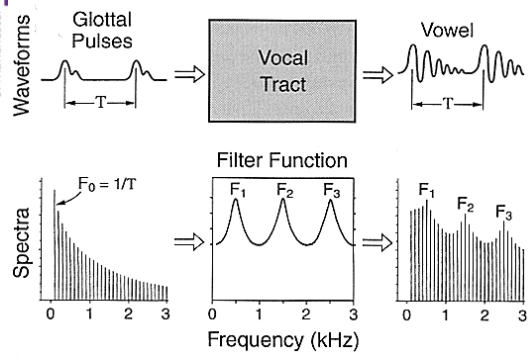
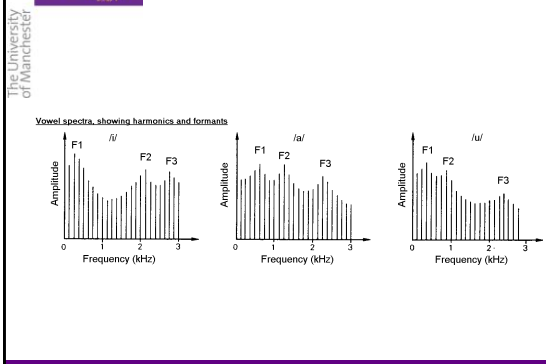
Learning Outcomes

- Understand how vowel sounds are produced
- Understand how formants are produced and how they determine the particular vowel
- Understand how vowel acoustics differ between speakers and across different contexts

Vowels

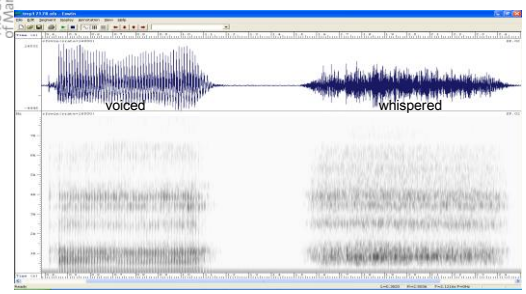
- Relatively long duration, usually voiced, higher energy sounds
- Tend to be dominated by low frequency energy
- Characterised acoustically by peaks in the spectrum – formants
- Formants are produced as a result of the acoustic resonances in the vocal tract
- Changes in shape of the vocal tract produce different formant frequencies – which characterise the different vowels
- Formants abbreviated here as F1, F2, F3 etc in ascending frequency order



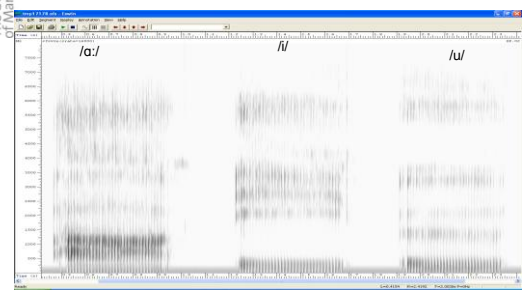


		F1 (Hz)	F2 (Hz)
Heed	/i:/	300	2300
Hid	/ɪ/	360	2100
Head	/e/	570	1970
Had	/æ/	750	1750
Hard	/ɑ:/	680	1100
Hod	/ɒ/	600	900
Hoard	/ɔ:/	450	740
Hood	/ʊ/	380	950
Who	/u/	300	940
Hub	/ʌ/	720	1240
herb	/ə/	580	1380

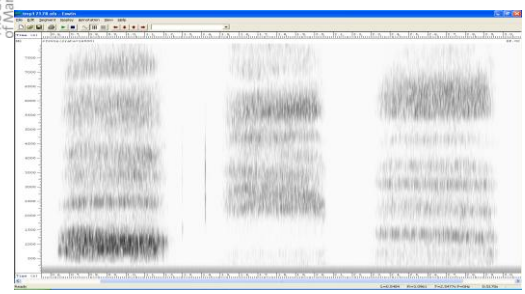
voiced & whispered /ɑ:/ vowel



Voiced vowels



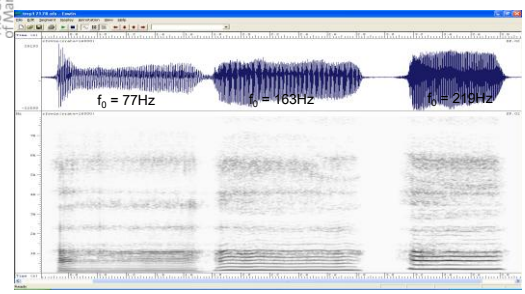
Whispered vowels



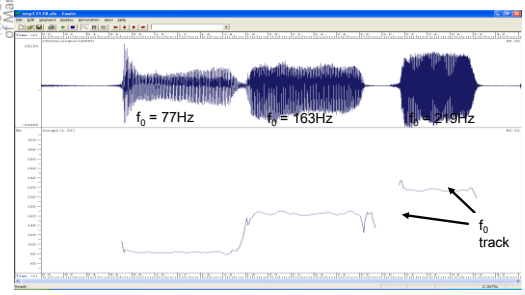
Voice pitch

- For many periodic sounds, we hear a ***subjective*** quantity known as ***pitch***
- Generally, the ***shorter the periodicity*** in the waveform, the ***higher the perceived pitch*** and vice versa
- Fundamental frequency (and hence voice pitch) varies between men, women and children.
- Voice pitch – intonation - is used to carry linguistic information (e.g. question/statement distinctions)

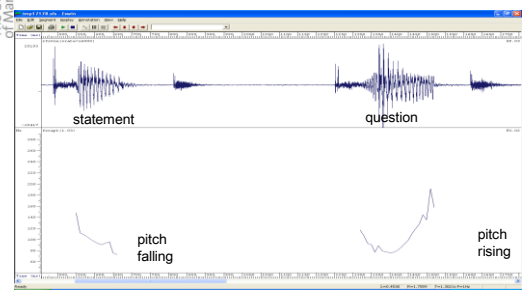
The /ɑ:/ vowel with different pitches

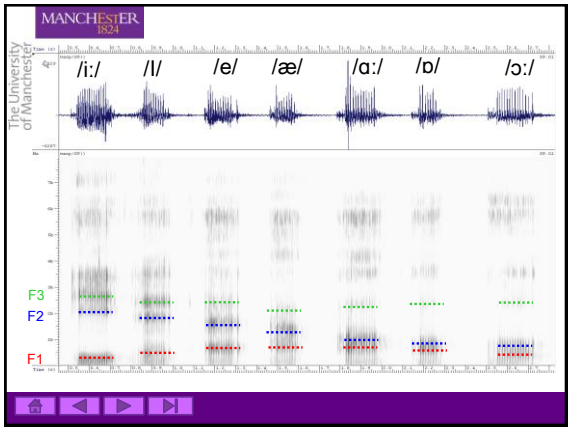


The same /ɑ:/ vowels with pitch track estimated



Statement/question – and voice pitch



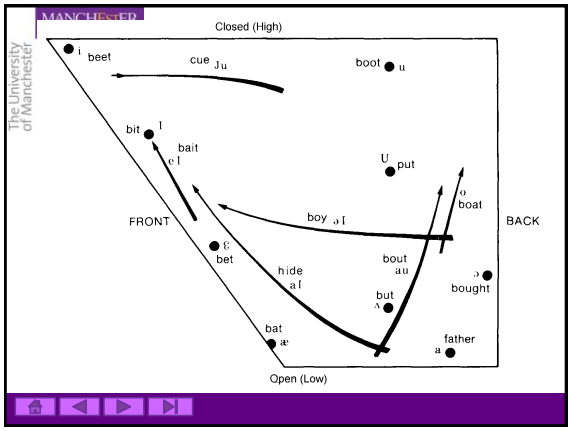


– For "front" vowels e.g. /i:/ F1 & F2 tend to be far apart

– For "back" vowels e.g. /u/, they tend to be closer together.

– If the vowel is "open" e.g. /ɑ:/ F1 tends to be at the high end of its frequency range.

– For a "closed" vowel e.g. /i:/ , F1 tends to be at the lower end of its frequency range.



F1 increases: male, female, child
formants increase: male, female, child

formant frequencies differ across vowels (males highlighted)

/i/

	male	female	child
F_1	270	310	370
F_2	2290	2790	3200
F_3	3010	3310	3730
f_0	136	235	272

/ɛ/

	male	female	child
F_1	530	610	690
F_2	1840	2330	2610
F_3	2480	2990	3570
f_0	130	223	260

/ɑ/

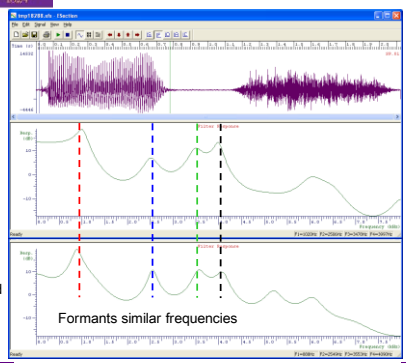
	male	female	child
F_1	730	850	1030
F_2	1090	1220	1370
F_3	2440	2810	3170
f_0	124	212	256

/u/

	male	female	child
F_1	300	370	430
F_2	870	950	1170
F_3	2240	2670	3260
f_0	141	231	274

Examples of formant and f_0 frequencies (from Raphael et al, 2003)

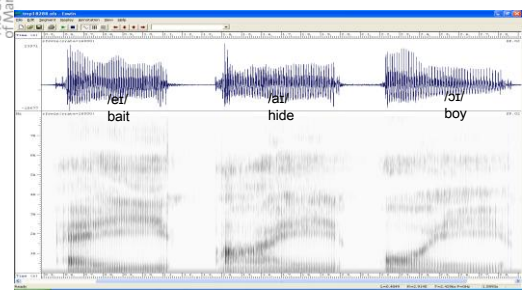
Voiced/voiceless /ɑ:/



Vocal tract doesn't change shape – only the source changes

- **Vowel transitions**
  - Formants stay at the same frequency for a steady state vowel
  - This rarely happens in speech
  - Usually the formant frequencies are in a state of change from one sound to the next
  - e.g. diphthongs as in "hide" or "bout" where the vowel portion of the utterance starts with one vowel and finishes with another

diphthongs



Context dependency

- When vowels follow (or precede) different consonants, the vocal tract changes shape during part of the vowel
- The vocal tract has one shape for the consonant, and then has to change shape for the vowel (or vice versa)
- Alternatively, if the same vowel is preceded by different consonants, the direction of formant change may be different depending on the consonant.

/di:/ /du/