

Contents

<i>Author's acknowledgements</i>	xiv
<i>Publisher's acknowledgements</i>	xv
1 Introduction: impressionistic phonetics and experimental phonetics	1
1.1 What is experimental phonetics?	1
1.2 Impressionistic phonetics	2
1.2.1 Assumptions	3
1.2.2 Methodology	4
1.3 The scope of experimental phonetics	6
1.4 The representation of speech sounds	9
1.4.1 Segments and phonemes	10
1.4.2 Mental representations	11
1.5 Experimental phonetics and the structure of sound systems	17
1.6 The structure and scope of this book	18
1.7 Further reading	18
Note	19
2 The nature of sound	20
2.1 Introduction	20
2.2 Sound waves	20
2.2.1 Describing a simple sound wave	21
2.2.2 From movements to pressures	23
2.2.3 Sound waves in space	26
2.2.4 Some definitions	26
2.3 Types of sound waves	28
2.4 The structure of sound waves	30
2.4.1 Specifying sound waves	32
2.4.2 The spectrum	35
2.4.3 Generating some vowel-like waveforms	36
2.4.4 Spectra of aperiodic sounds	38
2.5 Scaling and the spectrum	41
2.5.1 Amplitude, power and intensity	43
2.5.2 The decibel scale	44
2.5.3 The octave scale	46
2.6 Summary	47
2.7 Further reading	48
Notes	48

3	Analysing sound: the spectrograph	49
3.1	Introduction	49
3.2	Spectrography	49
3.2.1	Basic principles	49
3.2.2	An example spectrogram	54
3.2.3	Narrow band spectrograms	56
3.2.4	Pre-emphasis	57
3.2.5	Two-dimensional spectra	60
3.2.6	Supplementary displays: waveform, intensity and fundamental frequency	61
3.3	Recording	63
3.3.1	Recording as translation	63
3.3.2	Fidelity	64
3.3.3	Digital recording	66
3.3.3.1	Sampling rate	68
3.3.3.2	Quantisation	68
3.4	Digital spectrography	71
3.4.1	Recording for analysis	71
3.4.2	Calculating the power spectrum	72
3.4.3	Determining fundamental frequency (F_0)	76
3.5	Summary	77
3.6	Further reading	78
4	The acoustics of speech production	79
4.1	Introduction	79
4.2	Modelling a simple vowel	80
4.2.1	The voice source	80
4.2.2	The vocal tract filter	81
4.2.2.1	The concept of <i>filter</i>	81
4.2.2.2	Formant frequencies	82
4.2.3	Combining source and filter	84
4.2.4	The radiation function	84
4.2.5	Comparison with a spoken vowel	86
4.3	Varying the voice source	88
4.4	Varying the vocal tract filter	91
4.4.1	Simple models for three vowels	94
4.4.2	More realistic models of vowel articulation	94
4.4.3	A general model of vowel production	97
4.4.4	Phonological implications of modelling	98
4.5	Estimating filter characteristics: linear predictive coding	99
4.6	Extending the source-filter approach to other classes of speech sounds	99
4.6.1	Nasals, laterals and nasalised vowels	102
4.6.2	Obstruent consonants	103
4.7	Summary	104
4.8	Further reading	104
	Notes	

5	Perception and hearing	105
5.1	Introduction	105
5.2	From acoustic signals to perceptual objects: the search for acoustic cues	107
5.2.1	An example: Voice Onset Time	107
5.2.2	The problem of lack of invariance	114
5.2.3	Is speech special?	115
5.2.3.1	Categorical perception	116
5.2.3.2	Multiple cues and trading relations	117
5.2.3.3	Duplex perception	121
5.2.3.4	Bimodal perception	121
5.2.3.5	Arguments against the specialness of speech	122
5.2.4	Theories of speech perception	124
5.2.4.1	The Motor Theory	124
5.2.4.2	Direct Realism	125
5.2.4.3	The Fuzzy Logical Model	126
5.2.4.4	Strong theories relating the acoustic signal to phonological features	127
5.2.4.5	Non-analytic approaches	128
5.3	Hearing	130
5.3.1	Structure of the auditory system	131
5.3.2	Spectra in the auditory nerve	132
5.3.2.1	Voiceless fricatives	134
5.3.2.2	Vowels	136
5.3.3	The VOT boundary	137
5.3.4	Adaptation	139
5.4	Psychophysics and the auditory spectrograph	140
5.4.1	Scales of frequency based on auditory filters	140
5.4.2	Auditory spectra	143
5.5	Conclusion	143
5.6	Further reading	145
	Note	145
6	The acoustic description of vowels	146
6.1	Introduction	146
6.2	Formant frequencies and the vowel quadrilateral	147
6.2.1	The rounding dimension	149
6.2.2	Central vowels	151
6.3	Formant frequencies and vowel charts: the problem of psychological reality	151
6.4	The spectral integration hypothesis	152
6.4.1	Integration of F_2 with other formants	156
6.4.2	A role for F_0 ?	157
6.5	A system of binary features for vowels?	158
6.6	The traditional vowel quadrilateral revisited	159
6.7	Other dimensions of vowel classification	160

6.7.1	Nasalised vowels	161
6.7.2	Advanced Tongue Root (ATR) vowels	163
6.7.3	Rhoticity and pharyngealisation	166
6.8	Diphthongs	167
6.9	Alternative approaches to vowel quality	167
6.10	The problem of normalisation	169
6.11	Predicting the structure of vowel systems	170
6.12	Summary	172
6.13	Further reading	173
7	The acoustic description of consonants	174
7.1	Introduction	174
7.2	General concepts	175
7.2.1	Intervals and transitions	175
7.2.2	Acoustic dimensions in the description and classification of consonants	176
7.2.3	Acoustic boundaries and consonants	177
7.3	Stop consonants	177
7.3.1	General characteristics of stop consonants	177
7.3.2	Voicing and aspiration	178
7.3.3	Place of articulation	180
7.3.3.1	Stop bursts	180
7.3.3.2	Formant transitions	184
7.3.3.3	Spectral templates as invariant cues	186
7.4	Fricatives	190
7.5	Affricates	193
7.6	The fricative-affricate contrast	194
7.7	Phonological contrasts involving voicing in obstruents	195
7.8	Sonorant consonants	197
7.8.1	Nasals	197
7.8.2	Semivowels	199
7.8.3	Lateral approximants (L-sounds)	199
7.8.4	Rhotics (R-sounds)	202
7.8.5	An overview of manner contrasts involving sonorants	203
7.9	Acoustic phonetics and the structure of consonant systems	204
7.10	Further reading	207
	Notes	207
8	Speech production	208
8.1	Introduction	208
8.2	The airstream	210
8.2.1	Principles of air flow	211
8.2.2	Respiratory function in speech	212
8.2.3	Measuring and quantifying pressure and flow	216
8.2.3.1	Pressure	216
8.2.3.2	Flow	217
8.3	The larynx and the vocal folds	219
8.3.1	A simple description of the larynx	220
8.3.2	Vocal fold vibration	222

8.3.3	Aerodynamics of vocal fold vibration	225
8.3.4	Experimental investigation of the larynx	226
8.3.5	The laryngeal setting	226
8.3.5.1	Direct observation	226
8.3.5.2	Imaging	227
8.3.5.3	Electromyography	228
8.3.6	More indirect methods for monitoring vocal fold activity	229
8.3.6.1	Inverse filtering	229
8.3.6.2	Photoelectric glottography	230
8.3.6.3	Electroglottography (electrolaryngography)	230
8.3.6.4	Acoustic measures of phonation types	234
8.3.7	Models of vocal fold vibration and features of the larynx	235
8.3.8	Control of fundamental frequency	238
8.3.9	Control of voicing in obstruents	239
8.3.9.1	Problems of maintaining voicing: aerodynamic aspects	239
8.3.9.2	Strategies for maintaining and inhibiting voicing	240
8.4	Articulation	245
8.4.1	Imaging techniques	245
8.4.2	Point-tracking techniques	246
8.4.3	Palatography	248
8.4.4	Identifying articulatory dimensions: the case of vowels	249
8.5	Wider issues: relating phonological representations to speech production	252
8.6	Further reading	258
Appendix:	An overview of impressionistic-phonetic classification	260
A.1	Preliminaries: air flow in the vocal tract	260
A.2	Consonants	263
A.2.1	Sonorants and obstruents	263
A.2.2	The place dimension	265
A.2.3	The manner dimension	266
A.2.4	Simultaneous and sequential articulations	268
A.2.5	Non-pulmonic consonants	268
A.2.6	Refinements	270
A.2.7	Impossible and unattested sound types	270
A.3	Vowels	270
A.3.1	Dimensions of vowel classification	271
A.3.2	Refinements	272
A.3.3	Diphthongs	273
A.4	Suprasegmentals (prosodic features)	273
A.5	Using the IPA	275
A.6	Further reading	275
<i>Bibliography</i>		276
<i>Index</i>		290