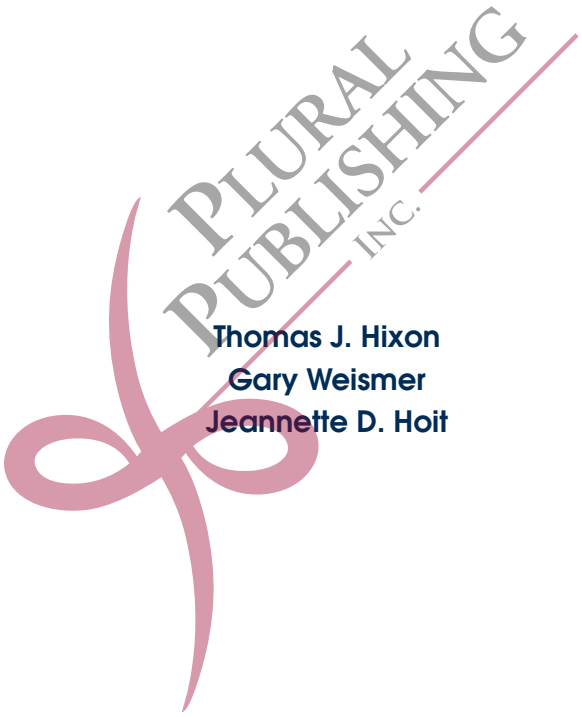
PRECLINICAL SPEECH SCIENCE

Anatomy, Physiology, Acoustics, Perception

SECOND EDITION



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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

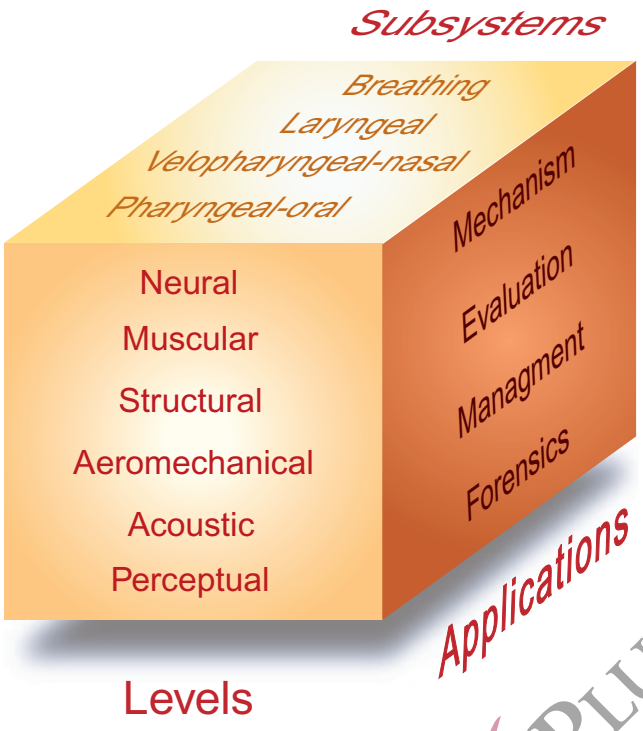

Figure 1–1. Domain of preclinical speech science.

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, hisslike, 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 differs 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.