosing deafness or hearing loss: universal newborn hearing screening

Early diagnosis of hearing loss is important. The earlier you find out your child has a hearing loss, the sooner your child can begin early intervention and develop language to communicate with.

In Australia, **universal newborn hearing screening** is an essential part of diagnosing deafness or hearing loss in children.

All Australian states and territories have a universal newborn hearing screening program that aims to:

- screen the hearing of all babies by 1 month of age
- refer any babies with possible hearing loss for diagnostic testing with an audiologist by 3 months of age to confirm whether they have hearing loss
- start early intervention for babies with hearing loss by 6 months of age.

During screening, special equipment plays specific sounds into your baby's ears and records the responses from your baby's brain. The screening technology might be different in different parts of Australia.

In most places, your baby will be screened in hospital, before you take your baby home. Each state has its own way of following up on babies who don't have a hearing screen in hospital.

Each state also has its own way of referring babies to audiology and supporting parents and families.

Hearing screening isn't compulsory. You have to give your permission for your baby to be screened, which means signing a consent form.

Signs of deafness or hearing loss

If your baby is deaf or has hearing loss, they won't hear people speaking. This means that your baby **might not respond to your voice** and other noises in the way you'd expect. As your baby gets older, you might notice that their speech and language aren't developing like other children's.

As a guide, **here's what you'd expect in a typically developing baby**. If your child isn't doing these things, it might be a good idea to talk to your GP or child and family health nurse.

- At **0-4 months**, your baby should startle at a loud noise, turn their head or move their eyes to locate the source of the sound. If your baby is upset by the noise, they should calm down when they hear your voice.
- At **4-8 months**, your baby should notice sounds nearby, smile when spoken to, babble and understand simple words like 'bye-bye'.
- At **8-14 months**, your baby should respond to their name, say simple words like 'mama' and 'dada', copy simple sounds and use their voice to get attention from people nearby.
- At **14-24 months**, your child will start to develop vocabulary, understand and follow simple instructions, and put 2 words together.

Even if everything seems OK but you still feel worried, you should see your GP or child and family health nurse.

Learning to communicate: deaf children and children with hearing loss

The most important thing for your child's development, and for your relationship with your child, is being able to communicate.

If your child is deaf or hard of hearing, they might use spoken language, sign language or a combination of sign and spoken language to communicate.

Many families choose to teach their child to both speak and sign, regardless of whether the child can use spoken language. If this is your family's choice, you and the rest of your family need to learn sign language too. You can ask the health professionals who are caring for you and your child for more information and support to learn sign language.

Listening devices for deaf children and children with hearing loss

There are devices that can help your child hear spoken language. And when your child can hear spoken language, they can start learning to use language.

The right type of device for your child will depend on the type of hearing loss they have and how severe it is. These devices, called **amplification devices or assistive listening devices**, include:

- hearing aids
- bone conduction implants
- cochlear implants
- personal frequency modulation (FM) systems.

Your child might use one device, or a **combination of devices**. Using a combination might give your child more opportunities to hear sounds because each device does a slightly different job. Your child might also use these devices in combination with spoken language and sign language.

Many children with hearing loss use assistive listening devices on both ears.

Your child's audiologist can help you tell whether the devices are helping your child.

Early intervention for deaf children and children with hearing loss

Early intervention is the best way to support your child's development. Early intervention includes **therapies, education and other supports** that will help your child reach their full potential.

Early intervention should also include helping you learn how to spend time with your child in ways that support their development. Children learn the most from the people who care for them and with whom they spend most of their time, so **everyday play and communication with you** can help your child a lot.

You and your child will probably work with many health and other professionals as part of your child's early intervention. These professionals include audiologists, speech pathologists and special education teachers.

It's good to see yourself as working in partnership with your child's professionals. When you combine your deep knowledge of your child with the professionals' expertise, you're more likely to get the best outcomes for your child.

Q.5 What is meant by pre-lingual deafness? What would be the difference in the language development of a congenitally deaf child and a child deafened at about five years of age?

Prelingual deafness refers to deafness that occurs before learning speech or language. Speech and language typically begin to develop very early with infants saying their first words by age one. Therefore, prelingual

deafness is considered to occur before the age of one, where a baby is either born deaf (known as congenital deafness) or loses hearing before the age of one. This hearing loss may occur for a variety of reasons and impacts cognitive, social, and language development.

Statistics

There are approximately 12,000 children with hearing loss in the United States. Profound hearing loss occurs in somewhere between 4 and 11 per every 10,000 children In 2017, according to the CDC, of the 3,742,608 babies screened, 3,896 were diagnosed with hearing loss before the age of three months or 1.7 babies per 1,000 births were diagnosed with hearing loss in the United States.

Causes

Prelingual hearing loss can be considered congenital, present at birth, or acquired, occurring after birth before the age of one. Congenital hearing loss can be a result of maternal factors (rubella, cytomegalovirus, or herpes simplex virus, syphilis, diabetes), infections, toxicity (pharmaceutical drugs, alcohol, other drugs), asphyxia, trauma, low birth weight, prematurity, jaundice, and complications associated with the Rh factor in the blood. These nongenetic factors account for about one fourth of the congenital hearing losses in infants while genetic factors account for over half of the infants with congenital hearing loss. Most of genetic factors are caused by an autosomal recessive hearing loss or an autosomal dominant hearing loss.[7][8] Autosomal recessive hearing loss is when both parents carry the recessive gene, and pass it on to their child. The autosomal dominant hearing loss is when an abnormal gene from one parent is able to cause hearing loss even though the matching gene from the other parent is normal. This can lead to genetic syndromes, such as Down syndrome, Usher syndrome or Waardenburg syndrome, which are concomitant with hearing loss. Acquired hearing loss can be the result of toxicity (drugs given as treatment when in the neonatal intensive care unit) and infections such as meningitis.

Treatment

Hearing aids and cochlear implants may make the child able to hear sounds in their hearing range—but they don't restore normal hearing. Cochlear implants can stimulate the auditory nerve directly to restore some hearing, but the sound quality isn't that of a normal hearing ear, suggesting that deafness cannot be fully overcome by medical devices. Some say that the benefits and safety of cochlear implants continues to grow, especially when children with implants receive a lot of oral educational support. It is a goal for some audiologists to test and fit a deaf child with a cochlear implant by six months of age, so that they don't get behind in learning language. In fact, there are expectations that if children get fit for implants early enough, they can acquire verbal language skills to the same level as their peers with normal hearing.

Social and cognitive impact

Children who are prelingually deaf and cannot hear noise beneath 60 decibels—about the intensity level of a vacuum cleaner—don't develop oral language comparable to their peers. Children born with profound hearing impairment, 90 decibels and above (about the level of a food blender), are classified as functionally deaf. These

children do not develop speech skills without help from a speech pathologist. Such children display speech comprehension difficulties, even when other modes of language (such as writing and signing) are up to their age level standard. Children who lose their hearing after they have acquired some amount of language, even if it is just for a short while, demonstrate a much higher level of linguistic achievement than those who have not had any language exposure.

In children, this type of hearing loss can lead to social isolation for several reasons. First, the child experiences delayed social development that is in large part tied to delayed language acquisition (e.g., language deprivation). It is also directly tied to their inability to pick up auditory social cues. A child who uses sign language, or identifies with the Deaf culture does not generally experience this isolation, particularly if they attend a school for the deaf, but may conversely experience isolation from their parents if they do not know, or make an effort to learn sign language. A child who is exclusively or predominantly an oral communicator can experience social isolation from their hearing peers, particularly if no one takes the time to explicitly teach them social skills that other children acquire independently by virtue of having normal hearing.

Language acquisition

Speech acquisition

Deaf children do not acquire speech the same as hearing children because they cannot hear the language spoken around them. Spoken language is based on combining speech sounds to form words which are then organized by grammatical rules in order to convey a message. This message is language.[15] In normal language acquisition, auditory comprehension of speech sounds precedes the development of language.[16] Without auditory input, a person with prelingual deafness is forced to acquire speech visually through lip-reading. Acquiring spoken language through lip-reading alone is challenging for the deaf child because it does not always accurately represent speech sounds. The likelihood of a deaf child successfully learning to speak is based on a variety of factors including: ability to discriminate between speech sounds, a higher than average non-verbal IQ, and a higher socioeconomic status. Despite being fitted with hearing aids or provided with oral instruction and speech therapy at a young age, prelingually deaf children are unlikely to ever develop perfect speech and speech-reception skills. Some researchers conclude that deaf children taught exclusively through spoken language appear to pass through the same general stages of language acquisition as their hearing peers but without reaching the same ultimate level of proficiency. Spoken language that may develop for prelingually deaf children is severely delayed.

Cochlear implants

Speech perception can be corrected prior to language acquisition with cochlear implants. After a year and a half of experience, researchers found the deaf culture[vague] was able to identify words and comprehend the movements of others' lips. There is a greater opportunity to hear a sound depending on the location of electrodes compared to the tissue and the number of remaining neurons located in the auditory system.[19] In addition,

individual capacities, as well as the neural supply to the cochlea, play a role in the process of learning with cochlear implantation.

Research has continuously found that early implantation leads to better performance than older implantation. Studies continue to show that children with prelingual deafness are able to interact in society comfortably when implantation occurs before the age of five. Exposure to non-auditory signals prior to implantation may negatively affect the ability to process speech after the implantation. Speech production is a slower procedure in the beginning since creating words requires more effort. Children who had almost two years of experience with cochlear implants were able to generate diphthongs and sound out most vowels. They develop skills to understand more information as well as put together letters.

Cochlear implants give deaf individuals the chance to understand auditory messages. Progress was analyzed after several groups of children were given vocabulary and language tests. After three years of practice, the children with the devices did as well as children that had no previous issues with hearing. Specifically, cochlear implants allow children with prelingual deafness to acquire skills similar to children with minimal or mild hearing loss.

Sign language acquisition

The ability to acquire speech is not the same as the ability to acquire language. The population's primary means of communication is produced orally; however, speech and language are dissociative factors. Although we are biologically equipped to use language, we are not biologically limited to speech. A child who has no access to a spoken language readily acquires sign language, and children deprived of both oral and sign language sometimes invent their own gestural communication system.

There is an innate desire to produce language in both hearing and deaf population. All babies vocalize to communicate. Deaf children who have not been exposed to sign language create their own gesture communication known as homesign for the purpose of expressing what they are feeling. This term refers to gestures that are being used by deaf individuals who were reared in isolation from other deaf signers. Homesign is viewed as a biological component of language because it originates directly from the deaf child and because it is a global occurrence, transcending culture.

Sign language, such as American Sign Language (ASL), is a well known form of communication that is linguistic for both hearing and deaf individuals. Deaf children learning a sign language such as ASL go through a series of language milestones from birth through one year of age. These milestones are similar to those of spoken language. A deaf child is aware of their environment, enjoys human interaction, smiles, and enjoys hand play from birth to 3 months of age. From 3–6 months a deaf child also begins to babble, referred to as finger babbling. These gestures of the deaf children do not have real meaning, any more than babble noises have meaning, but they are more deliberate than the random finger flutters and fist clenches of hearing babies. (Angier, 1991) Between 6–12 months, deaf children use manual communication and communicate with

gestures, such as pulling and pointing. Many deaf children sign their first word around 8 months and up to 10 or more signs by 12 months.

Reading and short-term memory

Learning three-dimensional grammar, such as in ASL, boosts the child's visual and spatial abilities to higher than average levels. To succeed at learning to read, the deaf child must have a strong language to base it upon. Additionally, communication difficulties with the teacher can impair reading.

Additionally, deaf children performed more poorly in short-term memory spans for written words in comparison to age-matched hearing children simply because they are not as familiar with English words. Short-term memory spans for signs and fingerspelling are also reduced in comparison to age-matched hearing children's span for spoken words. Deaf children vary widely in their developmental experience with sign language, which affects development of short-term memory processes. Children who begin language acquisition at older ages and/or have limited language input during early childhood have underdeveloped sign language skill, which, in turn, affects their short-term memory development.[22] However, with the linguistic element removed, deaf children's performance is equivalent to age-matched hearing children on short-term memory tasks.

Children of deaf parents

Mothers who are deaf themselves model signs during face-to-face interactions with their deaf babies. They mold the hands of their babies to form shapes of signs. They exaggerate their facial expressions and provide models in the direct line of vision of their deaf babies. Caregivers of both hearing children and deaf children reinforce the child's early attempts at communication, thus encouraging further and more elaborate communication.

Deaf students who have deaf parents outperform their deaf peers who have hearing parents on every subtest of the WISC-R performance scale. This is due to the fact that deaf parents are better prepared than hearing parents to meet the early learning needs of the deaf child; thus, they acquire language 'on schedule'. Additionally, deaf children of deaf parents pass through language development stages earlier because the visual pathways are fully myelinated at an earlier age than the comparable auditory pathways.

Neuropsychological function

Deaf children often have enhanced perceptual skills to compensate for the impaired auditory input, and this continues throughout adulthood. Congenitally deaf adults who used sign language showed ERPs that were 5-6 times larger than those of hearing adults over the Left and Right occipital regions and ERPs 2-3 times larger than hearing participants over the left temporal and parietal regions (which are responsible for linguistic processing).[24] Because both hearing and deaf adults using ASL showed larger ERPs occipital regions, the heightened response to visual stimuli is also due to knowing and using sign language and not only due to deafness.

Both hearing and deaf adults using ASL also show larger ERPs over the left than right hemisphere. Since the left hemisphere is responsible for language, this implies that sign movement is linguistically salient. The movement processed on the left side (language) implies that the right visual field is stronger in deaf and hearing ASL due to the hemispheric association being contralateral.

Sociocultural factors

Deaf children from a lower socioeconomic status are at a high risk for not being exposed to accessible language at the right time in early childhood. This is because in most countries poverty translates into a lack of access to the educational and clinical services that expose deaf children to language at the appropriate age.

Academic achievement of deaf students is predicted to a large extent by the same factors that predict the academic achievement of normally hearing students, such as social class and the presence of additional handicapping conditions. This means that deafness, by itself, does not determine academic success or failure but rather interacts with many other factors in complex ways.