# Four New Speech and Prosody-Voice Measures for Genetics Research and Other Studies in Developmental Phonological Disorders

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Research in developmental phonological disorders, particularly emerging subgroup studies using behavioral and molecular genetics, requires qualitative and continuous measurement systems that meet a variety of substantive and psychometric assumptions. This paper reviews relevant issues underlying such needs and presents four measurement proposals developed expressly for causal-correlates research. The primary qualitative system is the Speech Disorders Classification System (SDCS), a 10-category nosology for dichotomous and hierarchicalpolychotomous classification of speech disorders from 2 years of age through adulthood. The three quantitative measures for segmental and suprasegmental analyses are (a) the Articulation Competence Index (ACI), an interval-level severity index that adjusts a subject's Percentage of Consonants Correct (PCC) score for the relative percentage of distortion errors; (b) Speech Profiles, a series of graphic-numeric displays that profile a subject's or group's severity-adjusted consonant and vowel-diphthong mastery and error patterns; and (c) the Prosody-Voice Profile. a graphic-numeric display that profiles a subject's or group's status on six suprasegmental domains divided into 31 types of inappropriate prosody-voice codes. All data for the four measures are derived from one sample of conversational speech, which obviates the limitations of citation-form testing; enables speech assessment as a qualitative, semi-continuous, and continuous trait over the life span; and provides a context for univariate and multivariate statistical analyses of phonetic, phonologic, prosodic, and language variables in multiage. multidialectal, and multicultural populations. Rationale, procedures, validity data, and examples of uses for each measure are presented.

KEY WORDS: phonological disorders, assessment, prosody-voice, genetics, etiology

Major advances in molecular genetics have made it feasible to pursue fundamental questions about the origins of diseases, behavioral disorders, and human traits (cf. McKusick, 1991; Plomin, 1990). The measures to be described in this paper were motivated, in part, by the opportunities these advances offer for an eventual understanding of the antecedents of developmental phonological disorders. Specifically, they attempt to provide a means to obtain detailed segmental and suprasegmental descriptions for all subgroups of developmental phonological disorders, including phenotypes for those that may turn out to have a genetic origin. The first section of the paper reviews background information on measurement issues and needs in speech-genetics research. The second section provides an overview of specific measurement issues, followed by rationale, procedures, validity data, and research examples for each of four new assessment instruments.



FIGURE 1. A representation of the eight potential domains of involvement in developmental phonological disorders.

# MEASUREMENT ISSUES AND NEEDS IN SPEECH-GENETICS RESEARCH

#### Definitions

The clinical entity within communicative disorders historically termed *functional articulation disorders* has a rich research tradition. Since early formulations in the 1930s, changing theoretical perspectives have been accompanied by the development of new definitions and many individual tasks, analyses, and tests consistent with these definitions. The number of alternative classificatory terms for children with such adjective-adjective-noun labels as [*functional nonorganic developmental*], [*articulation phonological phonetic intelligibility speech*], and [*problems involvements handicaps delays disorders*] suggests the diversity of theoretical and clinical perspectives and accordingly, the potential domains to be represented in measurement operations. In the present context, the term *developmental phonological disorders* will be used as the cover term for this clinical population.

Figure 1 is a representation of the potential domains of involvement that have been observed in children with developmental phonological disorders. This scheme portrays eight levels of involvement, with each outer level subsuming interior levels. The most domain-limited or narrow form of the disorder, as represented by the innermost circle (Phoneme-Limited Distortions), is a speaker whose involvement is limited to a single type of articulatory distortion, such as one or more dentalized fricatives, one or more velarized liquids, or only a derhotacized /r/. As shown in Figure 1, such error patterns are distinguished from patterns involving two or more types of distortions within a single feature class (e.g., both dentalized and lateralized fricatives). Single, specific articulatory distortion errors are among the most frequently observed speech errors in older children and adults, reflecting the autonomous form of the disorder relative to all other potentially involved domains portrayed in Figure 1. The domain-general or broad form of the disorder is represented in the outermost circle (Cognitive-Psycholinguistic Involvement). Certain speakers, in addition to their particular pattern of productive speech errors and problems in comprehension of speech-language forms, may also have mild-to-moderate involvement of those cognitive-psycholinguistic processes thought to be associated with the pathogenesis of speechsound disorders. These appear to be the children whose early developmental speech-language disorders are associated with later problems in reading and spelling and with more general learning difficulties (e.g., Bishop & Edmundson, 1987; Hall & Tomblin, 1978; Shriberg & Kwiatkowski, 1988; Tyler & Edwards, 1986). As indicated by the dashed lines in Figure 1, ontogenetic development may require that a child be reclassified to other categories. The logical progression in such cases would be from outer to inner circles, with the possible retention of subtle, but demonstrable, involvement at "higher" levels of speech-language processing an important research question. Subsequent sections of this paper will discuss the five outer levels in Figure 1 subsumed by the term speech delay and the three remaining levels by the term residual errors.

Children with each of the eight forms of phonological disorders portrayed in Figure 1 are in evidence in the clinic. However, despite several proposals using approaches that Wilson and Risucci (1986) divide into quantitative-multivariate (e.g., Arndt, Shelton, Johnson, & Furr, 1977; McNutt & Hamayan, 1984; Prins, 1962; Winitz & Darley, 1980) and clinical-inferential (e.g., Duggirala & Dodd, 1991; Laufer, 1987; Ruscello, St. Louis, & Mason, 1991; Shriberg & Kwiatkowski, 1982a; Shriberg, Kwiatkowski, Best, Hengst, & Terselic-Weber, 1986), there are no widely used nosological systems to identify and classify such children. Rather, a clear trend has been to avoid classificatory labels, emphasizing only children's manifest behavior. This perspective is associated with debate on whether developmental speech-language delay represents only the lower end of ability or whether this clinical entity has the requisite qualitative differences to merit use of the term disorder and an elaborated classification nosology (e.g., Aram, 1990; Johnston, 1991; Lahey, 1990; Leonard, 1987, 1991; Liles & Watt, 1984; Snyder, 1982; Stark & Tallal, 1981; Tomblin, 1991; van Kleeck, 1990). In statistical perspective, the former view is of one of a continuous distribution of communicative ability, with speechlanguage delay aggregated in the lower tail. The latter view posits a discontinuity in the distribution of competence in a population, with scores for disordered individuals forming a smaller secondary peak in an overall bimodal distribution.

Definitional issues associated with domain-general versus domain-limited causality (Carey, 1990) and continuous versus discontinuous traits form the measurement background for emerging genetics studies in developmental phonological disorders (cf. Ludlow & Cooper, 1983; Shriberg, 1991; Stark, Mellits, & Tallal, 1983; Whitehurst, Smith, Fischel, Arnold, & Lonigan, 1991). One way to approach measurement issues in genetics is to consider the types of measures required, which can be divided into three categories: a classification system, a measure of severity of involvement, and measures that yield descriptive profiles. The following discussions provide brief overviews of the uses and attributes of each type of measure in genetics research.

#### **Classification Systems for Genetics Research**

Uses. The primary measurement need in speech-genetics research is for a theoretically coherent classification system. Classification systems are used for two associated tasks in molecular and behavioral genetics analyses. First, the validity of epidemiologic information on the incidence and prevalence of diseases and disorders within relevant demographic groups is entirely dependent on the sensitivity and specificity available in the categories of a classification system. That is, behavioral genetics methods require accurate data on the prevalence of the trait in the target population in order to calculate the risk or liabilities for the disorder within all relevant demographic groups. Second, classification systems are used in genetics studies to identify affected individuals (the probands and their relatives), as well as to characterize any lack of penetrance predicted by the candidate mode of transmission. These data are used in segregation programs (analyses that test the hypothesis of genetic transmission modes such as major locus, sex-linked, or multifactorial modes based on allele segregation during meiosis) and other quantitative methods. When dealing with suspected oligogenic, polygenic, or multifactorial modes of inheritance, for example, valid prevalence data based on a good classification system can be used to estimate the number of genes that may be contributing to the phenotype. Segregation analysis programs (e.g., Lalouel & Morton, 1981) require that liability parameters be set for the demographic composition of the sampled population. When well-validated and wellstratified epidemiologic and classification data are not available, it is typical to run a series of analyses using a range of liability estimates and classification models, each of which can be reflected in significant differences in program outcomes (Vogel & Motulsky, 1986).

There currently is no classification system that can meet the above measurement needs for genetics studies in developmental phonological disorders. Although there are many state- and local-level classification systems used for clinical and administrative purposes by school systems and health care providers, neither the discipline nor the profession has invested in the development of at least a nationwide classification system for communicative disorders. The speechlanguage component of the DSMIII-R system (American Psychiatric Association, 1987) used by clinical and research psychologists is not sufficiently developed for the tasks just described (Tallal, 1988). Hence, even large international projects, such as the genotype-phenotype mapping project in Down syndrome (Epstein et al., 1991), lack a well-developed, multistate speech classification system for the needs of their behavioral protocol.

Attributes. A primary attribute of a speech disorders classification system for genetics research is an underlying conceptual base that leads to the correct genotypes for each class of disorders. Thus, a clinical nosological system such as "multiple articulation errors" versus "single sound errors" might be an adequate dichotomous typology for service delivery needs, but it is likely to be inadequate for research on gene-behavior pathways (Johnston, 1987). Likewise, classification systems based on linguistic typologies (e.g., consistency of errors, level of intelligibility, degree of underlying phonological knowledge) are also not adequate for levels of explanation dealing with etiology and pathogenesis (cf. Bryant, 1990; Smith, Pennington, Kimberling, & Ing, 1990). Rather, the system needs to base classification on either putative causal or etiologic categories or on neurolinguistic or other processes plausibly related to the pathogenesis of the disorder (Aram & Nation, 1975; Garber & Hollon, 1991; Rapin & Allen, 1983; Tallal, 1988). Classification systems should not be based on degree of involvement, which in genetics research is a severity of expression issue (discussed below).

A second desirable attribute of a classification system for genetics research is that the categories be arranged in a conceptually motivated hierarchy (Reich, James, & Morris, 1972; Wilson & Risucci, 1986). To gain sensitivity and specificity, multistate classification systems are organized hierarchically, so the highest nodes dichotomize normal (nonaffected) from the broad form of the disorder, with lower nodes nesting successively more narrow forms of the trait. Moreover, because cell sizes in statistical analyses are always a constraint in genetics designs, hierarchical systems allow use of the data summed over lower-level and/or low frequency of occurrence classification categories.

Third, there is an array of sampling and psychometric constraints in genetics research that require consideration in constructing and implementing classification systems. There are the considerable number of practical problems of testing large numbers of living subjects in field conditions (i.e., probands and their relatives), as well as difficulties in dealing with record searches for deceased or unavailable subjects. There also is a complex of issues associated with multiage, multidialectal, and multicultural demographics, requiring measurement accommodations to assess linguistically diverse individuals as young as toddlers and as old as their great-grandparents. Furthermore, there are the psychometric requirements of adequate examiner and test reliabilities, adequate distributional properties for data to be used in parametric and nonparametric procedures in quantitative behavioral genetics, and practical matters of reasonable test efficiencies in time and costs. For the extraordinarily important goals of genetics research, researchers need to employ classification systems that have the attributes of being conceptually coherent, psychometrically stable, and procedurally efficient.

#### Severity Metrics in Genetics Research

**Uses.** In addition to characterizing and classifying the nature of involvement, there is also a need in genetics research to assess the severity of expression of the disorder. Severity of involvement is associated with the products of both structural and regulator genes as they influence phenotypic expression. More generally, severity of involvement is associated with additive and interactive models of causality, with certain amounts and combinations of gene dosages and other risk factors expected to be reflected in the severity of expression of the target behavior or disorder. The potential understanding of genetic versus environmental contributions to severity of expression is thus greatly dependent on the conceptual perspective on which the severity metric is based.

Attributes. In developmental disabilities, severity of involvement can be scaled in three ways, alternatively indexing time (of onset and/or normalization), severity, or error topography. In developmental traits or in disorders in which temporal issues are important, units such as age of onset, time until normalization, or some age-discrepancy criterion provide typical conceptual perspectives for the construct of severity of involvement. Alternatively, a researcher can use proportional units such as the percentage of a skill obtained or some cutoff score reflecting status relative to a population distribution (e.g., standard deviation units, percentile scores). Finally, severity can also be based on error topography, including the number and types of associated deficits in both the primary behavioral domain and deficits in associated domains, such as social or vocational consequences. As with the use of a particular classification system, theoretical clarity on how genes might code for behavior in the domain of interest underlies an investigator's choice of approaches to quantify severity of involvement.

Psychometric and test-efficiency characteristics are also crucial attributes of severity metrics used in molecular and behavioral genetics. Specifically, the validity of the complex quantitative procedures in behavioral genetics depends on metrics that meet, or at least do not violate, psychometric assumptions for parametric and nonparametric analyses. On close examination, many speech measures (e.g., skewed percentaged data on small groups containing frequent 0% and/or 100% scores) are not appropriate for parametric analyses. Importantly, speech can be viewed as a semicontinuous variable, having characteristics of a continuous trait during the developmental period and characteristics of a discontinuous or qualitative variable (i.e., normal vs. disordered) after the period of normal speech development. Life-span assessment of speech competence must accommodate both periods and their respective statistical distributions.

#### **Descriptive Profiles for Genetics Research**

A third type of measurement need in genetics research is descriptive profiles. A major problem in both medical and behavioral genetics research is the need to "sharpen" heterogeneous phenotypes (McKusick, 1991; Plomin, DeFries, & McClearn, 1990). A classification system and a severity metric accomplish the primary tasks for phenotype identification; uses and attributes of descriptive profiles are to provide the added detail needed for sensitivity/specificity validation and for phenotype refinement. Descriptive measures at the level of individual profiles should provide much more detail about the primary domain than is available from the classification or the severity metric findings. They also should provide subject detail on other potentially relevant domains, with the goal of attaining the greatest possible precision in setting the boundaries for each classification category.

#### Conclusion

Potential sources of explanation for the lack of a standard definition of a developmental phonological disorder involve the paradigmatic shifts in theoretical perspectives that have been documented in several places (e.g., Brown, 1985; Elbert, 1985; Grunwell, 1988; Shriberg, 1986; Stoel-Gammon, 1991a) as well as other discipline and professional issues. Virtually all of the available epidemiological data on developmental phonological disorders preceded the "new look" that occurred in the 1980s. Perhaps the primary question about this disorder to be addressed in the present decade is whether there are subsets that are genetically transmitted and, if so, whether some of these forms are autonomous relative to cognitive-psycholinguistic involvement. Because the phenotype for a behavioral trait or disorder is the end-product of genes and the environment, sufficient causal antecedents mediating the effects of genes on behavior might be identified at many levels of psycholinguistic processing subserving phonology. For example, although genes code for the complexity of cognitive-linguistic and motor-speech processes that underlie normal acquisition of sibilant fricatives, it may be too domain-specific to propose a "lisping gene" or even polygenetic or multifactorial models uniquely for fricative distortions. However, the possibility that such may be the case requires genetics research to employ measurement tools that have the sensitivity to enable the appropriate exploration.

Issues associated with the domain-level questions discussed in this overview are central to the conduct of all etiologic research in developmental speech disorders. However, only associated methodological issues are addressed in the next section. The following description of four new speech and prosody-voice measures developed specifically for the conduct of genetics and other subgroup research first reviews methodological issues and then presents rationale and sample validity data for each of the four measures.

# FOUR NEW MEASURES FOR GENETICS AND OTHER RESEARCH QUESTIONS IN DEVELOPMENTAL PHONOLOGICAL DISORDERS

The four measures to be described were developed in the context of a research program on the causal antecedents of phonological disorders of presently unknown origin. As stated above, the goals of these brief descriptions are methodological, with emphasis on the validity and utility of the measures for causality research, rather than on substantive issues raised by sample data obtained with the measures. Each of the measures deals with speech production, rather than any of the many levels of speech-language comprehension noted previously in Figure 1. Moreover, each has been developed from the design perspective of exploring whether the phenotypes for developmental phonological disorders might be identified using the most directly available levels of manifest speech. Because each measure requires a sample of continuous conversational speech, uses the construct of a phone or segment as the linguistic unit, and currently obtains data from perceptual transcription and coding procedures, brief discussion of each of these three methodological approaches is warranted.

# Methodological Issues

## Sampling Mode

Most of the available tasks, analyses, and measures of normal and disordered speech assess some level of production phonology. Word-, phrase-, and sentence-production tasks are used for a variety of descriptive purposes in speech pathology, with their obvious advantage of controlling linguistic and paralinguistic content. For the purposes of genetics research, in which the residuals of an earlier phonological disorder may be observed only in measures that tax speech production, production tasks composed of difficult-to-articulate words may be useful (cf. Catts, 1989; Lewis, Ekelman, & Aram, 1989; Lewis & Freebairn, 1992). At present, however, such production tasks are psychometrically underdeveloped for the demographics involved in genetics research. For example, certain elderly persons may have difficulty articulating or pronouncing multisyllabic words because of a number of educational, cultural, or health-related concerns unrelated to the premises of genetically based forms of phonological involvement.

In the realm of more well-developed assessment instruments to assess production phonology, the citation-form articulation test clearly is the most frequently used method to sample normal and disordered speech. Whether such measures are adequate and appropriate for genetics and other etiologic subgroup research remains a methodological issue. The validity of a corpus of citation-forms for the purpose of identification, scaling severity of involvement, and/or describing individual differences is a long-standing research question, involving diverse theoretical, methodological, sociolinguistic, and psychometric issues (e.g., Bernthal & Bankson, 1988; Butcher, 1990; Dyson & Robinson, 1987; Klein, 1984; McCauley, 1989; McCauley & Demetras, 1990; McCauley & Swisher, 1984a, 1984b; Smit, 1986; Stoel-Gammon & Dunn, 1985). Morrison and Shriberg (1992) recently reported that data obtained from the articulation test responses of 61 speech-disordered children consistently differed in statistically, clinically, and theoretically significant ways from data obtained in the same session from samples of these children's spontaneous conversational speech. Although citation forms from articulation tests and other word lists provide a

means to obtain phonetic inventory data on standardized tokens, they are decontextualized relative to the psycholinguistic processes underlying sentence production in discourse. As described above, in some views of the genetics of speech acquisition and performance, it is just these levels of speech processing that might reflect the enduring phenotypic consequences of genetic regulation.

In contrast to multisvllabic elicitation tasks or articulation tests, the measures to follow each are based on a sample of continuous conversational speech. Keating (1991) recently summarized trends "away from laboratory speech towards real speech" in her projections for the directions of phonetics research during this decade. For research in normal and disordered phonology, the validity, stability, and utility of conversational speech samples has been supported in a series of studies concerned with both segmental and suprasegmental variables (Morrison & Shriberg, 1992; Shriberg & Kwiatkowski, 1982b, 1985; Shriberg, Kwiatkowski, & Rasmussen, 1989a, 1989b; Shriberg & Lof, 1991; Shriberg & Widder, 1990). Detailed descriptive and inferential statistical analyses presented in these studies indicate that children and adults produce conversational speech samples that are robust within and across subjects for measures of utterance productivity; intelligibility; representativeness of canonical, grammatical, and intended segmental forms; and reactivity. The intersample and intrasample consistency of such distributional characteristics as parts of speech, type/ token ratios per min, number of intelligible words per min, canonical forms, percentage of occurrence of intended phonemes, and speech registers indicates that elicited conversational speech samples have stable structural, linguistic, and pragmatic characteristics. With appropriate procedural conventions to accommodate individual differences, particularly in demographic diversity (e.g., Haselager, Slis, & Rietveld, 1991; McKinley & Larson, 1991; Seymour, Huntley, & Green, 1991; Watkin & Gallagher, 1991), conversational speech sampling would seem to provide the only valid measurement context for the breadth of information needed in epidemiologic and genetics research.

#### Unit of Linguistic Analysis

In addition to issues concerning the mode of speech sampling, assessment for the purpose of genetics and other subgroup research must address the utility of various linguistic units of analysis. Speech pathology has witnessed a continued search for linguistic units that best capture the articulatory and phonological processing mechanisms that subserve articulate and nonarticulate speech. The many units that have been employed in tasks, analyses, and tests follow the chronology of paradigms within linguistics and phonology that have been assimilated into communicative disorders research and practice. Classification systems and severity of involvement measures at the outset of the discipline were initially based on the autonomous phoneme of structuralist phonologies and later shifted to the units and collateral analytic constructs associated with generative phonology (distinctive features; generative rules) and natural

phonology (phonological processes). More recently, applied analyses based on emerging nonlinear phonologies (e.g., autosegmental phonology, metrical phonology, feature geometry, lexical phonology, underspecification theory) promise increased descriptive power to characterize normal and disordered speech systems (e.g., Bernhardt, 1990; Chiat, 1989; Chin & Dinnsen, 1991; Goldsmith, 1990; Schwartz, 1992; Stemberger, 1988).

Each of the four measures to be described uses manifest speech sounds (phones) as the linguistic unit of analysis. Rationale is based on the appropriateness for genetics research of viewing speech as a biobehavioral trait. Unlike linguistic constructs that subsume misarticulations under one descriptive term such as a phonological process (e.g., consider the diversity of sounds, error-types, and word positions that are included in such cover terms as cluster reduction), an analysis at the level of speech sounds provides more direct ties to the cognitive, perceptual, and motor-speech processes that ultimately underlie both normal acquisition and the pathogenesis of disordered speech (Ashley & Lehr, 1991; Folkins & Bleile, 1990; Kent & Hodge, 1991; Locke, 1983; MacNeilage & Davis, 1990, 1991; see also related issues addressed by Maddieson, Hombert, Janson, Kingston, & Venneman, 1991). In combination with the classic structuralist perspective that manifest speech sounds occur in five forms relative to their phonemic status in a language (correct, omission, substitution, distortion, addition), severity and error-profile analysis based directly on speech-sound production would seem to allow the most direct (i.e., least abstract or least theoretically laden) approach to speech assessment for the complex of questions involved in phenotype research in developmental speech disorders.

## Perceptual Data Reduction

A third methodological issue concerns the methods used to reduce speech data. Acoustic procedures for speech measurement in phonological disorders are well-established alternatives to perceptual transcription approaches, especially for questions requiring sensitive measurement of specific segmental or suprasegmental events (cf. Weismer & Liss, 1991). However, acoustic procedures are not practical for questions requiring large amounts of detailed data encompassing all clinically relevant behaviors in conversational-length samples. For such broad-based needs, perceptual procedures may be the only feasible approach. In a study of the reliability of phonetic transcriptions of both conversational samples and articulation tests, Shriberg and Lof (1991) report that broad phonetic transcription by well-trained research personnel can vield adequate reliability figures, whereas narrow phonetic transcription of the allophones of normal and disordered child speech may be unreliable for certain research questions (e.g., Shaw & Coggins, 1991). For genetics research, which involves multiage, multidialectal, and multicultural demographics, attention to phonetic transcription conventions and response definitions (e.g., how much derhotacization is required for an /r/ distortion) and associated interjudge and intrajudge reliability issues is of paramount methodological concern. Ideally, some form of acoustically aided narrow phonetic transcription will provide the validity, reliability, and efficiency attributes required for the most discerning questions in genetics. In the interim, each of the measures to follow are based on phonetic transcription or prosody-voice coding of segmental and suprasegmental behaviors as they occur in spontaneous conversational speech.

# The Speech Disorders Classification System (SDCS)

#### Rationale

The Speech Disorders Classification System (SDCS) was developed to sort normal and disordered speakers throughout the life span into a hierarchical polychotomy. As discussed above, pedigree analysis programs test the fit of alternative modes of genetic transmission to family data. Such analyses include options to treat traits and diseases as both gualitative and guantitative variables. Both dichotomies and polychotomies are used for qualitative analyses, including polychotomies with nested categories. The SDCS was designed to provide such data for subgrouping studies, including epidemiologic and genetic research. As with clinical classification systems such as the DSMIII-R (American Psychiatric Association, 1987) that are available to study other behavioral traits, the SDCS can also be used to generate unique subordinate and superordinate classes to aggregate subjects for particular theoretical questions or psychometric constraints (e.g., limited cell sizes).

Figure 2 provides an overview of the Speech Disorders Classification System. The sample form displayed is from a hand-scored version of the procedure; more detailed forms are output from a computerized version of the SDCS. Beginning with the columns labeled "Age group (years)," the life span is divided into six age groups (each rounded up to the next age group at 11.5 months): Group A: 0-3 years, Group B: 4-6 years, Group C: 7-9 years, Group D: 10-12 years, Group E: 13-18 years, and Group F: 18 years and older. These six age divisions were selected to best accord with both developmental data on stage-like differences in phonological acquisition (Ingram, 1989) and speech motor development (Kent, 1976; Sharkey & Folkins, 1985) and because these periods generally correspond with developmental socioeducational epochs (i.e., infancy, preschool, early elementary school, middle school, high school, and adulthood). Speakers in each age division are assigned to 1 of 10 SDCS classes based on their pattern of correct and incorrect speech sounds as sampled in spontaneous conversational speech. As described below and described in detail in the Appendix, the classification criteria differ for each of the eight age groups for which reference data are currently available. Normative reference data of the type needed for SDCS classification are not presently sufficient for children younger than 2 years of age or older than 9 years of age. The considerable research effort directed at infant and toddler speech will undoubtedly yield valid indices of communicative delay from birth to 2 years. Similarly,

# SPEECH DISORDERS CLASSIFICATION SYSTEM (SDCS) FORM

Subject \_\_\_\_\_ Date \_\_\_\_\_

Date of Birth \_\_\_\_\_ Study \_\_\_\_\_

						••••	AGE G	ROUP (	YEARS)				
	SDCS CLASSIFICATION			λ		В			с		D	R	F
CLASS	TERM	ABBR.	2	3	4	5	6	7	8	9	10-12	13-18	18+
т	Normal Speech Acquisition	NSA											
II	Normalized Speech	NSX											
III	Questionable Speech Delay	QSD											
IV	Questionable Speech Delay+	QSD+											
v	Speech Delay	SD											
VI	Speech Delay+	SD+											
VII	Questionable Residual Errors	QRE							-				
VIII	Questionable Residual Errors+	QRE+											
IX	Residual Errors	RE											
x	Residual Errors+	RE+											

WORD SHAPES		
Sound inventory Vowels		
Consonants	Initial	Final
SOUND ERRORS	Common	Uncommon
Omissions		
Substitutions		
Distortions		

FIGURE 2. Summary form for the hand-scored version of the Speech Disorders Classification System (SDCS).

further SDCS subdivisions for adult speech will be possible as well-defined continuous speech data from adolescent through elderly speakers become available (e.g., Shipp, Qi,

Huntley, & Hollien, 1991; Steele & Campbell-Taylor, 1991). The following discussion provides rationale for each of the current 10 SDCS classification categories in Figure 2.

Normal Speech Acquisition and Normalized Speech. The first and second of the four major SDCS categories (to be illustrated in Figure 3) include two types of speech classed as normal at the time of assessment, Normal Speech Acquisition (NSA) and Normalized Speech (NSX). Normal Speech Acquisition fulfills the need for a category for children or adults who have acquired speech normally (i.e., who have never had a speech disorder). As with each of the classification categories in Figure 2, the Appendix provides the normative information on which the examiner (or computer program) makes these decisions for persons in each age group. It is important to note that children classified as NSA do not necessarily have perfectly articulated speech. Rather, their speech patterns are considered within the normal range for their chronological age, which for younger children may include specific types of deletions, substitutions, and distortions.

The second SDCS category, Normalized Speech (NSX), is used for persons who had a documented speech disorder at one time in their lives, but who later normalized. Thus, as shown in Figure 2, the "X" in NSX is a place-holder allowing for optional coding at the desired level of specificity (e.g., NS-SD+9 for a child formerly classified as having Speech Delay+ who normalized at 9 years of age; see below for a definition of Speech Delay+). This category is needed in pedigree and follow-up studies in which the current speech status of the proband and relatives of the proband requires documentation. Additional detail, such as the specific history of involvement and whether the person had received speech-language services, can be represented with supplementary subcodes.

Speech Delay and Residual Errors. The third and fourth superordinate classes in Figure 2 include the four categories of children or adults with Speech Delay (Questionable Speech Delay, Questionable Speech Delay+, Speech Delay, and Speech Delay+) and the four categories of children or adults with Residual Errors (Questionable Residual Errors, Questionable Residual Errors+, Residual Errors, and Residual Errors+). The four types of Speech Delay are appropriate for children or adults who have deletion and substitution errors beyond the ages at which they normally do not occur. Relative to the eight domains portrayed in Figure 1, the four forms of Speech Delay include involvement at any of the five outermost domains. The four classes of Residual Errors are appropriate for children or adults who maintain distortion errors beyond the normative ages. Relative to Figure 1, Residual Errors denotes involvement limited to the three innermost domains. Brief discussion is needed to clarify the distinction between Speech Delay and Residual Errors.

As proposed and later elaborated (Shriberg, 1980, 1982; Shriberg & Kwiatkowski, 1980, 1982a), speech-sound errors termed *deletions* and *substitutions* are assumed to reflect earlier stages of phonological processing—in both diachronic models of acquisition and in synchronic models of speech performance—than sound changes termed *distortions*. Specifically, deletions and substitutions are presumably due to constraints in both linguistic organizational levels (e.g., phonological contrasts and collapses; Grunwell, 1988; Williams, in press) and psycholinguistic processing (e.g., lexical access and retrieval), whereas the loci of distortion errors presumably involve inappropriate allophone-level rules and/or sensory-motor processing constraints. Thus, whereas

articulatory deletions and substitutions imply transient or persistent difficulty in the cognitive-linguistic aspect of speech processing (Shriberg & Widder, 1990; Smit & Bernthal, 1983), articulatory distortions (of place, manner, voicing, force [e.g., weak closures], or duration) are presumed to reflect transient or persistent difficulty in the representation of allophonic detail and/or with sensory-motor aspects of articulatory precision. Related issues have been discussed in detail in both the child and adult phonology literatures (e.g., Jordan, 1960; Shriberg & Kent, 1982; Smit, Hand, Freilinger, Bernthal, & Bird, 1990; Weiner & Wacker, 1982; Westman & Broen, 1989). Additional information about these distinctions is presented in the Appendix. In the present context, rationale for the use of each of these terms is based on empirical findings that few children retain articulatory deletions or substitutions beyond the developmental period, whereas articulatory distortions may persist for a lifetime. Thus, as subcategories of the SDCS cover term Speech Disorders, Speech Delay is typically (but not always) a time-limited, developmental disorder, whereas Residual Errors, by definition, persist past the developmental period.

Speech Delay+ (SD+) and Residual Errors+ (RE+). As shown in Figure 2, the categories of Speech Delay and Residual Errors have corresponding categories termed Speech Delay+ and Residual Errors+. Speakers in these latter two SDCS classifications could be considered similar for the purposes of certain research or clinical questions. However, because the goals of the SDCS require qualitative classification categories for speech disorders of both unknown and known origin, the speech error pattern categories must accommodate speech errors associated with both known developmental and acquired etiologies (e.g., cleft palate, cerebral palsy) and unknown, suspected, or subclinical involvements (e.g., hearing involvement associated with early recurrent otitis media with effusion, suspected motor speech involvement, suspected emotional involvement). The classifications Speech Delay+ and Residual Errors+ are used for speakers who have distortions such as nasal emissions and nasalized vowels/diphthongs, consonant and vowel duration errors, spirantization of stops, and other subphonemic place, manner, voicing, force, and duration errors. Most children who have atypical distortion errors do so in addition to having the typical error patterns associated respectively with Speech Delay and Residual Errors. However, the terms Residual Errors+ and Questionable Residual Errors+ (see below) are also appropriate for speakers who have only atypical distortions. Subclinical distortion types have been examined in the subgrouping studies of the present author and colleagues for their possible association with specific etiologies in children with speech disorders of presently unknown origin (see later sections of this paper). In the context of genetics studies in communicative disorders. divisions between Speech Delay/Speech Delay+ and Residual Errors/Residual Errors+ are deemed important to the search for the phenotypes for developmental speech disorders and specific modes of transmission. The specific speech-sound criteria differentiating among these SDCS classifications are provided in the Appendix. As shown in later figures, selection of the term Speech Delay+ was guided by the need for a theoretically neutral term and one that could readily be used to label mixed groups of children with speech delay. For example, a group of both Speech Delay and Speech Delay+ speakers can be referred to as Speech Delay(+).

Questionable Speech Delay (QSD), Questionable Speech Delay+ (QSD+), Questionable Residual Errors (QRE), and Questionable Residual Errors+ (QRE+). The remaining four SDCS categories in Figure 2 (each beginning with the term Questionable) accommodate two issues in contemporary research and practice: inconsistency in the available normative reference data on phonological acquisition and the fact that many children who appear to have a speech disorder in fact spontaneously resolve their error patterns. There are major gaps in the normative data and inconsistencies across studies in the ages assigned to mastery of sounds and error-types. Moreover, because there currently are no effective predictive instruments to identify children who will normalize without intervention, researchers and service delivery agencies must dichotomize children as normal or disordered. Impelled by federal and local service delivery mandates to provide services for young children, clinicians have observed that a relatively large number of children with speech delay appear to normalize essentially on their own (cf. Shriberg, Kwiatkowski, & Gruber, 1992). As described in detail in the Appendix, the classifications Questionable Speech Delay, Questionable Speech Delay+, Questionable Residual Errors, and Questionable Residual Errors+ meet both research and clinical needs in taking a conservative approach to labeling a young child "speech delayed." Note that the parentheses convention may also be used to refer to a group of children comprising a mix of Questionable Speech Delay, Questionable Speech Delay+, Speech Delay, and/or Speech Delay+ (i.e., (Questionable) Speech Delay(+)).

An important final perspective on the rationale underlying the SDCS categories is that a methodologically stable system cannot attempt to encompass too many domains. As described below, SDCS classification is based solely on the analyses of productive speech obtained from a conversational speech sample. Thus, it does not rely on additional historical or current information about subjects, such as their status on measures of language comprehension or language production, speech discrimination, or analyses of their phonological awareness, phonological comprehension, phonological knowledge, or their performance on other types of speech production tasks (see Figure 1). The current 10category system could readily be expanded to 30 categories. for example, to accommodate children who have no language involvement, involvement of only language production, and involvement of language comprehension and language production (i.e.,  $3 \times 10 = 30$  categories). Of course, actual use of such a system for genetics or other follow-up or subgroup research would be unwieldy, requiring extremely large numbers of subjects to test for differences across the 30 cells. As noted previously, the importance of speechdelayed children's cognitive and language status for longterm outcomes has been well documented. However, the SDCS is designed to characterize only the manifest speech status of individuals throughout the life span. For any particular research or clinical purpose, hybrid systems derived from the SDCS categories could be constructed.

#### Procedure

SDCS classification requires considerable procedural detail at each of several steps, including speech sampling, transcription, and classification assignment. The information used to assign subjects to 1 of the 10 SDCS classifications was consolidated from a number of sources, with most of the empirical findings limited to studies of young children. The Appendix provides an overview of this information and classification procedures, including information on speech sampling and transcription that is also used for the three other measures described later in this paper. The SDCS computer program processes information from a narrowly transcribed phonetic transcript, using sets of transcription and formatting procedures developed in prior work (Shriberg, 1986). When accomplished without the aid of software, the validity of SDCS assignments and each of the other measures depends on the fidelity and accuracy with which these procedures are followed. It is not too optimistic to envision the time when speech recognition software will allow the entire sampling, analysis, and clinical-research classification to be accomplished solely by microcomputer.

#### Validity Data

Figure 3 is a summary of SDCS findings taken from a group of 78 children with speech problems of unknown origin referred to a university-affiliated phonology clinic. The age range of the children at referral was 2:6 (years:months) to 10:7 (M = 4:5; SD = 1:6). The 78 children were classified using a paper-and-pencil version of the SDCS procedure, which was essentially similar to the finalized computer-assisted procedure. For the present purposes, none of the classifications was considered provisional (see Appendix for the criteria used to label a classification as provisional). Substantive discussions of related data are included in Kwiatkowski and Shriberg (in press). In the present context, the distributions of percentages in each category are of interest as evidence for the content and construct validity of the SDCS.

First, 3 of the 78 referrals (4%) would be considered as having speech within the normal range on the SDCS criteria for normal speech acquisition (NSA). The children's error patterns were primarily deletion of consonants in consonant clusters. At that time, however, these children were provided treatment and were dismissed after one semester. Thus, the total "false positive" referral rate for this clinical sample using the SDCS criteria was 4%, which appears reasonable given caregivers', physicians', and referring speech-language pathologists' varying perceptions, concerns, and clinical judgments (Records & Weiss, 1990; Tomblin, Records, & Freese, 1991).

Second, as shown in the remaining two boxes in the first row of Figure 3, a total of 69 children (89%) were classified as having one of the four types of Speech Delay, with the remaining 6 children (8%) having one of the four types of Residual Errors. These percentages are also consistent with



FIGURE 3. Summary of Speech Disorders Classification System (SDCS) findings for a retrospective sample of 78 children with speech problems of unknown origin referred to a university-affiliated phonology clinic.

the clinical population this clinic seeks to service in the community (i.e., children with moderate to severe intelligibility problems of unknown origin). The number and percategory percentages for the 6 children with residual errors are shown in Figure 3 only for completeness. Thus, the classification category termed *Residual Errors*, which also might be considered a false positive, was a low-occurrence referral category.

Third, the subcategory percentages for the 69 Speech Delay children shown in Figure 3 suggest that only approximately 20% have some speech difference meeting criteria for the "+" designation and that only approximately 20% of both the Speech Delay and the Speech Delay+ groups were classified as Questionable. These data also appear orderly, with approximate ratios of 4:1 for both Speech Delay:Speech Delay+ and Speech Delay:Questionable Speech Delay. Thus, the construct validity of the SDCS system would seem to be supported by the fact that children are represented in each of the nine relevant SDCS categories shown in Figure 3 and that the proportions across and within categories meet reasonable expectations consistent with the underlying conceptual framework.

Table 1 provides additional construct validity data for the SDCS. These SDCS data are taken from the same group of 78 children described above, minus the 3 children with normal speech acquisition (i.e., all percentages are based on a total of 75 children). Entries in the rows are the same SDCS classifications on the intake assessment as shown in Figure 3. Entries in the columns are classification data for a follow-up assessment at the end of one or two semesters of treatment. Therefore, the numbers in the cells and corresponding marginal totals and percentages provide a picture of original/follow-up outcomes for children in each of the SDCS classifications.

One obvious validity question of the SDCS is whether children classified as Questionable Speech Delay (QSD or QSD+) normalize sooner with or without speech services than those classified as Speech Delay (SD or SD+) children. Information bearing on this question for children receiving speech services is available in Table 1. Of the 13 Question-

Oleasification				Classifica	ation at t	he end of	i one or t	wo semest	ers of tr	eatment		
assessm	ent			Speech	delay			Residual	errors		Sum	mary
Class type	Subclass	NSX	QSD	QSD+	SD	SD+	QRE	QRE+	RE	RE+	n	%
Speech Delay		,		· ·								
,	QSD	3	5		2						10	13
	QSD+	1	1	1							3	4
	SD	12	2		31						45	58
	SD+	1		1	3	4		1		1	11	15
Residual Errors												
	QRE	1					1		1		3	4
	QRE+							1			1	1
	RE	2									2	3
	RE+										0	0
	п	20	8	2	36	4	1	2	1	1	75	
	%	27	11	3	48	5	1	3	1	1		

TABLE 1. Speech Disorders Classification System (SDCS) data for 75 children at initial referral to a phonology clinic and at the end of one or two semesters of treatment.

able Speech Delay (QSD(+)) children at intake, 31% (4 children) normalized in one or two semesters; of the 56 nonquestionable Speech Delay (SD(+)) children at intake, 23% (13 children) normalized. Thus, consistent with the conceptual organization of the SDCS, questionable status was not a predictor of normalization. Rather, it reflects only the gaps in the sensitivity of our normative literature on speech-sound delay.

A second validity question is whether the designation "+" is associated with intervention outcomes. Of the 55 questionable and nonquestionable Speech Delay ((Q)SD) children at intake, 27% (15 children) normalized, whereas only 14% (2 children) of the questionable and nonquestionable Speech Delay+ ((Q)SD+) children normalized. The finding that children classified as Speech Delay+ were less likely to normalize in one or two semesters of treatment supports the potential theoretical and predictive utility of SDCS classification. Such preliminary findings illustrate the kinds of research and clinical questions for which the SDCS procedure might be useful, including epidemiologic studies, studies of the phenotypes associated with the genetic transmission of phonological disorders, predictive studies, and studies in secondary and tertiary forms of prevention (American Speech-Language-Hearing Association, 1991).

## The Articulation Competence Index (ACI) \_\_\_\_\_

#### Rationale

There currently is no one measure that can be used to index the severity of speech involvement (assessed in the positive direction as articulation competence) from probands and their relatives, an age span that may cross four generations. The Articulation Competence Index (ACI) was developed to provide one score that most accurately reflects the measured severity of articulation involvement of persons in each of the 10 classification categories in the SDCS. As discussed previously, the three assumptions for this and each of the other measures in this paper are that speech measures should be based on a sample of conversational speech, that phone-size analysis units are most sensitive to the construct of speech as a biobehavioral trait, and that data reduction requires the sensitivity of narrow phonetic transcription. Issues associated with these perspectives were addressed previously. As described below in Procedures, the ACI is based on two characteristics of conversational speech: the percentage of consonants articulated correctly and the percentage of all incorrect consonants that is due to articulatory distortions. A brief background on both variables is needed to establish rationale for the ACI metric.

The Percentage of Consonants Correct (PCC) and Phoneme Distortions. The Percentage of Consonants Correct (PCC) metric was developed to index a construct titled "severity of involvement," as rated on an equal-interval appearing scale by speech-language pathologists and inexperienced listeners (Shriberg & Kwiatkowski, 1982b). Results of a multiple regression analysis of ratings of severity of involvement, completed by 52 experienced speech-language pathologists from three states and by 110 students in an introduction to communicative disorders course, indicated that percentage of consonants correct in a continuous speech sample accounted for a statistically significant 43% of the variance. The variables of age and prosody-voice status accounted for an additionally significant 34.5% of the variance in severity ratings. A PCC value of 85% was determined to be an appropriate cutoff point to distinguish normal speech or mild involvement from mild-moderate (65%–85%), moderate-severe (50%–65%), or severe (<50%) involvement. The original report (Shriberg & Kwiatkowski, 1982b) contains descriptive and inferential statistical data supporting these severity divisions, and a later paper (Shriberg et al., 1986) suggests additional guidelines for borderline decisions.

Although the PCC has been used as a severity measure in a variety of descriptive and intervention studies with speechdelayed children, it has a major limitation for genetics, subgrouping, and follow-up studies involving normally speaking children and children with Residual Errors. The PCC score reflects the total percentage of correct consonants, with each consonant's contribution to this total weighted by its frequency of intended occurrence in conversational speech. Because the PCC was validated for use with preschool and elementary schoolchildren whose delayed speech was specifically characterized by deletions and substitutions, its use with children or adults whose errors are only or primarily speech-sound distortions was considered inappropriate (Shriberg & Kwiatkowski, 1982b). That is, for most older children and adults, the only speech errors observed are common distortion errors classified as Residual Errors (e.g., dentalized fricatives, lateralized fricatives, derhotacized /r/) or uncommon distortions classified as Residual Errors+ (e.g., epenthetic stops, frication of stops) presumably associated with subtle hearing, structural, or motor-speech deficits. Therefore, although the original validation data and subsequent studies supported the use of the PCC with young children having moderate-to-severe speech delays, the PCC was not intended for use with older children or adults having only common or uncommon (see Appendix for definition of these terms) clinically relevant distortions. For example, for two 6-year-old children with PCCs of 75%, one error pattern could reflect deletions and substitutions for all fricatives and affricates, and the other could reflect only distortion errors on all of these same sounds. Therefore, what is needed is some procedure in which severity scores are adjusted for the relative proportion of distortion errors, with the procedure yielding statistical distributions for all age groups that meet requirements for parametric analyses. The Articulation Competence Index (ACI) was developed to meet these needs.

#### Procedures

The ACI is computed from two speech variables obtained from a sample of spontaneous conversational speech. An overview of procedures to obtain a usable conversational speech sample is provided in the Appendix (for discussion of related issues see Morrison & Shriberg, 1992; Shriberg, 1986; Shriberg & Kwiatkowski, 1985; Shriberg, Kwiatkowski, & Hoffmann, 1984; Shriberg & Kent, 1982; Shriberg & Lof, 1991). The first speech variable is the PCC score, a percentage that reflects the total



FIGURE 4. Relationships among Articulation Competence Index (ACI), Percentage Consonants Correct (PCC), and Relative Distortion index (RDI) scores for 60 speech-delayed children.

number of correct consonant sounds in the sample divided by the total number of intended consonants in the sample. The second speech variable is the Relative Distortion Index (RDI), a percentage that reflects the relative percentage of distortion errors in the speech sample. As discussed above, compared to consonant deletions and substitutions, consonant distortions are considered biologically and cognitive-linguistically "more mature" articulatory errors (cf. Anthony, Bogle, Ingram, & McIsaac, 1971) and socially less costly to perceptual estimates of intelligibility and severity of involvement (e.g., Coston & Ainsworth, 1972). As discussed for the Speech Disorders Classification System, persons with deletion and substitution errors beyond normative stages are classified as having Speech Delay, whereas those with only persisting speech-sound distortions are classified as having Residual Errors. The RDI is obtained by dividing the total number of distortion errors in a sample by the total number of articulation errors. Thus, the RDI is a percentage reflecting the proportion of a subject's errors that are due to the sum of common and uncommon distortions. The primary advantage of the RDI compared to the Absolute Distortion Index, which as discussed later is the actual percentage of distortion errors in a sample, is that the RDI is independent of the percentage of consonants correct. Thus the RDIs of severely involved and less severely involved subjects (i.e., low and high PCCs, respectively) can be directly compared without statistical dependence on their actual percentage of consonants correct.

The formula for the ACI is as follows:

Articulation Competence = Index Percentage Consonants Correct + Relative Distortion Index 2

Note that the higher the PCC and/or the RDI, the higher a

person's ACI score (i.e., the higher the indexed level of consonant mastery or articulation competence). In contrast, lower ACI scores reflect more speech involvement due to more consonants in error (lower PCC) and/or more of these errors involving omission and substitution errors (lower RDI). Dividing the sum of the PCC and the RDI by 2 yields a range of potential ACI scores (0–100%) that is more intuitively interpretable than the potential unadjusted ACI total (0–200%).

Speakers with PCC scores of 95% and above require special consideration for ACI computation. As described in the original validation study (Shriberg & Kwiatkowski, 1982b), the test-retest stability of PCC scores is considered to be approximately 4%, and the intrajudge reliability of a given examiner's narrow phonetic transcription adds an additional unknown source of variability to PCC scores. Thus, speakers with only a few errors on the PCC would have spuriously low ACI scores if those errors were not all transcribed as distortions. Therefore, the simple convention to derive an ACI score for speakers with 95%–100% PCC scores is to use their PCC score as their ACI score. A speaker with a PCC score of 95% would be assigned an ACI score of 95%; a speaker with a PCC score of 97.5% would be assigned an ACI score of 97.5%, and so forth.

Figure 4 illustrates the relationships among ACI, PCC, and RDI scores for 60 speech-delayed children. The ACI scores of these 60 children, which were chosen to illustrate a wide range of ACI scores, are arranged in a descending sort. Notice that the PCC and RDI scores are virtually mirror images of one another with higher PCC scores associated with lower RDI scores and vice versa. Thus, the ACI reflects an upwards adjustment of PCC scores for speakers with proportionally more distortion errors and a downward adjust-



FIGURE 5. Comparisons between Percentage Consonants Correct (PCC) scores (upper panel) and Articulation Competence index (ACI) scores (lower panel) for 117 speech-normal boys and girls and 199 speech-delayed boys and girls divided into six age-groups.

ment of PCC scores for speakers with proportionally more omission and substitution errors.

#### Validity Data

Figure 5 provides a comparison between PCC scores and ACI scores for a group of 117 speech-normal children and 199 speech-delayed children. As appropriate transcripts were not available for all subjects, classification into normal and disordered groups was accomplished by criteria established in associated studies, rather than by means of the SDCS. The data points in both panels are the means and standard deviations for each measure, with boys and girls in both groups divided into six 6-month age intervals. There were fewer children in the 5- to 6-year-old groups. The data in Figure 5 support two observations about speech develop-



FIGURE 6. Articulation Competence Index (ACI) scores for 117 speech-normal and 199 speech-delayed children divided into 20 5-point interval groups. The four panels provide data for 3-year-old children (upper left), 4-year-old children (upper right), 5-year-old children (lower left), and all-aged children (lower right).

ment as reflected in these indices. First, the ACI data in the lower panel provide a better separation of speech-normal compared to speech-delayed children than provided by PCC scores in the upper panel. Specifically, the ACI means for each age group comparison are further apart than the PCC means. Moreover, whereas PCC standard deviations overlap for nearly every normal speech-delayed speech comparison, ACI scores are well-separated for nearly every comparison. Second, as is known for both speech-normal and speechdelayed children during this period of development, the means scores on both measures are fairly flat, with only the ACI scores indicating some developmental change. If added respectively to the beginning and ending of the data in Figure 5, ACI scores for children younger than 3 years and older than 6 years would comprise the lower and upper bounds of this function.

Figure 6 was constructed from ACI scores of the same two groups of children whose data are displayed in Figure 5. ACI scores were divided into 20 5-point interval groups, with the data points indicating the percentage of children with ACI scores in each group. The distributions for each of the three age groups and for the totals over age groups indicate fairly good approximation to normality and excellent separation of scores. That is, even though the relatively small sample sizes for the three age-group panels yield some apparent deviations from normality, the overlaps in the tails of each distribution are modest. For the total groups aggregated over this age range (lower right panel), which is justified by the data in Figure 5 (see also Appendix, Table A), scores from the two sets of children form a distinctly bimodal distribution with each distribution having skew and kurtosis values consistent with normality (<  $\pm$  1.0).

The data in Figures 5 and 6 support the use of a speech-normal or speech-delayed child's ACI score as a parametric statistic. Presumably the separation between the normal-disordered ACI distributions would become greater with age for both Normal Speech Acquisition-Speech Delay and Normal Speech Acquisition-Residual Errors comparisons. As reviewed previously, distributional requirements are important for the quantitative procedures used in behavioral genetics and other types of developmental research. Several cross-sectional and longitudinal studies are in progress in which ACI scores are transformed into standardized severity of involvement scores, which in turn are used to compute gain scores. The advantage of the metric for repeated measures training studies is that it

reflects total performance including any tradeoffs that may occur across trained and nontrained targets. Although ACI data have not yet been collected for adults, the assumption is that articulation errors in otherwise normally functioning adults are exclusively distortions, and would thus yield ACI scores in the high 90s. A major need in speech-genetics research is to assemble life-span severity of involvement data.

# Speech Profiles

#### **Rationale and Procedures**

A third measurement approach for research in developmental phonological disorders is a series of graphic displays collectively termed Speech Profiles. Speech Profiles provide a standard way to quantize, compare, and portray speech data. A Speech Profile is a cover term for a series of six four-panel display formats used to report group-averaged or individual subject data. The six different Speech Profile formats (Speech Profile 1-Speech Profile 6) provide a way to manage large amounts of grouped or subject-level data on consonant and vowel/diphthong features, phones, and allophones. Individual panels provide information by singletoncluster, position of speech sound in the word, error type, and distortions divided into non-error differences and those considered clinical errors. As described below, the format of each Speech Profile contains two areas of information; (a) a graphic section, containing a descending-order sort of speech data arranged to display and statistically compare certain aspects of performance and (b) a numeric section. containing descriptive and inferential statistics at higher levels of the data than shown in the graphic section. Both the graphic and the numeric sections of each of the four panels in a Speech Profile contain, where appropriate, the results of inferential statistical significance tests. The type of inferential statistical test used in Speech Profiles depends on characteristics of the speech data; the examples below include both parametric and nonparametric statistics for independent and paired samples. All the displays shown in the following figures were produced by statistical and graphics enhancements to the PEPPER program (Shriberg, 1986) running on a VAXstation 3100.

The primary information in a Speech Profile 1 display is the data in the left panel in Figure 7. The values for this trend, which is a profile of consonant mastery, were taken from a group of 64 3- to 6-year-old speech-delayed children (Shriberg, Kwiatkowski, & Gruber, 1992). Severity of involvement of the 24 English consonants is represented as the percentage correct for each consonant sorted in decreasing order from left to right. Notice that the most obvious breaks in this function allow for a division of the 24 consonants into three groups of eight sounds termed the Early-8, averaging over 75% correct, the Middle-8, averaging 25%-75% correct, and the Late-8, including consonants averaging less than 25% correct in continuous conversational speech (/3/ is infrequently represented in young, speech-delayed children's spontaneous conversational speech). Relative to earlier discussions of the phone as a unit of analysis for production

phonology, notice that the left-to-right sequence of phonemes confounds tidy representation using the higher-order units of phonetic features, distinctive features, or phonological processes. That is, if viewed from the perspective of feature or process classifications, the ordering of sounds within the trend does not form an orderly sequence. The numeric information in the upper left panel provides means and standard deviations for each of the three eight-sound groups, separately for singletons (S), clusters (C), and a total for all sounds (T). The right-most total (T) across all sounds is the same value as the *Percentage of Consonants Correct* (*PCC*).

Each of the other three numeric panels in Figure 7 contains two values indicating the absolute (A) and relative (R) percentages of error types for each speech sound listed on the abscissa. The formulas for each of these sound-level values are similar to those described for the ACI, in which the absolute and relative indices were based on tokens of each consonant type. In the top right panel in Figure 7, for example, the Percent Absolute Omissions (A) (all such terms are made terse to accommodate space constraints in the graphics) reflects the number of omission errors on the speech sound(s) divided by the total number of intended occurrences of the sound(s) in the transcript. Percent Relative Omissions (R), in contrast, is calculated by dividing the number of omission errors on the speech sound(s) by the total number of errors on the sound(s). The graphics section in the top right and two lower panels contain the relative error types for each sound. The numeric sections in each of the three panels provide subtotals for the three eight-sound groups and for all sounds. Thus, this grouplevel Speech Profile displays the mean mastery and mean percentage of absolute and relative omissions, substitutions, and distortions for each consonant and each consonant subgroup.

Variants of the Speech Profile format are used to compare central tendency data on two or more groups of speakers, to display individual subject data, to compare subjects on repeated measures, to compare individual subject data to group reference data, and so forth. Speech Profile 2 (shown later as Figure 11) provides detailed data for consonants at the level of phonetic class features, including sonorants versus obstruents; voiced versus voiceless; and comparisons for nasals, glides, stops, fricatives, affricates, and liquids. Speech Profile 3 (Speech Profiles 3-6 are not shown here) provides information on vowels/diphthongs using the same format as shown for the consonants in Speech Profile 1. Speech Profile 4 provides detailed information on target and replacement consonant substitutions in word-initial and word-final position. Speech Profile 5 provides similar information for distortions, with the data subdivided to show targets/distortions for non-error and error allophones. Finally, Speech Profile 6 provides both substitution and distortion data for all consonant singletons and clusters occurring word-medially. The program produces associated output (termed a Detailed Report) that provides additional numeric information for all relevant variables in each display including token counts, means, standard deviations, skew, kurtosis, confidence intervals, and exact p values for all statistical comparisons.



FIGURE 7. Reference data for Speech Profile 1 based on a sample of 64 3- to 6-year-old children with speech delays of unknown origin. See text for description of the elements in each panel.



FIGURE 8. Comparisons between the consonant mastery data for a sample of 64 3- to 6-year-old speech-delayed children and consonant mastery data from six normative studies.

## Validity Data

Figure 8 provides normative literature comparisons to the Speech Profile's consonant mastery profile (the percentage of consonants correct separately for Early-8, Middle-8, and Late-8 sounds). The filled circles in each of the six panels are the average percentage of correct consonant sounds in the previously described group of 64 3- to 6-year-old speechdelayed children (Phonology Project Sample, 1991). The open circles in each of the other panels reflect the rankordered percentage of sound mastery by approximately 2- to 8-year-old, normally developing children. Beginning with the top left panel, the consonant mastery profile is compared to the consolidated consonant acquisition data from three normative studies described in Sander (1972). The Sander speech-sound data are plotted in rank order of acquisition as indicated on the right axis. The two rank orderings are fairly congruent, with 15 of the 24 consonant ranks (63%) from the Sander data falling within their putative early-middle-late groups on the consonant mastery profile. The most curious normative data departures from the consonant mastery profile are sounds in the Late-8 group, such as the /s/, /l/, and /r/, which Sander's articulation testing studies place in the percentage of mastery range of the Middle-8. As suggested below, these data points and the other departures from the



FIGURE 9. Phonological process data for a sample of 64 3- to 6-year-oid speech-delayed children divided into subgroups of 26 Language-Normal and 22 Language-Delayed children.

three-category consonant mastery profile—two sounds within the Early-8 and two sounds within the Middle-8—may be due to the substantial methodological differences between and among studies or may reflect true differences between the diachronic data of normal acquisition and the synchronic data from these speech-delayed children.

The remaining panels in Figure 8 provide similar comparisons, including the normative studies reported by Smit et al. (1990), Hoffmann (1982; see also Hoffmann & Shriberg, 1982; Shriberg & Hoffmann, 1982), and Prather, Hedrick, and Kern (1975). Comprehensive reviews of differences across these and other studies are available in several sources (e.g., Bernthal & Bankson, 1988; Smit, 1986; Stoel-Gammon & Dunn, 1985). Different ages, different modes of speech sampling (e.g., only the Hoffmann study was based on a continuous speech sample), different articulation test stimuli, differences in transcription levels, and differences in criteria for age-level mastery are evident among the three studies reflected in the Sander data and the three other studies. These differences notwithstanding, the general agreement of rank order of acquisition between and within the sequence of Early-8, Middle-8, and Late-8 sounds provides criterion validity support for the Consonant Mastery Profile. Thus, as a cross-sectional estimate of the rank-order of consonant mastery in speech-delayed children, the reference consonant mastery profile agrees quite well with estimates of the developmental order of consonant acquisition.

Figures 9 and 10 provide a comparison of the types of data yielded by one linguistic unit of analysis—alternative data summary by natural phonological processes—compared to the Speech Profile approach. These comparisons provide support for the construct validity of Speech Profiles. The data in Figure 9 are from the 64 speech-delayed children (Phonology Project Sample, 1991) divided into subgroups based on their language production status as indexed by structural stage (Miller, 1981). Using Miller's criteria, children were divided into three groups: age-expected performance, up to 1-year below expected performance, and over 1-year gap between obtained and expected performance. For the present purposes. Figure 9 includes the mean phonological process occurrence only for the age-adequate (Language-Normal) and over 1-year gap (Language-Delayed) groups. The means trends for each group clearly do not differ. Mann-Whitney W statistics (also termed the Wilcoxon-Mann-Whitney Test; MINITAB, 1989; Siegel & Castellan, 1988) adjusted for ties for each of the 20 comparisons yielded only one significant difference at the liberal family-wise alpha level of .01. As indicated in Figure 9, the Language-Delayed children had significantly more deletions of final consonants [W(26,22) = 498.0; p < .004]. Thus, when compared by the construct of phonological process, the error patterns of the language-normal and language-delayed subgroups were generally not significantly different.

Figure 10 is a Speech Profile comparison of the data for the same two subgroups of speech-delayed children as shown in Figure 9. Notice that the trends diverge in several ways. In the upper left panel, Panel A, the statistically significant dagger symbols in the numeric and graphic sections indicate that compared to the Language-Normal children (Group 1), the Language-Delayed children (Group 2) have lower average consonant mastery, particularly for the Early-8 and Middle-8 sounds. Between-group differences reach statistical significance on 6 of the 12 comparisons in the numeric panel (Mann-Whitney W range: 763.54-810.0) and on two of the individual speech sound comparisons in the graphic panel (Mann-Whitney Ws: /n/= 780.0, /t/=775.0). Note that the two language status groups differ significantly by over 4% on the total (T) of the correctly articulated Early-8 consonants, over 10% on the total of correctly articulated Middle-8 consonants, and by 5% totalled



FIGURE 10. Speech Profile 1 data for a sample of 64 3- to 6-year-old speech-delayed children divided into subgroups of 26 Language-Normal (Group 1) and 22 Language-Delayed (Group 2) children. The upper left and right panels are referred to in the text as Panels A and B, respectively; the two lower panels are referred to as C and D.

across all consonants occurring in singletons (S) and clusters (C).

The data in Panels B, C, and D in Figure 10 provide a clear picture of the error-pattern underlying the differences ob-

served in Panel A. As shown in the numeric and graphic sections of Panel B, the Language-Delayed children's average of 5% error differences on all consonants are primarily due to omission errors. The statistical contrasts in the numeric panel indicate that they have significantly more absolute (A) omission errors on both the Early-8 and Middle-8 sounds and significantly more absolute (A) and relative (R) errors across all sounds. Among other interesting hypotheses prompted by these data is the fact that omission errors occurred on the Early-8 sounds, rather than on only the presumably more motorically difficult Middle-8 and Late-8 sounds. Pending further examination of specific contexts for the omissions, such a finding could be interpreted as supporting the effects of their cognitive-linguistic constraints as these language-involved children attempt to process continuous conversational speech (see Figure 1). The point here is that in comparison with the phonological process analysis (Figure 9), the Speech Profile approach provided information that was sensitive to between-group differences within the early, middle, and late consonants and across the error types of omissions, substitutions, and distortions. For certain questions in etiologic subgroup studies, as suggested in the following examples, such sensitivity to phone class, severity, and error typology is crucial. To the degree that such information provides useful insights into the nature of speech disorders, they might be viewed as supporting the construct validity of Speech Profiles.

A final example of alternative Speech Profile comparisons is provided in Figure 11. The display is a Speech Profile 2 which, as indicated previously, provides a means to compare up to four sets of data at the level of class features (Sonorant, Obstruent), voice features (Voiced, VL (Voiceless)), and manner features (Nasal, Glide, Stop, Affricate, Fricative, and Liquid). The filled circles in Figure 11, labelled D in the legend, are the mean feature-level data for the group of 64 speech-delayed children identified in previous figures as the Phonology Project Sample (1991). The open circles, identified as A in the legend, are the mean data for 14 children with suspected apraxia of speech (Shriberg, Aram, & Kwiatkowski, 1992). The children were approximately 5-15 years old (M = 8 years), which was older than the mean age of the 64 3- to 6-year-old speechdelayed children (M = 4 years, 3 months). As shown in the graphic trends and in the statistical comparisons in the graphic and numeric sections, the two groups differed at the level of features in several ways. The children with suspected apraxia of speech had significantly better mastery of fricatives and liquids, which could be associated with their higher average age. However, compared to the speech-delayed children, the children with suspected apraxia of speech tended to have more relative omission errors, excepting glides, on which their errors were significantly more often distortions. Speech Profiles 3, 4, 5, and 6 were used to explore the nature of the distortions in both consonants and vowels/diphthongs. In the present context, the sensitivity of the Speech Profile approach to such differences is viewed as construct validity for the procedure. That is, the construct of developmental apraxia of speech would predict that its pathognomic segmental and suprasegmental (see next section) error profile would differ from the phenotype reflecting the "common" form of a developmental phonological disorder. The Speech Profile concept appears to provide a way to delineate the relevant contrasts.

The Speech Profile examples illustrated in this report represent only some of the ways this approach provides a means for analysis and display of large amounts of database information. Speech Profiles have been or will be used to compare speech production under different sampling conditions (e.g., imitative versus spontaneously evoked forms, phonetically simple versus phonetically complex strings, speech under several rate alterations) and for comparing and testing for significant differences in phonetic transcription. Speech Profiles also are useful for repeated measures studies and for displaying data from a variety of single-subject designs. Although the displays shown use the means data (for some very small data sets we have used 5% trimmed means), nonparametric statistical tests for independent and dependent samples (e.g., Mann-Whitney, Wilcoxon Matched-Pairs Signed Ranks, Mood Test, Kruskal-Wallis One Way Analysis of Variance, Friedman Two-Way Analysis of Variance [MINITAB, 1989; Siegel & Castellan, 1988]) are generally more appropriate given the typically small sample sizes, non-normal percentage distributions, and the high rate of 0% or 100% scores that cannot be successfully transformed using typical statistical recommendations, such as one of the arcsin transformations. The Detailed Report for each Speech Profile allows for the inspection of relevant distributional characteristics in association with the choice of inferential statistics. Rationale for adjusting the family-wise and experiment-wise alpha levels within and between Speech Profile panels to .01 and .001 is also an important methodological issue in relation to the goals and stages of the research inquiry. Although the sheer number of contrasts available for statistical significance testing makes the concept of statistical inference a moot issue (Efron & Tibshirani, 1991), there needs to be some way to deal with the possibility of Type I versus Type II errors of inference. Ultimately, the most secure research strategy is to encourage systematic cross-validation within and across research laboratories.

## The Prosody-Voice Profile \_\_\_\_\_

## Rationale

Prosody occupies a unique place in the study of normal and deviant communication. Unlike speech, language, fluency, voice, and hearing disorders, each of which has its own research literature and clinical subspecialities, the area of prosody disorders has no recognized subdiscipline. Relevant theories, research, and applied information on prosody are found in many fields, including descriptive linguistics, psycholinguistics, neurolinguistics, developmental linguistics, psychiatry, communication arts, the phonetic sciences, and communicative disorders. Theoretical frameworks and applications include proposals to characterize the underlying organization of prosody in languages and language users, algorithms to deal with prosodic information in speech recognition systems, models of the motor control and phonatory mechanisms subserving prosody in manifest speech, and functional analyses of prosody as a reflection of sociolinguistic mores and affective traits and states. Assessment methods for disordered prosody range



FIGURE 11. Speech Profile 2 data for 64 3- to 6-year-old speech-delayed children (D) and 14 children with suspected apraxia of speech (A).

from brief check lists, to elaborated scaling tasks, to a variety of instrumental approaches, with increasing availability of dedi-

cated devices and applications software to display and quantify relevant acoustic correlates.



FIGURE 12. Prosody-Voice Profile data for 62 3- to 6-year-old speech-delayed children (D) and 13 children with suspected apraxia of speech (A).

A perceptually based prosody-voice assessment procedure has been developed to meet the specific needs of genetics and other causal-correlates research in developmental phonological disorders. Complete rationale and an audio-tutorial to obtain prosody-voice data from a sample of conversational speech are described in Shriberg, Kwiatkowski, and Rasmussen (1990).

Content/Context	Environment	Register	States
C1 Automatic Sequential C2 Back Channel / Aside C3   Don't Know C4 Imitation C5 Interruption / Overtalk C6 Not 4 (+) Words C7 Only One Word C8 Only Person's Name C9 Reading C10 Singing C11 Second Repetition C12 Too Many Unintelligibles	E1 Interfering Noise E2 Recorder Wow / Flutter E3 Too Close to Microphone E4 Too Far from Microphone	R1       Character Register         R2       Narrative Register         R3       Negative Register         R4       Sound Effects         R5       Whisper	S1       Belch'

# **Exclusion Codes**

# Prosody-Voice Codes Prosody

Phrasing	Rate	Stress
<ol> <li>Appropriate</li> <li>Sound / Syllable Repetition</li> <li>Word Repetition</li> <li>Sound / Syllable and Word Repetition</li> <li>More than One Word Repetition</li> <li>One Word Revision</li> <li>More than One Word Revision</li> <li>Repetition and Revision</li> </ol>	1       Appropriate         9       Slow Articulation / Pause Time         10       Slow / Pause Time         11       Fast         12       Fast / Acceleration	1 Appropriate         13 Multisyllabic Word Stress         14 Reduced/Equal Stress         15 Excessive/Equal/         Misplaced Stress         16 Multiple Stress Features

Voice



FIGURE 13. Prosody-Voice Profile key for the elements and codes shown in Figure 12.

Technical information, including reliability and validity studies and reference data for 352 3- to 19-year-old speech-normal and speech-delayed children, are provided in Shriberg, Kwiatkowski, Rasmussen, Lof, and Miller (1992). For space considerations, and because the rationale, procedures, and validity data for this approach are available elsewhere, the following discussion provides only a brief description of the procedure and a construct validity example.

#### Procedures and Validity Data

Figure 12 is a Prosody-Voice Profile reflecting the averaged data from the same groups of children with delayed speech and suspected apraxia of speech described in Figure 11. Prosody-

voice data were available for only 62 of the original 64 children with delayed speech and 13 of the original 14 children with suspected apraxia of speech. Figure 13 is a sheet from the scoring form, which provides a key to the numbered Exclusion Codes and Prosody-Voice codes in Figure 12. The general arrangement of the four panels in Figure 12 is similar to the Speech Profile displays, with plotted data representing the percentages for variables listed along the bottom axis. The numeric and graphic sections of Panel A provide summary information on the six suprasegmentals scored in the prosodyvoice procedure: Phrasing, Rate, Stress, Loudness, Pitch, and Laryngeal and Resonance Quality. The data points in the graphic section are the percentage of utterances considered "appropriate," with the horizontal dashed lines indicating the 90% screening cutoff for *pass* and the 80% cutoff for *question-able pass* (cf. Shriberg et al., 1990; Shriberg et al., 1992). As shown in these averaged summary data, the suprasegmental performance of children with suspected apraxia of speech differs significantly from the average values of a younger group of speech-delayed children on the suprasegmentals of Phrasing, Rate, Stress, and Resonance Quality.

The remaining panels in the sample Prosody-Voice Profile in Figure 12 characterize specific inappropriate paralinguistic and prosody-voice behaviors during the speech sample. Panel B includes numeric and graphic information on the percentages of occurrence of 31 Exclusion Codes. As shown, the codes are divided into four groups reflecting different reasons why utterances in the speech sample were not eligible for prosody-voice coding. These data are important in their own right, quantifying technical and paralinguistic aspects of the sample and the speaker (cf. Shriberg et al., 1992).

The lower two panels in Figure 12 include code-level information for the six suprasegmentals summarized in Panel A. Each of the data points for the speech-delayed and suspected apraxia of speech group indicates the percentage of occurrence of each subtype of inappropriate prosody-voice. In the present example, the most apparent differences in the two groups were in codes for Phrasing, Rate, and Stress, with the children with suspected apraxia of speech having significantly (Mann-Whitney W) higher average scores for PV9: Slow Articulation/Pause Time, PV14: Reduced/Equal Stress, and PV15: Excessive/Equal/Misplaced Stress. Also, although their nasal resonance was significantly different from that of the speechdelayed children when summed over all three resonance codes (Panel A), neither PV30: Nasal nor PV31: Denasal differed significantly, PV32: Nasopharyngeal could not be tested for significance. There were several variables in the numeric sections of Panel C and Panel D on which the two clinical groups differed significantly.

These data are viewed as supporting the construct validity of Prosody-Voice Profiles for genetics and other etiologic subgroup research. They emphasize the importance of statistical assessment at both individual and summary levels of all relevant domains. Studies describing how segmental and suprasegmental behaviors covary in speakers could provide informative leads about genetic loci and modes of transmission. As with Speech Profiles, alternative ways to use Prosody-Voice Profile displays in other research include repeated-measures designs with Prosody-Voice Profile trends reflecting single-subject probes. Also, statistical treatment of the percentage variables includes both parametric and nonparametric procedures, depending on how well data meet relevant cell-size and distributional assumptions. Rationale for adjusting family-wise and experiment-wise alpha levels for the number of comparisons within and between each Prosody-Voice Profile panel is also an important methodological consideration.

#### CONCLUSION

The exciting potential of molecular and behavioral genetic techniques requires a discipline to examine closely its nosology and its array of measures. Emerging genetics technologies available to researchers in communicative disorders will permit designs posing the most basic questions of causality, prediction, and ultimately, prevention. Central to this goal in developmental phonological disorders is research aimed at specification of the phenotypes for genetically transmitted forms. As stated in a related discussion by Epstein et al. (1991), "... each feature of the phenotype [eventually] must be defined at the cellular, physiological, physical, and developmental levels" (p. 209). The four measures described in this paper have been developed in response to the needs and spirit of this challenging quest.

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## Appendix

#### Procedures for Speech Sampling, Phonetic Transcription, and the Speech Disorders Classification System (SDCS)

#### Speech Sampling

As described in detail elsewhere (cf. Shriberg, 1986; Shriberg & Kwiatkowski, 1980; Shriberg & Kwiatkowski, 1985), continuous conversational speech sampling for the purpose of phonological analyses requires consistent attention to technical and linguistic conventions. The following are brief summaries of the elements required to obtain representative and usable audio-recorded speech samples.

#### **Recording Equipment and Procedures**

Record the speech sample in a quiet environment. If this is not possible, minimize the negative effects of noise by reducing the mouth-to-microphone distance when the noise is constant and have the speaker (henceforth, the child) repeat the obscured utterance when the noise is transient. Use a high-quality audio tape recorder with an impedance-matched external microphone and high-quality audiocassette tapes. To avoid recording any noise emanating from the tape deck during recording, carefully position the tape deck on a different surface and as far as possible from the microphone. Place the microphone no more than 6-8 inches from the child's lips and adjust the volume control so that the child's vowels cause the needle on the VU meter to peak just below the distortion area. The consonants should be sufficiently audible to discriminate subphonemic features such as unaspirated and frictionalized stops. Volume levels between 1/3 to 3/3 of full scale usually yield the signal-to-noise ratios required for narrow or broad phonetic transcription.

#### Sampling Procedures

Use a variety of materials and introduce different topics as needed to keep the child talking and to obtain representative proportions of parts of speech, word shapes, and phonemes. Medial and final /3/ do not regularly occur in spontaneous conversational speech and therefore no special procedures are used to evoke them (normative criteria for /3/ do not enter into the classification procedures in the SDCS program; see Table A). Be casual about the presence of the microphone so that periodic adjustments of the volume level or the placement of the microphone do not disturb the child. Gloss the child's utterances in natural, conversational ways and allow the child opportunities to clarify utterances to increase intelligibility during later transcription. Make notes on articulatory behaviors that may not be perceptible on the audio recording, such as lip rounding/unrounding gestures, unreleased stops, fricative distortions, and any facial gestures that may accompany speech production. Finally, note the child's general health, motivation, and physical state (e.g., whether congested or irritable) for possible major or more subtle effects on speech production.

#### Narrow and Broad Transcription of Conversational Speech

The SDCS, ACI, and Speech Profiles require adherence to a set of transcription conventions that are integral to the validity of each measure. These conventions are available in three sources: Shriberg (1986), Shriberg and Kent (1982), and Shriberg, Kwiatkowski, and Hoffmann (1984). Although it is not possible to include here all the conventions used to generate the sample data for the three measures, it is important to at least summarize the guidelines for transcribing and scoring distortion errors. All the measures require some level of narrow phonetic transcription, although not all clinical populations require a full set of diacritics. The basic issue is that only certain common and uncommon speech sound distortions are scored as clinical errors crucial for SDCS classification. The following discussion of four types of speech-sound distortions (see also

Table A) provide rationale to transcribe all phonetic distortions for the SDCS, ACI, and Speech Profiles measures.

#### Four Types of Speech-Sound Distortions

The traditional term *speech-sound distortions* is generally ambiguous when used in technical discussions in the speech literature. A minor problem is that some texts distinguish between distortions versus additions, with distortions denoting some allophonic difference in place, manner, voicing, force, or duration, whereas an addition assigns phonemic status to an element "added" to the target phoneme. Following transcription, linguistic, and clinical speech pathology rationale discussed elsewhere (Shriberg, 1986; Shriberg & Kent, 1982) all potential additions in the present context (including epenthetic consonant sounds and vowel on-glides/off-glides) are classified as distortions.

Articulatory distortions comprise four subtypes formed by their status on two constructs: (a) *non-clinical* versus *clinical* import as speech-sound errors and (b) *uncommon* versus *common* occurrence during different ages of normal speech development.

Nonclinical distortions. Nonclinical distortions are speech-sound differences or allophones that are due to dialectal or idiolectal differences in linguistic background or speech-motor constraints. For example, palatalized /s/ ([s], sometimes called a "hissy s") and retroflexed /s/ ([s], sometimes called a "whistling s") are commonly heard nonclinical distortions in many regional and socioeconomic strata. There is no attempt here to list all such common and uncommon nonclinical distortions because there are few reliable databases from which to generalize. The interested reader is referred to Smit et al. (1990) and Shriberg (1986, Appendix C, Tables 3-5) for lists of common and uncommon nonclinical distortions observed in normally developing and speech-involved children. Included in this category are slight rather than "notable" distortions, with the obvious validity and reliability problem attendant to this perceptually based distinction. It should be noted here that the list of nonclinical errors in Shriberg (1986) includes a variety of deletions (e.g., deletion of initial /h/ in unstressed pronouns) and substitutions (e.g., substitution of glottal stop for /t/ in word-final position) that are considered acceptable forms in casual speech. Although common and uncommon nonclinical distortions are of interest for certain research and clinical questions, they are never considered speechsound errors in the measures discussed in this paper.

Clinical distortions. Clinical distortions comprise a much smaller category of allophones that, by historical consensus in the discipline of communicative disorders, are considered articulatory errors. The distinction between uncommon versus common clinical distortions refers to the relative prevalence data reported for distortions by age level in normative and clinical studies. Thus, whether or not a clinical distortion on a particular speech sound is actually to be scored as an error depends on the age of the child producing the distortion (see Table A). Whereas common or uncommon nonclinical distortions are never considered for treatment (excepting when involving the complex issues of second language and accent reduction), uncommon and common clinical distortions become candidates for treatment when children reach an age when such distortions are no longer "within the normal range." Whether or not treatment is recommended and actually provided depends on local service delivery issues, which are not relevant in the current context. The following list of common and uncommon clinical distortions are based on survey data, clinical consensus, and our own clinical-research findings on the approximate ages at which distortions normalize.

The five common clinical distortions, roughly in increasing order of prevalence, are as follows:

- 1. labialized /l/ or /r/
- 2. velarized /l/ or /r/
- 3. lateralized voiced or voiceless sibilant fricatives or affricates
- 4. derhotacized /r/, /3·/, or /3·/
- 5. dentalized voiced or voiceless sibilant fricatives or affricates

These five common distortion errors are transcribed as errors for the ACI and Speech Profile analyses no matter what the age of the speaker. As shown in Table A, however, for the purposes of SDCS classification, each speech-sound difference is a permitted error until a child reaches a certain age.

The following list of uncommon clinical distortions is obviously arbitrary, with few reliable data of this type available in the survey clinical literature. As reviewed in the previous section on phonetic transcription, there may be dialectal allophonic variants that should not be considered uncommon clinical errors, and there may be other distortions that should be added to the list. These segmental errors were assembled primarily from our database of normal and speechdisordered children and findings described by Smit et al. (1990), each of which used narrow phonetic transcription. Additional information was considered from the uncommon distortion findings of Dodd and Barker (1990), Khan and Lewis (1986), and Leonard (1985). Each of the uncommon clinical errors below is frequent in. and in some cases pathognomonic of, speech disorders of known structural, sensory, and motor constraints, including cleft palate, hearing loss, and dysarthria. Extensive descriptions of articulatory phonetics and implications of these error types are available elsewhere; they are listed below without discussion. Importantly, each of these uncommon clinical distortions is considered an error at all ages when tallied by the ACI and Speech Profiles programs. For the qualitative, classification output of the SDCS program, however, the following criteria are used for categorical assignment of transcripts that contain occurrences of any type or combination of uncommon clinical distortions (see Table A): 0%-10% occurrences (as percentaged over all intelligible words) = normal for the uncommon errors dimension; 10%-20% = provisional + (see Table A); and >20% occurrence = positive or + (e.g., Speech Delay+, Residual Errors+).

Uncommon clinical distortions. The four classes of uncommon clinical distortions are as follows:

- Weak consonants. Weakly articulated consonants are indicated by a [,] in the Shriberg and Kent (1982) system.
- Imprecise consonants and vowels. Imprecise sounds may be indicated by one or more of the following five transcription conventions:
  - (a) on-glides or off-glides (epenthetics) on consonants or vowels/diphthongs, excepting epenthetic stops on nasals (see below)
  - (b) notably lowered, raised, fronted, or backed vowels/ diphthongs
  - (c) notably lengthened or shortened durations of consonants and vowels
  - (d) notably aspirated stops
  - (e) notably frictionalized stops and fricatives
- (f) notably pharyngealized velar stops
- 3. Failure to maintain oral/nasal contrasts.
  - (a) nasal emissions
  - (b) denasalized nasal consonants (and epenthetic stops) in the absence of upper respiratory involvement
  - (c) nasalized consonants (i.e., /m/-like sound replacing /b/ or /p/; /n/-like sound replacing /d/, /t/, or /l/
  - (d) nasalized vowels/diphthongs in contexts other than those appropriate for assimilative nasality
- 4. Notable failure to maintain appropriate voicing. Reliable perceptual decisions about partial voicing and devoicing require many tokens to confirm. Voicing differences are generally not relevant in children under 5 years of age. For children 5 years and older the following voicing errors are considered clinical distortions only when notable and consistent across several speech sounds and sound classes: (a) notable nonaspiration of prevocalic voiceless stops

- (b) notable partial voicing of voiceless stops, fricatives, and affricates
- (c) notable partial devoicing of voiced stops, fricatives, and affricates

It should be noted that "full" voicing errors (saying /s/ instead of /z/) are treated as substitution errors, similar to substitutions involving place or manner.

Finally in this discussion of distortions, it is important to note that emerging emphasis on multicultural perspectives requires that this field reexamine its assumptions about what constitutes a clinical distortion. Specifically, although the identification of both clinical and nonclinical distortions continues to be useful for research and diagnostic assessment purposes, the only distortions that should be considered for clinical intervention are those distortions that continue to demonstrate negative consequences for the intelligibility or acceptability of speech in academic, social, or vocational contexts. Notwithstanding the few studies that have documented such consequences for children and adults with clinical distortion errors (e.g., Crowe Hall, 1991; Mowrer, Wahl, & Doolan, 1978; Silverman, 1976; Silverman & Paulus, 1989), the true impact of distortion errors in the ambient language community has never been comprehensively studied.

# Procedures for the Speech Disorders Classification System (SDCS)

The three-stage procedure to classify a speaker using the SDCS is as follows: (a) obtain a spontaneous conversational speech sample using the procedures for sampling described above, (b) transcribe the sample using the procedures described above, and (c) use the criteria listed in Table A to classify a speaker into one of the 10 SDCS categories. Although it is possible to hand-code a transcript, the time required for reliable coding is substantial. A software application (hereafter referred to as the computer program) uses the definitions and criteria in Table A to process the speech transcripts and assign each transcript to one of the 10 classification categories (see Figure 2). The following discussions provide rationale for the elements in Table A and a general overview of the coding procedures used in the computer program.

#### Criteria for Normal Speech Acquisition

There presently is no one account of speech development in the literature that (a) extends from birth through 12 years, (b) is based on samples of continuous speech, (c) is based on narrow phonetic transcription, (d) includes children with both normally developing speech and speech disorders of known and unknown origin, and (e) provides detailed data on initial, medial, and final consonant production in singletons and clusters. Therefore, the definition of normal speech acquisition at each age level is based on a complex rationale described in the following sections.

#### Eligibility Requirements and Provisional SDCS Classification

Rationale for placing restrictions on which words in the transcript are eligible for SDCS coding is based both on constraints in the normative reference data and on reliability and validity concerns. The SDCS program codes only those words that are completely intelligible (i.e., it does not code words for which the gloss is questionable). Both monosyllable and multisyllable words are coded. Vowels and diphthongs are coded in all positions, and consonant singletons and clusters are coded only in the initial and final positions. The program excludes medial (intervocalic) singletons and clusters from coding during the first pass because normative reference data are not available for this position. However, when the program is forced to provide a provisional classification, as described next, it does inspect medial sounds. The general task of the program is to find in the transcript at least two different word types (i.e., first-occurrence words) that provide appropriate tests of normal speech acquisition. That is, the Word Shape and Speech Sound Inventory requirements for the entries in Table A must occur on at least two different word types to meet criteria for Normal Speech Acquisition (NSA) at each of the age levels. This requirement provides conservative protection

from sampling and transcription reliability constraints that would be present if only one instance was required or if the criteria allowed two occurrences of a speech sound in the same word.

The concept of a provisional SDCS classification is required for three situations: (a) when a child is within 3 months of the next highest age level and classification by the criteria for the higher age level would differ from the category assigned for the lower age, (b) when there is only one or no eligible words upon which to base one or more Word Shape or Speech Sound Inventory decisions, and/or (c) when a child's percentage of uncommon clinical distortions is between 10% and 20% of the total eligible words in the transcript. Whenever any one or more of these constraints occur in the coding process, the program completes the classification using the available data, but places a square bracket around the classification abbreviation assigned to the transcript (e.g., [NSA], [QSD+]). Thus, provisional SDCS classifications account for marginal age variables in the available normative data, as well as validity and reliability issues associated with sampling variables and arbitrary cutoff criteria. The program provides specific output information on the bases for all such provisional classifications, allowing the user to judge the validity of the classification outcome. As in all assessment procedures (e.g., a questionable audiogram due to technical or subject-state factors), an SDCS classification may be deemed provisional, pending additional speech data that supports or fails to support the classification.

# Considerations Underlying the Age Criteria for Normal Speech in the SDCS

The literature on normal phonological development contains many contradictory findings. Three guidelines were followed in determining the speech-sound criteria used to define normal speech at each of the age levels shown in Table A.

The criteria reflect decisions about methodological precision. Potential effects of methodological variables on the validity of the available normative data were heavily considered (cf. Smit, 1986 for a discussion of relevant issues). Methodological issues that were reviewed included examiner training, procedures for selecting subjects, the transcription system that was used, procedures for reducing the data, and reliability. Data based on continuous speech were preferred over data based on citation forms. However, because most available sources used citation forms, data from continuous speech were most often used only to supplement data from citation forms. Two suitable sources that used continuous conversational speech were identified-a normative sample of 72 children ages 3 to 6 years (Hoffmann, 1982 as tabled in Shriberg, 1986) and data sets from Stoel-Gammon and her colleagues (Stoel-Gammon, 1985, 1987, 1991b; Stoel-Gammon & Dunn, 1985; Stoel-Gammon & Herrington, 1990; Stoel-Gammon & Stone, 1991). Although Irwin and Wong (1983) also used continuous speech, their data were considered unsuitable due to several methodological constraints and because speech-sound development was not reported by word position or for singletons versus clusters.

The criteria are heavily weighted by the most recent sources. The most recent studies and syntheses of normal speech acquisition (e.g., Smit et al., 1990; Stoel-Gammon, 1985, 1987) were weighted more heavily than earlier sources, for example, Sander's (1972) reorganization of the Wellman, Case, Mengert, and Bradbury (1931), Poole (1934), and Templin (1957) data. Most generally, contemporary response definitions for acceptable behaviors include normal allophonic variations and casual speech forms (cf. Smit et al., 1990).

The criteria are liberal. Several procedures were used to develop the most liberal definition of normal speech acquisition (i.e., to give a child the benefit of the doubt). First, when available, 90% of children at the age tested in a reference source had to have acquired the speech-sound to assign the sound to that normative age. Second, when cutoff criteria were not available, the criteria for normal acquisition were arranged to represent *typical* to *low-end of normal* speech at each of the age groups. Finally, beginning at 3 years of age, criteria for the category of Speech Delay requires greater than a 1-year delay from the reference data for normal speech acquisition. Thus, performance that is below normal for the child's chronological age, but at least equivalent to criteria for 1 year below chronological age, is classified as Questionable Speech Delay.

#### Reference Sources for the SDCS

The following discussion includes criteria and reference sources selected for normative data on word shapes, vowel and consonant inventories, and permitted errors. It is convenient to divide the discussion into two sections: the information for 2-year-olds and then the information for ages 3 through 9 years. Criteria for the uncommon clinical distortions discussed previously are the same for all age levels.

**Two-year-olds.** Reference data for the word shapes and speech sound inventory for the 2-year-old children are taken primarily from the work of Stoel-Gammon and colleagues (Stoel-Gammon, 1985, 1987, 1991b; Stoel-Gammon & Dunn, 1985; Stoel-Gammon & Herrington, 1990; Stoel-Gammon & Stone, 1991). Additional support for the vowel data is provided by Wellman et al. (1931). Indirect support for the decision to include most errors as permitted errors comes from the work of Khan and Lewis (1986) and Preisser, Hodson, and Paden (1988), who describe numerous active phonological processes in this age group. Additionally, the report of Preisser et al. on the rarity of initial consonant deletions (ICD) in 2-year-olds resulted in the decision not to include ICD as a permitted error.

Stoel-Gammon (1991b) and Stoel-Gammon and Stone (1991) present typical phonological systems both for 2-year-olds who have vocabularies of approximately 250 words and for those who are in the 50-word stage of development. Decisions regarding normalcy of development in 2-year-olds are based solely on word shapes and consonant inventory. Stoel-Gammon's data suggest that the critical elements in the phonological system of 2-year-olds with larger vocabularies are the presence of a range of manner classes, the production of labial and lingual consonants, and the use of both open and closed syllables that can be combined to make disyllabic words. In contrast, the critical elements for 2-year-olds within the 50-word stage appear to be the presence of supraglottal consonants, an oral-nasal distinction, a labial-lingual distinction, and the presence of CV syllables. These two phonological systems represent the extremes of a broad range of normal performance at 2 years of age. The typical system for children with approximately 250-word vocabularies (minus the final /r/, which Stoel-Gammon describes as optionally present in children who are developing normally) was selected as the reference data for normal. The more restricted lexical and phonological system was used to distinguish between Speech Delay and Questionable Speech Delay. Any child whose phonological system is more limited than that described for the more restricted system is classified as Speech Delay. If the child has an expressive vocabulary of fewer than 50 words, the program classifies the child as Speech Delay-Delayed Onset (SD<sub>o</sub>). Finally, any child whose phonological system does not meet criteria for normal, and is not more limited than that described for the restricted system, is classified Questionable Speech Delay, because positive or negative outcomes cannot be predicted from the restricted system at 2 years of age.

#### Three- to 9-year-olds.

1. Word shapes, Data from a normative study of 72 children, ages 3 through 6 years (Hoffmann, 1982; see also Shriberg, 1986), served as the primary reference for word shape development. Additional details were provided by the Khan and Lewis (1986) data for the resolution of phonological processes and Hodson and Paden's (1981) description of process use in normal 4-year-olds. Although average percent occurrence for all word shapes in the Hoffmann data was 95% or higher by 3 years of age, larger standard deviations (between 7% and 19%) for CnV, VCn, C(n)VCn, and 3+ syllables than for less complex word shapes suggest that the complex word shapes are more difficult for very young children. Word shapes containing clusters were included as options at age 3 because of the high frequency of cluster simplification (19%) and stridency deletion (12%) reported by Khan and Lewis for this age group. Furthermore, a 3+ syllable word shape requirement was not included at age 3 due to the persistence of syllable reduction at this age reported both by Shriberg (1986) (6%) and Khan and Lewis (3%). Inclusion of all syllables in 3+ syllable words is required at age 4 (Shriberg, 1986). The cluster word shape was also required at this age in consideration of the reduction in cluster simplification reported by Khan and Lewis for this age group (10%) and the absence of this process in 4-year-olds as reported by Hodson and Paden. By age 5, children are expected to be producing all word shapes, including 3+ syllable word shapes.

2. Vowel inventory. Reference data on vowel production are limited, with most studies focused on children younger than 3 years old (e.g., Hare, 1983; Otomo & Stoel-Gammon, 1992; Paschall, 1983). These data, together with the data of Templin (1957), indicate that most vowel development takes place before age 3. However, data summarized in Shriberg (1986) and Wellman et al. (1931) suggest continued learning of vowels by some children beyond age 3. Consistent with the plan to select the most liberal reference data for normal acquisition, the data from Wellman et al. were used as the reference for vowel acquisition for ages 3 and 4. In this study, however, a vowel was included at an age level if it was produced by 75% of the children at that age level. The decision to include the vocalic-r forms at the 6 year level comes from the persistence of substitution errors for some children until age 6 as reported in Shriberg (1986).

3. Consonant inventory. The primary source of data for the consonant inventory for children 3 through 9 years of age was Smit et al. (1990), using their recommended 90% criteria for age of acquisition. These findings, which are generally consistent with the findings in other normative studies (e.g., Arlt & Goodban, 1976; Haelsig & Madison, 1986; Poole, 1934; Prather, Hedrick, & Kern, 1975; Templin, 1957; Wellman et al., 1931), were selected for the SDCS for the following reasons: (a) well-developed methodology, which included the use of narrow phonetic transcription, detailed definitions for acceptable responses, comprehensive examiner training, adequate reliability assessment, replication, and explicit decisions regarding recommended ages of acquisition based on stability of performance (no dips in the 90% level once that criterion was reached) and error type (when performance was unstable); and (b) the availability of data regarding age of resolution of substitution errors on fricatives, affricates, and glides. This latter information was necessary to develop age criteria for both the speech-sound inventory-in which distortions, but not substitutions count as correctand for criteria to determine when certain substitution and distortion errors were/were not normal (Smit, 1991). To make the SDCS most conservative, the oldest recommended age for acquisition of a consonant, whether for male or female, was selected from the Smit

et al. data. In most cases, the ages for boys were used. Boys reached the 90% criterion before girls on only /n/ (3 years versus 3 years 6 months) and /t/ (3 years 6 months versus 4 years). However, because both of these sounds were already included in the speech-sound inventories for normal speech at 2 years of age (with the exception of final /t/), these sounds were included in the reference data indicating they were normal for age 3. The decision not to require the inclusion of final /t/ and /d/ in the consonant inventory prior to age 6 was based upon the frequency with which these sounds were deleted in conversational speech, as reported in the two normative studies summarized in Shriberg (1986).

4. Permitted errors. Data for SDCS decisions regarding permitted distortion errors come from Smit et al. (1990) and Smit (1991). Data for decisions regarding permitted substitution errors in children ranging in age from 3 years through 5 years come primarily from Khan and Lewis's (1986) normative data for process resolution and also from consideration of the Smit data. For children ages 6 and older, data from Smit were the only source of information. The Khan and Lewis data using citation forms were selected over the normative data on process resolution in continuous speech reported by Shriberg (1986) because they are more conservative. In the latter study, most of a restricted set of processes (i.e., the "natural" processes; Shriberg & Kwiatkowski, 1980, 1982a) were nearly resolved at age 3, occurring at a frequency of less than 10%.

The following procedure was used to identify permitted substitution errors. First, the sounds that had not reached the 90% criterion level at a designated age level were identified. Then, an attempt was made to identify potential errors on these sounds by using the Khan and Lewis (1986) data. A process had to be occurring an average of at least 10% of possible occurrences to be considered characteristic at the age group. For processes that met this criterion, typical error patterns included under the process label were considered permitted errors. For example, if Liquid Simplification met the 10% criterion, then the substitution of a glide for a liquid was considered a permitted error at the age level. For clusters at 3 years of age, both deletion and substitution errors are permitted. Beginning with age 4, only substitution errors are allowed. This decision was made to be consistent with the criteria for both word shapes and permitted errors on singletons. At age 4, clusters are a required word shape, and only substitution and distortion errors are permitted on any singleton consonant.

TABLE A. Classification criteria for the Speech Disorders Classification System (SDCS).

Description	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years +
I. Normal Speech Acquisition (NSA) A. Required word shapes	CV, VC, CVC, 2-syllable	CV, VC, CVC, Cn <sup>d</sup> or 2-syllable	CV, VC, CVC, C <i>n</i> C <i>n</i> , 2-syllable, 3-syllable	CV, VC, CVC, C <i>n,</i> C <i>n</i> , C <i>nCn,</i> 3+ syllable	Я	Ā	۶	IF
<ul> <li>B. Required speech- sound inventory</li> <li>1. Vowels</li> <li>2. Consonants</li> </ul>	One <i>high</i> , one <i>low</i> , one <i>back</i> , one <i>front</i>	i, ɛ, ʌ, ə, u, o, ɔ, ɑ, ɑi, ɑu, ɔī	i, <u>1, eī</u> , e, ε, <del>ε,</del> Λ, ə, u, <u>υ, ου,</u> ο, ɔ, α, <u>αι</u> , <u>αυ, ɔī</u>	i, ɪ. eɪ, e. ɛ. æ, ʌ ə, u, <u>ư, ou,</u> o, ɔ, ɑ, ɑɪ, ɑu, ɔɪ	All (i.e., including æ, æ)	AI	AI	AI
a. Nasals Initial Final b. Gildes	/m,n/ /m,n/	Both nasals /m,n/ Both glides	Both nasals /m,n/ Both glides	Both nasals /m,n/ Both glides	Both nasals /m,n/ Both glides	Both nasals All nasals Both glides	Both nasals All nasals Both glides	Both nasals All nasals Both glides
c. Stops Initial Final d. Fricatives Initial	/p,b,t,d,k,g/ /p,k/ /f/ or /s/,	All stops /p,b,k,g/ /f,s,h/	All stops /p,b,k,g/ /f,s,z,S,h/	All stops /p.b.k.g/ /f.v.s.z.C.h/	All stops All stops All except e	All stops All stops All except e	All stops All stops All fricatives	All stops All stops All fricatives
Final e. Affricates Initial Final	either position	h, s, h	/t.s.z.J/ /dʒ/ /dʒ/	/r,v,s,z,J/ /tf,dʒ/ /tf,dʒ/	All except e Both affricates Both affricates	Au except e Both affricates Both affricates	Both affricates Both affricates	Both affricates Both affricates
f. Liquids Initial Final C. Permitted errors			11	11	Both liquids /r/	Both liquids /r/	Both liquids Both liquids	Both liquids Both liquids
1. Deletions Initial	All except singleton	All but one consonant in	None	None	None	None	None	None
Final	consonants All	All but one consonant in Cn; /t,d/	/t,d/ in singletons and clusters	/t,d/ in singletons and clusters	None	None	None	None
2. Substitutions Initial	AI	b/v: t,s,f/e; d,v,z/ő; s/z,e, ő/Ś, t(, d3; t(ŷ) t,s,g/t(5; t,s,g/t(5; d,z,3/d3; w,j/i,r; one or more consonants in Cn_	b/v; t,s,f/e; d,v,z/ð; w,j/l,r; t,s,f/tf; one or more consonants in Cn	s,fle; d/ð; w.j/l,r	f/e, d/ð	fle	None	None

Description	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years +
Final 3. Common clinical	AI	n/ŋ; b/v; t,s,t/e; d,v,z/ð; s,z,e,ô/f,tf, d3; tf/f; J/tf; s/tf; t/ff; d/d3; d/3; d3/3 vowel/i,r; one or more consonants in	n/ŋ; b/v; t,s,f/e; d,v,z/ð; vowel/ı,r; one or more consonants in Cn	n'ıŋ; s,fle; d/ö; vowel/1,r	n/ij; fle; d/ð; vowel/l	f/a; vowel/l	None	None
distortions Initial	F	Ы	AI	AI	Lateral or dental sibilant fricatives & affricates; <u>1</u> , <u>3</u> , <u>3</u> , labialized and velarized	Dental sibilant fricatives and affricates; <u>r</u> ; <u>3</u> , <u>3</u> °; labialized and velarized /r/	Dental sibilant fricatives and affricates	ero N
Final	F	F	IF	AI	<i>Irl</i> , lateral or dental sibilant fricatives & afficiatives & afficiates; <u>(</u> , <u>3</u> , <u>3</u> , <u>3</u> , <u>1</u>	ווילאין); dental sibilant fricatives and affricates; נ פי, פי; abialized and velarized and velarized and	Dental sibilant fricatives and affricates	None
4. Uncommon clinical distortions	10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I)	10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I)	10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I) (F)	10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I) (F)	<i>N</i> 10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I) (F)	velarized // 10% or fewer on vowels, consonant singletons (I) (F), and consonant consonant clusters (I) (F)	10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I) (F)	10% or fewer on vowels, consonant singletons (I) (F), and consonant clusters (I) (F)
II. Normalized Speech (NSX)	Vot applicable	(r.) Speech data 2-year criteria for NSA but met 3-year criteria. (NS3)	Speech data did not formerly meet criteria for NSA but met 4-year criteria. (NS4)	Speech data did not formerly meet criteria for NSA but met 5-year criteria. (NS5)	Speech data did not formerly meet criteria for NSA but met 6-year criteria. (NS6)	Speech data did not formerly meer criteria for NSA but met 7-year criteria. (NS7)	Speech data did not formerly meet criteria for NSA but met 8-year criteria. (NS8)	Speech data did not formenty meet criteria for NSA but met 9-year + criteria. (NSX where x = child's current CA)

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Classification criteria for the Speech Disorders Classification System (SDCS), (continued)         cription       2 years       3 years       4 years       5 years       5 years         cription       2 years       3 years       4 years       5 years       5 years         cription       2 years       3 years       4 years       5 years       5 years         cription       2 years       3 years       4 years       5 years       5 years         cription       2 years       3 years       4 years       5 years       10% or         cription       2 years       3 years       4 years       5 years       10% or         cription       2 years       3 years       4 years       5 years       5 years         cription       2 years       3 years       5 years       5 years       5 years         cription       and there are 10% or       criteria for       NSA or SD and       NSA or SD and       Not         criteria for       criteria for       criteria for       NSA or SD and       Not       Not       Not         criteria for       criteria for       criteria for       NSA or SD and       Not       Not       Not         criteria for       criteria for       NSA or SD<		6 years 7 years 8 years 4	applicable Not applicable Not applicable Not applicable	applicable Not applicable Not applicable Not applicable	ech data do Speech data do Speech data do ti meet not meet not meet not meet not meet not meet and stand o Speech data do Speech data do stander and there and so, NSA, NSA, NSA, NSA, NSA, NSA, NSA, NSA
Classification criteria for the Speech data cription       2 years       3 years       4 years         cription       2 years       3 years       4 years         mable Speech data (SSD)       Speech data do not meet criteria for criteria for criteria for NSA or SD and there and there and there and there thewer uncommon clinical distortions.       3 years       4 years         mable Speech data (SSD)       Speech data do not meet thewer uncommon clinical distortions.       3 years       4 years         mable Speech data and there thewer uncommon clinical distortions.       3 years       4 years         meet criteria for fewer uncommon clinical distortions.       3 years       4 years         meet criteria for fewer uncommon distortions.       3 years       5 years         Delay (SD)       Speech data distortions.       3 year criteria for not meet criteria for not meet distortions.       5 years         Delay (SD)       Speech data distortions.       Speech data do not meet criteria for nocommon distortions.       10% or SD and distortions.         Delay (SD)       Speech data for nocommon distortions.       10% or fewer criteria for nocommon distortions.         Delay (SD)       Speech data do clinical distortions.       10% or SD and clinical distortion.         Delay (SD)       Speech data do clinical distortion.       10% or SD and clinical distortion.         Delay (SD)       Speech data distortio	System (SDCS). (continued)	5 years	not Speech data do not Not a meet criteria for and NSA or SD and or there are 10% or fewer uncommon ms. clinical distortions.	not Speech data do not Not a meet criteria for NSA or SD and there are >20% uncommon clinical ins. distortions.	not Speech data do not Spee for NSA and there cri are 10% or fewer NS uncommon clinical OF distortions. or un clinical distortions distortions distortions distortions or un clinical
Classification criteria for the Speech data (Casb) criteria for meet data (Casb) and there are 10% or criteria for NSA or SD and there are 10% or fewer uncommon clinical distortions. Speech data (Casb +) continued all there are >20% uncommon clinical distortions. Delay (SD) Speech data (Casb +) control and there are >20% uncommon clinical distortion, substitution, or common clinical distortions may not may not	beech Disorders Classification	3 years 4 years	speech data Speech data do do not meet meet criteria for criteria for NSA or SD an NSA or SD an NSA or SD there are 10% and there are 10% or clinical distortic fewer uncommon distortical distorticulations.	proceeds data Speech data do providente to the criteria for the criteria for NSA or SD and NSA or SD and there are >20% clinical distortic uncommon are >20% clinical distortic di distort distortic distort distortic di distorti	do not meet ata do la poech data do la poech data Speech data do not meet 3-year criteria for NS/ criteria for non there are uncommon there are uncommon clinical distortions.
	. Classification criteria for the Sp	scription 2 years	onable Speech Speech data S do not meet criteria for NSA or SD and there are 10% or fewer uncommon clinical	ionable Speech Speech data S + (QSD+) do not meet of not meet NSA or SD and there are >20% uncommon cliendione	h Delay (SD) Speech data S include all italicized entries in I.A. and I.B. above <sup>a b.c</sup> . The child may have deletion, substitution, o r common dinical distortion, but may not clinical distortions

	Description	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years +
, S	Speech Delay + (SD+)	Speech data do not include all italicized entries <sup>a b</sup> above and there are >20% uncommon clinical distortions <sup>c</sup>	Speech data meet criteria for SD except there are >20% uncommon clinical distortions.	Speech data meet criteria for SD except there are > 20% uncommon clinical distortions.	Speech data meet criteria for SD except there are > 20% uncommon clinical distortions.	Speech data meet criteria for SD except there are > 20% uncommon clinical distortions.	Speech data meet criteria for SD except there are >20% uncommon clinical distortions.	Speech data meet criteria for SD except there are >20% uncommon clinical distortions.	Speech data meet criteria for SD except there are >20% uncommon clinical distortions.
Ξ.	Questionable (QRE) (QRE)	Not applicable	Not applicable	Not applicable	Not applicable	Speech data meet all criteria for NSA and initial /// is velarized or labialized and there are 10% or fewer uncommon clinical distortions.	Speech data meet criteria for NSA except there is at least one common clinical distortion other than labialized or velarized or velarized or initial <i>N</i> .	Speech data meet criteria for NSA except there is at least one common distortion distortion other than labialized or velarized initial // or lateralized sibilant fricatives and/or	Not applicable
, III	Questionable Residual Errors + (QRE +)	Speech data meet criteria for NSA except there are > 20% uncommon clinical distortions	Speech data meet criteria for NSA except there are >20% uncommon distortions.	Speech data meet critieria for NSA except there are > 20% uncommon clinical distortions.	Speech data meet criteria for NSA except there are >20% uncommon clinical distortions.	Speech data meet criteria for NSA or ORE except there are > 20% uncommon clinical	Speech data meet criteria for QRE except there are >20% uncommon clinical distortions.	amricates. Speech data for QRE except there are >20% common clinical distortions.	Not applicable
×	Residual Errors (RE)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Speech data meet criteria for NSA except initial /// is labialized or velarized.	Speech data meet criteria for NSA except initial // is labialized or velarized and/or sibilant fricatives and/or affricates are lateralized.	Speech data meet criteria for NSA except there are common clinical distortions.

TABLE A. Classification criteria for the Speech Disorders Classification System (SDCS). (continued)

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TABLE A.	

Description	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years +
X. Residual Errors+ (RE+)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Speech data meet criteria for NSA or RE except there are >20% uncommon clinical distortions.	Speech data meet criteria for NSA or RE except there are > 20% uncommon clinical distortions.	Speech data meet criteria for NSA or RE except there are >20% uncommon clinical distortions.
<sup>a</sup> Vowel criteria require o bTbo criteria require	inly a high/low con	rast or a front/ba	ick contrast.					

<sup>or</sup>The glide criteria require /w/ or /J/. <sup>e</sup>If child also has an expressive vocabular of fewer than 50 words, classify child as SD<sub>o</sub> (Speech Delay-Delayed Onset). <sup>d</sup>Cn = A consonant cluster composed of 2, 3, or 4 consonants.