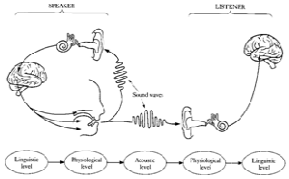
SPSC2003 Phonetic Science: Acoustics of Speech and Hearing

Week 1
Introduction,
Sounds and Vibrations

Overview

- Introduction to the course
- What is sound?
- Sounds caused by repeating vibrations
- How to measure simple vibrations
- First lab experiment

The Speech Chain

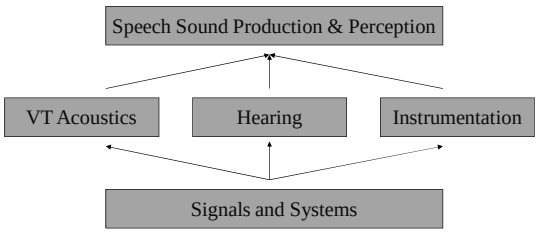


Phonological coding ➔ Articulation
Articulation ➔ Sound
Sound at Speaker ➔ Sound at Listener
Sound ➔ Neural activity from cochlea
Neural activity ➔ Acoustic cues
Acoustic cues ➔ Phonological decoding

Aims & Motivations

- How does the acoustic part of the speech chain work?
  - speech sound differentiation and variation
- How can we measure the speech signal?
  - quantitative not qualitative
  - use of instrumental analysis
- How is instrumentation used?
  - tape recorders, computer analysis, laryngograph
- What are consequences of disorder?
  - at each point in chain
  - effect on sound, effect on perception of listener

Syllabus



Administrative Details

- Classes
  - 20 lectures: 9am Tuesday, B01 Chandler House
  - 8 tutorials: 1 hour every fortnight (approx)
    - starting **this** week
  - 18 lab classes: 2 hours in Speech Sciences Lab
  - Revision day: term 3
- Assessment
  - 4 lab reports & 2 short-answer tests (30%)
  - 3hr written examination (70%)

Administrative Details

- Tutorial and Laboratory Groups
  - Tutorial group sheet
  - Includes 2801 clinical tutorials
  - Swap around at Christmas
  - No transfers! Only swaps (2801 permitting)

Learning Resources

- Moodle site **www.ucl.ac.uk/moodle**
  - Administrative details
  - Weekly planner with handouts & slides
  - Reading and web resource recommendations
  - Frequently asked questions (with answers)
  - Weekly quizzes
  - Report writing style guides & example report
  - Examination preparation
  - Links to software
  - Discussion board
- Text Book recommendations
- Introduction to Acoustics booklet
- Web tutorials

Knowledge & Skills

- No mathematics
  - Just arithmetic manipulation of data
- No previous physical science concepts
  - We provide everything you need
- Transferable skills
  - Working in the laboratory
  - Thinking about speech scientifically
  - Writing reports of experiments
- Be prepared to learn
  - Resources are there for you to make use of

Sounds & Vibrations

What is sound?

PHYSICS

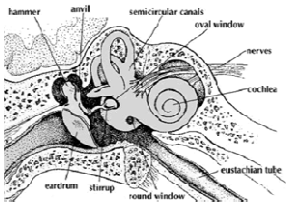
- "Sound is a longitudinal pressure wave in an elastic medium"
- Objective
- Easy to measure

PSYCHOLOGY

- "Sound is a sensation delivered to the brain by the hearing mechanism"
- Subjective
- Hard to measure

Sound sensation is **caused by** pressure variation

Hearing mechanism



- Variations in atmospheric pressure move ear drum in and out
- Movement of drum causes fluid flow in cochlea which causes nerves to fire
- We perceive sound in terms of that nerve activity

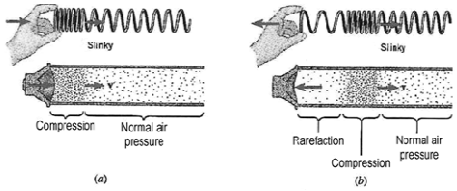
Terms to describe sound

Subjective terms for sound	
Loudness	"Quantity of sound"
Pitch	"Melody of sound"
Timbre	"Quality of sound"

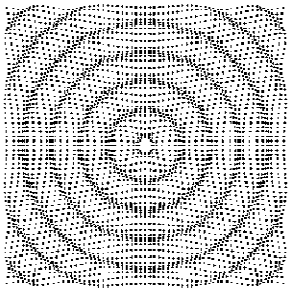
Loudness, Pitch and Timbre are the three basic dimensions of our perception of sounds.

Pressure variations in air

- Any moving or vibrating body affects local air pressure
- These fluctuations in pressure propagate away from the source (at high speed)



Pressure variations in air

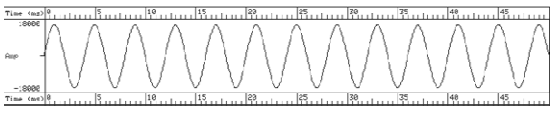


- Pressure variations *propagate* through the air in all directions
- As they travel they diminish in size
- Note that the air itself does not move

Some Numbers

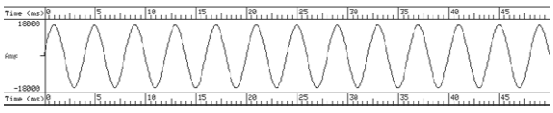
- Atmospheric pressure
  - 100,000Pa
  - i.e. 10 tonnes weight per square metre
- Typical sound
  - ± 0.1Pa
  - i.e. 0.0001% of atmospheric pressure
- Typical fluctuation duration
  - 0.001s = 1ms
  - i.e. 1000 fluctuations per second

Measuring Vibrations



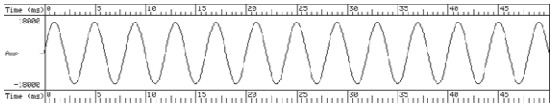
- This is a repeating or *periodic* vibration
- We can measure the duration of one cycle, this is called the *period*
  - 5 cycles in 20ms, so 1 cycle in 4ms = period

Measuring Vibrations



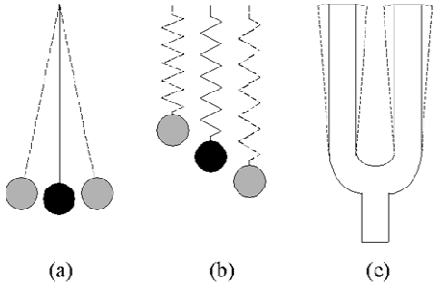
- Or we can calculate how many cycles occur in one second, this is called the *frequency*
- There are 1000ms in 1s, so
  - 1 cycle in 4ms, so 250 cycles in 1000ms
  - so 250 cycles in 1s, frequency is 250Hz (hertz)

Measuring Vibrations



- We can also measure the size of the vibrations, this is called their *amplitude*
- Here we see the largest positive peak is +10000, and the smallest negative peak is –10000
- We can write: amplitude = ±10000
- The units are not given, since we don't know if this is a sound wave (Pa), a microphone signal (V) or even movement of the ear drum (μm)

Simple Vibrating Systems



(a) Pendulum (b) Mass-on-a-spring (c) Tuning fork

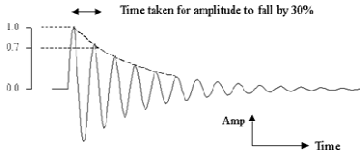
Natural Frequency

- When a pendulum is struck, it vibrates periodically at a characteristic frequency that is related to the size of the pendulum
- This is called the pendulum's **Natural frequency**
- Longer pendulums vibrate with a lower frequency (greater period) than shorter pendulums
- Note that the natural frequency is a characteristic of the pendulum, **not** of the vibration (a pendulum has a natural frequency even when it is not vibrating).

Amplitude and Damping

- The amplitude of the vibrations of a pendulum reduce over time – this is because it loses energy to the air
- We say the pendulum is **damped**.
- We can measure the degree of damping by measuring how quickly the amplitude of vibration reduces over time.

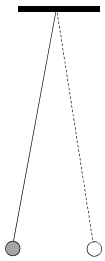
Measuring Damping



- If damping time is small, then the system is heavily damped and vibrates for a short time
- If damping time is large, the the system is lightly damped and vibrates for a long time
- Note that damping is a characteristic of the pendulum, not of the vibration (a pendulum has a degree of damping even when it is not vibrating)

First Lab Experiment

- The Damped Pendulum
  - A pendulum is an example of a simple vibrating system known as a **resonator**
  - If you strike it or push it then it vibrates periodically at its natural frequency
  - The amplitude of the vibrations gradually reduces with time, since the pendulum loses energy to its surroundings as it vibrates



First Lab Experiment

- The Damped Pendulum
  - The natural frequency depends on the physical size of the pendulum: can you uncover the relationship?
  - If we put a paper cone on the pendulum we can make it come to rest more quickly.
  - We say that the paper cone increases the **damping** of the system.
  - But how do you think this extra resistance to movement affects the natural frequency of the pendulum?

First Lab Experiment

- Key experimental skills:
  - Accurate measurements
  - Estimation of size of error
  - Calculations with and presentation of data
  - Analysis and interpretation of results
- It is not a test!
- Enjoy yourself!

Where am I going next?

- Groups A
  - 10.30 Tutorial in Room G06
- Group B
  - 11.30 Tutorial in Room G06
- Group C
  - 10.30 Laboratory session in B07 (Lab)
- Group D
  - 10.30 Laboratory session in B07 (Lab)
- Not on the list?
  - See Mark in his office (Room 320) after this lecture