

The Handbook of
**Phonetic
Sciences**
Second Edition



Edited by

**William J. Hardcastle,
John Laver, and Fiona E. Gibbon**

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Preface to the Second Edition

It is now over 10 years since the publication of the first edition of *The Handbook of Phonetic Sciences*. Since then the phonetic sciences have developed substantially and there are now many more disciplines taking a professional interest in speech-related areas. This multidisciplinary orientation continues to be reflected in the second edition.

In this second edition, 32 leading researchers have contributed 22 chapters in 5 major sectors of the contemporary subject. As with the first edition, an elementary knowledge of the field is assumed and each chapter presents an overview of a key area of the expertise which makes up the wide range of the phonetic sciences today.

There are a number of chapters retained from the first edition which have been substantially updated by the authors. These include the chapters by Stone, Shadle, Hirose, Mackenzie Beck, Farnetani and Recasens, Löfqvist, Gobl and Ní Chasaide, Stevens and Hanson, Moore, McQueen and Cutler, Ohala, Carlson and Granström. Other topic areas from the first edition have been given completely new treatment by newly commissioned authors (chapters by Harrington, Ackermann and Ziegler, Smith, Davis, Ellis, Renals and King). There are also two new chapters covering sociophonetics (Scobbie, Foulkes, and Watt) and phonetic notation (Esling). To reflect the increasing significance of the area of prosody in the phonetic sciences we have also included two commissioned chapters covering the areas of timing and rhythm (Fletcher), and tone and intonation (Beckman and Venditti).

For readers with complementary interests in phonology and clinical phonetics and linguistics the companion volumes to this handbook, *The Handbook of Phonological Theory* (Goldsmith, 2010, 2nd edn.) and *The Handbook of Clinical Linguistics* (Ball, Perkins, Müller, & Howard, 2008) are recommended.

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The editors

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Introduction

WILLIAM J. HARCASTLE, JOHN LAVER,
AND FIONA E. GIBBON

As with the first edition, the book is divided into five major sections. The first part begins with an account of the main measurement techniques, methodologies, and instruments found in experimental phonetic laboratories. The next part explores aspects of the anatomical and physiological framework for normal and disordered speech production. The third and largest part of the book focuses on the acquisition of speech and theories and models of speech production and perception. The fourth part deals with the linguistic motivation of much research in the phonetic sciences in covering a number of key areas of linguistic phonetics. The final part returns to experimental approaches to the phonetic sciences but this time focusing on speech signal processing and engineering in an overview of the main developments in speech technology. There are extensive pointers to further reading in each chapter.

Part I has four chapters on the topic of Experimental Phonetics. The section begins with a critical evaluation by Maureen Stone on current laboratory techniques that measure the oral vocal tract during speech. The focus is on instruments that measure the articulators directly and indirectly. Indirect measurements come from instruments that are remote from the structures of interest such as imaging techniques (e.g., X-ray, MRI, and ultrasound). Direct measurements come from instruments that contact the structures of interest, such as, point-tracking devices and electropalatography. References are made to current research using each instrument in order to indicate its applications and strengths.

Experimental approaches to speech production are explored further by Christine Shadle in the next chapter on the aerodynamics of speech. This chapter begins by defining aerodynamics and reviews the basic concepts of fluid statics and dynamics (including turbulence), and aerodynamically distinct vocal tract behaviors are discussed. This is followed by a section covering measurement methods, divided into basic methods such as pressure and flow velocity measurement, and speech-adapted methods such as the Rothenberg mask and methods for measuring or estimating lung volume and subglottal pressure, and the use of hot-wires to measure flow velocities in the vocal tract. A final section describes models of speech production that incorporate aerodynamics.

Acoustic phonetics is the subject of the third chapter by Jonathan Harrington. This new chapter provides an overview of the acoustic characteristics of consonants and vowels from the perspective of a broad range of research questions in experimental phonetics and laboratory phonology. Various procedures for the phonetic classification of the acoustic speech signal are reviewed including the identification of vowel height and backness from various transformed acoustic spaces, the derivation of place of articulation in oral stops from burst and locus cues, and techniques for distinguishing between fricatives based on parameterizing spectral shape. These techniques are informed by a knowledge of speech production and are related to speech perception, and they also establish links to pattern classification in signal processing.

Investigating the physiology of laryngeal structures is the subject of the final chapter in this section. In this chapter, Hajime Hirose describes specialized, newly developed techniques for observing laryngeal behavior during speech production, including flexible fiberoscopy, high-speed digital imaging, laryngeal electromyography, photoglottography, electroglottography, and magnetic resonance imaging. Basic behaviors of the laryngeal structures are described with reference to the results of observation obtained by the above techniques and the nature of laryngeal adjustments that take place under different phonetic conditions.

Part II contains three chapters on biological perspectives and opens with an exploration by Janet Mackenzie Beck on organic variation and the ways it affects the vocal apparatus. She points to two main sources of variation in speech performance: phonetic variation resulting from differences in the way individuals use their vocal apparatus, and organic variation depending on individual differences in inherent characteristics of the vocal organs. The chapter focuses on organic variation bringing together information from a variety of sources, anatomical, physiological, anthropological. Three main types of differences in the structure of the vocal apparatus are discussed: the life-cycle changes within an individual; genetic or environmental factors which differentiate between individuals; and differences which result from trauma or disease.

Hermann Ackermann and Wolfram Ziegler in their chapter on brain mechanisms underlying speech motor control begin with an overview of the topic. Their discussions draw upon data derived from three approaches, namely, electrical surface stimulation of the cortex, lesion studies in patients with neurogenic communication disorders, and functional imaging techniques. These discussions are preceded by a review of experimental studies in subhuman primates addressing the corticobulbar representation of orofacial muscles as well as the cerebral correlates of vocal behavior.

The final chapter in Part II is by Anne Smith and concerns the development of neural control for speech. She gives an integrative overview of studies of the development of the neuromotor processes involved in controlling articulatory movements for speech. The area of speech motor development has not been critically reviewed recently and this chapter provides a detailed summary of major advances in understanding the time course of maturation of speech motor control processes, which, contrary to earlier claims, are not adult-like until late

adolescence. Discussions of theoretical issues in speech motor development, such as the units involved in the language–motor interface and the issues of neural plasticity and sensitive periods in speech motor development, portray important, ongoing debates in this area.

Part III contains seven chapters on the topic of modeling speech production and perception. The first is a chapter on speech acquisition by Barbara Davis. She addresses the question of how young children integrate biology and cognition to achieve the necessary capacities for the phonological component of linguistic communication. The chapter outlines how contemporary theoretical perspectives and research paradigms consider the nature of speech acquisition. These include formalist phonological perspectives representing a consistent strand of proposals on acquisition of sound patterns in languages. She contrasts this approach with functionalist phonetic science perspectives that have focused on biological characteristics of the developing child and the ways in which these capacities contribute to emergence of complex speech output patterns.

The chapter by Edda Farnetani and Daniel Recasens presents an overview of the current knowledge concerning coarticulation and connected speech processes. The authors address the nature of coarticulatory and assimilatory processes in connected speech, and explore the foundations and predictions of the most relevant theoretical models of labial, velar, and lingual coarticulation (feature spreading, time-locked, locus equation, adaptive variability, window model, and coarticulatory resistance). They describe the significant theoretical and experimental progress in understanding contextual variability, which is reflected in continuously evolving and improving models, and in increasingly rigorous and sophisticated research methodologies.

Theories and models of speech production are developed further by Anders Löfqvist, particularly from the point of view of spatial and temporal control of speech movements. In his chapter, theoretical and empirical approaches to speech production converge in their focus on understanding how the different parts of the vocal tract are flexibly marshaled and coordinated to produce the acoustic signal that the speaker uses to convey a message. He outlines a variety of experimental paradigms and how these are applied to the problem of coordination and control in motor systems with excess degrees of freedom.

An area of key theoretical and technical importance is the nature of the voice source and how it varies in speech. The chapter by Christer Gobl and Ailbhe Ní Chasaide is concerned with acoustic aspects of phonation and its exploitation in speech communication. The early sections focus on the source signal itself, on analysis techniques, and provide acoustic descriptions of different voice qualities. The later sections describe how variations in the voice source are associated with segmental or suprasegmental aspects of the linguistic code, and discuss the role of voice quality in the paralinguistic signaling of emotion, mood, and attitude. The sociolinguistic function in differentiating among linguistic, regional, and social groups is briefly outlined, as well as its important role in speaker identification.

The next chapter by Kenneth Stevens and Helen Hanson focuses on articulatory–acoustic relations as the basis of distinctive contrasts. The chapter

provides a physical basis for the inventory of binary distinctive features or phonological contrasts that are observed in language. The chapter is a major update on the quantal nature of speech, and the authors show how aerodynamic and acoustic properties of speech production lead to quantal relations between the articulatory parameters and the acoustic consequences of these variations. The chapter also proposes how listeners might extract additional enhancing cues as well as cues relating to the defining quantally-based properties of the acoustic signal in running speech. Other approaches that have been proposed to account for variability in speech are also described.

The final two chapters in Part III deal with aspects of auditory processing and speech perception. The first chapter by Brian Moore reviews selected aspects of auditory processing, chosen because they play a role in the perception of speech. The review is concerned with basic processes, many of which are strongly influenced by the operation of the peripheral auditory system and which can be characterized using simple stimuli such as pure tones and bands of noise. He discusses the resolution of the auditory system in frequency and time, as revealed by psychoacoustic experiments. A consistent finding is that the resolution of the auditory system usually markedly exceeds the resolution necessary for the identification or discrimination of speech sounds. This partly accounts for the fact that speech perception is robust, and resistant to distortion of the speech and to background noise.

James McQueen and Anne Cutler in their chapter focus on the cognitive processes involved in speech perception. They describe how recognition of spoken language involves the extraction of acoustic-phonetic information from the speech signal, and the mapping of this information onto cognitive representations. They focus on our ability to understand speech from talkers we have never heard before, and to perceive the same phoneme despite acoustically different realizations (e.g., by a child's voice versus an adult male's). They show how processing of segmental, lexical and suprasegmental information in word recognition contributes significantly to listeners' processing decisions.

The five chapters in Part IV cover different aspects of linguistic phonetics, and begins with two new chapters on speech prosody. Janet Fletcher explores rhythm and timing in speech with a particular focus on how durational patterns of segments and syllables contribute to the signaling of stress and/or accent and prosodic phrasing in different languages. The chapter summarizes the contribution of durational patterns of segments, morae, and syllables to the rhythm and tempo of spoken language, and evaluates the different kinds of metrics that are often used in experimental investigations. What emerges is a complex picture of how speech unfolds in time, and crucially how the temporal signatures of prosody in a language are often accompanied by additional qualitative acoustic and articulatory modifications, rather than just adjustment of measurable duration alone.

In the second chapter on speech prosody, Mary Beckman and Jennifer Venditti examine tone and intonation. The authors begin by reviewing the ways in which pitch patterns are represented in work on tone and intonation. A key point in this review is that symbolic representations are phonetically meaningful only

if they are tags for parameter settings in an analysis-by-synthesis model of f_0 contours. The most salient functions of lexical contrast, prosodic grouping, and prominence marking are described in a way that makes clear that many aspects of the pitch pattern can simultaneously serve one, two, or all three of these functions. The authors conclude by suggesting that broad-scale typologies that differentiate only between two or three language “types” (e.g., “tone languages”) are overly simplistic.

The next chapter by John Ohala explores the relation between phonetics and phonology. In tracing the history of this relationship from the early part of the last century, he shows it has been affected by theoretical frameworks such as structuralist phonology, in which more attention was given to relations between sounds at the expense of substance of sounds. It is proposed that in order to explain sound patterns in language, phonology needs to re-integrate scientific phonetics (as well as psychology and sociolinguistics). The author provides examples where principles of aerodynamics and acoustics are used to explain certain common sound patterns.

John Esling’s chapter on phonetic notation reviews the theoretical constructs of how speech sounds are transcribed using phonetic notation. He presents the International Phonetic Alphabet (IPA) as a common core of standard usage that transcribers of language can universally refer to and understand. Orthographic, iconic, and alphabetic notation are differentiated, and the phonetic relationships between sets of symbols are addressed. A revised version of the IPA consonant chart is developed, as well as a novel way of looking at the IPA vowel chart. Place of articulation, manner of articulation, vowel classification, and secondary articulation are discussed where they present challenges to notational conventions. He also discusses notation for stress and juncture, strength of articulation, voice quality, and clinical usage for transcribing disordered speech.

The last chapter in Part IV is on sociophonetics. In this chapter, Paul Foulkes, James Scobbie, and Dominic Watt provide an overview of sociophonetics as an area of the phonetic sciences which takes into account the systematic subtle differences in phonetic systems which attach to social groups. This structured variation informs theoretical debate in fields such as sociolinguistics, phonetics, phonology, psycholinguistics, typology, and diachronic linguistics. In their chapter, Foulkes, Scobbie, and Watt survey work which touches on all these areas, although sociolinguistics features most strongly. The chapter addresses both production and perception studies, before moving on to consider contemporary methodological issues and the general theoretical implications that arise from the literature.

Part V contains three chapters that are concerned with issues relating to speech technology. Most speech technology applications rely on digital signal processing and Daniel Ellis presents an introduction to the topic of signal processing for speech. His chapter emphasizes an intuitive understanding of signal processing in place of a formal mathematical presentation. He begins with familiar daily experiences of resonance and oscillation, for instance as seen in a pendulum, and builds up to the ideas of decomposing signals into sinusoids (Fourier analysis), filtering, and the familiar speech-related tools of the spectrogram and cepstral