• Oral stops (plosives): Formant transitions, bursts

Background reading:

- *V&C* Ch 6, sec 6.2, "Stop consonants" (review)
- *AAP* Ch 8, chapter introduction
- *AAP* Ch 8, sec 8.2, "Vocal tract filter functions in stops"

0. Overview: Consonant acoustics

- Material for the midterm built up to applying the **source-filter model** of speech acoustics to **vowels**
- In the next part of the course, we will apply the source-filter model to **consonants**
- Still relevant:
  - Resonance frequencies of tubes
  - The glottal-source spectrum
  - Perturbation theory
- Today we will apply these concepts to **oral stops**

1. Oral stops: Overview and articulation

- **Oral stops** are often called simply *stops*
  - The term *plosive* may also be used — this refers specifically to oral stops produced with the **pulmonic egressive airstream mechanism** (more about this later)

- Which oral stops are found in **English**?

1. Oral stops: Overview and articulation

- Which oral stops are found in **English**?
  - Contrastive (phoneme) categories:

bilabial	*alveolar*	*velar*	
[p]	[t]	[k]	*voiceless*
[b]	[d]	[g]	*voiced*

  - Positional variants of other phonemes:

[p^h] [t^h] [k^h]	*voiceless aspirated*
[ʔ]	*glottal stop*

1. Oral stops: Overview and articulation

- What **articulatory properties** distinguish oral stops from other consonant classes?
  - How are they different from **fricatives** and **approximants** (=liquids and glides)?
  - How are they different from **nasal stops**?

1. Oral stops: Overview and articulation

- What **articulatory properties** distinguish oral stops from other consonant classes?
  - Complete **obstruction** in the oral tract
  - **No** nasal airflow

- Oral stops can **differ** in
  - **Voicing** (voiced/voiceless)
  - **Phonation type** (breathy voice/creaky voice)
  - **Aspiration** (voice onset time, VOT)

  → We'll look at these factors in more detail in later classes

1. Oral stops: Overview and articulation

- How does *AAP* divide the articulation of stops into **sub-stages**?

1. Oral stops: Overview and articulation

- How does *AAP* divide the articulation of stops into **sub-stages**? | **shutting, closure, release**

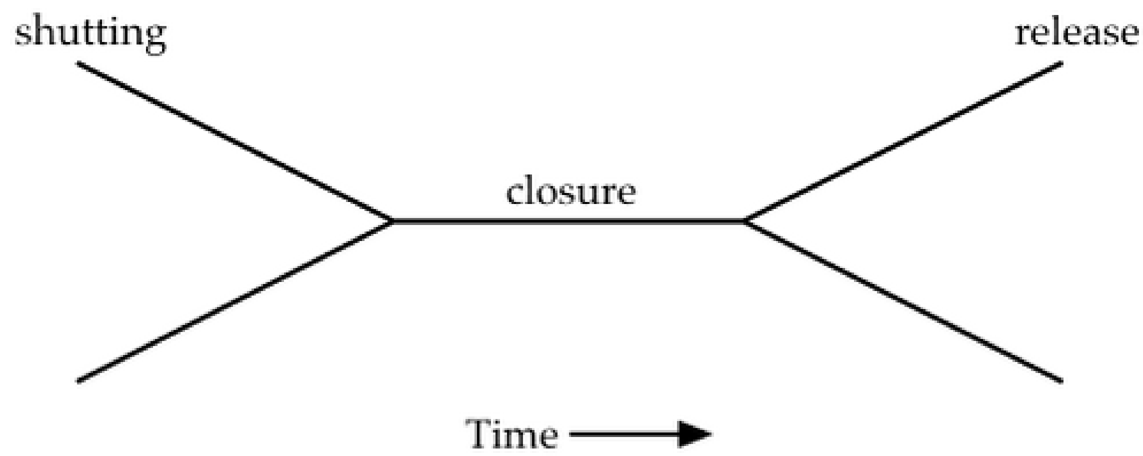


Figure 8.1 Three stages in the time course of stop or affricate production. The lines indicate articulators moving toward each other during the shutting stage and separating during the release stage.

- Be sure you understand how to read this articulator timing diagram — we will use these later also

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation:
  - What is the state of the <u>oral</u> tract during **schwa**?
  - What is the state of the <u>oral</u> tract during the **closure** stage of a **stop** (oral or nasal)?

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation:
  - What is the state of the oral tract during **schwa**?
    → Uniform tube
  - What is the state of the oral tract during the **closure** stage of a **stop** (oral or nasal)?
    → Completely closed
- What are the **acoustic consequences**?

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation → acoustics:
  - What is the state of the <u>oral</u> tract during **schwa**?

    → Uniform tube

    → Evenly spaced formants

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation → acoustics:
  - What is the state of the oral tract during the **closure** stage of a **stop** (oral or nasal)?
    → Completely closed
  - If the stop is **voiceless**, **no sound energy** at all
  - If the stop is **voiced**, the glottal source is filtered by the closed skull (see gray box, *AAP* p 175)
    - Only a few **low-frequency components** are audible ("voice bar" on spectrogram)

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation → acoustics:
    - What is the state of the <u>oral</u> tract during the **shutting** or **release** stage of a **stop**?
- What are the **acoustic consequences**?

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation → acoustics:
  - What is the state of the oral tract during the **shutting** or **release** stage of a **stop**?
    → A **transition** between uniform tube and complete closure
- What are the **acoustic consequences**?

2. Formant transitions and place of articulation

- Consider a stop between two schwa vowels
- Articulation → acoustics:
  - What is the state of the <u>oral</u> tract during the **shutting** or **release** stage of a **stop**?
    → **Transition** from uniform tube → closure
- What are the **acoustic consequences**?
  - Tube is gradually more and more (or less and less) **constricted** at C's **place of articulation**

→ $\boxed{\textbf{Formant transitions}}$

2. Formant transitions and place of articulation

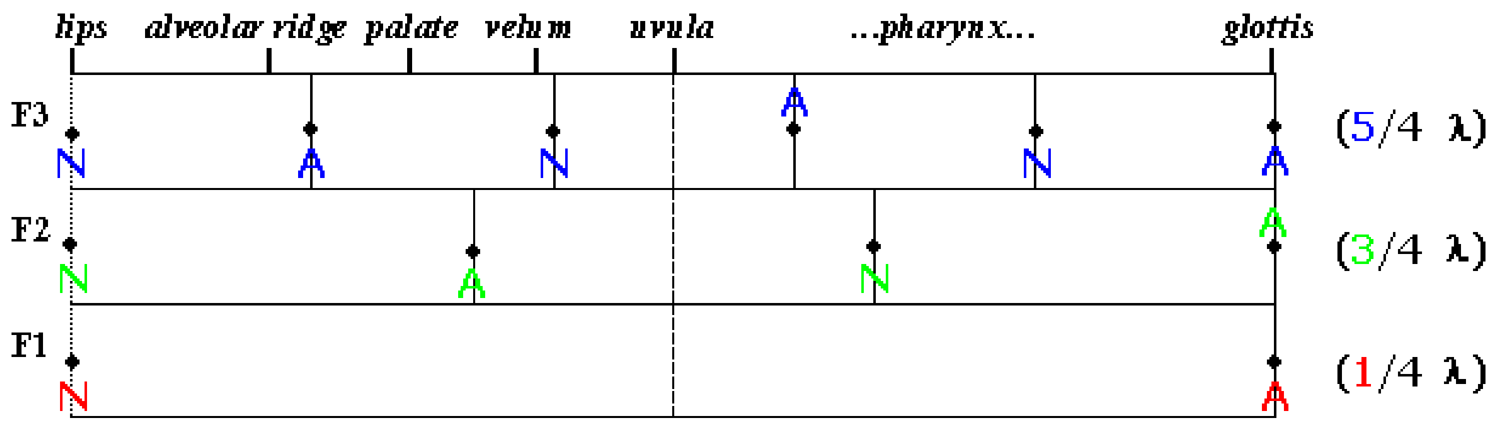
- **Formant transitions** are visible at the edge of a vowel when it is adjacent to a consonant
  - They reflect the effect of the consonant's **constriction** on the **formants** (vocal-tract resonances)
  - Formant transitions *happen* during the vowel, but they *provide information* about the **place of articulation of the consonant**

2. Formant transitions and place of articulation

- We know how to model the effects of a constriction at different locations in a tube | *how?*

2. Formant transitions and place of articulation

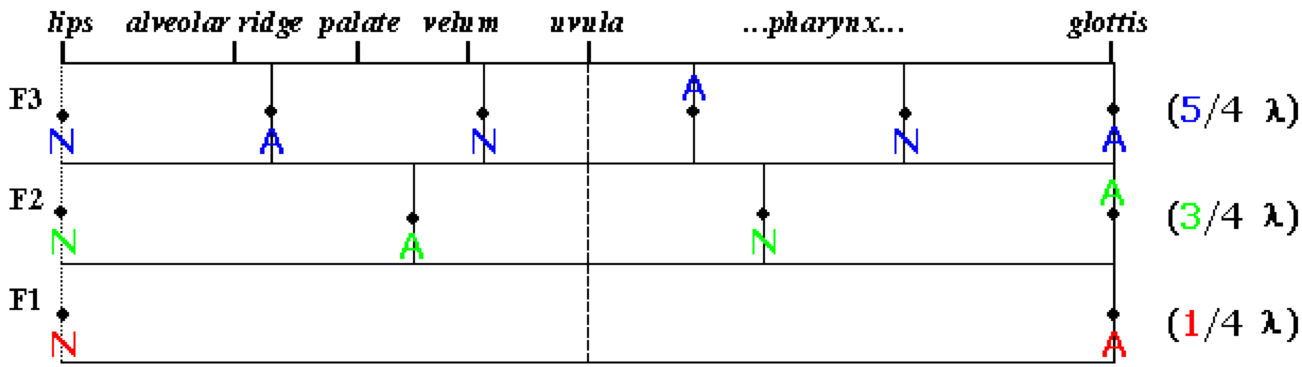
- We know how to model the effects of a constriction at different locations in a tube | pertubation theory!
- Consider the vocal-tract landmarks:



- What effect on schwa formants do we predict for **labial**, **alveolar**, **velar** closures?

2. Formant transitions and place of articulation

- Consider the vocal-tract landmarks:



- Predicted formant transitions (*into* the consonant):

labial	**alveolar**	**velar**
F3 ↓	F3 ↑	F3 ↓
F2 ↓	F2 ~	F2 ↑
F1 ↓	F1 ↓	F1 ↓

2. Formant transitions and place of articulation

- Look at these in Praat (get sound files from *V&C* web site IPA chart):

  [ə**b**ə] [ə**d**ə] [ə**g**ə]

2. Formant transitions and place of articulation

- The picture gets more complicated for perturbation theory if the vowel is not schwa
  - The vocal tract is already being perturbed by the **vowel** articulation
  - On top of that, we now add effects of the **consonant** articulation

- Multiple tube model is useful in principle, but also more complex to implement — lots of tubes!

2. Formant transitions and place of articulation

- What do we actually get for formant transitions on a non-schwa vowel?
  - **Labial** Cs usually do what we predict for schwa
  - **Velar** Cs usually do what we predict for schwa
  - **Alveolar** Cs usually do what we predict for schwa for **F1, F3**
    - What about **F2** transitions for alveolar Cs?
    - Look at these in Praat: Sound files from [di da du] spectrograms (synthesized) from Louis Goldstein, U Southern California

2. Formant transitions and place of articulation

- What do we actually get for formant transitions on a non-schwa vowel?
  - **Alveolar** Cs usually do what we predict for schwa for **F1, F3**
    - Whether **F2** shows a rising or falling formant transition with an alveolar consonant **depends** on the **vowel F2**
    - There is a **locus** for the F2 transition with an alveolar consonant
      (a frequency value it's "heading for")

2. Formant transitions and place of articulation

- Review: Any questions about **place of articulation** or **vocal-tract anatomy**?
  - Work on learning oral stop (*plosive*) IPA symbols
  - English examples: *V&C*, Table 6.1
  - The Interactive Sagittal Section (by Daniel Currie Hall) is a good way to review consonant articulators and IPA symbols

3. Stop bursts

- During an oral stop's closure stage, high air pressure has built up behind the oral constriction
  - This is because air continues to flow up from the lungs even during stop closure
- At the instant that the constriction is released, this air rushes out
- This is a **stop burst**
  - High volume velocity, narrow constriction
  - What does this resemble?

3. Stop bursts

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- At the instant that the constriction is released, this air rushes out
- This is a **stop burst**
  - High volume velocity, narrow constriction
  - Acoustically, it resembles a very short **fricative** for the appropriate place of articulation

3. Stop bursts

- **Warning:** *V&C* (pp 51–52) refers to a “burst of noise” that accompanies voiceless stops in English
  - The first part of this is the actual **stop burst**
  - The remainder is actually **aspiration**, which we will discuss next week

4. Affricates

- What is an **affricate**?

- Which affricates do we have in English?

4. Affricates

- What is an **affricate**?
  - Similar to an **oral stop followed by a fricative** at the same (or very similar) place of articulation
- Which affricates do we have in English?
  - Post-alveolar (palatoalveolar, “alveopalatal”)

    [ʧ] voiceless

    [ʤ] voiced

4. Affricates

- How can we **distinguish** an affricate from an actual oral stop + fricative sequence?
    - Sometimes an affricate has a faster ‘rise time’ — the amplitude increases more quickly once the stop closure has been released