King Saud University

College of Engineering

IE – 341: "Human Factors Engineering"

Fall – 2016 (1st Sem. 1437-8H)

Human Capabilities

Part – C. Speech Communications (Chapter 7)

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Lesson Overview

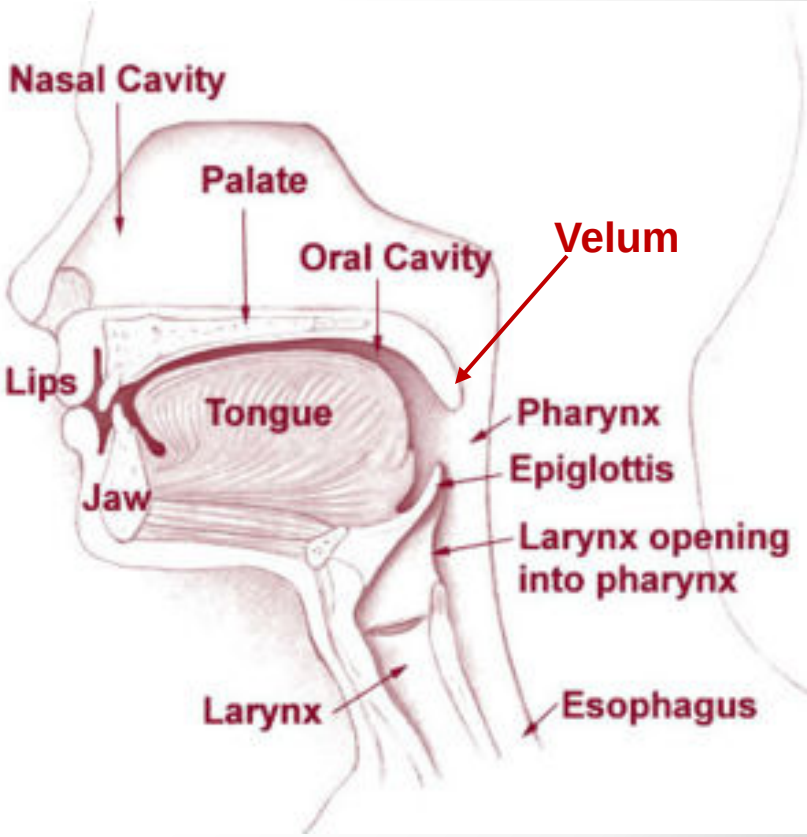
- Introduction
- The Nature of Speech
- Criteria for Evaluating Speech
- Components of Speech Communication Systems

Introduction

- Speech is form of "display"
  - i.e. form of auditory information
- Source of speech
  - Mostly human (focus of this lesson)
  - Could also be *synthesized*
    - i.e. machine; e.g. voice mail, access confirmation)
- Receiver of speech
  - Mostly human
  - Could also be machine: "voice recognition"
    - not advanced as synthesized sound

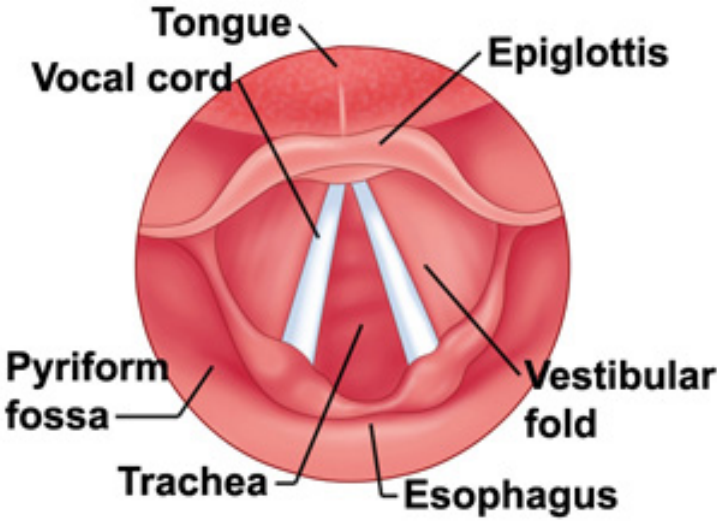
The Nature of Speech

- Speech: closely associated with breathing
- Organs associated with speech:
  - Lungs
  - Larynx
    - contains vocal cords
  - Pharynx
    - channel bet. larynx & mouth
  - Mouth (AKA: oral cavity):
    - tongue, lips, teeth, velum
  - Nasal cavity
  - Watch the following video: "how speech works" https://youtu.be/C2lRhe_Fc04



Cont. The Nature of Speech

- Vocal cords
  - Contains vibrating folds
  - Opening between folds: glottis / epiglottis
  - Vibrates 80-400 times/sec.
  - Rate of vibration of vocal cords: controls freq. of resulting speech sounds
  - Watch the following video on vocal cords: https://youtu.be/P2pLJfWUjc8
  - Speech/sound waves:
    - Produced by: vocal cords
    - Further modified by “resonators”:
      - pharynx, oral cavity, nasal cavity
    - Further articulated by “manipulators”:
      - Mouth: tongue, lips, velum
      - Nasal cavity: velum, pharynx muscles

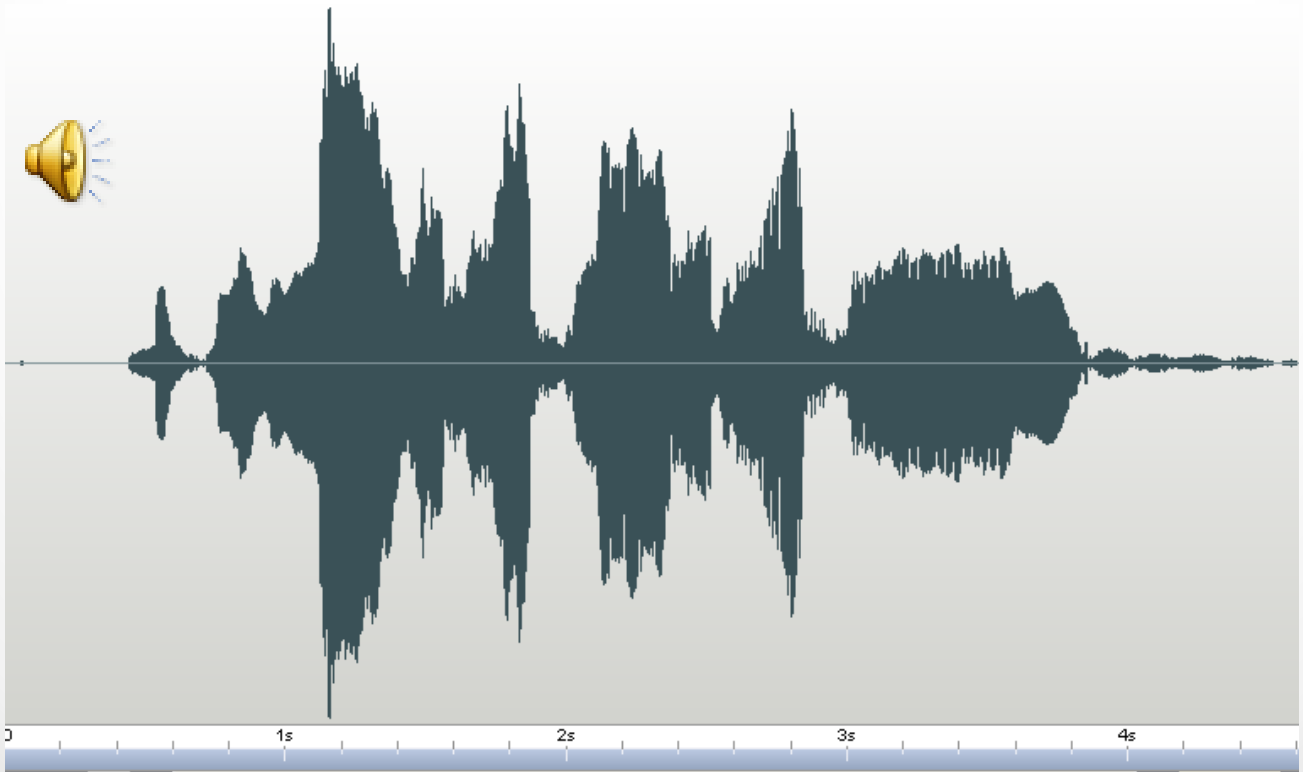


Cont. The Nature of Speech

- Types of Speech sounds
  - **Phonemes**
    - Basic unit of speech
    - Def^{n}: "shortest segment of speech which, if changed, would change the meaning of a word"
    - Phonemes in English language:
      - Vowel sounds: 13 (e.g. ***u*** sound in *put*, ***u*** sound in *but*)
      - Consonant sounds: 25 (e.g. ***g*** sound in *gyp*, ***g*** in *gale*)
      - Diphthongs (i.e. sound combinations): e.g. ***oy*** sound in *boy*; ***ou*** sound in *about*
      - Can you compare these to Arabic phonemes?
    - Combining phonemes:
      - Phonemes form syllables ⇒ syllables form words (e.g. **ac·a·dem·ic**) ⇒ words form sentences
      - Note Phonemes > letters (why?): since phonemes change when combined together (e.g. ***d*** in *di* different than *du*)

Cont. The Nature of Speech

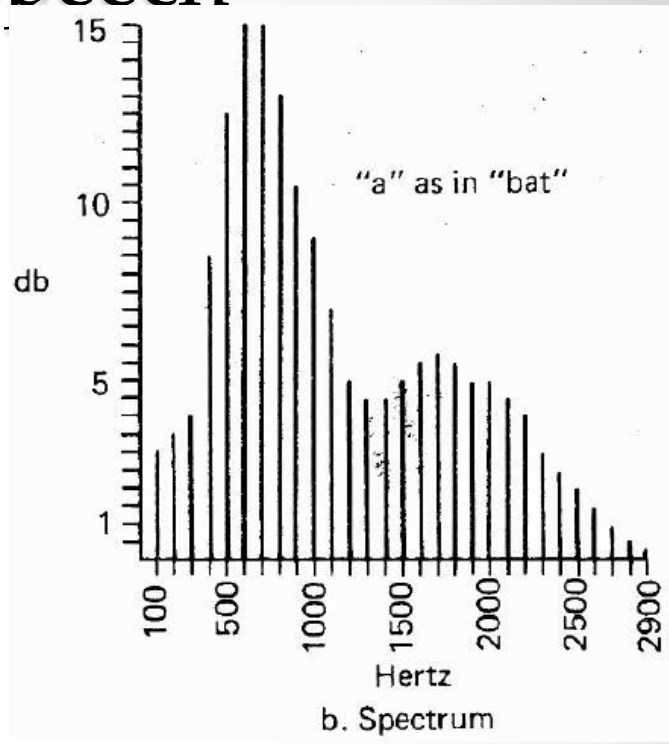
- Depicting Speech
  - Sound is generated by variations in air pressure
  - This is represented in several graphical ways
  - Method 1: **waveform**
    - Shows intensity variation over time (relative scale)
    - Listen to file below for verse "بسم الله الرحمن الرحيم"*



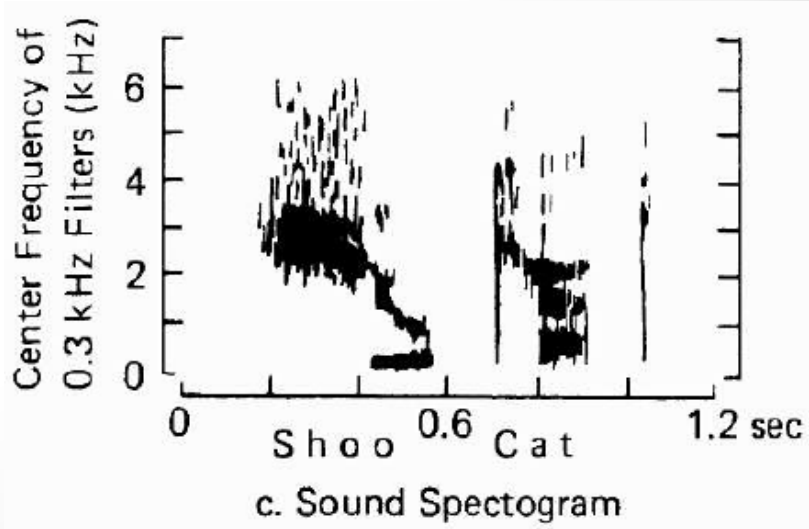
Cont. The Nature of Speech

- Cont. Depicting Speech

  - Method 2: **spectrum**
    - Shows for given phoneme / word: intensity of various frequencies in that sound sample (see right)
    - Which freq. has highest intensity in shown figure?

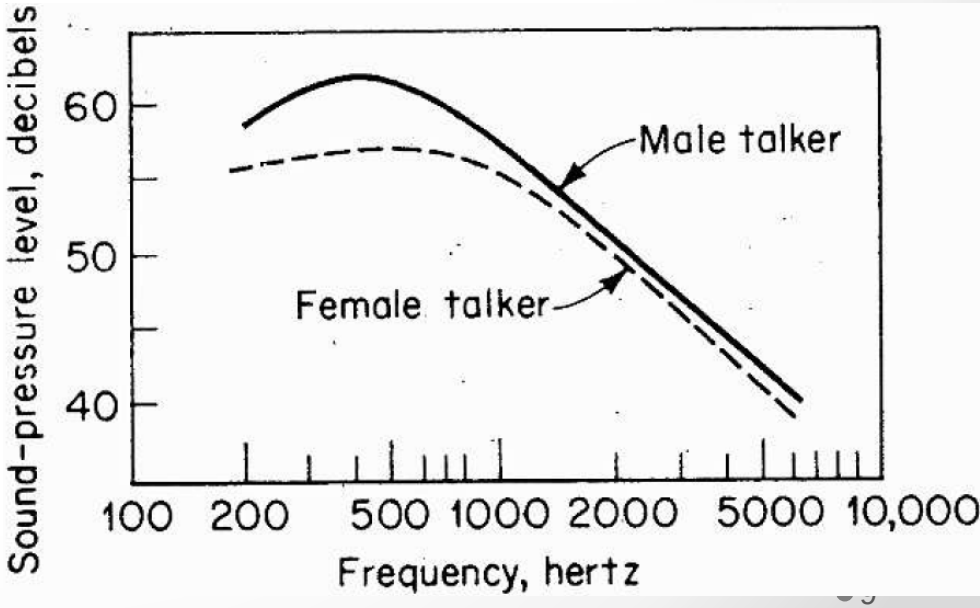


  - Method 3: sound **spectrogram**
    - Frequency: vertical scale
    - Time: horizontal scale
    - Intensity: degree of darkness on plot (see right)



Cont. The Nature of Speech

- Intensity of Speech (AKA "Speech Power")
  - Variation among phonemes
    - Vowels speech power **»** consonants
    - e.g. ***a*** in "*talk*" has speech power: 680 times > ***th*** in *then* (i.e 28 dB difference)
  - Variation among speech types
    - conversational speech: 45-55 dB*A**
    - Telephone/lecture speech: 65 dB*A*
    - Loud speech: 75 dB*A*
    - Shouting: 85 dB*A*
  - Variation: Male & Female
    - Male > female by 3-5 dB (in general)
    - Men in lower freq. has higher intensity than women (see right)



Criteria for Evaluating Speech

- Speech Intelligibility
  - Def^{n}: "degree/percentage to which a speech message (e.g. group of words) is *correctly* recognized"
  - This's *major* criterion for evaluating speech
  - Assessment of speech intelligibility:
    - Either repeating back read material
    - Or answering questions regarding material
  - Speech Intelligibility tests:
    - Nonsense syllables (e.g. un, us, mus, sub, sud, …)
      - these have least intelligibility
    - Phonetically balanced (PB) word lists
      - Nonsense syllables < words Intelligibility < sentences
    - Complete sentences
      - These have highest intelligibility, even when some words are not recognized (i.e. depends on context)
      - e.g. "Did you go to the store" may sound as "Dijoo …"
  - Watch the following videos regarding speech intelligibility:
    - Measuring speech intelligibility : https://youtu.be/pPS3Z11Wf7Q
    - Research study on speech intelligibility: https://youtu.be/hR7PeFEhnG0

Cont. Criteria for Evaluating Speech

- Speech Quality
  - Another criterion for evaluating speech
  - May be important in identifying a specific speaker
    e.g. on phone (i.e. absolute identification)
  - Also important to choose bet. different products
    e.g. speaker phone on home phones, mobile phones
  - Assessment of speech quality
    - Usually done using rating system
    - e.g. people listen to speech and asked to rate quality:
      excellent, fair, poor, unacceptable, etc.
    - May also be done by comparing to some standard speech quality

Components of Speech Communication Systems

- Components
  1. Speaker
  2. Message
  3. Transmission System
  4. Noise Environment
  5. Hearer
- Discussed here in terms of
  - Effects on intelligibility of speech communications
  - Methods to improve intelligibility of system

Cont. Speech Communication Systems

1. Speaker
   - Intelligibility of speaker usu. called "**enunciation**"
   - Research found higher intelligibility is caused by:
     - **Longer syllable** duration
     - Speaking with **high intensity**
     - Making **use of speech time** with spoken words and little pauses
     - Variation of **speech frequencies**
   - Differences bet. Intelligibilities generate from:
     - Structure of articulators (sound-producing organs)
     - Speech habits that people acquire
     - Speech training may improve speech intelligibility (but not very much)
   - Watch the following video on improving enunciation: https://youtu.be/pBDS6Li2WQM

Cont. Speech Communication Systems

2. Message

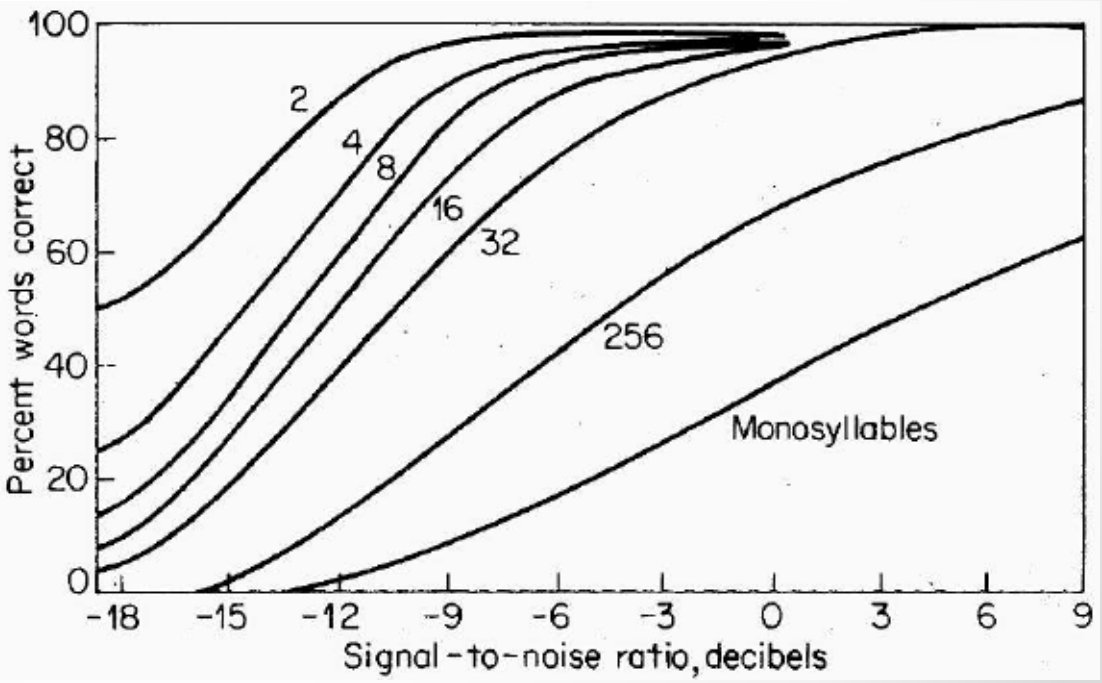
Affected by: phonemes used, words, context

- Phoneme Confusions
  - Some speech sounds more easily confused than others
  - e.g. letters in each group (consonants) can be confused with each other: **DVPBGCET**, **FXSH**, **KJA**, **MN**
  - Avoid using single letters in presence of noise
- Word Characteristics: for higher intelligibility use:
  - More **familiar words**
  - **Longer words**: for longer words even if part of word is dropped, rest can still be figured out
  - e.g. “word-spelling” alphabet: alpha, bravo, Charlie, delta, … instead of A, B, C, D

Cont. Speech Communication Systems

2. Cont. Message

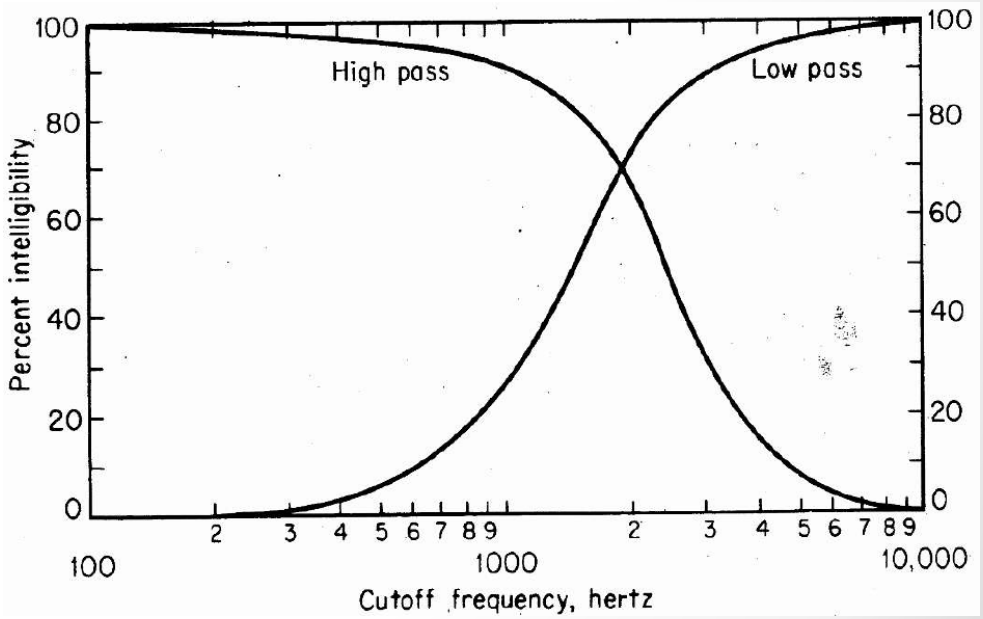
- Context features: for higher intelligibility use:
  - **Sentences** (rather than words)
  - **Meaningful sentences** (rather than non-sense phrases)
    - e.g. “This book is great” rather than “is great book this”
  - **Less vocabulary** (words) in the presence of noise
    - More words with noise ⇒ less intelligibility (see below)
    - Note, -ve SNR means noise is more intense than signal
    - Also note, monosyllable: words with only one syllable (e.g. hit, ant, cube, fish)



Cont. Speech Communication Systems

3. Transmission System

- Transmission Systems
  - Natural: air
  - Artificial: telephone, radio, etc.
- Artificial systems cause distortions, e.g.
  - Amplitude distortion
  - Frequency distortion
  - Filtering
    - Low-pass filter: eliminates freq. above some level
    - High-pass filter: eliminates freq. Below level
    - Filtering: freq. > 4000 Hz, < 600 Hz: little effect on intelligibility; but how about > 1000 Hz, < 3000 Hz?



Cont. Speech Communication Systems

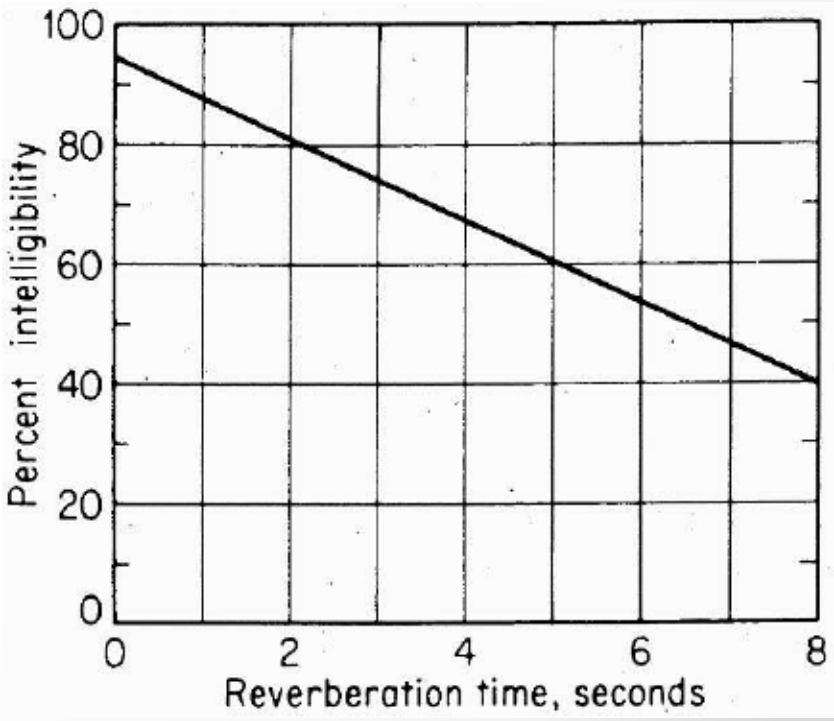
4. Noise Environment

- causes biggest harm to speech intelligibility
- **SNR** (signal to noise ratio):
  - Simplest way to evaluate impact of noise on intelligibility
  - Study: for noise level of 35-100 dB ⇒ SNR = 12 dB for threshold of intelligibility (what to do for loud noise?)
  - However, SNR does not take frequency into consideration (only intensity)
- Other measures (taking freq. into consideration):
  - **Articulation index** (AI): a measure (0-1) of speech intelligibility while knowing the noise environment
  - **Preferred-octave speech interference level** (PSIL): rough measure of effect of noise on speech reception
  - **Preferred noise criteria** (PNC) curves: suggest acceptable noise level for different work environments (e.g. offices)

Cont. Speech Communication Systems

4. Cont. Noise Environment

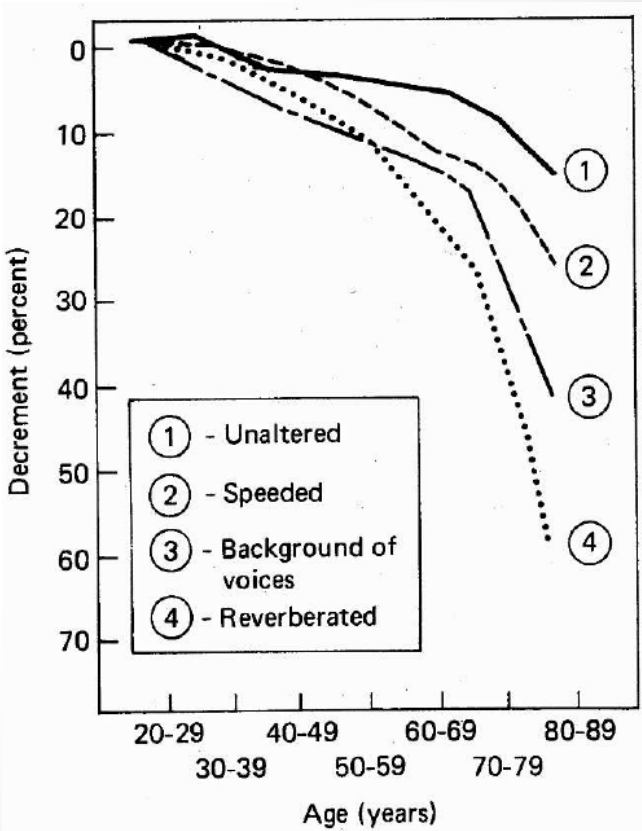
- **Reverberation**:
  - Bouncing effect of noise from walls, floor, ceiling in a closed room
  - Greatly decreases speech intelligibility (e.g. classrooms)
  - In general, the longer the reverberation time, the more the speech intelligibility decreases
  - Examine the linear relation (right) for a decaying 60 dB noise



Cont. Speech Communication Systems

5. Hearer

- To receive speech under noise: hearer should
  - Have normal hearing
  - Be trained to receive messages
  - Be able to withstand stress of situation
- Age
  - Also affects speech reception (i.e. intelligibility); see right
  - 20-29 age group: base level
  - Note, unaltered speech: 120 wpm vs. speeded speech: 300 wpm
- Hearing protection
  - Prevents hearing loss
  - May improve SI for noise >80 dB*A*
  - Decreases SI for noise <80 dB*A*



References

- ***Human Factors in Engineering and Design***. Mark S. Sanders, Ernest J. McCormick. 7th Ed. McGraw: New York, 1993. ISBN: 0-07-112826-3.