Frequency compression improving recognition of high-pitched phonemes - Michael Boretzki
Pre-conditions of understanding

- Presence of speech sound
- Phonetic identity
  - Detection
  - Distinction
  - Recognition
Effects of sensorineural hearing impairment

- Speech sounds getting less audible
- Speech sounds getting less distinguishable = more similar
- Speech sounds getting less recognizable = less intelligible
Effect of amplification alone

- Amplification improves audibility, by that distinguishability, by that recognition

- Three drawbacks

  - Speech sound, e.g. /s/, may be in a frequency region where frequency and time resolution is poor, by that reduced distinguishability!

  - Speech sound, e.g. /s/, may be in a frequency region where hearing is remarkably unpleasant

  - Amplification may not provide sufficient insertion gain due to feedback stability issues
Feedback stability

Feedback stability depends on frequency

Acoustic coupling:
- completely closed
- completely open
Frequency compression can move high-frequency sound components to lower frequency ranges...

- …with more insertion gain possible = better audibility, by that better distinguishability („bandwidth increase“)
- …with better auditory resolution = better distinguishability
- …with more pleasant hearing
Frequency compression
Pre-conditions of benefit

- Sufficient amount of amplification
- Frequency compression not too weak (otherwise no effect)
- Frequency compression not too strong (otherwise high-pitched consonants too similar)
Evidence of benefit of frequency compression with moderate and severe hearing losses

- SoundRecover has been shown to have very positive effect on speech intelligibility and detection and recognition of non-speech sounds
- McDermott & Kegel have shown in 2008 that 80% of moderate to severe hearing loss subjects prefer SoundRecover if offered to select between SoundRecover and conventional amplification alone
Benefit of frequency compression with mild hearing loss?

- People with mild hearing loss are a special challenge because aided hearing is competing with still powerful unaided hearing.
- People with mild hearing loss have intelligibility issues in noise and reverberant rooms.
- People with mild hearing loss have detection and recognition issues with very soft high-pitched sounds, e.g. /s/.
- Frequency compression by its nature can improve audibility and distinguishability.
- Focus of the study to be reported: Understanding in quiet, especially the high-pitched phoneme /s/. 
Typical spectra of female and male /s/

8 talkers speaking with moderate loudness

<table>
<thead>
<tr>
<th>Language</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>French</td>
<td>1</td>
<td>1</td>
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<td>Italian</td>
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<tr>
<td>German</td>
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</tbody>
</table>

Graph showing the 3rd octave level dB for Male and Female talkers across different frequencies.
Importance of /s/ detection and recognition

Assume that /s/ and /d/ are barely distinguishable!

„ Hồ “ denotes a class of sounds which are equally probable to be heard as /s/ or /d/

Saturday it was fun to see the sea and enjoy the sun all day long

Distinction between /s/ and /d/ matters!
Importance of /s/ detection and recognition

• With low phoneme predictability
  • Good /s/ recognition helps proper understanding, e.g. exotic names, unknown abbreviations, singular/plural distinction.
  • Bad /s/ recognition leads to words and sentences not being understood correctly

• With high phoneme predictability
  • Good /s/ recognition helps understanding because the mental load is not increased by phoneme prediction and completion based on the context.
  • Bad /s/ recognition leads to earlier mental fatiguation.
Question of this study

- Mild hearing loss subjects
- Listening in quiet environment
- Can frequency compression improve intelligibility of /s/ beyond the intelligibility level which is possible with pure amplification?

- Thanks to Andrea Kegel and Sven ten Holder who executed the experimental work
Experiment design
Experimental variables

• Independent variable
  • Hearing support condition
    Unaided hearing
    Aided hearing without frequency compression
    Aided hearing with frequency compression

• Dependent variables
  • Lab: Intelligibility thresholds for /s/ and other high frequency phonemes (test, retest)
  • Lab: Subjective clarity and pleasantness comparisons of everyday life sounds with and without frequency compression
  • Everyday life: Subjective clarity comparisons of a couple of sound classes, mainly speech
Experimental design
Subjects and devices

12 Listeners
- Partly experienced users, partly no experience with aided hearing
- Mild hearing loss

Hearing aids
- ExéliaArt with SoundRecover
Experimental design
Procedural steps

- Lab 1: Hearing aid fitting: gain and frequency compression
- Two weeks of acclimatization, task to compare program with and without frequency compression for a list of sound classes
- Lab 2: Intelligibility testing
- Lab 3: Intelligibility (retest), comparison of hearing with and without frequency compression when presented a set of everyday life sound recordings
Experimental design
Hearing aid fitting

- Hearing aids coupled to the ears with standard 3.1mm tube and as open as possible

- Adjustment of amplification
  - Below 3.5 kHz no insertion gain, above 3.5 kHz adjustment of gain settings such that
    - narrowband noises with 25 dB input level clearly audible
    - no feedback
    - no internal noise audible
    - 50 dB narrowband noises not sharp

- Adjustment of frequency compression
  - Precalculated setting was compared to adjacent settings regarding pleasantness and clarity of fitter‘s and own voice

- Two manual programs: With and without frequency compression
Experimental design
Measurement of intelligibility thresholds

Speech material should have lowest possible phoneme predictability in order to be actually sensitive to and specific for /s/ intelligibility.

Adaptive logatome test, developed by Katrin Meisenbacher in 2008 (diploma thesis at Fachhochschule Oldenburg and at Phonak)

- Stimuli: VCV-„words“, only consonant variable
- Recordings of German female talker
- Introductory sentence „My name is …“
- Stimuli for this study: Asa 9 kHz, Asa 6 kHz, Asha, Afa, Ata, Ada, Aka
- Two stimulus sets
  - Set 1: Asa 9 kHz, Asa 6 kHz, Ada
  - Set 2: Asa 9 kHz, Asa 6 kHz, Ada, Asha, Afa, Ata
Experimental design
Adaptive logatome test

Stimuli highly specific for consonant intelligibility
- Initial and final vowel: Same loudness, pitch
- All VCVs same length
- Stimuli created by placing recorded consonant segments between the vowels of one and the same „Ama“ recording
- Subjects cannot learn from vowel pitch, loudness or duration specialties which consonant has been said

<table>
<thead>
<tr>
<th>Asa 6 kHz</th>
<th>Asa 9 kHz</th>
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<tbody>
<tr>
<td>Asha</td>
<td>Ata</td>
</tr>
<tr>
<td>Aka</td>
<td>Ada</td>
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<tr>
<td>Afa</td>
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Experimental design
Adaptive logatome test

- Level adaptation rule: If stimulus was understood at previous level, then decrease level for this stimulus else increase level.
- Stepsizes: 10 dB, 5 dB, 3 dB, 2 dB.
- Result: Intelligibility threshold for each stimulus.
Experimental design
Adaptive logatome test

- Presentation via loudspeaker in front of subject, distance 1 m
- Responses via touch screen

Response screen for stimulus set 2
(Set 1: only Asa and Ada)
Results

Stimulus set 1, n=12

SRT dB relative to SRT unaided

SoundRecover on
SoundRecover off

SRT dB relative to SRT unaided

Asa 9 kHz  Asa 6 kHz  Ada
Results

Stimulus set 2, n=10

SRT dB relative to SRT unaided

- SoundRecover on
- SoundRecover off
Results

- Repeated measurement of recognitions thresholds: No effect
- Everyday life comparison of programs with and without SoundRecover: No effect
- Lab comparison of programs with and without SoundRecover using everyday life recordings: No effect on clarity, but on pleasantness: SoundRecover is slightly more pleasant!
- Lab SRT measurement: Recognition of /s/ clearly improved by SoundRecover
Summary

- Frequency compression allows to improve intelligibility of /s/ in soft speech even when the hearing loss is only mild!
  - This can help to better understand speech with low phoneme predictability.
  - This can reduce mental load and helps to avoid mental fatigue when listening to speech with high phoneme predictability.

- Frequency compression offers slightly more pleasant hearing with mild hearing losses.

- Everyday life test: Switching SoundRecover on and off obviously cannot make the subjects recognize that less mental load is necessary with frequency compression. A better measure for mental load and fatigue is required. In addition: We did not explicitly ask subjects to focus comparisons on soft or distant speech.

- Logatome SRT testing seems to be sensitive to intelligibility improvements with subjects having mild hearing loss.
Thanks for your attention!