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Noise Modeling in Reverberation: A Comparative Study of Speech Intelligibility in Cochlear Implant Users

Hussnain Ali, Oldooz Hazrati, Nirmal Srinivasan, and Philipos C. Loizou

Cochlear Implant Laboratory
The University of Texas at Dallas

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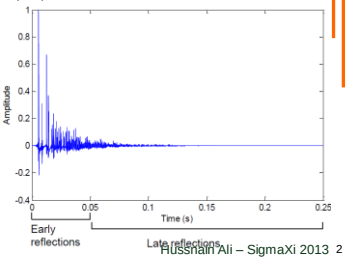
Reverberation

Reverberation: Collection of reflected sounds from the surfaces in an enclosure leads to temporal and spectral smearing and distorts both the envelope and fine structure of speech.

An example Room Impulse Response (RIR)
(T_{60} = 250 ms)

$$h(n) = \begin{cases} 0, & n < 0 \\ h_e(n), & 0 \le n < n_e \\ h_l(n), & n \ge n_e \end{cases}$$



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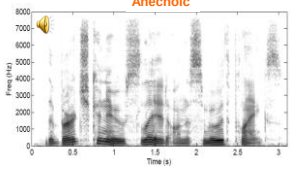
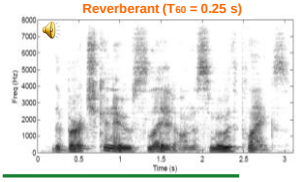
Reverberation

Anechoic



Reverberant (T_{60} = 0.25 s)



- Speech identification by normal-hearing (NH) listeners, not compromised until T_{60} < 1.0 s.
- Speech intelligibility in listeners with hearing loss deteriorates considerably:

T_{60} > 0.5 s

⇩

Human speech recognition can drop substantially in reverberation even in quiet.

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Noise

Speech intelligibility drops substantially with noise, specially in people with hearing loss

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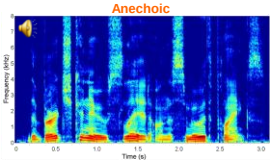
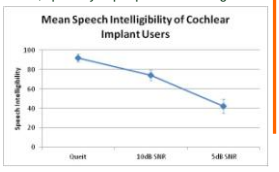
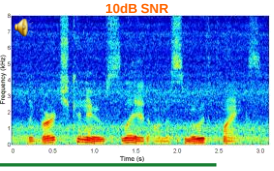
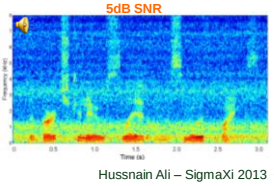




10dB SNR



5dB SNR



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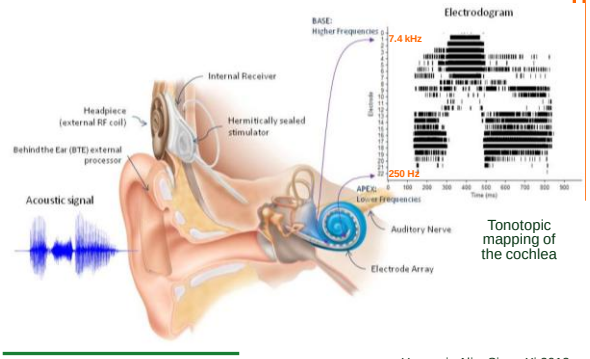

Tonotopic mapping of the cochlea

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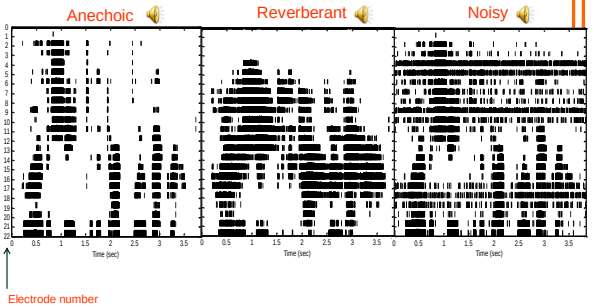
Electrodograms



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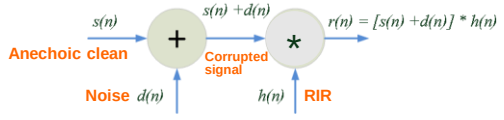
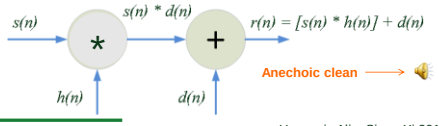
Reverberant Noisy vs. Noisy Reverberant

Reverberant Noisy (RN):



Noisy Reverberant (NR):



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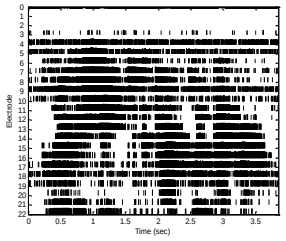
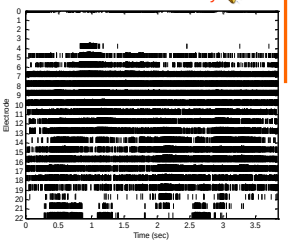
Electrodograms

Noisy Reverberant



Reverberant Noisy



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Methods

- **Listeners:**
  - ✓N = 6 (2 males and 4 females)
- **Speech Corpus:**
  - ✓IEEE sentences
  - ✓Speech-Shaped Noise
    - SNR = 10 & 15 dB
  - ✓RIRs (10.6 m × 6.65 m × 3.4 m)
    - T_{60} = 0.3 & 0.6 s

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Reverberant Noisy vs. Noisy Reverberant

Average word recognition scores.
T_{60} = 0.3 s, SNR = 10 and 15 dB.

R	N (10 dB)	N (15 dB)	NR (10 dB)	RN (10 dB)	NR (15 dB)	RN (15 dB)
64.57 (4.3)	70.75 (6.6)	87.17 (5.3)	39.88 (12.5)	23.84 (10.9)	55.46 (8.6)	40.58 (9.9)

Average word recognition scores.
T_{60} = 0.6 s, SNR = 10 and 15 dB.

R	N (10 dB)	N (15 dB)	NR (10 dB)	RN (10 dB)	NR (15 dB)	RN (15 dB)
47.22 (8.8)	70.75 (6.6)	87.17 (5.3)	31.42 (6.1)	11.94 (6.4)	36.59 (8.5)	28.59 (10.6)

The numbers in parenthesis indicate standard deviations.

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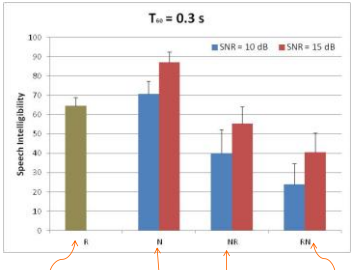
Reverberant Noisy vs. Noisy Reverberant



Reverberant-alone
Noise-alone
Noisy reverberant
Reverberant Noisy

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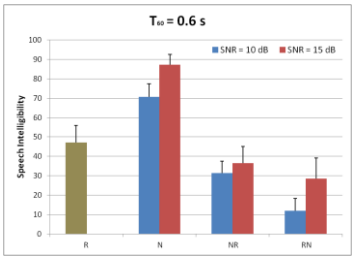
Reverberant Noisy vs. Noisy Reverberant



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Conclusion

- Noisy Reverberant
  - Simple model, good for general experiments (noise source close to the ear)
  - Underestimates the dynamics of noise in realistic environments
- Reverberant Noisy
  - Difficult listening experience
  - Better simulates the realistic environment (noise source not close to the ear)

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Thank you