The Physics of Making Sound by Maria Gini

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When air is expelled from the lungs, it rises up the trachea and runs into constriction at the larynx â€“ where the vocal cords, now called vocal folds, are housed - causing the vocal folds to vibrate or buzz. This buzzing quality to the speech is called voice or voicing. The vocal folds â€œchopâ€• the air stream up into a series of rapid â€œpuffsâ€• that create the sound. (It isnâ€™t the impact of the folds comi together that makes the sound.) This produces a fundamental tone frequency, (the lowest frequency in a harmonic series), accompanied by several non-harmonic overtones, (a natural resonance or vibration frequency of a sound system).

The resulting sound is modified by movements in the vocal tract, (where sound that is produced at the larynx, pharynx, and oral and nasal cavities is altered), by the volume of the airflow and by the degree of constriction of the vocal folds. (During speech the flow of air is relatively small because of constrictions of the vocal folds.)

The vocal vibration is varied to produce intonation, (the variation of pitch to express emphasis, contrast, emotion, etc.), and tone, (the use of pitch in language to distinguish words). This is accomplished by varying the pressure of the air column under the glottis, (the space between the vocal folds, located in the middle part of the larynx), as well as the tension in the vocal folds themselves. These actions produce changes in the frequency of vocal-cord vibration, which generates the fundamental pitch of the voice.

Resonation (Vibration)

The buzz created by the vocal folds resonates (vibrates) the air column and this, in turn, causes the structures above and around the larynx to vibrate, as well.

The parts of the body that can vibrate in harmony with the voice are often called resonators, which include the air column and formants (see section on formants below).

The following areas vibrate â€œsympatheticallyâ€• with the air column. The way in which each area vibrates acts as a cue to the quality of the sound created, giving tactile motor feedback to the brain, which works in conjunction with the hearing mechanisms. The following is a list of resonators and the pitches or vocal qualities that most easily activate them:

Chest and Lower Body â€“ low pitches and open sounds, like â€œahâ€•

â€¢ Throat â€“ mid-range, easy speaking tone

â€¢ Mouth â€“ upper mid-range, mid-vowels

â€¢ Nasal â€“ closed, front vowels, especially when followed by a nasal consonant such as â€œnâ€• or â€

â€¢ Facial â€“ high range, front vowels

â€¢ Sinus â€“ Given that there are so many sinuses, many different quality sounds activate them

â€¢ Bones and Skull â€“ falsetto and head voice, very high range, closed vowels.

â€œPlacementâ€• of the voice generally describes how the vibration of the air column interacts with these

structures to accentuate or diminish the size of the formants (see below). The term â€œplacementâ€• indicates where one feels the augmented vibration due to the change in the relationship of the formants to areas of the body.

Extending from the larynx to the lips, the air column vibrates at a natural frequency â€“ in much the same way that the pipes of an organ do. As the organ pipe is shortened, and thus the air column, the pitch gets higher. In speech, the rate of vibration of the vocal folds creates the fundamental frequency, or pitch of the sound. This frequency determines the musical pitch or note that is created by vibration over the full length of the air column. The frequency (or frequencies) at which the air column vibrates determines the quality of the tone.

The sound created by the vocal folds isnâ€™t a pure tone â€“ itâ€™s complex. It is made up of the fundam frequency, (the rate at which the folds vibrate), and a number of partials, which are harmonics of the fundamental frequency, vibrating two times, three times, etc. as fast as the fundamental. The voice is made up of a spectrum of the fundamental and these â€œovertonesâ€•, or formants â€“ see below. The lowest possible frequency and such multiples form the harmonic series.

Formants

In phonetics, formants are the distinguishing or meaningful resonant frequency components of human speech and of singing. They appear in spectrograms as peaks in the harmonic spectrum of the voice.

We distinguish between vowels - sounds in spoken language that are characterized by an open configuration of the vocal tract so that there is no build-up of air pressure above the glottis - by the frequency content of the vowel sounds. (This contrasts with consonants, which are characterized by a constriction or closure at one or more points along the vocal tract.) Formants are the characteristic partials that identify vowels to the listener. Most of these formants are produced by â€œtube and chamberâ€• resonance.

Since the larynx closes off at the bottom during phonation, it naturally resonates at the odd numbered multiples of the fundamental. These â€œstanding-wavesâ€• of sound are also known as formants. In shaping speech, the first three formants are the most important. In a way, it is as if each vowel is a â€œchordâ€•, like playing three notes together on the piano, where the bottom note stays the same and the notes above change.

What we recognize as vowels are actually changes in the quality of the tone. Our tongues allow us to change the shape of the â€œtubeâ€•, specifically changing the cross-sectional â€œwidthâ€• by sliding f and back. Lip rounding essentially lengthens the tube.

If the fundamental frequency of the underlying vibration is higher than the formant frequency of the system, the character of the sound imparted by the formant frequencies will be mostly lost. This is most apparent in the example of soprano opera singers, who sing high enough that their vowels become very hard to distinguish.

(Control of formants is an essential component of the vocal technique known as overtone singing, in which the performer sings a low fundamental tone, and creates sharp resonances to select upper harmonics, giving the impression of several tones being sung at once. There are many styles of this singing technique, including the chanting of the Tibetan Monks)

Phonation (Making Sound)

Phonation refers to the use of the laryngeal system to generate sound - an audible source of acoustic energy - which can then be modified by the articulatory actions of the rest of the vocal apparatus (see section on articulation below).

Sound is generated in the larynx - an organ in the neck involved in the protection of the trachea and

in sound production. The larynx houses the vocal folds, and that is why it is commonly referred to as the â€œvoice boxâ€•. It is situated just below the pharynx - the part of the neck and throat situated immediately behind the mouth and nasal cavity and cranial, and above the esophagus, larynx and trachea (the "windpipe").

The larynx is also where pitch and volume are manipulated. The strength of expiration from the lungs contributes to loudness, and is necessary for the vocal folds to produce speech.

Articulation (the Formation of Specific Speech Sounds)

Finally, air and vibration pass through the vocal tract and are shaped by the articulators into recognizable speech sounds.

Movable articulators are structures that can move and allow us to shape the sound, (i.e., the jaw, the lips and other facial muscles, the tongue, the soft palate â€“ the soft, movable tissue constituting the back of the roof of the mouth - and the pharynx).

Fixed articulators are those that cannot be moved by muscles, namely the hard palate and teeth. The hard palate is a thin, horizontal bony plate of the skull, located in the roof of the mouth, which spans the arch formed by the upper teeth. It forms a partition between the nasal passages and the mouth. (This partition is continued deeper into the mouth by the soft palate.)

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Maria Gini - About Author:
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