Auditory Rehabilitation: State of the Art Hearing Aids and Other Factors

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Overview

- Some statistics
- The impaired ear
- Causes of hearing loss
- Hearing aids
- Approaches to rehabilitation
- Prevention?
Hearing loss is a major health concern:

- 30 million in US with hearing impairment
- Prevalence increases with age: 21 million hearing-impaired in US over 45 years of age
- About 30% of people over age 65 need hearing aids
Of these a HUGE percentage are veterans:

- About 414,412 veterans are service-connected for hearing loss
- Another 1.6 million have service-related hearing loss but are not receiving compensation
Army/Marine VA Major Hearing Loss Disability Cases
Percent of Change Since 1986
Study of 141,856 active duty soldiers:

Post-deployment 68% had some form of noise induced injury vs. 4% of non-deployed soldiers

- 29% had permanent threshold shift
- 30% had tinnitus
- 16% had significant HL
- 5.6% had acoustic trauma

Helfer et al, 2005
Types of hearing loss

- Conductive
- Sensorineural
Conductive loss

- Damage to the outer or middle ear
- Effect is attenuate sound level (decrease ‘volume’)
- Maximum loss is about 60dB HL
- Often correctable with surgery

If not correctible, increasing the volume restores audibility & intelligibility
Sensorineural loss

- Damage to the hair cells
- Thresholds are increased
- Experience recruitment and poor frequency resolution

Raising the volume doesn’t solve problems

Much harder to correct with a hearing aid
Differential effects of changes in threshold
Recruitment
Recruitment

Normal UCL
Impaired UCL

Dynamic range of speech

Impaired threshold

Normal threshold

Level (dB HL)
Frequency resolution

- Can think of the cochlear as a bank of auditory filters
- These filters become broadened with SNHL
Picture of auditory filters

Filter response

Frequency
Filter response

Filter in unimpaired ear

Filter in impaired ear

1 kHz

NOISE

SIGNAL

NOISE
Hearing Aids

Hearing aid technology has vastly improved in the last 10 years.

However, hearing aids cannot fully remediate hearing loss.
Hearing aids: what are they?

- are basically sophisticated amplifiers
- cannot improve the signal-to-noise-ratio (yet)
- cannot determine what is ‘signal’ vs. what is ‘noise’
- cannot restore clarity
Hearing Aids: Satisfaction

The good news (Kochkin, 2005):

- HAs 1-4 yrs. old
- HAs <1 yr. old

[Bar charts showing positive and negative satisfaction rates from 1991 to 2004 for different age groups of hearing aids.]
The not-such-good news

Hearing aid use

- 1984: 23.8%
- 1989: 22.9%
- 1991: 22.6%
- 1994: 21.3%
- 1997: 20.4%
- 2000: 22.2%
- 2004: 23.5%

Penetration rate

(Kochkin, 2005)
Hearing Aids: Options

- Style
- Technology
  - Signal processing options
    - ‘Bells and whistles’
- The future
Hearing Aids: Styles

- Behind-the-ear
- In-the-ear
- In-the-canal
- Completely-in-the-canal
- Open canal
## Pros and cons of each style

<table>
<thead>
<tr>
<th>Style</th>
<th>Power</th>
<th>Feedback</th>
<th>Battery size</th>
<th>Ease of insertion</th>
<th>Visibility</th>
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<tbody>
<tr>
<td>BTE</td>
<td>+++</td>
<td>Least</td>
<td>Largest</td>
<td>Can be hard</td>
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<td>++</td>
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<td>Small</td>
<td>Easiest</td>
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<tr>
<td>CIC</td>
<td>+</td>
<td>Most</td>
<td>Tiny</td>
<td>Difficult</td>
<td>1</td>
</tr>
<tr>
<td>Open canal</td>
<td>low gain</td>
<td></td>
<td>Small</td>
<td>Can be hard</td>
<td>1</td>
</tr>
</tbody>
</table>
Hearing Aids: Signal Processing

- Digital versus analog
- Compression
- Directional microphones
- Noise reduction
- Feedback cancellation
Hearing Aids: Digital vs. Analog

- 90% of aids fitted in 2005 were digital
- Describes method of signal processing
- Provides more options but is not intrinsically superior to analog
Addressing threshold changes

Multiple channels that can each be programmed independently

Potentially better ability to meet frequency-gain target and loudness growth issues

In reality there is cross-over between channels i.e. they are not entirely independent
Addressing Recruitment

Compression: gain provided is dependent of level of input signal. With recruitment we want to shrink range of speech levels into a smaller dynamic range.
Recruitment

Normal UCL
Impaired UCL
Impaired threshold
Dynamic range of speech
Normal threshold

Level (dB HL)

0
10
20
30
40
50
60
70
80
90
100
110
120
Compression

Output signal level

Input signal level
Addressing poor frequency resolution

Need to improve the signal-to-noise (S/N) ratio

i.e. level of signal in relation to level of noise
Hearing Aids: Directional Microphones

- Multiple laboratory studies show HAs with directional microphones are more effective than omnidirectional microphones for listening in noise.
Hearing aids: Directional Microphones

Describes the directional sensitivity of the microphone

| BI-DIRECTIONAL | CARDIOID | HYPERCARDIOID | SUPERCARDIOID |
Considerations

- Users often forget to switch settings. Adaptive directionality overcomes this.
- Must mark orientation on impression so the manufacturer can orient mics correctly.
- Need to confirm directionality.
Some examples of polar plots we’ve measured

Banded Noise Polar Plot for Starkey 0307280277 dir

Banded Noise Polar Plot for HA0700259058R hyper

Banded Noise Polar Plot for HA0700258912L hyper

Banded Noise Polar Plot for HA0700258927R hyper
Hearing aids: Noise Reduction

- People like it
- Makes sound more pleasant
- No studies have shown measurable benefit

It has been said that "the best hearing aid is one that will be worn...."
Hearing aids:

Feedback Cancellation

Feedback: occurs when amplified sound leaks out of ear canal and back into amplifier.

Cancellation: the frequency of the feedback signal is estimated and then filtered.

Generally is effective without negative consequences.

Algorithms use an adaptive filter for ongoing control.
Hearing aids: Bells and Whistles

- **Multiple programs**
- **Remote control**
- **Volume control or not**
- **T-coil**

Coil of wire which converts electromagnetic into electrical

Different hearing aid settings are stored in each program. User switches programs as desired.

Small handheld device for switching between programs and controlling volume.

Are pros and cons.
Hearing aids: The Future

Binaural hearing aids: wireless between-aid communication (Blue tooth technology)

- Permits binaural (over bilateral) hearing: localization, release from masking, echo suppression
- Signal processing opportunities: noise cancellation, beam forming
Binaural hearing aids: wireless between-aid and other via (Blue tooth technology)

- cell phone to hearing aid
Hearing aids: User Issues

- Manual dexterity
- Cognitive status
- Expectations
- Lifestyle
Hearing Aids: Manual Dexterity

- Successful HA use requires good manual dexterity (insertion, manipulation, upkeep)
Hearing Aids: Manual Dexterity

Correlations between manual dexterity and HA outcome:

<table>
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<tr>
<th></th>
<th>Manual Dexterity</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Success using HAs</td>
<td>r = 0.555</td>
<td>p&lt; 0.01</td>
</tr>
<tr>
<td>Performance with HAs</td>
<td>r = 0.602</td>
<td>p&lt; 0.001</td>
</tr>
<tr>
<td>Satisfaction with HAs</td>
<td>r = 0.802</td>
<td>p&lt; 0.001</td>
</tr>
</tbody>
</table>

Kumar et al (2000)
Impacts of hearing impairment

- Social
- Psychological
- Occupational
- Family

“Family of non-users more often said the HI relative was CONFUSED, DISORIENTED, ARROGANT & NON-CARING than did family of hearing aid users.”

(Kochkin & Rogin 2000)
Benefits reported following acquisition of a hearing aid:

Hearing aid users & their relatives reported *improvements* in:

- relationships at home
- self-esteem
- mental health
- social, physical & emotional life
Questions to consider when planning auditory rehabilitation

- Is a hearing aid the best solution?
- Are there co-morbid conditions?
- How to assess its effectiveness?
- What individual factors should be considered?
Dual-Sensory Impairment

Presence of both hearing loss and vision loss

Prevalence:
- 1.7 million individuals in the US
- 21% of adults over age 70 have DSI

Veterans with DSI:
- 1995: 179,000
- 2010: 294,000

Goodrich, 1995
Dual-Sensory Impairment: Impacts

- DSI results in significantly more difficulties with ADLs and IADLs than single impairments
- Are the effects additive?
- Presumably 1 + 1 > 2
Dual-Sensory Impairment: Impacts

- Hearing people and vision people don’t communicate
- Dual Sensory Loss Consensus Conference in Portland 2004 revealed more questions than answers
Dual-Sensory Impairment: Clinical Considerations

- Selection of appropriate hearing aids
- Use of hearing aids
- Provision of information
- Functional measures
- Outcome measures
- Clinical collaboration
Cognitive status

Data shows interactions between cognitive status and ability to benefit from sophisticated signal processing

Should be considered when selecting hearing aid processing characteristics
Expectations

- It usually takes many weeks for individuals to decide to acquire a HA after learning they have hearing impairment.
- Thus, by the time of fitting, they have distinct expectations about the HAs.
Expectations

- Expectations affect outcome

Could go either direction:

- Expectations too high → disappointment
- Expectations too low → self-fulfilling prophecy
Lifestyle

Individual needs and wants vary, thus measured outcome might not reflect patient satisfaction if we aren’t helping the patient in situations in which they want to hear.

Water aerobics anecdote!
Assistive Listening Devices

- Personal use items: personal FM system
  - Microphone and FM transmitter
  - Receiver
  - Receiver attached via ‘audioshoe’ to BTE hearing aid

- Alerting devices: vibrating or flashing
  - Alerting devices, clocks etc., low frequency alarms, amplified phones, ring enhancers
Ecological Adjustments
i.e. Improving the Listening Environment

- Background noise
- Room lighting
- Room acoustics

• Move to a quieter place
• Look at the talker
• Turn off noise, e.g. TV, dishwasher
• Use good lighting
• Do not have talker sit in front of a window

Lip reading and facial expressions can increase speech understanding by 20% even without raining

- Use soft absorbent floor and furniture coverings
- Avoid restaurants with hard floors and bare walls
Auditory Retraining Therapies

Aim: to alter neural transmission of sound at the cortical and sub-cortical level to improve timing and synchronization of neural responses.

Relies on neural plasticity of the central auditory system.
**Auditory Retraining Therapies**

- Computer-based, interactive programs
- Require repetitive use
- Tasks are usually adaptive i.e. begin easy and get harder as performance improves
- Jury is out on effectiveness
- Central system or peripheral systems mucked up
- Holds promise for rehab in the future
- Although HL seems simple on surface it is highly complex
- Is a need for understand cause via appropriate eval. prior to rehab. beginning
- Technology has vastly improved
- Will continue to do so
- However, non-tech rehab still necessary
- When hearing loss is present and need rehab. a holistic approach should be used
REFERENCES


Add pretty picture

- Contact info.
- My email address
- Center website
- Director Steve F
My butt hurts!

What?!!