Restoration of interrupted speech:
What does it teach us for top-down speech repair in hearing impaired?

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Listening is complex
Perceptual restoration

Interrupted speech: Speech with gaps
Perceptual restoration

Fig. 2. Word articulation as a function of rate of interruption for a speech-time fraction of 0.5. Curve (1) was obtained with naive listeners, (2) with the same listeners after a few days practice, (3) again with the same listeners, but with a system having a more uniform frequency-response characteristic.

Miller and Licklider, JASA 1950
Perceptual restoration

Restoration:
• Sampling: Looks per word
• Forming an object: Grouping relevant segments
• Extraction of meaning
Perceptual restoration

Speech with gaps

Restoration:
- Grouping cues (Voicing, source direction)
- Linguistic knowledge and constraints
- Context
- Expectations
Perceptual restoration

Restoration:
• Top-down repair mechanism
• Possibly helps with speech perception in noise (where most hearing-impaired listeners have a problem)
Perceptual restoration

Research questions

• Does hearing impairment reduce restoration?
  - Hearing impairment => Bottom-up degradations
  - Age => Cognitive factors, linguistic knowledge

• Does front-end signal processing reduce restoration?

• Could such reduction partially contribute to difficulty of understanding speech in noise?
Perceptual restoration

Hearing impairment I

Intelligibility of interrupted speech (PC)

Hearing loss (PTA in HL)

$r=-0.867$

$p<0.001$

Başkent, JASA 2010
Perceptual restoration

Hearing impairment 1: Age and hearing loss co-varied

Fig. 2. Listener age shown as a function of listener PTA.
Perceptual restoration

Hearing impairment 2: Simulated, no age component

Bhargava and Başkent, JASA EL (in press)
Perceptual restoration

Hearing impairment 2: Simulated, no age component

Fig. 1. The mean RAU scores shown as a function of the filter order. The panels show the results for different cut-off frequencies, and within each panel, the results are shown separately for different filter orders. The error bars denote the standard deviations.

Bhargava and Başkent, JASA EL (in press)
Perceptual restoration

Cochlear implants

Intelligibility of interrupted speech (PC)

Interruption rate (Hz)

Bhargava and Başkent, unpublished
Perceptual restoration

Research questions

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Phonemic restoration

Speech with gaps

Gaps filled with noise
Phonemic restoration

Speech intelligibility (%)

With gaps

With noise

17% better

Basıkan et al, 2009, 2010
FIG. 1. A signal comprised of a low-intensity interrupted tone combined with a high-intensity noise burst, shown in the upper left corner. The dashed lines indicate the envelope of the combined signal. The upper right corner shows the same combination signal after amplitude ramps were added on the tone envelope preceding and following the noise burst, similar to stimuli used by Bregman and Dannenbring (1977). The lower left corner shows the combination signal after a WDRC gain was applied. Due to the release time constant of compression, a recovery ramp—namely, the undershoot distortion—may be observed on the tone envelope following the noise burst.
Phonemic restoration

Başkent et al, JASA 2009
Phonemic restoration

Başkent et al, JASA 2009
Conclusions

- Does hearing impairment reduce restoration?
  - Moderate levels of impairment
  - Reduced spectral resolution of cochlear implants
  - With or without ageing
Conclusions

• What exactly is the cause?

  - Weak cues for grouping (CIs)  
    (agreement with Janse and Ernestus, 2011)
  - Increased effort in intelligibility, reducing available cognitive resources
  - Reduced intelligibility from looks per word
Conclusions

- Does front-end signal processing reduce restoration?
  - If not paid attention, yes.
  - Many features: Noise reduction, amplitude compression
Summary

All combined:

Results show the fine balance between top-down and bottom-up processes of speech perception.

Top-down repair may fail with degradations in bottom-up speech signals, due to hearing impairment or hearing device processing, even without a reduction in cognitive skills.

An additional disadvantage for hearing impaired in understanding speech in noise?
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