Journal of Speech and Hearing Research, Volume 35, 1316–1332, December 1992

Contextual and Linguistic Correlates of Intelligibility in Children With Developmental Phonological Disorders

Audrey D. Weston
Idaho State University
Pocatello, ID

Lawrence D. Shriberg
University of Wisconsin-Madison

Listeners' glosses of children's intended words provided data for two studies of the potential influence of selected contextual and linguistic variables on word intelligibility. Several regularities associated with the occurrence of unintelligible words were identified. In Study I, intelligibility outcomes were associated with utterance length and fluency, word position, intelligibility of adjacent words, phonological complexity, and grammatical form. In Study II, intelligibility outcomes were associated with phonological complexity, syllabic structure, and grammatical form. Discussion considers the implications of these and other regularities associated with the occurrence of unintelligible words for a comprehensive perspective on the utterance-to-utterance intelligibility deficits of children with phonological disorders of unknown origin.

KEY WORDS: intelligibility, developmental phonological disorders, continuous speech-language samples, context variables, linguistic variables

Reduced intelligibility is a major clinical concern for children with developmental phonological disorders. Although citation-form sampling is used to determine the phonetic and phonologic inventories of such children, assessment procedures to estimate their intelligibility typically rely on some form of a continuous speech-language sample (e.g., Elbert & Gierut, 1986; Shriberg & Kwiatkowski, 1982; Stoel-Gammon & Dunn, 1985; Weiss, 1980; Weiss & Lillywhite, 1981). Although spontaneous conversational speech samples have ecological validity for estimating intelligibility, the many different speech production and nonspeech variables reflected in such samples (Connolly, 1986; Flanagan, 1972; Kent, Weismer, Kent, & Rosenbeck, 1989) make interpretation of computed scores difficult. To facilitate interpretation, intelligibility assessment in motor speech and other disorders has been invested primarily in highly structured sampling procedures, such as recitation of prescribed sentences (Enderby, 1983; Yorkston & Beukelman, 1981).

The present paper takes the position that the variety of speech production and nonspeech variables in transcripts of children's spontaneous conversational speech must be studied if a sufficient account of children's moment-to-moment unintelligibility is to be assembled. Unlike unintelligibility in neurogenic disorders, in which the sources contributing to reduced intelligibility may be relatively more constrained to speech variables, unintelligibility in children is presumed to be heavily influenced by pragmatic, contextual, and linguistic variables. Kent (in press) views children's intelligibility from a similar perspective, with interactions among multiple language form and function variables influencing various aspects of communicative competence. Currently, however, there is a lack of data addressing specific types of

© 1992, American Speech-Language-Hearing Association

0022-4685/92/3506-1316$01.00/0

interactions that may occur across language domains, thus limiting the clinical and research interpretations of children's reduced intelligibility.

We assume a systematicity in the occurrence of unintelligible words in samples of children's conversational speech that might be traced to contextual and linguistic variables. Other investigators have identified contextual and linguistic regularities associated with the occurrence of dysfluent words in transcripts of normal speakers (Gordon, Luper, & Peterson, 1986) and individuals with fluency disorders (Jayaram, 1984; Wall, Starkweather, & Cairns, 1981). Several variables, such as the sequential order of a word in an utterance (Wingate, 1976) and utterance length and syntactic complexity (Gaines, Runyan, & Meyers, 1991), apparently influence the occurrence of dysfluent moments. We assume that the probabilities associated with words being intelligible or unintelligible may also be associated with contextual and linguistic factors.

To develop the concept of an unintelligible word for the following discussion, consider the conventions that transcription procedures for free-speech sampling use to represent a word that is perceived but not understood. Such a linguistic event may be represented as, for example, "XX" (Miller & Chapman, 1985) or "**" (Shriberg, 1986) within an otherwise fully glossed utterance. The purpose of this paper is to determine whether specific variables available in transcripts of speech-language samples are associated with the occurrence of events transcribed as XX or **. In this report, the term *contextual variable* is used as a cover term for any variable associated with the context in which a word is embedded, including variables that might be considered linguistic (e.g., sentence length) or nonlinguistic (e.g., the intelligibility of contiguous words). Characteristics of words themselves are termed *linguistic variables.* The following literature review considers three potential sources of variance: articulatory, suprasegmental, and contextual or linguistic.

Articulatory Sources of Variance

Most recent investigations of the articulatory behaviors associated with children's intelligibility deficits have adopted the perspective of phonological processes, emphasizing both qualitative and quantitative differences in process-level profiles. Intelligibility has been associated with those phonological processes that occur frequently, are unusual, idiosyncratic, or optional (Edwards, 1983), and result in variability or produce the most deviant surface forms (Grunwell, 1985). Brief reviews of three studies, using the phonological process terms in the original studies, provide a perspective on the findings and interpretations.

Hodson and Paden (1981) examined the percentage of occurrence of phonological processes in relation to intelligibility in 4-year-old speakers with delayed and normal speech development. The unintelligible speakers had significantly higher percentages of occurrence of phonological processes, compared to rates for the normally developing, intelligible subjects (76% cluster reduction compared to 6%, respectively). Intelligible 4-year-olds had frequent occurrences of several processes, such as liquid deviation and final consonant deletions. Low-occurrence processes, including glottal replacement and backing, were observed only in the least intelligible speech-delayed subjects.

Billman (1986) assessed the relationship between mean phonological process percentage-of-occurrence scores and mean continuous speech intelligibility scores of 15 3- to 6-year-old children. She obtained a significant Spearman rank-order correlation (.79) between process scores and intelligibility scores, based upon the responses of four listeners who heard each utterance once. Additional analysis suggested that specific processes had differing consequences for intelligibility. For example, the two processes with the lowest overall percentage-of-occurrence scores (backing and prevocalic singleton omission) were associated with the highest obtained correlation coefficients with intelligibility (.77 and .75, respectively). Liquid /l/ and /r/ deviations—processes with the highest overall percentage-of-occurrence means—yielded insignificant correlation coefficients with intelligibility.

Yavas and Lamprecht (1988) examined phonological process characteristics and relative intelligibility rankings for four Portuguese-speaking children. Process variables included type (e.g., substitution processes, such as stopping, versus sequential processes, such as cluster reduction), co-occurrence, consistency, and typicality (i.e., process prevalence). The authors identified several characteristics statistically associated with intelligibility rankings, but a clear pattern applicable to all 4 subjects was not obtained. For example, Yavas and Lamprecht expected that the smaller the proportion of words exhibiting process co-occurrence, the better the intelligibility outcome; however, this was not the case for 2 of their 4 subjects.

Several investigators have used process constructs to scale the intelligibility of children's speech. Vihman and Greenlee (1987) used a procedure to generate phonological error scores for 10 normally developing 3-year-olds. Interpreted as an estimate of phonological advance, the derived scores reflected the age-appropriateness of phonological processes used, the contexts affected, and the consistency of process application. The authors reported a correlation of .79 between the scores obtained and intelligibility rankings that were based upon percentages of fully intelligible utterances averaged over judges. Hodson and Paden (1991) conceptualize a five-level continuum of speech deviancy reflecting intelligibility differences. Each severity level is associated with characteristic phonological processes, ranging from extensive omissions at the profound level to vowelization of postvocalic and syllabic /l/ at the level of acceptable variations. To characterize severity of involvement, they suggest the use of a phonological deviancy score (PDS), based upon the frequency of occurrence of selected phonological processes.

As suggested in these brief reviews, correlational designs using phonological process terms to describe speech sound error patterns have not resulted in a comprehensive perspective on the multiple sources of unintelligibility. In addition, methodological issues, including small sample sizes, nonsystematic definitions of sound changes, and assorted correlational assumptions, limit both internal and external validity.

Suprasegmental Sources of Variance

Several studies provide support for the secondary influence of suprasegmental factors on intelligibility. Shriberg, Kwiatkowski, and Rasmussen (1989) reported a correlation of .70 between Intelligibility Index and Percentage of Consonants Correct (Shriberg & Kwiatkowski, 1982) scores for a group of children with suspected apraxia of speech. In contrast, correlations for children with speech delays of unknown origin have been only in the low to middle .40s (Bishop & Edmundson, 1987; Shriberg & Kwiatkowski, 1982; Shriberg, Kwiatkowski, Best, Hengst, & Terselic-Weber, 1986). Shriberg et al. (1989) speculated that for at least the study group of children with suspected apraxia of speech, prosody-voice variables may interact with articulatory error types to lower overall intelligibility scores. They suggested that speech-delayed children's efforts to maintain intelligibility in the face of compromised segmental and suprasegmental status may make it difficult for investigators to determine which is the primary source and which reflects compensatory strategies.

Several studies involving children with hearing impairments suggest that suprasegmental and articulatory variables interact to influence intelligibility. Using a sentence-reading task, Smith (1975) reported a correlation of .80 between segmental error rates and percentage of intelligible words for a group of 40 children. However, she also noted many instances of divergence in the distribution of scores, with some children having similar proportions of segmental errors but differing in intelligibility by as much as 30 percentage points. Smith observed an association between the frequency of suprasegmental errors and the dispersion phenomenon. When the frequency of segmental errors predicted a higher than obtained intelligibility score, for example, the individual child was also likely to have a comparatively high frequency of suprasegmental errors, notably poor phonatory control and rate deviations.

Using Smith's (1975) data, Parkhurst and Levitt (1978) studied the association of a variety of factors with intelligibility, including pauses, pitch breaks, and excessive durations. The frequency of occurrence of the latter two behaviors was associated with intelligibility scores that were lower than predicted by articulation performance alone. Pauses, which occurred most often at natural language boundaries, were somewhat positively associated with intelligibility, suggesting that listeners may be helped by pauses that act as cues to syntactic segmentation.

In a study of acoustic variables in the speech of hearing-impaired children, Monsen (1978) found that variables indexing articulatory skills (e.g., VOT ratios for cognate stops) correlated more highly with intelligibility scores than mean sentence durations or fundamental frequencies. Monsen observed, however, that the importance of prosodic variables, in comparison to articulatory variables, is poorly understood. Regarding duration, he stated, "For speakers who already have well-developed skills in articulation, it is quite plausible that an improvement in their control over duration might have a beneficial effect on speech intelligibility. But, for those speakers who articulate phonemes poorly, it may not matter whether their poor articulation is slow or rapid" (p. 217).

Metz, Samar, Schiavetti, Sitler, and Whitehead (1985) used principal components analysis to study the relative contributions of specific segmental and suprasegmental variables to intelligibility. Their results suggest that prosodic variables such as sentence durations should be considered secondary factors. They emphasized, however, that the range of prosodic variables studied has been narrow and encouraged the exploration of other variables such as stress and intonation.

Contextual and Linguistic Sources of Variance

Using information available in a database of conversational speech-language transcripts (Shriberg, 1990b), Weston, Shriberg, and Kwiatkowski (1988) obtained descriptive data on children's unintelligible words. The sources of variance examined in association with the intelligibility status of words included contextual and linguistic characteristics of both the utterances in which words were embedded and the words themselves. Profiles of unintelligible words were compared to available data on intelligible words. Findings from this preliminary study, together with related data in the literature, suggested several working hypotheses about sources associated with children's intelligible versus unintelligible words. The preliminary findings will be cited in the following discussion; for expository clarity, the statistical significance levels associated with each finding are not included in the discussion.

Sources of variance at the utterance level. The data indicate that words that were intelligibility problems for transcribers tended to occur at the beginning of utterances, across a range of syntactic complexity (i.e., early- versus late-developing sentence types; Miller, 1981), and adjacent to other intelligibility problem words. Regarding potential sequential position effects, case study data (Chiat & Hirson, 1987; Crystal, 1987) suggest that, at least for some speech-language-delayed children, there may be an association between difficult-to-understand words and early utterance position. In the Weston et al. (1988) data, this was most apparent for the longer and more complex utterances.

Other reported observations suggest that syntactic complexity may influence the occurrence of unintelligible words. In a discussion of previous work, Vihman (1988) noted that among normally developing 3-year-olds, those children who are the most difficult to understand tend to use a high proportion of syntactically complex utterances. Because increases in sentence complexity may result in higher percentages of nonfluent words (Gordon et al., 1986; Haynes & Hood, 1978; Pearl & Bernthal, 1980), there may be a coincidental association between unintelligible words and verbal nonfluencies (i.e., mazes; Miller & Chapman, 1985).

The suggested adjacency effects may relate to findings on contextual effects on word intelligibility (Hudgins, 1949; McGarr, 1981; Subtelny, 1977). Sitler, Schiavetti, and Metz (1983) supported earlier findings for the facilitating effect of context on word intelligibility, although contextual facilitation depended upon a prerequisite level of overall intelligibility. That is, the finding that contextual forms were more readily recognized than citation forms was limited to only the more intelligible subjects. Intelligibility effects may be additive,

with the occurrence of one unintelligible word increasing the likelihood that others will occur.

Sources of variance at the word level. The Weston et al. (1988) findings support an association between canonical and grammatical forms and word intelligibility outcomes. First, among words that were intelligibility problems for transcribers, there were significantly fewer completely realized canonical forms, especially as intended forms were to include consonant clusters. Thus, it may be that children's deletion errors are especially disruptive of word intelligibility. Faircloth and Faircloth (1973) noted the importance of syllabic integrity to intelligibility. Their summary of research findings indicates that sound changes disrupting syllabic integrity tend to also disrupt word recognition. Other potential sources of variance in intelligibility at the word level include differences in the canonical form of syllables and in surface form stress differences (Selkirk, 1984). Campbell and Shriberg (1982) found that target words with primary linguistic stress were produced with fewer articulation errors in comparison to unstressed words.

The influence of grammatical form on intelligibility may be reflected by different intelligibility outcomes for verbs in comparison to nouns. Using Bennett's (1988) data for the unconditional distributions of form classes, the preliminary analysis suggested that there were comparatively more verbs than nouns among words that were intelligibility problems for transcribers. During early language development, nouns possibly represent easier production targets than verbs (Camarata & Leonard, 1986), but there are no comparable data for the 3- to 5-year-old speech-delayed children in the pilot data. In the Weston et al. (1988) study, both main verbs and verbal function words (e.g., *is, are, has*) were considered together. With regard to canonical strength, the content versus functor distinction implies different likelihoods for phonetic reduction in casual forms. Among function words, there are different likelihoods for surface form reduction, with certain monosyllabic forms, for example, those with sonorant codas such as *can* and *in,* especially prone to destressing (Selkirk, 1984). Syllabic reduction may be associated with intelligibility differences that would be especially apparent in children's speech production.

Summary

Studies of segmental and suprasegmental sources of variance in intelligibility have not yielded a good understanding of why some words in an utterance spoken by a child with a phonological disorder are unintelligible to even a trained listener. Methodological differences across studies make comparisons of findings difficult, including differences in the types of speech samples, listening conditions, transcription conventions, and units of analysis. Relative to speech sampling, for example, Bishop and Edmundson (1987) and several studies by Shriberg and colleagues have obtained speech error rates and intelligibility data from continuous speech samples, whereas most investigators use different types of sampling tasks to assess each variable. Some studies require transcribers to complete several playbacks of audiotaped samples to attempt a gloss, whereas in other studies intelligibility scores are based on only one listening (Billman, 1986).

The rationale underlying the following studies is that neither articulatory variables nor their presumed interaction with suprasegmental variables have provided a sufficient explanation for intelligibility deficits in children with developmental phonological disorders. Using methods developed in Weston et al. (1988), these studies investigate the contributions of a third potential source of variance in intelligibility, that is, contextual and linguistic factors.

STUDY 1

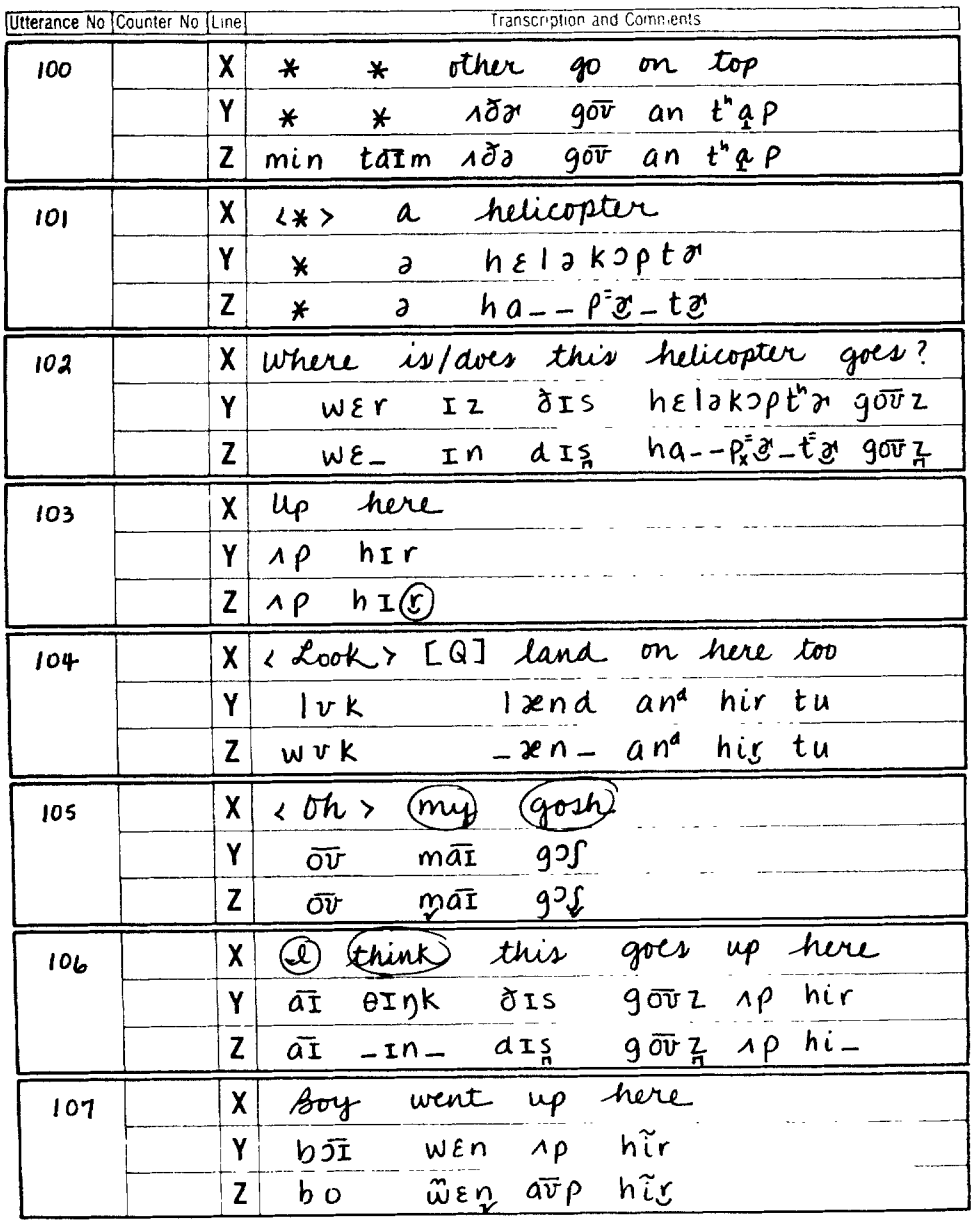
Method

Data

The data for Study 1 were 2,476 words taken from 19 continuous speech samples selected from a database of 64 narrowly transcribed transcripts previously collected from 4- to 5-year-old children (Shriberg, 1990b). Inspection of available database information regarding the language status of the 19 children indicated that 8 were language-involved, 4 had questionable linguistic status, and 7 were uninvolved. This distribution for language status is consistent with profiles of children with speech delays of unknown origin described in Shriberg et al. (1986). Transcription of the database samples followed the detailed guidelines for the coding of unintelligible forms, including segmentation conventions for successive unintelligible syllables, described in Shriberg (1986). The 19 transcripts met the criterion of having an Intelligibility Index score equal to or lower than 85% (M = 75.27; SD = 7.40). Because we were interested in regularities in the transcription of unintelligible words, no other individual subject characteristics were considered in the selection of words for the study. Words included in the study met two conditions to ensure that they occurred in a phrase context and in utterances of representative length. First, they occurred in utterances that were at least partially intelligible (i.e., contained at least one constituent word that had been glossed by the transcriber). Second, all utterances were three to seven words in length, which encompassed the 90th percentile for all utterances in the parent database.

Figure 1 is a page from a sample transcript illustrating three types of "words" coded for this study. The transcript entries in Figure 1 reflect guidelines for transcribing and formatting continuous speech-language samples for analysis with PEPPER (Shriberg, 1986). The top or X-line entry for each utterance reflects a transcriber's attempt to gloss the speaker's intended words. Glosses may be of five types. The most frequent entry, as illustrated by the words "other go on top" in Utterance 100, are words that are *fully intelligible* to the transcriber. The presumed underlying representations of such words are entered in the Y-line and a narrow phonetic transcription of the speaker's forms is entered in the Z-line.

The second and third types of word glosses illustrated in Figure 1 occur when the transcriber is unsure of the speaker's intended word. The circled orthographic X-line entries in



Utterance No	Counter No	Line	Transcription and Comments
100		X	* * other go on top
		Y	* * ʌðɚ goʊ̄ an tʰa̱p
		Z	min tāɪm ʌðə goʊ̄ an tʰa̱p
101		X	<*> a helicopter
		Y	* ə hɛlɔkɔptɚ
		Z	* ə ha--pɚ̄-tɚ̄
102		X	Where is/does this helicopter goes?
		Y	wɛr ɪz ðɪs hɛlɔkɔptʰɚ goʊ̄z
		Z	wɛ- ɪn dɪs̩ ha--pɚ̄-tɚ̄ goʊ̄z̩
103		X	Up here
		Y	ʌp hɪr
		Z	ʌp hɪ(r)
104		X	<Look> [Q] land on here too
		Y	lʊk lænd and hir tu
		Z	wʊk -æn- and hiɹ tu
105		X	<Oh> (my) (gosh)
		Y	oʊ̄ māɪ gɔʃ
		Z	oʊ̄ m̩āɪ gɔʃ
106		X	(I) (think) this goes up here
		Y	āɪ θɪŋk ðɪs goʊ̄z ʌp hir
		Z	āɪ -ɪn- dɪs̩ goʊ̄z̩ ʌp hi-
107		X	Boy went up here
		Y	bɔ̄ɪ wɛn ʌp hĩr
		Z	bo w̃ɛn̩ aʊ̄p hĩɹ

FIGURE 1. A page from a sample transcript illustrating three types of "word" entries tallied for the study.

Utterances 105 and 106 are conventions used to indicate that these entries are transcriber guesses about the speaker's intended words. The slashed word pair "is/does" in Utterance 102 indicates that the transcriber believes the speaker could have intended either of these two words. Words that are circled or separated with a slash are termed *partially intelligible*. Note that, as with fully intelligible words, phonetic transcriptions for these entries are also entered in the Y-line and the Z-line.

A fourth type of gloss, indicating a more severe intelligibility problem for transcribers, is entry of an asterisk in the X-line, as illustrated in Utterance 100. Such words are completely *unintelligible* to the transcriber. Unintelligible words symbolized with an asterisk in the X-line and Y-line may or may not have a corresponding phonetic entry in the Z-line, depending on how clearly the transcriber could segment the available speech signal. However, the unintelligible words selected for this study were restricted to those with phonetic entries so that a true word-like percept could be presumed.

Finally, a fifth entry made by transcribers is illustrated in Utterances 101 and 104. Both an asterisk and the word "look" are formatted using an angle bracket convention, indicating a word that is to be disregarded for certain computer analyses. Such *disregard words* in an audiotaped sample may represent words obscured by environmental noise or child behaviors (e.g., quiet speech, yawning, or nonword vocalizations). Disregard words were not included in the words sampled and coded for this study.

Figure 2 is a diagram of the different word intelligibility categories among the 2,476 transcript entries considered for

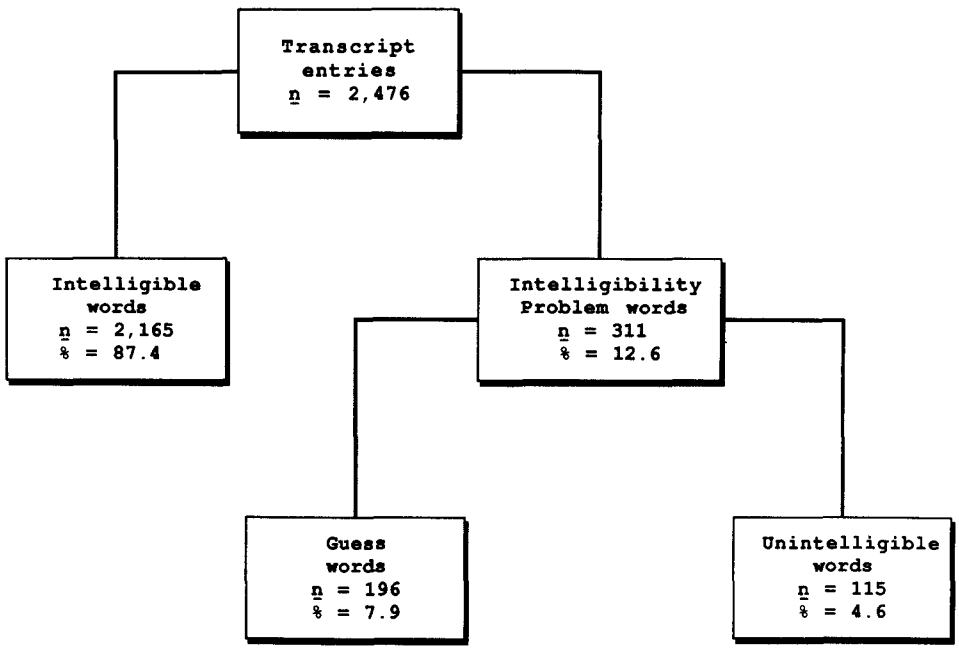


FIGURE 2. A diagram of the four word intelligibility categories coded for the study and the number and percentage of words in each category.

this study. The left branch includes 2,165 fully intelligible words (approximately 87% of the sampled entries), henceforth *Intelligible* words. The right branch includes 311 words that were intelligibility problems for the transcribers, henceforth *Intelligibility Problem* words. As shown, the category of Intelligibility Problem words (approximately 13% of the data set) includes 196 partially intelligible words (i.e., circle or slash convention), henceforth *Guess* words, and 115 completely unintelligible words (i.e., asterisks), henceforth *Unintelligible* words. These two subcategories represent, respectively, approximately 8% and 5% of the words in the data set.

Procedures

Study 1 explored potential relationships between the intelligibility status of the 2,476 words in the data set and eight variables derived from transcripts of continuous speech. Five contextual variables characterized the Intelligible and Intelligibility Problem words in relation to the utterances in which they were embedded. Three word variables characterized aspects of the words themselves. Three persons—the first author, a master's-level student, and a senior-level student majoring in communicative disorders—coded each of the 2,476 words on the five contextual and three word characteristics.

Table 1 includes coding status information for the eight independent variables. As shown, the three word variables could be coded only for the Intelligible and Guess words. The following is a description of the subtypes defined and coded for each of the five contextual and three word variables listed in Table 1. To ensure adequate cell frequencies for statistical analyses, the relatively small number of Guess and Unintelligible words in the sample required a limited number of subtypes.

TABLE 1. The eight independent variables and their coding status for Intelligible, Guess, and Unintelligible words. An "x" indicates that tokens were available for coding.

	Intelligibility category		
		Intelligibility Problem words	
Independent variable	Intelligible words	Guess words	Unintelligible words
Contextual variables			
Length	x	x	x
Complexity	x	x	x
Fluency	x	x	x
Position[a]	x	x	x
Contiguity		x	x
Word variables			
Canonical Form	x	x	
Consonant Form	x	x	
Grammatical Form	x	x	

[a]Coded only for words in fluent sentences.

TABLE 2. Percentage of agreement data for the eight independent variables.

Independent variable	*n*	Percentage of agreement	Kappa	*T* value	*p* value
Contextual variables					
Length	184	100.0	—	—	—
Syntactic Complexity	156	94.2	.80	15.1	<.001
Fluency	184	97.8	.93	12.7	<.001
Position	144	100.0	—	—	—
Contiguity	35	97.1	.93	5.5	<.001
Word variables					
Canonical Form	162	88.6	.78	12.5	<.001
Consonant Form	162	92.6	.73	14.7	<.001
Grammatical Form	162	87.7	.84	21.6	<.001

Contextual variables. *Length* was divided into two subtypes (disregarding words and part-words considered verbal nonfluencies): short utterances (three to four words) and long utterances (five to seven words). Utterances of all other lengths were not analyzed. *Complexity* subtypes characterize a developmental continuum of increasing complexity, as summarized by Miller (1981). However, because the noun and verb phrase utterances in this data set did not appear to represent a homogeneously low level of complexity, the subtypes included only three levels of complete sentences: simple sentences, simple sentences with object modifiers, and simple sentences with subject modifiers and/or true complex sentences. *Fluency* was divided into two subtypes: fluent utterances and nonfluent utterances, with the latter indicating the presence of any transcribed filler, false start, repetition, or revision. *Position,* which describes the relative position of words in an utterance, was coded only for words in fluent sentences. With all middle words excluded, the two codes were early words and late words (occurring in the first and second half of the utterance, respectively). Finally, *Contiguity* codes divided Intelligibility Problem words into two subtypes: contiguous Intelligibility Problem words (i.e., the target word was preceded and/or followed by at least one other Intelligibility Problem word) or isolated Intelligibility Problem words (i.e., the target word was adjacent to only Intelligible words).

Word variables. The second series of entries in Table 1 provides data on the three independent variables that characterize the 2,165 Intelligible words and the 196 Guess words. For two word variables, only monosyllabic words (approximately 86% of the Intelligible words and 91% of the Guess words) were coded to minimize potential confounding with other word variables. *Canonical Form* includes three types of monosyllabic words (Selkirk, 1984) that reflect a general pattern of increasing strength or resistance to destressing or articulatory reduction: open syllables with monophthongs, closed syllables with monophthongs, and syllables with diphthongs. Two *Consonant Form* subtypes reflected the phonological complexity of intended words (Kent, 1976; Shriberg et al., 1986): monosyllables containing only singleton consonants and monosyllables with initial or final clusters.

Finally, for *Grammatical Form,* transcript entries were first dichotomized into either function words or content words, as defined in children's corpora by Hubbell (1988). Two subgroups of function words were coded. Weak monosyllabic forms included 65 word types identified by Selkirk (1984, p. 353). These function words, such as *and,* characteristically occur in reduced form in casual speech (e.g., [n̩]) although more formal or emphatic forms may also occur (e.g., [ænd]). Strong function words (i.e., those less likely to occur in reduced form) included all occurrences of 23 monosyllabic forms, such as *up* and *by,* and multisyllabic forms, such as *over* and *behind.* Content words were divided into three traditional parts of speech: verbs, nouns, and modifiers.

Reliability

Classification coding for each of the variables was primarily a vigilance task, requiring attention to definitional criteria and clerical conventions rather than requiring ratings or scaling. All codes used for the study represented a consensus, with the first author monitoring agreement between the two coders. Variables with apparent inconsistencies were rechecked by one of the coders and the first author. Approximately 10% of the words in the study were recoded by both coders and examined by the first author. Table 2 is a summary of the obtained percentages of agreement of the recoded data with the original. Kappa values (Hollenbeck, 1978; SPSS Inc., 1991) were computed for each variable with an obtained percentage of agreement of less than 100. As shown in Table 2, based on the statistically significant percentages of agreement ranging from 87.7% to 100%, the reliability of coding each of the eight independent variables is considered adequate.

Results

Initial descriptive analyses yielded the intelligibility outcome data reported in Table 3. Cell entries are the number and percentage of each of the intelligibility categories available for the contextual and word variable subgroups. These central tendency data will be referred to in the context of each statistical analysis to follow. The percentage data shown in Table 3 reflect the conditional probabilities associated with each intelligibility outcome; comparison unconditional probabilities are reflected by the percentages of each outcome among the total 2,476 transcript entries (see Figure 2).

TABLE 3. Intelligibility data for Study 1. Cell entries are the number and percentage of Intelligible and Intelligibility Problem Words (also reported as the subordinate groups Guess and Unintelligible) observed for each of the contextual and word variable subgroups.

	Intelligibility category							
	Intelligible words		Guess words		Unintelligible words		Intelligibility Problem words	
Independent variable	*n*	%	*n*	%	*n*	%	*n*	%
Contextual variables								
Length								
Short	1,143	90.0	88	6.9	38	2.6	126	9.9
Long	1,022	84.7	108	8.9	77	6.4	185	15.3
Total	2,165		196		115		311	
Complexity								
Simple sentence	329	90.6	20	5.5	14	3.9	34	9.4
SS+ Obj.mod.	833	89.9	67	7.2	27	2.9	94	10.1
SS+ Subj.mod. or Complex sentence	566	90.0	45	7.2	18	2.9	63	10.0
Total	1,728		132		59		191	
Fluency								
Fluent	1,775	87.1	164	8.0	100	4.9	264	12.9
Nonfluent	390	89.2	32	7.3	15	3.4	47	10.8
Total	2,165		196		115		311	
Position[a]								
Early	732	42.1	85	9.8	52	6.0	137	15.8
Late	778	44.7	54	6.2	38	4.4	92	10.6
Total	1,510		139		90		229	
Contiguity								
Isolated Intelligibility Problem word			108	69.7	47	30.3	155	
Contiguous Intelligibility Problem word			88	56.4	68	43.6	156	
Total			115		196		311	
Word variables								
Canonical Form[b]								
Open monophthong	293	92.4	24	7.6				
Closed monophthong	1,119	90.1	123	9.9				
Diphthong	445	93.5	31	6.5				
Total	1,857		178					
Consonant Form[b]								
Singleton	1,844	91.8	164	8.2				
Cluster	237	88.1	32	11.9				
Total	2,081		196					
Grammatical Form								
Function words								
Weak	755	92.3	63	7.7				
Strong	405	88.2	54	11.8				
Total	1,160		117					
Content words								
Verb	417	92.5	34	7.5				
Noun	332	94.9	18	5.1				
Modifier	238	90.2	26	9.9				
Total	987		78					

[a]Fluent sentences only; [b]Monosyllabic words only.

TABLE 4. Summary of loglinear results for Study 1, including independence model statistics for each of the five analyses and best-fit association model statistics for the two multivariate analyses.

Analysis	Independent variable	Word intelligibility comparison	Loglinear statistics: Independence model χ_L^2	*df*	*p*	Association model χ_L^2	*df*	*p*	Interaction term
1	Length Complexity Fluency	Intelligible Words versus Intelligibility Problem Words	39.8	11	<.001	11.6	10	.31	Length × Fluency × Intelligibility Outcome
2	Position		10.3	1	.001				
3	Canonical Form Consonant Form	Intelligible Words versus Guess Words	11.2	5	.048	5.2	3	.16	Canonical Form × Intelligibility Outcome
4	Grammatical Form		14.0	4	.007	5.5	4	.24	Consonant Form × Intelligibility Outcome
5	Contiguity	Guess Words versus Unintelligible Words	5.9	1	.015				

Table 4 is a summary of the results of five loglinear analyses. Several factors discussed previously precluded use of a single multivariate test of differences among intelligibility outcomes, including both the limitations in the numbers of Guess and Unintelligible words and the structure of the data set (i.e., incomplete crossing of all variables). Therefore, the four word intelligibility categories diagrammed in Figure 2 were used to create three intelligibility outcome dichotomies (see Table 4, third column). Loglinear statistical procedures (Haberman, 1978), available in SPSS (SPSS Inc., 1991) in the VAX environment, were used to examine relationships between the three dichotomous dependent variables and combinations of qualitative independent variables. As shown in Table 4, a total of five logit analyses, two multivariate and three univariate, were completed. For the initial independence models, obtained significant Likelihood Ratio Chi-Square (χ_L^2) values (i.e., those meeting alpha levels of .05) indicated that intelligibility outcome was associated with levels of the independent variables. Following significant independence models, potentially explanatory interaction terms were systematically tested. Models of best-fit were those that included the interaction terms minimally required to produce nonsignificant χ_L^2 values (i.e., those that sufficiently explained observed cell frequencies). For univariate models that tested variables with multiple subgroups, standardized residuals exceeding a critical value of 1.96 identified word types significantly related to intelligibility outcome.

Analysis 1: Length, Complexity, and Fluency

The first intelligibility outcome assessed was Intelligible words versus Intelligibility Problem words, with an initial logit analysis testing the three contextual variables Length, Complexity, and Fluency. Following a statistically significant test of independence [$\chi_L^2(df = 11) = 39.8$; $p < .001$], the obtained best-fit association model [$\chi_L^2(df = 10) = 11.6$; $p = .31$] included the three-way interaction term Intelligibility Outcome × Length × Fluency. These results suggest that the significant differences in the proportional occurrence of Intelligibility Problem words are related to the contextual variables Length and Fluency.

The interaction between utterance Length and utterance Fluency is indicated by the intelligibility outcome data shown graphically in Figure 3. Short fluent utterances yielded approximately 9% Intelligibility Problem words, compared to approximately 12% for short nonfluent utterances. However, long fluent utterances yielded approximately 17% Intelligibility Problem words compared to only approximately 9% in long nonfluent utterances.

The lack of apparent influence of utterance Complexity on intelligibility outcome is shown in Table 3, with the percent-

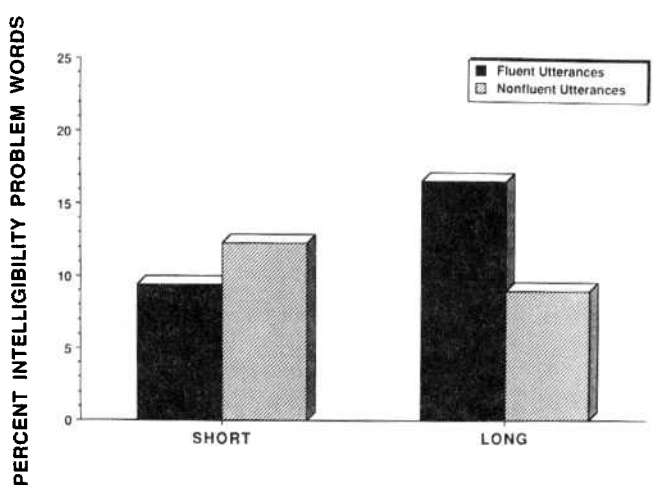


FIGURE 3. Percentage of Intelligibility Problem words among short and long, fluent and nonfluent utterances.

age of Intelligibility Problem words across the three Complexity subtypes averaging 9–10%.

Analysis 2: Position

The second univariate loglinear analysis shown in Table 4 yielded a significant Likelihood Ratio Chi-Square [$\chi_L^2(df = 1) = 10.3$; $p = .001$] for position of the word in the utterance. The Position data reported in Table 3 suggest that the intelligibility of words occurring early in a sentence may be more vulnerable than the intelligibility of words occurring later in a sentence. Approximately 16% of the early occurring words were Intelligibility Problem words, compared to approximately 11% for later-occurring words.

Analysis 3: Canonical Form and Consonant Form

Two loglinear analyses were also required for the second intelligibility outcome comparison, Intelligible words versus Guess words, as indicated in the third column in Table 4. The initial test of independence for the analysis of Canonical Form and Consonant Form was significant [$\chi_L^2(df = 5) = 11.2$; $p = .048$]. The observed cell frequencies are sufficiently explained by an interaction of intelligibility outcome with either Canonical Form [$\chi_L^2(df = 3) = 5.2$; $p = .16$] or Consonant Form [$\chi_L^2(df = 4) = 5.5$; $p = .24$]. Inspection of the percentage data for Guess words in Table 3 indicates that approximately 8% of words with singleton consonants were Guess words, compared to approximately 12% of the words with consonant clusters. Percentage differences for the Canonical Form subtypes are comparatively smaller, with percentages of Guess words of approximately 8%, 10%, and 7%, respectively, for monosyllabic forms including open monophthongs, closed monophthongs, and diphthongs.

Analysis 4: Grammatical Form

As summarized in Table 4, a univariate analysis of Intelligible and Guess words to test for differences in Grammatical Form also yielded a statistically significant independence model [$\chi_L^2(df = 4) = 14.0$; $p = .007$]. Standardized residuals exceeded the criterial value of 1.96 for two of the five Grammatical Form subgroups, strong function words, and nouns. As shown in Table 3, approximately 12% of the strong function words were Guess words, compared to approximately 7.5% of the weak function words. For nouns, the percentage of Guess words (approximately 5%) was reduced relative to verbs and modifiers (approximately 7.5% and 10%, respectively).

Analysis 5: Contiguity

The final analysis summarized in Table 4 tested for Contiguity differences between the two types of Intelligibility Problem words, Guess words, and Unintelligible words. The obtained Likelihood Ratio Chi-Square was significant [$\chi_L^2(df = 1) = 5.9$; $p = .015$]. The Contiguity data reported in Table 3 show that the 311 Intelligibility Problem words were equally likely to be isolated or contiguous. However, there were relative differences in the obtained percentages of Guess and Unintelligible words within the levels of the independent variable. Isolated problem words were divided into approximately 70% Guess words and 30% Unintelligible words, whereas contiguous problem words included approximately 56% Guess words and 44% Unintelligible words.

Summary of Findings for Study 1

Results of the loglinear analyses suggest that the canonical and consonant form of a word, the position of a word in an utterance, the position of a word relative to Intelligibility Problem words in the utterance, and the length and fluency of the utterance in which the word is embedded are all significantly associated with an intended word's potential intelligibility status. Findings for the influence of utterance complexity on word intelligibility were nonsignificant. Although the inferential statistics indicated a pattern of statistically significant and theoretically interesting findings, the absolute magnitudes of differences among the descriptive findings were relatively small.

STUDY 2

The goals of Study 2 were to cross-validate and expand the word-level findings of Study 1 with different listeners, different listening conditions, and a data set that included similar proportions of intelligible and unintelligible words. The assumption was that the effects found in Study 1 may have been attenuated due to the combination of stimuli, listeners, and mode of transcription. An existing source of data meeting the above conditions was determined appropriate for a more detailed analysis relating word characteristics to word intelligibility outcomes. As in Study 1, discussion will focus on proportional differences in the Low Intelligibility words (to be defined) associated with different word subtypes.

Method

Data

The data for Study 2 were a total of 1,400 words occurring in transcripts of 30 1-min continuous speech samples previously collected from 30 young children with speech delays of unknown origin. As described in Shriberg and Kwiatkowski (1982), sample utterances were selected from those that had been glossed by an experienced examiner, who repeated on the audiotape exactly what she believed were each child's intended words. Subsequently, all sample utterances were orthographically transcribed by 14 volunteer listeners who were senior-level or master's-level students in communicative disorders. Listeners had only one stimulus presentation, and the examiner's on-tape gloss was suppressed until students completed their gloss.

TABLE 5. The five word characteristics and their subtypes studied in Study 2.

Word characteristic	Subtypes
Consonant Form[a]	Singleton Initial cluster Final cluster
Vowel Form[a]	Diphthong Tense Lax
Coda Form[a]	Obstruent Sonorant
Syllabic Form	Monosyllabic Multisyllabic
Grammatical Form	Noun Verb Pronoun Modifier

[a]Monosyllabic words only

Procedures

Application of three inclusionary and exclusionary selection criteria based on token status, grammatical form class, and intelligibility status reduced the 1,400 words to a data set of 542 words. First, all word tokens occurring more than two times were excluded. Second, only representative noun phrase and verb phrase elements were included; proper nouns, articles, conjunctions, prepositions, and filler words (e.g., *oh, well*) were excluded. Third, to allow for comparisons between words differing in intelligibility outcome, two classes of words were defined based upon the percentage of agreement between the glosses of the 14 listeners and that of the experienced examiner who had access to contextual cues. A group of High Intelligibility words included those for which at least 13 of the 14 (93%) student listener glosses matched that of the experienced examiner. A total of 248 words met this criterion. A total of 294 words met criterion for Low Intelligibility words, with no more than 6 of the 14 (43%) listeners agreeing with the examiner.

Following identification of the High and Low Intelligibility words, the first author classified each of the 542 words on the five word characteristics listed in Table 5. The selection of these five word characteristics was based on findings from the preliminary study and Study 1, plus the opportunity to explore other potentially important word characteristics. As indicated in Table 5, only monosyllabic words were coded for Consonant Form, Vowel Form, and Coda Form. The generally equivalent numbers of words for the two intelligibility outcomes allowed an analysis of three Consonant Form subtypes, including words with only consonant singletons, initial consonant clusters, or final consonant clusters. Vowel Form subtypes were defined more precisely than possible in Study 1, including words with diphthongs, only tense vowels, or only lax vowels. Coda forms classified the consonants as either obstruents or sonorants. Syllabic forms and Grammatical forms coded for all 542 words in the data set included, respectively, the subtypes monosyllabic and multisyllabic, and the subtypes nouns, main verbs, pronouns, and modifiers.

With the exception of Grammatical Form, the order of the subtypes for each word characteristic listed in Table 5 reflects an assumption of increasing vulnerability to an intelligibility breakdown. Specifically, words with final clusters, lax vowels, sonorant codas, and multisyllabic shapes were expected to yield the highest proportion of Low Intelligibility words. For Grammatical Form, the only expectation based on Study 1 results was that nouns would yield the lowest proportion of Low Intelligibility words.

Results

The descriptive information for Study 2 intelligibility outcomes are summarized in Table 6. The cell entries are the number and percentage of High Intelligibility and Low Intelligibility words obtained for each of the word characteristic subtypes listed in the first column. Table 7 is a summary of the results of each of the three analyses, including independence model statistics and best-fit association model statistics. Two loglinear logit model analyses were completed for the monosyllabic words. To maintain minimum expected cell sizes, a univariate model approach was used for analysis of Consonant Form. A second, multivariate, model tested for Vowel Form and Coda Form influences on the number of observed Low Intelligibility words. For the complete data set, a multivariate model tested for differences among the subtypes of Syllabic Form and Grammatical Form. Association models were fit for the two multivariate analyses following obtained independence model Likelihood Ratio Chi-Square values meeting alpha levels of .05. Best-fit association models were those that included the interaction terms minimally required to obtain nonsignificant Likelihood Ratio Chi-Square values.

Analysis I: Consonant Form

The Likelihood Ratio Chi-Square for the independence model for Consonant Form was statistically significant [$\chi_L^2(df = 2) = 8.8$; $p = .012$]. Inspection of the observed percentages of Low Intelligibility words (see Table 6) for each of the three Consonant Form subtypes indicates a trend towards increasing percentages of monosyllabic Low Intelligibility words among those including only consonant singletons (approximately 49%), initial consonant clusters (approximately 61%), and final consonant clusters (approximately 71%).

Analysis 2: Vowel Form and Coda Form

The analysis for Vowel Form and Coda Form yielded a nonsignificant Likelihood Ratio Chi-Square [$\chi_L^2(df = 5) = 3.0$; $p = .697$] although the Vowel Form data (see Table 6) in Low Intelligibility words increase in the expected direction (diphthongs, approximately 44%; tense vowels, approximately 53%; lax vowels, approximately 58%) as do the Coda Form data (obstruents, approximately 51%; sonorants, 56%).

TABLE 6. Intelligibility data for Study 2. Cell entries are the number and percentage of High Intelligibility and Low Intelligibility words for each of the word characteristic subtypes.

	Intelligibility outcome			
	High (N = 248)		Low (N = 294)	
Independent variable	*n*	%	*n*	%
Consonant Form[a]				
Singleton	173	51.2	165	48.8
Initial cluster	14	38.9	22	61.1
Final cluster	13	29.5	31	70.5
Total	200		218	
Vowel Form[a]				
Diphthong	72	55.8	57	44.2
Tense	57	47.5	63	52.5
Lax	70	42.2	96	57.8
Total	199		216	
Coda Form[a]				
Obstruent	88	48.6	93	51.4
Sonorant	40	44.0	51	56.0
Total	128		144	
Syllabic Form				
Monosyllabic	200	47.8	218	52.2
Multisyllabic	42	37.2	71	62.8
Total	242		289	
Grammatical Form				
Noun	82	52.2	75	47.8
Verb	64	42.1	88	57.9
Pronoun	56	40.9	81	59.1
Modifier	23	44.2	29	55.8
Total	225		273	

[a]Monosyllabic words only

Analysis 3: Syllabic Form and Grammatical Form

The independence model for Syllabic Form and Grammatical Form resulted in a statistically significant Likelihood Ratio Chi-Square [$\chi_L^2(df = 7) = 17.8$; $p = .013$]. The best-fit association model included the two two-way interaction terms Intelligibility Outcome × Syllabic Form and Intelligibility Outcome × Grammatical Form [$\chi_L^2(df = 3) = 7.6$; $p = .054$]. Inspection of the descriptive data in Table 6 for these two variables indicates differences consistent with the expected percentages of Low Intelligibility words for the subtypes. For Syllabic Form, approximately 52% of monosyllables were

TABLE 7. Summary of loglinear results for Study 2, including independence model statistics for each of the three analyses and best-fit association model statistics for Analysis 3.

		Loglinear statistics						
		Independence model			Association model			
Analysis	Independent variable	χ_L^2	*df*	*p*	χ_L^2	*df*	*p*	Interaction term
1	Consonant Form	8.8	2	.012				
2	Vowel Form Coda Form	3.0	5	.697				
3	Syllabic Form Grammatical Form	17.8	7	.013	7.6	3	.054	Syllabic Form × Intelligibility Outcome Grammatical Form × Intelligibility Outcome

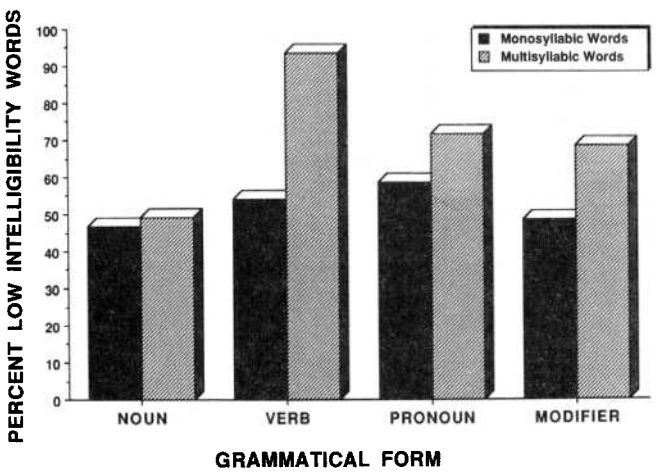


FIGURE 4. Percentage of Low Intelligibility monosyllabic and multisyllabic words among nouns, verbs, pronouns, and modifiers.

Low Intelligibility words compared to approximately 63% of multisyllabic words. For Grammatical Form, nouns yielded the smallest observed proportion of Low Intelligibility words (approximately 48%), with comparatively higher proportional yields for verbs (approximately 58%), pronouns (approximately 59%), and modifiers (approximately 56%).

Although these small observed differences between the Syllabic Form and Grammatical Form subgroups sufficiently account for the significant results for the independence model analysis, the obtained chi-square (7.6; $p = .054$) for the association model suggests that Syllabic Form and Grammatical Form interact to influence intelligibility outcome. The data presented graphically in Figure 4 indicate the nature of the interaction. As shown, nouns consistently include the smallest approximate proportions of Low Intelligibility words, regardless of whether they are monosyllabic (47%) or multisyllabic (49%). However, Syllabic Form differences are apparent for verbs, pronouns, and modifiers. In comparison to monosyllabic nouns, each of the other three monosyllabic grammatical forms yielded only slightly higher approximate percentages of Low Intelligibility words, from approximately 49% for modifiers to 57% for pronouns. However, for each of the three forms, the approximate percentages of Low Intelligibility multisyllabic words range from 68% for modifiers to 93% for verbs.

Summary of Findings in Study 1 and Study 2

The general finding of these studies is that several contextual and linguistic variables are associated with occurrences of unintelligible words in both narrowly transcribed transcripts and listener glosses. In Study 1, transcribers were significantly more likely to make unintelligible word entries when glossing children's longer sentences, with the influence of length most apparent for fluent sentences. Words were also less intelligible to transcribers when they met any of the following conditions: (a) they occurred early in sentences; (b) they were adjacent to other intelligibility problems; (c) they included consonant clusters and/or monophthongs in closed syllables; and (d) they were not classified grammatically as nouns. Sentence complexity was not statistically associated with transcription entries. The absolute magnitudes of percentage differences associated with statistically significant results were apparently small, but the number of Intelligibility Problem words (particularly Guess words) for each subtype of the independent variables was also relatively small.

In Study 2, listener glosses indicated three word characteristics significantly associated with reduced intelligibility. As in Study 1, consonant cluster words, especially those with final clusters, were less intelligible than singletons. Multisyllabic words were less intelligible than monosyllabic words, with the influence of Syllabic Form most apparent for words coded as verbs. Grammatical Form findings suggest that the intelligibility of nouns is relatively more robust than that of verbs, pronouns, and modifiers. Vowel Forms and Coda Forms were not significantly associated with word intelligibility.

Discussion

Before considering theoretical and clinical implications of these findings, it is appropriate to comment briefly on some methodological issues.

Measurement and Statistical Issues

The diverse domains of the independent variables investigated in this project required the development of arbitrary classification and scaling systems to code utterances and words. Although the procedures used to define these nominal variables would appear to have content validity, the consequences for the data of alternative conceptual and psychometric decisions are unknown. The metrics used in Studies 1 and 2 are those products of the preliminary studies that were most theoretically coherent and appropriate for cell size constraints in the database, but their psychometric properties were not subjected to rigorous inspection. Moreover, the statistical models that were appropriate to test for differences in the conditional probabilities associated with the variables investigated limit inference and interpretation. For example, few assumptions about possible additive effects among the different variables could be tested.

It is also important to acknowledge that the measures of the independent variables lack sensitivity. For example, the intelligibility outcome consequences of particular consonant clusters, grammatical functors, or individual types of multisyllabic words may be associated with greater differences than observed at the level at which they were measured. Thus, these data were "noisy" with respect to many potential lower-level variables that, if treated as factors in the statistical design, could have removed variance acting to attenuate the magnitudes of the actual percentage differences. Therefore, estimates of true effect sizes must be deferred, pending examination at more discerning levels of each contextual and linguistic construct. Future database research using software to assemble larger subgroups of types and tokens within each of the levels of the independent variables tested in these studies could allow for such fine-grained inquiry.

Theoretical Issues

As suggested in the literature review, an important prerequisite to the development of a comprehensive account of the utterance-to-utterance intelligibility of speech-delayed children is to attempt gross division of the variance into main and interaction sources reflecting the speaker's articulation and the listener's lexicalization processes. Because phonetic transcriptions of the realized speech forms of the Intelligible and Guess words were not included as part of the present design, there is no direct way to determine the degree to which the differences in intelligibility outcomes were associated with the number and type of speech errors on those or other words in the utterances. Speech production constraints obviously must play the major role in intelligibility outcomes because otherwise normal speakers without speech production problems are essentially fully intelligible.

Until data are available for testing the interactive influences of specific speech errors in specific contextual and linguistic environments using appropriate multivariate designs, inferences about these influences must be based on probabilistic associations using a speaker's error patterns in intelligible words as the measures of severity and error typology. As reviewed earlier, studies taking just that approach report that only approximately 20% of variance in intelligibility is associated with a speaker's severity of involvement (Bishop & Edmundson, 1987; Shriberg & Kwiatkowski, 1982; Shriberg et al., 1986; Thielke & Shriberg, 1990). The additive, or more likely overlapping, effect of the small percentage differences observed for the contextual and linguistic factors addressed in the present studies is not apt to reduce much of the remaining non-error variance. What variables might provide a more complete account? As suggested above and reviewed below, the specific pattern of the speaker's phonological errors is the most likely source. The following discussion considers evidence supporting the view that trends in the present data are at least primarily due to speaker-based production deficits.

Speech production and intelligibility. The programmatic research of Panagos and colleagues has linked increases in length and syntactic complexity to increases in segmental errors (Panagos & Prelock, 1982; Panagos, Quine, & Klich, 1979; Prelock & Panagos, 1989, 1991). The trend for increased utterance length, at least for fluent sentences, to be associated with intelligibility problems is consistent with these findings; however, the lack of significant results for complexity effects represents a departure. It may be that length effects in the loglinear model sufficiently accounted for complexity as well. Given the broadly defined complexity subgroups, a length-complexity relationship in the present data can reasonably be assumed (Scarborough, Rescorla, Tager-Flusberg, Fowler, & Sudhalter, 1991). Alternatively, from the perspective of competing production demands hypothesized by Panagos and colleagues, the complexity subgroups defined for the sentences of three to seven words included in the data set may not have represented contexts that taxed speech production accuracy.

It is more difficult to speculate on possible bases for the apparent interaction between utterance fluency and length. The overall trends for longer utterances to yield more unintelligible words were most apparent for fluent utterances, whereas differences between short utterances and long nonfluent utterances were comparatively small. Conceivably, children's long fluent sentences may be produced at relatively higher speaking rates, resulting in decreased speech production accuracy. Data regarding utterance length and speech rate interactions are not currently available for phonologically delayed children. In a recent study of normally speaking children of comparable age, however, sentence length and speech rate were not significantly associated (Walker, Archibald, Cherniak, & Fish, 1992).

Alternatively, intelligibility differences might be traced to discourse variables. In the 19 source transcripts in Study 1, for example, hesitation vowels represented the most frequently occurring type of nonfluency (approximately half of all nonfluencies). Further, many of these events were noted to occur before the first word in a sentence, suggesting that many nonfluent sentences may have occurred as responses to specific examiner queries. Therefore, a trend toward a similar language function for nonfluent sentences may have limited the opportunities for different sentence lengths to be associated with different proportions of unintelligible words. Interpretation of the trends for both complexity and fluency may depend upon consideration of the present findings in relation to language profiles for subgroups of subjects.

The interpretation that decreased intelligibility for words associated with phonetic complexity, syllabic complexity, and certain grammatical forms is mediated by increased speaker errors is supported, respectively, by many studies that have documented: (a) increased deletion errors associated with consonant clusters (Dukes & Panagos, 1973; Hodson & Paden, 1981; Oller, Jensen, & Lafayette, 1978; Shriberg et al., 1986), (b) increased and more atypical articulation errors in polysyllabic words (Klein & Spector, 1985; Shriberg et al., 1986), (c) increased articulation errors in unstressed contexts (e.g., function words; Campbell & Shriberg, 1982), and (d) disproportionally better articulation of nouns by children at the early-word stage (Camarata & Leonard, 1986). Comparable findings have been reported for subgroups of speakers with motor speech disorders, with increases in articulatory errors related to variables such as word length, grammatical class, and sentence position (Darley, 1982). Thus, there is ample literature support for the interpretation that the lowered intelligibility outcomes for words meeting certain contextual and linguistic characteristics in the present study were mediated primarily by children's reduced articulatory precision in segmentally taxing contexts.

Listener lexicalization and intelligibility. Several trends in the present data might also be interpreted as support for the contribution of listener lexicalization problems to the reduced intelligibility outcomes for certain words. Specifically, a significantly higher proportion of intelligibility problem words were found among words with contextual and linguistic features that could have disrupted lexical access for listeners. Such an inference is suggested by an extensive literature on intelligibility ratings and contextual redundancy (Beukelman & Yorkston, 1980; Kalikow & Stevens, 1977) and several factors influencing word recognition, including contextual predictability and frequency effects (Austin & Carter, 1988; Cole & Jakimik, 1980; Marslen-Wilson & Welsh, 1978;

Tyler & Wessels, 1983). First, listener-based processes are implicated by the finding that, in comparison to isolated Intelligibility Problem words, adjacent Intelligibility Problem words yielded a significantly higher proportion of the most severe Intelligibility Problem words—that is, Unintelligible words rather than Guess words. Such an effect may suggest that for transcribers, intelligibility effects are additive, with the occurrence of one Intelligibility Problem word disrupting the ability to gloss other words nearby in the utterance. Second, the finding that Intelligibility Problem words occurred more often early in the utterance suggests that glossing may be particularly difficult when a transcriber's ability to lexicalize words can not be facilitated by contextual support in relation to the discourse topic.

Related notions about several demonstrated listener lexicalization influences in addition to word predictability, for example, lexical stressing (Cutler & Ladd, 1983; Nakatani & Schaffer, 1977), may also explain the similar findings for grammatical form in both studies. In addition to the possibility that nouns represent easier production targets, their intelligibility may also have been facilitated by other factors. Over 75% of the nouns sampled in both studies were object nouns; thus, they tended to occur following most other words in sentences. In this position, their intelligibility may have been enhanced both by contextual predictability and lexical stressing. Similarly, word recognition effects may have influenced other grammatical form findings as well. For example, Selkirk's (1984) group of monosyllabic function words characteristically realized in phonetically reduced forms did not yield a higher than expected proportion of unintelligible words. These presumably frequently occurring, grammatically obligatory words (e.g., *at* and *for*), may have been highly predictable in context. In contrast, transcribers glossed more intelligibility problems among a word subtype including both multisyllabic forms (e.g., *either*) and other typically less reduced monosyllabic forms (e.g., *might*)—a grammatical functor subtype that may not have been similarly enhanced by lexicalization effects. The trend for a poor intelligibility outcome for the multisyllabic verbs in Study 2 may also have been mediated by similar lexicalization phenomena.

Speech production and listener lexicalization. Both speaker-based production and listener-based perception processes are implicated by the intelligibility findings of the two studies. Although the methodology allows limited inferences about possible additive effects (e.g., syllabic structure and grammatical form) of multiple contextual and linguistic factors, we presume that the intelligibility outcome for any given word may depend on many influences from either perspective that could potentially either facilitate or hinder intelligibility. For example, a monosyllabic, lexically stressed noun that includes only singleton consonants may provide the context for a child's best articulatory precision. If the noun were coincidentally an object noun, thus occurring late in the utterance, a favorable intelligibility outcome would again be probable due to facilitative processes involving both speech production and speech perception. In contrast, the intelligibility of a phonologically complex word such as *except,* that occurs early in a long utterance in relatively unstressed form, may be particularly vulnerable due to nonfacilitating processes in both speaker and listener domains.

Toward A Comprehensive Perspective on Children's Intelligibility

To integrate speaker-based articulatory factors and listener-based lexicalization processes in a comprehensive theoretical framework for intelligibility, the authors advocate an approach consistent with current functionalist-based models of language and language intervention as reviewed recently in Owens (1991). From this perspective, which emphasizes pragmatics as the organizing aspect of language, we view the child as variously skilled in manipulating the many parameters of a linguistic event that, from a listener's orientation, are prerequisite to successful communication.

The present findings support the position that articulatory variables represent an incomplete picture of communicative breakdowns (Kent, in press). Although they may account for relationships among phonologic complexity and intelligibility, articulatory variables alone fail to account sufficiently for associations between intelligibility and many other variables (e.g., the apparently close relationship between utterance length and utterance fluency). Regarding utterance length, a critical issue is to determine what children's longer utterances represent in relation to communicative intent. Many studies have consistently documented the influence of speech-language sampling variables, such as conversational topics (Cazden, 1970), discourse function and genre (Masterson & Kamhi, 1991; Wren, 1985), examiner control (Fey, Leonard, & Wilcox, 1981; Longhurst & Grubb, 1974), and contextual support (Atkins & Cartwright, 1982) on utterance length, as well as a variety of other structural parameters. Similarly, Masterson and Kamhi report that both intelligibility and percentage of consonants correct scores for a group of primary-school language-learning disabled children were lower for information that listeners shared in comparison to similar information unfamiliar to listeners. Consequently, it may be that for at least some speech-delayed children, pragmatic considerations will be essential for an eventual understanding of the origin and topography of their intelligibility breakdowns.

Perhaps an equally important consideration is the integrity of a child's language system. The findings of Shriberg et al. (1986) suggest, for example, that approximately 60% to 80% of speech-delayed children have concomitant delays in syntax production. Approximately 30% may have lexical retrieval problems. For children with language involvements, production errors such as inappropriate verb forms and unique lexical choices may interact with speech production deficits to lower overall intelligibility.

Conclusion

The current emphasis on articulatory parameters as the critical focus of analysis in intelligibility assessment precludes recognition of the pragmatic and related suprasegmental and language variables that contribute to communicative breakdowns. For children with speech-language disorders, analysis of discourse-level variables is viewed as essential to the identification of relevant sources of word- and utterance-level breakdowns in intelligibility. These and related validity issues (Kwiatkowski &

Shriberg, 1992; Morrison & Shriberg, 1992; Shriberg, 1990a), emphasize the appropriateness of conversational speech sampling as the only context from which multivariate accounts of intelligibility may eventually be assembled. At the group level, such accounts may capture theoretically and clinically significant amounts of variance. However, a comprehensive framework will likely require consideration of etiologic-based or processing-based subgroups within the currently clinical entities termed *specific language impairments* and *developmental phonological disorders*. Specifically, yet to be determined is how much of the utterance-to-utterance and moment-to-moment variability in intelligibility of speech-language disordered children is due to concomitant trait and state characteristics associated with these children's primary communicative deficit.

Acknowledgments

This research was supported by a grant to the second author from the Public Health Service, NIDCD, Grant No. DC00496. We thank Joan Kwiatkowski for assistance in developing the analytic approach, Sara Hoffman and Amparo Ortez for compiling the distributional data, Doris Kistler for statistical consultation, and Lorraine Argyle and Dorothy Rorick for editorial assistance. We also wish to acknowledge the contributions of the anonymous editorial consultants to the final version of this manuscript.

References

Atkins, C., & Cartwright, L. (1982). An investigation of the effectiveness of three language elicitation procedures on Head Start children. *Language, Speech, and Hearing Services in the Schools, 13,* 33–36.

Austin, N. J., & Carter, E. (1988). Nonacoustic contributions to the perception of fluent speech. *Language and Speech, 31,* 21–41.

Bennett, C. (1988, November). *Spontaneous expressive vocabulary development: 2–15 years.* Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, Boston, MA.

Beukelman, D. R., & Yorkston, K. M. (1980). Influence of passage familiarity on intelligibility estimates of dysarthric speech. *Journal of Communication Disorders, 13,* 33–41.

Billman, K. S. (1986). *Phonological processes and intelligibility of spontaneous utterances in young children.* Unpublished master's thesis, San Diego State University, CA.

Bishop, D. V. M., & Edmundson, A. (1987). Language-impaired 4 year-olds: Distinguishing transient from persistent impairment. *Journal of Speech and Hearing Disorders, 52,* 156–173.

Camarata, S., & Leonard, L. B. (1986). Young children pronounce object words more accurately than action words. *Journal of Child Language, 13,* 51–65.

Campbell, T. F., & Shriberg, L. D. (1982). Associations among pragmatic functions, linguistic stress, and natural phonological processes in speech-delayed children. *Journal of Speech and Hearing Research, 25,* 547–5453.

Cazden, C. B. (1970). The neglected situation in child language research and education. In F. Williams (Ed.), *Language and poverty: Perspectives on a theme.* Chicago, IL: Markham.

Chiat, S., & Hirson, A. (1987). From conceptual intention to utterance: A study of impaired language output in a child with developmental dysphasia. *British Journal of Disorders of Communication, 22,* 37–64.

Cole, R., & Jakimik, J. (1980). *Perception and production of fluent speech.* Hillsdale, NJ: Lawrence Erlbaum.

Connolly, J. H. (1986). Intelligibility: A linguistic view. *British Journal of Disorders of Communication, 21,* 371–376.

Crystal, D. (1987). From conceptual intention to utterance: A study of impaired language output in a child with developmental dysphasia. *British Journal of Disorders of Communication, 22,* 37–64.

Cutler, A., & Ladd, D. R. (1983). *Prosody: Models and measures.* New York: Springer-Verlag.

Darley, F. L. (1982). *Aphasia.* New York: Saunders.

Dukes, P., & Panagos, J. (1973). Repetition of comprehensible sentences by children with deviant speech. *British Journal of Disorders of Communication, 8,* 139–145.

Edwards, M. (1983). Selection criteria for developing therapy goals. *Journal of Childhood Communication Disorders, 7,* 36–45.

Elbert, M., & Gierut, J. (1986). *Handbook of clinical phonology: Approaches to assessment and treatment.* San Diego, CA: College-Hill Press.

Enderby, P. M. (1983). *Frenchay dysarthria assessment.* San Diego, CA: College-Hill Press.

Fairclcth, S., & Fairclcth, M. (1973). *Phonetic science.* Englewood Cliffs, NJ: Prentice Hall.

Fey, M., Leonard, L., & Wilcox, K. (1981). Speech-style modifications of language-impaired children. *Journal of Speech and Hearing Disorders, 46,* 91–97.

Flanagan, J. L. (1972). *Speech analysis, synthesis, and perception.* New York: Springer-Verlag.

Gaines, N. D., Runyan, C. M., & Meyers, S. C. (1991). A comparison of young stutterers' fluent versus stuttered utterances on measures of length and complexity. *Journal of Speech and Hearing Research, 34,* 37–42.

Gordon, P. A., Luper, H. L., & Peterson, H. A. (1986). The effects of syntactic complexity on the occurrence of disfluencies in 5-year-old nonstutterers. *Journal of Fluency Disorders, 11,* 151–164.

Grunwell, P. (1985). *Phonological Assessment of Child Speech (PACS).* San Diego, CA: College-Hill Press.

Haberman, S. (1978). *Analysis of qualitative data* (Vol. 1). New York: Academic Press.

Haynes, W., & Hood, S. (1978). Disfluency changes in children as a function of the systematic modification of linguistic complexity. *Journal of Communication Disorders, 11,* 79–93.

Hodson, B., & Paden, E. (1981). Phonological processes which characterize unintelligible and intelligible speech in early childhood. *Journal of Speech and Hearing Disorders, 46,* 369–373.

Hodson, B., & Paden, E. (1991). *Targeting intelligible speech* (2nd ed.). Austin, TX: Pro-ed.

Hollenbeck, A. R. (1978). Problems of reliability. In G. Sackett (Ed.), *Observing behavior: Data collection and analysis methods, II* (pp. 90–93). Baltimore, MD: University Park Press.

Hubbell, R. D. (1988). *A handbook of English grammar and language sampling.* Englewood Cliffs, NJ: Prentice Hall.

Hudgins, C. V. (1949). A method of appraising the speech of the deaf. *Volta Review, 51,* 597–638.

Jayaram, M. (1984). Distribution of stuttering in sentences: Relationships to sentence length and clause position. *Journal of Speech and Hearing Research, 27,* 338–341.

Kalikow, D. N., & Stevens, K. N. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *Journal of the Acoustical Society of America, 61,* 1337–1351.

Kent, R. D. (1976). Syllabic complexity and syntagmatic rules for syllable production. A comment on aspects of the syntax of behavior by D. G. MacKay. *Quarterly Journal of Experimental Psychology, 28,* 483–489.

Kent, R. D. (in press). Speech intelligibility and communicative competence in children. In A. P. Kaiser & D. B. Gray (Eds.), *The social use of language: Research foundations for early language intervention.* Baltimore, MD: Brooks Publishing Co.

Kent, R. D., Weismer, G., Kent, J. F., & Rosenbeck, J. C. (1989). Toward phonetic intelligibility testing in dysarthria. *Journal of Speech and Hearing Disorders, 54,* 482–499.

Klein, H. B., & Spector, C. C. (1985). Effect of syllable stress and serial position on error variability in polysyllabic productions of speech-delayed children. *Journal of Speech and Hearing Disorders, 50,* 391–402.

Kwiatkowski, J., & Shriberg, L. D. (1992). Intelligibility assessment in developmental phonological disorders: Accuracy of caregiver gloss. *Journal of Speech and Hearing Research, 35,* 1095–1104.

Longhurst, T., & Grubb, S. (1974). A comparison of language samples collected in four situations. *Language, Speech, and Hearing Services in the Schools, 5,* 71–78.

Marslen-Wilson, W., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10,* 29–63.

Masterson, J. J., & Kamhi, A. G. (1991). The effects of sampling conditions on sentence production in normal, reading-disabled, and language-learning-disabled children. *Journal of Speech and Hearing Research, 34,* 549–558.

McGarr, N. S. (1981). The effect of context on the intelligibility of hearing and deaf children's speech. *Language and Speech, 24,* 255–264.

Metz, D., Samar, V., Schiavetti, N., Sitler, R., & Whitehead, R. (1985). Acoustic dimensions of hearing-impaired speakers' intelligibility. *Journal of Speech and Hearing Research, 28,* 345–355.

Miller, J. F. (1981). *Assessing language production in children.* Baltimore, MD: University Park Press.

Miller, J. F., & Chapman, R. S. (1985). *Systematic analysis of language transcripts.* Madison, WI: University of Wisconsin-Madison.

Monsen, R. (1978). Toward measuring how well hearing-impaired children speak. *Journal of Speech and Hearing Research, 21,* 197–219.

Morrison, J. A., & Shriberg, L. D. (1992). Articulation testing versus conversational speech sampling. *Journal of Speech and Hearing Research, 35,* 259–273.

Nakatani, L. H., & Schaffer, J. A. (1977). Hearing "words" without words: Prosodic cues for word perception. *Journal Acoustical Society America, 63,* 234–245.

Oller, D. K., Jensen, H., & Lafayette, R. (1978). The relatedness of phonological processes of a hearing-impaired child. *Journal of Communication Disorders, 11,* 97–105.

Owens, R. E., Jr. (1991). *Language disorders: A functional approach to assessment and intervention.* Columbus, OH: Macmillan.

Panagos, J. M., & Prelock, P. (1982). Phonological constraints on the sentence productions of language-disordered children. *Journal of Speech and Hearing Research, 25,* 171–177.

Panagos, J. M., Quine, M. E., & Klich, R. J. (1979). Syntactic and phonological influences on children's articulation. *Journal of Speech and Hearing Research, 22,* 841–848.

Parkhurst, B., & Levitt, H. (1978). The effect of selected prosodic errors on the intelligibility of deaf speech. *Journal of Communication Disorders, 11,* 249–256.

Pearl, S., & Bernthal, J. (1980). The effect of grammatical complexity upon disfluency behavior of nonstuttering preschool children. *Journal of Fluency Disorders, 5,* 55–68.

Prelock, P. A., & Panagos, J. M. (1989). The influence of processing mode on the sentence productions of language-disordered and normal children. *Clinical Linguistics and Phonetics, 3,* 251–263.

Prelock, P. A., & Panagos, J. M. (1991). Discourse-sentence interaction in the speech of language-disordered and normal children. *Clinical Linguistics and Phonetics, 5,* 79–88.

Scarborough, H., Rescorla, L., Tager-Flusberg, H., Fowler, A. & Sudhalter, V. (1991). The relation of utterance length to grammatical complexity in normal and language-disordered groups. *Applied Psycholinguistics, 12,* 23–45.

Selkirk, E. (1984). *Phonology and syntax: The relation between sound and structure.* Cambridge, MA: The MIT Press.

Shriberg, L. D. (1986). *PEPPER: Programs to Examine Phonetic and Phonologic Evaluation Records.* Hillsdale, NJ: Lawrence Erlbaum.

Shriberg, L. D. (1990a). Measurement validity. In L. B. Olswang, C. K. Thompson, S. F. Warren, & N. J. Minghetti (Eds.), *Treatment efficacy research in communication disorders* (pp. 63–78). Rockville, MD: American Speech-Language-Hearing Foundation.

Shriberg, L. D. (1990b). *The Phonology Project Database.* Madison, WI: University of Wisconsin-Madison. Supported by NIDCD Grant No. DC00496.

Shriberg, L. D., & Kwiatkowski, J. (1982). Phonological disorders III: A procedure for assessing severity of involvement. *Journal of Speech and Hearing Disorders, 47,* 256–270.

Shriberg, L. D., Kwiatkowski, J., Best, S., Hengst, J., & Terselic-Weber, B. (1986). Characteristics of children with speech delays of unknown origin. *Journal of Speech and Hearing Disorders, 51,* 140–161.

Shriberg, L. D., Kwiatkowski, J., & Rasmussen, C. (1989). *The prosody-voice screening profile (PVSP): II. Reference data and construct validity.* Paper presented at the American Speech-Language-Hearing Association Annual Convention, St. Louis, MO.

Sitler, R. W., Schiavetti, N., & Metz, D. E. (1983). Contextual effects in the measurement of hearing-impaired speakers' intelligibility. *Journal of Speech and Hearing Research, 26,* 30–34.

Smith, C. (1975). Residual hearing and speech production in deaf children. *Journal of Speech and Hearing Research, 18,* 795–811.

SPSS Inc. (1991). *SPSS advanced statistics: User's guide.* Chicago, IL: SPSS Inc.

Stoel-Gammon, C., & Dunn, C. (1985). *Normal and disordered phonology in children.* Austin, TX: Pro-ed.

Subtelny, J. D. (1977). Assessment of speech with implications for training. In F. Bess (Ed.), *Childhood deafness* (pp. 183–194). New York: Grune and Stratton.

Thielke, H. M., & Shriberg, L. D. (1990). Effects of recurrent otitis media on language, speech, and educational achievement in Menominee Indian children. *Journal of Native American Education, 29,* 25–35.

Tyler, L. K., & Wessels, J. (1983). Quantifying contextual contributions to word-recognition processes. *Perceptions and Psychophysics, 34,* 409–420.

Vihman, M. M. (1988). Later phonological development. In J. Bernthal & N. Bankson (Eds.) *Articulation and Phonological Disorders* (pp. 110–144). Englewood Cliffs, NJ: Prentice Hall.

Vihman, M. M., & Greenlee, M. (1987). Individual differences in phonological development: Ages one and three years. *Journal of Speech and Hearing Research, 30,* 503–521.

Walker, J. F., Archibald, L. M., Cherniak, S. R., & Fish, V. G. (1992). Articulation rate in 3- and 5-year-old children. *Journal of Speech and Hearing Research, 35,* 4–13.

Wall, M. J., Starkweather, C. W., & Cairns, H. (1981). Syntactic influences on stuttering in young child stutterers. *Journal of Fluency Disorders, 6,* 283–298.

Weiss, C. (1980). *Weiss Comprehensive Articulation Test.* Allen, TX: DLM Teaching Resources.

Weiss, C., & Lillywhite, H. (1981). *Communication disorders: Prevention and early intervention.* St. Louis, MO: C. V. Mosby Co.

Weston, A. D., Shriberg, L. D., & Kwiatkowski, J. (1988, November). *Unrecognized words in continuous speech-language samples: Determinants of intelligibility.* Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, Boston, MA.

Wingate, M. E. (1976). *Stuttering: Theory and treatment.* New York: Irvington Publishers.

Wren, C. (1985). Collecting language samples from children with syntax problems. *Language, Speech, and Hearing Services in Schools, 16,* 83–102.

Yavas, M., & Lamprecht, R. (1988). Processes and intelligibility in disordered phonology. *Clinical Linguistics and Phonetics, 2,* 329–345.

Yorkston, K. M., & Beukelman, D. R. (1981). *Assessment of intelligibility of dysarthric speech.* Tigard, OR: C.C. Publications.

Received September 25, 1991
Accepted April 15, 1992

Contact author: Audrey D. Weston, Department of Speech Pathology and Audiology-Boise Location, Idaho State University, 1078 North Cole Road, Boise, ID 83704.

Contextual and Linguistic Correlates of Intelligibility in Children With Developmental Phonological Disorders

Audrey D. Weston, and Lawrence D. Shriberg
J Speech Hear Res 1992;35;1316-1332

This information is current as of June 28, 2012

This article, along with updated information and services, is located on the World Wide Web at:
http://jslhr.asha.org/cgi/content/abstract/35/6/1316

AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION