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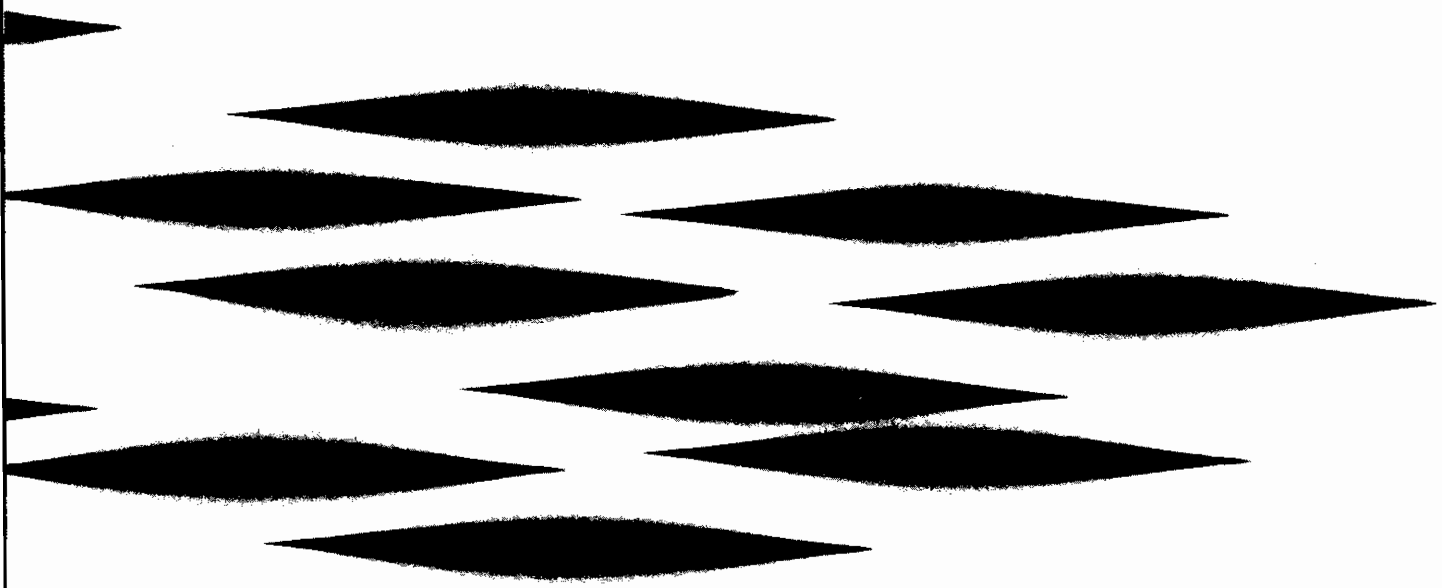
PHONOLOGICAL THEORY AND THE MISARTICULATING CHILD



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PHONOLOGICAL THEORY AND THE MISARTICULATING CHILD

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Edited by

Mary Elbert
Department of Speech and Hearing Sciences
Indiana University

Daniel A. Dinnsen
Department of Linguistics
Indiana University

Gary Weismer
Waisman Center
University of Wisconsin–Madison

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Preface

The work described in this monograph is the product of an interdisciplinary effort that ironically began in a totally atheoretical, informal, and fortuitous way. One of us attended a graduate-level seminar conducted by another of us, and quickly decided that the understanding of the material was strongly dependent on an extensive background in an unfamiliar discipline; however, the novice and instructor soon began a dialogue that suggested that their respective disciplines may, in fact, have something to say to each other. In a short time this twosome evolved into a trio, whose lunch meetings at Bear's Place were concerned largely with the topics of this monograph. We discovered that we shared an interest in speech production in general, and specifically in the sound systems of languages. Elbert's interests had been directed at the modification of disordered sound systems in children, especially those the field of speech-language pathology has referred to as *functional* articulation problems. Dinnsen's work in the area of theoretical phonology was concerned with the typological aspects of the world's sound systems, as well as the implications of such typologies for the "primitives" of sound systems in general. Weismer's research had focused on the acoustic-phonetic structure of normal adults' speech production, with specific attention to context and task effects on speech segment timing. We discovered, as a result of numerous discussions, questions, and arguments, that our respective interests yielded a practical amalgam that could be applied to the problem of so-called "phonological" disorders in children. A close examination of both the research literature and materials (manuals and kits) associated with phonological disorders led us to the conclusion that a substantial effort of scientific inquiry—both in the clinical and nonclinical domains—was required before abandoning traditional articulation analyses in favor of phonological analyses. But the issue seemed to be even more complicated, because we became convinced (and remain so) that most of the extant phonological analyses of disordered articulation are merely relabeled traditional analyses. This latter aspect of the problem seemed especially important, because we firmly believed that a redefinition of a speech-language disorder should be more than a repackaging; rather, a redefinition of a speech disorder, if it is to be useful to speech-language clinicians, should be the outcome of a better empirical understanding of the disorder.

The papers that form this monograph represent our initial attempts to deal with these issues. The work has been going on for approximately 4 years, and we hope it will continue in the future. We have learned that the empirical exploration of phonological disorders is time-consuming, and that assistance in the various aspects of data collection and analysis is a prerequisite to production of even a modest monograph such as this one. Fortunately, we can negate the old cliche and state, "Good help is *not* hard to find these days." Those who helped run subjects include Becky Braunagel, Sharon Roehrig, Cyndi Chicouris, Debbie Smanda, Tom Powell, Cathy Friedman, Hilary Schlesinger, and Laura Abednejad. Kathleen Turner, Debbie Smanda, Cyndi Chicouris, and Suzanne Sampson assisted in various aspects of data analysis, and Susan Ellis Weismer helped compile a comprehensive bibliography. Helpful comments on earlier drafts of various chapters were furnished by Ralph Shelton, Jerry Sanders, Kathleen Houlihan, Phil Connell, and Fred Eckman. Finally, although they have contributions in this monograph, we would especially like to express our gratitude to Edith Maxwell, Leija McReynolds, and Barbara Rockman, whose encouragement and critical assessment of all we thought and said were indispensable to the completion of the project.

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M. E.
D. A. D.
G. W.

Chapter 1
Introduction

Mary Elbert Daniel A. Dinnsen
Indiana University–Bloomington

Gary Weismer
University of Wisconsin–Madison

Speech-language pathology as a scientific discipline is still in the early stages of development. Our 50-plus years of existence have led us down many paths; we have moved away from acceptance of authoritative statements about assessment and treatment in disordered speech and toward the pursuit of an empirical basis for our work. This monograph attempts to pursue this direction.

When new and appealing ways of viewing articulation disorders are presented, speech-language pathologists are eager to examine and test these ideas, realizing that there are extensive gaps in our understanding of the disorders. This enthusiasm is appropriate for a new field and often leads to inquiry and progress; however, at times our enthusiasm has led us to accept ideas that later prove disappointing and are rejected, or worse, to embrace ideas that have appeal but are never supported with data. When we combine our enthusiasm with research, the ideal situation exists and our knowledge and strength as a scientific discipline grows.

This monograph has developed from a collaborative effort to examine a recent and promising idea that has emerged from the discipline of linguistics. It has been suggested that articulation errors are essentially linguistic in nature and can most accurately be described as arising from phonological processes. Whether this notion adds to our understanding of articulation disorders needs to be tested. The possibility exists that we may be relabeling an existing phenomenon with a new (and perhaps to some, more prestigious) title. The question is, does this proposed view allow us to develop new insights into assessment and treatment?

The purposes of this monograph are:

1. to impart information from the discipline of linguistics on the theoretical principles and methods of phonological analysis
2. to review and evaluate theoretical assumptions concerning the crucial issue of the type of underlying representations attributed to children
3. to review studies of acoustic analysis applied to the normally articulated and misarticulated speech of children
4. to present results obtained in training studies with misarticulating children relating to current views of phonological process analysis
5. to discuss the relationship that may obtain between the child's phonological system and subsequent learning patterns
6. to describe linguistic analysis based on methods used in a standard generative phonological approach
7. to provide raw data that will provide other investigators with a more comprehensive view of the data base.

These ambitious goals represent the content of the chapters contained in this monograph and are the culmination of the efforts of the authors to integrate information from two disciplines, linguistics and speech and hearing sciences. The focus of this interdisciplinary work has been on the misarticulating child.

The first section of this monograph, chapters 2 and 3, provides basic information about linguistic analysis including detailed explanations of terms that are often poorly understood by readers without a background in linguistics and linguistic theory. The crucial concept of *underlying representations* is examined in some detail and the importance of this concept in determining the presence of *phonological processes* is stressed.

A great deal of the impetus for the recent interest in linguistic approaches can be traced to David Stampe (1973, Donegan & Stampe, 1979) who introduced the theory that the speech of normal children developing a phonological system is affected by a large number of universal "processes" that must be suppressed in order to attain the standard adult form of speech. Among the behaviors that Stampe identified as processes were deletion of final consonants, cluster reduction, and stopping. These behaviors (processes) are all too familiar to the speech-language pathologist. We are most actively engaged in trying to teach children to include the final sound in words, to use both consonant elements in blends, and to produce fricatives instead of stops when appropriate. It is no surprise that we would be interested in a theory that seems to relate directly to the errors we most commonly seek to change.

Other linguists, such as Smith (1973) and Ingram (1976), have contributed information that has been extremely influential in our reexamination of the errors children produce. Smith has provided us with an account of his own child's speech during the time in which the phonological system was emerging and added an invaluable appendix detailing the utterances of his child as a data base for his ideas. The raw data have served as the source for other studies (Braine, 1976; Macken, 1980) that have reanalyzed, challenged, and provided further information about children's phonological acquisition. Ingram compiled information from many sources in his book *Phonological Disability in Children* (1976). This book was directed toward speech-language pathologists and attempted to explain many concepts from linguistics that were new to our discipline. He offered, from a linguist's view, his notions of how these ideas might lead to new approaches to assessment and remediation.

The stimulation from these recent writings has resulted in many assessment manuals (Compton & Hutton, 1978; Hodson, 1980; Ingram, 1981; Shriberg & Kwiatkowski, 1980; Weiner, 1979). It would seem that the notion of describing articulation errors as processes has been readily accepted by many investigators. Others (Elbert & McReynolds, 1980; Dinnsen, Elbert, & Weismer, 1979; McReynolds & Elbert, 1981a, 1981b; Weismer, Dinnsen, & Elbert, 1981) have viewed the new information with more reserve and caution, suggesting the need for additional research.

Caution seems necessary before we accept most misarticulated speech as having resulted from phonological processes. Research findings in general argue against treating all individuals with misarticulations as a homogeneous group. The frustrating and fascinating feature of most research is the individual differences that always emerge. If only one view is considered, important distinctions related to learning may be missed. It may be more profitable, in terms of more comprehensive gains in knowledge, to remain open-minded. When a speech corpus is obtained from an individual and examined, we may see different types of errors, phonetic as well as phonemic. Many of these errors may be attributable to the operation of phonological processes; however, others may not.

Again, caution is necessary when new terms from a discipline outside of speech and hearing sciences are being adopted. Appropriate use of these terms may require more than simply incorporating them into our vocabulary; it may require intensive study to understand the specialized meanings attached to the terms by phonologists. Perhaps we can reach agreement on the definition of *phonological,* but we have more difficulty with *processes.* Indeed, linguists seem to have different definitions. Speech-language pathologists, who often lack a sufficient background in linguistics, may find a variety of explanations to choose from when they search for the meaning of *phonological processes.*

Chapter 2 provides an explanation of terms and an introduction to linguistic concepts common to generative phonologists. Basic classes in linguistics usually contain examples from foreign languages to help explain aspects of theory and analysis; we are left to translate this information to the area of misarticulated speech. This chapter contains examples from misarticulated speech that we hope will improve our translations.

Chapter 3 may also help us to understand Stampe's theory of natural phonology, which has been the basis for much of the interest in phonological processes. This theory essentially views a child in a passive role during phonological acquisition. According to Stampe, the child possesses a set of adult phonological forms, but these forms are simplified by the application of innate phonological processes and, thus, childish forms are produced (Ingram, 1976).

Other phonologists, either from a traditional or generative orientation, view the child in a much more active role (Dinnsen et al., 1979; Ferguson & Macken, 1980; Grunwell, 1981, 1982; Jakobson, 1968). They do not appeal to innate functions but rather they use the productions of the child as data to determine the existence of underlying forms and phonological processes. The discipline of linguistics, like speech and hearing sciences, has different theories to explain the same phenomena. In any case, the theories need to be understood and examined before they can be tested. The explanations in Chapter 2 are intended to help clarify the facts and issues.

Chapter 4 offers information obtained when the speech of misarticulated children is examined through acoustic analysis. Acoustic analysis techniques can often add vital facts about speech production to either support or negate claims. Acoustic analysis certainly adds a vital link between our perception of speech products and the physiological aspects of the productions themselves.

Chapter 5 deals with remediation. Ultimately our "business" is remediation and, to borrow a business term, the bottom line on this issue will be the effects of a new theoretical approach on children's learning. One of the claims made for the efficacy of viewing errors as phonological in nature relates to the ability to describe the relationship among errors rather than consider each misarticulated sound as a separate entity. If patterns emerge, then treatment can be directed toward a group of related errors and more efficient remediation should result. This, of course, is an enormously appealing concept and one that has already been embraced by speech-language pathologists.

The traditional place-voice-manner analysis has been utilized for many years (Fisher-Logemann, 1971; Turton, 1973). Description of children's errors by a rule such as "fricatives are replaced by stops" has allowed us to examine the relationships among misarticulations for a particular child. McReynolds and her associates (McReynolds & Huston, 1971; McReynolds & Bennett, 1972) have demonstrated that articulation errors can be described in terms of distinctive features, so that an error can be economically viewed as a problem with a particular feature. The fact that the speech of individuals with articulation problems can be described in terms of patterns or rules or relationships has been a part of our body of knowledge and practice for a number of years. This seems to be important and highly useful information. Whether we gain explanatory power or remediative efficiency by describing misarticulated speech in terms of phonological processes is an open question and is discussed in Chapter 5.

In Chapter 6 the relationship between children's unique phonological systems and their subsequent learning patterns is examined. A phonological analysis was performed for four children prior to their participation in a training study. The analyses revealed the facts pertinent to each child's knowledge or lack of knowledge about the phonological system of the language. This knowledge was shown to be related to their learning patterns and offers at least a partial explanation for individual differences.

Chapter 7 describes the procedures used in obtaining speech samples from the misarticulating children we have studied and provides a step-by-step example of an analysis.

The appendix is extensive. In it we present the raw data for one misarticulating child from which analyses have been made.

Published papers are often criticized for not presenting the speech data from which phonological rules were derived; however, it is difficult to present these data in articles. We offer these data not only for clarification of our own work, but as a potential source of information for future research efforts.

Smith (1973) provided a valuable data source by publishing the speech of a child during normal phonological acquisition. We are presenting comparable longitudinal data for one misarticulating child to show the change that occurred during the period of his remediation and afterward.

Finally, like all empirical efforts, ours involves some basic assumptions, or what laypersons may label "biases." When we present our work at professional meetings, there is sometimes concern that we don't appeal to perceptual evidence to affirm or deny the existence of the underlying forms we hunt for in production data. The idea that accurate perception of a phoneme, or discrimination between phonemes, is a prerequisite to appropriate use of the phoneme in production is a longstanding one in our field, but one that has received surprisingly little experimental support. In fact, examination of the research literature dealing with the relationship between speech sound discrimination and production forces one to conclude in many instances that no such relationship has been demonstrated convincingly (see review and data in Locke, 1980a, 1980b). Add to this the observations that misarticulating children are no better than normally articulating children at understanding their own error productions (Dodd, 1975; Locke & Kutz, 1975), and that children often correct adults' imitations of their articulatory errors, and the logic of requiring perceptual data to "validate" underlying forms for use in production becomes increasingly suspect. In other words, there seems to be no compelling scientific evidence that the productive and perceptual phonologies are always one and the same. This is hardly a new thought; indeed, the separation of the productive and perceptual phonologies was a basic tenet of the Prague school of phonology (Jakobson & Waugh, 1979) and American Structuralism (Hockett, 1961), and has been mentioned by both Locke (1971) and Moskowitz (1975) as one explanation for experimental observations. Moreover, recent theoretical statements by Menn (1980) and Straight (1980) suggest compelling reasons for keeping the input and output phonologies conceptually distinct. There are, of course, arguments on the other side for the dependence of production on perception (e.g. Winitz, 1969, 1975). We acknowledge this controversy over the relationship between perception and production. Clearly, more research is required to resolve this issue. It is also clear, however, that research on perception or production can proceed independently—leaving open any questions about the relationship between the two. Ideally, research in one or the other area will lead to insights about their relationship. While we maintain a profound interest in the relationship between perception and production, we offer this work as an initial statement of production-oriented phonologies, taking no position on the question of these children's perceptual abilities.

We want to emphasize that our exclusive reliance on production data is an empirical assumption, because future work could show a strong dependence of the productive phonology on perceptual factors. Currently, however, we are willing to adopt the more modest assumption and limit our investigation to the accumulation of production-oriented descriptions.

The work presented in this monograph is the result of a collaborative effort of several years. We have attempted to approach a given set of data from the different perspectives of speech-language pathology, speech science, and linguistics. Each of us approached the data with different sets of knowledge and concerns. Our goal has been to learn more about misarticulating children.

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Chapter 2
Methods and Empirical Issues in Analyzing Functional Misarticulation

Daniel A. Dinnsen
Indiana University

Linguists have long been interested in the language systems associated with organic and functional (nonorganically based) speech disorders, (e.g., Jakobson, 1942), largely because of what they reveal about the nature of language. For instance, language associated with organic disorders, when compared with unimpaired language, helps delimit the role of the physical apparatus mediating speech production. As a result of specifying these peripheral aspects of language, we come a little closer to identifying the remaining deeper or inner aspects of language. Language associated with functional speech disorders, on the other hand, is of interest to linguists because it constitutes a system different from the system of the surrounding (ambient) speech community. Usually, children are expected to acquire the same system as the ambient community's, provided, of course, there is ample exposure to the primary linguistic data of that speech community. Since children with functional speech disorders acquire language systems different from the ambient language, linguists are faced with the fact that there may be several different learnable language systems compatible with the same body of primary linguistic data. What does this say about the nature of language?

Linguists concerned with the issues of second language acquisition would find the study of speech disorders, and especially the remediation of these disorders, quite interesting. That is, a prima facie case can be made that the problems confronting linguists and speech-language pathologists are quite similar. The typical second language learner has acquired his or her own native system and is trying to learn a different (target language) system. The functionally misarticulating child has learned his or her own disordered system and through remediative intervention is trying to learn the ambient (target language) system. See Eckman (1977, 1981) for an interesting discussion of second language acquisition.

Admittedly, linguists may be interested in speech disorders for different reasons than speech-language pathologists. But what linguistic theory, analysis, and methodology reveal about the nature of language in general and functional misarticulation systems in particular may be of value to both linguists and speech-language pathologists.

If we are interested in revealing the nature of the language system that underlies functional misarticulations, we must study them without biases or a priori assumptions about how they are constructed. We can study them as linguists study any unfamiliar, novel language—reconstructing or discovering the pieces of the system through empirical investigations. This chapter, which represents such a linguistic approach to the analysis of functional misarticulation, has three purposes:

1. to present some of the methods and theoretical principles guiding data collection and analysis of functional misarticulations in children as employed in this monograph and in other papers (Dinnsen, Elbert, & Weismer, 1979, 1980; Weismer, Dinnsen, & Elbert, 1981; Maxwell, 1979; Maxwell & Weismer, 1981),
2. to specify and underscore the empirical considerations motivating phonological analysis, and
3. to outline some implications of this approach for the characterization and remediation of functional misarticulation systems.

There has been considerable interest in applying various aspects of phonological theory and analysis to the description and remediation of functional misarticulations. A principal concern of much of this work has been the identification of the phonological rules or processes operating in misarticulating systems. These rules describe what have traditionally been termed omissions, substitutions, and/or distortions. An important step in the discovery of phonological rules is the postulation or determination of underlying representations. The construct *underlying representation* will be elaborated below but, for the moment, an underlying representation may be viewed as a lexical representation comprising the meaning and all idiosyncratic, learned phonological properties of a morpheme. A morpheme may have different phonetic realizations under different phonological circumstances, but there would be only one underlying representation for that morpheme. Phonological rules would then convert the underlying representation into its different phonetic manifestations as determined by the phonetic context. Since phonological rules convert underlying representations into phonetic realizations, the form and function of such rules depend on the specific nature of the underlying representations.

At least two opposing positions have been proposed for the correct determination of underlying representations in cases involving functional misarticulations. Briefly, some (Compton, 1970; Ingram, 1974, 1976a, 1976b[1]; Shriberg & Kwiatkowski, 1980; Weiner, 1979) have assumed that the misarticulating child's underlying representations are the same as those of the

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[1] Although Ingram states that it is possible for children to have their own unique underlying representations, nowhere does he motivate or develop this claim.

surrounding (ambient) community. No empirical evidence is offered in support of claims about the child's underlying representations. The opposing view is that claims about the child's underlying representations can and should be supported by empirical evidence. See Maxwell (1984) for a more thorough discussion of the two positions.

One of the purposes of this chapter is to detail the empirical considerations relevant to questions about the nature and determination of underlying representations. If we demand empirical support for claims about underlying representations, then we may discover that not all misarticulating children share the same underlying representations as the ambient speech community. Moreover, we may find that among themselves misarticulating children demonstrate different underlying representations. The finding that children's tacit knowledge of the sound system may differ from that of the ambient speech community and may, moreover, differ within disordered populations is pertinent to planning remediation. The appropriate remediation strategy may depend upon what a child already knows about sound systems.

The problem of determining what a child knows about his or her sound system can be illustrated by considering the functionally deviant speech of a child, Matthew, age 3:11 (yrs:mos), who regularly omits word-final obstruent stops. The following representative tokens are transcriptions of Matthew's spontaneous speech:

[dɔ]	"dog"	[bɛ]	"bed"
[wɛ]	"red"	[bɛi]	"plate"
[dʌ]	"truck"	[bɛ]	"bread"

Based on this type of evidence, some researchers might claim that Matthew's system includes a phonological rule of final consonant deletion formulated as follows:

$$\begin{bmatrix}-\text{sonorant}\\-\text{continuant}\end{bmatrix} \rightarrow \emptyset / \_\_\_\_ \#$$

This formalism may be interpreted conventionally as claiming that obstruent stops (p t k b d g) are deleted in word-final position. The basic assumption behind such a claim is that there *are* word-final obstruent stops in the child's underlying representations. That is, it is assumed that Matthew knows, and thus includes as part of his underlying representations, a word-final obstruent stop. For example, the morpheme *dog* would be represented underlyingly as /dɔg/ but pronounced as [dɔ]. It must be emphasized that the postulation of a *g* in the underlying representation of this morpheme is an assumption, not a fact. It is equally possible as an alternative that this morpheme is represented underlyingly the way it appears phonetically, that is, as /dɔ/ without the *g*. Under this assumption, a phonological rule of final consonant deletion would be unnecessary because there is no obstruent stop in word-final position to be deleted. Depending, then, on which assumption is made about the underlying representations, a particular phonological rule may or may not be necessary and thus may or may not be identified as a rule in the child's system.

It is our contention that, in at least those cases where there is no obvious motor or organic problem, the correct determination of underlying representations is a linguistic matter and thus an empirical issue. Empirical evidence of a productive nature can be adduced in support of claims about underlying representations and need not be assumed a priori. The intent of this chapter is to detail these empirical considerations. To do this, however, it will first be necessary to present some background information about the theoretical framework in which these analyses are formulated and define some of the relevant linguistic concepts and terminology. In course, the following questions will be addressed: What are underlying representations? Under what conditions are we justified in assuming underlying representations to be different from phonetic representations? If a child's speech is not properly described by a phonological rule deleting word-final consonants, what would account for the general absence of word-final consonants?

Much of the current work on functional misarticulation (Compton, 1970, 1975, 1976; Ingram, 1974, 1976a, 1976b; Lorentz, 1976) has attempted to draw its analytical techniques, concepts, and theoretical bases from the framework of generative phonology as developed by Chomsky and Halle (1968) for natural language phonologies. Occasionally, some of these works have also drawn in part from the competing theoretical framework of natural phonology as developed by Stampe (1969, 1973), Donegan and Stampe (1979), and others. The reference to natural phonology has usually involved appeal to the construct *natural process.* This has no doubt caused some confusion because within a natural phonology framework, there is an intended distinction between the constructs *natural process* and *rule.* Within a generative phonology framework, however, these two terms are used interchangeably with no intended distinction. As the term *natural process* has been used in the functional misarticulation literature, it appears nowhere to be crucial whether or not there is a motivated distinction between a process and a rule. Consequently, the discussion that follows applies equally to processes or rules, whatever one's theoretical persuasion. The terms are used interchangeably.

There are, however, important and controversial differences between the theories of natural phonology and generative phonology. It would take us too far afield to explicate these two theories and their differences here. I think it would not be unfair to say that many linguists (including myself) have found it difficult to comprehend natural phonology. The problem has been that it is not easy to see how many of the claims of natural phonology can be tested, even in principle. Despite these difficulties, some have found natural phonology attractive because of its treatment of phonological acquisition in the child. However, Hastings (1981) and Leonard, Newhoff, and Mesalam (1980) have provided a convincing demonstration that natural phonology is incapable of accounting for the facts of phonological acquisition.

Elements of Phonological Systems

Phonological rules express regularities and patterns in the pronunciation of a given speaker. Some typical examples of regularities expressed by different types of rules found in phonological systems include the following: All obstruents occurring before voiceless consonants are voiceless; all obstruents are stops; all consonants that follow a vowel are nasal consonants; obstruents between vowels are voiced. These are just some examples of phonological regularities that can and have been attributed to different languages. This is not to say that any one particular language would evidence all or even any of these specific examples. Rules are presumed to constitute only part of a speaker's internalized tacit knowledge of his or her sound system. In addition to phonological rules, of which there are several distinct types within a system (to be elaborated below), a number of other elements combine to constitute a complete system. These other elements include a phonetic inventory (the sounds that occur in pronunciation), a phonemic inventory (the minimal set of segments that function to distinguish meaning), and underlying representations (lexical representations).

Phonemic and Phonetic Inventories

Within the speech-language pathology literature, the term *phoneme* is too often interpreted to mean an actual speech sound. Under such an interpretation, there would, of course, be no difference between the phonetic and phonemic inventories. They would be the same. There are, however, empirical reasons to distinguish *sounds*, on the one hand, from *phonemes*, on the other. The term *phoneme* as it is used in this chapter and throughout the linguistic literature does not mean a sound, but rather an abstract theoretical construct. Under one view, this construct is defined in terms of a class of sounds with particular distributional properties. Under another view, the construct is a psychological entity. Under yet another view, the phoneme is defined in terms of oppositions within the system. These views are not in all instances distinct and thus are not necessarily incompatible. The important point is that phonemes are not sounds per se but rather linguistic units that function to distinguish meaning. This opens up the possibility that the set of phonemes in a system may differ from the set of phones (sounds) in that system in several ways.

One way in which the phonemic and phonetic inventories may differ is in the number of segments in each. In one instance, there can be more segments in the phonetic inventory than there are in the phonemic inventory. For example, a child may produce phonetically voiced and voiceless obstruents. Depending on the empirical fact of how these obstruents are distributed within a word, it can be determined whether there are also voiced and voiceless obstruent phonemes.

The following data illustrate a speech sample where voiced and voiceless obstruents are not phonemic, but rather are allophones of the same phoneme.

[kʌk] "duck"
[kʌgi] "duckie"
[kʌk] "Doug"
[kʌgi] "Dougie"
[kɔk] "dog"
[kɔgi] "doggie"

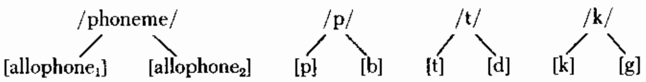
[pɪk] "pig"
[pɪgɪ] "piggie"
[wai̯t] "write"
[wai̯dɪŋ] "writing"
[wai̯t] "ride"
[wai̯dɪŋ] "riding"

[swip] "sleep"
[swibiŋ] "sleeping"
[wʌp] "rub"
[wʌbiŋ] "rubbing"

Both voiced and voiceless obstruents occur in these data; however, voiced obstruents do not occur in any of the same contexts in which voiceless obstruents occur. That is, obstruents between vowels are always and only voiced, while obstruents elsewhere are voiceless.

Given traditional empirical criteria for phonemic analysis, if voiced and voiceless obstruents occur in complementary distribution (e.g., voiced obstruents occur only between voiced sounds, and voiceless obstruents occur elsewhere), then it would be claimed that there are voiceless obstruent phonemes, but no voiced obstruent phonemes. The occurrence of the voiced obstruents would be predicted (specified) by a particular type of phonological rule, namely, an allophonic rule. In this instance, then, for each voiced and voiceless obstruent phone in the phonetic inventory, there would be one voiceless obstruent phoneme. In other words, each voiceless obstruent phoneme would have two allophones—one voiced and the other voiceless.

One-to-many relationship between phonemic and phonetic inventories

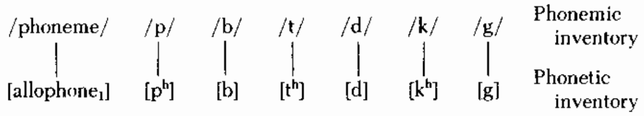


The claim that two sounds are allophones of the same phoneme is equivalent to saying that the two sounds are different manifestations of the same thing. The phonetic difference between the two sounds does not distinguish meaning and, furthermore, the phonetic difference can (largely) be determined by the context in which the class of sounds occurs.

This one-to-many relationship between phoneme and allophones is evident in standard English and other languages generally. For example, aspirated and unaspirated voiceless stops such as [p^h] and [p] occur in complementary distribution (e.g., [p^{h}ɪt]/[spɪt]). While these sounds are different, they are associated with the same phoneme, /p/. The different phonetic realizations of this phoneme are predicted by allophonic rule(s). Below, I will describe in greater detail the characteristics of allophonic rules. In addition I will discuss how allophonic rules relate phonetic and phonemic inventories as well as the special considerations that may be associated with the remediation of allophonic phenomena.

It is equally possible, however, that in another sound system the number of segments in the phonetic and phonemic inventories is the same. For example, if both phonetic voiced and voiceless obstruents occur in some context (e.g., word-initially), and if there is, moreover, an associated difference in meaning (e.g., [p^{h}ɪg] "pig"/[bɪg] "big"), then it is claimed that there are both voiced and voiceless obstruent phonemes.

One-to-one relationship between phonemic and phonetic inventories



Some of these phonemes may, of course, have other allophones (e.g., aspirated and unaspirated voiceless stops as discussed above). In this instance, there is no rule specifying a relationship between voiced and voiceless obstruents since they contrast with one another or are distinct.

Underlying Representations

The unpredictable properties of a sound and word compose an underlying representation. *Unpredictable* means those properties of a sound or word that are idiosyncratic, must be learned language-specifically, and/or do not follow from any rules. For example, the underlying representation of the word "pig" in

English is comprised of one morpheme meaning "swine" represented phonologically as /pɪg/. Some of the unpredictable information specified by this underlying representation includes the following: the fact that there are three segments associated with the morpheme; the fact that it begins with the phoneme /p/ as opposed to some other phoneme; the fact that the second segment is a vowel, a particular type of vowel; the fact that it ends with the phoneme /g/ as opposed to some other phoneme. It is totally unpredictable, for example, that the initial segment of this word is bilabial, is a stop, and is voiceless. All this information must be learned in association with the particular morpheme meaning "swine."

Some information about the pronunciation of this morpheme is, however, predictable and need not be specified underlyingly. That is, given that a morpheme begins underlyingly with a bilabial voiceless stop phoneme, it is predictable by a general allophonic rule that the initial consonant is aspirated. Therefore, the property of aspiration is not incorporated in the underlying (phonemic) representation of any segment. Allophonic information of this type is fully predictable and thus is excluded from underlying representations.

Underlying representations also incorporate other information from which phonological rules can predict variant realizations of a particular morpheme (i.e., account for allomorphy). For example, the plural morpheme in English has three different phonetic realizations or allomorphs. They are [-s], [-z], and [-əz], as seen in the following words: [k^{h}æts] "cats," [p^{h}ɪgz] "pigs," and [dɪšəz] "dishes." One and only one allomorph of the plural morpheme is appropriate with any given noun stem, and the selection of the appropriate allomorph can be stated in terms of its phonological context (i.e., the type of segments that surround it). [-əz] is affixed to stems that end with [s, z, š, ž, č, ǰ]; [-s] is affixed to stems that end in voiceless consonants; [-z] is affixed to stems elsewhere, that is, stems ending in voiced consonants or vowels. For a discussion of the phonological account of plurals in English, see Dinnsen (1980a), Moravcsik (1981), and Miner (1972). One form of the plural morpheme is posited as the underlying representation, /-z/. The claim is that a speaker of English must learn only one representation for the plural morpheme and phonological rules that are capable of converting that representation into the appropriate phonetic realizations. The individual allomorphs need not be learned but rather are derived by rule(s).

The following illustrates the relationship between underlying and phonetic representations and the derivation of plurals:

Underlying representations	/pɪgz/	/kætz/	/dɪšz/
[ə]-insertion rule	–	–	dɪšəz
Devoicing rule	–	kæts	–
Aspiration rule	p^{h}ɪgz	k^{h}æts	–
Phonetic representations	[p^{h}ɪgz]	[k^{h}æts]	[dɪšəz]

In every case, the plural morpheme is represented underlyingly the same—as /-z/. Depending on the type of segment in the noun stem that precedes the plural morpheme, one or another phonological rule may or may not be applicable. In the case of /dɪšz/, English (as well as some other languages) disallows phonetic sequences such as [-šz]. [ə] is thus inserted by a phonological rule to break up the impermissible sequence. This rule is not applicable to any of the other forms cited above since they do not contain the impermissible cluster. In the case of /kætz/, English and all other languages disallow syllable-final sequences such as [-tz] (i.e., a voiceless followed by a voiced obstruent). The [-z] is thus devoiced by a phonological rule converting it to [s]. The devoicing rule does not apply to any of the other forms cited above because they do not contain the impermissible sequence. /pɪgz/ is realized the way it was postulated underlyingly (except for aspiration of the initial consonant) because no rules are applicable.

In accounting for allomorphy, the general considerations that justify an underlying level of representation different from the phonetic level are (a) the same meaning is associated with several different phonetic realizations of a morpheme, (b) there are phonetic similarities among the allomorphs, and (c) the phonetic differences among the allomorphs can be attributed to phonological properties of the context, that is, derived by phonological rule(s). While these considerations justify a level of representation (i.e., the underlying level) in addition to the phonetic level, they do not say anything necessarily about which allomorph (or combination of allomorphs) is to be posited as the specific underlying representation. That is, why is /-z/ postulated as the underlying representation for the English plural morpheme and not /-s/? More will be said below about how underlying representations are determined and how the particular properties of an underlying representation can be motivated/validated empirically.

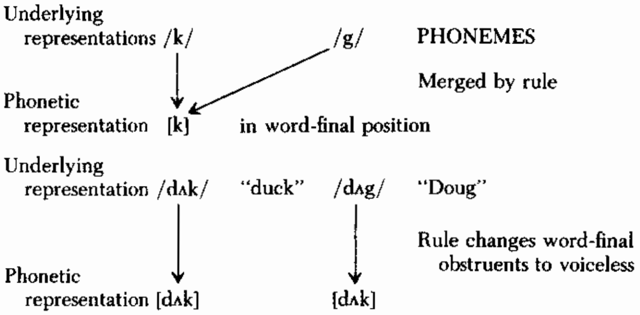
In sum, underlying representations incorporate the unpredictable, learned properties of sounds and morphemes. Phonological rules utilize the information given in underlying representations to specify further the predictable properties of pronunciation. The predictable properties (not incorporated in underlying representations) include, among other elements, allophonic variation and allomorphy. Phonological rules must, therefore, be formulated to express the appropriate generalizations about allophonic variation and allomorphy. There are, of course, other predictable properties of pronunciation not incorporated in underlying representations, and they, too, are specified by rule. Some of these other predictable elements are generalizations about how sounds or phonemes are sequenced (i.e., phonotactics). In the next section, I will discuss the various types of phonological rules and constraints that account for these predictable properties of pronunciation.

Phonological Rules

There are a number of different types of phonological rules. These various types are functionally and formally distinct. Each type thus embodies different claims about the tacit knowledge possessed by a speaker, and each is motivated by different empirical considerations. Because these rule types also relate to the description of functional speech disorders and the differential knowledge possessed by misarticulating children, they are of interest to speech-language pathologists. The types of rules and constraints to be discussed include neutralization rules, phonotactic constraints, and inventory constraints. Allophonic rules were discussed earlier in the section on phonemic and phonetic inventories.

Neutralization Rules

Neutralization rules (sometimes called morphophonemic rules) serve the function of obliterating or merging a phonemic contrast in certain phonological contexts. For example, a rule that devoices obstruents at the end of a word may be viewed as a neutralization rule. The phonemic contrast between voiced and voiceless obstruents would be neutralized in word-final position in favor of voiceless obstruents. The neutralizing effect of the phonemic merger may be schematized as follows:



(Note that "Doug" and "duck" are phonetically homonymous.)

The rule responsible for the merger would be formulated as follows:

$$[-\text{sonorant}] \rightarrow [-\text{voice}] / \underline{\qquad} \#$$

(All obstruents in word-final position are specified as voiceless.)

The following representative misarticulation data illustrate the effects of a word-final devoicing rule:

[dʌk] "duck"
[dʌki] "duckie"
[dʌk] "Doug"
[dʌgi] "Dougie"
[dɔk] "dog"
[dɔgi] "doggie"

[pɪk] "pig"
[pɪgi] "piggie"
[wai̯t] "write"
[wai̯tɪŋ] "writing"
[wai̯t] "ride"
[wai̯dɪŋ] "riding"

[swip] "sleep"
[swipɪŋ] "sleeping"
[wʌp] "rub"
[wʌbɪŋ] "rubbing"

The facts of this situation are:

1. All obstruents in word-final position are voiceless, that is, there is no voice contrast in obstruents word-finally.
2. Both voiced and voiceless obstruents can occur between vowels ([dʌki] "duckie"/[dʌgi] "Dougie") with an associated difference in meaning, that is, there is a voice contrast in obstruents in some position within a word that could be neutralized.
3. Voiced obstruents between vowels *alternate* with voiceless obstruents word-finally (e.g., [dɔgi] "doggie"/[dɔk] "dog"). This last point about *alternation* will be elaborated below.

Several claims are made by a rule of word-final devoicing and thus certain facts are accounted for. First, obstruents in word-final position are always and only voiceless. There is no phonemic contrast between voiced and voiceless obstruents word-finally. Second, underlying voiced obstruents that come to appear in word-final position through morphological processes are changed to voiceless. A devoicing rule formulated as above is an empirically motivated neutralization for a number of natural languages including German, Catalan, and Russian.

Several empirical conditions must obtain in order to identify a neutralization rule. First, since the function of a neutralization is to neutralize a phonemic contrast, there must be evidence of a contrast somewhere in the system in order for it to be neutralized. The place to look for evidence of the contrast is in some position of the word where the rule presumably does not apply. That is, rules are formulated to apply only in a particular context. The devoicing rule, for example, applies only in word-final position. Consequently, in order to establish that there is, in fact, a voice contrast in the language to be neutralized, one would look to contexts other than those specified by the rule. That is, there should be a voice contrast in some context other than word-final position, for instance, word-medially. If both voiced and voiceless obstruents occur in word-medial position with an associated difference in meaning (e.g., [pʰɪgi] "piggy"/[pʰɪki] "picky;" [dʌgi] "Dougie"/[dʌki] "duckie"), then there is evidence of a contrast that could potentially be neutralized elsewhere. The question, then, "Is the rule neutralizing?" can be answered affirmatively if there is first evidence of the contrast in some contexts so that it can be neutralized in other contexts.

The second empirical condition that must obtain in order to identify a neutralization rule is the absence of the particular contrast in a well-defined context. All neutralization rules are formulated to apply in a particular context. The devoicing rule, again, is restricted to apply only in word-final position. It is word-final position, then, that should fail to evidence the voice contrast. This means that the only obstruents that can occur word-finally are voiceless. Wherever there is a characteristic absence of a contrast, it is noteworthy in identifying the operation of any neutralization rule. The context that fails to realize the contrast may serve as the context of the rule.

It is equally important, then, in the identification of a neutralization rule, to note those contexts in which the contrast does occur as well as those contexts in which there is no contrast. Those contexts in which there is no contrast may constitute the context in which the rule applies, thus describing the fact that there is no contrast in that position of the word. A neutralization rule does not apply in those contexts in which there is a contrast.

The third empirical condition that must obtain in the identification of a neutralization rule (although it is not limited to this type of rule) is *alternation*. More specifically, words are composed of one or more morphemes, and any given morpheme may vary in its pronunciation by having different phonetic realizations (allomorphs). The phonetic variation evident in a morpheme constitutes an alternation, sometimes called a "morphophonemic alternation." The English plural morpheme discussed above is an example of alternation. Segments of the plural morpheme are phonetically realized in alternate ways depending on the adjacent sounds in the noun stems. Cases of this kind of allomorphy provide examples of alternation. The particular alternation in the English plural morpheme involves [s] alternating with [z] alternating with [əz]. This alternation is symbolized as follows: s ~ z ~ əz.

Alternations are perhaps the most important type of empirical evidence for at least two reasons. First, they reveal a *dynamic* situation, that there is a process. Second, alternations reveal some of the details or properties of underlying representations. On the first point, different phonetic realizations of a morpheme can be correlated with different contexts. Consequently, as the context of a morpheme changes or varies, so will the pronunciation of the morpheme change. The English plural is generally realized as [-z] (e.g., [dɔgz] "dogs"/[tʰou̯z] "toes"). However, if the plural is affixed to a morpheme that ends in a strident coronal like [s], then a schwa [ə] must be inserted (e.g., [dɪš] "dish"/[dɪšəz "dishes"). Moreover, if the plural is affixed to a morpheme that ends in a voiceless consonant, then again the plural must be changed to a voiceless consonant (e.g., [kʰæt] "cat"/[kʰæts] "cats"). Changes of this sort in a morpheme reveal that a rule is operating. Phonological rules thus express not only static properties such as the absence of a contrast in a particular context (e.g., syllable-final obstruents are voiceless after voiceless consonants) but also dynamic properties such as changing a segment into another segment (e.g., changing [-z] to [-s] in conformity with the static constraint above). In order, then, for a rule to have this dynamic effect, it is essential that there is something to be changed. The dynamics of this type of rule will be contrasted below with the exclusively static property of a different type of rule, namely a phonotactic constraint.

The second reason that alternations are important is because of what they reveal about the underlying representation. This is important because it is not always obvious what the underlying representation of a morpheme is, especially when there are alternate pronunciations for a given morpheme or when a child's pronunciation of a morpheme differs from that of the surrounding speech community. It is important in this regard to keep in mind that an underlying representation is not a fact; it is not directly observable. It is a theoretical construct, an abstraction, a claim about what is learned in association with a particular morpheme. It is a representation of how the morpheme is stored in a speaker's lexicon. While underlying representations are only claims, it is nonetheless possible to bring empirical evidence to bear in support of such claims. In fact, it seems to us that whatever claims are made need to be supported by empirical evidence if they are to be taken seriously. Consequently, the different phonetic realizations of a morpheme do provide some evidence of what the underlying representation is. The general working assumption in linguistics is that knowledge of one's language is largely reflected in one's productions. Given that the representation of this linguistic competence or knowledge is not always directly observable, it is often necessary to piece together the details of this knowledge from particular aspects of the phonetic productions. If a morpheme such as the plural has several different phonetic realizations, it would be reasonable to expect that one of the phonetically occurring allomorphs would be taken as the underlying representation (would be learned) and the other allomorphs would be derived by phonological rules in particular well-defined contexts. It is also possible that none of the allomorphs per se is taken as the underlying representation but rather some single form that bears no resemblance whatever to any of the allomorphs. The problem is, however, that it becomes more and more difficult to present empirical reasons for postulating a particular underlying representation if that postulated underlying representation differs from any one or some combination of the allomorphs or, even worse, is totally unlike the allomorphs. Why should a child internalize (learn) underlying representations that are radically different from anything that he or she ever produces? Moreover, why should we attribute to a child (especially a misarticulating child) underlying representations, the details of which are never realized in his or her phonetic productions?

Questions of this type about the nature of underlying representations have concerned linguists for over a decade. This involves what is known as the "abstractness controversy" (cf. Kenstowicz & Kisseberth, 1977, 1979; Kiparsky, 1968, 1976). The term *abstractness* deals with the degree of difference between an underlying representation and its phonetic realizations. An underlying representation that is identical to one of the allomorphs is considered nonabstract or concrete and thus is consistent with the naturalness condition (Postal, 1968). At the other extreme, an underlying representation that bears no resemblance to any one or some combination of allomorphs is judged to be abstract. An example of an abstract representation would include in some instances postulating segment-types that never occur in the phonetic inventory. With regard to functional misarticulation systems, it would be highly abstract to attribute the segment /g/, for example, to any underlying representation if it never occurred phonetically in the child's speech. An underlying representation of a morpheme is also judged to be abstract if it contains a segment that is not associated with any of the allomorphs of that morpheme even though that segment may occur elsewhere in other words in the system. For example, a functionally misarticulating child (such as Matthew, referred to earlier) who says [bɛ] for "bed" is omitting the final /d/. He does produce /d/s in other words, but only in word-initial position. However, he never produces /d/ in association with this morpheme. For example, he says [bɛi bai] for "beddy-bye." That is, the morpheme that means "bed" does not alternate. /d/ does not alternate with null in this morpheme. Consequently, in the absence of an alternation (i.e., in the absence of any productive evidence of /d/ being associated with the underlying representation of this morpheme), the question arises: Does the child know productively and represent underlyingly this particular morpheme as /bɛd/ with the /d/ or as /bɛ/ without the /d/? The abstract analysis would say the underlying representation is /bɛd/. This would be considered abstract and a violation of the naturalness condition because there is no empirical evidence from production to support the contention that the child knows there is a /d/ associated with this particular morpheme. The concrete analysis would say the underlying representation is /bɛ/. This is concrete because the underlying representation only includes details that are evident phonetically. The presumption is that if the functionally misarticulating child knew more about this morpheme, it would be evidenced in some productive way such as a /d/ produced in association with the morpheme at least sometimes.

Alternations thus help resolve any controversy over the abstractness of an underlying representation. It is agreed by all that alternations probably provide the most direct and unequivocal empirical evidence about the nature of an underlying representation. Controversy arises only when there are no alternations. Even though there is controversy over how to represent a morpheme underlyingly in the absence of an alternation, it is nevertheless agreed by all that the representation is *abstract* if it includes segments that are not realized phonetically or that are not associated with any of the morpheme's allomorphs.

The issue in the controversy is whether an analyst is justified in attributing to a child/speaker underlying representations, the details of which are never evidenced phonetically. The concrete approach relies heavily on the availability of empirical evidence in order to support claims about underlying representations. The abstract approach apparently does not require much empirical support for claims about underlying representations. The analyst's choice of one approach over the other seems, then, to depend on how important it may be to motivate claims about underlying representations on empirical grounds.

From a linguistic perspective, an essential element of what a child (or for that matter, any speaker) knows about his or her phonological system is the underlying representations of morphemes; accordingly, any substantive claims about the child's tacit knowledge must be empirically well-supported. Aside from general linguistic considerations that underscore the importance of underlying representations, the requirement of empirical support (as detailed above) for claims about underlying representations has an interesting and possibly important consequence for differentiating children in terms of their tacit knowledge of the sound system. In particular, the concrete approach results in phonological analyses whereby some misarticulating children can be shown to have underlying representations that are (nearly) identical to the ambient speech community's, while other misarticulating children under more or less comparable circumstances cannot be shown to have the same underlying representations (Dinnsen, 1981; Dinnsen & Elbert, 1984; Dinnsen, Elbert, & Weismer, 1980; Weismer, Dinnsen, & Elbert, 1981). Under the concrete approach, then, misarticulating children would not be characterized as a homogeneous population. It remains to be demonstrated, of course, that the typology resulting from the concrete approach is in fact the correct typology. Some evidence of a phonetic character on this point was presented in Weismer, Dinnsen, and Elbert (1981). Another type of evidence could come from training studies in which functionally misarticulating children with demonstrably different underlying representations (i.e., different from child to child) respond differently to the same training. It may be that individual differences in the extent of generalization due to training can be attributed at least in part to individual differences in phonological systems across children. See especially Dinnsen and Elbert (1984) for an example of a training study combined with differing phonological analyses. The concrete approach allows children's phonological systems to differ at least in terms of the underlying representations of morphemes, where these differences can moreover be assessed empirically.

The following section presents data that illustrate one typical functionally misarticulating child, Jamie (age 7:2), whose underlying representations can be shown to be (nearly) identical to those of the ambient speech community. Consider first the following utterances:

[pæ]	"pat"	[kæ:]	"cab"
[dɔ:]	"dog"	[ka]	"cop"
[dʌ]	"duck"	[kɪ:]	"kid"
[mʌ:]	"mud"		

Note that obstruents are omitted word-finally in every instance. These data resemble Matthew's data discussed at the beginning of this chapter. In fact, the questions asked about Matthew's phonology are the same here. In this instance, does Jamie have a rule to delete obstruents word-finally? In order to answer this question, we must first attempt to determine Jamie's underlying representations for these words. This is important because if Jamie does not know that these words have postvocalic obstruents associated with them, then it would be descriptively inappropriate to claim that Jamie has a rule (in particular, a neutralization rule) deleting obstruents word-finally. It is, moreover, difficult to understand from a logical point of view what it would mean to talk of a child deleting something of which he or she has no knowledge. In the absence of any productive evidence in support of such claims, it must be clear that it is only assumed that the child represents individual morphemes in the same way as the ambient community. It has been my contention throughout that this assumption is unnecessary. It may be a correct assumption, at least in some cases, but it is not something that has to be assumed a priori. Rather, it can be demonstrated empirically. In addition, there are particular empirical consequences (to be discussed below) if such a claim is not assumed a priori. In any case, by simply assuming what the child's underlying representations are, an analysis results whereby rules are postulated and attributed to the child. These rules may serve no purpose other than to convert the postulated underlying representations (which are themselves empirically unjustified and which resemble the productions of the ambient speech community) into the child's actual phonetic productions. Rules of this type express a correspondence between the ambient community's speech and the child's speech. While these correspondences may constitute valid statements about systematic pronunciation differences between the ambient system and the child's system, it is not at all clear that such correspondence rules exist in anyone's head, much less form a primary component of the child's grammar.

The peculiar character of correspondence rules can be seen if one considers describing pronunciation differences between two languages, for example, German and English. While it may be possible to express in rules the pronunciation differences between these two languages, no linguist would claim that these rules are necessarily in the heads of native German speakers speaking German or in the heads of native English speakers speaking English. Such correspondence rules would describe neither English nor German—only the differences between them. Correspondence rules connect two independent systems, and are thus dependent on the character of the two independent systems. The description provided by correspondence rules thus describes a connecting network, the dependent system only, and fails to provide a description of what underlies that dependent system. When a linguist analyzes a language and writes a grammar of that language, the proposed rules or observed generalizations must at least constitute a description of that language system, independent of any other system. Naturally, after a particular system has been described on its own terms, it may be appropriate or reasonable to contrast that system with some other system much the same way applied linguists do contrastive analysis to identify areas of possible difficulty in second language acquisition. It should be emphasized, however, that contrastive analysis recognizes that the languages being compared are independent systems and appeals to the descriptions of each system.

Returning to the particular question of how Jamie represents the morphemes above, evidence can be adduced that shows that Jamie does know or does represent these words underlyingly with the appropriate postvocalic obstruents, that is, that he represents them the same way we do, but that his pronunciation of these words is governed by a phonological rule of final obstruent deletion. In this instance, then, the rule is more than a valid correspondence statement; it is a rule of Jamie's phonology motivated by facts internal to Jamie's speech and independent of any facts or assumptions about the speech of the ambient community. This evidence is available in his pronunciations of these words or morphemes in their inflected forms, that is, in morphophonemically related words. The following data from Jamie's speech show words that are morphophonemically related to the words above:

[pæti] "patty"
[dɔgi] "doggie"
[dʌki] "ducky"
[mʌɾi] "muddy"

[kæbi] "cabbie"
[kapou̯] "copper"
[kɪdou̯] "kidder"

These data reveal that for each morpheme the omitted consonant in question is not omitted when that consonant is in word-medial position. The consonant in question is realized phonetically in association with the given morpheme under certain circumstances. For example, the morpheme meaning "duck" is pronounced [dʌ] without the final *k* in its uninflected form but as [dʌk] with the *k* when inflected with the diminutive morpheme [-i] as in [dʌki]. Morphophonemic evidence of this sort (e.g., *k* alternating with null) provides clear evidence that Jamie knows that the morpheme meaning "duck" must be represented underlyingly with a postvocalic *k*. Similar alternations of other consonants with null (e.g., b ∼ Ø, p ∼ Ø, t ∼ Ø, g ∼ Ø, etc.) under the same circumstances as above (medial versus final position) reveal the underlying structure of the cited morphemes in the same way.

Other evidence is available that supports the claim that Jamie's underlying representations are correct (i.e., the same as the ambient community). A given morpheme may have alternate pronunciations under apparently the same circumstances. Note, for example, the following productions from Jamie's speech:

[pɪː]/[pɪg] "pig"
[dɔː]/[dɔg] "dog"
[mʌː]/[mʌd] "mud"

These forms show quite clearly that Jamie represents these morphemes underlyingly with postvocalic obstruents. Otherwise, there would be no way to explain why some words end in *g*s and others end in *d*s. This type of unpredictable contrastive information must be included in the underlying representations. Alternate pronunciations of a morpheme as above are accounted for by the rule of final obstruent deletion discussed previously, but these forms reveal that the rule is "optional." This means that the rule does not always apply and that no more specific conditions have been identified that would determine when the rule should and should not apply.

Phonotactic Constraints

The following section illustrates two points: (1) It introduces a rule-type, phonotactic constraint that is distinct from other rule types such as neutralization rules discussed earlier. (2) It presents functional misarticulation data from a child who fails to evidence the correct (ambient-like) underlying representations. The situation in this section thus contrasts with that of the previous section, in which a child (Jamie) did evidence correct productive knowledge of underlying representations. Children's differential knowledge of underlying representations is, in my view, the essential basis for a typological characterization of functional misarticulation.

Phonotactic constraints typically express two types of generalizations. One type specifies what sounds can occur in a language. For example, some possible phonotactics (inventory constraints) would be: All obstruents are voiceless; all vowels are nonnasal (oral); all obstruents are anterior (labial or alveolar). More will be said below about this type of phonotactic constraint in relation to the characterization of functional misarticulation. The other type of generalization expressed by phonotactics specifies possible sequences of phonemes. An example of this type of generalization might be: Any consonant within a word must be followed by a vowel. A consequence of this constraint would be the exclusion of consonant clusters and the exclusion of word-final consonants. The domain of phonotactic constraints is somewhat broader than that of neutralization rules. That is, neutralization rules express generalizations about how phonetic representations are to be realized, but they say nothing about the possible form of underlying representations, which are at the nonphonetic level, the level of lexical representation. This means that a neutralization rule can have as its input an underlying representation that does not conform (because of its juxtaposition with some other morpheme) to the surface phonetic constraints (requirements of pronunciation). Neutralization rules change that representation so as to make it conform to the appropriate phonetic representation. Phonotactics, on the other hand, do not change representations. They express static constraints about possible sequences of phonemes not only at the level of pronunciation but also at the level of constructing morphemes. This means that the internal composition of a morpheme must conform to the laws of pronunciation. An empirical characteristic of phonotactics is the absence of alternations in a given morpheme. That is, since phonotactics specify the appropriate (sequences of) sounds within a morpheme underlyingly and within a word phonetically, the morpheme will not have to be changed phonologically in any way to conform to the phonetic laws. Thus, in those instances where there is an observed generalization about possible sequences of phonemes, and where there is an absence of morphophonemic alternations (allomorphy), the generalization is interpreted as a consequence of a phonotactic constraint.

In view of this discussion of phonotactic constraints, let us reconsider Matthew's misarticulated speech discussed at the beginning of this chapter. Matthew, like Jamie, omitted word-final obstruents, as can be seen in the following words:

[dɔ] "dog"
[wɛ] "red"
[dʌ] "truck"

[bɛ] "bed"
[bɛi] "plate"
[bɛ] "bread"

Considering these data alone, the fact of final obstruent omission could be accounted for by either a rule of final obstruent deletion or a phonotactic constraint that excludes obstruents after vowels. The former solution implies that the child represents morphemes underlyingly with final obstruents and then deletes them phonologically. The latter solution implies that the child represents morphemes underlyingly without obstruents immediately after vowels. It should follow, then, that the morphemes in question would never evidence an alternation between an obstruent and null—even when another morpheme is juxtaposed. In other words, the morphemes in question should never appear with a postvocalic obstruent in any context. This prediction is borne out in the following nonalternating pairs:

[dɔ] "dog"	[dai] "doggie"
[dæ] "dad"	[dæi] "daddy"

It should follow from the phonotactic solution that other morphemes would consistently fail to realize postvocalic obstruents word-medially. This prediction is also borne out in the following:

[bɛin] "spreading"	[bʌə] "brother"
[dæɪn] "standing"	[wʌɪn] "looking"
[wɪo] "little"	[wæɪ] "rabbit"
[ʌmbʌi] "somebody"	[diə] "zebra"
[wɪən] "ribbon"	[bɛə] "better"
	[mɛi] "maybe"

These data reveal the possible occurring sequences of phonemes: consonant-vowel (CV), vowel-vowel (VV), and vowel-nasal (VN). It is striking, however, that there are no sequences, even morpheme-internally, of a vowel followed by an obstruent.

A phonotactic constraint or set of such statements can be formulated to allow the occurring sequences and disallow the nonoccurring sequences of phonemes as specified above. In the literature, there have been several alternative formal notations for the expression of phonotactics in a grammar. Under one alternative, phonotactics are stated negatively. For example, the phonotactic evident in Matthew's speech might be formulated as follows:

*Vowel–Obstruent

This is read: "The sequence *vowel followed by an obstruent* is ungrammatical." Sequences of phonemes are checked against such negative statements. Any sequence not explicitly excluded by the negative statements is presumed to be an acceptable sequence in the language.

An alternative to the negative formulation is a list of possibly occurring sequences stated positively, for example: vowel-vowel, consonant-vowel, vowel-nasal. Such a list is presumed to be exhaustive. Any sequence of phonemes that does not match at least one of the positively stated sequences is excluded as a possible sequence in the language.

Another possibility adopts a formulation similar to rules. Some of the rule-like statements needed to express the phonotactic facts would be the following:

$$C \rightarrow [+\text{nasal}]/V \;\underline{\qquad}$$

(Any consonant after a vowel is a nasal.)

$$[-\text{nasal}] \rightarrow [+\text{sonorant}]/V \;\underline{\qquad}$$

(Any nonnasal sound after a vowel must be sonorant.)

For a comprehensive discussion of phonotactics and alternative formulations, see Wheatley (1981). For our purposes, it is inconsequential which formal notation one might choose. It is more important to recognize the difference in function and domain between phonotactics and neutralization rules.

Some of the words in the examples above, such as *rabbit*, are monomorphemic. Consequently, the putative word-medial obstruent (in *rabbit, b*) could never appear in word-final position. Nevertheless, the obstruent does not appear phonetically after a vowel morpheme-internally. This is relevant because such forms would not involve potential alternations caused by word-final position. They fail to evidence postvocalic obstruents even where word-final position is irrelevant.

The absence of vowel-obstruent sequences is a general and unequivocal fact of Matthew's speech. On the other hand, this is not a characteristic of Jamie's speech. While Jamie failed to realize postvocalic obstruents word-finally (sometimes), he did evidence postvocalic obstruents in morphophonemically related forms and in word-medial position. Consequently, while a rule of final obstruent deletion might account for the absence of word-final obstruents in Matthew's speech, it cannot explain the absence of postvocalic obstruents in morphophonemically related forms or the absence of postvocalic obstruents that appear word-medially in unrelated words.

The phonotactic solution explains the absence of word-final obstruents as a consequence of a general constraint excluding obstruents after vowels at any and all levels of representation independent of what follows the obstruent. Because an obstruent in word-final position can be a particular instance of a postvocalic obstruent, the phonotactic that excludes all sequences of vowel-obstruent will exclude or disallow vowel-obstruent word boundary sequences. In this sense, the phonotactic acts as a filter that disallows entry to the lexicon of any representation that does not conform to the phonotactic. In order, then, for a form to be represented in the lexicon, it must be internalized in some way that is consistent with the phonotactics of the language.

The phonotactic solution in the case of Matthew thus provides a unified account of a number of seemingly unrelated facts, namely, the absence of word-final obstruents, the absence of allomorphy, and the absence of postvocalic obstruents word-medially.

The phonotactic solution also provides a characterization of Matthew's speech that is quite different from that of Jamie's. The main difference between the two children's phonologies may be summarized as follows:

Matthew's phonology	Jamie's phonology
A. Incorrect (simplified) underlying representations	A. Correct (ambient-like) underlying representations
B. Phonotactic constraint specifying restrictions on underlying and phonetic representations	B. Optional neutralization rule specifying restrictions on phonetic representations

The fundamental differences in how the two phonologies are characterized appear to be well motivated in light of the empirical differences in the two children's speech. In fact, the only similarity in their speech is the omission of word-final obstruents (and even there, there are differences). The empirical differences in their speech are summarized as follows:

Matthew	Jamie
A. No morphophonemic alternations	A. Morphophonemic alternations
B. Obligatory nonoccurrence of word-final obstruents	B. Optional occurrence of word-final obstruents
C. Nonoccurrence of postvocalic obstruents word-medially	C. Occurrence of postvocalic obstruents word-medially

There are further differences in these two children's speech as reported in Weismer, Dinnsen, and Elbert (1981). Specifically, Jamie maintains a systematic difference in vowel length before omitted word-final obstruents while Matthew fails to do so. This fact is interpreted as further support for the correctness of the claims about the children's underlying representations. That is, Jamie maintains the vowel length distinction in accordance with the voice feature of his underlying postvocalic obstruents. Matthew, on the other hand, evidences no productive knowledge of obstruents after vowels and a fortiori the voice feature of obstruents in that context. Consequently, if vowel length distinctions are somehow dependent on properties of following obstruents, and if Matthew fails (as he does) to evidence any systematic vowel length distinctions, it would be reasonable to conclude that Matthew does not know that obstruents can follow vowels, let alone that they condition vowel length.

It is, of course, possible to maintain that Matthew's underlying representations are correct, ambient-like underlying representations—just like Jamie's. However, this claim would be wholly without empirical support. The absence of evidence in support of it would have to be regarded as an accident. Moreover, the facts of Matthew's speech cited above would have to be treated in totally unrelated ways.

The particular approach to phonological analysis sketched in this chapter provides for the phonological differentiation of children's misarticulated speech based on empirical differences. It is possible to typologize functional misarticulation in terms of these phonological analyses (Dinnsen, Elbert, & Weismer, 1980; Maxwell, 1981). The fundamental distinguishing factor among functionally misarticulating children would be the character of their underlying representations. That is, some children can be shown to evidence the same knowledge of underlying representations as the ambient speech community. Other children, however, cannot be shown to have this same knowledge of the underlying representations and may thus have rather different underlying representations. These two general groups of children would also be differentiated in terms of their rule types (i.e., neutralizing, allophonic, phonotactic) and the substantive details of rules within a rule type. The differences across children attributable to rules are, however, secondary because rules are dependent on particular claims about underlying representations. This is so because rules simply mediate between underlying and phonetic representations.

In typologizing misarticulated speech, it is important to recognize the possibility that for a given child some of his or her underlying representations may be correct (ambient-like) while others may not. In such cases, the correct versus incorrect underlying representations may themselves exhibit a characteristic pattern. For example, a child may omit all obstruents word-finally. However, only labial obstruents evidence an alternation, for example, [ba] "Bob"/[babi] "Bobbi." In this instance, word-medial *b* alternates with word-final null. Compare this with the absence of an alternation in the following pairs:

[dæ] "Dad"	[dæi] "Daddy"
[dɔ] "dog"	[dɔi] "doggie"

Notice that the nonalternating forms above do not evidence dental or velar obstruents (*d* and *g*) after vowels. These data thus suggest that some of the child's underlying representations are correct, that is, /bab/ "Bob," supported by an alternation; other underlying representations are not correct, that is, /dæ/ "Dad" and /dɔ/ "dog," supported by the absence of an alternation. The correct versus incorrect underlying representations reveal a pattern that dental and velar obstruents cannot occur after vowels (incorrect underlying representations). Labial obstruents can, however, occur after vowels but only in word-medial position (correct underlying representations). This prohibition against postvocalic dental and velar obstruents is a phonotactic constraint. This constraint thus explains why dental and velar obstruents do not occur word-finally, why they do not occur word-medially, and why certain morphemes do not alternate. The alternation of *b* with null appears to be a consequence of a neutralizing rule deleting (labial) obstruents word-finally. This child's speech would thus be characterized by a phonology with some correct and some incorrect underlying representations along with two different (and possibly competing) rule types. Such a characterization represents a point on the continuum somewhere between a Jamie-like phonology at one extreme and a Matthew-like phonology at the other.

A typological account of functional misarticulation rejects the patently false claim that these children constitute a homogeneous speech population. Instead, it maintains that they can be differentiated from one another in terms of their knowledge of the underlying representations. It should follow from this claim that there will be characteristic and systematic empirical differences in the speech of different children with differing underlying representations. It should also follow that the learning task will be measurably different among these children because they possess differential knowledge about the underlying representations. It does not follow, however, from anything said so far that the misarticulated speech of children with correct underlying representations will be easier or more difficult to remediate. The reason for this cautionary note is that little is known, even in the area of second language acquisition, about the relative ease/difficulty of learning new lexical representations versus unlearning a phonological rule. This is obviously an empirical issue of interest to linguists, psychologists, and speech-language pathologists that needs further research. Training studies involving misarticulation should provide valuable insights on this issue. Such studies are, of course, dependent on a proper and correct analysis of the child's phonological system. Amassing empirical support for each claim of an analysis thus becomes all-important.

Let us return to the other major type of phonotactic constraint, namely, inventory constraints. These constraints specify restrictions on the sounds that can occur in a language, independent of context. It is important to identify this type of phonotactic in a speech sample, especially in the analysis of functional misarticulation, because many putative and seemingly unrelated substitutions are more generally the result of a phonotactic inventory constraint.

An examination of Matthew's misarticulated speech from his first session (age 3:10, see appendix) reveals that *b* and *d* are the only obstruents in his system. This means that there are no fricatives or affricates at any point of articulation and no velar consonants. The phonotactic generalization about Matthew's obstruent system is that all obstruents are anterior (labial or alveolar) voiced stops. This generalization may be formulated as follows:

$$[-\text{sonorant}] \rightarrow \begin{bmatrix} +\text{anterior} \\ +\text{voice} \\ -\text{continuant} \end{bmatrix}$$

Notice that this statement is formulated without any contextual restrictions. This means that if an obstruent occurs, it must be realized as an anterior voiced stop independent of context. It does not mean, however, that anterior voiced stops will be substituted for all obstruents in the ambient system. Whether or not an obstruent is substituted for some sound in the ambient system depends on the phonotactic possibilities of the child's system as discussed previously. The phonotactic statement above also has the effect of limiting the range and number of possible phonemic contrasts in the child's system. In other words, there is no voice contrast, no manner contrast, and only a limited, two-way point-of-articulation contrast, that is, labial versus alveolar. Morphemes must, therefore, be constructed from the range of phonemes and phoneme sequences possible in that system. The words *dog* and *go,* for example, both include velar obstruents in the ambient system, although in different contexts. Matthew pronounces these words [dɔ] and [do], respectively, without velars. A substitution analysis, which assumes ambient-like underlying representations, must delete the velar in word-final position in some cases and change the velar to *d* in word-initial position in other cases. Under such an analysis, there is no formal or functional explanation for why specifically velar obstruents are affected. It is thus claimed that the two processes affecting velars accidentally co-occur in this child's system. The phonotactic account, on the other hand, explains these two facts as related. Velars do not occur word-finally or word-initially because velars are not possible sounds in this child's system as stated by the phonotactic constraint above. The nonoccurrence of any obstruent word-finally is a consequence of another independently motivated phonotactic discussed previously, which excludes any obstruent, including a velar, from occurring postvocalically.

There is a further problem with the substitution analysis in this instance, and that is the absence of empirical support for its claims about underlying representations. Under the substitution analysis, a large number of phonemes would presumably make up Matthew's phonemic inventory and thus would be available for the construction of the underlying representation of morphemes. The full range of phonemic contrasts would be postulated at the abstract underlying level of representation, but these contrasts would everywhere be reduced by rules to the minimal phonetic contrasts in Matthew's speech. The postulation of a /g/ phoneme, for example, in Matthew's speech is totally without empirical support at any level of representation. There are no [g]s phonetically. There is no evidence that substitutions for *g* are phonetically distinct from other phonetic segments, and there are no alternations of any kind that could be related to *g*s. The phonotactic account, on the other hand, expresses directly the range of possible phonemic contrasts and thus attributes to Matthew only those contrasts (and thus phonemes) that can be empirically justified. In so doing, *g*s are excluded everywhere because they are not [+anterior]. As a result of the same phonotactic constraint, *t*s and *p*s are excluded everywhere as well because they are not [+voice]. Similarly, *f*, *s*, *v*, and *z* are excluded everywhere because they are not [−continuant].

Inventory constraints thus constitute one type of phonotactic specifying the range of possible sounds and contrasts within a system independent of context. The identification of these constraints is essential to questions about the underlying representations of morphemes since underlying representations are constructed from the phonemic inventory of that system.

Conclusion

In this chapter, I have attempted to explicate a particular approach to the phonological analysis of functional misarticulation. Needless to say, this approach differs in some respects from that employed in some of the current speech-language pathology literature. It is, however, the approach employed by generative phonologists in the analysis of other natural language phonologies. The controversy between these approaches rests on two related issues: (1) assumptions about underlying representations, and (2) empirical motivation. On the issue of underlying representations, it is maintained herein that it is not necessary to assume that all children with functional misarticulations have ambient-like underlying representations. In fact, it is suggested that children's functional misarticulation systems can be differentiated or typologized in terms of the relative similarity of their underlying representations to the ambient community's underlying representations. Consequently, some children can be described as having ambient-like underlying representations while other children cannot be so described. This raises some very interesting and important questions that need to be investigated further. One such question concerns reconciling claims about underlying representations with the child's receptive (perceptual) abilities. It remains yet to be established whether or not a child who does not have ambient-like underlying representations has ambient-like receptive abilities. Children who have the appropriate receptive abilities may have two separate but related sets of underlying representations—one corresponding to a receptive level and the other to the productive level. This would appear to be a very different problem from the child whose productive and receptive underlying representations match but are unlike those in the ambient system. In any case, answers to these questions and a fuller understanding of functional misarticulation would clearly benefit from a coordination of perception research and the approach to analysis sketched here.

On the issue of empirical motivation, it should be clear from the discussion in this chapter that most elements of a phonological system are not directly observable. It is thus necessary to discover the nature and character of those elements through hypotheses that presumably fit available empirical findings. If we are to have confidence in any of the claims or hypotheses made about a particular child's phonological system, it is important to amass empirical support for these claims. One piece of evidence of tremendous value in assessing claims about underlying representations is the presence/absence of morphophonemic alternations. Also, the character of phonological rules/constraints is aided by facts of distribution and context, that is, where particular sounds can occur within a word.

One major point of this chapter (and this approach) is that it is possible and presumably valuable to examine functional misarticulation systems independently of the ambient system. That is, in analyzing functional misarticulation systems it is not necessary to assume the underlying representations to be the same as those of the ambient system. Misarticulation systems can be treated as a linguist would treat any new, unfamiliar foreign language. Through such an approach, if it is appropriate for the underlying representations to be posited as ambient-like, empirical evidence will suggest different underlying representations. The presumed value of the approach lies in the typological characterizations which follow from it and the implication that these characterizations have for remediation strategies.

Linguists are always careful to point out (and properly so, I believe) that there are no adequate "recipe" or "cookbook" procedures to phonological analysis. It is simply not possible to crank out an adequate, insightful analysis in a mechanical fashion. I am accordingly dubious of any manuals that purport to yield a phonological analysis by filling in some form sheets. I am more inclined to adopt an approach that attempts to address the following questions:

1. What sounds occur in the speech sample? This determines the phonetic inventory. A spontaneous speech sample is preferable because it more likely reflects the fluent, unguarded speech capabilities of the child.
2. Are there any observable constraints on the occurrence of sounds in the phonetic inventory? The phonotactic inventory constraints answer this question.
3. Are there any observable restrictions on the distribution of sounds within words? Answers to this question would reveal much about the phonemes, allophones, and phonotactics of the system. For example, if certain sounds can occur in some same context with an associated difference in meaning, they must be contrastive or phonemes. If certain sounds characteristically occur in complementary distribution, they must be allophones of the same phoneme. If certain sequences of sounds occur but certain others don't, a phonotactic constraint may be involved (especially if there are no alternations). If there are certain contexts in which they do not contrast, and if there is an alternation in those contexts, a neutralization rule may be involved.
4. What are the underlying representations of morphemes? This must be determined for each morpheme at issue and must be based on empirical evidence. Morphemes are constructed only from the phonemes that can be justified empirically in that system and that are consistent with the phonotactics of that system (see question 3). Evidence of morphophonemic alternations can be checked by examining the realization of a morpheme in different phonetic contexts (under different phonological conditioning).

These four general questions and this chapter are not presumed to be comprehensive or exhaustive. I do believe, however, that answers to these questions should reveal the essentials of a phonological system and should accordingly reveal much about what a child knows tacitly about his or her sound system. My intent throughout has been to emphasize those elements of phonological theory and analysis that have yielded empirically well-supported descriptions of natural languages and that appear promising for both the analysis and treatment of functional misarticulation.

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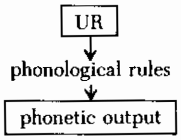
Chapter 3
On Determining Underlying Phonological Representations of Children: A Critique of the Current Theories

Edith M. Maxwell
Kurzweil Speech Systems, Inc.

One aspect of the phonological analysis of natural languages is the determination of the form in which words are stored in the speaker's lexicon or "mental dictionary." If there is systematic variation because of phonetic context in the production of a word, one form must be selected as the phonemic or underlying lexical representation; the variant form will be derived by a phonological rule. The determination of underlying representations (URs) is equally important in the phonological analysis of child speech, whether that speech is being acquired normally or is that of a misarticulating older child.[1] If the child's production system is to be described, the description must include a statement of the underlying representations for the words the child uses. There have been claims recently that child lexical representations are identical to adult phonetic productions, and that phonological rules link the child's UR to his or her phonetic output. This approach, with its basic assumption that the child has stored forms that he/she never produces, is linguistically rather unconventional. Others have suggested that analyzing a child's phonology according to established linguistic methodology may yield a rather different set of URs from those proposed by the group just mentioned. The question of URs is not only intrinsically important, it also affects what kind of phonological rules are attributed to the child. That is, as illustrated by the schematic model below, lexical representations provide the input to any rules that may be operating in the child's phonology.



If, under different theoretical assumptions, two URs differ for a same surface form, the rules required to produce that surface form will also differ.

The two major and opposing positions (and their respective proponents) on the nature of child URs for both normal and misarticulated speech are:

1. Child URs are in all cases identical to adult surface forms (Braine, 1974; Donegan & Stampe, 1979; Ingram, 1974, 1975, 1976a, 1976b; Menn, 1978; Smith, 1973; Stampe, 1973, and others), and
2. Child URs are not always identical to adult surface forms and can in some cases be unique to the child's own system (Braine, 1976; Dinnsen, 1984; Dinnsen & Elbert, 1984; Dinnsen, Elbert, & Weismer, 1979, 1980; Kornfeld, 1971; Kornfeld & Goehl, 1974; Macken, 1980; Macken & Ferguson, in press; Maxwell, 1979, 1981; Maxwell & Weismer, 1982; Smit, 1980; Weismer, Dinnsen, & Elbert, 1980, and others).

The supporters of these two positions propose, in some cases, radically different kinds and sets of phonological rules in order to derive child surface forms from URs. Three kinds of evidence have been used to support the proposed URs: (a) perception/discrimination test results, (b) attested production forms, and (c) the nature of change in the system.

The purpose of this chapter is to critically review and evaluate the theoretical assumptions, evidence, and justification that are claimed to support positions (1) and (2) above. The progression of this chapter is as follows: The first section will present the arguments of various Position 1 proponents with reference to the assumptions they hold, the evidence they bring to bear, and the models they propose. The second section will present the views of some proponents of Position 2 with reference to the same three points. The last section will present tentative conclusions on the most preferable model. This chapter is not meant to be an exhaustive historical survey; rather it discusses some of the more representative positions taken in the recent literature. This of course runs the possible risk of being an arbitrary selection.

POSITION 1: CHILD UR = ADULT SURFACE FORM

Smith

Smith (1973) was one of the first to specifically address the question of the nature of child URs. His work, a longitudinal case study of one normally developing child, presented two alternative analyses of the same data. One analysis assumed adult surface forms to be identical to the child URs, and proposed a set of extrinsically ordered[2] realization rules to account for

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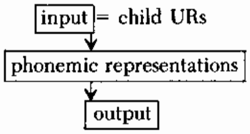
[1] The term *functional misarticulation* is typically used to describe those speakers whose chronic articulatory errors cannot be attributed to any obvious organic problems (such as cleft palate or hearing impairment). Whether or not the clinical cases of misarticulation that are described as functional are purely so is a matter for debate, because some minimal damage to the central nervous system (which would not be an obvious organic problem) could be responsible in part for defective articulation.

[2] The extrinsic ordering of phonological rules adds to the complexity of a grammar. There are universal principles of rule application that should be able to accommodate rule ordering (Koutsoudas, Sanders, & Noll, 1974); if these principles cannot be adhered to, the analysis is both theoretically problematic and suspect.

the facts of production. The other analysis attributed some autonomy to the child's system: It proposed a set of child phonemes arrived at by a traditional structuralist contrastive analysis, and a set of morpheme structure conditions[3] to restrict co-occurrence of the phonemes in words. Smith concluded in favor of the first analysis—the adult-to-child mapping rules. A schematic model of this system is shown in (1).

(1) Model of child phonological system based on conclusions in Smith (1973).



The three main kinds of evidence on which he based this conclusion consist of (a) informal discrimination test results, (b) differential plural formation, and (c) the nature of change in the system.

One of Smith's primary assumptions (one his study shares with the others to be presented in this section) is that the surface forms in the ambient language (that is, the adult language that surrounds the child) are the same as the child's URs. Because Smith assumed that discrimination test data would reflect URs, and because the child (referred to as *A*) could in some informal tests discriminate between the adult productions of two words *A* produced as homonyms, Smith concluded that the ambient language (input) is what determines the shape of lexical representations for the words the child knows. There is, however, some question about and some controversy over the interpretation of discrimination/perception test results. That is, because of the multiplicity of acoustic cues and short-term memory limitations (see Locke, 1980a, 1980b, for critical comments on the discrimination tests and criteria for designing useful tests of child speech perception), discrimination test results do not conclusively prove that the child is or is not perceiving and registering what is distinctive to the adult listener/experimenter. To extend informal discrimination "test" results to claim that the adult productions of the words being tested are identical to the URs of the child's phonology may not be valid.

Smith claimed, however, that his discrimination test results are supported by differential plural formation and the nature of change in the system. Certain plurals were formed differently for words that end in different segments in the adult's system but that ended with the same segment in *A*'s speech. The examples given (from Smith, 1978) were as in (2).

(2) *A*'s plural formation.

"cloth" → klɔt "cloths" → klɔtid
"cat" → kæt "cats" → kæt
"horse" → ɔːt "horses" → ɔːtid

According to Smith, the fact that "cat" and "horse" have different plurals that correspond to the presence or absence of [ə] in adult speech is evidence for the child having the adult final segment /t/ or /s/ underlyingly. He fails to note, however, the discrepancy in "cloths" between the adult and the child forms. That is, "cloths" in adult speech does not form a plural with a schwa (or [ɨ])—rather it should resemble the plural of "cat" in *A*'s speech. Smith's data in fact support an "own-system" analysis, which would say that the child knows the difference between any word-final stop corresponding to adult stops and any word-final stop corresponding to adult fricatives, and forms plurals according to his own rule.

This kind of own-system analysis, similar to that in Maxwell (1979) but different from the kind of analysis Smith concluded in favor of, might mark one stop with a diacritic that would trigger the [-id] plural formation; what is crucial here is that Smith's data directly contradict his assertion that in the case of "cloth," *A* knows there is a [θ] in the UR. There is no evidence offered to support this assertion. A possible alternative interpretation of these data within Smith's framework is that the plural formation rule was applying overgenerally: nonstrident adult coronals [θ, ð] were triggering the [−əz] plural allomorph as well as strident [s]. Smith (1973) mentioned something to this effect in a footnote on p. 69, although there appears to be a serious typographical error. Smith presented some comparable data to the [klɔtid], [ɔːtid] forms from a later stage: "bath" → [baːs], "baths" → [baːsiz], "Smith" → [smis], "Smiths" → [smisiz], "spot" → [spɔt], "spots" → [spɔts]. He then stated, "It would seem that the [-iz] plural allomorph has been generalized to all [-cor, -del rel] segments—not to [-strid] segments." It appears that all of the above negative values should be changed to positive ones in order to support his point. Nevertheless, the only thing the plural data show is that *A* was treating ambient fricatives differently than ambient stops; it is a large step to then assert that the child has a /θ/ underlyingly when it never appears on the surface.

Smith's other support for child surface form being identical to adult surface form is the across-the-board nature of change in the child's productions. If the child's URs were "correct" and if production data were the result of rules operating on those URs, then loss of a rule would be expected to result in the correct URs surfacing to be phonetically correct in production all at once. That is, if the child already knows the correct UR for a given word, after a rule has been lost the child should not have to hear the word again in order to know how to say it. Smith (1973) claimed that this was, in fact, what happened in *A*'s speech: across-the-board change, that is, an exceptionless "neogrammarian" type of sound change.

Using system change to support a hypothesis about the nature of URs can be seen as making a testable prediction about future change and/or change in the systems of other children: If lexical change toward adult forms is piecemeal, the child may have internalized idiosyncratic or systematically different URs. In fact, as will be discussed in more detail later, Braine (1976) and Macken (1980) have pointed out that Smith ignored crucial variability and exceptions to the across-the-board change. (Also see Elbert & McReynolds, 1979, for lack of support for across-the-board change.) These exceptions indicate that the child in Smith's study had not in all cases internalized the correct UR. Smith later acknowledged Macken's argument that misperception had occurred, and he incorporated (in Smith, 1978) some

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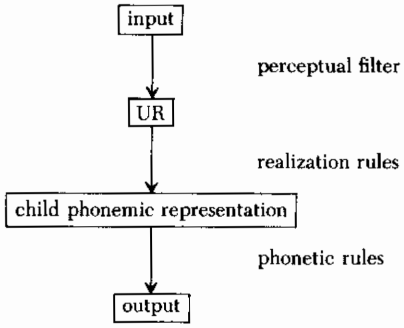
[3] Morpheme structure conditions restrict the possible occurrence of certain sounds in certain places in morphemes and words (cf. Dinnsen, 1984, for a discussion of phonotactic constraints, which impose similar constraints to those imposed by morpheme structure conditions).

type of "perceptual filter" into his new model of child phonology as shown in (3).

(3) Smith (1978) model.



The realization rules in both (1) and (3) are an expression of the systematic correspondences between the ambient language and the child's speech. The perceptual filter in (3) was incorporated to account for the "piecemeal change" words, but a form for the filter is nowhere proposed. Smith (1973) further claimed that the proportion of words subject to perceptually induced malformation is small, although he offered no evidence to that effect and did not specify how small. The phonetic rules in (1) and (3) were claimed in Smith (1973) to be low-level allophonic rules, which would, for example, account for *A*'s obstruent stops being voiceless and unaspirated word-initially, voiced and unaspirated word-medially, and voiceless and aspirated word-finally.

Smith (1978), however, stated in a footnote that it was not clear to him that the "child's phonemic representation" is psychologically real and distinct from the phonetic representation of the output, and that it would be difficult to find evidence that would demonstrate conclusively the difference between these two levels. As it was Smith himself who originally proposed this level, it would seem that his having discarded it might merit more than a footnote. Furthermore, Smith's use of conventional linguistic terms like *underlying representation* and *phonemic level* is somewhat confusing because it does not coincide with current usage of such terms. That is, underlying lexical representations are conventionally (Anderson, 1974; Chomsky & Halle, 1968) considered to be equivalent to phonemic representations (or the phonological feature matrices that constitute phonemes). Smith's use of *underlying representation*, however, corresponds to the *input*, the ambient language, and not any level at which the contrasting distinctive sounds of the child's productions are specified. His *phonemic level* probably corresponds to conventional phonemic levels. His *phonetic rules* seem to correspond to conventional phonological rules, although these phonetic rules were nowhere fully presented or explained (see Smith, 1973, pp. 50–51) and they seem to include statements about both morphophonemic alternations and surface redundancies (i.e., "sonorants are always voiced," p. 50). The realization rules are similar to sound correspondence rules, statements of regularities between two similar systems (except, as pointed out by Dinnsen (1984), it is a unidirectional correspondence—the adults are never claimed to know the realization rules).

The consequences of proposing that a child's phonology approximates a model like Smith's (3) are that a high degree of empirically unmotivated abstractness[4] and a large number of complex phonological rules are attributed to the knowledge a child possesses. Smith's type of model has been criticized in more detail by Dinnsen (1984) with reference to functionally misarticulating children. The main point is that there are empirically and theoretically based criteria from established linguistic theory and methodology for determining the form of underlying representations. To abandon these criteria is to ignore not only all the recent controversy on abstractness but also general principles of phonological analysis—contrast, alternations, context-sensitive rules, and so forth. One cannot claim to work within a theory while ignoring the theory's methodology. Dinnsen has pointed out that even if correspondence rules across systems were to be written, there must be an internal system for each speaker to correspond to, and he has advised that the first task at hand should be the discovery of the internalized system of the child. Although his work refers to the speech of children with functionally disordered (or perhaps only delayed) phonologies, the above points apply equally well to the analysis of normally developing phonologies.

Having concluded that the majority of the child URs are equivalent to the surface forms of the ambient language, Smith (1973) proceeds to lay out four universal tendencies that he views as constraints on the types of realization rules available to children. These are shown in (4).

(4)

a) consonant or vowel harmony ("duck" → [gʌk])
b) cluster reduction ("blue" → [bu:])
c) systemic simplification (neutralization of "mat," "mass," "mash," "match" to [mæt])
d) grammatical simplification ("eye" and "eyes" → [ai])

Any exceptions to the above tendencies would be, according to Smith, perceptual mistakes and would be expected to show piecemeal change.

While the constraints in (4) do describe many common misarticulations of both normal and phonologically delayed children, they can only be considered *rules* if they have adult URs as their input. A different view of constraints on rules and URs will be discussed in the next section.

In summary, Smith's most recent position (1978) was that in the majority of cases, the child's URs are equivalent to adult surface forms, and the child uses a set of psychologically real and universally constrained mapping rules to change those URs into his or her production forms.

Donegan and Stampe

A similar position to Smith's was taken by Stampe (1973) and Donegan and Stampe (1979) within their theory of natural phonology. Although it is at times difficult to ascertain precisely what their operating assumptions were, their basic position was that a large number of universal "processes" operate on children's speech; a child must learn to suppress enough of those processes to approximate the ambient language.

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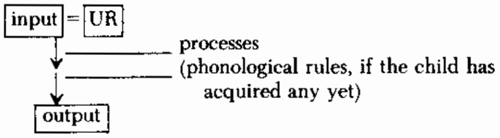
[4] It is the general consensus among linguists that abstract analyses are to be avoided. The more a UR resembles its surface form, the less abstract it is. Analyses like Smith's propose completely abstract URs: forms that never occur in the child's production.

A *process* was defined as a mental substitution that systematically but subconsciously adapts phonological intentions to phonetic capacities and that enables speakers to perceive others' intentions underlying superficial phonetic adaptations (Donegan & Stampe, p. 126). Donegan & Stampe distinguished *process* from *phonological rule* in the following ways: (1) processes are "phonetically motivated" whereas rules lack current phonetic motivation; (2) processes apply involuntarily and subconsciously, while rules are formed through the observation of linguistic differences of which the speaker is conscious; (3) processes may be optional (or suppressed) whereas rules are obligatory. Processes are apparently the same for any speaker of a language, whether child or adult.

Donegan & Stampe presented their position on child underlying representations in opposition to Jakobson's (1942) model of phonological development, which states that the child's system grows by the step-by-step mastery of oppositions. Donegan & Stampe claimed rather that there is much evidence that "the child's mental representations cannot be deduced from his [sic] utterances," according to the structuralist definition of the phoneme, and also that "they correspond rather closely to adult phonemic representations" (p. 131). The only references cited are Stampe's own 1969 paper and Edwards (1973). This assertion was repeated in a footnote (p. 169), again citing only Stampe and Smith (1973) for the "evidence."

In summary, a schematic model of the Donegan & Stampe approach is shown in (5).

(5) Model based on claims in Donegan and Stampe (1979).



Donegan & Stampe admitted that their position entails attributing to a child a far more complex mapping from phoneme to phonetic representation than the adult mapping (p. 131). They said, however, that the paradox of the child having many more rules than the adult "disappears" when the mappings are not seen as rules but as "natural processes motivated by the innate restrictions of the child's phonetic faculty" (p. 131).

This last statement must be interpreted as a claim about children's motoric capabilities: Child productions are governed only by phonetic difficulty, not by any cognitive organization of linguistic distinctions, according to the Donegan & Stampe approach. One problem with this approach is that a definition of phonetic ease or difficulty and the concept of phonetically motivated processes or rules are far from well-established. Donegan & Stampe included prosodic, articulatory, and perceptual difficulty as kinds of motivations for phonetic processes; there will be one process for any single difficult property (p. 137). Nowhere did they present any experimental studies or references to studies that might support their claims of phonetic difficulty[5] (see Dinnsen, 1980, for a more detailed critique on this point). There is research in progress, in fact (Fourakis, 1979; Fourakis, 1980), that is examining certain phonological rules that have been claimed to be predictable from universal constraints on the articulators (a prime case of phonetic difficulty) such as stop epenthesis in nasal-fricative clusters in English. This particular rule is actually not only not phonetically necessary, in contradiction to previous claims, but the putatively inevitable stop is even deleted by a phonological rule in Catalan (Dinnsen, 1980). This rule shows that a sequence of segments claimed to be universally difficult can actually be selected by a language—this lessens the impact of the claim that phonetic ease is always striven for.

Also, it is unclear how phonetic ease or difficulty could even in principle be defined. To measure the activity of one or more muscles involved in the production of even a single sound (which in speech would rarely if ever be unaffected by surrounding segments) would have to be counterbalanced against the coordination at one moment or over time of the articulators (Robert Port, personal communication). This has not been done to date, and enough variables are involved to make it a formidable task. Donegan & Stampe certainly have not attempted it.

To sum up the immediately preceding, Donegan & Stampe have based their entire "natural' theory on phonetically motivated rules, but have failed to offer anything but impressionistic evidence about such motivation (see also Householder, 1979, for critical comments on Donegan & Stampe).

Another problematic consequence of their theory, similar to that found in Smith's work and remarked on above, is the very high degree of abstractness imputed to the child's system. Although Donegan & Stampe's apparent attempt to develop a concrete and phonetically based theory of phonology is laudable, the move away from abstractness holds only as regards adult phonologies; their treatment of child phonology goes in entirely the opposite direction because they would attribute a massive set of neutralization rules or processes to a child, as mentioned above. A high degree of neutralization implies URs that are abstract and without empirical defense.

An additional point with regard to underlying representations should be made: It appears that Stampe at least was proposing more than one level of URs. Stampe (1973) said that processes may govern underlying representations. As an example, he cited the process [ŋ] → [n] as being a process barring [ŋ] from URs in English (p. 29). An underlying representation, according to any linguist's definition, is a learned and unpredictable form that is not rule-governed; Stampe's position is a major departure from current linguistic theory. This approach to URs tends to take significance away from the concept of underlying representation. That is, if a process can govern a UR, then presumably a single word could have two or more URs on different levels, with different processes intervening. And if a process could precede a given UR, what is that process operating on?

The kind of evidence Donegan & Stampe used was largely anecdotal or impressionistic, although they did cite production data from Velten (1943) and Smith (1973). Hastings (1981) offered an interesting reexamination of the Velten data. Donegan & Stampe also used system change to support their claim of process reorderings.

To conclude the discussion on Donegan & Stampe, then, the URs they have proposed for child phonologies are in essence no different from those in Smith (1973), even though the theories underlying the two approaches are quite different.

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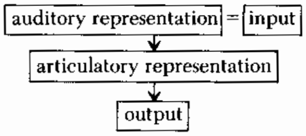
[5] Of over 100 references cited in Donegan and Stampe (1979), only four are phonetic studies (Marios Fourakis, personal communication).

Braine

Another proponent of Position 1 was Braine (1974), who attempted to outline the properties of a learnable phonology. Although in some of the discussion Braine seemed to allow that children might have unique and less distinctive lexical representations than adults, later in the paper he adopted an approach modeled on Stampe's (1969). Braine proposed the existence of primitive phonotactic rules (like Stampe's processes), and the precedence of perception over production in order of acquisition. When the primitive rules or tendencies are suppressed, Braine claimed, the child will approximate the adult system by gaining control over articulation.

Braine did not consider rules such as "final consonant deletion" to be neutralizations because he assumed that perceptual competence is ahead of articulatory competence, and that, as regards word-final consonants, the child has a "more or less good auditory image of them in his [sic] lexical entry" (p. 285). Braine placed a great deal of weight on perceptual evidence, yet he did not cite or perform any experimental studies to support his claims. The production data he cited are taken from Velten (1943), Braine's son Jonathan, and an otherwise unidentified child, Steven. A model based on Braine's discussion is shown in (6).

(6) Model based on claims in Braine (1974).



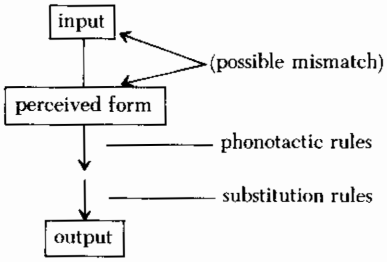
One of the problems inherent to Braine's model is the same as Stampe's and Smith's: To propose rules that link a child's UR to his or her production form, the rules must have a more or less full-fledged adult form to operate on. Braine did not demonstrate with any linguistic evidence that these adult-like URs are appropriate for the phonologies of the children he discussed. Another problem (also seen in Smith's work) is Braine's use of possibly misleading terminology. He outlined an "inventory" of the primitive phonotactic tendencies, and referred to one type of tendency as "syllable structure constraints" (p. 285). One might expect that these would be constraints on the structure of syllables, underlying or otherwise. Braine went on, however, to claim that a constraint of this kind in its most extreme form would cause any final consonant marked in the lexical entry to be deleted in the output. If he had labeled this process a rule of final consonant deletion, because that is what his claim in effect is, his position would have been clear from the start. His constraint applies only to syllables on the surface phonetic level.

Braine's approach to URs is, in summary, similar to that of the other supporters of Position 1.

Ingram

Another supporter of Position 1 is Ingram (1974, 1975, 1976a, 1976b). He has discussed underlying representations in both normally developing and delayed phonologies, and his treatment of both is similar. Ingram's operating assumptions and claims are sometimes contradictory. In Ingram (1974), he began by stating that perception data will reflect URs, and went on to claim that in cases of incorrect perception, the child will have a unique underlying system (p. 51). A model of Ingram's claims is shown in (7).

(7) Model based on discussion in Ingram (1974, 1975, 1976a).



Ingram allowed *noise* to be represented by *X* in the UR, noise being defined as any part of the adult word that is never represented in the child's utterance. Ingram immediately went on, though, to describe the common rules that children use: cluster reduction, final consonant deletion, and so forth. If the child has a different UR from the adult, it is difficult to see the necessity for a rule of the sort he mentioned that would additionally alter that UR. It is also unclear how Ingram arrived at the proposed unique URs if not via the production forms. Therefore, if a child never produces, say, fricative-stop clusters, according to Ingram the underlying system will not contain any fricative-stop clusters; rather these adult clusters will be represented by whatever the child uses in their place, perhaps an apparently voiced stop.[6] Why, then, would a rule of cluster reduction be needed? This is a serious internal contradiction in Ingram's work.

There is a similar inconsistency in his (1976a) book on child phonological disorders, which is directed toward clinicians and researchers in speech-language pathology. (Also see McReynolds, 1978, for a critical review of Ingram.) He instructed the reader, in the final chapter ("Issues in Remediation"), to determine in initial, medial, and final position which vowels and consonants are used contrastively in the child's speech. He then suggested comparing the contrasts in use to those used by normal children at a comparable stage of acquisition and attempting to establish new contrasts through remediation on the basis of the comparison. The final instruction, however, was to "do this by eliminating those processes that stop the target contrasts from occurring" (p. 149). Again, if a child is lacking a contrast between two or more sounds, the absence of a distinction is implied rather than the presence of a phonological process. Such processes have been presented throughout the book, though, again without justification or empirical linguistic evidence for the existence of anything for such processes to operate on.

Ingram (1976b) presented a somewhat more developed theoretical model for the analysis of child phonology. He included perceptual "conditions" that link the adult utterance to the child's perceptual representation, organizational rules going from the perceptual representation to the organizational represen-

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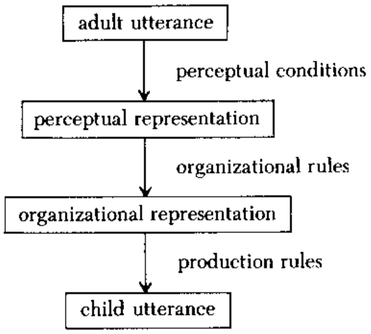
[6] It could be that these apparently voiced stops are actually voiceless unaspirated stops, which would correspond to the segment that follows /s/ in initial clusters in adult speech. Acoustic analysis can resolve this kind of question.

tation, and production rules transforming the organizational representation into the child's output. A schematic of this model is shown in (8).

(8) Model taken from Ingram (1976b, p. 6).



Ingram proposed that the perceptual conditions will be more like constraints than like rules, and might effect, say, a child having a perceptual representation of [ma] for "mop" if there is a condition prohibiting final consonants. This view on consonants is similar to that of Dinnsen et al. (1984). Ingram then proposed that organizational rules such as "cluster reduction" would eliminate clusters on the organizational level. Production rules would reflect the limitations on the child's articulatory ability. Ingram failed to provide, however, any guide to decide on which level an input form becomes reduced or any criteria to distinguish something such as absence of final consonants from absence of consonant clusters. In fact, he went on to discuss the possibility that the three kinds of processes that mediate between levels may not in any appreciable way differ from one another, and that there may be a Stampean universal set of phonological processes in acquisition that "slide" through the various levels (p. 7). A process would operate first as a perceptual condition, then as an organizational rule, and then as a production rule until the process is finally suppressed. It is not clear what Ingram's motivation was for positing three different levels of rules; he offered no empirical justification for any of them—they seem rather to be abstract constructs with no data-based rationale for them.

The assumptions in one of Ingram's most recent publications (1981) do not differ in any appreciable way from those in his prior work.

In summary, then, Ingram's assumptions and proposals throughout his articles and his book largely reflect an adult-system approach to child phonology and are consistent with the other proponents of Position 1.

Compton, Lorentz

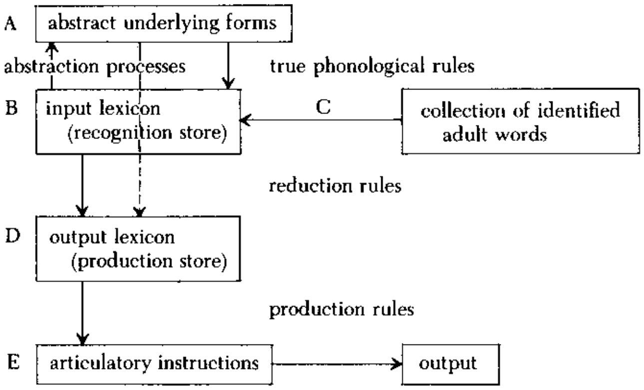
Much of the published work on the phonologies of functionally misarticulating children has been within a Position 1 framework. Compton (1970, 1976), Lorentz (1976), and Weiner (1979) operate under the assumption that the child in all cases has the adult surface form as his/her underlying representation. A critique of their specific approach has been presented in more detail in Maxwell (1979) and Dinnsen (1984); the assumptions and basic framework of Compton and Lorentz do not differ in any critical way from any of the basic points of, say, Smith (1973).

Menn

Another apparent proponent of Position 1 is Menn (1978), who has discussed normally developing phonologies. She has proposed a model that in part resembles those presented above—adult input is identical to child UR—but has added an additional component: phonotactic constraints on the output. Her model is shown in (9).

Menn's operating assumptions include the precedence of perception over production in phonological development and the child's invention of rules relating the adult form to the child's production. The main claim of the paper is that many rules are best seen in terms of the satisfaction of output constraints (p. 162). As it pertains to the nature of child URs this model proposes that, because the child's perception is ahead of production, words that he/she knows will be stored in basically the adult form, and reduction and production rules will be necessary because of the child's limited motoric abilities. Menn did not present any evidence that the form of the child's output is due to strictly motoric difficulties rather than a unique child phonological organization. She did state that the child abstracts underlying representations from the stored input forms; this approach would appear to allow the possibility of a child "abstracting" a UR that is unique to his/her system, but Menn did not discuss that possibility and claimed the necessity for rules that have the effect of carrying out constraints on the output. In support of her claims about URs and rules, Menn asserted that prior work has adequately established the validity of such claims. She cited data from her own work (Menn, 1971; Menn, unpublished) and from that of Kiparsky and Menn (1977), Moskowitz (1970), Ingram (1974), Greenlee (1973), and others to support her arguments about output constraints. A constraint against, for example, word-initial or word-medial fricatives could be achieved by metathesis, deletion of nonfinal fricatives, cluster simplification, substitution of a stop for a nonfinal fricative, or avoidance of adult words that do not obey the constraint. Positing phonotactic-type constraints has also been done by Position 2 proponents such as Dinnsen et al. (1979); they differ from Menn in not presuming the additional existence of adult → child substitution rules. The Dinnsen et al. type of constraint furthermore would hold at all levels of the production phonology.

(9) Menn (1978, p. 163) model of child's speech production.



Discussion

To conclude this section, some questions will be addressed to the points of similarity among the various Position 1 approaches outlined above: (1) Are the proposed URs and the resultant kinds of rules empirically verifiable? (2) What predictions for change are implied by this approach? (3) Has the acquisitional precedence of perception over production been established?

Because adult → child correspondence rules are justified only by positing an adult UR, the two parts of Question 1 can be dealt with as a unit. As discussed above, claiming that a child has an adult-like UR entails positing a highly abstract lexical representation with reference to the child's surface productions. If a child never produces clusters, say, or never utters a word-final consonant, there will be no empirical evidence that could support the claim that those clusters or those word-final consonants are distinctive to the child and part of his/her phonemic/phonological system. There would likewise be no empirical support for the rules that are claimed to link the abstract URs to the child's productions.

As for Question 2, the Position 1 approach would predict that two children with identical surface forms should change in identical ways once they had "unlearned" the rule that changed their correct URs into their production forms. Smith would further claim that such change, the casting off of a rule, should occur across-the-board; that once a rule disappears, all the correct URs that fit the structural description for that rule should surface at once as they were postulated underlyingly.

Finally, addressing Question 3, because all of the proponents of Position 1 depend on the child having apparently perfect perception of the ambient language and its distinctions, some remarks about the acquisition of perception are in order. Barton (1978), in his study of normal acquisition, claimed that although in general the adult surface form is registered by the child, the child makes hypotheses about what is distinctive in the language, and that "children may even entertain incorrect hypotheses and in fact frequently do so" (p. 126). Barton conceded that the "full perception hypothesis" (term from Braine, 1976—see the beginning of this section) "is in no way proven" (p. 127) and that much more data on child phonology is needed. Broen and Strange (1980) agreed, and discussed several different theoretical positions on child perception that have been presented in the literature. These include:

1. The child's perception of the adult phonological system is complete by the time the child begins to gain productive control over phoneme contrasts;
2. the child produces all and only the contrasts he/she perceives and, therefore, the child's entire phonological system differs from that of the adult;
3. the child's perception and production proceed gradually, with perception sometimes preceding production.

They also note that individual cases of production preceding perception have been reported, and that there is no logical reason to exclude this from happening. Macken and Ferguson (in press), also discussed below, point out the frequent independence in development of the production and perception systems, as does Straight (1980).

There appears, then, to be no consensus on the precedence of perception over production, and therefore no solid ground for the assumptions of the Position 1 proponents who base theoretical claims on those assumptions. Position 2 proponents, who claim that in at least some cases children can have unique, nonadult URs, will now be presented.

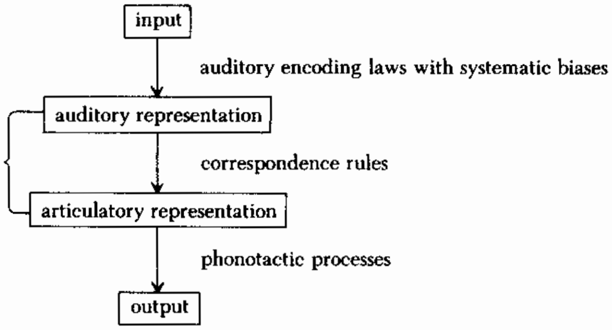
POSITION 2: CHILD UR CAN BE UNIQUE

Braine

Braine (1976), in a review of Smith (1973), made some changes from the approach adopted earlier (1974) by Braine (see the beginning of the above section). Braine outlined three possible hypotheses, and claimed that they would posit a richer internal representation than the "own system" analysis would allow (p. 41). The third of these allows for a child to have systematic perceptual biases that cause some lexical items to be represented uniquely. This has been labeled by Braine as the "partial perception" hypothesis. The first hypothesis that he proposed, the "articulation hypothesis," is similar to that of Position 1 of this paper—the child perceives accurately and stores an auditory representation but has not yet discovered the full set of articulatory features necessary to produce the word. The child therefore must also store an articulatory representation; the features that appear in this latter "are those for which there is evidence of at least sporadic control in the child's output" (p. 492).

Because the partial perception hypothesis is the only one of the three that allows unique child URs,[7] a model of it is shown in (10).

(10) Model of Braine (1976) partial perception hypothesis.



One of Braine's operating assumptions (p. 491) is that children know more about words than can be represented in the output system, but it is not clear why, for the model shown in (10), Braine continued to include correspondence rules that split the auditory and articulatory representation levels; he did not offer an explanation for the split. A possible explanation might be that partial misperception occurs, but that there is still a mismatch between the perceived form and the set of articulatory features the child commands.

Braine also did not state which of the perception hypotheses

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[7] The full perception hypothesis could, on the level of the articulatory representation, be viewed as also allowing unique URs, but as it is otherwise more similar to Position 1, and as Braine ultimately assigns it to Smith's analysis, it will not be dealt with here.

he favored although he stated that "children's ability to discriminate perceptually among phonemic contrasts is often far from perfect" (p. 494) and that this strongly supports the partial over the full perception hypothesis.

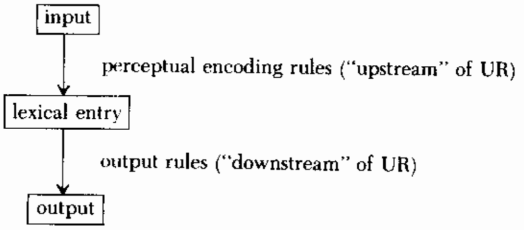
The evidence from Smith (1973) that Braine brought to bear in support of his point is the famous puzzle-puddle-pickle example, and the occurrence of recidivism. In the "puzzle" example Smith's child *A* produced [pʌgəl] for "puddle" but [pʌdəl] only for "puzzle." This shows that the misproduction of "puddle" was not due to motor difficulties or lack of control of articulatory features, since the correct sequence was produced for a different word. Braine asserted that the child made a mistake in his judgment of the articulatory basis of a sound he heard, and that this argues for the perception hypothesis. The recidivism case was presented by Smith (p. 153) as the loss of a systematic contrast or correct form after it has once been established by the child. So, for example, at Stage 1 in Smith's data, /s/, /ʃ/, and /l/ were generally realized as [d]. Then the child, *A*, learned [l] and because /s/ and /ʃ/ were still realized as [d], *A* maintained a distinction between /l/ and /s/. In the next stage, however, the child, according to Smith, hypothesized that [continuant] rather than [fricative] was the crucial feature characteristic of /s/ and /ʃ/ as well as of /l/, and proceeded to realize any segment containing the features [+cor, +cont] as [l], the only coronal continuant he could produce (p. 153). Braine argued that this example also clearly favored the perception hypothesis, rather than the articulation hypothesis, because the child reorganized his perceptual/phonemic categories independently of his motoric abilities.

Braine (1976), then, allowed for the possibility of children misperceiving or failing to perceive distinctions in the ambient language and thereby registering nonambient lexical representations.

Macken

Macken (1980) also treated the Smith (1973) data, taking Braine's review as a starting point. She simplified Braine's model, however, since she noted that he admitted that the correspondence-rule level of his model is unlikely to be well-defined. Macken's model is shown in (11).

(11) Model based on Macken (1980).



Macken proposed two hypotheses associated with the perception model: (1) perceptual encoding rules will be associated with lexical exceptions, and change in these rules will be evidenced in only a few words ("piecemeal" change); (2) when the perceptual encoding rule changes, it will be applied incorrectly to some words that also meet its structural description (the recidivism case). Changes in the output rules (which are to have the properties of Smith's realization rules, according to Macken, and are the formal opposite of the perceptual encoding rules) would be across-the-board. Macken, after carefully examining the data from the appendix in Smith (1973), supported the above hypotheses. She concluded that Smith cannot claim that the adult surface form is the child's lexical representation in all cases, and in those cases where it is not, the child has mistakenly represented the lexical shape of particular words. She does agree that in some cases (instances of across-the-board change and plural formation) the child does have words stored in an essentially adult-like form.

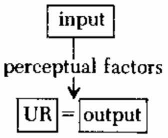
As questions that remain to be answered, Macken suggested: (1) To what extent do perception versus production "incompetence" rules account for the structure of the child's lexicon? (2) Are there other factors—distinct from perception incompetencies—that account for nonadult components in the child's lexical representation? To answer these questions will take many more detailed phonological analyses of child speech, both longitudinal and synchronic. Longitudinal studies of individual children will contribute to the study of system change, but careful, in-depth, single-time data analysis is also necessary.

Recent work by Macken and Ferguson (in press) outlined a more developed theory of phonological acquisition. The focus was not on underlying representations per se, but some of the claims are relevant to this discussion. That is, their model stresses the formation of creative hypotheses by young children acquiring a phonology, and claims that those hypotheses are tested and often changed during the course of acquisition. Categories of sounds or words and rules affecting those categories may change as the child recognizes new patterns in the language, experiments with them, and forms new hypotheses about related categories. Macken and Ferguson have pointed out the similarity of their model to more general models of cognitive development.

Kornfeld and Goehl

Kornfeld (1971) and Kornfeld and Goehl (1974) are also proponents of Position 2. Kornfeld's basic position (1971) was that a child whose phonology is developing might be selecting a subset of adult features to realize his/her productions, and might be making distinctions not in the adult system. She claimed that although differences between child and adult systems may be due to motor and linguistic factors, the difference would be due primarily to perceptual factors. This claim approximates the partial perception hypothesis outlined in Braine (1976). A probable model of the Kornfeld approach is shown in (12).

(12) Model based on Kornfeld (1971) (this author's interpretation).



The evidence cited in Kornfeld (1971) is a long-term study of word-initial obstruent-obstruent and obstruent-liquid clusters of 13 normal children. Acoustic analyses were made of the productions whose targets were clusters; results showed that the [w] produced for /r/ showed consistent second formant differences from [w] for target /w/. These two kinds of [w] were furthermore not perceived as distinct by adult listeners; this observation corresponds with similar ones by Macken and Barton (1980) and Maxwell and Weismer (1982), where adults do not always perceive child production distinctions. Kornfeld also argued that because target /s/-stop clusters were produced as noisy onset plus aspirated stop the child had reanalyzed the adult /st/-cluster as an initial singleton strident stop and therefore produced it as such.

Kornfeld and Goehl (1974) adopted the same approach as Kornfeld (1971) in a more detailed examination of the w/r phenomena of older children. They claimed that children with a w/r problem have an underlying representation something like /r^w/, which "allows the child to relate the [r]s of other speakers to his [sic] abstract segment" (p. 214). /r^w/ would represent a feature matrix composed of features that would define a liquid consonant distinct from /w/ and /l/ but containing enough shared features with /r/ to allow the child to perceive an adult /r/ accurately. This hypothesis would offer an explanation for why adults, trying to imitate the child's [wæbɪt] "rabbit" and producing a real [w], would be rejected by the child. It also proposes a specific difference between normal and w/r children.

The major contribution of Kornfeld, and Kornfeld and Goehl, has been to at least suggest that children might not have completely adult-like underlying representations. Children, in fact, might utilize subsets of adult features to represent certain ambient speech sounds. Kornfeld and Goehl concluded: "If there is any analysis that might be unnatural, it would be one that requires a child to learn a mature underlying form, and then to have to learn special rules to convert this form to something that is unacceptable to adults" (p. 217).

Dinnsen, Elbert, Weismer, and Maxwell

Some of the most recent work within a Position 2 framework has been that of Dinnsen, Elbert, and Weismer (1979, 1980), Weismer, Dinnsen, and Elbert (1981), Dinnsen (1984), Dinnsen and Maxwell (1981), Maxwell (1979, 1981), and Maxwell and Weismer (1982). These researchers have proposed empirical criteria for determining the existence of a phonological rule in a child's system. They have dealt specifically with misarticulating children, but the criteria are taken from established linguistic methodology, and should hold for normal children and adults in any language.

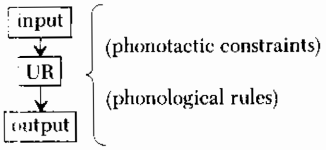
The type of "processes" or rules most often described by Position 1 proponents resemble neutralization rules: An adult contrast is neutralized in the child's speech. Dinnsen (1984) claimed that the following three empirical criteria are necessary for the valid postulation of a neutralization rule within a child's phonology: (1) the absence of a phonemic contrast in a particular well-defined context, (2) a morphophonemic alternation, and (3) a phonemic contrast between the alternating segments in one of the alternating contexts. It is further claimed, in Dinnsen et al. (1979), that there are several constraints on neutralization rules; that is, a neutralization rule cannot completely obliterate all evidence of the underlying representation on which it acts. The constraints are as follows: A neutralization rule must (a) apply optionally, (b) apply to a very limited class of segments, and/or (c) co-occur with an "anti-neutralization process." Antineutralization processes would be of the type described in Weismer et al. (1981), where children evidencing the absence of word-final stops retained the vowel length appropriate to the voicing of the absent (deleted) stop. Further examples were presented in Maxwell (1981), and in Connell and Parks-Reinick (1982). For Dinnsen (1984), a rule of neutralization in a child's phonology can only apply to a word that has an ambient-like UR. The postulation of ambient-like URs is supported by such evidence as morphophonemic alternations, optional application of a rule, and/or the retention of something like proper vowel length, that is, anything that allows the UR or a trace of it to be phonetically manifested. A child who, say, never produced final consonants, never evidences those consonants between vowels, and does not exhibit the proper vowel length, would be said by Dinnsen et al. not to possess the ambient UR. That type of child would instead have a general phonotactic constraint that disallows at all levels of representation an obstruent consonant after a vowel.

Dinnsen et al. (1980) described a typology of misarticulating systems, and claimed that there are at least three distinct types. Two have been described above: (1) A child with ambient-like URs and a set of phonological rules not completely congruent with those in the ambient system, and (2) a child with unique URs and phonotactic constraints. A third type would have the same *number* of distinctions as the ambient system but they would not be the *same* distinctions. Examples of this type of child have been presented in Kornfeld (1971) and Maxwell (1979). This type of child would also have rules not totally congruent with those in the ambient system. This typology has recently been revised by Maxwell (1981). The revision proposed more autonomy of rule-type and UR-type, and instituted a fourth type. The new category includes misarticulating children whose speech evidences the right number and kind of distinctions relative to adult speech, but those distinctions are in no direct correspondence with the adult distinctions.

Dinnsen et al. have cited evidence from a number of their own phonological and acoustic analyses of misarticulating children, as well as the Weismer et al. vowel length study (1981), the data in Maxwell (1979), and the Maxwell and Weismer (1982) VOT study. This last study, similar in principle to the Weismer et al. paper, also made a contribution to the discovery of child URs. It is a voice onset time (VOT) analysis of word-initial stops in one child's speech; the stops analyzed were all apparently [d], and represented 20 different distinctions in adult speech. Results showed that the child was making a statistically significant VOT distinction that corresponded to the adult voice contrast, which illustrates that this child knows more about the ambient language than was apparent from an auditorily based analysis of his phonology. Remediation, therefore, may not need to be directed at teaching this child the voice contrast—efforts can be applied toward correcting one of his other misarticulations. Maxwell and Weismer (1982) also described a follow-up VOT study on the same child after he had learned the voice, manner, and place contrasts correctly. Results indicate that the child is following normal but delayed stages of the acquisition of VOT (cf. Macken & Barton, 1980, for data on normal acquisition).

The various papers of Dinnsen, Elbert, and Weismer on the phonology of misarticulation, as typified in this monograph, as well as those of Maxwell (1979, 1981), do not enter into any perceptual testing or make any claims regarding child perception and the integration of ambient language input into a child's phonology. As discussed in the section on Position 1, Dinnsen, Elbert, Weismer, and Maxwell have attempted to discover the internalized, production-based systems of the speakers they have described. The only explanation they seem to offer for why a child without defensible rules might have a nonambient system is that he or she lacks knowledge about possible distinctions or sequences in the language. As contrasts are learned and adequate syllable/morpheme/word structure formation is acquired, the child's system should gradually approximate the adult's. (See Maxwell, 1981, chapter 6, for suggestions about the stages of constraints and rules that children might pass through in their phonological development.) A possible model based on the papers of Dinnsen, Elbert, and Weismer is shown in (13).

(13) Model based on Dinnsen, Elbert, and Weismer.



This model should be interpreted as allowing for the possibility of a child having either rules or constraints or both, or possibly neither.

One consequence of attempting by means of empirical criteria to establish defensible URs in misarticulating children's phonologies is that children with different systems may merit different remediation programs. That is, a child who needs to unlearn a rule of final consonant deletion may need different therapy than a child who needs to learn that it is both possible and distinctive to utter word-final consonants. Dinnsen, Elbert, Weismer, and Maxwell are attempting to distinguish different systems and to make testable claims about what a misarticulating system can and cannot be.

Smit

Smit's recent dissertation (1980) is another example of a study that used various kinds of linguistic evidence in support of claims about misarticulation phonologies and that concluded that some of the children studied may have had unique and only partially correct underlying representations.

Her very thorough study involved a group of "syllable-reducers" (children who consistently did not produce word-final obstruents or the /s/ in word-initial /s/ + stop clusters), a group of "substituters" (children who consistently substituted a different sound for an adult phoneme), a group of normal child controls, and a group of normal adult controls. Aspects of both speech perception and production of all groups were assessed; production analyses included spectrographic data of VOT and vowel durations.

Smit concluded that some of the syllable-reducers had only partially correct underlying representations. That is, for children who demonstrated appropriate vowel durations even in the absence of the word-final obstruent, or who marked all target voiceless obstruents with a glottal stop and all target voiced obstruents with a glide, Smit claimed they were demonstrating a knowledge of the adult feature of voice. She further claimed that to say these children knew any more than [+voice] about the target final obstruents was not defensible. Smit had perception task results available to her, but since there was no statistical correlation between the production and the perception results, they did not affect her position as just stated.

Smit, then, went into her investigation without the assumption of children having adult-like URs, and found some children with adult-appropriate URs and some with only partially "correct" URs.

Discussion

In summary, it has been suggested that advocates of Position 2 allow for the possibility of children having idiosyncratic nonadult URs. They maintain that empirical evidence must be brought to bear in support of claims about adult-like URs in child phonology; if such evidence is lacking, they would propose a concrete analysis based on production. Braine, Macken, and Kornfeld would claim that misperception is the cause of many "own-system" child URs which differ from adults'; Dinnsen et al. and Maxwell do not address the perception question; Smit found no correlation between perception and production, and largely based her claims on production evidence.

Allowing for different kinds of URs in child phonology makes a prediction about change in a child's system. As stated more clearly in Macken (1980), and in Dinnsen et al. (1979), different kinds of system change (e.g., across-the-board vs. piecemeal) should result if two children had different URs for the same word or words. This claim, which is applicable to both normal and misarticulating children, can be tested with controlled longitudinal studies.

Finally, it has been shown that the Position 2 approach encompasses the Position 1 approach; that is, proponents of Position 2 would posit adult URs for children, given proper empirical support. Position 1, however, completely excludes Position 2; the existence of nonadult URs is not allowed.

CONCLUSIONS

To conclude, a summary of the issues discussed in this paper and the supporters of those issues will be presented, followed by a discussion of an optimal model for child phonology.

The primary issue discussed above was that of the nature of underlying representations. The main supporters of the hypothesis that children's phonologies contain only adult-like URs were seen to be Smith, Stampe, Donegan and Stampe, Braine (1974), Menn, Ingram, and others. Supporters of the view that children can in some cases have unique URs were Braine (1976); Macken; Kornfeld and Goehl; Dinnsen, Elbert, and Weismer; Maxwell; Smit; and others. This chapter also discussed other topics around which child phonologists cluster: (a) perception as the cause of the discrepancy between adult and child phonologies, (b) the positing of phonotactic constraints, (c) the source of phonological processes, and (d) the use of empirical evidence to support claims about a child's system.

First, researchers who would claim that misperception is a major cause of the difference between children's and adults' phonologies include Kornfeld, Macken, Braine (1976), Ingram (1976b), and Smith (1978). Donegan and Stampe, Dinnsen et al., and Maxwell apparently have not treated the perception issue as a crucial one; Menn has assumed the acquisitional precedence of perception over production; and Smit investigated both perception and production experimentally and in some detail and did not ascribe a causal relationship between the two.

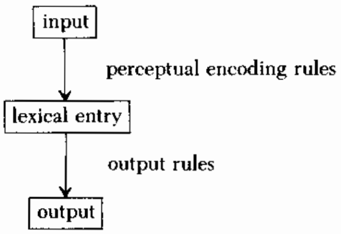
Second, Ingram (1976b), Menn, Dinnsen et al., and Maxwell all propose some type of phonotactic constraints to be included in a model of child phonology, but the types of constraints are substantively different from each other. Ingram's perceptual "conditions" (1976b, p. 6) are not appreciably different from his organizational or production rules, and are proposed to change from the perceptual to the organizational to the production level as a child progresses. Menn's phonotactics are a type of redundancy statement for the rule components: the constraints are summary statements of the effects of the rules reducing adult-like URs to the child's phonetic forms. Dinnsen et al.'s phonotactic constraints are proposed to hold at all levels of the phonology and are not rule-produced.

Third, different sources or causes of phonological processes have been proposed. Donegan and Stampe, and Ingram, claim that child phonological rules are natural, universal, and stem from a need to resolve phonetically "difficult" sound sequences. Dinnsen et al. would propose that children's rules are a part of their phonologies for the same "reasons" as rules existing in an adult's phonology, and would not claim a necessary phonetic etiology for the existence of the rules.

Finally, it was discussed above that the proponents of Position 1 are largely without either production or perception evidence to support their claims about child URs, whereas the majority of Position 2 proponents at least have production evidence that directly supports the phonologies they propose.

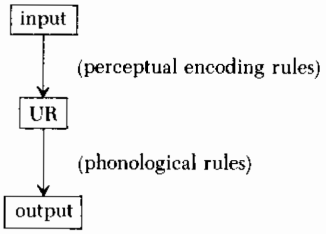
In conclusion, a discussion of an appropriate model of child phonology is in order. It is clear that any discrepancy between the acoustic input and the child's output must be accounted for. Macken's model, restated in (14), would appear to be the best solution to this problem; even it may need revisions, however.

(14) Model based on Macken (1980).



The two rule components of the model may be in some sort of complementary distribution for specific sounds or words. That is, if a sound is misperceived, it would be entered in the UR in its misperceived form, and "output" rules would not be necessary. If, however, there is evidence of a correct UR and some unique phonological rule, then the perceptual encoding rules would not be necessary. The phonological system of a child may contain both correct and incorrect URs, necessitating phonological (output) rules for some words and perceptual encoding rules for some words. Furthermore, even perceptual encoding rules may not be necessary in some instances of incorrect UR. If, for example, a child hears neither vowel length nor final consonants as distinctive, and never produces them, then that child may have a UR that is the same as his/her surface form, and there is simply a lack of perception. A final model, based on Macken, is shown in (15), where the parentheses indicate the possibility of the nonexistence of that type of rule for a particular child.

(15) Final model (after Macken, 1980).



This model should be interpreted as allowing for the possibility that neither type of rule applies—the "lack of perception" case just described. Future work, including both in-depth synchronic and longitudinal studies of child phonologies, should further clarify the issues discussed above, the accuracy of the model, and the various claims that are attempts to resolve the issues dealt with in this paper.

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Chapter 4
Acoustic Analysis Strategies for the Refinement of Phonological Analysis

Gary Weismer
University of Wisconsin–Madison

Several of the articles contained in this monograph describe the various strategies that can be employed for a phonological analysis of functional misarticulations in children. Presumably, many clinicians believe that the advantage of a *phonological* analysis, as compared to *traditional* analysis, is the specification of the sound *system* used by the child to produce meaningful utterances. This system will include, among other things, sound contrasts that are phonemic, phonotactic constraints, and those morphophonemic rules that specify the phonetic representation of certain phonemes in alternating forms of lexically related words. [See Chapter 2 (Dinnsen, 1984) for a review of these concepts.] If the aim of our analysis is to gain a real understanding of a child's sound system, we should have sensitive and reliable techniques that will permit the components of a phonology to be demonstrated. A time-honored approach to the description of phonemic, phonotactic, and morphophonemic components of a phonology involves auditory analysis of a corpus of utterances supplied by a speaker (*informant*, in the terminology of linguists); the record of this analysis is in the form of a phonetic transcription that, when combined with the knowledge of the speaker's intended utterances, can be examined in detail for evidence of phonemes, sound sequence constraints, and so forth. In many cases, this auditory analysis can provide a comprehensive view of a phonology, especially when the person performing the analysis is highly skilled in phonetic transcription. Even those persons less skilled in phonetic transcription—that is, those who can provide an adequate broad transcription but have difficulty with narrow transcription—can gain valuable information concerning the above-mentioned components of a phonology. For example, identification of many phonemes and morphophonemic rules, and certain sound sequence constraints, are easily extracted from a broad phonetic transcription.

There are many cases, however, in which a broad phonetic transcription may miss important aspects of a phonology. This is especially so when we are dealing with an unfamiliar language, or a familiar language that is more or less distorted by errors of sound production. An example of the former case is relevant here, and it points to the potential problems in obtaining an accurate view of a phonology in the latter case. When we, as speech-language pathologists, broadly transcribe the stops of a Korean speaker we would probably decide that these stops have a voicing opposition like that in English, namely, voiced-voiceless. A native speaker of Korean, however, would detect not two but three types of voicing for a given Korean stop. The three types of stop voicing revealed by narrow phonetic transcription would include (1) a voiced stop, that is, one involving vocal fold vibration during the closure interval, (2) a voiceless unaspirated stop for which voicing is absent during closure but begins almost immediately following stop release, and (3) a voiceless aspirated stop, for which voicing is absent during closure as well as a substantial interval (at least 30 milliseconds) following release of the stop. Even though there is a consistent and measurable phonetic difference between stops (1) and (2), the nonphonetician English-speaking listener will hear both as voiced because the phonetic difference is not phonemic in English.

Now consider the child who is seen for a speech-language evaluation, and whose stop productions are transcribed as exclusively voiced. These results might lead us to conclude that the child does not produce a voicing distinction for stops and, therefore, lacks a phonemic distinction for stops based on voicing. It may be the case, however, that the child is producing a very consistent distinction between our voiced and voiceless stops, but one unlike that used by "normal" speakers. If the child's distinction is finer than the sensitivity of the clinician's tool for detecting distinctions (that is, broad phonetic transcription), at least one component of the child's phonology will be misrepresented by the analysis.

This clinical scenario is more than hypothetical, for it has been demonstrated that certain children who sound as if they are producing only voiced stops are, in fact, producing phonetic distinctions to "mark" the voicing opposition for the word-initial stops. This research, which is described more fully below, takes advantage of acoustic analysis techniques capable of revealing phonetic distinctions that may be difficult to detect by auditory analysis.

The overall purpose of this chapter is to review these techniques and describe situations in which their application may potentially refine a phonological analysis of misarticulated speech. In addition, a brief review of the literature concerning acoustic studies of normally articulated speech in children is provided as a backdrop against which analysis of misarticulated speech can be interpreted.

ACOUSTICS STUDIES OF "NORMAL" SPEECH PRODUCTION IN CHILDREN

The acoustic study of speech production may involve a number of dimensions, some of which may be more relevant than others to the phonological evaluation of misarticulated speech. For example, acoustic analysis of a speech waveform could be focused on intensity, fundamental frequency (in the case of periodic waveforms), duration, and/or spectrum. Under the assumption that the highest-yield acoustic analysis of misarticulated speech is that which provides information about segmental articulation (that is, articulation of speech sounds), duration and spectrum would seem to supply the most valuable information. This is because the relations of these dimensions to segmental articulation are rather well understood, whereas the same cannot be said of intensity and fundamental frequency. The present review focuses, therefore, on temporal and spectral studies of children's speech, although we admit that further research might show intensity and fundamental frequency to have value in understanding a child's phonology. For the sake of brevity, the textual review emphasizes general findings and areas of knowledge rather than experimental details and issues of interpretations. Summary tables that include more specific details concerning the cited studies are provided for the interested reader. An excellent review of relevant work conducted prior to 1975 has been published by Kent (1976).

Temporal Studies

The measurement of speech sound durations in adult speech has been of interest because the data may bear on the physiological capabilities and limitations of the speech mechanism as well as certain aspects of phonology (for a review see Klatt, 1976). In recent years, investigators have asked to what extent children produce temporal characteristics of segments like those known to be produced by adults. The child research has been concerned with durations of vowels, singleton and clustered consonants, as well as the interval between the release of a stop consonant and the onset of vocal fold vibration [that is, voice-onset time (VOT)].

Research on children's vowel production (DiSimoni, 1974b; Kent & Forner, 1980; Krause, Fisher, & Wightman, 1978; Naeser, 1970; Raphael, Dorman, & Geffner, 1980; Smith, 1978; Weismer, Ellis, & Chicouris, 1979) suggests that children's vowel durations are longer and more variable than adult vowels. A summary of results from these investigations is provided in Table 1. It may be noted that the data from some investigations (e.g., DiSimoni, 1974b; Krause et al., 1978; Smith, 1978) indicate average vowel durations for children 2–6 years old that are much greater than those reported in other studies (Kent & Forner, 1980; Weismer et al., 1979). The latter investigations probably provide a better estimate of typical child vowel durations because the data are derived from connected, meaningful discourse, as compared to imitation and repetition of isolated words or nonsense materials. Note also in Table 1 the larger intrasubject standard deviations associated with child, as compared to adult, vowel durations (Kent & Forner, 1980). If the magnitude of a standard deviation is taken as an index of speech motor control (see Kent & Forner, 1980, and Weismer & Elbert, 1982), these variability data may indicate that children have somewhat poorer control over their speech mechanisms than do adults. This interpretation would seem appealing because similar, age-related variability differences are observed for consonant durations (Kent & Forner, 1980) and for nonspeech motor tasks as well (Eckert & Eichorn, 1977; Surwillo, 1971, 1977).

Children as young as 3 years of age also appear to produce vowel durations that show an adult-like sensitivity to the voicing feature of a following stop or fricative (Raphael et al., 1980). Because this sensitivity cannot be explained on physiological grounds alone (see Klatt, 1976, for relevant discussion), it seems as if children show at least one phonological influence (that is, sensitivity to voicing feature) in their phonetic repertoire as early as 3 years of age, if not earlier. The developmental course of this sensitivity is not well understood, however (compare DiSimoni, 1974b, to Krause et al., 1978), so additional research is needed to clarify the phenomenon. Other timing aspects of children's vowel production, including stress and speaking rate effects, as well as so-called "inherent" duration characteristics due to vocal tract openness and tenseness/laxness (Weismer et al., 1979), are poorly understood and thus also are good candidates for further inquiry.

Studies of consonant timing by children (DiSimoni, 1974a, 1974c; Hawkins, 1973, 1979; Kent & Forner, 1980; Smith, 1978; Weismer & Elbert, 1982) are summarized in Table 2. Like vowels, children's consonant durations tend to be longer and more variable than those of adults. Here, too, a variety of variables known to influence adult consonant durations have not been investigated systematically in child speakers (but see cluster research, below), and the available information on semivowels, nasals, fricatives, and affricates is incomplete. Relevant data are badly needed, especially for semivowels and fricatives, because members of these sound classes are often misarticulated by children with articulatory disorders.

A summary of data bearing on children's timing of clustered consonants (Gilbert & Purves, 1977; Hawkins, 1973, 1979; Weismer, unpublished data) is contained in Table 3. Typically, adults produce a clustered consonant in word-initial position with shorter duration than when the consonant is produced as a singleton (O'Shaugnessy, 1974). This appears to be true for all word-initial clusters in English, although stops in stop-liquid clusters may sometimes be slightly longer than their singleton counterparts. Whereas most of the child research shows a similar trend for clustered consonants to be shorter than singletons in the same word position (Gilbert & Purves, 1977; Weismer & Elbert, 1982), Hawkins's data (1973, 1979) indicate that some children may actually produce longer /s/ durations in /s/ + stop clusters. It is difficult to reconcile this finding with the data of Weismer and Elbert (1982), however, because only one of the 14 children studied produced longer /s/ durations in clustered as compared to singleton contexts.[1] In addition, the limited data on the developmental course of timing in consonant clusters (Gilbert & Purves, 1977) suggest that, at least from age 5 onward, there are few systematic ways in which the timing of consonant clusters differs as a function of age. The one exception to this trend may occur for stop-/l/ and fricative-/l/

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[1] Hawkins's (1973) data may be contaminated by measurement difficulties because several of the singleton stop durations reported in her tables [30–45 ms] are much too short to be considered as accurate estimates of stop-closure intervals.

TABLE 1. Summary of vowel duration data reported in literature. All values are reported in milliseconds (ms); bars above numbers indicate mean values.

Study	*Analysis type*	*Subjects*	*Task/Speech sample*	*Data*	*Comments*
Naeser (1970)	Oscillographic	Nine between 21 and 36 months	Spontaneous monosyllabic word production, and repetition of taped CVC words	$\overline{228}$–$\overline{396}$ for all vowels studied $\overline{264}$ before voiceless C $\overline{454}$ before voiced C (No variability data reported)	Vowel duration range is across a 10-month period, from approx. 21 to 36 months; data summarized here are from spontaneous task only; data from the repetition study tends to be slightly shorter than spontaneous productions. This report contains numerous tables of data.
DiSimoni (1974b)	Oscillographic	Ten 3-yr-old ($\bar{x}$ = 3;7) Ten 6-yr-old ($\bar{x}$ = 6;7) Ten 9-yr-old ($\bar{x}$ = 9;9)	Repetition of taped CVC nonsense words	Preceding [− voice]C / Preceding [+ voice]C 3 yr: $\overline{231}$ (278) / $\overline{411}$ (306) 6 yr: $\overline{217}$ (264) / $\overline{492}$ (244) 9 yr: $\overline{226}$ (118) / $\overline{514}$ (99)	This study also found that vowels preceding fricatives were longer than vowels preceding stops; values in parentheses are intersubject (group) standard deviations.
Krause et al. (1978)	Spectrographic	Ten 3-yr-old Ten 6-yr-old Ten 9-yr-old	Monosyllabic test words, elicited by picture-naming	Preceding [− voice]C / Preceding [+ voice]C 3 yr: $\overline{185}$ / $\overline{319}$ 6 yr: $\overline{204}$ / $\overline{304}$ 9 yr: $\overline{208}$ / $\overline{269}$ (No variability data reported)	Vowel duration data extrapolated from Figure 7 in Krause et al.
Smith (1978)	Oscillographic	Ten between 2:9 and 2:11 Ten between 4:1 and 4:7 Ten adults 23–40	Nonsense mono- and disyllables repeated after live-voice model	Range 2:9–2:11 yr: $\overline{170}$–$\overline{410}$ 4:1–4:7 yr: $\overline{147}$–$\overline{374}$ Adults: $\overline{123}$–$\overline{326}$ (No variability data reported)	Variability within reported ranges is due to syllables, stress, and phonetic context (see Table 2, p. 49).
Weismer et al. (1979)	Spectrographic	One 3:6	Spontaneous speech	Range Nonprepausal: $\overline{97}$–$\overline{160}$ [30–65] Prepausal: $\overline{120}$–$\overline{210}$ [46–127]	Data are pooled across vowels and following voicing contexts.
Raphael et al. (1980)	Spectrographic	Nine 3-yr-old Eleven 4-yr-old	Object/action naming minimal pairs such as *rope-robe*	Preceding [− voice]C / Preceding [+ voice]C $\overline{100}$–$\overline{228}$ / $\overline{196}$–$\overline{325}$ (No variability data reported)	Data are pooled across age groups. On average, vowels preceding voiced stops are 91 ms longer than vowels preceding voiceless stops.
Kent & Forner (1980)	Spectrographic	Ten 4-yr-old Ten 6-yr-old Ten 12-yr-old Adults	Sentence recitations (e.g., "The box is blue and red")	4 yr: $\overline{172}$ (80) [9–50, $\overline{27}$] 6 yr: $\overline{165}$ (50) [5–37, $\overline{16}$] Adult: $\overline{131}$ (22) [5–13, $\overline{7}$]	Data derived from graphs; data in parentheses are intersubject (group) standard deviations, data in brackets are ranges and means of intrasubject standard deviations. Note that these data are for the vowel [a] in "box."

clusters, for which adult-like timing patterns are not achieved until 11 years of age.

Finally, the well-known interval voice-onset time (VOT) has probably received more research attention than any other phonetic interval in children's speech. Data from relevant studies (Barton & Macken, 1980; Eguchi & Hirsh, 1969; Gilbert, 1977; Kent & Forner, 1980; Kewley-Port & Preston, 1974; Macken & Barton, 1980; Menyuk & Klatt, 1975; Zlatin & Koenigsknecht, 1976) are summarized in Table 4. Consistent with the data on vowels, consonants, and consonant clusters, children's VOTs tend to be more variable than those of adults. There seems to be a wide range across studies of absolute VOTs, especially in the case of voiceless stops (compare the data of Gilbert, 1977, to that of Eguchi & Hirsh, 1969). Some of the variation in VOT values across studies is due to speech task differences, and possibly to differences in measurement criteria, but these factors cannot explain the unusually large values reported by Gilbert (1977; cf. Barton & Macken, 1980, pp. 167–168, for related discussion).

One of the interesting aspects of the VOT phenomenon concerns the manner in which children learn to produce voiced and voiceless stops with unique VOT values. When measured from spectrograms or oscillograms, VOT is the time interval between the stop burst and the initial glottal pulse of the following vowel. Characteristically, adults produce voiced stops with VOTs in the 0–20 ms range, whereas voiceless stops have VOTs ranging between 50 and 80 ms.[2] There is general agreement (Kewley-Port & Preston, 1974; Macken & Barton, 1980; Zlatin & Koenigsknecht, 1976) that children's early stop productions are consistently characterized by short and undifferentiated VOTs for both voiced and voiceless stops. The manner in which this phonetic pattern is modified toward the adult-like VOT pattern, however, appears to be the subject of some controversy. Zlatin and Koenigsknecht (1976) have claimed, for example, that the developmental change from undifferentiated to adult-like VOT values involves a continuous lengthening of VOT from short to long values for voiceless stop targets. The data of Macken and Barton (1980) suggest a somewhat different situation, whereby VOTs for voiced and voiceless stops are initially distinguished by a continuous lengthening for voiceless targets, followed by a discrete change of voiceless VOT to rather long values. More specifically, Macken and Barton (1980) have proposed a three-stage model of VOT acquisition, which can be summarized as follows:

Stage I:	VOTs for both voiced and voiceless stops are short and thus in the region usually appropriate for voiced stops; statistically, the average values for voiced and voiceless target stops are not significantly different.
Stage II:	VOTs for both voiced and voiceless stops are in the region usually appropriate for voiced stops, but are at opposite ends of the voiced range; statistically, the average values for voiced and voiceless target stops are significantly different.
Stage III:	VOTs for voiced stops are short, and VOTs for voiceless stops are long, approximating adult VOT values for the voicing contrast; there may actually be some "overshoot" of average adult VOTs for voiceless stops, resulting in some unusually long (greater than 100 ms) VOTs.

Stage II is perhaps the most interesting phase of this developmental sequence because the children are making a systematic voicing distinction for stops, but not the one used by adults. Most importantly, the Stage II distinction is apparently not perceptible to the majority of adults because VOTs for both voiced and voiceless stops fall into the range associated with voiced stops in the adult linguistic community (see Macken & Barton, 1977, p. 111, and the section below entitled "Phonological Analysis Supplemented by Acoustic Analysis"). If we are confronted with a child in Macken and Barton's Stage II, therefore, we are faced with a problem very similar to the one described earlier in which our Korean speaker produces a contrast that we do not "hear."

Spectral Studies

The literature dealing with spectral characteristics of children's speech sounds is not extensive, and studies that have been reported (Bennett, 1981; Dalston, 1975; Daniloff, Wilcox, & Stephens, 1980; Eguchi & Hirsh, 1969; Kent, 1978; Kent & Forner, 1979; Pentz, Gilbert, & Zawadski, 1979; Weismer, Elbert, & Whiteside, 1980) have been concerned primarily with static spectral characteristics only. There are virtually no published data concerning context-conditioned effects on speech-sound spectra, or on dynamic spectral characteristics in children's speech production.

Studies of vowel production (Bennett, 1981; Eguchi & Hirsh, 1969; Kent, 1978; Kent & Forner, 1979) typically find increasingly lower formant frequencies as children get older (see Kent, 1979, for a review of these relationships). This trend is presumed to be related largely to growth of the vocal tract, as longer "tubes" are known to be characterized by lower resonant frequencies. Given the relationship between vocal tract length and vowel formant frequencies, it is no surprise that children have substantially higher formant frequencies than adults. The actual differences between the formant frequencies of children and adults are very dependent on the particular vowel and, in fact, on the formant *number* within a vowel. There is, therefore, no constant transformation that can be applied to adults' formant frequencies to predict corresponding formant data in children accurately. There is also some recent evidence (Bennett, 1981) that prepubescent children above the age of 7 years may show sex-related differences in formant frequencies, although not of the same magnitude as seen in adults.

The studies cited above also have shown that children's production of vowel formant frequencies is, like the temporal dimension of speech sounds, more variable than adult production. This variability difference also seems to apply to fricative spectra (Pentz et al., 1979; Weismer et al., 1980), wherein the location of major aperiodic energy is less stable in child productions.

Dalston's (1975) investigation of /w/, /r/, and /l/ production has provided a limited amount of dynamic acoustic data on children's speech. These sounds have vocalic-like formant structures (see Figure 11 and associated discussion), and are char-

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[2] These VOT ranges should be considered as appropriate for prestressed stops (stops preceding the vowel of a stressed syllable) spoken in connected speech at a conversational speaking rate. VOT values for voiced or voiceless stops may fall outside the stated ranges under certain conditions.

TABLE 2. Summary of consonant duration data reported in literature. All values are reported in milliseconds (ms); bars above numbers indicate mean values.

Study	Analysis type	Subject	Task/Speech sample	Data				Comments
Hawkins (1973)	Oscillographic	Seven between 4 and 7 yrs	Single words preceded by schwa; limited data on short phrases		Word-initial	Word-final		Speakers of British English used in this study. All durations are derived from the /ɪ/ vowel context, with the exception of word-final/p/ which is data for all vowel contexts. Each mean in the ranges is for a particular speaker; the low range values for word-initial /p/ and /t/ are almost certainly in error, as nonflap stops are typically produced with durations no shorter than 60 ms. This paper contains numerous tables of data; see Hawkins (1979) for a follow-up study.
				w	$\overline{87}$–$\overline{124}$			
				l	$\overline{103}$–$\overline{141}$	$\overline{143}$–$\overline{267}$		
				f	$\overline{122}$–$\overline{205}$	$\overline{186}$–$\overline{337}$		
				s	$\overline{166}$–$\overline{200}$	$\overline{157}$–$\overline{356}$		
				p	$\overline{37}$–$\overline{118}$	$\overline{45}$–$\overline{193}$		
				t	$\overline{34}$–$\overline{126}$	$\overline{50}$–$\overline{170}$		
					(No variability data reported)			
DiSimoni (1974a)	Oscillographic	Ten 3-yr-old Ten 6-yr-old Ten 9-yr-old	Imitation of taped nonsense VCV disyllables where C = /s/		/s/ duration			Duration and intersubject (group) standard deviations (in parentheses) are derived from DiSimoni's Figure 1, p. 360.
				3 yr	$\overline{222}$ (80)			
				6 yr	$\overline{183}$ (73)			
				9 yr	$\overline{179}$ (64)			
DiSimoni (1974c)	Oscillographic	Ten 3-yr-old Ten 6-yr-old Ten 9-yr-old	Imitation of taped nonsense VCV disyllables where C = /p/; VCVs produced both isolated and in short carrier phrase		Isolated	In phrase		Duration and intersubject (group) standard deviations (in parentheses) are derived from DiSimoni's Figure 1, p. 1353. Note the large effects on /p/ durations and variability of "speaking mode" (isolated vs. phrasal production).
				3 yr	$\overline{188}$ (242)	$\overline{152}$ (128)		
				6 yr	$\overline{144}$ (126)	$\overline{98}$ (68)		
				9 yr	$\overline{106}$ (46)	$\overline{80}$ (38)		
Gilbert & Purves (1977)	Oscillographic	Five each between 5:0 and 5:6 7:0 and 7:6 9:0 and 9:6 11:0 and 11:6 23 and 28 (Total = 25 subjects)	Imitation of monosyllabic words (CVC) in short phrase		/s/	/f/	/l/	Data in parentheses are intersubject (group) standard deviations.
				5:0–5:6	$\overline{195}$ (42)	$\overline{167}$ (52)	$\overline{95}$ (42)	
				7:0–7:6	$\overline{196}$ (38)	$\overline{162}$ (34)	$\overline{87}$ (21)	
				9:0–9:6	$\overline{169}$ (29)	$\overline{151}$ (39)	$\overline{77}$ (22)	
				11:0–11:6	$\overline{166}$ (31)	$\overline{149}$ (32)	$\overline{70}$ (24)	
				Adult	$\overline{167}$ (26)	$\overline{143}$ (37)	$\overline{84}$ (19)	
Smith (1978)	Oscillographic	Ten between 2:9 and 2:11 Ten between 4:1 and 4:7 Ten between 23 and 40	Imitation of mono- and disyllabic nonsense syllables		Range across contexts			Values taken from Smith's Table II (p. 49). These are group ranges, across stress location, segments (/b/, /d/, or /t/), and position-in-syllable. Unstressed /d/ yields shortest durations for all groups; word-final /t/ yields longest durations for all groups. "Word" variability data are reported in Smith's Table I.
				2:9–2:11	$\overline{81}$–$\overline{212}$			
				4:1–4:7	$\overline{66}$–$\overline{195}$			
				Adults	$\overline{65}$–$\overline{120}$			
					(No variability data reported for segments)			

Kent & Forner (1980)	Spectrographic	Ten 4-yr-old Ten 6-yr-old Ten 12-yr-old Adult	Sentence recitations (e.g., "The box is blue and red")	 4 yr 6 yr Adult	/k/ data $\overline{83}$ (54) [5–28, $\overline{17}$] $\overline{67}$ (28) [5–26, $\overline{15}$] $\overline{58}$ (20) [1–20, $\overline{8}$]	Data derived from graphs; data in parentheses are intersubject (group) standard deviations, data in brackets are ranges and means of intrasubject standard deviations. These data are for the [k] in "box."
Weismer & Elbert (1982)	Oscillographic	Seven normally articulating between 4:3 and 5:6 Seven misarticulating between 4:3 and 6:0 Seven between 22 and 35	Imitation of recorded speech; carrier-phrase followed by nonsense monosyllables and disyllables with /s/ and /s/ + stop clusters	 Norm. artic. children Adults	/s/ data $\overline{229}$ (30–38) [18–36, $\overline{25}$] $\overline{205}$ (25–27) [11–26, $\overline{17}$]	Mean data is pooled across vowel contexts, and intersubject (group) standard deviations are reported as a range across four vowel contexts. Range and means of intrasubject standard deviations are in brackets. Data not given here for /s/-misarticulating children.

acterized by rapid changes in formant frequencies as a function of time. These rapid changes were quantified by Dalston by use of the measure ***transition rate***, which is an index of the speed with which a formant frequency changes. Dalston's data indicate that preschool children have somewhat slower transition rates than adults, which suggests slower articulatory movements for these sounds. Additional research of this kind is needed to understand better the dynamic characteristics of children's articulatory performance.

PHONOLOGICAL ANALYSIS SUPPLEMENTED BY ACOUSTIC ANALYSIS

To date, there have been only a few attempts to supplement phonological analysis of misarticulated speech with acoustic analysis. The available data are reviewed below, together with some examples and observations concerning the measurement of child speech waveforms.

Omission of Final Consonants

Most speech-language pathologists are familiar with the problem of final consonant omission among children with articulatory disorders. Within the framework of traditional descriptions of articulatory disorders (Darley, 1978; Prins, 1963), this particular problem is typically labeled only as *sound omission*, which implies that a child presenting such a speech pattern simply does not produce a sound found in the "normal" version of the articulatory sequence. Consideration of some literature dealing with normal articulatory development, however (Naeser, 1970; N. V. Smith, 1973; Velten, 1943), suggests that children may actually produce a phonetic distinction when the "normal" phonemic distinction is apparently omitted. For example, Velten's (1943) phonetic analysis of his child's speech indicated that the words *back* and *bad* were distinguished solely by vowel length (that is, [bæt] vs. [bæːt]). Velten's observation (as well as those of Naeser, 1970, and N. V. Smith, 1973) is intriguing because it is well known that when English-speaking adults produce minimal pairs such as *bat-bad* they do so with greater vowel duration preceding the voiced stop (Chen, 1970; Klatt, 1975b). Moreover, the same phonetic effect was identified in experiments using normally articulating child speakers as young as 3 years of age (Raphael, Dorman, & Geffner, 1980; B. L. Smith, 1978). It might be reasoned, therefore, that some children whose speech was characterized by omission of final consonants as a clinical entity may, in fact, "know" more about the missing sounds than the description of "omission" would imply.

Data relevant to this issue were obtained by eliciting appropriate minimal pairs (e.g., /kæp/-/kæb/), in isolation and sentential contexts, from three children who were each diagnosed in a speech and hearing clinic as having "omission of final consonants" as one component of an articulatory disorder (see Weismer, Dinnsen, & Elbert, 1981). Data have also been collected under the same conditions for two additional children whose results have not been reported previously.

The measurement of interest in these studies was the vowel duration preceding the "omitted" stop. All measurements were

TABLE 3. Summary of cluster data reported in literature. Data reported as mean percentage duration change from singleton to clustered contexts. Minus values indicate that the clustered segment was shorter than the singleton segment; plus values indicate the opposite.

<table>
<tr><th><i>Study</i></th><th><i>Analysis type</i></th><th><i>Subjects</i></th><th><i>Task/Speech sample</i></th><th><i>Data</i></th><th><i>Comments</i></th></tr>
<tr><td>Hawkins (1973)</td><td>Oscillographic</td><td>Seven between 4 and 7 yrs</td><td>Single words preceded by schwa; limited data on short phrases</td><td>
<table>
<tr><th colspan="2">Mean % duration change from singleton to cluster</th></tr>
<tr><td>/s/ → /st/</td><td>−19 to +18</td></tr>
<tr><td>/t/ → /st/</td><td>−44 to +55</td></tr>
<tr><td>/s/ → /spr/, /str/</td><td>−19 to +30</td></tr>
<tr><td>/t/ → /str/</td><td>−36 to +88</td></tr>
<tr><td>/p/ → /spr/</td><td>−24 to +165</td></tr>
</table>
</td><td>Each value in the range of "% duration change" is for a single subject, so there are typically seven values per range. In /st/ clusters, three of the seven subjects produced longer clustered than singleton /s/, whereas data collected by Weismer (unpublished) show that all normally articulating children produce shorter /s/ in clusters (see below).</td></tr>
<tr><td>Gilbert & Purves (1977)</td><td>Oscillographic</td><td>Five each between
5:0 and 5:6
7:0 and 7:6
9:0 and 9:6
11:0 and 11:6
23 and 28
(Total = 25 subjects)</td><td>Imitation of monosyllabic words [(C)CVC] in short phrase</td><td>
<table>
<tr><th colspan="5">Mean % duration change from singleton to cluster</th></tr>
<tr><th></th><th>/s/ in /sl/</th><th>/l/ in /sl/</th><th>/f/ in /fl/</th><th>/l/ in /fl/</th></tr>
<tr><td>5 yr</td><td>−18</td><td>+22</td><td>−2</td><td>+14</td></tr>
<tr><td>7 yr</td><td>−12</td><td>+8</td><td>−12</td><td>+3</td></tr>
<tr><td>9 yr</td><td>−15</td><td>0</td><td>−20</td><td>+5</td></tr>
<tr><td>11 yr</td><td>−20</td><td>−3</td><td>−21</td><td>−10</td></tr>
<tr><td>Adult</td><td>−19</td><td>−14</td><td>−17</td><td>−18</td></tr>
</table>
</td><td>Note that all fricatives in clusters show shortening trends, and that clustered /l/ is shortened only by the 11-yr and adult groups. Group variability data indicate smaller standard deviations for older age groups for both singleton and clustered segments.</td></tr>
<tr><td>Weismer (unpublished)</td><td>Oscillographic</td><td>Seven between 4:3 and 5:6
Seven adults</td><td>Imitation of recorded speech; carrier phrase followed by nonsense monosyllables with /s/ and /s/ + stop clusters</td><td>
<table>
<tr><th colspan="3">Mean % duration change from singleton to cluster</th></tr>
<tr><th></th><th>/s/</th><th>/t, k/</th></tr>
<tr><td>Children</td><td>−38 to −14</td><td>−31 to +25</td></tr>
<tr><td>Adults</td><td>−36 to −4</td><td>−43 to −20</td></tr>
</table>
</td><td>Each value in the range of "% duration change" is for a single subject, so there are seven values per range. Note that no child subjects produce longer /s/ durations in clusters; two child subjects produce longer stop durations in clusters, and the remaining five subjects produce reductions in clustered stop durations of between 2 and 25% of the singleton stop durations.</td></tr>
</table>

made by examining oscillographic displays of speech waveforms and applying measurement rules to locate the onset and offset of the vowels. These rules, it should be noted, are only operational definitions that can be applied across different speech samples with some degree of consistency and that presumably would allow other investigators to replicate the measurement strategies with a minimum of ambiguity. The rules are not meant to designate the true beginnings and endings of vowels in children's speech. Note that the location of operationally defined boundaries often does involve some subjectivity, because the designated feature may not show clearly in a given speech waveform (see Allen, 1978). The potential for subjectivity in the application of measurement rules is apparently greater for child than adult speech waveforms, as shown by Weismer et al. (1981) and Weismer and Elbert (1982).

Several typical speech waveforms generated by children and adults are shown in Figure 1 (A–F). These are all waveforms of open syllables (i.e., CV syllables), which, in the case of children, were misarticulated forms of CVC target words (e.g., [bi] for "beat," [pɑ] for "pop," and [tɑ] for "top"), and in the case of adults were intended as open syllable productions. The operational definitions of vowel onset and offset were as follows:

Onset: The release (burst) of the word-initial stop, as indicated by a transient-like deflection from the waveform baseline.

Offset: The final glottal pulse of the vowel in the target word, as indicated by the final quasi-periodic waveshape in the oscillographic display.

The application of these measurement rules to the speech waveforms shown in Figure 1 is indicated by arrows pointing to the operationalized boundaries. In most cases, the onset rule is easy to apply because word-initial stop consonants usually have clearly defined release bursts. When voiced stops have a substantial amount of prevoicing (vocal fold vibration during the closure interval) the vowel onset is most reliably located at the point in the waveform where a sudden increase in quasi-periodic energy is observed. This type of onset identification is exemplified by the waveforms in panels (B) and (E) of Figure 1. In the case of voiceless stops, the designated onset will be followed by a brief interval of aperiodic energy, which is often referred to as the "aspirated" portion of a voiceless stop; this pattern is illustrated in panels (C), (D), and (F) of Figure 1.

The application of the offset rule, however, can involve a considerably greater degree of subjectivity because it is not always obvious which feature of the waveform display should be taken as "the final glottal pulse of the vowel." For example, in Figure 1 (A, C, D) the child speech waveforms are characterized by a substantial amount of aperiodic energy toward the end of the vowel; the indicated offsets are based on best estimates of the final periodic waveshape in the display. It is obvious that the adult, open-syllable waveforms in Figure 1 (E, F) are not characterized by noisy signals, and that the offset boundary can be located by an unambiguous application of the offset rule. In our own investigations, we have noticed that noisy vowel waveforms are much more frequent among children than adults.[3] Thus, one would expect greater difficulty in locating an offset glottal pulse for child than for adult speech waveforms. This has been confirmed empirically by Weismer et al. (1981).

Table 5 contains the vowel duration data from Weismer et al. (Subjects A, B, and C) as well as from two additional subjects (D and E). Although each subject produced 30 versions of words ending in both voiced and voiceless stops, the means reported in Table 5 are based only on those items that were unanimously judged by three speech-language pathologists as having omitted word-final stops. The data in Table 5 are based on test words that were produced imitatively by the children at the end of short, multisyllabic utterances such as "He's a nice kid" and "He drives a cab" (see Weismer et al., 1981, p. 327). As these data show, some children do show a clear vowel duration sensitivity to the voicing characteristics of the final stop even though the final stop is omitted. This is an intriguing finding, for it suggests that some children who have "missing" final consonants as part of their clinical profile may not, in fact, be missing all of the final consonant (see below, "Omission of Final Stops: Spectral Features"). In other words, a description of this articulation problem as "omission of final consonants" fails to attribute any knowledge of the word-final consonant to the child. Such a description, in the absence of the acoustic analysis of vowel durations, would therefore misrepresent the sound contrasts that characterize the phonologies of children like Subjects A, B, D, and E in Table 5.

The vowel duration data in Table 5 may help refine another level of phonological description, wherein phonological rules are hypothesized to be responsible for the missing final consonants. In the present case, some phonological analyses (e.g., Ingram, 1976) would describe the phonologies of all children with missing final consonants as being characterized by a rule of final consonant deletion. In these analyses, the rule is thought to operate on the adult target form which, in turn, is assumed to be the child's underlying form (see Dinnsen, 1984). As we have argued elsewhere (Weismer et al., 1981), there is no a-priori reason to assume that adult word forms are the child's underlying forms (see also Menn, 1980; Straight, 1980); one alternative is to employ the techniques of standard generative phonology (Kenstowicz & Kisseberth, 1979) and provide empirical demonstration of the child's underlying phonological forms. When these phonological analysis techniques are combined with the kinds of vowel duration data presented in Table 5, an interesting view emerges of the possible relationship between phonology and phonetics. Specifically, if a child who omits word-final consonants provides independent evidence of the correct underlying form for the missing consonant (via morphophonemic alternations: see Dinnsen, 1984), then it must be argued that the child has some knowledge concerning that missing consonant. Given this knowledge, perhaps it is not too surprising that certain children show some sensitivity to certain characteristics of the omitted consonant. One such characteristic could be voicing, and the sensitivity to this characteristic could be reflected by the kinds of systematic differences in vowel duration reported in Table 5. As discussed by Maxwell (1981), this is very possibly a case of *incomplete neutralization,* wherein a phonological rule that deletes word-final stops apparently eliminates part but not all of a word-final consonant contrast. Such incomplete neutralization of a contrast by rule would be difficult to detect by auditory analysis alone; moreover, the acoustical demonstration of partial neutralization for children

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[3] This may reflect age-related differences in efficiency of glottal closure for vowel-like sounds. Detailed consideration of this issue is beyond the scope of this report.

TABLE 4. Summary of voice-onset time (VOT) data reported in literature. All values are reported in milliseconds (ms); bars above numbers indicate mean values.

Study	*Analysis type*	*Subjects*	*Task/Speech samples*	*Data*	*Comments*
Eguchi & Hirsh (1969)	Spectrographic	84 between ages of 3 and 13 yrs; approx. 9 to 10 subjects per year	Sentence recitation	Ranges p $\overline{49}$–$\overline{68}$ [10–26] t $\overline{60}$–$\overline{84}$ [10–29]	No significant differences as a function of age, so data ranges given here are across age. Data in brackets give ranges across age for intrasubject standard deviations; a definite trend exists for smaller standard deviations to be associated with older subjects (Figure 12, page 29).
Kewley-Port & Preston (1974)	Spectrographic	Three between approx. 0:8 and 2:6 (see comments)	Spontaneous vocalizations		Apical stops analyzed; the majority of children's productions fall into the 0-to-20-ms range. Specifically, 64% of children's productions have VOTs less than +20 ms, 31% have VOTs greater than +30 ms. By age 2 yrs, two of the children had more than 50% of apical stops in the "adult" VOT range (that is, greater than +30 ms).
Menyuk & Klatt (1975)	Spectrographic	Eleven between ages of 3:3 and 4:6	Isolated words and words in sentences	Singletons: Ch., Ad.; Clusters: Ch., Ad. b $\overline{23}$ $\overline{12}$ $\overline{27}$ $\overline{18}$ d $\overline{15}$ $\overline{15}$ $\overline{46}$ $\overline{31}$ g $\overline{15}$ $\overline{23}$ $\overline{45}$ $\overline{34}$ p $\overline{68}$ $\overline{34}$ $\overline{102}$ $\overline{65}$ t $\overline{56}$ $\overline{60}$ $\overline{118}$ $\overline{100}$ k $\overline{80}$ $\overline{64}$ $\overline{118}$ $\overline{97}$ (No variability data reported)	Clusters investigated are all stop + liquid, stop + glide, and stop + retroflex. The increase in VOT from singleton to clustered contexts reported here does not apply to some other clusters, such as /s/ + stop clusters. Whereas no tabled variability data are reported, the authors have noted that the data are characterized by great variability, and their Figure 3 (p. 228) is an excellent source of individual subject data and variability.
Zlatin & Koenigsknecht (1976)	Spectrographic	Ten 2-yr-old (2:6–3:0) Ten 6-yr-old (6:1–6:11) Twenty adult (23:7–40:1)	Isolated words, children naming pictures, and adults reading lists	2 yr old; 6 yr old b $-\overline{11}$ (11), $\overline{6}$ (16); $-\overline{4}$ (34), $-\overline{3}$ (24) d $\overline{11}$ (12); $\overline{12}$ (20) g $\overline{21}$ (14); $\overline{19}$ (27) p $\overline{69}$ (36), $\overline{65}$ (35); $\overline{76}$ (25), $\overline{68}$ (26) t $\overline{69}$ (33); $\overline{68}$ (23) k $\overline{80}$ (34); $\overline{80}$ (25)	Data in parentheses are intersubject (group) standard deviations; no intrasubject standard deviations are reported. Although not included here, their adult VOT data show greater values than their child data, a finding at odds with other investigations which typically show longer values for children, especially for voiceless stops.

Gilbert (1977)	Spectrographic	Six between 2:7 and 3:3	Spontaneous speech	d	$\overline{29}$ (19)				Highly selective processing of data, resulting in a very small number of tokens per subject. Analysis was performed by running tape into spectrograph at half-speed; the unusually large VOT values (especially for /t/) may have resulted from a failure to divide the measurements by two, since their means divided in half look very similar to other VOT data on 3-year-olds.
				t	$\overline{140}$ (63)				
Hawkins (1979)	Oscillographic	Seven between 3:10 and 8:3	Isolated nonsense syllables		Child	Adult			Results show larger group standard deviations for child than for adult data.
				p	$\overline{63}$				
				t	$\overline{97}$				
				k	$\overline{87}$				
				pr, pl	$\overline{89}$, $\overline{78}$	$\overline{51}$, $\overline{58}$			
				kr, kl	$\overline{97}$, $\overline{88}$	$\overline{77}$, $\overline{68}$			
				tr	$\overline{124}$	$\overline{104}$			
				str	$\overline{44}$	$\overline{43}$			
Macken & Barton (1980)	Spectrographic and oscillographic	Four between 1:5 and 2:4 (see comments)	Spontaneous speech		Initial sampling pd.		Final sampling pd.		Ranges given for means and intrasubject standard deviations (in brackets) are across the four children (that is, four values per range). These are longitudinal data, over an 8-month sampling period, summarized here by data from the first and last sampling points from that period. At the last sampling period, only one of the four subjects was still producing voiceless stops in the "short-lag" range, which accounts for the low range values of 8, 0, and 20 ms for /p/, /t/, and /k/, respectively.
				b	−$\overline{14}$–$\overline{4}$	[13–36]	−$\overline{11}$–$\overline{13}$	[5–38]	
				d	$\overline{2}$–$\overline{25}$	[6–12]	$\overline{3}$–$\overline{17}$	[4–36]	
				g	$\overline{13}$–$\overline{29}$	[4–9]	$\overline{12}$–$\overline{54}$	[9–60]	
				p	−$\overline{2}$–$\overline{40}$	[7–26]	$\overline{8}$–$\overline{93}$	[9–48]	
				t	$\overline{11}$–$\overline{47}$	[7–40]	$\overline{0}$–$\overline{109}$	[21–69]	
				k	$\overline{20}$–$\overline{60}$	[12–36]	$\overline{20}$–$\overline{126}$	[13–74]	
Barton & Macken (1980)	Spectrographic and oscillographic	Four between 3:10 and 4:2	Spontaneous speech	b	$\overline{3}$ (29)	[5–48]			Group standard deviations are in parentheses, and ranges of intrasubject standard deviations are in brackets. Children tend to show longer VOTs in isolated words than in sentences. When these data are compared to adult data, the child VOTs are longer.
				d	$\overline{17}$ (12)	[9–13]			
				g	$\overline{20}$ (22)	[7–38]			
				p	$\overline{75}$ (36)	[32–43]			
				t	$\overline{79}$ (44)	[32–57]			
				k	$\overline{86}$ (39)	[22–54]			
Kent & Forner (1980)	Spectrographic	Ten 4-yr-old Ten 6-yr-old Ten 12-yr-old Adults	Sentence recitations (e.g., "I saw you hit the cat")		/t/	/k/	/b/		Data derived from graphs, data in parentheses are intersubject (group) standard deviations, data in brackets are ranges and means of intrasubject standard deviations.
				4 yr	39 (18) [5–20, $\overline{11}$]	73 (99) [9–67, $\overline{28}$]	29 (28) [1–22, $\overline{14}$]		
				6 yr	34 (17) [1–22, $\overline{10}$]	49 (32) [9–36, $\overline{21}$]	24 (20) [4–23, $\overline{11}$]		
				12 yr	39 (26) [1–10, $\overline{6}$]	45 (34) [4–17, $\overline{11}$]	Not reported		
				Adult	39 (20) [4–17, $\overline{7}$]	40 (20) [0–11, $\overline{7}$]	14 (18) [1–14, $\overline{8}$]		

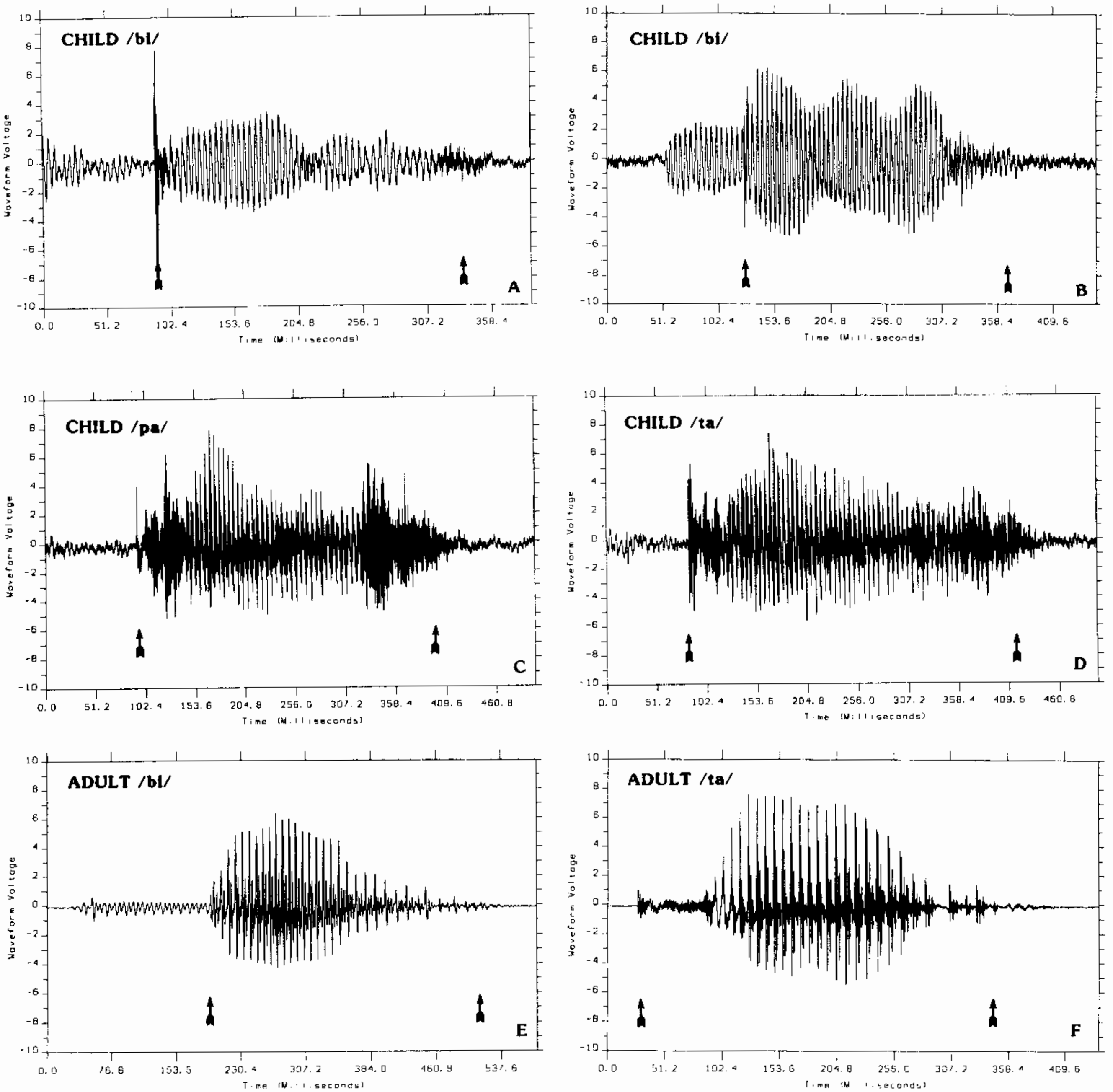

FIGURE 1. A series of oscillograms showing the acoustic waveforms corresponding to child and adult productions of open (CV) syllables. In each panel, the vowel onset and offset boundaries are indicated by the left- and right-hand arrows, respectively. Note that whereas the time divisions along the abscissa are indicated in steps of 51.2 ms for each panel, the scale factor for those steps varies slightly from panel to panel. The two examples of child /bi/ (panels A and B) were produced by two different children; panels C and D were produced by a third child. Panels E and F were produced by the author.

such as Subjects A, B, D, and E (Table 5) dovetails nicely with their ability to produce the missing word-final consonants in inflected forms (e.g., [dɔ] ~ [dɔgi]). The inflected productions provide evidence of the correct underlying form, which implies that the form is accessible to (i.e., can be recovered by) the child. The "recoverability" of the correct underlying form is supported in turn by the phonetic evidence of sensitivity to some characteristic of the phoneme in question. Other examples of partial neutralization of voicing contrasts have been reported recently by Smit and Bernthal (1983) and Catts and Jensen (1983).

It may not always be the case, however, that a child will provide evidence of having an appropriate phonological form. In standard phonological analysis, when a speaker omits word-final consonants and fails to produce those consonants in grammatical inflections, the correct underlying forms for word-final consonants are said to be missing from his/her phonology. This situation has some interesting implications, for if the underlying form is absent from the phonology, partial neutralization is logically impossible. Thus, a child whose inflections do not include production of the consonant that is omitted in word-final position should not be expected to produce different vowel durations according to the voicing of the (omitted) final consonant. The data in Table 5 for Child C are relevant here, because this child never produced a postvocalic consonant in morphophonemic alternations (Weismer et al., 1981). As predicted by the failure to demonstrate underlying forms for word-final consonants, this child did not produce a systematic difference in vowel duration dependent on the voicing of the (omitted) following consonant.

These examples provide one demonstration of how acoustic analysis can aid in phonological analysis, and how certain predictions from an auditory phonological analysis may be evaluated by acoustic techniques. It should be pointed out that this particular acoustic analysis may not always provide clarification or verification of phonological analysis, nor is it the only way in which acoustic analysis may be applied to omission of final consonants. The former and latter considerations may very well be related, as is illustrated by the following hypothetical situation. Suppose a child provides the necessary evidence of the appropriate underlying form for word-final consonants, but fails to produce a systematic vowel duration difference dependent on the voicing characteristic of the final consonant. One might be tempted to say that in this case the phonological evidence is not supported by the phonetic evidence, but it is probably more appropriate to state that these particular phonetic data do not support the phonological analysis. After all, the omitted final consonants may contrast on characteristics of place and/or manner of articulation as well as voicing. Thus, an acoustic analysis of vowel duration alone could not reveal partial neutralizations of place or manner features, because the effects of place and manner contrasts on vowel duration are small or nonexistent. Other kinds of acoustic analysis are necessary to evaluate the partial neutralization hypothesis for these contexts; one of these analyses is described in the next section.[4]

TABLE 5. Means, standard deviations, and numbers of tokens for child vowel durations in target words which were judged to contain an omitted final stop. Age of each subject is indicated under the subject letter code.

Subject		*Voiceless*	*Voiced*
A	$\bar{x}$	179	237
(7:2)	*SD*	33	33
	N	28	29
B	$\bar{x}$	172	276
(7:6)	*SD*	28	82
	N	9	15
C	$\bar{x}$	276	307
(3:10)	*SD*	86	84
	N	23	27
D	$\bar{x}$	193	300
(3:10)	*SD*	47	96
	N	24	26
E	$\bar{x}$	376	619
(4:0)	*SD*	78	186
	N	29	30

Note. For all subjects except C, vowel durations preceding voiced and voiceless final-stop targets were significantly different ($p < .05$) according to *t* tests.

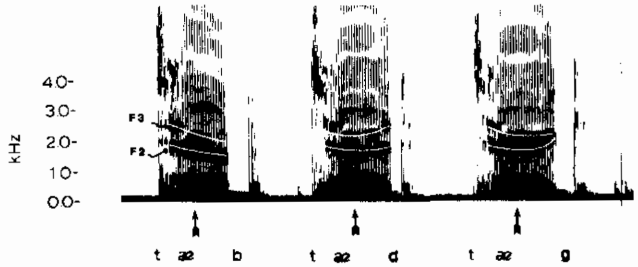

FIGURE 2. Spectrographic displays of the utterances "tab," "tad," and "tag," with trajectories of the second and third formant frequencies (*F*2 and *F*3) traced by white lines. These words were produced by a man.

Omission of Final Consonants: Spectral Features

In this section we focus on possible partial neutralization of the place feature in errors of final consonant omission. Later, a brief discussion is provided of how partial neutralization of the manner feature might be evaluated using acoustic techniques.

Figure 2 shows broad-band spectrograms of the utterances "tab," "tad," and "tag." The characteristics of interest in these displays are the trajectories over time of the second and third formant frequencies, as indicated by the hand-drawn curves. Comparison of the three second formant (*F*2) trajectories in Figure 2 shows clearly the strong influence exerted on *F*2 by varying place of articulation of the final consonant. These effects are well known by researchers interested in the perception (Delattre, Liberman, & Cooper, 1955) and production (Lehiste & Peterson, 1961) of speech. Within the framework of acoustic analysis of disordered articulation, the effects can be exploited to obtain information on a child's attempts to produce a consonantal place of articulation.

Consider first an adult male speaker such as the author, who produced the three utterances shown in Figure 2. When measurements of *F*2 are taken at the temporal middle of the vowel /æ/ (see arrows, Figure 2), values of around 1650 Hz are obtained. These values are in good agreement with *F*2 data for /æ/ reported for men by Peterson and Barney (1952, p. 183) and Lehiste and Peterson (1961, p. 269). The so-called locus theory (Delattre et al., 1955), which posits place-specific starting and ending frequencies for a vocalic *F*2 transition away from

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[4] Although beyond the scope of this chapter to pursue in detail, several issues associated with this discussion should be mentioned here. First, it is conceivable that a child could provide evidence of the correct underlying forms, yet still show complete neutralization of word-final consonant contrasts at the phonetic level. We have not seen a child who fits this description, but there are no a-priori reasons for ruling out such an occurrence. Second, there is a question of why partial neutralization may be reflected in certain articulatory features to the exclusion of others. Why, for example, should a voicing feature be maintained, but not a place feature, or vice versa? As additional information becomes available concerning partial neutralization in children's delayed speech, it will be useful to record the relative frequency of the various phonetic phenomena which are taken as evidence for partial neutralization.

(i.e., CV) or into (i.e., VC) a stop consonant, predicts some fairly dramatic changes in the $F2$ of /æ/ as a result of the consonantal influence. For example, the locus theory predicts that the $F2$ transition in a syllable such as [æp] should point in the direction of 700 Hz, or the assumed bilabial locus. Similarly, the $F2$ transitions in [æd] and [æg] should point in the directions of 1800 Hz and (approximately) 2300 Hz, respectively. Speech production experiments (Lehiste & Peterson, 1961; Stevens, House, & Paul, 1966) have shown that the place-specific loci originally derived from perception experiments (Delattre et al., 1955) are actually quite variable in production data, and are not nearly as mutually exclusive by place of articulation as the original theory might have suggested. However, the production experiments do suggest that certain vowels, when paired with the three places of articulation for English stops, might result in $F2$ locus values that are reasonably different according to place of articulation. One such vowel is /æ/, which appears to have average $F2$ loci of approximately 1325, 1700, and 2120 Hz for bilabial, lingua-alveolar, and dorsal places of articulation, respectively (derived from graphs in Stevens et al., 1966). Given a vowel "steady-state" value for $F2$ of 1650 Hz (measured at the temporal middle of the vowel), and the $F2$ transition loci described above, it should be possible to examine a spectrogram of a VC utterance in which V = /æ/ and C = a bilabial, lingua-alveolar, or dorsal stop and make an educated guess of the stop place of articulation based on the direction of the formant transition into the stop.

The application of this basic research to the problem of partial neutralization in disordered articulation can now be described. It is not unusual for speech-language pathologists to observe some articulatory "groping" toward final consonants among children who omit final consonants. A description of the nature of this groping may provide insight to a child's "knowledge" of the omitted consonant. For example, a child who produces multiple repetitions of the word *tag* and who is judged to omit the word-final stop may nevertheless be making articulatory gestures that approximate the place of articulation for /g/. Alternatively, the child may make no systematic lingual movement to produce the /g/, or may produce an incomplete gesture toward a nondorsal place of articulation.

Figure 3 presents $F2$ trajectory data for four children who omitted the /g/ in /tæg/; the target words were derived from five repetitions of the utterance "Give him a tag." In each panel of Figure 3, the heavy-lined trajectory represents $F2$ over time as produced by a normally articulating 5-year-old child; this $F2$ trajectory should not be assumed as the correct one for a child's production of *tag*, but simply as a model when the word is produced with the word-final stop. The five thin-lined trajectories in each panel represent the $F2$ trajectories for the five repetitions of [tæː] produced by a particular child. Inspection of the four panels in Figure 3 suggests that even though all four children may be described as final-consonant omitters, they may not be homogeneous with respect to the articulatory patterns that underlie the omissions. For example, Child A and especially Child D seem to show a tendency to produce an articulatory gesture in the direction of the appropriate place of articulation. Children B and C, however, have $F2$ trajectories that are essentially flat, suggesting an absence of sensitivity to the place feature of the omitted stop. Care must be taken in interpreting flat $F2$ trajectories such as those in panels B and C, however. It may be tempting to regard flat $F2$ trajectories as evidence that a child is merely generating a vocal-tract shape appropriate for the vowel, and maintaining the configuration throughout the syllable. An equally plausible interpretation, though, is that the child does change the vocal-tract geometry for a word-final stop articulation, but in a manner appropriate to a lingua-alveolar articulation. This follows because the $F2$ value at the vowel-consonant interface in /æd/ is only slightly greater than typical $F2$ values for the steady-state portion of /æ/; thus, an incomplete stop gesture for a word final /d/ in /æd/ may be associated with a minimum of $F2$ change over time (see Figure 2, $F2$ trajectory for [*t*æd]). One way to sharpen the inferences to articulatory behavior from the formant trajectory displays would be to include trajectories for $F3$, which are also known to vary in systematic ways according to place of articulation, as seen in Figure 2. The $F3$ transition in [tæd] is more dramatic than the corresponding $F2$ transition, so an incomplete lingua-alveolar stop gesture might be more easily deduced if some evidence of an appropriate $F3$ transition could be presented. For example, Figure 4 shows simultaneous $F2$ and $F3$ trajectories for Child B of Figure 3, as well as the $F2$ and $F3$ trajectories for normally articulated [tæd] and [tæg]. Because both $F2$ and $F3$ trajectories are flat for this child we would have greater confidence in concluding that he is not making a partial stop gesture. Rather, he appears to maintain the vowel configuration throughout the open syllable. To reiterate, the flat $F2$ trajectory implies no gesture toward the dorsal place of articulation, but does not rule out a partial lingua-alveolar gesture; the flat $F3$ trajectory in the same utterance would seem to rule out a partial lingua-alveolar gesture.

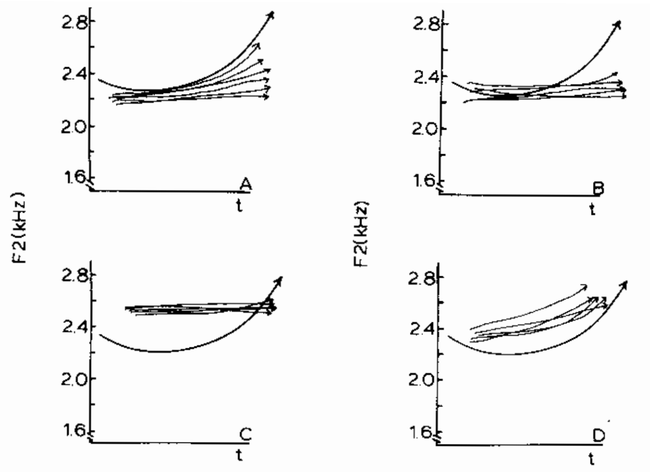

FIGURE 3. $F2$ trajectories for the word "tag," produced by four children who omitted the word-final /g/. In each panel, the heavy-lined curve shows an $F2$ trajectory for "tag" produced by a normally articulating child 5 years of age. The five thin-lined curves in each panel show the $F2$ trajectories for five repetitions of the target word produced by each of the misarticulating children. All trajectories were traced from scale-expanded (0–4 kHz) broad-band (500-Hz filter) spectrograms.

The most ideal use of formant trajectory data to infer articulatory behavior associated with final consonant omission is to have a triad of words that differ only in the place of articulation of the final consonant (see Figure 2; i.e., tab/tad/tag). One

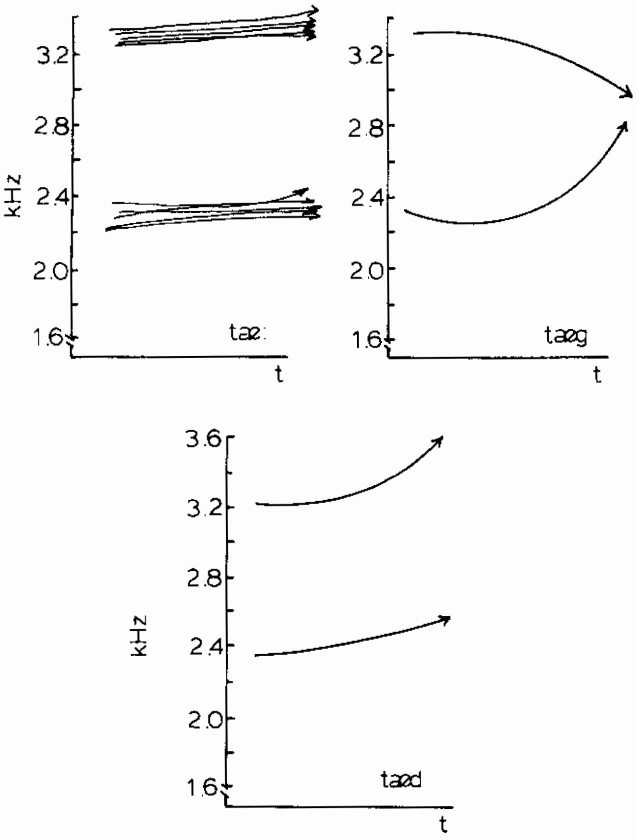

FIGURE 4. Simultaneous $F2$ and $F3$ trajectories associated with five [tæ:] for "tag" errors produced by Child B of Figure 3. Also shown are the simultaneous $F2/F3$ trajectories for normally articulated "tad" and "tag" produced by a 5-year-old child.

must still exercise caution in interpreting such data, however, and it must be realized that the clinical utility of formant trajectory information depends on an investigatory rather than a cookbook attitude on the part of the clinician. Interpretation of formant trajectory data depends most importantly on vowel identity, and possibly on the identity of the word-initial consonant. The interested clinician is referred to Stevens, House, and Paul (1966) for an in-depth research treatment of formant transitions associated with various vowels and consonants spoken by adults. Unfortunately, a corresponding investigation of children's speech is not currently available.

Voicing Distinction For Word-Initial Stops: VOT

In the literature on speech sound development, it has often been noted that children produce unaspirated stops earlier than aspirated stops (for a review, see Mowrer, 1980, pp. 121–122). Stated in phonemic terms, children appear to substitute voiced for voiceless stops early in phonological development and thus seem to neutralize the voicing distinction for word-initial stop consonants. As indicated in our review of VOT production, however, during the course of normal articulation development some children may produce a VOT distinction for voiced and voiceless stops that is not perceptually salient to the English-speaking listener.

An apparent neutralization of the voicing distinction for word-initial stops may also be observed among some functionally misarticulating children. This apparent substitution of voiced for voiceless stops has been traditionally labeled by speech-language pathologists as b/p, d/t, or g/k errors, whereas those who adhere to the notions of contemporary "delayed phonology" might attribute the errors to a "process of prevocalic voicing" (Ingram, 1976, p. 44). Each of these descriptions is derived from the perceptually based transcription of a child's speech, and may therefore be misleading concerning the child's productive distinctions.

The diagnostic utility of acoustic analysis in the case of an apparent neutralization of the voicing contrast for word-initial obstruents can be illustrated by the following data from a boy aged 3:11 (yrs:mos) (Maxwell & Weismer, 1982). This child was classified as having a severe articulation disorder of nonorganic origin. Among his errors were substitutions of voiced for voiceless obstruents in a variety of word positions. When 11 speech-language pathology students who were unfamiliar with the child's speech heard his attempts at word-initial voiceless obstruents, they identified 70% as voiced. Spectrographic analysis of voice onset time showed, however, that the child was maintaining some phonetic voicing contrasts associated with word-initial obstruents. For example, the difference between the mean VOT for singleton voiced (9 ms) and voiceless (43 ms) stop targets was statistically significant, as was the difference between all voiced (16 ms) and voiceless (34 ms) obstruents (i.e., including clusters) (Maxwell & Weismer, 1982). This combination of perceptual and acoustic data would seem to provide strong evidence that the clinician's auditory evaluation of a child's speech may yield an inadequate representation of a child's knowledge of contrasts. In this particular example, the child clearly produces a systematic phonetic distinction—at least on the VOT dimension—which nevertheless is not used reliably by listeners to identify a linguistic contrast.

Several aspects of VOT analysis as applied to the evaluation of obstruent voicing distinctions should be mentioned here to facilitate the clinician's use of this strategy. As in previous examples of acoustic analysis of misarticulated speech, it is important to obtain multiple repetitions of speech samples. VOT in particular appears to be highly variable in children's speech production, so care must be taken to collect sufficient data to warrant confidence in the estimate of typical performance. Although it is unclear how many repetitions are needed to provide a stable estimate of VOT central tendencies (or, for that matter, central tendencies of other segment durations), a minimum of five repetitions per stimulus word is recommended. With several words per category (i.e., category = voiced obstruents, or voiceless obstruents, etc.), a sample of 20–30 segments may be submitted to acoustic analysis.

It is important to recognize the limitations of VOT analysis for the refinement of phonological description. If a child appears to be neutralizing the voicing distinction for word-initial obstruents and does not provide evidence of a systematic productive distinction via acoustic analysis of VOT, one is not justified in concluding that the child does not make a productive distinction between voiced and voiceless obstruents. This is because VOT is not the only means by which a voicing distinction can be realized for stops. Three other reasonable candidates for producing a voicing distinction are (1) presence versus absence of voicing during part or all of the closure interval, (2) a difference in burst amplitude, and (3) a difference in fundamental frequency immediately following release of the stop. Candidate (1) is relatively easy to measure, and therefore may be a good prospect for clinical utility, whereas the appropriate evaluations for (2) and (3) involve recording and/or analysis techniques that may not be accessible to a large number of clinicians. The important point here, though, is that a "positive" VOT finding may allow a clinician to posit a productive contrast in the speech of a child who appears to neutralize the voicing distinction, whereas a "negative" VOT finding permits only the conclusion that the child does not use the VOT dimension to effect a contrast.

Cluster Production and Reduction: Temporal Features

In the contemporary child phonology literature, a process of cluster reduction has been identified as relatively common in normal and disordered articulation development. The process is considered to be a component of a disordered (delayed) phonology when it persists past a time when cluster articulation is mastered by most children. For the present discussion, we will focus primarily on /s/ + stop clusters, which appear to be mastered in word-initial position around the age of 4 years, and in word-final position somewhat later (Templin, 1957).[5] The notion of cluster reduction as a process is that one phonemic constituent of the cluster is eliminated, usually the one defined by linguistic markedness theory (Chomsky & Halle, 1968) as more *marked* (Ingram, 1976; Shriberg & Kwiatkowski, 1980). (Note that clusters may also be reduced by substituting a singleton segment, not part of the original cluster, for the target cluster.) Thus the expected cluster reduction in a word such as *spot* yields the broad phonetic form [pɑt], because markedness theory defines /s/ as more marked than /p/. For the same reasons, *state* and *skate* should become [te͡ɪt] and [ke͡ɪt], respectively.[6] Authors who have discussed a "process of cluster reduction" within the framework of "phonological" disorders have emphasized the "simplification" nature of the process (Ingram, 1976; Shriberg & Kwiatkowski, 1980). That is, the child simplifies the task of cluster articulation by eliminating one of the obstruents from the cluster.

It is important to appreciate the implications of this notion of phoneme *elimination* as the output of the cluster reduction process. The surface (phonetic) form [pɑt] that results from the application of the process to *spot* should be identical to the surface form for *pot*. Clinicians know, however, that when children produce something broadly transcribed as [pɑt] for *spot*, it is often quite different from the [pɑt] produced to represent *pot*. Acoustic analysis may permit a more quantitative assessment of these differences, and point to a more precise understanding of children's misarticulation of clusters.

Figures 5 and 6 illustrate the potential contribution of speech waveform analysis to a descriptive account of stop cluster articulation. Because the speech samples shown in these figures are derived from spontaneous speech, multiple repetitions of the same words are not necessarily available, thus precluding any precise statements concerning the acoustic variability of these misarticulated clusters. The reader therefore should not consider these data to be representative of the typical acoustic phonetics associated with cluster misarticulation. Rather, they should be regarded as examples of cluster misarticulation, the generality of which should be tested carefully with constructed speech materials and larger numbers of children.

Figure 5 shows oscillograms of one normally articulating child's production of several /s/ + stop clusters, along with oscillograms of the same child's production of singleton /s/ and selected stops. The acoustic dimension of interest in these displays is duration, particularly as it applies to what we will call the *obstruent interval* of the speech waveform. In the case of /s/ + stop clusters, the obstruent interval includes the frication interval associated with /s/ production and the closure interval associated with stop articulation; it can be defined operationally for measurement purposes as extending from the final glottal pulse preceding the /s/ frication to the burst of acoustic energy which corresponds to the release of the stop. These boundaries are indicated for /st/ and /sk/ clusters by the lower arrows in Figure 5, panels (A) and (B). Panels (C) and (D) of Figure 5 show waveforms of singleton [tɑ] and [kɑ] produced by the same child; obstruent interval boundaries are indicated as before by the lower arrows. As noted earlier, children tend to produce clustered obstruents such as /t/ and /k/ with durations shorter than those observed when the consonant is produced as a singleton. Clustered consonants typically are not shortened to such an extent, however, that the sum of the fricative and closure duration (that is, the obstruent interval) in an /s/ + stop cluster equals the duration of a singleton stop closure. These temporal relations are illustrated by comparing the duration of the cluster obstruent intervals in Figure 5, panels (A) and (B), to the singleton obstruent interval (stop closure) in Figure 5, panels (C) and (D). The duration of the cluster obstruent interval is obviously a good deal longer than the duration of the singleton obstruent interval.

These *phonetic* facts can be brought to bear on the notion of cluster reduction as a phonological process. Phonological processes, as described in Chapter 2, are implemented by rules that operate between the underlying representation and the surface form. If such a rule deletes a phoneme in the underlying representation, there should be no evidence of the phoneme in the surface (phonetic) representation of the utterance (see Weismer et al., 1981, p. 326, for related discussion). For the child whose delayed phonology is said to include a process of cluster reduction, then, we should expect that the duration of the re-

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[5] The reader should understand that the word *mastery* is used in the most general sense only, since authors define it in various ways (see Sander, 1972).

[6] The theoretical status of markedness theory cannot be discussed here, but the reader is referred to Cairns, Cairns, and Williams (1974) and Hyman (1975) for tutorial reviews of markedness, and to Blumstein (1973) and Cairns et al. (1974) for applications of markedness analysis to aphasic speech and functional misarticulation, respectively. That markedness theory accounts well for children's reduction of clusters is not a scientifically established fact, but rather an intuition of some writers who have examined diaries and other small amounts of data. It would be useful to know more about patterns of cluster misarticulation in a wider range of children, phonetic contexts, speaking modes, and so forth.

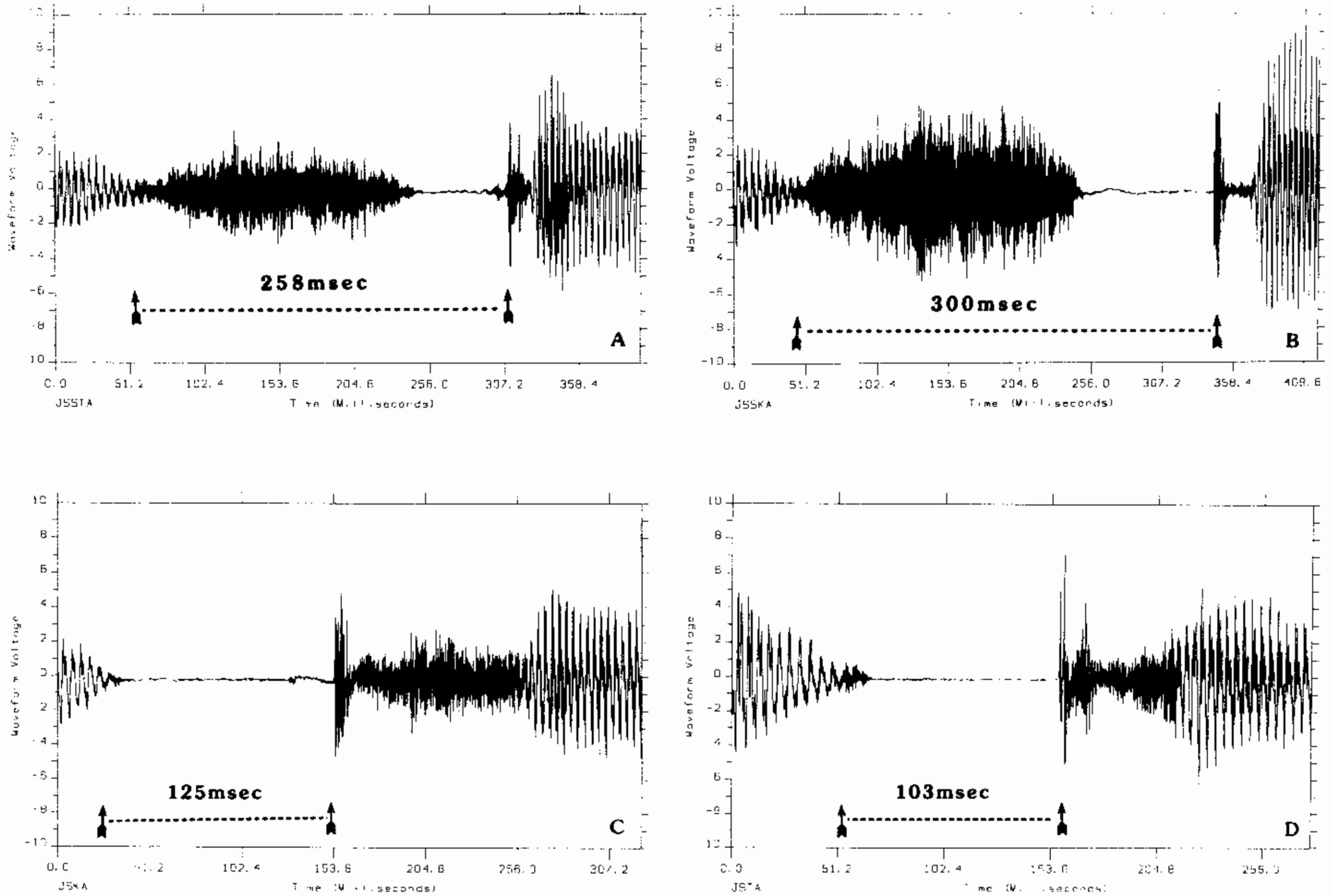

FIGURE 5. Oscillograms of /st/ and /sk/ clusters (panels A and B, respectively) and stops /t/ and /k/ (panels C and D, respectively) produced by one normally articulating child aged 5 years. For each panel, the duration of the obstruent interval is given, and the boundaries of that interval indicated by arrows. In the case of /s/ + stop clusters, the obstruent interval includes the frication noise as well as the stop closure, whereas for singleton stops it includes the closure interval.

duced obstruent interval should be roughly the same as the duration of the corresponding singleton obstruent interval. To reiterate the example given above, but from the more quantitative perspective afforded by acoustic analysis, the closure duration for /p/ in the reduced form [pɑt] ("spot") should be the same as in the correctly articulated [pɑt] ("pot").

Figure 6 presents acoustic data for one boy, aged 7:2, who had a severe articulation disorder including misarticulation of /s/ + stop clusters. Transcription of this child's productions of these clusters generally indicated that the fricative was not articulated; his cluster production would be characterized by contemporary phonological analyses (e.g., Ingram, 1976; Shriberg & Kwiatkowski, 1980) by a "process of cluster reduction." A comparison of the various obstruent interval durations in Figure 6, however, clearly indicates longer intervals for the reduced clusters (panels D, E, and F), than for the singleton stops (panels A, B, and C). This suggests that the child's cluster productions should not be described as straightforward simplifications of the target clusters, because he seems to have produced a temporal "slot" for the missing fricative articulation. For the selected waveforms shown in Figure 6, which represent singleton and cluster productions from the same general phonetic environment (intervocalic and prestressed), the cluster obstruent intervals are on average approximately 60 ms longer than the singleton obstruent intervals. Note that in several of these singleton and cluster obstruent intervals, the onset boundary is placed prior to the cessation of vocal fold vibration. The periods that follow the onset boundaries almost certainly occur during the obstruent part of the articulatory sequence, as evidenced by their low amplitude and reduced high-frequency energy.[7] The child who produced the waveforms in Figure 6 often produced voiceless obstruents that were partly voiced, as illustrated by his attempted /s/ production shown in Figure 7.

The data from this misarticulating child provide evidence for the utility of acoustic analysis in refining phonological descriptions. Moreover, data such as these lead to important questions regarding the precise interpretation of a process of cluster

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[7] Vocal fold vibrations that occur during an obstruent articulation often cause vibrations of the vocal tract walls which are picked up by air microphones as primarily low-frequency, weak-intensity vibrations. The absence of higher-frequency energy in these cycles is due to the low-pass filter characteristic of the vocal tract walls. An excellent example of a waveform display of vocal fold vibration during obstruent articulation is seen in the prevoicing vibrations to the left of the onset arrow in Figure 1(E).

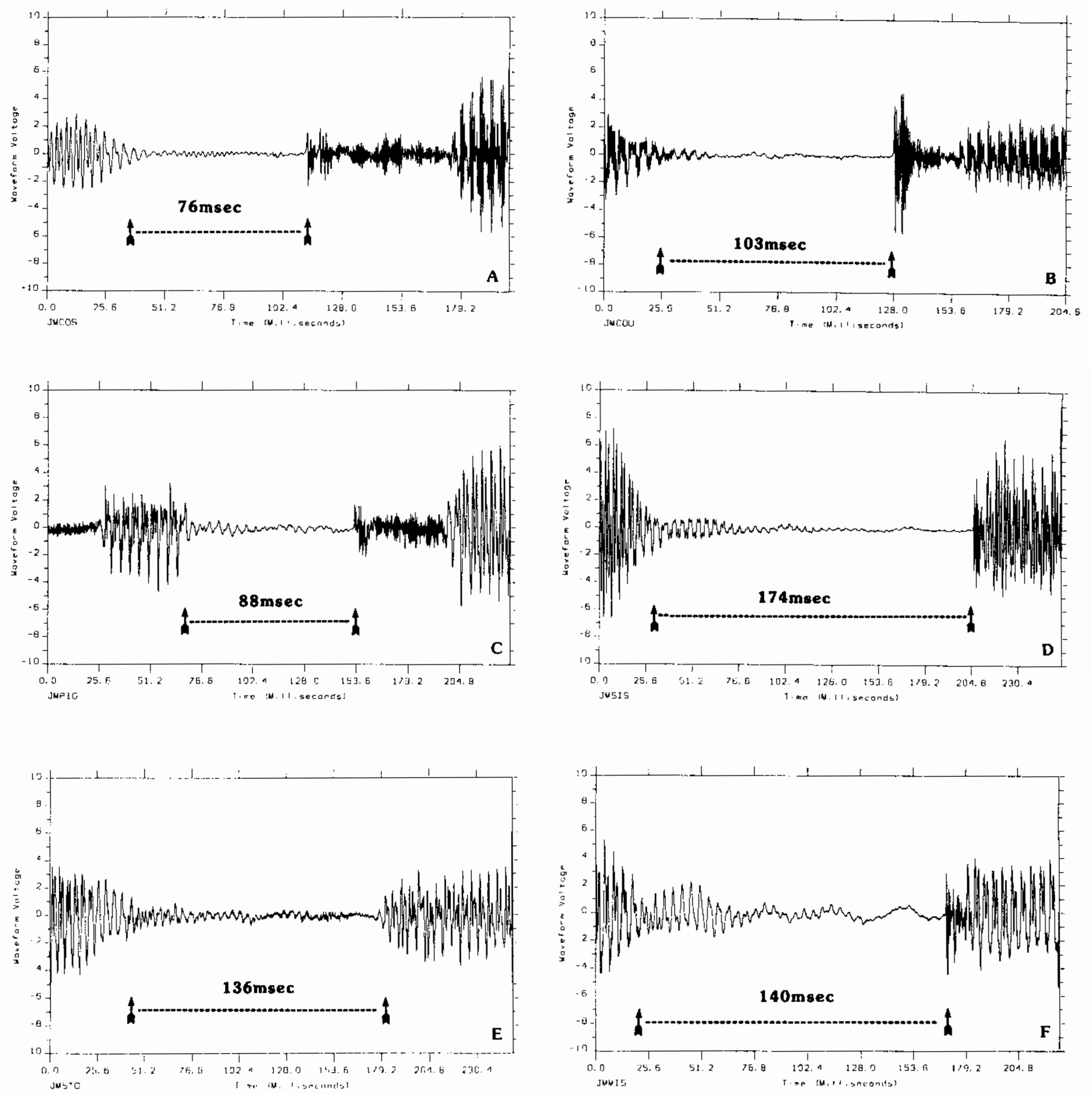

FIGURE 6. Oscillographic examples of singleton stop and "cluster" productions of one misarticulating child who "reduces" /s/ + stop clusters. Panels A, B, and C show boundaries (arrows) and durations of obstruent intervals for the stops [k], [k], and [t], respectively. Panels D, E, and F show boundaries and durations of obstruent intervals for attempted clusters /sk/, /sk/, and /st/, respectively. These examples were drawn from spontaneous speech, and all obstruent intervals are from an intervocalic, prestressed phonetic environment.

reduction because the expected phonetic result of such a process may be much less complex than the actual phonetic facts. Perhaps the cluster production of this child is additional evidence of partial neutralization, in which a cluster/singleton contrast that is apparently neutralized by the cluster reduction process actually is partially maintained by means of a duration difference.

At least one other type of acoustic analysis may contribute to a better understanding of how a child's misarticulated /s/ + stop clusters relate to the underlying representation. It is well known that the "long-lag" VOTs (45–75 ms, on average) observed for singleton voiceless stops are greatly reduced when the voiceless stop is produced in a syllable-initial /s/ + stop cluster (Davidsen-Nielson, 1969, 1974; Klatt, 1975a). In fact, VOTs in such clusters are actually in the "short-lag" range associated with singleton voiced stops (5–25 ms). Bond and Wilson (1980) have suggested that the VOT characteristics of

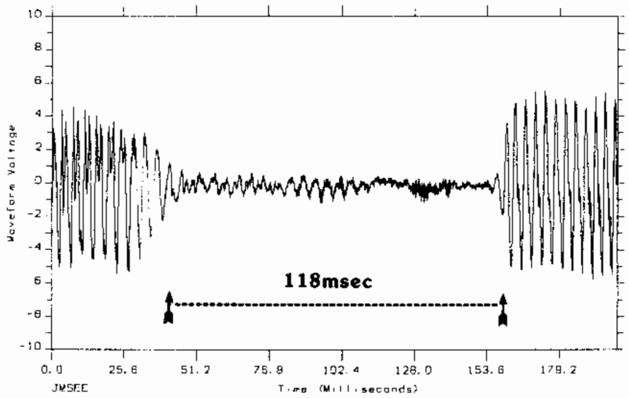

FIGURE 7. An attempted /s/ production by the misarticulating child who produced the waveforms shown in Figure 6. The boundaries (arrows) and duration of the obstruent interval are given; note the persistence of vocal-fold vibrations into the obstruent interval, even though the segment is phonologically voiceless and transcribed as [s].

stops substituted for /s/ + stop clusters may give insight to the phonological status of the stop, and therefore of the cluster. Bond and Wilson observed both short-lag and long-lag stops substituted for clusters, and reasoned that the more frequent substitution[8] of long-lag stops may reflect a tendency to represent the target cluster by aspiration (that is, by long-lag VOT). We would view the phonological implications of the possible substitution patterns for /s/ + stop clusters somewhat differently. The substitution of short-lag stops for /s/ + stops would seem to be a better approximation to correct cluster production than the substitution of long-lag stops. An extension of this reasoning is that the child who substitutes short-lag stops is more likely to have /s/ + stops represented phonologically than the child who substitutes long-lag stops. A more extensive data base (see footnote 8) as well as a detailed theoretical consideration of this issue is required before we can make confident statements concerning the relationship between stop VOT and phonological representation of /s/ + stop clusters.

Acoustic Analyses Associated With Other Processes

To this point, we have considered the use of acoustic analyses as a tool for refining our auditory-based phonological descriptions of misarticulated speech. The acoustic techniques appear to be particularly useful where so-called phonological processes of final consonant deletion, prevocalic voicing, and cluster reduction are concerned. It is reasonable to ask how acoustic techniques might be employed to clarify the status of other processes that have been mentioned frequently in the literature. Here we will confine ourselves to the six processes identified by Shriberg and Kwiatkowski (1980) for phonological analysis of misarticulated speech that have not yet been discussed in this chapter. Because no acoustic data that relate to these processes are available, the discussion for each will be brief and focus on measurement considerations.

Velar fronting. This process is one of narrow scope, applying only to the description of errors where the velar articulation for /k/ and/or /g/ is supposedly "fronted" by rule and produced at the alveolar place of articulation (Ingram, 1974, 1976). Based on Ingram's (1974) theoretical analyses, we might expect fronting to be observed more frequently in word-initial than in word-final position. If a velar fronting process is applied to a word like *gab*, the expected result is [dæb]; the process thus effectively neutralizes the velar/alveolar distinction for stop place of articulation.

For the most part, we assume that acoustic analysis would not contribute much to a better understanding of velar fronting. This is because the t/k and d/g errors, which are the output of velar fronting, seem to be highly accessible perceptually and therefore handled adequately by an auditory-based phonological analysis. There may be cases, however, in which a child's errors for /k/ or /g/ appear to be articulated somewhere between the velar and alveolar places of articulation. Most speech-language pathologists have probably heard a child produce a stop sound that could not quite be classified within the three-place stop system of English. In these cases, analysis of formant trajectories might indicate whether the error is closer to the velar or alveolar place of articulation. The conditional nature of interpreting such an analysis is emphasized here because (a) changes in formant trajectories are not necessarily related in a linear fashion to metric increments between the velar and alveolar places of articulation (see Stevens, 1972), and (b) perceptual uncertainty as to stop places of articulation may be the result of "double-stop" articulations, the relationship of which to speech acoustics is poorly understood.

If velar fronting neutralizes the velar/alveolar contrast for stops, it would be interesting to know whether the resulting homonyms are acoustically identical or distinct. If it could be shown by acoustic techniques that a child's production of [dæb] for *gab* is systematically different from his production of [dæb] for *dab*, it might be reasonable to state that another example of partial neutralization has been demonstrated. Because acoustic data bearing on this issue are unavailable, we can only speculate on the acoustic basis of a claim of partial neutralization associated with velar fronting. The two versions of [dæb], for example, conceivably might differ systematically with respect to VOT, syllable duration, stop burst frequency, or other factors. These kinds of questions concerning acoustic distinctions that may not be accessible perceptually have been addressed previously by Menyuk (1972), Kornfeld and Goehl (1974), and Dalston (1975).

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[8] Bond and Wilson (1980) reported more frequent substitutions of voiceless than voiced stops for /s/ + stop clusters, but certain aspects of their data suggest that caution should be exercised when evaluating these results. For the five children who substituted stops for /s/ + stop clusters, Bond and Wilson stated, "If VOT in excess of +30 msec is taken as appropriate for voiceless stops, then 58% of the substituted stop tokens lie in the voiceless stop (long-lag range)" (p. 155). Examination of individual subject data shows, however, that two children produced 100% of the substituted stops in this operationally defined long-lag range, whereas the remaining three children produced 56, 44, and 0% VOT in this long-lag range. Moreover, the goodness of these individual subject estimates of "percentage of substitution type" must be questioned, because each subject produced a very small number of usable tokens for the substitution analysis, and no individual subject standard deviations are reported. Given these problematic aspects of the data, it is curious that Bond and Wilson focused their discussion on substitution of voiceless stops for clusters (see p. 156, Conclusion).

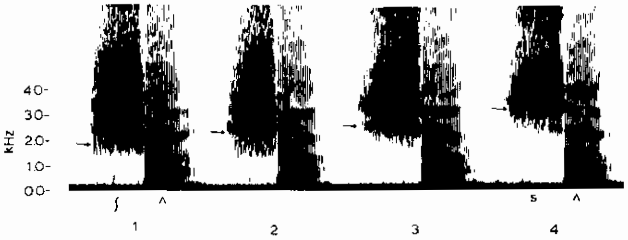

FIGURE 8. A series of spectrograms showing change of major lower frequency energy (arrows) for fricative productions ranging between [ʃ] and [s]. The speaker began with a clear [ʃ] production (1), and advanced his tongue in small steps (2, 3) until a clear [s] was produced (4). Fricatives 2 and 3 are productions "in between" [ʃ] and [s]. As the tongue moves forward in the vocal tract, the lower frequency limit of the fricative noise can be seen to increase.

Palatal fronting. This is also a narrow-scope process that changes the palatals /ʃ/, /ʒ/, /tʃ/, and /dʒ/ to more front-articulated sounds, particularly alveolars. The acoustic measurements that might bear on issues of partial neutralization associated with palatal fronting will often be different from those described for velar fronting, largely because velar fronting involves only stops whereas palatal fronting may affect fricatives and affricates. In the case of fronted /ʃ/ or /ʒ/, it might be useful to compare the spectrum of the error sound (possibly transcribed broadly as [s] or [z]) to the spectrum of normally produced /s/ and /z/. As the place of articulation moves forward in the mouth, the lower limit of substantial frication energy should be displaced to higher frequencies (see Hughes & Halle, 1956, and Figure 8). Or, as in the case of velar fronting, formant trajectory analysis may provide information regarding the child's articulatory placement.

Affricates are produced by first creating a complete (i.e., stop-like) supraglottal constriction and then releasing this constriction more slowly than is typical for singleton stops. For this reason, Lisker (1974) has described affricates as "slowly released stops." According to the literature on phonological disorders (Ingram, 1976; Shriberg & Kwiatkowski, 1980) palatal fronting is likely to result in the replacement of affricates by singleton stops (/t/, /d/) and/or fricatives (/s/, /z/). Given these kinds of substitution, the use of acoustic analysis to gain insight to the problem would seem to be understood best within the cluster analysis framework described earlier. The basis for that analysis was the comparison of durations associated with correctly articulated singletons (such as /t/) and singleton-for-cluster errors (such as [tɑp] for /stɑp/). If the [t] of the reduced cluster is systematically of greater duration than the singleton /t/, the notion that the child is simply eliminating one consonant from the cluster can be rejected. The general reasoning is the same for affricates, although there are some differences that should be mentioned. The duration of the component consonants in an /s/ + stop cluster are typically shorter than the corresponding singleton durations, but the shortening is not nearly to such an extent that the overall cluster duration equals the singleton duration.[9] Affricates also consist of a stop and fricative-like interval, both of which are substantially shorter than singleton stops and fricatives; it appears, however, that overall affricate duration is only slightly greater than singleton consonant duration.[10] Thus, the comparison of, for example, singleton /s/ duration to the /s/ duration associated with the s/tʃ error generated by palatal fronting may not be as easily interpreted as the comparison described above for singleton /t/ and the t/st error generated by cluster reduction. When palatal fronting results in a t/tʃ (or d/dʒ) error, however, it might be useful to compare the singleton and error /t/ (or /d/) durations. The small amount of available data (Umeda, 1977) suggests that the word-initial closure duration in /tʃ/ or /dʒ/ is approximately 20 ms shorter than closure duration for singleton /t/ or /d/. If children's t/tʃ or d/dʒ errors could be shown to have closure durations consistently shorter than singleton /t/ or /d/, it might reflect the child's "knowledge" that the target is an affricate, or at least some segment which is different from a singleton alveolar stop.

Stopping. This process is thought to be responsible for errors in which fricative targets are replaced primarily by homorganic stops. Nothing is known about the acoustic phonetics of stopping, but our general model of comparing the error sound to the same sound produced correctly (i.e., comparing the /t/ sounds in [tʌn] "sun" with [tʌn] "ton") provides a structured approach to the problem. If stopping does not result in simple stop-for-fricative substitutions, we can suggest two likely ways in which the phonetic difference between an error and correct stop may be manifest. First, the error stop may be spirantized, which would be evidenced in a spectrographic or oscilloscopic display by frication noise during the closure interval (Figure 9). Spirantization of error stops, but not correct stops, might reflect the child's "knowledge" of the target fricative segment. If the child is attempting a fricative-like segment but has difficulty controlling the precise constriction requirements of fricative articulation, the target configuration may be overshot, the result of which is an error having stop-like qualities. Attempts by the child to correct this overshoot by reconfiguring the supraglottal constriction according to fricative requirements (i.e., a tight but not leak-proof constriction) could result in episodes of turbulent flow during the "closure" interval. The acoustic correlate of these turbulent episodes is the kind of spirantization identified above and illustrated in Figure 9. We suggest that a determination of whether or not spirantization is occurring might be best accomplished with the lingua-alveolar obstruents. This is because the detection of spirantization of bilabial stops may require very sensitive recording techniques, and it is not uncommon for normal speakers to spirantize dorsal stops (/k/, /g/) (see Weismer, 1984).

The second possibility is that the release of a stop-for-fricative error would appear acoustically more like the release of an affricate than a stop. The release phase of an affricate is characterized by 60–80 ms of frication noise (relatively intense, aperiodic energy associated with turbulent flow at a supraglottal

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[9] Weismer (in preparation) has demonstrated that 4-6-year-old children shorten fricatives in clusters much more reliably than stops; in fact, some children seem to produce clustered stops with slightly longer duration than the corresponding singleton stops.

[10] This last assertion is based on the author's occasional measurement of affricate durations produced by himself and several other speakers. Apparently, a systematic study of affricate timing does not exist for either adults or children.

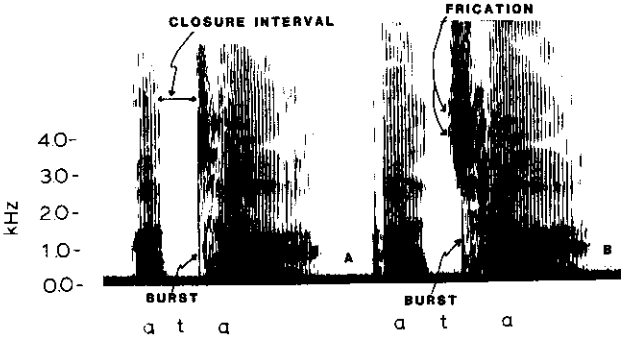

FIGURE 9. Spectrographic examples of normally produced and spirantized stop. Utterance A has a closure interval free of energy, whereas utterance B shows frication energy (spirantization, indicated by upper arrows) occurring prior in time to the stop burst (indicated by the arrow at baseline). The obstruents in both utterances were transcribed as /t/. These utterances were produced by an adult with Parkinson's disease, but the analysis principles are appropriate for children's speech.

constriction), whereas a stop release has a briefer (25–40 ms) interval of frication noise followed by approximately 40 ms of aspiration noise (relatively weak, aperiodic energy associated with turbulent flow at the glottis). The spectrographic displays of /ɛtɛ/ and /ɛtʃɛ/ presented in Figure 10 show clearly these differences. If a child's difficulty with fricatives is manifest by stopping, a slower release of the constriction may occur as an attempt is made to modify the error articulation. This speculation is based on the same notions, discussed above, of spirantization as a potential indicator that the child's stopping errors are influenced by a fricative "target." The reader should understand that both analyses are qualitative in nature; one focuses on bursts of energy during a closure interval, whereas the other depends on an assessment of the relative duration and intensity of aperiodic energy during a stop-release phase.

Assimilation. Regressive and *progressive* assimilation are processes that are characterized by one consonant in a word influencing aspects of another consonant in the word. For example, if a child says [gɔg] for *dog* it is classified as a regressive assimilation of the initial to final consonant; an error of [tæt] for *tack*, on the other hand, would represent a progressive assimilation of the final to initial consonant. Acoustic analysis would not seem to be particularly useful for gaining insight into these processes, especially when the assimilation errors are unambiguous. If the assimilation is ambiguous, as when a place of articulation seems to be between two of the place categories of English, analysis of formant trajectories may be useful.

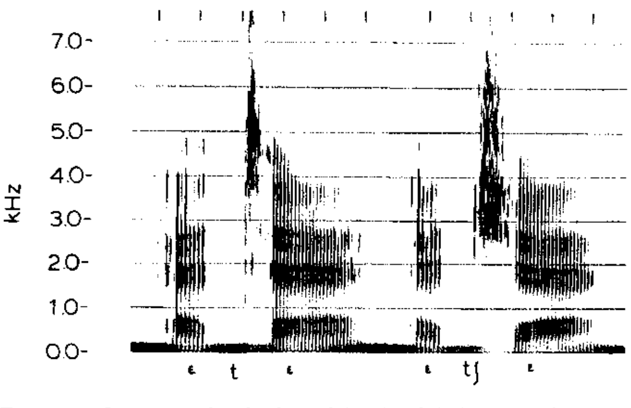

FIGURE 10. Spectrographic displays of /ɛtɛ/ and /ɛtʃɛ/. Note the longer frication interval (interval of relatively intense aperiodic energy) in /ɛtʃɛ/, as compared to /ɛtɛ/.

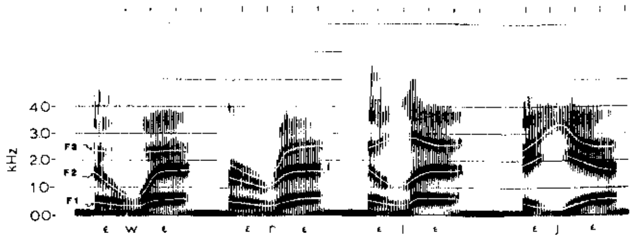

FIGURE 11. Spectrographic displays of /w/, /r/, /l/, and /j/. Note that each of these semivowels is characterized by fairly extensive $F2$ and/or $F3$ transitions, as indicated by the superimposed formant trajectories.

Liquid simplification. This process changes the liquids /r/ and /l/ to one of the glides /w/ or /j/. The "simplification" notion is derived from the assumption that liquids are more difficult to articulate than glides. Both liquids and glides are characterized spectrographically by vocalic formant structures, which tend to show rapid changes over time (transitions), as seen in Figure 11. These rapid transitions are the acoustic result of the dynamic articulatory gestures associated with the production of glides and liquids. When we apply our analysis strategy of comparing the error sounds to correctly articulated exemplars of those sounds, we therefore might want to look at both the steady-state formant frequencies and their trajectories over time. For example, an apparent [w]-for-/r/ substitution could be compared acoustically to correctly produced [w] to see if the error [w] showed any characteristics typical of /r/. A logical focus for this comparison would be the third formant ($F3$), which, according to child data published by Dalston (1975), is approximately 1000 Hz lower for /r/ than for /w/; moreover, the $F3$ transition duration and rate (i.e., the frequency change per unit time) are much greater for /r/ production (see Figure 11). Thus, any tendency for the error [w] to differ from correct /w/ by having a lower $F3$ or faster $F3$ transition may indicate some influence of the target /r/ on the error articulation (see Kornfeld & Goehl, 1974, and Hoffman, Stager, & Daniloff, 1983). Similar acoustic comparisons could be worked out for /l/ errors and their correctly articulated counterparts.

Unstressed syllable deletion. Shriberg and Kwiatkowski (1980) have regarded unstressed syllable deletion as the least frequently occurring of the eight NPA processes. The occurrence of this process among children with articulation disorders is poorly documented, and the phonetic manifestations of the process throughout normal development have been subject only to impressionistic analyses (see Ingram, 1974, p. 30). A reasonable question is whether or not the phonetic forms that are the presumed output of the process show any acoustic evidence of the alleged deleted syllable. One approach to obtaining such evidence would make use of word pairs that have identical forms when an unstressed syllable is removed from one of the words. Word pairs such as *nana/banana* could be incorporated in sentences that locate the test word following a short stretch of speech. If this process results in a true deletion of unstressed syllables, its application to productions of sentences such as *My nana is at home* and *My banana is at home* should yield identical acoustic manifestations for the second word in each sentence. A measurement likely to reveal consistent differences between word pairs, if they exist, is word duration, because a child may choose to indicate in some way the temporal "slot" normally occupied by the unstressed syllable.[11] A slight pause preceding the word, or lengthened initial segment ([n:] in the case of [n:ænæ]) could serve this purpose.

Some Concluding Remarks

The types of analysis described in this chapter are often concerned with speech-acoustic phenomena that defy reliable auditory analysis. Thus, we anticipate an objection that such analyses may not have much clinical utility given the central focus of the remediative process, which is to modify the child's speech in conformity with the auditory requirements of the linguistic community. In other words, the standards of the "normal" linguistic community should regard a b/p substitution derived from auditory analysis as a real b/p substitution, regardless of what acoustic analysis may reveal. If we are committed to a phonological analysis of speech sound errors, however, an analysis that relies solely on auditory skills is unacceptable. This is because an important part of phonological description is the contrastive function of linguistic units, and data presented in this chapter and published previously (Maxwell & Weismer, 1982; Weismer et al., 1981) demonstrate in certain cases the occurrence of reliable acoustic contrasts in the absence of reliable auditory contrasts. Advocates of phonological analyses of misarticulated speech seem to reason that the phonological approach is preferable to traditional approaches (omission-substitution-distortion; place-voice-manner analysis, etc.) because of descriptive and/or explanatory elegance. For example, Shriberg and Kwiatkowski (1980, p. 4) have stated:

> The term *natural process* moves beyond description to an explanatory-level account of sound change. . . . For clinical needs too, processes may have the conceptual and methodological adequacy that to date, neither segmental analyses, . . . structural analyses, . . . featural analyses, . . . or generative phonological analyses . . . have been able to achieve.

We believe, however, that this kind of phonological process analysis suffers from the same kind of descriptive and explanatory weakness that is thought to characterize traditional analyses. Thus, when a child omits final consonants, attributing the errors to a "phonological process of final consonant deletion" does no more to explain partial neutralization—as revealed by vowel duration or formant trajectory analysis—than the traditional description of "omitted final consonants." Similarly, designating a /b/ for /p/ or /d/ for /t/ error as the outcome of a "phonological process of prevocalic voicing" (Ingram, 1976) is no more informative of the nature of the problem than the description "+ voice/− voice substitution," if the child is producing a contrast as discussed on pages 43–44.

Both phonological and traditional analysis approaches have some meritorious descriptive capabilities, and both apparently can benefit from supplementary acoustic analysis. It is important to point out, though, that acoustic analysis should not be viewed as a panacea for all the shortcomings of auditory analysis. Many of the acoustic analysis strategies outlined in this chapter are little more than reasoned guesses as to what characteristics of a speech signal may provide useful information concerning the sound systems of misarticulated speech. Moreover, the application of these strategies may be somewhat limited, for they demand that the child produce an error sound correctly in some instances. That is, the comparisons usually involve three kinds of sound: (a) the error (e.g., [t] for /s/), (b) a correct articulation of the error sound (e.g., [t] for /t/), and (c) a correct articulation of the target sound (e.g., [s] for /s/). If a child does not produce a correct version of an error sound, or fails to produce a correct target sound, it may be difficult to assess the acoustic relationship between speech sound errors and correct articulations. In some cases, of course, it may be possible to compare error sounds to an expected "normal" acoustic pattern derived from the literature (as in formant trajectory analysis). We emphasize, however, that acoustic analyses cannot replace auditory analysis, because the selection of acoustic analyses depends on the initial auditory analysis of error and target sound articulation.

Finally, the kinds of acoustic analyses discussed in this chapter could be extended into the remediative process by serving as a metric of progress. It is possible that remediative efforts are responsible for subtle articulatory changes which are not detected by the clinician. This, of course, is an empirical question that should be addressed by the appropriate methods. If subtle articulatory change is shown to occur, however, acoustic analysis can serve as the clinician's auditory microscope in assessing the therapy effort.

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[11] This statement assumes that, in the present example, the [nænæ] sequence from correctly articulated "banana" and "nana" would have the same duration. This may not be the case, because research on adults (Fowler, 1981, p. 42) suggests that a stressed syllable may shorten slightly when an unstressed syllable precedes it. We point this out so that caution is exercised when applying this analysis strategy to evaluation of unstressed syllable deletion. The conditional nature of the importance of Fowler's data to this problem is emphasized, because her effects are of very small magnitude, and a parallel study for child speakers does not exist.

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Chapter 5
Phonological Processes in Articulation Intervention

Leija V. McReynolds
University of Kansas

Mary Elbert
Indiana University

Application of linguistic concepts to disordered communication has yielded valuable insights to understanding communicative problems. A most recent application has been to misarticulation problems, namely that children with severe articulation problems display phonological problems. The popular version is that phonological processes are operating and are reflected in the relationships demonstrated by error patterns.

Phonologists have for a long time postulated the concept of processes in normal populations. The regularities observed in languages are, they suggest, the result of processes. Yet, as the previous chapters in this monograph have demonstrated, phonologists are not in total agreement in regard to the definition of *processes*, how they should be identified, from where they arise, and how many there may be. These are issues in linguistics that presently are being discussed and examined.

Some individuals who have applied the concept of processes to misarticulating children do not appear to regard that concept as a topic for discussion or examination as the linguists do. By conducting a surface analysis of a child's error sounds, and noting that errors on more than one sound can be placed into patterns, they conclude that a phonological process has been identified. They may be entirely correct, but it seems that they too, just as the linguists, might benefit from attempts to examine what has been discovered in categorizing errors. Do these patterns reflect processes? What is a useful definition of a process for understanding articulation problems? And, if the patterns do reflect processes, what is the nature of these processes? Are they general processes affecting more than one class of sounds, or are they narrow processes involving one sound, two sounds, or only one class of sounds? And finally, whether general or narrow, what is meant by "treatment of articulation errors"?

Speech-language pathologists are faced with another issue that is not relevant to linguists: elimination of processes that appear to be responsible for articulation errors. The premise, of course, is that eliminating a process should result in changing the error sound productions resulting from the process to correct target sound productions. This is a reasonable goal in remediation of articulation errors. However, it has been suggested that processes can be eliminated without recourse to correct target sound production. Remediation, therefore, might be described as having two goals: eliminating a process and training correct target sound production. This definition of process elimination has been offered by Weiner (1981) in a study in which training was directed at elimination of several processes (final consonant deletion, stopping, and fronting). During training the children began to produce sounds, or approximations to sounds, in place of the error sounds, but did not necessarily produce the correct target sound. According to Weiner (1981),

> correct productions were those that resulted in elimination of the process rather than in correct production of the target word. That is, in the case of deletion of final consonants, production of any final consonant was regarded as a correct production and was appropriately reinforced. For stopping, any initial fricative was reinforced and for fronting, any velar stop was reinforced. (p. 98)
>
> Another methodological consideration is our definition of correct responses. In this investigation, correct responses were based on the presence of phonological processes rather than on whether sounds were produced correctly. (p. 102)

Other speech-language pathologists define process elimination as correct target sound production rather than approximations toward the target sound (Elbert & McReynolds, 1980; McReynolds & Elbert, 1981a; McReynolds & Elbert, 1981b). That is, their criterion for concluding that a process is eliminated is that the child has learned to replace the error sound with the correctly produced target sound.

There is little or no support in the literature for one or the other definition. However, Ingram (1976) has discussed the manner in which processes are relinquished by normal children and his statements may have relevance to the issue. For example, he has stated, "Phonological processes that result in incorrect productions predominate until around age 4 when most words of single morphological structures are *correctly* (italics added) spoken" (p. 11). Ingram (1976) has postulated that children go through stages as processes are eliminated; that is, "children *gradually* (italics added) lose these simplifying processes" (p. 40). Two more statements in Ingram's (1976) discussion bear on the definition of process elimination. He stated, in regard to the cluster reduction process, "This process is one that has *several stages* and lasts in *some form* for a long time *before finally being lost* (italics added)" (p. 31). And finally, "Data like this show the points of acquisition of the clusters, but not the stages that occur *between the first attempts at clusters and final correct production* (italics added)" (p. 32).

Ingram appears to consider a process to be eliminated when target sounds are produced correctly. Production of other sounds or approximations during process elimination are stages through which productions go as they approach the terminal goal of elimination. This viewpoint seems to reflect, or to represent more accurately, the behavior children go through in learning to articulate target sounds and therefore presents a more acceptable definition of process elimination. That is, as children learn to change error sound productions to correct target sound productions, they produce approximations, but these are not the correct terminal productions. However, it is recognized that definitions differ. These differences in definitions need to be examined because the issue is not solely a methodological one. In fact, it is a philosophical and theoretical issue as well, that overlaps with the issues presented elsewhere in the monograph in regard to the relevance of the concept of phonological processes to articulation disorders and their remediation.

Studies have been designed to examine some of the questions that were posed earlier in the hope that a clearer understanding of the usefulness of the concept of processes and elimination of processes would emerge. It is the intent in this chapter to report a series of studies in which the questions were raised in progressive steps and to discuss the issues that arose when the results were analyzed.

STUDY 1: CRITERIA FOR PHONOLOGICAL PROCESS ANALYSIS

The first question concerned how processes could be identified. That is, how would we distinguish an error that reflected operation of a process from an error that reflected simply a surface pattern or an error on specific sounds? We had little luck in finding operational definitions of processes that allowed this distinction. We were familiar with the traditional phonologists' definition of process and had been exposed to some others less operationally defined. To present two examples, Schane (1973) stated:

> When morphemes are combined to form words, the segments of neighboring morphemes become juxtaposed and sometimes undergo change. Consider the morphologically related forms *electric, electrical, electricity,* and *fanatic, fanatical, fanaticism.* Here the final *k* of electric and *fanatic* becomes *s* before a morpheme beginning with *i*. Changes also occur in environments other than those in which two morphemes come together—for example, word initial and word final positions, or the relations of a segment vis-a-vis a stressed vowel. All such changes will be called *phonological processes.* (p. 49)

Stampe (1973) stated:

> A phonological process is a mental operation that applies in speech to substitute for a class of sounds or sound sequences presenting a specific common difficulty to the speech capacity of the individual, an alternative class identical but lacking the difficult property. (p. 1)

Dinnsen (1984) has explained the traditional definition in which specific criteria are required to be met before a pattern is said to reflect operation of processes. He and the authors of other preceding chapters present an empirical approach that can be used to provide evidence that a process is or is not operating.

We were less successful in our search in the literature on misarticulations. Criteria appeared to involve only that a child produce an error that could be listed within a category labeled by linguists as a process. A sample of definitions are included in the following statements:

> Phonological processes refer to kinds of changes, which apply to classes of sounds, not just individual sounds, that children make in simplifying adult speech. . . . The postulation of phonological processes instead of individual substitutions has the advantage of bringing related sound changes together and provides a more explanatory description of development. (Ingram, 1981, p. 6)

> A phonological process is defined as a rule in which an opposition in adult phonology, like voiced-voiceless, is realized as "that member of the opposition which least tries the restrictions of the human speech capacity" (Weiner, 1981, p. 72, quoting Stampe, 1969, p. 433)

Hodson (1980) stated that "recent phonological research has identified systematic patterns which may be targeted across phonemes, thereby expediting intelligibility gains and reducing the total number of hours of intervention necessary" (Preface). Shriberg (1979) pointed out that "many clinicians have begun to view children's articulation errors as the reflection of phonological tendencies called *natural processes*" (p. 278). On the same page he quoted Oller (1973): "Essentially, natural processes act to simplify the speech of children learning any language."

The definitions were difficult to understand because of a lack of definition of the terms within the definitions (e.g., *phonological tendencies, simplification strategies, kinds of changes that children make*). What constitutes a tendency, or a simplification? The definitions did not specify measurements to apply in order to identify *processes.* Scientific identification of processes is not possible when these measurements are not available. It seemed essential that operational definitions be substituted for these somewhat nebulous ones. Perhaps the first place to start was to attempt to develop some specific quantitative parameters that could be measured objectively, in addition to the qualitative parameters described by Dinnsen (1984).

A logical place to start was to ask how many sounds had to be involved and how often errors had to occur on each sound in order to differentiate a process from single error productions. These factors were not part of the criteria offered in the literature. Conceivably, one error on one sound could be attributed to a process operation. How then, we wondered, did such a broad definition separate errors due to processes from errors not due to processes? In other words, how did such a definition differ from what speech-language pathologists had always used as criteria for misarticulations? Moreover, would there be differences in identification of processes if more stringent criteria were applied so that some evidence could be brought to support presence of a process as opposed to just an inventory of error sounds without recourse to process explanations?

Dinnsen has listed the qualitative criteria to be applied in his chapter. We were also concerned that reliability be strengthened and for this we needed quantitative criteria. Stronger evidence for the presence of processes could be presented if it could be shown that several sounds, both within and across classes, were involved, and if it could be demonstrated that each was in error over a number of productions.

Study 1: Procedures and Results

The first study (McReynolds & Elbert, 1981a) was directed toward exploring if application of quantitative criteria would make any difference in how often a process could be claimed to be operating. Speech samples were obtained from 13 children with functional articulation problems and their errors were submitted to two analysis procedures. In the first analysis, designated as a nonquantitative analysis, the only criterion for demonstrating the presence of a process was that a child's error conform to the description of a process. For example, if a child omitted the /k/ in "make," the production was listed under the process of final consonant deletion; this procedure was in keeping with what had been proposed in the literature. The second analysis, designated as a quantitative analysis, imposed two specific criteria: (a) the specific error had to have an opportunity to occur in at least four instances, and (b) the error had to occur in at least 20% of the items that could be affected by the process. These criteria were arbitrarily chosen as reasonable, that is, not overly stringent and yet possibly reflecting a clinical cut-off point.

The total number of processes identified was substantially decreased (by more than 50%) when the quantitative analysis was applied. Some processes that appeared to be common across subjects when a nonquantitative analysis was utilized appeared as less common or rarely used when quantitative criteria were applied. The individual subjects' process profiles also differed between the two analyses. Fewer processes were identified with application of quantitative criteria. The process profiles that emerged from the two analyses were different enough to lead to different views regarding the extent of a child's articulation problem and identification of presence of processes.

Obviously there is a difference in the number of processes identified if even minimal quantitative criteria are used to define them. Such findings pose a problem. Are processes eliminated just by demanding that their presence meet some kind of consistency (reliability) criteria? Where, then, do processes reside? Quantitative criteria, apparently, are insufficient to define processes in a meaningful manner. For instance, who is to say that a process is not operating, just because only one sound is affected, and only a few times? This led us to a reexamination of the definitions offered in the phonological disorders literature to see what had been missed.

STUDY 2: GENERALIZATION OF CORRECT ARTICULATION IN CLUSTERS

Careful reading of definitions and explanations revealed that processes operate to simplify speech in classes of sounds. Consider for example Ingram (1981), who stated:

> Phonological processes represent descriptions of children's simplifications of adult sounds that group individual changes into general patterns. For example, we can group a child's tendency to drop /s/ in /s/ plus consonant clusters with the tendency to delete /l/ in consonant plus /l/ clusters into a general process of Cluster Reduction. Consequently, such an analysis attempts not just to describe a child's substitutions, but to explain them, although the explanatory power of such analyses will always be only as strong as our understanding of the processes that children use. (p. 77)

It appeared that an important factor had been missed in the definitions and explanations; processes affect classes of sounds, not just specific sounds. The authors emphasized that differentiation of processes from just an inventory of specific error sounds can be made by determining if a pattern is evident across sounds and classes of sounds. That implies that finding and identifying the operation of processes yields a more realistic profile of children's articulation problems than simply making a list of the children's error sounds because processes affect classes of sounds. Only process analysis can reveal that children's misarticulations are systematic and related. The relationship, furthermore, is established by demonstrating that a child treats sounds or classes of sounds in an identical manner (e.g., all final consonants are deleted regardless of the class to which they belong). Thus, the current definition of processes appears to dictate that a similar error pattern occurs on more than one sound, that an entire class or classes of sounds reveals the same error form. Indeed, the concept of processes in misarticulations depends on demonstrating involvement of entire classes of sounds, as is evident from the definitions cited. Use of this definition eliminates the possibility that a process can be identified when errors are confined to single sounds, a condition met if quantitative criteria are applied.

This further delineation and description of processes offered more precise criteria for isolating processes from other sources responsible for error patterns, and it presented a potentially objective criterion that is helpful in definition and identification of phonological processes as opposed to other error forms. If, as claimed, it could be shown that classes of sounds were affected, one might more comfortably postulate the presence of processes. True, the definitions were not clear about the extent of sound involvement. Ingram (1981), for example, wondered if processes were restricted or general:

> A more serious situation arises when we attempt to decide how to define a process. Consider, for example, the process of Stopping, in which the child changes adult fricative sounds into stops. Suppose we have a child who changes all fricatives into corresponding stops, for example f → p, s → t, ʃ → t or k. We can say that Stopping has occurred. Another child, however, may produce /f/ correctly, but changes /s/ to /t/ 50% of the time and /ʃ/ to [t] all of the time. We can say that Stopping is less frequent now, yet we could also discuss three processes, /s/ Stopping, /f/ Stopping, and /ʃ/ Stopping, because all these show different patterns. If we do this (not an unreasonable decision), then we are in the awkward situation of claiming that the child with the more advanced language has more simplifying processes than the less advanced child. (p. 6)

Most authors, however, offer less specific speculations of the possible reach of processes by stating only that processes operate across classes of sounds, setting no particular limits. Ingram's speculations are perhaps more realistic because he recognizes that processes may be narrow, involving only a few sounds within a class, or broad, involving more than one class of sounds. The point is, there are no empirical data to help in identifying boundaries for process operations, or determining if boundaries even exist. For this reason, the speech-language pathologist has no criteria for determining which errors should be classified as processes-originated and which should not. Particularly relevant is the question of how meaningful it is to classify one or two errors as arising from phonological processes. As stated earlier, it is reasonable to inquire how a process classification helps our understanding of articulation disorders and their treatment. For example, would a demonstration that entire classes of sounds are affected make simplification processes a better conceptualization for planning remediation than other available conceptualizations? It may be a moot inquiry because all authors argue strongly that processes occur across many sounds and sound classes. Therefore, it is axiomatic that processes function across sounds and sound classes. Nevertheless, data to support these arguments were not presented by those making the claim. Therefore, this study was designed to examine the extent to which proposed processes were present in terms of the number of sounds involved and whether sounds in more than one class were involved.

This was not a difficult task initially. Anecdotal evidence in the literature was abundant, although descriptive in nature. Samples of speech were analyzed and errors were categorized according to patterns. According to the authors, these patterns represented processes (Hodson, 1980; Ingram, 1979, 1981; Shriberg & Kwiatkowski, 1980; Weiner, 1979). The evidence presented indicated that similar errors occurred across several sounds, and frequently across more than one class of sounds. Notwithstanding the fact that quantitative data were sorely lacking in the descriptive studies, the evidence nevertheless pointed to the fact that errors described in terms of processes involved classes of sounds. Therefore, on a descriptive level the definition offered in the literature was supported by the data if one overlooked the scarcity of the data base.

But descriptive data should not be used to infer a functional relationship. They can be used to offer speculations about a functional relationship, but they do not demonstrate it. [In general, the words *processes* and *patterns* have been used interchangeably, but the terms have not been used in an explanatory way, as Ingram (1981) has suggested. Whether an error pattern is the same as a phonological pattern has not been explored, and yet a process implies more than a pattern.]

We thought that a more convincing way to provide data to support the presence of processes, to show that more than surface descriptions were necessary to obtain the data, was available. Immediately, the definitions offered by authors brought to mind the way in which the data could be acquired. Processes could be explored experimentally, something which others had not undertaken. [Since completion of our studies, one other experimental study has been conducted by Weiner (1981).] The ultimate test of a hypothesis, as well as a theory, is to submit it to experimental manipulation, and there was a way to do that so that boundaries of processes could be identified.

The question had been posed for us by other authors, but mainly by Ingram (1981). Experimentally, it would be possible to investigate whether processes were narrow, general, or even present. It could not be established that processes *caused* children's articulation errors, but at least the generality of the patterns observed in the descriptive studies could be explored by determining whether changes occurred on single sounds, within sound classes, or across sound classes as a child progressed in articulation training designed to "eliminate processes." The greater the number of sounds changed as training was provided on one sound, the greater the generality of the process.

Study 2: Procedures and Results

We took at face value the criteria offered in the literature with the exception that the children had to demonstrate quantitatively that their errors were consistent within sounds, within sound classes, and across sound classes. Only by demonstrating this consistency could the extent to which a process was present and the extent to which changes occurred be measured. Qualitative criteria were not employed because they had not been used in descriptive studies to establish the presence of processes. Therefore, if children displayed a consistent error pattern on several sounds and sound classes, the pattern was defined as a process. It was not necessary that the children demonstrate alternations. Instead it was assumed that the underlying form in all cases was the adult form. These assumptions met the criteria used by authors in their descriptive studies. The process we chose to explore was Cluster Reduction.

Six children were involved in the Cluster Reduction Study (McReynolds & Elbert, 1981b). Generalization to /s/, /r/, and /l/ clusters on which children frequently produce articulation errors was the behavior measured to identify process boundaries. The study used a multiple baseline across behaviors, single-subject experimental design with counterbalancing across subjects. Briefly, all subjects misarticulated the /s/ (e.g., st, sk, sp, sm, etc.) and either the /r/ (e.g., tr, kr, gr, fr, etc.) or /l/ (e.g., pl, bl, fl, etc.) in clusters involving those sounds. Each child received training to produce the sounds in appropriate cluster contexts. Correct sound production of both consonants in the cluster was necessary to define cluster acquisition (i.e., elimination of the process). Three children received training on producing the /s/ in an /s/ cluster first and then /r/ in an /r/ cluster. Two of the remaining children learned to produce the /r/ cluster first, and then the /s/ cluster. One child received /s/-cluster training followed by /l/-cluster training. The dependent variable consisted of each child's generalization patterns to untrained cluster items. The children were tested on both /r/ and /s/ clusters (/l/ clusters for one child) throughout training. The degree of generality of the Cluster Reduction process was measured by testing all clusters regardless of whether the clusters involved the /s/ or the /r/. We speculated that if Cluster Reduction was a general process affecting several sounds, and more than one class of sounds, then generalization from training on one cluster would occur not only to the sound class being trained but to the other class as well. Specifically, if the process was a general one as the definition in the literature stated, then children would change articulation on both /r/ and /s/ clusters although they were trained only to eliminate the process in one of them (either /s/ or /r/ or /l/). Thus, the children learned to produce the target sound in items representing one of the clusters and after learning to produce the cluster correctly in a few items at a stable rate, they were tested on untrained items in two classes: (a) items from the cluster class on which they had been trained, (b) items from the cluster class on which they had received no training. If they did not generalize to the untrained cluster class, they received training on that cluster until criterion on correct production of that cluster was reached. After training they were tested on items from both cluster classes again.

In the first phase of the study the children who learned to produce /s/ clusters were tested on /s/ clusters and /r/- or /l/-cluster items. Similarly, the three children trained to produce /r/ clusters in the first phase were tested on both /s/- and

/r/-cluster items. In the second phase, if generalization to the untrained cluster had not occurred, the children were trained to produce that cluster. For the /s/ children either the /r/ or /l/ cluster was trained, and for the /r/ children the /s/ cluster was trained.

The results on generalization did not support the operation of a general cluster reduction process. Children generalized, but not across classes of clusters. When /s/ clusters were trained, children began to produce untrained /s/-cluster items correctly, but not untrained /r/-cluster items; conversely, when /r/ clusters were trained, no generalization to /s/ clusters occurred. Only one child who received training on /s/ in the first phase began to produce /r/ clusters correctly before she was administered /r/-cluster training. Generalization to the second cluster was obtained from all children when training on that cluster was initiated in the second phase. Therefore, generalization was restricted to within-class items, and a general process operating across sound classes was not identified in the children's generalization patterns irrespective of whether the /s/, /r/, or /l/ cluster was involved.

Although the study of consonant cluster errors indicated that a process of cluster reduction was not generalized, it was possible that this finding was an exception, that other processes might have a higher degree of generality in their composition. We could be more positive of the results if another process frequently attributed to children was examined, trained, and tested for generality. Deletion of final consonants is often mentioned as a common error pattern and was the choice for further study (Elbert & McReynolds, 1980).

STUDY 3: THE GENERALIZATION HYPOTHESIS; FINAL CONSONANT DELETION

This investigation was designed to examine relationships among sounds that might be affected by the purported process of Final Consonant Deletion. Specifically, the purpose was to determine whether children who omitted final plosive and fricative sounds would generalize across these sound classes when they were trained on one of the classes.

Study 3: Procedures and Results

Four subjects who consistently omitted final plosives and fricatives were tested and trained with a single-subject multiple-baseline design. The children who omitted both final fricative and plosive sounds were trained first on one class of sounds and tested only on the second. The second class of sounds was trained only if generalization to the second class had not occurred. Training was counterbalanced across subjects. Imitative and spontaneous probe items were presented prior to, during, and after training to assess generalization. Subject responses to these untrained probe items served as the dependent variable in the study and were used as indicators of generalized learning within and across sound classes.

Two of the subjects generalized after the first training phase, whereas the other two subjects required further training before generalization occurred. The children's generalization patterns were restricted to the class being trained; that is, when plosives were trained, correct responses were obtained to untrained plosive items but not to fricative items. Conversely, fricative training resulted in generalization only to untrained fricative items, but not to plosives. This generalization pattern was obtained regardless of which sound class was trained first.

Thus, the results on generalization of final consonants corroborated the results in the consonant cluster study. The children generalized, but only to the items in the sound class receiving training. The results did not support the concept of general phonological processes that function across all error sounds displaying a similar error pattern.

DISCUSSION

Implicit in the notion of processes is the concept of organization of errors. The data obtained in the two experimental studies helped to reveal the system-internal organization of children's responses. It appears that an a priori categorization of all final consonants as members of one group similarly affected by an all-encompassing process labeled Final Consonant Deletion, or of all cluster errors forming a cohesive group under a Cluster Reduction process, breaks down when actual learning patterns are examined. The subjects in the two studies appeared to organize their responses differently from the way some theorists have speculated.

When results from the Final Consonant Deletion study corroborated findings from the Cluster Reduction study, the lawfulness of the data allowed greater confidence in the conclusion that processes, if they exist, are restricted and not general. Data from all three studies aided in examination and evaluation of the concept of phonological processes and, simultaneously, the label *phonological disorders*, so ardently embraced in current speech-language pathology literature.

In Weiner's (1981) study, the two children may have generalized across sound classes during the Final Consonant Deletion training. Both fricatives and plosives were tested on the generalization probes, but results were not presented in terms of sound classes. It is difficult to compare results from his study with ours because of definitional, criterial, and methodological discrepancies between the studies, and because the children's generalization patterns in the Weiner study were described in total percentages. Thus, in his study Subject A generalized to 58% of the probe words, and Subject B to 42%, on the items testing final consonant production. But the specific consonants were not identified. Neither study has presented detailed descriptions of the subjects so it is difficult to determine how similar the subjects were across the studies, particularly in regard to their articulatory status. Perhaps the biggest discrepancy is in the definition and criteria used to demonstrate that a process was eliminated. The children in Weiner's study were not required to produce correctly the target sound receiving training, whereas in our studies the criterion was correct target sound production. The studies differed methodologically also. For example, in the Weiner study counterbalancing across sounds was not included in the design so possible order effects were not controlled for. Obviously, because of the sparsity of experimental data, replications are needed to provide additional evidence regarding the nature of processes.

Nonetheless, evaluation of the results from our three studies led to the conclusion that data are not available to support the notion that phonological processes are responsible for all articulatory errors in misarticulating children. Data from the two training studies indicated that it was unnecessary to call the error patterns processes to obtain the generalization patterns that were obtained. It would have been sufficient, for example, to identify that the children omitted final plosives, to train the plosive in a few exemplars, and then test for generalization to other final plosives without ever referring to the concept of phonological processes. Saying that the errors represented operation of a process did not contribute to development of the training procedure, selection of training items, or selection of generalization items for testing. Neither did it facilitate or enhance acquisition or generalization of target sounds.

On the basis of the findings it is recommended that adoption of the label *phonological disorders* be delayed until further research on the concept of phonological processes is conducted. We have no wish to ignore the notion of processes and phonological disorders. Instead, we concur with phonologists' use of the concept for research purposes to lead them to a better understanding of phonology and phonological acquisition. Speech-language pathologists could profit from its use for the same purposes in studying articulation disorders. However, the concept is not ready to be used to (a) describe children's articulation errors, (b) explain the source of articulation errors, or (c) plan and implement remediation programs that promise greater generalization than other articulation training programs.

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Chapter 6
On the Relationship Between Phonology and Learning

Daniel A. Dinnsen Mary Elbert
Indiana University

It has been argued in this monograph and elsewhere (Dinnsen, 1981; Dinnsen, Elbert, & Weismer, 1979, 1980; Dinnsen & Maxwell, 1981; Grunwell, 1981, 1982; Haas, 1963; Maxwell, 1979, 1981a; Weismer, Dinnsen, & Elbert, 1981) that children with functional misarticulation problems may have phonological systems (in particular, underlying representations) that differ from the system of the surrounding speech community. Moreover, these systems may differ across the misarticulating population. The essential factor differentiating these systems is the knowledge that a child possesses about his/her underlying representations; different children may represent their lexical items differently. Individual differences in the knowledge of underlying representations have been demonstrated in two ways: through conventional linguistic analysis and through instrumental phonetics. Conventional linguistic analysis has typically appealed to facts about sound distributions, morphophonemic alternations, and so on. Instrumental phonetic analysis has typically identified acoustic differences (or the absence of any difference) associated with phonological distinctions (or the absence of a phonological distinction). These two types of analysis mutually support claims about a child's underlying representations in particular and his/her phonology in general.

The descriptions derivable from these analytical techniques may be of value to speech-language pathologists. The presumed value would lie in the fact that these phonological descriptions constitute claims about what a child knows and what has yet to be learned about the ambient phonological system. These descriptions could in turn provide a basis for developing individualized training programs appropriate to particular children's needs. To date, there is no empirical evidence that phonological descriptions have such practical or clinical value. The intent of this chapter is to present such evidence by relating phonological analyses of the type subscribed to in this monograph to the results of training studies. Phonological descriptions would be of value clinically if it could be shown, for example, that they result in predictions that account, at least in part, for individual differences in learning as a result of training.

In this chapter we relate differences in four children's phonologies to the individual differences evident in their learning patterns following training. The results of two independently conducted studies will be discussed. Each study was designed to address very different questions. The subjects in the two studies were, however, the same four functionally misarticulating children. All four children omitted final obstruents. One investigation was a training study in which generalization based on training final obstruent contrasts was examined, and the results were reported by Elbert and McReynolds (1980). The other study involved a phonological analysis of each child's speech before training. The particular approach to analysis was that subscribed to in this monograph, and the results were reported in part by Dinnsen and Maxwell (1981). It revealed important differences between the children's phonologies, including differences in underlying representations and rule types.

It should be emphasized that each of the two studies was conducted without knowledge of the findings of the other study, and neither study addressed the relationship between phonology and learning. The intended contribution of this chapter is to integrate and reinterpret the results of these studies and to show how these data bear directly on this relationship. This effort should not only underscore the clinical value of the phonological descriptions, but it should also provide an independent test for evaluating the correctness of the claims embodied in the descriptions.

In the first section of this chapter we present a description of the subjects as well as a summary of the training techniques and results from the Elbert and McReynolds study. In the next section, we present a more detailed description of each child's phonology taken partly from the Dinnsen and Maxwell study. In the final section we attempt to integrate the results of training with the results of the phonological analyses.

SUBJECTS

Subjects for the training study were selected from among the children referred to the Indiana University Speech and Hearing Clinic for speech evaluations. Four boys (M.B., C.P., A.H., and P.P.) ranging in age from 3 years, 6 months to 4 years, 9 months were selected as subjects on the basis of their consistent omissions of final consonants. All subjects received audiometric testing and demonstrated hearing within normal limits bilaterally. No organic problems were observed in any of the children.

Subject selection criteria required omission of at least 60% of stops (plosives) (/p, b, t, d, k, g/) and fricatives (/s, z, f, v, θ, ʃ) in word-final position (a) on the Goldman Fristoe Articulation Test (Goldman & Fristoe, 1966), (b) in a conversational speech sample containing at least 100 words, and (c) on probe tests presented imitatively on three separate occasions and spontaneously on one occasion (Baseline). In addition, each subject was required to produce stops and fricatives imitatively in syllable-final position or in isolation in at least two of three trials.

TRAINING STUDY: GENERALIZED LEARNING

Design. A single-subject multiple baseline design was used in which the subject served as his own control. Imitated and spontaneous test (probe) items were presented prior to training and during training to assess generalization.

Probe tests. The probe items shown in Table 1 consisted of 48 (or 53, as discussed below) words. All items were tested by spontaneous naming of pictures and by imitation. The probe items were randomized and tape recorded for presentation to the subjects to obtain the imitated responses.

The imitated words were tested on three occasions prior to training and throughout training at specific times related to the subject's performance on the training items. Spontaneous probe items were tested once before training began and once at the completion of training.

Scoring and reliability. An experimenter and observer were present at each session to score live responses to training and probe items simultaneously. Responses to the probe items were described phonetically using broad transcription. Responses to a word were considered correct if the final consonant was articulated correctly. Item-by-item percentage of agreement on each probe test ranged from 83 to 100%.

TABLE 1. Forty-eight words used as probe items both in imitated and spontaneous production for subjects C.P. and M.B. and fifty-three words used as probes for subjects P.P. and A.H.

	Plosives			*Fricatives*		
/p/	rope		/s/	bus		
	cup			juice		
	stop			dress		
	sheep			goose		
					(base)	
/b/	bib		/z/	cheese		
	tub			(rose)		
	web			peas		
	robe			hose		
		(tube)				
/t/	cat		/f/	leaf		
	boat			calf		
	hat			roof		
	kite			knife		
		(shoot)			(beef)	
/d/	sled		/v/	stove		
	bed			glove		
	road			sleeve		
	slide			five		
/k/	milk		/ʃ/	fish		
	bike			mustache		
	rake			splash		
	lock			brush		
/g/	pig		/θ/	bath		
	frog			teeth		
	dog			mouth		
	flag			tooth		
		(fog)				
Total	24			24		= 48
		(3)			(2)	= 53

Training procedures. The training sequence was divided into three phases with four steps within each phase. Subjects M.B. and P.P. were trained first on stops followed by fricative training. The reverse order was used for A.H. and C.P. The training for the first order is described below.

Phase I—Stops

Step 1. Two training items, /a/ and /ab/, paired with nonsense drawings were presented for imitation. Approximately five sets of 20 stimulus-response trials were administered at each session. Training continued until the subject reached a criterion of 18 correct responses of 20 presentations, two times. Each correct response was followed by praise and a marble. Marbles were exchanged for tokens, and tokens could be traded after a session for candy or toys.

Step 2. Training continued on the same training items, but the schedule of reinforcement was changed from continuous to a variable ratio in which praise and marbles were presented on approximately every third correct response (VR3).

Step 3. A spontaneous response to the nonsense drawings was obtained and the VR3 schedule of reinforcement was continued.

Step 4. The 48 (or 53) probe items were presented for imitation to determine whether generalization of these untrained items had occurred after this limited amount of training. If fewer than 70% of the stop items were produced correctly, a second stop syllable was trained.

Phase II—Stops

Steps 1–4. The training items /a/ and /at/ were trained using the same procedures as in Phase I.

Phase III—Stops

Steps 1–4. The training items /a/ and /ag/ or /ak/ were trained as in Phases I and II. Subject A.H. received training on /ak/ because of difficulty in obtaining correct voicing on /g/. The other three subjects were trained on /ag/.

After Step 4. The subjects were shifted to fricative training if generalization to fricatives had not occurred. Fricatives were trained using the procedures described. The three fricative training syllables were /as/, /az/, and /af/.

The amount of training described above was sufficient to obtain generalization for Subjects M.B. and C.P. However, Subjects P.P. and A.H. required additional training before generalization occurred. The additional training utilized the same general procedures with the following changes. First, words replaced nonsense syllables, but the words contained the same final consonants trained previously: *bay-base, row-rose, bee-beef, two-tube, shoe-shoot,* and *fa-fog.* These words were randomly inserted into the 48-word probe list resulting in an increased number (53) of probe items. Second, an additional practice step was included in which previously trained words were presented in a mixed arrangement. For example, P.P., after completing training on *two-tube* and *shoe-shoot,* received training on both word pairs. After the third word pair was trained, all three stop word pairs were presented for practice prior to the next probe.

RESULTS OF TRAINING

Two of the subjects, M.B. and C.P., demonstrated generalization to the untrained probe items after receiving training on the syllable pairs. The other two subjects, P.P. and A.H., began to generalize after the additional training.

The generalization pattern was similar for M.B. and C.P. That is, when stops were trained, generalization occurred only to untrained items containing final stops. Similarly, generalization to untrained fricative items was obtained only after fricatives were trained. This pattern was obtained regardless of whether stops were trained first and fricatives second, or vice versa.

Subjects P.P. and A.H. showed essentially no generalization after syllable training. However, both subjects began to generalize after receiving the additional training, and their patterns of generalization were similar to those of the other two subjects.

A more detailed description of the training procedures and the results of training are described elsewhere (Elbert & McReynolds, 1980).

PHONOLOGICAL ANALYSES: INTERNALIZED KNOWLEDGE

How a child represents his/her morphemes underlyingly constitutes an important part of what the child knows about his/her sound system. Underlying representations thus constitute tacit knowledge. It is the purpose of this section to describe in some detail the phonological knowledge of each of the four subjects prior to training. This knowledge is assessed through techniques of linguistic analysis as described in Dinnsen's chapter in this monograph (Dinnsen, 1984). We will focus on those elements of each child's phonology that may relate descriptively to the omission of final obstruents. This includes statements about the phonetic inventory, phonemic contrasts, phonotactic constraints, underlying representations of morphemes, and phonological rules.

The data for each phonological analysis are drawn from phonetically transcribed spontaneous conversations and the Maxwell and Rockman Screening Test (1984).

Subject: P.P.

P.P. omits obstruents word-finally as exemplified in the following forms:

[dʒi]	"jeep"
[pa]	"popped"
[ʌ]	"up"
[da]	"dog"
[ko]	"coke"
[trɛi]	"trade"
[bʌ]	"buzz"
[kɪ]	"kiss'
[bʌ]	"Bud"
[wai]	"ride"
[gɛ]	"get"
[ba]	"Bob"
[plɛi]	"place"
[mɪ]	"miss"
[wæ]	"laugh"

Not all of these words, however, exhibit an alternation between word-final null and some word-medial consonant. Note, for example, the alternating and nonalternating pairs shown below:

[ba]	"Bob"	~	[babi]	"Bobbie"
[pe]	"pep"	~	[pʌpi]	"peppie"
[ʌ]	"up"	~	[ʌp]	"up"
[kæ]	"cap"	~	[kæp]	"cap"
[ba]	"Bob"	~	[bab]	"Bob"
[dʒi]	"jeep"	~	[dʒip]	"jeep"
[da]	"dog"	~	[dai]	"doggie"
[wai]	"write"	~	[wain]	"writing"
[kɪ]	"kiss"	~	[kɪˀɪŋ]	"kissing"
[bʌ]	"buzz"	~	[bʌˀɪŋ]	"buzzing"
[wæ]	"laugh"	~	[wæˀɪŋ]	"laughing"
[mɪ]	"miss"	~	[mɪˀɪŋ]	"missing"

The alternating pairs involve word-medial labial stops alternating with word-final null. Labial stops can occasionally also occur word-finally in alternation with null. The nonalternating pairs omit dental and velar stops and all fricatives medially and finally.

It is clear from the alternating forms that P.P. knows that certain morphemes can be and are represented underlyingly with final labial stops, for example, /bab/ "Bob," /ʌp/ "up," /dʒip/ "jeep." It is only in the case of the nonalternating pairs that a question arises about the underlying representation of morphemes that might end in dental or velar stops or fricatives. That is, does P.P. know that certain other morphemes can end in either dental stops, velar stops, or fricatives? The answer to this question appears to be "no"; he does not represent morphemes underlyingly with final dental stops, final velar stops, or final fricatives.[1]

This claim is based on several facts. First, as regards the exclusion of final fricatives, it should be noted that the only fricatives evident anywhere in P.P.'s speech are labial, that is, [f, v]. These fricatives moreover are limited in their distribution so that they occur only word-initially. They never occur after a vowel, even word-medially. The inventory and distributional constraints above are instances of phonotactic constraints. They represent this child's limited knowledge of fricatives, in general, and exclude postvocalic fricatives from underlying and phonetic representations.

The problem surrounding dental and velar stops is slightly different from the fricative problem noted above. These sounds are part of the child's phonetic inventory. He thus has knowledge of dental and velar stops. However, this knowledge is limited in that dental and velar stops do not occur after vowels word-medially or word-finally. They only occur word-initially. In fact, the only obstruent consonants that occur after a vowel are labial stops, for example, [babo] "bubble," [babi] "Bobby," [kʌbi] "cowboy," [pipo] "people."

Postvocalic dental and velar stops are thus excluded from underlying and phonetic representations by a phonotactic constraint. Consequently, those morphemes that would otherwise

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[1] While some of these morphemes do alternate, e.g. [mɪ] ~~ [mɪˀɪn], the alternation is between [ˀ] and null. Intervocalic fricatives in the ambient system often (but not always) correspond with glottal stops in this child's system. In any case, the point remains that this child represents these morphemes differently than they are represented in the ambient system.

require postvocalic dental or velar stops in underlying representations will be represented differently in this child's system.

To summarize, the claim is being made that this child does not have (productive) knowledge of postvocalic dental and velar stops, nor does he have (productive) knowledge of postvocalic fricatives. In these instances, the child's underlying representations are different from those of the ambient speech community. This child's underlying representations are, however, the same as those of the ambient speech community in the case of morphemes ending in labial stops. The omission of word-final obstruents is accounted for, then, by phonotactically constrained underlying representations in some well-defined instances and by an optional neutralization rule deleting obstruents in certain other well-defined instances.

Subject: C.P.

C.P. omits word-final obstruents as exemplified by the following forms:

		[bʊ]	"bulb"
[ʃi]	"sheep"	[pɪ]	"pig"
[dɛi]	"grape"	[da]	"dog"
[bʌ]	"Bud"	[tʃa]	"sock"
[fai̯]	"five"	[dai̯]	"dive"

However, C.P. does evidence knowledge of some of the omitted obstruents as shown below:

[baɪb]	"Bob"			[babi]	"Bobby"
[roz]	"rose"			[bʌʃ]	"brush"
[hæos]	"house"			[biz]	"bees"
[fɪʃ]	"fish"			[fĩʃ]	"finish"
[ʃi]	~	[xip]	"sheep"		
[dɛi̯]	~	[dɛi̯ps]	"scrape"		

These forms reveal the possibility of underlying postvocalic labial stops and certain postvocalic fricatives, that is, [s, z, ʃ] ([+coronal, +strident, +continuant]). The following forms suggest, however, that this child's knowledge about postvocalic obstruents is limited:

[da]	"dog"	~		[dai]	"doggie"
[pɪ]	"pig"	~		[pɪi]	"piggy"
[bʌ]	"Bud"	~		[bʌi]	"Buddy"
[dai̯]	"dive"	~		[dai̯ĩ]	"diving"
[fwa]	"frog"	~		[fwai]	"froggie"
		[nais]	"knife"		
		[wʌʃ]	"laugh"		
		[muʒ]	"move"		
		[tus]	"tooth"		

In particular, dental and velar stops are omitted word-medially and word-finally. That is, there is no alternation of dental and velar stops with null, which parallels the labial stops alternation. Moreover, incorrect (from the point of view of the ambient system) fricatives are realized postvocalically in certain well-defined cases, namely, in cases where the fricative would otherwise not be [+coronal, +strident]. In other words, if the fricative in the ambient system is either labial or nonstrident, then this child substitutes an incorrect fricative, one that is [+coronal, +strident]. Of course, sometimes there is no substitute or consonant of any kind.

It is argued from this evidence that this child represents some of his morphemes correctly in underlying representations and others incorrectly. Correct underlying representations are arrived at in essentially two well-defined cases. One involves postvocalic labial stops, and the other case involves postvocalic fricatives that are [+coronal, +strident]. Incorrect underlying representations are arrived at when the postvocalic obstruent would otherwise be either a dental or velar stop or some other fricative—either labial or nonstrident.

A phonological analysis of final consonant omission for this child must take several factors into account. First, it must provide for the fact that obstruents are not always omitted word-finally. This is achieved by postulating underlying representations that include final obstruents in at least certain cases and an optional deletion rule. The analysis must also account for the fact that not all morphemes evidence a consonantal alternation. In fact, only certain morphemes involving a well-defined class of obstruents evidence the alternation, that is, those that end in either labial stops or [+coronal, +strident] fricatives. The incorrect underlying representations exclude postvocalic dental and velar stops and fricatives that are either labial or nonstrident. These particular limitations on underlying representations are achieved by phonotactic constraints. One such constraint expresses the generalization that all postvocalic fricatives are [+coronal, +strident]. The other constraint expresses the generalization that all postvocalic stops are labial.

Subject: A.H.

A.H. omits all obstruents word-finally as can be seen in the following words:

[hæ]	"have"	[dɔə̯]	"dog"
[tʌ]	"tub"	[bi]	"big"
[nai̯]	"knife"	[bæ]	"bath"
[wʊ]	"roof"	[nɛi]	"snake"
[sai̯]	"slide"	[pi]	"peas"
[hæo]	"house"	[wɛi]	"rake"
[dʒu]	"juice"	[di]	"these"
		[du]	"goose"

A.H. does evidence underlying knowledge of at least some of the omitted obstruents as can be seen in the following forms:

[wob]	"robe"			[kap]	"stop"
[fit]	"feet"			[wop]	"rope"
[tæp]	~	[tæ]	"cap"		
[tæk]	~	[tæ]	"tack"		

Forms of this type reveal that at least labial, dental, and velar stops can occur word-finally. In order for these obstruents to appear phonetically, it must be the case that A.H. represents these morphemes underlyingly with the appropriate final stop obstruent. Consequently, some morphemes are represented underlyingly with the correct final obstruent, in particular those ending in labial, dental, or velar stops.

A.H. evidences no productive knowledge of postvocalic fricatives. Fricatives never occur word-finally whereas stops do, and fricatives never occur word-medially after a vowel. There is, therefore, never an alternation involving fricatives. These

TABLE 2. Summary of phonological analyses showing each subject's knowledge of postvocalic obstruents in underlying representations.

	Knowledge about postvocalic obstruents in underlying representations	
Subjects	*Known*	*Unknown*
P.P.	Labial stops.	All fricatives. Dental and velar stops.
C.P.	Labial stops. Some fricatives, i.e. [s, z, ʃ].	Dental and velar stops. Other fricatives, i.e. [f, v, θ].
A.H.	All stops.	All fricatives.
M.B.		All stops. All fricatives.

facts support the claim that A.H. represents morphemes underlyingly without postvocalic fricatives.

In sum, the phonological analysis of this child's final consonant omissions must take into account the fact that consonants are not always omitted word-finally. This is achieved by postulating underlying representations that end in obstruents and an optional phonological neutralization rule deleting obstruents word-finally. The analysis must also account for the fact that only certain morphemes evidence a postvocalic obstruent, namely those ending in labial, dental, or velar stops, but not otherwise. This is achieved by representing at least some morphemes that should otherwise end in labial, dental, or velar stops with the appropriate stop in the underlying representation. This means that at least some of these morphemes will be represented correctly (relative to the ambient system) in underlying representations. Postvocalic fricatives are excluded from underlying representations (and thus phonetic representations) by a phonotactic constraint that expresses the generalization that all postvocalic obstruents are stops. This constraint also accounts for the fact that there are no fricative alternations. In the case, then, of morphemes that should end in fricatives relative to the ambient system, this child's underlying representations are incorrect.

Subject: M.B.

M.B. is Matthew, whose phonology has been described extensively elsewhere in this monograph. We will, therefore, only briefly review the essentials of this child's phonology. M.B. omits all obstruents word-finally, and he shows no productive knowledge of the omitted obstruents. This claim is based on the fact that there are never any consonantal alternations and more generally that obstruents never appear phonetically after vowels, whether word-medial or word-final.

These facts are accounted for phonologically by postulating underlying representations that omit postvocalic obstruents. That is, all of this child's underlying representations will be incorrect relative to those in the ambient system with postvocalic obstruents. The exclusion of postvocalic obstruents from underlying (and phonetic) representations is achieved by a phonotactic constraint that expresses the generalization that all postvocalic consonants are nasal.

The omission of final obstruents in this child's system is accounted for, then, not by a phonological neutralization rule that deletes final obstruents, but rather by a phonotactic constraint that excludes postvocalic obstruents from underlying and phonetic representations.

SUMMARY OF PHONOLOGICAL SKETCHES

We have presented evidence that each subject can be described differently in terms of phonological knowledge of underlying representations. The crucial differences are summarized in Table 2.

It is useful to look at a child's knowledge of underlying representations in terms of what was known and what was unknown to the child about the occurrence of postvocalic obstruents in underlying representations. If our hypotheses about each child's phonological knowledge are correct, and if there is a relationship between phonology and learning, then we would expect observed differences in a child's performance on final obstruents after training on final obstruent contrasts where these differences are accounted for by differences in what was previously known as opposed to what was previously unknown.

AN INTEGRATED APPROACH

In this section, we take a closer look at the results of training to see if, in fact, a demonstrable relationship exists between a child's generalization patterns and the child's phonological knowledge of underlying representations. We also attempt to identify the factors that may account for individual learning patterns.

The results of training for each child are reported in Tables 3–6 and in Figures 1–4. The data represent the number of correct responses for particular classes of postvocalic obstruents

TABLE 3. Number of correct responses on postvocalic obstruents out of total number possible on the probe list for subject P.P. The classes of obstruents reflect the child's phonological knowledge of underlying representations.

Postvocalic obstruents	*Number possible correct responses*	*Number of actual correct responses*						
Labial stops[a] [p, b]	9	6	9	9	9	9	9	9
Dental and velar stops [k, t, d, g]	18	0	0	2	3	3	3	6
Fricatives [f, v, s, z, θ, ʃ]	26	0	0	1	2	2	9	10
		B	I	II	III	IV	V	VI
		Probe sessions						

[a] Known.

TABLE 4. Number of correct responses on postvocalic obstruents out of total number possible on the probe list for subject C.P. The classes of obstruents reflect the child's phonological knowledge of underlying representations.

Postvocalic obstruents	*Number possible correct responses*	*Number of actual correct responses*						
Labial stops[a] [p, b]	8	1	0	0	2	3	6	7
Some fricatives[a] [s, z, ʃ]	12	4	2	7	3	7	9	9
Dental and velar stops [t, d, k, g]	16	1	0	0	0	0	4	7
Other fricatives [f, v, θ]	12	0	0	0	1	3	3	4
		B	I	II	III	IV	V	VI
					Probe sessions			

[a] Known.

in each probe session both prior to training (Baseline) and during the training phase. The particular classes of postvocalic obstruents specified in the tables and figures correspond with particular claims about each child's knowledge of postvocalic obstruents in underlying representations. For example, in the case of P.P. (Table 3 and Figure 1), postvocalic labial stops are reported separately from dental and velar stops and fricatives because P.P. evidenced phonological knowledge of postvocalic stops in underlying representations but not of any other postvocalic obstruents.

In Figure 1 these same facts are represented in terms of percentage correct responses. The data points marked by triangles (△) correspond in this case to P.P.'s performance on labial stops. Labial stops constitute what was previously known to P.P. before training began. The data points marked by circles (O) correspond in this case to his performance on dental and velar stops and on all fricatives, that is, what was previously unknown.

Several general observations emerge from these data. First and most important, a child's performance on phonologically known possibilities can be distinguished from performance on phonologically unknown possibilities. This is evident in all three subjects for whom the distinction was appropriate, namely P.P., C.P., and A.H. The distinction was inappropriate for M.B. because he evidenced no knowledge of postvocalic obstruents. In the case of P.P., for example, the effect is dramatic. His performance on labial stops (phonologically known possibilities) is quite different from his performance on all other postvocalic obstruents (phonologically unknown possibilities). Moreover, the phonologically unknown possibilities, while including different classes of obstruents (i.e., dental and velar stops and all fricatives), tend to pattern alike. This is not to say that there are no differences among the phonologically unknown possibilities. The differences are slight, however, and are likely attributable to other factors to be discussed below, which include order of training and integrity of obstruent classes. This first observation supports the correctness of the phonologically determined distinction between what is known and what is unknown about underlying representations.

The second general observation is that before training (or during testing prior to training) a child's performance on phonologically known possibilities is better, that is, reflects a higher percentage of correct responses, than performance on phonologically unknown possibilities. Moreover, baseline performance on phonologically unknown possibilities is close to zero. This is evident in the baseline performance of all four subjects.

It is probably not at all surprising to anyone that a child performs better during baseline on known than on unknown possibilities. Traditionally, this better performance might have been related to what is often termed *stimulability* and/or *inconsistency*. That is, the child can produce the appropriate sounds and occasionally does produce them in the appropriate context. We would like to suggest, however, that something deeper than motor ability is involved here. In particular, we pose the following question: Why does the child sometimes produce the correct sound in the appropriate context? We suggest that context stimulability and inconsistency will only arise where the child has correct underlying representations. Stimulability and inconsistency are in this view just surface manifestations of deeper phonological knowledge. While all of the subjects in this study who evidenced some knowledge of underlying representations were stimulable and inconsistent with regard to that knowledge, we do know of other children who can be shown to have correct underlying representations but

TABLE 5. Number of correct responses on postvocalic obstruents out of total number possible on the probe list for subject A.H. The classes of obstruents reflect the child's phonological knowledge of underlying representations.

Postvocalic obstruents	*Number possible correct responses*	*Number of actual correct responses*						
Stops [p, b, t, d, k, g][a]	27	7	5	7	3	8	18	20
Fricatives [f, v, s, z, θ, ʃ]	26	1	7	13	15	9	16	20
		B	I	II	III	IV	V	VI
					Probe sessions			

[a] Known.

TABLE 6. Number of correct responses on postvocalic obstruents out of total number possible on the probe list for subject M.B. The classes of obstruents reflect the child's phonological knowledge of underlying representations.

Postvocalic obstruents	*Number possible correct responses*	*Number of actual correct responses*						
Stops [p, b, t, d, k, g]	24	3	7	11	14	21	24	24
Fricatives [f, v, s, z, θ, ʃ]	24	0	0	0	0	3	10	20
		B	I	II	III	IV	V	VI
					Probe sessions			

are not otherwise stimulable or inconsistent (cf. Maxwell, 1981a, 1981b). Such a situation calls for morphophonemic alternations motivating correct underlying representations that are governed by an *obligatory* phonological rule as opposed to an optional rule. We would not expect inconsistency to occur with a child who otherwise evidences no knowledge of the correct underlying representation.

Another general observation is that at any point during training a child's performance on previously known possibilities is better than performance on the previously unknown possibilities. This is clear in the case of P.P. (Figure 1) and C.P. (Figure 2). It does not appear to be entirely true, however, in the case of A.H. (Figure 3). During the first three probes, A.H. performed better on fricatives (previously unknown) than on stops (previously known). We attribute A.H.'s better performance on the unknown possibilities to two factors. The first is the training itself. That is, during the period of the first three probes, training on fricatives was being administered. In other words, A.H. performed better on the class of postvocalic obstruents being trained. It might be claimed, then, that a child's performance on the class being trained will be as good or better than performance on the untrained class independent of any other considerations. This factor appears to take precedence over the distinction known/unknown.

This same effect can be observed in all four subjects. Considering A.H. further, he, for example, performed better on stops only after training began on that class of obstruents (probes 4–6).

Note also that C.P. (Figure 2) was trained first on postvocalic fricatives, and his performance on fricatives during that training phase was better than on the untrained class (postvocalic stops) during the same phase (probes 1–3). The relevant comparisons in this case are between previously known fricatives and previously known stops. Similarly, comparisons can be made between previously known fricatives and previously unknown stops. For example, during fricative training (probes 1–3), C.P. (Figure 2) performed somewhat better on previously unknown fricatives than on unknown stops. Also, after training on stops commenced, C.P. performed as well or better on known stops than on known fricatives (probes 5–6). This is also true of his performance on unknown obstruents, that is, after training on stops began, his performance on previously unknown stops was as good or better than on unknown fricatives.

This training effect is also evident in the case of M.B. (Figure 4). M.B. was trained first on stops. His performance on stops during the training of stops is quite good. Note that there was no generalization to fricatives during training on stops. Also, once training on fricatives began, his performance on fricatives improved dramatically. If training on a particular class of obstruents were the sole determinant of improved performance on that class, one might expect that M.B.'s performance on fricatives during the fricative training phase should have been as good or better than his performance on stops. Such an expectation was warranted for the other three subjects, at least within the category of previously known stops and fricatives or within the category of previously unknown stops and fricatives.

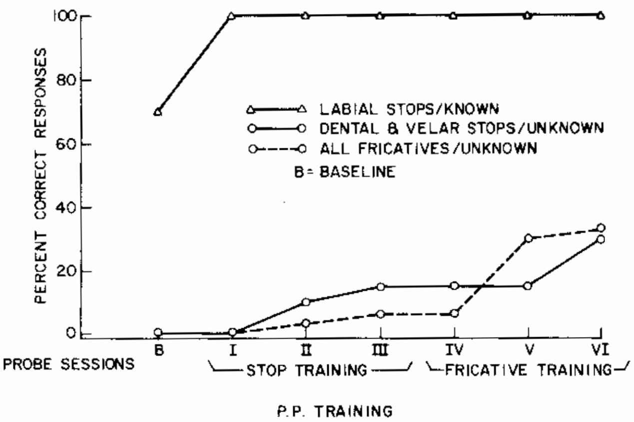

FIGURE 1. Percentage correct responses to fricative and stop probe items based on the results of the phonological analysis showing knowledge of underlying representations for subject P.P. The first three probe tests were administered during training of stops and the last three during training of fricatives.

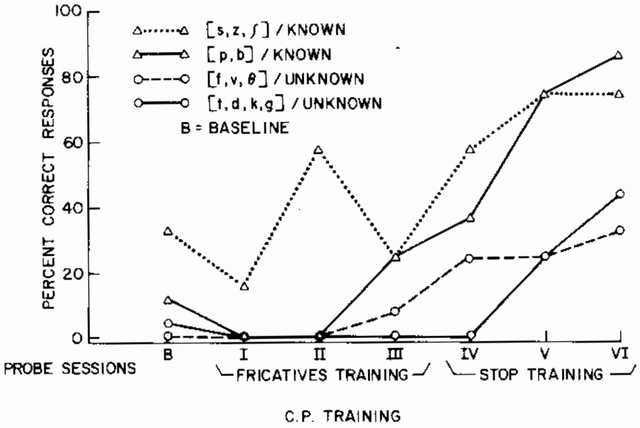

FIGURE 2. Percentage correct responses for fricative and stop probe items based on the results of the phonological analysis showing knowledge of underlying representations for subject C.P. The first three probe tests were administered during fricative training and the last three during training of stops.

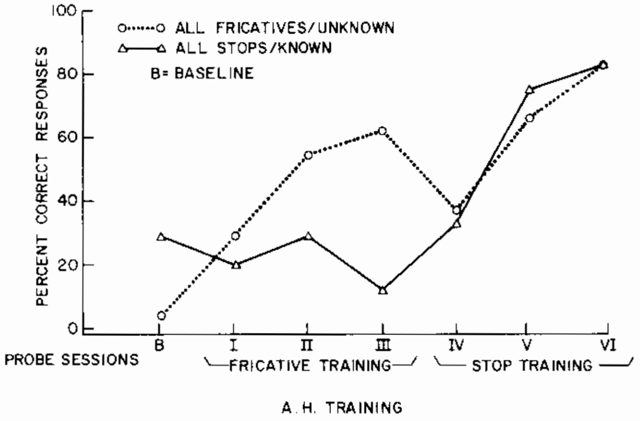

FIGURE 3. Percentage correct responses to fricative and stop probe items based on the results of the phonological analysis showing knowledge of underlying representations for subject A.H. The first three probe tests were administered during fricative training and the last three during training of stops.

It might be noted in this regard that M.B. was the only subject for whom the distinction between previously known and previously unknown was empirically unjustified. We suggest that a child who evidences some knowledge of adult (ambient) underlying representations (P.P., C.P., and A.H.) will render a different learning pattern than a child with more limited knowledge of underlying representations (M.B.). In other words, it appears that correct (adult-like) knowledge of some underlying representations enhances the effect of training a particular class and thus results in better performance on the class being trained than on the untrained class. Conversely, incorrect knowledge of all underlying representations (as in the case of M.B.) allows an effect on the trained class, but not so dramatic as to exceed the performance on the previously trained class. This, of course, is highly speculative at this point. More subjects with a M.B. type phonology would need to be studied where, for example, the order of training is reversed.

Let us return to the question of why A.H. performed better on fricatives (previously unknown) during fricative training. The reason given above is that performance will be better on the trained class of obstruents than on the untrained class. Another reason for A.H.'s better performance on fricatives may well be that his knowledge of stops was not complete. That is, while A.H. demonstrated knowledge of the possibility of any obstruent stop occurring after a vowel, he did not represent all morphemes correctly in underlying representations.[2] This incomplete knowledge of postvocalic stops has the effect of diminishing performance on stops and rendering them more like a class of previously unknown obstruents. It is probably fair to say that A.H.'s phonology is in a transitional stage.

The effects of order of training, (i.e., training stops before training fricatives versus training fricatives before stops) on performance must be considered. It was observed in the Elbert and McReynolds study (1980) that subjects do not generalize from one class (stops or fricatives) of obstruents to the other regardless of order of training. Such a finding suggests at least that the class of postvocalic stops is unrelated to the class of postvocalic fricatives. Training fricatives, then, should not affect stops, and training stops should not affect fricatives, or at least there should be no difference between effects. It may be the case, however, that training fricatives before stops enhances the learnability of stops. Thus, even though there may be no generalization from one class to the other, performance on stops will approach congruity with fricatives. This is evident in the two subjects who were trained first on fricatives, namely C.P. and A.H. (Figures 2 and 3, respectively). In the case of C.P., for example, compare his performance on known fricatives with his performance on known stops. The same comparison can be made between unknown fricatives and unknown stops. It seems that whatever classes are compared, the differences in performance are diminished when fricatives are trained first. This is in sharp contrast with the two subjects who were trained on stops first, namely P.P. and M.B. (Figures 1 and 4, respectively). Note, for example, that P.P.'s performance on known stops was consistently about 60% better than his performance on other fricatives or stops. Similarly, M.B.'s performance on stops was on the average about 50% better than his performance on fricatives.

When viewed in this light, there does appear to be a relationship between the classes of postvocalic stops and fricatives. The relationship is implicational and unidirectional in nature such that training fricatives enhances (in the sense described above) performance on stops; the converse is not true.

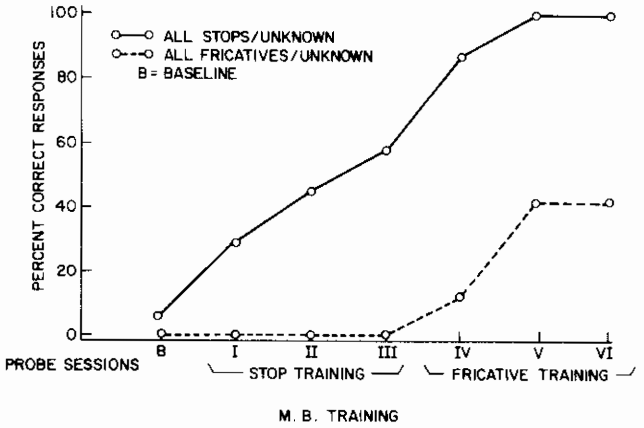

FIGURE 4. Percentage correct responses to fricative and stop probe items based on the results of the phonological analysis showing knowledge of underlying representations for subject M.B. The first three probe tests were administered during training of stops and the last three during training of fricatives.

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[2] This is not to say, however, that all morphemes from the ambient system ending in labial, dental, or velar stops will be represented underlyingly in this child's system with the appropriate final obstruent. Note especially the following forms which evidence no medial obstruent or alternation: [dæi] "daddy" ∼∼ [dæ] "dad," [bei] "baby," [iin] "eating." These forms suggest that the postvocalic obstruent is omitted in the underlying representations of these morphemes. Consequently, this child's knowledge of morpheme final stop obstruents is not complete. This point will be relevant to the interpretation of the training results for this child.

There may be an explanation for this implicational relationship between stops and fricatives from markedness theory (Jakobson, 1968). That is, the occurrence of fricatives in a language implies the occurrence of stops in that language, but not vice versa. Fricatives are thus more marked than stops. The suggestion is that fricatives are more difficult in some sense than stops. Receiving training then on a more difficult sound and learning it may reasonably enhance the learnability of an implied or easier sound.

In the preceding discussion three general factors were identified that account for the individual learning patterns of the subjects of this study and that are offered as testable hypotheses for further study: (a) class being trained; (b) knowledge of underlying representations; and (c) order of training.

Each factor can be stated in terms of explicit hypotheses:

A. *Class being trained.* A child's performance on the class of postvocalic obstruents being trained will be as good or better than performance on the untrained class, independent of the distinction known/unknown.

B. *Knowledge of underlying representations.* A child's performance on phonologically known possibilities can be distinguished from performance on phonologically unknown possibilities. At any point in time, a child's performance on phonologically known possibilities will be better than performance on previously unknown possibilities.

C. *Order of training.* Training postvocalic fricatives before training stops enhances the learnability of stops.

These various hypotheses, while independent, do interact in specifiable ways to yield predictions of relative ease/difficulty with regard to learning particular classes of obstruents as a result of training. The class being trained takes precedence over knowledge of underlying representations such that a child's performance on postvocalic obstruents can be scaled from successful (easiest) to unsuccessful (most difficult) as follows:

1. phonologically known possibilities within class being trained
2. phonologically unknown possibilities within class being trained
3. phonologically known possibilities within untrained class
4. phonologically unknown possibilities within untrained class.

The order of training does not affect the relative ranking; it only conditions the magnitude of the effects associated with the other factors noted above.

None of these factors is sufficient by itself to explain all of the variations in individual learning patterns. Together, however, they do account in considerable detail for the patterns observable in these data. Of course, it would be very difficult to show that these factors are necessary in view of the limited number of subjects. It is nonetheless striking that these patterns correlate with each subject's individualized knowledge of underlying representations. It must be noted as well that any approach to phonological analysis that simply assumes that the child's underlying representations are the same as those of the surrounding community provides no explanation for why there should be differences in a child's performance that correspond with empirically based assessments of phonological knowledge. Any of the patterns in this study that we related to the distinction *known/unknown* in underlying representations must be regarded by these other approaches as purely accidental.

A number of hypotheses have been formulated as a tentative account of individual differences in learning observed in four children. We hasten to point out that despite the apparent strength of these claims, this is essentially a descriptive study and certainly is not definitive. We do believe, however, that despite the need for tentativeness in accepting these hypotheses, it is essential to formulate these hypotheses explicitly for the purpose of further testing.

It is essential to generate many more descriptions of misarticulation systems. From such descriptions, we can begin to characterize the range of possible grammars compatible with functional misarticulation data. The present study deals with phonological variation limited to final consonant omission. Similar studies involving other error patterns would serve as a further test of these claims. Finally, our analysis of these data is just that—an analysis, an interpretation—and other interpretations are obviously possible. A truly compelling case would show that at least the most obvious alternatives are not in fact alternatives. In this case, the most obvious alternative that we can imagine is that all four subjects have internalized the correct underlying representations. That is, the subjects are not differentiated in terms of their knowledge of underlying representations. They would then have to be differentiated in terms of their phonological rules. Individual differences in the learning patterns would have to be correlated with having internalized different phonological rules. It is not clear to us that such a correlation is possible. However, even if possible, the correlations would entail phonological rules that are not otherwise independently motivated. We submit that our interpretation is preferable on the grounds that the rules involved in our analysis are independently motivated.

ACKNOWLEDGMENTS

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Chapter 7
Procedures for Linguistic Analysis of Misarticulated Speech

Edith M. Maxwell
Kurzweil Speech Systems, Inc.

Barbara K. Rockman
Indiana University

In recent years, applications of linguistic methodology and phonological theory to the area of articulation disorders have become so widespread that many question whether all misarticulations might not be regarded as phonological problems. As a result of this increased interest in phonological theory, several instruments for the phonological analysis of misarticulated speech have been devised (see Edwards, 1982). While these procedures differ in their methodologies, all are based on the same assumption—that the child is attempting to produce the phonemes contained in the adult target, and that the child has the correct (adult) underlying form for the word attempted (see Maxwell, 1984, chapter 3 of this volume). Given this assumption, discrepancies between the target adult word and the child's incorrect production must be explained. These discrepancies have been attributed to the application of specific phonological processes or rules to the child's correct underlying forms with the effect of simplifying them. The analysis procedures referred to above are concerned with identifying these phonological processes in children's speech. Because the procedures are based on the assumption that the child is attempting the correct adult form of a word, these phonological process analyses remain grounded in traditional substitution or *error* analysis, which assumes that one phoneme has been produced when another was actually intended.

In this chapter we discuss an alternative approach to the analysis of children's misarticulated speech, traditional generative phonology, and examine how assumptions based on this model differ from those on which most of the existing instruments are based. In essence, this approach does not assume that the child shares the adult's phonological knowledge. Instead, it uses standard linguistic methodology to determine the child's knowledge of the phonological units of the language.

It should be noted that the use of generative phonology in the analysis of children's speech has been claimed by several writers, Smith (1973) in particular. However, Grunwell (1982), in her description of the use of generative phonology in the analysis of children's speech, noted that with few exceptions these investigators also have assumed that the child has the correct, adult underlying form, and they have used the methodology to describe the relationships between adult and child productions. This approach to generative analysis would seem to violate one of the defining principles of generative phonology—that the speaker's underlying forms are posited based on evidence provided by the speaker. Grunwell expressed serious reservations about the way generative analysis has been used to date for children's speech, and she noted that the phonological rules that have been written continue to be correspondence rules linking the adult and child systems.

The generative approach we describe in this chapter is based on very different assumptions. Because it does not assume that the child is attempting the adult form of a word, it does not begin from a substitution or error framework. The child's speech is analyzed as an independent system, and conclusions concerning the child's underlying forms and phonological knowledge are based on evidence from his or her own system. Thus, claims concerning the child's phonological knowledge are based on empirical data rather than on a priori assumptions.

Any speech analysis, regardless of the assumptions on which it is based, will include certain steps, such as obtaining a speech-language sample, reducing the data in some fashion, categorizing the data, and interpreting the results. Before presenting the procedures used in the generative phonological approach, it may be of value to examine several of the current instruments for the phonological analysis of misarticulated speech in terms of these steps. Such an examination should make clear the similarities among these instruments and the differences between them and the approach presented in this chapter.

SPEECH-LANGUAGE SAMPLE

The Compton-Hutton Phonological Analysis (Compton & Hutton, 1978) and the Assessment of Phonological Processes (Hodson, 1980) use spontaneous naming of a fixed set of stimulus items, 50 pictures for the former and 55 objects for the latter, as their speech sample. In the Procedures for Phonological Analysis (Weiner, 1979), a combination of a single word and phrase responses is elicited by use of 136 pictures and both sentence-completion and delayed-imitation procedures. Thus, each of these three procedures uses specific preselected stimulus words for the analysis. In Natural Process Analysis (Shriberg & Kwiatkowski, 1980) a spontaneous speech-language sample is collected. A sample of 200–250 words appears to be large enough to yield the 90 different words that are used in the actual process analysis. Ingram's Procedures for the Phonological Analysis of Children's Language (1981) leaves the form of the sample to the individual clinician, noting that spontaneous language samples, phonological diaries or elicitation, and testing procedures are all appropriate. Ingram gave no specific guidelines regarding the length of the sample to be used in the analysis.

Many of the authors have discussed the problems of gathering a representative sample of the phonemes of English and the enormous intelligibility problems that arise when using spontaneous speech as the speech sample. Thus, several have elected to use preselected stimulus words to ensure that the child attempts all phonemes and to make the intended word clear. At the same time, it is generally agreed that these procedures sacrifice important information available from connected speech samples. The procedures reported in this chapter are based on a combination of elicited stimulus items and spontaneous speech. Thus, there are two types of data, which are used as cross-references during analysis. Another important aspect of the procedure presented in this chapter is that of the second data collection session. The procedures used typically yield several preliminary findings, which then may be empirically tested. The individual performing the analysis constructs or devises several additional "test" forms, based on these preliminary findings, which are taken back to the child in a brief second session. The results of this step (the child's productions of these additional forms) provide the necessary data to support or refute the earlier, tentative findings. None of the procedures discussed earlier provide for the collection of additional data, and analysis of results is based only on the initial sample taken.

ORGANIZATION OF THE DATA

The procedures listed above generally provide specific guidelines for organizing the transcribed data from the speech-language sample. Both Shriberg and Kwiatkowski (1980) and Ingram (1981) used a variety of forms to organize the data before performing their analyses. Shriberg and Kwiatkowski included only the first production of a word in their analysis and they used 90 different words. Monosyllables were categorized according to five syllable structures and the position of each adult consonant within each syllable structure. Two-syllable words and words of more than two syllables were also noted. Ingram (1981) first organized the data alphabetically by the first letter of the adult word. The data were then further organized according to the initial, final, and ambisyllabic (consonant between two vowels) position of the phonemes in the adult word. For those procedures that elicit single words (Compton & Hutton, 1978; Hodson, 1980; Weiner, 1979) there is not a clear-cut division between organizing the data and performing the actual analysis. Each provides a form or score sheet on which the transcribed item is entered and on which the analysis itself is then performed.

The present procedure provides no specific forms for organizing the conversational data and one form for consolidating the data from the elicited word task. This form is organized to allow for examination of possible alternations in the child's use of sounds (production of a sound under certain morpheme conditions but not under others) and determination of the child's use of phonemic contrasts (see Dinnsen, 1984, chapter 2 of this volume). No attempt is made to organize the data by position of phonemes as they occur in the adult form, and the method of organizing the data, therefore, is largely left to the individual performing the analysis.

PHONOLOGICAL PROCESS ANALYSIS

The most striking similarity among the instruments described above is that each uses a predetermined category system for assigning the child's errors to phonological processes. Whether a closed or fixed set of processes is used (Hodson, 1980; Shriberg & Kwiatkowski, 1980; Weiner, 1979) or an open set allowing for any process noted to be included in the analysis (Ingram, 1981), all operate directly on the discrepancy between child production and adult form. Thus, there is a "matching" procedure in which each error is examined to see whether a given process on the list could have applied. If the error is explainable in terms of a specific process, the error is assigned to that process. No additional evidence is required to support or refute the presence of a process although the problem of how many occurrences constitute a process has been raised by several authors, notably Ingram (1981).

In the Compton-Hutton (1978) procedure, 40 "phonological rules" that have been noted to occur commonly in the speech of young children are listed and the clinician circles those that apply. Thus the patterns observed (e.g., final /l/ is omitted) are expressed as phonological rules (e.g., 39. (Final) /l/ → Ø). Weiner (1979) listed 20 phonological processes arranged in three major categories: syllable structure, harmony, and feature contrast processes. Each of the child's responses is analyzed to determine whether any of the processes that a given word was intended to sample is present. Thus, if the child's error is explainable by a specific process, that process is assumed to have applied. Similarly, Hodson (1980) listed 42 types of processes or deviations on her analysis sheet, although not all processes are possible for all stimulus words. Discrepancies between child production and adult word are noted in any of the 42 categories that may account for them; more than one process may be invoked to account for one discrepancy.

Shriberg and Kwiatkowski (1980) have limited the number of processes that they look for to eight "natural processes": final consonant deletion, velar fronting, stopping, liquid simplification, regressive assimilation, progressive assimilation, cluster reduction, and unstressed syllable deletion. Processes are coded in a fixed sequence so that, with one exception, each sound change is only attributed to one process. Ingram (1981) listed 27 processes for which the clinician initially examines the data. The clinician is then encouraged to postulate processes for those substitutes not described by the 27 processes listed. As in the Hodson procedure, two or more processes may operate on a segment simultaneously and both are recorded.

It should be clear on the basis of the procedures described that the traditional substitution analysis serves as the basis for this type of phonological analysis. For the most part, any correspondence between a child's error and a phonological process that could result in such an error is interpreted as evidence that that process, in fact, has applied. As noted by Ingram (1981), when each discrepancy between child and adult form is thus categorized, one is faced with the question of how many occurrences constitute a process (see McReynolds & Elbert, 1981). Each of the procedures provides for quantifying the occurrence of the various processes. That is, a percentage of occurrence may be calculated, which shows how many times a process applied in relation to the number of opportunities there were for its occurrence. The writers have suggested different guidelines or cutoff points for counting error occurrences as phonological processes.

Because of the similarity in the underlying assumptions on which these procedures are based, it seems quite likely that all would yield much the same results. The generative approach described in this chapter, however, is not based on these assumptions. There are no lists of processes with which to examine the data because the child's speech is analyzed as an independent system. Any conclusions that are drawn concerning the child's phonological knowledge are based on his or her own system. This approach allows for the possibility that the child is attempting to produce the "correct" sound, but does not assume such a possibility to invariably be the case. Unless the child's actual phonological knowledge can be demonstrated, there is always the risk of attributing greater phonological knowledge to the child than is deserved. The generative approach, by allowing for the possibility of differential phonological knowledge, also allows for the possibility that children may respond differentially to remediation based on their phonological knowledge. Ultimately, it is this possibility that warrants our attention. In the following pages, we present the steps used in the generative phonological analysis and examples from the speech of a misarticulating child. At the end of the chapter, two analyses are shown for the same child at two points in time.

RELIABILITY

The analysis procedures described and the data included throughout the chapter are drawn from one child, M.B., who was 3½ years old when first seen in our program. He remained in the program for approximately 18 months; thus, there was opportunity for repeated phonological analysis of his speech. The data presented were transcribed by one of two recorders who worked with the child, one a speech-language pathologist, the other a linguist, both well versed in phonetic transcription. To establish reliability between these two recorders, speech samples of several children with multiple misarticulations were transcribed independently by these two listeners and analyzed for agreement. Agreement for consonant production ranged from 92 to 98% for whole-word transcriptions of the single words from several standard articulation tests. On sentence-length utterances from conversational speech, agreement ranged from 85 to 98%. Thus, using a range of children and a range of tasks, point-by-point agreement concerning consonant productions was never less than 85%; therefore, it was felt that the transcriptions of one or the other of these recorders would be representative and reliable for further analysis.

DATA COLLECTION 1

The data for the initial analysis were taken from two kinds of samples of the child's speech. The sample and the procedures for gathering them are described below.

Spontaneous Sample

First, a tape recording of spontaneous speech was obtained. (See Appendix, page 85.) In the clinical setting, this was usually taken from a session involving one or two clinicians, the child, and perhaps a parent, all seated in a quiet room. The child was encouraged to speak, to describe pictures or toys, or to tell about activities in his daily life. An articulation test was sometimes used in picture naming to obtain words and sentences in a conversational context. It has been shown (Maxwell & Weismer, 1981) that even though some children can, in imitated isolated words, produce an inventory of speech sounds that is very similar to that of the ambient language, the same children will not use those sounds linguistically in their running speech. It is therefore important to obtain a sizable sample of spontaneous connected speech. The sample should contain at least 100 words and preferably more. The samples on which the work in this volume was based were transcriptions of at least an hour of child speech. The session was "translated" orally, phrase by phrase, by the clinician(s) so that transcribers working with the tape at a later time had a key to the meaning content of the phrase or sentence. This is particularly important with severely unintelligible children. Although these children's phonologies often differ radically from the ambient phonology, their semantic (meaning) systems are not different and will need to be referred to in the organization of the data.

Many of the available phonological analysis procedures point to the difficulty of obtaining conversational samples from these children because of their poor intelligibility. They therefore assess only single-word responses. Use of the parent as informant, however, can overcome the intelligibility barrier to a great extent; the importance of context cannot be overemphasized.

Delayed Imitation Sample

The second source of data is a delayed-imitation phonological screening task (see Appendix A). This task was constructed to meet several needs because it became apparent that a spontaneous speech sample often lacked crucial alternations or exhibited other data gaps. The task includes 89 words. It first samples all of the contrasting sounds (see Dinnsen, 1984) of the adult language in near minimal pairs so that the distribution of the child's sounds (the pattern of sounds in the child's speech) may be seen. Voice, place, and manner contrasts of English are tapped in all word positions. Second, to examine how phonemes change according to phonological context (alternations), different forms of the same morpheme are elicited, for example, a word-final consonant is also elicited between vowels: *miss, missing*. Several word-initial consonant clusters are also explored and contrasted with forms that would result if one member of the cluster were not produced: *try, tie*. In other words, the task elicits forms that contrast in the adult language to note whether these distinctions are maintained or collapsed in the child's speech. The task has been revised and expanded several times to provide data for more complete analyses. The final version was not devised until after the first analysis of the subject discussed in this chapter was carried out.

The screening task consists of a series of imitated 4-word sentences, with each target word as the final element of a sentence. Each test word is preceded by the word *say* (e.g., I can say ______). Although the sentences are imitated directly after the clinician's production, because of the delay in saying the target word, the child produces it not purely as an imitation, but as part of his or her spontaneous speech mode. While one clinician elicited the sentences, another followed and transcribed the target words live-voice to provide a reliability check with the later transcription of the tape-recorded responses. Live transcription is recommended whenever possible.

DATA ANALYSIS 1

Transcription, organization, and analysis of the data for M.B. are described below.

Transcription

The spontaneous speech sample was "glossed," that is, translated or written in terms of its adult or standard language equivalent. For example, if the child said [aɪ oweɪ da wʌn], the utterance was written as "I already got one." Next, using the tape, the utterances were phonetically transcribed above the gloss or translation. A complete transcribed set of data for the spontaneous speech sample appears in the Appendix to this Monograph. Generally, a broad transcription in International Phonetic Alphabet (IPA)[1] symbols is sufficient for analysis, but any nonambient-sounding consonants should be indicated with diacritics. For example, partial absence of voicing on voiced obstruents or presence of voicing on voiceless ones by M.B. was marked by an open dot below the symbol: [d̥] indicates a partially voiceless consonant. Unusual lack or presence of aspiration, lateral fricatives, unusual vowel length, and so forth, were also indicated. It has been our experience that the vowels of children labeled as functional misarticulators do not show any crucial deviations from the ambient vowel system (see Tallal & Curtiss, 1976, for a possible explanation of this phenomenon). Because the transcription of vowels is further complicated by marked regional differences, vowels were transcribed broadly (or *phonemically*, in the sense of Dinnsen, 1984). In cases of doubt about specific factors (e.g., voicing of a consonant), spectrographic analysis (also see Dinnsen, 1984) was used as a backup reliability check.

The target words on the screening task were transcribed from tape recordings. See Appendix B for an example of M.B.'s screening test used in the second analysis of his speech (based on stimuli slightly different from those in the final version—Appendix A).

Data Organization and Analysis

Following the administration of the morphophonemic screening task, the child's transcribed responses were transferred to another form or worksheet, shown in Appendix C, on which the target words are grouped according to the problem each set of words was designed to probe. This form has been organized so that related forms can be examined within each problem set. Thus, many forms for comparison are listed more than once (e.g., *sty, sigh, tie; sly, sigh, light*). Forms that are frequently produced as errors are shown in parenthesis, for example, (*white*).

Once all of the data has been transcribed and prepared as described, analysis can begin. But first a comment on the analysis of human language is in order. Although there are established linguistic methodologies for the description and analysis of the various components of a speaker's grammar, these take the form of general instructions, and cannot be followed as if they constituted a recipe. The phonology of a child is no less a component of a human language than the phonologies of adult English or adult Japanese or adult Swahili, and therefore should not be dealt with as if it were a uniformly categorizable set of "processes." Our approach has been to treat the speech of each child as a human language, capable of all the variation that other languages demonstrate. Human language is systematic and rule-governed, and is subject to universal constraints on what it can and cannot be, but the analyst must (a) provide evidence in support of any rule claimed to be operating, and (b) be ready to acknowledge variation when it occurs.

The assumptions and methods of the published tests for phonological processes in the speech of misarticulating children, reviewed in the beginning of this chapter, preclude both the possibility of real variation occurring and the bringing to bear of system-internal evidence in support of the rules that are proposed. Asserting that there are x and only x number of processes possible in a child's phonology, and that error y implies the existence of process z, is to disregard both individual and system variation, and may result in inappropriate analyses.

The analysis methods that follow, then, do not provide an easy formula for describing the child's phonology; there are no quantitative measures to be entered on profile sheets. It is required, however, that appropriate linguistic evidence must be presented before a rule can be claimed to be operating.

Phonetic Inventory

The first step in finding such evidence was to list the child's phonetic inventory. This is shown below for M.B., Stage 1.

Analysis 1: M.B., age 3:10, June 1979

PHONETIC INVENTORY

b	d		ʔ
m	n		
w		j	h

Vowels as in adult English

Even if a child uses a sound that is not part of the adult phonetic inventory, such as /x/ for English, it is still included in the phonetic inventory. This inventory is also not sensitive to where or how frequently a sound is used; any and all sounds produced are listed.

---

[1] Portions of the data in this chapter were transcribed using the American Phonetic Alphabet, typically used in the linguistic literature.

Contrasts

The next step was to investigate the contrasts that the child used. Dinnsen (1984) has explained more fully the rationale behind the concept of contrasting sounds, but in brief, two sounds that are used contrastively will make a difference in meaning between two otherwise identical words. For example, if the only difference between *pat* and *bat* are the two sounds /p/ and /b/, and if these two words have different meanings, then /p/ and /b/ are said to contrast and will be included as *phonemes* of the language.

The screening task provides examples of the contrasting consonants of English in initial, intervocalic, and final position in words. The screening task data and the spontaneous speech sample allow one to examine the sounds the child uses contrastively and list them according to place, manner, and voice, and by position. For example, the voice contrast was examined first. M.B. did not have a voice contrast in stops in initial or medial position at the time of the first analysis; he used only apparently voiced stops. Because this child did not use postvocalic obstruents (except after a nasal consonant or before a stressed syllable, a very limited distribution), stops in final position could not be discussed. He also did not use fricatives or affricates, and it therefore was not relevant to discuss the voice contrast in those cases. The screening task gave a clue that this contrast was not yet well established, but because the test contained such a limited number of items, further data supporting this analysis had to be drawn from the spontaneous sample.

The statement of contrasts is basically a description of how the sounds are distributed in the system. That is, if both stops and fricatives can occur at the beginning of a word in a particular child's speech, then a manner contrast exists for stops in initial position. If, however, the distribution of stops is limited to, say, initial and final position, and that of fricatives to medial position, then stops and fricatives would not contrast (again, see Dinnsen, 1984, for a more detailed explanation of distributions and contrasts). M.B.'s contrasts at Stage 1 are shown below.

CONTRASTS

No voice contrast in stops:

[bɛni]	*penny*	[du]<	*to*	[dæn]	*can*
[bɛ]	*bed*		*do*	[dan]	*gone*

No manner contrast or place contrast in obstruents except for labial/dental:

adult segment		
f	[bæ]	*fast*
v	[bæˀum]	*vacuum*
p	[bɛni]	*penny*
b	[bɛ]	*bed*
spr	[bɛin]	*spreading*
fl	[bai̯]	*fly*
fr	[bɛ]	*Fred*
bl	[bu]	*blue*
br	[bɛ]	*bread*
pl	[bɛi̯]	*plate*
t	[du]	*to*
d	[du]	*do*
ð	[dæˀ]	*that*
θr	[do]	*throw*
θ	[diŋ]	*thing*
k	[dao̯]	*cow*
g	[dɪ]	*give*
kl	[dao̯u̯n]	*clown*
gl	[dæ]	*glass*
dʒ	[dʌ]	*just*
tʃ	[di]	*cheese*
dr	[diˀn]	*drinking*
tr	[dʌ]	*truck*
st	[dæɪn]	*standing*
sk	[di]	*ski*
tw	[dɪn]	*twin*
kw	[din]	*queen*

Oral/Nasal contrast present:

[mæ] *mask* / [bæ] *fast*
[nɛi̯] *snake* / [dɛi̯] *sail*

Contrast between glides present:

[wɛ]< *legs* *red* / [jɛo] *yellow*

Phonemic Inventory

Once the contrasts were established, a phonemic inventory was formulated. This was either done in the same way as the phonetic inventory, listing the phonemes of the system according to place, manner, and voice, or the phonetic inventory was used as a background and the phonetic segments that corresponded to the phonemes were circled. Thus, if the phonemic inventory was a subset of the phonetic, which often is the case, the differences between the two could be easily compared. In M.B.'s case, at Stage 1 the phonemic and phonetic inventories did not differ. The difference is more clearly illustrated with the Stage 2 phonetic and phonemic inventories shown here.

Analysis 2: M.B., age 4:2, October 1979

PHONETIC INVENTORY

p b t d k g ʔ
f θ s z ʃ
tʃ
m n ŋ
w j h
l

Vowels as in adult English

PHONEMIC INVENTORY

p b t d k g
f s ʃ
tʃ
m n ŋ
w j h
l

Vowels as in adult English

This stage of the analysis is still a preliminary one. It often happened that crucial data were not available in either the spontaneous sample or the screening task. For this reason the screening task was revised, as mentioned above, to include a more complete set of data. As the analysis proceeded, a list of words needed to complete and support the analysis was kept; these words were elicited at the next possible opportunity (see Data Collection 2, p. 74). This kind of data might include the other half of a needed minimal pair, or a morphophonemic alternation for an already collected word.

There is an element of timeliness in performing analyses such as those under discussion here. If, after the initial data collection, more than 1 or 2 weeks are spent in the initial analysis or if the analysis is put aside for more than 2 weeks, the speech of any child undergoing remediation is very likely to change, and the additional items to be elicited will perhaps no longer be available.

Syllable Structure and Occurrence Restrictions

The next step in the initial analysis was to determine the child's general *syllable structure* and *occurrence restrictions* (e.g., Can obstruents occur word-finally? Are weak syllables produced? Are there any multisyllabic words? Can a consonant occur after vowels?) and to propose phonotactic constraints and/or phonological rules to account for the child's speech production system. To accomplish this, the data were searched for patterns of sound usage and occurrence. For example, M.B.'s general syllable and word structure disallowed word-final obstruent consonants at the first analysis; all words ended in vowels (with the regular exception of word-final nasal (nonobstruent) consonants). M.B.'s Stage 1 syllable structure and occurrence restrictions are shown below.

OCCURRENCE RESTRICTIONS AND SYLLABLE STRUCTURE

1. Obstruents occur (a) word-initially: [dæ] *dad*, [dæi] *daddy*, [dɔ] *dog*, [dɔi] *doggy;* (b) word-medially only when (i) preceded by a nasal, or (ii) preceding a stressed syllable.

(i)	[ʌmbʌi]	*somebody*	(ii)	[maj̩dɛo]	*myself*
	[æmbUU]	*hamburger*		[bidʌ]	*because*
				[dɪʔbɪ]	*disappeared*
				[Udɛiʔo]	*potatoes*

2. Nasals occur initially and finally as in the ambient language; when absent medially or finally the preceding vowel is nasal:

[mami]	*Mommy*	[bɛni]	*penny*
[ɪm]	*him*	[dæ̃in]	*standing*
[pʌ̃ʔn̩]	*pumpkin*	[dɪŋ]	*thing*
[nomæn]	*snowman*	[wɪ̃]	*ring*
[nomæ̃]		[bɪŋo]	*finger*

Once this was observed, the data were reexamined for morphophonemic alternations where a nonproduced target word-final obstruent might have been produced between vowels (e.g., dog and do*gg*ie). For this particular child, however, no alternations were found; he produced no postvocalic (or syllable-final) obstruents. This child was therefore said to have a phonotactic constraint against postvocalic obstruents (see Dinnsen, 1984, for more detail).

On the other hand, a child who had evidenced intervocalic but not word-final obstruents in an alternation (/dɔgɪ ~ dɔ/) would be said to have a phonological rule deleting word-final consonants and not to have a general phonotactic constraint operating in his or her system. That is, the fact that the consonant is produced as part of the morpheme as long as it does not occur word-finally, constitutes evidence that there is a segment to be deleted.

This section of the analysis, which in fact is its core and essence, is crucially system-internal. A rule should not be written that deletes a segment if the child never produces that segment; such a rule would be only a statement of the correspondence between the child's and the adult's systems rather than an accurate description of the child's own phonology. The distribution of sounds in a child's system according to context and word position, contrasts, and morphophonemic alternations must all be thoroughly investigated to describe the phonology, and are the kinds of evidence necessary to support such a description.

Once the initial analysis was done, a list of words were needed to complete and support the claims of the analysis. For example, as shown in Sample Analysis 1 (Appendix D), the child did not produce obstruents either word-finally or intervocalically on the screening task, although one example of a word-medial obstruent did appear: /bidɔ/*because*. The intervocalic /d/, however, precedes a stressed syllable; the list for further elicitations therefore included more possible examples of intervocalic pre-stressed-syllable obstruents to provide support for the analysis, (e.g., po*t*atoes, my*s*elf, disa*pp*eared, etc.).

DATA COLLECTION 2

This second data collection was much briefer than the first, but the same techniques were employed. The necessary words were elicited from the child in spontaneous conversation about pictures, objects, and activities, and the session was tape recorded. If the child failed to produce certain words on the list, the delayed imitated sentence method was again used. The tape was again glossed and transcribed by two listeners.

DATA ANALYSIS 2

With the addition of the supplementary words, the final analysis was carried out. If a pattern or rule in the child's speech had been observed, but items illustrating the rule's operation were not initially elicited, the final analysis involved merely inserting the supporting data into the report. It sometimes, however, entailed redoing the initial analysis if items obtained at the second data collection showed the first analysis to be incorrect or overgeneral. The second analysis in this case was then repeated with the same techniques as were used previously. It was occasionally necessary to collect additional data and to revise the analysis more than once. This was done with all possible speed, as mentioned above, to avoid the possibility of the child's speech changing under remediation.

A final analysis, then, is a complete report on a child's phonological system at one point in time; it includes a phonetic and phonemic inventory, a statement of contrasts and syllable structure, and a statement of any constraints and rules operating in the child's system. Each section should include the supporting data for the analysis. There are occasionally pieces of data that do not fit into the regular patterns of the rest of the system, and in this case a statement of the inconsistencies or exceptions should be included. An example is the Notes section shown below for M.B., Stage 1.

NOTES

A different strategy is employed for adult /s/ and /ʃ/ than for other obstruents which are realized as [d] or [b]:

1. Adult /s/ has a Ø realization:

[aoṷˀ]	*salt*	[wɪŋ]	*swing*
[wo]	*slow*	[da]	*star*
[nɛo]	*snail*	[bɛɪn]	*spreading*

2. Adult /ʃ/ is realized as [j]:

[ju]	*shoe*
[juə̣]	*sure*
[ʌnjuə̣]	*unsure*

A separate acoustic phonetic analysis revealed the various [d] productions to be differentially produced with respect to voice onset time (VOT). The child is distinguishing three categories corresponding to the adult voice contrast plus target /d/ in the adult language (see Maxwell & Weismer, 1980).

The final section of this paper contains two sample final analyses from one child, M.B. (see Appendices D and E). This child was followed over time and through remediation, and the analysis procedures outlined above were repeated three times; only two representative analyses are included here. The change in his phonology was substantial over a short period of time; change occurred not only in his phonetic inventory and distribution of sounds, but also in the shift from only phonotactic constraints to several identifiable phonological rules and fewer constraints. Examples of these rules and the supporting data from M.B., Stage 2, are shown below.

RULES AND OCCURRENCE RESTRICTIONS

As stated in CONTRASTS, intervocalic stops are subject to one of two rules, depending on their voicing. Voiceless fricatives also appear to undergo the rule that stops do, although supporting evidence is not complete.

1. *Voiceless consonant glottalization*

$$[-\text{voice}] \rightarrow \begin{bmatrix}-\text{cons}\\ -\text{cont}\end{bmatrix} / \ [+\text{syl}] \underline{\qquad} [+\text{syl}]$$

(Voiceless obstruents become glottal stops between vowels)

[dʌk]	[dʌˀi]	[pɛp]	[pʌˀi]
duck	*ducky*	*pep*	*peppy*

[dɪˀə]	[pɪˀo]	[dɛi̯ˀɪn]	[tuˀɛik]	[hæˀi]
dishes	*pickles*	*chasing*	*toothache*	*happy*

2. *Voiced consonant deletion*

$$\begin{bmatrix}+\text{voice}\\ -\text{son}\end{bmatrix} \rightarrow \emptyset / \ [+\text{syl}] \underline{\qquad} [+\text{syl}] \quad \text{OPT.}$$

(Voiced obstruents optionally delete between vowels)

[dɔg]	[dɔi], [dɔgi]	[bɛi], [bɛi̯bi]
dog	*doggy*	*baby*

Again, supporting evidence for Rule 2 is not complete. There are few instances of voiced obstruents occurring between vowels, and examples such as

[wæɪ] *rabbit,* [nobʌi] *nobody,* [mʌɪ] *mother,* and [foɛə] *forever*

may reflect the underlying representations of the words, not the output of Rule 2 (that is. there may be no underlying consonant). If the rule's application is general, we would expect to see occurrences of

*[bai] for *Bobby* (cf. [bab] *Bob*, [babi] *Bobby*), and
*[pɛi] for *piggy* (cf. [pɪg] *pig*, [pɛgi] *piggy*).

(* = unattested)

Interacting with the availability of supporting evidence for the above rules is a generally applying optional rule of Final Consonant Deletion.

3. *Final consonant deletion*

$$[-\text{son}] \rightarrow \emptyset / \underline{\qquad} \# \quad \text{OPT.}$$

(Obstruents may delete word-finally)

[hæ] [hæd]	*had*	[lai̯] [wai̯ˀ]	*like*	[mɛo] [mɛok]	*milk*	[jɛi̯] [jɛi̯k]	*shake*
[dɔ] [dɔg]	*dog*	[dʌm] [dʌmp]	*jump*	[bæ] [bæˀs]	*bath*	[bæˀtʌ] [bæˀtʌb]	*bathtub*

No generalization can be made about the conditioning environment beyond the word boundary.

In summary, we have presented data for one child that is based on a system-internal generative phonological analysis. This type of analysis is unquestionably more time-consuming than the process analysis procedures described earlier and requires a greater degree of linguistic training. Nonetheless, we believe that it is a crucial heuristic tool for studying the phonological systems of children with severe phonological disorders. By moving beyond the categorization of the child's productions as a set of phonological processes and by examining the system-internal evidence that is provided by such an analysis, we are able to make certain claims concerning the child's phonological knowledge or, in some cases, lack of adult-like knowledge. This kind of information, collected from a large number of children, will allow us eventually to expand these claims into empirically testable predictions concerning the treatment of phonological disorders. A specific linguistic approach to remediation may be found to be best suited for specific phonological knowledge or, conversely, for specific gaps in phonological knowledge. As noted earlier, it is this possibility that ultimately warrants our attention.

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APPENDIX A

Name: ______________________
Date: ______________________
Transcriber: ______________________

Phonological Screening Task

1. I can say *thin* ______________________
2. We always say *smiling* ______________________
3. You can say *pat* ______________________
4. You always say *zoo* ______________________
5. We can say *dry* ______________________
6. Mom can say *Buddy* ______________________
7. He can say *blade* ______________________
8. I always say *buy* ______________________
9. Bob can say *duckie* ______________________
10. I can say *scrape* ______________________
11. We always say *pie* ______________________
12. You can say *stream* ______________________
13. Mom can say *fight* ______________________
14. I always say *mist* ______________________
15. They can say *breathe* ______________________
16. You always say *smile* ______________________
17. Mom can say *Patty* ______________________
18. Bob can say *toothache* ______________________
19. I always say *guy* ______________________
20. They always say *peppie* ______________________
21. We can say *bright* ______________________
22. Mom can say *sigh* ______________________
23. You always say *right* ______________________
24. I can say *steam* ______________________
25. They can say *sly* ______________________
26. You always say *van* ______________________
27. Mom can say *spry* ______________________
28. I always say *Bud* ______________________
29. Bob can say *tooth* ______________________
30. I can say *no* ______________________
31. You can say *die* ______________________
32. They can say *breathing* ______________________
33. Bob can say *spy* ______________________
34. I can say *Bob* ______________________
35. Mom can say *masking* ______________________
36. You always say *twine* ______________________
37. I can say *push* ______________________
38. Mom can say *watching* ______________________
39. You always say *coming* ______________________
40. We can say *charge* ______________________
41. They can say *then* ______________________
42. I always say *hear* ______________________
43. Mom can say *snow* ______________________
44. Bob can say *charging* ______________________
45. You can say *misty* ______________________
46. We always say *tie* ______________________
47. I can say *climb* ______________________
48. They always say *Mac* ______________________
49. We can say *pry* ______________________
50. Bob can say *duck* ______________________
51. We can say *missing* ______________________
52. They can say *singing* ______________________
53. Mom can say *shine* ______________________
54. I can say *miss* ______________________
55. We always say *mask* ______________________
56. Bob can say *quite* ______________________
57. Mom can say *Bobbie* ______________________
58. You always say *sky* ______________________
59. You can say *white* ______________________
60. We always say *sing* ______________________
61. Bob can say *try* ______________________
62. I can say *love* ______________________
63. You always say *pep* ______________________
64. Mom can say *laughing* ______________________
65. We can say *light* ______________________
66. You can say *cry* ______________________
67. I always say *pig* ______________________
68. Bob can say *swipe* ______________________
69. Mom can say *fly* ______________________
70. You always say *loving* ______________________
71. We can say *sty* ______________________
72. I can say *buzz* ______________________
73. Bob can say *fry* ______________________
74. I always say *grape* ______________________
75. Mom can say *watch* ______________________
76. I always say *mass* ______________________
77. I can say *play* ______________________
78. Bob can say *hearing* ______________________
79. I always say *mitt* ______________________
80. You can say *shining* ______________________
81. I can say *laugh* ______________________
82. Bob can say *buzzing* ______________________
83. He can say *come* ______________________
84. You always say *yes* ______________________
85. I can say *mile* ______________________
86. We always say *glide* ______________________
87. Bob can say *piggie* ______________________
88. I always say *kite* ______________________
89. He can say *pushing* ______________________

APPENDIX B

Phonological Screening Task

M. B., October 1979

1. *Final Consonant and Alternations*

Stops:

pep	pɛp
peppie	pʌˀɪ
Pat	pæˀ
Pattie	pæɪ
duck	dʌᵏ
duckie	dʌˀɪ

Bob	bɑb
Bobbie	bɑbɪ
Bud	bʌ'
Buddie	bʌɪ
pig	pɪg
piggie	pɛgɪ

Clusters and others:

mist	mɪθ
misty	mɪˀɪ
ask	æ
asking	æˀn̩
breathe	bi
breathing	biən
tooth	tu
toothache	tuˀeɪk

small	mɑ
smaller	mɑə
spill	pɪᵒ
spilling	pɪwɪn
hear	hɪə
hearing	hɪɪn
miss	mɪ
missing	mɪˀɪn

2. *S-Clusters and Forms for Comparison*

Word-initial:

spy	baɪ
spry	baɪ
sty	taɪ
steam	dim
stream	dim
sky	daɪ
scrape	teɪ
snow	no
small	mɑ
slime	daɪm
sly	daɪ

sigh	saɪ
pie	paɪ
buy	baɪ
tie	taɪ
die	daɪ
guy	daɪ
kite	kaɪᵗ
no	no
so	no
mall	mɑ
Saul	sɑ
light	waɪt

Non-word-initial:

mist	mɪθ
misty	mɪˀɪ
mitt	mɪt
miss	mɪ
toothpaste	tupeɪ
ask	æ
asking	æˀn
asked	æˀs̓
aspirin	æˀən

APPENDIX B—*Continued*

3. *Liquid Clusters and Forms for Comparison*

Liquids

light	waɪt
right	waɪˀ
(white)	waɪˀ

Stop + Liquid

/r/					
pry	pai	*bright*	baɪˀ	*(twine)*	waɪ
try	taɪ	*dry*	daɪ		
cry	kaɪ	*dream*	dim		
		grape	deɪp		
/l/					
play	peɪ	*blue*	bu	*(quiet)*	kaɪ ɪˀ
climb	kaɪm	*glide*	daɪ		

Fricative + Liquid

fly	faɪ	*(fight)*	faɪˀ
fry	faɪ	*(sigh)*	saɪ
sly	daɪ		

4. *Other*

/s/ = /z/

Sue	su
zoo	du

/θ/ – /ð/

tooth	tu	*with*	wɪˀʃ	*breathe*	bi
toothache	tuˀeɪk	*without*	wɪˀæ°	*breathing*	biən
toothpaste	tupeɪ				

APPENDIX C

Name: ____________________
Date: ____________________
Recorder: ____________________

Phonology Screening Data Sheet

A. Final C* and Alternations: Inventory

Stops:	Labial	Labio-Dental	Linguadental	Alveolar	Palatal	Velar
	63 *pep* ______ 20 *peppie* ______			3 *Pat* ______ 17 *Pattie* ______		50 *duck* ______ 9 *duckie* ______
	34 *Bob* ______ 57 *Bobbie* ______			28 *Bud* ______ 6 *Buddy* ______		67 *pig* ______ 87 *piggie* ______
Fricatives/Affricatives:		81 *laugh* ______ 64 *laughing* ______		54 *miss* ______ 51 *missing* ______	37 *push* ______ 89 *pushing* ______	
		62 *love* ______ 70 *loving* ______		72 *buzz* ______ 82 *buzzing* ______	- -	
			29 *tooth* ______ 18 *toothache* ______		75 *watch* ______ 38 *watching* ______	
			15 *breathe* ______ 32 *breathing* ______		40 *charge* ______ 44 *charging* ______	
Nasals:	83 *come* ______ 39 *coming* ______			53 *shine* ______ 80 *shining* ______		60 *sing* ______ 52 *singing* ______
Liquids*:				16 *smile* ______ 2 *smiling* ______	42 *hear* ______ 78 *hearing* ______	

* /h/, /j/, /w/ do not occur in word-final position.

B. Other Alternations: Clusters

55 *mask* ______ 14 *mist* ______
35 *masking* ______ 45 *misty* ______

C. Additional Items to Complete Inventory:

4 *zoo* ______ 1 *thin* ______ 41 *then* ______ 84 *yes* ______ 26 *van* ______

D. S-Clusters and Related Forms for Comparison

Word-Initial:		Non-Word-Initial:	
33 *spy* ______ 27 *spry* ______	22 *sigh* ______ 11 *pie* ______ 8 *buy* ______ 23 *right* ______	14 *mist* ______ 45 *misty* ______	54 *miss* ______ 79 *mitt* ______
71 *sty* ______ 24 *steam* ______ 12 *stream* ______	22 *sigh* ______ 46 *tie* ______ 31 *die* ______ 23 *right* ______	55 *mask* ______ 35 *masking* ______	48 *Mac* ______ 76 *mass* ______

APPENDIX C—*Continued*

58 *sky* ______ 10 *scrape* ______	22 *sigh* ______ 88 *kite* ______ 19 *guy* ______ 23 *right* ______
16 *smile* ______	22 *sigh* ______ 85 *mile* ______
43 *snow* ______	22 *sigh* ______ 30 *no* ______
25 *sly* ______	22 *sigh* ______ 65 *light* ______
68 *swipe* ______	22 *sigh* ______ 59 *white* ______

E. Liquid Clusters and Related Forms for Comparison: (forms in parentheses are related, nonliquid forms)

Liquids:

65 *light* ______
23 *right* ______
59 (*white*) ______

Stop + Liquid:

	(labial)		(alveolar)		(velar)
/r/					
49 *pry* ______ 21 *bright* ______	11 *pie* ______ 8 *buy* ______ 23 *right* ______ 59 (*white*) ______	61 *try* ______ 5 *dry* ______ 36 (*twine*) ______	46 *tie* ______ 31 *die* ______ 23 *right* ______ 59 (*white*) ______	66 *cry* ______ 74 *grape* ______	88 *kite* ______ 19 *guy* ______ 23 *right* ______ 59 (*white*) ______
/l/					
77 *play* ______ 7 *blade* ______	11 *pie* ______ 8 *buy* ______ 65 *light* ______ 59 (*white*) ______	______		47 *climb* ______ 86 *glide* ______ 56 (*quite*) ______	88 *kite* ______ 19 *guy* ______ 65 *light* ______ 59 (*white*) ______

Fricative + Liquid:

/r/					
73 *fry* ______	13 *fight* ______ 23 *right* ______ 59 (*white*) ______	______		______	
/l/					
69 *fly* ______	13 *fight* ______ 65 *light* ______ 59 (*white*) ______	25 *sly* ______	22 *sigh* ______ 65 *light* ______ 59 (*white*) ______	______	

APPENDIX D

Phonological Sample Analysis 1

M.B., age 3:10, June 1979

PHONETIC INVENTORY

b d ˀ
m n ŋ
w j h

Vowels as in adult English

CONTRASTS

No voice contrast in stops:

[bɛni]	*penny*	[du]	*to* *do*	[dæn]	*can*
[bɛ]	*bed*			[dan]	*gone*

No manner contrast or place contrast in obstruents except for labial/dental:

adult segment		
f	[bæ]	*fast*
v	[bæˀum]	*vacuum*
p	[bɛni]	*penny*
b	[bɛ]	*bed*
spr	[bɛin]	*spreading*
fl	[bai̯]	*fly*
fr	[bɛ]	*Fred*
bl	[bu]	*blue*
br	[bɛ]	*bread*
pl	[bɛi̯]	*plate*

adult segment		
t	[du]	*to*
d	[du]	*do*
ð	[dæˀ]	*that*
θr	[do]	*throw*
θ	[diŋ]	*thing*
k	[dao̯]	*cow*
g	[dɪ]	*give*
kl	[dao̯u̯n]	*clown*
gl	[dæ]	*glass*
dʒ	[dʌ]	*just*
tʃ	[di]	*cheese*
dr	[diˀn̩]	*drinking*
tr	[dʌ]	*truck*
st	[dæɪn]	*standing*
sk	[di]	*ski*
tw	[dɪn]	*twin*
kw	[din]	*queen*

Oral/Nasal contrast present:

[mæ] mask / [bæ] fast [nɛi̯] snake / [dɛi̯] sail

Contrast between glides present:

[wɛ] < legs / red / [jɛo] yellow

PHONEMIC INVENTORY

b d ˀ
m n
w j h

Vowels as in adult English

OCCURRENCE RESTRICTIONS AND SYLLABLE STRUCTURE

1. Obstruents occur (a) word-initially: [dæ] *dad*, [dæi] *daddy*, [dɔ] *dog*, [dɔi] *doggy;* (b) word-medially only when (i) preceded by a nasal, or (ii) preceding a stressed syllable.

(i)	[ʌmbʌi]	*somebody*	(ii)	[mai̯dɛo]	*myself*
	[æmbʊʊ]	*hamburger*		[bidʌ]	*because*
				[dɪˀbɪ]	*disappeared*
				[ʊdɛiˀo]	*potatoes*

2. Nasals occur initially and finally as in ambient language; when absent medially or finally the preceding vowel is nasal:

[mami]	*Mommy*	[nomæn]	*snowman*	[dɪŋ]	*thing*
[ɪm]	*him*	[nomæ̃]		[wĩ]	*ring*
[pʌ̃ˀn̩]	*pumpkin*	[bɛni]	*penny*	[bɪŋo]	*finger*
		[dæ̃in]	*standing*		

NOTES

A different strategy is employed for adult /s/ and /ʃ/ than for other obstruents which are realized as [d] or [b]:

1. Adult /s/ has a Ø realization:

[aou̯ˀ]	*salt*	[wɪŋ]	*swing*
[wo]	*slow*	[da]	*star*
[nɛo]	*snail*	[bɛin]	*spreading*

2. Adult /ʃ/ is realized as [j]:

[ju]	*shoe*
[juə̣]	*sure*
[ʌnjuə̣]	*unsure*

A separate acoustic phonetic analysis revealed the various [d] productions to be differentially produced with respect to voice onset time (VOT). The child is distinguishing three categories corresponding to the adult voice contrast plus target /d/ in the adult language (see Maxwell & Weismer, 1980).

APPENDIX E

Phonological Sample Analysis 2

M.B., age 4:2, October 1979

PHONETIC INVENTORY

p b   t d   k g ˀ
f   θ s z ʃ
tʃ
m   n   ŋ
w   j   h
l

Vowels as in adult English

CONTRASTS

Voice contrast evident for stops initially and finally:

[pɛp]	*pep*	[tai̯]	*tie*	[kæo̯]	*cow*
[bɔb]	*Bob*	[dai̯]	*die*	[gu]	*goose*
		[fit]	*feet*	[dʌk]	*duck*
		[bɛd]	*bed*	[pɪg]	*pig*

Voice contrast for stops between vowels realized as:

a. [ˀ] for voiceless target stops
[dʌk] *duck* ~ [dʌˀi] *ducky*
[pɛp] *pep* ~ [pɛˀi] *peppy*

b. Ø for voiced target stops, optionally:
[dɔg] *dog* ~ [dɔi], [dɔgi] *doggy*

No good evidence of voice contrast for fricatives or affricates:

[sæo̯u̯ˀ]	*south*	[naif]	*knife*	[fæwɪ]	*flowers*
[du]	*zoo*	[hæ]	*have*	[ɛibʌi]	*everybody*
[tʃɛi]	*cherry*	[θɛi]	*sled*	[bæˀs]	*bath*
[pɛi]	*page*	[dæ]	*that*	*[dʌz]	*does*

* [dʌz] only evidence of a voiced fricative or affricate.

Place contrast for obstruents illustrated above. For nasals:

[mai̯]	*my*	[dami]	*jammies*	[dʌm]	*drum*
[nu]	*knew*	[ʌnə]	*under*	[fai̯n]	*find*
				[tæŋ]	*Tang*

For glides:

[ju] *you*   [wi] *weeds*

No place contrast for liquids:

[wai̯ˀ] >like   [wai̯t] right
[lai̯]

Manner (strident vs. nonstrident) distinction between /s/ and /θ/ is not clearly established:

[θi] *seed*	vs.	[si] *three*
[sæoˀ] *south*		[θi] *three*
		[θi] *see*
[mɪθ] *mist*		[bæˀs] *bath*
[ɪnθai̯d] *inside*		[æoˀsai̯] *outside*
[ɛisɪŋ] *everything*		[ɛniθɪŋ] *anything*

PHONEMIC INVENTORY

p b t d   k g
f   s   ʃ
tʃ   (Note contrast discussion for fricatives; only voiceless segments have been posited as phonemic.)
m   n   ŋ
w   j   h
l

Vowels as in adult English

APPENDIX E—*Continued*

RULES AND OCCURRENCE RESTRICTIONS

A. As stated in CONTRASTS, intervocalic stops are subject to one of two rules, depending on their voicing. Voiceless fricatives also appear to undergo the rule that stops do, although supporting evidence is not complete.

1. *Voiceless consonant glottalization*

$$[-\text{voice}] \rightarrow \begin{bmatrix}-\text{cons}\\ -\text{cont}\end{bmatrix} / [+\text{syl}] \underline{\hspace{2em}} [+\text{syl}]$$

(Voiceless obstruents become glottal stops between vowels)

[dʌk]	[dʌˀi]	[pɛp]	[pʌˀi]
duck	*ducky*	*pep*	*peppy*

[dɪˀə]	[pɪˀo]	[dɛi̯ˀɪn]	[tuˀɛik]	[hæˀi]
dishes	*pickles*	*chasing*	*toothache*	*happy*

2. *Voiced consonant deletion*

$$\begin{bmatrix}+\text{voice}\\ -\text{son}\end{bmatrix} \rightarrow \emptyset / [+\text{syl}] \underline{\hspace{2em}} [+\text{syl}] \quad \text{OPT.}$$

(Voiced obstruents optionally delete between vowels)

[dɔg]	[dɔi], [dɔgi]	[bɛi], [bɛi̯bi]
dog	*doggy*	*baby*

Again, supporting evidence for Rule 2 is not complete. There are few instances of voiced obstruents occurring between vowels, and examples such as

[wæɪ] *rabbit*, [nobʌi] *nobody*, [mʌɪ] *mother*, and [foɛə] *forever*

may reflect the underlying representations of the words, not the output of Rule 2 (that is, there may be no underlying consonant). If the rule's application is general, we would expect to see occurrences of

*[bai] for *Bobby* (cf. [bab] *Bob*, [babi] *Bobby*), and
*[pɛi] for *piggy* (cf. [pɪg] *pig*, [pɛgi] *piggy*).

(* = unattested)

B. Interacting with the availability of supporting evidence for the above rules is a generally applying optional rule of Final Consonant Deletion.

3. *Final consonant deletion*

$$[-\text{son}] \rightarrow \emptyset / \underline{\hspace{2em}} \# \quad \text{OPT.}$$

(Obstruents may delete word-finally)

[hæ] [hæd]	*had*	[lai̯] [wai̯ˀ]	*like*	[mɛo] [mɛok]	*milk*	[jɛi̯] [jɛi̯k]	*shake*
[dɔ] [dɔg]	*dog*	[dʌm] [dʌmp]	*jump*	[bæ] [bæˀs]	*bath*	[bæˀtʌ] [bæˀtʌb]	*bathtub*

No generalization can be made about the conditioning environment beyond the word boundary.

C. There is a general phonotactic constraint against obstruent clusters.

i. For words that in the ambient language contain an /s/ cluster, there is free variation between using a voiced or voiceless stop word-initially. (Acoustic analysis might reveal otherwise; these stops might be in a perceptual borderline region for VOT, but a distinction might be being maintained.

[pɪo]	*spilled*	[daˀai̯n]	*stop sign*	[tɔ]	*squirrel*
[bai̯]	*spy*	[tap]	*stop*	[dɔ]	

That this lack of voice contrast contradicts the voice contrast otherwise present word-initially indicates some knowledge of the difference between, for example, *sty*, *die*, and *tie*.

ii. Although in medial position ambient morpheme-internal clusters undergo Rule 1 just as do singleton consonants, clusters that are the result of compounding (that is, where a morpheme boundary intervenes), appear to be kept distinct. This is illustrated by

[bætʌ] *bathtub* (not *[bæˀʌ]), and [tupɛi̯] *toothpaste*

(cf. [bæˀs] *bath* and [tu] *tooth*) in which the intervocalic voiceless consonant has not become a glottal stop by Rule 1. Instead, it appears that the final consonant of the first morphemes blocks the application of Rule 1 and then deletes.

APPENDIX

SPONTANEOUS SPEECH SAMPLE

M.B., June 1979

Spontaneous speech in response to interaction with clinician:

1. ə dʌɔ bʌˀ   wi da əˀɔ bʌ̃n   ai ɛi̯ ɪˀ
   a dull book   we got a whole bunch   I hate it
2. ai̯ ai̯ du iˀ æni ba   ai̯ wiowi ɛi̯ ɪˀ   miˀ   æmbʊʊ
   I like to eat candy bars   I really hate it   meat   hamburger
3. bɛˀ ʊdɛiˀo   aouˀ   bʊni   ai̯ du   wɪo bɪˀ   wʌn
   baked potatoes   salt   bologna   I do   a little bit   run
4. ai̯ du dɪ   dai̯n   mɛ̃i ai̯ ɔ̃n dãi ɪˀ   wi da ə jɛo bɛ du
   I do this   fine   maybe I can find it   we got a yellow bed too
5. ai̯ da ə daˀ bu bɛ   a bai̯ mai̯dɛᵊ   ai̯ a ə uˀ mi ʌ
   I got a dark blue bed   all by myself   I gotta scoot me up
6. wə mɛi̯ mi du dæ
   what made me do that?

Spontaneous speech in response to interaction with clinician and in response to Weiner (1979) Phonological Process Analysis Delayed Imitation Task:

7. fai̯ ba   wə ɪ hi duɪn   hoɪ̃n ə bʌʰ   dɛ̃i ã ə wʊ
   five balls   what is he doing?   holding a bug   standing on the roof
8. dɪ   dɪ   pʊˀ ɪ ʌn ə dɪ   dæ̃ɪn   nɪ hɪ bʌə
   this   dish   putting it in a dish   standing near his brother
9. dʌ wai̯ˀ ɪm   ʌ̃nˀo bɛ   d̥ɪ̃n bʌə   dao̯n   dɛə
   just like him   uncle Fred   twin brother   down   dress
10. hi mai̯ bi mami dɛn   dain dʌ   mʌi ə ai   mɛi
    he might be mommy then   driving a truck   maybe an eye   maybe
11. wʊˀɪn æˀ ə bai̯   mi du   i ə buˀ   dæin ã ə boə
    looking at a fly   me too   eat the fruit   standing on the floor
12. do ə bai̯   di   bʌˀ an ɪˀ əə di   da
    throw the pie   ski   putting on his other ski   star
13. wʌɪn æˀ ə da   ai̯ nou a dɛm mai̯dɛᵊ   wipin   wiˀən
    looking at the star   I know all them myself   sleeping   sleeping
14. dɛ   boin ə dɛ   wʊˀin ã ə wiŋ   wo bæ̃
    sled   pulling the sled   ?sitting on a swing   ?
15. bɪ̃   wiˀm̩   wiˀn̩   ai̯ ai̯ bu ən bɛə   awai̯ˀ
    finished sweeping   sweeping   I like blue one better   all right
16. ʰnɛo   õɪ̃ ə nɛo   bo u ɪ ma   dai du bæ
    snail   holding a snail   boy who is small   driving too fast
17. ɪ dʌ mai̯ bi ɛwi   wuin æ ə bʊ ɪ̃ ə nɛə
    it just might be scary   looking at the birds in the nest
18. õi wʌ̃   æˀ ɪ dɛ   mæ di   wɪ̃ŋ   ai̯do   wi
    only one   at his desk   mask three   ring   Bible   read
19. mai̯ˀ   wʌn   mai̯ dæɪ bʊ mai̯ du aoᵘt a bai̯ hɪdɛᵊ
    might   run   my daddy pulled my tooth out all by himself
20. dɛ̃ɪ hi bɪˀ mai̯ dʌŋ   dɛi̯ dɪ   dʒɪˀ wʌn dɛi̯
    dentist he bit my tongue   they did   just one day
21. ai̯ õ æ u du   dɛi̯ dɪ   ñ do wʌ dɛi̯ dɪ
    I don't have a tooth   they did   and (you) know what they did?
22. du bʌ bɛwi   du bɛwi   u mai̯ dɪŋ ɪ dan
    tooth brush fairy   tooth fairy   oo, my thing is gone
23. a wɪ̃ dɪˀbɪ   ai̯m dai̯ə   ai̯m ɛˀn̩ dai̯ə   hi fʌ̃i
    the ring disappeared   I'm tired   I'm getting tired   he's funny
24. hi wʊ wai̯ mami wɛ̃ i dɪ ɪ   dɛ i ɪ
    he looked like mommy when he did it   there he is
25. hi dɪ̃ bʊ ɪˀ ã ɪ bɛi̯   ai̯ õ du ɪˀ   am ɔ̃ du dæˀ wʌn
    he didn't put it on his plate   I don't do it   I'm gonna do that one

26. da ə bɪ no du bɪo də i jo joʳˀ nɛˀ du dɛ̃n
got a big nose to build cause he's so short next to a tent

27. dæ dɪŋ doin wo do hoĩn a dæn ə bɛi̯nˀ jɛˀədɛi̯
that thing's going slow though holding a can of paint yesterday

28. ni ə ɪŋ æn hoĩn ʌˀ ɪˀ æn wʌˀ
near the sink hand holding up his hand what

29. boə hɪ bʌ mai̯ mʌˀdæ nɛ du ɛə̃wə̃nˀ
for his brother might moustache next to the elephant

30. wə ɪ i wa ɛn ju da daoᵘn
what if he walks and you fall down

31. taˀn̩ u əmbʌi an ə ɛəˀon
talking to somebody on the telephone

32. bʌ ɪ dʌn̩ wɛˀ mi daˀ an ə ɛəon wɪo bɪˀ
but she doesn't let me talk on the telephone little bit

33. hoin ə ʌmbɛwə mʌˀ bi ə bai̯ˀ anobɛ°
holding an umbrella must be a bite envelope

34. hi dʌ̃ bi fʌni wɛin ə dãi hi doɪn dɛi̯
he's gonna be funny wearing pajamas he's gonna sail

35. hoĩn ə tubʌ daiŋ ə bʌ toɪŋ ə dɪˀə
holding a toothbrush driving a bus closing a zipper

36. dæ̃ɪŋ ɪ̃ ə ɪˀən boi̯ hi wʌ bʌ̃ni ji əˀə dei̯
standing in the kitchen boy he was funny the other day

37. hoɪŋ ə dɪˀə duɪŋ ə wɪˀo boɪŋ ə wɪˀo pɛnˀo
holding the dishes doing a whistle blowing a whistle pencil

38. ai̯ aʷ ɪˀ wʊˀɪn æˀ ə bɪ ə ɪ mʌɚ fʌm
I saw it looking at a picture of his mother thumb

39. ai̯ˀ iə wə ə wɪən bao̯ dʰi
right here what's a ribbon? balls three

40. dændɪŋ nɛˀ du ə ɛi̯o wɛˀo wɛɪŋ ə wɛə din
standing next to a table sweater wearing a sweater queen

41. dæ̃nin nɛˀ du din bidʌ i mai̯ˀ wɛi̯ ʌ wiˀn̩
standing next to queen because he might wake up sleeping

42. bʌ ai̯m wɛˀin ʌ ju dʌ bʊ waə bai̯ə mo
but I'm waking up you just put water fire smoke

43. dæin nɛˀ du dɪˀn̩ fɪn fæ fɪn fæ dɔ(ɪ)
standing next to kitten thin fat thin fat dog

44. pɛin ə dai ə ən ɪ jɛlo tʰi iˀn̩ ə di
petting a doggie the sun is yellow teeth eating a cheese

45. ə dʌ bɛ wʊo dai̯ə hi dɛˀɪn dɛi̯ bai̯ ə dʰai̯ə
a duck Fred little tiger he's getting chased by a tiger

46. tɪˀ ta gɪˀ ka ə nu wɪŋ wəˀ wɛɪ dəˀ bai̯
tick-tock tick-tock a new ring right leg just bite

47. nɛi̯ ba dæin nɛˀ du ə baɪ
snake block standing next to a block

48. mai̯ wɛ a dɛˀɪn dai̯ə (pɪ) oɪ (pɪ) ɪˀɪn ə bɪ
my legs are getting tired pig horse pig riding a pig

49. pʌ̃ˀn̩ ta a dain ə a doɪn wɪo bæ
pumpkin car car driving a car going real fast

50. bidʌ ə om to ʌnˀo bɛ do owə dai̯
because a comb toe under Fred's toe tie tie

51. dɛˀ mai̯ ju a ai̯m bʊˀɪn mai̯ oᵘn ju ã
take my shoe off I'm putting my own shoe on

52. ai̯ dɪŋ hi hʌ̃ ɪ bɪŋo ai̯ i wʌˀ i duɪn
I think he hurt his finger I see what he's doing

53. ai̯ i wʌˀ i duɪn pʌˀɪ hoɪŋ ə pʌˀɪˀ taɪˀ
I see what he's doing puppet holding a puppet target

54. juɪn ɛo æˀ ə daɪˀ ã ɪ ɛ hɛ dæ
shooting arrows at a target on his head head cab

55. dain ə dæ ai ˀn̩ ɪə ju oɪn ə ba
driving a cab I can hear you holding a frog

56. mai̯ bi wə aouˀ ə ɪə oɪn ə bæ bæ
my feet want out of here holding a flag bad

57. dɪˀ wʌn ɪ bæ ṇ dɪˀ wʌ ɪ du bʊˀ an ɪˀ əə dʌ
this one is bad and this one is good put on his other glove

58. aj ɛˀ dæˀ woɪ ai̯ ɛ ɪ mɛwin ə wo dʌˀin ɪ no
I ate that rose I ate it smelling a rose touching his nose

59. u wʌɪŋ æˀ ʌ̃ ɪˀ an bai̯ə hoin ə bæə̃ai̯n
soup looking at sun it's on fire holding a valentine

60. owə dai̯ daˀ dai̯ dɛ nɛi̯ˀ an de°
over side cross over there's a snake on there

61. dæin ʌ̃ əᵊ wi bæ dɛi̯in ə bæ bæˀun ĩə
standing under a leaf bath taking a bath vacuum cleaner

62. iin jʊɪ ai̯ wai̯ˀ jʊɪ jɛ° dɪin ə o wɪ ə jɛ°
eating sugar I like sugar shovel digging a hole with a shovel

63. ju bʊˀ an ɪ əə ju hoin ə wɛi̯ə dæ
shoe put on his other shoe holding a razor glass

64. hoin ə dæ a dʊˀin ə wʊ wɪˀ ə a
holding a glass saw cutting the wood with a saw

65. hoɪn ə bʌ bæˀwai̯ˀ hoin dæ bæˀwai̯ˀ
holding a brush flashlight holding that flashlight

66. hoin ə dʌˀ dɛəˀ iˀin ə dɛə hoin ə dai̯ˀ
holding a duck carrot eating a carrot holding a kite

67. da dain ə a wɪo bɪ nɛəˀ a ə aˀ o bɪ
car driving a car little big never saw a car so big

68. jæʷə dɛi̯ˀin ə jæʷə bɛi ə ə do jæ°
shower taking a shower afraid of the ghost shadow

69. hi bɛi̯ ə ə jæ° mũn wʊˀin æˀ ə mun dæmo
he's afraid of his shadow moon looking at the moon camel

70. wai̯ ə dæ̃o nomæ̃ bɪwin ə nomæ̃n hoin ə bʰɛni
riding a camel snowman building a snowman holding a penny

71. dæ diˀṇ diˀṇ mɛ°ˀ wʊin æ ə mæ° nɛ°
glass drinking drinking milk looking at the mouse nail

72. iˀin ə nɛˡo nai
hitting a nail knife

73. hi dɛi̯ ə nai̯ ɛn i dʌˀ ə bɛ wɪˀ əˀ nai̯
he takes a knife and he cuts the bread with the knife

74. wɪˀṇ du ə wɛˡo iˀ wɛ dænin nɛˀ du waˀɪˀ
listening to the radio its red standing next to rocket

75. wæˡ hoin ə wæˡˀ wa dain ə wa i wæ
rabbit holding a rabbit log sawing a log he laughs

76. hi dɛˀin dɛi bai ə wai̯ən dɪˀ bʌ ɪ na wɪo ɪˀ
he's getting chased by a lion this bug is not little little

77. bɪ wʊin bɪˀ ə ˀɪ baə bʌɪ bɛin ɪ bʌɪ
big looking picture of his father butter spreading his butter

78. dain ə wæɪ iˀin ə pɪˀəˡ æ ə wɛi̯ˀ wɪ ə dʊə
climbing a ladder eating a pickle have a race with a turtle

79. baə diˀṇ bʌ̃m ə baə bʌˀṇ oin ə bʌˀṇ
bottle drinking from a bottle button holding a button

80. dɪˀ ɪˀ da ɛn dɪ ɪ baṃ æ ə baṃ
this is top and this is bottom at the bottom

M.B., October 1979

Spontaneous speech in response to interaction with clinician:

81. wɛ̃i si ju pɛ̃ˀo wi da ə wæɪ ai kaˀ moə
lemme see your pencil we saw a rabbit I caught more

82. hi dæk ɛn hi wə hi nɛi̯m wɪˀgi wɛn fɪˀən
he's Jack and he's what's his name? Ricky went fishing

83. hi wə ɪ̃ ə hʌi hi dəˀ hi dæˀə ɛn hi dæˀɪ
he was in a hurry he caught his jacket and . . . his jacket

84. ɪˀ fɛo dæoᵘn ai digaˀ ai on hæ wʌn tudɛi̯ dɪˀbʊ
he fell down I forgot I don't have one today zipper

85. aj gaˀ wʌn wɪo bɛi wʌn wɪo tĩː wʌn wã θi mãi
I got one little baby one little teeny one wanna see mine?

86. wɪˀgi dɛi̯ wɛn fɪˀɪn n̩ dɛi̯ hə ə noi̯ ə da wæˀ ə
Ricky they went fishing and they heard a noise

87. wæˀkun dɔ dɛi̯ hə ə noi̯ dɛi̯ˀɪn ə dɔ
racoon squirrel they heard a noise chasing a squirrel

88. wæˀi dɛi̯o dɛi̯ ka θʌm fɪ dɛi̯ wə hæˀi
Ricky Dale they caught some fish they were happy

89. ai on mɛ̃mə wʌn tu si foə fai sɪ
I don't remember one two three four five six

90. sɛən ɛiˀ nain tɛn wɛən tətin tɛdin
seven eight nine ten eleven thirteen ?

91. sɛətin θɪˀtin foˀin θliˀhi wiˀi no
seventeen sixteen fourteen sleepy sleepy no

92. nʌˀɪn dɛi̯ wɛ̃ ʌ̃n ə hæo dɛi̯ taˀ nobʌi wʊ lʊk
nothing they went under the house they thought nobody would look

93. fai̯n ɛm dɛi tʰa wʊˀi mʌɪ wʊˀi mʌə fæoᵘn am
find them they saw Ricky's mother Ricky's mother found them

94. wæˀkun mæᵒˀ tɔ a du ɪˀ mai̯θɛo wʰə kai̯n dɛi̯m
racoon mouse squirrel I do it myself what kind of game?

95. ti dʌndæoᵘn ai̯ dõ no wə ə doi abæoᵘˀ
tree rundown I don't know what the story's about

96. ʌmbʌi hɛᵒp mi wʌi gɛʷi hæ ə pɛi̯ wɪˀ i dʌm
somebody help me read? Jerry had to play with his drum

97. bʌˀ hi wan . . . ɪ dai̯n tɛi̯ ə bæ ɛn hi pɛi̯
but he wants? it's time take a bath and he play

98. wɪ wɛ wægn̩ ɛn ə ba tən ə pɛi̯ pɛin ai̯ don no
with red wagon and a ball turn the page playing I don't know

99. ɪ tai̯ fo ɪm tɛi̯ ə bæ dʌmin
it's time for him take a bath drumming

100. ã: mɛi̯ˀ fʌ̃i noi̯ wɪ ə dʌm ju no wʰai̯ ikʌ
I can make funny noise with a drum you know why? because

101. ɛn dɛ i wə ɪn ə bætʌ do ɛˀ fɛ ã ə fo
and there he was in the bathtub soap it fell on the floor

102. æoᵘˀsai̯ i bæˀtʌ wi æ ə doə wɪno
outside the bathtub we have a door window

103. hi wə bʌˀn̩ hɪ ti ɛn hi pɪo tupɛi̯ ã i bæn nu dami
he was brushing his teeth and he spilled toothpaste in his brand new jammies

104. bu tɔ̃ pɛi̯ ɛn dɪn i jan fɛo dæoᵘn jan
blue turn page and then he yawned fell down yawn

105. mai̯ dai jan hi jɛi̯k hi wɪo jɛi̯ wɪ i pa
my doggy yawn he shakes he really shakes with his paw

106. hi ɪ̃ dʌm hi n̩ du ɛniθɪ̃ŋ ju to ɪm tu
he isn't dumb he can do anything you told him to

107. ai̯ æ ə hɛᵒp hɪm ai̯ dɪ ɛn hi wʊˀ hi ə ʃi wʌ hi fʊˀ
I have to help him I did and he ripped his uh sheet with his foot

108. wʰiˀn̩ ʃiˀ fʊ ɪˀ wɪə hɛo mai̯ bɪ̃
sleeping sheet foot it's weird hello Matt Bean

109. maˀju bin wai̯ wi dun dæˀ ai n̩ taˀ ɛidɛi̯
Matthew Bean why we doing that? I can talk every day

110. bei bɛd bɪb dɛ no bʌi bɛibi wop
baby bed (crib) there's no baby baby rope

111. wopdʌmp dʌmpwop ai n̩ dʌm o:ʷɪˀ ə dãi̯ ɛn wæ̃ ã mai̯ fit
rope jump jump rope I can jump over it the sky and land on my feet

112. wɪb mai̯ dæⁱ dʌz bu n̩ wai̯t n̩ gin n̩ jɛo ɛn pɪŋk
robe my daddy does blue and white and green and yellow and pink

113. ɛn wai̯t pʌˀo bæon bæk mai̯ dæ wɛ ɪˀ a nai̯ˀ
and white purple brown black my dad wears it all night

114. ai nu dæˀ ə bæˀs ɪ̃ ə bæˀtʌb ai̯ no wə ɪ do: bi
I knew that a bath in a bathtub I know what it's going to be

115. fip dʌk gu kæoᵘˀ noə sæoᵘˀ noə
sheep duck goose south north south north

116. wʰai̯ wɛ dɛ kæn θi wɛo dɛi̯ wɛˡn fɛɪ
why well they can see well they wearing feathers

117. dɛi̯ hæd kʌi ta mɛo ai̯ dɪŋ a ɪˀ
they had cookies chocolate milk I drink all of it

118. tʃaɪˀ mɛok taˀgɪˀ dʊ haˀ taˀɪˀ moə
chocolate milk chocolate stir hot chocolate more

119. fai̯ wʌ̃ tu θi foə fai̯ θɪ θɛɪn
five one two three four five six seven

120. ɛi̯ nain tɛn wɛən tʌtin foˀtin θɪˀtin
eight nine ten eleven thirteen fourteen sixteen

121. kæˀ ɪː wi hæ ə dagˡ do dæ dʌ̃ bai̯
cat it is we have a dog though that doesn't bite

122. ɛn i dʌᵈn̩ no ɛnibʌi hi bai̯ˀ dɛm lai̯ dɪ
when he doesn't know anybody, he bites them like this

123. wʌn tai̯m ə da hæ ə ho lai̯ dæˀ an mai̯ wʌɪ bʌ i dɪn gɛˀ mi
one time the dog had a hold like that on my sweater but he didn't get me

124. ɛn ai̯ dɛi̯ ɪndai̯ foɛə kæo kæf bɛi kæo hæoᵘˀ
and I stayed inside forever cow calf baby cow south

125. sæoᵘˀ noə bɛi kæoᵘ mæˀs mæᵒ fɔg θai̯d
south north baby cow mouth mouth frog slide

126. wi hæ wʌn bʌ ɪ boˀn̩ dæoᵘn ti dɛˀɪn ə pʌ
we had one but it broken down teeth stepping in a puddle

127. bæˀs bæ ɛbʌi mʌ wə ɛiwʰɛə wɛi̯k
splash splash everybody mud was everywhere take

128. bæˀtʌᵇ bæˀs ai wai̯ˀ ɪnθai̯d dɛm bin θi tɛi
bathtub bath I like inside them bean seed cherry

129. tʃei ai gɪʌp pi mʌˀdæs pai̯ɪ pai̯ɪwɛb
cherry I give up peas moustache spider spiderweb

130. daˀai̯n tap pi fɪ bai̯ɪᵒ bai̯ˀsɪˀo bai̯k
stop sign stop peas fish bicycle bicycle bike

131. ai̯ hæ ə bai̯k ə bɛg wʌn ɛn ɪ do a ə wɛi̯ ʌˀ ɪn ə dai̯
I have a bike a big one and it goes all the way up in the sky

132. wak hæˀ bɛd kai̯ˀ fæg oi̯n du ai̯ hæ tæŋ
rock hat bed kite flag orange juice I had Tang

133. tʃio wɪˀ tæŋ ɪn mai̯ tʃio pɛg tuˀbʌ sai̯
cheerios with Tang in my cheerios pig toothbrush slide

134. no sai̯ θɛɪ do no dʌ boˀ wod
show slide sled go snow dress boat road

135. hæᵒ wʌf nai̯ nai̯f tu dɛi̯
house roof knife knife tooth David

136. dɛi̯ hæ tu tu æo ai̯m naˀ o ɪnʌ am foə fai̯
David has two tooth out I'm not old enough I'm four five

137. hi wʌˀ hɪə tu dobʌ haˀ dɔg
he works here too schoolbus hot dog

138. bʌ ai̯ ai̯k kon n̩ hæmbʌgə n̩ pɪˀo
but I like corn and hamburgers and pickles

139. fwiˀ pɪˀo n̩ sa pɪo hoˡ pɛi̯ waə
sweet pickles and sour pickles hose play water

140. ju wa juθɛo a fæwɪ gaɪn
you wash yourself off flowers garden

141. ai̯ pʌ pɛm æoˀ fo mai̯ dæˡ dæ a a wɛi̯ ɪn ə gæoᵘn
I pull them out for my daddy that are all the way in the ground

142. hi on no hæo ə pʌ wi æoᵘˀ ai̯ du
he don't know how to pull weeds out I do

143. ai̯ mɛi̯ ɛɪsɪŋ ɪᵘwi ai̯ hɛoˀ hu waˀ dɪˀə
I make everything easy I help her wash dishes

144. ai̯ du a ə ɛɪsɪŋ fo ɛibʌi ai̯ du a ə ɪˀ ɪn wʌn θɛˀn̩
I do all of everything for everybody I do all of it in one second

145. ai̯ on do tu fʌt dɛi̯
I don't go to first grade

Screening Test (See Analysis Procedures, Chapter 7, for more detail)

M.B., October 1979

146. pɛp pʌˀi bab babi pæˀ pæi bʌ' bʌi
pep peppie Bob Bobby pat pattie Bud Buddie

147. dʌk dʌˀi pɪg pɛgi mɪθ mɪˀi æˀən
duck duckie pig piggie mist misty aspirin

148. æ æˀn̩ æˀs bi biən tu tuˀɛi̯k
ask asking asked breathe breathing tooth toothache

149. tupɛi̯ wɪˀʃ wɪˀæᵒ ma maə plo
toothpaste with without small smaller spill

150. plwɪn hɪə hɪɪn mɪ mɪˀin mɪt bai̯
spilling hear hearing miss missing meet spy

151. bai̯ sai̯ pai̯ bai̯ tai̯ dim dim tai̯
spry sigh pie buy sty steam stream tie

152. dai̯ dai̯ tɛi̯ dai̯ kai̯t no ma daim
die sky scrape guy kite snow small slime

153. dai̯ su du no ho ma sa wai̯t wai̯ˀ
sly Sue zoo no so mall saul light right

154. wai̯ˀ pai̯ tai̯ kai̯ bai̯ˀ dai̯ dim dɛi̯p
white pry try cry bright dry dream grape

155. pɛi̯ kaim bu dai̯ kai̯'ˀ wãi̯ fai̯ fai̯
play climb blue glide quiet twine fly fry

156. fai̯ˀ
fight

M.B., March 1980

Spontaneous speech in response to interaction with clinician:

157. jæ hət æˀ skiːn əfoə ai̯ min wi wə g . . .
yea what? went skiing before I mean we were g . . .

158. wi mɛi̯bi go skiɪn dɛi̯ hæwɪn wɛsɪns jæ ɪˀ hi go ai̯ kæn
we maybe go skiing Dave's having lessons yea if he goes I can

159. dɪˀ wɪdo ai̯ juwi go skiɪn m̩ tu nʌfɪn no
this little I usually go skiing me too nothing no

160. no bʌɾ ai̯ θa ə pɪg əfo ai̯ θaw ə stɪŋki pɪg əfoə stɪŋki
no but I saw a pig before I saw a stinky pig before stinky

161. hoə ə hoˀ wə stɪŋki ə pig ga hĩ stɪŋki wi dʒʌ̃m ɪn wadə
horse a horse was stinky a pig got him stinky we jump in water

162. mai̯ dag dʌz θʌmɚ tai̯m ai̯ no bʌ ɪˀ . . . bʌ dɪˀ ɪˀ daˀ wɛi̯
my dog does summer time I know but it but this is that way

163. wɛi̯nbo o dæˀ ə koən ɪˀ nɛi̯m ɪz pɪg mə ɪz ɪˀ
rainbow oh that's a corn his name is pig what is it?

164. skɛəkwo wɛo aj no tʃwi bikʌ ə wæm
scarecrow well I know tree because of a ram

165. bikʌ ə ə mantsə hi wɪl hɪ wɪl gɛˀ ʌ
because of a monster he will he will get us

166. hi wɪl gɛˀ huɛə kʌm to mai̯ hæoˀ hi wɪl gɛˀ dɛm
he will get whoever comes to my house he will get them

167. hɪl pʌntʃ dɛm wɪo had hadɚ ɛn u mʌsɪls bʌ nat ʌs
he'll punch them real hard harder than your muscles but not us

168. no maj dag dʌz kalə kali pwənts hi kæn bai̯t
no my dog does collie collie prince he can bite

169. hi wɪl bai̯t pipəl bwæon θɔd ʌf θɔd ə wai̯ˀ bwæk
he will bite people brown sort of sort of like black

170. wai̯t kn̩ dʒʌm an hɪ dag hæou̯s ɪts dɪs bɪg hi wɪdo dag
white can jump on his dog house it's this big he little dog

171. diˀ wɪdo ɪn ðə ʃɛlf ɪ̃ ʃɛlf o ai̯ min ɪˀ ɪ̃ mai̯ mæof
this little in the shelf in shelf oh I mean it's in my mouth

172. bʌˀ ɪˀ naˀ wɛ nobʌi kæn θi ɪˀ inθai̯d
but it's not where nobody can see it inside

173. wʌn tai̯m hi pup ɪn a hæoᵘs sʌmtai̯m hi kʌm ɪn ə hæoᵘs
one time he pooped in our house sometimes he comes in the house

174. hi dɪ ɪ̃ ə wɪ̃in wum wɪˀ ə snɛi̯k dʌn sta wɔ
he did in the living room with a snake gun star wars

175. swikʌm bæg aso ə mɪki mæọˀ bæg swipn̩ bæg
sleeping bag also a Mickey Mouse bag sleeping bag

176. ã mai̯ plʌg ai̯ bon ə maikəfon ə kʊk ɪˀ an
on my plug I bring a microphone to cook it on

177. wɪd ə ho bʌˀ ə snɛi̯ks də wædo snɛi̯ks
with a whole bunch of snakes the rattle snakes

178. as ɔ ai̯ swip wɪˀs dɛi̯ndʒɚʌs wʌns
that's all I sleep with dangerous ones

179. dæt kæn gɛˀ ju ɪn ə sɛkɪn
that can get you in a second

180. ai̯ θa ai̯ wɪv wɪs a wɪwi dɛi̯ndʒəwʌs wʌn gɛˀ wəˀ
I thought I live with a really dangerous one guess what?

181. mɪˀ eɪ̃əmal mɪˀ æ̃əməl du ai̯ go fɪʃɪn wɪθ ə bʌˀʊˀwo
which animal? which animal do I go fishing with? a buffalo

182. jæ ai̯ no ai̯ go fɪʃɪn wɪˀ ə bʌˀʊˀwo
yea I know I go fishing with a buffalo

183. wɛ dɛ ə ho bʌntʃ əz ʃaks θʌmwɛr dæ ju n̩ no
where there's a whole bunch of sharks somewhere that you don't know

184. ɛn aθo dɛ dɛi̯ndʒuwɪˀ ʃak ɛˀ a ə wɪo dʒaz
and also there's dangerous shark (at all?) a real Jaws

185. ɛn ai̯ ga ə wɪo dʒaz ɪn mai̯ wɛi̯k hiz its hi its mət
and I got a real Jaws in my lake he eats he eats what?

186. hi its bondz hi it pipəl bʌˀ naˀ mi no hi don iˀ hɪ bʌi
he eats bones he eats people but not me no he don't eat his buddy

187. ai̯ sogɛˀ hi bɪgəː n dɪˀ wum hi bign̩ dɪˀ bɪodɪŋ
I forget he's bigger than this room he's bigger than this building

188. hi bɪgə ðɪn mai̯ mam bɪg n̩ ɛˈfənt
he's bigger than my mom bigger than elephant

189. ðɪn dɪˀ ho woᵊd hi ɪz muvi hi goz fæst
than this whole world he is movie he goes fast

190. wo wʌnə wi ga ə watʃ tivi hi pʊt ðɛm ɪn ðə fai̯jə
road runner we got to watch TV he put them in the fire

191. flæʃ sɛkɪnd hɛi̯ wʊd stwa dɛi̯ amos gaˀ kʊkt
flash second hay wood straw they almost got cooked

192. ə tu wɪo pɪgz hi sɛ ã gõ iˀ ju
the two little pigs he said I'm gonna eat you

193. hi tʳai̯d də gɛ ðɛm ə fai̯jə fo sʌfə pʌf pʌfin sɪli
he tried to get them a fire for supper puff puffing silly

194. sɪk fɛi̯wɪt tʃakɪt mɛok skwæmbo ɛg owʊ
sick favorite chocolate milk scrambled eggs over

195. kʌz θwi wʊfs naˀ ə bɪk wʌn
cause three wolfs not the brick one

196. bikʌ bwɪks a so tʌf dɪs aˀ ə mai̯ fʊt sʌm
because bricks are so tough this off of my foot some

197. θɪn θɪk wals gɛˀ wʌˀ wʊ paˀli bwɪk
thin thick walls guess what? wood partly brick

198. pakli vai̯mɪn
partly vitamin