

Acoustics of Speech and Hearing

Lecture 2-4 Fricatives

Overview

- Source-filter model reminder
- Sources of turbulence
- Shaping of source spectrum by vocal tract
- Acoustic-phonetic characteristics of English voiceless fricatives
- Voiced fricatives
- Bursts and aspiration

Source-Filter Model

Source →  → Speech Sound

- Vowel production
 - Vowel spectrum is the result of the resonances of the vocal tract shaping the spectrum of the sound generated by larynx vibration

Source-Filter Model

Source →  → Speech Sound

- Vowel production
 - Vowel spectrum is the result of the resonances of the vocal tract shaping the spectrum of the sound generated by larynx vibration
- Fricative production
 - Fricative spectrum is the result of the resonances of the vocal tract shaping the spectrum of the sound generated by turbulence

Turbulence

- Dictionary Definition!

“When describing complex evolution in space and time, turbulence is applied where spatially localized behavior is chaotic and behavior at spatially separated points is decreasingly correlated as the separation increases. In fluids this appears as vortices and eddies of all sizes and at all length scales. Though originally used to describe fluid complexity, the term is now applied to any spatiotemporal complexity of this type”. *Academic Press Dictionary of Science and Technology*

Turbulence Take 2

- Turbulence
 - is random or chaotic fluid flow
 - is often caused by forcing fluid through a constriction or onto a sharp edge
 - causes random pressure fluctuations - as if multiple independent sound sources
 - ‘noise’ like source

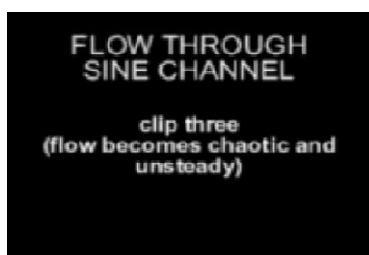
Laminar flow



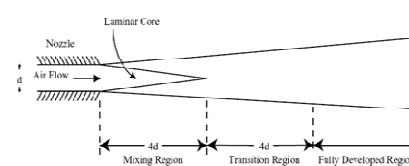
Faster Flow - Vortices



Turbulent Flow



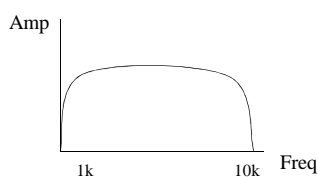
Sources of turbulence



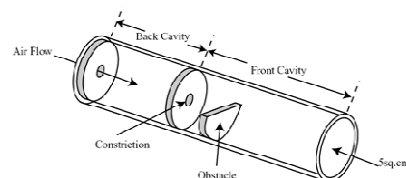
- In a constriction
 - air forced through narrowing
- At an obstacle
 - when a jet of fast-moving air hits an obstacle
 - or rushes into stationary air

Fricative source spectrum

- Typically noise spectrum with wide bandwidth:



Shaping by Filter



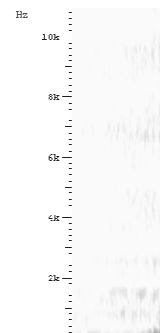
- Shadle model of fricative production
- Components: source of high pressure air, back cavity, constriction, front cavity, obstacle
- Most shaping done by front cavity

English Fricatives

- Order by Place:
 - Glottal
 - Palatal
 - Alveolar
 - Dental
 - Labio-dental

Characteristics of /h/

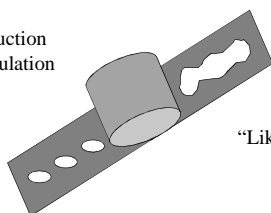
- Source of frication
 - at Glottis (constriction between vocal folds)
- Spectrum shaping
 - entire length of vocal tract
 - vowel-like resonances (F1 250-700Hz)
- Special character
 - different before different vowels
 - “co-articulation”



Co-articulation

- Articulators always moving from target to target
- At any one time, the position of an articulator depends on more than one phonetic segment

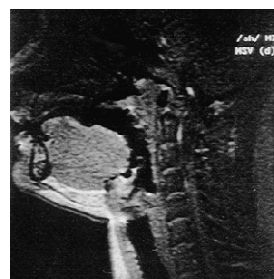
Co-Production
Co-Articulation



“Like eggs being crushed
on a conveyor belt”
- Hockett

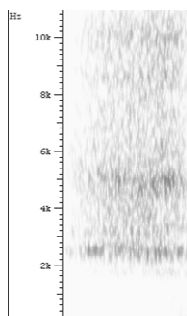


Articulation of /ʃ/

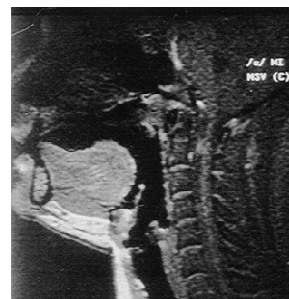


Characteristics of /ʃ/

- Source of frication
 - jet caused by groove
 - hits back of lower teeth
- Spectrum shaping
 - large front cavity
 - resonances at 2.5kHz, 5kHz, etc
- Special character
 - intense (sibilant)

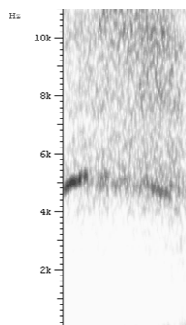


Articulation of /s/

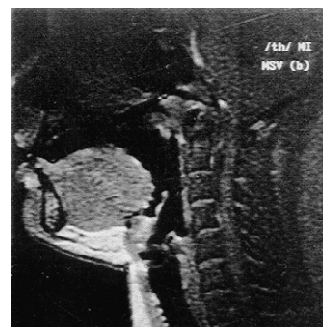


Characteristics of /s/

- Source of friction
 - jet caused by groove
 - hits back of upper teeth
- Spectrum shaping
 - medium front cavity
 - resonances at 4kHz, 8kHz, etc
- Special character
 - intense (sibilant)

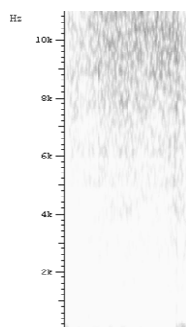


Articulation of /θ/

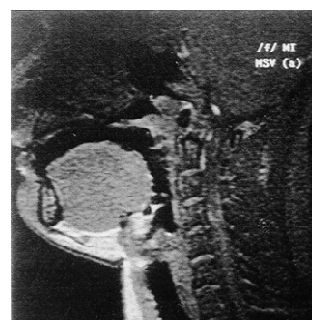


Characteristics of /θ/

- Source of friction
 - constriction between tongue and upper teeth
- Spectrum shaping
 - small front cavity, highly damped
 - resonances at 8kHz, etc
- Special character
 - weak
 - tends to be short (dental plosive?)

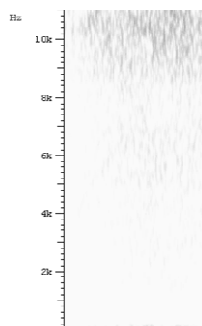


Articulation of /f/



Characteristics of /f/

- Source of friction
 - constriction between lip and upper teeth
- Spectrum shaping
 - little shaping, highly damped
 - resonances at 10kHz, etc
- Special character
 - weak



Voiced Fricatives

- Two excitation sources
 - air-flow through larynx causing vocal fold vibration
 - air-flow through constriction causing friction
- Special character
 - tricky to maintain pressure differences
 - amplitude of turbulence varies with vocal fold opening & closing (“pulsed turbulence”)



Bursts

- Bursts are short intervals of frication occurring as plosive is released
- Sound comes from turbulence close to the place of obstruction
- Sound is shaped by resonances of opening vocal tract: often the same resonances that shape homorganic fricatives



Aspiration

- Aspiration is frication occurring at glottis which occurs as part of the production of some plosives
- Voiceless, syllable-initial plosives in English tend to be aspirated
- Aspiration is like a short [h] fricative before voicing of vowel
- Coarticulates to plosive and vowel



Summary

- Source of excitation in fricatives
- Shaping of fricative excitation in vocal tract
- Characteristics of English fricatives
- Excitation in voiced fricatives
- Characteristics of bursts and aspiration
- Introduced the concept of 'coarticulation'

Lab Experiment

- Analyse Sentence
 "The thin fish swims in heaving seas"
- Analyse /h, ʃ, s, z, θ, ð, f, v/
- Plot spectral cross-sections
- How do your fricatives vary with place and voicing?
- Listen to fricatives of a child with a phonological disorder