Hearing aid technology and the future

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Improving signal to noise ratio:

Directional microphones
Effect of decreasing noise

Percent words correct vs. Signal to noise ratio (dB)

BKB sentences: Moore, Johnson, Clark & Pluvinage, 1992
Directional microphones
Directional microphone

Principles

Front

\[ d \]

\[ + \]

\[ - \]

\[ T \]
The cardioid family

Super

Hyper

Figure-8
Figure 7.4 A simple adaptive directional microphone with steerable nulls.

Source: Dillon (2001): Hearing Aids
Figure 2.8  Directional sensitivity of (a) an omnidirectional (solid line) and (b) a directional (dotted line) microphone, mounted on the head at 2 kHz. Data adapted from Knowles, TB21.
Multi-band adaptive directional microphone

Diagram showing a system with components labeled "Filter," "Adapter," and "Output." The system includes a symbol representing a filter, an addition symbol, and a subtraction symbol, with arrows indicating the flow of data.
Super-directional microphone

Combined cancellation

Front
Figure 7.1 (a) Block diagram of a subtractive directional microphone comprised of either a single microphone with two ports, or two separate microphones with one port each. The negative sign next to one of the inputs of the summer indicates that the two signals are subtracted. (b) A delay-and-add directional microphone array with four ports.

Source: Dillon (2001): Hearing Aids
Figure 7.3 End-fire and broadside microphone arrays.

Source: Dillon (2001): *Hearing Aids*
Room acoustics

- SPL
- Critical distance
- Total
- Reverberant
- Direct
- Distance
Question 3: What are the characteristics of the everyday listening situations that favor either the OMNI or the DIR microphone mode?

Answer: Environmental characteristics that favor...

<table>
<thead>
<tr>
<th>Omnidirectional</th>
<th>Directional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talker located other than front</td>
<td>Talker located in front</td>
</tr>
<tr>
<td>Background noise absent, very soft, or very loud</td>
<td>Moderate background noise present</td>
</tr>
<tr>
<td>In cars or out-of-doors</td>
<td>Talker distance &lt; 20 feet</td>
</tr>
<tr>
<td>Smaller rooms</td>
<td>Larger Rooms</td>
</tr>
<tr>
<td></td>
<td>People as background noise</td>
</tr>
</tbody>
</table>

B Walden
Directional microphones – where?

- Directionality works when:
  - Talker or dominant noise are closer than about 2x critical distance
- Adaptive directionality provides extra benefit when:
  - Dominant noise or noises are closer than about 2x critical distance
Occlusion and occlusion reduction
Occlusion effect generation
Generation mechanism
Occlusion effect generation as a function of earmold length

Increase in SPL in the ear canal (relative to no earmold) when a person talks, for the octave centred on 315 Hz.

![Graph showing occlusion effect generation as a function of earmold length.](image)
Solution 1 – deep fitting

Super soft material required!
**Figure 5.17** Axial view of earmolds or shells that produce a very strong occlusion effect (A), and a very weak occlusion effect (B). The mold or shell shown in (C) will produce a weak occlusion effect and will also have minimal leakage of sound from the hearing aid. In each case, the wavy lines show the vibrating anterior wall and the arrow shows the primary direction in which bone conducted sound will travel once it enters the ear canal. The looseness of fit in each diagram has been exaggerated for clarity.

Source: Dillon (2001): *Hearing Aids*
Solution 2a: Large vent BTE

Relies on feedback cancellation
  – Probable further improvements
Solution 2b: Open fitting BTE

Relies on feedback cancellation
– Probable further improvements
Figure 5.16 The mean increase in SPL (relative to no earmold) in the ear canal for 10 subjects, as they talked while wearing earmolds with vents of different sizes (May & Dillon, 1992).

Source: Dillon (2001): Hearing Aids
Figure 5.10 Effect of different sized vents on the frequency response of amplified sound, relative to the response with a tightly fitting earmold or earshell (Dillon, 1985).

Source: Dillon (2001): Hearing Aids
Feedback management

- Whistling occurs when amplification > leakage

- Standard solutions:
  - plug ear tightly  
  - decrease high frequency amplification  
  - turn volume down  

[Diagram of ear with feedback]
Feedback management

Desired

Hearing aid gain (dB)

Frequency (Hz)
Unsophisticated aid

Desired
Feedback management

Hearing aid gain (dB)

Frequency (Hz)

125 250 500 1000 2000 4000 8000
Feedback cancelling

External leakage path
A Trainable Hearing Aid

Justin Zakis, Gitte Keidser, Liz Convery, Hugh McDermott
Existing hearing aids

- Fitted in a quiet clinic, away from real-life environments encountered in everyday life.
- Fitted with a prescription based on averages
- No customization possible in real-life environments
- User returns to clinic if aid unsatisfactory
- User returns hearing aid if too unsatisfactory
Trainable hearing aid concept

• Fitted in a clinic with a prescriptive procedure, in a similar way to a typical hearing aid.

• The **aid user** then customizes the amplification settings to his/her individual preference *outside the clinic*, in everyday acoustic environments.

• The **aid** notes the users’ preferences and the characteristics of the environment at that time.

• The aid **predicts** the user’s preference in every future environment, but will accept future training at any time.

*Dillon, NAL*
Aid user adjusts settings...
Aid user adjusts settings...
...then presses voting button
Process repeats for other sounds
After training, preferred settings are automatically applied...
After training, preferred settings are automatically applied...
After training, preferred settings are automatically applied...
After training, preferred settings are automatically applied...
Training gain, CR, CT.

Gain (dB)

Input level (dB SPL)
Trainable aid – general structure

Diagram:
- Acoustic measurement module
- Learning algorithms
- Programmable amplifier
- User Control(s)
Prototype trainable aid

- Stereo Hearing Aid Research Processor (SHARP)
- Fully-programmable digital hearing aid

Dillon, NAL
First and Second Comparison Trial Results

* p < 0.05
** p < 0.01

Only S201 had a statistically significant difference in scores between comparison trials (p = 0.0176)

Dillon, NAL
Advantages for Clients

• Can customise the sound of aid in environments they encounter, which cannot be reproduced in a clinic.

• More parameters can be trained, simultaneously or sequentially, than can be practically set in the clinic.

• Can retrain the aid at any time if preferences or environments change.

• Fewer return visits to the clinic.

• Better hearing in more environments.

• Greater confidence to use hearing aid more often.

• Sense of ownership and personalisation over fitting process and the aid.  

Dillon, NAL

/ resynthesis
Advantages for Audiologists

• No return visits to adjust the gains for different acoustic conditions
• No return visits due to acclimatisation effects
• More time to see new clients
• More time to spend on counseling, assistive listening devices, use with telephone, etc.
• Less need to accurately adjust the aid during fitting
• Less need for real-ear measurements

Dillon, NAL
Blind Source Separation and APD
Time differences

Variation of the source direction in the horizontal plane.

\[ t = \frac{d}{c} \]

Far ear       Near ear

Source: Dillon (2001): Hearing Aids
Head-shadow effect
Reduced auditory processing ability
Linked binaural noise reduction

- combined inputs from both sides of the head to improve SNR

6 mm

Jorge Mejia
Integration with communication devices
Things in your ears

- **Now:**
  - mobile phones,
  - MP3 players,
  - portable DVD players,
  - personal digital assistants,
  - and of course ..... hearing aids.

- **In the future:**
  - personal navigation aids,
  - ultra-localised communication systems (e.g. museums),
  - local area (human communication) wireless networks,
  - ........ all voice controlled, of course
Integration with communication devices

- Headset device as a hearing aid, with Bluetooth communication to:
  - mobile phone
  - personal digital assistant

Diag. mic + rem control

Bluetooth

FM

Acoustic
Integration with communication devices

- Bluetooth receiver on hearing aid:
Integration with communication devices

- Communication device look-alike hearing aids
- Telephone with bone-conduction output
- Mobile phones with multi-band compression processing, programmable for individual
- ......... Headset device as a hearing aid, with Bluetooth communication to:
  - mobile phone
  - personal digital assistant
MP3 player?

The Listenor® assistive listening device from Westone
Acquiring a hearing aid (2010)
- I need a wireless earpiece for my mobile phone & PDA
- Oh, it works as a hearing aid too?
- I don’t need that, but since it’s included …

Consequence of integration and effectiveness:
- Hearing aids are high tech devices

Necessity for devices to merge?
Bimodal devices

Teresa Ching, Emma van Wanrooy, Mandy Hill
Binaural-bimodal fitting

Hearing aid

Cochlear implant
Benefit from binaural-bimodal

Speech perception

- Sentences in Quiet
- Sentences in Noise
- Words in Quiet
- Sentences in spatially separated Noise

CIHA - CI scores (%)

Averaged thresholds at 0.5, 1, 2 kHz (dB HL)

Ching et al, in press
Complementary nature of hearing aids and cochlear implants

For people with severe hearing loss:

- Hearing aids - most effective for low-frequency cues and pitch / timing
- Cochlear implants - most effective for high frequency cues and spectral shape
- Implanting does not destroy potential for conventional acoustic aiding …..
Combining hearing aids and implants

1. Hearing aids and implants in opposite ears
   - Now recommended practice
   - Fine-tuning of hearing aid beneficial

2. Hearing aid and implant in same ear
   - Separate devices
   - Short electrode used so far

3. Combined hearing aid and implant
Hearing loss characteristics

Doubling of patients for each 12 dB decrease

Implant-equivalent hearing loss
But for how long …..?
Growing hair cells (in chickens and mice)

Li, Roblin & Heller 2003
Replacing the battery

- Scala vestibuli
- Scala media
- Scala tympani
- Organ of Corti
- Basilar membrane
- Auditory nerve
- Stria vascularis
- Battery
Thanks for listening

Slides from:

www.nal.gov.au