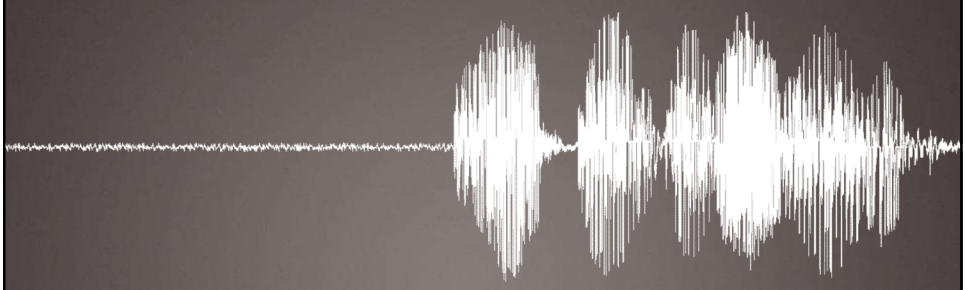


Foundations of Cochlear Implants: Electrical Stimulation of the Ear

Amy Isaacs Donaldson, AuD, CCC/A
Professional Education Manager, Cochlear Americas
Audiology Online (2 Aug 2017)

Hear now. And always

Cochlear®

Cochlear's Mission

We help people hear and be heard.

We **empower** people to connect with others and live a full life.

We **transform** the way people understand and treat hearing loss.

We **innovate** and bring to market a range of implantable hearing solutions that deliver a lifetime of hearing outcomes.

Learning Goals

After participating in this session, professionals will be able to:

- Identify and define the parameters of electrical stimulation important for programming cochlear implants
- Explain how a cochlear implant stimulates the auditory nerve
- Describe user controls available for recipients and when to use each

This course is part of the "Foundations of Cochlear Implants" series

Cochlear™ Nucleus® Cochlear Implant System

Internal Devices

CI532 Slim Modiolar

CI512 Countour Advance®

CI522 Slim Straight

*Hybrid™ L24**

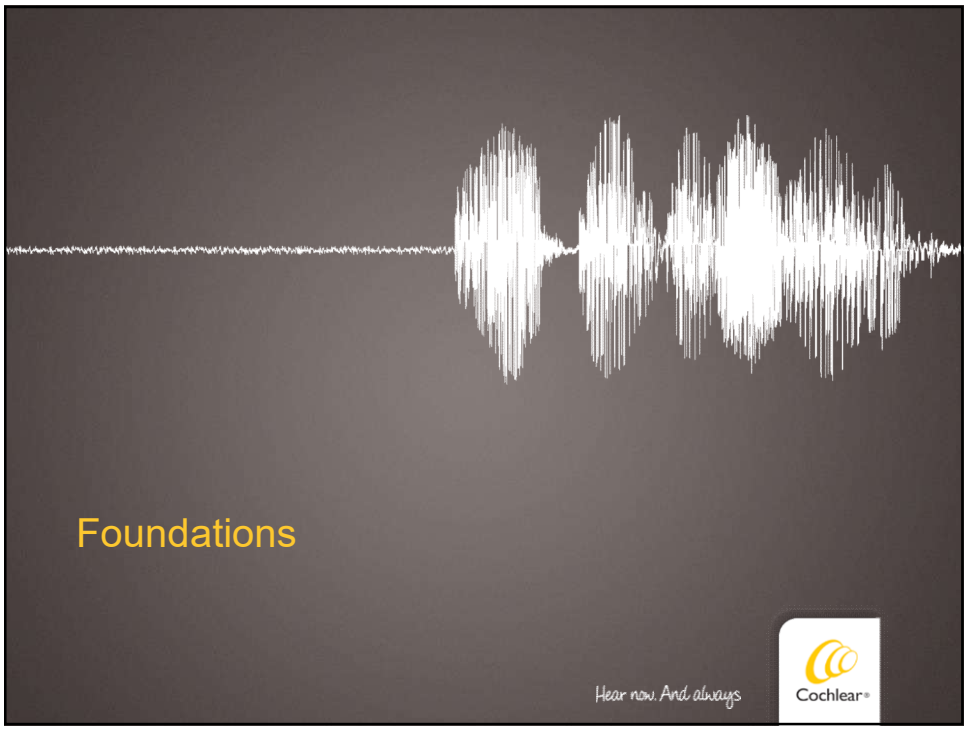
Sound Processors

Nucleus® 7

*Nucleus® 7 with acoustic component**

Nucleus® Kanso

*The Acoustic Component should only be used when behavioral audiometric thresholds can be obtained and the recipient can provide feedback regarding sound quality. The Hybrid L24 Implant is approved in the US for adults ages 18 and older.

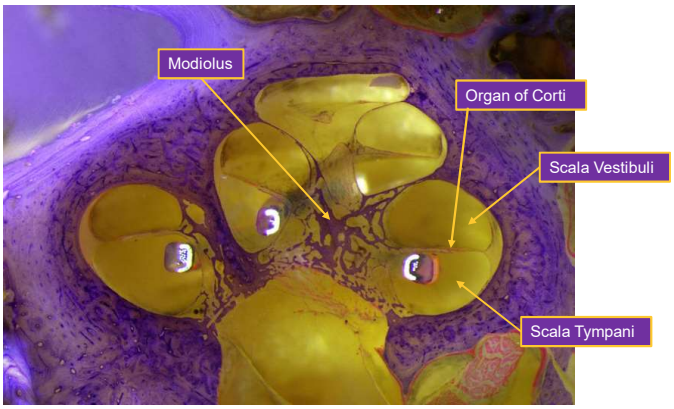


Pioneers

(video)

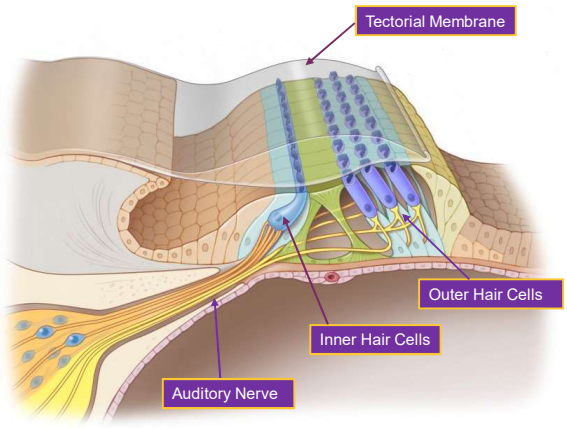
Review of Inner Ear Physiology

Cross-section of the Cochlea



Review of Inner Ear Physiology

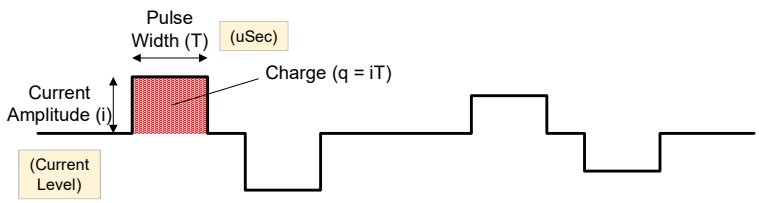
Organ of Corti



- As the stereocilia on the hair cells move, they open channels that depolarize the hair cell
- Once the hair cell is depolarized, calcium channels at the base of the hair cell are opened triggering the release of glutamate
- This sends an electrical signal through the auditory nerve and into the auditory cortex of the brain

Stimulation of the Auditory Nerve

To electrically stimulate the auditory nerve, we must use a charge-balanced bi-phasic pulse to avoid direct current (which damages tissue)



Current Level (1-255): represent the amplitude of the biphasic pulse in microamperes (μA) on a log scale similar to dB

Pulse Width: The amount of time the pulse is on, measured in microseconds

Early Electrical Stimulation of the Cochlea

- Studies of electrical stimulation to produce an auditory sensation began as early as the 1800's[1]
- Research in human subjects began in the 1960's and 70's[1]
- Early coding strategies required only timing to be coded since only one channel was available – this resulted in some hearing but no open-set understanding[1]
- To improve speech understanding, both timing AND frequency had to be coded[1]

1 – Clark (2008) Personal reflections on the multichannel cochlear implant and a view of the future. Journal of Rehabilitation Research and Development, 45(5): 651-694

Early Breakthrough

"I discovered in 1977 that by inserting blades of grass into a turban shell, a large-scale replica of the cochlea, I could achieve an appropriate insertion depth if the electrode bundle was flexible at the tip and became increasingly stiff toward its proximal end."[1]

PROFESSOR GRAEME CLARK

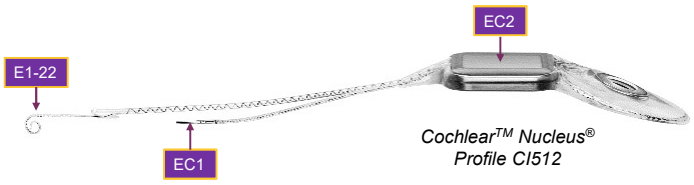
1 – Clark (2008) Personal reflections on the multichannel cochlear implant and a view of the future. Journal of Rehabilitation Research and Development, 45(5): 651-694

Coding Strategy

Hear now. And always.

Monopolar Stimulation

Introduced in 1997 with the Nucleus® 24 System, Monopolar Stimulation required lower current levels[1] and allowed clinicians to measure fewer channels during mapping.[2]



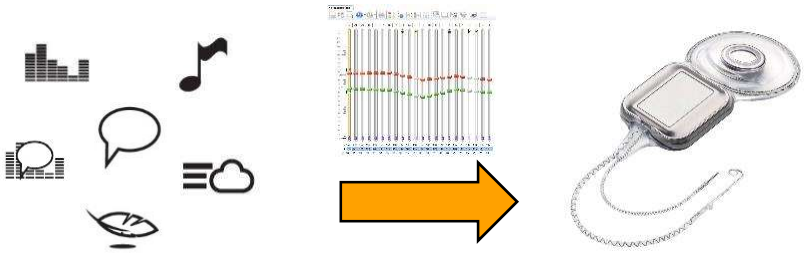
Monopolar Stimulation: Active electrodes are coupled with external ground electrode(s).
We now use MP1+2, which means active electrodes in the cochlea are grounded to both EC1 and EC2.

Other modes of stimulation are still available for complex cases or older implants if needed

1 – Zwolan et al (1996) Patient performance with the Cochlear Corporation "20+2" implant: Bipolar versus monopolar activation. *Otology & Neurotology*, 17(5).
2 – Plant et al (2005) Evaluation of streamlined programming procedures for the Nucleus cochlear implant with the Contour electrode array. *Ear & Hearing*, 26(6): 651-68.

MAP

The process of programming incoming sound for the implant came to be known as "MAPping."



Coding Strategy: A set of rules that will code sound and can be individualized for the recipient

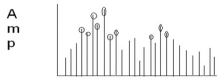
MAP: The personalized set of parameters for a particular recipient

ACE explained

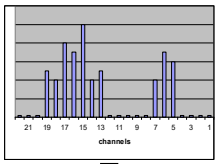
- (video)

How ACE Works

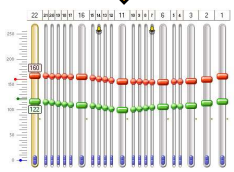
1. Frequencies are split into 22 bins



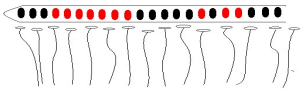
2. Frequencies with largest amplitudes are chosen as Maxima



3. Maxima are then coded to stimulate at a certain current level (dependent on T and C levels)



4. The stimulation of the physical electrode then causes stimulation of the corresponding neural elements



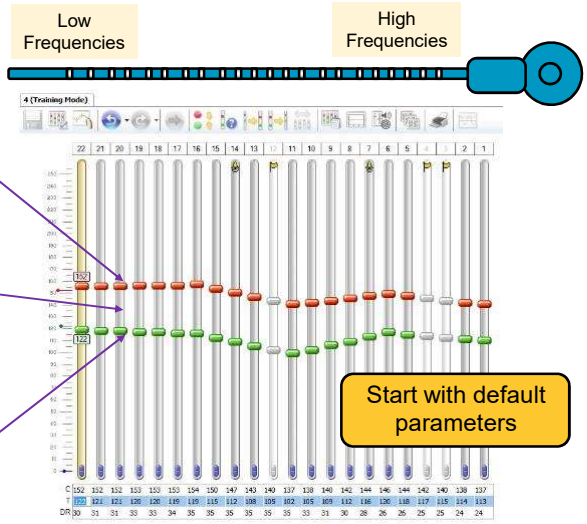
Cochlear Implant Programming

Computer with Programming Software

Programming Interface (wired or wireless)

Recipient

Creating a MAP



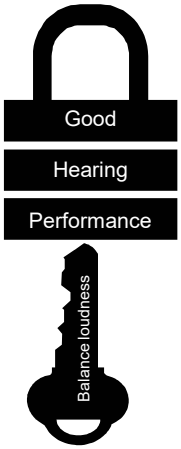
C-level: The highest comfortable current level on each channel

Dynamic Range: The range between the T and C level

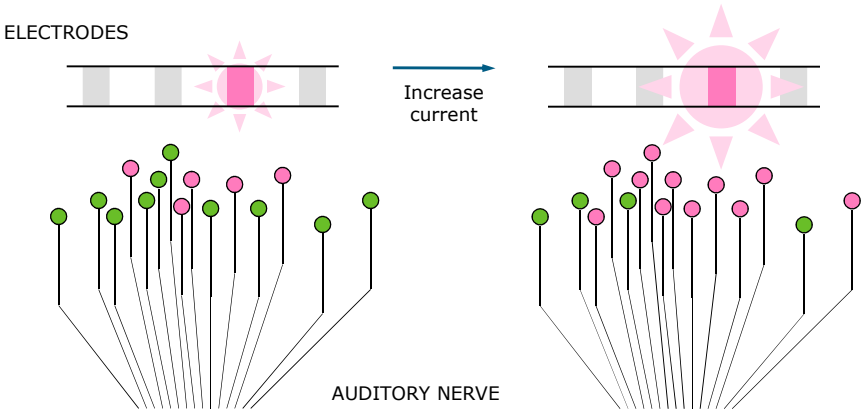
T-level: The lowest current level on each channel that produces a sensation of hearing in the recipient

The Clinician's Goal

- The amount of charge required to produce a sensation of hearing and growth of loudness can vary
  - It can vary widely between patients
  - It can vary from visit to visit, especially in the first few weeks of implant use
- Our goal as clinicians is to establish and maintain a true and comfortable loudness percept for the patient across all channels



Loudness Percept Increases with Current

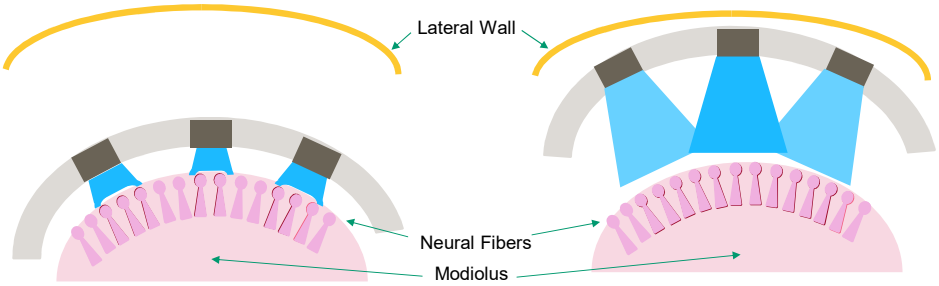


Loudness is determined by **how many** auditory fibers we stimulate – to make it louder, increase the charge

Perception of Loudness

Perimodiolar vs Lateral Wall stimulation of the auditory nerve.

- An electrode closer to the modiolus provides more focused stimulation[1]
- A perimodiolar array allows for less channel interaction[2]

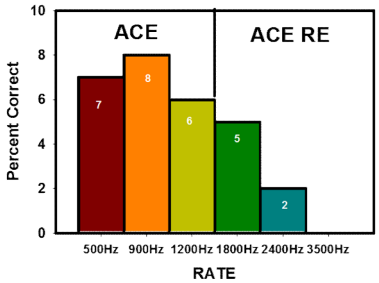


1 - Cohen et al (2004) Spatial spread of neural excitation: Comparison of compound action potential and forward-masking data in cochlear implant recipients. International Journal of Audiology 43(6)
2 – Hughes & Abbas (2006) Electrophysiologic channel interaction, electrode pitch ranking, and behavioral threshold in straight versus perimodiolar cochlear implant electrode arrays. JAAA 119(3)

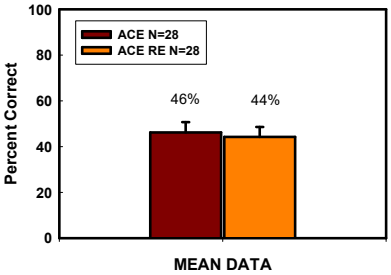
Stimulation Rate

More stimulation rates became possible with the Nucleus® Freedom® System which gave a range of rates to choose for recipients – data shows that faster is not necessarily better[1]

Recipient Preference



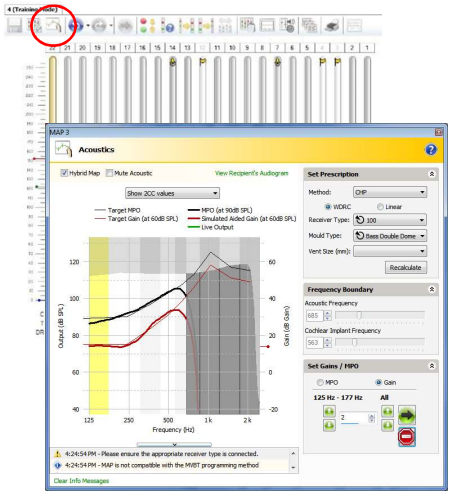
Recipient Performance



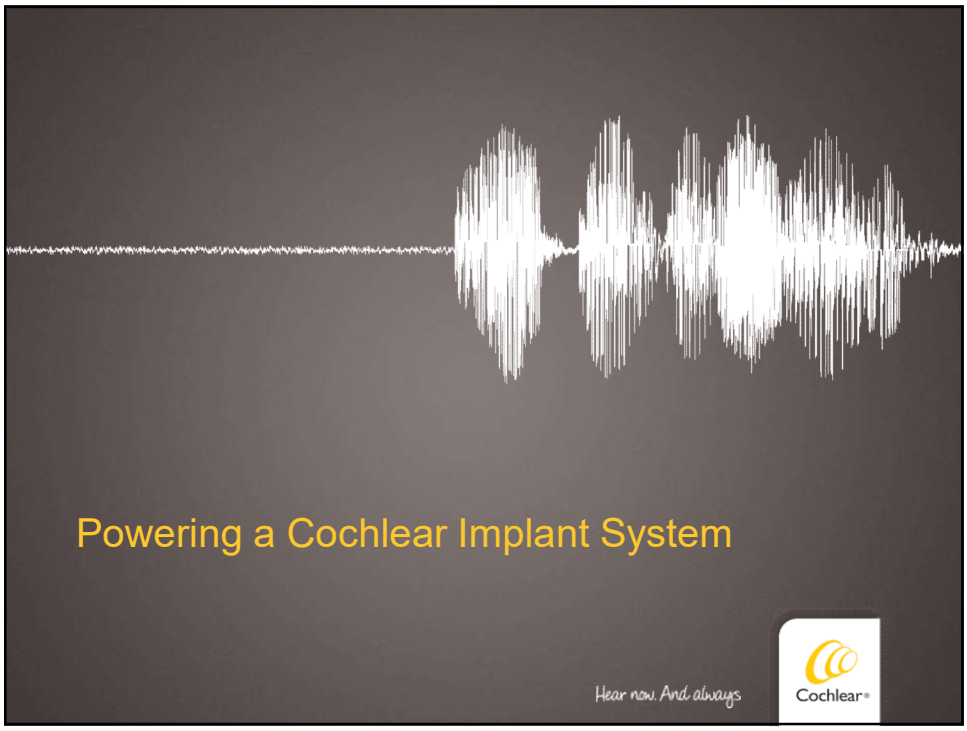
Stimulation Rate: How many times per second each electrode is stimulated during pulsatile stimulation

1 - Pijl, S., Clark, M., Menapace, C., & Hazard, L. (2006) North American Freedom Clinical Trial : Preliminary results in Adults. Cochlear Limited White Paper.

Adding Acoustic Stimulation to MAP



- If recipients are able to utilize residual hearing after surgery, acoustic stimulation can be combined with electrical stimulation
- Frequency boundaries can be set separately for both the acoustic stimulation and the electrical stimulation
- An acoustic component is then used by the recipient



Processor Development

Early sound processors were worn on the body and had a large battery, so power efficiency was not as critical

Ear-level devices mean a need for power efficiency in a small package

Power optimization: Ensuring all channels have enough voltage while maximizing battery life

Powering a CI System

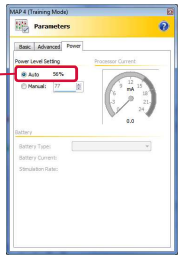
- Typical total power consumption for a cochlear implant system is 30 mW

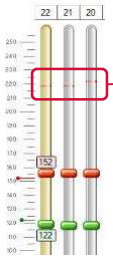
RF Link: Transmission of the signal and power across the skin flap

Powering a CI System

- All power for the implant comes from the batteries on the processor and must be transmitted across the RF link
- When a MAP is loaded to the processor (ie, you "go live" or write maps to processor), Custom Sound® programming software will measure the required power level and also provide compliance limits for the map

Power Level: Ensures the parameters of the map (rate, pulse width, etc) can be maintained

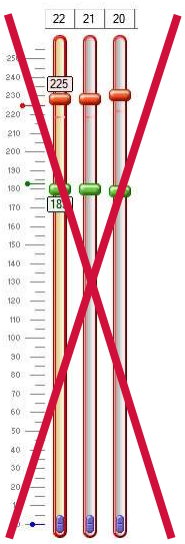


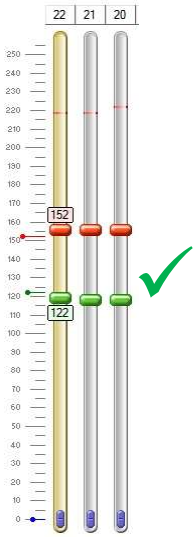


Compliance: Ensures the implant has sufficient voltage to stimulate based on the skin flap, impedances and current level

Powering a CI System

- In the Nucleus® system, the clinician is provided with the information needed to adjust parameters and optimize power
- The following can affect power level and can cause high battery drain:
  - Higher rates of stimulation
  - Higher numbers of Maxima
  - A very thick (or very thin) skin flap
- Do not leave channels out of compliance since recipient can report poor sound quality and have poor performance
  - Increase pulse width to reduce T and C levels and get channels into compliance





HearYourWay™

Cochlear

- Cochlear has a range of options to ensure patients hear their best in any situation
- The majority of our recipients take advantage of SmartSound iQ with SCAN technology

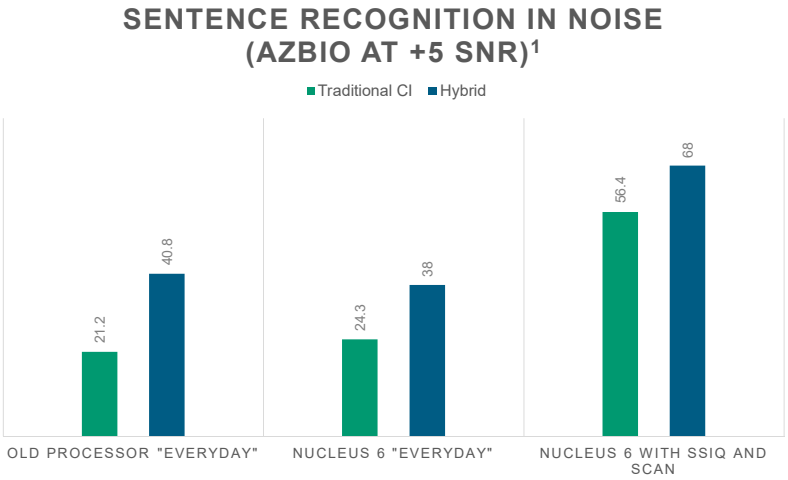
SmartSound® iQ with SCAN

For the best hearing outcomes, recipients need a system that can manage different types of sound automatically.

SmartSound® iQ* has a range of individual technologies that are designed to work together seamlessly.

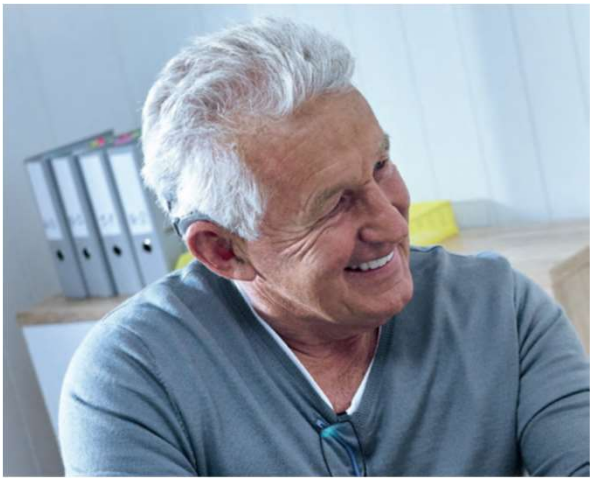
*SNR-NR and WNR are approved for use with any recipient ages 6 years and older, who is able to 1) complete objective speech perception testing in quiet and in noise in order to determine and document performance 2) report a preference for different program settings.

Improving Performance with SSiQ



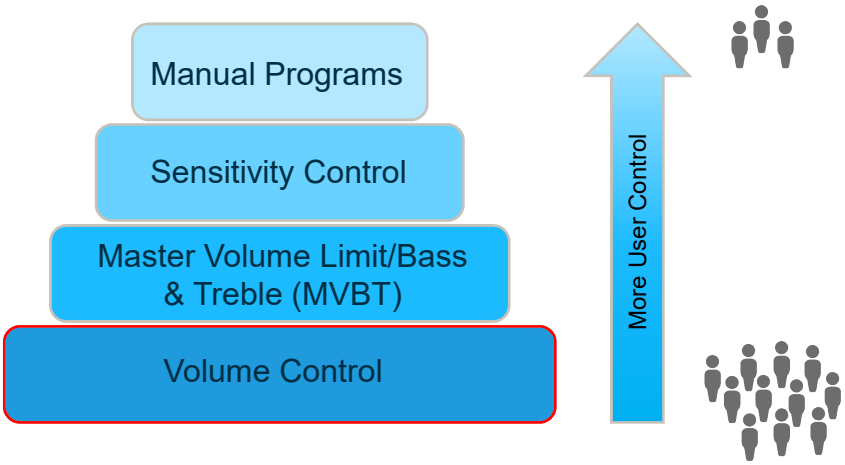
1 – Gilden et al (2015) Improved hearing in nosie using new signal processing algorithms with the Cochlear Nucleus 6 sound processor. Journal of Otology 10(2015): 51-56.

HearYourWay™



- While the majority of recipients will utilize SmartSound iQ with SCAN, some may need more manual control over their listening
- Clinicians can decide on the level of control to provide to each recipient, depending on their needs

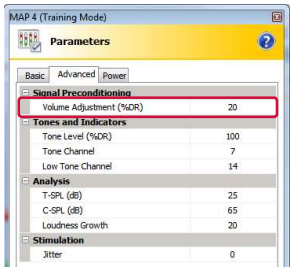
HearYourWay™

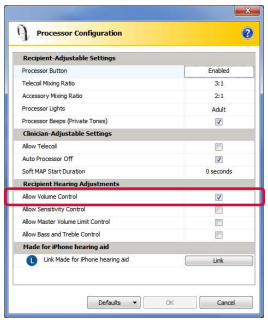


Volume Control

- Controls the output of the implant
- Volume of 10 means stimulation all the way up to C levels
- Set as a percentage of Dynamic Range
  - If set at default of 20%, then Volume of 1 means the highest stimulation levels are set 20% below C levels

Note: because volume affects C levels, it does not have any impact on the volume of the acoustic component





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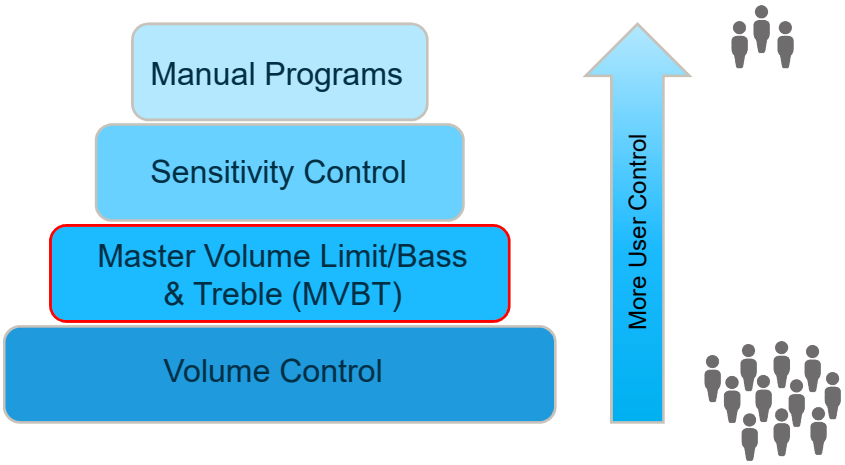
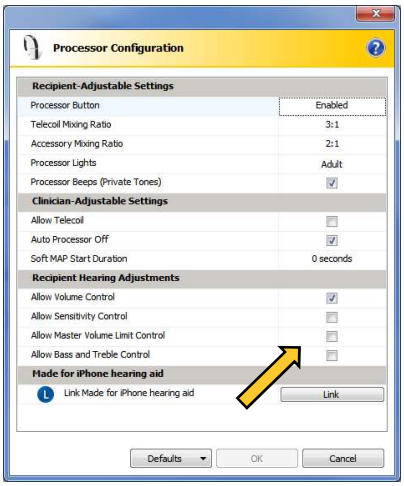


Master Volume Limit, Bass and Treble

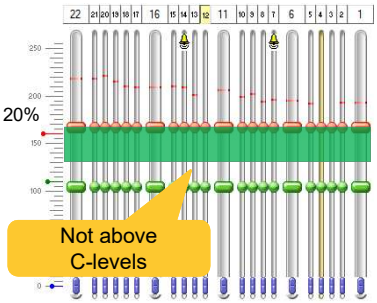
- Gives the recipient the ability to increase the output *above* the originally set C levels either across the electrode (Master Volume Limit) or just in portions of the array (Bass and Treble)
- Only enabled by clinician if it is useful to give this type of control
  - Initial Activation
  - Patients with fluctuating C levels
- Some MAPs may not allow
  - Not available on Hybrid™ MAPs, CIS strategy MAPs and some others
  - Software will warn you if it is unavailable



Volume vs. Master Volume Limit

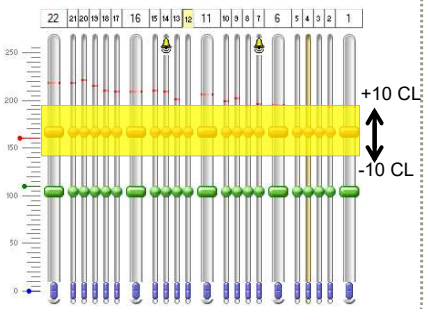
Volume

provides access to the top 20% of the electric dynamic range



Master Volume Limit: 10 CL

provides range just a little above and below the C-levels



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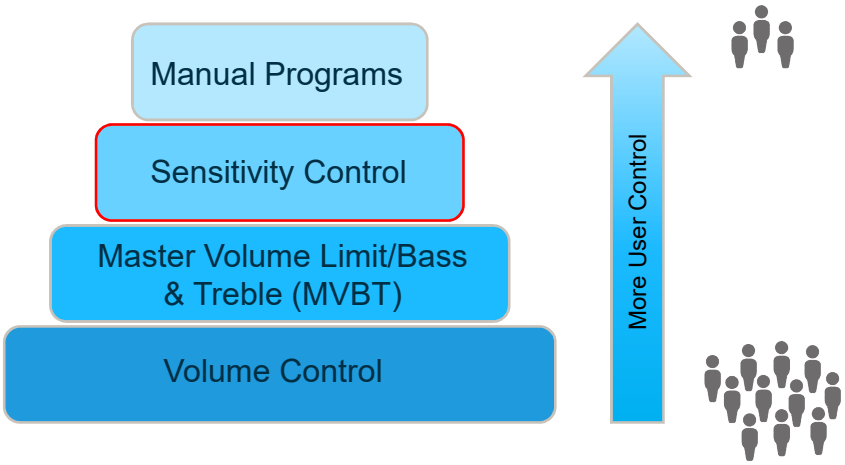
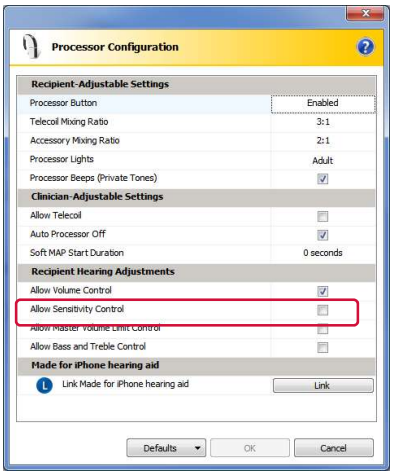


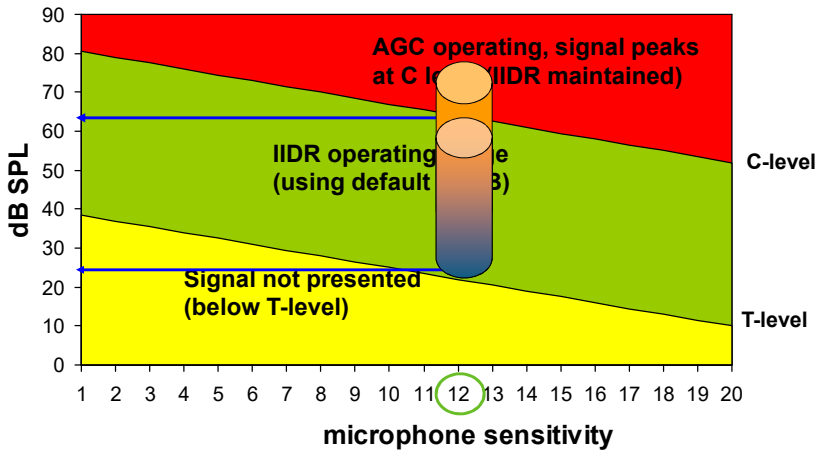
Sensitivity Control

- Controls the input into the processor
- Autosensitivity Control (ASC) is used by most individuals; this is a feature that controls sensitivity automatically
- Manual sensitivity control can be enabled in the processor if desired
- If sensitivity is reduced, input to the processor will be reduced

Note: Sensitivity affects the Acoustic Component output



Sensitivity in Action



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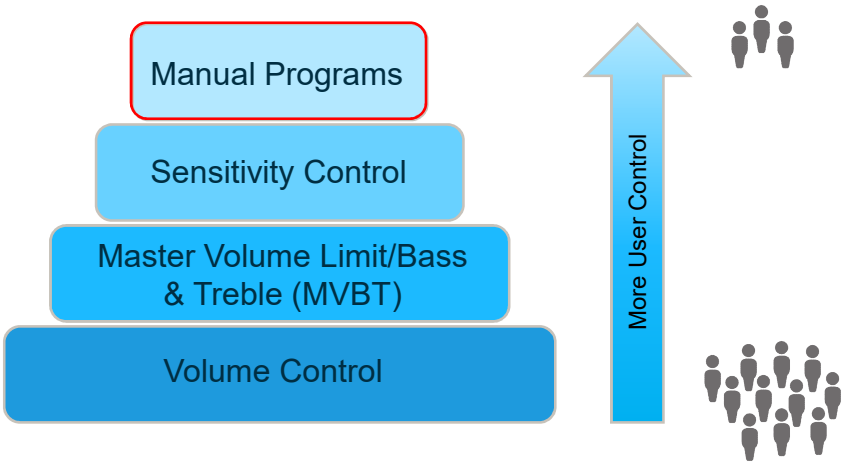
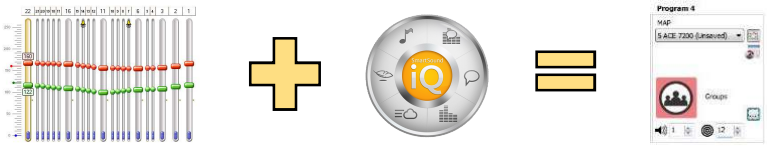


Manual Programs

Four program slots available:

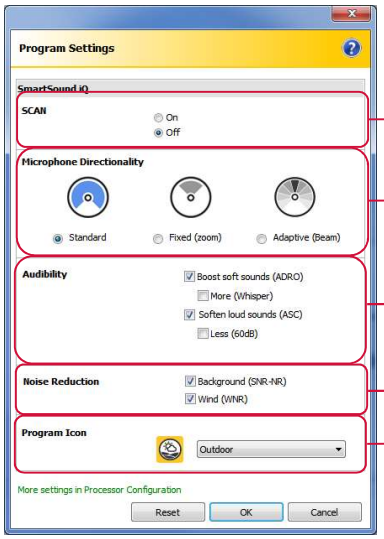


MAP

SmartSound® iQ options

Program

SCAN and SSiQ Options in Custom Sound



SCAN may be

If SCAN is off, clinician can select microphone

Increase or decrease audibility with

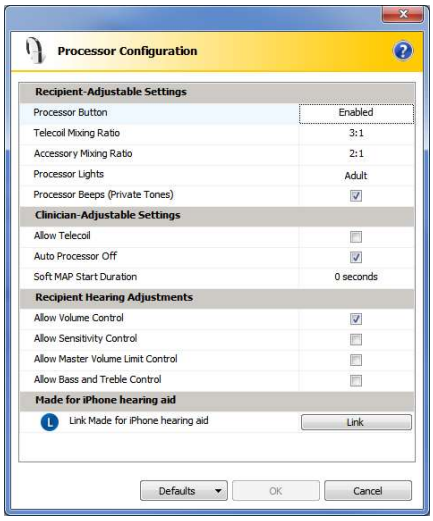
Noise reduction and wind noise

Change the icon the recipient sees for their program

Other User Controls

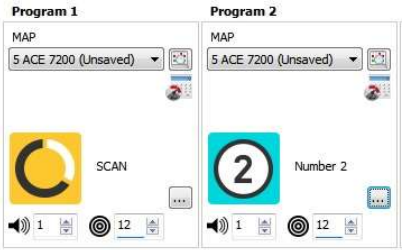
Processor Configuration

- Mixing ratios for Telecoil and Accessories
- Processor lights and alarms
- Soft MAP start duration
- Allow recipient adjustments
  - Volume
  - Sensitivity
  - Master Volume Limit
  - Bass and Treble Control
- Defaults (Adult/Pediatric)



Program Defaults

- Two programs – one SCAN and one manual "everyday" program (with standard mic directionality)
- Volume control enabled
- Master Volume disabled
- Sensitivity control disabled



"Set it and forget it!"

Case Examples

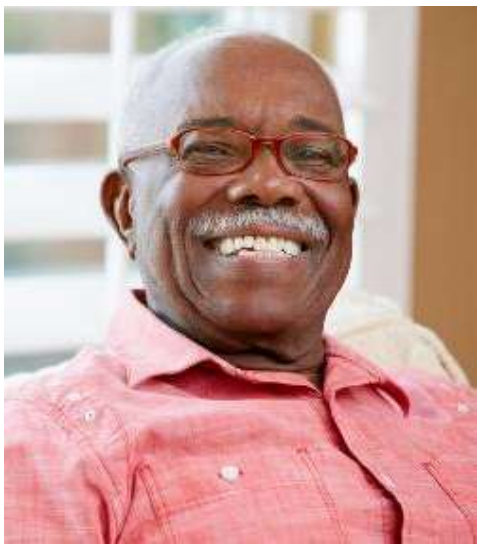
Hear now. And always

Cochlear

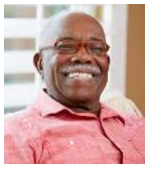
Oscar

Cochlear

- 64 year old man with longstanding sensorineural hearing loss in both ears (unknown etiology)
- Oscar is an electrical engineer who uses an FM system and has several different programs on his current hearing aids that he uses for different situations
- At his first MAPping session, Oscar has a very narrow dynamic range



Oscar (cont.)



- What user options might be useful for Oscar?
- How would you counsel him about the use of these options?

Suggestions:

- Consider giving Master Volume Limit since his dynamic range is so narrow
- He may appreciate volume control
- Begin with default SCAN program and discuss accessory use
- Consider Manual Programs down the road depending on individual needs

Darlene

- 42 year old with longstanding high frequency hearing loss who was a candidate for Hybrid
- Hearing was preserved with a Hybrid L24 implant and Darlene is using the acoustic component[1] along with her Nucleus 6 Sound Processor
- Darlene owns a florist shop which is “busy and noisy”

Darlene (cont.)

- What user options might be useful for Darlene?
- How would you counsel her about the use of these options?

Suggestions:

- A SCAN program is likely to be the most beneficial in her noisy work setting
- Sensitivity affects acoustic component but Volume does not
  - If adjustment is desired for the Acoustic Component, consider Manual Programs with different gain settings

Alex

- Alex is a 3 year old who had a profound sensorineural hearing loss at birth and was implanted at age 2 ½
- Alex spends time at home as well as pre-school and her grandmother's house during the day
- Alex has been wearing her processor regularly and she is starting to make progress with her speech and language development

Alex

- What user options might be useful for Alex?
- How would you counsel Alex's parents about the use of these options?

Suggestions:

- SCAN is disabled by default for Alex's processor because she is under 6
- A single program (Pediatric default of an omnidirectional microphone, Autosensitvitiy and ADRO) might be helpful for ease of use by different caregivers
- Pediatric defaults for user controls include child processor lights and 1:1 mixing ratio for FM; may also disable processor buttons

Review

- MAPs are created by measuring a recipient's Threshold (T) and Comfort (C) levels
- Our goal as clinicians is to ensure a true and comfortable loudness percept across all channels within the voltage compliance (power) limits of the cochlear implant system
- Cochlear's software allows for maximum flexibility in programming; Cochlear's defaults give you a research-based starting-point for your recipients
- User-based controls can be selected and used as desired for each recipient, depending on their preferences and needs

Questions?

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