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Phonologic Error Distributions in the Iowa-Nebraska Articulation Norms Project: Consonant Singletons

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The errors on consonant singletons made by children in the Iowa-Nebraska Articulation Norms Project (Smit, Hand, Freilinger, Bernthal, & Bird, 1990) were tabulated by age range and frequency. The prominent error types can usually be described as phonological processes, but there are other common errors as well, especially distortions of liquids and fricatives. Moreover, some of the relevant phonological processes appear to be restricted in the range of consonants or word-positions to which they apply. A metric based on frequency of use is proposed for determining that an error type is or is not atypical. Changes in frequency of error types over the age range are examined to determine if certain atypical error types are likely to be developmental, that is, likely to self-correct as the child matures. Finally, the clinical applications of these data for evaluation and intervention are explored.

KEY WORDS: phonological, development, articulation, typical, atypical

Study of children's speech sound errors[1] is an important aspect of the larger study of children's acquisition of language. Children's speech sound errors at different stages of development are the driving force behind theories about the processes by which children acquire the phonology of the ambient language. Studies of children's speech sound errors are also vital to the practice of speech-language pathology, because information about typical errors helps to delineate the normal course of acquisition; consequently, a child's delayed or disordered phonologic development can be evaluated against normal or typical error patterns.

Certain error patterns characterize children's early use of meaningful speech, before they acquire the full adult phonology. These patterns are so regular and so well known that they have been enshrined in the literature as *natural processes* (e.g., Shriberg & Kwiatkowski, 1980; Stampe, 1973) or as *phonological processes* (e.g., Grunwell, 1987; Hodson and Paden, 1991; Ingram, 1989). They include such processes as stopping of fricatives, gliding of liquids, and cluster reduction. Phonological processes perpetuate tendencies present in the babbling that precedes the onset of meaningful speech, such as the tendency to use stops, nasals, and glides rather than other consonants, and the tendency to use CV syllables in preference to more complex syllables. The existence of these common tendencies has led to hypotheses that there is a strong biological/genetic component in the acquisition of phonology (Kent and Hodge, 1991; Locke, 1983; Stampe, 1973; Studdert-Kennedy, 1986).

Phonological processes are used with great frequency by children in the second year of life, although there is considerable variation among children in the range of

[1]The term *error* as used in this paper refers to differences from, or mismatches with, the adult phonologic system, and not to any evaluation of these differences as representing deviance.

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applicability of specific processes, in the particular sounds they choose to use, in the degree to which processes can apply concurrently, and in the degree to which the child appears to be experimenting. After the second year, the phonology gradually becomes quite regular as children progress toward the adult system. However, children with disordered phonology typically continue to use phonological processes beyond the age at which children with normally developing speech cease to use them.

In spite of the widely accepted usefulness of phonological processes as descriptors and as guides to intervention, their use has several drawbacks. First of all, phonological processes may be restricted in scope of application (e.g., the process of fronting may apply to word-initial consonants only). In addition, phonological processes do not completely specify the range of errors that children actually make; for example, the process of stopping covers the use of just one stop for many fricatives as well as use of a variety of stops for these same fricatives. Moreover, phonological processes do not encompass all possible errors—distortions in particular. Finally, data on the frequency of process use at specific ages has become available only recently (Bankson & Bernthal, 1990; Preisser, Hodson, & Paden, 1988).

In the early stages of meaningful speech, there is a great deal of variability both within children and across children acquiring the same language (e.g., Vihman & Greenlee, 1987). For children beyond this early experimentation stage, which may last until about 3 years of age, the frequency of a particular error type at a particular age assumes importance to speech-language pathologists. These clinicians must often decide whether uncommon or atypical errors are developmental, that is, whether the errors have the potential to self-correct as the child matures. From the clinical point of view, children may exhibit (a) typical errors that are likely to be developmental, (b) typical errors that may not be developmental, (c) atypical errors that may be developmental, and (d) atypical errors that may not be developmental. The first set, typical errors that are also likely to be developmental, covers at least two age ranges (Stoel-Gammon & Dunn, 1985, p.43): phonological processes that usually disappear by about age 3 (e.g., final consonant deletion) and processes that persist after age 3 (e.g., cluster reduction). Typical errors that may not be developmental are those errors common to younger children but exhibited by older children, especially those with phonological disorders (e.g., gliding of /l r/ at the age of 10). In other words, these errors are no longer developmental because it is highly unlikely that they will self-correct.

Atypical errors, whether developmental or not, are those about which little is known except that they characterize children with diagnosed phonologic disorders. Leonard (1973) has pointed out that most children with severe disorders of phonology exhibit at least a few unusual, bizarre, or idiosyncratic errors that cannot be considered developmental, that is, they are not likely to correct as a result of maturation. Despite corroboration of Leonard's observation from other sources (e.g., the summary presented by Stoel-Gammon & Dunn, 1985, p. 117), the general tendency in clinical speech-language pathology has been to assume that most speech sound errors are developmental, unless the errors are consistent with an obvious explanatory factor such as cleft palate. This tendency comes about because clinicians often use age-of-acquisition norms for specific phonemes without consideration of the type of error, although analyses of phonological processes require some information about error types. Nevertheless, speech-language pathologists need to be concerned about children with unusual speech sound errors that develop or persist after the early, highly variable phase of phonologic development. In such cases, the question of whether the child is a candidate for intervention needs to be addressed. Unfortunately, the clinician who looks for verification that a child's particular variant is indeed atypical will have difficulty finding it.

The most typical manifestations of the common phonological processes should undoubtedly be considered developmental errors when they occur in the appropriate age ranges, whereas less common variants may not be developmental. Additionally, many distortion errors may not be developmental. However, as Locke (1980) points out, little systematic work has been done on the numerical distribution of the actual error variants that children use. The exception is a study by Snow (1963), who studied the production of consonant singletons by first-grade children.

The purpose of this report is to present comprehensive data about the typical and atypical errors made by English-speaking children when they produce consonant singletons, with emphasis on the error sounds actually used (including both distortions and phonological process errors), on the frequency of these errors at various ages, and on the scope of phonological process application. These descriptive data will then be used to develop clinical criteria for determining when a child's production is atypical and is not likely to be developmental, so that intervention can be provided as appropriate.

The Iowa-Nebraska Articulation Norms Project (Smit et al., 1990) is the source for the error data on consonant singletons to be reported here. These data were obtained for most word-initial and word-final consonants in English and for a few intervocalic consonants as well as initial consonant clusters. The error data for word-initial consonant clusters will be reported separately (Smit, 1993).

Method

The Iowa-Nebraska data were elicited from children ages 3 to 9. For the present study, these data have been augmented by additional data from children ages 2:0 and 2:6, who had not been included in the Iowa-Nebraska report because of small group size and potential bias. However, the 2:0 and 2:6 age groups were added to the error study because there was impressive quantitative and qualitative continuity between their error data and the error data from the 3:0 and 3:6 groups. Table 1 shows all the age groups and the numbers in each, divided by sex.

The error data were taken from single word productions by the children, who named photographs. An elicitation sequence was used to encourage as many instances of spontaneous naming as possible. The children's productions of target consonants in each word were recorded in narrow

TABLE 1. Numbers of girls (F) and boys (M) in each age group.

	Age groups											
Sex	**2:0**	**2:6**	**3:0**	**3:6**	**4:0**	**4:6**	**5:0**	**5:6**	**6:0**	**7:0**	**8:0**	**9:0**
F	12	21	22	26	37	51	45	45	68	62	62	65
M	5	14	25	29	54	44	50	47	72	73	68	52
Total	17	35	47	55	91	95	95	92	140	135	130	117

transcription using a system based on Shriberg and Kent (1982). For each target phoneme or cluster, the testers used a checklist of productions and variants that were likely to occur for that target, although the testers could also note productions that were not included in the checklist. For example, the list of possible productions for initial /k/ included [k t g d ø], frictionalized stop, and deaspirated [k t].

The testers were 160 speech-language pathologists employed in the public schools of Iowa and Nebraska. They were selected on the basis of their transcription reliability from a larger group of clinicians who had received training in narrow transcription. Reliability was established using videotapes from two children, one a 3-year-old girl with normally developing speech and the other an 8-year-old boy with moderate-to-severe impairment of speech.

In order to estimate point-to-point reliability of the testers, a smaller group of 25 clinicians was randomly selected from the group. For the normally developing 3-year-old who served as a reliability subject, these 25 clinicians' mean point-to-point agreement with a consensus transcription was 76%, and for the 8-year-old with impaired speech the mean point-to-point agreement was 74%. No clinician's transcription reliability was lower than 70%. These percentages appear to be within acceptable limits for narrow transcription. Further information about methods used in data collection and analysis may be found in Smit et al. (1990).

For the analyses that follow, the error data from boys and girls have been combined at each age level. In the original report, ages of acquisition were provided separately for boys and girls in the preschool years because there were significant differences between the sexes in total scores within that age range. In contrast, the error tabulations for boys and girls at each age level were determined to be very similar. To investigate any possible differences between the sexes with respect to error usage, type-token ratios were calculated for boys and for girls at every age level for every consonant and consonant cluster. Based on inspection of these data, it was determined that there were no large or systematic differences between boys and girls at any age level. That is, in general, neither sex exhibited a wider variety of error types than the other.

In addition, the data were inspected to assess whether girls and boys used different types of errors for any consonant or consonant cluster. These inspections showed that girls and boys almost always used the same variants. Furthermore, boys and girls tended to concentrate their errors on the same error types. Based on these two inspections—of type-token ratios and of error-type concentrations—the error data for girls and boys were combined.

Results

The error distributions for initial and final consonant singletons are shown in Tables 2–6. Abbreviations used in these tables, together with conventions for symbol usage, are defined in the Appendix. The data in these tables include every error made by every child in every age group.

Each data column in these tables is headed by a range of percents, which indicates the frequency of use for column entries. In general, when a range of percents is given, one can assume that the percent values for the groups within an age range cover the range indicated in the column heading, unless there is a footnote to the contrary. For example, in Table 2 for final /ŋ/, the error [n] appears in the 5–15% column for the age range of 4:0–9:0. This age range includes the age groups 4:0, 4:6, 5:0, 5:6, 6:0, 7:0, 8:0, and 9:0. The percent of the children's total productions that were [n] for each of these age groups is 8%, 17%, 16%, 9%, 13%, 8%, 6%, and 6%, respectively. In order to simplify the tables, uniform percent-of-use ranges have been adopted for each table. However, if the percentage exhibited by an age group within an age range exceeds the stated percent-of-use range by more than about 5%, then a footnote is added to the table. "Occasional" errors are those used by most groups in an age range at frequencies of 1–4%, or by just a few groups in an age range with a frequency of 4–10%, so that the central tendency is less than 4%. "Rare" errors occur in just a few groups in an age range, and with a frequency of less than 3%, so that the central tendency is less than 1%. In practice, it is possible to estimate the total number of errors of a given type by using the midpoint of the larger percentage intervals (or slightly less than the midpoint), for example, 9–10% for the percentage range 5–15%, a value of 2% for "occasional" errors, and a value of 0.5% for "rare" errors.

The age ranges used in these tables were not chosen arbitrarily but rather reflected points of shift in the error distributions. For example, the most frequent error for word-initial /r/ is [w], as can be seen in Figure 1. It is clear that there is a marked drop in the frequency of [w] use between ages 3:0 and 3:6, because frequency of use by children aged 2:0–3:0 is in the 30–80% range, whereas for children between 3:6 and 6:0, frequency of use is in the 15–30% range. After age 6:0, frequency of [w] use drops to below 10%. Consequently, in Table 4 (to be discussed in detail later) these age ranges are the ones used for the word-initial /r/ frequency distribution. In general, once decisions had been made about age ranges based on shifts in the use of the more-common errors, then the less common error types were tabulated within those age ranges.

TABLE 2. Distribution of children's errors in producing nasals and glides. Frequency of use is expressed as percent of total responses to each target phoneme. (The stimulus words are shown in parentheses.)

Phoneme	Frequency of use				Phoneme	Frequency of use			
Age group	**15–35%**	**5–15%**	**Occ.**	**Rare**	**Age group**	**15–35%**	**5–15%**	**Occ.**	**Rare**
NASALS									
/m-/ (mouse)					/-m/ (thumb, gum)				
2:0–9:0 (A: 98%)	---	---	*dns*	g	**2:0–9:0** (A: 95%)	---	---	*dns*	Ø,p,n,ʔ,mb,mp,ŋk,*int*
/n-/ (nose)					/-n/ (gun, van)				
2:0–9:0 (A: 96%)	---	---	*dns*	m,nd,d,*int*	**2:0–4:0** (A: 94%)	---	---	Ø,m,ŋ	(*nsl*)VØ,d,ʔ,nd,*int*,*dns*
					4:6–9:0 (A: 96%)	---	---	*dns*	(*nsl*)VØ,d,ʔ,nd
					/-ŋ/ (wing)				
					2:0–3:6 (A: 60%)	n	ŋg/ŋk[a]	Ø	ʔ,n>ŋ,*dns*
					4:0–9:0 (A: 73%)	---	n,ŋg/ŋk	g	Ø,ʔ,d,k,ŋd,*dns*,n>ŋ,ŋ>l
GLIDES									
/h-/ (hat, hose)									
2:0–3:0 (A: 92%)	---	Ø[b]	---	j,t,ʔ					
3:6–9:0 (A: 98%)	---	---	---	Ø,f,ʔ,d,hj					
/w-/ (wing, watch)									
2:0–4:0 (A: 94%)	---	---	Ø	b,m,g,l,r,j,muw,wj,sw					
4:6–9:0 (A: 99%)	---	---	---	r,uw,(*ne*)hw					
/j-/ (yawn)									
2:0–3:0 (A: 60%)	Ø	w	d	h,l,z,n,wj					
3:6–6:0 (A: 90%)	---	---	Ø[c],w,h,l	s,n,ð,θ					
7:0–9:0 (A: 99%)	---	---	---	hj					

Note. Occ. = occasional. A = estimated percent acceptable use. A guide to definitions, symbols, and abbreviations used in this table may be found in the Appendix.
[a]The 2:0 group did not use these variants. [b]Concentrated in lower part of this percentage range. [c]Concentrated in younger groups in this age range.

Nasals and Glides

Nasals and glides are typically mastered early by children learning English. Error distributions for initial and final nasals and for initial glides are shown in Table 2.

Nasals. Denasalization is the most common error for /m n/, and it should be noted that the testing clinicians often wrote notes on the test forms indicating that the children who denasalized nasal consonants appeared to have a cold. Final /n/ is substituted by [m ŋ] occasionally, and it is deleted occasionally. For final /ŋ/, the most common errors are [n] substitution and addition of a velar stop. The rare errors for nasals appear to be unsystematic, but there are far more of them for word-final nasals than for word-initial nasals.

Glides. Perusal of the first two columns of data for initial-position glides in Table 2 reveals that the only error these glides have in common is deletion, although in the youngest age groups, deletion of /j/ is far more common than deletion of /h w/. Other than deletions, few errors affect /h w/, but for /j/, [w d h l] are relatively common substitutions. The rare substitutions for these phonemes appear to be unsystematic, except that some of them may represent assimilations, for example, [n] for /j/ in *yawn.*

Stops

Table 3 shows the errors made for stop consonants. The data for initial voiceless stops show that deaspiration (sometimes given the phonological process name of Initial Consonant Voicing) is relatively common in the preschool years. Fronting of initial velars to alveolars is common, but fronting affects initial stops far more often than final stops. Backing of alveolar stops to velars is not at all common. For final stops, deletions are prominent (reflecting the process of final consonant deletion), but deletions are somewhat less common for velars than for labial or alveolar stops. The children use a wider variety of rare variants for final voiceless stops and initial velar stops than for the other stops.

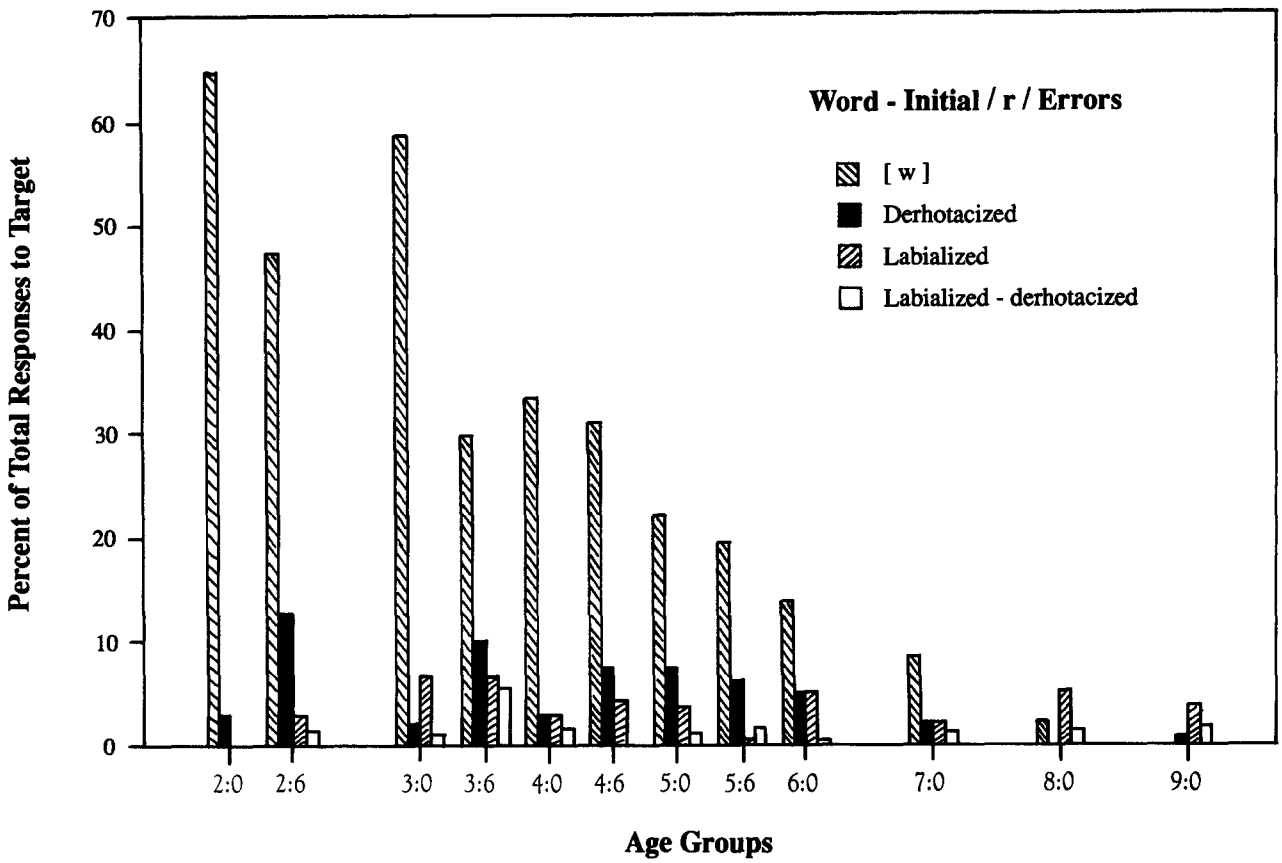

FIGURE 1. Distribution by age group of the most common errors used for word-initial /r/.

The rare productions include errors in voicing, place, or manner, together with a small number of distortions.

Liquids

Table 4 contains the error distributions for the liquids /l r/. In the youngest age groups, liquids were produced in error far more often than they were produced correctly. Examination of these data shows that just a few error types predominate—[w] for initial /l r/, as well as rounded vowels, deletion, and schwa for final /l r/. These prominent types reflect the very common processes of gliding (initial liquids) and vocalization (final liquids). It is clear from these data that use of gliding is suppressed at different rates for initial /l/ and initial /r/. By age 6:0, [w] is used for initial /l/ only occasionally, whereas the frequency of [w] for initial /r/ remains in the 5–15% range at the same age. Error patterns for intervocalic /l r/ closely resemble those for initial /l r/, respectively, except that in addition to [w] substitutions, [d] and flaps are used for intervocalic /l/.

Initial liquids (Table 4) and glides (Table 2) are the only initial consonant singletons to be deleted often (in the youngest age groups), although /θ z dʒ/ are occasionally deleted (see Tables 5 and 6). Examination of deletions occurring for initial and intervocalic /l r/ reveals that the frequency of these deletions is quite comparable to the frequency with which initial glides are deleted (Table 2).

Notable among the rare errors for initial liquids is the addition of consonants that result in clusters, that is, [bl fl gl br pfw]. Of these, the [br] cluster for initial /r/ appears to be an assimilation ("brainbow" for *rainbow*), and the others could plausibly represent assimilations to later elements in the target word. Other probable assimilations among the less frequent errors include [b m] for /r/ ("bainbow," "mainbow") and [n v] for /l/ ("nightning" for *lightning*, "veaf" for *leaf*).

Among the rare errors in all word positions are several distortions such as interdentalization (which includes tongue protrusion), labialization, and velarization of /l/, some of which occur rarely in the youngest groups but more prominently in older groups. Among the rare errors for final liquids are the creation of new syllables and use of certain distortions for final /l/, as well as use of a wide variety of diphthongs for final /r/.

The consonant /r/. Table 4 also shows the frequent use of distortions, particularly for /r ɚ/. The common /r/ distortions (labialization, derhotacization, and labialization-derhotacization) tend, in general, to make the liquid production more glide-like. However, these distortions are used far less commonly than [w].

Because /r/ is very commonly in error and is a frequent target of intervention, the question of whether certain /r ɚ/ errors might be developmental, and others not, was investigated further. Figure 1 is a graphic display of the four prominent error types used for initial /r/. The [w] is clearly

TABLE 3. Distribution of children's errors in producing stops. Frequency of use is expressed as percent of total responses to each target phoneme. (The stimulus words are shown in parentheses.)

Phoneme	Frequency of use			Phoneme	Frequency of use		
Age group	5–15%	Occ.	Rare	Age group	5–15%	Occ.	Rare
/p-/ (pipe)				/-p/ (pipe, cup)			
2:0–2:6 (A: 85%)	b	h,ø	---	**2:0–3:0** (A: 87%)	ø	k	f,t,V:p
3:0–5:0 (A: 96%)	---	b	t	**3:6–9:0** (A: 96%)	---	ø	b,f,t,k,V:p,pə,ʔ,*ne*
5:6–9:0 (A: 99%)	---	---	b				
/t-/ (teeth)				/-t/ (cat, goat, hat)			
2:0–3:6 (A: 92%)	---	d	f,k,ts,ps	**2:0–3:6** (A: 84%)	ø	k	d,p,tə,ft
4:0–9:0 (A: 99%)	---	---	h,*int*	**4:0–9:0** (A: 92%)	ø[a]	---	d,V:t,k,p,*pal,int*,tə
/k-/ (cake, cat, cup)				/-k/ (duck, sock, cake)			
2:0–3:6 (A: 84%)	t	g,d	p,b,s	**2:0–3:6** (A: 94%)	---	ø,t	s,kə
4:0–5:0 (A: 95%)	---	t,g	h,d,s,*pal*	**4:0–9:0** (A: 98%)	---	ø,k	t,g,V:k,*pal,phar*
5:6–9:0 (A: 99%)	---	---	t,g,*pal,dnt,phar*				
/b-/ (bib, bag, bed)				/-b/ (bib)			
2:0–3:0 (A: 98%)	---	---	p,d,g,f,d͡b	**2:0–2:6** (A: 75%)	ø,p	d,nd	---
3:6–9:0 (A: 99%)	---	---	p,k,mb,br	**3:0–9:0** (A: 94%)	---	ø,p	ʔ,m,v,θ,d,t,*ne*
/d-/ (dog, duck, deer)				/-d/ (bed)			
2:0–3:0 (A: 96%)	d	---	b,n,t	**2:0–2:6** (A: 77%)	ø,t	ʔ	p
3:6–9:0 (A: 99%)	---	---	h,g,t,ð,nd,*pal,int*	**3:0–4:0** (A: 93%)	---	ø[b],t,ʔ	g
				4:6–9:0 (A: 98%)	---	---	ø,t,ʔ,*int*
/g-/ (goat, gun)				/-g/ (dog, bag)			
2:0–3:6 (A: 85%)	d[c]	---	k,t,b,dʒ,s,ʃ	**2:0–3:6** (A: 85%)	k	ø[b],d[b]	t
4:0–5:0 (A: 95%)	---	d	ø,b	**4:0–9:0** (A: 95%)	---	k,ʔ	ø,t,d,*int*
5:6–9:0 (A: 99%)	---	---	ʔ,k,d,*dnt,phar*				

Note. Occ. = occasional. A = percent acceptable use. A guide to definitions, symbols, and abbreviations used in this table may be found in the Appendix.
[a]Concentrated in lower part of this percentage range. [b]Concentrated in younger groups in this age range. [c]5–20%.

developmental, having a very high frequency in the youngest age groups and virtually disappearing by ages 8:0 and 9:0. Derhotacized variants may also be developmental—they are never high in frequency, but they appear to have a developmental course, and they also disappear by ages 8:0 and 9:0. On the other hand, labialized and labialized-derhotacized variants of [r] may not be developmental. Although the frequency of these errors is not high, they persist throughout the preschool and school-age range. These data on initial /r/ need to be interpreted with caution because they depend crucially on transcription reliability, and /r/ distortions are notoriously difficult to transcribe. Inspection of the reliability data from 25 randomly selected testers showed that a very large majority agreed with consensus transcriptions of the initial /r/ productions of the two videotaped reliability subjects. However, these two children consistently used [w] for /r/ substitutions, rather than distortions. On the other hand, a considerable portion of the training sessions for the clinicians was spent on the discrimination of /r/ variants.

Fricatives and Affricates

Labial and dental fricatives. Error distributions for the fricatives /f v θ ð/ are shown in Table 5. In this table and subsequent tables dealing with fricatives, some error categories are collapsed, for example, /s/-variants. Evidence of two very common childhood errors may be seen in the data for initial consonants in Table 5, namely use of stops for

TABLE 4. Distribution of children's errors in producing liquids. Frequency of use is expressed as percent of total responses to each target phoneme. (The stimulus words are shown in parentheses.)

Phoneme	Frequency of use					Phoneme	Frequency of use				
Age group	**30–80%**	**15–30%**	**5–15%**	**Occ.**	**Rare**	**Age group**	**30–80%**	**15–30%**	**5–15%**	**Occ.**	**Rare**
/l-/ (leaf, lightning)						/-l/ (bell, snail)					
2:0–3:0 (A: 40%)	w[a]	---	ø	j,d,t	z,v,n,*int, lab,vlr*	**2:0–3:0** (A: 15%)	*(rnd)*V[b]	---	ø	---	*(hi-frnt)*V, ln,ə
3:6–4:0 (A: 72%)	---	w	---	ø,j,r,n, *int*	θ,sʊl,bl	**3:6–5:0** (A: 50%)	*(rnd)*V[a]	---	---	ø,ə,*int*	wə,jo,ol,ɔl, Vl(*int*)
4:6–5:6 (A: 81%)	---	---	w	ø,j,n,*int*	r,fl,bl	**5:6–7:0** (A: 82%)	---	---	*(rnd)*V	ø,*int*	ə,*vlr,lab,* lg,ɔl
6:0–9:0 (A: 96%)	---	---	---	w,*int*	n,gl	**8:0–9:0** (A: 97%)	---	---	---	*int*	ʔ,*lab*
/r-/ (rope, rainbow)						/-ɚ/ (deer, car, spider, beard)					
2:0–4:0 (A: 22%)	w	---	*drh*[c]	ø,b,j,*lab, d–l*	m,l,w,r,br, pfw	**2:0–3:0** (A: 43%)	---	*(rnd)*V	ø,ə	*(hi-frnt)*V, *lab,drh,d–l*	k,ol,aI,io,ou, ʊə,jə,ɔɚ
4:6–6:0 (A: 65%)	---	w	*drh*	*lab,d–l*	ø	**3:6–7:0** (A: 95%)	---	---	*(rnd)*V	ø,ə,*lab, drh,d–l*	*(hi-frnt)*V,oI, aʊ,aI,io,ou, ʊə,ɔɚ,ɛɚ,əd
7:0–9:0 (A: 92%)	---	---	w[d]	*lab,d–l, drh,vlr*	*(vclss)*r	**8:0–9:0** (A: 96%)	---	---		*(rnd)*V,ø,*d–l*	ə,*lab,drh*
INTERVOCALIC /-l-/ (color)						/-r-/ (earring)					
2:0–3:0 (A: 38%)	---	ø	w[e],d[e]	j,dʒ,b *flp,int*	---	**2:0–3:0** (A: 25%)	w	ø	---	j,*lab,drh, d–l*	ʊ
3:0–4:0 (A: 73%)	---	w	d	j,*flp,int*	ʔ,n,θ,*lab*	**3:6–5:6** (A: 61%)	---	w	*drh*	*lab*	ø,*d–l*,aw, r>w,nr
4:6–6:0 (A: 83%)	---	---	w	d,ð,*int*	*flp*	**6:0–7:0** (A: 82%)	---	---	w	*lab,drh, d–l*	---
7:0–9:0 (A: 96%)	---	---	---	d,*int*	w,t,θ,ð, *flp*,ʔl	**8:0–9:0** (A: 96%)	---	---	---	w,*lab,drh, d–l*	---

Note. Occ. = occasional. A = estimated percent acceptable use. A guide to definitions, symbols, and abbreviations used in this table may be found in the Appendix.
[a]30–50%. [b]50–80%. [c]Age 2:6 only. [d]Concentrated in younger groups in this age range. [e]5–25%.

fricatives and use of [f] for /θ/. The process of stopping appears to affect initial fricatives primarily, except that [b] is often used for final /v/ as well as initial /v/. Stopping is more frequent for voiced than for voiceless fricative targets. Table 5 also shows that although stopping is the most commonly used process, substitution for a target fricative by another fricative is relatively common. In the case of initial /v/, the fricative is the cognate [f], whereas for other targets, substitution of a fricative at another place of articulation is relatively common. In fact, for final /f/ and /θ/ in both word positions, fricative substitutions (including [s]-variants, as well as [f] for the interdentals) are far more common than stop substitutions. Finally, the word *leaf,* which was used to elicit final /f/, often elicited [v], an error that was common in the older age group and rare at the younger ages. Presumably, children who used [v] in this context had overgeneralized from the plural form *leaves.*

Another noteworthy aspect of Table 5 is that the kinds of errors used for /θ/ and /ð/ are so different that one questions whether children treat these dental phonemes as cognates of each other. The most prominent errors for initial /θ/ are fricatives, but the most prominent errors for initial /ð/ are stops. That is, the [f] and variants of [s] are common for initial /θ/, but [v] and variants of [z] are only infrequently used for initial /ð/; instead, [d] is by far the most common error for initial /ð/.

Alveolar and palatal fricatives and affricates. Table 6 shows the error distributions for /s z ʃ tʃ dʒ/ in both initial and final position. For these fricatives and affricates, there are many prominent error types, but few of them occur with a frequency greater than 30%. Examination of Table 6 provides evidence of a number of common processes, although several are restricted in their scope of application:

- final consonant deletion in the youngest age groups, affecting fricatives more frequently than affricates.
- stopping of fricatives and affricates in the youngest age groups. As is evident for the more anterior fricatives, stopping occurs largely in initial position.
- devoicing of final voiced obstruents. This process is relatively frequent for both final /z/ and /dʒ/, although it also affects the initial fricative /z/.
- depalatalization of initial and final palatals (with manner preserved) is frequent for all palatals.
- for the affricates, deaffrication with preservation of the fricative is a common error only for the voiceless /tʃ/ (in both word-positions) and not for the voiced /dʒ/. Also for the affricates, there are prominent errors that reflect both depalatalization and deaffrication, for example, [s]-variants for /tʃ/, and these errors again are more common for /tʃ/ than for /dʒ/.

Although many common processes are evident in the error distributions from Table 6, there are other errors as well, such

TABLE 5. Distribution of children's errors in producing anterior fricatives. Frequency of use is expressed as percent of total responses to each target phoneme. (The stimulus words are shown in parentheses.)

Phoneme	Frequency of use					Phoneme	Frequency of use				
Age group	**30–80%**	**15–30%**	**5–15%**	**Occ.**	**Rare**	**Age group**	**30–80%**	**15–30%**	**5–15%**	**Occ.**	**Rare**
/f-/ (fish)						/-f/ (leaf)					
2:0–3:0 (A: 79%)	---	---	p/b	---	h,w,t,ʃ, dʒ,fw,bw	**2:0–2:6** (A: 55%)	---	(*dnt*)s[a]	ø,s	---	p,d,v,ft
3:6–6:0 (A: 95%)	---	---	---	---	p/b,w,ɸ,v,ʃ	**3:0–9:0** (A: 87%)	---	---	v	t	ø,p,ɸ,b,k, (*dnt*)s,s,fə
7:0–9:0 (A: 100%)	---	---	---	---	---						
/v-/ (van)						/-v/ (glove)					
2:0–3:6 (A: 45%)	b	---	f	m,w	β,p,bf	**2:0–4:0** (A: 65%)	---	b	f[a],ø[a]	ɸ,d	β,p,g
4:0–5:0 (A: 84%)	---	---	b	---	f,β,w	**4:6–9:0** (A: 90%)	---	---	b[a]	f	β,vf,*l–d stp*
5:6–7:0 (A: 95%)	---	---	---	---	b,βf						
/θ-/ (thumb, thunder)						/-θ/ (teeth)					
2:0–3:0 (A: 25%)	f	---	s-var, t/d-var	ø	p,k,h,l,w,fs, sw,fl	**2:0–3:0** (A: 15%)	s-var[a]	f	ø[a]	--- t-var	p,k,tθ,fp
3:6–5:0 (A: 53%)	---	f	s-var, t/d-var[a]	---	ø,h,l,w,fl,fr	**3:6–5:6** (A: 60%)	---	f	s-var[a]	---	ø,*lat*,ɸ,p, t-var,tθ,fs,st
5:6–9:0 (A: 87%)	---	---	f[a]	ø	s-var,t/d-var, *lat*,*pad*,dʒ,fl	**6:0–9:0** (A: 87%)	---	---	f[a]	---	s-var,ø,*lat*,t,tθ
/ð-/ (there)											
2:0–3:0 (A: 25%)	d[b]	---	---	b,v,j	ø,z,h,g						
3:6–4:0 (A: 56%)	d[c]	---	---	---	v,j,z,θ,w						
4:6–7:0 (A: 88%)	---	---	d[a]	---	t,b,v,j,ðə						
7:0–9:0 (A: 100%)	---	---	---	---	---						

Note. Occ. = occasional. A = estimated percent acceptable use. A guide to definitions, symbols, and abbreviations used in this table may be found in the Appendix.
[a]Concentrated in younger groups in this age range. [b]50–80%. [c]30–50%.

as deletion of initial /z dʒ/ by the youngest children. There are also important distortions. Chief among these distortions are dental, lateral, and post-alveolar[2] variants of all the alveolar and palatal fricatives and affricates.

The consonant /s/. In clinical settings, /s/ is perhaps the most frequently treated phoneme of all. Consequently, the frequency and developmental course of /s/ play a large role in clinical decision-making. The /s/ data are shown in detail in Figures 2 and 3, which illustrate the relative prominence of the most important errors on /s/.

Figure 2 shows the error distribution across age groups for initial /s/. Stopping errors are common only in the three youngest age groups. Dental distortions remain common throughout, although in the oldest age groups the use of dental distortions appears to have decreased to a plateau at about 10%. Lateral distortions generally remain at a low level throughout, as do post-alveolar distortions. The picture for final /s/ in Figure 3 is very similar, except that deletion rather than stopping is seen in the youngest groups.

Dentalizations of fricative targets are very common in these data, and it is important to note how dentalizations were defined. Dentalizations included both dental and interdental variants as well as substitutions transcribed as [θ ð]. No attempt was made to rate the severity of these distortions, so that a portion of them are actually mild or slight dentalizations rather than moderate or severe distortions.

These data, like the /r/ data, must be interpreted cautiously. A randomly selected group of 25 testers appeared to have very high levels of agreement with the consensus transcription of /s/ for the two videotaped reliability children. These children's productions were quite homogeneous, as the large majority of their /s/ productions were dentalized. However, a substantial proportion of the time spent training clinicians was devoted to the whole range of fricative and affricate distortions.

Rare errors in Table 6 include distortions, but when these were classed as "rare" for one group on one target, they usually occurred in greater numbers for other age groups producing that same target. Other than the distortions, the

[2]Post-alveolar distortion (*pad* in Table 6) was a category of error that could affect /s z ʃ ʧ dʒ/. The category was developed after preliminary study by three experienced transcribers showed that they could not reliably distinguish among retroflexed fricatives and other nonlateral, nondental distortions.

TABLE 6. Distribution of children's errors in producing non-anterior fricatives and affricates. Frequency of use is expressed as percent of total responses to each target phoneme. (The stimulus words are shown in parentheses.)

Phoneme	Frequency of use					Phoneme	Frequency of use				
Age group	30–50%	15–30%	5–15%	Occ.	Rare	Age group	30–50%	15–30%	5–15%	Occ.	Rare
/s-/ (sock, sun)						/-s/ (mouse, bus)					
2:0–3:0 (A: 59%)	---	*dnt*	t/d-var	*lat*	k,w,h,n,*pad*, ʃ,*ne*,st,ʃt,θj	**2:0–3:0** (A: 60%)	---	*dnt*	ø	f/ɸ,ʃ,*pad*,ts	ʔ,ə,t,k,*lat*,sf
3:6–5:6 (A: 70%)	---	*dnt*	---	t/d, ʃ[a], *pad*,*lat*	h,f,st	**3:6–5:6** (A: 72%)	---	*dnt*	---	*lat*,ts	ø,t,f/ɸ,ð,*pad*,ʃ
6:0–9:0 (A: 85%)	---	---	*dnt*	*lat*,*pad*	---	**6:0–9:0** (A: 84%)	---	---	*dnt*	*lat*,*pad*	z,sə,(*wh*s)z
/z-/ (zipper)						/-z/ (nose, hose)					
2:0–3:0 (A: 40%)	---	d	*dnt*,dʒ, *s/ts*	ø,w,ʒ, (*dnt*)s	j,*pad*	**2:0–3:0** (A: 43%)	---	s/ts	ø,*dnt*	d,*pad*,(*dnt*)s	ʔ,g,t,z,ʃ,dz,sv
3:6–5:6 (A: 65%)	---	---	*dnt*[a],s/ts	(*dnt*)s,d,*lat*	ø,h,w,j,l,*pad*,ʒ, dʒ,v,dəw, fw,ð,w,sl	**3:6–5:6** (A: 64%)	---	---	*dnt*,s/ts	(*dnt*)s,ʒ,dʒ, *lat*,*pad*	ø,d,t,f,(*lat*)s,sv
6:0–9:0 (A: 84%)	---	---	*dnt*	*pad*,s/ts	d,(*dnt*)s,*lat*,dʒ	**6:0–9:0** (A: 72%)	---	---	*dnt*,s/ts	ø,*pad*,(*dnt*)s	*ne*,*lat*,ʒ,(*lat*)s, dz
/ʃ-/ (sheep, shoe)						/-ʃ/ (fish)					
2:0–3:0 (A: 41%)	---	s-var[a]	t/d[a]	θ,tʃ,dʒ,*dnt*, *lat*,*pad*	h,w,k,sz,θj	**2:0–3:0** (A: 40%)	s-var (not *dnt*)	---	ø,(*dnt*)s	*dnt*,*lat*,*pad*	t,k
3:6–4:6 (A: 75%)	---	---	s-var	t/d,tʃ,θ,*dnt*, *lat*,*pad*	k,sj,se	**3:6–5:0** (A: 77%)	---	---	s-var (not *dnt*)	(*dnt*)s,*dnt*, *lat*,*pad*	t,tʃ,ʃə
5:0–9:0 (A: 90%)	---	---	---	s-var[a],tʃ, *dnt*,*lat*,*pad*	t/d,h,θ	**5:6–9:0** (A: 89%)	---	---	---	s-var,*dnt*, *lat*,*pad*	tʃ,(*dnt*)s
/tʃ-/ (chip, chair)						/-tʃ/ (watch)					
2:0–3:0 (A: 48%)	---	t/d	ʃ-var, ts-var	s-var,*dnt*, *lat*	w,k,*pad*, dz,tʃt	**2:0–3:0** (A: 45%)	---	ts-var	ʃ-var, s-var	ø,t-var,k, *dnt*,*pad*	ʔ,p,*lat*
3:6–4:6 (A: 78%)	---	---	ʃ-var	ts-var,s-var, t/d,*dnt*, *lat*,*pad*	dʒ,kl,tw	**3:6–5:0** (A: 75%)	---	---	ts-var	ʃ-var,s-var, *dnt*,t-var, *lat*,*pad*	ø,dʒ,ʃt
5:0–9:0 (A: 90%)	---	---	---	ʃ-var,s-var, *dnt*,*lat*,*pad*	*t/d*,*h*,*dʒ*,*tʃs*	**5:6–9:0** (A: 90%)	---	---	---	ʃ-var,ts-var, *dnt*,*lat*,*pad*	s-var,tʃə,t-var
/dʒ-/ (jam)						/-dʒ/ (cage, bridge)					
2:0–3:0 (A: 47%)	d	---	---	dz-var, s/z-var, ø,g,*lat*,tz	ʃ,ʒ,*dnt*	**2:0–3:6** (A: 55%)	---	---	tʃ-var, dz-var	ts-var[a],ø,d, g,s,z-var,ʒ, *dnt*,*lat*,*pad*	ŋg,t-var,k,ʃ, θ,dʒg
3:6–4:0 (A: 90%)	---	---	d	dz-var,s/z-var,ʒ,*dnt*	tʃ,*lat*	**4:0–5:0** (A: 79%)	---	---	---	tʃ-var,dz-var, z-var,tʃ,ʒ, *dnt*,*lat*,*pad*	ts-var,v,b,d,s
4:6–9:0 (A: 90%)	---	---	---	s/z-var, d,ʒ,*dnt*, *lat*,*pad*	dz-var,h,tʃ	**5:6–9:0** (A: 90%)	---	---	---	tʃ-var,*dnt*, *lat*,*pad*	dz-var,v, z-var,b,d,s,ʒ

Note. Occ. = occasional. A = estimated percent acceptable use. A guide to definitions, symbols, and abbreviations used in this table may be found in the Appendix.
[a]Concentrated in younger groups in this age range.

rare errors listed for a given target appear to be heterogeneous for any given age group; however, a degree of systematicity can be found by looking at these very infrequent productions across consonant targets. Glides and clusters with glides are substituted for all the word-initial targets except /dʒ/, for which only one glide appears. In the youngest groups, velar stops are used at least once for all these targets. A range of palatal variants is used for both /s z/. Between the ages of 2:0 and 5:6, labial fricatives ([f ɸ v fw sf sv]) occur for /s z/, but not for palatals. Finally, it should be noted that there are very few full assimilations of sounds ("nun" for *sun* is an exception), although a case can sometimes be made for partial assimilation, in which some but not all the features of a nearby sound are assimilated, for example, the labial feature in "wipper" for *zipper.*

Summaries

The following summaries reflect general tendencies and findings that apply to the error data. The summaries include limitations on the scope of phonological processes, prominent errors that do not yet have the status of phonological processes, and notations about rare errors.

Limitations on the scope of phonological processes. It is clear from these data that many of the phonological

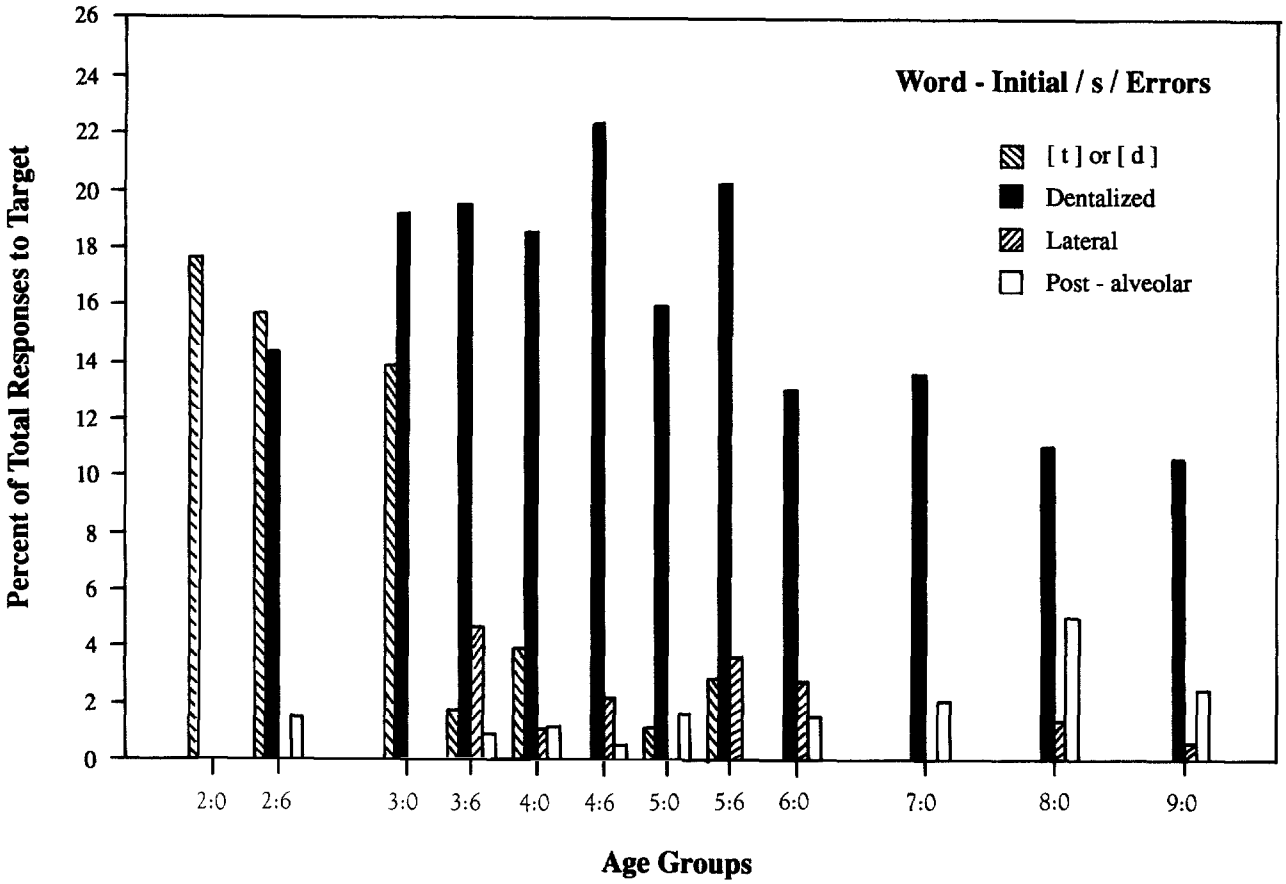

FIGURE 2. Distribution by age group of the most common errors used for word-initial /s/.

processes do not in fact apply to all consonants or word-positions to which they nominally could apply. These restrictions include the following:

- Prevocalic voicing is limited to stops, including stops that substitute for fricatives. If fricative manner is preserved in an error, then this process does not apply. Because in English, voicing of initial stop consonants is signalled by aspiration rather than voicing during the stop interval, a more appropriate name for this process is deaspiration of initial voiceless stops (Locke, 1983, p. 65).
- At the youngest ages, stopping is more prominent than other errors only for /f v ð z tʃ dʒ/ and not for /θ s ʃ/. Stopping occurs primarily in initial position, except in the case of final /v/, and stopping is used more frequently for voiced targets than for voiceless.
- In the youngest age groups, final consonant deletion applies 5–15% of the time for /p b t d f v θ s z ʃ/, but it occurs considerably less often for /k g tʃ dʒ/.
- Fronting of velar stops to alveolars is primarily, but not exclusively, a phenomenon affecting initial position in a word. In final position, fronting of the oral stops /k g/ is far less common than fronting of the nasal /ŋ/ (to [n]).[3]
- Deaffrication that results in maintaining a fricative applies only to /tʃ/ and not to /dʒ/.

[3]This error does not reflect colloquial use of [n] for /ŋ/ in progressive "-ing" verb forms because the target word was a noun: *wing*.

Two phonological processes appear to have application over the entire spectrum of consonants that might be affected, namely final consonant devoicing and depalatalization (fronting of palatals to alveolars).

Prominent errors that do not have the status of phonological processes. This summary includes a variety of errors that occur more than 5% of the time in at least one age range:

- Epenthesis (in this case, addition of a consonant) is a very common error for final /ŋ/ in all age groups. The added consonant is usually a velar. All other additions to consonant targets are rare, with the exception of additions that result in affrication.
- Devoicing of initial voiced consonants (substitution of the voiceless cognate) affects primarily /v z/, but not /ð dʒ/ and not stops. This error may have the status of a process because it affects more than one member of a class of phonemes. It should be noted that *partial* devoicing of initial voiced consonants was considered to be within the range of acceptable productions (see Smit et al., 1990, Appendix, p. 798).
- Distortions of /r ɚ/ are less prevalent than use of gliding or vocalization, but they still occur with some frequency. Of these, derhotacization is the most prominent. Derhotacization appears to have a developmental course, whereas labialization and derhotacization-labialization do not.
- The substitution of [f] for /θ/ occurs in both word-

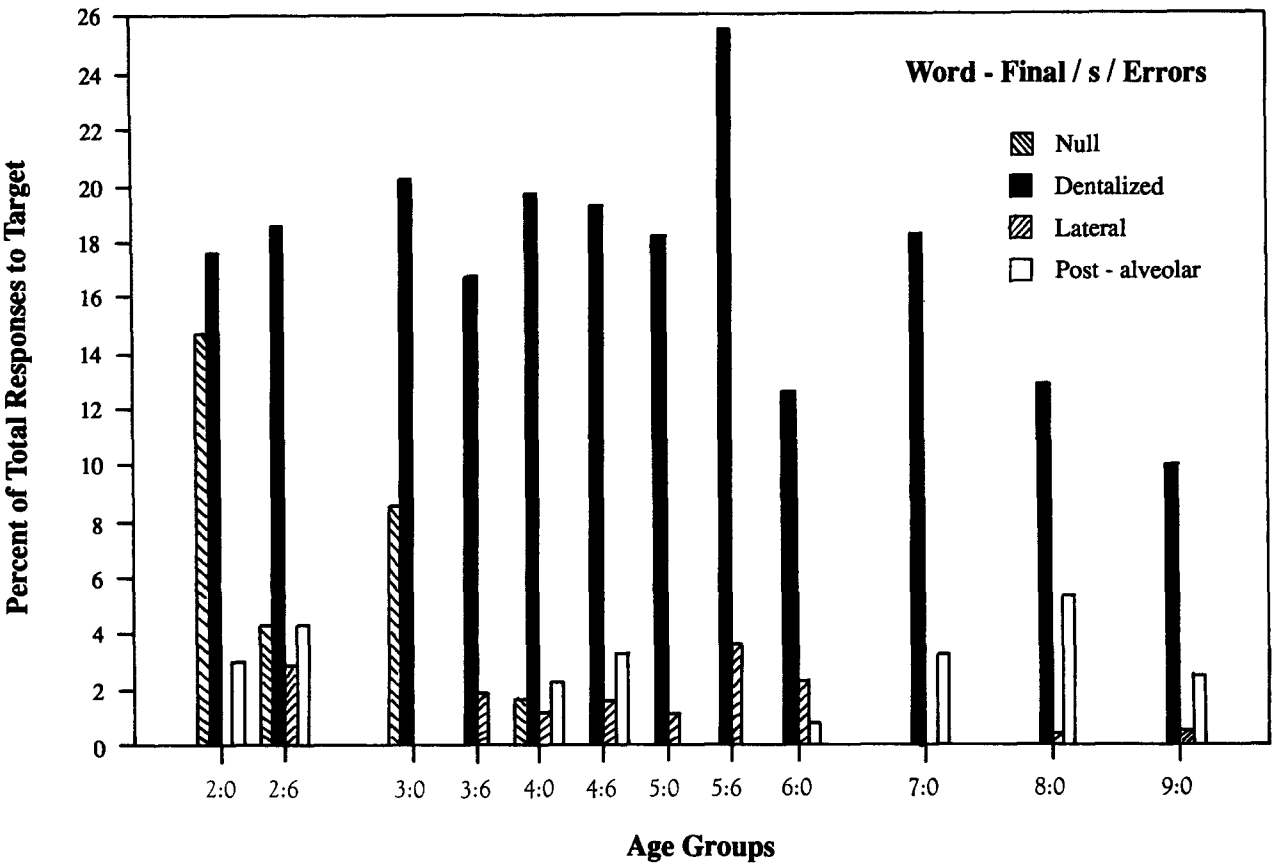

FIGURE 3. Distribution by age group of the most common errors used for word-final /s/.

positions with great frequency. Although some might consider that these errors represent a process called labialization, in fact, it applies to only one phoneme and not to a class of sounds.

- In the youngest age groups, deletion of initial consonants occurs at a rate of 5–15% for /h j l/ and occasionally (1–4%) for /w p r θ z dʒ/. Deletion is rare for the other initial consonants.
- Dentalization is by far the most common error for /s z/ over the age range studied. Dentalization, in contrast to lateralization and post-alveolar distortion, appears to be a developmental error, although even at age 9:0, dentalization is still used at a rate of about 10%.

Two additional points can be made about the prominent errors. First of all, for most cognate pairs, children make very similar errors on the cognates. However, children make very different types of errors for the cognates /θ ð/. Second, when a phoneme is assessed in both initial and final positions, there is usually a wider variety of errors in word-final position than in initial. The one exception is that initial and final /k/ are about equal with regard to variety of errors.

Atypical errors. The atypical errors used by children include both "rare" and "occasional" errors, and they are a heterogeneous group. Of course, some of the unusual errors represent error types that are common in another age range, for example, the use of [d] for initial /g/ in the oldest groups (Table 3). A few of the unusual errors actually represent the process of assimilation within the target word. The unusual errors are largely unpatterned except that many of them share at least one feature (place, manner, or voicing) with the target consonant. It is also interesting to note what does not occur. For example, replacement of a consonant with a glottal stop is very unusual for sounds other than final /t/, even in word-final position and even in the youngest groups. (Glottal replacement for final /t/ was considered to be an acceptable variant and so is not tabulated here—see Smit et al., 1990, Appendix, p. 798.)

Discussion

The Iowa-Nebraska data illustrate the range of English-speaking children's error productions when they are producing single words. At least one portion of the present data, that for children ages 6 to 7, is in general agreement with Snow's (1963) data on substitutions used by first-graders with respect to the types of errors made and their relative frequency. Differences from Snow's data appear to result from the use of narrow transcription in the present study. Partial corroboration of the Iowa-Nebraska error data comes also from a study by Preisser et al. (1988). Quantitative data on process use by the oldest children they studied (ages 2:2–2:5) are very similar to those of the youngest Iowa-Nebraska children. Further corroboration may be seen in work by Dyson (1988), who reported common elements in phonetic inventories of 2-

and 3-year-old children, and by Stoel-Gammon (1985), who reported inventories for children aged 15 to 24 months. These inventory elements correspond quite well to a listing of the common error phones used by the Iowa-Nebraska subjects.

The data tables show clearly that although a wide range of variants is possible for most phonemes, in fact, only one or two of these variants are commonly used for each phoneme target. These variants fall in the categories of glides and stops and early developing fricatives. Thus the common or typical variants used as error substitutions overlap the group of sounds used in early meaningful speech. These data, therefore, provide support for theories that emphasize the importance of a genetic component in phonological acquisition.

Not surprisingly, the Iowa-Nebraska data show that phonological processes account for a large portion of children's errors. The data also make clear that phonological processes sometimes apply differentially to particular phonemes and word positions. Finally, the data show that for some phonemes, nonprocess errors are as prominent as process errors.

It is important to note that the Iowa-Nebraska error data are language-specific and cannot be assumed to hold for other languages, even when the phonemes involved appear to be quite similar. For example, Bortolini and Leonard (1991) have presented information showing that the common substitutions for children acquiring Italian /l/ are [r n] and not [w]. Undoubtedly, such differences arise because of differences in the phonetic characteristics (which may be subtle) and in the phonologic function of similar speech sounds in different languages.

The Differential Application of Processes

Several authors have commented on the range of phonemes or word-positions over which children apply processes (Ingram, 1989; Locke, 1983, pp. 62ff). Their comments have been based largely on diary studies of children acquiring English as well as a variety of other languages. What has been lacking is a large data set that can be used to generate definitive statements about the application of processes in one language (in this case English).

The results showing differential application of the processes of stopping, final consonant deletion, fronting, and deaffrication can be exploited by clinicians who use a developmental model of treatment. For example, if a child's phonology includes deletion of all final obstruents, then the clinician may wish to begin intervention with final /k g tʃ dʒ/ rather than other obstruents, because in normal development, final consonant deletion affects these phonemes much less often.

Other Prominent Errors

Nonprocess errors. There are several very common errors that do not fit neatly into a process description because they are phoneme-specific and do not affect a class of sounds. The very common errors include the use of [f] for /θ/ in both initial and final positions and the addition of a velar stop to final /ŋ/. Both of these errors are so common that their use by any child younger than 8 or 9 years of age should no doubt be considered typical and developmental.

A potential phonological process. The Iowa-Nebraska data include a set of errors that might be described as a phonological process, but that have not usually been considered so, namely the devoicing of initial voiced fricatives. This devoicing process applies commonly to initial /v z/ and less often to /ð dʒ/. Devoicing of initial fricatives is by no means as common as the phonological processes of stopping or fronting, but it occurs often enough that in some age groups such devoicing should be considered normal. This process, which leads to the perception of voicelessness in initial position, is in contrast to the phonological process deaspiration of initial voiceless stops, which leads to the perception of voicing in the same word position.

Very few authors who report on children's speech mention devoicing of initial fricatives, although Locke (1983, p. 66) mentions that his reanalysis of Snow's (1963) data indicates that devoicing of fricatives in all word-positions is 26 times more frequent than stop devoicing. Devoicing of fricatives in all word-positions also appears to be common in adult speech. Haggard (1978) has reported research based on acoustic measures showing that the average extent of devoicing in adult spoken English ranges from 8% to 100%, depending on the phoneme and the context. Haggard posited that fricative devoicing is due to physiological and aerodynamic constraints. Such constraints would certainly be expected to affect children as well as adults. Initial fricative devoicing, then, may be a process in the same sense that final consonant devoicing is a process: Final consonant devoicing is seen in adults and in more extreme forms in children, and there are physiological explanations for it (e.g., Smith, 1979).

Distortions. Among the very common errors are two distortions: derhotacized variants of /r ɚ/ and dentalized variants of /s z/. Both kinds of distortions appear to follow a developmental course. In the case of derhotacization, it appears that a substantial minority of children as old as age 6 use this variant. Between the 2:0–3:0 and the 3:6–6:0 age ranges, there is an increase in derhotacizations and a decrease in [w]. This synchrony suggests that for some children, derhotacization may serve as one step in a sequence from early use of [w] for /r/ to later correct use of /r/. However, the present data are cross-sectional, and speculation about stages in /r/ acquisition must be confirmed in longitudinal studies.

In the case of dentalization, a reduction in proportion of children at older ages who use dental variants is clear (Figures 2 and 3), but dentalization errors continue at a rate of about 10% even in the oldest child groups studied. No information about the frequency of dentalizations in children older than 9 is available, but further reduction in the use of dentalization is probable, because only a small proportion of the general adult population exhibits such errors. Another factor to consider is that some of these dentalizations were noted by the testing clinicians but would not have been considered clinically significant because they were mild distortions.

/θ/ versus /ð/. The statement that children appear to treat /θ ð/ very differently in terms of patterns of error ([f] for /θ/, but [d] for /ð/) has been made by other writers (e.g., Moskowitz, 1975; Vihman and Greenlee, 1987). Moskowitz in particular attempted to explain these discrepancies, which she attributed to a kind of suppression that affects /θ/ greatly and /ð/ hardly at all. In her view, this situation arises because the child has learned to suppress [θ] after experimenting with [θ] phones as realizations of /t s f/, which are acquired before /θ/. In contrast, [ð] is acquired simultaneously with [z] and [v] and does not have a history of being suppressed. Consequently, the child is free to make articulatory approaches to /ð/, and these attempts are often in the form of stops, which have not previously been suppressed.

Instability of final consonant singles. The proliferation of error types for final consonant singles in very young children has been demonstrated and discussed for very young children by Moskowitz (1970) and for older children by Templin (1957). Instability in final position undoubtedly reflects the later acquisition of word-final consonants in the early word-learning phase of acquisition (Stoel-Gammon, 1985).

Atypical Errors

The Iowa-Nebraska error data generally corroborate the diary studies; that is, strong propensities in the error data correspond to strong propensities in the diary data. The present data also reinforce statements that several authors have made about rare events in phonology. For example, Locke (1983, p. 64) comments that substitution of palatals for alveolar fricatives is uncommon in normal acquisition (although common in phonological disorders). The Iowa-Nebraska data show that palatals substitute for /s z/ occasionally (in about 1–4% of attempts at these sounds), although in the youngest age range [dʒ] for initial /z/ occurs in 5–15% of attempts. Another example is a comment by Ingram (1989, p. 116) that the use of [l] for /s/ is very unusual; in the present data, liquids, glides, and clusters with liquids and glides are among the rare forms used for initial fricatives.

The most important clinical question about these data is whether some atypical errors should be regarded not only as mismatches with an adult model, but as forms representing deviance. There are certainly many atypical forms that appear in Tables 1–6, and some of them are unusual or even bizarre, for example, [w] for /s z/. Leonard's (1973) comment that children with phonological disorders exhibit not only the error patterns of younger normal children but also unusual errors suggests that the presence of nondevelopmental errors in a child's phonology may be a diagnostic sign of phonological disorder. On the other hand, Ingram's (1991) caveat about unusual patterns of production must be kept in mind. He pointed out that at present there is no theory of normal phonologic variation that allows one to distinguish between unusual, possibly deviant, errors in children with disordered phonology and comparable errors in normal children, who are viewed as linguistically creative. This conflict may, however, be resolved through the study of the fate of unusual errors when they occur in a young child with otherwise normal phonology and when they occur in a somewhat older child whose phonology may not be normal.

Although it is not the purpose of this report to develop a theory of normal phonologic variation, these data can constitute the basis for a quasi-statistical determination that an error form is or is not outside the normal range of variation. In most formal test instruments, the poorest scoring 5–10% at a given age level are judged to be outside of normal limits. When a comparable guideline is applied to the present data, a reasonable definition of productions that are inside and outside the normal range of variation would be as follows:

> Speech sound errors are considered to be typical if they occur at frequencies greater than 5% in one age range. Errors are candidates for consideration as atypical errors if they occur at frequencies no greater than "occasional" (i.e., less than about 5% of total responses) in Tables 2–6 except for the following:
>
> - Forms used at low frequencies by one age group but at higher frequencies by another age group should be considered typical. For example, in the 6:0–9:0 age range, [w] for /l/ is an occasional error, but it should still be considered a typical error at that age because this error variant is used extensively by younger children. Thus in the age range 6:0–9:0, [w] for /l/ would be a holdover of the gliding process, and the error type would be considered typical (although possibly not developmental).
> - Forms that appear to be due to assimilations within a test word should be ignored unless the assimilation appears to be part of a larger pattern of assimilations and the child is older than about 3 years of age. (Assimilations are seen most often in the younger age ranges—Stoel-Gammon & Dunn, 1985).

All other errors would be candidates for atypical status. Ideally, these atypical errors would be subject to longitudinal research to determine whether or not they self-correct. The present data, although they are cross-sectional, provide evidence about the potential for self-correction. For example, Figure 1 suggested that derhotacized variants of /r/ self-correct, but that the labialized and derhotacized-labialized variants do not.

Published data corroborate the cross-sectional findings about the developmental course of /s/-variants. The Iowa-Nebraska data show that lateral and post-alveolar variants persist at low levels throughout the age range studied, that is, they do not show a developmental course, whereas dentalizations decrease in frequency in older age groups. Stephens, Hoffman, and Daniloff (1986) followed changes in /s z/ production in groups of 5-year-old children who used dental, lateral, and bladed distortions. Dental and lateral distortions appear to have been defined much as they were in the Iowa-Nebraska study, although the definition of bladed errors is unclear (Stephens et al. may have included [ʃ] for /s/, which was not included with post-alveolar distortions in the present study). Of the three groups studied by these investigators, the children with dental and bladed productions showed a degree of spontaneous change to adult forms, but there was no change in the children with lateralizations. This finding is strong evidence that use of lateralized variants of

/s z/, which is atypical by the criteria stated above, is also not developmental. Unfortunately, there appear to be no other reports of longitudinal group studies that identify which errors might be developmental and which might not.

Clinical decisions about atypical errors. Having determined that an error is atypical and probably not developmental, the clinician faces the question of whether intervention is warranted. A very important consideration is that atypical or unusual errors tend to have disproportionate effects on intelligibility. Other considerations include the clinical indicators of potential for change (e.g., consistency across stimuli, stability over time, stimulability, and perceptual status of the target phoneme) and the child's and family's level of concern about the errors.

The clinician is also concerned about typical errors that may not be developmental. Certainly, typical errors that persist beyond the period when most children cease to make them may require treatment. However, if a child exhibits both typical and atypical errors, and none are considered to be developmental, the atypical errors may have higher priority for treatment because they usually pose a more serious impediment to intelligibility.

An example of clinical decision-making that makes use of error type as well as other considerations may be found in the recommendations of Smit et al. (1990) for dealing with distortions of /s z/. The recommendations include treatment before the age of 7 for lateralized variants, for other atypical variants, and for socially disapproved variants. For dentalized variants, the /s z/ should be evaluated together with clinical indicators (e.g., inconsistency, stimulability) at age 7. If treatment is not indicated at that time because the clinical indicators are positive, the clinician should re-evaluate at age 8 and again at age 9 if necessary.

Conclusions

The error data presented here show the range of English-speaking children's speech sound errors. These data confirm that there are constraints on certain common phonological processes such that they apply differentially to their nominal targets. It is also clear from these data that other types of errors, including distortions, occur very extensively for certain phonemes. Finally, a metric based on frequency of occurrence is proposed for deciding when an error is atypical, and the clinical application of this metric is explored.

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Appendix

Definitions

Occasional (Occ.): Used by a few groups in an age range with a frequency of 4–10% or by most groups in that age range at frequencies of 1–4%.

Rare: Occurs with a frequency of less than 3%, and in only a few groups in an age range.

Symbols

/	and/or	>	change during production
:	lengthened	( )	refers to adjacent symbol
+	plus	V	vowel
C	consonant	ɸ	phi, voiceless bilabial fricative
ø	null, deletion		
ʔ	glottal stop	β	beta, voiced bilabial fricative

Cə schwa release (considered to be an error only if it occurs for final voiceless obstruents)

Note: The symbols [p], [t], and [k] refer to voiceless aspirated stops when in initial position. The symbols [b], [d], and [g] refer to the cognate voiceless, unaspirated stops in initial position.

Abbreviations

err	errors
var	variants
dns	denasal
dnt	dentalized
drh	derhotacized
d–l	derhotacized and labialized
flp	flapped
hi-frnt	high front (vowel)
int	interdental
lab	labialized
lat	lateralized
l–d	labiodental
ne	nasally emitted
nsl	nasalized
pad	post-alveolar distortion
pal	palatalized
phar	pharyngealized
rnd	rounded
stp	homorganic stop
vcless	voiceless
vlr	velarized
whs	whistled