LING 210 **Handout: Stops** **Spring 2009**

Thursday, April 9th

Stops involve a complete closure of the oral tract, blocking all airflow through the mouth. Stops can be oral (with a raised velum to block nasal airflow) or nasal (with a lowered velum to allow nasal airflow), but the term ‘stop’ is often used just to refer to oral stops.

Airstream Mechanics

The **airstream mechanic**, or what Catford calls the **initiation**, of a sound is the source and direction of the airflow. The default airstream mechanic is **pulmonic**, with the lungs being responsible for airflow, and **egressive**, with air flowing out of the vocal tract. The vast majority of sounds in the world’s languages are made with a pulmonic egressive airstream mechanic. It is possible to have a pulmonic **ingressive** airstream mechanic, with airflow being sucked into the lungs, but this is rare.

There are two other major sources of airflow that are possible in human languages: **glottalic** (with closure at the glottis being responsible for airflow) and **velaric** (with closure at the velum being responsible for airflow). Both of these kinds of airstream mechanics can be egressive or ingressive, though velaric airstream mechanics tend to be ingressive only.

Phonation

Phonation is the state of the vocal cords during a sound, which is largely determined by how close together they are. If the vocal cords are maximally spread apart, airflow through the glottis will cause no vibration, causing the sound to be **voiceless**. As the vocal cords are brought closer together, airflow through the glottis will cause them to vibrate, causing the sound to be **voiced**. True **modal voicing** occurs at the exact position that results in the maximum amount of vocal cord vibration. If the vocal cords are vibrating, but are more open than for modal voicing, the sound is **murmured** (often referred to as **breathy voiced**). In the opposite direction, if the vocal cords are vibrating, but more closed than for modal voicing, the sound is **creaky voiced**. The following table summarizes these phonation types, and gives IPA symbols for sounds made with each phonation type:

	voiceless	murmured (breathy)	modal voiced	creaky voiced	glottal stop
glottal opening	maximally open	mostly open	medium	mostly closed	fully closed
vibration	none	some	maximal	some	none
IPA symbol	p	b̤ or bʱ	b	b̰	ʔ

In addition, voiceless sounds can be further distinguished by their **voice onset time (VOT)**, which is how long it takes from the release of the sound until the vocal cords move close enough together to allow voicing to occur. If the VOT is long (typically greater than about 0.04 sec), the sound is **aspirated**. During this period of time, the sound produced is very turbulent, creating aperiodic white noise. If the VOT is shorter than about 0.04 sec, **unaspirated** or **plain**, which means that it has very little noticeable white noise. If VOT is negative, voicing starts before the release, which means the sound is voiced. It is possible for voicing to only occur during part of the closure, in which case, the sound is **partially voiced**. Partially voiced sounds are sometimes more precisely described by giving the ratio of the VOT to the entire closure duration.

Plosives

Plosives are egressive pulmonic stops, made with a single closure in the oral tract. As air flows into the oral tract from the lungs, pressure builds up behind the closure. After a brief pause, the closure is released, and the built-up air pressure is quickly equalized as the air flows out of the mouth. All plosives are thus characterized by two primary acoustic properties: a period of silence or near silence during the closure, and a short transient, called the **release burst**, when the stop is released.

Plosive Closures

The acoustic properties of the closure of a plosive depend primarily on its phonation type. If the plosive is voiceless (unaspirated or aspirated), then the closure is silent. In the waveform of a sound, the closure will just be a flat line, while on a spectrogram, it will be essentially blank.

However, if the plosive is voiced (murmur, modal, or creaky), the vocal cords will vibrate during the closure, which will show up in the waveform as a low intensity, generally periodic wave during the closure. On a spectrogram, this voicing will often be visible as a faint, low intensity **voicing bar**. Because modal voiced sounds involve maximum vibration, their closure voicing will typically be louder than for murmured or creaky sounds, which shows up in the waveform as higher amplitude and in the spectrogram as a darker voicing bar. Due to resonance in the mouth, the glottal vibrations during the closure of a voiced sound can create very faint formant-like resonance, if they are said particularly loudly or recorded with very sensitive equipment.

In addition, the acoustic properties of the closure of a plosive can depend somewhat on its place of articulation. The more forward the plosive closure is, the longer it can be kept closed while air pressure increasingly builds up behind it. Thus, a bilabial plosive can generally be held longer than an alveolar plosive, which can usually be held longer than a velar plosive. So, the closure duration of a plosive will sometimes correspond to its place of articulation. However, plosives are typically so short that there is usually no opportunity for air pressure build-up to make a difference in difficulty in keeping the closure, so this is not a reliable acoustic property.

Plosive Releases

The acoustic properties of the release of a plosive depend on both its place of articulation and its phonation type.

The farther back the plosive closure is, the more quickly air pressure builds up behind it. The higher the pressure is, the louder the release will be as the air pressure is equalized. Thus, a velar plosive will generally have a louder release burst than an alveolar plosive, which in turn will generally have a louder release burst than a bilabial plosive.

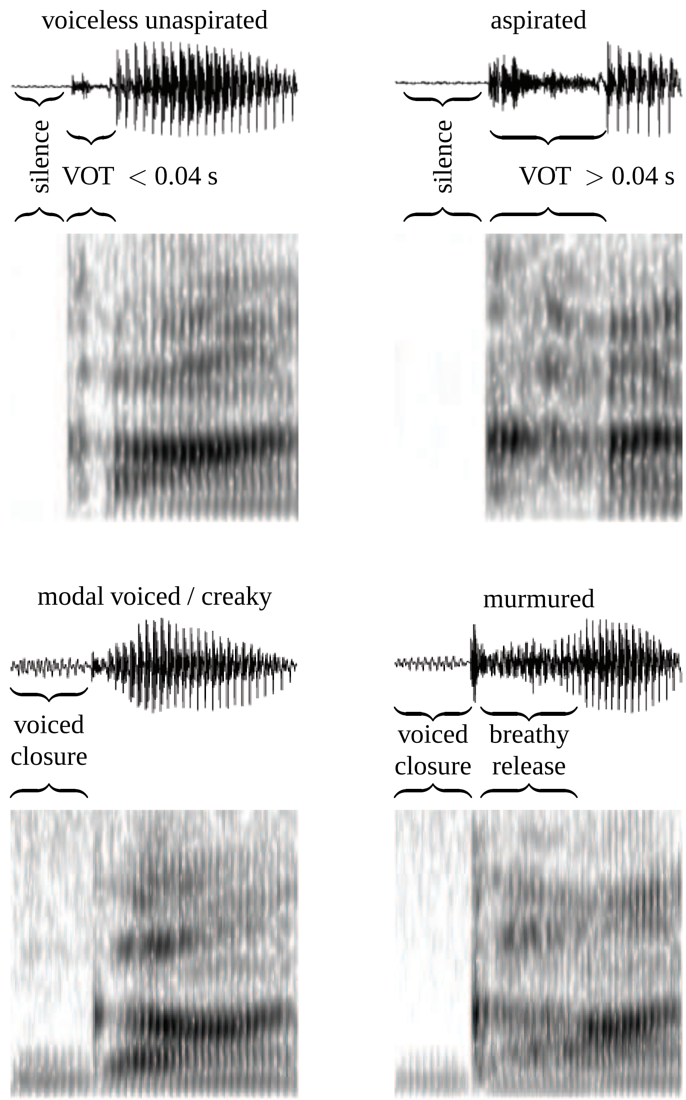
The release burst also resonates in the remaining portion of the mouth, which enhances certain frequency ranges within the burst. The farther back in the mouth the plosive closure is, the longer the tube is that the release burst will resonate in. Longer tubes have lower frequencies, so a velar plosive's release will generally be louder at lower frequencies than an alveolar plosive's release. Bilabial plosives have no remaining tube to cause resonance, but the release can be reflected back into the mouth, causing some [ə]-like resonance.

As stated before, the time it takes for voicing to begin after the release is the VOT. For voiceless sounds, VOT is positive, which means there is a brief period of time after the release that is voiceless, which can be seen as white noise. For unaspirated plosives, this period of white noise is very short, typically less than about 0.04 sec. For aspirated plosives, the white noise lasts longer, typically more than 0.04 sec.

Murmured plosives also usually have a long, noisy release, but it coincides with voicing from vocal cord vibration. This breathy release looks an combination of the following vowel with the white noise seen inthe aspirated release of an aspirated plosive. However, the white noise in a breathy release is softer, and the formants of the following vowel are darker and easier to see.

Creaky plosives look much like modal voiced plosives, though the frequency of the closure voicing tends to to have a lower frequency and a lower amplitude.

Plosive Summary



place	bilabial	alveolar	velar
burst intensity	softest	medium	loud
burst frequencies	none / [ə]	high	low
closure duration	longest	medium	short

Implosives

Implosives [ɓ ɗ ɠ] are ingressive glottalic stops, which are made by trapping air between two closures: one at the primary place of articulation and one at the glottis. The larynx then lowers, which decreases the pressure of the trapped air. However, it is difficult to keep the glottis completely closed during this maneuver, because air is naturally flowing out of the lungs as we speak. Thus, some air tends to leak through the glottis, causing it to spontaneously vibrate as it lowers. Thus, implosives are naturally voiced (though they can be forced to be voiceless). Once the larynx has lowered, the closures are released, and air flows into the mouth from outside before the airstream shifts to its normal pulmonic egressive flow. Because the air pressure does not change as much as for plosives, an implosive release is much softer than for plosives. Acoustically, implosives sound similar to voiced plosives, but have a weaker release, and an 'odd' sound because of its ingressive airflow.

Ejectives

Ejectives [p' t' k'] are egressive glottalic stops, which are made by trapping air between two closures: one at the primary place of articulation and one at the glottis. The larynx then raises along with the normal pulmonic airstream behind it. This raising of the glottal closure increases the air pressure of the trapped air. The primary stop closure is then released, and the high pressure air rushes out of the mouth (the glottal closure remains closed to prevent the air from traveling backwards). Then the glottis opened, and the pulmonic airstream behind it is released.

Ejectives are characterized acoustically by two transients: one for the oral release and one for the glottal release. The silence separating the releases can be 0.05 sec or longer. The intensity and resonance of the first release are the same as for plosives, while the second (glottal) release is much weaker and shows no resonance or formant transitions.

Clicks

Clicks are ingressive velaric stops, which are made by trapping air between two closures: one at the primary place of articulation and one at the velum. The tongue then lowers, which decreases the pressure of the trapped air. Because the trapped air is so small, it is very easy to change its pressure significantly. Then the closures are released, and air rushes into the low pressure area.

Clicks are characterized acoustically by a very loud transient (due to the very high pressure differential) followed by a period of silence as the tongue moves into position for the following vowel and the airflow switches from ingressive to egressive. Acoustically, they are somewhat similar to ejectives, but clicks only have a single release burst, not two.

Bilabial clicks [ʘ] are less intense than vowels, because the soft cheeks absorb much of the sound. It doesn't take long for air to fill the cavity, because the lips can move quickly and create a large opening, so the transient for a bilabial click is short ($\sim$0.01 sec). It also doesn't take long for the tongue to move into position for the following vowel, because the front of the tongue is not used in producing a bilabial click and can be in position already, so bilabial clicks also have a short silence after the transient ($\leq \sim$0.02 sec). Because of the dampening effects of the cheeks, bilabial clicks have spectral peaks over a range of high and low frequencies.

Dental clicks [|] are less intense than vowels, because the teeth diffuse the incoming air. It takes longer for air to fill the cavity, because it must travel around the teeth, so the transient for a dental click is long ($\geq \sim$0.02 sec). It also doesn't take long for the tongue to move into position for the following vowel, because the front of the tongue is released almost directly into a vowel-like position, so dental clicks have a short silence after the transient ($\leq \sim$0.02 sec). Because the click cavity is very flat, dental clicks have high frequency spectral peaks ($> \sim$2000 Hz).

Alveolar clicks [!] are more intense than vowels, because the sound echoes off the hard palate instead of the cheeks. It doesn't take long for air to fill the cavity, because the tongue tip can move out of the way quickly, so the transient for an alveolar click is short ($\sim$0.01 sec). It also doesn't take long for the tongue to move into position for the following vowel, because the front of the tongue is released almost directly into a vowel-like position, so alveolar clicks have a short silence after the transient ($\leq \sim$0.02 sec). Because the click cavity is very deep, alveolar clicks have low frequency spectral peaks ($< \sim$2000 Hz).

Palatal clicks [ǂ] are more intense than vowels, because the sound echoes off the hard palate instead of the cheeks. It doesn't take long for air to fill the cavity, because the tongue tip can move out of the way quickly, so the transient for a palatal click is short ($\sim$0.01 sec). It also doesn't take long for the tongue to move into position for the following vowel, because the front of the tongue is released almost directly into a vowel-like position, so palatal clicks have a short silence after the transient ($\leq \sim$0.02 sec). Because the click cavity is very small, palatal clicks have high frequency spectral peaks ($> \sim$2000 Hz).

Lateral clicks [ǁ] are more intense than vowels, because the sound echoes off the hard palate instead of the cheeks. It takes longer for air to fill the cavity, because it must travel around the tongue, so the transient for a lateral click is long ($\geq \sim$0.02 sec). Unlike other clicks, it also take comparatively longer for the tongue to get into position for the following vowel, because after the initial lateral release, the tongue tip is still touching the alveolar ridge, so lateral clicks have a long silence after the transient ($\geq \sim$0.05 sec). Because the click cavity is very flat, lateral clicks have high frequency spectral peaks ($> \sim$2000 Hz).

	bilabial [ʘ]	dental [ǀ]	alveolar [!]	palatal [ǂ]	lateral [ǁ]
transient intensity	soft		loud		
transient duration	$\sim$0.01 s	$\geq$ 0.02 s	$\sim$0.01 s		$\geq$ 0.02 s
post-transient silence	$\leq$ 0.02 s				$\geq$ 0.05 s
spectral peaks	varied	$>$ 2000 Hz	$<$ 2000 Hz	$>$ 2000 Hz	

Spectrograms for Non-Pulmonic Sounds