Perceptual benefits of Siemens hearing aid features: Supporting research evidence

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About this presentation

- Summarizes all (important) recent studies and publications on benefits of Siemens hearing aid features
- Each study is summarized on two slides: study design & main result
- Contents are also included in an elearning course ("Hearing it all: The Innovations in Siemens Hearing Systems")
- Intended use: presentation of select chapters in customer meetings (e.g. only studies on e2e wireless or just one study per feature)
Evidence-based Fitting Principles

Considerations when formulating evidence-based fitting principles

1. Does the technology work in an ideal setting?
2. Does the technology work in the real world?
3. Is the cost of the technology worth the benefit to the wearer?
Evidence-based Fitting Principles

**Efficacy**: Does it work in an ideal setting?

**Effectiveness**: Does it work in the real world?

**Efficiency**: Is it worth it?

These terms are defined in, and part of the AAA Guidelines for the Audiological Management of Adult Hearing Impairment.

Website: [http://www.audiology.org/](http://www.audiology.org/)
Efficacy: Does it work in an ideal setting?

This is the extent to which an intervention does more good than harm. This type of testing is often conducted under relatively ideal circumstances (e.g., adaptive directional microphone technology compared with a fixed polar pattern in an anechoic room).
Effectiveness: Does it work in the real world?

Assesses if an intervention does more good than harm when used in a the real world (e.g., adaptive directional microphone technology compared with a fixed polar pattern under actual patient use conditions).
Efficiency: Is it worth it?

Is the effect of an intervention worth the additional cost that may be related to its use? Is the intervention cost-effective? (e.g. is the additional cost to the patient worth the benefit obtained with directional microphones?)
Perceptual Benefits
Supporting Research Evidence

- Speech & Noise Management System
- SoundSmoothing
- Directional Microphone System
- TruEar
- e2e wireless 2.0
- Learning
- Pediatrics
- eARena
Recent studies with Siemens hearing aids employing the Speech & Noise Management System:

- Amplification with Digital Noise Reduction and the Perception of Annoying and Aversive Sounds (Palmer et al. 2006)
- The Effects of Digital Noise Reduction on the Acceptance of Background Noise (Mueller et al. 2006)
- Sound Quality Measures for Speech in Noise through a Commercial Hearing Aid “Implementing Digital Noise Reduction” (Ricketts & Hornsby 2005)
- Study finds real-world benefit from digital noise reduction (Powers et al. 2006)
Amplification with DNR and the Perception of Annoying and Aversive Sounds (Palmer et al. 2006)

Palmer CV, Bentler RA, Mueller HG. Trends in Amplification, 10(2), 95-104.

- Conducted at the University of Iowa, USA.

- 49 hearing-impaired subjects and 30 normal-hearing individuals rated their unaided and aided (DNR-on) annoyance for two different stimuli: dinner party noise and traffic noise.

- The noises were rated on an 11-point scale ranging from: 0= Very Annoying to 10=Not Annoying At All.

- Using paired-comparisons, subjects selected preference for the “on” or “off” setting.
Amplification with DNR and the Perception of Annoying and Aversive Sounds (Palmer et al. 2006)

This DNR algorithm reduces annoyance from noise to that of young, normal-hearing individuals.

- Traffic noise
- Dinner noise

Not annoying at all

Very annoying

Unaided
Aided (DNR max)
Normal

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The Effects of Digital Noise Reduction on Acceptance of Background Noise (Mueller et al. 2006)


- Conducted at Vanderbilt University, USA.

- ANL = MCL (of conversational speech) – BNL (acceptable background noise level).

- ANLs of 10 dB or less are predictive of successful hearing aid use.

- ANL was measured with 22 subjects in three conditions: unaided, aided DNR-On, aided DNR-Off.
The Effects of Digital Noise Reduction on Acceptance of Background Noise (Mueller et al. 2006)

This DNR algorithm reduces the annoyance of noise to a level that has been shown to improve hearing aid satisfaction.
Sound Quality Measures for Speech in Noise through a Commercial Hearing Aid Implementing Digital Noise Reduction (Ricketts & Hornsby 2005)


- Conducted at Vanderbilt University, USA

- Subjects listened to speech-in-noise for two different noise conditions:
  - “Low”: overall level of 71 dB, SNR of +6 dB
  - “High”: overall level of 75 dB, SNR of +1 dB

- Testing was conducted for both omni and directional settings and with DNR on and off in both conditions.

- Using paired-comparisons; subjects selected preference for the “on” or “off” setting.
Sound Quality Measures for Speech in Noise through a Commercial Hearing Aid Implementing Digital Noise Reduction (Ricketts & Hornsby 2005)

This DNR algorithm is preferred for different laboratory listening conditions.
Study Finds Real-World Benefit from Digital Noise Reduction (Powers et al. 2006)


- Data collected at two independent clinics.
- 21 subjects rated their preference for DNR “off” versus “on” in real world for 10 days.
- Subjects were blinded regarding what program was DNR-off and what program was DNR-on.
- Synchronized bilateral settings ensured by activating e2e wireless.
Study Finds Real-World Benefit from Digital Noise Reduction (Powers et al. 2006)

This DNR algorithm is preferred by subjects in the real world.
Recent studies with Siemens hearing aids employing the Speech & Noise Management System show that:

- This DNR algorithm reduces annoyance from noise to that of young, normal-hearing individuals (Palmer et al. 2006).
- This DNR algorithm reduces the annoyance of noise to a level that has been shown to improve hearing aid satisfaction (Mueller et al. 2006).
- This DNR algorithm is preferred for different laboratory listening conditions (Ricketts & Hornsby 2005).
- This DNR algorithm is preferred by subjects in the real world (Powers et al. 2006).
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Recent studies investigating SoundSmoothing:

- Evaluation of a noise-reduction algorithm that targets non-speech transient sounds (Keidser et al. 2007)
- Comparison of Transient Noise Reduction Systems (Chalupper & Branda 2008)
Evaluation of a Noise-Reduction Algorithm that Targets Non-Speech Transient Sounds (Keidser et al. 2007)


- National Acoustics Laboratories, Australia

- 21 hearing-impaired subjects rated preference in a forced choice, paired comparison test

- Two conditions: SoundSmoothing on and off

- Stimuli: Speech in six different acoustic situations
Strong preference for SoundSmoothing in situations with transient sounds.
Comparison of Transient Noise Reduction Systems (Chalupper & Branda 2008)


- Electroacoustic measurements recorded from KEMAR using slim tube BTE with closed tip: attenuation of transients and difference between RMS and transient level

- Frequency response of Siemens CENTRA Life set to match that of competitive device to rule out difference effects.

- Test stimuli:
  - Real-world sounds (e.g. hammering, clattering dishes)
  - Synthetic sounds providing added control over the input signal
  - Presented and recorded at different input levels & durations
Comparison of Transient Noise Reduction Systems (Chalupper & Branda 2008)

SoundSmoothing is more effective than competitive transient noise reduction systems
Recent studies investigating SoundSmoothing show:

- SoundSmoothing is strongly preferred in situations with transient sounds (Keidser et al. 2007).
- SoundSmoothing is more effective than competitive transient noise reduction systems (Chalupper & Branda 2008).
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Recent studies with Siemens hearing aids employing adaptive directional microphones:

- Hearing-in-Noise: Comparison of Listeners with Normal and (Aided) Impaired Hearing (Bentler et al. 2004)
- Adaptive Directional Benefit in the Near Field: Competing Sound Angle and Level Effects (Ricketts et al. 2005)
- An Evaluation of Directional Technology Utilizing Frequency-Specific Adaptive Polar Patterns (Hamacher et al. 2006)

- Multi-center study at University of Iowa and University of Pittsburgh, USA

- Speech intelligibility in noise of 48 young, normal-hearing listeners was compared to the performance of 46 listeners with documented hearing loss.

- Speech presented from front, noise randomly presented from six loud speakers around subject (diffuse sound field)

- Speech intelligibility in noise assessed with the HINT (Hearing In Noise Test)
Hearing-in-Noise: Comparison of Listeners with Normal and (Aided) Impaired Hearing (Bentler et al. 2004)

With this directional microphone system, hearing-impaired individuals performed similarly to young normal hearing listeners.
Adaptive Directional Benefit in the Near Field: Competing Sound Angle and Level Effects (Ricketts et al. 2005)

Ricketts TA, Hornsby WY, Johnson EE. Seminars in Hearing, 26(2), 59-69.

- Vanderbilt University, USA
- Fourteen bilaterally fitted adult listeners with sloping, sensorineural hearing loss
- HINT benefit (relative to omni) for fixed and moving noise was measured
- Comparison of fixed and adaptive polar pattern
Adaptive Directional Benefit in the Near Field: Competing Sound Angle and Level Effects (Ricketts et al. 2005)

This adaptive directional microphone system improves speech intelligibility even for moving noises.
An Evaluation of Directional Technology Utilizing Frequency-Specific Adaptive Polar Patterns (Hamacher et al. 2006)


- Hörzentrum Oldenburg
- 20 hearing impaired subjects
- Speech performance measured with three microphone modes (omni, broadband fixed, multichannel adaptive)
- Adaptive Oldenburg Sentence Test used
An Evaluation of Directional Technology Utilizing Frequency-Specific Adaptive Polar Patterns (Hamacher et al. 2006)
In special environments, multichannel directivity can improve speech intelligibility by ~1dB
Recent studies with Siemens hearing aids employing adaptive directional microphones proved that:

- With this directional microphone system, hearing-impaired individuals performed similarly as young, normal hearing listeners (Bentler et al. 2004)

- This adaptive directional microphone system improves speech intelligibility even for moving noises (Ricketts et al. 2005)

- This multichannel adaptive directional system reduces noise more effectively than a broadband system if noise sources with differing spectra are present (Hamacher et al. 2006)
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Perceptual benefits
TruEar

Recent study with Siemens hearing aids employing TruEar:

- The effect of frequency-specific directionality on horizontal localisation (Keidser et al. 2008)
The Effect of Frequency-Specific Directionality on Horizontal Localisation (Keidser et al. 2008)


- National Acoustics Labs, Australia
- Localization measurement with 24 hearing impaired subjects: Front-back discrimination errors
- Omni vs. TruEar vs. Full directional
- 5 different stimuli:
  - 3 kHz octave band noise
  - 0.4 kHz octave band noise
  - Cockatoos
  - Traffic
  - Speech
For all signals with components above 2 kHz, TruEar significantly reduces front-back confusion.
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Recent studies with Siemens hearing aids employing e2e wireless:

- The effect of WDRC, DNR, and directional microphone on horizontal localization performance in hearing aid wearers (Keidser et al. 2006)
- Real world preferences for linked hearing aids (Smith et al. 2008)
- Benefits of wireless functionalities in hearing aids (Chalupper 2008)
- Strategies for Telephone Listening for People with Hearing Loss (Ricketts et al. 2008)
- Evaluation of a trainable hearing aid: effectiveness of volume and treble control (Keidser et al. 2008)
- Benefit of treble control for interactive finetuning of hearing aids (Stephan & Latzel 2008)
The effect of compression, noise reduction, and directional microphone on horizontal localization performance in hearing aid wearers (Keidser et al. 2006)


- National Acoustics Labs, Australia
- 12 subjects fitted bilaterally with BTEs
- Horizontal localization tested using a 360 degree speaker array & broad band pulsed pink noise
- Microphone configurations:
  - Cardioid / Cardioid
  - Cardioid / Omnidirectional
  - Cardioid / Figure 8 (bidirectional)
The effect of compression, noise reduction, and directional microphone on horizontal localization performance in hearing aid wearers (Keidser et al. 2006)

Synchronized microphones required for good localization.
Real-world Preferences for Linked Bilateral Processing (Smith et al. 2008)


- University of Manchester, England

- 30 participants, 3 locations (Leicester, Manchester and Wrexham) crossover design

- Test conditions:
  - One hearing instrument
  - Two instruments without synchronization
  - Two hearing instruments synchronized

- Preference after daily use
Real-world Preferences for Linked Bilateral Processing (Smith et al. 2008)

Majority of subjects prefers linked hearing aids in real world
Benefits of wireless functionalities in hearing aids
(Chalupper 2008)

Chalupper J, presented at the convention of the Audiological Society of Australia, Canberra, 2008

- SAT, Erlangen, Germany
- 10 subjects
- Experiment 1: Sound quality when watching TV
- Experiment 2: Speech intelligibility with Tek Connect
Benefits of wireless functionalities in hearing aids (Chalupper 2008)

Experiment 1: TV

- Sound quality when watching TV with low delay Bluetooth transmitter (“Tek Transmitter”)
- 10 subjects, moderately sloping hearing loss
- Bilaterally fitted with Pure 700 S (open and closed domes)
- Watching TV, sound transmitted via Bluetooth AND acoustically

- Quantitative sound quality:
  
  extremely unpleasant  →  extremely pleasant
Benefits of wireless functionalities in hearing aids (Chalupper 2008)

Experiment 1: Quantitative sound quality

Wireless conditions equal (open) or better (closed)

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Benefits of wireless functionalities in hearing aids
(Chalupper 2008)

Experiment 2: Phone

- Speech intelligibility in noise (at wearer end and caller’s end) for wireless “binaural” phone
- 10 subjects, moderately sloping hearing loss
- Bilaterally fitted with Pure 700 S (open and closed domes)
- 55 dB noise at wearer end, SNR varied at caller’s end (German triplet digit test, phone service)

- Monaural microphone
- Monaural wireless (Mic attenuated by 6 dB)
- Binaural wireless (Mic attenuated by 6 dB)
Benefits of wireless functionalities in hearing aids (Chalupper 2008)

Experiment 2: Phone

Binaural wireless can improve SNR by 4 dB compared to microphone
Strategies for Telephone Listening for People with Hearing Loss (Ricketts et al. 2008)

Ricketts T, Picou E. In preparation.

- Vanderbilt University, USA

- 20 subjects with mild-to-moderate sloping loss

- Test conditions:
  - Telephone acoustically
  - Clean (Bluetooth only) and mixed (BT + Mic) monaural
  - Clean (Bluetooth only) and mixed (BT + Mic) binaural

- Question 1: Improvement binaural vs. monaural?
- Question 2: Improvement re telephone acoustically?
Binaural wireless phone transmission can improve SNR by up to 5.7 (!) dB compared to monaural transmission.
Binaural wireless phone especially beneficial for more severe hearing losses (Motion). Mild losses can use direct sound (Vibe).
Evaluation of a trainable hearing aid: effectiveness of volume and treble control (Keidser et al. 2008)


- NAL, Australia
- 29 subjects with bilateral, sensorineural hearing loss
- Pure 700 + Tek Connect

Question 1: Do patients use SoundBalance in real world?
Question 2: Do user controls (VC & SoundBalance) help to improve speech clarity and sound comfort?
Evaluation of a trainable hearing aid: effectiveness of volume and treble control (Keidser et al. 2008)

Tek Connect is easy to use. Majority of patients use both VC and SoundBalance
With Tek Connect, hearing aid users achieve better speech clarity and sound comfort most of the times.
Benefit of treble control for interactive finetuning of hearing aids (Stephan & Latzel 2008)

Stephan K, Latzel M. In preparation.

- Medical University Innsbruck, Austria
- 15 experienced subjects with mild-to-moderate sloping loss
- Pure 500 & Tek Connect in real life
  - Condition 1: VC only
  - Condition 2: VC & SoundBalance
- Categorical rating (0 – 10) of satisfaction and listening effort
SoundBalance improves real world satisfaction and reduces listening effort.
Recent studies with Siemens hearing aids employing e2e wireless or Tek:

- Synchronized microphones are required for good localization (Keidser et al. 2006)
- Majority of subjects prefers linked hearing aids in real world (Smith et al. 2008)
- Binaural wireless phone can improve SNR by 4 dB compared to microphone (Chalupper 2008)
- Binaural wireless phone transmission can improve SNR by up to 5.7 (!) dB compared to monaural transmission (Ricketts et al. 2008)
- With Tek Connect, hearing aid users achieve better speech clarity and sound comfort most of the times (Keidser et al. 2008)
- SoundBalance improves real world satisfaction and reduces listening effort (Stephan & Latzel 2008)
Perceptual benefits
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Recent studies with learning hearing aids from Siemens:

- Changing how gain is selected: The benefits of combining datalogging and a learning VC (Chalupper & Powers 2006)

- From Data Logging to Data Learning (Powers, Chalupper, Heuermann 2007)

- Optimizing compression, frequency shape and overall gain in everyday life (Chalupper et al. 2008)
Changing How Gain is Selected: The Benefits of Combining Datalogging and a Learning VC (Chalupper & Powers 2006)


- Hörzentrum Oldenburg, Germany
- 18 experienced hearing instrument wearers with moderate-to-severe hearing loss
- Bilaterally fitted with the CENTRA P
- Three different programs:
  - “Universal”
  - “Music”
  - “Telephone”
Changing How Gain is Selected: The Benefits of Combining Datalogging and a Learning VC (Chalupper & Powers 2006)

- On the average, gain was optimal after First Fit
- Most people are different than “average”!
- VC Range: -6 dB to 9 dB
Loudness preferences are individual and program specific.

- Hörzentrum Oldenburg, Germany

- 2 groups of subjects with downward sloping, symmetrical SNHL:
  - 19 subjects as new wearers of amplification
  - 20 subjects were experienced wearers of amplification

- Bilaterally fitted with the CENTRA P & target matched to NAL-NL1

- Real world learning for 1 week was recorded, then gain reset to target. Week 2 real world learning then recorded & compared to week 1.
Preferred loudness is learned with high precision.

- SAT, Erlangen, Germany
- 8 adult subjects with moderately sloping, symmetrical SNHL. All were experienced wearers of amplification
- Initial fitting: NAL-NL1 minus 3 dB
- Bilaterally fitted with the Pure RIC BTE
- Only 1 program available during study
Optimizing Compression, Frequency Shape and Overall Gain in Everyday Life (Chalupper et al. 2008)

Visit 1
- Starting point = First Fit
- Speech test, questionnaires, probe mic

Home trial week 1: learning

Visit 2
- Speech test, questionnaires, probe mic

Home trial week 2: learning cont’d

Visit 3
- Speech test, questionnaires, probe mic

Home trial week 3: Preference
- SoundLearning & VC/TC disabled
- Prog A: Trained setting, Prog B: First Fit
Most subjects are able to teach gain and treble without degrading speech intelligibility – even for soft input levels.
Most subjects clearly prefer learned setting over initial setting.
Recent studies with learning hearing aids from Siemens show:

- Learning VC accounts for individual, situation specific loudness preferences (Chalupper & Powers 2006)
- Preferred loudness is learned with high precision (Powers, Chalupper, Heuermann 2007)
- Most subjects clearly prefer learned setting over initial setting (Chalupper & Powers 2008)
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Research on signal processing features in pediatric fitting

- Impact of Digital Noise Reduction on Pediatric Performance (Bentler et al. 2008)

- Evaluation of Directional Microphones in Hearing Aid Fittings for Children (Ching et al. 2008)
Does DNR affect sound quality, speech intelligibility and novel word learning?

Subjects:
- 50 children (28 boys, 22 girls)
- Age 5 – 10 years (mean 8.05)

Tasks:
- Speech intelligibility in noise
- Novel word learning
- Sound quality
Impact of Digital Noise Reduction on Pediatric Performance (Bentler et al. 2008)

Small, but significant improvement of speech intelligibility

CASPA (Phoneme recognition)
- Small, but significant improvement of speech intelligibility

![Graph showing word recognition percentage with and without noise reduction]

- SR off
- SR on
Impact of Digital Noise Reduction on Pediatric Performance (Bentler et al. 2008)

In most situations, noise reduction improves ease-of-listening for the majority of children.
Impact of Digital Noise Reduction on Pediatric Performance (Bentler et al. 2008)

DNR does not affect novel word learning
Language acquisition not degraded
National Acoustics Laboratory (AUS)
Teresa Ching, Anna O’Brien, David Hartley, Lisa Hartley, George Raicevich, Catherine Morgan, Harvey Dillon

What proportion of time do pre-school age children benefit from directional microphone technology in hearing aids?

Subjects:
- 27 children
- 6 months to 6 years of age

Tasks:
- Listening behavior in everyday life situations
- Directional benefit in these situations
Evaluation of Directional Microphones in Hearing Aid Fittings for Children (Ching et al. 2008)

**Scenario 1:**
child interacting with parent/caregiver

**Scenario 2:**
child’s home, child plays by him/herself with a parent elsewhere in the same room

**Scenario 3:**
child with a small number of children and adults around, and speech is not always directed to the child (e.g. mother’s group)

**Scenario 4:**
child playing outdoors with other children and adults

![Graph showing directional advantage dB for different scenarios and microphone positions (Front, Side, Back)]
Effect of age: $p = 0.4$

Effect of hearing: $p = 0.09$

Effect of scenario: $p < 0.001^{**}$

Proportion forward looking not affected by age or hearing loss

Directional mics can be fitted at any age!

Proportion forward looking not affected by age or hearing loss

Directional mics can be fitted at any age!
Evaluation of Directional Microphones in Hearing Aid Fittings for Children (Ching et al. 2008)

With automatic microphone system children get the full benefit of directional microphones

Scenario 2:
- Dir disadvantage
- Dir mic should be switched off
- Automatic mic deactivates dir mic in scenario 2
- Automatic mic should be activated

Overall advantage in real life:
weight advantage = dB front * %front + dB side * %side + dB back * %back
Digital Noise Reduction Conclusions:

- DNR significantly improves ease-of-listening and speech intelligibility for normal hearing children.
- DNR does not degrade novel word learning.
- Activate only DNR algorithms for which benefit has been shown in clinical studies with hearing impaired children.
Perceptual Benefits
Pediatrics

Directional Microphone Conclusions:

- Directional microphones provide up to 3 dB benefit in different scenarios.

- Age (10m – 6.5 yrs) does not affect proportion of time children look at the talker.

- Both NH and HI children look at the talker >50% of the time with child-directed speech.

- Automatic microphone system should be activated for children.

- Counsel caregivers and professionals on making the most of directional advantage.
  - Face the child when talking
  - Teach the child to look at the talker
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- Pediatrics ✓
- eARena
Chalupper, J. Presented at the 52\textsuperscript{nd} International Congress of Hearing Aid Acousticians – Nuremberg

- Subjects were split into 3 groups (40 subjects each):
  - Group 1: personal auditory training
  - Group 2: PC-based auditory training
  - Group 3: no training (control group)
  - 50\% experienced / 50\% first-time wearers

- All subjects were fitted bilaterally with CENTRA BTE

- NAL-NL1 acclimatization level 2 (\textasciitilde NAL-NL1 -3 dB)

- Lab measurements and questionnaires (e.g. SSQ) before and after 4 week home trial
What Is the Relationship Between Acclimatization, Learning Hearing Systems and Auditory Training?(Chalupper 2007)

eARena significantly improves hearing aid benefit with regards to subjective speech intelligibility
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There are heaps of recent publications from renown researchers proving the effectiveness of Siemens hearing aid features.

Siemens is the only manufacturer to have research evidence on:
- SoundSmoothing
- Learning
- Wireless technology
- TruEar

Siemens hearing instruments are a good choice if you want to do evidence-based practice.
References


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