Introduction

Bilingual Phonetics and Phonology

An Interdisciplinary Field of Inquiry

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Bilingualism, loosely defined as the ability to use two languages, is in many ways unexceptional and more common than monolingualism in many parts of the world. It has been estimated that probably more than half of the world's population is bilingual (Bialystok, Craik, & Luk, 2012; Grosjean, 2021) and that two-thirds of the children in the world are raised in bilingual environments (Crystal, 1997). Despite this prevalence of bilingualism, the empirical study of monolingual speakers has traditionally outpaced the study of bilinguals because "it is precisely a monolingual perspective which modern linguistic theory takes as its starting point in dealing with basic analytical problems" (Romaine, 1989, p. 1). In spite of this monolingual bias, it is important to note that over the last three decades there has been a monumental growth in interest and research into bilingualism and multilingualism, leading to a better understanding of the linguistic, sociolinguistic, and cognitive aspects of the bilingual individual.

With an ever-increasing presence across multiple disciplines, the field of bilingual phonetics and phonology is also a fast-growing area of inquiry that has been experiencing a rising interest among linguists, researchers, and practitioners. Studies on the phonetics and phonology of bilingualism have examined the speech production, perception, and processing abilities of early and late bilingual individuals, during their infancy, childhood, and as adults, uncovering the linguistic and extralinguistic factors that shape their bilingual phonetic performance. This research has been conducted in speech sciences, with psycholinguistics and sociolinguistics interfacing with studies in second language acquisition (SLA) and second language (L2) pedagogy. In spite of the remarkable development in all of these areas, there is still the absence of a common platform for interdisciplinary discussion on bilingual phonetics and phonology. Our field of study has matured enough to warrant a volume that includes the current and critical accounts of the most important research developments in the field as well as discussions of future directions. For this, I am pleased and proud to present this volume.

The Cambridge Handbook of Bilingual Phonetics and Phonology provides a state-of-the-art survey of and comprehensive guide to research on bilingual phonetics and phonology, striking a balance between depth of coverage in the most widely studied areas and breadth of coverage across sub-areas of the field. The Handbook is aimed at advanced undergraduate students as well as PhD students, but it is also meant to serve as a manual and source book for senior lecturers, professors, and researchers alike. It should be of interest to all linguists, in particular phoneticians, phonologists, as well as psycholinguists, applied linguists, speech pathologists, communication and language acquisition experts, and those interested in cognitive science and language learning. This volume reflects a variety of approaches, theoretical assumptions, and methodological tools that are applied to collect, analyze, and interpret bilingual speech data. The breadth of coverage and the diversity of approaches contained in this volume further ensure that this collection serves readers working on bilingualism, L2 acquisition, laboratory phonology, acoustic phonetics, psycholinguistics, sociophonetics, and language contact. The thirty-five chapters in the Handbook are organized into six sections based on their relationship to one another but also reflecting the diversity of inquiry within those overarching areas. In the remainder of this Introduction, I provide a brief review of the content of each chapter in the form of abstracts, followed by concluding remarks.

Part I: Approaches to Bilingual Phonetics and Phonology

Chapter 1: Generative Approaches to Bilingual Phonetics and Phonology (Broselow)

Generative phonologists share the goal of modeling the internalized grammars that allow members of a linguistic community to produce and understand utterances they have not previously encountered. But while most generativists assume that the internalized grammar maps lexical to surface representations, they may disagree on the nature of that mapping, the makeup of the mental representations of phonological structure, and the role of universal well-formedness constraints in grammar. Broselow's chapter surveys analyses of data from multilinguals, foreign language learners, and loanword adapters within different generative models, exploring both strengths and limitations of competing approaches. In doing so, it explores the strengths and limitations of different models of phonology in accounting for data from bilingual speakers, including the realization of L2 phonemes, allophones, syllables, and suprasegmental structures.

Chapter 2: Usage–Based Approaches to Bilingual Phonetics and Phonology (Brown)

Usage-based approaches maintain that speakers' experiences with language shape how language is stored. Experiences with specific words and word combinations in particular linguistic, discursive, and social

contexts accrue in memory and subsequently contribute to patterns of variability evident in speech productions. In this chapter, Brown introduces chief postulates common to usage-based approaches to language, and then presents an overview of studies exploring the connection between usage patterns and bilingual sound systems as well as studies examining evidence of interlingual influence arising from bilingual lexical storage. The chapter concludes with suggestions for potential avenues for future usage-based research into bilingual phonetics and phonology.

Chapter 3: Sociolinguistic Approaches to Bilingual Phonetics and Phonology (Díaz–Campos, Cole, & Pollock)

Díaz-Campos, Cole, and Pollock account for various contact phenomena in sociolinguistic analysis, and provide context for elaborating on quantitative methodologies in sociophonetic research. Their chapter starts with a background of theoretical concepts that are important for the understanding of sociophonetic contact in the formation of bilingual sound systems. The following sections focus on key social factors that play a major part in sociolinguistic approaches to bilingual phonetics and phonology at the segmental and suprasegmental levels, including language dominance and age of acquisition, as well as topics of language attitudes and perception, and frequently used quantitative methods in sociolinguistics.

Chapter 4: Psycholinguistic Approaches to Bilingual Phonetics and Phonology (Gavino & Goldrick)

Psycholinguistic theories conceptualize the mind as a set of mechanical processes that map between levels of mental representation. Gavino and Goldrick explore how this conceptualization frames psycholinguistic research questions. They first examine how the idea of "mind as computer" leads psycholinguists to examine two broad types of questions. Some studies focus on the structure of mental representations (e.g., Are "similar" speech sounds associated with one vs. two representations across languages?). Others focus on the number and the nature of the processes underlying behavior (e.g., To what extent do speech perception and speech production rely on distinct vs. shared processes?). They then turn to connectionism, a specific computational framework that has dominated psycholinguistic theories of bilingualism. Connectionism's conceptualization of processing as spreading activation has driven studies of representation (e.g., Assuming there are distinct representations in each language, what are the consequences of coactivating the two representations?) and processing (e.g., Assuming there are distinct lexical and phonological processes, what are the consequences of allowing both levels to be simultaneously activated for bilingual processing?). Gavino and Goldrick conclude by considering how psycholinguistic theories can inform as well as be informed by other perspectives.

Chapter 5: Neurolinguistic Approaches to Bilingual Phonetics and Phonology (Llanos & Zinszer)

Llanos and Zinszer provide a cross-sectional overview of current neuro-imaging techniques and signals used to investigate the processing of linguistically relevant speech units in the bilingual brain. These techniques are reviewed in light of important contributions to the understanding of perceptual and production processes in different bilingual populations. The chapter starts with a presentation of several noninvasive technologies that provide unique insights into the study of bilingual phonetics and phonology. This introductory section is followed by a brief review of the key brain regions and pathways that support the perception and production of speech units. Next, they discuss the neuromodulatory effects of different bilingual experiences on these brain regions from shorter to longer neural latencies and timescales. As they show throughout their chapter, bilingualism can significantly alter the time course, strength, and nature of the neural responses to speech, when compared with monolinguals.

Chapter 6: Computational Approaches to Bilingual Phonetics and Phonology (Adriaans)

Computational models allow researchers to formulate explicit theories of early language acquisition, and to test these theories against natural language corpora. While the past two decades have seen great advancements in the modeling of phonetic and phonological acquisition in a monolingual setting, only very few studies have begun to address the modeling of bilingual acquisition. In this chapter, Adriaans puts the problem of bilingual phonetic and phonological acquisition in a computational perspective. He shows how computational modeling can be used to address crucial questions regarding bilingual phonetic and phonological acquisition, which would be difficult to address with other experimental methods. The chapter first provides a general introduction to computational modeling, using a simplified model of phonotactic learning as an example to illustrate the main methodological issues. Adriaans then gives an overview of recent studies that have begun to address the computational modeling of bilingual phonetic and phonological acquisition, focusing on phonetic and phonological cues for bilingual input separation, bilingual phonology in computational models of speech comprehension, and computational models of L2 speech perception. He concludes by discussing several key challenges in the development of computational models of bilingual phonetic and phonological acquisition.

Part II: Theoretical Models of Bilingual Phonetics and Phonology

Chapter 7: The Perceptual Assimilation Model: Early Bilingual Adults and Developmental Foundations (Tyler & Best)

The Perceptual Assimilation Model (PAM) accounts for how native-language (L1) experience shapes speech perception. According to PAM, infants develop phonological categories by attuning to the critical phonetic features that set phonological categories apart (*phonological distinctiveness*) and to the phonetic variability that defines each category (*phonological constancy*). Infants consolidate or improve on their discrimination of L1 contrasts as they attune to the phonological categories, but this is associated with a decline in their discrimination of certain non-native contrasts. The effects of L1 attunement on perception can also be seen in adults. Further, PAM generates predictions about discrimination accuracy for non-native contrasts by comparing how the non-native phones are perceived in terms of L1 phonological categories. The extent to which perception might be altered further by experience with an L2 is outlined by PAM-L2. While PAM has focused on L1 attunement in monolinguals, and PAM-L2 on L2 acquisition in adulthood, their principles also apply to early bilingual language acquisition. In their chapter, Tyler and Best consider the various contexts of acquisition and language use in early bilinguals to sketch out how experience with more than one native language shapes perception and how childhood L2 acquisition might modify the emerging phonological system.

Chapter 8: The Second Language Linguistic Perception Model (Escudero & Yazawa)

Escudero and Yazawa's chapter describes the Second Language Linguistic Perception Model (L2LP), with its five ingredients to explain speech development from first contact with a language or dialect (initial state) to proficiency comparable to a native speaker of the language or dialect (ultimate attainment), and its empirical, computational, and statistical method. They present recent studies comparing different types of bilinguals (simultaneous and sequential) and explaining their differential levels of ultimate attainment in different learning scenarios. Escudero and Yazawa further show that, although the model has the word "perception" in its name, it was designed to also explain phonological development in general, including lexical development, speech production, and orthographic effects. The studies reviewed in the chapter include new methods for examining lexical development and speech production, via implicit word learning and corpus-based analyses, respectively, as well as a novel suprasegmental example of the L2LP Subset problem, which was conceptualized as the reverse of the more common New Scenario, where L2 learners are phased with target contrasts that do not exist in their L1. This chapter also reviews a recent study on the effect of bidialectalism on

L2 acquisition, showing that the L2LP model's explanations apply to speakers not only of multiple languages but also of multiple dialects. Finally, the authors present other topics and future directions, including phonetic training, going beyond segmental phonology, and the formalization of orthographic effects in phonological development. Escudero and Yazawa demonstrate that the L2LP model can be regarded as a comprehensive theoretical, computational, and probabilistic model or framework for explaining how we learn the phonetics and phonology of multiple languages (sequentially or simultaneously) with variable levels of language input throughout the life span.

Chapter 9: The Automatic Selective Perception Model (Shafer)

Perception of L2 speech sounds often is challenging, even for the highly proficient L2 speaker/listener. Speech perception is an active process that requires rapid sampling of the auditory input to recover phonological identity. Even highly proficient L2 listeners can show degraded performance under difficult listening conditions. The Automatic Selective Perception (ASP) model posits that listeners make use of selective perceptual routines (SPRs) that are fast and efficient for recovering lexical meaning. These SPRs serve as filters to accentuate relevant cues and minimize irrelevant information. Years of experience with the L1 lead to fairly automatic L1 SPRs; consequently, few attentional resources are needed in processing L1 speech. In contrast, L2 SPRs are less automatic. Under difficult task or stimulus conditions, listeners fall back on more automatic processes, specifically L1 SPRs. Further, L2 speech perception suffers where there is a mismatch between the L1 and the L2 phonetics because L1 SPRs may not extract the important cues needed for identifying L2 phonemes. After introducing key constructs, factors underlying L2 speech perception, and the ASP model, Shafer presents behavioral and neurophysiological evidence that supports the ASP model, but which also indicates the need for some modification. Finally, Shafer offers suggestions for future directions in extending this model.

Chapter 10: The Ontogeny Phylogeny Model (Major)

Major's chapter discusses the Ontogeny Phylogeny Model (OPM), which focuses on the formation and development of second language phonological systems. It proposes an interrelationship among L2 native-like productions, L1 transfer, and universal factors. The model argues that chronologically, and as style becomes increasingly formal, the L2 native-like processes increase, the L1 transfer processes decrease, and the universal processes increase and then decrease. It further claims that the roles of universals and L1 transfer are mediated by markedness and similarity, both of which slow L2 acquisition. Specifically, in similar phenomena L1 transfer processes persist, while in marked phenomena universal processes persist. The OPM also argues that these same principles obtain for learners acquiring more than one L2,

monolingual and bilingual acquisition, and L1 attrition. In addition to the chronological stages and variation of the individual learner, the model claims that these relationships hold true for language variation and change, including pidgins and creoles.

Chapter 11: Bilingual Speech and Exemplar Theory (Babel, Kamigaki–Baron, & Soo)

A large body of research suggests that users of language have knowledge of both abstracted categories and subphonemic details, providing support for hybrid models of phonetic encoding. Evidence that listeners attend to and track subphonemic phonetic details is indicated by listeners' ability to reliably connect subphonemic variation and, often, socio-indexical associations in ways that align with the patterns realized in production. Bilinguals are presented with the task of not only associating within-language variation (e.g., social group X is connected to a particular range of phonetic realizations within language Y), but also attending to how ethnolects and bilingually accented speech index social categories across languages. Having access to multiple languages also gives bilingual speakers a larger repertoire with which to index language- and community-specific social meaning. In their chapter, Babel, Kamigaki-Baron, and Soo outline the linguistic structures bilinguals may connect across their languages and then present a specific exemplar model, noting the opportunities within the model's structure for bilingual dynamics. The heterogeneity of bilingual individuals and speech communities is also addressed, as this dynamic adds to the complexity and the intrigue of studying bilingual populations.

Part III: The Phonetics and Phonology of the Bilingual Child

Chapter 12: The Speech Perception of Bilingual Infants (Sundara)

Infants hearing more than one language have the complex task not only of detecting patterns of regularity in each of their languages but also of keeping them separate. Sundara's chapter discusses behavioral and neurophysiological findings about how bilinguals perceive spoken language in the first three years of life. This research demonstrates that bilingual and monolingual infants use similar core mechanisms to learn from differing linguistic input. Crucially, comparing their acquisition trajectories allows us to make inferences about the early linguistic representations of bilingual infants. Her chapter begins by presenting key constructs and debates about bilingual language acquisition. She then discusses the representation of suprasegmental properties (lexical stress and tone), word-forms, words, and sound categories. Toward the end, Sundara raises some key considerations on individual differences and processing efficiency for familiar words.

Chapter 13: The Speech Production of Bilingual Children (Kehoe)

Kehoe reviews research on the phonetic and phonological production patterns of children exposed to two or more languages in early childhood (simultaneous bilinguals, consecutive bilinguals, and childhood L2 learners). Much of the research has examined whether bilingual children differ from monolinguals in their production patterns and, when differences have been found, whether such patterns can be explained by language-internal (e.g., the influence of the phonological properties of one language on the other), language-external (e.g., language input or dominance), or other factors (e.g., the developing lexicon). Kehoe considers evidence for monolingual–bilingual differences across an array of phonetic and phonological domains such as voice onset time, rhythm, syllable structure, and segmental acquisition. In particular, she focuses on language-internal influences, also referred to as cross-linguistic interaction, and reviews models that have been used to account for this interaction. Kehoe's review reveals that, while systematic differences between monolingual and bilingual speech exist, the differences are not large and may be explained by multiple factors. The chapter concludes with a discussion of research limitations, which include small participant numbers and a predominance of certain language pairs, factors that have hindered attempts to model cross-linguistic interaction.

Chapter 14: Phonological Disorders in Child Bilingualism (Babatsouli)

This chapter examines phonological disorders in child bilingualism with the goal of informing researchers and speech language pathologists on current definitions, key constructs, tenets, available resources, and challenges in the field, serving to tighten the existing, but overall loose, connection between the study of child bilingual phonological development cross-linguistically and the diagnosis, assessment, and therapy protocols in the context of bilingual children's speech disorders. By drawing on the history of the study of child phonological disorder and summarizing reflections of bilingual acquisition theory within this niche, Babatsouli provides an overarching review of apposite literature to date, discussing the evolution of terms and key issues, and their relevance in bridging the gap between psycholinguistics research, theory, and clinical practice for bilingual children's speech sound disorders. Ultimately, the chapter utilizes existing knowledge to project the canonical perspective that a universal classification of phonological disorder can only be informed by a single mechanism driving its manifestations across children, one that albeit needs to take into consideration every child's spot on the spectrum of disorder, and on the global map of linguistic and cultural diversity.

Chapter 15: Acquisition of Segmental Phonology in Child Bilingualism (Bosch)

Bosch focuses on the acquisition of segmental phonology in simultaneous bilingual children, highlighting the factors that help explain variability in the pathways toward the construction of language-specific phonological systems. She notes that studies so far are still limited and only partial, often restricted to the effects of interaction between specific segments or categories from the two systems to which the bilingual is exposed, and that there is currently no comprehensive theoretical model related to segmental acquisition and the factors that can affect production of language-specific segments in simultaneous bilingualism. Therefore, a broader perspective is suggested in order to better characterize the complex interplay of the elements in this domain. These elements include the properties of the input languages, the young learner's perception–production skills, parallel vocabulary growth, social factors, and language use in bilingual learning contexts. She offers a review of the literature which groups studies by age of participants, a strategy that captures the dynamic nature of the segmental learning processes. It also reveals differences in the methodological approaches for assessing bilingual children's phonological learning, from the production of their first words to more mature levels of phonological knowledge. As a general view, segmental acquisition seems to be characterized by differentiated but interconnected systems, including realignments along this extended developmental process. However, more nuanced approaches are needed, especially related to the perception–production connection and input quality factors, to reach a more comprehensive view of the acquisition of segmental phonology in young simultaneous bilinguals.

Chapter 16: Acquisition of Suprasegmental Phonology in Child Bilingualism (Pronina & Prieto)

Pronina and Prieto's chapter provides the state-of-the-art of the available research on the development of suprasegmental phonology in bilingual children, from infancy through childhood. First, they discuss word-level prosodic phenomena, with a special focus on the bilingual acquisition of word stress and syllable structure, which has been a lively area of research. They also present recent data on the acquisition of tone, which remains a less investigated topic, and consider the acquisition of phrase-level prosody, namely, rhythm and intonation. For each domain of prosodic development, they briefly review monolingual patterns and discuss how learning two (or more) phonological systems can affect developmental trajectories, showing that there can be different cross-linguistic interactions such as transfer, delay, acceleration, or fusion. Pronina and Prieto also consider potential influencing factors that can trigger different tracks in the development of prosody, for example age of onset, amount of exposure, language dominance, and simultaneous or sequential language acquisition. Finally, the chapter concludes with a discussion of avenues for future research.

Part IV: The Phonetics and Phonology of the Bilingual Adult

Chapter 17: The Speech Perception of Bilingual Adults (Antoniou)

Antoniou outlines studies within the domain of speech perception by bilingual adult listeners. The chapter first discuses studies that have examined bilinguals' perception of L1 and/or L2 speech segments, as well as those that have tested perception of unfamiliar, non-native speech segments. In turn, Antoniou examines each of the factors that are known to affect bilinguals' perception of speech, which include age of L2 acquisition, effects of L1:L2 usage as they pertain to language dominance and proficiency, and short-term contextual effects on speech perception. Additionally, he provides an overview of the literature on bilinguals' perception of suprasegmentals. To conclude, Antoniou explores what he considers to be some of the crucial questions facing the field of bilingual speech perception.

Chapter 18: The Speech Production of Bilingual Adults (Casillas)

Adults learning a new language can attest to the difficulty involved in producing the sounds and prosody of the target language. A principal aim of research on adult speech production is to comprehend the mechanisms and processes that differentiate adult bilingual speech development from bilingual speech that develops earlier in life. It is clear that individuals who learn an additional language in adulthood typically encounter some difficulties that early learners do not. In particular, these difficulties arise at the segmental level when acquiring novel sound categories and novel sound contrasts, as well as at the suprasegmental level when learning to produce non-native prosodic structures related to intonation, stress, rhythm, tone, and tempo. In his chapter, Casillas provides a selective overview of the current state-of-the-art in adult bilingual speech production. Furthermore, he considers theoretical and methodological areas for improvement, as well as avenues for future research.

Chapter 19: Phonological Processing and Lexical Encoding in Bilingual Speech (Darcy & Rothgerber)

Bilinguals' recognition of spoken L2 words is characterized by L1 interference in relation to how words are phonologically encoded in the mental lexicon, and how they are activated during comprehension. Darcy and Rothgerber provide an overview of phonological processing during spoken word recognition in bilinguals. Their chapter first describes how phonological knowledge in L1 impacts the processing of native and non-native speech for various phonological dimensions. They then survey major experimental findings in L2 phonological perception and lexical access processes, highlighting the connection between the two, and showing that the phonolexical representations created by L2 learners are L1