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Fundamentals Still Matter:

Compression in Hearing Aid Fittings

Kevin Liebe, AuD

Kevin Liebe, AuD

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- Presenter Disclosure: Financial: Kevin Liebe is the President and CEO of Hearing Health & Technology Matters. He received an honorarium for this course. Non-financial: Kevin Liebe has no relevant non-financial relationships to disclose.

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Learning Outcomes

After this course, participants will be able to:

- Explain the purpose of compression in hearing aid fittings.
- Describe how compression can impact sound quality for the hearing aid wearer.
- Explain the difference between compression and expansion.

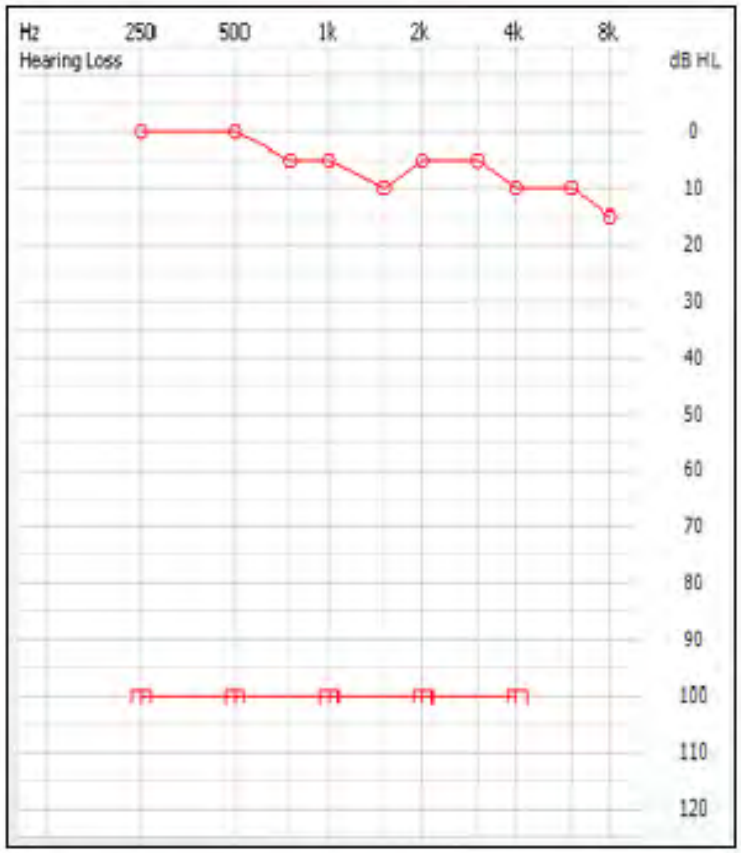
Why Talk about Compression?

- Is this *really* necessary?
- Algorithms and software have improved, but the basics still matter
  - As fitting software has continued to improve and constantly change, compression issues can sometimes be less obvious to the HCP

What Purpose Does Compression Serve in Hearing Aids?

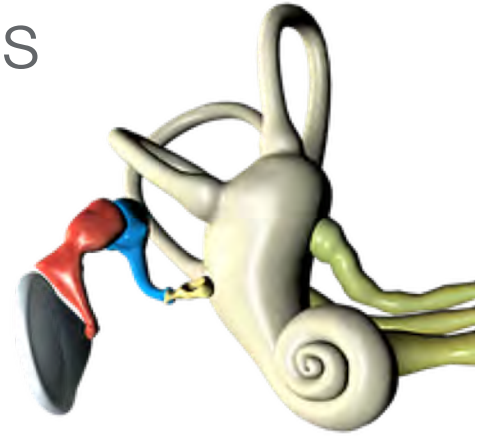
- Maintain listening comfort
- Restore normal loudness perception
- Limit output of hearing aid without distortion
- Prevent over-amplification

A Step Back…


Hz
250
500
1k
2k
4k
8k
Hearing Loss
dB HL
0
10
20
30
40
50
60
70
80
90
100
110
120

Sensorineural Hearing Loss

- Unlike the middle ear system, which is a linear amplifier, sensorineural hearing loss reduces the dynamic range.
- The cochlea is a non-linear amplifier
  - The outer hair cells amplify soft sounds
  - At high sound level the basilar membrane moves adequately without help of the outer hair cells



Dynamic Range of Hearing

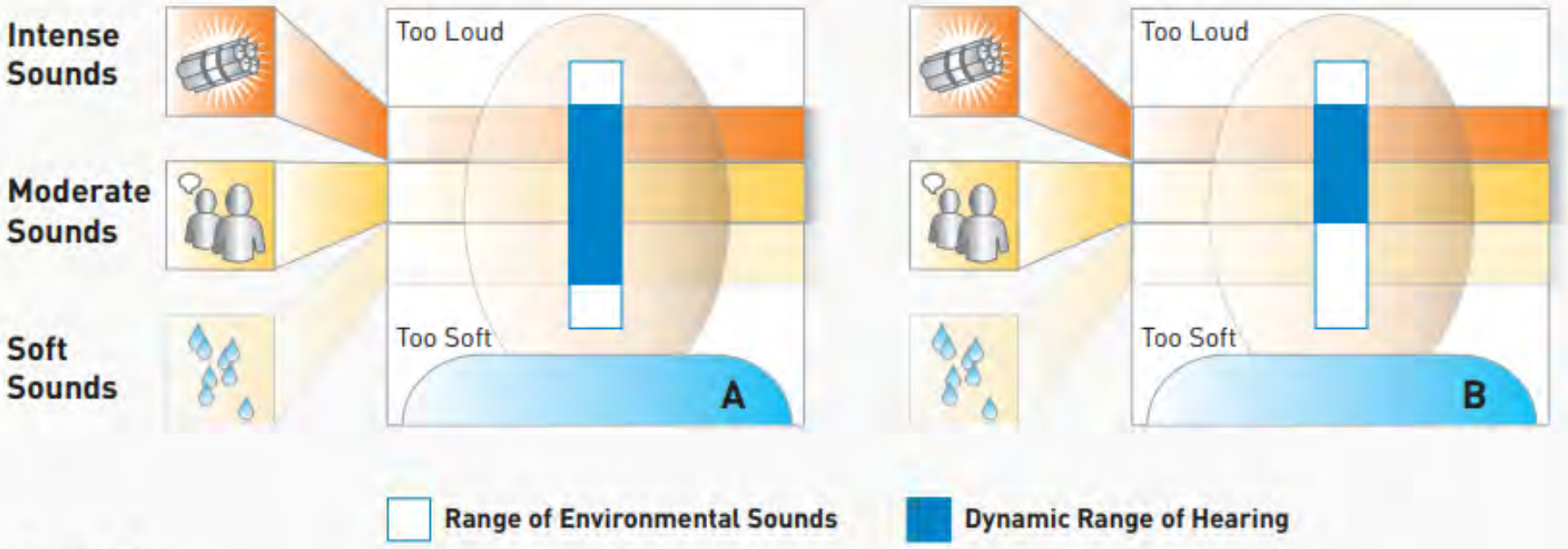
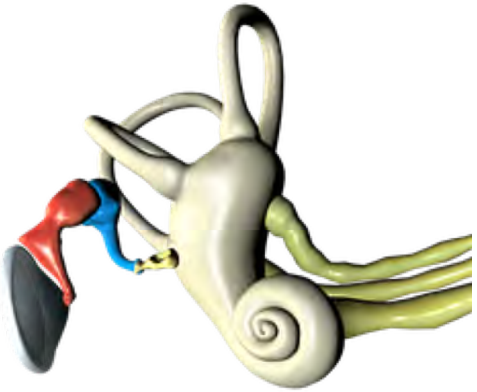


Figure 1-1
The relationship between the range of sounds in the environment and the dynamic range of hearing for persons with: (A) normal hearing, and (B) sensorineural hearing loss.

**image courtesy Starkey*

Sensorineural Hearing Loss

- Loss of outer hair cells = Loss of our ear's natural compression system
- Recruitment
  - *Rapid growth in loudness*
  - *Can lower 'ceiling' of tolerance to loud sounds, further reducing the dynamic range*



Dynamic Range of Hearing: Revisited

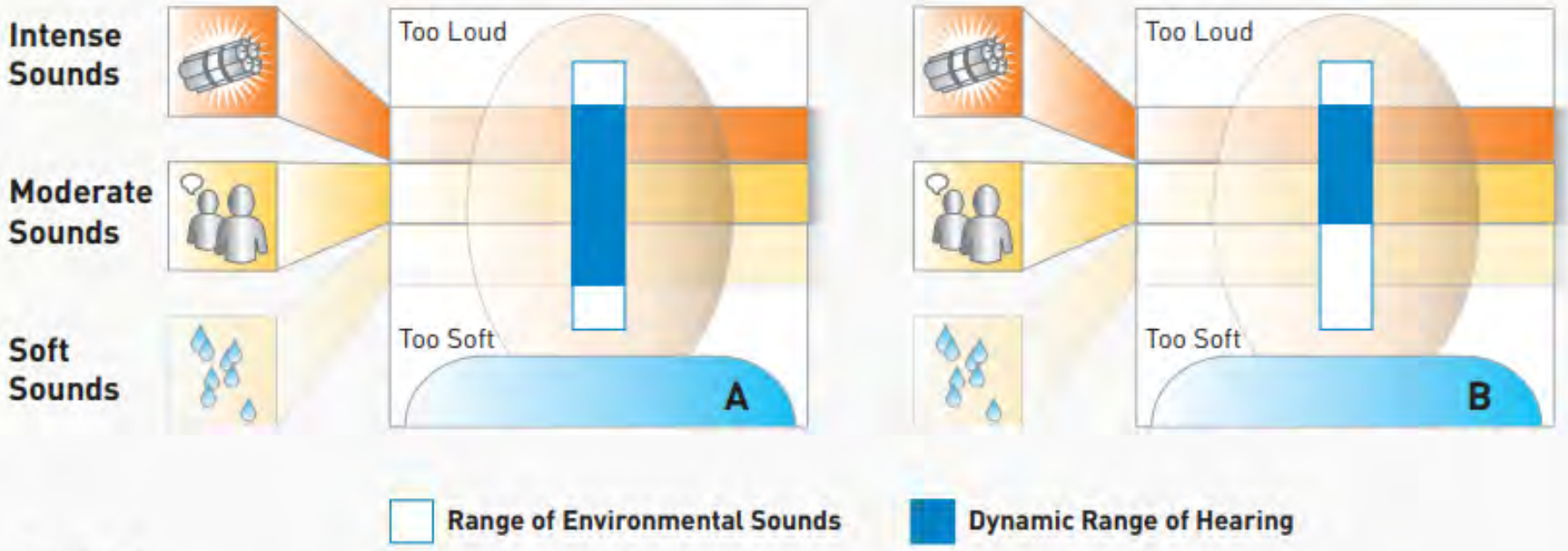


Figure 1-1
The relationship between the range of sounds in the environment and the dynamic range of hearing for persons with: (A) normal hearing, and (B) sensorineural hearing loss.

**image courtesy Starkey*

Dynamic Range of Hearing: Linear v. Non-Linear Amplification

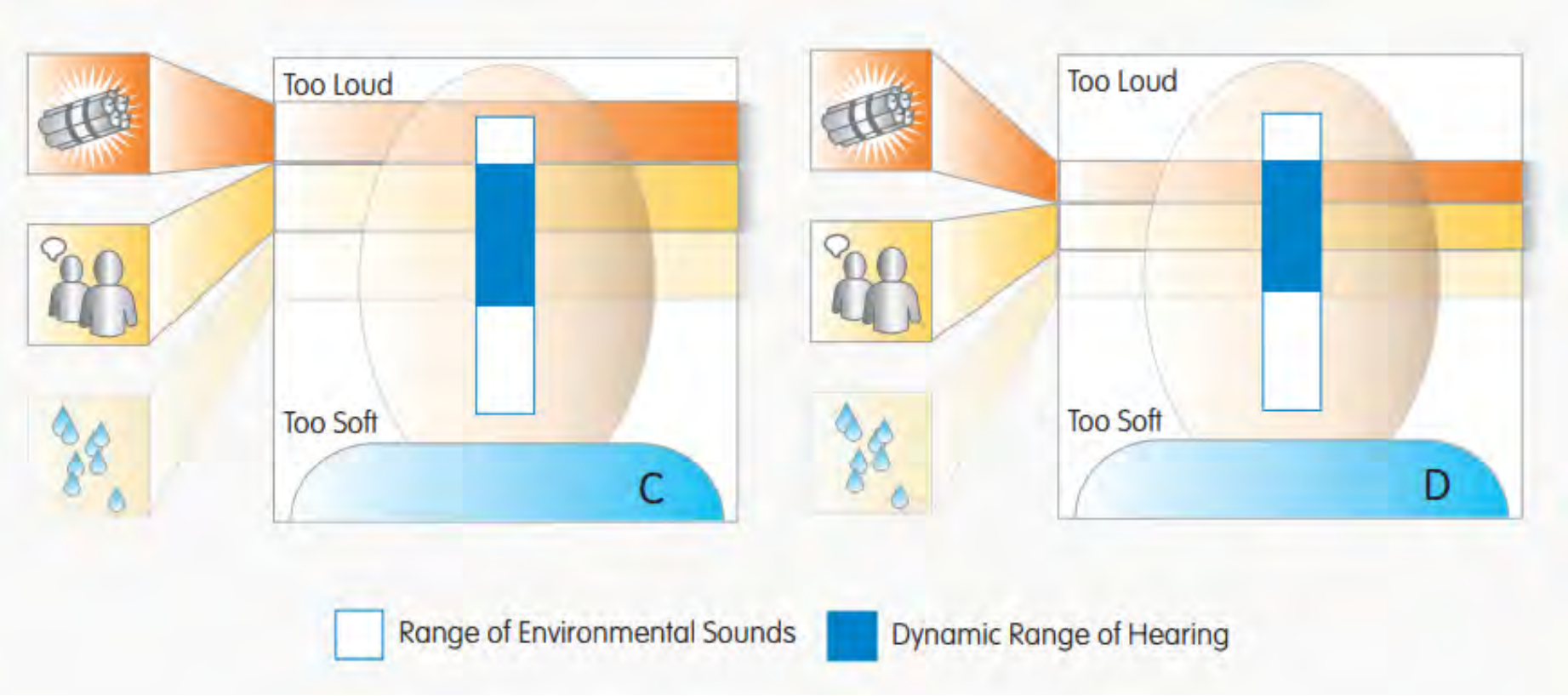


**image courtesy Starkey*

Goal: Meeting Patient Needs

- Ultimately the most common reason compression is used in hearing aids is to adjust the amount of gain added to the incoming signal to better meet the needs of the wearer's (reduced) dynamic range
  - Soft sounds made audible
  - Loud sounds not uncomfortably loud

I/O Function

- Input/Output functions are ways we can graphically represent the output of a hearing aid at different input levels
- Output is shown on the Y-Axis, with Input on the X-axis

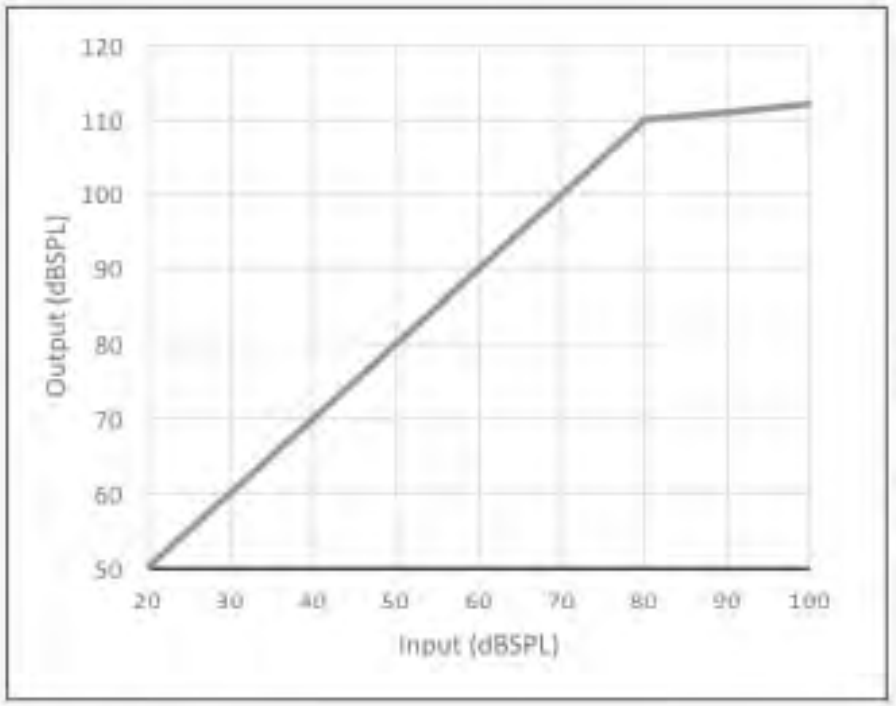


Figure 1-4
Sample input/output function of a hearing aid.

**image courtesy Starkey*

I/O Function

- In this example, linear amplification of 30dB is being applied
  - *40 dBSPL input becomes 70dBSPL output*
  - *60 dBSPL input becomes 90dBSPL output*

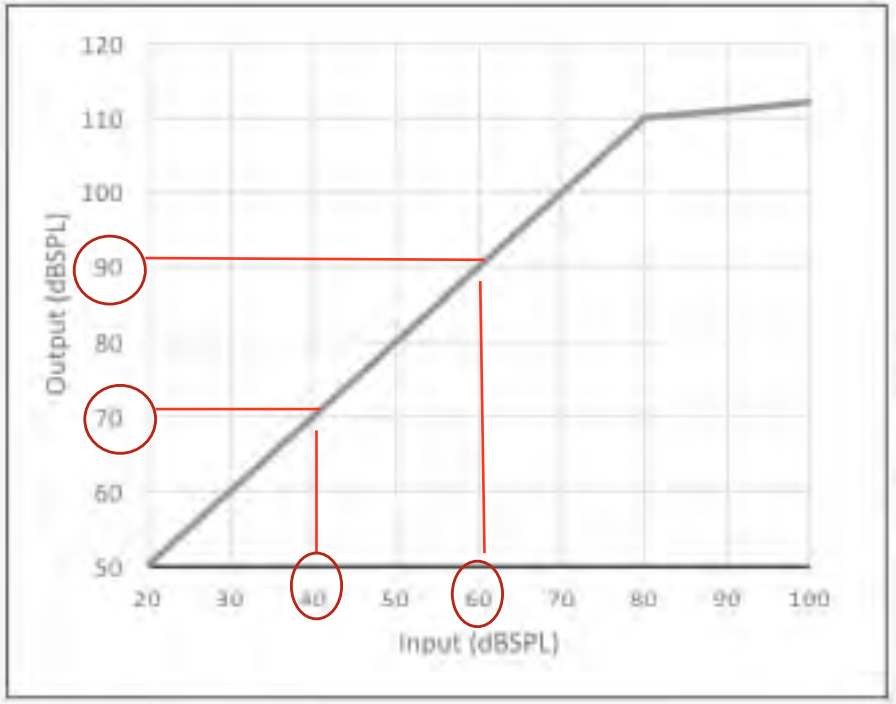


Figure 1-4
Sample input/output function of a hearing aid.

**image courtesy Starkey*

Linear Amplification

- In linear amplification, the same amount of gain is applied until the maximum power is reached.
- In the example, 30dB is applied across input levels until MPO is reached at 110dBSPL
  - At max power, in linear devices, gain is generally reduced through Peak Clipping, which can introduce distortion

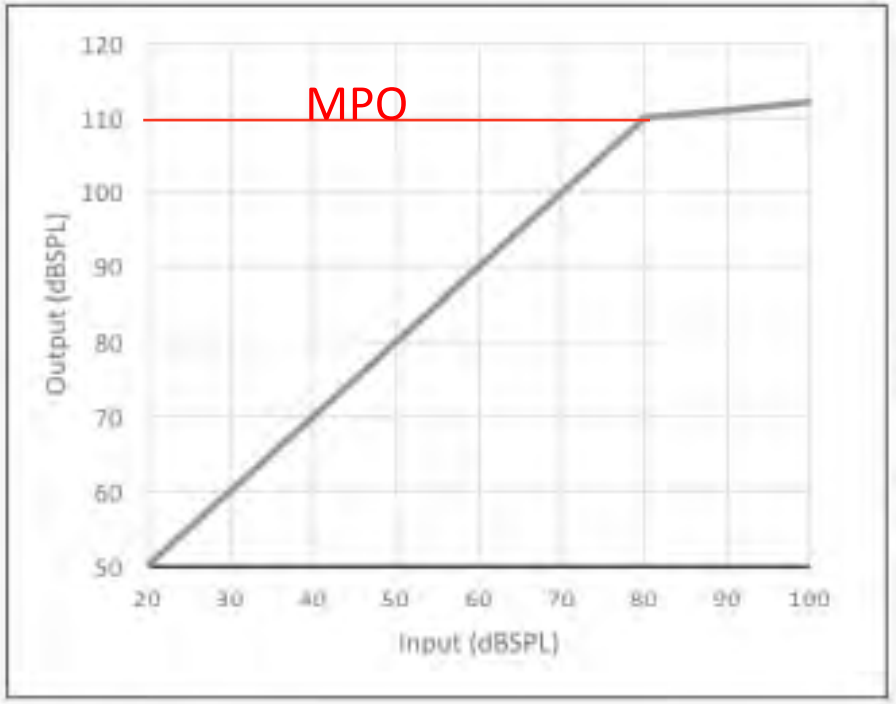


Figure 1-4
Sample input/output function of a hearing aid.

**image courtesy Starkey*

Linear Amplification

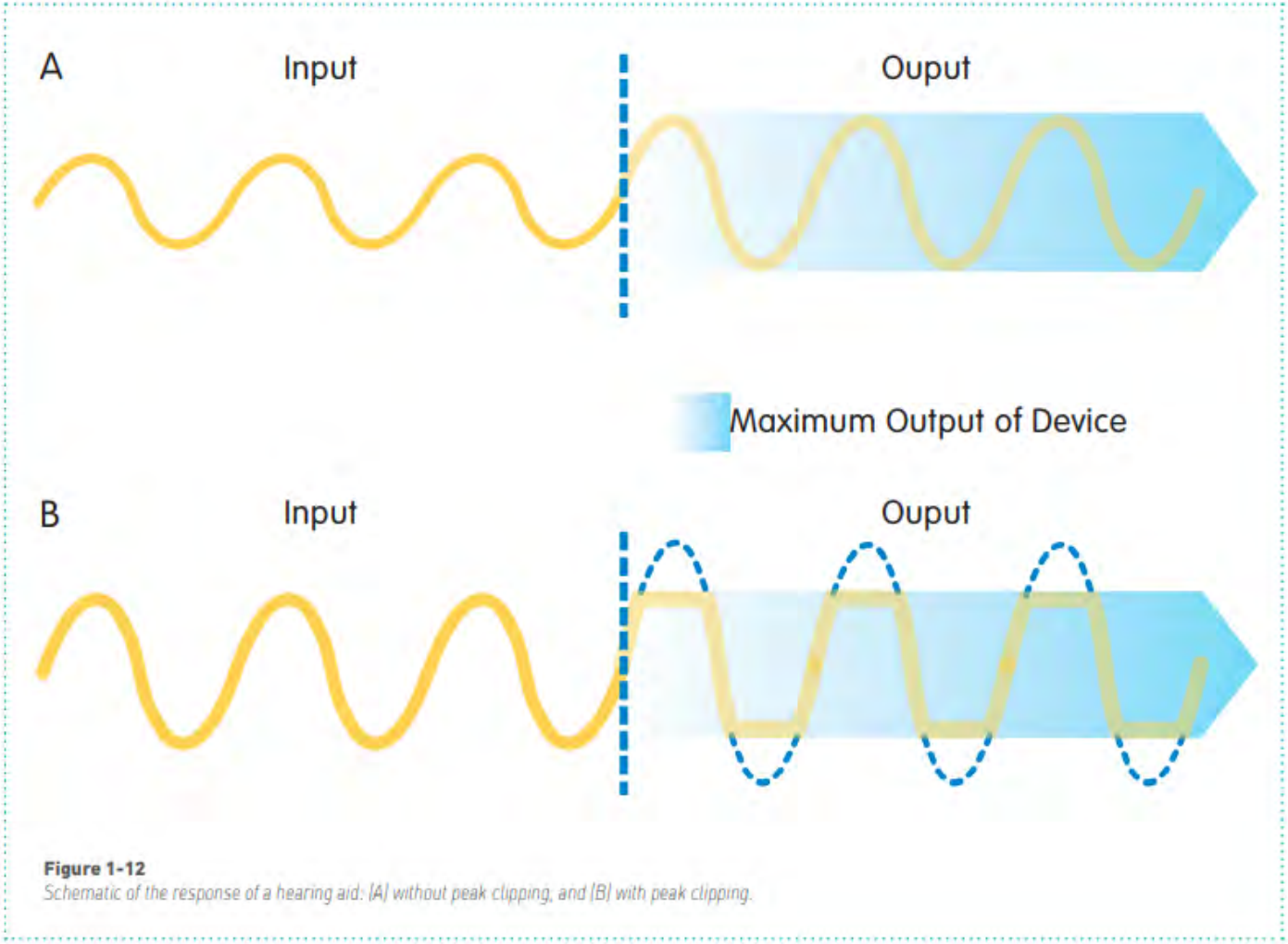


Figure 1-12
Schematic of the response of a hearing aid: [A] without peak clipping, and [B] with peak clipping.

**image courtesy Starkey*

Understanding Compression

- Compression helps us squeeze sound into patient's dynamic range, reduced by SNHL

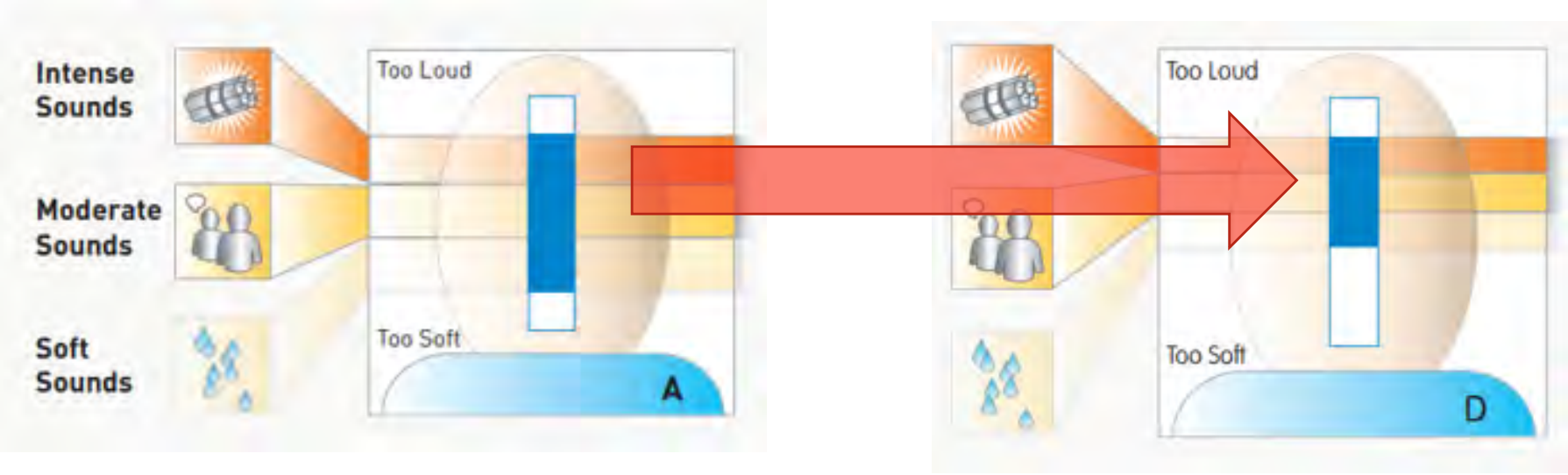


*image courtesy Starkey

Understanding Compression

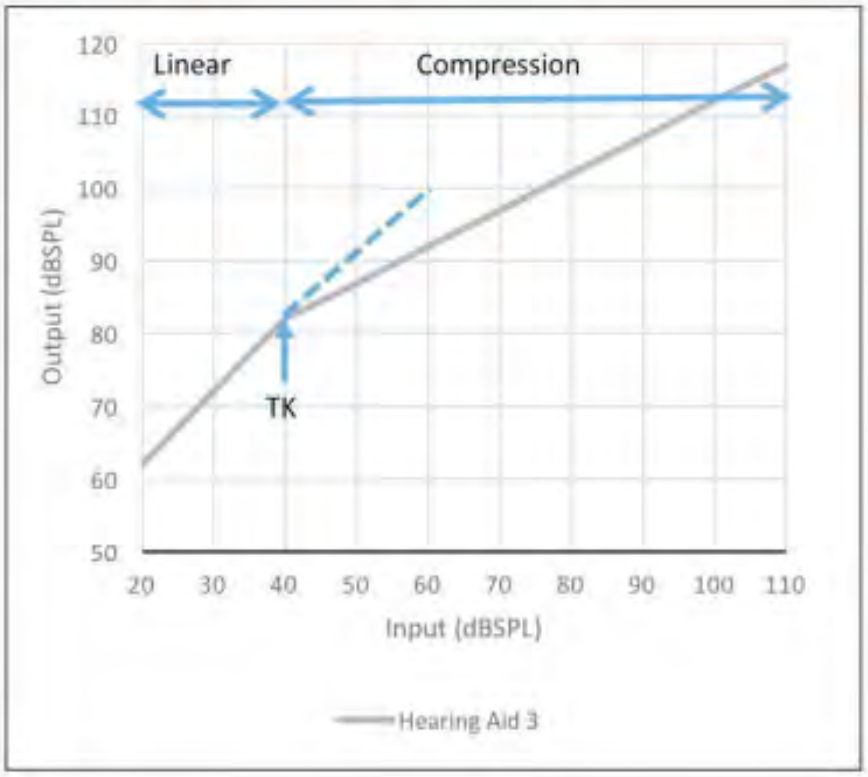


Figure 2-4
Sample input/output function for a hearing aid showing the compression threshold (CT) and the threshold knee point (TK).

**image courtesy Starkey*

- TK = threshold kneepoint
  - *In the example the amplification is linear until 40dB, then becomes non-linear above 40dB input levels*

Compression Ratio - Defined

The compression ratio (CR) is defined as the change in input over the change in output

$$CR = \frac{\text{Change in input}}{\text{Change in output}}$$

Compression Ratio - Defined

Linear amplification is a 1:1 relationship

$$CR = \frac{\text{Change in input}}{\text{Change in output}}$$

Example

$$CR = \frac{25}{25} = 1:1$$

***also displayed as 1.0 in hearing aid fitting software*

Compression Ratio - Defined

Non-linear amplification is anything other than a 1:1 relationship

- A CR of 2:1 (or 2), for example, means that a 2dB change in input will result in a 1 dB change in the output.
- Similarly, a CR of 3:1 would mean that a 3 dB change in input will result in a 1 dB change in output.

Attack & Release Time

Attack Time: How long it takes compressor to react to increase in input level and reduce gain

Release Time: How long it takes for compressor to react to a reduction in the input level and restore gain

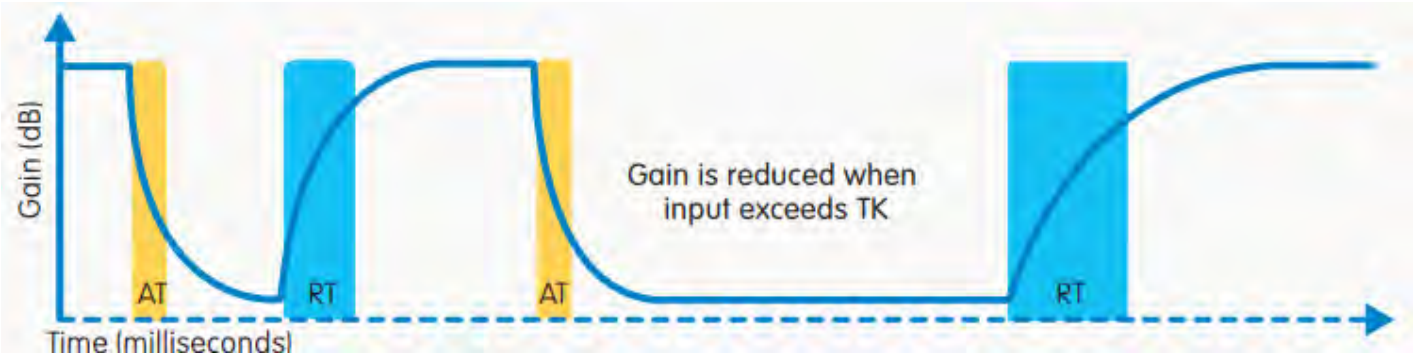


**image courtesy Starkey*

Attack & Release Time

Many hearing aids today use a fast AT, but there is some variability on RT

If RT too short, undesirable ‘pumping’ may occur, annoying the user

Some evidence suggests those with poorer cognitive abilities might do better with longer RTs

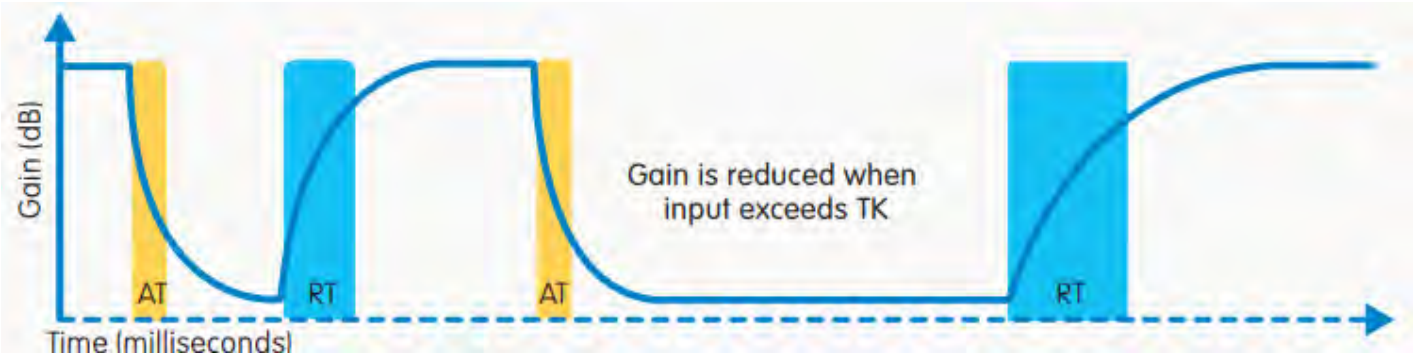


*image courtesy Starkey

Compression in Practice

Bear in mind, with non-linear amplification we are trying to find the proper **balance** between meeting the user's hearing needs and also avoiding sound quality issues.

- The higher the CR, the greater chance of sound quality complaints/issues.
  - *This is especially true for music!*

Types of Compression

To better understand types of compression systems, it's helpful to revisit the basic components of a hearing aid circuit

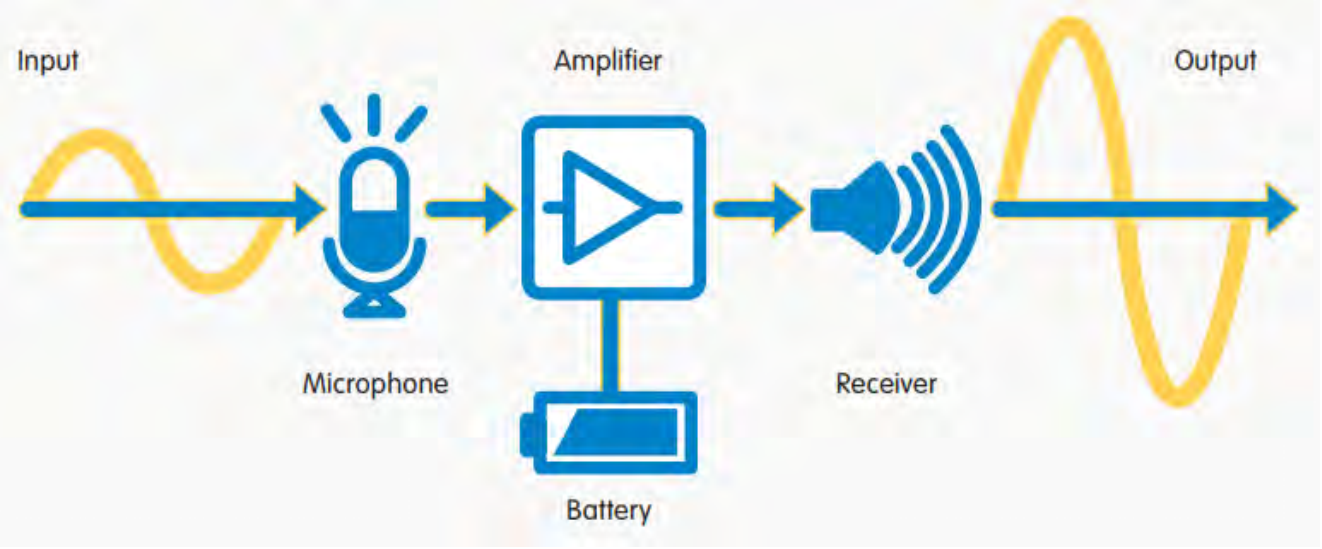


image courtesy Starkey

Automatic Gain Control (AGC)

Automatic gain control (AGC) is the term used to describe compression circuits because the amount of gain applied is automatically determined by the signal level.

All compression circuits utilize a level detector and the position of this detector, relative to the VC, will influence how it operates.

AGC-i: Input Compression

- Compression that occurs before the volume control is called AGC-i (Automatic Gain Control - Input related).
- Activation only dependent on intensity of input.
- WDRC is a type of AGC-i

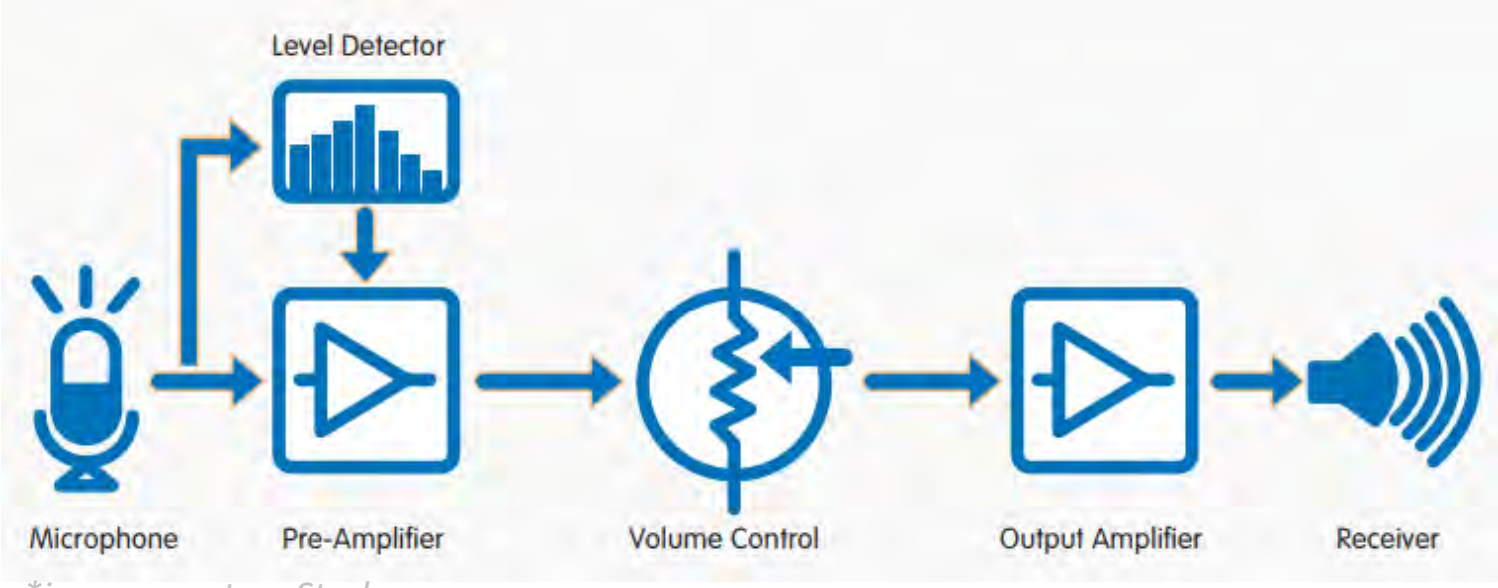


*image courtesy Starkey

AGC-i: Input Compression

Why do we use it?

- To normalize loudness
- Maximize speech intelligibility
  - Forms part of the rationale behind commonly used prescriptive methods (NAL-NL2, DSL i/o, etc.)
  - Compression is used to achieve recommended gain targets for specific losses

AGC-i: WDRC

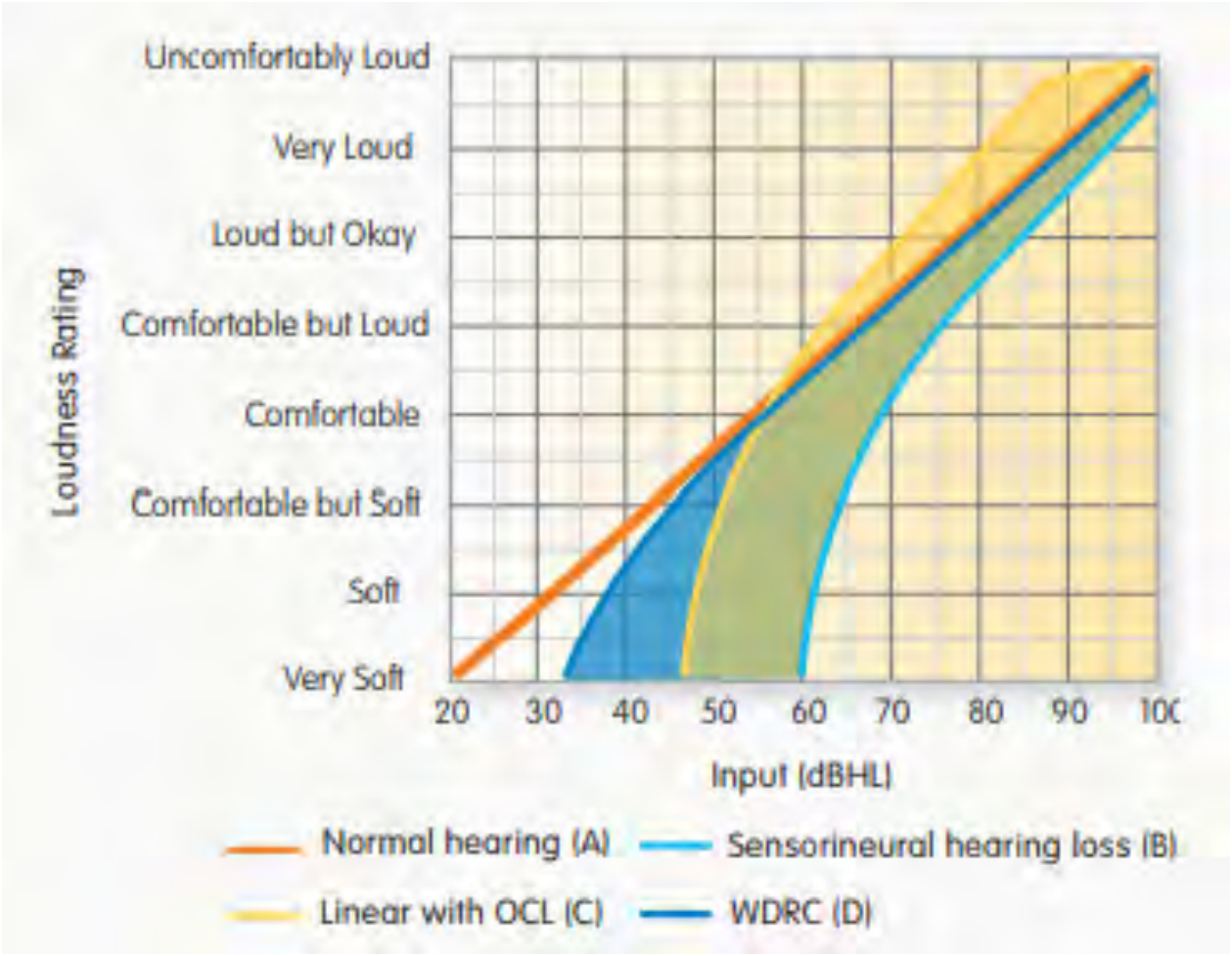


*image courtesy Starkey

AGC-O: Output Compression

- Compression that occurs after the volume control is called AGC-O (Automatic Gain Control - Output related).
- The compression circuit is positioned so that it monitors the output signal before it reaches the speaker.

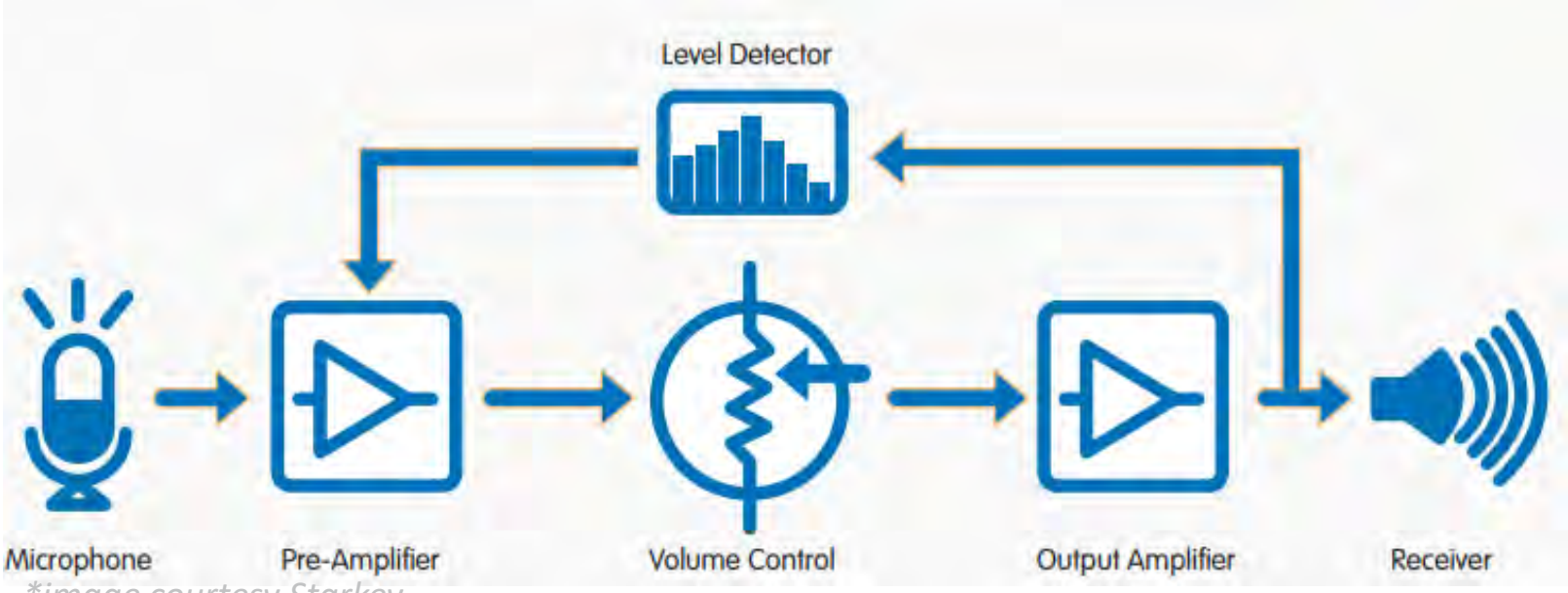
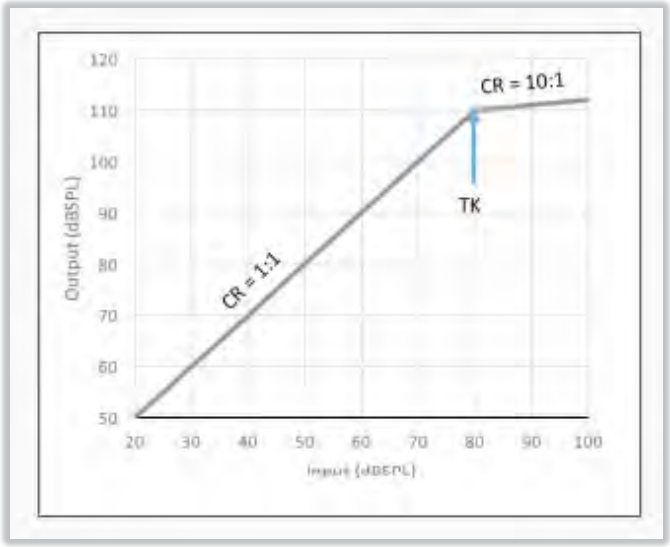


*image courtesy Starkey

AGC-O: Compression Limiting

- Peak clipping causes distortion – one way to avoid this is through **compression limiting**.



	Peak Clipping	Compression Limiting
Pros	Greater output can be achieved for severe/profound hearing losses	Significantly less distortion of the signal
Cons	Significant distortion of signal	Reduced output vs. peak clipping approach

A Note About Expansion

Technology designed to reduce the amount of gain for very soft sounds is called **expansion**.

- Signals below the compression threshold will receive reduced gain rather than maximum gain
  - This helps reduce soft environmental noise and device circuit noise becomes less audible

A Note About Expansion

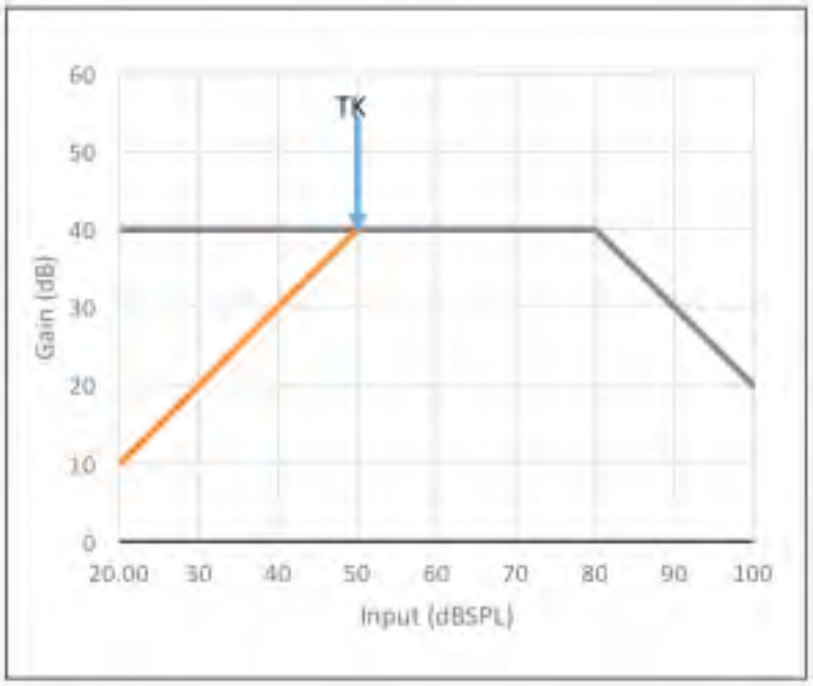


Figure 5-3
Sample input/gain functions showing linear amplification and output compression limiting (OCL), with and without expansion below the threshold knee point (TK).

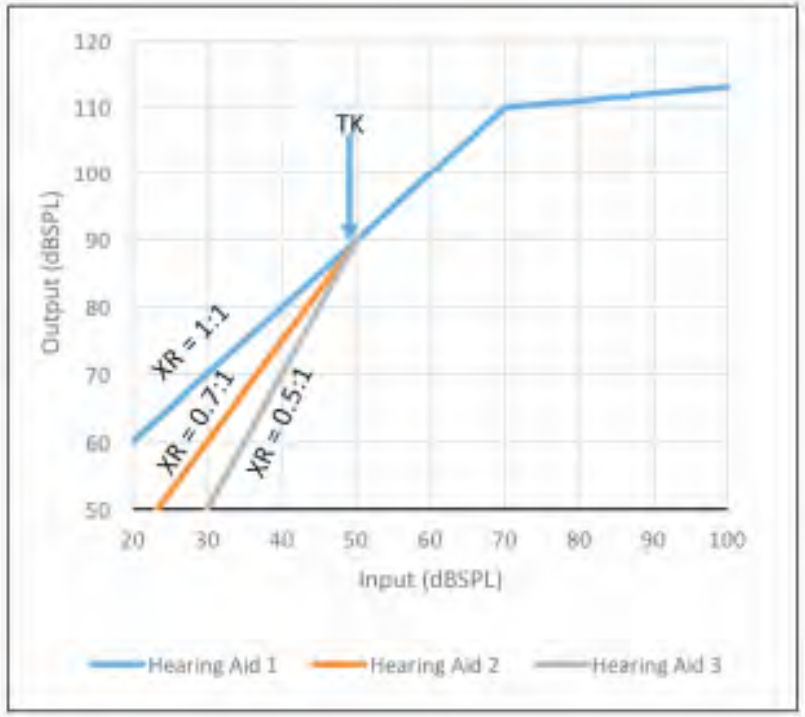


Figure 5-6
Sample input/output functions showing three hearing aids with the same threshold knee point (TKexp) and different expansion ratios (XR).

**images courtesy Starkey*

Practical Examples

Should you trust spec sheets?

Maybe…. Maybe not?

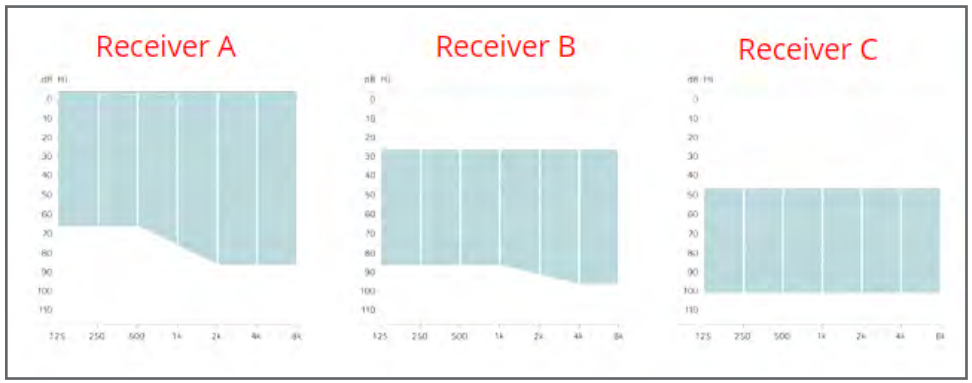
Should you trust spec sheets?

While spec sheets are great and give a lot of insight to the electroacoustic function of a hearing aid, often the display of the 'fitting range' of a particular speaker/matrix can be misleading.

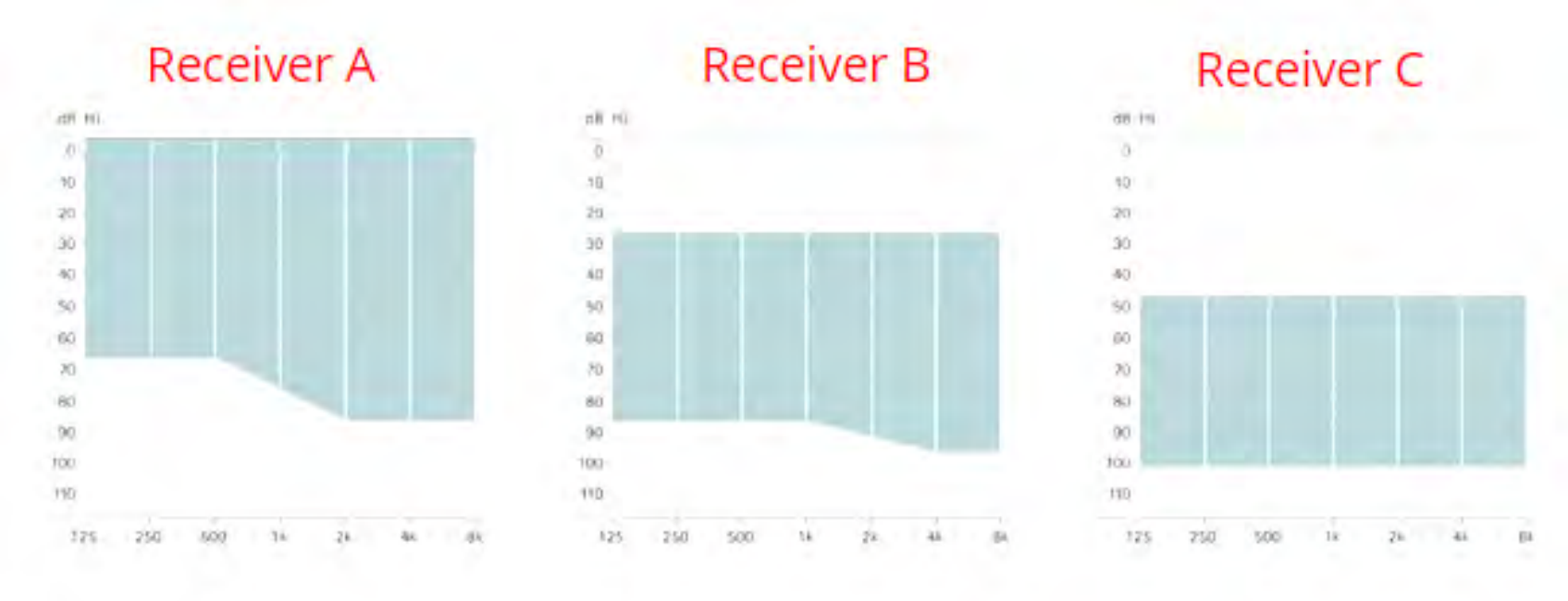
- ALL manufacturers do this
- Clinicians must interpret suggested fitting ranges with caution.

Should you trust spec sheets?

If you select a speaker/matrix that is not powerful enough, it's possible you will encounter issues with compression being too high at some frequencies.



Should you trust spec sheets?



***Despite being in the 'fitting range' for Receiver A, if you tried to fit a 60 dB flat/sloping loss, you would likely encounter sound quality issues due to elevated compression*

First Fit vs. Experienced

Most, if not all, manufacturer's new/inexperienced user 'First Fit' settings are designed for acoustic comfort

- In addition to reduced gain, often the comfort fitting involves elevated compression settings
- Sometimes dramatic differences in CRs can be observed between standard and new user for comfort fittings, which will have sound quality ramifications

Real world example

- First fit video(s)

Fitting Wizards

The so-called ‘fitting wizards’ found in most hearing aid fitting software today can make troubleshooting sound quality issues a ‘simple’ fix by clicking a button

- These wizards can sometimes cause more harm than good
- Be mindful that compression can be altered significantly by these systems

Real world example

- Fitting wizard video(s)

The Lady and the TV: Case Study

An elderly woman and her daughter were seen for a follow-up after being fit for hearing aids for the first time a few weeks previously.

- The woman reports that when she leaves her room and walks into the dining room, the hearing aids seem to ‘open up’ and sound ‘normal’ again
- What was going on?

The Lady and the TV: Case Study

Upon further discussion, the daughter says her mother still plays her TV at the same volume as before (too loud).

- Turns out she's relatively close to the television, in a small space.
- The hearing aids, utilizing compression, were trying to prevent over-amplification and when she left the room, they returned to their normal state

The Lady and the TV: Case Study

After counseling, the woman reduced the volume of her TV and the problem was resolved.

At lower volume levels the hearing aid amplified appropriately

Common Issues – Troubleshooting

Complaint	Possible solution
Hearing aid doesn't sound clear	Decrease high-frequency CRs
Distant sounds heard better than close sounds	Decrease overall CRs
Hearing aid sounds 'noisy'	Turn on expansion
Hearing aids seem weak	Decrease overall CRs
Clanging dishes and cutlery sounds too loud	Increase HF CRs

**Remember, reducing CRs can involve either *increasing* or *decreasing* gain at certain input levels – depending on what you're trying to achieve.

Common Issues – Troubleshooting

Compression offers a number of benefits for patients, but we have to strike a good balance between providing adequate audibility and listening comfort.

- Rule of thumb – Keep your CRs below 3
  - *For music, keep as close to 1.0 as possible!*
- Interpret spec sheets and suggested fitting ranges with caution, regardless of the manufacturer.
- Fitting wizards aren't all they're cracked up to be and can get you in trouble
  - *After making changes – always check your fitting screen*

References

- The Compression Handbook, 4th Edition, Starkey Hearing Technologies
- Dillon H., Hearing Aids, 2nd Edition (2012), Boomerang Press