Course: Speech & Hearing (682)
Semester: Spring, 2022

ASSIGNMENT No. 1

Q.1 What do you understand by waveforms of a pure tone? Is speech a simple or a complex sound wave?

In psychoacoustics and signal processing, a **pure tone** is a sound or a signal with a sinusoidal waveform; that is, a sine wave of any frequency, phase-shift, and amplitude.

A pure tone has the property – unique among real-valued wave shapes – that its wave shape is unchanged by linear time-invariant systems; that is, only the phase and amplitude change between such a system's pure-tone input and its output.

Sine and cosine waves can be used as basic building blocks of more complex waves. As additional sine waves having different frequencies are combined, the waveform transforms from a sinusoidal shape into a more complex shape.

Acoustic phonetics is the study of the physical properties of speech**,** and aims to analyse sound wave signals that occur within speech through varying frequencies, amplitudes and durations.

One way we can analyse the acoustic properties of speech sounds is through looking at a waveform. Pressure changes can be plotted on a waveform, which highlights the air particles being compressed and rarefied, creating sound waves that spread outwards. A tuning fork being struck can provide an example of the pressure fluctuations in the air and how the air particles oscillate (move in one direction rhythmically) when we perceive sound.

In clinical audiology, pure tones are used for pure-tone audiometry to characterize hearing thresholds at different frequencies. Sound localization is often more difficult with pure tones than with other sounds.

Sine waves are waveforms that have very simple, regular repeating patterns. The number of 'cycles' in the waveform (the number of complete repetitions in the period waveform) reflects the number of times the vocal folds have opened within the time frame displayed. This is known as the **fundamental frequency (f0)**, which is measured in Hertz (Hz). A frequency of 200Hz means that there are 200 hundred complete cycles per second within the waveform, so 200 times the vocal folds have opened. In reality, most speech sound waves have a rather complex pattern, and are known as **complex waves**. These are made up of two or more simple sine waves, and the fundamental frequency can also be calculated on complex waveforms by counting the number of cycles per second on a waveform. Sine and complex waveforms are **periodic**, meaning their cycles are regular and repetitive. The types of speech sounds that would appear as a periodic sound wave are voiced sounds, such as vowels or nasals. Since such sounds have regularly repeating waveforms, they can also be decoded through '**Fourier analysis**' which breaks down the component sine waves. This type of graph is called a **spectrum**, which does not measure time. Instead, the x-axis measures frequency, and the y-axis represents the sound pressure level.

The fundamental frequency on this type of graph can be worked out by selecting the lowest frequency component of this complex wave. This is usually the first complete peak on the spectrum. From this fundamental frequency peak, **harmonics** occur at evenly spaced integer multiples. Harmonics are known as the '**natural resonances**' within the vocal tract, which are the amplified frequencies. On the spectrum, these correspond to each peak.

On the other hand, speech sounds can also be **aperiodic** when analysing them acoustically. This means that they do not have a regular repeating pattern, rather, they have a very random pattern meaning that a fundamental frequency cannot be calculated. This means that the aperiodic speech sounds are voiceless, such as a voiceless fricative.

Another way to analyse a sound acoustically is through looking at a **spectrogram**. They provide much more complex information than what we can see on a waveform. Similarly to waveforms, time is displayed on the x-axis, but the y-axis measures the frequency of the sound. Amplitude is represented by the darkness in the acoustic energy. The louder the sound, the darker it appears on a spectrogram and is therefore more intense. Spectrograms allow us to see the high frequency energy that comes with aperiodic sounds.

Q.2 Write a detailed note on detection and discrimination skill development for any kind of sound stimuli?

Auditory training is an intervention method used in rehabilitative audiology that aims to help individuals with hearing loss use their residual hearing maximally. It emphasizes the development of listening skills to improve the recognition and interpretation of speech sounds despite limited hearing ability. This chapter explains how auditory training techniques may be adapted to help medical students and physicians improve their listening skills for heart auscultation. First, research supporting auditory training efficacy for enhancing sound perception in people with and without hearing loss is reviewed, followed by a discussion of some of the auditory training strategies that are believed to promote auditory learning. The chapter then briefly describes how principles of auditory training have been applied to the design of a computer-assisted auditory training program that helps medical students and physicians develop a better mastery of the auditory skills necessary for differentiating between innocent and pathological heart murmurs.

In the field of audiology, auditory training refers to the process involved in improving the auditory skills of individuals with hearing loss through structured and repetitive listening exercises. In a nutshell, auditory training consists of exercises, also known as listening trials, where the person (1) listens to a large number of presentations of speech sounds or other kinds of sounds, (2) makes a judgement after listening to each presentation such as identifying the sound heard, and (3) receives feedback after each attempt about whether the judgment was correct or incorrect. A basic premise to this type of intervention is the notion that hearing is a sense but listening is a skill that can be improved with practice. Hearing loss is not only characterized by a reduction in the detection of auditory signals, but is often also accompanied by deficits in frequency and temporal resolution which can cause auditory signals to be perceived in a distorted fashion. Degraded auditory signals make speech recognition more difficult, particularly in the presence of background noise. While many people with hearing loss can be helped adequately with hearing aids or cochlear implants alone, others require more intensive hearing rehabilitation, including auditory training, for optimal speech perception with their hearing devices. Auditory training does not improve hearing levels; rather it helps individuals with hearing loss listen more effectively so that their ability to recognize speech sounds may be improved. Originally primarily used with children with hearing loss (and now integrated into auditory-verbal therapy), auditory training is also advocated for adults with auditory deficits acquired later in adulthood**1-4** and for normally hearing children with auditory processing disorders**5,6** or language learning difficulties**7,8** Although most research on this topic has addressed primarily the benefits of auditory training for the identification of speech sounds, some attention has also been given to the impact of such training on the perception of other kinds of sounds. Therefore, auditory training may also be a valuable approach in teaching listening skills for auscultation of heart sounds.

Auditory training efficacy

Support for auditory training efficacy is well documented in speech perception research and in the neuroscience literature**2,3,7,9-22**. Hearing aid and cochlear implant users have been shown to make gains in the perception of speech sounds following intensive auditory training**10,11,15**. For example, in the study by Woods and Yund**10**, older adults fitted with hearing aids received an auditory training program consisting of numerous repetitions of listening exercises involving 54 nonsense syllables recorded by two talkers. Research participants underwent approximately one-hour long training sessions, five days per week for a period of eight weeks. Post-training, they showed significant improvement in their ability to identify the syllables compared to the test sessions prior to training. Improvement was noted within one week of training and performance continued to increase steadily over the course of the eight weeks. Moreover, the enhanced ability to identify the syllables generalized to untrained voices. That is, improvement was observed not only for the two voices used for the training program, but also for two novel talkers who were recorded speaking the same syllables and used only for the test sessions.

Other researchers have examined the impact of auditory training on the perception of more complex speech materials such as words and sentences**2,3,12-14**. After a 12-week training program that included repeated presentations of a set of 150 words, adults with hearing loss improved their performance on the trained words by about 40% and maintained their performance for at least three months post-training**12**. In a separate study3 using a much larger set of different words (600 words) but a similar duration of training paradigm, thus resulting in less training time on each word, participants showed a smaller, albeit significant, improvement in scores. That is, scores improved only by 20% post-training. As pointed out by Humes et al**3**, these data suggest that listening to many repetitions of a smaller set of words may lead to greater gains in auditory perceptual skills than listening to fewer repetitions of a much larger number of words.

The ultimate goal of auditory training is to help individuals who use hearing aids or cochlear implants recognize messages spoken during everyday conversations. Adults with hearing loss have been shown to improve significantly on measures of self-reported hearing difficulties during everyday social interactions after completing the Listening and Communication Enhancement (LACETM) auditory training program**2**. Such transfer of skills to daily situations relies on two critical issues in auditory training: first, the generalization of auditory skills to situations involving listening to novel materials, i.e., words or sentences not used during training, and second, the generalization of skills when listening to novel speakers or untrained voices. A speech sound can be somewhat acoustically different when it is articulated by different talkers who vary in voice pitch, voice level, and articulation patterns; therefore people with hearing loss must be able to transfer their auditory skills when listening to novel and unfamiliar talkers. Several studies have used multiple talkers during training to facilitate the transfer of auditory perceptual skills to talkers not used during training**2,3,10-12,14,20**; and, in general, data show that the improved skills do generalize to novel talkers.

The effect of auditory training has also been investigated in normally hearing individuals, using non-speech stimuli. Research by Moore and Amitay**7** showed that normally hearing adults can significantly improve their ability to perform frequency discrimination tasks after listening to 1500 to 2000 trials in less than two hours of training. In this study, participants were asked to listen to two or more pure tones varying in frequency and requested to identify the higher or lower pitch pure tone through matching exercises or picking the odd tone out of a set. The difficulty of the listening task was adaptive, such that the trial immediately following a correct response included pure tones that were closer in frequency whereas an incorrect response was followed by a trial with pure tones more disparate in frequency, thus keeping the task sufficiently challenging. Following training, participants demonstrated a decrease in the frequency difference that they required to discriminate between the pure tones.

There is also strong neurophysiologic evidence that suggests that auditory listening exercises can affect neural activity in the auditory system**17-22**. Tremblay, Kraus, McGee, Ponton, and Otis**18** trained young normally hearing adults to identify subtle differences between two acoustically similar syllables ("mba" and "ba") and measured their brain activity using auditory cortical evoked potentials before and after training. Initially, the two syllables were both perceived as "ba" but with training, participants were able to distinguish between "mba" and "ba". As the participants' ability to distinguish between the two sounds progressed, there were accompanying changes in auditory cortical evoked potential waveform morphology. Neurophysiological changes post auditory training have been observed to occur rapidly, i.e., after 45 minutes of training,19 to precede improvements in auditory perceptual skills in some people**19**, and to be maintained at least 36 hours after training**22**. Moreover, neurophysiological changes have been shown to generalize to novel sounds not used during training**20**.

Principles of auditory training

Many auditory training programs share a number of common training principles, such as allowing for multiple repetitions of the sounds used for training, providing listeners with immediate feedback on their performance following each listening trial, and progressively increasing the difficulty level of the listening tasks. The next sections of this chapter outline some of the auditory training parameters that are viewed as essential for promoting auditory learning.

Multiple repetitions of stimuli

It is well accepted that the optimal condition for auditory perceptual learning to occur incorporates intensive training that involves actively listening to many, many items during successive training sessions conducted over a relatively short period of time[2-4,10,23,24]. However, it is less clear which specific training protocols are most effective. Some researchers have used fairly long training regimes, such as approximately one hour of training several days per week for three to four consecutive weeks[14,15,24] or even up to eight to 12 weeks[3,10,12]; however, auditory perceptual changes were generally observed within the first week or two of training, with performance continuing to improve over the subsequent weeks of training[2,10]. In contrast, others researchers have documented auditory perceptual learning after much shorter training paradigms, such as a total of four to six training sessions all concentrated in one week[16,18,21,25]. Studies that have documented neurophysiological changes induced by auditory training typically observed such changes following a small number of auditory training sessions[18,21] or even following a single training session[19,22]. Individual variability in auditory learning following training has also been noted on perceptual tasks, with some individuals learning at a faster rate than others[7,19,25], as well as in the maintenance of neurophysiological changes post-training[22].

In appears that whether one conducts auditory training sessions daily versus weekly may have less influence on improvements in performance than the actual amount of training or total number of training sessions. Nogaki et al[25] compared perceptual skills of normally hearing listeners after completing five auditory training sessions that were delivered either within one week, three times per week, or once per week for five weeks. Results showed that training rate did not have an impact on performance. On the other hand, the specific auditory training task may be more likely to have an effect on the number of repetitions needed to yield an improvement in performance. Wright and Sabin[26] investigated the number of trials needed for normally hearing young adults to show an improvement on a pure tone frequency discrimination task and a temporal-interval auditory discrimination task. Participants listened to either 360 trials or 900 trials daily for six days. For the temporal-interval task, improvement was shown with 360 listening trials per day, and subjecting the listeners to additional practice trials did not lead to greater gains. In contrast, for the frequency discrimination task, 360 listening trials were insufficient to produce auditory learning but improvements occurred with 900 trials. Also using a frequency discrimination task with normally hearing adults, Moore and Amitay[7] noted auditory perceptual improvements after 500 trials, which continued to increase with additional trials until a plateau was reached after 1500 to 2000 trials.

Q.3 Explain the historical background to the development of speech tests for children.

The original speech language evaluation didn't contain any relevant background history details, so prior to seeing a child for a reassessment I sent detailed intake questionnaires to the parent asking in depth questions regarding the child's biological parents (which was accessible to the adoptive parents). After a little digging, it turned out that both biological mother and grandmother of the child had significant language delays and started speaking after the age of 3. The child's biological mother was even reported to "make up her own language" to such an extent that the family had to interpret her words.

Sure enough about 10 minutes into the assessment after meeting and interacting with the child I knew that she presented with a severe phonological disorder. She was actually chattering quite a bit with appropriate prosody, pitch and loudness, good range of vowels as well as frequent spontaneous verbalizations. She was just very unintelligible due to decreased phonetic inventory and phonotactic repertoire as well as simplification of sound sequences. This diagnosis also explained why she wasn't making any progress in speech therapy. The treating therapist was not using appropriate intervention strategies relevant to the treatment of her phonological disorder. After appropriate interventions were implemented, therapy gains were seen on the first session.

Recently, I was asked to perform a second opinion evaluation on a bilingual 4.5 year old preschooler, whose parents were concerned about his language abilities and pre-academic readiness. This child had previously been assessed by the school district SLP and found to be not eligible for services. At that time the assessing clinician judged that the child's limited English proficiency was due to limited English exposure and stronger primary language, stating that given English language immersion, the child will 'catch-up'. However, the parents became very concerned when after a 1.5 years of significant English immersion in a private preschool, the child still continued to fall further and further behind both monolingual and bilingual peers with respect to language abilities and academic performance.

The first thing I did following the evaluation referral was look over the child's initial evaluation report to review the findings. While the report contained observations, as well as formal and informal testing results, it contained no information regarding this child's background history beyond the minimal requisite blurb in the beginning of the report explaining why the child was referred for an assessment. So I asked the parents to fill out the intakes pertinent to the child's early language development as well as family history. Lo and behold, parental input revealed a family history of reading and learning disabilities on maternal side of the family, as well as history of late primary language development. The reassessment confirmed my suspicions. The child's language difficulties were not due to a language difference but to a legitimate language disorder, which originated in the child's primary language and later transferred to English. After therapy services were implemented and the necessary support to the child was provided, immediate gains were noted.

Since the school based language assessment did not contain any of the child's background pre-and post adoption history (nor did the school have any of these records) I asked the child's parents to provide me with this information, prior to initiating my assessment. In addition to a variety of useful documents the pre-adoption records contained a court order from the child's birth country, which stated that prior to the orphanage placement, the child's biological mother's rights were revoked by the court due to alcohol abuse and child neglect. Coupled with parental interviews regarding this student's post adoption language development, this information revealed to me that the child wasn't merely 'misbehaving' but probably had undiagnosed alcohol related deficits, which were adversely impacting his academic functioning in the school.

A language reassessment did confirm the presence of significant social pragmatic language deficits. A subsequent referral to the relevant medical team also substantiated the diagnosis of alcohol related disability, which was not readily apparent due to the child's age as well as relatively high academic and linguistic functioning. After the child began receiving social pragmatic therapy services and relevant behavior management techniques were implemented, many of the above described behaviors significantly improved.

That is why it is critical that SLPs and other related professionals (e.g., psychiatrists, psychologists, social workers, etc) obtain a detailed background information of the child's early development and family history as it will allow them to make an appropriate and accurate diagnosis of the child's difficulties, which will in turn allow the child to receive relevant classroom placement, appropriate accommodations and modifications as well as targeted and relevant therapeutic services.

Q.4 Write a detailed note on the selection criteria of hearing-aids for varied age groups.

All hearing aids use the same basic parts to carry sounds from the environment into your ear and make them louder. Most hearing aids are digital, and all are powered with a traditional hearing aid battery or a rechargeable battery.

Small microphones collect sounds from the environment. A computer chip with an amplifier converts the incoming sound into digital code. It analyzes and adjusts the sound based on your hearing loss, listening needs and the level of the sounds around you. The amplified signals are then converted back into sound waves and delivered to your ears through speakers, sometimes called receivers.

Hearing aids vary a great deal in price, size, special features and the way they're placed in your ear.

The following are common hearing aid styles, beginning with the smallest, least visible in the ear. Hearing aid designers keep making smaller hearing aids to meet the demand for a hearing aid that is not very noticeable. But the smaller aids may not have the power to give you the improved hearing you may expect.

Completely in the canal (CIC) or mini CIC

A completely-in-the-canal hearing aid is molded to fit inside your ear canal. It improves mild to moderate hearing loss in adults.

A completely-in-the-canal hearing aid:

- Is the smallest and least visible type
- Is less likely to pick up wind noise
- Uses very small batteries, which have shorter life and can be difficult to handle
- Often doesn't include extra features, such as volume control or a directional microphone
- Is susceptible to earwax clogging the speaker

In the canal

An in-the-canal (ITC) hearing aid is custom molded and fits partly in the ear canal. This style can improve mild to moderate hearing loss in adults.

An in-the-canal hearing aid:

- Is less visible in the ear than larger styles
- Includes features that won't fit on completely-in-the-canal aids, but may be difficult to adjust due to its small size
- Is susceptible to earwax clogging the speaker

In the ear

An in-the-ear (ITE) hearing aid is custom made in two styles — one that fills most of the bowl-shaped area of your outer ear (full shell) and one that fills only the lower part (half shell). Both are helpful for people with mild to severe hearing loss and are available with directional microphones (two microphones for better hearing in noise).

An in-the-ear hearing aid:

- Includes features that don't fit on smaller style hearing aids, such as a volume control
- May be easier to handle
- Uses a larger battery for longer battery life, with several options for rechargeable batteries
- Is susceptible to earwax clogging the speaker
- May pick up more wind noise than do smaller devices
- Is more visible in the ear than smaller devices

Behind the ear

A behind-the-ear (BTE) hearing aid hooks over the top of your ear and rests behind the ear. A tube connects the hearing aid to a custom earpiece called an ear mold that fits in your ear canal. This type is appropriate for people of all ages and those with almost any type of hearing loss.

A behind-the-ear hearing aid:

- Traditionally has been the largest type of hearing aid, though some newer mini designs are streamlined and barely visible
- Has directional microphones
- Is capable of more amplification than are other styles
- May pick up more wind noise than do other styles
- May be available with a rechargeable battery

Before you buy

When looking for a hearing aid, explore your options to understand what type of hearing aid will work best for you. Also:

- **Get a checkup.** See your doctor to rule out correctable causes of hearing loss, such as earwax or an infection. And have your hearing tested by a hearing specialist (audiologist).
- **Seek a referral to a reputable audiologist.** If you don't know a good audiologist, ask your doctor for a referral. An audiologist will assess your hearing, help you choose the most appropriate hearing aid and adjust the device to meet your needs. If you have hearing loss in both ears, you will get best results with two hearing aids.
- **Ask about a trial period.** You can usually get a hearing aid with a trial period. It may take you a while to get used to the device and decide if it's right for you. Have the dispenser put in writing the cost of a trial, whether this amount is credited toward the final cost of the hearing aid and how much is refundable if you return the hearing aid during the trial period.
- **Think about future needs.** Ask whether the hearing aid you've chosen is capable of increased power so that it will still be useful if your hearing loss gets worse. Hearing aids do not function indefinitely, but they should last about five years.
- **Check for a warranty.** Make sure the hearing aid includes a warranty that covers parts and labor for a specified period. Some dispensers may include office visits or professional services in the warranty.

Q.5 What specific training is required for a child recently fitted with a hearing aid? Who is responsible to initiate the training?

The receiver-in-canal (RIC) and receiver-in-the-ear (RITE) styles are similar to a behind-the-ear hearing aid with the speaker or receiver that sits in the ear canal. A tiny wire, rather than tubing, connects the piece behind the ear to the speaker or receiver.

A receiver-in-canal hearing aid:

- Typically has a less visible behind-the-ear portion
- Has directional microphones
- Has manual control options
- May be available with rechargeable battery
- Is susceptible to earwax clogging the speaker

Open fit

An open-fit hearing aid is a variation of the behind-the-ear hearing aid with a thin tube or the receiver-in-the-canal or receiver-in-the-ear hearing aid with an open dome in the ear. This style keeps the ear canal very open, allowing for low-frequency sounds to enter the ear naturally and for high-frequency sounds to be amplified through the hearing aid. This makes the style a good choice for people with better low-frequency hearing and mild to moderate high-frequency hearing loss.

An open-fit hearing aid:

- Is often visible

- Doesn't plug the ear like the in-the-ear hearing aid styles, often making your own voice sound better to you
- May be more difficult to insert into the ear due to the noncustom dome
- Some optional features of hearing aids improve your ability to hear in specific situations:
- **Noise reduction.** All hearing aids have some amount of noise reduction available. The amount of noise reduction varies. Some also offer wind noise reduction.
- **Directional microphones.** These are aligned on the hearing aid to provide for improved pickup of sounds coming from in front of you with some reduction of sounds coming from behind or beside you. Some hearing aids are capable of focusing in one direction. Directional microphones can improve your ability to hear when you're in an environment with a lot of background noise.
- **Rechargeable batteries.** Some hearing aids have rechargeable batteries. This can make maintenance easier for you by eliminating the need to regularly change the battery.
- **Telecoils.** Telecoils make it easier to hear when talking on a telecoil-compatible telephone. The telecoil reduces the sounds from your environment and picks up the sounds from the hearing-aid-compatible telephone. Telecoils also pick up signals from public induction loop systems that can be found in some churches and theaters, allowing you to hear a speaker, play or movie better.
- **Wireless connectivity.** Increasingly, hearing aids can wirelessly interface with certain Bluetooth-compatible devices, such as cellphones, music players, computers and televisions. You may need to use an intermediary device to pick up the phone or other signal and send it to the hearing aid.
- **Remote controls.** Some hearing aids come with a remote control, so you can adjust features without touching the hearing aid. Some hearing aids connect wirelessly to a cellphone and have a cellphone application that allows use of the cellphone as a remote control.
- **Direct audio input.** This feature allows you to plug in to audio from a television, a computer or a music device with a cord.
- **Variable programming.** Some hearing aids can store several preprogrammed settings for various listening needs and environments.
- **Synchronization.** For an individual with two hearing aids, the aids can be programmed to function together so that adjustments made to a hearing aid on one ear (volume control or program changes) will also be made on the other aid, allowing for simpler control.

Getting used to a hearing aid takes time. You'll likely notice that your listening skills improve gradually as you become accustomed to amplification. Even your own voice sounds different when you wear a hearing aid.

When first using a hearing aid, keep these points in mind:

- **Hearing aids won't return your hearing to normal.** Hearing aids can't restore normal hearing. They can improve your hearing by amplifying soft sounds.

- **Allow time to get used to the hearing aid.** It takes time to get used to your new hearing aid. But the more you use it, the more quickly you'll adjust to amplified sounds.
- **Practice using the hearing aid in different environments.** Your amplified hearing will sound different in different places.
- **Seek support and try to stay positive.** A willingness to practice and the support of family and friends help determine your success with your new hearing aid. You may also consider joining a support group for people who have hearing loss or are new to hearing aids.
- **Go back for a follow-up.** Specialists may include the cost of one or more follow-up visits in their fees. It's a good idea to take advantage of this for any adjustments and to ensure that your new hearing aid is working for you as well as it can.

Your success with hearing aids will be helped by wearing them regularly and taking good care of them. In addition, an audiologist can tell you about new hearing aids and devices that become available. He or she can also help you make changes to meet your needs. The goal is that, in time, you find a hearing aid you're comfortable with and that enhances your ability to hear and communicate.