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## Making Speech More Distinct

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**Presented by:**  
**Donald J. Schum, PhD**  
**Vice President, Audiology & Professional Relations**  
**Oticon, Inc.**

**Moderated by:**  
Carolyn Smaka, Au.D., Editor-in-Chief, AudiologyOnline

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## Expert e-Seminar

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**Making Speech More Distinct**

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Donald J. Schum, PhD  
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## Agenda

- The Nature of Speech Understanding
- The Acoustics of Speech in Conversation
- Naturally Produced Enhanced Speech
- Requirements for Computer Enhancement
- Some Past Examples
- Looking Forward

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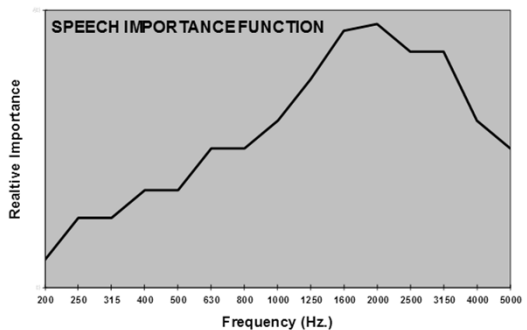
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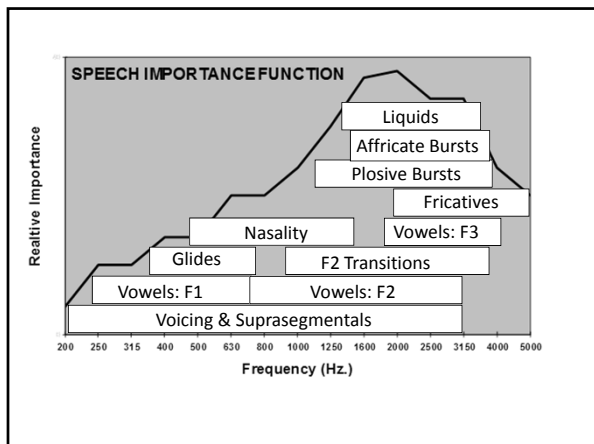
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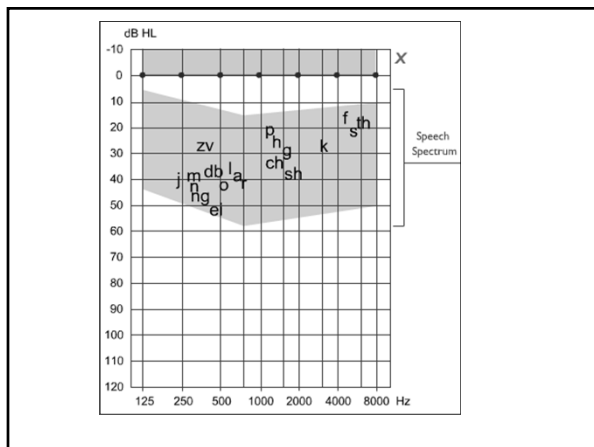
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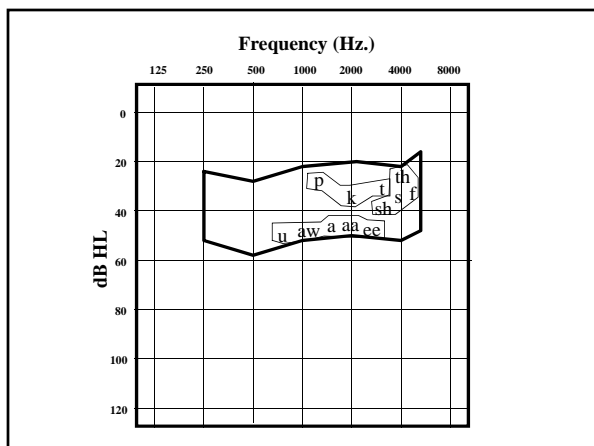
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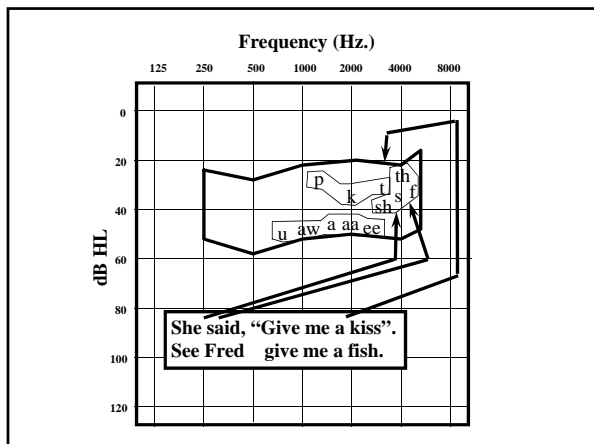
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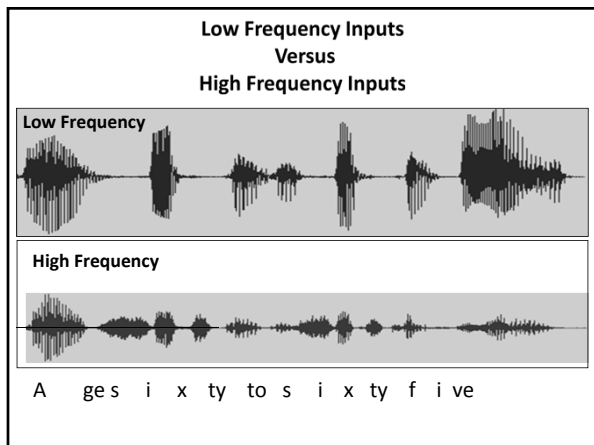
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**Examples of Dynamic Based Contrasts**

- fricatives versus affricates: sh vs. ch
- plosives versus fricatives: d vs. z
- diphthongs versus vowels: oi vs. o
- CV & VC transitions

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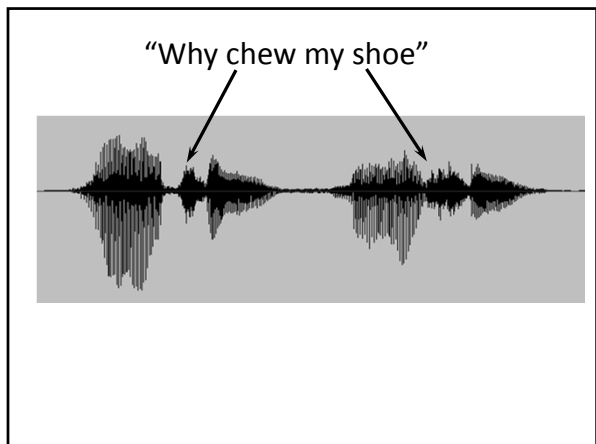
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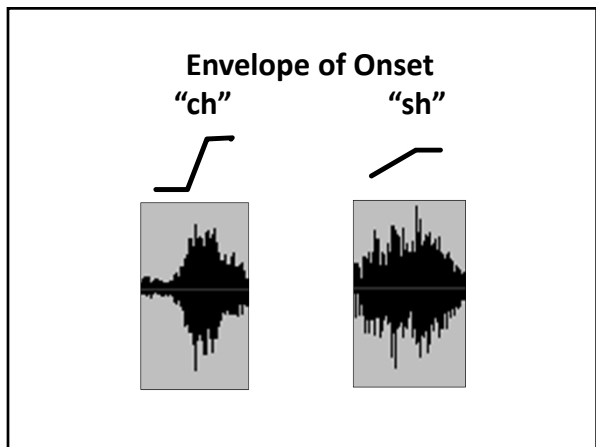
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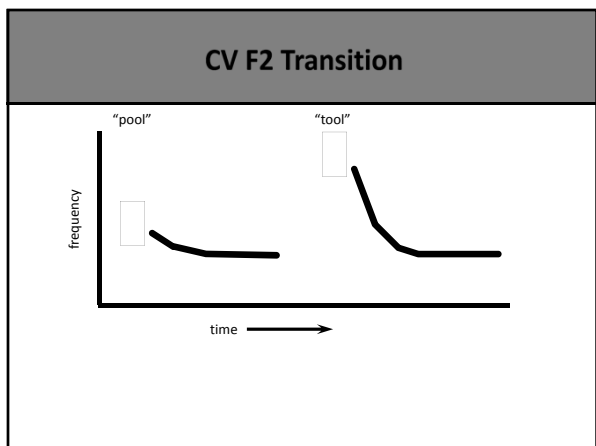
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**Speech is Movement**

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**Slip knot**

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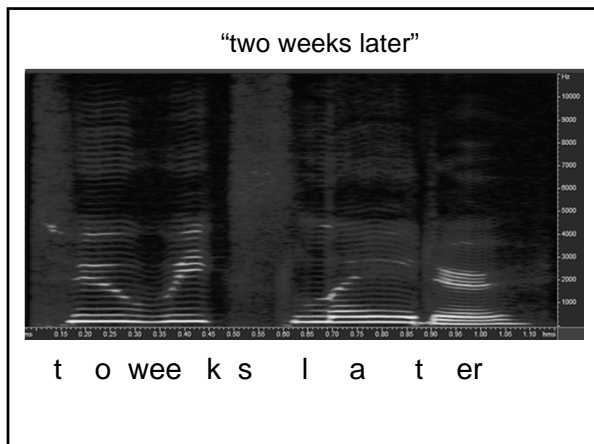
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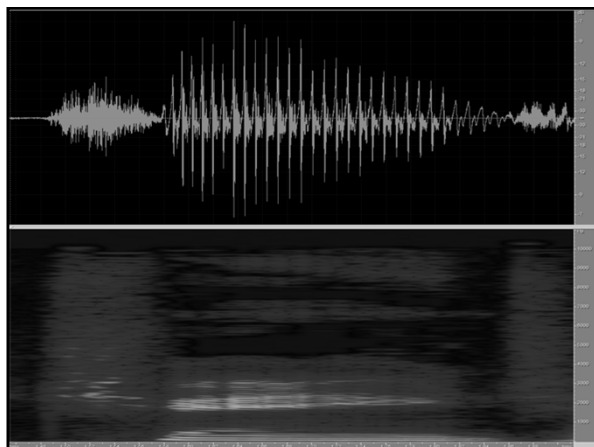
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**How Do We Talk?**

- Minimal Effort
  - Minimal Contrasts
  - Minimal Durations
  - Reductions
- Only as clear as we need to be
  - General human tendency: Conservation of energy
- We adjust to environment, but . . .
- Assume normally hearing listener

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## Speaker-to-Speaker Variability

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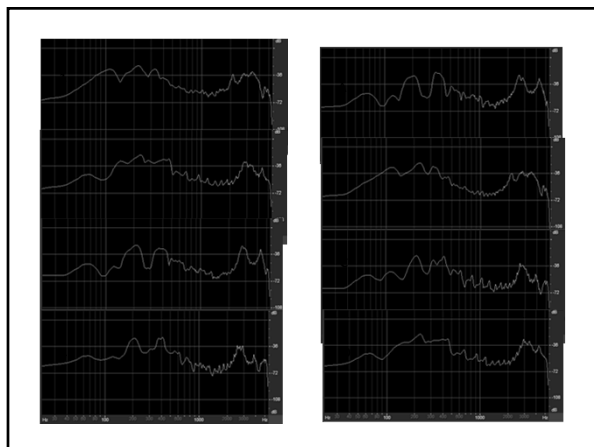
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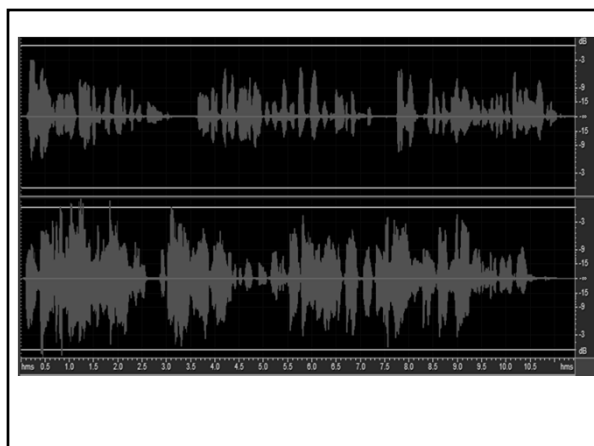
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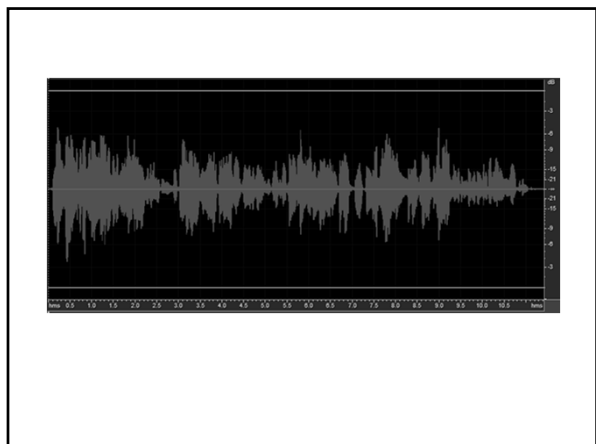
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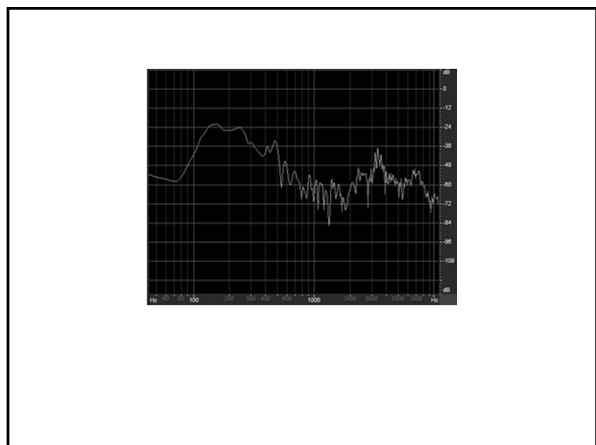
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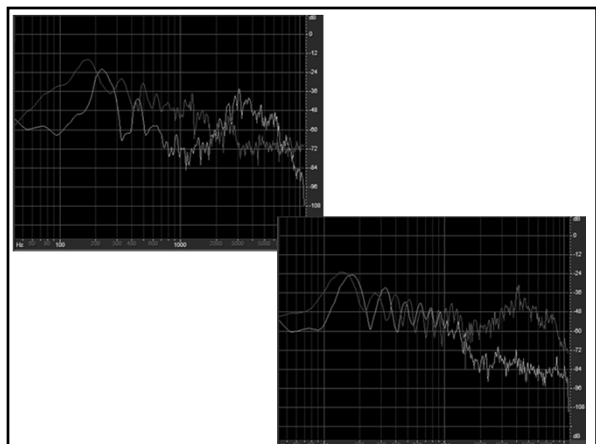
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## Clear Speech

- Natural acoustic changes which occur when a talker attempts to produce speech which is precise and accurate.

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*Journal of Speech and Hearing Research, Volume 28, 96-103, March 1985*

### SPEAKING CLEARLY FOR THE HARD OF HEARING I: INTELLIGIBILITY DIFFERENCES BETWEEN CLEAR AND CONVERSATIONAL SPEECH

MICHAEL A. FICHENY\* NATHANIEL I. DURLACH LOUIS D. BRAIDA  
*Massachusetts Institute of Technology, Cambridge*

This paper is concerned with variations in the intelligibility of speech produced for hearing-impaired listeners under two conditions. Estimates were made of the magnitude of the intelligibility differences between attempts to speak clearly and attempts to speak conversationally. Five listeners with sensorineural hearing losses were tested on groups of nonsense sentences spoken clearly and conversationally by three male talkers as a function of level and frequency-gain characteristic. The average intelligibility difference between clear and conversational speech averaged across talker was found to be 17 percentage points. To a first approximation, this difference was independent of the listener, level, and frequency-gain characteristic. Analysis of segmental-level errors was only possible for two listeners and indicated that improvements in intelligibility occurred across all phoneme classes.

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### Clear Speech: Research History

- Picheny, Braida, & Durlach: Mid 1980's
  - coined the term, contrasted to “conversational style speech”
  - documented acoustic changes
  - documented intelligibility improvement

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### Acoustic Changes

- Slower rate of speech
- More frequent and longer pauses
- Longer phoneme durations (consonants & vowels)
- More released word-final stops
- Greater differentiation of vowels
- Improved Consonant/Vowel ratio

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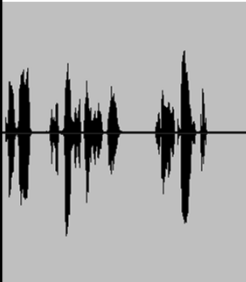
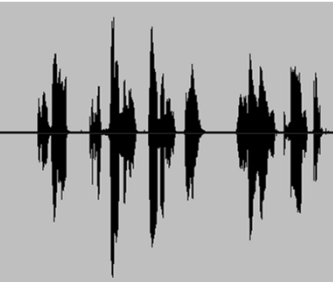
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“Tuborg is a famous Danish beer. So is Carlsberg.”

Conversational	Clear
	

•Slower Rate    •Higher Level    •More & Longer Pauses

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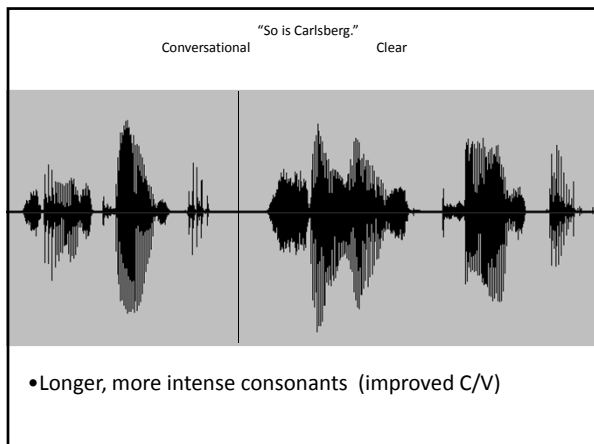
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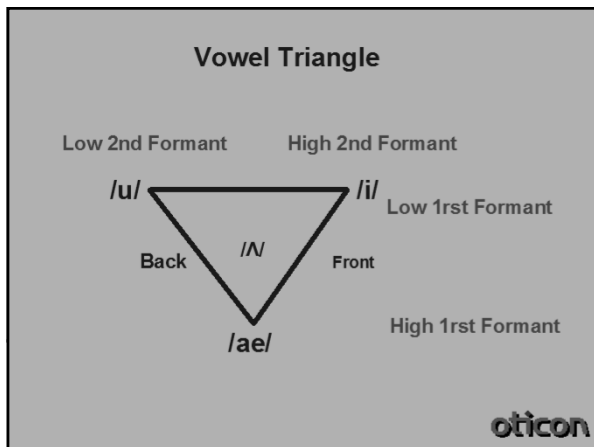
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**Effect on Intelligibility?**

**At least 15 to 20% in word recognition**

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### Schum (1996) Study

- Elderly & young, inexperienced talkers
- 5-10 minutes of training and practice
- Materials played back in noise to patients with SNHL (mild-mod sloping)

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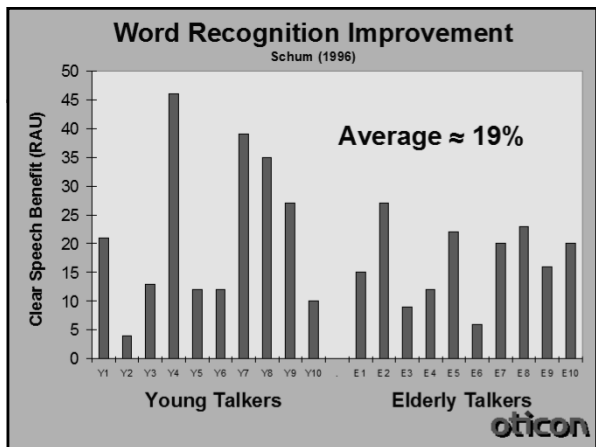
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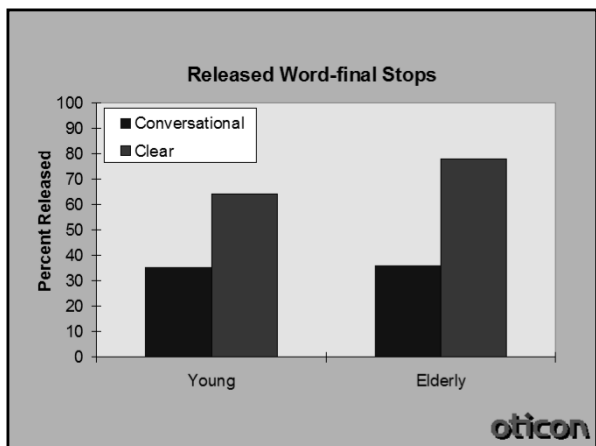
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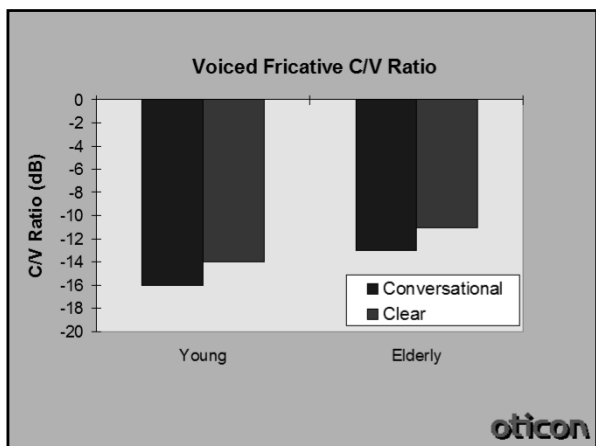
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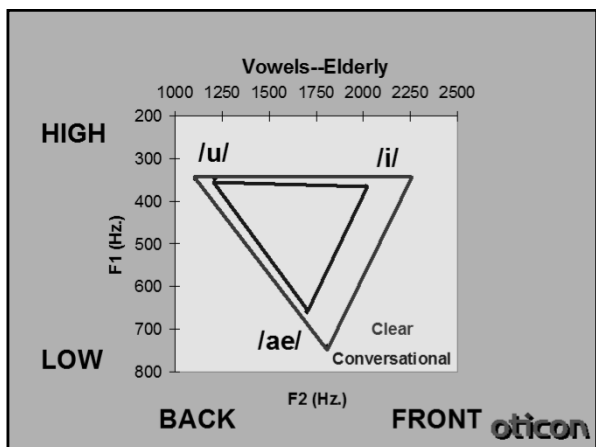
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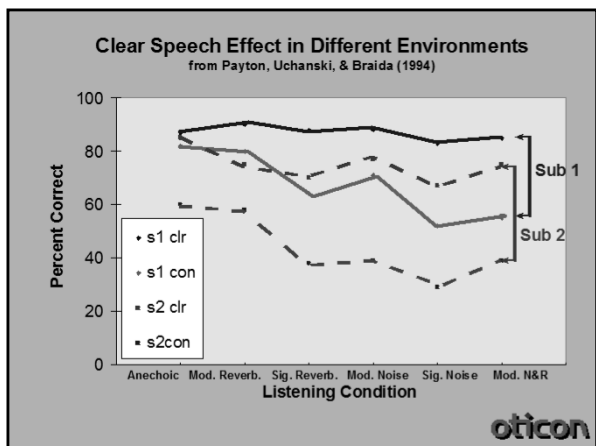
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**Automatic Speech Recognition**

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**Accurate  
Automatic Speech Recognition**

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**Robust  
Automatic Speech Recognition**

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Automatic Speech Recognition:  
**How good is it?**

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**How good is it?**



0 dB S/N   +5 dB S/N   +10 dB S/N   +15 dB S/N   +20 dB S/N

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**+5 dB S/N Babble**

- |                                     |                             |
|-------------------------------------|-----------------------------|
| 1. The boy fell from the window     | The boy know from           |
| 2. The wife helped her husband.     | the wife helped her husband |
| 3. Big dogs can be dangerous.       | and gods in the game        |
| 4. Her shoes were very dirty.       | or shoes.                   |
| 5. The player lost a shoe.          | Her player lost issue       |
| 6. Somebody stole the money.        | somebody still for          |
| 7. The fire was very hot.           | my player was very          |
| 8. She's drinking from her own cup. | he's drinking from her own  |
| 9. The picture came from a book.    | secure gain from            |
| 10. The car was going too fast.     | the car was going to that   |

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**Sentences in Quiet**

- |                                     |                                  |
|-------------------------------------|----------------------------------|
| 1. The boy fell from the window     | To myself from the window        |
| 2. The wife helped her husband.     | the life helped her husband      |
| 3. Big dogs can be dangerous.       | big dogs can be dangerous        |
| 4. Her shoes were very dirty.       | her shoes were very dirty        |
| 5. The player lost a shoe.          | the player lost a shoe           |
| 6. Somebody stole the money.        | somebody stole the money         |
| 7. The fire was very hot.           | the fire was very hot            |
| 8. She's drinking from her own cup. | cheese drinking from her own cop |
| 9. The picture came from a book.    | the picture came from a book     |
| 10. The car was going too fast.     | the car was going too fast       |

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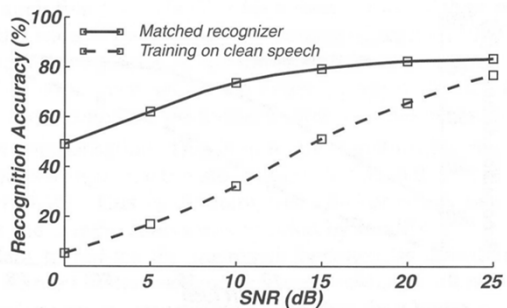
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Davis, 2002

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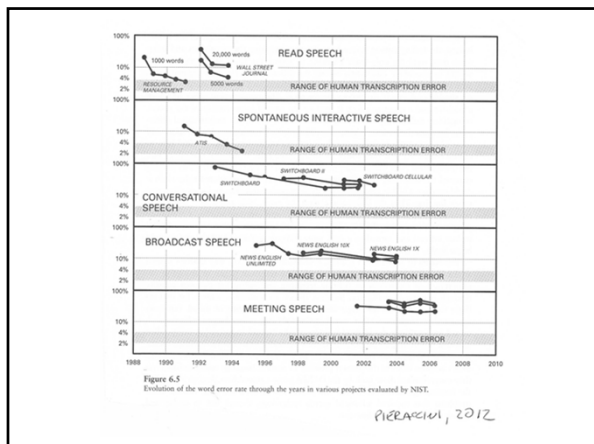
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## Real Time Automatic Speech Recognition

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## Multi-dimensional Enhancement Scheme

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**Natural Clear Speech**

- Individual correlations between 15 x 3 acoustic variables and Clear Speech Performance benefit for 20 talkers
- Best single correlation .45
- Most <.2
- ...
- Stepwise analysis drove correlations to >.9
- ...but needed 9 or 10 dimensions

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**Naturalness**  
**(“The Avatar Effect”)**

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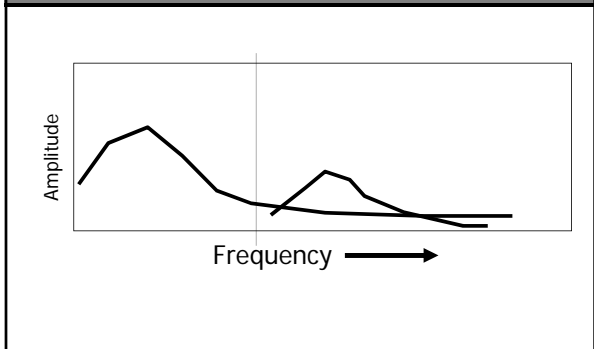
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### Multichannel Compression



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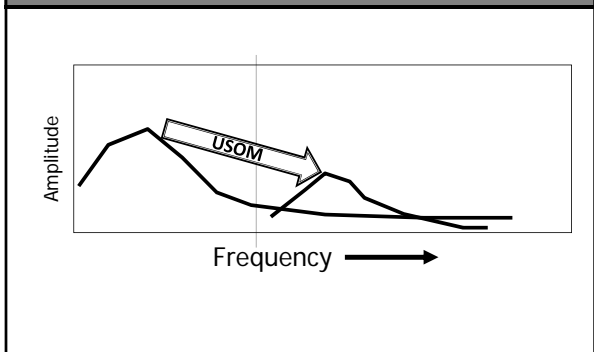
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### Multichannel Compression



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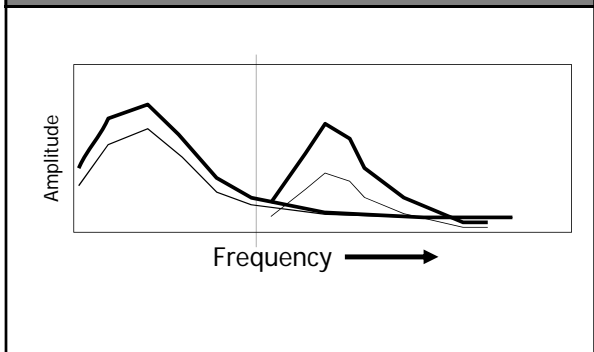
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### Multichannel Compression



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**Clear Speech as a  
Signal Processing Technique**

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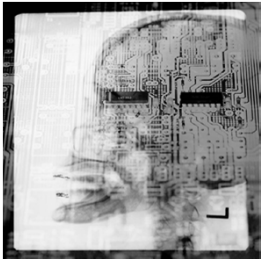
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**Can a computer based hearing instrument be taught to produce Clear Speech?**



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**Can Clear Speech be Created by a DSP based Hearing Instrument?**

- Naturally produced Clear Speech is an extremely complex combination of acoustic changes
  - Not just...increased C/V ratio
  - ...longer consonant durations
  - ...more pauses
  - ...changes in intonation contours (linguistically meaningful)
- DSP approach unlikely to mimic this effect
  - Finding/manipulating phonemes is difficult
  - Time marches on
  - Manipulating one or two dimensions is not enough

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# Phoneme Enhancement

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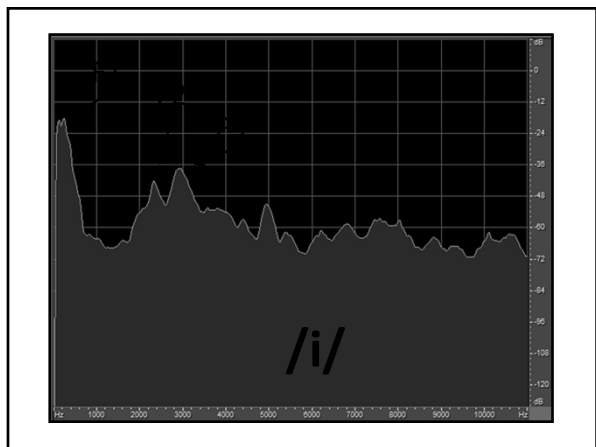
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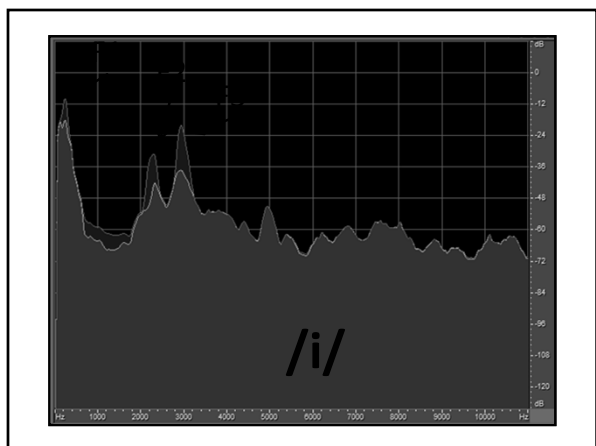
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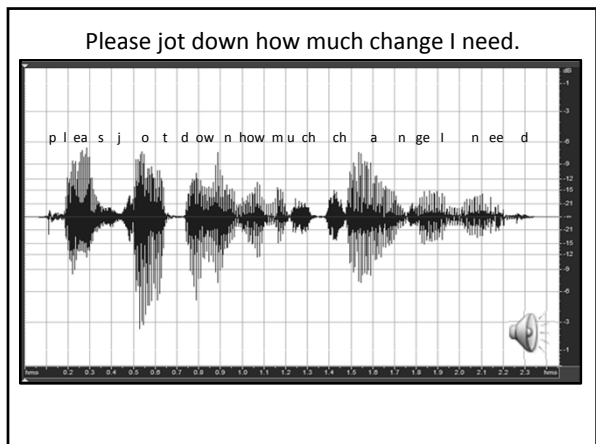
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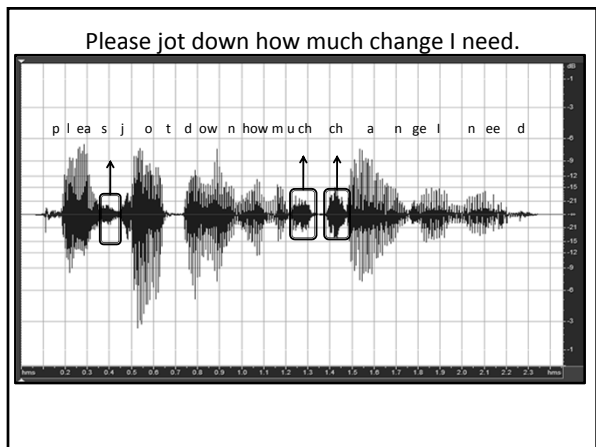
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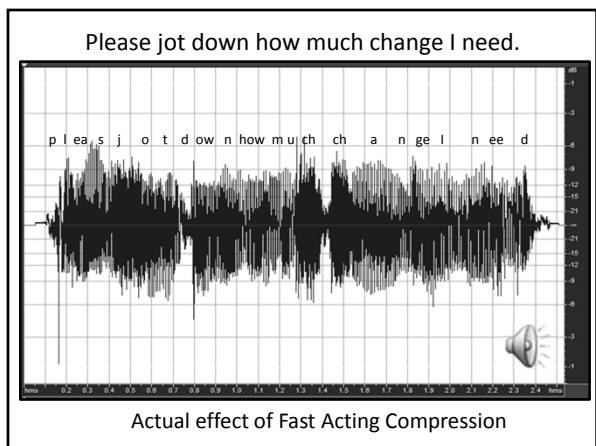
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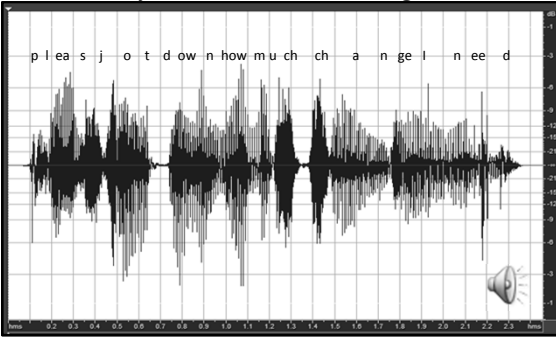
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Please jot down how much change I need.



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