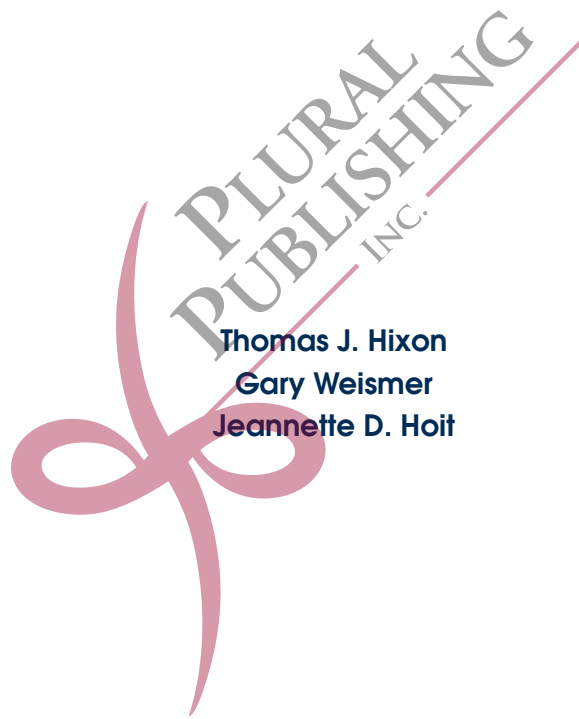


PRECLINICAL SPEECH SCIENCE

Anatomy, Physiology, Acoustics, Perception

SECOND EDITION



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Contents

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xvii

1	INTRODUCTION	1
	Focus of the Book	1
	Domain of Preclinical Speech Science	1
	Levels of Observation	1
	Subsystems of Speech Production and Swallowing	3
	Applications of Data	4
	Review	4
2	BREATHING AND SPEECH PRODUCTION	7
	Introduction	9
	Fundamentals of Breathing	9
	Anatomical Bases of Breathing	9
	Skeletal Superstructure	9
	Breathing Apparatus and Its Subdivisions	10
	Forces and Movements of Breathing	13
	Forces of Breathing	13
	Realization of Active and Passive Forces	20
	Movements of Breathing	20
	Adjustments of the Breathing Apparatus	24
	Pulmonary Apparatus	24
	Chest Wall	24
	Pulmonary Apparatus-Chest Wall Unit	25
	Output Variables of Breathing	27
	Volume	27
	Pressure	28
	Shape	31
	Neural Control of Breathing	33
	Neural Substrates	33
	Control of Tidal Breathing	34
	Control of Special Acts of Breathing	35
	Ventilation and Gas Exchange During Tidal Breathing	36
	Breathing and Speech Production	38
	Breathing in Extended Steady Utterances	38
	Breathing in Running Speech Activities	43
	Adaptive Control of Speech Breathing	47
	Body Position and Speech Breathing	47
	Extended Steady Utterances in the Supine Body Position	48
	Running Speech Activities in the Supine Body Position	50
	Speech Breathing in Other Body Positions	52

Ventilation, Gas Exchange, and Speech Breathing	53
Drive to Breathe and Speech Breathing	53
Cognitive-Linguistic Factors and Speech Breathing	55
Conversational Interchange and Speech Breathing	56
Body Type and Speech Breathing	57
Development and Speech Breathing	57
Age and Speech Breathing	59
Sex and Speech Breathing	59
Measurement of Breathing	59
Volume Measurement	59
Pressure Measurement	62
Shape Measurement	63
Speech Breathing Disorders	63
Clinical Professionals and Speech Breathing Disorders	64
Review	65
References	68
3 LARYNGEAL FUNCTION AND SPEECH PRODUCTION	73
Introduction	74
Fundamentals of Laryngeal Function	75
Anatomy of the Laryngeal Apparatus	75
Skeleton	75
Laryngeal Joints	80
Internal Topography	83
Forces and Movements of the Laryngeal Apparatus	88
Forces of the Laryngeal Apparatus	88
Movements of the Laryngeal Apparatus	96
Adjustments of the Laryngeal Apparatus	97
Abduction of the Vocal Folds	97
Adduction of the Vocal Folds	98
Changing the Length of the Vocal Folds	99
Changing the Position and/or Configuration of the Ventricular Folds	101
Changing the Position and/or Configuration of the Epiglottis	101
Changing the Position of the Laryngeal Housing	101
Control Variables of Laryngeal Function	102
Laryngeal Opposing Pressure	102
Laryngeal Airway Resistance	103
Glottal Size and Configuration	104
Stiffness of the Vocal Folds	105
Effective Mass of the Vocal Folds	106
Neural Substrates of Laryngeal Control	107
Laryngeal Functions	109
Degree of Coupling Between the Trachea and Pharynx	109
Protection of the Pulmonary Airways	109
Containment of the Pulmonary Air Supply	109
Sound Generation	109
Laryngeal Function in Speech Production	109
Transient Utterances	109
Sustained Utterances	111

Turbulence Noise Production	111
Voice Production	112
Running Speech Activities	125
Fundamental Frequency	126
Sound Pressure Level	127
Spectrum	127
Development and Laryngeal Function in Speech Production	128
Age and Laryngeal Function in Speech Production	130
Sex and Laryngeal Function in Speech Production	131
Measurement of Laryngeal Function	134
Endoscopy	134
Electroglottography	136
Aeromechanical Observations	138
Acoustic Observations	139
Laryngeal Disorders and Speech Production	141
Clinical Professionals and Laryngeal Disorders in Speech Production	142
Review	144
References	147
4 VELOPHARYNGEAL-NASAL FUNCTION AND SPEECH PRODUCTION	155
Introduction	157
Fundamentals of Velopharyngeal-Nasal Function	157
Anatomy of the Velopharyngeal-Nasal Apparatus	157
Skeletal Superstructure	157
Pharynx	159
Velum	161
Nasal Cavities	162
Outer Nose	162
Forces and Movements of the Velopharyngeal-Nasal Apparatus	164
Forces of the Velopharyngeal-Nasal Apparatus	164
Movements of the Velopharyngeal-Nasal Apparatus	172
Adjustments of the Velopharyngeal-Nasal Apparatus	173
Coupling Between the Oral and Nasal Cavities	173
Coupling Between the Nasal Cavities and Atmosphere	175
Control Variables of Velopharyngeal-Nasal Function	175
Velopharyngeal-Nasal Airway Resistance	176
Velopharyngeal Sphincter Compression	177
Velopharyngeal-Nasal Acoustic Impedance	178
Neural Substrates of Velopharyngeal-Nasal Control	179
Ventilation and Velopharyngeal-Nasal Function	180
Nasal Valve Modulation	180
Nasal Cycling (Side-to-Side)	182
Nasal-Oral Switching	183
Velopharyngeal-Nasal Function and Speech Production	184
Velopharyngeal-Nasal Function and Sustained Utterances	184
Velopharyngeal-Nasal Function and Running Speech Activities	187
Gravity and Velopharyngeal-Nasal Function in Speech Production	188
Development of Velopharyngeal-Nasal Function in Speech Production	190
Age and Velopharyngeal-Nasal Function in Speech Production	192

Sex and Velopharyngeal-Nasal Function in Speech Production	194
Measurement of Velopharyngeal-Nasal Function	196
Direct Visualization	196
X-Ray Imaging	196
Aeromechanical Observations	197
Acoustic Observations	198
Velopharyngeal-Nasal Disorders and Speech Production	200
Clinical Professionals and Velopharyngeal-Nasal Disorders in Speech Production	202
Review	204
References	207

5 PHARYNGEAL-ORAL FUNCTION AND SPEECH PRODUCTION 213

Introduction	215
Fundamentals of Pharyngeal-Oral Function	215
Anatomy of the Pharyngeal-Oral Apparatus	215
Skeleton	215
Temporomandibular Joints	218
Temporomandibular Joint Movements	218
Internal Topography	220
Forces and Movements of the Pharyngeal-Oral Apparatus	222
Forces of the Pharyngeal-Oral Apparatus	222
Movements of the Pharyngeal-Oral Apparatus	234
Adjustments of the Pharyngeal-Oral Apparatus	235
Adjustments of the Pharynx	235
Adjustments of the Mandible	235
Adjustments of the Tongue	236
Adjustments of the Lips	237
Control Variables of Pharyngeal-Oral Function	237
Pharyngeal-Oral Lumen Size and Configuration	237
Pharyngeal-Oral Structural Contact Pressure	239
Pharyngeal-Oral Airway Resistance	239
Pharyngeal-Oral Acoustic Impedance	240
Neural Substrates of Pharyngeal-Oral Control	241
Pharyngeal-Oral Functions	242
Degree of Coupling Between the Oral Cavity and Atmosphere	242
Chewing	243
Swallowing	243
Sound Generation and Filtering	243
Pharyngeal-Oral Function in Speech Production	243
The Speech Production Code	243
Vowel-Coding Scheme	244
Diphthong-Coding Scheme	245
Consonant-Coding Scheme	245
The Speech Production Stream	247
A Primer on Theories of Speech Production	248
Traditional Theory of Feature Spreading	249
Articulatory Phonology or Gesture Theory	252
Development and Pharyngeal-Oral Function in Speech Production	254
Age and Pharyngeal-Oral Function in Speech Production	256

Sex and Pharyngeal-Oral Function in Speech Production	259
Measurement of Pharyngeal-Oral Function	260
X-Ray Imaging	260
Strain-Gauge Monitoring	261
Articulatory Tracking	261
X-Ray Microbeam Imaging	261
Electromagnetic Sensing	262
Optoelectronic Tracking	263
Electropalatographic Monitoring	263
Magnetic Resonance Imaging	264
Ultrasonic Imaging	264
Aeromechanical Observations	266
Acoustic Observations	266
Pharyngeal-Oral Disorders and Speech Production	267
Clinical Professionals and Pharyngeal-Oral Disorders in Speech Production	269
Reviews	270
References	274
6 BRAIN STRUCTURES AND MECHANISMS FOR SPEECH, LANGUAGE, AND HEARING	281
Introduction	281
The Nervous System: An Overview and Concepts	281
Central Versus Peripheral Nervous System	282
Anatomical Planes and Directions	283
White Versus Gray Matter, Tracts Versus Nuclei, Nerves Versus Ganglia	286
Gray Matter and Nuclei	286
White Matter and Fiber Tracts	287
Ganglia	287
Efferent and Afferent	288
Lateralization and Specialization of Function	288
Cerebral Hemispheres and White Matter	291
Cerebral Hemispheres	291
Frontal Lobe	291
Parietal Lobe	295
Temporal Lobe	296
Occipital Lobe	298
Insula	299
Limbic System (Limbic Lobe)	299
Cerebral White Matter	300
Association Tracts	300
Striatal Tracts	304
Commissural Tracts	304
Descending Projection Tracts	305
Ascending Projection Tracts	309
Subcortical Nuclei and Cerebellum	310
Basal Ganglia	310
Thalamus	315
Cerebellum	315
Cerebellum and Basal Ganglia: New Concepts	317

Brainstem and Cranial Nerves	317
Surface Features of the Brainstem: Ventral View	319
Ventral Surface of Midbrain	320
Ventral Surface of Pons	320
Ventral Surface of Medulla	320
Surface Features of the Brainstem: Dorsal View	321
Dorsal Surface of Midbrain	321
Dorsal Surface of Pons	321
Dorsal Surface of Medulla	323
Cranial Nerves and Associated Brainstem Nuclei	323
Cranial Nerve I (Olfactory)	323
Cranial Nerve II (Optic)	325
Cranial Nerve III (Oculomotor)	326
Cranial Nerve IV (Trochlear)	326
Cranial Nerve V (Trigeminal)	327
Cranial Nerve VI (Abducens)	332
Cranial Nerve VII (Facial)	332
Cranial Nerve VIII (Auditory-Vestibular Nerve)	334
Cranial Nerve IX (Glossopharyngeal)	335
Cranial Nerve X (Vagus)	337
Cranial Nerve XI (Spinal Accessory Nerve)	338
Cranial Nerve XII (Hypoglossal)	339
Cortical Innervation Patterns	340
Why These Innervation Patterns Matter	341
The Cranial Nerve Exam and Speech Production	343
Spinal Cord and Spinal Nerves	343
Spinal Cord	343
Spinal Nerves	344
Nervous System Cells	345
Glial Cells	346
Neurons	347
Cell Body (Soma)	347
Axon and Terminal Button	348
Synapse	349
Resting Potential, Action Potential, and Neurotransmitters	349
Resting Potential	350
Action Potential	352
Synaptic Transmission and Neurotransmitters	354
Neuromuscular Junction	356
Meninges, Ventricles, Blood Supply	357
Meninges	358
Dura Mater	359
Arachnoid Mater	359
Pia Mater	360
Meninges and Clinically-Relevant Spaces	360
Ventricles	360
Lateral Ventricles	360
Third Ventricle	361
Cerebral Aqueduct, Fourth Ventricle, and Other Passageways for CSF	361

Production, Composition, and Circulation of CSF	362
Blood Supply of Brain	363
Anterior Circulation	363
Posterior Circulation	363
Circle of Willis	364
MCA and Blood Supply to the Dominant Hemisphere	365
Blood-Brain Barrier	368
Speech and Language Functions of the Brain: Possible Sites and Mechanisms	369
DIVA: Speech Sound Map (IvPMC)	370
DIVA: Articulatory Velocity/Position Maps (PMC)	373
DIVA: Auditory and Somatosensory Processing: Parietal Cortex and Frontal-Parietal	
Association Tracts	373
DIVA: Where is Aphasia, Where are Dysarthria Types?	374
Review	375
References	376
7 ACOUSTICS	379
Introduction	379
Pressure Waves	380
The Motions of Vibrating Air Molecules Are Governed by Simple Forces	380
The Motions of Vibrating Air Molecules Change the Local Densities of Air	382
Pressure Waves, Not Individual Molecules, Propagate Through Space and Vary as a Function of Both Space and Time	383
The Variation of a Pressure Wave in Time and Space Can be Measured	383
Temporal Measures	384
Spatial Measures	385
Pressure Waves: A Summary and Introduction of Sinusoids	387
Sinusoidal Motion	388
Sinusoidal Motion (Simple Harmonic Motion) Is Derived from the Linear Projection of Uniform Circular Speed	388
When the Linear Projection of Uniform Circular Speed Is Stretched Out in Time, the Result is a Sine Wave	389
Sinusoidal Motion Can Be Described by a Simple Formula, and Has Three Important Characteristics: Frequency, Amplitude, and Phase	390
Sinusoidal Motion: A Summary	391
Complex Acoustic Events	391
Complex Periodic Events Have Waveforms That Repeat Their Patterns Over Time, and Frequency Components That Are Harmonically Related	391
A Complex Periodic Waveform Can Be Considered as the Sum of the Individual Sinusoids at the Harmonic Frequencies	393
Complex Aperiodic Events Have Waveforms in Which No Repetitive Pattern Can Be Discerned, and Frequency Components That Are Not Harmonically Related	394
Complex Acoustic Events: Summary	396
Resonance	397
Mechanical Resonance	398
A Simple Spring-Mass Model Can Be Used to Explain the Concept of Resonance	398
The Relative Values of Mass (M) and Elasticity (K) Determine the Frequency of Vibration of the Simple Spring-Mass Model	398
The Effects of Mass and Stiffness (Elasticity) on a Resonant System: A Summary	400

Acoustic Resonance: Helmholtz Resonators	401
The Neck of the Helmholtz Resonator Contains a Column, or Plug of Air, That Behaves Like a Mass When a Force Is Applied to It	401
The Bowl of a Resonator Contains a Volume of Air That Behaves Like a Spring When a Force is Applied to It	402
Acoustic Resonance: Tube Resonators	403
Resonance in Tubes: A Summary	407
Resonance Curves, Damping, and Bandwidth	408
Energy Loss (Damping) in Vibratory Systems Can Be Attributed to Four Factors	408
Time- and Frequency-Domain Representations of Damping in Acoustic Vibratory Systems	408
An Extension of the Resonance Curve Concept: The Shaping of a Source by the Acoustic Characteristics of a Resonator	411
Resonance, Damping, and Bandwidth: A Summary	412
Review	412
References	413
8 ACOUSTIC THEORY OF VOWEL PRODUCTION	415
Introduction	415
What Is the Precise Nature of the Input Signal Generated by the Vibrating Vocal Folds?	416
The Time Domain	416
The Frequency Domain	419
The Periodic Nature of the Waveform	420
The Shape of the Waveform	421
The Ratio of Open Time to Closed Time	423
Nature of the Input Signal: A Summary	423
Why Should the Vocal Tract Be Conceptualized as a Tube Closed at One End?	423
The Response of the Vocal Tract to Excitation	425
How Are the Acoustic Properties of the Vocal Tract Determined?	425
Area Function of the Vocal Tract	427
How Does the Vocal Tract Shape the Input Signal? (How Is the Source Spectrum Combined with the Theoretical Vocal Tract Spectrum to Produce a Vocal Tract Output?)	429
Formant Bandwidths	434
Acoustic Theory of Vowel Production: A Summary	434
What Happens to the Resonant Frequencies of the Vocal Tract When the Tube Is Constricted at a Given Location?	435
The Three-Parameter Model of Stevens and House	440
Tongue Height	443
Tongue Advancement	444
Configuration of the Lips	444
Importance of the Stevens and House Rules: A Summary	447
The Connection Between the Stevens and House Rules and Perturbation Theory	447
Why Are the Stevens and House Rules Important?	449
Another Take on the Relationship Between Vocal Tract Configuration and Vocal Tract Resonances	450
Confirmation of the Acoustic Theory of Vowel Production	451
Analog Experiments	451
Human Experiments	451
Review	453
References	453

9	THEORY OF CONSONANT ACOUSTICS	455
	Introduction	455
	Why Is the Acoustic Theory of Speech Production Most Accurate and Straightforward for Vowels?	455
	What Are the Acoustics of Coupled (Shunt) Resonators, and How Do They Apply to Consonant Acoustics?	456
	Nasal Murmurs	457
	Energy Loss in the Nasal Cavities, Antiresonances, and the Relative Amplitude of Nasal Murmurs	461
	Nasal Murmurs: A Summary	461
	Nasalization	461
	Nasalization: A Summary	464
	The Importance of Understanding Nasalization	464
	Coupled (Shunt) Resonators in the Production of Lateral Sounds	465
	Coupled (Shunt) Resonators in the Production of Obstruent Sounds	467
	What is the Theory of Fricative Acoustics?	467
	Fluid Flow in Pipes and Source Types	467
	Aeromechanic/Acoustic Effects in Fricatives: A Summary	471
	A Typical Fricative Waveform and Its Aeromechanical Correlates	471
	Mixed Sources in Fricative Production	473
	Shaping of Fricative Sources by Vocal Tract Resonators	473
	Measurement of Fricative Acoustics	475
	Spectral Measurements	476
	Temporal Measurements	477
	The Acoustic Theory of Fricatives: A Summary	478
	What is the Theory of Stop Acoustics?	478
	Intervals of Stop Consonant Articulation: Aeromechanics and Acoustics	480
	Closure (Silent) Interval	480
	Release (Burst) Interval	481
	Frication and Aspiration Intervals	482
	Voice-Onset Time	483
	Shaping of Stop Sources by Vocal Tract Resonators	483
	The Nature of Stop Sources	483
	The Shaping of Stop Sources	484
	Measurement of Stop Acoustics	485
	Spectral Measurements	485
	Temporal Measurements	486
	Stop Consonants: A Summary	486
	What Is the Theory of Affricate Acoustics?	487
	What Kinds of Acoustic Contrasts Are Associated with the Voicing Distinction in Obstruents?	487
	Review	488
	References	488
10	SPEECH ACOUSTIC ANALYSIS	491
	Introduction	491
	A Brief Historical Prelude	492
	The Original Sound Spectrograph: History and Technique	497
	The Original Sound Spectrograph: Summary	501
	Interpretation of Spectrograms: Specific Features	501
	Axes	502

Glottal Pulses	503
Formant Frequencies	504
Silent Intervals and Stop Bursts	505
Aperiodic Intervals	507
Segmentation of Spectrograms	507
Speech Acoustics is Not All About Segments: Suprasegmentals	510
Digital Techniques for Speech Analysis	512
Speech Analysis by Computer: From Recording to Analysis to Output	513
Sampling Rate	514
Sampling Rate Sidebar: Anti-Aliasing Filters	515
Quantization (Bits)	516
Analysis and Display	517
Review	519
References	520

11 ACOUSTIC PHONETICS DATA 521

Introduction	521
Vowels	521
Vowel Acoustics, Dialect, and a Multicultural View of Acoustic Phonetics	527
Within-Speaker Variability in Formant Frequencies	530
Summary of Vowel Formant Frequencies	532
A Brief Note on Vowel Formant Frequencies Versus Formant Trajectories	533
Vowel Durations	534
Intrinsic Vowel Durations	535
Extrinsic Factors Affecting Vowel Durations	536
Consonant Voicing	536
Stress	536
Speaking Rate	536
Utterance Position Effects	537
Speaking Style	537
Diphthongs	538
Nasals	541
Nasal Murmurs	542
Nasal Place	544
Nasalization	548
Semivowels	550
Semivowel Durations	554
Fricatives	554
Formant Transitions and Fricative Distinctions	561
Fricative Duration	561
/h/ Acoustics	566
Stops	567
Closure Interval and Burst	568
Flap Closures	570
Closure Duration and Place of Articulation	571
Stop Voicing: Some Further Considerations	571
Bursts	574
Acoustic Invariance and Theories of Speech Perception	578
Acoustic Invariance at the Interface of Speech Production and Perception	580

Affricates	581
Acoustic Characteristics of Prosody	581
Phrase-level F0 Contours	581
Phrase-level Intensity Contours	584
Stress	585
Rhythm	586
Review	587
References	587
12 SPEECH PERCEPTION	593
Introduction	593
Early Speech Perception Research and Categorical Perception	593
The /ba/-/da/-/ga/ Experiment	594
Categorical Perception: Some General Considerations	595
Labeling Versus Discrimination	598
Categorical Perception: So What?	598
Speech Perception Is Species Specific	600
Categorical Perception of Stop Place of Articulation Shows the “Match” to Speech Production	600
Duplex Perception	601
Acoustic Invariance	605
The Competition: General Auditory Explanations of Speech Perception	608
Sufficient Acoustic Invariance	608
Replication of Speech Perception Effects Using Nonspeech Signals	609
Animal and Infant Perception of Speech Signals	611
The Competition: Direct Realism	611
A Tentative Summary	613
Speech Perception and Word Recognition	614
Why Should Speech-Language Pathologists Care About Speech Perception?	615
Speech Intelligibility	616
“Explanatory” Speech Intelligibility Tests	616
Scaled Speech Intelligibility	617
Review	619
References	620
13 SWALLOWING	623
Introduction	624
Anatomy	625
Breathing, Laryngeal, Velopharyngeal-Nasal, and Pharyngeal-Oral Structures	625
Esophagus	625
Stomach	626
Forces and Movements of Swallowing	627
Oral Preparatory Phase	628
Oral Transport Phase	630
Pharyngeal Transport Phase	630
Esophageal Transport Phase	632
Overlap of Phases	633
Breathing and Swallowing	633
Neural Control of Swallowing	635

Role of the Peripheral Nervous System in Swallowing	635
Role of the Central Nervous System in Swallowing	636
Variables that Influence Swallowing	637
Bolus Characteristics and Swallowing	637
Consistency	637
Volume	638
Taste and Temperature	638
Swallowing Mode	639
Single Versus Sequential Swallows	639
Cued Versus Uncued Swallows	640
Body Position and Swallowing	640
Development and Swallowing	641
Age and Swallowing	642
Sex and Swallowing	642
Measurement of Swallowing	642
Videofluoroscopy	642
Endoscopy	644
Ultrasonography	645
Manometry	645
Swallowing Disorders	646
Clinical Professionals and Swallowing Disorders	647
Review	648
References	650
NAME INDEX	655
SUBJECT INDEX	667



1

Introduction

Welcome to *Preclinical Speech Science: Anatomy, Physiology, Acoustics, Perception, Second Edition*. Two preliminaries are offered here. One is a discussion of the focus of the book, the other a discussion of the domain of preclinical speech science.

FOCUS OF THE BOOK

Preclinical Speech Science: Anatomy, Physiology, Acoustics, Perception is designed as an introduction to the fundamentals of speech science (inclusive of voice science) that are important to aspiring clinicians and practicing clinicians. The text is suitable for courses that cover the anatomy and physiology of speech production and swallowing, and the acoustics and perception of speech. The material is user friendly to beginning students, yet integrative and translational for graduate students and practicing speech-language pathologists. Certain topics in the text are novel to the speech science and speech-language pathology literatures and suggest important new conceptualizations.

This book is an outgrowth of the three authors' many years of teaching experience with several thousand undergraduate and graduate students. The development of the book is the result of a sifting and winnowing of the broad range of facts, principles, and methods associated with its topics. The outcome is an integrated fabric that is a logical precursor for clinical study and practice. Chapters in the book are infused with clinical scenarios, sidetracks of clinical and historical interest, considerations of the scientific bases of clinical protocols and methodologies, and discussions of clinical personnel involved in the evaluation and management of disorders of speech production, speech, and swallowing.

The illustrations, done by an extremely talented artist, are a key feature of this book. These original illustrations, largely in full color, are supplemented by a small number of illustrations from other sources. The original illustrations were carefully chosen and drafted to convey only salient features, an approach in line with the written text. Occasional cartoons lighten the material, but carry educational messages.

DOMAIN OF PRECLINICAL SPEECH SCIENCE

The domain of preclinical speech science is portrayed in Figure 1–1. This domain encompasses speech production, speech acoustics, speech perception, and swallowing. Within this domain, consideration is given to levels of observation, subsystems of speech production and swallowing, and applications of data.

Levels of Observation

Speech production and swallowing are processes. They result in acoustic products (more so for speech than swallowing) and perceptual experiences. These processes, products, and experiences involve different levels of observation. Six such levels are represented in Figure 1–1: (a) neural, (b) muscular, (c) structural, (d) aeromechanical, (e), acoustic, and (f) perceptual.

The neural level of observation encompasses nervous system events during speech production and swallowing. These include all events that qualify as motor planning and execution and all forms of afferent and sensory information that influence the ongoing control of speech production and swallowing. The neural level of observation pertains to the parts of

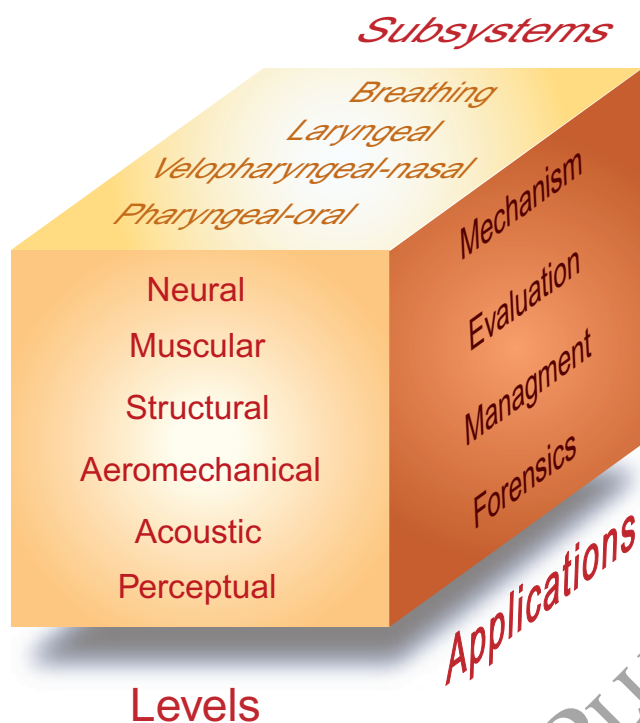


Figure 1-1. Domain of preclinical speech science.

the brain, spinal cord, and cranial and spinal nerves important to speech production and swallowing and to all underlying neural mechanisms, some voluntary and some automatic, some that involve awareness, and some that do not. Neural data are often derived from physical or metabolic imaging methods that reflect patterns of activation of different regions of the brain. Activation at the neural level can also be inferred from events associated with other (downstream) levels of observation.

The muscular level of observation is concerned with the influence of muscle forces on speech production and swallowing. Muscle forces are responsible for powering these two processes. Muscles are effectors that respond to control signals from the nervous system. The muscular events of speech production and swallowing are manifested in mechanical pulls and are often indexed at the periphery through the electrical activities associated with muscle contractions. Inferences about muscle activities are also made from measurements of the forces or movements generated by different parts of the speech production apparatus and swallowing apparatus. Nevertheless, there are ambiguities introduced when attempting to infer individual muscle activities from forces or movements because

forces and movements are usually accomplished by groups of muscles working together. Such inferences, if they can be made at all, require a detailed knowledge of anatomy and physiology.

The structural level of observation deals with movements of the speech production apparatus and swallowing apparatus. This level of observation is concerned with the displacements, velocities, and accelerations/decelerations of structures and how they are timed in relation to the movements of other structures. Certain structural observations can be made with the naked eye, whereas others are hidden from view or are too rapid to be followed with the naked eye and require the use of instrumental monitoring. To the person on the street, the structural level of observation is public evidence of speech production and swallowing. Speech reading (lip reading) has its roots at this level of observation.

The structural movements of speech production and swallowing give rise to an aeromechanical level of observation. It is at this level that air comes into play. Movements of structures impart energy to the air by compressing and decompressing it and causing it to flow from one region to another. The raw airstream generated in association with the aeromechanical level is modified by structures of the speech production apparatus and swallowing apparatus that lie along various passageways. The products of the aeromechanical level are complex, rapid, and nearly continuous changes in air pressures, airflows, and air volumes. These products are usually "invisible," especially for swallowing. However, those who speak and smoke at the same time or who speak in subfreezing temperatures often provide the observer with the opportunity to visualize certain aeromechanical events.

The acoustic level of observation is fully within the public domain. Although certain aspects of swallowing may be accompanied by sounds, primacy at this level pertains to the generation of speech sounds. The raw material of the acoustic level is the buzzlike, hiss-like, and poplike sounds that result from the speaker's valving of the airstream in different ways and at different locations within the speech production apparatus. This raw material is filtered and conditioned by its passage through the apparatus and radiates from the mouth or nose, or both, in the form of nearly continuous changes in atmospheric pressure. The sound waves that are formed propagate spherically from the speaker and can be coded in terms of frequency, sound pressure level, and time. These sound waves are what constitute speech, an acoustic representation of language. The acoustic level is important in face-to-face

communication and in the use of telephones, radios, televisions, and various forms of recording. It is this level that makes it possible for many listeners to be engaged simultaneously and makes it possible to communicate effectively around corners, through obstacles, in the dark, and over long distances.

The perceptual level of observation has somewhat different manifestations for speech production and swallowing. For speech production, it pertains primarily to auditory events. Kinesthesia (movement sensation), proprioception (position-in-space sensation), and touch-pressure sensation are important as bases for staying informed about ongoing speech production events, but the principal factor is audition (hearing sensation). Visual information is sometimes important as well, and experience and knowledge of the language is critical for extracting meaning from speech. In contrast, swallowing is highly dependent on kinesthesia, touch-pressure sensation, and even taste, with relatively little reliance on auditory or visual information. Cognitive processes contribute to various degrees at the perceptual level of observation for both speech production and swallowing.

The levels of observation portrayed in Figure 1-1 are not completely separate entities, but have important interactions. These interactions are not shown in the figure, but are discussed in subsequent chapters.

Subsystems of Speech Production and Swallowing

The speech production apparatus and the swallowing apparatus perform different activities. However, they share many structural and functional components and, although different in their control and movement, can be viewed along similar lines. It is convenient, for discussion purposes, to partition the speech production apparatus and swallowing apparatus into subsystems. Speech production subsystems may differ when chosen by a linguist versus a speech scientist versus a speech-language pathologist. And swallowing subsystems may differ when chosen by a swallowing scientist versus a gastroenterologist versus a speech-language pathologist. For the purposes of this book, four subsystems are used for speech production and swallowing. As illustrated in Figure 1-1, these include the: (a) breathing apparatus, (b) laryngeal apparatus, (c) velopharyngeal-nasal apparatus, and (d) pharyngeal-oral apparatus. The role of each of these subsystems is considered in detail in subsequent chapters. The functional significance of each of the four subsystems dif-

fers between speech production and swallowing, but each subsystem is critically important to its respective behaviors and each manifests in clinical signs that can reveal abnormality.

The breathing apparatus is defined in the present context to include structures below the larynx within the neck and torso. These are, most importantly, the pulmonary apparatus (pulmonary airways and lungs) and chest wall apparatus (rib cage wall, diaphragm, abdominal wall, and abdominal content). During speech production, the breathing apparatus provides the necessary driving forces, while simultaneously serving the functions of ventilation and gas exchange. During swallowing, the breathing apparatus engages in a period of apnea (breath holding) to protect the pulmonary airways and lungs from the intrusion of unwanted substances (food and liquid). The breathing apparatus is the largest of the subsystems and its role in speech production and swallowing is fundamentally important.

The laryngeal apparatus lies between the trachea (windpipe) and the pharynx (throat) and adjusts the coupling between the two. At times, the laryngeal airway is open to allow air to move in and out of the breathing apparatus, whereas at times it is adjusted to obstruct or constrict the airway. During speech production, obstructions and constrictions enable the generation of transient and sustained noises, respectively. Very rapid to and fro movements of the vocal folds within the larynx create voiced sounds and give the laryngeal apparatus its colloquial label “voice box.” During swallowing, the laryngeal apparatus is active in closing the laryngeal airway to protect the pulmonary airways. Food and liquid are then able to pass over and around the larynx and into the esophagus on their way to the stomach.

The velopharyngeal-nasal apparatus consists of the upper pharynx, velum, nasal cavities, and outer nose. When breathing through the nose, the velopharyngeal-nasal airway is open. When speaking, the size of the velopharyngeal port varies, depending on the nature of the speech produced. For example, consonant sounds that require high oral air pressure are typically associated with airtight closure of the velopharyngeal port, whereas nasal consonants are produced with an open velopharyngeal port. Function of the velopharyngeal-nasal apparatus during swallowing is concerned mainly with keeping the velopharynx sealed airtight. This prevents the passage of food and liquid into the nasal cavities, while substances are moved backward and downward through the oropharynx.

The pharyngeal-oral apparatus comprises the middle and lower pharynx, oral cavity, and oral vesti-

bule. During running speech production, the apparatus is typically open during inspiration and makes different adjustments for consonant and vowel productions during expiration, including the generation of transient, voiceless, and voiced sounds and the filtering of those sounds. During swallowing, the pharyngeal-oral apparatus prepares food and liquid and propels it to the esophagus.

Applications of Data

There are many applications of data obtained about speech production and swallowing. These applications depend on who selects and defines the data and what the goals are for collecting and analyzing them. For the purposes of this book, applications of data are categorized into four areas: (a) mechanism, (b) evaluation, (c) management, and (d) forensics. These are shown in Figure 1–1.

One application of data is the understanding of mechanism. This use provides the foundational bases for knowing how speech is produced and how swallowing is performed. Such foundational bases are important for their heuristic value in elucidating fundamental processes and working principles and for differentiating normal from abnormal.

Another application of data is its use in evaluation. This use is usually practical in nature and involves quantitative determinations of the status and functional capabilities of an individual's speech production, speech, and swallowing. Evaluation first enables a determination as to whether or not abnormality exists. If abnormality does exist, then appropriate evaluation may contribute to: (a) making a diagnosis, (b) developing a rational, effective, and efficient management plan, (c) monitoring progress during the course of management, and (d) providing a reasonable prognosis as to the extent and speed of improvement to be expected. For example, a specific use of subsystems analysis in the evaluation of speech production is the determination of how individual subsystems contribute to deficits in speech intelligibility. Two individuals may have equivalent intelligibility problems as determined by formal tests, but have different subsystems "explanations" for their deficits. The careful evaluation of subsystems performance can point to which parts of the speech production apparatus may be particularly responsible for speech intelligibility deficits, and how those parts should be addressed in management. Evaluation relies on an understanding of what constitutes normal function.

A third application of data is management. Different interventions may be based on any of the six levels of observation and include any of the four subsystems of speech production and swallowing. Different management strategies may include adjusting individual variables or combinations of variables, staging the order of different interventions, and providing feedback about speech production and swallowing processes, products, and experiences. Management data provide information about outcome and whether or not interventions are effective, efficient, and long lasting. Management data can also be used to compare and contrast different interventions to arrive at optimal choices.

The remaining application of data is their use in forensics. This application is concerned with scientific facts and expert opinion as they relate to legal issues. The speech scientist and speech-language pathologist are sometimes called on to give legal depositions or to testify in courts of law in a variety of forensic contexts. Forensic uses of data may include issues pertaining to speaker identification, speaker status under the influence of drugs or alcohol, and speaker intent at deceit, among others. Forensic uses of data may also relate to personal injury claims or malpractice claims. These may involve speech production, speech, or swallowing alone, or in different combinations, and may include adversarial depositions and testimonies of other experts. Under such circumstances, the status and capabilities of the individuals claiming personal injury or malpractice may be considered from the perspective of underlying mechanism, evaluation, and management.

REVIEW

Preclinical Speech Science: Anatomy, Physiology, Acoustics, Perception is intended as an introduction to the fundamentals of speech science (inclusive of voice science) that are important to aspiring clinicians and practicing clinicians.

The text is suitable for different courses that cover anatomy and physiology of speech production and swallowing, and the acoustics and perception of speech.

The material in the text is strongly integrative and translational, applicable to both undergraduate and graduate students, and a source of continuing education and reference for practicing speech-language pathologists.

The domain of preclinical speech science encompasses different levels of observation, different subsystems of speech production and swallowing, and different applications of data.

Levels of observation include the neural, muscular, structural, aeromechanical, acoustic, and perceptual levels.

Subsystems of speech production and swallowing include the breathing apparatus, laryngeal apparatus, velopharyngeal-nasal apparatus, and pharyngeal-oral apparatus.

Applications of data include the understanding of mechanism, evaluation, management, and forensics.

Sidetracks

Throughout the book you'll find a series of sidetracks. These are short asides that relate to topics being discussed in the main text. Many of the sidetracks in the book are a bit less formal and a bit more lighthearted than the main text they complement. This is intended to enhance your reading enjoyment and to put some fun in your study of the material. We hope you enjoy reading these sidetracks as much as we enjoyed writing them.

