Music 170: The Voice

Tamara Smyth, trsmyth@ucsd.edu

Department of Music,
University of California, San Diego (UCSD)

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Voice and Speech Production

- Where wind instruments have a *bore, bell and reed*, the voice has a *vocal tract, a mouth, and vocal folds*.

- In speech, air from the lungs travels through the
  1. the **larynx**, 
  2. the **glottis**: the aperature between the **vocal folds**, 
  3. the **vocal tract**: 3 main cavities: the **pharynx**, the **nasal** and **oral** cavities.

  and is radiated from the mouth and nose.
The Vocal Folds

- The vocal folds act as a pressure-controlled valve and serve as a primary mechanical resonator in speech.

- The vocal folds are a ligament extending from
  1. the *thyroid cartilage* in the front,
  2. to the *arytenoid cartilages* at the back.

![Figure 1: The Vocal Folds (Sundberg).](image)

- The arytenoid cartilages are moveable and control the size of the V-shaped opening between the vocal folds, called the *glottis*.
• The vocal folds act in several different ways:
  – completely closed: flow of air is cut off;
  – open suddenly: a cough or glottal stop (“idiot!”);
  – completely open: unvoiced sounds, e.g. “s”, “sh”, “f” etc.;
  – half closed/open: “h”;
  – rapidly opening and closing: modulate air to produce vowels and voiced consonants.
• See vocal folds in action
• See vocal folds up close while singing

• The **fundamental frequency** of vibration is controlled mainly by the surrounding muscles.

• The **amplitude** is controlled mainly by the subglottal pressure, controlled by the respiratory muscles.
  – relationship is *nonlinear* as demonstrated by octave leaps (as in a cow mooing (time 0:09))

• Vocal synthesis in 1791:
  Wolfgang von Kempelen’s speaking machine
The Vocal Tract and Resonance

- The vocal tract consists of 3 main sections:
  1. the **pharynx**,  
  2. the **oral cavity** (mouth)  
  3. the **nasal cavity** (nose)

- Though sounding pitch is determined mainly by the frequency of the **vibrating vocal folds**, sound spectrum is strongly shaped by the resonances of the **vocal tract**:  
  - resonances distinguish one phoneme (unit of speech sound, e.g. vowels and consonants) from another.
Resonance and Formants

- Peaks in the spectral *envelope* independent of harmonic peaks are called *formants*.
  - each formant corresponds to one or more resonances in the vocal tract,
Tract Shape and Frequency

- A cylindrical tube consists of alternating nodes and antinodes.
- Constricting the tube near a pressure node (displacement antinode):
  - forces molecules to pass through a narrower opening
  - assuming pressure that propels them remains the same, more time is needed to complete the motion;
  - wave slows down and frequency decreases.
- antinode (displacement node):
  - reduces volume;
  - additional molecules produces increase in density and pressure;
  - system effectively becomes stiffer—responds faster, so frequency increases.
Tract Shapes for Different Vowels

- A as in “Bart”

- AE as in “Bat”

- U as in “Food”

- I as in “Beet”
Pitch and Formants

- The pitch of the voiced sound and the formant frequencies are virtually independent.
  - male and female voices are pitched about an octave apart but their formants usually differ by less than a musical third.
- Though the pitch is mostly determined by vocal folds, loudness and timbre depend on both the vocal folds and the resonances (formants) of the vocal tract.
- A formant may enhance the fundamental or a higher harmonic (or may be tuned to do so).
  - e.g. if a bass sings “ah” with a pitch G₂ \( (f = 98 \text{ Hz}) \), the first formant gives its greatest boost to the seventh harmonic (the pitch remains at G₂).
Spoken Versus Sung Vowels

Though vowels are fundamentally the same whether sung or spoken, modifications improve musical tone when singing:

1. the larynx is lowered;
2. the jaw opening is larger;
3. the tongue tip is advanced in the back vowels “oo”, “oh” and “ah”;

Spectrum of the vowel “ae” (“bat”) spoken and sung:

- the first formant is practically unchanged
- the second formant of the sung vowel is lower in frequency.
- the third and fourth formants are markedly stronger for the sung vowel.
Singer’s formant

• How can a singing voice be heard above an orchestra?
• Trained singers show a strong formant around 2500-3000 Hz, which carries the voice more efficiently.
• The “singer’s formant” is
  – independent of the vowel and the pitch,
  – produced by lowered larynx and widened pharynx forming an additional resonance cavity.
• Vowel /a/ sung with a high and low larynx:

• Untrained singers tend to raise their larynx as they raise the pitch.
Formant tuning by sopranos

• Sopranos do much of their singing in a pitch range that exceeds the frequency of the first formant and thus do not benefit from its boost.

• Compensation is done by “tuning” formants so they coincide with the fundamental or one of the overtones of the note being sung.

• The vowel “ee” sung at F₅ (698 Hz) will have a first formant at 310 Hz.
  – by opening the lips slightly wider, the formant can be pushed up to the vicinity of the sung pitch.

• The vowel “ah” at a pitch of A₄ (440 Hz) will have a first formant at around around 700 Hz:
  – the singer would likely raise the 700 Hz formant to match the second harmonic at 880 Hz.

• See how a computer program is being used to help singers visualize the correct vocal shape when producing vowels:

  The Art, and Science, of Singing Vowels
Registers in Singing

- A register is the frequency range in which all tones are perceived as being produced in a similar way and possess a similar voice timbre.

- There are three registers corresponding to the differences in tone caused by adjustments of the larynx:

  1. Chest (heavy)
  2. Middle
  3. Head (light)
Playing with Registers

- In males, these are often labeled *chest, head, and falsetto*.

- Yodeling is a singing technique where the “breaks” between chest and head registers are exaggerated. [Yodling–Franzl Lang](https://www.yodling-lang.de/)

- Some will say that women don’t have a falsetto, but rather a whistle register: [Mariah Carey](https://www.youtube.com/watch?v=94lJdGkbh1U)

- Because there is no universally accepted approach to defining registers, it may be preferable to refer to two models of vocal fold vibration:

  1. *heavy* mechanism or *chest* voice,

  2. *light* mechanism or *head* voice (falsetto)
Tuvan Throat Singing

- In Tuva, the herdsman will sing to imitate the natural sounds of their rural environment, e.g. gurgling water and swishing winds, that are rich in harmonics.
- Their technique involves a single vocalist producing two distinct tones simultaneously.
- One tone is low, drone-like, and the second is a series of flute-like harmonics, which resonate high above the drone.
- The general term for this singing is khoomii, from the Mongolian word for “throat”.

Throat Singing
Mechanism for Throat Singing

- The mechanism for achieving two tones involves three interrelated components which increase the coupling between the source and filter:

  1. tuning a harmonic (by raising or lowering the fundamental) to the center of a formant peak—this makes it stronger.
  2. lengthening the closing phase of the open-close cycle of the vocal cords to reduce leakage down the windpipe.
  3. creating abrupt closures leads to higher frequencies
  4. narrowing the range of frequencies over which the formant will affect harmonics

- It is not limited to the physiology of the Turco-Mongol people—anyone can do it!
  - changing from “ee” to “oo” and back again; the harmonics come out naturally:

  How to sing overtones