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Overview

The first two years of life constitute a period of dramatic change, not least because it is in that period that most children begin to make use of words or phrases of the adult language and to combine them into their first sentences. And indeed the first questions to be asked about phonological development, based on early diary studies, related to infant production of speech in the first two years. How universal is the order of learning of speech sounds, for example, in different language communities and different children, and how, if at all, is babbling related to speech (Jakobson, 1941/68)? And how do infants with bilingual exposure manage so successfully to produce two languages like native speakers (Leopold, 1939)?

Later, with advances in technology, it became possible to ask about speech perception: How do children learn to distinguish between the speech sounds that they hear, for example, and how do they begin to discover words in the rapidly changing speech signal, where words are not marked off by pauses (Jusczyk, 1997)? Perceptual discrimination is remarkably acute in the first months of life, as became clear from the first experimental studies in the 1970s, but these early capacities become increasingly attuned to the particular language or languages to which the child is exposed over the first year. We can then ask, how does this process of attunement support word learning (Werker & Curtin, 2005)? Equally basic is the issue of the relation of

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perception to production: How does the infant's early discriminatory skill translate into vocal practice and word formation (Kuhl et al., 2008)?

Additional questions have received attention and analysis only more recently: How important is the 'music' of speech, or speech rhythm or prosody, for phonological development (Mehler et al., 1988; Nazzi, Bertoncini & Mehler, 1998)? And to what extent does word learning itself support advances in knowledge of sounds and sound patterns (Ferguson & Farwell, 1975; Vihman & Keren-Portnoy, 2013)?

The essential mystery of language acquisition, the child's move from having no linguistic system to the beginnings of system, is deeply rooted in the first two years of development. However, to gain insight into that mystery we must look beyond studies of speech perception and vocal production *per se* to consider the findings of research into the developmental changes occurring in parallel in other domains. Before word use is observed, for example, the notion of intentional communication itself must emerge, followed by understanding of the possibility of communicating by vocal means. These pragmatic advances make up one of the strands that prepare the child for language use.

Changes in neuromotor control as well as in attentional mechanisms enable the child to participate more and more actively in social exchanges over the course of the first year. Early perceptual capacities come to be supplemented by increasingly adult-like vocal expression, leading to preparedness in terms of the phonetic prerequisites for word use. The third preparatory strand is increasing representational capacity. This can be understood as referring to advances in working memory, or the ability to maintain more than one item in mind while preparing a vocal or gestural action; these advances build on the child's emergent pragmatic and phonetic skills and social experiences to complete the set of essential precursors to language use.

We will largely restrict ourselves here to the foundational period of language development for several reasons. First, since change is so rapid, close attention is warranted to each of the successive phases of maturation and learning. Second, a wealth of research, deriving mainly from linguistics, psychology and speech science, has addressed these changes in the past several years; the literature available for review is now so considerable that a longer period could scarcely receive adequate coverage in a single volume.

Finally, the age of two is a sensible demarcation point, if only because this is the age at which 'late talking toddlers' are generally identified. These are 2-year-olds who have not yet reached the end of the single-word period – that is, who have fewer than 50 words in production and/or few if any word combinations. These children are considered to be at risk for specific language impairment (SLI), although at least half of them will reach the basic lexical and syntactic developmental milestones by age 2.5 and thus be reclassified as 'typically developing', or '[late-]bloomers' (Fernald & Marchman, 2012). There is good reason to believe that difficulties with phonological and lexical development in the single-word period can account to some extent for later difficulties with overall language development (Vihman, Keren-Portnoy, Whitaker, Bidgood & McGillion, 2013). This is an important finding, underlining both the critical significance of the first two years and the relevance of research in

phonological development for those interested in understanding language development more generally, and also for clinicians and other practitioners who deal with children.

Biological Foundations of Language Development

Some of the motivating questions of the field of phonological development pertain to language development more generally: How can children learn language so quickly, for example? What special skills or resources do they have? Alternative ways of responding to these questions, taking radically different approaches, fall together under the rubric of 'biological foundations'. Here we consider the theoretical divide that is central to the field of linguistics and thus also language development, and take up the related question, what kinds of explanations are available? What sources of information can we draw on, to account for the timing and processes of phonological development?

Chomsky and the origins of the LAD and UG

A common non-specialist view holds that children learn language remarkably quickly and easily. This everyday view was enshrined in linguistic theory with the publication of Noam Chomsky's *Aspects of the Theory of Syntax* (1965), which soon became a key linguistic text, as structuralism was replaced by the theory that grew out of it, generative grammar (Harris, 1993). Chomsky was not centrally concerned with language development, which he has never claimed as a field of expertise. However, given the complexity of the adult linguistic system, for which he could provide ample evidence, he was presumably struck by the paradox of the rapidity and ease with which children – considered rather incompetent in most domains – appeared to 'pick it up', without the benefit of explicit instruction.

Chomsky's first foray into this territory was his review of *Verbal Behavior*, published in 1957 by one of the foremost behavioral psychologists of his day, B. F. Skinner. Based on his work on the effects of conditioning on animals, Skinner saw reinforcement as 'a necessary condition for language learning' (as cited in Chomsky, 1959, p. 36) and specified that acquisition of 'verbal behavior' occurs

> when relatively unpatterned vocalizations, *selectively reinforced*, gradually assume forms which produce appropriate consequences in a given verbal community … *Differential reinforcement* shapes up all verbal forms … (Skinner, 1957, p. 31, emphasis added)

Chomsky's sharply critical review of Skinner's book has generally been seen as marking the end of behaviorism's acceptance as a potential account of language learning. In particular, Chomsky argued successfully that the idea that specific 'reinforcement' should be a cornerstone of language acquisition was untenable. Chomsky also attacked the idea that frequency ('a very misleading measure of

strength': p. 34) plays any important role in learning. Instead, Chomsky argued in his later work that infants must be born with *foreknowledge of linguistic principles*, or, as he put it, with a 'language-acquisition device' or LAD (Chomsky, 1965). This clever acronym was soon replaced by Universal Grammar (UG: Chomsky, 1967, 1981b), although the basic idea remained the same.

Despite Chomsky's continued dominance or near dominance of linguistics, his rejection of frequency and reinforcement as playing any role in learning has begun to be quietly set aside, in light of current understanding of the role of implicit alongside explicit learning mechanisms (see Bybee & Hopper, 2001; Ellis, 2002a), of 'statistical learning' and its relevance for infants (Saffran, Aslin & Newport, 1996), and of the social context within which vocalizations gain value for the child, an indirect form of 'reinforcement' with no specific pedagogical intent (Bloom & Esposito, 1975; Hsu & Fogel, 2001; Goldstein & Schwade, 2008). We return to these issues in chapters 2–5.

Chomsky's radical claims galvanized researchers interested in child language. It is fair to say that the present highly dynamic field of psycholinguistics largely developed in response to Chomsky's ideas, which both inspired supporters and stimulated sceptics or potential critics. The ideas themselves gradually became linguistic orthodoxy in mainstream linguistics, especially in the United States, but they have now begun to be widely questioned by cognitive linguists and others who adopt an 'emergentist' or 'usage-based' stance, as we will be doing here (Barlow & Kemmer, 2000; Bybee, 2001, 2010; Pierrehumbert, 2003a, 2003b; cf. also the critique from typologists Evans & Levinson, 2010 and the commentaries that follow in *Behavioral and Brain Sciences*, 32).

Analysis of an argument

Before moving to issues more directly concerned with phonological development we will give Chomsky's position a little more attention, since it has been so very influential for such a long time. Chomsky clearly sets out his position in a single sentence:

> A consideration of the character of the grammar that is acquired, the degenerate quality and narrowly limited extent of the available data, the striking uniformity of the resulting grammars, and their independence of intelligence, motivation, and emotional state, over wide ranges of variation, leave[s] little hope that much of the structure of the language can be learned by an organism initially uninformed as to its general character … (1965, p. 58)

This exceptionally complex statement can be more readily understood if divided into its component premises (1–4) and the conclusion that follows:

1 a consideration of the character of the grammar that is acquired … *(premise 1: language is complex)*

2 the degenerate quality and narrowly limited extent of the available data *(premise 2: the input speech to which children are exposed constitutes a limited and poorly structured sample for learning)*
3 the striking uniformity of the resulting grammars *(premise 3: adult grammars (of a given language) are all much the same – i.e., there is little in the way of individual differences among adults)*
4 and their independence of intelligence, motivation, and emotional state, over wide ranges of variation *(premise 4: individual differences among children also make very little difference to acquisition)*

The organism must be initially informed as to its general character … *(conclusion: some kind of innate 'blueprint' or template must exist or acquisition would not be possible)*.

In his later work Chomsky has repeated some or all of these arguments in numerous books and papers, with no significant change in his thinking on this matter. For example, Elbers and Wijnen (1992) cite a similar passage from Chomsky (1981a, p. 356), in which two additional premises are included: ' … a rich and complex system of rules and principles [premise 1, Complexity] is attained in a uniform way [premise 3, Uniformity], rapidly [premise 5, Speed of acquisition], effortlessly [premise 6, Ease of acquisition], on the basis of limited and rather degenerate evidence [premise 2, Limited sample]' (Chomsky, 1981, p. 356).

Premises 1, 5 and 6: Complexity of the adult language system, speed and ease of acquisition. In a chapter illustrating the effort that children can be seen to put into the many years of active learning that are actually required to achieve adult-like command and fluency, Elbers and Wijnen (1992) comment as follows:

> The only constituents of Chomsky's contention that do not seem to have invited much criticism are the claim that language knowledge consists of 'a rich and complex system of rules' and the claim that language acquisition is effortless … Yet, it is precisely in the conjunction of these two claims that a confusion of professional and nonprofessional reasoning is evident. The rich-and-complex-system claim [Premise 1] is a professional judgment, based on detailed and extensive linguistic investigation. The no effort claim [Premise 6], however, is a layman's contention, based on casual and superficial impression rather than on careful observation and research. But propositions of such a differing status should not be combined; it seems just as mistaken to hold that development *is* effortless just because it *seems* effortless as it would be to hold that language itself *is* simple just because it *seems* rather simple to the ordinary speaker who is not a professional linguist. (pp. 339–340)

Accepting Chomsky's first premise as beyond argument, then, we can go on to look briefly at each of the others.

Premise 2: Limited and poorly structured sample. First, does the speech that children hear actually provide only a 'limited' and 'degenerate' sample of the grammar?

This premise, later elaborated as the 'poverty of the stimulus' argument in support of UG (see Pullum & Scholz, 2002), has led to decades of research into infant-directed speech (IDS) and its consequences (for reviews, see Soderstrom, 2007; Gathercole & Hoff, 2007; we discuss the prosody of IDS in ch. 5). The general finding is that talk to children is unlike talk between adults: It involves much shorter sentences along with a much higher rate of repetition of all or parts of utterances. Although it may feature sentence fragments (phrases rather than sentences), it includes few or no false starts or self-corrections, the kind of language use that Chomsky presumably intended by the term 'degenerate' but which is more typical of high-level academic discourse than of talk to small children.

Thus, the input, although certainly providing a limited sample, is in many ways tailored for the child, given its adherence to topics that a small child might understand (and, more importantly, its typical orientation toward the child's own actions and focus of attention) and the necessarily repetitive lexicon of words and phrases that accompany child-rearing routines. And yet, despite all of this, it has proven difficult to find evidence that 'tailored speech' is actually necessary for first-language learning.

Premise 3: Uniformity of adult grammars. Next we can ask, are adult grammars 'uniform' – that is, the same for all adults in a speech community? This premise has been severely challenged by variationist sociolinguistics, which evolved in the 1960s and 1970s (Labov, 1963, 1980; Weinreich, Herzog & Labov, 1968). The general understanding today is that variation (within and across speakers) is a basic characteristic of language in any speech community (Docherty, Foulkes, Tillotson & Watt, 2008; cf. also the more specific demonstrations of individual differences in grammar among adult native speakers in Street & Dąbrowska, 2010; Dąbrowska, 2012).

What are the consequences of this potential criticism of Chomsky's premises for our understanding of language development, however? Although Labov, Dąbrowska and others have made it clear by now that we cannot assume that all speakers have 'the same grammar', it is pertinent here to ask whether the inter-individual differences have their origins in 'errors of transmission' (i.e., from parent to child), also known as 'imperfect learning'. There has been a line of thinking within generative linguistics that this is the case (e.g., Kiparsky, 1965). The data so far brought to bear on the question have not supported the idea that children's errors are a factor in language change (yet the notion continues to be maintained and asserted as fact, despite the lack of supporting evidence: e.g., Lightfoot, 1999; Blevins, 2004; Kiparsky, 2008): If they were, then the variability that gives rise to change might be traced back to infant mislearning.

In reality, although children do make errors of many kinds, they come in due course to faithfully reproduce the language they hear around them, shifting from parental models to peer group models as they grow older. (Furthermore, despite the superficial similarity between some developmental and historical processes, the younger children whose language remains incompletely mastered are hardly influential members of a community whose speech patterns could be expected to lead to

variability and change in the adult language: Foulkes & Vihman, 2013). Thus, adult grammars are not well characterized as 'strikingly uniform' in the first place. Second, the variability across different adults' speech in a given community is more likely to be related to differing social experiences than to have its origins in developmental differences, so that the extent of similarity of adult grammars would seem to provide no real clue, one way or another, to the nature of children's language acquisition.

Premise 4: Individual differences in children. Do children's differences in 'intelligence, motivation, and emotional state' result in differential success in language acquisition? Since the vast majority of children free of developmental disorder do learn to talk on roughly the same time scale, and since no non-human animals have demonstrated linguistic comprehension or expression in any way comparable to what children have typically learned by age 3 or 4, something in the human inheritance – some biological advantage – must support the learning process. Chomsky postulates that this advantage is *linguistically specific knowledge* rather than some more general cognitive capacity unique to our species; it is that foreknowledge of linguistic principles that he refers to by the term UG. Here, however, we will look for broader biological bases for language, drawing on the unique human production capacities and the powerful learning mechanisms that have just begun to be understood (for a similar view based on somewhat different supporting capacities, see Kuhl, 2004). We discuss these learning mechanisms briefly below (and see ch. 2).

It is important to add that not all children do manage to learn language successfully: 'specific language impairment' (SLI) affects around 7% of American and Canadian 5-year-olds (Tomblin et al., 1997; Johnson et al., 1999). If it is possible for children to be 'impaired' specifically – that is, exclusively – for language, this might support a nativist position that accounts for the difficulty in terms of a blocking of access to UG (Van der Lely & Marshall, 2011). However, the 'specificity' of SLI is debatable, since both low non-verbal ability and certain behavioral disorders and sensory impairments commonly co-occur with the linguistic difficulties (Snowling & Hayiou-Thomas, 2010). Furthermore, recourse to 'non-access to UG' merely moves the explanation a step further: What is the basis for such blocked access? An alternative view is that SLI (like dyslexia) is rooted in impairment to more basic aspects of brain function. Language, with its particularly complex demands in terms of both representational structure and processing, may simply be the behavior most affected (Bishop & Snowling, 2004).

Premise 5: Speed of acquisition. Finally, we return to the question, how rapid is language acquisition? On the one hand, the question cannot really be answered, since learning is never complete but continues over the lifetime. On the other hand, we can assume that Chomsky was referring to the apparent speed with which children move from *not speaking* – before age 12 months or so, say – to *communicating in complete sentences*, in a way that is intelligible even to non-family members – typically by around age 4 or 5 years. Whether we see a period of four to five years for language

learning as 'fast' or 'slow' is a matter of taste – but it is important to note that a great deal of learning takes place in the first year, in the 'prelinguistic' period, and much of it is indeed remarkably rapid. We return to this issue below.

The course of language development

Chomsky (1959) rightly discredited the behaviorist approach. Imitation and selective reinforcement are wholly insufficient to explain the kind of creative construction, overgeneralization and idiosyncratic rule or pattern formation that is repeatedly seen in studies of language acquisition. In contrast with the insistence on the 'meticulous training' thought to be needed for children to learn word meanings and syntactic patterns in the 1940s and 1950s (Chomsky, 1959, p. 39, n. 17), Chomsky pictured language development as maturationally controlled behavior, with only minimal support from the environment (exposure to a 'trigger'). The idea derives from *ethology*, or the study of animals in their natural habitat (Chomsky, 1959, pp. 41ff.). What was completely original with Chomsky was the suggestion that the kinds of automatically triggered behaviors seen in certain animals could be extended to language acquisition. But what are the criteria for identifying such behavior?

- Upon reaching the critical stage, the individual should begin to show the behavior automatically; the behavior should not be seen before that stage.
- An appropriate trigger in the environment is also required – so that even once the 'stage is set', the behavior may fail to appear in the absence of appropriate environmental stimulation.

For language, a critical question is how the trigger might be identified or recognized: *How is UG meant to interact with information in the speech signal?* Furthermore, if language is a 'maturational program' that unfolds when appropriately triggered by exposure – like the automatic 'following' of the mother duck by ducklings – then changes should occur instantaneously, 'across the board', when children identify the appropriate cues in the input; initially inaccurate forms (errors) should be followed by more accurate forms (this is known as 'linear advance').

Such 'across-the-board' changes are sometimes reported for phonological development but that is not what is typically found, as will be amply demonstrated in the chapters that follow. The single most consistent empirical finding in cross-linguistic longitudinal observational studies of child language production is that the earliest word forms and uses of inflectional morphemes (most notably, irregular morphology) are *more accurate* than later forms. A 'U-shaped curve' (or nonlinear advance) characterizes development in phonology and inflectional morphology, with the early accurate forms generally being of high input frequency. Generalization ('rule' or 'pattern learning') begins a bit later and results in a period of 'regression' or lesser accuracy, as a productive pattern is extended beyond its domain in the adult targets. We will illustrate this at some length in later chapters and also consider ways of accounting for it.

Alternative approaches to Chomskyan biological foundations

To propose that children learn to speak without the benefit of specifically linguistic foreknowledge of what all languages have in common – in other words, without access to anything resembling UG – is not to return to the 'empiricism' of the first half of the twentieth century. Instead, at the end of chapter 2 we introduce a contemporary model of learning that posits a dual memory system (Squire & Zola, 1996). In this model two quite distinct memory mechanisms combine in a uniquely human way:

1 *Attention-based item learning* (e.g., one-off rapid learning of arbitrary sound–meaning links, followed by consolidation, or the integration of that learning with prior knowledge: Gaskell & Ellis, 2009): This was once assumed to be the only way that children or adults can learn.
2 *Distributional or statistical learning* (e.g., unconscious learning of phonotactic and syntactic sequences and of phonetic categories): That both children and adults also learn in this way, over a period of time, based on repeated exposure to similar stimuli or procedures, is now well established, based on studies carried out mainly in the past 15 years. Enthusiasm for these experimental findings sometimes leads to an over-emphasis on this as the only kind of learning, however.

In our view, only the combination of attention-based learning with 'incidental' or unconscious learning results in a sufficiently powerful mechanism to account for language development. Such a dual mechanism alone is capable of deriving from input speech, in context, both systematic relations and arbitrary form–meaning associations, and of both retaining specific items and deriving from them generalized patterns or categories. Postulation of a dual memory system that functions in children as well as adults responds to Chomsky's paradox in a way that relies on 'biological foundations' but not on specifically linguistic foreknowledge (Bates & Elman, 1996).

In addition, in its focus on phonological development this book will describe the early perceptual capacities of infants and how they are shaped, among other things, by more slowly maturing production capacities. Here we will draw on the developmental approach of dynamic systems theory, which sees perception and action as inextricably interwoven, with relatively simple skills interacting to create more complex ones (Thelen & Smith, 1994). Both the dynamic systems approach and the dual memory system conceptualization provide a strong biological basis for language, one which is increasingly supported by evidence from neuroscience.

One basic issue for the nativist line of thinking is the 'explanatory cost' of positing LAD or UG without such neuropsychological evidence. This has been glossed over by linguists for 40 years, but the time limit on what Lindblom (1992) termed a 'loan on cognition' may have expired. Mention is sometimes made of the 'language areas' of the brain – but the specialization by hemisphere and by area (auditory, visual etc.) comes with *development and use*, not as a pre-fixed template, as is now well

understood (see Mareschal et al., 2007). To continue to subscribe to Chomsky's proposals, in the present state of our knowledge, we would require answers to two fundamental questions: (1) Where is UG located in the brain, or what neurological systems support it, and what phylogenetic or evolutionary processes can be supposed to have led to its presence in the newborn brain? (2) Given innate linguistic knowledge in the form of UG, by what mechanism does exposure to input speech trigger choices between differing possible structures? These difficult questions should be addressed if Chomsky's radical proposal is to continue to form a basis for acquisition studies.

Phonological Development: Goals and Challenges

In her chapter 'Where's phonology?' Macken (1992) raised another issue that divides formalist and functionalist approaches. Macken suggested that the study of phonological development in the 1980s was largely concerned with the 'phonetics of acquisition', which seemed to imply that no abstract phonology is learned. As her title suggests, Macken is contrasting the period of babbling and first words, which she takes to reflect variable phonetic production, with a later period of structurally informed patterns, or 'phonology'. The distinction between these terms is defined somewhat differently by different linguists, not all of whom endorse the need to make a distinction at all (see Critique and appreciation, ch. 10).

Phonetics and phonology

Let us consider the *basic constructs of phonology*. The most essential of these is no doubt *contrast between phonological categories*, which refers to the occurrence, in a single phonological context, of phonetically similar speech sounds that signal different meanings: These are the *phonemes* of structural linguistics (that is, for English, /k/ : /g/, as in *coat : goat*, /d/ : /n/, as in *pad : pan*, /ɪ/ : /i/, as in *pick : peak*). Beyond that, the *natural classes* of speech sounds or phonemes reflect the universal occurrence of what could be called *paradigmatic patterning*, that is, the more or less symmetrical distribution of different places of articulation (labial, coronal, dorsal …) across the different manner classes (stops, fricatives, nasals …). These natural classes can be formally expressed through the construct of *distinctive features*. The distinctive features, in turn, reflect, among other things, the repeated uses, within a single phonological system, of the same articulatory gestures (see Clements & Ridouane, 2011). At the same time, *prosodic structure* and *phonotactics* refer to *syntagmatic regularities*, or constraints on the possible sequencing of speech sounds, at different levels of linguistic organization (syllable, word, phrase …).

In contrast to these elements of phonological structure, *phonetics* is generally taken to refer to gradient ('sub-categorical') knowledge of speech sounds and sequences based on frequency and contextual effects. Phonetic forms are variable by speaker, speech rate, speaker's emotional state and conversational intentions, etc., whereas

phonology encodes the essential differences between forms, and constraints on their possibilities of sequential combination, in a structured system that supports differences in meaning. The terms 'phonetic' and 'phonological' are by no means used consistently in the developmental literature, however.

The interaction of perception and production

The effort to trace links between perception and production in order to arrive at a more complete understanding of phonological development received little empirical or theoretical attention until the 1990s (e.g., Vihman, 1991, 1993a), with studies adopting this perspective few and far between for several years thereafter. In recent years, however, evidence of links between perception and production in the first year have begun to appear (DePaolis, Vihman & Keren-Portnoy, 2011; Lewkowicz & Hansen-Tift, 2012; Yeung & Werker, 2013; Majorano, Vihman & DePaolis, 2013; DePaolis, Vihman & Nakai, 2013).

Within the field of infant speech perception interest in production has been minimal (cf., e.g., Jusczyk, 1997; Kuhl, 2004; Werker & Curtin, 2005). As regards adults, proponents of the motor theory of speech perception have assumed that there is a critical link between the two domains but have not been interested in its development, taking a biologically based connection between perception and production to be axiomatic: The perceptuomotor link underlying speech is 'not a learned association … but innately specified, requiring only epigenetic experience [or some exposure to speech] to bring it into play' (Liberman & Mattingly, 1985, p. 3). Not all motor theorists take this position, however. Studdert-Kennedy (1993), for example, emphasized that 'a central function of perception in the infant is surely to guide production: by learning to listen the child learns to speak' (p. 150); he went on to endorse the view that 'with the discovery of correspondences between the sounds it hears and the sounds it makes, the infant begins to focus attention on the phonetic (articulatory) properties of native sounds' (p. 152).

Our view is that the interaction of perception and production is key to an understanding of the early stages of phonological development. Accordingly, we begin by surveying in alternating chapters infant speech perception (chs. 3, 5) and vocal development (ch. 4); in our review of the transition to language use (ch. 6) we bring the two areas together as we sketch a model of their mutual influences and growing linkage over the course of the first year. A production-oriented approach will be evident in our account of the word-learning studies reviewed in chapter 7, and perception–production interaction will be considered again in our concluding chapter (11).

Cross-linguistic perspectives

Although studies of phonological development in a variety of languages have long been available, much of the literature continues to make reference to specific characteristics of the acquisition of English as if they were universal properties of child

language development. To take just one example, the prevalence of monosyllables among the early word productions of English-learning children is often cited as the characteristic starting point for phonological development. However, even within the period of production of the first 50 words, over half the words produced by children acquiring French, Japanese and Swedish are disyllabic or longer, in accordance with the adult models that they are attempting, while monosyllables dominate the production of children acquiring English (Boysson-Bardies et al., 1992; Vihman, 1993a; see also ch. 8).

Studies of the earliest period of development have revealed influence from the ambient language on both perception and production, alongside strong evidence of universal perceptual biases and production constraints; we review the extent of ambient language influence on both early perception and speech processing (chs. 3 and 5) and production (chs. 4 and 6). Furthermore, studies of children acquiring two languages from infancy provide additional insight into cross-linguistic similarities and differences in both perception and production (ch. 8).

The significance of individual differences

Each child must individually forge a path to language; this is clear from production studies, which focus on individuals, although it goes largely unremarked in perception experiments, which generally report only group results. Every careful production study of more than one child reveals a range of differences and individual strategies. Macken (1992) goes so far as to propose that

> the central acquisition mechanism is a constrained hypothesis formation mechanism … where the linguistic constraints are not so restricted as to result in invariance but, rather, so closely replicate the formal constraints on languages in general as to render any set of ten or twenty learners (of even the same language) a virtual typological study of language parameters. (p. 250)

We would argue that both biological predispositions and salient aspects of the ambient language constrain the child's initial progress in language acquisition; nevertheless, multiple individual factors enter into the child's approach to language, as regards both timing and manner of acquisition. Attempts to reduce this individual variation to a single pair of contrasting learning styles (such as referential vs. expressive, analytic vs. holistic) have not, on the whole, yielded definitive or generally satisfying results (Nelson, 1981; Bates, Bretherton & Snyder, 1988; Lieven, Pine & Dresner Barnes, 1992; Bates et al., 1994). Instead, it seems that, within the given constraints, children vary widely in maturation rate and individual disposition along several parameters, both social (interest in communicative interaction) and linguistic (sensitivity to vocal patterns, motoric skill). Even more important perhaps is apparent variation in the child's deployment of the cognitive elements of acquisition: Attention and effort must be integrated through the internalized representations of adult forms and of the child's own vocal capacities; these must

then be interrelated and molded into a viable set of production patterns which can gradually be brought into line – over a period of two to three years at the very least – with the target adult system.

Methodologies: Data Sources and Theoretical Perspectives

As increasingly rapid technological changes have made new methods available for the study of infants the field of phonological development has diversified dramatically. Today, such methods include audio and video recordings, with increasingly sophisticated ways of transcribing and coding while simultaneously listening to the audio and watching the video, often with further support from a view of the sound wave or full spectrogram, affording the option of carrying out acoustic analysis alongside segmental transcription and with due consideration of the situational context; audio-only or cross-modal experimental studies using the head turn and preferential looking paradigms, eye-tracking for more automatic analysis of infant responses to audio-visual correspondences, and event related potentials (ERPs), which permit investigation of the neurophysiological response to critical stimuli on a fine temporal scale (see ch. 7). Additional new techniques for gaining understanding of the infant brain include near-infrared spectroscopy (NIRS: see Gervain et al., 2011) and magnetoencephalography (MEG), which provides a way of combining temporal and spatial information. However, no studies based on these techniques, only recently adapted for use with infants, will be covered here.

A conference in 2001 brought together psychologists who use behavioral experimental techniques to study speech processing and word learning with developmental linguists whose investigations are largely based on formal phonological analysis of production data within a deductive theoretical framework (see ch. 9). Peperkamp (2003) summarizes the goals of the conference, expressing her disappointment at the lack of experimental tests of phonological hypotheses:

> Since the founding work of Chomsky & Halle (1968), linguists have made detailed proposals concerning phonological representations and the derivations by which abstract underlying forms are mapped onto concrete surface forms. Most aspects of these proposals have not been looked at in experimental work on phonological acquisition. Furthermore, within the framework of generative grammar, it is assumed that there is a common core of phonological knowledge across speakers of all human languages. This common core is typically supposed to be innate (even though there is no a priori reason that universals could not emerge during the course of acquisition). Whether innate knowledge is used or not during phonological acquisition … remains to be investigated experimentally. (p. 88)

Peperkamp goes on to note that

> the reverse is equally true: Linguistic approaches to phonological acquisition have been little concerned with experimental evidence regarding early phonological

> development … [Due to emphasis on production, these studies] sidestep the fact that before uttering their first words, infants acquire important parts of their native language's phonology. (p. 93)

These comments invoke all three of the main lines of current empirical research into phonological development:

1 Individual or small group production studies focus on one or more infants, whether family-member diary or outsider observational studies. These time-honored research methods have led to the formulation of many of the issues that continue to concern investigators. The results are generally based primarily on phonetically transcribed word lists, with more or less attention to variability across tokens. To counter the increasing tendency to disregard earlier work (cf. Menn's 2006 subtitle, 'Making sure that old data survive new theories') we list in Appendix 1 all of the readily available studies of this kind that we are aware of, categorized to indicate the language(s) to which the participant children were exposed, the number, age and lexical range of those children, the data source and whether or not a full list of child word forms is included.

Appendix 1 shows that although only three studies of phonological development were published between 1938 and 1967, in the following half-century 13 new studies of 1 to 10 children were published in every decade (Table 1.1; 24 of these studies include full word lists for one or more children). Of the 65 studies listed, however, 20 focus on 28 children learning English only. Germanic languages heavily dominate the picture, with 8 studies of the monolingual acquisition of Dutch or German accounting for an additional 19 children; Finnish is the only other language to include a substantial number of children. Altogether, phonological descriptions and/or analyses of the word patterns of over 100 children are available, covering the period of the first 50 to several hundred words in a total of 25 different languages (counting European and American variants separately). Of these studies, 16 focus on bilingual children (see ch. 8).

Table 1.1 Small group and case studies, 1938–2013

Years	*Studies*	*Languages*	*Children*
1938–1967	3	3	4
1968–1977	13	7	14
1978–1987	10	3	13
1988–1997	21	4	40
1998–2007	11	5	27
2008–2013	7	3	21
Total	**65**	**25**	**119**

In addition, in the past few years Yvan Rose, in collaboration with Brian MacWhinney, has designed a software program, PHON, to support phonetic transcription and phonological analysis in conjunction with the well-established CLAN (Computerized Language ANalysis) programs that support analysis of data stored in the CHILDES database (MacWhinney & Snow, 1985). PHON supports multimedia data linkage, segmentation, multiple-blind transcription and systematic comparisons between target (model) and actual (produced) phonological forms (Rose et al. 2006; Rose & MacWhinney, 2013). The associated database, PhonBank, complements CHILDES; it currently includes data from 19 languages, six of them not represented in Appendix 1 (Berber, Cree, Greek, Indonesian, Swedish, Taiwanese). This new resource should make it far easier to conduct well-grounded cross-linguistic investigations of patterns of phonological development in the future.

2 Larger group studies of infant speech production, whether cross-sectional or longitudinal or a mix of the two, are typically designed to establish norms and/or to test phonetic and phonological theories of development. Recently, a number of PhD theses or large funded research projects have been dedicated to studies of phonological development in 10 or more children acquiring a range of different languages, including Finnish (Kunnari, 2000), French (Braud, 2003; Wauquier & Yamaguchi, 2013), Greek (Tzakosta, 2004) and Italian (Majorano, 2005). Whereas the case studies generally emphasize individual differences, the group studies are often intended to identify universal constraints on early development or to support or challenge theories of phonological development (Fikkert, 1994; Levelt, 1994; Kehoe, 1998; Kehoe & Stoel-Gammon, 1997a, 1997b, 2001; Wauquier-Gravelines, 2005). Where the study is longitudinal and provides phonological analyses of the word forms of individual children it has been included in Appendix 1.

3 Experimental studies of infant perceptual responses to speech address the nature of development in perceptual discrimination, segmentation, word recognition and comprehension over the course of the first two years. These group studies use a variety of techniques, including both head turn paradigms and, in more recent years, ERPs (ch. 7). Experimental studies of infant responses to speech have dominated the literature in phonological development for the last 15 years. The studies are generally based on groups of infants who may or may not receive training or conditioning with particular stimuli as part of the experimental procedure. In the first 15 years or so after the first such study of infant speech perception (Eimas, Siqueland, Jusczyk & Vigorito, 1971) infant capacities for discrimination of speech sounds were explored in some depth (ch. 3), with a primary focus on English. Later research turned to advances in knowledge of the ambient language and the role of infant speech perception in laying the groundwork for learning syntax, segmentation and statistical learning (ch. 5).

An important benefit of recent work in both perception and production has been the beginnings of an expansion from a heavily anglocentric field to the more common collection of data from other languages. Unfortunately, studies combining more than one methodological approach remain rare (although there have been some recent attempts to derive individual child measures from group perception studies: Tsao, Liu & Kuhl, 2004; DePaolis et al., 2011). Each methodology has also tended to have its own preferred vocabulary, framework of interpretation and conclusions.

Overview

The central goals of this book are to survey what has been learned about phonological development and to raise questions for further study. We will interpret these goals broadly, however, going well beyond the phonological rules or processes that were the primary concern of linguists interested in child phonology when it first emerged as a field in its own right in the 1970s. Placing our topic within the wider domain of inquiry into the possibility of a system arising (or 'self-organizing') out of no system, we will adopt a functionalist approach. We will be concerned with tracing the beginnings of phonology (and of language) in the infant's perceptual capacities, now well understood to be quite remarkable already at birth or soon thereafter, in the growing repertoire of vocal resources of the first year, and in the emergence of a link between perception and production. We will then consider the transition to language use, endeavoring to identify critical communicative and cognitive developments that permit the construction of a system of interconnected sound patterns along with a dawning understanding of the nature of naming and reference.

Before we embark on a roughly chronological account of phonological development in the first two years (focusing mainly on perception in chapters 3, 5 and 7 and production in chapters 4 and 6), however, chapter 2 provides a broad outline of infant development in the first 18 months, drawing on studies of the development of attention and joint attention, for example, to supplement a focus on more specifically language-related concerns.

Chapter 8, on bilingual phonological development, reviews another lively area of current research, language differentiation and category formation in bilingual infants, as well as the older and less dynamic area of bilingual child production, which has only recently begun to be enriched by studies of small groups of children in addition to the classic case study. Although bilinguals constitute the majority of the population, empirical study of infants raised bilingually is made more challenging by the many variables that affect bilingual language processing and use – such as extent of exposure to each language, in the home and in the community; differences in the phonological or rhythmic distance between the child's languages; changes in language dominance with changes in input conditions, and so on. In the light of the practical and theoretical difficulties involved, most researchers in the perception subfield, in particular, tended until recently to see

establishment of the characteristics of monolingual development as an essential 'baseline' before the findings of bilingual studies could be fairly evaluated.

We consider the theoretical models that have been put forward to account for phonological development in chapters 9 and 10. These chapters are delayed to that point so that the reader initially uninformed about infant development could come to them prepared to use the information presented so far – that is, evidence regarding the nature and course of development and change – to better appreciate the strengths and limitations of the competing theoretical models. Finally, chapter 11 briefly reconsiders two of the main themes of the book, the critical interaction of perception and production and the effects of lexical advance, and of language use, on further development.