

The Handbook of
**Phonetic
Sciences**
Second Edition



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

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Praise for *The Handbook of Phonetic Sciences*

“With this second edition, *the Handbook of Phonetics Sciences* will continue to be an outstanding resource for students, providing wide-ranging critical overviews of the development of key scientific topics and of the debates which are at the heart of contemporary phonetic research.”

Gerard Docherty, Newcastle University

“This *Handbook* is an outstanding collection of state-of-the-art surveys and original contributions. Revised and refreshed, it is essential reading for anyone engaged in understanding phonetic aspects of speech.”

John Local, University of York

“This new edition updates its coverage of a wide range of topics, reflecting the most recent trends in research. I will use it as a reference for both my teaching and my research.”

Patricia Keating, University of California, Los Angeles

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*William J. Hardcastle,
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For Peter Ladefoged and Gunnar Fant, who led the field

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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.

We would like to thank a number of colleagues for their assistance with editorial work, including Annabel Allen, Pauline Campbell, Erica Clements, Sue Peppe, and Sonja Schaeffler. Special thanks are also due to Anna Oxbury for her meticulous and thoughtful copy-editing.

The editors

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 fiberscopy, 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