Ch. 4: Phonatory System

Myoelastic-Aerodynamic Phonation

Life Span Changes

Vocal Quality & Register

Larynx

Larynx

Anatomy & Physiology

- Find your larynx
  - Top bump on throat

- This video: https://youtu.be/Aoa_N1vQS4M (< 2 min)
- Other useful A&P videos: https://jessicafilson.wixsite.com/speechsubsystems

Larynx & Phonation (extra/fun)

- Other useful review videos:
  - Larynx anatomy (<2 mins)
    - https://youtu.be/Aoa_N1vQS4M
  - A&P (<3 mins)
    - https://youtu.be/b89RSYCaUBo
- For fun:
  - singing in MRI: https://youtu.be/J3TwTb-T044

Voicing cycle

- MATP
- Duty cycle

Myoelastic-Aerodynamic Theory of Phonation (MATP)

- Most accepted model of voice production
  - Voice production (phonation) = Interaction of muscle force (myo), tissue elasticity (elastic), and air pressures and flows (aerodynamic)
- Vocal folds (VFs) act as a sound generator
  - VFs vibrate the air coming from lungs to the larynx
  - Creates a sound wave in the vocal tract
    - How…

MATP: Steps in Voicing

1. Vocal folds close to initiate vibration
   - Laryngeal muscles exert **medial compression** to hold VFs closed
2. Air pressure beneath the VFs (subglottal pressure, P_s) builds up, then forces the vocal folds apart
3. Puff of air escapes, vibrates air in vocal tract
   - Laryngeal valves modify the sound wave

MATP: Steps in Voicing

4. Vocal folds are pulled back together:
   - Elasticity causes VFs to recoil toward midline
   - Closing VFs form a narrow channel
   - The air passing through the channel speeds up and drops in pressure (**Bernoulli Principle**)
   - The negative pressure pulls VFs back together

Duty Cycle

- One VF cycle of vibration (**duty cycle***) has four phases:
    1. opening
    2. open
    3. closing
    4. closed
- Occurs hundreds of times per second

** Note that this description starts at a different point than the prior description of the MATP cycle*

Mucosal Wave

- Vocal folds do not move as one mass
  - The bottom parts move before the tops (Fig 4.16)
    - P_s pushes on the bottom parts first
    - Bottom parts start to recoil before the top parts, making a channel at the bottom before the top, etc.
  - The back opens before the front
  - BUT the front closes before the back
  - https://youtu.be/9kHdhbEnhoA
- Result: VFs move in **mucosal wave** motion, producing complex periodic sound
  - Summary: https://youtu.be/Aoa_N1vQS4M?t=0m48s

Measures of voicing

Phonation Threshold Pressure

- **PTP**: The minimum amount of subglottal pressure (P_s) needed to begin VF vibration
  - PTP for speech: 3-6 cm H_2O
  - PTP for yelling: 50 cm H_2O
  - P_s must be higher than pressure above VFs (supraglottal)
  - Difference in pressures (**transglottal pressure**) forces air up through glottis

Acoustic Features

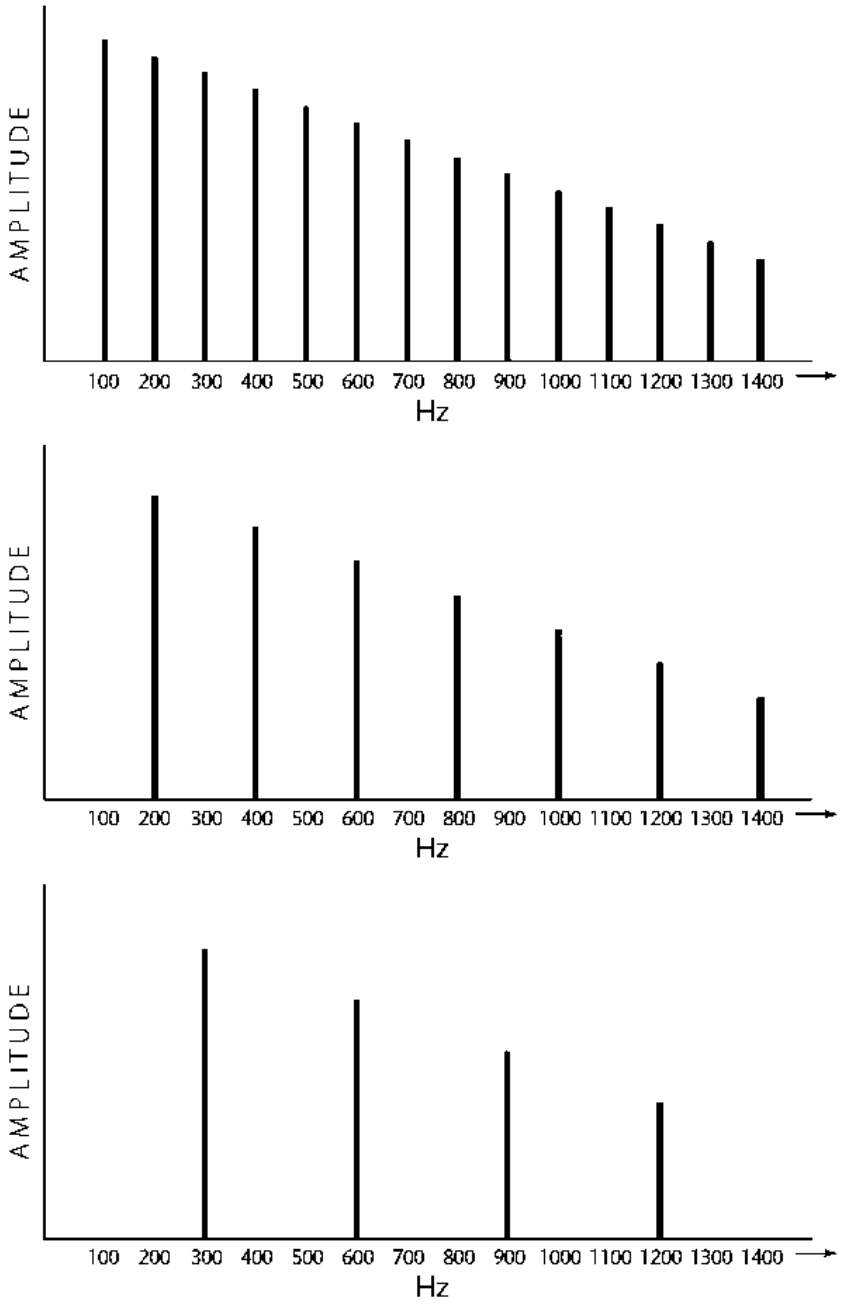
- Measureable acoustic traits of vibrating VFs:
  - Fundamental frequency (F_0)
    - Lowest frequency of the complex sound wave
  - **Spectral slope**
    - **Roll off rate**: amplitude decrease between harmonics
    - F_0 has the largest amplitude, each harmonic is smaller
    - Amplitude near 0 around 4000 or 5000 Hz
  - **Harmonic spacing**
    - Frequency difference between harmonics (= F_0)
    - Number of harmonics $\tilde{}$ wave complexity
  - Periodicity: **Jitter** & **Shimmer**

Harmonic Spacing

- Harmonics: Whole multiples of F_0 ("count by" F_0)
- **Harmonic spacing**: difference btw. harmonics (= F_0)
  - F_0 100 Hz (man)
    - Harmonics: 200, 300, 400, 500 … 4800 Hz = 47 harmonics
    - Spacing: 100 Hz
  - F_0 200 Hz (woman)
    - Harmonics: 400, 600, 800, 1000 … 4800 Hz = 23 harmonics
    - Spacing: 200 Hz
  - F_0 300 Hz (child)
    - Harmonics: 600, 900, 1200, 1500 … 4800 Hz = 15 harmonics
    - Spacing: 300 Hz
- Higher F_0 = wider spacing = fewer harmonics = less complex wave = "thinner/purer" sound

Glottal Spectrum

- Line spectrum of F_0 and harmonics of a voice
  - From a microphone placed right above the glottis, before its waves are modified by the vocal tract



Periodicity

- The human voice is not completely periodic, but has tiny cycle-to-cycle fluctuations (perturbations) in frequency and amplitude
    - Causes: asymmetrical vocal folds, variations in lung pressure, turbulence, articulator movement…
  - **Jitter**: Frequency perturbation
    - Normal values: 0.2 – 1 %
    - Higher for children and older adults
  - **Shimmer**: Amplitude perturbation
    - Normal values: < 0.5 dB

Laryngeal changes across the lifespan

Childhood Larynx/Voice

- Infants
  - Tiny vocal folds (~3 mm)
  - F_0 of 400–600 Hz
- Childhood
  - Larynx and VFs increase in size
  - VFs lengthen steadily (~0.4–0.7 mm/yr)
  - F_0 lowers to ~230 Hz by preteen years

Puberty

- Both sexes: lots of growth
- Females
  - VFs lengthen ~34% (~4 mm)
    - Adult length: ~12-18 mm total
  - F_0 lowers to ~220 Hz
- Males
  - VFs lengthen ~63% (~11.5 mm)
    - Adult length: ~17-25 mm total
  - F_0 lowers to ~120 Hz

Aging

- **Presbylaryngis**: laryngeal aging
  - Muscle atrophy, less control
  - Incomplete glottal closure
    - Menopause: VF mass increases, vibration rate slows
  - Decline starts in 30s/40s ☹
- **Presbyphonia**: resulting vocal changes
  - Hoarseness, increased fluctuations
  - Breathiness
  - Pitch changes:
    - Older men: F_0 raises
    - Older women: F_0 lowers

Vocal Quality (VQ)

Vocal Quality

- No exact definition
  - Used in different fields for different meanings
- Related to manner of vocal fold vibration
  - And shape of vocal tract

Normal Voice Quality

- "An accepted definition of normal voice does not exist. … Attempting to set standards might be likened to defining what constitutes normal appearance." Colton & Casper (1996)

- For our purposes "normal" = non-pathological
  - Clear
  - Appropriate pitch, loudness for age, sex, situation
  - No undue effort, strain, pain, fatigue
  - Satisfactory for speaker's social, emotional needs

Normal Voice Quality

- Parameters contributing to normal quality:
  - Average fundamental frequency (F_0, pitch)
    - Within expected range for age, sex, social identity…
  - Frequency range (2-3 octaves)
  - Maximum phonation time (adults: 15–25 sec)
  - Amplitude (loudness) range (20–30 dB)
  - Periodicity of VF vibration (**jitter** < 1%)
  - Noise (**additive** or **spectral noise**)
    - Turbulent air: abnormally high energy in high frequencies → breathy, hoarse, rough

Abnormal Voice Qualities

- **Dysphonia:** voice that sounds deviant in terms of tone, pitch, and/or loudness
  - Sounds "strident, rough, raspy, shrill, harsh, hoarse, tinny, strained"…
  - Pathological, uncontrolled by speaker
- Common, acoustically-measurable terms related to manner of VF vibration:
  - Breathiness
  - Roughness/hoarseness

Breathy & Rough/Hoarse Voice

- VFs don't close completely, air leaks through the glottis during the closed phase
  - Turbulent air makes frication noise in addition to VF frequencies
    - **Breathy**: noise in higher frequencies > 5 kHz
    - Video: https://youtu.be/9cKnUFZjs8k
    - **Rough/Hoarse**: noise in lower frequencies < 1 kHz
    - Video: https://youtu.be/6d4Z303XGb4
  - Waveforms less periodic
  - Occur w/ aging, voice disorders

Contributors

- Vocal fold closing
  - **Hypoadducted** (VFs don't close tight/ often enough) → "breathy, weak" voice
  - **Hyperadducted** (VFs close too much/ often) → "tense, harsh" voice
- Velopharyngeal valving
  - **Hypernasal** (port doesn't close well) → "nasal"
  - **Hyponasal** (port closed too much/often) → "stuffed up"

Vocal Registers

Vocal Registers

- VF vibration “settings”
  - Modal: most speech
  - Pulse (aka creaky voice, glottal fry, vocal fry)
  - Falsetto (aka loft)
- Different manners of VF vibration
- Pulse, falsetto: not pathological unless speaker always uses them or can’t control when

Modal

- Most speech
- Smooth mucosal wave
- VFs are open/closed about 50/50% of the cycle
- Video: https://youtu.be/FJRv-6T9X4A

Pulse/Creaky/Fry

- VFs are short and thick; false VFs may come into contact with true VFs
- Irregular vibration, can hear individual VF pulses (sounds like very low pitch)
- VFs are closed ~90% of cycle
- **Multiphasic closure**: Close incompletely during some cycles
- Video: https://youtu.be/BYSZS1LaABQ

Falsetto/Loft

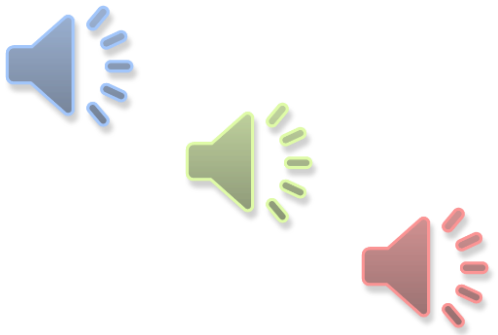
- Tense vocal folds
- Very high pitch
  - Fewer harmonics = less complex wave → "thin" quality
- Video: https://youtu.be/G10EkAW12yk

Linguistic uses of VQ

Linguistic Uses: Phonemes

- Some languages use breathy and/or creaky voice to distinguish phonemes
  - Many languages of India, North America

- Mazatec (a language of Mexico) has modal, breathy, and creaky vowel phonemes
  - Modal “for a while” [tʰǽ]
  - Breathy “horse” [ⁿdǽ̤]
  - Creaky “becomes” [nǣ̰]



Linguistic Uses: Phonemes

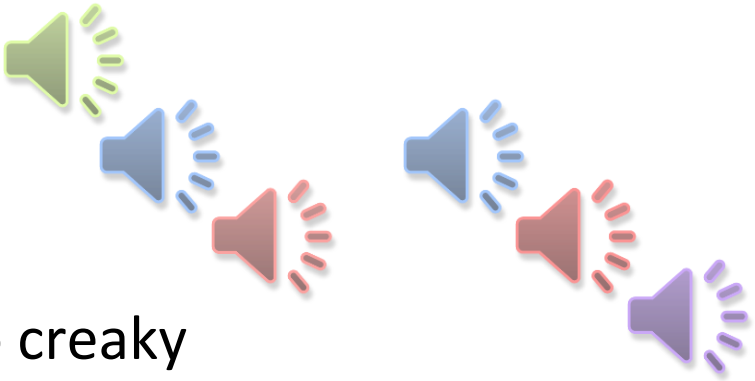
- Gujarati (a language of India) has modal and breathy vowel phonemes
  - Modal: [mɛl] ‘dirt’
  - Breathy: [mɛ̤l] ‘palace’
- Hupa (a language of California) has modal and creaky vowels and nasals
  - Modal: /xoŋ/ ‘s/he’
  - Creaky: /xoŋ̰/ ‘fire’

Linguistic Uses: Phonetic Cues

- Creaky or breathy voice can accompany certain phonemic tones or change their pitch
  - Ex: Mandarin Chinese has four tone contours that appear on vowels to distinguish words
    - One tone dips low in pitch and then goes back up
    - Or it dips low and ends in creaky voicing
- Creaky voice can accompany/replace consonants
  - /ʔ/ in Native American languages, /t/ in English

Linguistic Uses: Social

- Creaky voice is used in English to signal the end of utterances – and social meaning
  - Age, gender (not only young women), social position, sexual orientation, expressiveness…
  - Ex: young women from the Pacific Northwest
    - Breathy
    - Modal
    - Creaky
    - Modal to creaky



Linguistic Uses: Social

- Falsetto is used in African American English for social and stylistic meaning
  - Some: Indignation; resistance to cultural power
- Many other reported uses:
  - Expressiveness: Gay identity
  - Toughness: Chicana gang girls
  - Cuteness: talking to babies/pets
  - Mocking: Reporting others' speech

Activity

Team Activity

- **Search** for info/videos on:
  - Vocal fry (creaky voicing)
  - Falsetto
  - Dysphonia
    - Breathy voice
      - Vocal fold paresis/paralysis, Transgender voice…
    - Rough/hoarse voice
      - Parkinson's…
  - Singing registers/voices/styles
    - Find more on: Vocal fry, chest, head, falsetto, whistle…
    - Tyley Ross "Singing in the MRI" https://youtu.be/J3TwTb-T044

Post (Discussion board)

1. How is the voice quality made?
   a. What are the VFs doing?
   b. Tips for making it
2. What do (regular) people think/feel about it?
3. Evaluate what you found: good/bad info/advice