LING3701/PSYCH3371: Lecture Notes 7
Speech perception and phoneme recognition

Contents

7.1 Speech perception

Speech perception starts when speech sounds enter ears...

1. The **pinna** modifies sound behind you so you can localize front/back.
2. The **eardrum** is connected via bones in the middle ear to the membrane of the **cochlea**.

   (It protects the cochlea from water, bacteria, Q-tips.)
3. Phase-locked delay line carries low frequencies from cochlea to **nucleus laminaris**.

   The difference in phase helps triangulate the sound source in binaural audition.

   (It only works for waves larger than 1/2 size of your head.)
4. Vibrations in the cochlea vibrate small/med/large **cilia** in the **basilar membrane**.

   (These are killed when you go to a concert; the ringing tone afterward is tinnitus.)
5. Cilia in the basilar membrane are connected to neurons.

   (These can be stimulated artificially with cochlear implants.)
6. Spatially-encoded neural stimuli form features in a concept space.

   (These are like color, but resolve with 40 or so dimensions.)

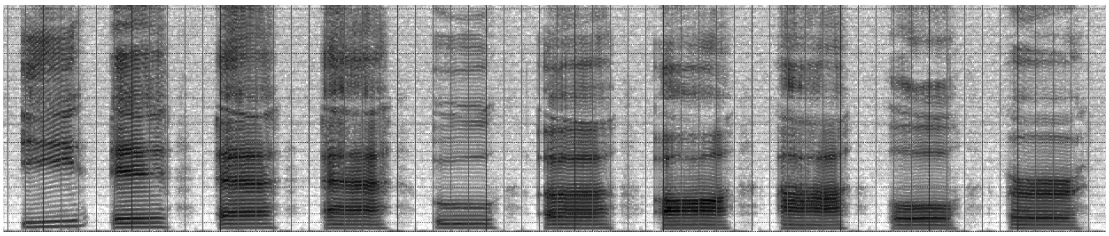
7.2 Spectra

We can 'see' speech / other sound using spectrogram (~how brain 'sees' it)

- We can multiply the signal by sin,cos function at different frequencies to get +/- resonances.

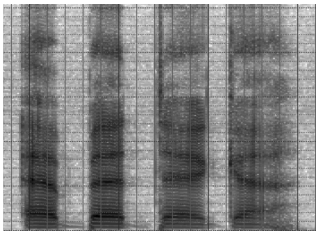
  (These are similar to hairs physically resonating with different signals.)

  (Sin,cos differ by 1/4 phase, triangulate magnitude of signal at any phase.)

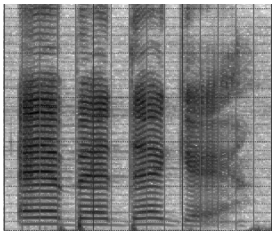


[i ɪ ɛ æ u ə ɔ a l r]

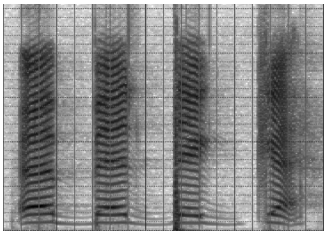
- Main **fundamental frequency** comes from the larynx: the note speaker is singing/saying.



male [ɛ b ɛ d ɛ g ɛ]



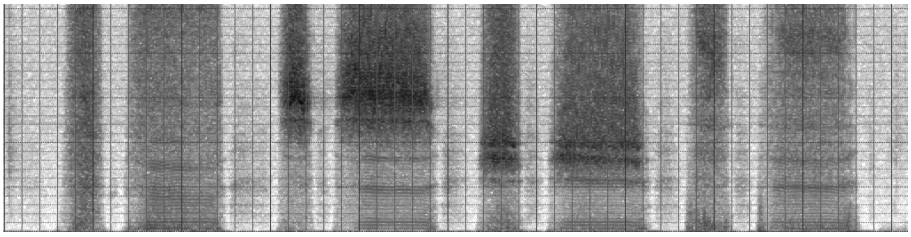
female [ɛ b ɛ d ɛ g ɛ]



child [ɛ b ɛ d ɛ g ɛ]

- Also, **harmonics** at each integer multiple above fundamental frequency.

  Like pushing a swing (actually, pushing hair); pushing every n^{th} cycle still works.
- The first big peak across harmonics is **first formant**: resonance in pharynx.
- The second big peak is **second formant**: resonance in oral cavity.
- Above that, a few more formants (timbre).
- Then **frication** noise, from back obstr. to front: ch/k, sh, s/t.



[f v s z ʃ ʒ θ ð]

(Telephones cut off at 8kHz, can't tell /s/ from /f/.)

7.3 Phoneme recognition

Phonemes are partially defined by formant/frication frequencies:

- Sine wave speech is understood as speech.
- Phonemes correspond to contiguous regions of formant space.

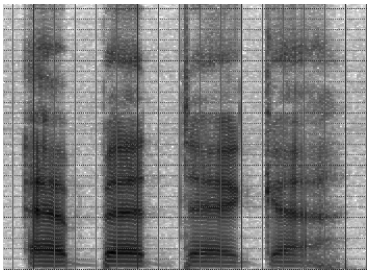
  (Classifications of sound, as words are classifications of ideas.)

- Categorical perception / perceptual magnet effect:

  We can detect difference between phonemes better than within phonemes.

But speech does not consist of simple sequence of phonemes:

- There is no sound for stop phonemes; isolating them on a tape just gives chirps.



  [ɛ b ɛ d ɛ g ɛ]

- Voiced/unvoiced stops are both technically unvoiced, differ only in VOT.
- Phonemes are coarticulated (distributed across signal):
  - progressive assimilation: frication in seat higher freq. than in suit
  - regressive assimilation: frication in key higher freq. than in koo
  - regressive assimilation: vowel in con more nasal than cop
  - regressive assimilation: cannonball → /kænəmbɔl/

Phonemes are not fixed classes either:

- There is variability across speakers:
  - age, sex produce different fundamental frequencies, formants
  - accent changes phoneme characteristics
  - voice characteristics (voices are identifiable)
- There is variability across utterances:
  - different speed (/b/ in slow speech equals /p/ in fast speech)
  - different emotional state raises/lowers frequencies
  - ambient noise:
    - other voices, traffic, room walls, . . . masks speech characteristics
    - Lombard effect: increase loudness, pitch, duration
  - context:
    - speakers increase distance from neighboring phones/words

    - whisper
    - sarcasm, humor, dopey voice

Phoneme recognition takes information from several sources:

- from visual cues:
  - McGurk effect: play audio of /ga/, video of /ba/ → subjects hear /da/

    (Why /da/? Closer in sound to /ga/ than /ba/, but has closed mouth)
- from vocal stress
- from orthography: apsurd
- from language predictions:
  - lex knowledge in phone reconstruction: *'s_lice'* → splice (not stlice, etc)
  - frequency: *'a girl with kaleidoscope eyes'* → a girl with colitis goes by
  - semantic: *'They hae slain the Earl o' Moray and layd him on the green'*

    → They hae slain the Earl o' Moray and Lady Mondegreen

Bottom-up / top-down processing (we'll see later)

Speech perception interleaves with production

- split utterances: A: we didn't finish... B: our sentences? I noticed.