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# THE IOWA ARTICULATION NORMS PROJECT AND ITS NEBRASKA REPLICATION

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The purpose of the Iowa Articulation Norms Project and its Nebraska replication was to provide normative information about speech sound acquisition in these two states. An assessment instrument consisting of photographs and a checklist form for narrow phonetic transcription was administered by school-based speech-language pathologists to stratified samples of children in the age range 3–9 years. The resulting data were not influenced by the demographic variables of population density (rural/urban), SES (based on parental education), or state of residence (Iowa/Nebraska); however, sex of the child exerted a significant influence in some of the preschool age groups. The criteria used to determine acceptability of a production appeared to influence outcomes for some speech sounds. Acquisition curves were plotted for individual phoneme targets or groups of targets. These curves were used to develop recommended ages of acquisition for the tested speech sounds, with recommendations based generally on a 90% level of acquisition. Special considerations were required for the phonemes /ŋ s z/.

**KEY WORDS: articulation, phonology, development, normal, ages of acquisition**

Normative ages for speech sound acquisition have played an important role in the practice of speech-language pathology since the 1930s, when Wellman, Case, Mengert, and Bradbury (1931) and Poole (1934) first reported ages of acquisition for particular phonemes. In the mid-1950s Templin (1957) published her study of ages of phoneme acquisition, and in the 1970s two partial replications were reported (Arlt & Goodban, 1976; Prather, Hedrick, & Kern, 1975).

Normative ages for speech sound acquisition continue to be widely used, especially in school settings. Most states and/or school districts use guidelines based on such normative data to qualify children with phonologic delays or disorders for speech-language intervention. For example, the Nebraska Department of Education guidelines have allowed children to qualify for intervention services if they were one chronological year past the age of 90% acquisition for their error phoneme and if they exhibited a minimum number of phoneme errors.

In 1984 the Iowa Department of Education adopted as one of its top priorities the development of acquisition data for speech sounds that were both current and representative of the population of Iowa. Data collection for a normative study was carried out in Iowa during the 1985–86 school year in cooperation with the Department of Speech Pathology and Audiology at the University of Iowa. During 1987–88 the Nebraska Department of Education replicated the study on a smaller scale in cooperation with Kansas State University.

## METHOD

### *Subjects*

Children who participated in the study were within 2.5 months of the target age for the age groups 3:0, 3:6, 4:0, 4:6, 5:0, and 5:6 (years:months), or within 3.5 months of the target age for the age groups 6:0, 7:0, 8:0, and 9:0.[1] The children were monolingual and had normal hearing in at least one ear (25 dB HL at 500, 1000, 2000, and 4000 Hz) (ANSI, 1969) as assessed within 1 year of the speech sound test date. For school-age children, data from routine hearing screenings were available; however, most of the preschoolers had hearing assessments within a few weeks of the test date because data from routine screenings were not available. Although subjects were not limited to one racial background, only data from children speaking standard Midwestern dialect were included. Numerous public schools in widely dispersed regions of each state cooperated in locating subjects, as did public and private preschools serving the general population. In all cases, parental consent and information about the selection variables were obtained prior to testing.

If the testing clinician noted or knew of any potentially disabling condition, it was recorded on the assessment form. Data from children with such characteristics as motor speech involvement or repaired cleft were not

[1]Although children at the ages of 2:0 and 2:6 were also tested as part of the project, data from children in these two age groups will not be reported here because (a) the numbers were extremely small (17 and 35 subjects, respectively), (b) many children did not tolerate the test procedures, thus biasing the data toward those who could be tested in this manner, and (c) even those children who tolerated the entire test administration frequently refused to attempt particular words (see Smit, 1986). In addition, children in the 2:0 and 2:6 age groups were mostly female. By the age of 3:0, the youngest age level included in this report, virtually all children who began the testing procedure also completed it, and refusals to attempt particular words were rare.

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used, nor were data used if the clinician noted concerns about hearing status at the time of testing. Data from children who were receiving intervention for articulation were included up to the approximate proportion they represented in the population at their age level, based on data from the Iowa and Nebraska Departments of Education. That is, if parents returned a consent form for a child who was receiving intervention for articulation, that child was included in the pool of potential subjects. After data collection, if the proportion of such children was larger than proportions indicated by Department of Education data for a particular age group, subjects receiving intervention for articulation were eliminated randomly.

*Demographic variables.* An attempt was made to represent the population of each state on the basis of sex, population density (rural, small urban, large urban), and educational level of the parent (high school or less, 1–3 years beyond high school, 4 or more years beyond high school).[2] Data on these distributions were obtained from the 1980 United States Census (U.S. Bureau of the Census, 1980) for each state.

Subject selection took place in local special education service units according to a preassigned distribution based on the demographics of the region served by that unit. Whenever possible, children were selected as subjects on a random basis. However, if few consent forms were available to the service unit for children in a particular cell (for example, 4-year-old rural males whose parent had up to 3 years of education after high school), all potential subjects were tested, provided that they met the other subject criteria.

[2]The original design included a fourth level of parental education that was "did not complete high school" (estimated at 10–14% of the population). After data collection it was apparent that very few subjects in this stratum were obtained, and so the lowest stratum for education was combined with the next higher education level ("completed high school"). One probable reason for the paucity of such subjects is that the parent questionnaire asked the respondent to indicate the level of education of the parent with the greater amount of education. It is likely that a parent with less than a high school education had children with a person who completed high school. Another possible reason, and one that would unavoidably bias the results, is that parents with less than a high school education may not have returned questionnaires at the same rate as other groups. However, attempts were made specifically to locate and obtain permission from such parents.

Table 1 shows the number and sex of Iowa and Nebraska children in each age group. Table 1 also shows that in spite of extensive efforts by educational personnel in both states to find and test preschoolers from the whole range of demographic environments, some of the preschool groups were small. Information from the testing clinicians about these efforts suggested that locating young preschoolers was difficult, especially in rural areas where there were few preschools. Subsequent loss of potential preschool-age subjects occurred primarily because children either did not meet the criterion for normal hearing in one ear, or they were not available on the day they were to be tested.

## *The Assessment Instrument*

A single-word instrument was developed to assess all word-initial and word-final consonant singles except /ʒ/ and /-ð/, and with the addition of intervocalic /r l/, syllabic /l̩/, post-vocalic /ɚ/, and most word-initial consonant clusters. Some phoneme targets were elicited in two, three, or four words, while in some words both initial and final sounds were transcribed.[3] Vowel productions were not

[3]The /ʒ/ was not included because it is rarely used by speakers of Midwestern dialect. The word-final /ð/ was not assessed because of its rarity in English words, because words containing /ð/ tend to be difficult to picture, and because such words are not likely to be known by most of the children in the age range sampled.

The assessment instrument included samples of most, if not all, of the phonologic processes mentioned in the literature, usually with four or more instances of potential application and never less than two instances (McReynolds & Elbert, 1981). Potential assimilations were also assessed, together with controls for each.

Multiple test items occurred for some targets because of the number of items needed to satisfy criteria for use of phonologic processes and because of the need for control items for potential assimilations. Multiple items were also included in order to assess word-to-word consistency across the phoneme range used in English. Multiple samples were obtained for targets frequently in error (liquids and alveolar and palatal fricatives). Additionally, multiple test items were included for at least one member of every major sound class in initial position and in final position.

Intraword consistency was also assessed (in Iowa children only) by having each child repeat five to seven items at the end of the test. Finally, approximately one tenth of the subjects

TABLE 1. Number and sex of Iowa and Nebraska children in each age group (age expressed in years:months).

| | *Age groups* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *State* | *3:0* | *3:6* | *4:0* | *4:6* | *5:0* | *5:6* | *6:0* | *7:0* | *8:0* | *9:0* |
| Iowa | | | | | | | | | | |
| Male | 18 | 19 | 39 | 31 | 31 | 18 | 25 | 35 | 33 | 25 |
| Female | 16 | 16 | 29 | 35 | 32 | 21 | 28 | 26 | 26 | 29 |
| Nebraska | | | | | | | | | | |
| Male | 7 | 10 | 15 | 13 | 19 | 29 | 47 | 38 | 35 | 27 |
| Female | 6 | 10 | 8 | 16 | 13 | 24 | 40 | 36 | 36 | 36 |

assessed because of evidence that vowel errors are rare by the age of 3:0 (Templin, 1957).

The assessment instrument used photographic stimuli in order to increase the probability that children would spontaneously identify the picture using the intended name (Harrington, Lux, & Higgins, 1984). For the same reason, the pictures were arranged by semantic category, for example, animals and vehicles. In developing the photographic stimuli, multiple photographs of each item were taken and then presented to a representative group of children. The photograph most often named correctly was chosen for the assessment instrument. The assessment instrument included 80 photographs and 108 phoneme targets. A standard elicitation sequence was used in order to avoid a direct imitation by the child unless a production could not be obtained otherwise.

### *Transcription System*

The testing clinicians used a narrow transcription system based on Shriberg and Kent (1982), with modifications that included a category of post-alveolar distortions of /s z ʃ tʃ dʒ/. A preliminary study by a group of three experienced transcribers suggested that they could not reliably distinguish among retroflexed fricatives and other nonlateral, nondental distortions. Other modifications to the Shriberg and Kent system were the introduction of the words "light" and "dark" to describe the two most common allophones of /l/, and the addition of "nasal release," usually applicable to word-final obstruents.

The testing clinician recorded the child's responses on a checklist form, a portion of which is shown in Figure 1. The checklist format was used to increase reliability of transcription by reducing the memory load required for narrow transcription symbols. The checklist for each phoneme contained the options of a fully correct production and probable substitutions (based largely on work by Snow, 1963), distortions, or other variants. The clinician circled the number for each relevant symbol or descriptor. An "Other" box to the right of the form allowed the clinician to note productions for which the listed options were not appropriate.

### *Data Entry and Tabulation*

Item numbers and numerical codes for responses indicated by the clinicians were entered into computer files. Prior to data entry, all responses noted in the "Other" box had been assigned appropriate numerical codes. In order to locate data entry errors, each assessment form was entered twice, on the assumption that data input errors were unlikely to be entered in exactly the same way twice. The two versions were compared using computer software to find discrepant entries, which were then checked against the original scoring form and corrected.

### *Definition of Acceptable Responses*

Children's responses were judged to be "acceptable" if (a) they were recorded as fully correct by the testing clinicians, or (b) they were not fully correct but were in a category considered "marginal." In general, the following types of responses were considered marginal:

1. Variants that might occur in adult speech under some circumstances, for example [ʔ] for /-t/.
2. Variants not likely to be noticed by an untrained listener or to affect intelligibility or word meaning, for example, dentalized /t d n l/ (although interdental variants were considered to be errors because of the distracting visual component).
3. Variants likely to be the result of producing a word in citation form, for example, unreleased final stops.
4. Variants likely to occur in emphatic productions, for example, affricated initial /ð/.
5. Variants likely to be intermittent, for example, weak production of a fricative.

The responses we considered to be marginal were generally phone types that Shriberg, Kwiatkowski, and Hoffman (1984) annotated in their transcription system with nonerror diacritics. A summary of the most frequent marginal responses used by Iowa-Nebraska children at different age levels is shown in the Appendix. It should be noted that although lack of a recorded response was treated as an error, such instances were rare.

### *Clinicians and Their Training*

The speech-language pathologists who were trained to use the transcription system and the test instrument were all employed in the public schools, had at least one year of professional experience, and had been recommended by their supervisors to participate in transcription training. The clinicians who actually performed the testing were selected from this larger group of clinicians after training had been completed.

The clinicians received 5 or 6 hours of training from authors Smit and/or Hand using videotaped training materials to teach the transcription system, to provide practice, and to assess interjudge reliability. The reliability videotapes consisted of two children saying the test items, one a 3-year-old girl with normally developing speech and language, and the other an 8-year-old boy with moderate-to-severe impairment of speech. Three persons who were experienced with the transcription system developed narrow transcriptions by consensus for each of the two reliability subjects.

The testers were selected from the larger group of trained clinicians on the basis of the following criteria: (a) a minimum of 70% agreement with the consensus transcription for each of the 2 reliability subjects, and (b) a

provided a spontaneous speech sample by talking about action photographs in which some of the test items were featured. Data relating to all these special features of the assessment instrument are currently being analyzed.

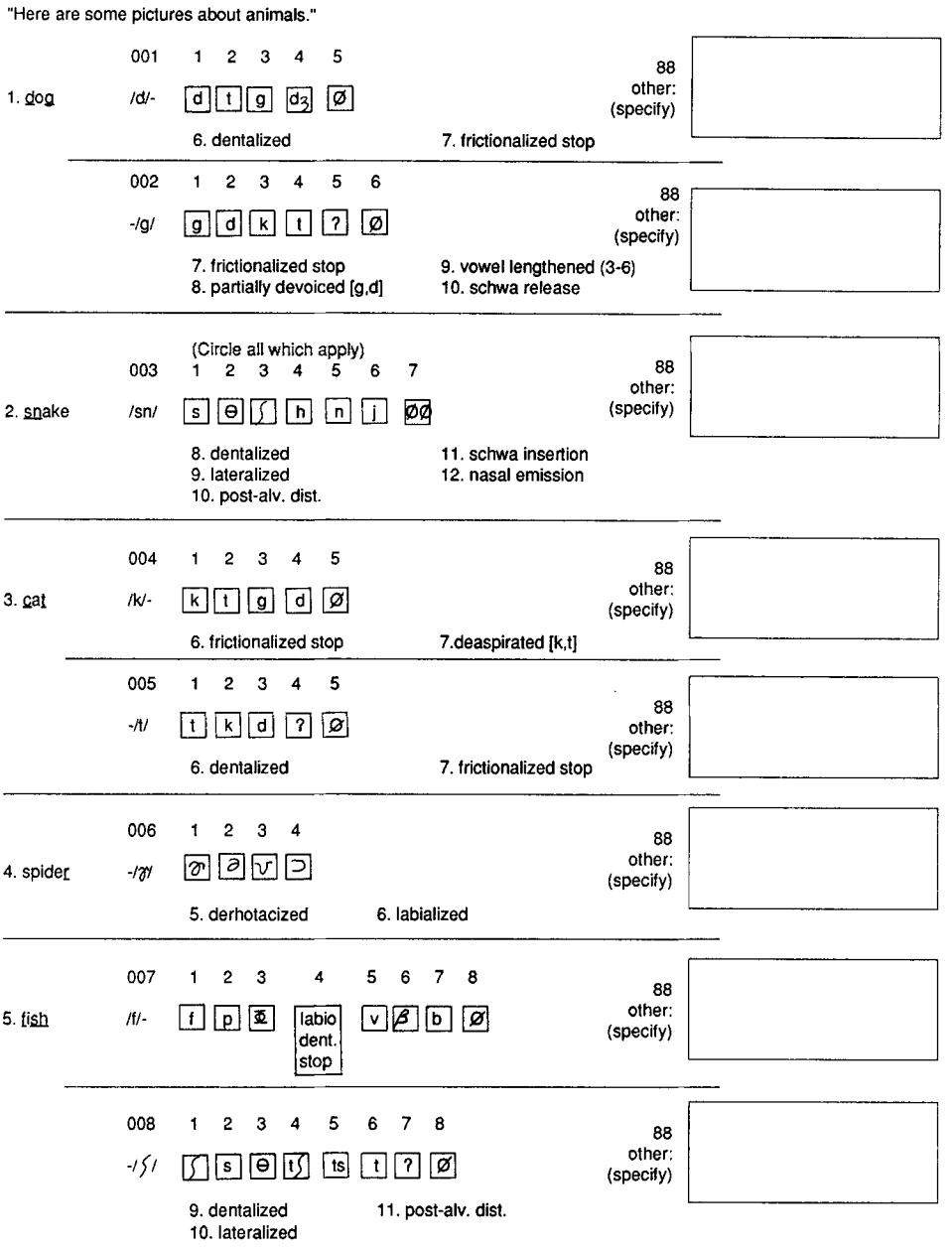


FIGURE 1. Portion of checklist transcription form used for the Iowa-Nebraska Articulation Norms Project.

minimum average of 72.5% agreement over the 2 reliability subjects.[4]

In Iowa approximately 300 clinicians participated in training; in Nebraska, approximately 100 participated. Reliability data on the 160 clinicians who were selected to serve as testers are shown in Table 2. It might be noted that only one third of those trained in Iowa qualified as testers, compared to two thirds of the clinicians in Nebraska. The discrepancy probably resulted from an upgrading of the video training and reliability materials prior to the Nebraska replication.

The reliability data in Table 2 represent point-to-point agreement with a consensus transcription. In order to estimate how reliable the testers were in judging that an acceptable response was acceptable and that an error

[4]In making these tallies, certain distinctions recorded by clinicians were collapsed. Dentalized /s z/ and /θ ð/ were treated as equivalent when these variants were recorded for /s/ and /z/ targets, respectively. With respect to word-final voiced obstruents, partial devoicing and full devoicing with preceding vowel lengthened were also treated as equivalent. Preliminary study showed in each case that while these fine distinctions were not agreed upon, there was general agreement that a dental variant had been used for /s/, or that a word-final obstruent had undergone some degree of devoicing.

response was an error, we examined the reliability transcriptions of 25 testing clinicians who were selected randomly from the larger group of testers. Their level of agreement with the consensus transcriptions was determined for acceptable responses and for error responses. For the normal 3-year-old who served as a reliability subject, these 25 clinicians' mean point-to-point agreement with the consensus transcriptions was 76%, and their mean agreement on acceptable responses was 94% of 100 acceptable responses. These clinicians also coded 11% of 43 error responses as acceptable, on average. For the 8-year-old child who served as a reliability subject, the mean point-to-point agreement with the consensus transcription was 74% for this group of testers. This group's mean level of agreement that acceptable responses were acceptable was 96% of 70 responses. These 25 clinicians also coded acceptable responses for 15% of the child's 73 errors, on average. These figures were regarded as reasonable for the measures used in the present study.

### *Data Analyses*

*Total scores.* For each child a total score on the assessment instrument was computed on the basis of acceptable responses. The total score was weighted for the number of times a given phoneme occurred in a given word position. For example, a child's score for /p-/ was 1.0 if he used an acceptable production for the single /p-/ item. On the other hand, the test item /d-/ was assessed in three different words, and if a child used acceptable responses for only two of the three /d-/ tokens, then her score for /d-/ was .67. The maximum total score was 75.

*Group performance on phoneme targets.* The percentage of acceptable responses to each phoneme target was calculated for each age group or age-by-sex group. The group data were graphed over the age range tested to produce acquisition curves.

## RESULTS

### *Results Based on Total Scores*

*Validation.* In order to validate the ages of acquisition reported in this study, total scores on the assessment instrument were plotted against age for boys and girls separately (Figure 2). These curves were compared in a general way with the earlier data of Templin (1957) as plotted in Figure 3.

Figure 2 shows the mean total scores for Iowa-Nebraska girls and boys plotted against age group. As would be expected, curves for both girls and boys were characterized by a rapid increase in total score in the youngest age groups, followed by a more gradual rise up to age 9:0. However, there was a notable difference between the curves for the two sexes. The girls' curve was essentially monotonic, while the boys' curve appeared to reach a plateau between the ages of 3:6 and 4:0 or 4:6.

Figure 3 shows comparable total score data taken from Table 4 of Templin's (1957) monograph. The curves for Templin's data were quite similar in shape to the curves plotted in Figure 2 for the Iowa-Nebraska data. Templin's data also exhibited a clear plateau in the boys' curve (although the plateau began a half year later in Templin's data).

A final point relevant to validation is that the variability of scores on many measures related to speech motor development typically decreases with increasing age (Kent, 1976). In the Iowa-Nebraska data the standard deviations of total scores decreased monotonically as age increased, from 16.0 for girls at 3:0 to 4.4 for girls at 9:0, and from 15.2 for boys at 3:0 to 5.1 for boys at 9:0.

*Effects of demographic variables.* For each demographic variable (state, population density, parental education, and sex) analysis of covariance (ANCOVA) was performed with total score as the dependent variable and with age group as the covariate, using BMDP software (Dixon, 1988). Table 3 shows the results of these ANCOVAs. The only demographic variable of significance was sex of the subjects. Subsequent *t* tests between boys and girls in each age group indicated differences significant at the .05 level for children in the age groups 4:0, 4:6, and 6:0.

Based on the negative results from the ANCOVAs, the data from Iowa and Nebraska were combined, data from rural and urban environments were combined, and data from the different levels of parental education were combined. Acquisition data for each speech sound were kept separate for boys and girls in the age groups 3:0 through 6:0 because of the significant differences between the sexes in some of the younger age groups. However, in the age groups 7:0 through 9:0 the acquisition data for boys and girls were combined, with weights applied for the relative numbers of boys and girls in each group.

TABLE 2. Number of testing clinicians, their median years of clinical experience, and the mean and range of their percent agreement with the consensus transcription for the 2 children featured in videotaped reliability samples.

| State | Number of clinicians | Median years experience | % agreement (normal 3-year-old) | | % agreement (disordered 8-year-old) | |
|---|---|---|---|---|---|---|
| | | | *M* | *Range* | *M* | *Range* |
| Iowa | 101 | 9[a] | 76.4 | 70–83 | 73.9 | 70–84 |
| Nebraska | 59 | 11 | 78.2 | 70–86 | 75.3 | 70–87 |

[a] Based on the responses of 60 Iowa clinicians who returned a follow-up questionnaire.

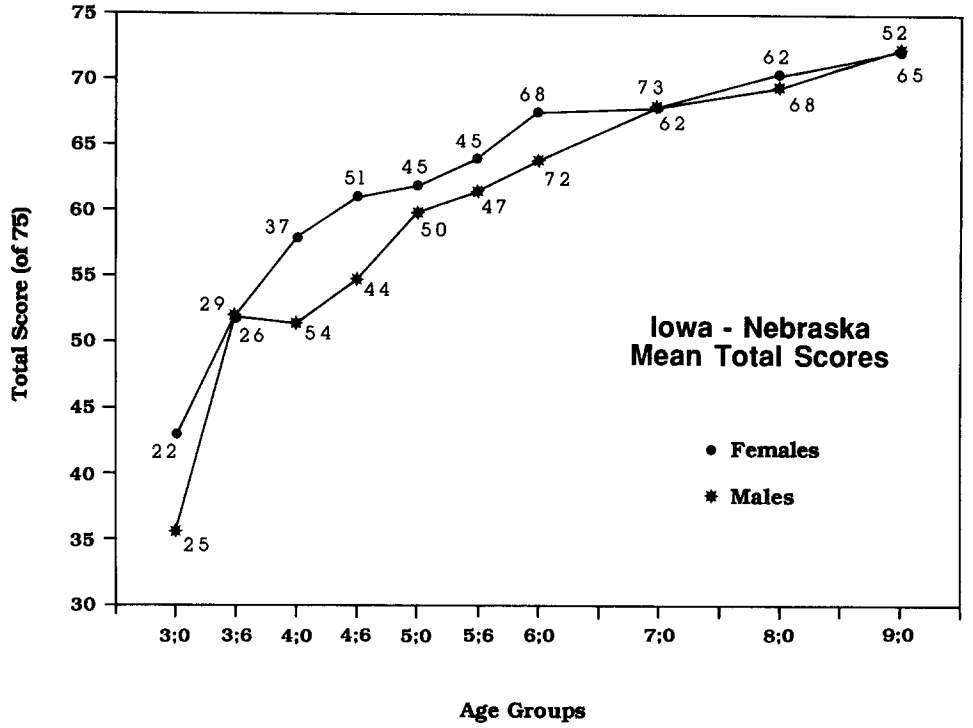


FIGURE 2. Mean total scores by age (in years and months) and sex on the assessment instrument used in the Iowa-Nebraska Articulation Norms Project. The number near each data point indicates the *n* for that mean.

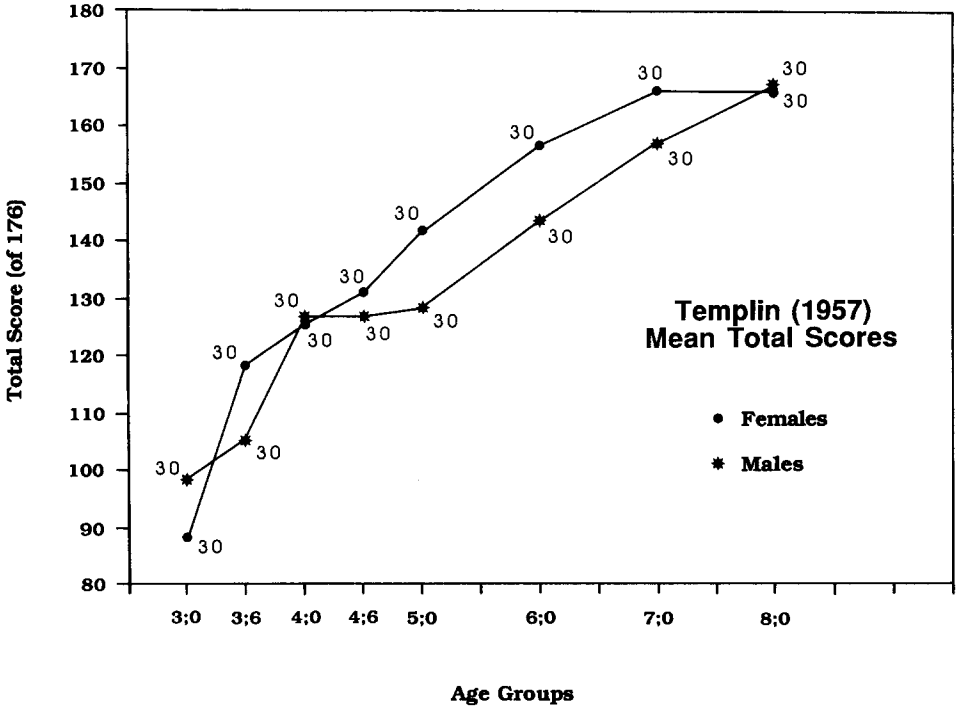


FIGURE 3. Mean total scores by age (in years and months) and sex on the assessment instrument used by Templin (1957), the *Templin-Darley Tests of Articulation* (1969). The number near each data point indicates the *n* for that mean.

TABLE 3. Results of analyses of covariance for state, population density, parental education, and sex, with age group as the covariate.

| *Variable* | *F* | *df* | *p* |
|---|---|---|---|
| State (Iowa/Nebraska) | .2929 | 1, 994 | .583 |
| Population (rural/small urban/ large urban) | .4747 | 2, 993 | .616 |
| Parental education (≤HS, 1–3 college, ≥4 college) | 1.9689 | 2, 993 | .150 |
| Sex | 11.4349 | 1, 994 | .001* |

*Significant at .05.

### *Performance on phoneme targets*

Table 4 shows the performance of each age group on individual phoneme targets based on the acceptable responses produced by the children in each group. Table 4 shows that nasals, glides, and stops reached high levels of accuracy at young ages. Fricatives, affricates, and liquids reached comparable levels of accuracy at later ages, and clusters still later.

### *Comparisons with Templin (1957)*

Table 5 compares the Iowa-Nebraska data on consonant singles (using the age at which 75% accuracy was first reached) to findings from Templin (who reported 75% acquisition ages). The Iowa-Nebraska data generally showed 75% acquisition at ages equal to or younger than ages reported by Templin. Major exceptions were /ŋ/ and /r/, which reached the 75% criterion relatively late in the Iowa-Nebraska data.

Table 6 is a comparison of the Iowa-Nebraska data on word-initial clusters with Templin's data on the same clusters. It should be noted that Templin's 75% ages of acquisition for clusters were generally earlier than her reported ages of acquisition for component consonant singles; however, in the Iowa-Nebraska data, clusters tended to reach the 75% criterion at the same age as or later than the age at which the later-developing component single reached criterion. For example, girls first used 75% acceptable /s/ at age 3:0, but achieved comparable levels of accuracy for two-element /sC-/ clusters in the age range 4:6–6:0.

### *Graphic Presentation of the Iowa-Nebraska Data*

Figures 4–30 are graphic representations of acquisition levels by age for many of the speech sound targets assessed in the Iowa-Nebraska project. Not included are phonemes that reached 90% levels of acquisition by age 4:0 (see Table 4). Figures 4–30 may be regarded as acquisition curves for target phonemes or clusters. The following features of these curves are important for their interpretation:

1. In most of the curves for single phonemes, the mean of the group performance on word-initial and word-final targets was represented; however, when very different patterns of acquisition were seen for initial and final targets, they were presented separately.
2. For all singles except /θ/ the data from boys and girls were combined in the age groups 7:0–9:0. For /θ/ there were large differences between girls and boys in this age range, and so separate curves were presented.
3. Curves for related phonemes or groups of clusters have been combined in cases where curves clearly overlapped and where the combining of curves would not misrepresent the data.
4. On each curve, lines representing the 75% level and the 90% level of acceptable production have been indicated as aids to interpretation.

These curves were frequently not smooth, and often they were not monotonic. Nevertheless, they tended to represent certain general trends in the data. All the curves generally showed increases in level of performance with age. Also, the curves shown for boys were generally lower than those for girls, although major exceptions occurred for /r/ and for /Cr-/ clusters at the middle age levels.

The acquisition curves for clusters suggested a trend related to the plateau noted in boys' total scores shown in Figure 2, a plateau that began at age 3:6. The large majority of cluster curves also showed either a plateau or a dip in the boys' performance beginning at age 3:6. Comparable plateaus or dips were seen in only a few of the curves for consonant singles. Because clusters represented 27 of the 75 points on the Iowa-Nebraska test instrument, they had a strong influence on total scores.

## DISCUSSION

### *Demographic Variables*

An unexpected finding was that demographic variables other than sex had no significant effects on these data. Although Templin (1957) had reported that upper-socioeconomic-status (SES) children performed significantly better than lower SES children in her sample, SES had no significant effect on these data. Differences between the two studies may have had a role in the different outcomes: Templin's measure of SES was paternal occupation, and all her subjects lived in a large city, whereas in the present study the measure of SES was parental education, and children were drawn from both rural and urban environments.

The selection variable of population density (rural, small urban, large urban) also failed to influence these data. A recent study by Coleman, Ganong, Clark, and Madsen (1989) suggested that rural and urban parents have differing emphases in childrearing. Rural parents see themselves as fostering intellectual and emotional development to a greater extent than do urban parents, while urban parents emphasize social development more than rural parents. Differences of this kind in parents'

TABLE 4. Percentages of responses to each target that were considered "acceptable."

| Phoneme (# of test items) | Age[a] group | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3:0 | | 3:6 | | 4:0 | | 4:6 | | 5:0 | | 5:6 | | 6:0 | | 7:0[b] (n: F = 62 M = 73) | 8:0[b] (n: F = 62 M = 68) | 9:0[b] (n: F = 65 M = 52) |
| | F (n = 22) | M (n = 25) | F (n = 26) | M (n = 29) | F (n = 37) | M (n = 54) | F (n = 51) | M (n = 44) | F (n = 45) | M (n = 50) | F (n = 45) | M (n = 47) | F (n = 68) | M (n = 72) | | | |
| m- | 91 | 100 | 100 | 100 | 97 | 100 | 98 | 100 | 100 | 98 | 100 | 100 | 100 | 96 | 100 | 98 | 99 |
| -m (2) | 89 | 92 | 98 | 98 | 96 | 98 | 100 | 98 | 100 | 98 | 97 | 99 | 99 | 94 | 98 | 97 | 98 |
| n- | 82 | 100 | 100 | 97 | 97 | 98 | 100 | 93 | 98 | 98 | 100 | 100 | 100 | 94 | 99 | 98 | 98 |
| -n (2) | 80 | 90 | 100 | 95 | 93 | 95 | 99 | 94 | 98 | 97 | 100 | 98 | 99 | 96 | 99 | 97 | 99 |
| -ŋ | 50 | 72 | 69 | 66 | 70 | 70 | 73 | 66 | 73 | 72 | 82 | 72 | 81 | 75 | 72 | 82 | 88 |
| h- (2) | 98 | 90 | 96 | 100 | 96 | 94 | 99 | 98 | 100 | 100 | 100 | 100 | 100 | 99 | 100 | 100 | 100 |
| w- (2) | 100 | 94 | 96 | 100 | 99 | 97 | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 99 | 100 | 100 | 100 |
| j- | 59 | 68 | 77 | 93 | 95 | 81 | 92 | 84 | 93 | 92 | 100 | 96 | 97 | 94 | 99 | 100 | 100 |
| p- | 95 | 88 | 100 | 97 | 97 | 96 | 98 | 98 | 100 | 92 | 100 | 96 | 100 | 99 | 100 | 100 | 99 |
| -p (2) | 93 | 94 | 98 | 100 | 99 | 97 | 98 | 99 | 99 | 94 | 100 | 99 | 96 | 98 | 97 | 98 | 98 |
| b- (3) | 98 | 99 | 100 | 100 | 100 | 99 | 99 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| -b | 91 | 92 | 88 | 97 | 95 | 89 | 98 | 93 | 100 | 94 | 98 | 98 | 99 | 94 | 99 | 99 | 98 |
| t- | 95 | 88 | 92 | 93 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 100 | 100 | 99 | 99 | 100 | 100 |
| -t (3) | 85 | 80 | 82 | 87 | 91 | 93 | 90 | 95 | 87 | 92 | 90 | 91 | 93 | 90 | 95 | 96 | 95 |
| d- (3) | 97 | 95 | 99 | 100 | 98 | 98 | 100 | 98 | 100 | 99 | 100 | 100 | 99 | 99 | 99 | 99 | 100 |
| -d | 91 | 80 | 96 | 93 | 97 | 96 | 96 | 100 | 98 | 96 | 98 | 96 | 97 | 93 | 99 | 98 | 100 |
| k- (3) | 77 | 76 | 92 | 89 | 100 | 90 | 99 | 95 | 99 | 91 | 100 | 99 | 100 | 99 | 99 | 99 | 100 |
| -k (3) | 92 | 97 | 94 | 92 | 99 | 97 | 97 | 98 | 99 | 99 | 99 | 99 | 100 | 98 | 99 | 99 | 100 |
| g- (2) | 82 | 80 | 92 | 88 | 100 | 93 | 96 | 98 | 100 | 96 | 100 | 100 | 100 | 98 | 98 | 99 | 100 |
| -g (2) | 82 | 90 | 88 | 88 | 96 | 93 | 96 | 92 | 99 | 98 | 97 | 96 | 96 | 94 | 96 | 97 | 97 |
| f- | 86 | 64 | 92 | 93 | 100 | 96 | 100 | 100 | 98 | 96 | 100 | 98 | 100 | 100 | 100 | 100 | 100 |
| -f | 82 | 72 | 77 | 86 | 81 | 76 | 76 | 84 | 78 | 88 | 93 | 94 | 91 | 90 | 96 | 97 | 99 |
| v- | 41 | 52 | 62 | 66 | 78 | 76 | 90 | 80 | 91 | 84 | 98 | 96 | 99 | 94 | 99 | 99 | 100 |
| -v | 64 | 56 | 54 | 66 | 86 | 72 | 90 | 75 | 87 | 86 | 91 | 91 | 93 | 90 | 95 | 99 | 97 |
| θ- | 30 | 34 | 50 | 43 | 59 | 44 | 68 | 56 | 71 | 56 | 78 | 60 | 93 | 78 | 91 | 98 | 100 |
| -θ | 27 | 24 | 54 | 38 | 59 | 48 | 67 | 50 | 71 | 54 | 82 | 77 | 91 | 78 | 90 | 96 | 98 |
| ð- | 32 | 20 | 58 | 52 | 76 | 43 | 90 | 64 | 91 | 74 | 98 | 87 | 97 | 83 | 96 | 100 | 100 |
| s- (2) | 75 | 48 | 75 | 71 | 69 | 71 | 74 | 69 | 83 | 79 | 81 | 69 | 89 | 79 | 86 | 85 | 90 |
| -s (2) | 77 | 46 | 79 | 83 | 72 | 64 | 77 | 70 | 83 | 79 | 77 | 66 | 87 | 79 | 79 | 83 | 90 |
| z- | 41 | 44 | 50 | 69 | 54 | 65 | 71 | 68 | 76 | 64 | 80 | 64 | 84 | 75 | 81 | 88 | 92 |
| -z (2) | 48 | 38 | 65 | 47 | 58 | 59 | 60 | 66 | 76 | 69 | 69 | 63 | 83 | 75 | 80 | 80 | 87 |
| ʃ- (2) | 68 | 44 | 75 | 69 | 88 | 70 | 85 | 76 | 86 | 87 | 89 | 81 | 90 | 88 | 94 | 94 | 97 |
| -ʃ | 64 | 44 | 69 | 69 | 86 | 70 | 86 | 66 | 84 | 86 | 80 | 85 | 90 | 88 | 94 | 92 | 99 |
| tʃ- (2) | 66 | 42 | 67 | 67 | 80 | 69 | 87 | 77 | 89 | 89 | 90 | 82 | 91 | 89 | 91 | 96 | 98 |
| -tʃ | 64 | 36 | 69 | 66 | 76 | 78 | 88 | 73 | 80 | 82 | 89 | 85 | 93 | 89 | 93 | 95 | 95 |
| dʒ- | 73 | 52 | 73 | 72 | 86 | 78 | 90 | 80 | 91 | 88 | 91 | 89 | 94 | 92 | 96 | 95 | 98 |
| -dʒ (2) | 61 | 46 | 77 | 69 | 74 | 73 | 86 | 76 | 83 | 84 | 86 | 85 | 90 | 87 | 93 | 97 | 95 |
| l- (2) | 77 | 36 | 79 | 69 | 82 | 58 | 86 | 75 | 93 | 74 | 94 | 86 | 98 | 96 | 97 | 98 | 100 |
| -l (2) | 36 | 14 | 54 | 38 | 53 | 49 | 75 | 53 | 64 | 64 | 86 | 74 | 90 | 76 | 90 | 96 | 98 |
| -l̩ | 36 | 20 | 54 | 41 | 51 | 46 | 71 | 50 | 62 | 66 | 78 | 68 | 87 | 75 | 88 | 93 | 98 |
| -l- | 59 | 28 | 73 | 72 | 84 | 69 | 80 | 73 | 87 | 78 | 91 | 87 | 94 | 90 | 95 | 94 | 99 |
| r- (2) | 25 | 26 | 46 | 52 | 62 | 56 | 67 | 47 | 63 | 71 | 69 | 78 | 79 | 76 | 87 | 92 | 96 |
| -ɚ (4) | 45 | 43 | 61 | 68 | 85 | 68 | 71 | 61 | 74 | 84 | 76 | 81 | 85 | 82 | 86 | 96 | 97 |
| -r- | 45 | 36 | 46 | 55 | 70 | 54 | 71 | 59 | 71 | 70 | 71 | 79 | 79 | 76 | 87 | 95 | 97 |

TABLE 4. (Continued)

| *Phoneme (# of test items)* | *Age[a] group* | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *3:0* | | *3:6* | | *4:0* | | *4:6* | | *5:0* | | *5:6* | | *6:0* | | *7:0[b] (n: F = 62 M = 73)* | *8:0[b] (n: F = 62 M = 68)* | *9:0[b] (n: F = 65 M = 52)* |
| | *F (n = 22)* | *M (n = 25)* | *F (n = 26)* | *M (n = 29)* | *F (n = 37)* | *M (n = 54)* | *F (n = 51)* | *M (n = 44)* | *F (n = 45)* | *M (n = 50)* | *F (n = 45)* | *M (n = 47)* | *F (n = 68)* | *M (n = 72)* | | | |
| Clusters | | | | | | | | | | | | | | | | | |
| tw- | 59 | 56 | 88 | 90 | 92 | 83 | 96 | 86 | 91 | 90 | 98 | 89 | 97 | 93 | 99 | 96 | 96 |
| kw- | 68 | 52 | 85 | 83 | 97 | 87 | 86 | 89 | 93 | 84 | 98 | 91 | 97 | 96 | 99 | 94 | 99 |
| sp- | 45 | 28 | 58 | 66 | 62 | 63 | 76 | 61 | 80 | 76 | 80 | 64 | 78 | 81 | 81 | 84 | 91 |
| st- | 55 | 24 | 58 | 62 | 62 | 57 | 76 | 59 | 78 | 80 | 78 | 66 | 84 | 81 | 82 | 80 | 93 |
| sk- | 41 | 24 | 58 | 66 | 62 | 59 | 78 | 70 | 78 | 74 | 80 | 68 | 81 | 79 | 83 | 85 | 89 |
| sm- | 36 | 24 | 65 | 72 | 59 | 59 | 71 | 59 | 73 | 74 | 80 | 70 | 84 | 71 | 82 | 80 | 89 |
| sn- (2) | 34 | 20 | 60 | 69 | 58 | 61 | 68 | 64 | 72 | 77 | 79 | 59 | 84 | 76 | 79 | 82 | 89 |
| sw- | 45 | 28 | 69 | 69 | 54 | 63 | 76 | 64 | 73 | 74 | 80 | 70 | 82 | 78 | 80 | 78 | 87 |
| sl- | 41 | 12 | 62 | 41 | 62 | 39 | 59 | 52 | 71 | 64 | 71 | 57 | 81 | 72 | 80 | 84 | 91 |
| pl- | 50 | 24 | 65 | 55 | 76 | 52 | 84 | 70 | 87 | 74 | 91 | 85 | 99 | 94 | 96 | 99 | 98 |
| bl- | 50 | 28 | 58 | 55 | 76 | 56 | 82 | 73 | 84 | 80 | 87 | 85 | 93 | 93 | 92 | 98 | 98 |
| kl- (2) | 41 | 24 | 58 | 40 | 77 | 55 | 83 | 74 | 90 | 72 | 92 | 83 | 96 | 92 | 97 | 99 | 97 |
| gl- | 41 | 20 | 62 | 55 | 70 | 52 | 82 | 75 | 80 | 78 | 89 | 89 | 97 | 93 | 95 | 96 | 98 |
| fl- | 36 | 16 | 54 | 52 | 73 | 52 | 78 | 66 | 87 | 72 | 91 | 83 | 93 | 89 | 95 | 98 | 99 |
| pr- | 23 | 20 | 46 | 52 | 70 | 50 | 63 | 55 | 69 | 70 | 69 | 77 | 84 | 75 | 87 | 94 | 97 |
| br- | 34 | 28 | 52 | 55 | 62 | 52 | 62 | 53 | 63 | 68 | 68 | 71 | 83 | 76 | 81 | 93 | 87 |
| tr- | 32 | 24 | 54 | 59 | 70 | 48 | 67 | 43 | 67 | 74 | 64 | 77 | 78 | 76 | 86 | 92 | 93 |
| dr- | 45 | 16 | 46 | 62 | 65 | 56 | 71 | 52 | 71 | 76 | 60 | 70 | 84 | 78 | 84 | 95 | 93 |
| kr- | 27 | 20 | 46 | 55 | 65 | 50 | 75 | 55 | 67 | 70 | 64 | 79 | 82 | 78 | 86 | 96 | 97 |
| gr- | 36 | 24 | 50 | 55 | 65 | 46 | 63 | 50 | 71 | 70 | 67 | 77 | 82 | 75 | 87 | 95 | 97 |
| fr- | 14 | 24 | 50 | 55 | 65 | 59 | 65 | 52 | 71 | 70 | 71 | 77 | 87 | 75 | 87 | 95 | 97 |
| θr- | 23 | 8 | 27 | 21 | 46 | 22 | 59 | 32 | 60 | 50 | 60 | 64 | 72 | 60 | 78 | 84 | 87 |
| skw- | 32 | 20 | 58 | 59 | 59 | 59 | 76 | 64 | 71 | 68 | 78 | 62 | 81 | 74 | 82 | 85 | 91 |
| spl- | 23 | 12 | 35 | 34 | 57 | 37 | 61 | 45 | 62 | 54 | 67 | 60 | 78 | 64 | 79 | 83 | 91 |
| spr- | 14 | 12 | 31 | 45 | 46 | 31 | 55 | 41 | 60 | 56 | 58 | 57 | 71 | 60 | 69 | 82 | 89 |
| str- | 32 | 8 | 31 | 41 | 46 | 30 | 57 | 41 | 51 | 52 | 58 | 53 | 69 | 57 | 65 | 75 | 88 |
| skr- | 23 | 8 | 35 | 38 | 46 | 30 | 55 | 36 | 58 | 52 | 53 | 55 | 65 | 56 | 71 | 81 | 88 |

*Note.* "Acceptable" = either "fully correct" or "marginal"; see text for definitions.
[a]Age expressed in years:months. [b]These data represent the average for males and females weighted by their relative numbers.

approaches to childrearing might be expected to have consequences for their children's language development and perhaps also for their speech development; however, in the Iowa-Nebraska data there were no differential effects of rural versus urban residence.

Finally, as expected, there were no significant differences between data from Iowa and data from Nebraska. Iowa and Nebraska are contiguous Midwestern states, have similar proportions of rural and urban populations, have small populations relative to their size, tend toward ethnic homogeneity, have similar agriculture-based economies, and have strong educational systems, including comprehensive special education services.

The fact that several demographic variables failed to influence the Iowa-Nebraska acquisition data suggests two possibilities: (a) There may have been considerable homogeneity in the environments of children in these two states, and (b) the variables used in this study to assess demography are not important variables in phonologic acquisition. With respect to the homogeneity-of-environment hypothesis, it is likely that the mass media, because of their pervasiveness, have been sources of common inputs to these children. It is also possible that the children were exposed to similar curriculum in elementary schools and in preschool child care settings.

The second hypothesis is that the demographic variables of parental education and rural/urban residence do not influence speech sound development in an important way. These variables were used primarily to ensure that subject samples were representative of the two states; in addition, such variables have been shown in the past to be relevant to studies of speech sound acquisition; for example, Templin reported in 1957 that SES discriminated among her subjects.

TABLE 5. Comparisons among 75% levels of acquisition of specific phonemes as determined in the Iowa-Nebraska Articulation Norms Project and by Templin (1957). For Templin, both two-position data (I,F) and the original three-position data (I,M,F) are shown.

| | *Age (years:months)* | | | |
|---|---|---|---|---|
| | *Iowa-Nebraska (I,F)* | | *Templin* | |
| *Sound* | *Females* | *Males* | *(I,F)* | *(I,M,F)* |
| m | ≤3:0 | ≤3:0 | ≤3:0 | ≤3:0 |
| n | ≤3:0 | ≤3:0 | ≤3:0 | ≤3:0 |
| ŋ | 5:6[b,c] | 6:0[c] | ≤3:0 | ≤3:0 |
| h | ≤3:0[a] | ≤3:0[a] | ≤3:0 | ≤3:0 |
| w | ≤3:0[a] | ≤3:0[a] | ≤3:0 | ≤3:0 |
| j | 3:6[a] | 3:6[a] | 3:6 | 3:6 |
| p | ≤3:0 | ≤3:0 | ≤3:0 | ≤3:0 |
| b | ≤3:0 | ≤3:0 | 4:0[c] | 4:0[c] |
| t | ≤3:0 | ≤3:0 | ≤3:0[c] | 6:0 |
| d | ≤3:0 | ≤3:0 | 4:0 | 4:0 |
| k | ≤3:0 | ≤3:0 | 4:0 | 4:0 |
| g | ≤3:0 | ≤3:0 | 4:0[c] | 4:0[c] |
| f | ≤3:0 | 3:6 | ≤3:0 | ≤3:0 |
| v | 4:0 | 4:6 | 6:0 | 6:0 |
| θ | 5:6 | 6:0 | 6:0 | 6:0 |
| ð | 4:0[a] | 5:6[a] | 7:0 | 7:0 |
| s | 3:0[c] | 5:0[c] | 4:6 | 4:6[c] |
| z | 5:0[c] | 6:0 | 7:0 | 7:0 |
| ʃ | 4:0 | 5:0 | 4:0 | 4:6[c] |
| tʃ | 4:0 | 5:0 | 4:6 | 4:6 |
| dʒ | 4:6 | 4:0 | 7:0 | 7:0 |
| l | 4:6[c] | 6:0 | 6:0 | 6:0 |
| r | 6:0 | 5:6 | 4:0 | 4:0 |

*Note:* I = word-initial; M = medial; F = word-final.
[a] Tested only in initial position. [b] Tested only in final position. [c] A reversal occurs in older age groups.

TABLE 6. Comparisons of 75% levels of acquisition for word-initial clusters as determined in the Iowa-Nebraska Articulation Norms Project and by Templin (1957).

| | *Age (years:months)* | | |
|---|---|---|---|
| | *Iowa-Nebraska* | | |
| *Clusters* | *Females* | *Males* | *Templin* |
| tw- | 3:6 | 3:6 | 4:0 |
| kw- | 3:6 | 3:6 | 4:0 |
| sp- | 4:6 | 5:0[a] | 4:0[a] |
| st- | 4:6 | 5:0[a] | 4:0 |
| sk- | 4:6 | 6:0 | 4:0[a] |
| sm- | 5:6 | 7:0 | 4:0[a] |
| sn- | 5:6 | 5:0[a] | 4:0[a] |
| sw- | 4:6[a] | 6:0 | 7:0 |
| sl- | 6:0 | 7:0 | 7:0 |
| pl- | 4:0 | 5:6 | 4:0[a] |
| bl- | 4:0 | 5:0 | 4:0 |
| kl- | 4:0 | 5:6 | 4:0 |
| gl- | 4:6 | 4:6 | 4:0 |
| fl- | 4:6 | 5:6 | 5:0 |
| pr- | 6:0 | 5:6 | 4:0[a] |
| br- | 6:0 | 6:0 | 4:0[a] |
| tr- | 6:0 | 5:6 | 4:0 |
| dr- | 6:0 | 5:0[a] | 4:0 |
| kr- | 4:6[a] | 5:6 | 4:0[a] |
| gr- | 6:0 | 5:6 | 4:6 |
| fr- | 6:0 | 5:6 | 4:6 |
| θr- | 7:0 | 7:0 | 7:0 |
| skw- | 4:6[a] | 7:0 | 6:0 |
| spl- | 6:0 | 7:0 | 7:0 |
| spr- | 8:0 | 8:0 | 7:0 |
| str- | 8:0 | 8:0 | 5:0 |
| skr- | 8:0 | 8:0 | 7:0 |

[a] A reversal occurs in older age groups.

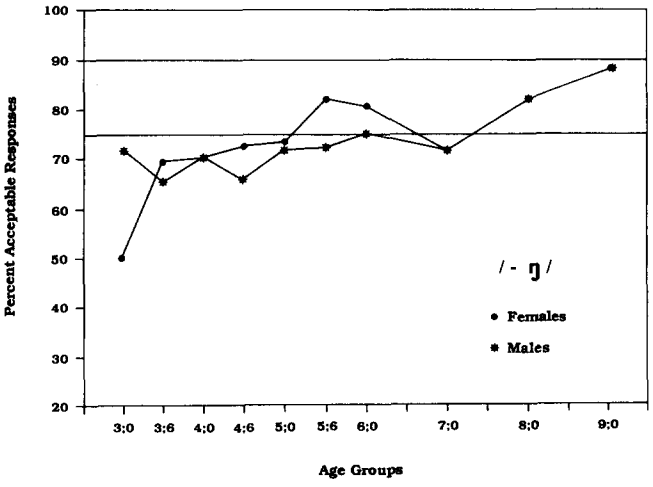


FIGURE 4. Growth of acquisition for word-final /ŋ/ (age in years and months).

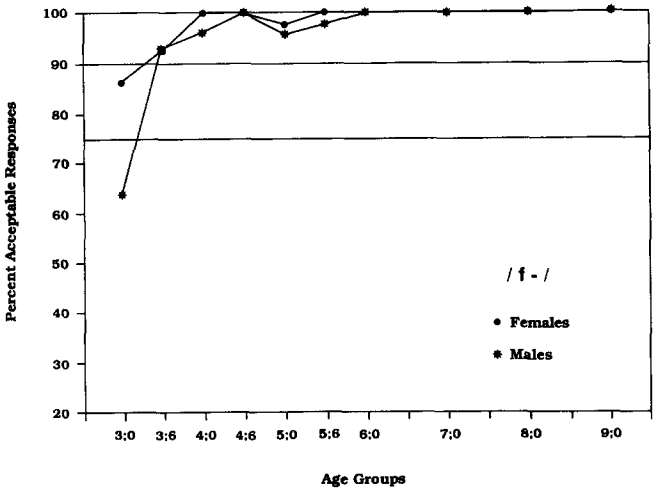


FIGURE 5. Growth of acquisition for word-initial /f/ (age in years and months).

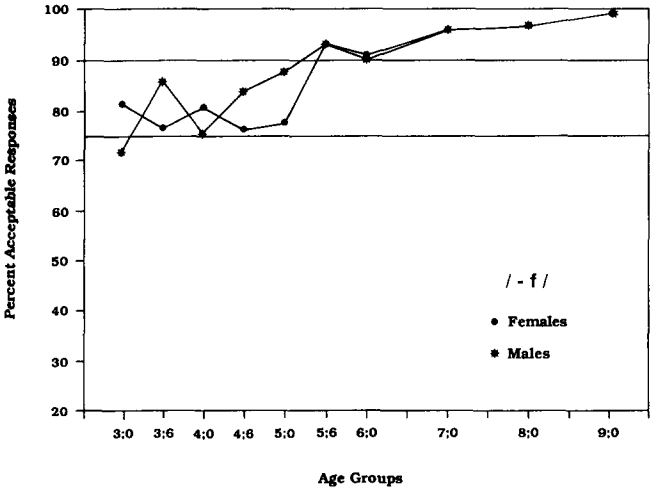


FIGURE 7. Growth of acquisition for word-final /f/ (age in years and months).

Although the Iowa-Nebraska data appear to suggest that SES was not related to speech sound acquisition, this finding may be true only for SES above poverty levels. It is likely that there are relatively few children living in severe poverty in these two states, assuming that level of parental education is a valid index of the likelihood of poverty status. One important characteristic of Iowa and Nebraska is that the average level of education is quite high. For example, the 1980 Census of Population (U.S. Bureau of the Census, 1980) reported data on the number of persons 25 years and over who had completed high school. For the entire United States the percentage of high school graduates was 66.5% of this population, while in Iowa the comparable percentage was 71.5% and in Nebraska it was 73.4%. The Iowa and Nebraska percentages were still higher (85–90%) in the adult age groups assumed likely to have children as old as those in the present study.

Clearly, caution is needed when the Iowa-Nebraska norms for speech sound acquisition are used with populations that do not share the demographic characteristics of these states. Another reason to be cautious when using the Iowa-Nebraska data elsewhere is that these states share a Midwestern dialect. There may be subtle differences in speech sound acquisition due to dialect variation in other parts of the United States.

*Differences between girls and boys.* The Iowa-Nebraska girls appeared to acquire sounds at somewhat earlier ages than the boys, although this effect reached statistical significance only at age 6:0 and younger, and not in every preschool age group. Templin (1957) found a statistically significant overall difference favoring girls in her data, but none of the differences between her boy and girl groups at particular age levels reached significance.

A recent review and meta-analysis of sex differences in verbal behavior led Hyde and Linn (1988) to conclude that although earlier investigations reported female superiority on verbal measures (especially after age 11), recent investigations tended not to reflect substantial differences favoring females. However, in their breakdown of verbal behaviors, Hyde and Linn reported that the largest differences occurred

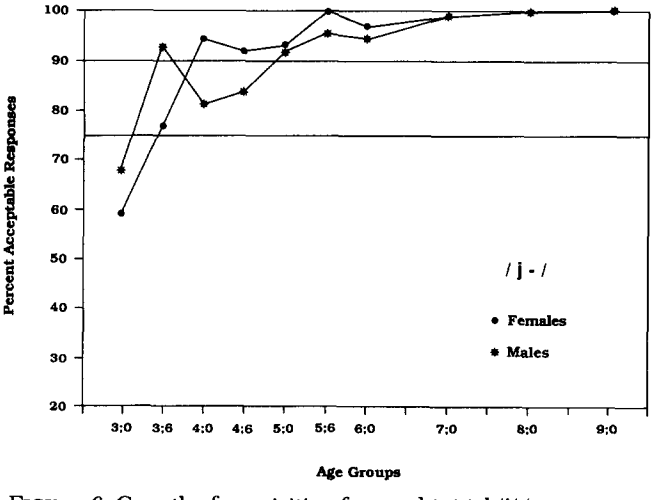


FIGURE 6. Growth of acquisition for word-initial /j/ (age in years and months).

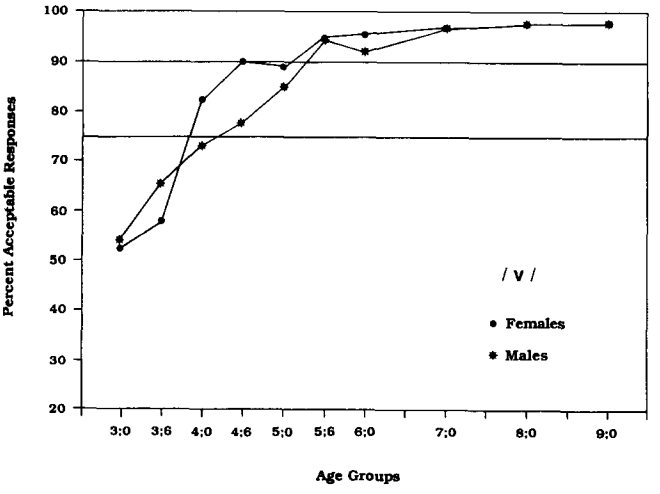


FIGURE 8. Growth of acquisition for /v/ (age in years and months).

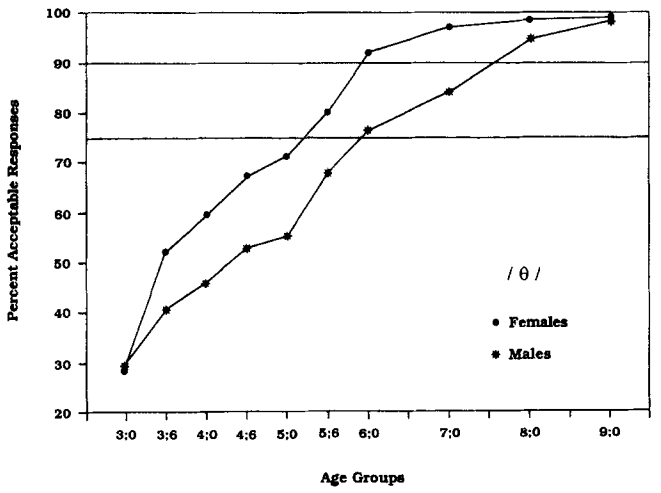


FIGURE 9. Growth of acquisition for /θ/ (age in years and months). Separate curves for females and males are shown at ages 7:0, 8:0, and 9:0.

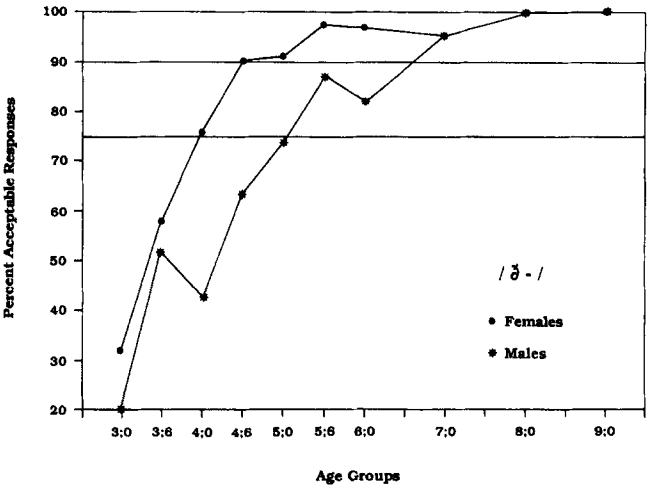


FIGURE 11. Growth of acquisition for word-initial /ð/ (age in years and months).

in measures of speech production, and that these differences tended to favor females, although none of the studies they reviewed had included speech sound development.

The fact that sex differences were present in Templin's data and are also present in our data suggests that speech sound acquisition is an area in which sex differences favoring girls persist, at least in the early years. Moreover, it is a well-known fact that boys are at much greater risk than girls for delayed speech, and this propensity continues to be reported (e.g., Shriberg, Kwiatkowski, Best, Hengst, & Terselic-Weber 1986).

Other information on speech sound acquisition published since Templin's (1957) study lends at least partial support to the finding of sex differences. Arlt and Goodban (1976) showed earlier ages of acquisition for girls than for boys, although the authors did not test for the significance of these differences. A similar instance occurred in the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 1986), on which scores for girls were almost always slightly higher than for boys. Again, the significance of these differences was not reported. Khan and Lewis (1986) also noted that the performance of girls on their test of phonological processes was consistently better than that of boys, but they considered these differences negligible. More recently Kenney and Prather (1986), who elicited multiple productions of frequent error sounds, reported significant differences favoring girls in the age range 3:0 through 5:0.

## *Ages of Acquisition*

*Consonant singles.* When a 75% criterion was used for acquisition, most ages of acquisition obtained in the Iowa-Nebraska study were slightly younger than those obtained by Templin (1957). This discrepancy may be due to methodological differences, including use of different measures of SES. It is also likely that the two studies used different measures of response adequacy. Unfortunately, we cannot examine such differences be-

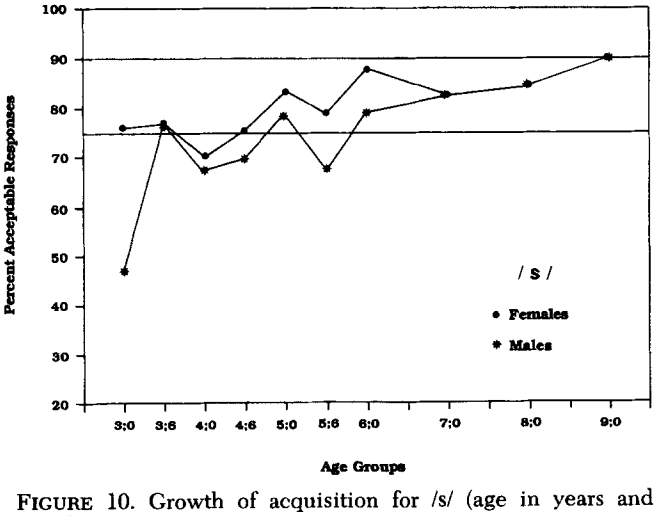


FIGURE 10. Growth of acquisition for /s/ (age in years and months).

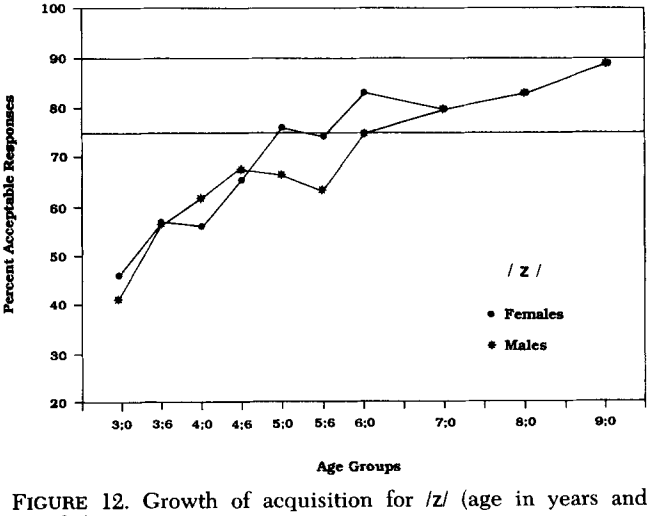


FIGURE 12. Growth of acquisition for /z/ (age in years and months).

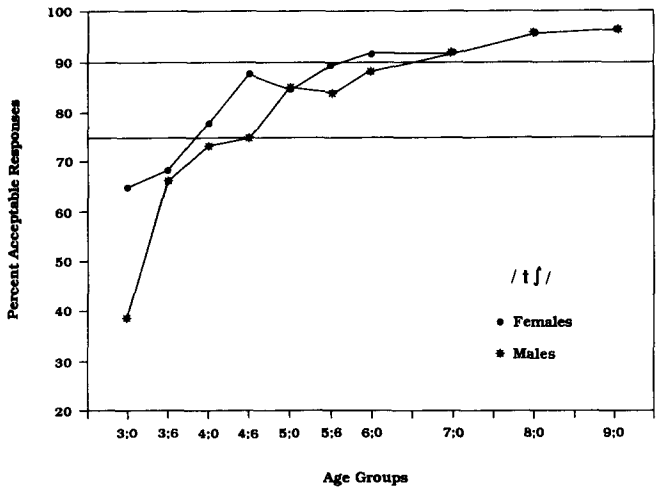


FIGURE 13. Growth of acquisition for /tʃ/ (age in years and months).

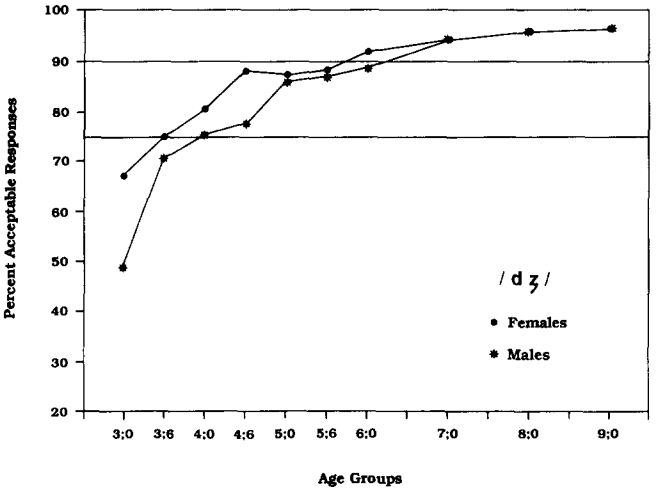


FIGURE 15. Growth of acquisition for /dʒ/ (age in years and months).

cause Templin did not specify criteria for response adequacy in her 1957 monograph. In the present investigation we were obligated to define response adequacy, if only because of the abundance of information obtained when using narrow phonetic transcription. Differences in results between our work and Templin's could be due to this variable, but with the exception of /ŋ/ (see discussion below), we could not estimate the direction of any effects. It is interesting to note that if definitions of response adequacy had effects on ages of acquisition, the effects were different for consonant singles (which were generally acquired earlier than Templin reported) from effects for consonant clusters (which were often acquired at later ages than Templin reported).

*Variability in production.* A number of authors have reported data showing reversals in production of particular speech sounds. That is, a predetermined criterion for acquisition is reached by one age group but not by an older age group. Such reversals have been reported most often for /s/ targets (Kenney & Prather, 1986; Poole, 1934; Prather, Hedrick, & Kern, 1975; Templin, 1957). Table 5 shows that reversals also occurred in the Iowa-Nebraska data for /s/ when a 75% acquisition criterion was used, and that this reversal occurred for both boys and girls. It is difficult to explain such reversals, because they imply that children exhibit phonologic regression at ages considerably older than previously reported. One possible explanation is that variation from group to group represents sampling error. In these data considerable group-to-group variation occurred for a number of sounds, among them /-f/ (Figure 7), /l-/ (Figure 16), /-l/ (Figure 18), /r-/ (Figure 17), and postvocalic /ɚ/ (Figure 19). The extent of group-to-group variability for /s/ (Figure 10) appears to be no greater than for these other sounds. If sampling error is a reasonable explanation, then the same explanation should apply to all of these sounds.

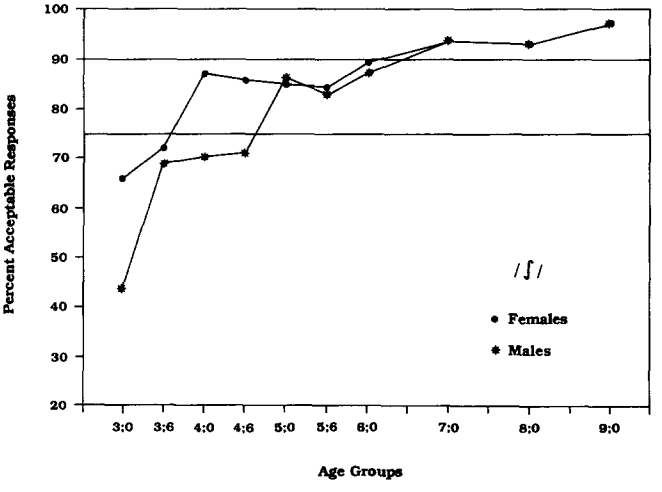


FIGURE 14. Growth of acquisition for /ʃ/ (age in years and months).

Another explanation of reversals is one advanced by Kenney and Prather (1986), namely that reversals affecting /s/ might be due to shifting standards of examiners, who may unconsciously tolerate greater deviations in younger children than in older children. We suggest that such a bias would be more likely in a paradigm that required a right/wrong response from the clinician. In the Iowa-Nebraska paradigm, the testing clinician was trained to transcribe the details of the production, and the training materials included samples of mildly deviant /s/ productions from young children. Consequently, examiner bias was minimized.

A third explanation for /s/ reversals would be that some children do in fact acquire an acceptable /s/ early in development and then adopt an error variant for a time before reverting to an acceptable production. The available longitudinal data on this point are sketchy. Sax (1972) reported longitudinal data showing that some children in the early school years exhibit this kind of regression, and she noted that "the high incidence of first-grade regression appears related to an increase in /s/ and /z/ errors" (Sax, 1972, p. 46). However, no quantitative data were provided to support this point, and the study was apparently vulnerable to the kind of examiner bias mentioned by Kenney and Prather (1986). In addition, first-graders are somewhat

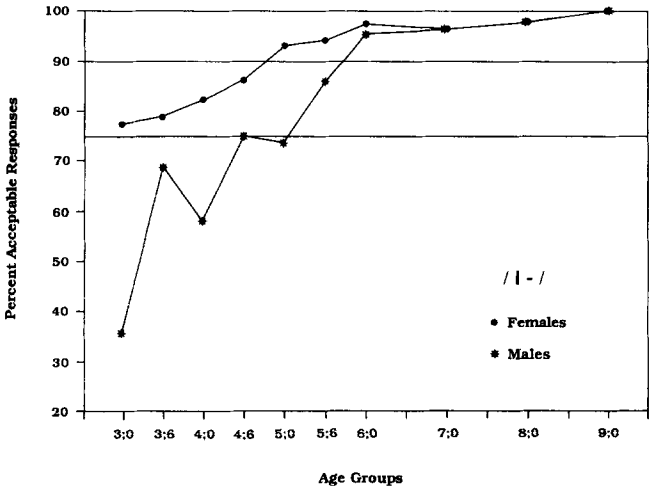


FIGURE 16. Growth of acquisition for word-initial /l/ (age in years and months).

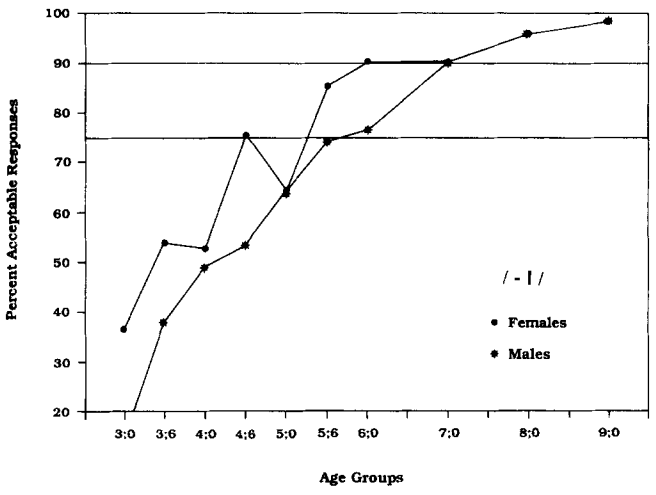


FIGURE 18. Growth of acquisition for word-final /l/ (age in years and months).

older than the age groups for which reversals are usually seen in cross-sectional data. Because of this consideration and the others mentioned previously, it appears that an explanation for reversal of /s/ requires longitudinal study directed to that specific issue.

*Consonant clusters.* Acquisition curves for initial consonant clusters (Figures 20–30) showed that by the time children reached age 6:0, at least 75% of them were using /Cw-/, /sC-/, /Cl-/ and /Cr-/ clusters acceptably. It is worth noting that although any one consonant cluster is relatively infrequent in English, clusters as a group are very common, even in the speech of young children. For example, *spoon, clown, three, green, black, school,* and *smell* are common vocabulary for preschool and young school-age children. Moreover, phonologic processes that affect clusters can have a serious effect on intelligibility. Consequently, clusters should not be ignored when using acquisition data to determine a child's eligibility for services.

Another important aspect of cluster acquisition is that one source of the differences between boys and girls appeared to lie in acquisition of clusters in the preschool years. At ages 3:6 and 4:0 the boys experienced either a plateau or a decrease in the acquisition curves for clusters (Figures 20–30), which appeared to influence their total score curves (Figure 2). Of course, sampling error was a possible explanation for the shapes of curves in this age range. However, the presence of a comparable plateau in Templin's total scores (Figure 3) argues against sampling error as the cause. Rather, these data seem to indicate that boys experienced more difficulty than girls in acquiring clusters. Explanations for sex differences in cluster acquisition are not readily apparent.

## *Recommended Ages of Acquisition for Speech Sounds*

In both Iowa and Nebraska, state Department of Education guidelines set the primary criterion used to qualify school-age children for intervention for a particular pho-

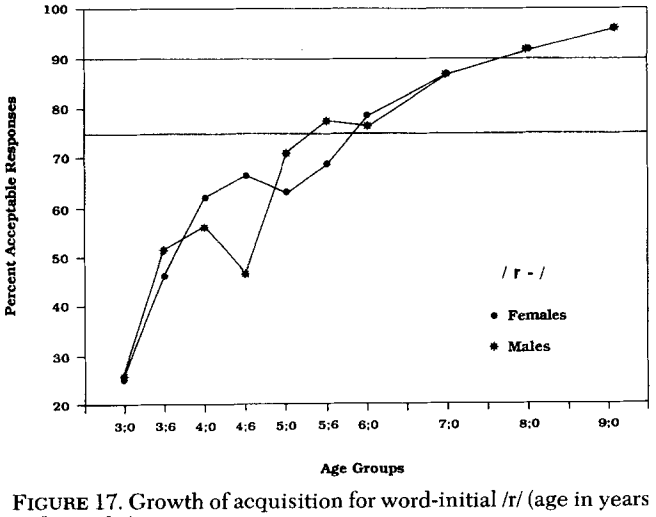


FIGURE 17. Growth of acquisition for word-initial /r/ (age in years and months).

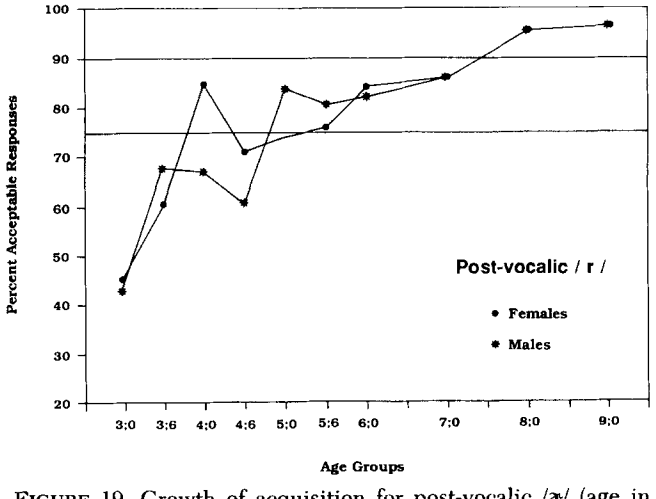


FIGURE 19. Growth of acquisition for post-vocalic /ɚ/ (age in years and months). Data from word-final and preconsonantal contexts are combined.

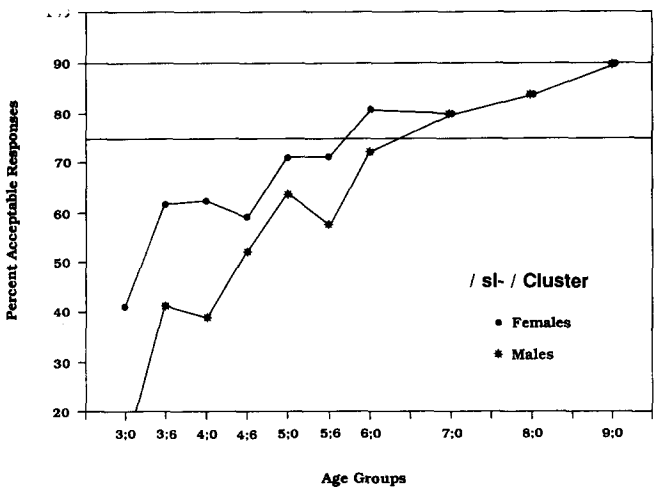


FIGURE 20. Growth of acquisition for the word-initial clusters /tw kw/ (age in years and months).

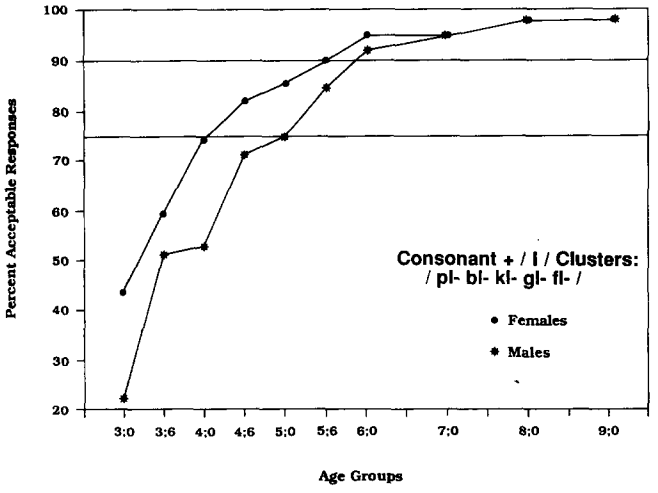


FIGURE 22. Growth of acquisition for the word-initial clusters /sm sn/ (age in years and months).

neme at the 90% acquisition level. This criterion was judged to be reasonable because both states' guidelines also paid appropriate attention to other factors such as total number of errors and overall intelligibility. Additionally, a 90% criterion is roughly in accord with accepted educational and psychometric practice that considers only the lowest 5–10% of performances on a standardized instrument to be outside the normal range. Finally, many of our acquisition curves showed that children steadily increased the accuracy of production until the 90% acquisition level was passed. In most instances, the level of their performance did not plateau until after that level was reached.

Our recommendations for ages of acquisition of speech sounds were made after considering several issues relevant to these data. One important concern was that the acquisition curve for each target show stability after the recommended age was reached. Lack of stability was defined as a dip below the 90% level, or if a curve never reached the 90% level, a decrease of 10% over a 1-year age span. In the latter cases, we also considered the nature of children's errors in arriving at our recommendations. Table 7 shows our recommended ages of acquisition for the phoneme and cluster targets assessed in the Iowa-Nebraska Articulation Norms Project. Table 7 also includes references to the appropriate table or figure in which the supporting data may be found.

It is possible to compare our 90% ages of acquisition with a chart provided by Sander (1972), which is a bar chart showing lower and upper boundaries for an age span over which each phoneme single develops. Sanders used a 90% criterion level to determine upper age boundaries, basing his chart on acquisition data developed by Templin (1957) and others. He combined data from boys and girls, and he combined data over word positions. Our recommended ages of acquisition differ somewhat from Sander's upper boundary ages, the most notable differences being that (a) /t/ and /v/ were acquired 2 or more years earlier than Sander's upper boundary, and (b) /ŋ/ and /r/ reached criterion 2 years later than Sander's upper

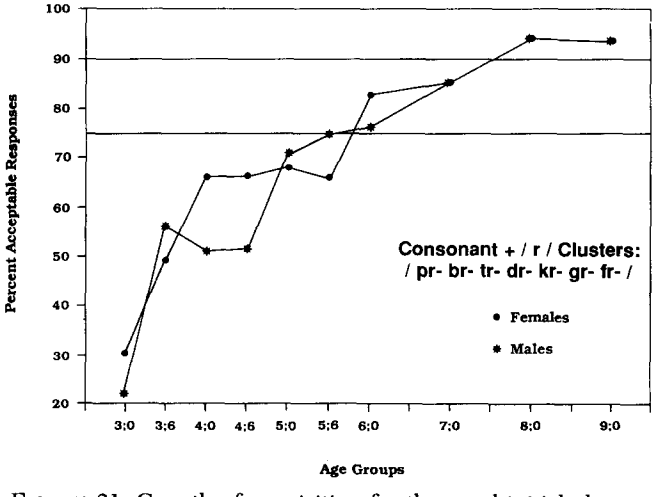


FIGURE 21. Growth of acquisition for the word-initial clusters /sp st sk/ (age in years and months).

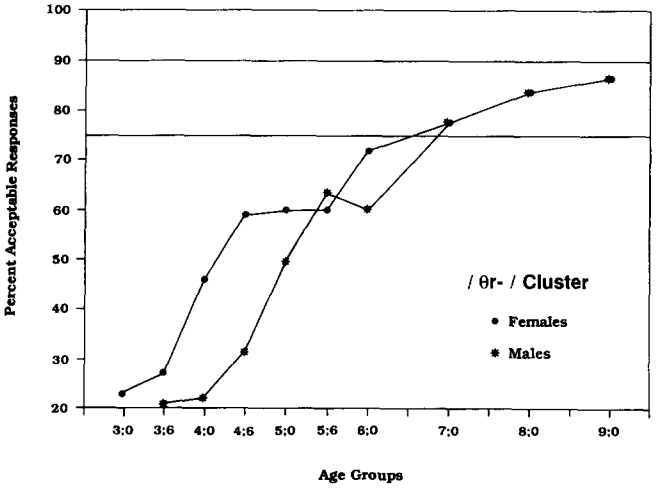


FIGURE 23. Growth of acquisition for the word-initial cluster /sw/ (age in years and months).

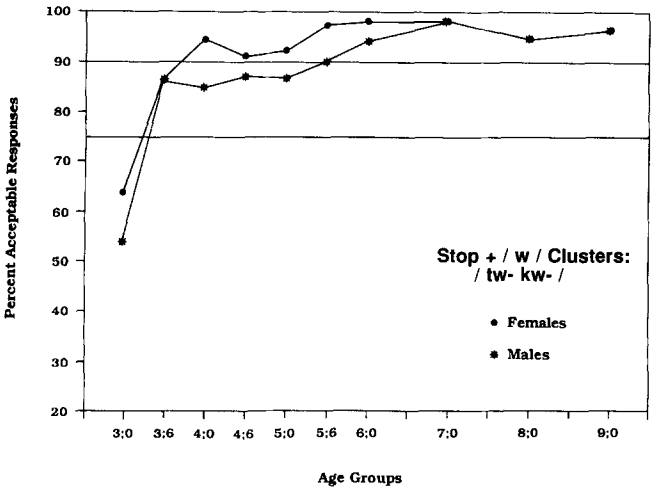


FIGURE 24. Growth of acquisition for the word-initial cluster /sl/ (age in years and months).

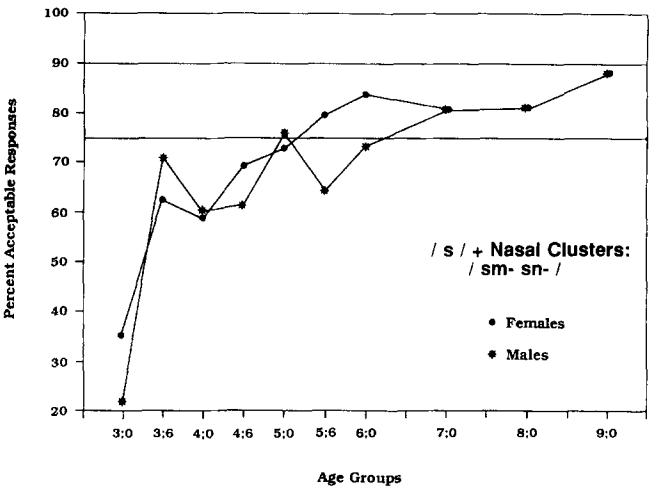


FIGURE 26. Growth of acquisition for the word-initial clusters /pl bl kl gl fl/ (age in years and months).

boundary. In the case of /t/, Sander acknowledged that his upper boundary was influenced by what he inferred was Templin's "demanding criterion" that intervocalic /t/ be "clearly articulated," that is, completely voiceless, and he noted that most speakers exhibit a degree of voicing of /t/ in this context.

Analysis of error data provided no ready explanation for the relatively early acquisition of /v/ nor for the relatively late acquisition of /r/. However, the error data suggested that the criteria used to determine acceptability of responses to /ŋ/ influenced the recommended age of acquisition for this phoneme.

*Recommended age of acquisition for* /-ŋ/. The acquisition curve for /-ŋ/ never reached the 90% level (Figure 4), whereas in the data of Templin and of others, the /-ŋ/ was reported as acquired relatively early. The discrepancy undoubtedly was related to the criterion for an "acceptable" response. The /-ŋ/ was tested in the word *wing*, and many children responded with the addition of a sound, as in [wɪŋg]. As a general principle, additions of consonants adjacent to a word-final target were considered to be errors on the target sound. Inspection of the error data suggested that if the addition of [g] or [k] in these cases had been considered "acceptable," /-ŋ/ would have reached the 90% criterion level by approximately age 7:0. Therefore we recommend that predictive assessment of /-ŋ/ begin at age 7:0. If the child produces the [ŋ] phone followed by a velar stop, then no intervention should be provided, and the child should be rechecked at ages 8:0 and 9:0. If a child of 7:0 uses some other type of error, then intervention can be considered at that age.

*Ages of acquisition for* /s z/. Recommended ages of acquisition for /s z/ require special consideration because of the unexpected results for these two phonemes—the acquisition curves did not reach the 90% criterion level used for other phoneme targets until age 9:0 (Figures 10 and 12). The /s z/ are frequent in English and they are prominent in the morphology as well as the phonology of English. In the present data, the large majority (80%) of /s z/ responses were acceptable by age 7:0, and improvement occurred gradually

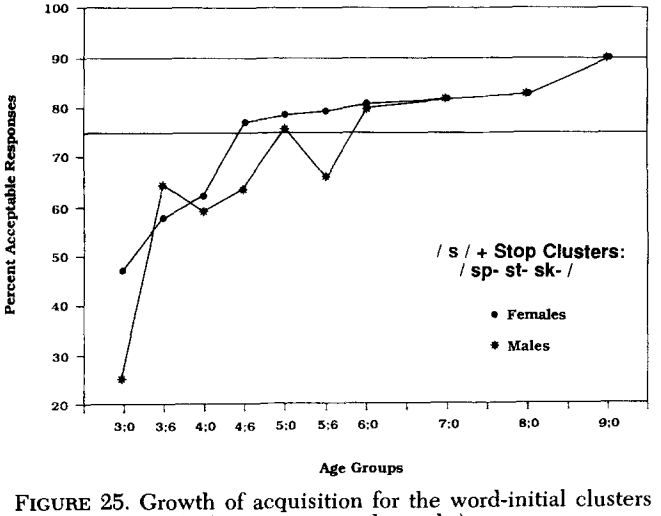


FIGURE 25. Growth of acquisition for the word-initial clusters /pr br tr dr kr gr fr/ (age in years and months).

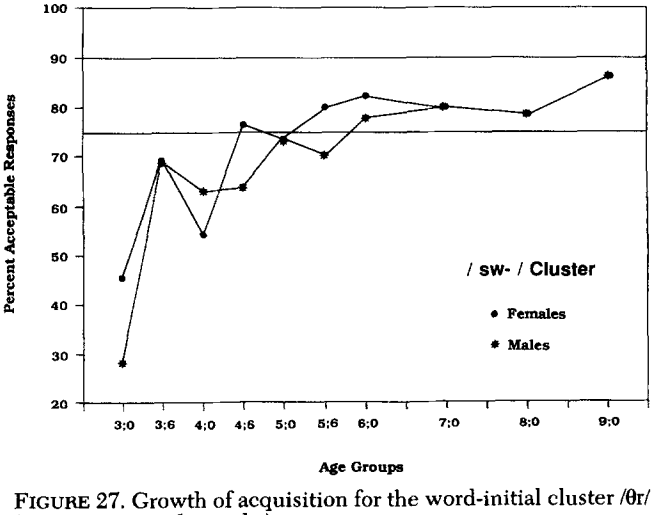


FIGURE 27. Growth of acquisition for the word-initial cluster /θr/ (age in years and months).

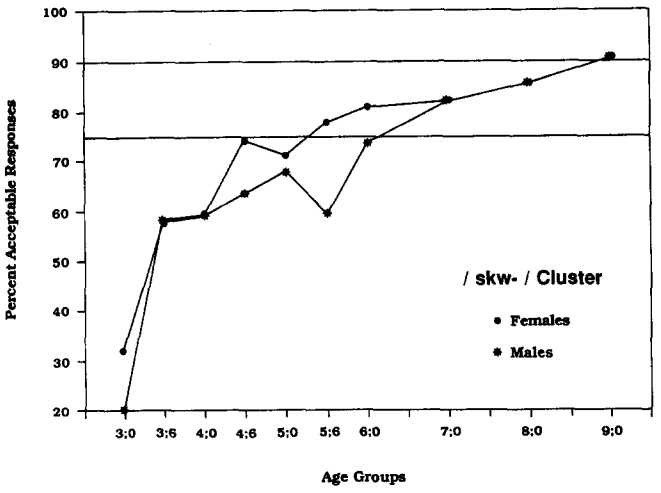


FIGURE 28. Growth of acquisition for the word-initial cluster /skw/ (age in years and months).

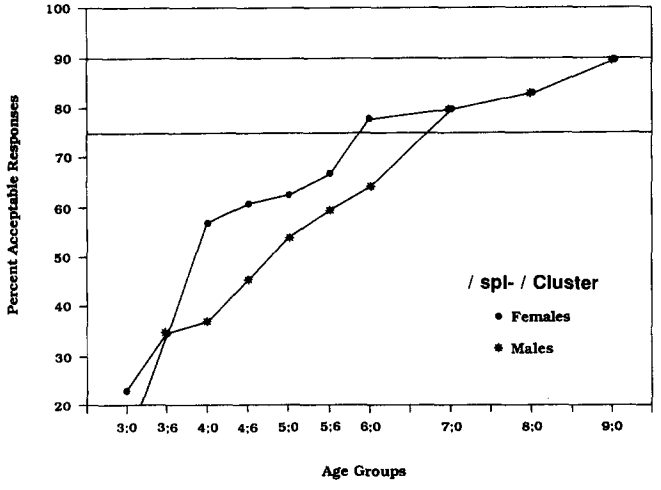


FIGURE 29. Growth of acquisition for the word-initial cluster /spl/ (age in years and months).

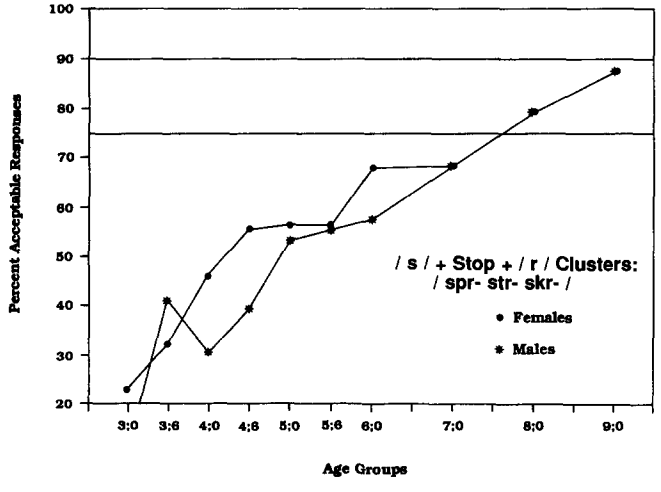


FIGURE 30. Growth of acquisition for the word-initial clusters /spr str skr/ (age in years and months).

TABLE 7. Recommended ages of acquisition for phonemes and clusters, based generally on 90% levels of acquisition.

| *Phoneme* | *Recommended age of acquisition (years:months)* | | *Source* |
|---|---|---|---|
| | *Females* | *Males* | |
| /m/ | 3:0 | 3:0 | Table 4 |
| /n/ | 3:6 | 3:0 | Table 4 |
| /-ŋ/ | 7:0–9:0 | 7:0–9:0 | Figure 4[a] |
| /h-/ | 3:0 | 3:0 | Table 4 |
| /w-/ | 3:0 | 3:0 | Table 4 |
| /j-/ | 4:0 | 5:0 | Figure 6 |
| /p/ | 3:0 | 3:0 | Table 4 |
| /b/ | 3:0 | 3:0 | Table 4 |
| /t/ | 4:0 | 3:6 | Table 4 |
| /d/ | 3:0 | 3:6 | Table 4 |
| /k/ | 3:6 | 3:6 | Table 4 |
| /g/ | 3:6 | 4:0 | Table 4 |
| /f/ /f-/ | 3:6 | 3:6 | Figure 5 |
| /-f/ | 5:6 | 5:6 | Figure 7 |
| /v/ | 5:6 | 5:6 | Figure 8 |
| /θ/ | 6:0 | 8:0 | Figure 9 |
| /ð-/ | 4:6 | 7:0 | Figure 11 |
| /s/ | 7:0–9:0 | 7:0–9:0 | Figure 10[b] |
| /z/ | 7:0–9:0 | 7:0–9:0 | Figure 12[b] |
| /ʃ/ | 6:0 | 7:0 | Figure 14 |
| /tʃ/ | 6:0 | 7:0 | Figure 13 |
| /dʒ/ | 6:0 | 7:0 | Figure 15 |
| /l/ /l-/ | 5:0 | 6:0 | Figure 16 |
| /-l/ | 6:0 | 7:0 | Figure 18 |
| /r/ /r-/ | 8:0 | 8:0 | Figure 17 |
| /-ɚ/ | 8:0 | 8:0 | Figure 19 |
| Word-initial clusters | | | |
| /tw kw/ | 4:0 | 5:6 | Figure 20 |
| /sp st sk/ | 7:0–9:0 | 7:0–9:0 | Figure 21[b] |
| /sm sn/ | 7:0–9:0 | 7:0–9:0 | Figure 22[b] |
| /sw/ | 7:0–9:0 | 7:0–9:0 | Figure 23[b] |
| /sl/ | 7:0–9:0 | 7:0–9:0 | Figure 24[b] |
| /pl bl kl gl fl/ | 5:6 | 6:0 | Figure 26 |
| /pr br tr dr kr gr fr/ | 8:0 | 8:0 | Figure 25 |
| /θr/ | 9:0 | 9:0 | Figure 27 |
| /skw/ | 7:0–9:0 | 7:0–9:0 | Figure 28[b] |
| /spl/ | 7:0–9:0 | 7:0–9:0 | Figure 29[b] |
| /spr str skr/ | 7:0–9:0 | 7:0–9:0 | Figure 30[b] |

*Note:* These recommended ages are for phonetic acquisition only: If a child's error on phoneme or cluster is reflected in a phonological process affecting other, similar sounds, that process should be treated at an age appropriate for that process. Sources of supporting information are indicated in the last column.

[a]Discussion in text.

[b]Assess/remediate nondevelopmental errors before age 7:0; discussion in text.

thereafter. Although one might recommend 9:0 as the age of acquisition for the /s z/, the high rates of acceptable performance in children 2 years younger and the subsequent slow rise in the acquisition curve argue against such a late cutoff. Moreover, experience suggests that in some cases, intervention for /s z/ should *not* be delayed until 9:0 or later. Consequently, we recommend that unless certain error types are used at earlier ages, predictive assessment of phonetic errors on /s z/ should begin at age 7:0 with attention to the following variables:

1. *Nature of the error.* It is well to remember that the 10–20% of error productions in the age groups 7:0, 8:0, and 9:0 represented a mixture of error types. For example, there was no separate coding for "slight" distortions; rather, these responses were all coded as errors. Consequently, both minor and clinically significant errors were combined in these data.

A second consideration is the question of whether rare error types should routinely be considered developmental. Analysis of error data suggested that by age 6:0, virtually all error types were dental, ranging from interdental [s] or [θ] to slight dentalizations. Lateralizations and post-alveolar distortions were 0–5% of the total responses, depending on the age group. Other error types were extremely rare after the age of 6:0. Stephens, Hoffman, and Daniloff (1986) found that at least one of these rare errors, namely lateralizations of /s z/, did not undergo spontaneous improvement with age. We interpret their findings to mean that lateralizations should not be considered developmental, and that such errors might be treated earlier than other /s/ errors. Other rare error types might also be treated at relatively early ages, especially those that are likely to have social consequences. Such variants would include visually distracting errors, such as a protruded tongue curling up over the upper central incisors during /s z/, or acoustically distracting errors such as pharyngealized /s z/.

2. *Inconsistency.* In the past, the notion of inconsistency has not been adequately defined (House, 1981), nor has it been adequately evaluated with respect to prediction. However, if a child's /s/ or /z/ is produced acceptably in any context, many clinicians would consider this child to be more advanced in /s z/ development than another child who never produced any acceptable /s z/.

Moreover, the percent-acceptable data presented in the present study undoubtedly represented inconsistency on the part of some children. Because of the way the responses were tallied, the percent-acceptable measures reflect *percent of total* /s z/ *responses* that were acceptable, rather than the *percent of children* with acceptable /s z/. While the /z-/ target was assessed in only one word, /s- -s -z/ were assessed in two target words each. Therefore, these totals include responses from children who produced /s- -s -z/ targets acceptably in one test word but not in the other test word. A child exhibiting this kind of inconsistency would not usually be considered for intervention unless the so-called inconsistency was governed by a phonological rule or was powerfully conditioned by phonetic context or had persisted for a year or more.

3. *Stimulability.* Stimulability has been suggested as a predictor variable (see Diedrich, 1983, for a review of relevant studies), and stimulability should be considered when doing predictive assessment for /s z/. A promising start in using stimulability (as assessed by elicited imitation) in a predictive manner has been reported by Li and Riley (1989).

4. *Dentition.* The child's dentition may be an important variable if the upper incisors have not erupted. Although many children who lack one or more incisors have fully correct /s z/, for other children the change in the anterior morphology of the mouth may be an important aid to acquisition of /s z/ (Bankson & Byrne, 1962).

In summary, the determination of whether intervention for /s z/ is warranted depends heavily on other clinical findings. Moreover, as with any communication problem, the clinician needs to consider whether social factors might warrant providing service to a child—for example, to the child who is self-conscious about her incorrect productions and is reluctant to talk, to the child who is teased about his speech, and to the child whose parents or teacher have requested intervention because of their concerns about the child's errors. Our recommendation for evaluating /s z/ in the school-age population is as follows:

1. Consider intervention for lateralized variants, other rare variants, and variants that appear to have damaging social consequences at or before age 7:0. In these cases early intervention is indicated, even for preschoolers, provided that (a) the child appears able to respond favorably to treatment (a decision that might be based on the outcome of a brief period of diagnostic remediation); and (b) there are no indicators of spontaneous or impending improvement.

2. For any other kinds of phonetic errors, evaluate at age 7:0, but delay intervention if the deviation is considered slight *or* if any one of the following positive indicators is present: (a) Acceptable /s z/ is used in any single or clustered context, even if the acceptable sound is used in only one or a few words; (b) the child is stimulable for acceptable /s/ or /z/; or (c) the permanent upper incisors have not erupted.

3. Recheck the child at age 8:0. Provide intervention only if there has been no change in indicators or if there has been negative change.

4. Recheck at age 9:0 and provide intervention for children who still have clinically significant errors on /sz/.

5. Use the same kinds of criteria for each word-initial cluster with /s/ *if* the primary error on the cluster involves the /s/. If the primary error on the cluster involves another element, for example, /r/ in /spr str skr/, then use age 9:0 as the age of acquisition.

## *Comments on Recommended Ages of Acquisition*

*Phonetic versus phonologic acquisition.* It is important to make clear that the potential use of these data in a normative way is appropriate in the context of phonetic acquisition of speech sounds but is not appropriate if the child is failing to learn the sound pattern or phonology of English. Certainly, if a child's error on one sound is repeated for other, similar sounds, and if those errors reflect a phonologic pattern or process, then the pattern or process needs to be evaluated against norms for the process rather than norms for individual phoneme targets. For example, if a child deletes word-final /tʃ/ and also deletes most other final obstruents, this clearly represents the process of final consonant deletion. Final consonant deletion, which is extremely damaging to intelligibility, is usually suppressed by age 3:0 (Stoel-Gammon & Dunn,

1985). Intervention for this phonologic process is appropriate at much younger ages than is intervention for phonetic errors on /tʃ/.

*Waiting periods.* Some state guidelines for providing speech-language services to children require the child to be 1 year older than the age of 90% acquisition for error phonemes before the child can receive intervention. One of the principles on which we based our recommended ages of acquisition dealt with the amount of change seen in curves after the recommended age of acquisition. In most cases, there was very little change after that age. Therefore, our recommended ages of acquisition provide little support for service guidelines that require a child to be 1 year older than the age level at which a 90% criterion is reached before intervention will be provided.

## SUMMARY

The findings from the Iowa-Nebraska Articulation Norms Project suggest that ages of acquisition for most of the tested consonant singles have either remained constant as compared with Templin's classic work of 1957 or have moved to earlier ages. Ages of acquisition for a few phoneme singles and for most clusters have either remained constant or have moved to slightly later ages. The results show also that the criteria used to determine whether a production is acceptable or in error can influence the results, in some cases substantially. Demographic variables that might have been expected to influence the outcomes failed to do so, although sex of the child was a significant factor in the preschool years. Finally, when curves of acquisition were plotted for speech sounds, they provided an important aid to the principled recommendation of ages of phonetic acquisition, which in our study were based generally on a 90% level of acquisition.

## ACKNOWLEDGMENTS

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## APPENDIX

Summary of responses classified as marginal and used by subjects in the Iowa-Nebraska Articulation Norms Project. Marginal responses that occurred for less than 1% of responses are not shown. Frequency codes are as follows:

"Occasional": variant occurred in 1–4% of responses
"Frequent": variant occurred in 5–12% of responses
"Common": variant occurred in 13–30% of responses

| | *Variant* | *Frequency* |
|---|---|---|
| 1. | Variants in release of word-final stops, including unreleased, aspirated, etc. | Each variant occasional in almost every age group |
| 2. | Labiodental variants of bilabials | Occasional, in very few age groups, and especially in initial position |
| 3. | /t d n l/ dentalized, in all word positions | Occasional to frequent, depending on age group |
| 4. | Partial devoicing of word-final voiced obstruents | Common |
| 5. | [ʔ] for /-t/ | Frequent |
| 6. | Frictionalized velar stops | Occasional, especially in younger groups |
| 7. | Labiodental stops for /f v/ | Occasional |
| 8. | Affrication of initial /θ ð s/ | Occasional |
| 9. | Partial devoicing of initial voiced fricatives and affricates | Frequent, especially in younger groups |
| 10. | Schwa-release of final nasals, voiced stops, and voiced fricatives | Occasional to frequent |
| 11. | "Light" allophone for final /l/ | Frequent |
| 12. | Schwa-insertions in initial consonant clusters | Occasional to frequent, depending on age group and on cluster |
| 13. | Schwa-insertion between first and second elements of initial three-element clusters | Occasional |
| 14. | Schwa-insertion between second and third elements of initial three-element clusters | Occasional |