

Phonetics

*Transcription, Production, Acoustics,
and Perception*

Second Edition

Henning Reetz

Allard Jongman

WILEY Blackwell

Contents

Preface to the First Edition	xi
Preface to the Second Edition	xiii
About the Companion Website	xiv
1 About this Book	1
1.1 Phonetics in a nutshell	2
1.2 The structure of this book	6
1.3 Terminology	8
1.4 Demonstrations and exercises	8
2 Articulatory Phonetics	9
Articulation in a nutshell	9
2.1 Phonation at the larynx	10
2.2 Basic articulatory terms	11
2.3 The articulation of consonants	14
2.3.1 Place of articulation	15
2.3.2 Manner of articulation	15
2.3.3 Other classification schemes	18
2.4 The articulation of vowels	20
3 Phonetic Transcription	24
Transcription in a nutshell	24
3.1 Types of transcription	25
3.2 Consonants	28
3.2.1 Plosives	29
3.2.2 Nasals	30
3.2.3 Fricatives	30
3.2.4 Affricates	31
3.2.5 Approximants	32
3.3 Vowels	33
3.4 Diacritics and other symbols	38
3.5 Transcription of General American English	39
3.5.1 Consonants	40
3.5.1.1 Aspiration, voicing, and devoicing	40
3.5.1.2 Coarticulation	41

3.5.1.3	Consonantal release	42
3.5.1.4	Flaps and taps	43
3.5.1.5	Glottal plosives	43
3.5.1.6	Velarization	44
3.5.1.7	Syllabic consonants	45
3.5.1.8	Intrusion	45
3.5.1.9	Duration	46
3.5.2	Vowels	48
3.5.2.1	Duration	48
3.5.2.2	Effects of following consonants	49
4	Place and Manner of Articulation of Consonants and Vowels	52
4.1	Consonants	53
4.1.1	Labials	55
4.1.2	Coronals	56
4.1.3	Dorsals	57
4.1.4	Gutturals	59
4.2	Additional manners of articulation	59
4.3	Vowels	60
4.4	Secondary articulations	63
5	Physiology of the Vocal Apparatus	66
	Physiology in a nutshell	66
5.1	The subglottal system: lungs, bronchi, and trachea	69
5.1.1	Anatomy of the subglottal system	69
5.1.2	Movements of the lungs	71
5.1.2.1	Breathing in (inspiration, inhalation)	71
5.1.2.2	Breathing out (expiration, exhalation)	72
5.1.3	The volumes of the lungs and their control over time	72
5.1.4	Loudness and the air pressure in the lungs	74
5.2	Structure and function of the larynx	74
5.2.1	Anatomy of the larynx	75
5.2.2	Vocal fold vibration	78
5.2.2.1	The Bernoulli effect and the aerodynamic theory	78
5.2.2.2	The myoelastic theory of vocal fold vibration	81
5.2.2.3	Two-mass theory of vocal fold vibration	83
5.2.2.4	Muco-viscose, cover body, and flow-separation theory	84
5.2.2.5	One cycle of vocal fold vibration	85
5.2.3	Loudness and larynx signal	86
5.2.4	Register	88
5.3	Vocal tract	89
5.3.1	Pharynx	89
5.3.2	Nasal tract and velum	90
5.3.3	Oral tract	92

6	Airstream Mechanisms and Phonation Types	95
	Airstream mechanisms and phonation in a nutshell	95
6.1	Airstream mechanisms	96
	6.1.1 Glottalic airstream mechanisms	96
	6.1.2 Velaric airstream mechanism	100
6.2	Phonation types	102
6.3	Voicing, voicelessness, and aspiration in plosives	103
6.4	Common and rare sounds	110
7	Basic Acoustics	113
	Basic acoustics in a nutshell	113
7.1	Sound waves	115
	7.1.1 Sound waves are variations in air pressure	115
	7.1.2 Origin and propagation of sound waves	115
	7.1.3 The speed of sound	118
	7.1.4 Relative positions within a sound wave	119
	7.1.5 Longitudinal waves and transverse waves	120
7.2	Measuring sound waves	120
	7.2.1 The microphone	121
	7.2.2 The oscillogram or waveform	122
7.3	Acoustic dimensions and their units of measurement	123
	7.3.1 Frequency	123
	7.3.1.1 Period duration	124
	7.3.1.2 Period duration and period frequency	125
	7.3.1.3 Period frequency and wavelength	127
	7.3.1.4 Representing F_0 over time	128
	7.3.2 Amplitude	129
	7.3.2.1 Representing amplitude changes over time	134
	7.3.3 Phase	136
8	Analysis Methods for Speech Sounds	139
	Analysis in a nutshell	139
8.1	Digitizing acoustic signals	141
	8.1.1 Digitizing in the time and amplitude domains	142
	8.1.2 Sampling rate	143
	8.1.3 Quantizing resolution	145
8.2	Types of acoustic signals	148
8.3	Analyzing acoustic signals	151
	8.3.1 Fourier transformation	152
	8.3.1.1 Summing up signals: Fourier synthesis	152
	8.3.1.2 Decomposing signals: Fourier analysis	154
	8.3.1.3 Harmonic frequencies	155
	8.3.1.4 Discrete Fourier transformation and “fast Fourier transformation”	158
	8.3.1.5 Fourier transformation for non-periodic signals	158

8.3.2	What information can be seen in a spectrum?	159
8.3.3	“Windowing” in spectral analysis	161
8.3.3.1	The relation between window size and spectral resolution	164
8.3.3.2	The relation between resolution in the time and frequency domains	165
8.3.4	Other spectral representations: the spectrogram	166
8.3.5	The LPC spectrum	169
8.3.6	The cepstrum and cepstrally smoothed spectrum	172
9	The Source–Filter Theory of Speech Production	175
	The source–filter theory in a nutshell	175
9.1	Resonance	176
9.1.1	Resonating frequencies of cylindrical tubes	177
9.1.2	Resonating frequencies of non-cylindrical tubes	180
9.2	Damping	183
9.3	Filters	183
9.3.1	Vocal tract filter	187
9.3.2	Radiation at the lips and nostrils	187
9.4	Formants	189
9.4.1	Formant frequencies	190
9.4.2	Formant bandwidth and quality	192
9.5	Sources for speech sounds	193
9.5.1	The glottal source: phonation for a modal voice	193
9.5.1.1	Jitter	196
9.5.1.2	Shimmer	197
9.5.1.3	Harmonics-to-noise ratio (HNR)	198
9.5.1.4	H1-H2 measure and spectral tilt	198
9.5.2	Breathy voice	198
9.5.3	Creaky voice	200
9.5.4	The noise source: turbulence	201
9.5.4.1	Whisper	202
10	Acoustic Characteristics of Speech Sounds	206
	Acoustic characteristics in a nutshell	206
10.1	Vowels	207
10.2	Consonants	213
10.2.1	(Central) approximants	213
10.2.2	Fricatives	215
10.2.3	Plosives	219
10.2.4	Nasals	221
10.2.5	Lateral approximants	223
10.2.6	Affricates	224
10.3	Summary	226
10.4	Variability and invariance	227
10.4.1	A theory of acoustic invariance	228

11	Syllables and Suprasegmentals	234
	Syllables and suprasegmentals in a nutshell	234
11.1	Syllables	236
11.2	Stress	238
11.3	Length	243
11.4	Tone and intonation	245
	11.4.1 Tone	246
	11.4.2 Intonation	249
12	Physiology and Psychophysics of Hearing	256
	Hearing in a nutshell	257
12.1	The external ear	258
12.2	The middle ear	259
	12.2.1 Increase in pressure in the middle ear	259
	12.2.2 Sound attenuation in the middle ear	260
	12.2.3 Pressure equalization in the tympanic cavity	261
	12.2.4 The oval window	262
12.3	The internal ear	262
	12.3.1 Pressure waves in the cochlea	263
	12.3.2 The basilar membrane as an oscillating body	265
	12.3.3 Resonance theory	265
	12.3.4 Objections to the resonance theory	266
	12.3.5 Traveling wave theory	266
12.4	The structure of the basilar membrane	267
	12.4.1 Outer hair cells	268
	12.4.2 Inner hair cells	269
	12.4.3 Frequency coding along the basilar membrane	270
	12.4.4 Oto-acoustic emissions	271
12.5	Auditory frequency scales	272
	12.5.1 Linear scales	272
	12.5.2 Logarithmic scales	273
	12.5.3 Mel scale	274
	12.5.4 Bark scale	275
	12.5.5 Equivalent rectangular bandwidth (ERB) scale	277
12.6	Auditory loudness scales	278
12.7	Auditory time scales	279
13	Speech Perception	281
	Speech perception in a nutshell	282
13.1	Vowels	284
	13.1.1 Extrinsic versus intrinsic normalization	285
13.2	Consonants	288
	13.2.1 Approximants	289
	13.2.2 Fricatives	290
	13.2.3 Nasals	291
	13.2.4 Plosives	292

13.3	Contributions of the motor theory of speech perception	295
13.3.1	Categorical perception	296
13.3.2	Is speech “special”?	301
13.3.2.1	Non-speech perception	303
13.3.2.2	Animal perception	304
13.4	Theories of speech perception	305
13.5	The role of linguistic experience in speech perception	309
13.6	Summary	313
Appendices		
A.1	Mass, Force, and Pressure	315
A.2	Energy, Power, and Intensity	317
A.3	The Decibel (dB)	320
A.3.1	RMS amplitude	320
A.3.2	RMS amplitude and loudness	324
A.3.3	Calculations with dB values	327
B.1	Physical Terminology	330
B.2	Mathematical Notations	332
C.1	Formant Values	336
C.2	Fundamental Frequency Values	337
D.1	Glossary	338
References		355
Index		368