SPAU332

Hearing Aids I

Notes

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Table of Contents

Chapter One: Introduction

Psychosocial aspects:

Psychosocial: the factors in the life of the person [the social and psychological] that gets affected by something else

→ Relating to the processes and factors that are both **social** and **psychological** in origin

- What are some examples of psychosocial problems in terms of hearing loss? [class answers]
  - **Academically →** in terms of hearing loss, if one is unable to hear well it can affect their learning and social wise
  - **Communication →** in terms of communication, if the person cannot hear well, then how will they communicate with those around him
    - → *One*: can be because the person themselves is unable to communicate
    - → *Two*: can be because the person themselves don't try to communicate
      - The environment plays a role as well, even if the person put 100% effort and the environment doesn't try to help or make it slightly easier and more motivated then it will affect the person.
  - **Work →** the person may be unable to deal with their own problem [and thus this work may not be well suited for those who have hearing loss]
    - → Or one's colleagues may not be well prepared or well-equipped in order to deal with the problem
  - **Participation Restrictions [quality of life] →** some activities one is unable to do even if they wanted to
    - → *Example*: the hearing aids are not allowed to get wet so they are unable to go out in the rain or go swimming, etc. [they are unable not that they don't want to]
  - **Anxiety →** some people are unable to speak because of anxiety where they overthink and don't wish to speak to make it easier on themselves

- Psychosocial problems in the context of hearing loss:
  - **Social support:** those around them play a role in this aspect
    - → How they can adjust to their lifestyle or situation may depend on social support
    - → How much support they have from family, friends, colleagues, country, environment, etc.
    - → Can be a problem in terms of psychosocial aspect of hearing loss
  - **Loneliness:** it has a connection with anxiety
    - → Many people may prefer to stay alone rather than interact with others
    - → Many people, even if they go out with others, prefer to listen rather than say anything at all
      - because if they were to speak they have to be on the same topic and they might not hear everything being said so they would rather be quiet and hear what they can
      - they might also not put all their effort into listening or grabbing everything being said
  - **Social status:** can affect people's image

- → Example: Mahmoud Abbas wears hearing aids but those hearing aids are small and barely show for his image
- → There may be others who don't want to show it at all [expecially bosses and etc.]
- → There may be others of lower social status that don't care and as long as they can work well and live their life peacefully
- → What they can get, etc.

- **Work environment**: the person may be unable to deal with their own problem [and thus this work may not be well suited for those who have hearing loss]
  - → Or one's colleagues may not be well prepared or well-equipped in order to deal with the problem
- **Mourning**: when the person one with hearing loss usually depends on, it will affect them in different aspects
  - → *Example*: a wife with hearing loss depends on her husband when it comes to taking schedules / appointments, phone calls, and when they are talking to someone and doesn't catch what they said, she goes back to her husband in order to understand what she missed in the conversation
    - o If her husband died, she will go through mourning and it will affect her life in more than one aspect [he won't be around to help her anymore] and she will go through many more difficulties → a whole new change [long term]
- **Marriage status**: the relationship between both people
  - → one may ignore purposefully
  - → one may higher the volume of the TV in order to block one's voice out [at some point]
  - → one may higher the volume of the TV because they can't hear it and they won't be able to hear those around them [ex: usually the old people]
  - → it can be with one who's single and they are urging them to get married [both male and female]
- **Social integration**: refers to the attachments individuals sustain with the larger society and are typically measured in terms of *occupational*, *organizational*, and *community* roles

World Health Organization International Classification of Functioning Disability and Health (2001) [ICF]

Body Functions and structures: the body structures and functions that were affected

Structure: cochlea, etc.
Function: hearing

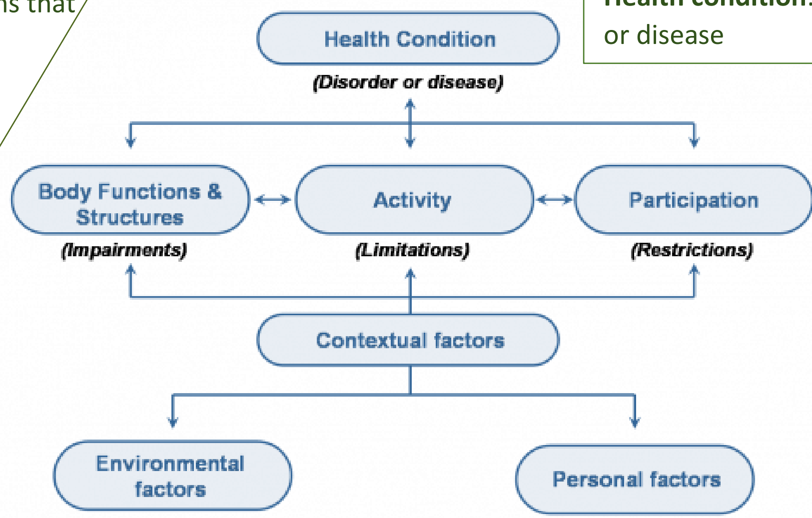
Activity limitations: what are the activities the person is unable to participate in because of the problem?

Participation restrictions: problems an individual may experience in involvement in life situations

Health condition: can be a certain disorder or disease

We look at it through 3 aspects:

I. Body functions and structures
II. Activity limitations
III. Participation restrictions



- It was placed in order to state that we don't look at a disability as *only* a disability
- We connect the problem with the other aspects of life that is affected and is then considered a disability → the disability itself isn't the focus → the other aspects connected to this disability becomes the focus [if we can find some sort of solution for it]
- A **catalyst** for change in health management
- Moves towards a **holistic approach** to patient care

<u>WHO (2001)</u>

- Based on the **biopsychosocial** model → we don't look at a disability as *only* a disability
- Highlights **individual health** rather than **disability**

➢ Describes functioning from three perspectives:
  - → Biological (function and structure)
  - → Individual (psychological)
  - → Social (participation)

➢ The International Classification of Functioning, Disability and Health (ICF) organizes information in two parts:
  - → Functioning and disability
  - → Contextual factors

➢ **Impairments** → Problems in body function and structure such as significant deviation or loss
➢ **Disability** [subjective]→ the result of how the impairments affects one's life

Health condition depends on:

1. **Body functions** → *the body functions that were affected*

→ The physiological functions of body systems (including psychological functions):

→ Hearing:
  - o Presence of sounds
  - o Discriminating location, pitch, loudness, quality of sound

→ Others related:
  - o Cognition [attention, memory]
  - o Emotion
  - o Vision
  - o Personality

Impairments

2. **Body structures** → *the body structures that were affected*

→ Anatomical parts of the body such as organs, limbs and their components.

→ Hearing
  - o External ear
  - o Middle ear
  - o Inner ear

3. **Activity** → Execution of a task or action by an individual

→ *Activity limitations*: Difficulties an individual may have in executing activities

→ Hearing:
  - o Swimming [because of hearing aids]
  - o Walking under the rain
  - o Entering moist atmospheres

Disability

4. **Participation** → Involvement in a life situation

→ *Participation restrictions*: problems an individual may experience in involvement in life situations.

→ Hearing:
  - o Listening
  - o Conversation
  - o Family relationships
  - o Community life

Contextual factors [social factors]:

1. **Environmental factors** → everything that makes one perceives their disability and how it affects them

→ **Physical**, **social** and **attitudinal environment** in which people live and conduct their lives

→ Immediate family

→ Health professionals

→ Education and work

→ Societal attitudes

→ Health services, systems and policies

- [3rd person disability] → one person's life gets affected from someone else's disability [ex: can't go swimming because of someone else with hearing aids]

2. **Personal factors** → how one perceives their disability
   - → How their personality is
   - → Their age
   - → If they are a positive or negative person
   - → Do they put effort into doing what needs to be done or whatever that comes their way they are fine with it

- The traditional hierarchical structure of the team [health team] in terms of what's given above?
   - → Team members become **equal partners** in the team where their **contributions** are valued and **an environment is created in which any appropriate team member may coordinate the management of a patient**

Economic consequences of hearing loss:

- In developing countries, children with hearing loss and deafness rarely receive any schooling
- Adults with hearing loss also have a much higher **unemployment rate**
- Among those who are employed → a higher percentage of people with hearing loss are in the lower grades of employment compared with the general workforce
- **Total global burden of adult onset HL** estimated to be → *24.9 million YLD's* (years lived with disability)
   - This represents 4.7% of total YLD due to all causes
   - HL is **2nd leading cause of YLD** after **depression** & gives it a larger non-fatal burden than alcohol use disorders, and osteoarthritis

Hearing loss, anxiety and depression:

- Studies have shown relationships between hearing loss and anxiety and depression
- Anxiety provoking situations (examples):
   - Vulnerability: [ex: entering an unknown office]
   - Being pressured into doing something
   - Facing financial burdens [even if someone else pays it instead]
   - Meeting new people and having trouble hearing
   - Filling out questionnaires and case history → talking about related and unrelated health issues
   - Claustrophobic → being in a small area
   - Taking hearing exam and talking about the results → confrontation
   - Concerned about cosmetic of hearing aids
   - Realizing hearing aids amplification doesn't solve all of the problems
   - The nuisance of taking care and wearing the hearing aids

- Sometimes there are support groups where they talk about their problems about what they have and thus it helps the person feel like they aren't the only ones experiencing that problem and may help psychologically [they talk about their experiences]

- There may be some people where they won't calm down because they think they have a problem and go to make sure at the specialist's office → once they finally officially know that what they have is an actual problem, they may calm down and feel better.
  - → There are cases where it's vice versa:
    - One may think they have a problem, and when they find out they don't they can relax
    - One may think they don't have a problem, and end up having a problem
    - One may think they have a problem and actually have a problem

Hearing Loss and Cognition

- Recent studies show correlations between:
  - Hearing loss
  - Cognitive function
  - Risk of developing dementia

  - ❖ Hearing loss and cognition:

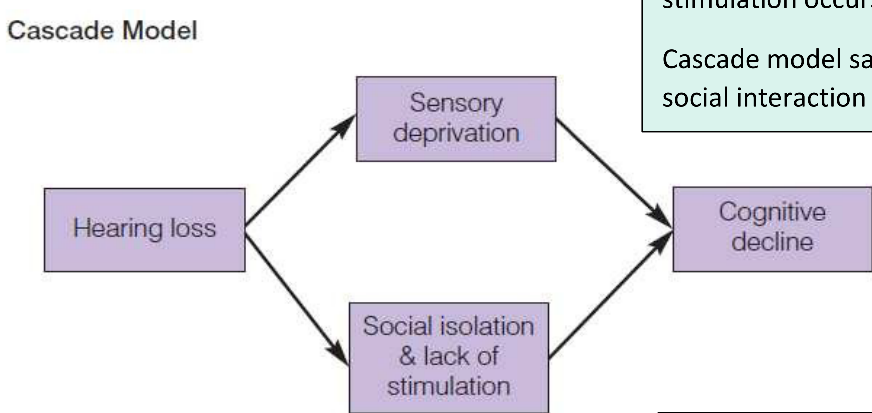
There are two models:

<u>Cascade Model:</u> [in general]
One has HL and that will have 2 consequences:
1. Sensory Deprivation: [if its peripheral/central then the signals won't reach the brain] → no neural impulses → no stimulation

- [if someone wears hearing aids there is stimulation]

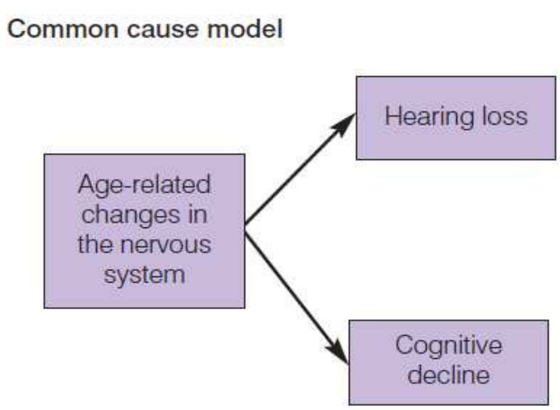
2. Social isolation: one doesn't interact and thus no stimulation occurs

Cascade model says that sensory deprivation and lack of social interaction leads to cognitive decline



<u>Common cause model:</u> [usually age related but doesn't have to be]
This model says that the changes in the nervous system tends to lead to:
1. Hearing loss
2. Cognitive decline

In older people, they used their cochlea more and thus the cochlea hair cells may be weaker and decline



Holistically: in a way that treats the whole person, taking into account mental and social factors, rather than just the symptoms of a disease

Chapter Two: Person-Centered Approach to Audiological Rehabilitation & Personal-Adjustment Counselling

Person centered approach:

Person centered approach: [it has to do mainly with the providence of services]

- In person-centered care, the individual is considered **holistically** and optimal outcomes are achieved with input and accountability from the person and other professionals working collaboratively
- **Main goal:** Improve quality of life by eliminating or reducing activity limitations and participation restrictions
  - *Identify individual needs* → We listen to the patient
  - *Set specific goals* → We find out what their goals are
  - *Make shared, informed decisions* → We place a plan with them involved and with more effort on the patient
  - *Support self-management* → they're able to deal with their problem
    → It helps with motivation
    - They feel in charge of their problem
    - They have more confidence
    - This also encourages and helps the patient have confidence in the audiologist

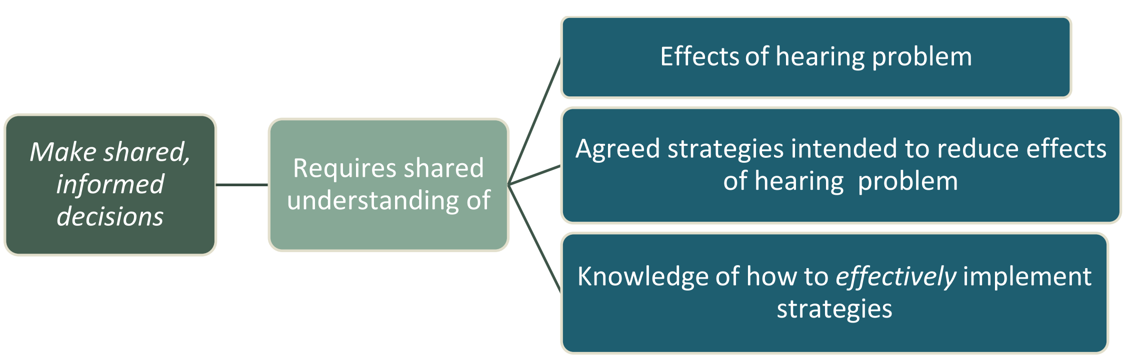
1. **Identifying individual needs**

- *Impaired function*
- *Activity limitation*
- *Participant restriction*
- Associated environmental factors
- Consideration of *third-party disability* experienced by close family members/ friends/ significant others

2. **Setting joint goals**

- Important to **involve** patients, communication partners and all relevant clinical professional
- Requires relationship based on trust, respect and empathy

3. **Make shared, informed decisions**



4. **Supporting self-management**

- Essential factors for successful self-management:
    - Knowledge of the condition and its effects
    - Ability to adapt behavior appropriately

Individualized Plan of Care

- Audiologists have unique expertise that allows them to contribute to *individualized plans of care* for those with **hearing**, **balance**, and **auditory system disorders**.
- The scope of audiology is encompassed in the spokes of this wheel.

Benefits of Person-Centered Care:

- **Improves** functional outcomes
- **Includes** personal support systems
- **Reduces costs** and **improves safety**
- **Improves** quality of life
- **Ensure** efficient care coordination
- **Enhances** individual **satisfaction**

Aims of patient education and counseling:

- **Understand** the nature of their hearing loss
  - → its consequences and treatment/management options
- **Acknowledge** that they have a hearing loss and work through the consequential negative emotions that restrict enjoyment of life
- **Overcome** obstacles associated with engaging in any form of rehab
- **Use and care** of hearing aids or other assistive listening devices
- **Acquire** additional communication skills
- **Do they need hearing therapy**?

The IDA Institute motivational tools

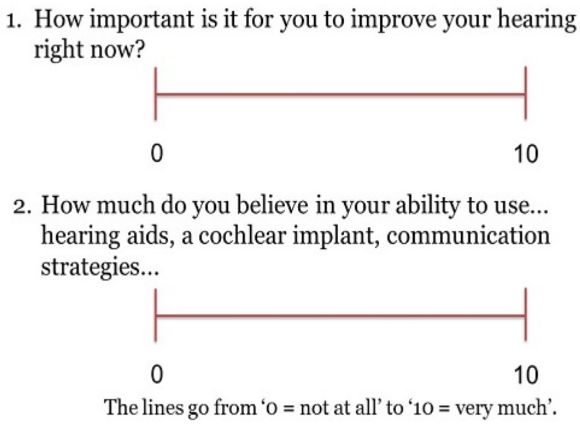
The **IDA Motivation Tools** help the specialist **open communication** with their clients and achieve a better understanding of their thoughts and needs.

The IDA motivational tools:

1. The Line
2. The Box
3. The Circle

1. **The Line** → A simple, effective tool that is based on a line, two questions, and the patients/clients' responses
   - You can use the Line in the first session with your client, in a follow up appointment, or repeated over time.
     - → It is often used with first-time clients or to increase the motivation of those who are no longer wearing their hearing aids
   - Usually two questions are asked and on a line [from 0 to 10] they rate their answer
     - → **Question 1**: Allows the clinician to assess how important their client/ patient feels it is for them to improve their hearing
     - → **Question 2**: Helps the clinician appraise how confident their patient/client is that they can follow through with recommended treatment

- *Example:*



1. Ask the patient to mark their position on the scale from 0-10 on the first line ' **How important is it for you to improve your hearing right now?'**
2. Then ask them about their reasoning:

This helps you understand their ambivalence

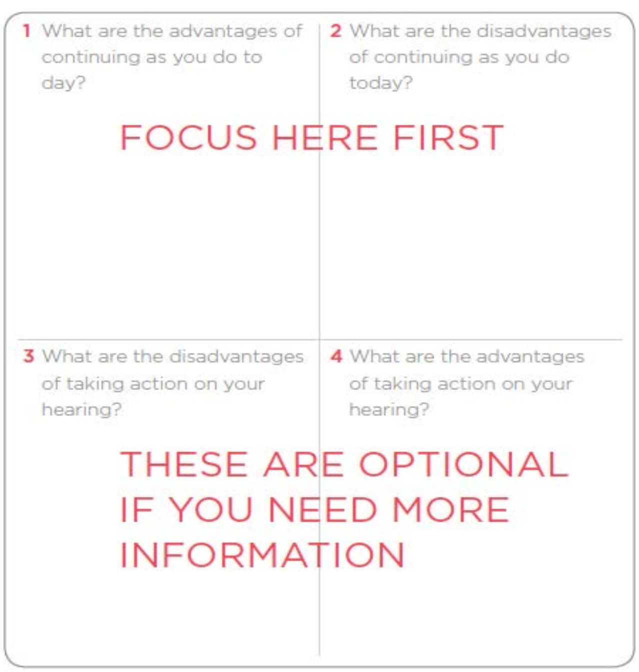
This helps your patient reinforce their motivation and reasoning

3. Move on to the second line '**How much do you believe in your ability to use...**' and follow the same procedure.

TIPS AND SUGGESTIONS

- Give the patient the time and space to elaborate on their decision - the discussion is important, not the score.
- Try to remain quiet as long as possible, and listen to the patient's response.

2. **<u>The box</u>** → An effective way to help ambivalent clients and explore with them what might encourage them to take action on their hearing loss
   - Advantages and disadvantages
   - You focus on the first 2 boxes, if you don't get the amount of information you need, you do all 4
   - It is important that the clients fill out the Box **themselves**.
     → Afterwards, ask follow-up questions and **encourage** the clients to elaborate
   - The Box can be used in combination with the Line for a more **complete** picture of the client's thoughts about their hearing loss and motivation to act on it
   - *Example*:



1. Focus on the two top boxes first. Ask the patient to fill in both sides, i.e. questions 1 and 2.
2. Summarize their responses by contrasting the advantages and disadvantages.
3. Ask 'How would you like to move on from here?'
4. Be sure to accept the patient's decision. If they prefer to continue as they do today, provide them with information and encourage them to reflect on their hearing and return later if they wish.

1 BENEFITS OF NO ACTION

No need to hear anymore than I do now!

Are there any situations you avoid because of your hearing difficulties?

Have you considered that your communication partners may be unhappy or dissatisfied because you miss out on things?

I do not have a hearing problem!

You never find that people mumble?

Have you experienced any situations in which it is difficult to hear?

2 COSTS OF NO ACTION

I can't really think of any

You never feel exhausted when you are in group contexts?

Would your communication partners agree to that?

I will feel excluded from social contexts

In which situations do you feel excluded?

I might lose my job!

Is it only in job situations that you have hearing problems?

3 THE POTENTIAL COSTS OF TAKING ACTION

Hearing aids whistle!

Have you experienced that?

Other people might not like me because hearing aids are unattractive!

What do you think when you see other hearing aid users?

Have you considered that the relationship to other people might suffer if you can't hear them or you misunderstand them?

4 THE POTENTIAL BENEFITS OF TAKING ACTION

I can participate more

It will be less tiring for me if I don't have to pretend that I know what people are talking about

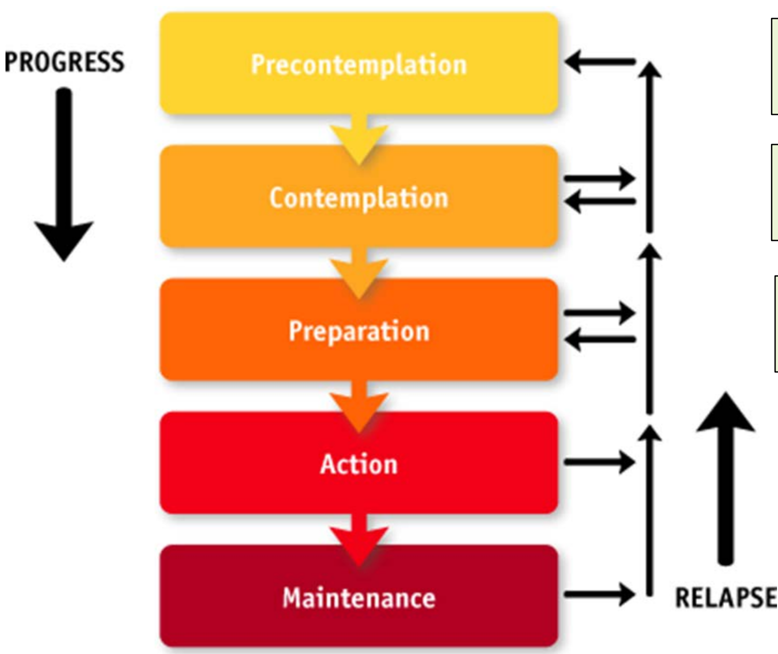
It will help me keep my job

There will be less conflicts in the family

Acknowledge the response and ask if there are any other benefits – get as many benefits as possible on the list to keep the motivation

1) What are the benefits of no action? *I look normal*	2) What is the cost of no action? *I feel left out and isolated*
3) What are the potential costs of taking action? *People will know I'm deaf*	4) What are the potential benefits of taking action? *I'll be able to join in family conversation*

- **The Transtheoretical Model (TTM)**
  - → The model describes behavioral change as an intentional process that unfolds over time and involves progress through a series of stages
  - → *Endorsed by the World Health Organization*
  - → Has been widely used across different sectors of healthcare to **assess people's motivation for change** and **develop intervention programs to address various health concerns** – from *smoking*, to *diet*, *alcohol consumption*, and *physical activity*.



Pre-contemplation: Denial and ignorance of the problem

Contemplation: Ambivalence and conflicted emotions

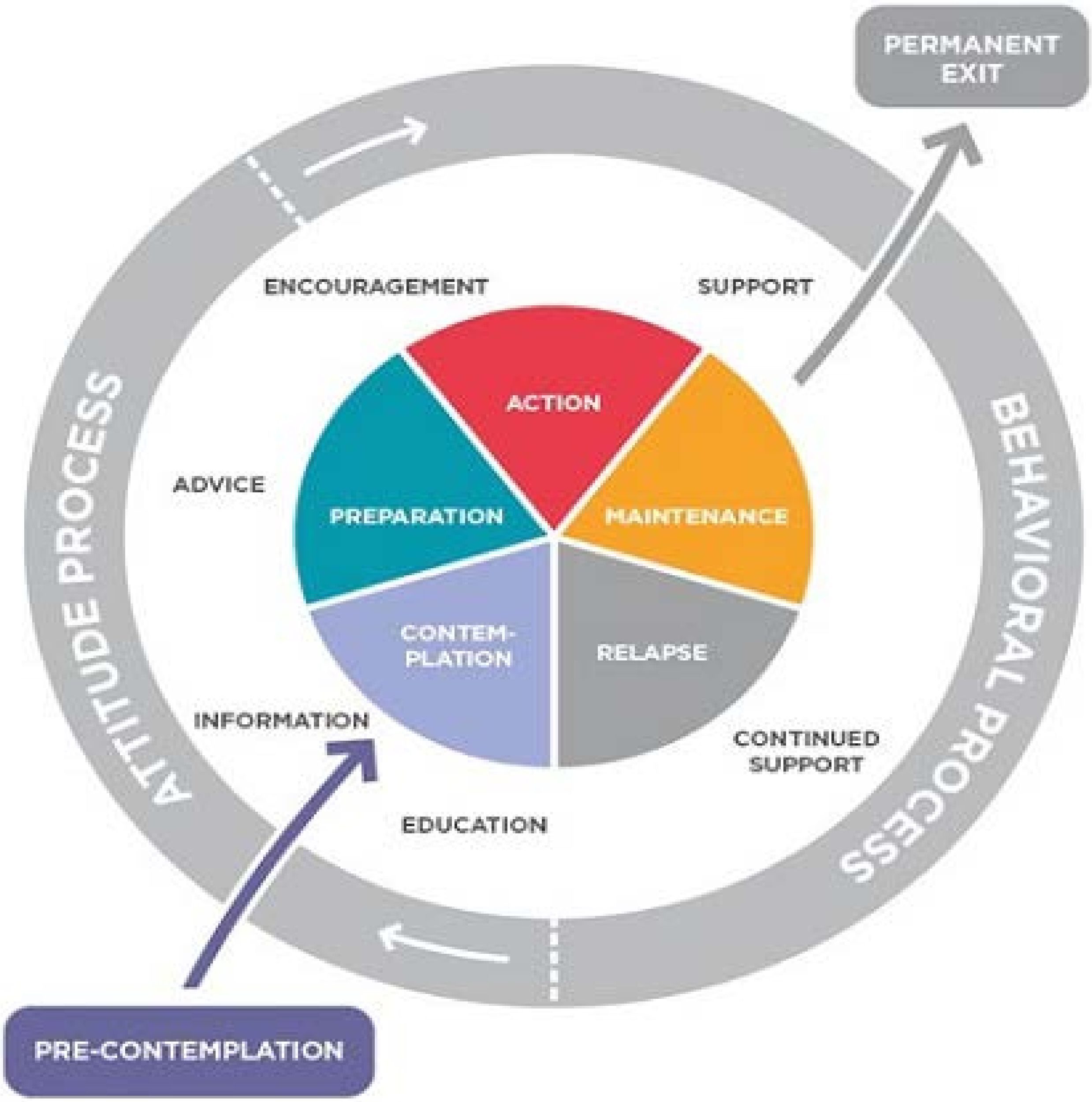
Preparation: Collecting info about change and experimenting with small changes

Action: Taking direct action toward a goal

Maintenance: Avoiding temptation and maintaining new behavior

Relapse: Disappointment, frustration and feelings of failure

3. **<u>The circle:</u>** → Involves the different stages of **behavior change**
   - Helps both, the clinician and patient identify what stage the patient is at and where they are heading so we know how to deal with them
   - If they aren't motivated, we should motivate them



PRE-CONTEMPLATION

'I DON'T HAVE A PROBLEM'

- Review the Patient Journey with your patient and explore the impact of hearing loss on communication partners.
- Give the patient information to review at home and suggest they book a new appointment when ready.

CONTEMPLATION

'I MIGHT NEED HEARING AIDS'

- Listen to the patient and explore their experiences with hearing and communication.
- Explore the patient's ambivalence and motivation using the Line.

PREPARATION

'I NEED HEARING AIDS'

- Review possible action steps with the patient. Listen and answer patient questions.
- Use the Box if the patient continues to express ambivalence.

ACTION

'I AM GETTING HEARING AIDS'

- Create a joint strategy for moving forward in line with the patient's views and needs.
- Highlight the personal benefits of improved communication.

MAINTENANCE

PERMANENT EXIT

'I AM USING MY HEARING AIDS'

- Ask how the patient is managing their hearing loss and answer questions.
- Provide support and information on communication strategies.
- If the patient is ambivalent, then use the Box to explore their situation.

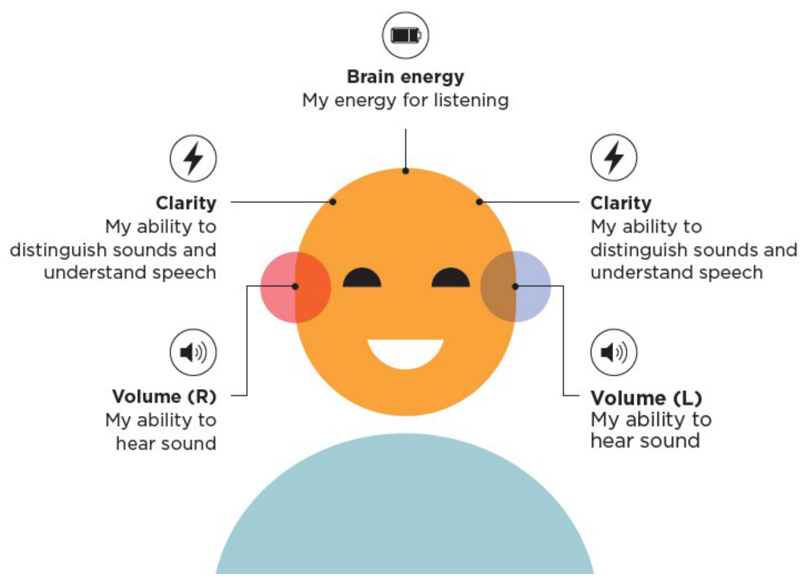
RELAPSE

'I DON'T LIKE USING MY HEARING AIDS'

- Listen to the patient and explore their positive experiences with the hearing aids.
- Use the Line and Box again if the patient continues to express ambivalence.

My Hearing Explained:

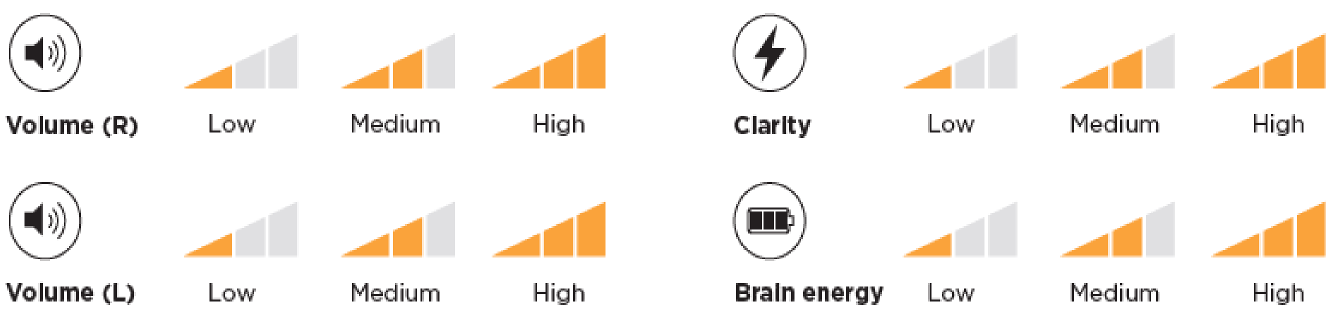
- The **audiogram** is a **valuable tool** for hearing care professionals, but research shows that it can be difficult for clients and their communication partners to understand
- **My Hearing Explained** is a conversation guide for relaying hearing test results in *person-centered terms*
- **Benefits**:
  - → **Relate** hearing test results in easy-to-understand language
  - → **Help people** explain their hearing loss to others
  - → **Save time** in the appointment by focusing on what matters to your client
  - → **Guide** your client through personalized recommendations based on their needs
  - → **Helps to guide your conversation** about hearing test results to make them **easier to understand**



Clarity: ability to distinguish sounds and understand speech

Volume: the ability to hear sound (severity of hearing loss) → amplitude

Brain energy: the energy for listening



Volume:

- Example:
  - o moderate → medium
  - o mild → low

Clarity:

- low frequency hearing loss → affects vowels and most of the noise [most environmental sounds] → those with low loss will be affected more than high
- high frequency hearing loss → affects consonants and the beginning and ends of words

Brain energy:

- those who read lips and do other outside efforts in order to help them listen and pay attention can drain them mentally and tire them

Link sounds: [a, o, e, m, s, sh]

Chapter Three: Physiological & Psychological Aspects of HL

Physiological and psychological aspects of HL

Physiological → relating to the branch of biology that deals with the normal functions of living organisms and their parts

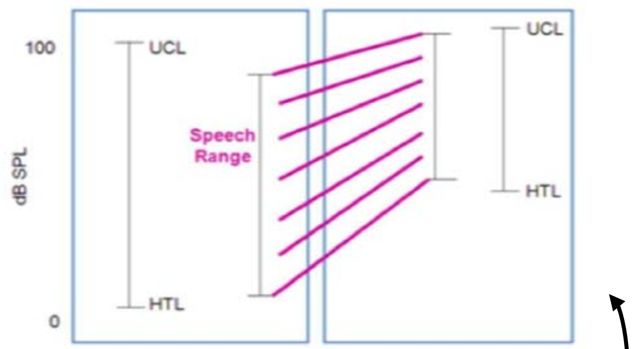
Physiological effects of HL:

1. *Decreased Audibility* → raising the threshold of hearing
2. *Decreased Dynamic Range*
3. *Decreased Spatial Resolution*
4. *Decreased Temporal Resolution*
5. *Decreased Frequency Resolution*

Physiological Effects of HL:

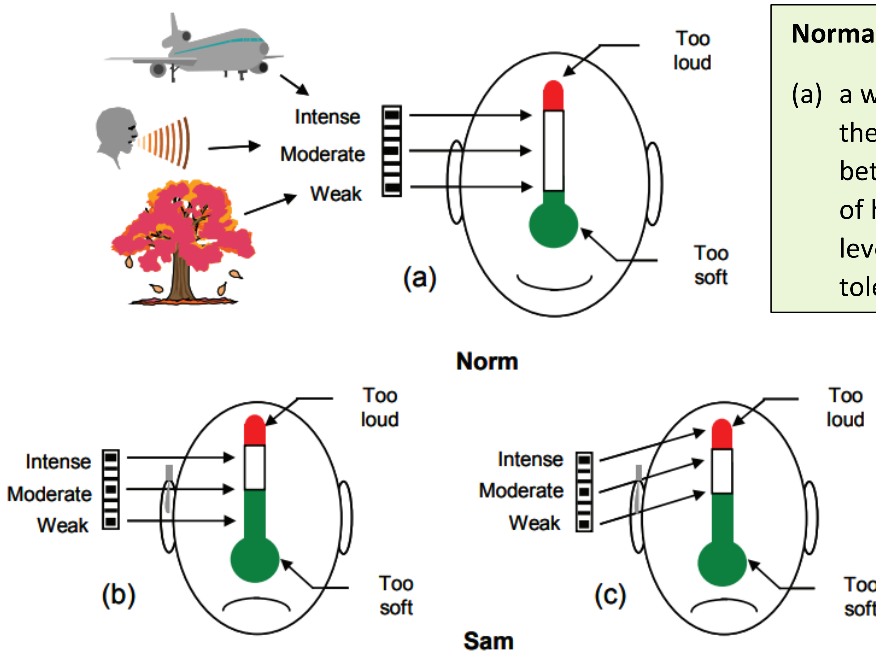
I. **Decreased Audibility**
- Increased hearing thresholds that causes some sounds to be **inaudible**
- The ***greater*** the degree of HL, the ***worse*** speech is perceived
- Other sounds *can* be detected because **part of their spectra is audible** but cannot be identified because **other parts of their spectra is not audible** (typically the high-frequency parts).

➢ To recognize speech sounds, the auditory system must determine which frequencies contain the most energy.
  - → *Example*: the vowel ["oo"], is differentiated from the vowel ["ee"] by the location of the **second intense region** (the second **formant**)
  - → Because the loudness of speech mostly originates from the low-frequency components, *hearing-impaired people* may not realize that they are hearing **less** of the speech signal, even when they cannot understand speech in many circumstances
  - → Common statements are: ***"speech is loud enough, but not clear enough and if only people would not mumble"***



II. **<u>Decreased Dynamic Range (DR)</u>**

- **Dynamic range (DR)** of an ear is defined as the range of levels between the **weakest sound** that can be heard (AC thresholds) and the most intense sound that can be **tolerated** (usually referred to as UCL/LDL).
- A wide **DR** is important to perceive soft sounds soft and intense sounds intense
- The threshold can decrease but the ceiling stays the same and doesn't change at all even if the hearing loss gets worse (the range doesn't get bigger, only smaller)



Normal

(a) a wide range of sounds in the environment can fit between Norm's threshold of hearing and the loudest level he can comfortably tolerate

Sensorineural → with no amplification

(b) Weak to moderate sounds are not heard

Sensorineural → with constant amplification at all levels

(c) The medium to intense sounds now become excessively loud

Figure 1.2 The relationship between the dynamic range of sounds in the environment and the dynamic range of hearing for: (a) normal hearing, (b) sensorineural hearing loss without amplification, and (c) sensorineural hearing loss with a constant amount of amplification for all input levels.

- **SNHL** increases the **HTLs** [hearing threshold levels] much more than it increases the **UCLs** [uncomfortable loudness levels]
- People with reduced DR hear sounds louder than normal hearing people because of **recruitment.**
- **Recruitment** →is defined as an **abnormal loudness perception** which means that each increase of sound level produces a bigger loudness increase when compared to normal-hearing people.
  - → A phenomenon that is observed with almost all cases of *outer hair cell loss*
  - → **Base/ Apex – Low/ high**: we don't live in a place with pure tone and so we hear all types of frequencies. The hearing and comfortably depends on the best and affected part of the cochlea
- **Compression** → squashing of a large dynamic range of levels in the environment into a smaller range of levels at the output of the hearing aid
- **Usual reflex** → around 70 dB but those with hearing loss may not have this reflex because of recruitment
- A **wide DR** is important to perceive soft sounds soft and intense sounds intense
  - → *Example:* they have HL and they found that at 100 is annoying, if their hearing loss got worse, they will still find it at 100 annoying.
- The range only gets smaller because the top doesn't get affected
- Speech gets broken down to frequencies and amplitude and so when they do the hearing aids they have to take the range in consideration. (It has to do with something called compression)
  - → *The softest sound will be made so that they can hear it but barely, the moderate keep it moderate, and when it comes to loud sounds is to compress the other sounds within the range. So the hearing aids, depending on the PTA, the speech will be taken and each frequency will be fixed in order for the patient to hear it comfortably.*

III. <u>Decreased Frequency Resolution/Selectivity</u>

- **Decreased frequency resolution is (DFR)**: it is defined as the **reduced ability** to **detect** and **analyze** energy at one frequency in the presence of energy at other frequencies.
  - → This results in difficulty separating sounds of different frequencies which affects speech understanding.
- This happens due to loss of **OHCs function**: *increasing the sensitivity of the cochlea* for frequencies to which the corresponding part of the cochlea is tuned.
  - → The significance of this deficit is that even when a **speech component** and a **noise component** have different frequencies, if these frequencies are **too close** the cochlea will have a single broad region of activity rather than two separate regions. → the brain is unable to untangle the signal from the noise
  - → *Outer hair cells*: helps give a boost depending on the tuning of the cochlea
- **Frequency resolution** helps the brain to **separate speech sounds from background noise** containing energy at similar frequencies.

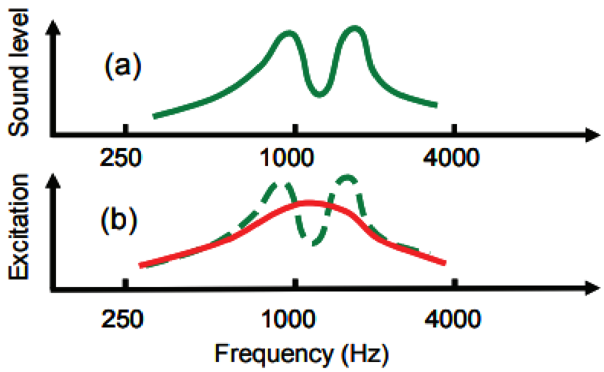


Figure 1.3 (a) Sound spectrum, and (b) possible representation in the auditory system for normal hearing (dotted green line) and sensorineural hearing impairment (solid red line).

(a) A **normal hearing cochlea** would send a message to the brain that two separate bundles of energy existed in the region around 1000 Hz.
(b) The **impaired cochlea** may send a message to the brain that there is just a broad concentration of energy around 1000 Hz (one bundle).
→ Consequently, the brain has no chance of being able to separate the signal from the noise.

- Even without the presence of background noise, decreased frequency resolution can adversely affect speech understanding.
- **Upward spread of masking →** If **frequency resolution** is **sufficiently decreased**, relatively intense **low-frequency** parts of speech (e.g. the first formant in voiced speech sounds) may mask the **weaker higher frequency** components (e.g. the second and higher formants, and high-frequency frication noise from the vocal tract)
  → **Low frequency**: vowels
  → **High frequency**: consonants
  → *Example:* someone has moderate low frequency hearing loss → they don't want to do too much amplification because they might affect the mid-frequency ranges
  → Most of the sounds are low frequency
- The degree of **reduced frequency selectivity**, and its impact on speech understanding, *increases* with the degree of hearing loss
- There is a chance that the hearing aids may not help this problem
- Low frequency but high amplitude → that's why when we hear vowels, they seem *louder* than the other sounds

IV. Decreased Temporal Resolution

- **Decreased Temporal Resolution (DTR)**: it is defined as the **decreased ability** to hear a signal that rapidly follows, or is rapidly followed by, a different signal
- A **decreased temporal resolution** is related to the **inability of the cochlea to increase its sensitivity** when the masking sounds stops like in normal hearing people. This is related to the reduced precision in timing of neural firing.
- Hearing-impaired individuals suffer from **increased temporal masking →** It happens when **intense sounds mask weaker sounds** that immediately precede them or follow them, thus affecting speech perception.

- Hearing system keeps changing depending on the frequencies and sounds we hear. Our hearing system will make adjustments for us to hear it. (Keeps changing sensitivity)
    - → If it's too loud, it lowers sensitivity
    - → If it's not loud, it highers sensitivity

In normal cases

- Those with hearing loss may take a *different* amount of time in order for their **sensitivity to change** and it changes differently and not as accurately.
- It has to do with the cochlea increase and decrease sensitivity
- Noise energy fluctuates and normal hearing people tend to make use of the very short noise reduction period to understand what is being said, known as ***listening in the gaps***
- **Listening in the gaps**— when there is chaos and one is focusing with someone who is speaking, you can grab certain words and piece things together. Those with hearing loss have a problem and can't really do listening in the gaps
    - → HL people cannot make use of that because of **decreased temporal resolution** especially where SNR [signal-to-noise ratio] is low.
    - → a **higher SNR** is needed for hearing-impaired people to just understand speech
- Hearing aids can help a little in compensating for **decreased temporal resolution ability**.
    - → *Fast-acting compression*, where:
        - o **The gain is rapidly increased during weak sounds** and **rapidly decreased during intense sounds**, → will make the weaker sounds more audible in the presence of preceding stronger sounds, and so will make them slightly *more intelligible*.

V. <u>Reduced Spatial Resolution</u>

- **Reduced Spatial Resolution (RSR)**: it refers to the reduced ability to separate sounds on the basis of the direction from which they arrive *<u>[peripheral]</u>*
- When we (normally) are able to do sound localization, our brain pays attention to 2 certain things:
    - → **The time**
        - o If the sound comes from the right, then it will reach the right ear faster than the left → that's how we know the sound is from the right
        - o If the sound comes from the left, then it will reach the left ear faster than the right → that's how we know the sound is from the left
        - o If the sound comes from the middle, it will be the same both ways
        - o Also affected by **Head Shadow effect**
    - → **The level**
        - o **Head shadow effect**: Sound coming from the "deaf side" has to pass through the head to get to the functioning ear on the other side.
            - → *This makes it **hard** to hear sounds from coming from the direction of the deaf ear*
        - o The **interaural level difference** is the difference in *loudness* and *frequency distribution between the two ears*
            - → This happens in the **superior olivary complex** (**SOC**)

Psychological effects of HL:

- **Factors that affect the severity of the psychological effects of HL**:

Factors that might affect the range and extent of any psychosocial effects are:
- Age at onset
- Severity of loss
- Rapidity of loss

Age of onset:
There is a difference if it was an elder or a child. The elders usually have many problems and thus adding HL as one of them can make things harder for them than for children (unless the child has more than one problem like the elder)

- In addition to HL → **aging** is associated with other multi-factorial problems → the **overall effect of more than one problem** that are related to ageing.
  - → These problems may include: motor problems, visual problems and cognitive decline
- Having **more than one health issue** may mean that a HL has a **greater psychological effect**

Severity of loss:
There isn't a relation between the severity and psychological study wise. **The relation has to do with speech perception**.

But there is a relation when the person has a degree of loss and a problem with speech perception
Example: profound HL and speech perception problem

- There is **no linear relationship** between degree of loss and psychiatric disturbance
- However, in patients with **severe loss + poor speech discrimination** → the increase in psychiatric disturbance usually is dramatic
  - → *Example: anxiety and depression*

In terms of **severity**, those with worse hearing aren't necessarily those who need the hearing aids more.

Those who accept the fact that they need hearing aids are more in need of them.

Example: one who is used to the problem won't really accept the idea of hearing aids since they lived with the problem all of their life.

Example: another who recently got the problem and is having a hard time coping with the problem (but their hearing loss is not that severe) would be in need of hearing aids more.

Rapidity of loss:
Was the HL gradual or sudden?

The **sudden** HL has a higher effect when it comes to the psychological effects

- **Sudden onset** loss may result in very different psychosocial effects compared to a **gradual onset** loss.
- Usually, **sudden onset HL** is associated with *serious psychological effects* compared to **gradual HL**

1. Psychiatric disturbance was not found to be related to **duration of deafness** or **HA usage**.
2. The effects of a **congenital HL** are likely to be very different than of an **acquired HL**.
3. In terms of unilateral and bilateral HL, bilateral has a higher effect on the psychosocial area because they **can't hear in both ears**. In terms of unilateral, they have the ability to hear in one ear at least.

Ramsdell's 3 Levels of Hearing:

- **Ramsdell's 3 levels of hearing** → The psychology of the **hard-of-hearing** and the **deafened adult**

  - **Ramsdell's model classifies the consequences of HL into <u>three levels</u>**:
    1. Symbolic or Speech level
    2. Loss of signals/warnings
    3. Loss of auditory background

I. <u>Symbolic or Speech level</u>

- This level is related to **the consequences** arising from the **reduced ability to understand speech** as a result of HL
- It may involve:
  - Fatigue → due to increased listening effort and lip-reading
  - Embarrassment → due to inappropriate responses
  - Depression and anxiety
  - Reduced quality of life

II. <u>Reduced awareness to signals or warnings</u>

- This refers to the **effects related to reduced awareness** to one's surroundings
- It may involve:
  - Loss of security
  - Stress and anxiety
  - Detachment from the real world

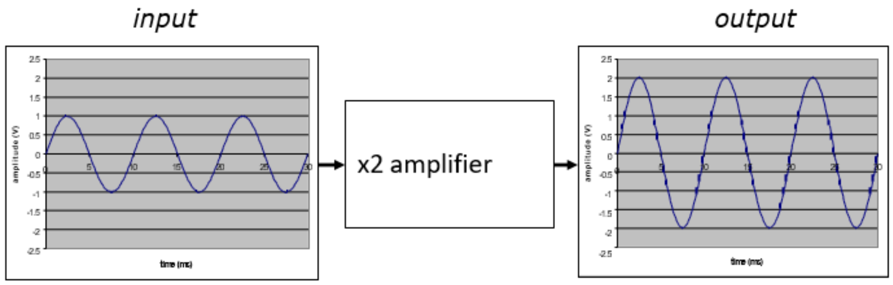
III. <u>Loss of auditory background</u>

- This level refers to **the loss of everyday general auditory background input**
  - → Sounds you aren't aware of but make you feel connected to the world
  - → *Example: a clock ticking, wind sound, etc*.

Chapter Four: Physics of Sound and Acoustics

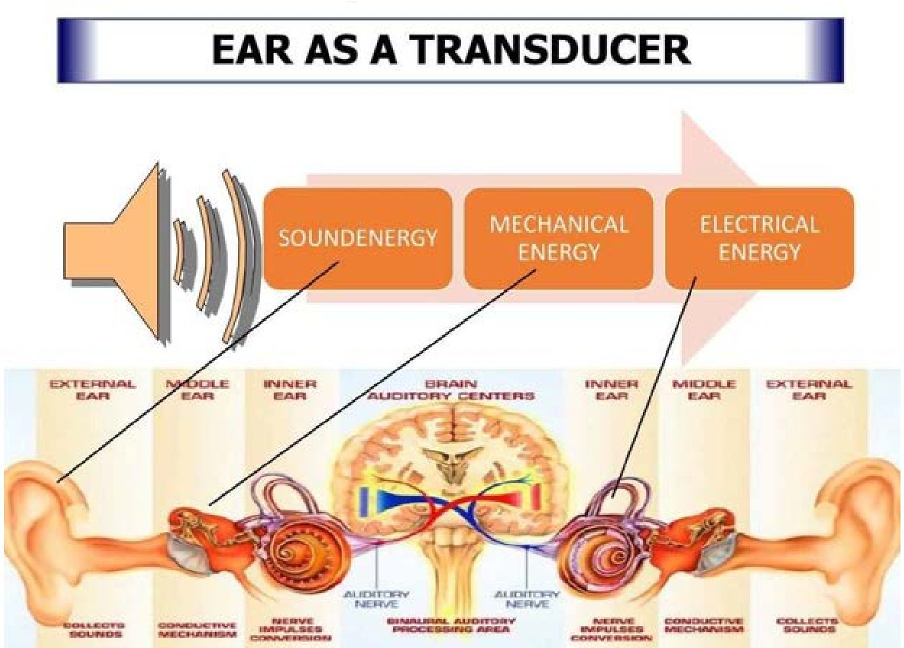
System and Signals:

- **Systems** perform an operation on [or transformation of] a **signal** (or *waveform*)
- Concentrate on systems with **one input** and **one output**



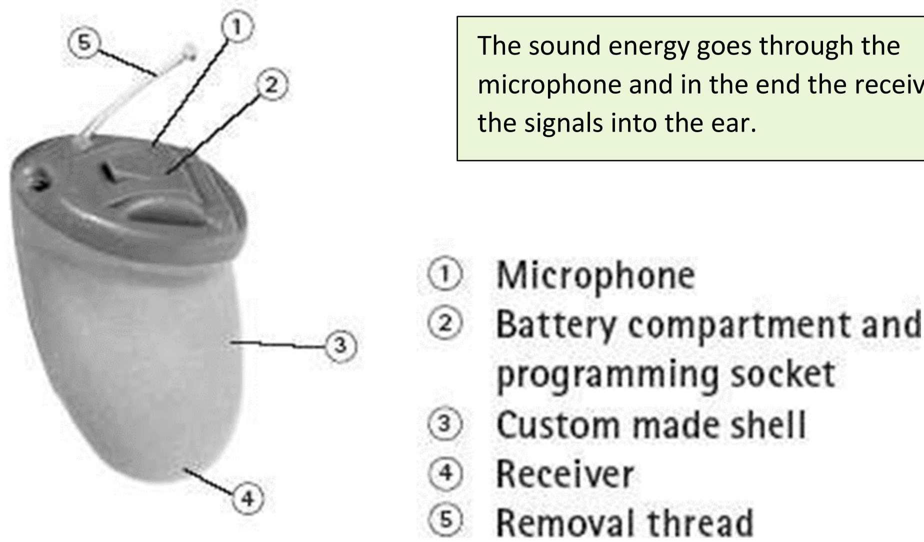
- Example:
  The ear: sound energy [air pressure] → mechanical energy → electrical energy

Air particles | The ossicles | Neural impulses



❖ **Hearing Aid** → another system

- **input** = sound wave (variations in pressure)
- **output** = sound wave (modified in some way)

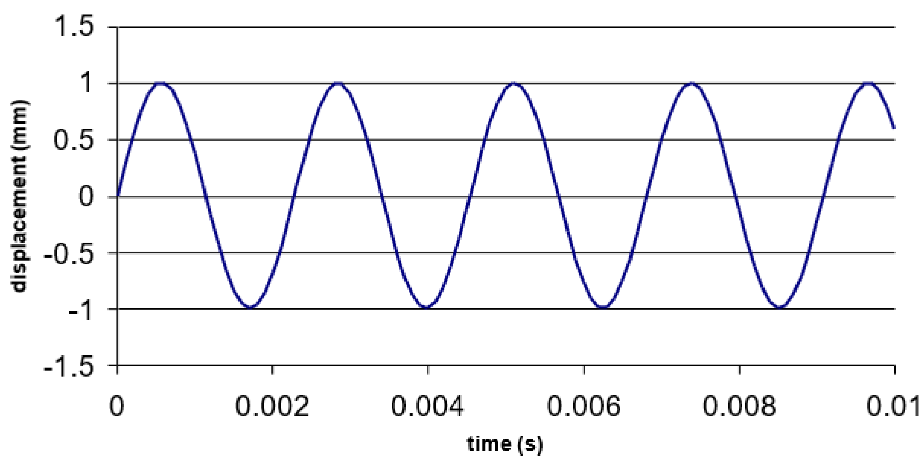


The sound energy goes through the microphone and in the end the receiver sends the signals into the ear.

Signals as waveforms:

➢ A graph of the *instantaneous* value of amplitude over time
  → **x-axis** is usually **time** (s, ms, µs)
  → **y-axis** is usually a *linear instantaneous* **amplitude** measure (Pa, mPa, µPa, V, m)

Amplitude



Time

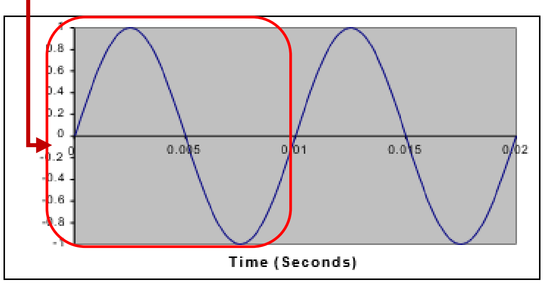
- Waveforms are of **<u>two major types</u>**:
    1. **Periodic**
    2. **Aperiodic**

I. Periodic waveforms

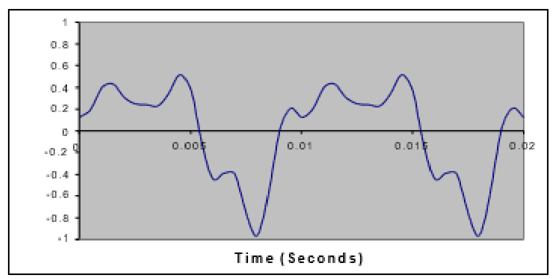
→ Repeats its shape
→ Consist of a basic unit or cycle
→ that repeats in time
→ typically have a strong pitch
→ comes in <u>two types</u>:
- o **Simple** [Sinusoid] → *example: PTA*
- o **Complex** → *example: repeating a word*

Period

simple (= sinusoid)



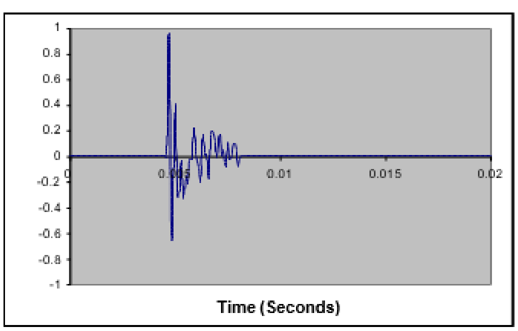
complex



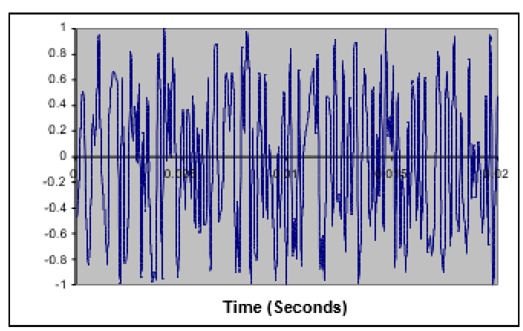
II. Aperiodic waveforms

→ Does not repeat
→ comes in two types *(but the distinction is not so important as for periodic waves)*
- o **transient** → Example: *plosives* → *example: [p] , [b]* → comes and goes
- o **continuous** [can be random] → *example: narrowband noise* → keeps going

transient



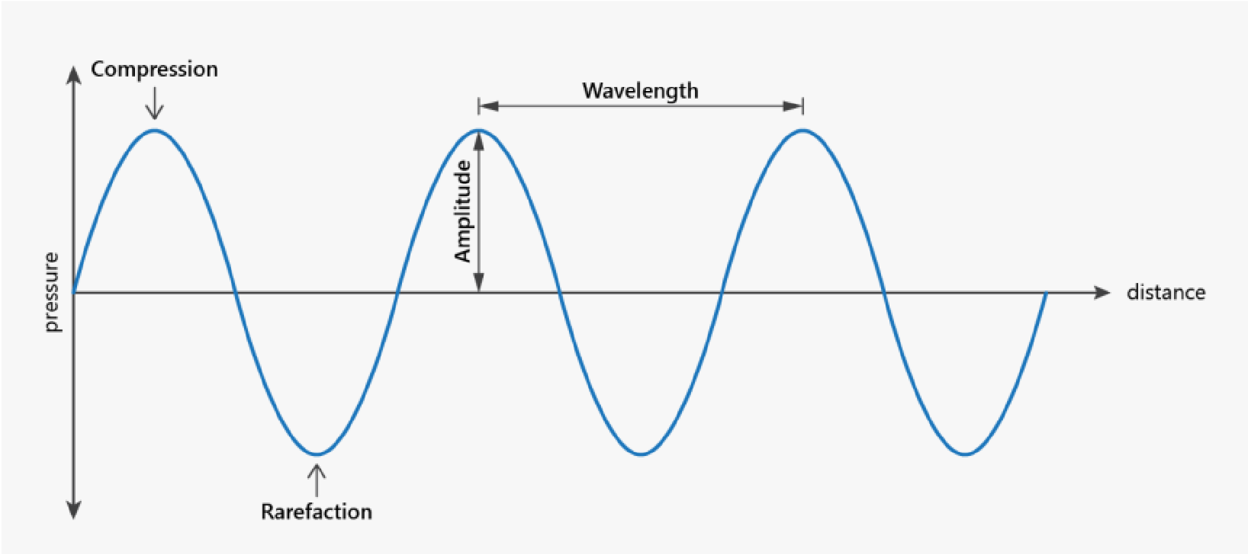
continuous (can be random)

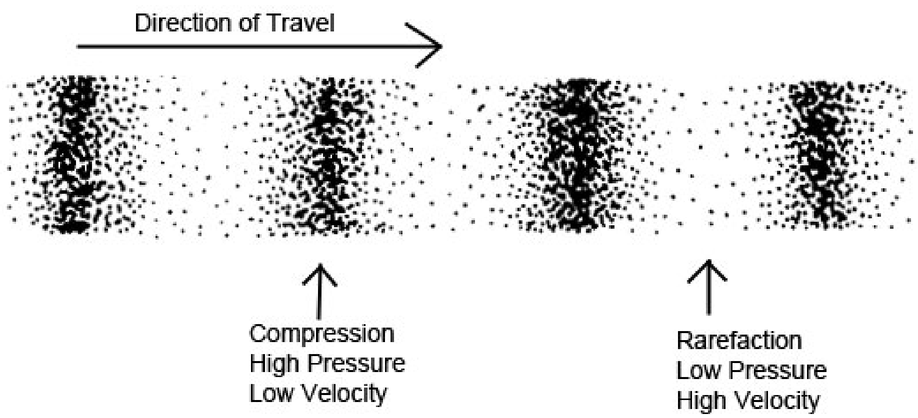


What is sound?

Sound:

- **Sound** is a vibration that propagates as an audible mechanical wave of pressure and displacement, through a medium such as *air* or *water*.
- Sound is **oscillation** of air pressure (pressure wave)
- Sound travels as a series of **compression** and **rarefactions** (of air molecules)
    - → **high pressure [compression]**: air molecules bunched up
    - → **low pressure [rarefaction]**: air molecules spread out
- Air molecules do **not** travel through space to carry sound
- Sound is **measured as the pressure changes over time at one point in space**





Sinusoids:

Characteristics of sinusoids:

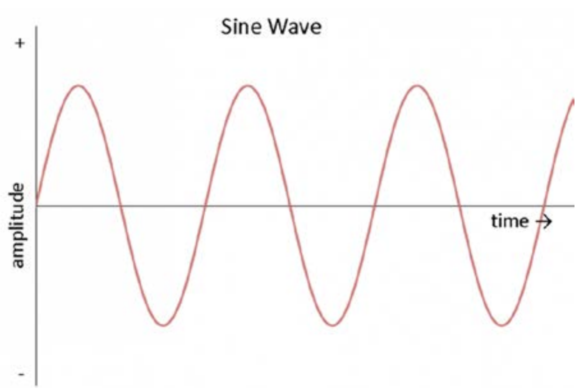
- Sinusoids are a **unique** shape
  - → Not just any vaguely regular form, but the precise shape of many natural movements *[example: a swinging pendulum]*
  - → are **periodic** → a basic **cycle** repeats over and over
  - → can be constructed from **uniform circular motion**

Sinusoids can only differ in three ways:

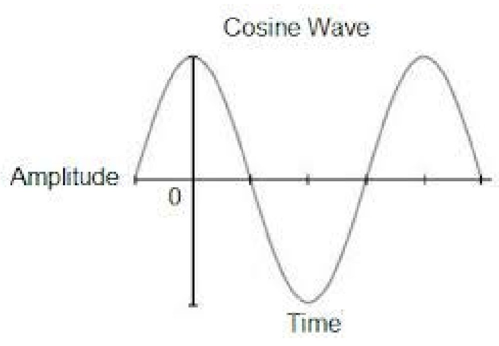
1. **frequency**
2. **amplitude**
3. **phase** (generally less important because phase changes are typically not perceived)

I. **Phase**

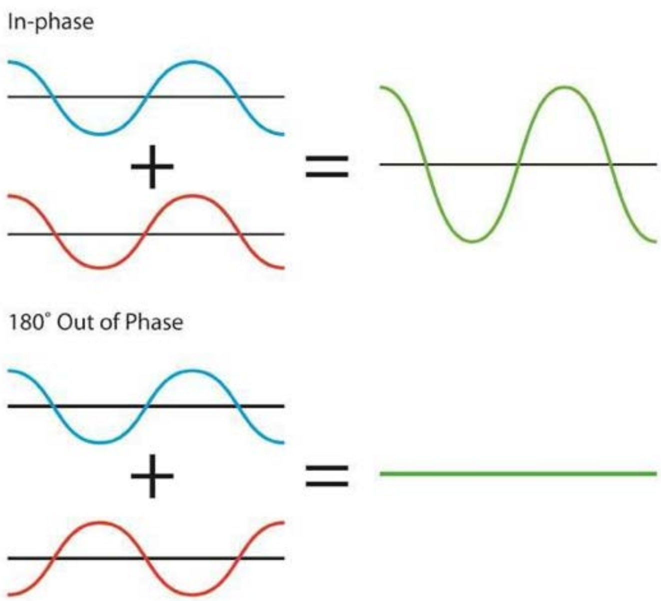
- Where a sinewave starts relative to some arbitrary time
- The **angle of displacement** at a specific point in time
- Measured in **cycles** or **degrees** (or radians)
  - → 360˚ = 1 period = 2π rads
  - → 180˚ = ½ period = π rads
  - → 90˚ = ¼ period = π/2 rads
- Relatively **little effect on perception**
- **Sine wave**:



- **Cosine wave**:



- There are two types of phases:
  - → **In phase** → both phases are the same and thus become louder (same amplitude, pitch, time)
  - → **180˚ out of phase** → both phases are the exact opposite and cancel each other out



Sometimes when sound in hearing aids have leakage, it will return the sound into the hearing aid and become annoying.

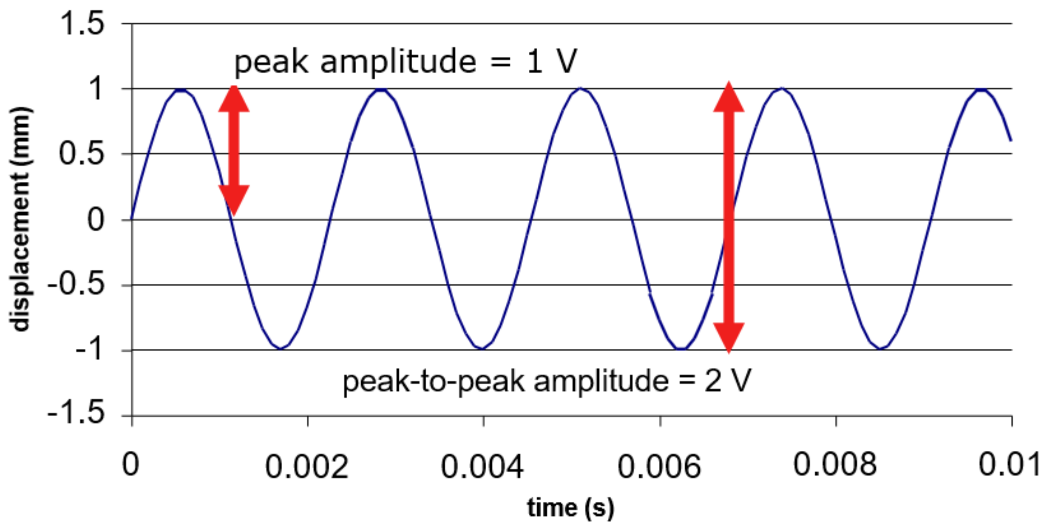
In hearing aids, they use the **180˚ out of phase** in order to cancel out those certain sounds

II. **Periodicity [frequency]**

- The **period (p)** is **the time to complete one cycle of the wave**
- The **frequency (f)** is **the number of cycles that are completed in one second**
- $f=1/p$ and $p=1/f$
- Unit: cycles per second (cps)
  - → But a special unit name is used: **Hz**
- Period and frequency are **indirectly proportional**
  - → Increases in frequency → decreases in period
    - o The **increase of frequency/decrease of period** lead to **increases in subjective pitch**

III. **Amplitude**

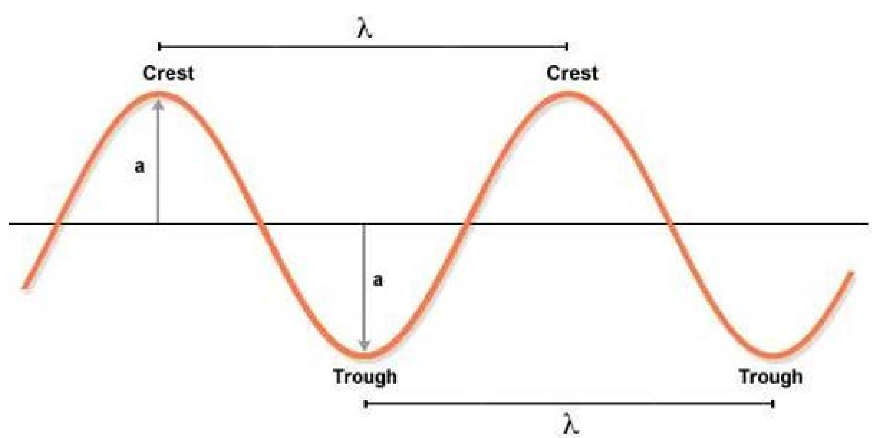
- It is crucial to distinguish *instantaneous measures* (as in a waveform) from some kind of average
- *Instantaneous measures* always linear
  - → example: **pressure** in **Pa**, **voltage** in **V**, **displacement** in **meters**
- But also want a single number to be a good summary of the **'size'** of a wave
- Average measures can be **linear** or **logarithmic** (dB)
- How much energy



- **Increases in amplitude** lead **to increases in perceived loudness**

IV. <u>Wavelength (λ)</u>

- The **distance between any two successive points with the same phase** (between crests, or troughs, or corresponding zero crossings)
- Unit: Measured in **meters** (m)



<u>Speed of sound in Air</u>:

- The **speed of sound** in air is **343 m/s**. (it's different in other media)
- The following formula defines the relationship between **speed**, **frequency** and **wavelength** of sound:

  → $V = f * \lambda$

- V: velocity of wave
- F: Frequency
- λ: Wavelength

Types of Sound Waves:

- **Pure tones**: a tone with a sinusoidal waveform (example: a sine or cosine wave)
- **Complex/Harmonic tones**: a tone composed of a different mixture

Psychophysics:

- **Psychophysics:** refers to the branch of psychology that deals with the relations between physical stimuli (e.g. sound) and mental perception

Loudness: is the human perception of sound **intensity**.	• **Soft** sound refers to **low** intensity sound. • **Loud** sound refers to **high** intensity sound.
Pitch: is the perception of sound frequency.	• **High pitch** refers to **high frequency.** • **Low pitch** refers to **low frequency**.

Measuring amplitudes with dB:

- **Not a linear unit** like Pascal's
- A **logarithmic measure** with an arbitrary **reference point**
  - → **0 dB** does not mean no sound → it means the **same level as the reference**
  - → **Any positive number** of dB means greater than the reference (e.g., 10 dB)
  - → **Any negative number** of dB means less than the reference (e.g., -10 dB)
- Many different kinds of dB (SPL, HL, etc.) which differ essentially in the meaning of 0 dB.

- **20µPa** is the standard reference pressure
  - approximately equal to human threshold
- **$\log_{10}$(*ratio*)** turns ratio into power of 10.

$$\text{Intensity}(dB\ SPL) = 20\log_{10}\left(\frac{\text{Pressure}(Pa)}{20\mu Pa}\right)$$

dB SPL Examples

- Threshold of Hearing (20 μPa)

  $20 \times \log_{10}(20\ \mu Pa / 20\ \mu Pa)$

  $= 20 \times \log_{10}(1) = 20 \times 0$

  $= 0$ dB SPL

- Distinct Pain! (200 Pa)

  $20 \times \log_{10}(200\ Pa / 20\ \mu Pa)$

  $= 20 \times \log_{10}(10000000) = 20 \times 7$

  $= 140$ dB SPL

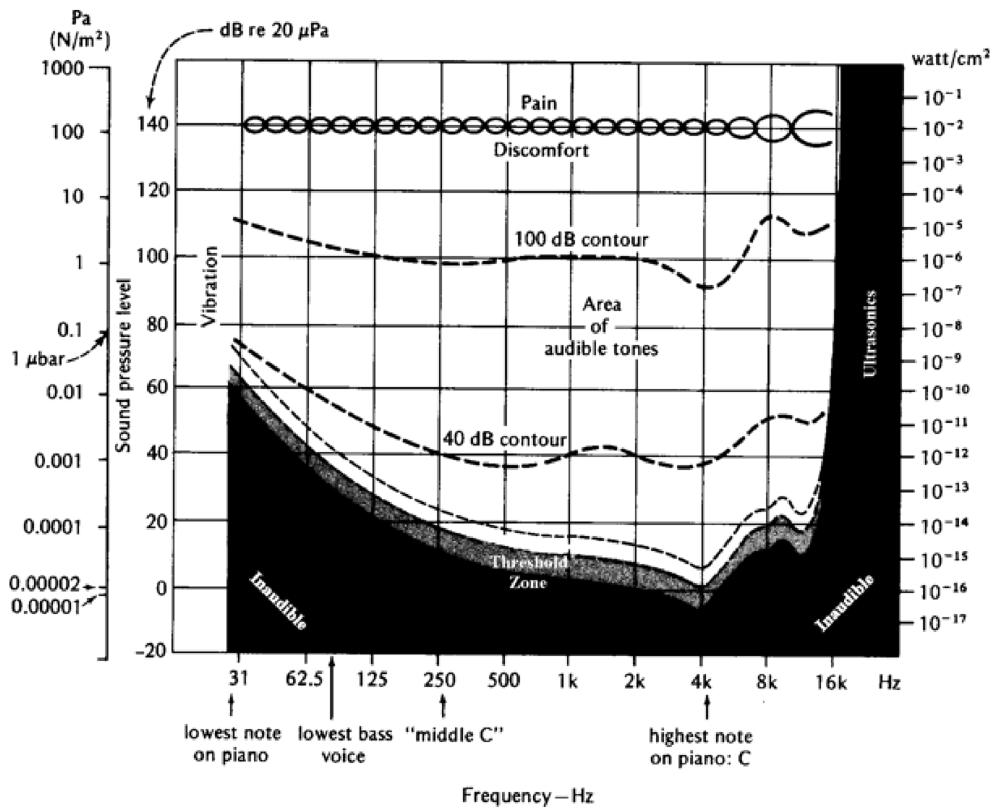
- An inaudible sound (2 μPa)

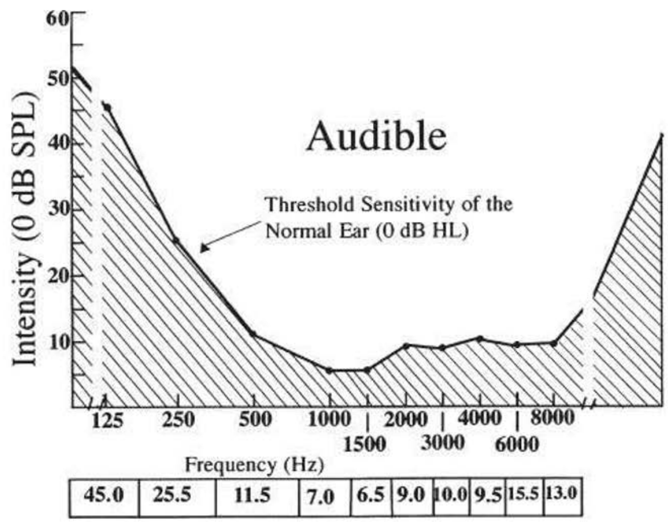
  $20 \times \log_{10}(2\ \mu Pa / 20\ \mu Pa)$

  $= 20 \times \log_{10}(0.1) = 20 \times -1$

  $= -20$ dB SPL

<u>Human hearing for sinusoids</u>:





Here is the ANSI S3.6-1996 standard to convert dB SPL to dB HL.

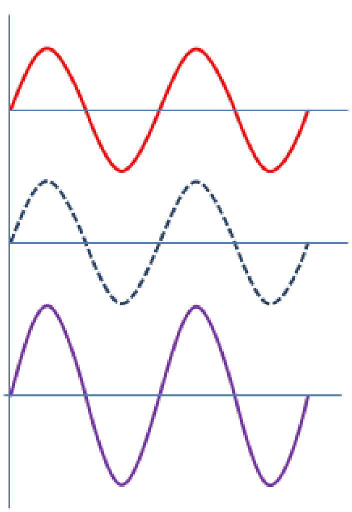
Frequency Hz	dB SPL	dB HL
125	45.0	0
250	27.0	0
500	13.5	0
750	9.0	0
1000	7.5	0
1500	7.5	0
2000	9.0	0
3000	11.5	0
4000	12.0	0
6000	16.0	0
8000	15.5	0

Wave Interference:

- **Wave interference** refers to the phenomenon in which two waves superpose to form a resultant wave of greater, lower, or the same amplitude.
  - There are two types of interference:
    - → **Constructive interference**.
    - → **Destructive interference**.

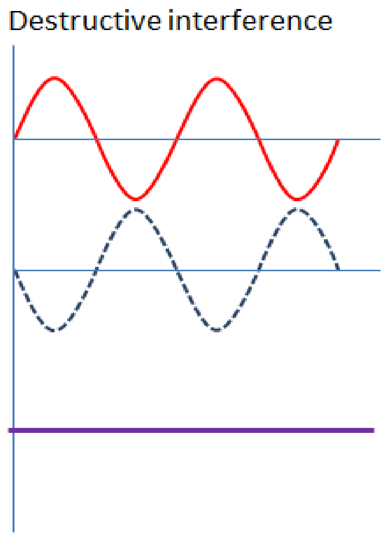
1. **Constructive/ In-phase Interference**
   - Refers to the interference of **two or more waves** of **equal frequency and equal phase**.
   - The **result** is a signal with an amplitude equal to the sum of the amplitudes of the individual waves.

Constructive interference



Added together and became larger

2. **<u>Destructive/ Out-of-phase Interference</u>**
    - Refers to the interference of two waves of **equal frequency** and **opposite phase**.
    - The **result** is <u>cancellation of both waves</u>, as the negative displacement of one wave always coincides with the positive displacement of the other wave.

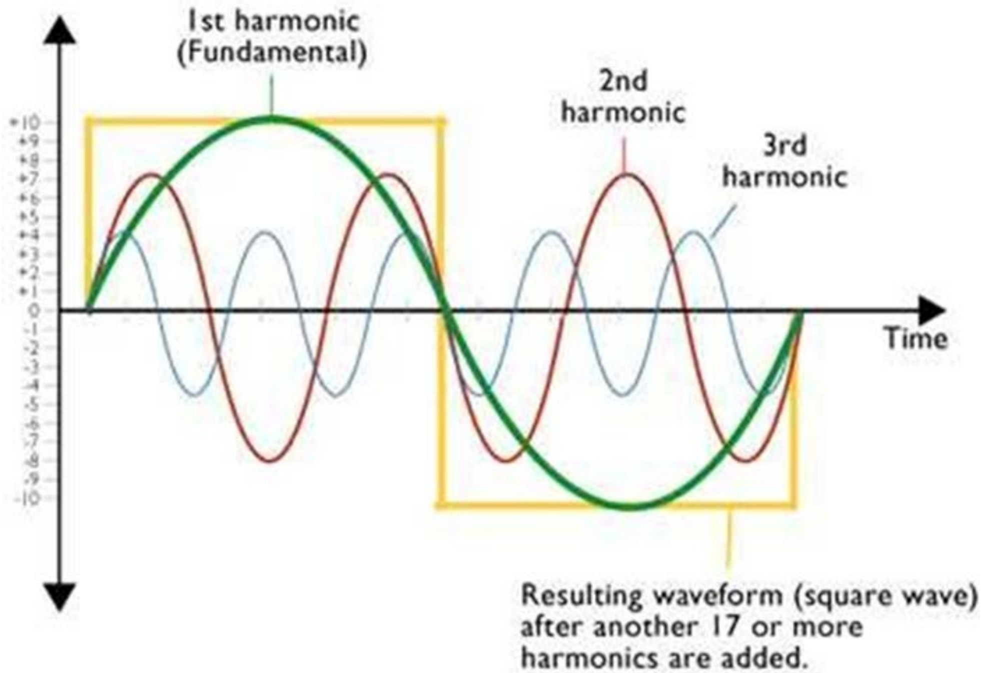


Canceled each other out and have nothing

Harmonics:

Harmonics:

- **Harmonics** are waves with a frequency that is a positive multiple of the frequency of the original wave, known as the **fundamental frequency**.
- The original wave is also called the **1st harmonic**, the following harmonics are known as **higher harmonics** (2^{nd}, 3^{rd} harmonics etc.).



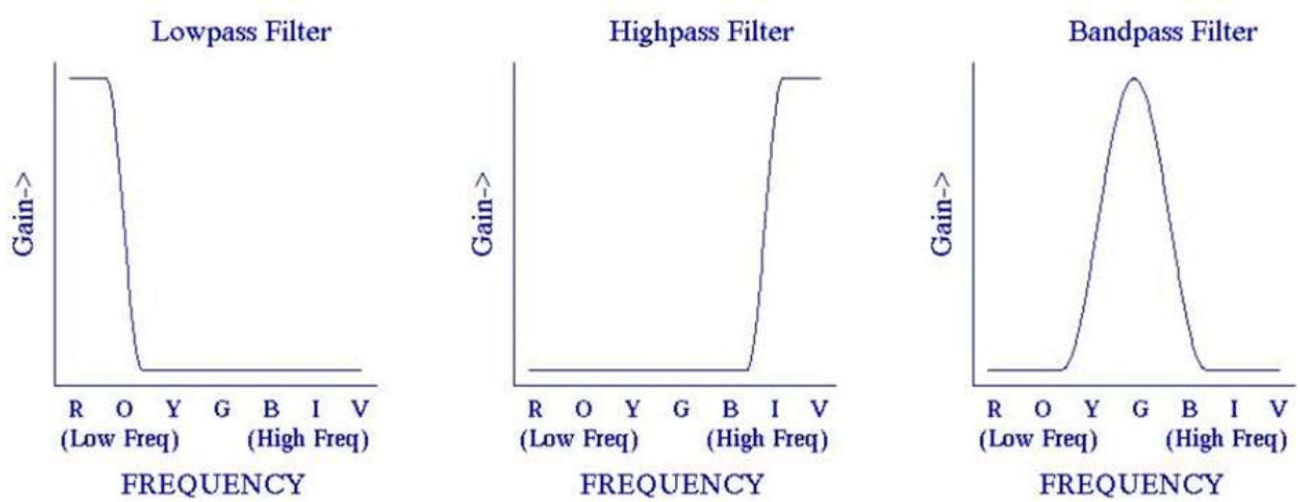
Octaves:

- An octave is a logarithmic unit for ratios between frequencies, with one octave corresponding to a **doubling of frequency**
    - *For example, the frequency one octave from (or above) 40Hz is 80Hz*

Acoustic Filters:

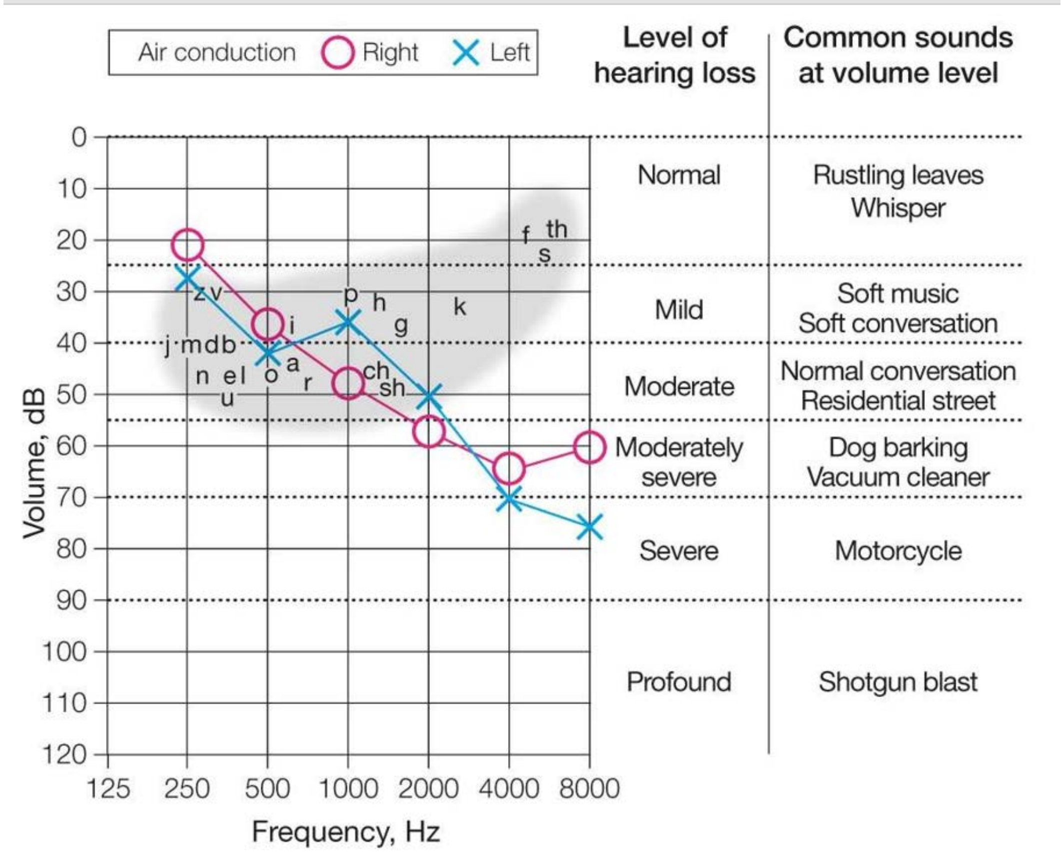
Acoustic filters:

- **Acoustic filter**: is a device that isolates a certain frequency band from a complex sound.
- There are three types of acoustic filters:
    - → **High-pass filters**: an acoustic filter that passes all frequencies above a specific frequency
    - → **Low-pass filters**: passes all frequencies from a certain value up to some specified frequency
    - → **Band-pass filters**: passes a more or less narrow frequency range between two specific frequencies



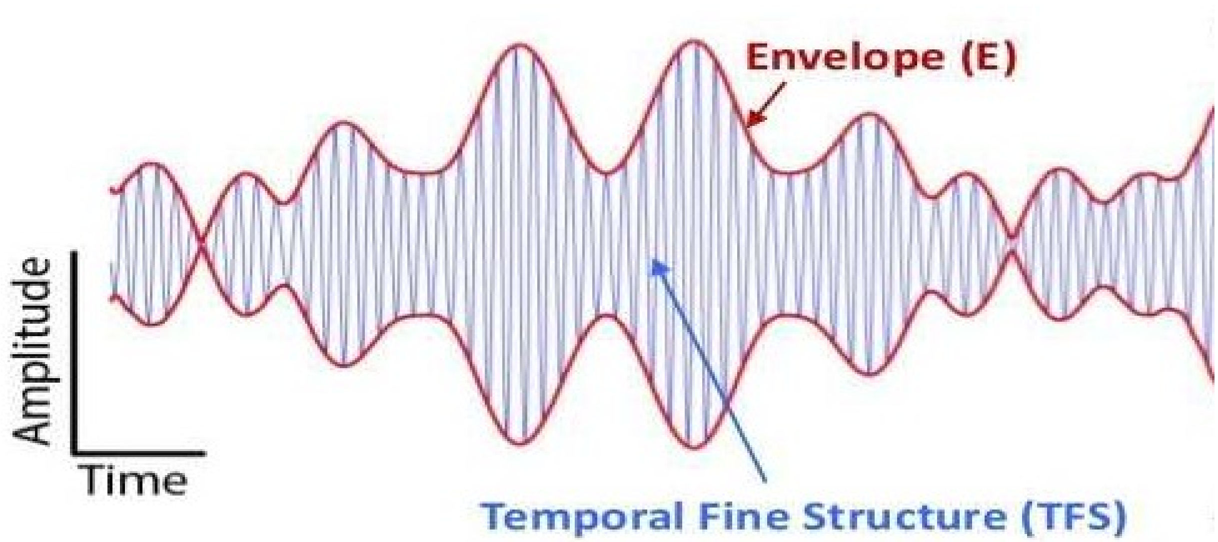
Acoustics of speech:

- Speech sounds have a **wide range** of intensities.
    - → Average sound level of **vowels** is **65-70 dB SPL in conversation**.
    - → Average sound level of **constants** is **35-40 dB SPL in conversation**.
    - → Speech may be imbedded in noise that is **10 to 20 dB** higher and still be partially understood by normal hearing people.



Speech Waves:

- **Speech waves** are complex waves (composed of a mixture of frequencies)
  - There are two components of speech that are important:
    - → The **envelope** of speech spectrum: represents the **loudness fluctuation of speech**. It **includes very important info to understand speech**.
    - → The **fine structure** of speech: **provides details** on the **quality of sounds** or timber



Chapter Five: Hearing Aid Components and Principles

Hearing instruments:

What are hearing instruments?

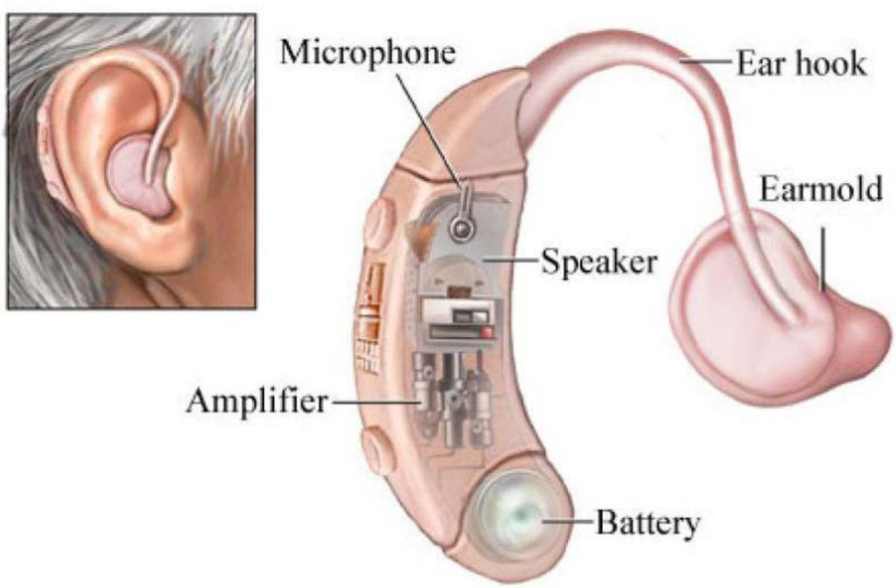
→ They are **miniature public address systems**

What do hearing instruments do?

→ **Amplifies the frequency range** most important for **understanding speech**

What do they contain?

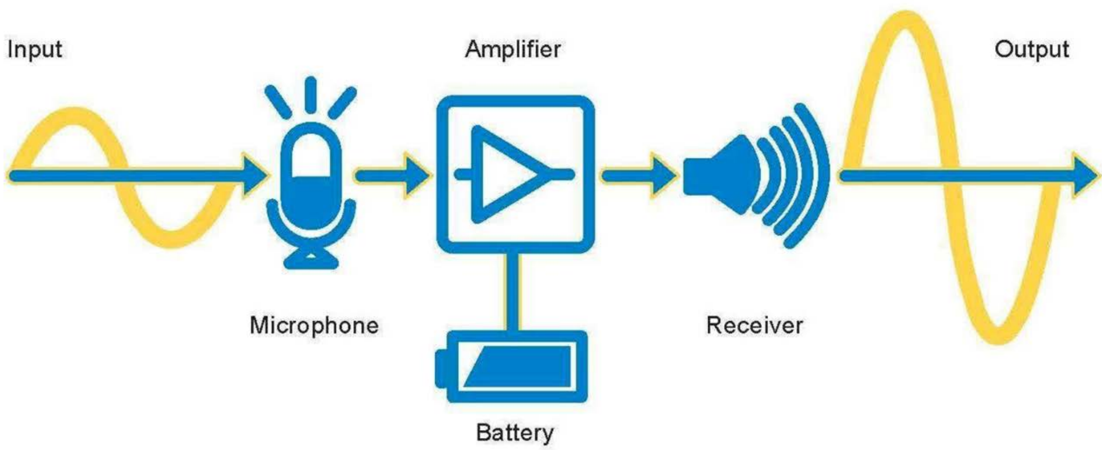
- **Microphone**
- **Amplifier**
- **Speaker**
- **Battery**



Amplification:

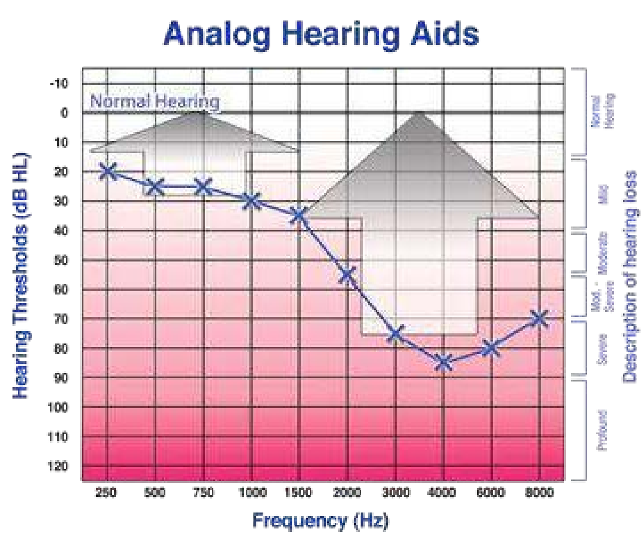
Amplification: the process of increasing the volume of sound, especially using an amplifier

- ➢ Hearing aids are programmed for a person's individual hearing loss → only **the frequencies** a person **struggles to hear will be amplified,** and those **frequencies will be amplified** at the **correct volume** for **optimal hearing**



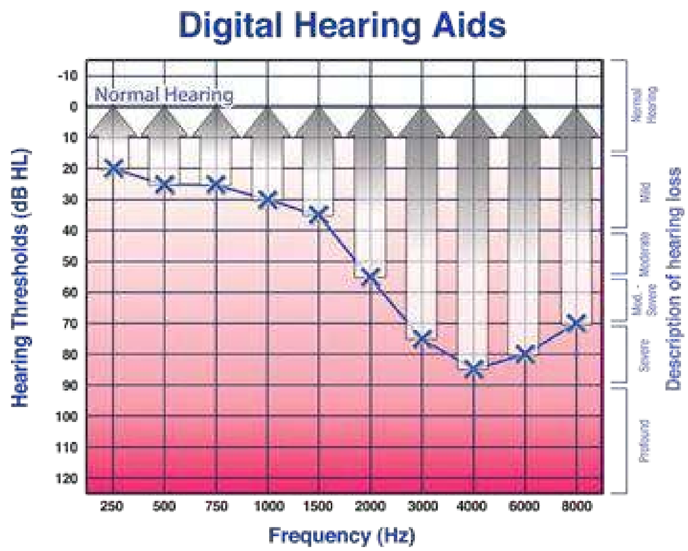
❖ <u>**Analog hearing aids**</u>:

- An analog hearing aid is a device that is designed to amplify all sounds the same way: continuous sound waves are made louder.
- That means that speech and noise are amplified in the same manner.
- A volume control wheel allows the user to increase or decrease volume as needed; however, this can become cumbersome and tedious when in a complex listening environment.
- Analog hearing aids are becoming less and less common.



❖ <u>**Digital hearing aids**</u>:

- A digital hearing aid is a device that uses a computer chip to convert sound waves into a digital signal.
- This results in more complex processing of input sounds.
- The computer chip is able to recognize and analyze speech versus background noise, resulting in clearer sound quality.
- Additionally, the signal is processed according to input volume.
- A loud sound is treated differently than a soft sound.
- Soft speech is made audible while loud speech is kept comfortable.
- Features are also available that help reduce background noise and wind noise while maintaining speech audibility.



❖ <u>**Analog Versus Digital hearing aids**</u>:

- **Analog**: Old hearing aids technology.
- The difference between digital and analog HAs is:
  - → ***in the way that they process sound***
  - → ***the individual benefits that they offer***
- Analog Hearing aids use conventional electronics (analogue circuit) to convert sound into electrical signals that are amplified
- The electrical current is analogous to the acoustic sound pressure
- **Analog Hearing aids**:
  - → ***Components are of bigger size***
  - → ***Have Less than 3 frequency bands***
  - → ***Poor quality of output signal***
  - → ***Signal processing is limited to amplification and frequency shaping***
  - → ***Lower prices on average***
  - → ***Easier to set up***

Hearing Aid Batteries:

❖ *Most commonly* zinc/air:

- Relatively **high energy density**
- **Inexpensive materials**
- **Constant voltage rate** over **a relatively long time**
- Very **low self-discharge rate** under **sealed condition**
- **Relatively long-lasting** under **low power conditions**
- **Proven technology**
- Once the **seal is broken self-discharge starts** irrevocably and **at a high rate**
- **Not rechargeable**

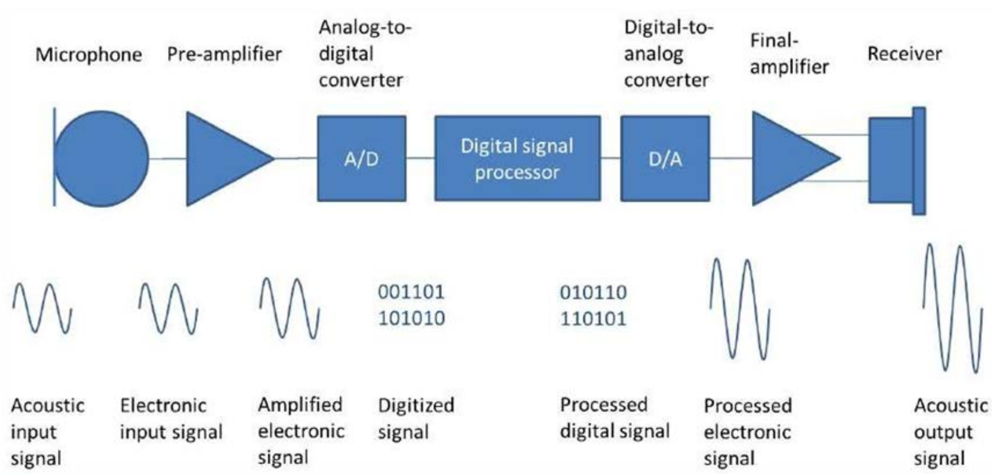
❖ Rechargeable batteries advantages:

- More Accessible for Older Users
- Environmentally Safer
- No Extra Costs
- Energy Efficient
- Etc.

Transducer:

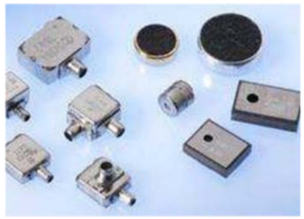
A **transducer** is: any device that changes energy from one form to another

Digital hearing aid components:



1. ***Microphones and Receivers***:

- Microphones:
  - **Input transducer**
    → Converts **acoustical sound** to **electrical energy**
  - Has **internal noise** due to components of the **electrical circuit**
  - **Wind** striking the microphone **causes noise**
  - **Easily damaged** by **debris**



- Receivers:
  - **Output transducer**
    → converts the **amplified electrical signal** into **acoustic form**
  - The **size of the receiver** determines its **output**
  - The receiver is a **major consumer** of the **hearing aid battery**
  - **Easily damaged** by **debris**
  - **Easily damaged** by **dropping** (may continue to work but could be distorting)
  - **Receiver vibrations** can lead to **vibratory feedback** due to proximity to other components

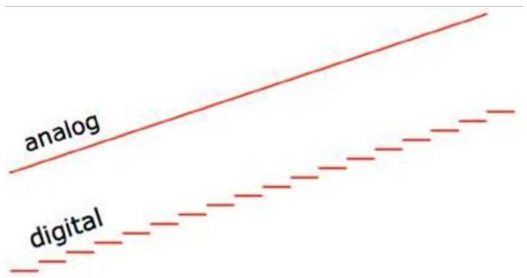
2. ***Digital Amplifiers***:

- Analog-to-digital converter:
  - **Digitizes electrical waveform**
  - Samples at discrete points in time

- Digital Amplifier:
  - Able to **manipulate information** at speed
  - Allows for:
    → **Less internal noise**
    → **Less distortion**
    → **Great shaping flexibility** of **incoming sound**
    → Ability to **perform changes** in the **frequency response** *(example: noise suppression, feedback management, etc.)*

❖ <u>Digital-to-analog converter</u>:

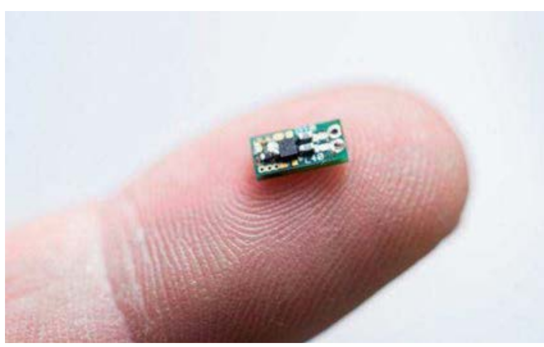
- Converts digital waveform back to analog output



3. ***Digital signal processing (DSP)***:

❖ DSP:

- Amplifier performs series of very fast calculations
- Chip technology
    - → **Electronics** on **integrated circuit board**
    - → **New chip** every **two** to **three years**
    - → All major manufacturers use one chip for an entire line of products
- **Smaller components** *(e.g. tiny microchip)* that can handle **complex signals**
- Consumes **less power**
- **Less internal noises**
- **Multi-frequency bands** processing
- Increasingly **complex directional mic systems**
- **Potential for improvements** in **background noise**
- **Improved solution** to **feedback problems**
- More **precise processing** that produces **better signal quality**



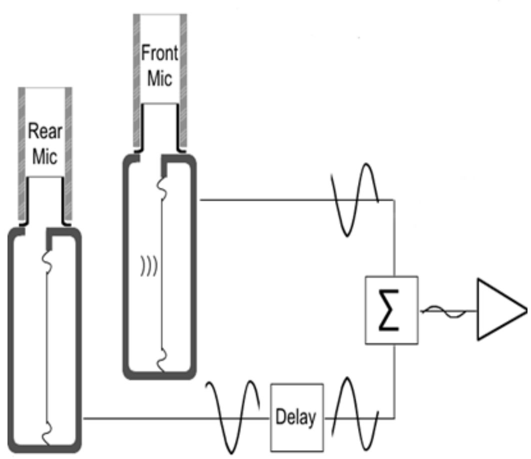
Additional features:

1. <u>Telecoil</u>:

- **Induction loop facilities** found in **facilities**
    - → *Example: public theatres, banks, places of worship*
- **Improves signal-to-noise ratio**
- **Prone** to **interference**

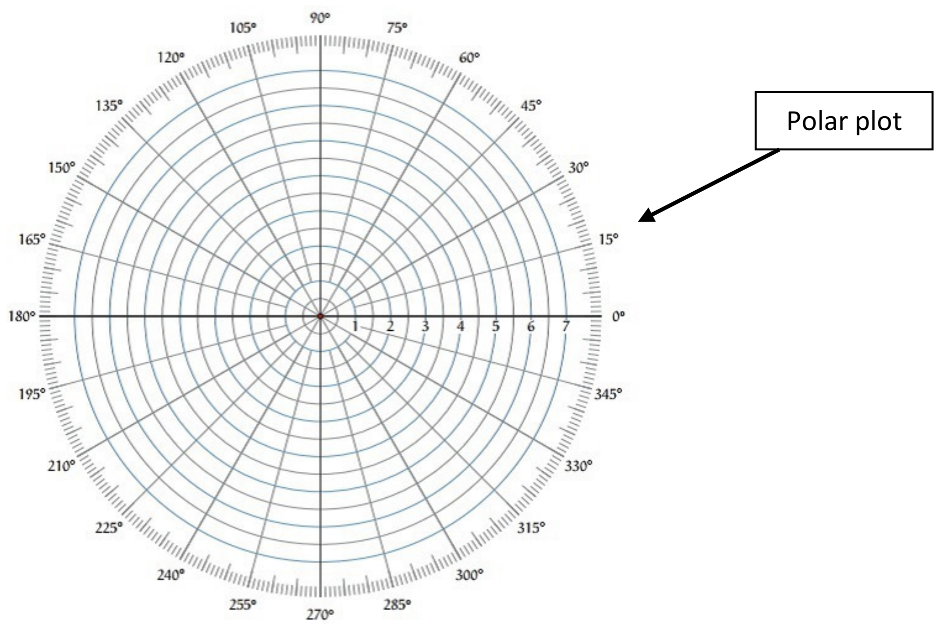
- **Another type** of **input transducer**
- Uses **electromagnetic energy** present **around telephone**
- Bringing the phone **close to the aid** allows the **magnetic signal** from the **telephone** to pass **directly into the hearing aid**
- Using a **magnetic connection** (rather than an airborne signal) **eliminates feedback** from the signal

2. Directional microphones:
    - **Inability to hear speech** in the **presence of background noise** is major reason hearing aids are rejected
    - **Directional microphones** depend on **noise being spatially separated** from **speech**
    - **Reduce sound** coming from **behind** rather than **increasing sound** from in **front**
    - **Improve signal-to-noise ratio** (SNR)

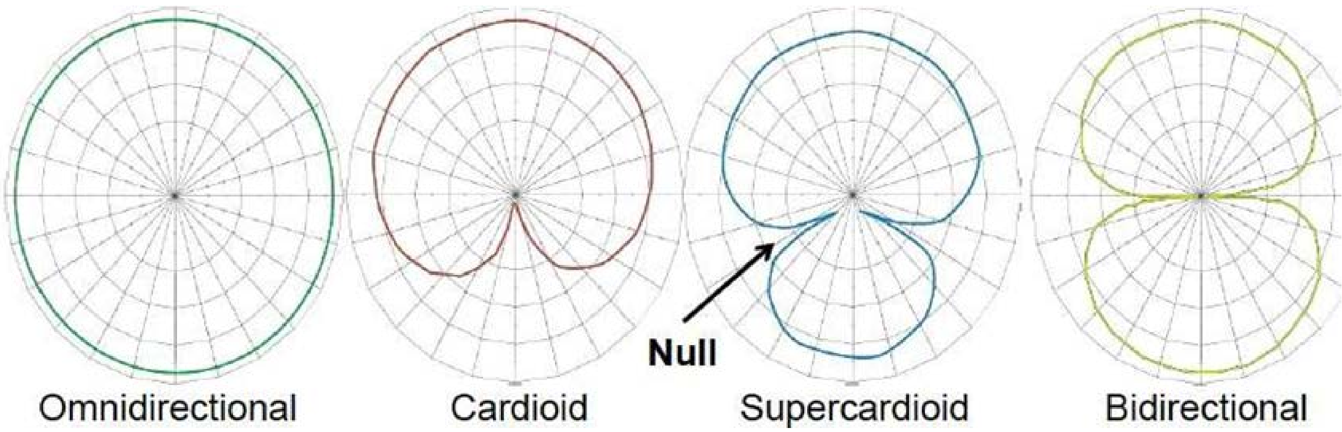


- Two **omnidirectional microphones** *[receiving signals from or transmitting in all directions]*
- **Delay from rear microphone** is created **electronically**
- **Electrical signals** from **front** and **rear microphones** cancel each other when **input is from the rear**

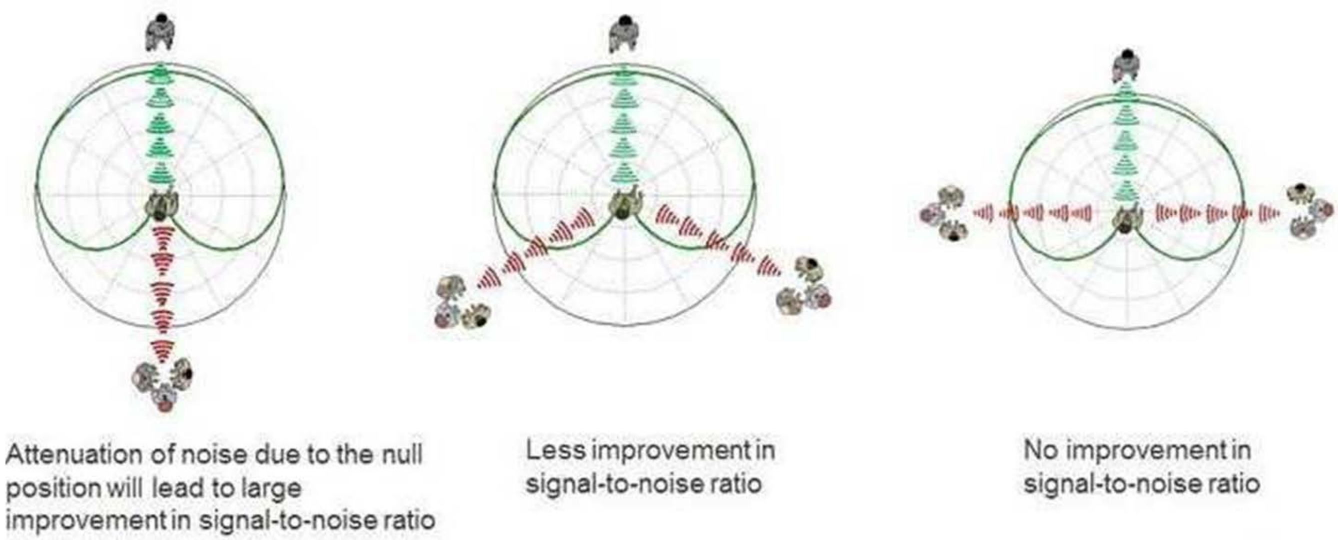
- **Sound enters the microphones** where the **acoustic energy** is **converted to electrical energy**
- The **two signals** are sent through an **electrical network** where a **time delay** is applied to the **rear microphone signal**
- The **two signals** are **subtracted** to **produce directivity**
- When **both microphones are active** → a **directional pattern** is achieved
- When an **omnidirectional condition** is desired, the **rear microphone** is **shut off**
- A variety of **spatial directional patterns** can be achieved by changing the **time delay applied to the signals**
- <u>**Directivity index (DI)**</u>
  → Standard for measurement of effectiveness of directional microphones
- **The greater the DI** → the **more effective the separation of signal and noise**
- Current directional microphones have a **DI** of up to **6 dB**
- **DI** are represented using **polar plots**



- Plot of **output intensity** for **a 360-degree pattern** for sound arriving at the microphone
- Constructed by measuring **the output** of the hearing aid **at several points** within an **imaginary sphere** around the **microphone**
- **Fixed directional**
  → Nulls are always at the same angle of the pattern
  → Common directional polar plots:



- **Directionality** is **most effective** when the **signal of interest** is in front of the listener and within about **two meters of them**
- Beyond this distance → **directional microphones** do not provide significant benefits
- **Directional microphones** work best when the **noise and signal of interest** are spatially **separated** *(coming from different directions)*



- With **fixed directionality** users have to **manually switch programs** in noisy environments, but:
  - → Some users **do not switch** between settings
  - → Some users **do not know** when to switch
  - → Some users **do not want** to manually switch

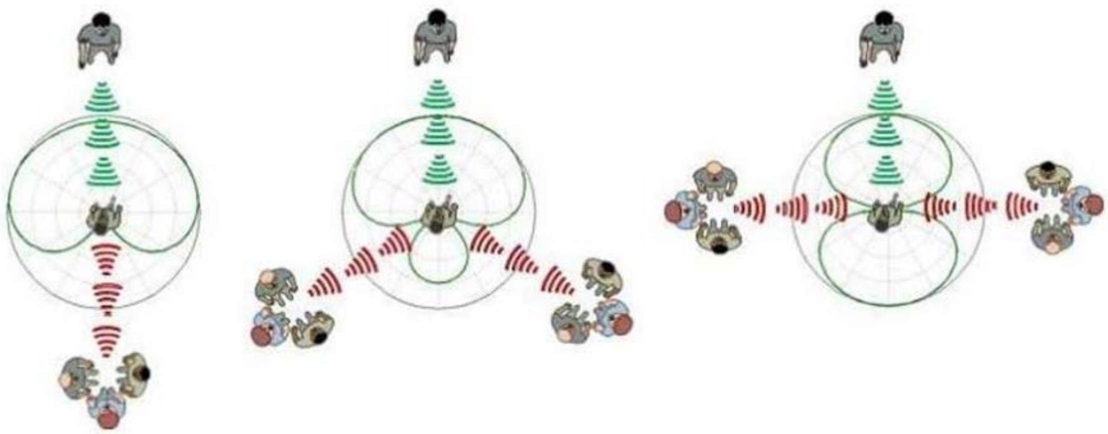
❖ **Automatic switching**:

- Hearing aid **automatically changes** from an **omnidirectional setting** to a **directional setting** depending on the environment
- **Switching algorithm** depends on **environmental classification systems** within the hearing aids

→ Analyses **acoustic scene** and decides which **microphone mode** would be most beneficial

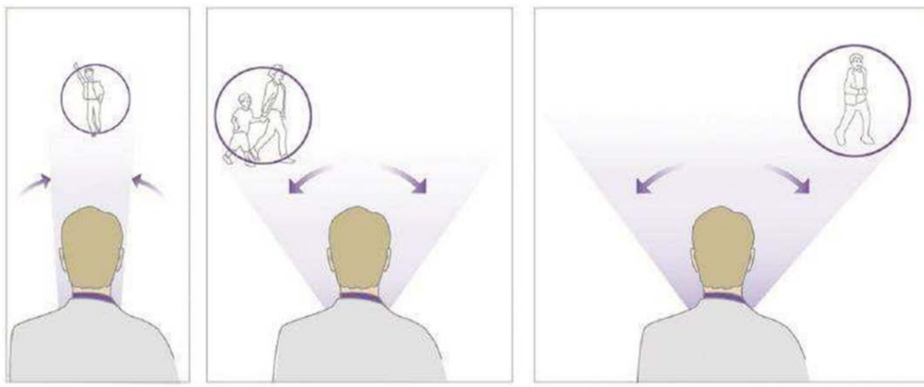
❖ **Adaptive directionality**:

- **Benefit**:
  → When most or all the noise is coming from a particularly location the hearing aid can put the point of maximum attenuation at this location to improve the signal-to-noise ratio
- **Limitation**:
  → Systems are limited by the accuracy of the classification system and have no ability to determine the hearing aid user's intent in complex listening situations



❖ **Beam forming**:

- Front beam can be narrowed or widened depending on signal level to the front



<u>Key information about Directional microphones:</u>

- **Improve SNR by 2-6 dB**
- **Fixed** and **adaptive directional microphones** perform equally in everyday listening situations
- **Automatic directional technology** may be **easier to use** as at least one-third of hearing aid users either forget to switch or do not understand how to switch to a directional mode

- Most adults will **benefit from directional microphone technology** to some degree. Will depend on:
  - → ***Person's hearing loss***
  - → ***The signal-to-noise ratio of their common listening situation***
  - → ***For people who do not benefit sufficiently, personal assistive listening technology is available***

Noise Reduction Algorithms:

Noise reduction algorithms → aim to reduce **unwanted background noise**

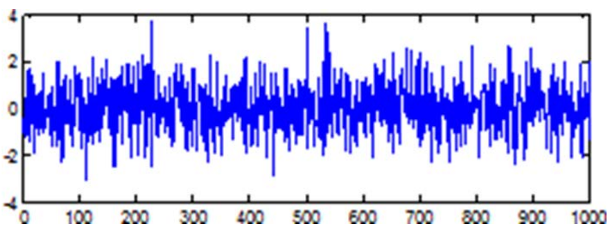
- Two approaches/algorithms:
  1. **Noise suppression**
  2. **Spectral subtraction**

Noise suppression:

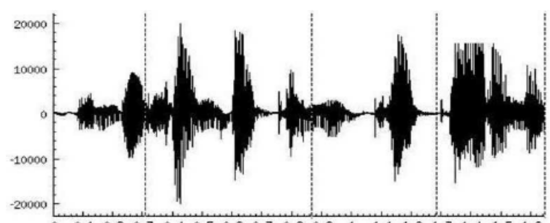
Noise suppression involves two modes of action:

1. **Modulation detection**
2. **Synchrony detection**

- **Modulation detection**:
  - AKA amplitude modulation noise reduction
  - There is an assumption: **noise is stationary** → which means that there is **almost no modulation/fluctuation in the amplitude**
  - **Reduces the gain** in channels dominated by the stationary noise



- **Synchrony detection**:
  - Attempts to **detect** the **presence of speech** in **different frequency bands** based on the following assumptions:
    - → **Voiced speech sounds** have **dominant low frequency fundamental frequency** and **harmonics**
    - → Identifies **speech sounds** by their **fundamental frequencies** (F0) and **harmonics** (F1, F2, F3)



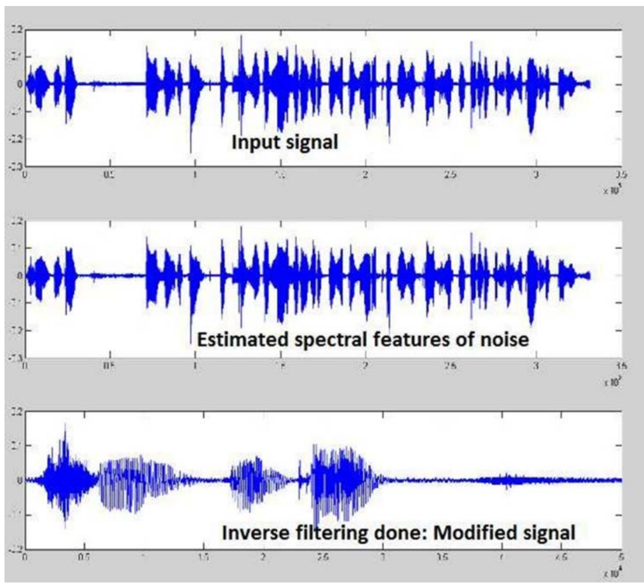
❖ Combined Analysis:

- In **noise suppression** → both **modulation** and **synchrony detection** work together
- **Synchrony detection** accurately identifies the presence or absence of speech.
- **Modulation detection** provides info on the amount of noise in each channel.
- Therefore the **gain is reduced** at these channels accordingly.

Spectral subtraction:

Aim: to estimate the spectral characteristics of the noise during pauses of speech

→ Then **subtract it** from the speech using **inverse filtering**



Factors influencing the effectiveness of noise reduction:

- The **accuracy** of the **identification of noise and speech**
- The **type of noise**
- The **number of channels**
- The **amount of noise detected in each channel**
- *Ricketts & Hornsby (2005)*: reduced loudness and annoyance of noise without reducing speech perception: spectral characteristics of speech and noise overlap which doesn't result in improved SNR
- **Less cognitive load/effortful listening**
- *Boymanset al. (1999)*: no improvements in speech intelligibility but it doesn't decrease speech intelligibility either
- Evidence is inconclusive

Acoustic feedback:

Acoustic feedback is:

- Caused by **the leakage of the sound** from the Hearing aid speaker (rec) back to the mic
- This **sound wave leakage** from the OP back to the IP produces a **form of instability** → resulting in an **audible feedback sound**
- **Feedback** typically occurs between 2-5 KHz and is often initiated by **high – frequency gain** of the Hearing aid
- **Reduced the max amplification** that can be used in the hearing aid without making it unstable

❖ **Feedback reduction algorithms**:
  - Two approaches:
    1. **Gain reduction method**
    2. **Feedback phase cancellation**

Gain reduction:

❖ Reducing the overall gain (old approach):
  - ***Disadvantage***: compromises audibility

❖ **Identifies the frequencies** at which **the feedback** is occurring and **reduces the gain in this frequency region** using a **narrow band filter**
  - ***Disadvantage***: may compromise speech components in the targeted frequency region

Feedback Phase cancellation:

❖ Identifies the **feedback signal** then ***inverts*** the signal making it out of phase → cancels the signal
  - ***Advantage***: tries to cancel just the feedback noise

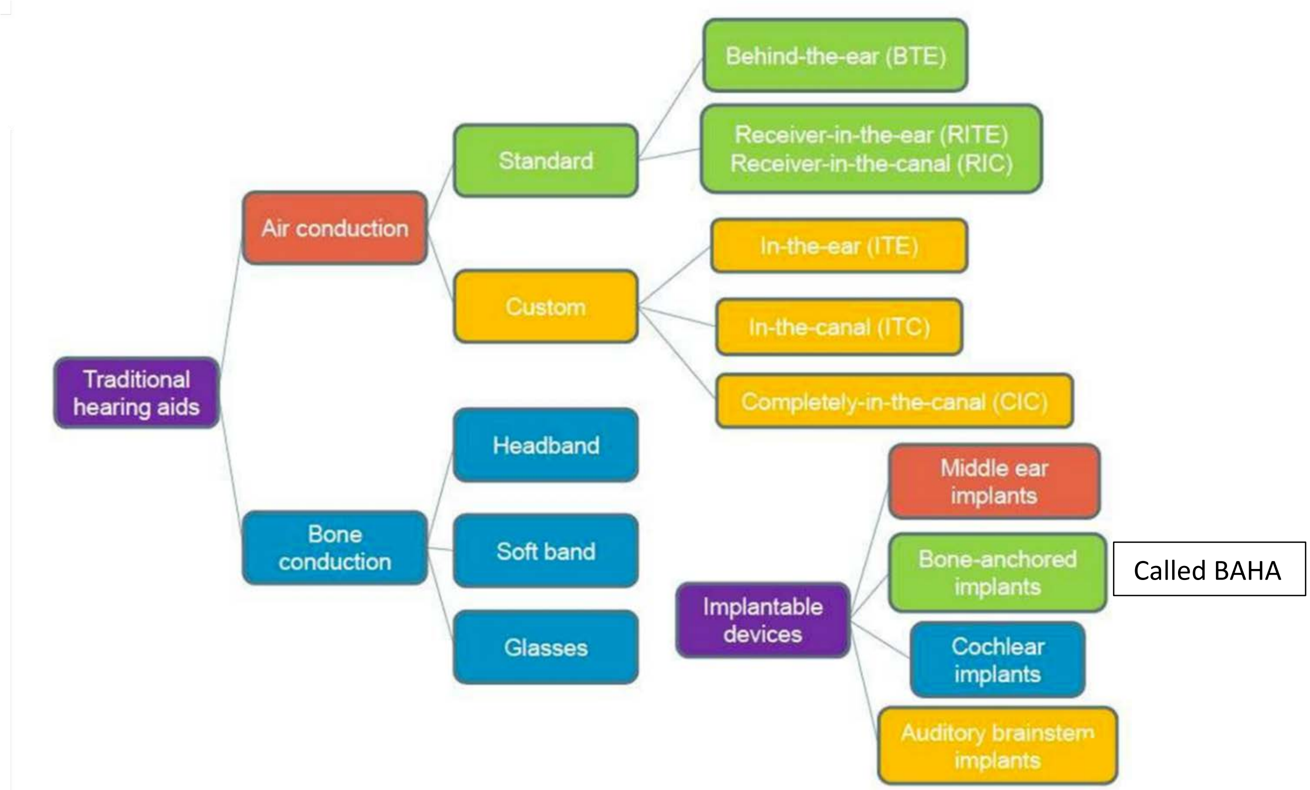
Chapter Six: Treatment Options for Hearing Loss

Types of Hearing Aids:

The **primary objectives** of listening devices are:

- Make speech audible and intelligible, while avoiding distortion or discomfort
- Restore a range of loudness experience

The hearing devices:



Air Conduction Hearing Aids:

STANDARD HEARING AIDS

1) Behind-the-ear (BTE) HA
   - This hearing aid can be fitted to **a wide range of hearing losses** from **mild to severe or profound**
   - It can be coupled with **a variety of earmoulds** and **thin-tube coupling systems** to provide more or less occlusion
   - **Space in the housing/casing** provide options for **batteries** (power), **controls** (programmes, microphones), **telecoil**, **direct audio input**, and etc.
   - It has **fewer repair problems** than other HA styles
   - **Advantages:**
     → **More reliable than ITE** [in the ear] devices
     → **Easy to clean**

- **Disadvantages:**
  → **Cosmetics** may be a concern
  → **Susceptible** to wind noise

2) Receiver-in-the-ear (RITE) HA or Receiver-in-the-canal (RIC)
   - For those with **mild** to **moderate hearing loss**
   - The casing houses **all components** apart **from the receiver** (speaker)
   - **Advantages:**
     → **Less prone** to feedback
     → **Occlusion** generally **less of a problem**
     → **More natural sound** due to **open ear canal**
     → **Small** and **lightweight**
   - **Disadvantages**:
     → Receiver end **vulnerable to moisture** in ear canal therefore **frequent repairs** to receiver required

CUSTOM HEARING AIDS

1) In-the-ear (ITE) HA
   - From **mild** to **moderate** HL
   - **Advantages**:
     → Very easy to use with telephone
     → Very easy to insert in the ear
     → Less visible than BTEs
     → Less sensitive to wind noise than bigger/BTE devices
   - **Disadvantages**:
     → **Higher cost** compared to BTEs
     → **Expensive to remake** [if lost or damaged]
     → **Custom made** so cannot swap to other ear if one of a pair is faulty or patient has fluctuating loss in other ear
     → **Size limitation** sometimes makes **direct audio input** and **telecoil options unavailable**
     → **Manipulating user controls may be difficult** for patients with **diminished manual dexterity**

2) In-the-canal (ITC) HA
   - From **mild** to **moderate** HL
   - **Advantages**:
     → **Reduction** of **feedback** (if no vent)
     → **Improved sound localization**
     → **Less gain required**
     → **Elimination** of **wind noise**
     → **Enhanced telephone** use
     → Virtually **invisible**

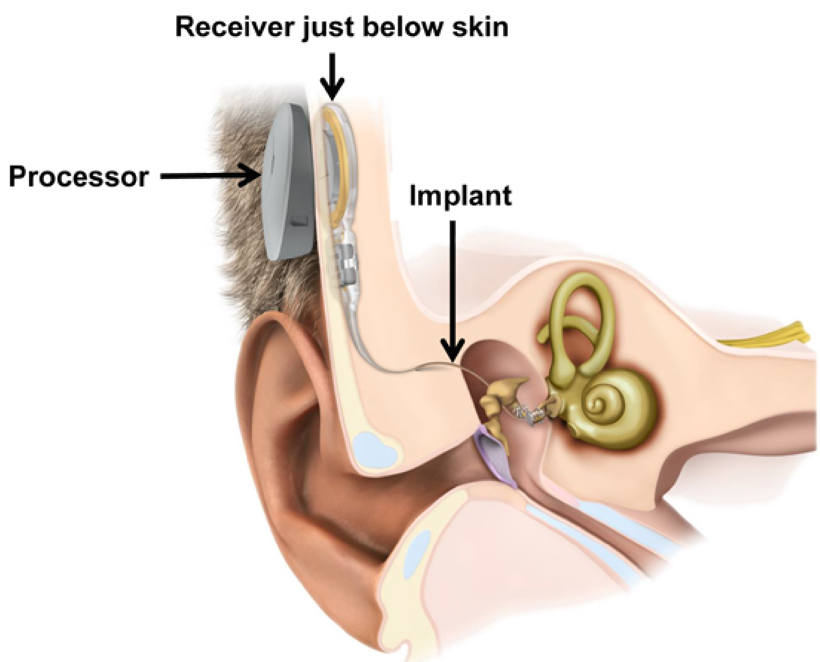
→ **Greater high frequency gain achievable**

- **Disadvantages**:
  → **High maintenance** devices
  → **Cerumen/wax build-up** –frequent cleaning necessary
  → Due to size, **cannot house some features** [for example: direct audio input, telecoil, directional mics]
  → **Occlusion**
  → **Less overall gain**

3) Completely-in-the-canal (CIC) → Completely invisible hearing aids
- Fits **mild** to **moderately-severe** hearing loss
- Fitted by Lyric trained audiologist or ENT
- Worn for **24 hours per day**
- Battery lasts for up to **120 days**
- **Expensive, subscription required**

IMPLANTABLE DEVICES

1) Middle ear implants
- **Option** for patients who **cannot wear an external hearing aid**
- **Converts sound** to **micromechanical vibration** –transmitted directly to the **ossicular chain**
- **Surgically implanted**

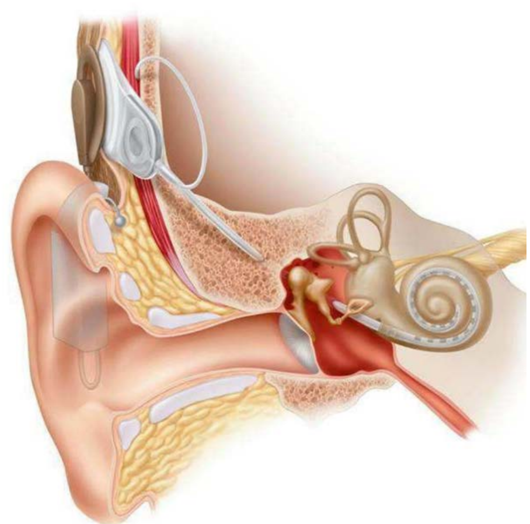


2) <u>Bone conduction devices/implants [BAHA]</u>

- Screw **surgically implanted into skull**
- **Sound transmitted** <u>directly</u> to **cochlea via bone conduction**
- Suitable for patients with **conductive** or **mixed hearing loss**

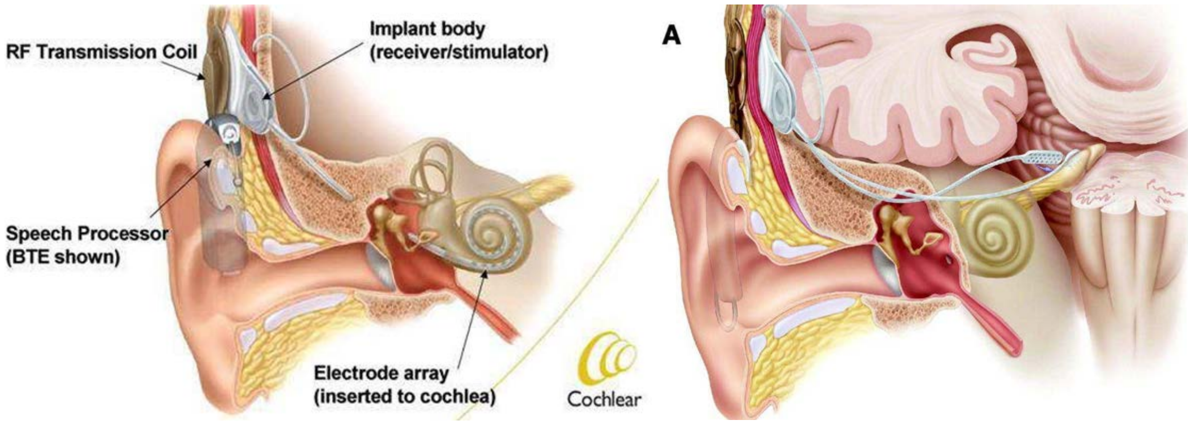
3) <u>Cochlear implants</u>

- Internal components **surgically implanted**
- **External components** typically worn **behind the ear**
- Suitable for patients with **severe** to **profound hearing**



4) <u>Auditory Brainstem Implant</u>

- May be helpful for those with **absent** or **damaged auditory nerves**



❖ **<u>Assistive listening devices</u>**:

- **Radio aid systems**, **infrared systems**, **induction loop systems**
- **Telephone amplifiers**
- **Vibrating alarm clocks** –placed under the user's pillow
- **Flashing alarm clocks** –light flashing signals the alarm
- **Doorbell coupled to a lamp** –flashes when doorbell is rung
- **Smoke detector** –light flashes to signal presence of smoke
- **Text messaging** on mobile phones and other text message display systems
- **Baby cry alert system**

Chapter Seven: Earmolds and Coupling systems

Earmould Styles:

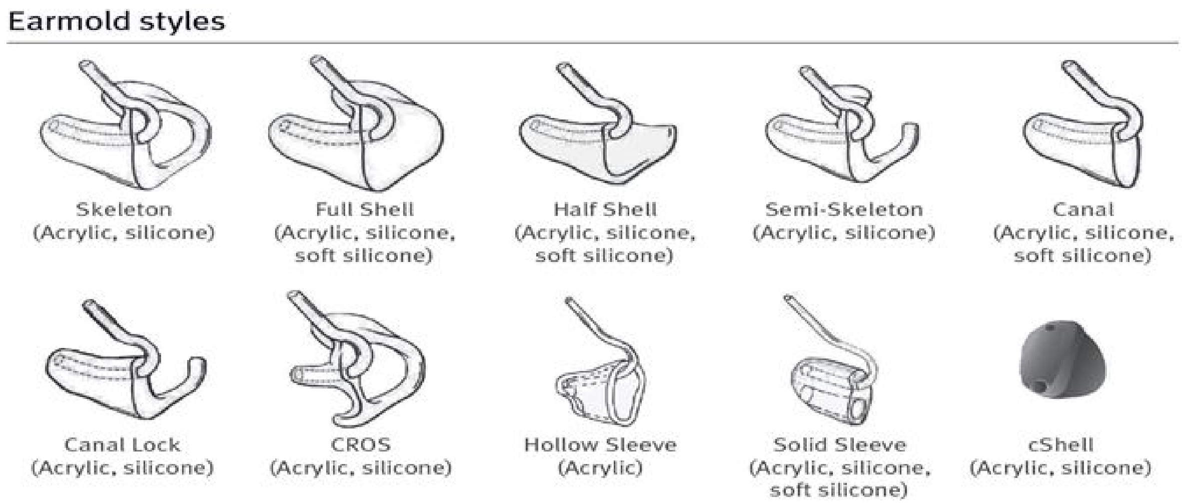
Earmolds and shells of different styles fill different portions of the concha and the canal.

It will affect 4 aspects:

1. **Appearance** → the look
2. **Acoustic Performance** → more occlusion and better amplification
3. **Comfort**
4. **Security and Retention of Aid** → how long the HA can sit behind the ear or in the ear

There are 2 <u>types of materials</u> for the molds:

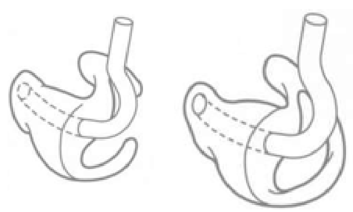
- **Acrylic** → hard
- **Silicon** → soft



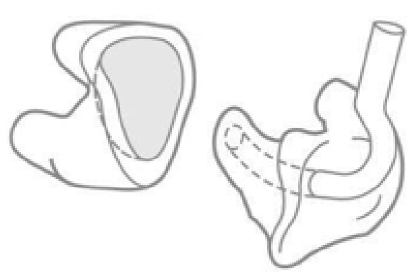
CROS: Contralateral routing of signals

1. Skeleton
   - One of **most common styles** used
   - with **BTE hearing aids**
   - Can be used with **a wide range of hearing losses**, from **mild to severe**
   - Can be **easily modified** to other styles [for example: *semi-skeleton*]
   - **Placement** and **Removal is easier** than the shell
   - More amplification can cause more opposite feedback

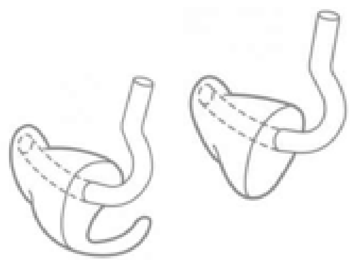
The more the HL was → the softer the material should be



2. Shell
   - Fills **entire concha** for better seal
   - Often used for **severe to profound hearing losses** and for **younger children**
   - Canal portion can **be made thicker** for a **better seal** or **thinner** for **better cosmetics**
   - Can be fitted with a snap ring instead of tubing [for example: *for powered stethoscopes*]
   - **Carved shell** offers **better sealing properties**
   - Can **be difficult** to **insert if tight fitting**



3. <u>Canal mold</u>
   - **Small**, **cosmetically appealing**
   - Suitable for **mild** to **moderate** losses
   - **Suitable** for patients with **a deformed pinna**
   - **Retention** can be a problem
   - Can be modified with **'concha lock'** to improve retention



- Some people's hearing loss is **not that bad** and thus instead of a tube mold, they are given a **thin tube with a dome**.
- The **thin tube custom**: → the molds with it are gained from impressions
  - → **Prevents** feedback
  - → **Improves** retention
  - → **Increases** gain
- **RIC custom** → For use with **Receiver In the Canal** products

Ear mold Materials:

- Three primary families of **ear mold materials**:
  - **Acrylic/Lucite** → hardest
  - **Polyvinyl chloride** (PVC) → inbetween
  - **Silicone** → softest

- Physical properties:
  - **Degree of softness**:
    - Described by **shore value**
    - The **lower the shore value** the **softer the material**
  - **Finishing characteristics**
  - **Extent of shrinkage**

<u>Acrylic/Lucite</u>:

Positives	Negatives
Very hard → possible to make thin ridges	Will **not bend** or **compress** to get past narrow openings on insertion
Keeps shape without shrinking	More prone to feedback
Durable	**Not** recommended for children
Easy to modify	**Not flexible**
Easy to insert and **remove**	x
Fairly **hypoallergenic**	x

<u>Polyvinyl chloride (PVC)</u>:

Positives	Negatives
Softer and **more comfortable** than acrylic	**Not very durable**
Appropriate for **children**	Soft nature makes **modification more difficult** than for acrylic
Appropriate for **hearing losses** in the **moderate** to **severe** range	Prone to **discoloration over time**
Although not as slick as acrylic and not as tacky as silicone → therefore **reasonably easy to insert**	**Problematic** for people with **vinyl allergies**

<u>Silicone</u>:

Positives	Negatives
Soft and **tacky nature** makes silicone ideal for **severe** to **profound** HL	Soft nature makes **modification more difficult** than for acrylic
Appropriate for **children**	**Soft** and **tacky nature** makes it **the most difficult** to **insert** and **remove**
Fairly **hypoallergenic**	Can cause **skin abrasions** in patients with **fragile skin**
x	**Tubing adhesive** does <u>not</u> bond well so may need **mechanical tubing lock**

❖ **Hard and soft acrylic combined (popular)**:

- **Tip of ear mold** is made of **soft acrylic** → **rest of mold** is made of **hard acrylic**
    - Cosmetic properties (doesn't cover the whole ear) and ease of fitting of hard acrylic
    - Added comfort and acoustic sealing of soft acrylic

❖ Earmolds:

- the **greater the hearing loss** → the larger the earmold needed
    - **Accuracy of the earmold impression** is as important as the style when thinking about **maximum amplification** before **feedback**
- **Variety** of **canal lengths** are possible
  → Longer canal lengths generally associated with less ___________
- **Tapering** *(becoming thinner or narrower towards one end)* the end of the canal may make **insertion easier** but **increases chance of feedback**
- **Avoid tacky materials** for <u>older patients</u> with thin skin to **prevent insertion abrasions**
- **Buffing** and **grinding** works well for <u>modifications of acrylic</u>
- **Scalpel** or **razor blade** needed for minor modifications of **soft materials**, <u>major modifications not possible</u>

Domes:

Thin tube and dome systems (in general):

- ➢ The tube has **very narrow diameter**
- ➢ Manufacturer specific
- ➢ **RIC style** also **available**
- ➢ Can have **problems with retention**

- Large array of products from all manufacturers
- **Hook/tubing** comes in **different lengths**

Three types of domes:

- Power domes
- Closed domes
- Open domes

The difference between them has to do with the severity of **HL of the client**

*For example: one has moderate HL but refuses a mold, we can give them a **power** dome.*

→ We chose **power** because it is **two layers**. This gives it a **higher occluding affect**

Hearing aids with domes are best for those with **mild-to-moderate hearing loss** → especially those with **high frequency hearing loss**—the most common type of age-related hearing loss, known as **presbycusis**

<u>Power dome</u>: Two layers
<u>Closed dome</u>: One layer
<u>Open dome</u>: tiny holes

- Domes known as **“power domes”** or **“double domes”** do <u>not provide</u> an open fit as they significantly **occlude the ear canal**.

  → It may be tempting to use them to solve feedback issues with **an open fit**, but they are more likely to generate **occlusion-related complaints**.
  → A **hollow ear mold reduces occlusion** with a *smaller diameter vent* than a solid ear mold.
  → This can help strike the balance between adequate high frequency gain and acceptable occlusion.

- The ear canal must be **occluded to some degree** in order to provide **low frequency gain**. In other words, individuals who have low frequency thresholds exceeding 40 dB HL and who are likely to need 10 dB or more of low frequency gain cannot be fit adequately with open domes or tulip domes.

- Individuals requiring a lot of low frequency gain won’t get it with power domes or double domes. A **custom ear mold** is required for **severe low frequency hearing losses**.

<u>When deciding on a dome, we take two things into consideration</u>:

1. The **size** of the dome
2. The **HL** of the client

The tube with the dome:

Just as the dome comes in different sizes, the length of the tube may vary.

- <u>The tube for the mold</u>: The tube is cut based on the length from **the opening of the ear** to where **the hearing aid is placed.**
- <u>The tube for the dome</u>: this thin tube comes in different sizes like 0, 1, 2, 3 → a measurement tool comes with it and with that tool, we can tell what the best length may be. [this is already done and is not cut like the one for the mold]

Receiver-in-the-ear systems:

- Different **dome/mold options**
- Different **wire lengths**
- Different **receivers sizes**

The receiver is wrapped with either **a dome** or **a mold**.

The smaller the ear canal → the less need there is for more occlusion.

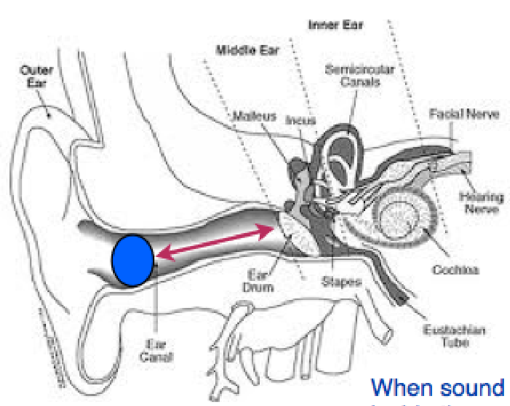
Occlusion:

The **occlusion effect** occurs when an object fills the outer portion of a person's ear canal

- Caused by **bone-conducted sound vibrations reverberating off the ear mold**
- When the ear canal is blocked → the vibrations are reflected **back** towards the eardrum
- Can boost **<u>low frequencies</u>** (below about 500 Hz) in the ear canal by **20 dB or more**
- When talking or chewing → these vibrations normally escape through an open ear canal
  - → Most people are **unaware** of these sounds
- **Hollow** or **booming** *echo—like* perception of their own voice
- Initial **increase in ear mold canal length elevates occlusion effect**
- Extending past the second bend (acoustic seal area) significantly reduces occlusion effect

Low frequency has most power [amplitude]

- The sounds that are meant to leave, re-enter the canal and gives more power to the sound and it can go against each other and cause **distortion**.
- In order to try and solve the occlusion problem, there is something called **<u>a vent</u>**.



When sound is trapped inside the ear canal, the sound trapped becomes amplified.

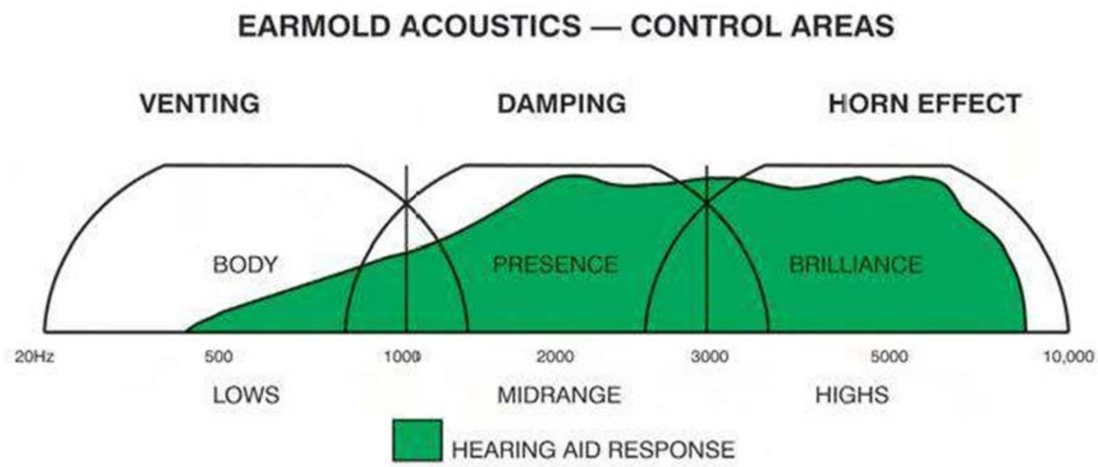
Feedback is when the sound escapes the ear canal and re-enters through the microphones and affects the amplification of the other sounds creating an annoying sound.

Earmold acoustics:

The ear mold affects:

- **Comfort** and **appearance** of the hearing aid
- **Acoustic response** of the hearing aid when mounted on the ear
- **Self-perceived quality** of the patient's voice
- Likelihood of **feedback**

Ear mold acoustic control areas:

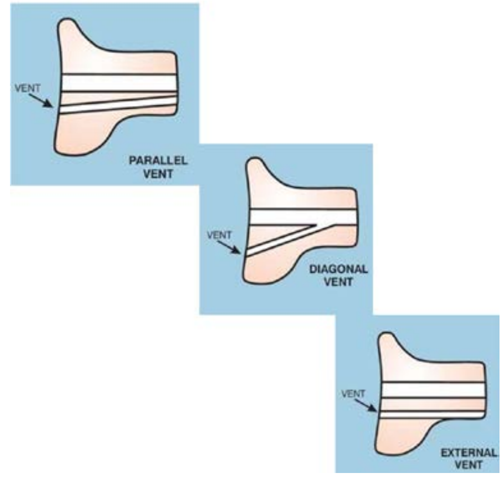


Venting:

In general, Venting:

- Allows **low-frequency signals to escape**
- When hearing is normal in the low frequencies
- Allows **low-frequency signals** to enter **unimpeded** (non-obstructed)
- **Sound quality** may be **improved** if **low frequency sounds** enter unprocessed by the hearing aid
- Allows **low-frequency signals generated** in the **ear canal to escape**
- Allows **pressure relief**
- **Allows aeration** of the external ear
- **Prevents moisture/condensation** in the ear mold

- ➢ Any vent **less than 1mm** doesn't help with occlusion and is called **"comfort vent"** → which exists only for ventilation.
- ➢ Someone who has **profound hearing loss**, the maximum you can put for them is **1mm**. → if you put more than 1mm that creates **feedback**.
- ➢ As **vent size increases**, the amount of **acoustic leakage increases**, and therefore the **probability of feedback increases**



Types of vents:

1. **Parallel vent**
   - **Most preferable**
   - Comes **in different sizes**
   - **Same level** as the opening of the canal
   - The sound bore and the vent travel through the earpiece **side-by-side** and **do not intersect**
   - most **popular form** of venting because **feedback is minimized**

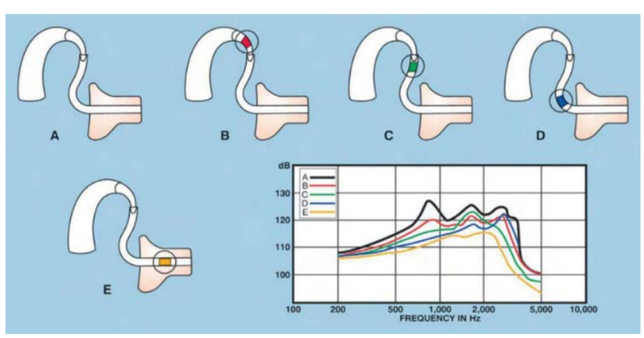
2. **Diagonal vent**
   - Used for **small ear canals**
   - May **increase risk of feedback**
   - This version intercepts the **sound bore at an angle** and can **result** in **a greater tendency to feedback**
3. **External vent**
   - Preferable to **diagonal vent** because it does **not disturb bore**
   - They're grooved on the **outside of the ear mold**

- Increase the canal portion of the mold to after the second vent → the occlusion perception decreases (why?)
  - → **Decrease space** between **ear mold** and the **ear drum**
  - → **Acoustic features**: Bone absorbs more sound than cartilage → the sound is being trapped in the bony portion and some of it is being absorbed from the bone and that's why the **occlusion perception decreases**.

Damping:

Dampers: are **used to decrease gain** and **maximum output** at frequencies corresponding to resonances in the sound bore

- Primarily affects frequencies between **750** and **3000 Hz**
- **Historically** used to **smooth out resonant peaks** introduced by **ear hook** or **tubing**
- **Modern digital** hearing aids use **digital filtering** to **smooth out resonances**
- If **nonstandard tubing** is used some **undesirable resonances** may remain – **reduced by damping**



Dampers are placed on the hook or tube.

- ➢ The more the damper is placed <u>within</u>, the more the graph <u>looked smoother</u> (no sudden high peaks) → **lower gain**
- ➢ Why does the **gain decrease** the more the damper went in?
  - → **Dampers** are **most effective** if they are placed at locations where **the resonance causes the fastest flow of air particles**
  - → For wavelength resonances, **particle velocity** is <u>least</u> at **the end of the tube** that joins to the receiver

Horn effects:

Horn effect:

- **Enlarging** the sound bore → **enhances** high frequencies
- **Reducing** the sound bore → **reduces** high frequency components

- ➢ Give boost to the **high frequencies** if the hearing aids is unable to do so electronically (higher gain at high frequencies)
- ➢ If the **opening** for the tube is bigger, the **more boost** it gives **the gain** (3nm, 4nm, 5nm)
- ➢ the **shorter the horn** → the **higher the frequency** of when the boost begins
- ➢ gives a **boost of 2 or 3 decibels** (not more than that)

Horn, Venting, and Damper:

	Low frequencies	Mid frequencies	High frequencies
Technique	**Venting**	**Dampers**	**Horn effect**
Effect	Allows **low-frequency** signals to escape	Changing acoustic resistance (the damper) varies the **mid frequency peaks**	Horn effect emphasizes and boosts the **high frequencies**

Chapter Eight: Hearing Aid Candidacy

Hearing aid Candidacy:

Factors that need to be considered:

1) Audiological Status
2) Psychological Status
3) Physical Status
4) Sociological Status
5) Communication Status

Audiological Status:

- <u>Type/pathology of hearing loss</u>
  - → **Sensorineural hearing loss** –requires compensation for loss of sensitivity and compression to address reduced dynamic range
  - → **Continued middle ear disorders** –may need more ventilation of ear canal & systems that bypass middle ear structures
  - → *In cases of a discharging ear, is a hearing aid the best option?*
  - → **Retrocochlear conditions** –mixed outcomes from amplification. However may find features such as directionality, noise reduction, remote mic, T settings and FM systems useful

- <u>Degree and contour of hearing loss/dynamic range</u>
  - → Determines **amount of required amplification**
  - → Also the **ear mold/hearing aid style** – *do **low frequencies** need amplification more or less than **mid/high***
  - → *Audibility vs comfort*
  - → ULLs indicate **dynamic range**

- <u>Speech discrimination (in quiet & noise)</u>
  - → **Providing amplification** is not just about making sounds audible, but about **improving speech intelligibility**
  - → For this reason tests of **speech discrimination** in **quiet & noise** provide indications of **hearing aid benefit** and **how much SNR (signal to noise ratio) boost is required**

  - ❖ *When should we provide a hearing aid?*
    - → Fitting hearing aids when people **first begin to experience hearing loss** results in **better long-term outcomes** than when getting hearing aid fittings are delayed
    - → Defining this point varies on **shape** and **degree of hearing loss**. Generally when thresholds fall below 30 dB HL at 2 kHz, we could expect noticeable benefit from aiding.

Psychological Status:

- <u>Cognitive and mental status</u>
  - → **Cognitive function** → **working memory** is a predictor of <u>hearing aid benefit in older adults</u> but <u>**less so** for younger adults</u>
  - → **Social isolation** and **cognitive decline** → aiding <u>**lowers risk**</u> of **cognitive disorders** including Alzheimer’s disease and dementia.
  - → **Self-efficacy beliefs** → an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments. *Does the patient feel able to manage the hearing aids?*

- Motivation
  - → *Why has the patient come in to see you?*
  - → *Are they ready to take action to address their communication challenges?*
  - → **History taking** and **questionnaires** can provide this information
  - → It is important to note that decisions about whether and when to fit hearing aids should not be based primarily on **the degree of hearing loss**.
  - → A systematic review found that **hearing sensitivity of pure-tone audiometry** is a poor predictor of **hearing aid use** and that **self–perceived activity limitations** are better predictors

- Attitude and perceptions
  - → *Has the patient tried hearing aids before?*
  - → **Cosmetics**
  - → **Disclosure of hearing status** to others
  - → **Perception of patient's own hearing difficulties**

Physical Status:

- **Craniofacial status** (Cleft palate – ME problems)
- Structure of **outer & middle ear**
- **Visual status**
  - → Handling of hearing aid
  - → Accessing support material
- **Manual dexterity** → handling of hearing aid
- **General health**
  - → Conditions affecting hearing loss and ability to manage *'daily wear'*

Sociological Status:

- Family support
  - → Living arrangements
  - → Lifestyle

- Employment/education

- Social and Physical environments
  - → Hobbies and activities

Communication Status:

- **Auditory speech perception**
- **Auditory-visual speech perception**
- Are the hearing aids for **speech perception** or **awareness of sound**
  - → The latter [awareness of sound] is common in patients who predominantly communicate using SL

Hearing Aid Selection:

When selecting a hearing aid, there are two different characteristics:

- **Electroacoustic** characteristics
- **Non-electroacoustic** characteristics

❖ <u>Electroacoustic characteristics</u>

- **Fitting range**
    - *Does the hearing aid provide adequate amplification?*
    - *Is there scope for increasing gain if the hearing changes?*
- **Acoustics**
    - *Think about the hearing loss contour and how the ear mold/custom fitting may change the acoustics of the ear*
- **Frequency shifting/lowering**
- **Additional hearing aid features**
    - Noise reduction algorithms
    - Feedback reduction
    - Directional microphones

❖ <u>Non-electroacoustic characteristics</u>

- **Unilateral or bilateral**
    - Binaural processing:
        - → Loudness **summation**
        - → Localization - **interaural time differences** (ITDs) and **interaural level differences** (ILDs)
        - → Speech intelligibility particularly **in noise**
        - → Auditory **deprivation**
- **Form factor**
    - Ease of handling
        - → Insertion/removal
        - → changing batteries
    - Appearance of hearing aids
        - → motivation is the best predictor of self-perceived benefit
- **Controls**
    - Volume control
        - → Consider accidental activation
        - → Key requirement in fluctuating hearing loss
    - Profiles/programs
        - → Balance between giving the patient control over what they hear and ensuring consistent auditory input.
- **Connectivity solutions**
    - Broadly help with *improving the SNR*
    - Multiple devices can be confusing for some patients
    - Can help other patients with accessing telephone, TV, and remote mic

- **Cost**
    - Substantial investment for patient and/or department
    - Devices need replacing after approximately 5 years (some shorter/longer lifespans)

Chapter Nine: Basics of Compression

Cochlear nonlinearity:

There will be low and high sounds entering the ear and they are all not the same level. We can differentiate the:

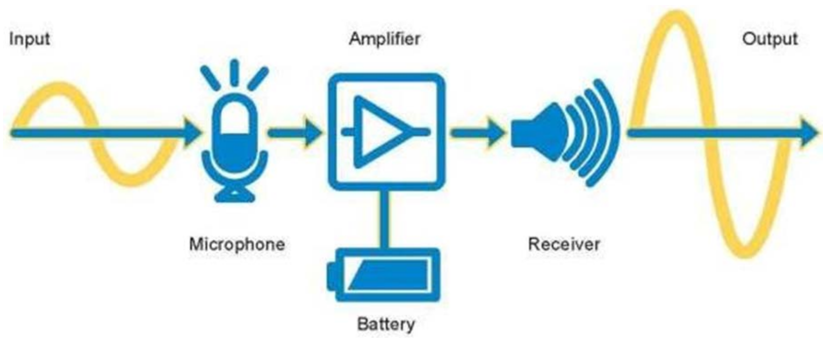
- Amplitude difference
- Pitch difference

We don't want to raise everything at once at the same level because → the mid becomes high and the high becomes uncomfortably high.

→ In order not to go through this we go do something called **compression**

Compression: instead of heaving linear amplification, we go through ***nonlinear amplification***.

Sound enters the **microphone**, then the sound goes through the receiver **amplified**



In compression, we squeeze all of sounds within the range.

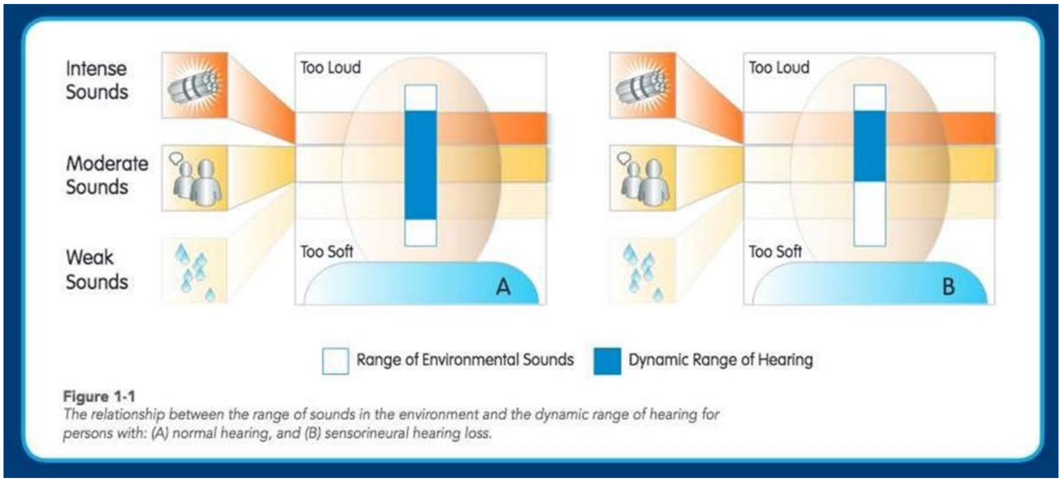


Figure 1-1
The relationship between the range of sounds in the environment and the dynamic range of hearing for persons with: (A) normal hearing, and (B) sensorineural hearing loss.

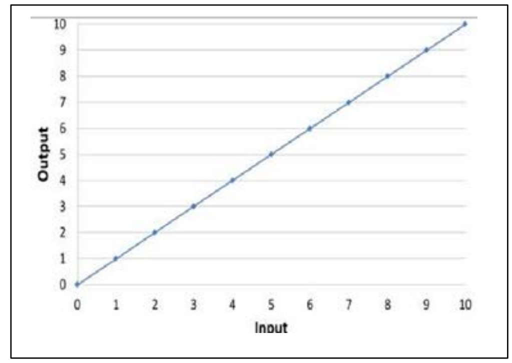
→ **Low sounds** we <u>amplify more</u> than the moderate sounds
→ And the intense sounds may not need to be amplified

Cochlear nonlinearity:

- **Basilar membrane** response is **nonlinear**
- We want to preserve this **nonlinearity** when fitting hearing aids

<u>Linear response example</u>

→ Change in input results in the same change in output



Input-output function:

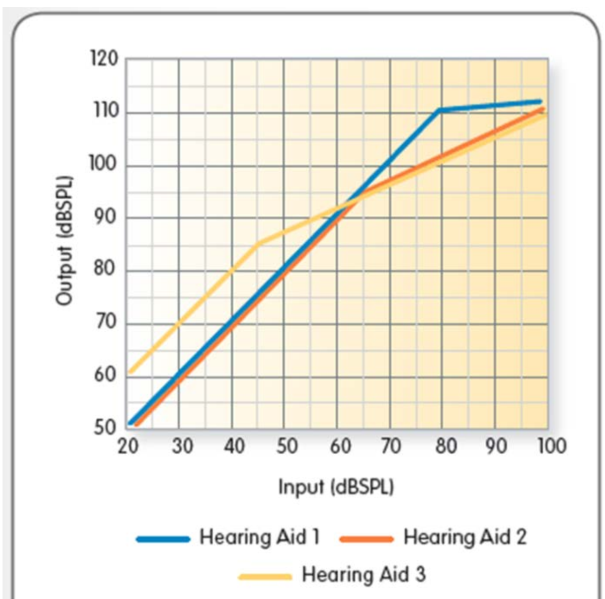


Figure 1-5
Sample input/output functions for three different hearing aids.

Hearing at 1 & 2 at 40:

- Input 40 → output 70

Hearing aid 3 at 40:

- Input 40 → output 80

We can assume that the one with HA 3 is the one with the highest HL.

Larger dynamic range → the more you can squeeze in

Smaller dynamic range → the less you can squeeze in

This affects and changes from one person to another on how they perceive sounds

Normal range: -10 dB to 120dB → 140 dB range

HL (ex): 30 dB range

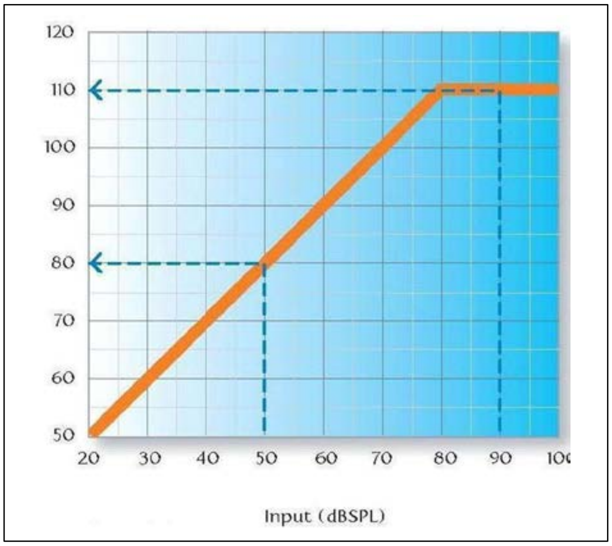
Hyperacusis is a hearing disorder that makes it hard to deal with everyday sounds.

→ In order to give a HA, we get them used to the sounds little by little so their sensitivity decreases and it becomes normal (before HA)
→ If they were given a HA before then that won't help because they'll be annoyed with everything and they won't be able to gain anything from the speech perception because the dynamic range is very little.

Gain:

Gain is the **amount of amplification** applied to the **input signal**

→ Difference between **output SPL** and **input SPL**
→ **Gain** = **Output** – **Input**



Input-gain function:

Graphical representation of the gain of a hearing aid at **various input levels**

→ **Output** = **Input** + **Gain**

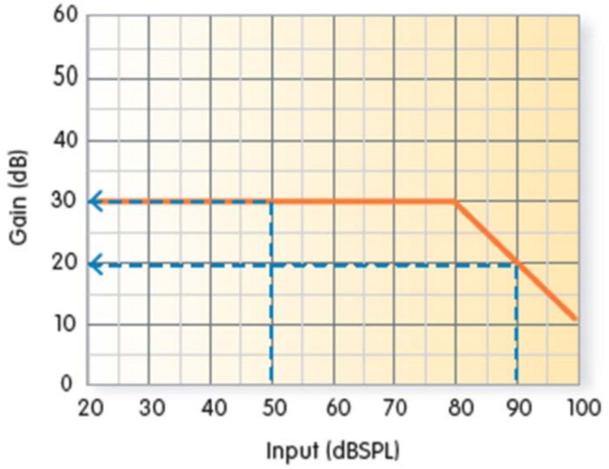


Figure 1-6
Sample input/gain function of a hearing aid.

When the:

Input 80 → gain 30

80 + 30 = **output 110**

What do we take into consideration?

- HL is at different frequencies
- Input level is different

So gain will be different at different inputs

❖ <u>Frequency response curve</u>:

- Graphical representation of hearing aid output as function of frequency
- Input level and overall gain are fixed when measuring frequency response curve
- We don't want the **low frequencies** to be too loud because it could cause an **upwards spread of masking**
- the **peak** is always **in the mid frequencies** and the low shouldn't go above the mid

- **Output varies** across frequencies
- **Shape of curve** may change as **input level increases**

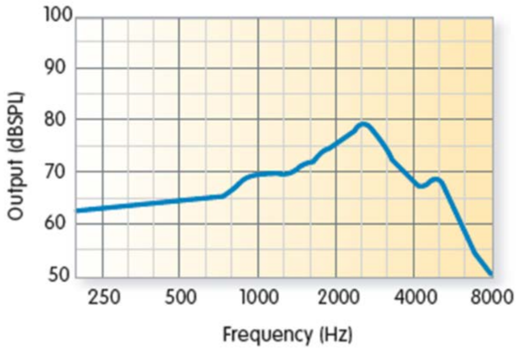


Figure 1-9
Sample frequency response curve of a hearing aid to an input level of 60 dBSPL.

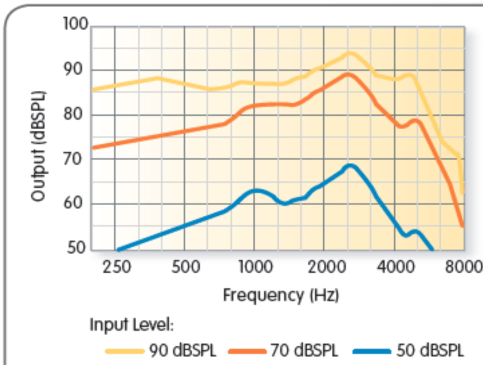


Figure 1-10
Sample frequency response curves of a hearing aid to speech presented at three different input levels.

Threshold Kneepoint: is the **input level** where compression begins to **reduce gain**

→ for example the gain was 10 dB, they reached close to the end of the dynamic range then it starts to go by 5 dB

Compression: is a decrease in gain as the input sound gets louder

❖ <u>Frequency gain curve</u>

- Gain of hearing aid as function of frequency

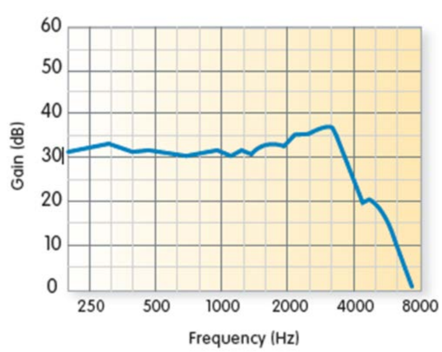
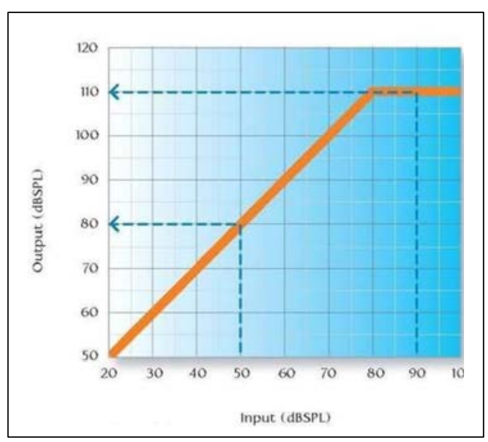


Figure 1-11
Sample frequency-gain curve of a hearing aid to an input level of 60 dBSPL.

Linear Hearing Aids:

Linear Hearing aids:

- **Amplify all levels of a frequency by the same amount**
- **Problem** – louder sounds become uncomfortably loud
- **Solution** – use some type of limiting to prevent this



o <u>Doesn't help</u> with **speech perception** because it keeps the **signal-to-noise ratio** the same thing

Maximum output:

- **Highest possible signal** that a hearing aid is capable of delivering
- Determined by the characteristics of the microphone, amplifier and receiver

Saturation:

- When **input level** and **gain** exceed **maximum output**
- Leads to distortion

Peak clipping:

- *Example*: we have a sound above 90 dB (the maximum output), the hearing aids erase/cut it

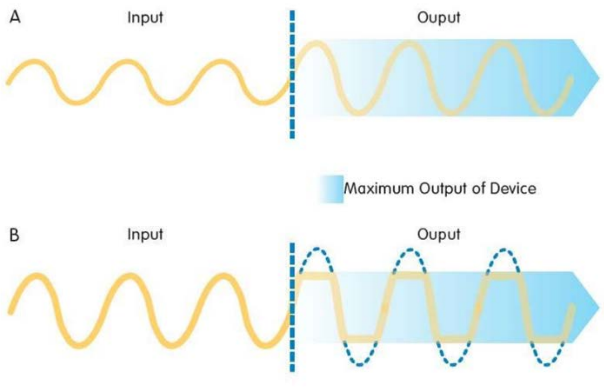


Figure 1-12
Schematic of the response of a hearing aid: (A) without peak clipping, and (B) with peak clipping.

Distortion:

Distortion: Presence of frequency components in the output of a hearing aid that were not present in the input signal

There are two types:

- **Harmonic distortion**: **output** contains frequency components that are **integer multiples** of the input signal frequency
- **Intermodulation**: generated by the interaction of at least two signals of different frequencies

Compression:

- **Non-linear amplification**
- A compressor is **an amplifier** which turns **down its gain** as the **input to the amplifier increases**
- Squeezes range of environmental sounds to fit within reduced dynamic range of person with SNHL
- **Weak sounds**: audible
- **Moderate sounds**: comfortable
- **Intense sounds**: loud without being uncomfortable

Compressor characteristics:

Two characteristics:

- **Static features**
  - o Compression threshold/threshold kneepoint
  - o Compression ratio
- **Dynamic features**
  - o Attack time
  - o Release time

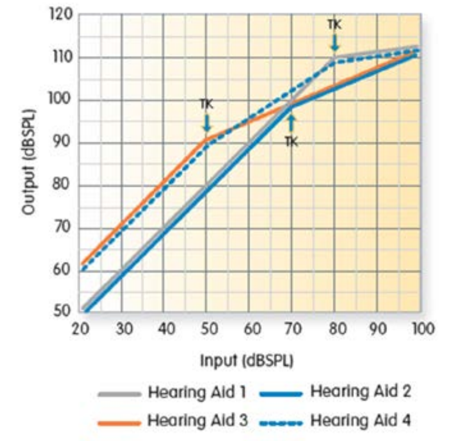


Figure 2-5
Sample input/output functions showing threshold kneepoints (TK) for four different hearing aids

❖ <u>Compression threshold/threshold kneepoint</u>

- Predetermined intensity level where gain is reduced
- Input SPL
- the **input level** where compression begins to **reduce gain**

❖ <u>Compression ratio</u>

- Determines **how much signal will be compressed**
- Relates **a change in the input level** (ΔInput) to **a change in the output** (ΔOutput)
- **CR = ΔInput / ΔOutput**

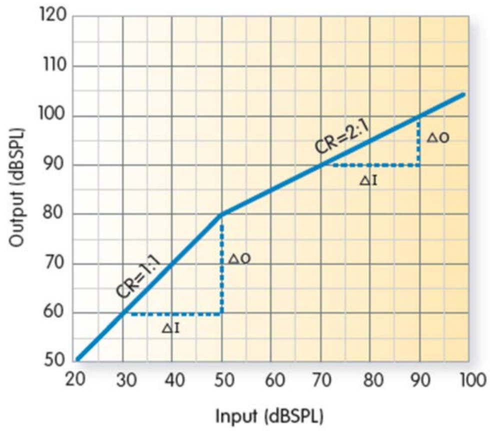
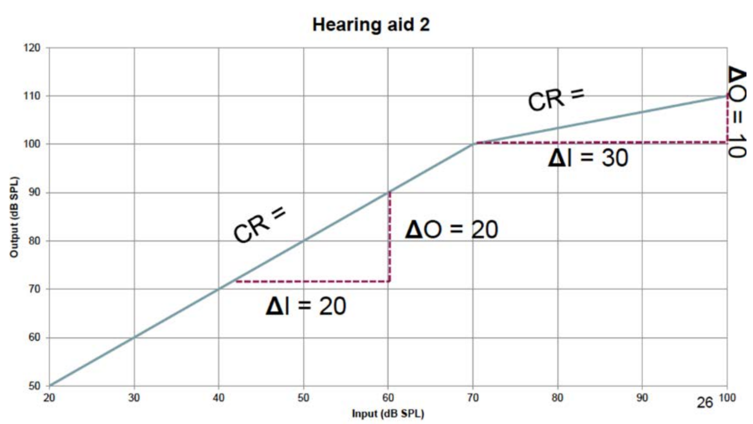


Figure 2-6
Calculating compression ratios (CRs) from an input/output function. ΔI = Change in input, ΔO = Change in output.

3. Input = 20
   Output = 20
   CR = 20:20 or 1:1

4. Input = 20
   Output = 10
   CR = 20:10 or 2:1



1. Input = 20
   Output = 20
   CR = 20:20 or 1:1

2. Input = 30
   Output = 10
   CR = 30:10 or 3:1

Attack and Release time:

❖ Attack and Release time:

- When **incoming signal changes** abruptly in level from below TK to above → the compressor is unable to **change the gain instantaneously**
  - → **Gain** decreases take time to occur
  - → **Output** of amplitude has overshoot "spike" followed by decline to steady value

Attack time:

- **Attack time**: the time it took to add compression **[lessen the gain]**
- **Time delay** that occurs between **onset of input signal** loud enough to **activate compression** and resulting reduction of gain to its target value
- Defined as the **time interval** between the moment when **the input signal level** is increased abruptly by a stated number of decibels and the moment when the output SPL from the hearing aid stabilizes at the elevated steady–state level within ±2dB

➢ **The time** it takes to stabilize around the predetermined point is called the attack time.
➢ **Lessens the gain**
➢ Can be fast or slow → that has its own points

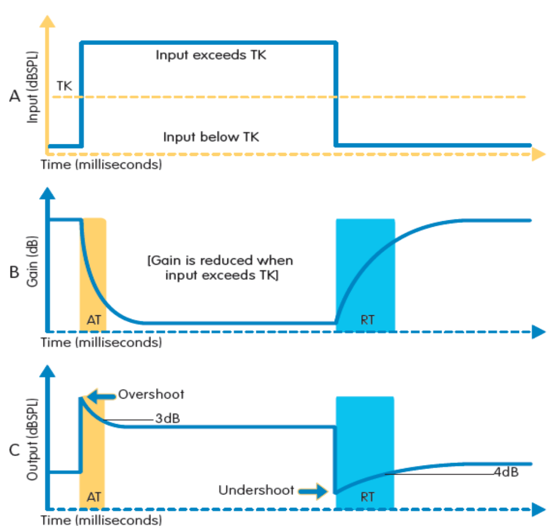
- If it was **too fast** → might not hear everything
- If it was **too slow** → it can be uncomfortable because it will take too long to lessen the gain

Release time:

- **Release time**: it's the opposite of the attack time → **the time it takes to stabilize** around the **original point** is called release time [higher the gain]
- **Higher the gain**

➢ Can be fast or slow → advantages and disadvantages for each depending on the point

- If it was **too fast** → it can be uncomfortable
- If it was **too slow** → one may not catch everything that was said



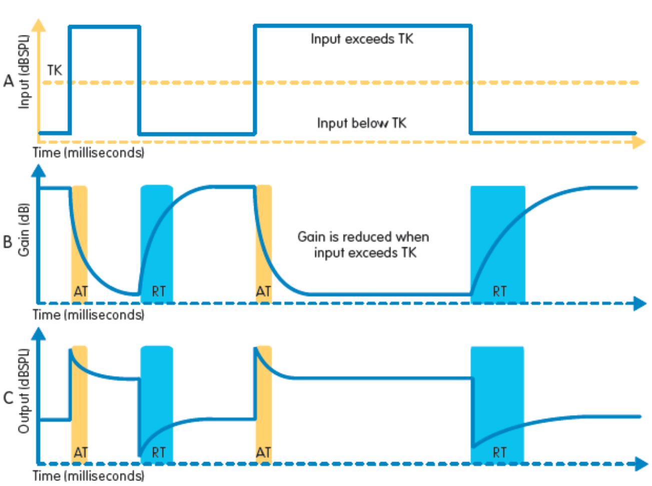


Figure 2-9
Schematic representation of variable release time. The input level, gain and output of the hearing aid are shown in panels A, B, and C, respectively. The attack time (AT) and release time (RT) are indicated by the shaded areas. TK = Threshold kneepoint.

Frequency band → the frequencies that are affected are spread around to the bands

- If one has cognitive disability → both should be slow
- It's easier that the HA lessen the gain (attack) and thus it's shorter than gaining it (release time)
- Speech intelligibility → it's better that the release time is faster than the attack time

Fast attack time:

- Short duration of overshoot
- Shorter period of time hearing aid is over amplifying
- Desirable when compression used to limit maximum output of hearing aid

Release time:

- **Release time** generally longer than **attack time**
- **Fast release time (less than 20 ms) combined with fast attack time** may result in pumping sensation where *level of background noise increases and decreases*
- **Slow release time (more than 2 s) combined with fast attack time** will adversely affect audibility of speech that follows immediately after **gain reduction** to loud sound

Attack and release times:

- **Short time constants** offer **best audibility**, because they **maximize the gain for soft consonants within a word** → Better **consonant audibility** translates into **better intelligibility**
- **Short release time** can distort usable speech cues
- Listeners prefer **longer release times** when speech quality and comfort are listening goals.
- Some data suggest that adults with lower **cognitive abilities** have **higher speech intelligibility with longer release times**.

Automated gain control (AGC):

AGC:

- **Amount of gain applied** is automatically determined by the signal level
- **Level detector** is therefore essential component of any compression circuit
- Two types **depending on position of level detector** relative to volume control
  - → AGC-I: Input-controlled compression
  - → AGC-O: Output-controlled compression

AGC-I:

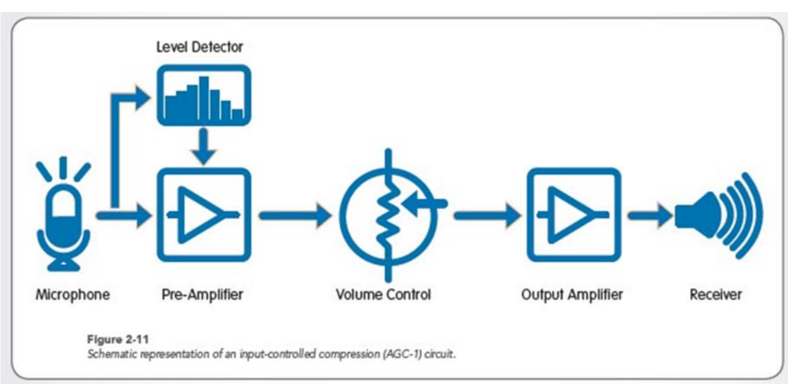


Figure 2-11
Schematic representation of an input-controlled compression (AGC-1) circuit.

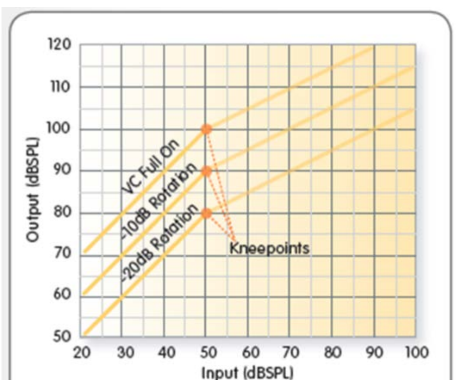


Figure 2-12
Sample input/output functions for an input-controlled compression (AGC-1) circuit showing the effects of volume control rotation.

AGC-O:

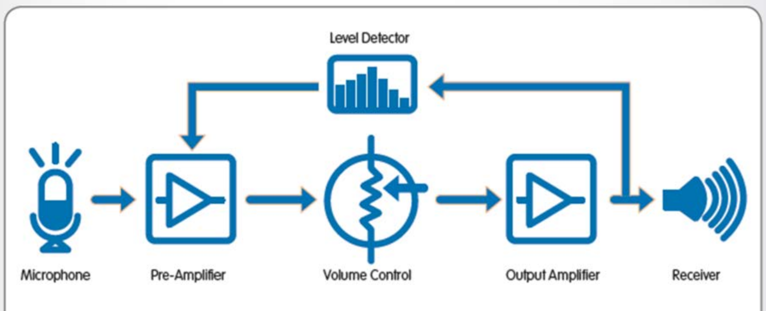


Figure 2-13
Schematic representation of an output-controlled compression (AGC-O) circuit.

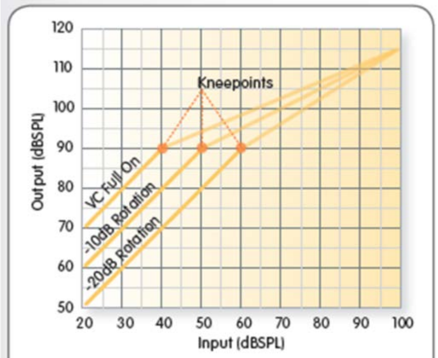


Figure 2-14
Sample input/output functions for an output-controlled compression (AGC-O) circuit showing the effect of volume control rotation.

Channels and bands:

Frequency bands:

- **Independently controlled areas** for **gain adjustment**
- **Increasing** or **decreasing the gain** in a frequency band will equally affect the response to **different intensity sounds** <u>within that band</u>
- **Compression parameters** are unaffected

Compression channels:

- Allow **separate adjustments** for weak and intense input levels

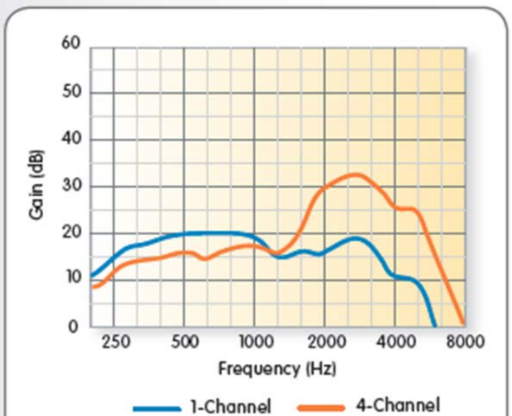


Figure 2-15
Sample frequency-gain curves for a 1-channel and a 4-channel hearing aid in the presence of a 90dBSPL pure tone at 500 Hz.

Distortion, discomfort, damage:

Intense sounds:

- Force hearing aid into **saturation** causing **distortion**
- May be amplified beyond LDLs causing discomfort

- If left unchecked, may cause **amplification-induced hearing loss**

Wide dynamic range compression (WDRC):

- **Weak sounds**: audible
- **Moderate sounds**: comfortable
- **Intense sounds**: loud without being uncomfortable

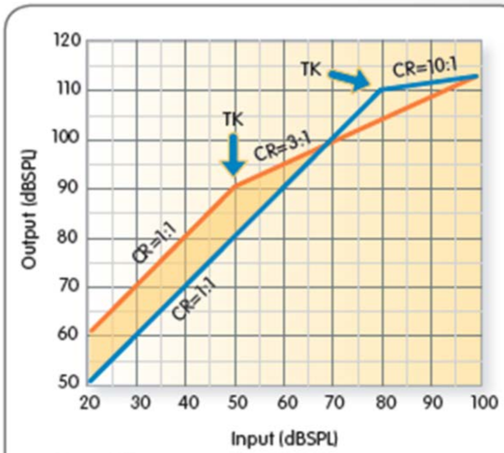


Figure 3-4
Sample input/output functions for a hearing aid with wide dynamic range compression (Hearing Aid A) and a linear hearing aid with output compression limiting (Hearing Aid B).

Desirable characteristics of WDRC:

- **AGC-I**: Amount of gain applied depends on the level of the incoming sound
- **TK**: as low as possible in order to make weak sounds audible
- **Low CR**: compression acts over wide range of inputs
- **AT and RT**: Faster than duration of typical syllable to provide more amplification for weaker components than for the more intense components of speech
- **Multichannel compression**: Used to accommodate different audiometric configurations. Amplify weak consonant sounds independently of more intense vowel sounds

Reducing adverse effects of noise:

- Digital hearing aids have complex algorithms for noise reduction
- Effects of compression on reducing noise – two assumptions:
  - → **Overall level of sound** is <u>relatively high</u> in **noisy environments**
  - → The hubbub of **noisy environments** such as restaurants and parties is dominated by energy in the **low frequencies**
- Multi-channel compression
  - → **No assumptions** made regarding **frequency composition of noise**
  - → **Gain** is reduced **only in frequency regions** where a **great deal of noise is**
  - → present – **gain** and **audibility** in remaining channels are unaffected
  - → When **spectra of signal** and **noise** are different, improvement in **overall signal- to-noise ratio** when <u>outputs of channels with poor SNR are reduced</u> relative to those where SNR is good

Reasons to use WDRC:

- **Optimize use** of the **residual dynamic range**
- Normalize the **perception of loudness**
- **Maintain listening comfort**
- **Maximize the intelligibility of speech**
- **Reduce** the **adverse effects of noise**
- **Minimize loudness discomfort**
- **Prevent damage** to **the auditory system**
- **Limit hearing aid output** without **distortion**

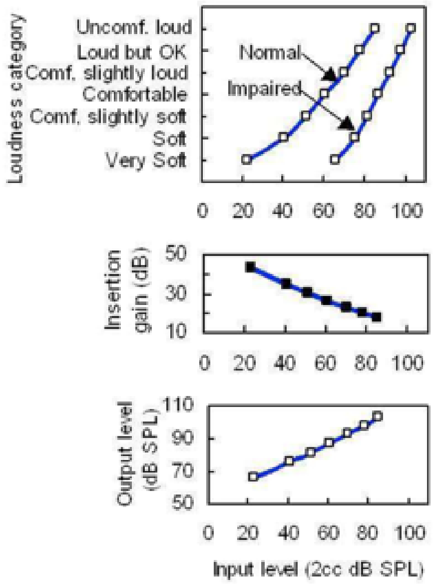
Chapter Ten: Hearing Aid Prescription Algorithms

General concepts behind hearing aid prescriptions:

- **Hearing losses** vary widely in their:
  - → *degree*
  - → *configuration*
  - → *type*
- **Amplification characteristics** must be appropriate for individual
- Achieved using **prescription procedure**
- **Prescription** requires there to be some known (or assumed) relationship between a person's **hearing characteristics** and the **required amplification characteristics**

Mirroring of the Audiogram:

- Every **1 dB increase** in hearing loss **requires 1 dB** of **additional gain** to **compensate**
- But for **SNHL** the gain needed to restore normal loudness perception is **equal to the threshold loss only when the person is listening at threshold**
- For all higher levels, this amount of gain would be excessive



❖ **Half gain rule**:
- The next development was to **base gain needed** on the **person's most comfortable level** (MCL) rather **than on thresholds**
- It was observed that the **amount of gain chosen** by the **most satisfied hearing aid users** was approximately **half the amount of threshold loss**
- Did not take into account the **variation of speech energy** across **frequency**
- Cannot predict how **much gain** is needed at **each frequency** unless **speech intensity** taken into account
  - → **Low frequency components** are more intense than **high frequency components**
  - → Therefore **half gain rule** has to be modified (either a little less low-frequency gain or a little more high frequency gain)

Current Perspective approaches:

❖ Loudness normalization
- **Restore loudness perception** to **same loudness perceived** a listener with normal hearing
- Usually for **certain frequency bands**
- **Soft, medium, and loud speech sounds** [as heard by a normal hearer] are appropriately amplified to the **categorical rating descriptor** of "soft" "average" and "loud" by an **individual with hearing impairment**
- **Strict loudness normalization procedures** did not account for the fact that **all speech frequencies are** not equally **important**
- Only **so much loudness** we can work with before patient finds **amplified sounds too loud**

❖ Loudness equalization
- **Equalize the perception of loudness** over **a range of frequencies**
- **Lower frequencies** do not dominate loudness (as is the case for normally hearing listeners)
  - → *Example: frequency range of 500 to 4000 Hz can be amplified so that the loudness perception of 500 to 4000 Hz as well as narrow bands in between are*

National Acoustics Laboratory Prescription:

National acoustics laboratory prescription:

- **Original NAL method**, 1976
- **NAL-Revised** (NAL-R), 1986
- **NAL-Revised for severe and profound losses** (NAL-RP), 1990
- **NAL-Nonlinear 1** (NAL-NLI), 1998

- *Loudness equalization*:
  - → Does not try to preserve the **normal loudness relationships** among different frequency bands of speech.
  - → Tries to make **all frequency elements** of speech equally loud.
- Aims: to make **speech intelligible and overall loudness comfortable**
- Concerned with **effective audibility**, not just audibility

❖ **Effective Audibility**:
- For patients with **severe or greater hearing loss** → a **small sensation level** might give some amount of information, while a **high sensation level** will not necessarily add much more information for understanding speech
- For those with **profound hearing loss** → audibility might be accompanied with **virtually no added 'effective audibility'**

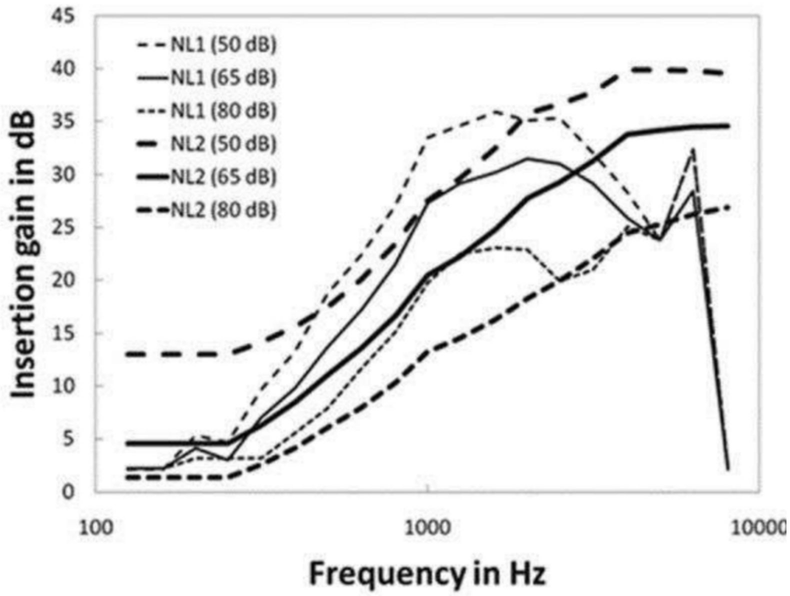
NAL—NL2:

❖ NAL—NL2:
- Released in **2011**
- **Second generation** of **prescription procedures** from NAL for fitting WDRC instruments
- **Rationale**
  1. **Maximize intelligibility** by **increased gain in the frequency response**
  2. **Modify gain** so that the **loudness** is not **greater** than that **perceived by normal hearing listeners**
  3. **Consistent** with **previous versions of NAL**
- **Adaptive neural network** to **calculate gain** based on audiogram
- **Optimal gain-frequency responses** derived for **240 audiograms**
  - → *Wide range of severity and slopes*
  - → *Seven speech input levels*
- **Optimized gain values** from all audiograms and input levels drawn together into single composite
- Prescribe hearing aids to:
  - → *Make speech intelligible*
  - → *Make loudness comfortable*
- Prescription also affected by:
  - → *Localization*
  - → *Tonal quality*
  - → *Detection of environmental sounds*

→ *Naturalness*

❖ <u>Differences between NAL—NL1 and NAL—NL2</u>:

- **NAL-NL2** prescribes **relatively more gain** across **low and high frequencies** and **less gain** across **mid frequencies than NAL**
- **NAL—NL2** → <u>*more gain on **low** and **high** frequencies*</u> [less gain on mid]

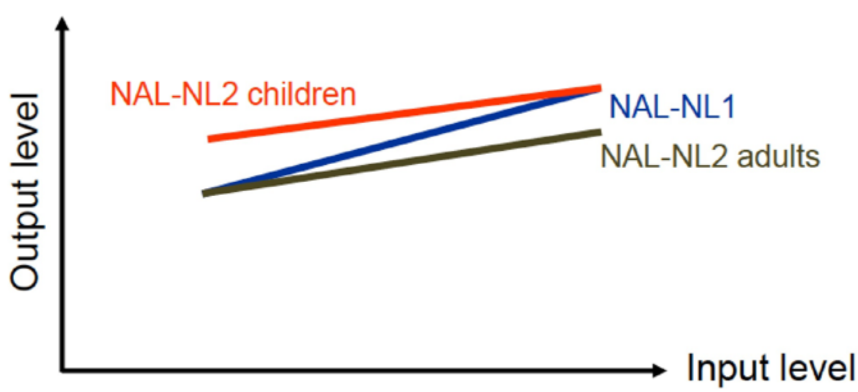


❖ <u>NAL—NL2 takes into account</u>:

- Age
- Gender
- Language type
- Binaural/monaural fitting
- Hearing aid experience

1. *NAL—NL2: Age*

- **Children** tend to **prefer more gain** than **adults**

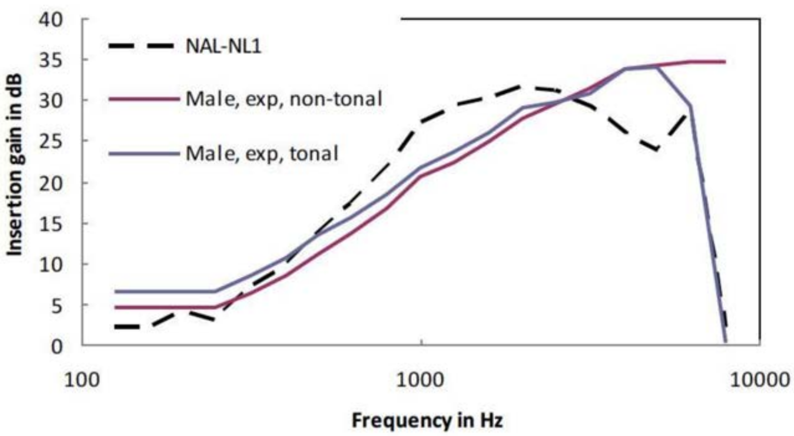


2. *NAL—NL2: Gender*

- **Women** prefer an **average of 2 dB less gain** than **men**
- Gender differences are therefore factored into the prescription formula
  → NAL-NL2 prescribes **2 dB higher gain** for **males** than for **females**

3. NAL—NL2: Effect of Language

- **NAL—NL2** ensures that **sufficient gain** is applied at the **frequencies** that **are most important for speech understanding**
- **Low frequencies** are <u>more important</u> in **tonal languages** → which are most common across Asia and Africa, than in non-tonal languages
- **Slightly more gain** is prescribed across the **low frequencies** for **tonal** than for **non-tonal languages**



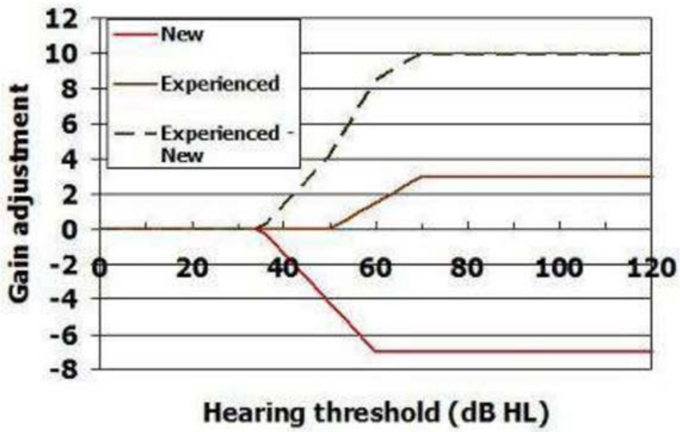
Tonal and non-tonal languages:
English **and** ***Arabic*** **are** **<u>non-tonal languages</u>**

4. NAL—NL2: Binaural Fitting

- Listening with **two ears** provides **more loudness** than listening with **one**
- **Less gain** is therefore used for **bilateral fittings** → especially at **higher input levels**
- In NAL-NL2, the **bilateral correction** is:
  → **2 dB** across the **low input levels**
  → increasing up to **6 dB** for **high input levels**

5. NAL—NL2: Hearing Aid Experience

- No difference in the **gain preferences** between **new** and **experienced hearing aid users** with a **<u>mild hearing loss</u>**.
- However, new hearing aid users with a **<u>moderate hearing loss</u>** did prefer significantly **less gain** than did experienced hearing aid users with a **<u>moderate hearing loss</u>**.
- **Experience** therefore is taken into account for hearing aid users with **<u>moderate/severe hearing loss</u>**



❖ NAL—NL2: compression speed
- Listeners with **severe** or **profound** **hearing loss** prefer **lower compression ratios** than those prescribed by NAL-NL1, when fitted with **fast-acting compression**.
- However, there is evidence to suggest that **higher compression ratios** could be used in this population with **slow-acting compression**.
- Therefore, in the case of **severe** or **profound** **hearing losses**, NAL-NL2 prescribes **lower compression ratios** for fittings with **fast-acting compression** than those with **slow-acting compression**.
- For **mild** and **moderate** **losses**, compression speed does not affect prescribed compression ratios.

Desired Sensation Level Prescription Formulae (DSL):

Desired sensation level prescription formulae (University of Western Ontario):

- DSL (1985)
- DSL [i/o] (1995)

❖ **DSL [i/o]**:
- DSL(i/ol
- **Main Goal**: Audibility
  - → Of vowel/consonant combinations
  - → Especially important for children learning language.
- **Secondary Goal**: Comfort
- Seeks to make **speech comfortably loud in each frequency range** → but does not attempt **equal loudness in each frequency range**
- **RECD** is an **integral portion of the formula**
- **SPLO gram** is the **main feature**
- Everything is read in **SPL**
- Uses **REAR** only

❖ **DSL v5.0**:
- Released in 2005
- **More flexible fitting targets** than previously

- Family of targets based on **type of fitting**
- Three target populations:
  - → *Infants*
  - → *Children*
  - → *Adults*
- Takes into account:
  - → **Type of audiometric measurement** including corrections for ABR and ASSR measurements
  - → **Type of fitting**: *binaural vs monaural*
  - → **Type of hearing loss**: corrections for **mixed** and **conductive hearing losses**
  - → **Enhanced normative data** for RECDs with ear tip / mould
  - → **Algorithm improved** for **more comfortable adult targets** and targets for different **listening environments**

Differences between NAL—NL2 and DSL v5.0:

1. ***NAL—NL2 and DSL v5.0: Experience***

- **DSL v5.0** does not **incorporate a correction for gain** based on **experience with hearing aids**
- **NAL—NL2** incorporates **adjustments** that differ as a **function of hearing loss** and include an increase for **experienced hearing aid users** and a **decrease for new users**

2. ***NAL—NL2 and DSL v5.0: Gender***

- **DSL v5.0** does not include an **adjustment for gender**
- **NAL—NL2** increases gain by **1 dB for male** hearing aid wearers and reduces gain by **1 dB for female** wearers

3. ***NAL—NL2 and DSL v5.0: Binaural Fittings***

- **DSL v5.0** targets for speech are reduced **by 3 dB** across **input levels** for **bilateral fittings** compared to **unilateral fittings**
- **NAL—NL2** has a correction for binaural summation of **2 dB at low input levels** up to **6 dB at high levels**

4. ***NAL—NL2 and DSL v5.0: Listening in Noise***

- **DSL v5.0** targets are reduced by **3-5 dB** for **low-importance frequencies** for listening in noise
- **NAL—NL2** does not have **corrections for listening in noise**

5. ***NAL—NL2 and DSL v5.0: Correction for air-bone gap***

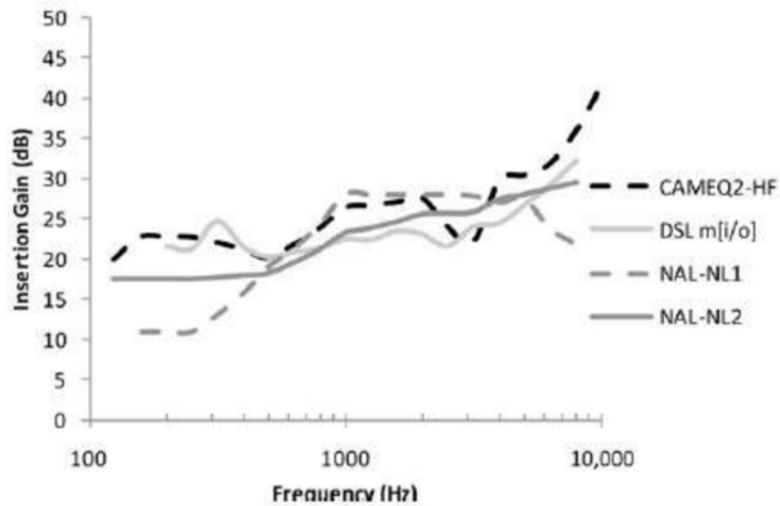
- **DSL v5.0** correction adds **5-9 dB of gain** depending on **hearing level**
- NAL—NL2 applies **prescribed gain** for **sensorineural component** of the hearing loss and then adds **75% of the air-bone gap** to this value

6. ***NAL—NL2 and DSL v5.0: Loudness discomfort***

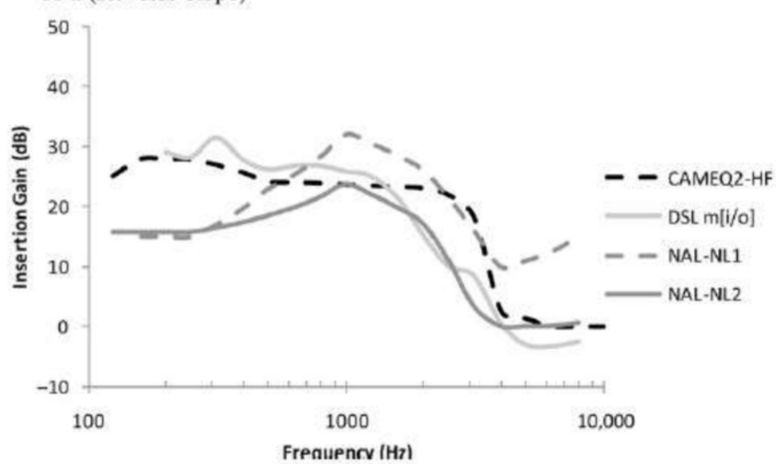
- **DSL v5.0** alters the prescription of **gain** and **output** for **high input levels** that approximate the **loudness discomfort measure**

- NAL—NL2 <u>does not</u> **alter gain** or **output based** on **patient-specific uncomfortable listening levels** (ULLs)

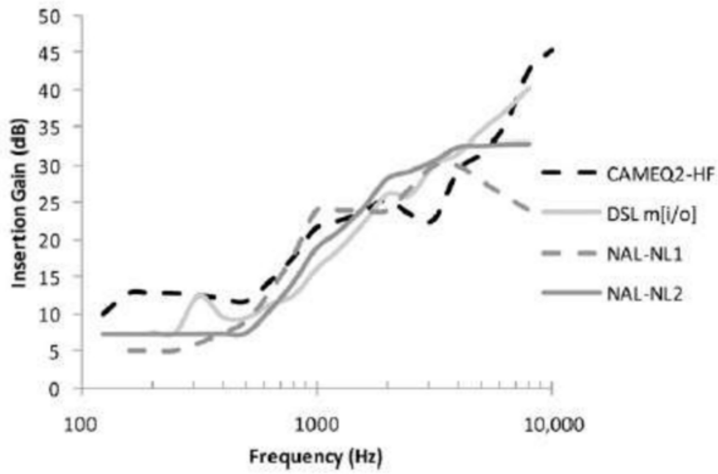
A-1 (Flat moderate)



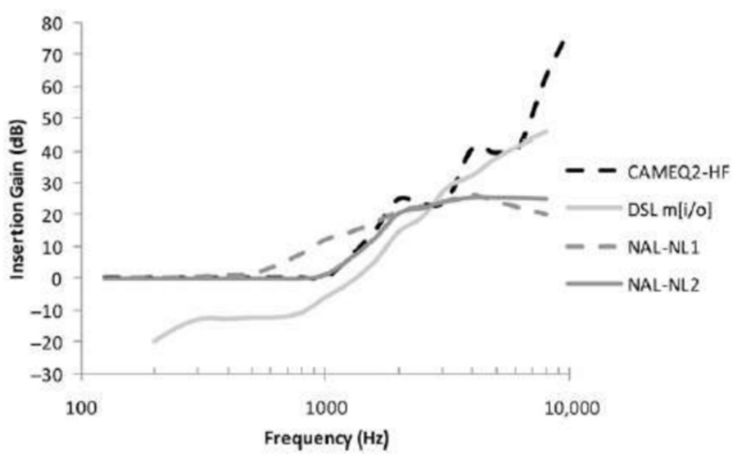
A-2 (Reverse slope)



A-3 (Moderately sloping)



A-4 (Steeply sloping)

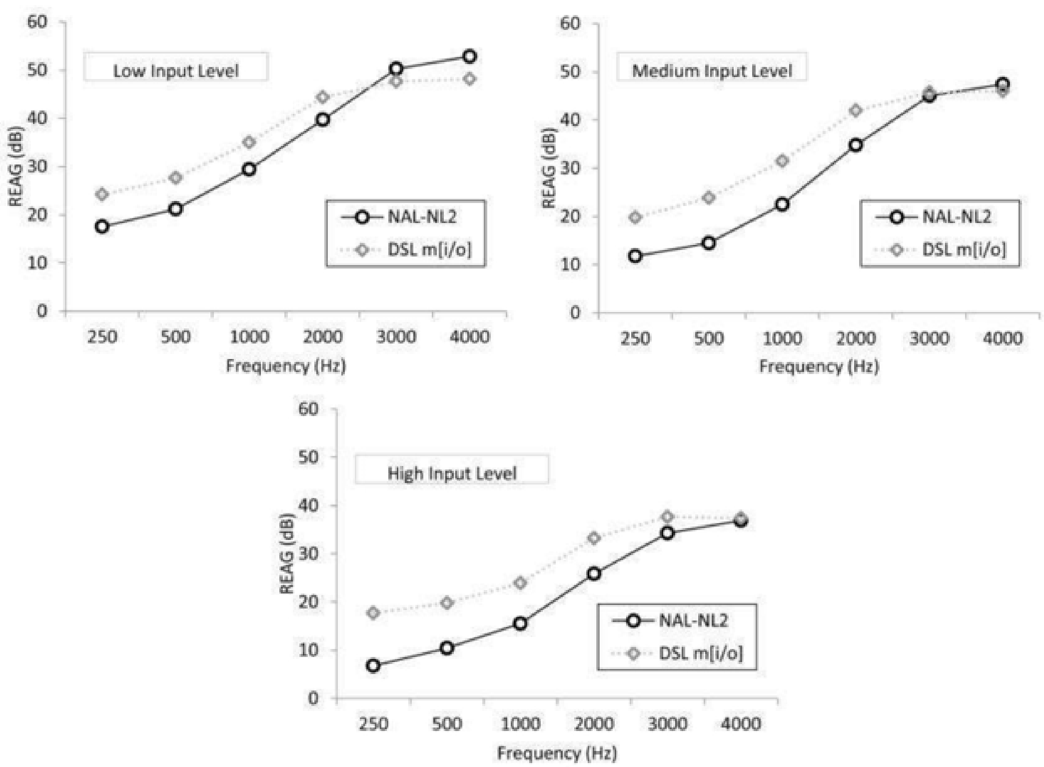


Clinical outcomes for DSL and NAL:

- Outcomes from 48 children fitted with NAL—NL1 in Australia and DSL v4.1 in Canada
- Collaborative & double-blind study between NAL and UWO
- **Speech perception** were **good** for **both prescriptions in quiet & in noise**
- SRTs and consonant scores were similar to normal hearing children
- Parents' and teachers' observations revealed no effect of prescription
- **Children's own observations** revealed **strong preference** for **NAL-NL1** in **real world noisy situations**
- More **<u>negative comments</u>** about **problems in noise** for **DSL v4.1**
- More **<u>positive comments</u>** about **loudness comfort** for **NAL—NL1**

- More **<u>positive comments</u>** about **listening to softly spoken speech** or **speech at a distance** with **DSL 4.1** than NAL—NL1
- To achieve **optimum audibility** of **soft speech**, ***<u>children need more gain</u>*** than is prescribed by **NAL—NL1**
- To achieve **listening comfort in noisy places**, ***<u>children need less gain</u>*** than **DSL v4.1**

Comparison of DSL and NAL formulae:



Device-independent fitting strategies:

- NAL
- DSL
- Fig-6
- VIOLA

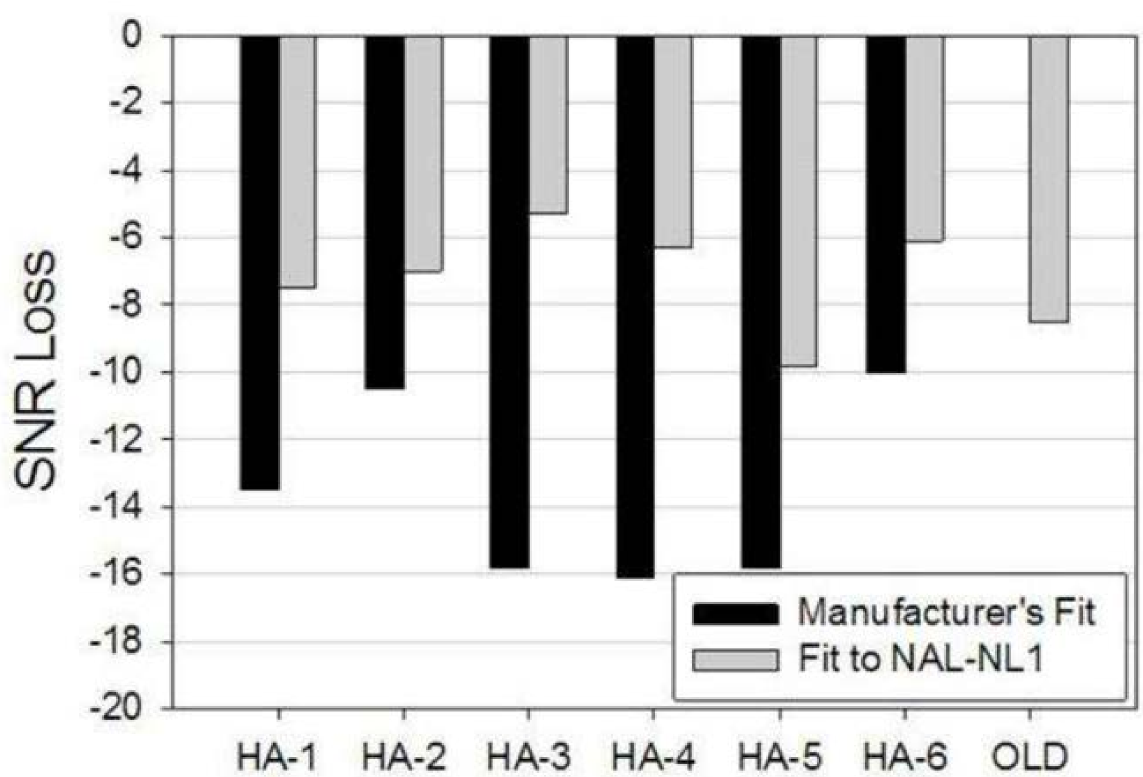
- Camfit

Proprietary fitting strategies → Found in **individual manufacturers'** fitting software

Device-independent vs proprietary fitting strategies:

❖ **Device independent fitting strategies**:
  - **Prescription formula** is not **hearing aid dependent**
  - When entering the **audiometric data** → the generated target can be applied to **any hearing aid**
  - Usually published by **noncommercial research groups**
  - Supported by a **stronger evidence base**
  - **Information** is **out in public domain**

❖ **Proprietary fitting strategies**:
  - Related to **particular circuitry/technology**
  - After entering the **individual patient data** → the algorithm prescribes all the signal processing features of the Hearing aid
  - **All hearing aid manufacturers** have their **own proprietary fitting rules**
  - **Information** about these rules are **usually protected**



Chapter Eleven: Introduction to Probe Microphone Measurements (PMMs)

Probe microphone measurements:

- **Aim**: To ensure that the **hearing aid** is **delivering the sound we want it to** in the **patient's ear** with the **patient's earmould/modular coupling system**

- **Use**: Not using **probe microphone measurements** to verify hearing aid fitting is **unethical**

❖ **Equipment**:
- **Reference microphone**
  - → *Monitor test signal*
  - → *Near the head and microphone of hearing aid*
- **Measurement microphone**
  - → *Probe tube attached*

❖ **Input signal:**
- Depend on **equipment** and **purpose of test**
  - → ***Swept pure-tones*** — for MPO testing
  - → ***Broadband noises*** *(e.g speech-shaped noise)* — for testing noise reduction
  - → ***ISTS***
  - → ***ICRA***
  - → ***Live speech*** — for demonstration and counselling purposes
  - → ***Music, CDs, instruments***, etc.

➢ **ISTS**
- **International Speech Test Signal**

  Mostly used
- **Standard test stimulus**
- Allows for **reproducible measurement conditions**
- **21 female speakers** in **six different languages** (American English, Arabic, Mandarin, French, German, Spanish) speaking a phonetically balanced passage ('The north wind and the sun')

➢ **ICRA**
- International Collegium of Rehabilitative Audiology
- Artificial noise signal with speech-like spectral and temporal properties

❖ **Equipment Setup**:
- ***Quiet room***
  - → **Test signal** should be at least **10 dB above** the **noise floor** in all frequency bands
  - → The **loudspeaker** and the **reference microphone** when positioned on the patient, should both be 1 meter away from the nearest reflective surface

❖ **Prescriptions**:

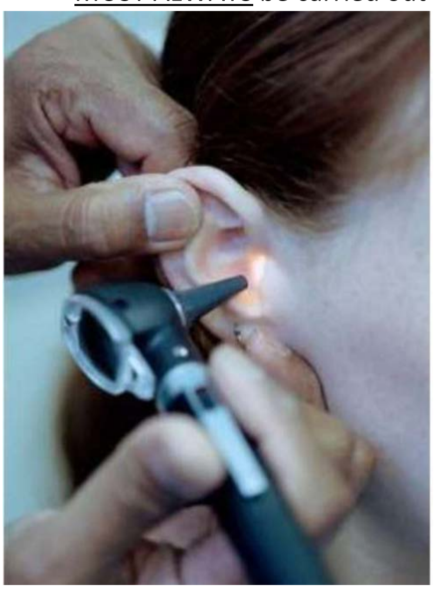
National Acoustic Laboratory	NAL—NL2	Desired Sensation Level	DSL v5

❖ **Room Calibration**:

- **Room calibration** adjusts the **sound spectrum** to take **speaker** and **room characteristics** into account in order to **play back signals** reliably in the **sound field**
- **Important to calibrate** at **frequent intervals**

❖ **Otoscopy**:

- MUST ALWAYS be carried out before PMMS



❖ **Patient Preparation**:

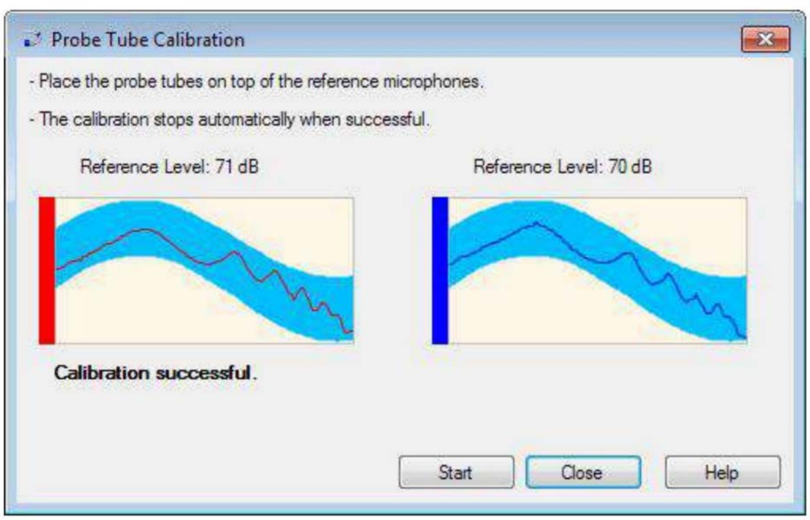
- The patient should be seated so that the ear under test is:
  - → At **45°** or **0°** to the loudspeaker
  - → At a **distance of 80—100 cm** from the loudspeaker, at level with the centre of the loudspeaker

- The patient should be instructed to **sit as still as possible** during recording, in particular to **maintain the same head position**
- They should also be informed that they **may interrupt the test at any time in the case of discomfort**

Calibration:

❖ **Probe tube calibration**:

- Every time a **new probe tube** is used
- Can detect **damaged** or **poorly-coupled** probe tube



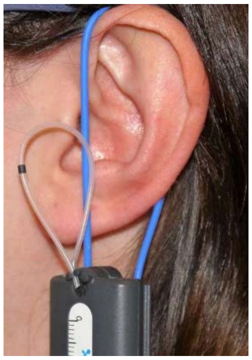
❖ **System Calibration**:

➢ *Occluded fittings*

- Modified pressure method with **concurrent equalization** (MPMCE)
- **Reference microphone** is switched on
- **Patient present**
- **Speaker sound continuously automatically adjusted** to compensate for movement

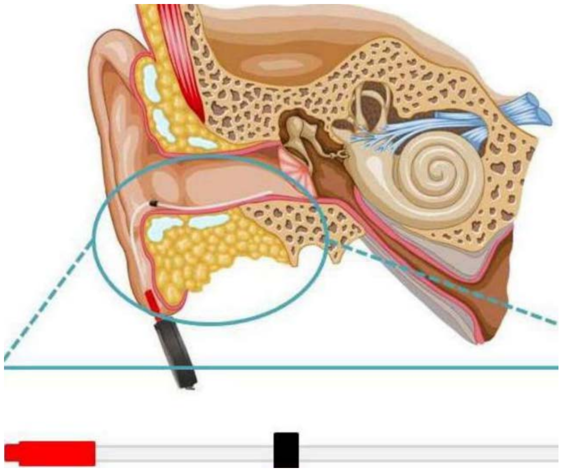
➢ *Open fittings*

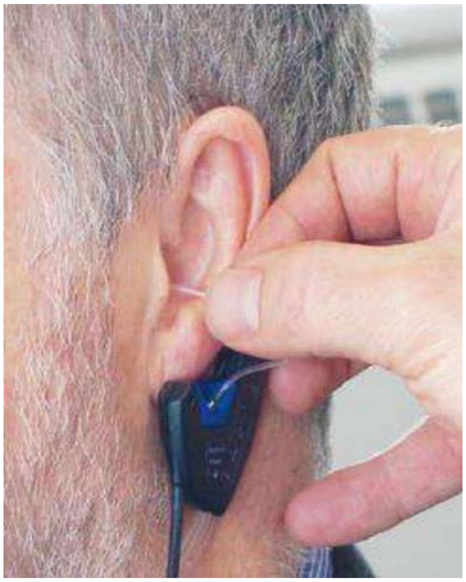
- Risk that **amplified sounds** may **leak out** to **reference microphone** and **contaminate results**
- Modified pressure method with **stored equalization**
- **Patient present**, **hearing aid muted**
- Speaker sound measured and stored to be used with other measurements
- **Any change** in **position requires repeat**



Probe tube placement:

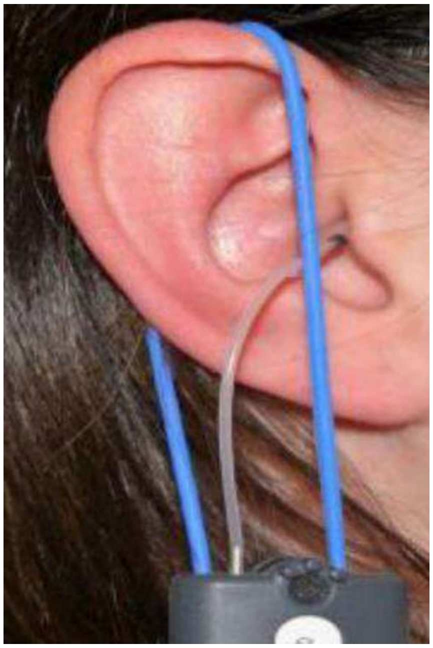
- Use a **new probe tube** for **each patient**
- Sound inlet should be
  - → **Within 5 mm** of the **tympanic membrane**
  - → At least **5 mm beyond** sound outlet of hearing aid





- Use **probe tube marker**
- General guidelines for **insertion depths** in adults:
  - → **28 mm (women)**
  - → **30 mm (men)**

- Check placement of probe using **otoscopy**
- Take care <u>not to</u> push probe tube further into



PMM terminology:

Probe microphone measurement terminology:

- **REUR/G**: Real ear unaided response/gain
- **REOR/G**: Real ear occluded response/gain

- **REAR/G**: Real ear aided response/gain
- **REIG**: Real ear insertion gain

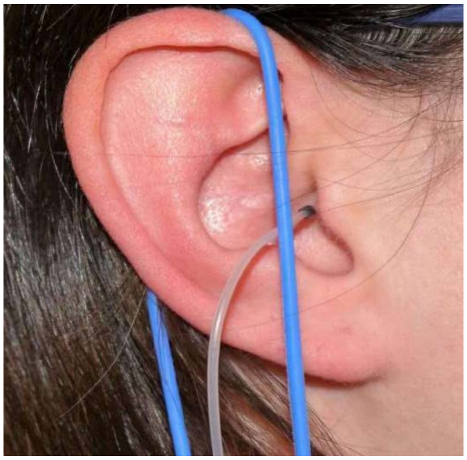
<u>Remember</u>:

- A response is measured in **dB SPL** → it is an **output measure**.
- **Gain** is always the **difference between two measurements** and is expressed in **dB**

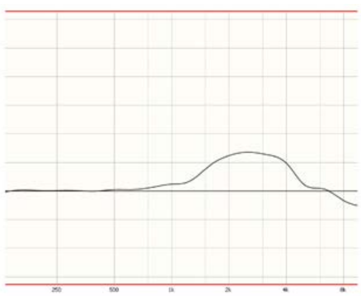
Measurements:

❖ ***<u>Real ear unaided measures</u>***:

- Calibrate **probe microphone system**
  - → Position patient appropriately
  - → Position probe tube at correct depth in ear canal
  - → Present a calibrated signal



- Measure of what the **open ear does to sound by itself**
- Used to **ensure optimum tube placement**
- Notch between **4 kHz** and **8 kHz**
  - → **Lowest point of notch** should <u>not fall below</u> **-5 dB**

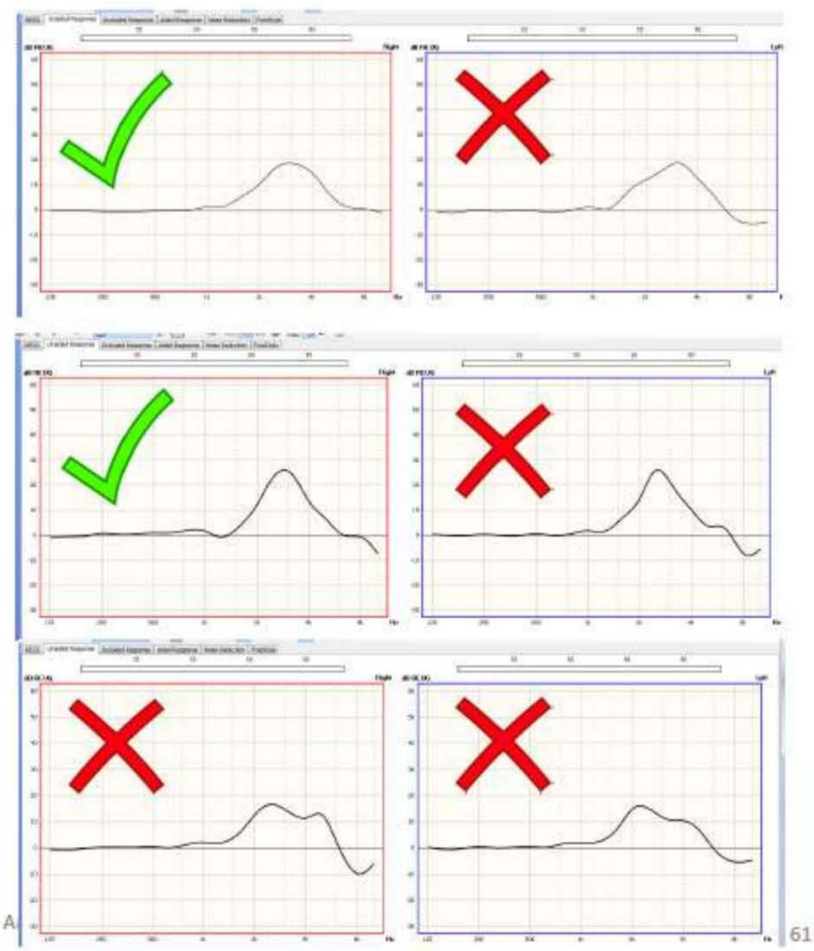


NOTE: REUR and standing wave effect

A standing wave is a wave in which its peaks (or any other point on the wave) do not move spatially.

The most common cause of standing waves is the phenomenon of resonance, in which standing waves occur inside a resonator (in this case the ear canal) due to interference between waves reflected back and forth at the resonators resonant frequency (ear canal resonance 2-4kHz). In general the smaller the ear canal the more amplification at high frequencies.

FOR REMS: Ensure that your REUR does not run through 6kHz, it should be flat on 6kHZ. If not this will result in a standing wave and your hearing aid response will not change in the high frequencies, no matter how much you increase or decrease gain.



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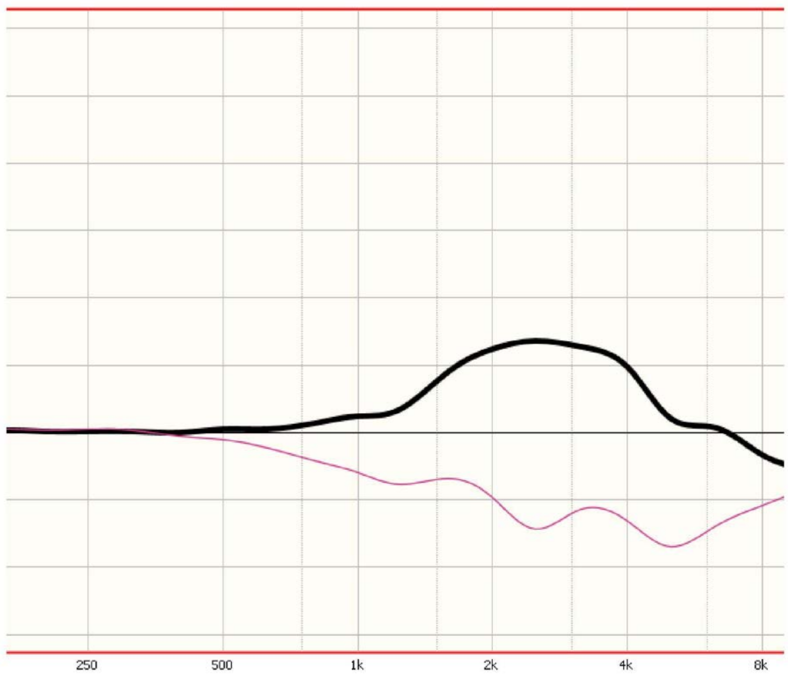
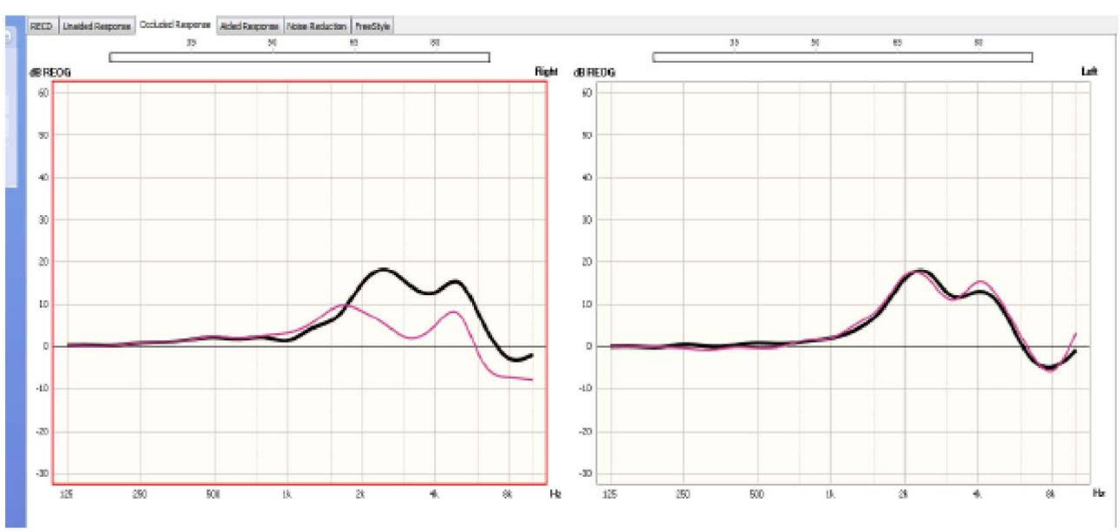
- ❖ ***Real ear occluded measures***:
  - Calibrate **probe microphone system**
  - Position **patient appropriately**
  - **Position probe tube** at **correct depth** in ear canal
  - Place the **earmould/modular system/custom fit hearing aid** in the ear but <u>do not</u> **turn it on**
  - Present a **calibrated signal** (typically the same as used for the REUR)

- Measurement of the **response in the ear canal** when **the hearing aid is in place** and **switched off**
- Measures the **venting characteristics** or **extent of occlusion** —how open the fitting is

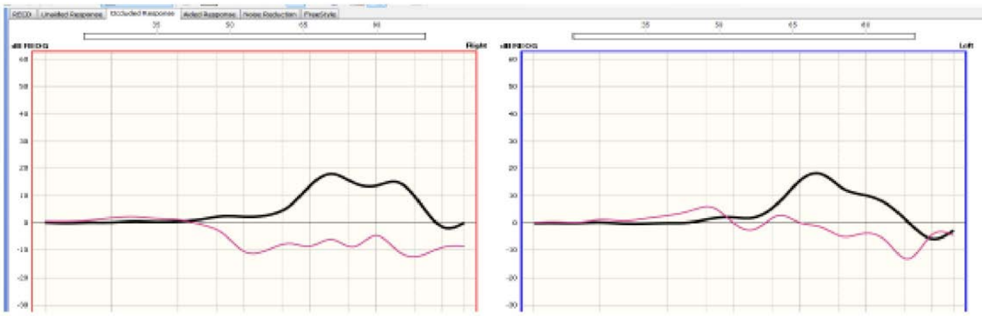


Different types of REOR
Open fit

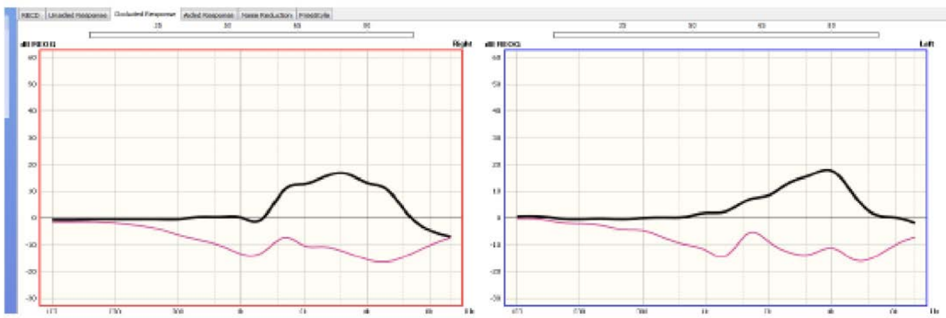


Open fit: with **closed dome** Open fit: with **open dome**

Different types of REOR - Mould fit



Mould with small vent   Mould with large vent



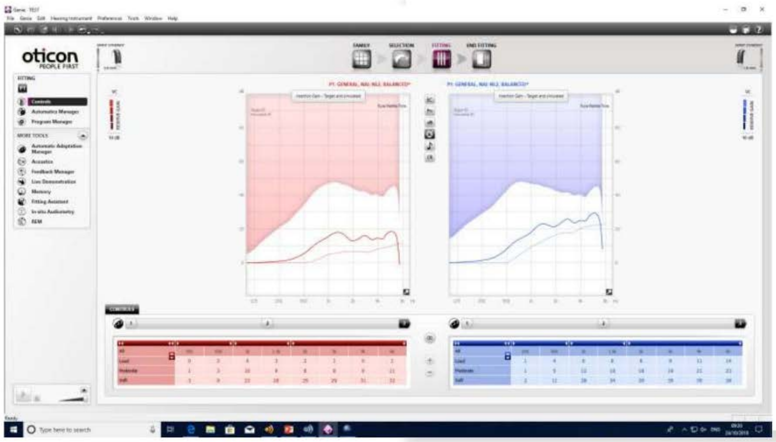
Completely occluding mould

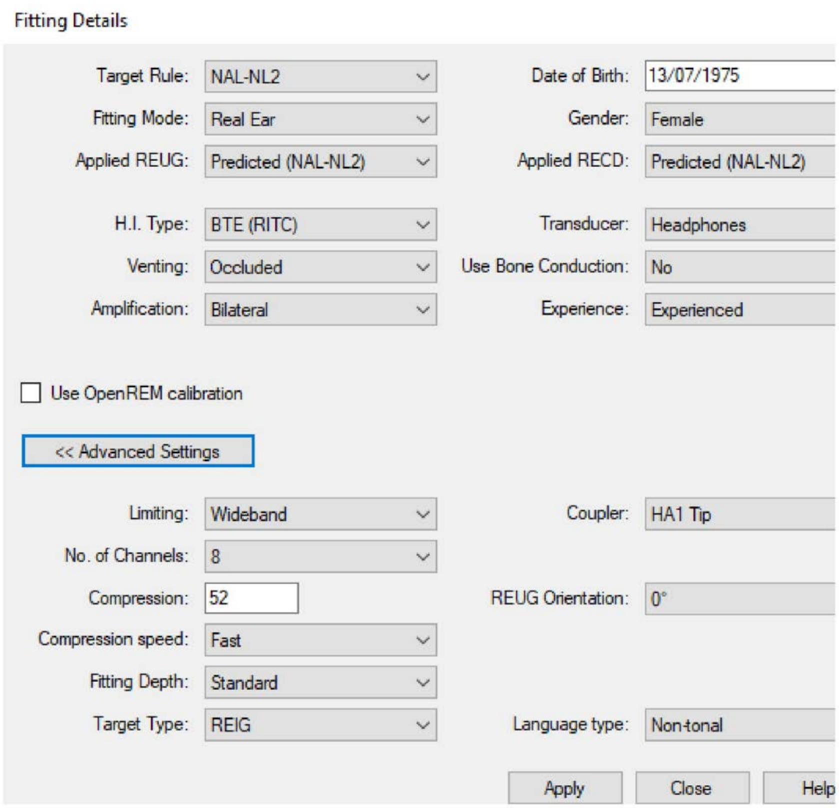
❖ ***Real ear aided measures***:

- Place the **ear mould/modular system/custom fit hearing aid** in the ear and **turn it on**
- All **usual features left on** *(apart from frequency lowering)*
- Set **hearing aid software** to **highest acclimatization level**

Auditory acclimatization is considered to be **a process of perceptual learning**, whereby an individual learns over time to make use of the change in acoustic information provided by the hearing aid.

Acclimatization level



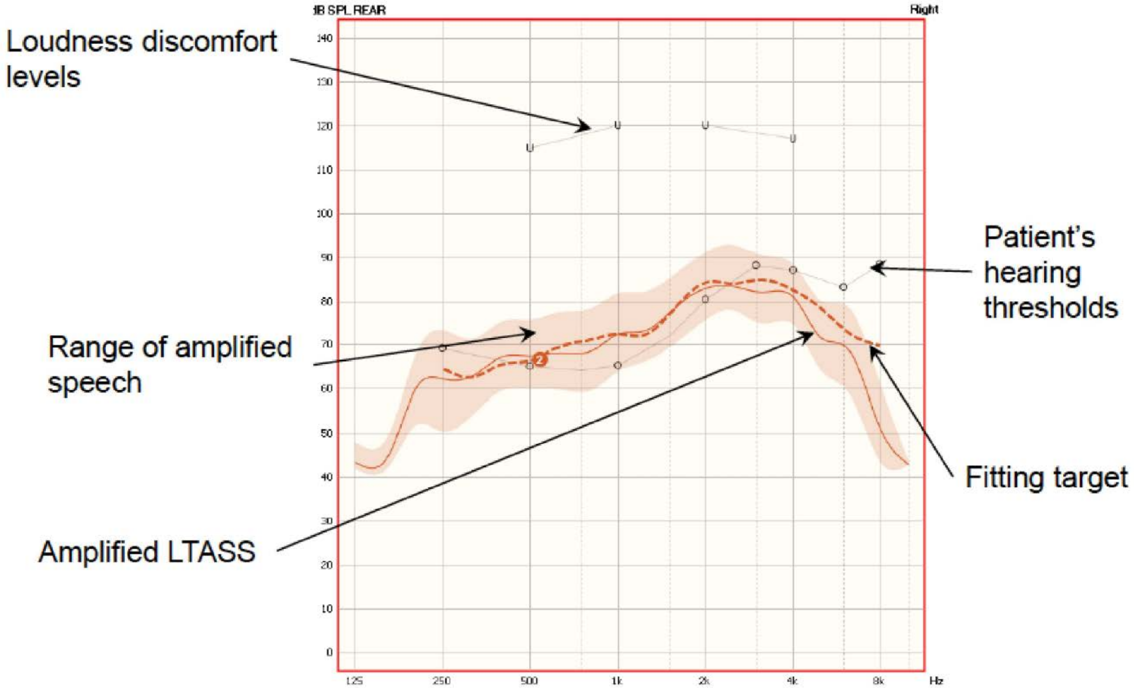


Real ear aided measures

- Select the **desired prescription target**
- Check **parameters**

- Select a **moderate input level (65 dB SPL)** of a **calibrated real-speech** or **speech-like signal** *(example: ISTS)*
- Compare **measured response** to **target values**
- Adjust the **device gain** if necessary

- **Real ear aided response (REAR)**
- The **frequency response** of a hearing aid that is turned on, measured in the ear canal, for a particular input signal



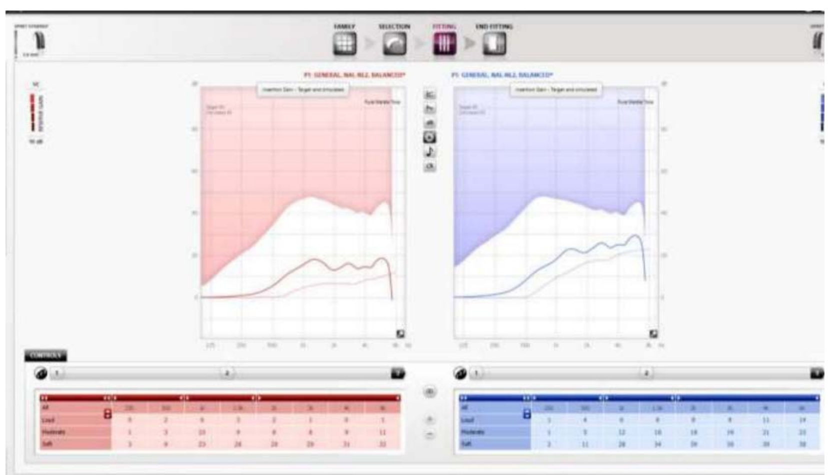
Real ear aided measures

- Verify at:
  - → **Quiet level** (50 dB SPL)
  - → **Loud level** (80 dB SPL)
- **If adjustments to gain made** → for **quiet/loud levels** need to **re-check 65 dB SPL input**

Input Levels

- **Primary input** level of **65 dB SPL**
- **Secondary levels** of **50 dB SPL and 80 dB SPL**

- If the hearing aid output does not match the prescription adjust the gain in the hearing aid software

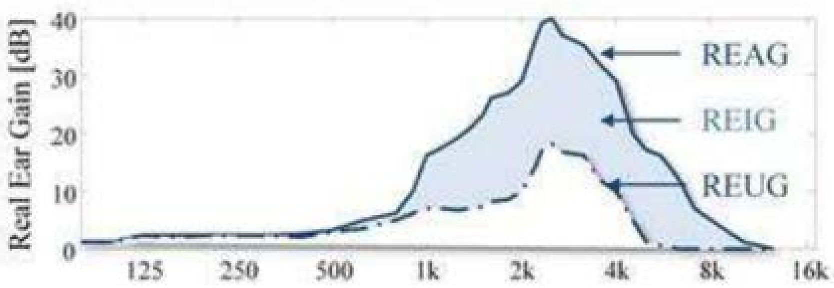


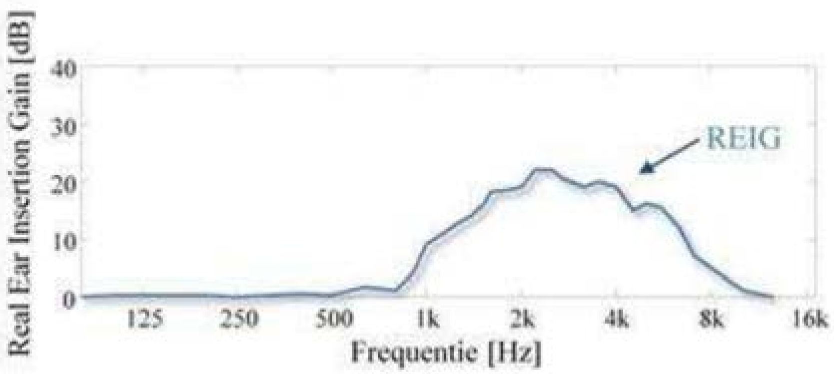
<u>Tolerance</u>

- **Response curves** should fall **within a tolerance** of **+/- 5 dB** to the **prescription target** between **250Hz and 6000Hz**

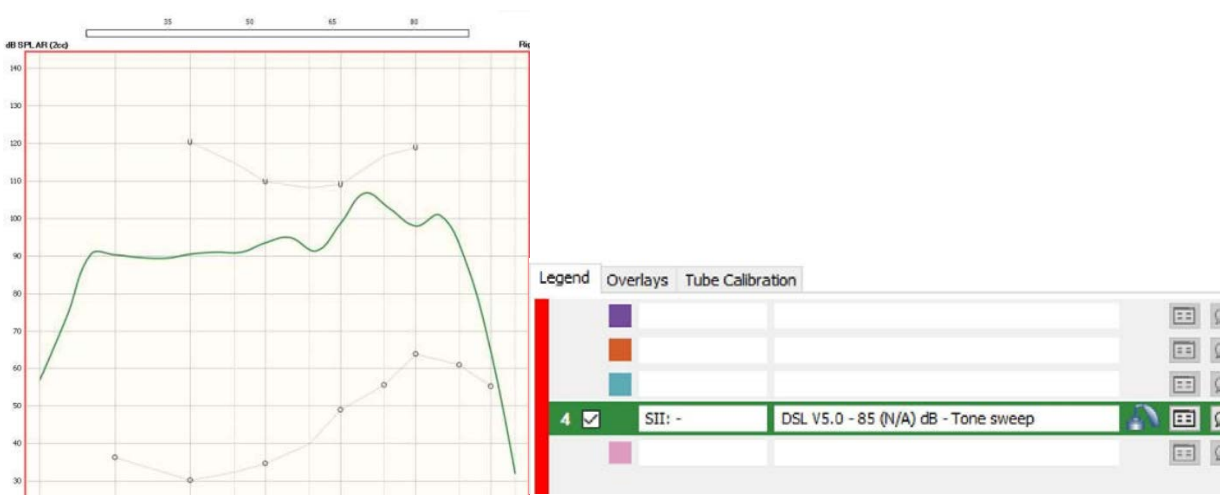
❖ ***<u>Real ear insertion measures:</u>***

- **REIG** = **REAG** – **REUG**
- **REIG** = **REAR** – **REUR**
- **'Net' acoustic benefit**
- The difference in dB as a function of frequency → between the **REAR** and **REUR** or between the **REAG** and **REUG**





- **<u>Maximum Sound pressure level</u>**:
  - Corresponds to **patient's uncomfortable loudness levels**
  - **Swept warble tone**
  - Use coupler measurement if any suspicion of abnormal loudness discomfort



Otoscopy:

When do we do otoscopy?

- **Before inserting** probe tube
- **To check** probe tube placement
- **After removing** probe tube

Subjective listening checks:

- Must be done **after PMMs**
  → Uncomfortable loudness levels

Contraindications for PMM:

- **Excessive wax or foreign object in canal**
- **Infections**
- **Post-operative ears**
- **Patient unable to sit still [example: Parkinson's, tremor, etc.]**

Reasons for using probe microphone measurements:

- **PMMs** provides **graphical confirmation** to the audiologist that **the intended prescription/processing strategy** has **been implemented by the hearing aid software**.
- **PMMs** therefore **help the audiologist** understand **the process of hearing aid fitting**
- **PMMs** are **useful in counselling the patient** and **family members** around **what they can and cannot hear**

Review:

1. The first step is to do an **Otoscopy** to check the outer ear and the ear canal.
2. **Real Ear Un-Aided Response (REUR)**: This step is the second step. This is when the probe microphone is positioned in the ear without the hearing aid and mould. It is a measurement of the ear canal without any hearing device assisting it and it shows the patients ear acoustics. This measurement helps make a consideration of the ears natural amplification of sound. (For the adult female—the probe tube is inserted **28 mm** past the intertragal notch)
3. An **Otoscopy** is done again afterwards in order to check on the probe tube.
4. **Real Ear Occluded Response (REOR)**: This is the fourth step. This measurement has the hearing aid on with the mould, but it is muted or turned off with the probe tube. This allows consideration for the attenuation that is caused by the mould and the effect it has on external sounds.
5. **Real Ear Aided Response (REAR)**: This is the fifth step. This measurement has the hearing aid on with the mould, but this time, the hearing aid is turned on (with the probe tube). This allows the measurement of the hearing device's amplification effect within the patients' ear alongside the effect of the patients' ear acoustics.
6. Another **otoscopy** afterwards

- ***Real Ear Insertion Gain (REIG)***: this measurement is the measurement of the REAR subtracted by REUR *[in other words: REIG = REAR – REUR]*. It is the net acoustic benefit.

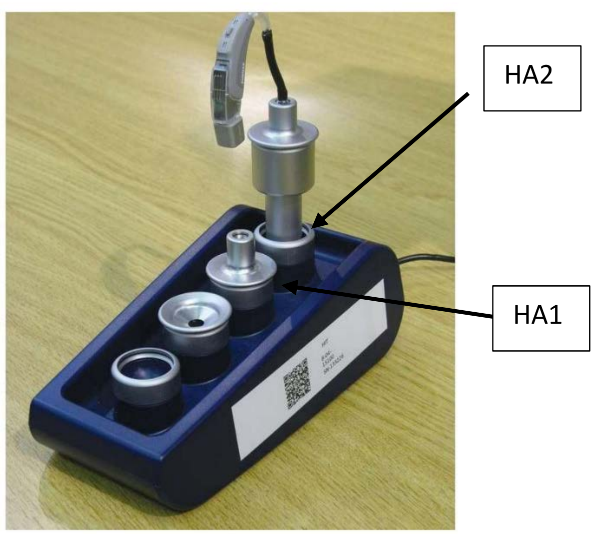
Chapter Twelve: Electroacoustic performance & measurement of hearing instruments

Measurements in couplers and ear simulators:

- We cannot know **how a HA performs** unless **we measure its response**
- **Standard couplers** and **ear simulators** exist to enable **standardized measurements** which are **highly repeatable**
- **Standard couplers** are **hearing aid characteristics** to those provided by the **hearing aid manufacturers**
- We usually use the **real ear measurements**, but it won't work for everyone → *[example: children, those with Parkinson's, etc.]*
- **Click and fit** is another alternative if the **real ear measurements** don't work

❖ **Coupler:**

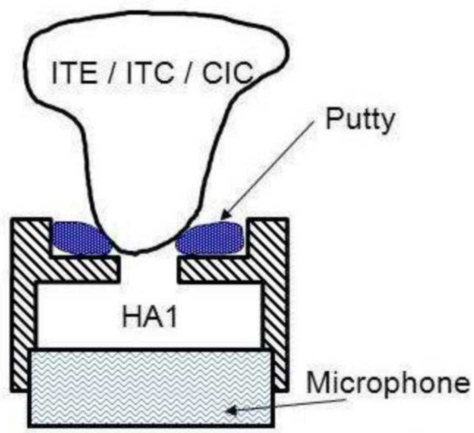
- Coupler = cavity
- It gives us an alternative other than **the ear**
- It takes the **average of the ear canal volume of the adults** so we can use it instead of the **ear canal itself** *[but not everyone is the same so it's somewhat similar]*
- **One end** connected **to a HA**, **other end** connected **to a microphone**
- **Standard coupler** has a volume of **2 cubic centimeters** → trying to represent the volume of an **adult ear canal past the earmould** (residual ear canal volume)
- Not **a good approximation of the average adult ear canal volume** and **acoustic impedance** of the ear at **high frequencies**



- Couplers need to be connected to **any type of hearing aid**, and this is achieved by having a **range of adapters available**
- HA1 → For **ITE, ITC aids**. Has **no ear mould simulator**. Use putty to connect to coupler
- HA2 → used for **BTE's** → Has **earmould simulator**, connected to BTE via tubing

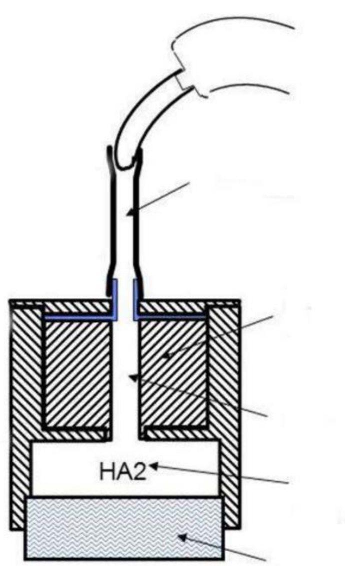
❖ **HA-1 Coupler:**

- Used to **measure acoustic pressure** generated by an **ITE hearing aid**
- Most **ITC** and **CIC** hearing aids can also be measured using this coupler
- Hearing aid **held in place** and **sealed** with putty (similar to blue tac)



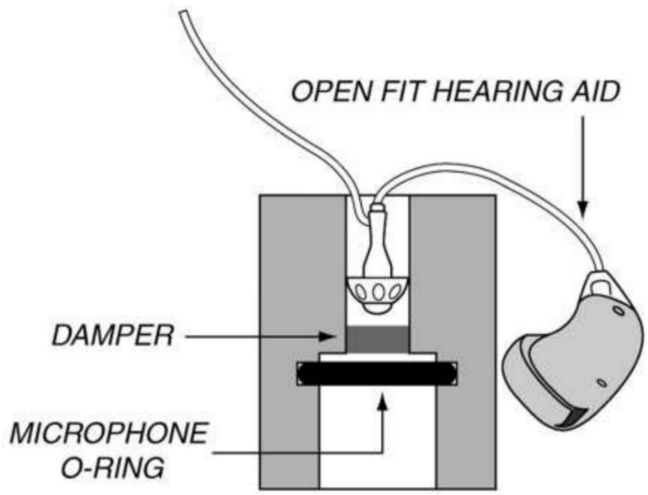
❖ **HA-2 Coupler:**

- Used to **measure acoustic pressure** generated by **BTE hearing aids**
- Hearing aid is **attached directly** to the **tubing**



❖ **<u>Open-fit coupler</u>**:

- <u>Not</u> a **standard 2cc coupler** (biggest ear canal volume but we use it for average)
- Work on **standardization in progress**
- Also used for **RIC hearing aids**
- Can also use adaptor on **HA-1 coupler**



Limitations of 2cc couplers:

- The **volume of the coupler is**, on average, **too large compared with the residual ear canal volume** of a typical hearing aid fitting
- The **impedance characteristics** of the **human ear canal** and **middle ear** are <u>not</u> **well represented**
- The plumbing *(e.g. the earmould)* alterations are **not accurately represented** by the **hard-walled cavity**

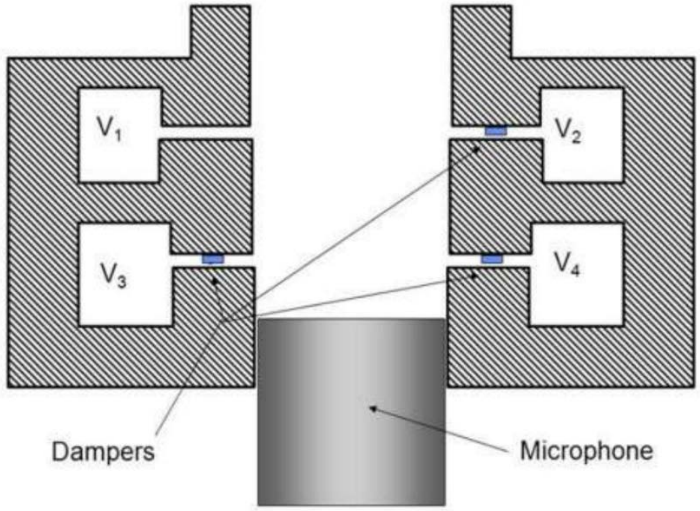
Real-ear simulators:

- Try to **better mimic** the **impedance of a real ear canal**
- **More accurate** than **2cc coupler** → but still cannot show the SPL present in the individual's ear
- <u>Two standardized real-ear couplers</u> are currently used around the world:
  → *Zwislock coupler*
  → *IEC711 real-ear simulator*

❖ **<u>Zwislock coupler</u>**:

Stopped being made

- Has **several cavities**
- Typically **more expensive** than **2cc couplers**
- As the **frequency rises** → the **impedance of the tubes rise**, they effectively **close off**, therefore **causing the effective total volume to gradually fall**
  - o **High frequency** → less volume (the chambers start to close) → more impedance
  - o **Low frequency** → more volume → less impedance
- **Little connecting tubes** can become **easily blocked**



❖ **<u>IEC711 real ear simulator</u>:**

- Similar to Zwislocki coupler but with **only two cavities**
- **711** will **become dominant ear simulator** as Zwislocki coupler is no longer being manufactured or supported by any company

➢ ***<u>Kemar</u>***:

- Knowles electronics manikin for **acoustic research**
- **IEC711 coupler placed in head**
- More **realistic measure** of the **head, body** and **torso effect** on **acoustic stimuli**

Hearing Aid test box:

- **Sound treated box**
- **Main components**:
  - → *Tone or noise generator*
  - → *Amplifier*
  - → *Loud speaker (sound source)*
  - → *2cc coupler (HAI, HA2)*
  - → *Reference microphone (control microphone) → compares the sound coming out of the loudspeaker and what's going through to the hearing aid*
  - → *Measurement microphone*

A. Reference microphone
B. BTE adapter tube
C. The coupler assembly
D. Battery simulator
E. Cable groove
F. Elevation plate
G. Coupler microphone sockets
H. Sound absorbing foam lining
I. Main loudspeaker
J. Rear loudspeaker
K. The AURICAL HIT lid

Cable groove: some HAs can't be connected via Bluetooth and thus need a cable to connect it → the cable groove keeps it in place

❖ **Functions of Test box**:

- To **generate** and **present sounds** of a **required SPL** to **the microphone of the hearing aid**
- To **attenuate ambient noise**:
  - → The **lid seals well** to the box so **excluding external noise**
  - → Possesses **solid dense walls**
  - → The **internal absorbent material** decreases **internal sound reflections** so that **most of the sound reaching the microphone** comes **directly from the speaker**
  - → The **reduction** in **reflected sound waves** makes it easier for the **control microphone** to **achieve the desired SPL** at the **hearing aid input**

❖ **Reference microphone**:

- **Monitors the SPL reaching** the **HA from the loudspeaker**
- If the sound is **higher/lower** than it should be → the **control mic system** turns the volume **up/down** to ensure the **correct level of sound is delivered to the HA**

❖ **Measurement signals**:

- Test boxes generally use **two different types of measurement signals**
- ***Pure tones***
  → Automatically sweeps in frequency across the desired range (typically 125 Hz to 10 kHz)
- ***Broadband noise like signals***
  → All frequencies are presented simultaneously

International Hearing Aid test Standard:

- Several standards specifying how hearing aids should be tested have been published by:
  → ***American National Standards Institute*** (ANSI)
  → ***International Electrotechnical Commission*** (IEC)
- ANSI S3.22 (2014) → American
- IEC 60118-0 (2015) → European
- Both specify consistent methods to measure and verify the performance of systems and devices

❖ **Main parameters of interest**:

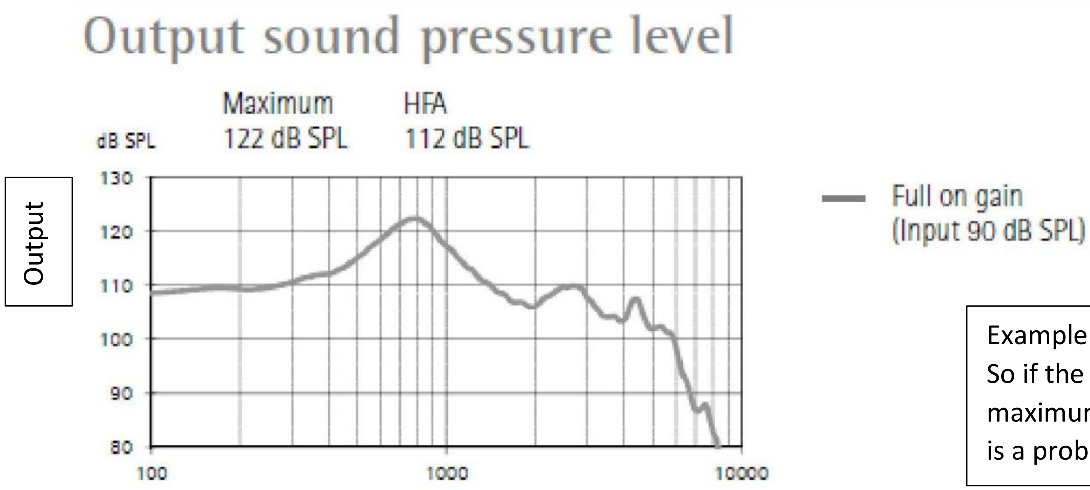
- **Output sounds pressure level with 90 dB input** (OSPL90)
- **Acoustic gain measures**
- **Frequency response**

❖ **Other parameters of interest**:

- **Harmonic distortion**
- **Equivalent input noise level**
- **Battery current drain**
- **Telecoil response**

1. OSPL90

- The sound pressure level produced in the 2cc coupler or ear simulator with an **input sound pressure level of 90 dB SPL** at a **specified frequency** or **frequencies**,
- The gain control is in the **full-on position** (removes limitations) and the **other controls are set for maximum gain** and **output**
- **Input** of **90 dB SPL**
- **Output** in dB SPL
  → Typically maximum output of the hearing aid
- **Varies with frequency**
- Plotted as a **function of frequency**
- **Tolerance**: 3 dB for OSPL90 → +/- 4 dB for HFA-OSPL90
- **Check performance** of Hearing aid



Example of norms:
So if the HA gave me a maximum of 90, there is a problem

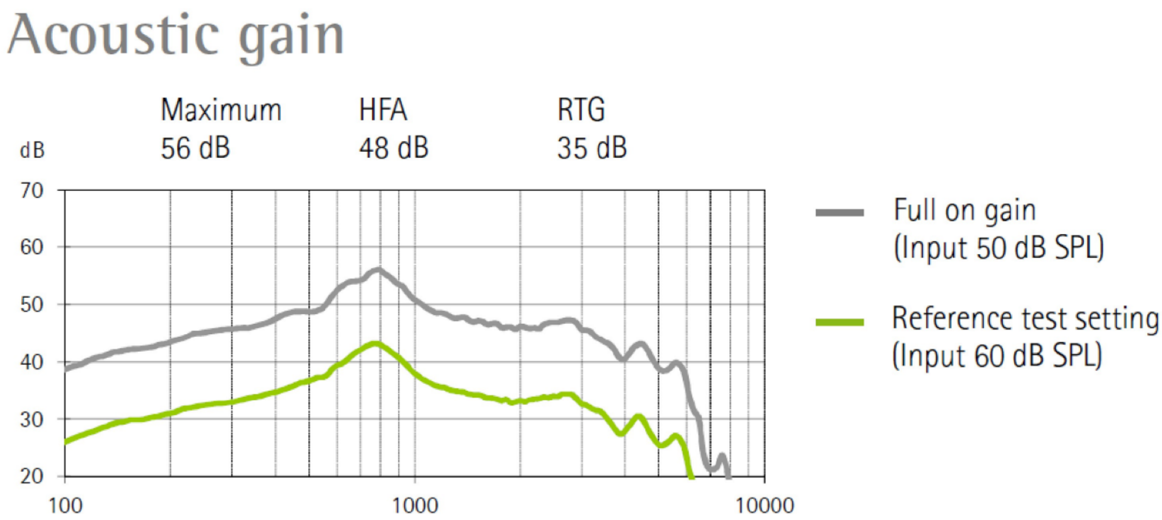
2. ***<u>Acoustic gain measures:</u>***

- **Full on gain**
- Measured with and **input of 50 dB SPL**
- **Volume control** set at **maximum**
- The value should <u>not deviate</u> from the value provided by the manufacturer **by more than +/-5 dB**
- **Also has a norm sheet like OSPL90**
- *<u>Reference test gain</u>*
  - → Measured with and **input of 60 dB SPL**
  - → Amount of gain measured with a hearing aid depends on where the volume control and other features are set.
  - → if the **volume is full-on** → **full on gain** measured
  - → But may not want to measure settings when hearing aid saturated for mid-level input signals, so use reference test gain
  - → RTG is stated for information only and therefore no tolerance information is required

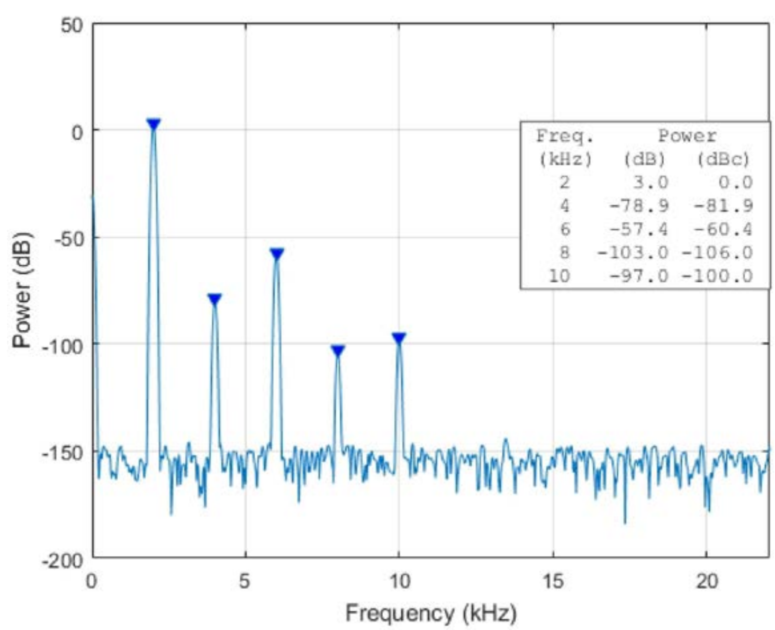
3. ***<u>Frequency response</u>***:

- **Input** of **50/60 dB SPL**
- **Output** in dB SPL
- **Varies with frequency**
- Plotted as a function of frequency

Acoustic gain and frequency response measures



1. ***Harmonic Distortion:***
    - An ideal hearing aid would produce an **output identical** to the **input signal**, **only amplified**
    - Hearing aids are not capable of doing this and invariably **the output is also a slightly distorted version** of the **original input signal**
    - The term **distortion** is used to describe **unwanted non-linearity**
    - Hearing aids should produce as **little unwanted distortion** as possible



- **Harmonics** are multiples of the **original frequency**
- Take a pure tone of 2 kHz
    - **Original tone or fundamental frequency**
      = 2 kHz
    - **First harmonic**
      = 1 x 2 kHz = 2 kHz
    - **Second harmonic**
      = 2 x 2 kHz = 4 kHz
    - **Third harmonic**
      = 3 x 2 kHz = 6 kHz

- **Harmonic distortion** is measured by **filtering out the fundamental frequency** from the **output signal** and **measuring the remaining harmonic content**
- Measurements usually only consider **the second and third harmonics** → these can be considered separately or together in terms of 'total harmonic distortion'.
- **Harmonic distortion** should <u>not exceed</u> the **value provided by the manufacturer plus 3%**
- *Example:*

Harmonic distortion

Frequency range	<100 Hz - 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	5%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

2. ***<u>Battery current drain</u>***:
    - Battery life is affected by a number of variables:
        → **Battery capacity** in **mAh** (battery rating)
        → Hearing aid factors such as **gain control**, **signal intensity**, **sound input**, and **discharge voltage level**
        → Other factors such as **temperature and humidity**, **dry-aid kit usage**, and **other environmental factors**
    - **Higher than expected battery drain** usually indicates **impending mechanical failure of device**

Battery current drain

Frequency range	<100 Hz - 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	5%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

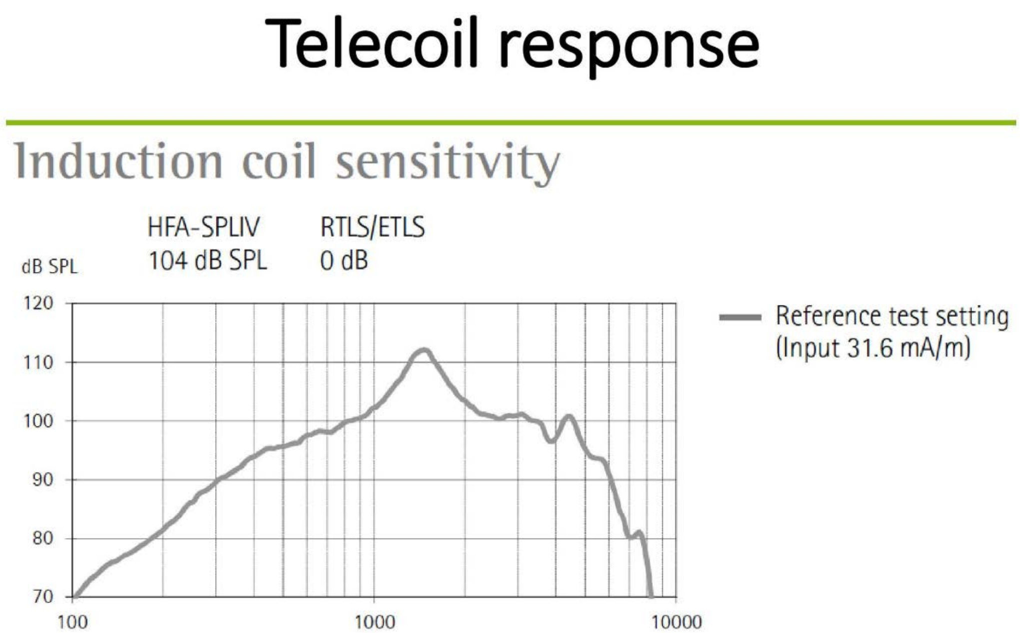
3. ***Equivalent input noise level:***
    - Hearing aids generate **their own internal random noise** that must be minimized to prevent the **masking of important quieter sounds**
    - **Internal noise** is usually analyzed in **one—third octave bands** and is expressed as an equivalent **input noise level**
    - Should not exceed the **maximum value specified by the manufacturer plus 3 dB**

Equivalent input noise level

Frequency range	<100 Hz - 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	5%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

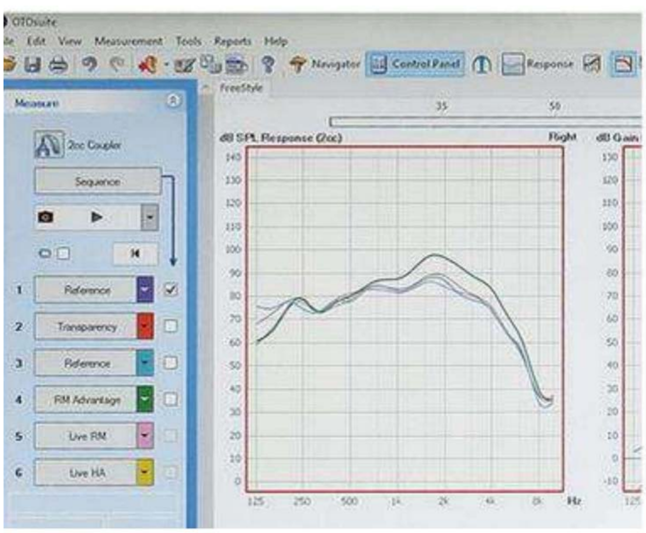
4. ***Telecoil response:***

- A **strong magnetic field** is generated in the test box and the gain control on the hearing aid is set to the **reference test position** or **full-on position**
- The **magnetic response** is displayed as a **graph of output SPL against frequency** → A **frequency response curve** can be recorded between **200 & 5000Hz**
- Values should be within **+/- 6 dB** of the manufacturer's values



Coupler-based verification:

- Substitute for PMMs
- Can run the same tests as you would for PMMs in a coupler



65 → 50 →80 → maximum

Chapter Thirteen: Hearing instrument Validation (outcome measures)

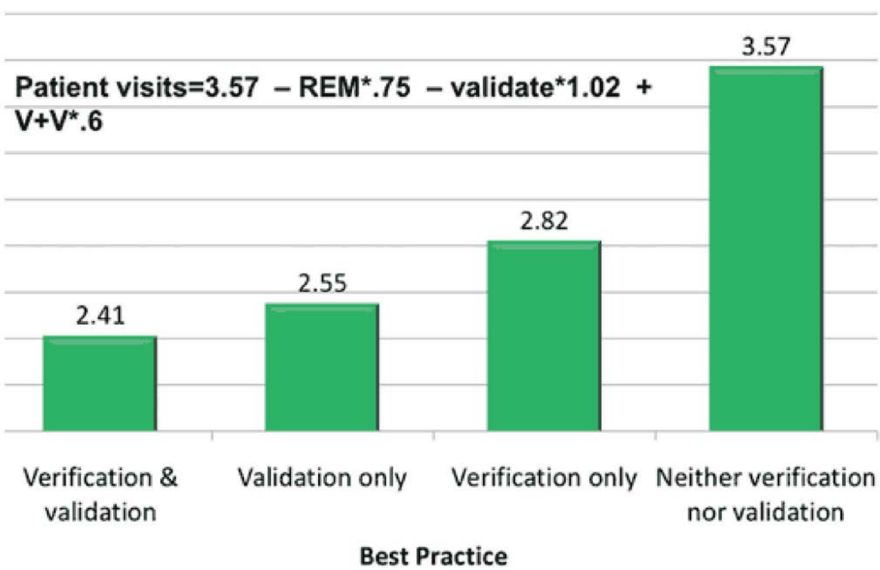
Outcome measures:

What are outcome measures?

- Allow us to **quantify the impact of management or treatment**
- Important for answering the following questions:
    - → *How did the intervention impact the individual?*
    - → *Did the management improve the communication abilities of the individual?*
    - → *Did we meet our intervention goals that were identified?*

Why use outcome measures?

- **Validate** a **successful hearing aid fitting**
- **Provide information** on **benefits of new technologies or protocols**
- **Provide information** for **service funders/providers that service is achieving goals**
- **Provide feedback** to **patients**
- **Provide feedback** to **suppliers** *(example: hearing aid companies, ear-mould manufacturers, etc.)*



- **Comparison** of **different sites or staff members**
- **Comparison** of **different fitting procedures across groups of patients**
- **Counselling effectiveness** across **groups of patients**
- **Documentation** of **service effectiveness**

What domains could we use as outcome measures?

- **Listening effort**
- **Use time**
- **Quality of life**
- **Naturalness of sound**
- **Sound quality** (especially for music)
- **Annoyance** for **loud environmental sounds**
- **Sound awareness** (especially for soft environmental sounds)
- **Social interaction**
- **Satisfaction with device**
- **Reduced burden** for the **significant other**(s)

Validation:

❖ **Types of validation methods**:
  - **Perception methods**
    - → *Sound quality*
    - → *Speech perception*
  - **Usage**
  - **Reports** from **significant others**
  - **Self-report measures** (most common approach)

❖ **Usage**:
  - Person is unlikely to **receive benefit from amplification** unless they **wear the device**
  - Two aspects of usage:
    - → ***Frequency of use*** (how often & how long)
    - → ***Contextual usage*** (in which situations)
  - Investigate usage by:
    - → ***Data logging***
    - → ***Patient diary***
    - → ***Web-based reporting system***

Benefit and Satisfaction:

❖ **Benefit and Satisfaction**:
  - **Benefit**
    - → **Aided** minus **unaided performance**
    - → **Lab-based** measures
    - → Relatively **objective**
  - **Satisfaction**
    - → More **subjective**
    - → Relates to **expectations**

❖ **Benefit**:

- Used at the **beginning** and towards the **'end' of the rehabilitation process**
- The **improvement gained** in an **aided vs unaided** listening conditions
- To determine if **patient's goals and expectations were met**
- To indicate if **aural rehab** should be **modified** or **extended**

❖ **Satisfaction**:

- **Reflects a patient's contentment** with **their current situation**
- Satisfaction is positively correlated with benefit, but can also be influenced by patient's expectations, professionalism of staff, cleanliness of consultation room, waiting time, and parking!

❖ **Benefit or Satisfaction**?

- I love my new hearing aids
- I notice a difference with my hearing aids in noisy places
- When I put my hearing aids on I can turn down the TV
- I told a friend to come see you for getting new hearing aids
- I wear my hearing aids 12 hours a day without any trouble, they really help me understand speech
- These hearing aids don't help

Questionnaires:

❖ **Validated questionnaires**:

- Abbreviated profile of hearing aid benefit (APHAB)
- **Glasgow hearing aid benefit profile** (GHABP)
- Satisfaction with amplification in daily life (SADL)
- Device oriented subjective outcome (DOSO)
- International outcome inventory for hearing aids (IOI-HA)
- **Client Oriented Scale of Improvement** (COSI)
- Profile of aided loudness (PAL)
- Speech, spatial and qualities of hearing scale (SSQ)
- Hearing handicap inventory for the elderly (HHIE)

❖ COSI:

- **Open-ended scale**
- Patients target up to **five listening situations** for **improvement with amplification**
- **Situations ranked by patient** according to **importance**
- **16 general listening categories** (for conducting group analysis)
- Carry out on day patient decides to accept hearing aids:
    - → Each item needs to be specific as possible
    - → After all situations are identified, review and rank

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NAL
CLIENT ORIENTED SCALE OF IMPROVEMENT

Name : ______ **Category.** **New** ____ **Return** ____
Audiologist : ______
Date : **1. Needs Established** ______
2. Outcome Assessed ______

Degree of Change

Final Ability (with hearing aid)
Person can hear
10% 25% 50% 75% 95%

SPECIFIC NEEDS

Indicate Order of Significance

Specific needs	Worse	No Difference	Slightly Better	Better	Much Better	CATEGORY	Hardly Ever	Occasionally	Half the Time	Most of Time	Almost Always
☐											
☐											
☐											
☐											
☐											

Categories
1. Conversation with 1 or 2 in quiet
2. Conversation with 1 or 2 in noise
3. Conversation with group in quiet
4. Conversation with group in noise
5. Television/Radio @ normal volume
6. Familiar speaker on phone
7. Unfamiliar speaker on phone
8. Hearing phone ring from another room
9. Hear front door bell or knock
10. Hear traffic
11. Increased social contact
12. Feel embarrassed or stupid
13. Feeling left out
14. Feeling upset or angry
15. Church or meeting
16. Other

- At follow up appointment:
    - → Bring out **original form**
    - → **Discuss items again** (listening tasks that are no longer meaningful can be removed and others added if necessary)
    - → Can be assessed in <u>two separate ways</u>:
        - o ***Degree of change*** (improvement provided by the hearing-aids)
        - o ***Final hearing ability with hearing aids*** (absolute measure of communication ability)

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NAL
CLIENT ORIENTED SCALE OF IMPROVEMENT

Name : ______ **Category.** **New** ______
Audiologist : ______ **Return** ______
Date : **1. Needs Established** ______
2. Outcome Assessed ______

SPECIFIC NEEDS

Indicate Order of Significance

Specific Needs	Degree of Change: Worse	No Difference	Slightly Better	Better	Much Better	CATEGORY	Final Ability (with hearing aid) Person can hear: Hardly Ever 10%	Occasionally 25%	Half the Time 50%	Most of Time 75%	Almost Always 95%
4 Hearing friends when playing cards at the local coffee shop											
2 Wife complains TV too loud –would like to listen at her level											
1 Hearing at meetings at work when seated around a table											
3 Hearing wife while driving car											

Categories
1. Conversation with 1 or 2 in quiet
2. Conversation with 1 or 2 in noise
3. Conversation with group in quiet
4. Conversation with group in noise
5. Television/Radio @ normal volume
6. Familiar speaker on phone
7. Unfamiliar speaker on phone
8. Hearing phone ring from another room
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12. Feel embarrassed or stupid
13. Feeling left out
14. Feeling upset or angry
15. Church or meeting
16. Other

19

❖ <u>**Glasgow Hearing Aid Benefit Profile**</u> (GHABP):

- Consists of **four fixed listening situations** and up to **four listener-specified situations**
- Designed to be **used clinically** to gather **multidimensional information** in a **short span of time**
- **Sensitive enough** to **differentiate** between **the benefit of two different hearing aids**
- Hard copy as well as computer version

GLASGOW HEARING AID BENEFIT PROFILE

Date of Assessment ....

Date of Review ....

Hospital Number..

Name ....

Address ....

....

Does this situation happen in your life? 0 ___ No 1 ___ Yes	**LISTENING TO THE TELEVISION WITH OTHER FAMILY OR FRIENDS WHEN THE VOLUME IS ADJUSTED TO SUIT OTHER PEOPLE**				
How much difficulty do you have in this situation?	How much does any difficulty in this situation worry, annoy or upset you?	In this situation, what proportion of the time do you wear your hearing aid?	In this situation, how much does your hearing aid help you?	In this situation, <u>with your hearing aid</u>, how much difficulty do you <u>now</u> have?	For this situation, how satisfied are you with your hearing aid?
0__N/A 1__No difficulty 2__Only slight difficulty 3__Moderate difficulty 4__Great difficulty 5__Cannot manage at all	0__N/A 1__Not at all 2__Only a little 3__A moderate amount 4__Quite a lot 5__Very much indeed	0__N/A 1__Never/Not at all 2__About ¼ of the time 3__About ½ of the time 4__About ¾ of the time 5__All the time	0__N/A 1__Hearing aid no use at all 2__Hearing aid is some help 3__Hearing aid is quite helpful 4__Hearing aid is a great help 5__Hearing is perfect with aid	0__N/A 1__No difficulty 2__Only slight difficulty 3__Moderate difficulty 4__Great difficulty 5__Cannot manage at all	0__N/A 1__Not satisfied at all 2__A little satisfied 3__Reasonably satisfied 4__Very satisfied 5__Delighted with aid
Does this situation happen in your life?	**HAVING A CONVERSATION WITH ONE OTHER PERSON WHEN**				

- For **first-time hearing aid users**
- Needs to be **administered via conversation** between **patient and audiologist**
- Do not **suggest specific situations**
    - → Ask **what tasks** patient performs and what environments
- **Automated** (on AuditBase)
- For each condition:
    - → ***Patient reports whether they encounter the situation***
    - → ***Patient responds to six dimensions***
    - → ***Possible answer***
        - o *No difficulty*
        - o *Only slight difficulty*
        - o *Moderate difficulty*
        - o *Great difficulty*
        - o *Cannot manage at all*
- **Establishes**:
    - → The **patient's initial disability** and **handicap prior to the fitting of a hearing aid** at the **initial assessment** (Before Fitting -Part 1)
    - → **Use, benefit, residual disability and satisfaction** after patient management at the **follow-up appointment**, ***6—12 weeks*** after fitting (After Fitting-Part 2)