Digital Noise Reduction Hearing Aids: What is the Evidence of Benefit in Adults?

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Outline of the Presentation

• How does digital noise reduction (DNR) work?
• What evidence do we have on benefits of DNR?
• Systematic review of the available evidence.
• DNR benefit in the pediatric population.
• We have come a long way but we still have a long way to go

• In 2005 when CNN celebrated its 25 years, it counted the top 25 innovations during their existence.

A real digital hearing aid chip
Evolution of the Integrated Circuit

Image courtesy: Steve Armstrong of Gennum
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Making sense of the scale

1 millimeter = 1,000 µm = 1,000,000 nm

- Human hair: 100 µm
- Small transistor: 65 nm
- Size of an Atom: 0.1 nm
Benefits of faster chips

• More processing power: implementation of complex algorithms.
• More ancillary operations: e.g. saving audio samples of low battery indicator in 32 languages
• Hearing aids acting as personal devices: e.g. daily reminders about medication.
• Each generation of chip continues to get smaller while delivering more power.
Algorithm Integration

• Advanced hearing aids employ sophisticated signal detection and analysis step.
  – What is the intensity of the signal?
  – Is it loud or soft?
  – Is it speech or noise?
  – Which frequency bands contain noise?
  – Is there a feedback loop?

• More and more signal processing algorithms are “talking to each other” before acting on the signal.
Digital Noise Reduction

• How does it work?
• What is the clinical evidence?
• Clinical tips for fitting adults vs. children
How do we separate speech from noise?

Speech

Noise
How can we separate speech from noise?

Speech vs. Noise

- Temporal domain
- Spectral domain
- Spatial domain
How can we separate speech from noise?

Speech vs. Noise

- Temporal domain
- Spectral domain
- Spatial domain
Separating speech from noise in the temporal domain

- Modulation frequency
- Modulation depth
Modulation frequency of speech

Modulation frequency of noise

Noise reduction based on modulation frequency

Noise reduction based on modulation depth

How can we separate speech from noise?

Speech vs. Noise

- Temporal domain
- Spectral domain
- Spatial domain
Separating speech from noise in **spectral domain**

- Gain reduction at low frequencies
- Spectral subtraction
  - Adaptive Wiener filtering
Patient benefit with DNR

• Digital noise reduction is effective at reducing gain when there is no speech present.

• When speech and noise are present together, the noise reduction algorithm does not reduce gain.
  – Improves comfort
  – Does not improve intelligibility
How can we separate speech from noise?

- Temporal domain
- Spectral domain
- Spatial domain
Separating speech from noise in spatial domain

• Adaptive directionality
  – Substantial evidence supporting benefits from directional microphones.
  – Real world directional benefit is reduced compared to laboratory results.
  – Hearing aids with adaptive directionality defaults to “omnidirectional” mode when there are multiple noise sources.
Factors affecting directional benefit

- Frequency of the signal
- Venting / open fit
- Reverberation
- Distance between the two microphones
- Head angle
- Microphone matching
Examples of DNR by manufacturers

Listening comfort even in noisy situations

With just one tap at a button you reduce the level of noise and focus on what's important without losing sense of the environment around you.

Hear the difference with ReSound Noise reduction

Want to try out noise reduction yourself? Find your nearest hearing care professional.

Click here →
Examples of DNR by manufacturers

Speech in Car
Reduces broadband noise in the car to create a stable listening environment for easy communication, reduced effort.
PERFORMANCE OF NOISE REDUCTION ALGORITHMS IN A LABORATORY SETTING
Audio samples of DNR in commercially available hearing aids

Oticon

Phonak

Widex

Starkey

Resound

Signia
Real Ear Aided Response with and without DNR
SYSTEMATIC REVIEW OF THE LITERATURE
Purpose of this review

A critical review of hearing-aid single-microphone noise-reduction studies in adults and children

Foong Yen Chong and Lorienne M. Jenstad

ABSTRACT
Purpose: Single-microphone noise reduction (SMNR) is implemented in hearing aids to suppress background noise. The purpose of this article was to provide a critical review of peer-reviewed studies in adults and children with sensorineural hearing loss who were fitted with hearing aids incorporating SMNR.

Method: Articles published between 2000 and 2016 were searched in PUBMED and EBSCO databases.

Results: Thirty-two articles were included in the final review. Most studies with adult participants showed that SMNR has no effect on speech intelligibility. Positive results were reported for acceptance of background noise, preference, and listening effort. Studies of school-aged children were consistent with the findings of adult studies. No study with infants or young children of under 5 years old was found. Recent studies on noise-reduction systems not yet available in wearable hearing aids have documented benefits of noise-reduction on memory for speech processing for older adults.
Systematic review

Total number of records identified through electronic databases
N = 857

Search criteria:
- Five electronic sources (PubMed, ERIC, Scopus, Cochrane, ComDisDome)
- Search terms: hearing aid AND noise reduction
- Studies published after 2000

Total number of unique hits after duplicates removed
N = 264

Inclusion criteria:
- Studies published after 2000
- Peer-reviewed publications
- Used commercially available hearing aids with digital noise reduction
- Included adult human subjects for testing
- Dependent variable: Speech understanding

Total number studies confirming to all inclusion criteria
N = 16
Systematic review

• The review includes articles published from the year 2000 to 2016.
• The effect size (r) is estimated for each study and overall effect size is calculated for each measure.
• Effect size here simply means the magnitude of DNR benefit or practical significance of DNR benefit.
How to measure DNR benefit?

- Speech understanding
- Listening effort
- Other measures
  - ANL
  - Subjective rating
Speech recognition outcome

- A total of 12 studies compared DNR vs. No DNR condition in 22 comparisons (different noise reduction algorithms, different strengths).
Evidence

• Out of 12, ten studies (20 comparisons out of 22) showed no significant improvement of speech recognition measure with DNR compared to no DNR condition.

• Effect size ($r$) was calculated for 7 comparisons out of 22 and it ranged from 0.09 (small) to 0.55 (large).
Studies showing improvement with DNR
Confidence interval of \( r \)

<table>
<thead>
<tr>
<th>Study</th>
<th>Effect size</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peeters et al. (2009)</td>
<td>0.50</td>
<td>0.04 to 0.78</td>
</tr>
<tr>
<td>Kuk et al. (2011)</td>
<td>0.51</td>
<td>-0.13 to 0.85</td>
</tr>
</tbody>
</table>


Evidence cont...

- The overall (or average) effect size was small (0.28) with zero credibility interval.
- Zero credibility interval translates to zero effect of DNR on speech recognition measure in population 95% of the time.
- This was due to huge sampling error variance in the studies.
Evidence

LISTENING EFFORT
Listening effort

- Subjective rating
  - Results in lesser rating of effort compared to no DNR condition

- Dual-task paradigm
  - Reduces cognitive effort and makes it available for secondary task
  - Reaction time and performance are compared across conditions
Evidence

• Four studies (24 comparisons) investigated the effect of DNR on listening effort.
• Two studies (three comparisons) showed significant improvement (or reduction) in listening effort with DNR algorithm.
ANL and other subjective measures

Acceptable Noise Level (ANL)

Noise annoyance

Ease of communication

Speech naturalness

Overall preference
Evidence

• Eight studies (41 comparisons) examined the effect of DNR on subjective rating and two studies on Acceptable Noise Levels (ANL).
• Four studies (22 comparisons) showed significant improvement in subjective ratings
• Two studies (two comparisons) showed significant improvement in ANLs.
Summary

- Effect size was calculated for 7 studies (12 comparisons).
- The effect size ($r$) ranged from 0.066 (small) to 0.74 (large).
- The overall effect size was calculated for listening effort and subjective ratings together and there was a medium effect (0.46 ±10).
SYSTEMATIC REVIEW OF THE LITERATURE

Pediatric Patients
DNR benefit in children

- Children are more affected by noise compared to adults.
- DNR may help children to participate in multi-speaker conversations and discussions compared to FM systems.
HOW TO MEASURE DNR BENEFIT??

Speech Recognition outcome

• Four studies explored the effect of DNR on speech recognition and found no significant improvement with DNR.
• The effect size ($r$) ranged from -0.04 to 0.24 (McCreery et al., 2012). This is similar to small effect size ($r=0.28$) seen with adults.
Speech and language outcomes

• The studies investigated the effect of DNR on novel word learning and word categorization.
• All three studies showed no significant improvement in word learning or categorization with DNR algorithm.
• The effect size ($r$) estimated ranged from 0.10 (small) to 0.54 (large) (McCreery et al., 2012).
Hearing aid self report and parental report

• Three studies used self report and/or parental report to examine the effect of DNR.
• DNR had no significant effect.
SUMMARY AND CONCLUSION
• Noise reduction algorithms do not improve speech recognition significantly in adults and children.

• It helps to improve subjective perception such as quality, ease of listening.

• There is dearth of evidence to show DNR benefit on listening effort.
Questions and Comments?

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