English Speech Sound Development in Preschool-Aged Children From Bilingual English–Spanish Environments

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In the United States, 47 million people, representing 18% of U.S. households, speak a language other than English. This population has more than doubled in the past 20 years (Shin & Bruno, 2003). Spanish is the second most frequently spoken language in the United States, spoken by more than 28 million people in more than 10% of U.S. households. The Spanish-speaking population is young, with more preschool-aged Hispanic children than children of any other ethnic group (Bernstein, 2004). Because English is the language of education in the United States, most children from Spanish-speaking households will develop into bilingual English–Spanish adults.

The typical course of speech sound acquisition in bilingual children has not been widely investigated (Goldstein, 2004; Holm & Dodd, 2001; Lleó & Keloe, 2002). Available data indicate that 10% to 15% of monolingual preschool children exhibit speech sound disorders (Plante & Beeson, 1999). This rate may be similar for bilingual preschool children. Currently, limited understanding of typical speech sound acquisition in bilingual children makes it difficult for speech-language pathologists (SLPs) to validly identify more errors than did bilingual children who were predominantly exposed to English. Both bilingual groups showed higher error rates than English-only children overall, particularly for syllable-level error patterns. All language groups decreased in some error patterns, although the ones that decreased were not always the same across language groups. Some group differences of error patterns and accuracy were significant. Vowel error rates did not differ by language group.

Conclusion: Exposure to English and Spanish may result in a higher English error rate in typically developing bilinguals, including the application of Spanish phonological properties to English. Slightly higher error rates are likely typical for bilingual preschool-aged children. Change over time at these time points for all 3 groups was similar, suggesting that all will reach an adult-like system in English with exposure and practice.

KEY WORDS: bilingualism, speech sound development, Spanish, children, phonology
speech sound disorders or delays in these children. Because English is the predominant language spoken in U.S. classrooms, often only one of a bilingual child’s two languages is observed on an ongoing basis. This aspect of the school environment increases the likelihood that decisions about bilingual children will be based on comparisons to monolingual English learners. However, normative acquisition data for monolinguals may not validly characterize the course of bilingual speech sound development, resulting in over- and underidentification of speech sound disorders in bilingual children. Overidentification can result in unnecessary speech therapy, with economic consequences for schools, increasing SLP caseloads, and educational consequences for children due to inappropriate removal from valuable classroom learning (Lidz & Peña, 1996). Alternatively, SLPs may be more conservative in referring bilingual children for speech services. As a result, bilingual children with a speech sound disorder may be underidentified based on inadequate information on bilingual acquisition (Kritikos, 2003), delaying needed clinical intervention. Clear understanding of typical bilingual speech sound acquisition is needed to form a valid basis for assessment and intervention protocols in this growing population.

Languages-in-Contact

When languages come into contact, phonology, morphology, syntax, and semantics exhibit mutual influences (Döpke, 2000). Languages modify each other to different degrees, influenced by factors such as the amount of contact and the structure of the specific languages. The amount of contact with each language has been shown to influence vocabulary size in each language (Pearson, Fernández, Lewedeg, & Oller, 1997), with more inconsistent influence on morphosyntax (Paradis, Crago, Genesee, & Rice, 2003). Cross-linguistic effects in the area of phonology have been noted for English–Spanish bilinguals (Goldstein, Fabiano, & Washington, 2005; Goldstein & Washington, 2001), as well as for Cantonese–English bilinguals (Holm & Dodd, 1999). Yet, it is unclear how much the amount of exposure moderates language contact effects. A languages-in-contact proposal (Döpke, 2000; see also MacWhinney, 2005) applied to phonological development suggests that when there are structural similarities in the two languages, a learner can transfer what they know about one language to the other language in order to achieve the basic sound quality of the phoneme in the second language. For example, /ɔ/ and /u/ occur in English and Spanish, and it is likely that the knowledge of these phonemes in one language will be transferred to the second language in the bilingual speaker. On the other hand, changes may occur at the phoneme level in the target language when the two have phonemes with subtly different characteristics. An example of these more subtle differences may be in learning to produce and acoustically discriminate the English low front /æ/ and low back /ɑ/ versus the Spanish low central /a/. These vowels are close enough in acoustic properties and production characteristics that production in one language could have a negative effect on the vowels in the second language. When there are less ambiguous differences between the two languages, such as the Spanish alveolar trill /ɾ/ and the English palatal liquid /l/, those structures are less likely to be carried over cross linguistically.

The goals of this study were to describe speech sound patterns in typically developing preschool children with differing degrees of exposure to English and Spanish. Comparison of monolingual English children, English–Spanish bilingual children who were predominantiy exposed to English, and relatively balanced English–Spanish bilingual children was employed to consider the effects of degree of exposure to sound acquisition profiles at this stage of acquisition. A languages-in-contact perspective helps to make predictions about likely influences between the two languages. We explore whether differences in degree of exposure to the two languages had an effect on the rate and timing of speech sound acquisition.

English and Spanish Phonology

As a background to considering English–Spanish bilingual phonological acquisition, we compare the general phonological properties of English and Spanish (more in-depth discussion of Spanish phonology can be found in Goldstein, 1995, and Zapf, 1994). The following consonants occur in both languages: /b p t g k m n l ṭ j s ʃ},{. There are several differences between the two languages. Alveolar phonemes in English are produced as dental cognates in Spanish, and the voiceless aspirated stops of English are unaspirated in Spanish. Spanish consonant phonemes without English equivalents include /x p t r/. English phonemes /θ z ñ / are not used for phonemic contrast in most dialects of Spanish, including the dialect of Mexican Spanish that was spoken by the children in our study. Consonant allophones differ in English and Spanish. The primary allophonic distinctions of English are substitutions of /c/ and /d/ intervocally with [r] after a stressed vowel, and /t/ word finally with [θ]. Frequent Spanish allophones include the spirantization of voiced stops intervocally, resulting in the production of /b d g/ as the fricatives [β ð ɣ]. Spanish does not include the allophonic velar /l/ that is frequent in English words. English consonants /θ ɣ ñ / may occur as allophones in Mexican Spanish; however, their allophonic occurrence is less frequent and less systematic than spirantization.

The vowel systems of English and Spanish differ in complexity and type. The vowels /i/ and /u/ occur in both languages. American English also contains the vowels /æ e a AE a O o ɑ ə e o/ with /u/ occurring in some common English dialects. Additional Spanish vowels include /a o ò/. The latter two vowels are allophonic variations of the vowels /e/ and /e/ in English. Word and syllable shapes also differ between English and Spanish. In Spanish, most words end with a vowel; permissible word-final consonants are /d n s r l/. In addition to a low rate of closed syllables, consonant clusters are less frequent and cluster types are more constrained in Spanish. In contrast, word length (in number of syllables) is significantly longer in Spanish than in English (Perea, Gotor, & Miralles, 1988, as cited in Vitevich & Rodriguez, 2005).

Monolingual and Bilingual Speech Acquisition

Speech sounds that are produced during the early word stages of acquisition are highly similar regardless of language environment or number of languages that a child is exposed to. Although slight differences in sound frequencies are reported cross linguistically, reflecting ambient language tendencies (Boysson-Bardies & Vihman, 1991), children from various monolingual and bilingual language environments, including English, Spanish, and English–Spanish environments, produce mainly coronal and labial stops,
nasals, and glides, as well as simple CV syllable shapes in early words (Anderson & Smith, 1987; Boysson-Bardies & Vihman, 1991; Eilers, Oller, & Benito-Garcia, 1984; Goldstein & Cintrón, 2001; Oller & Eilers, 1982; Oller, Eilers, Urbano, & Cobo-Lewis, 1997; Vihman, Ferguson, & Elbert, 1986). Research on children from different monolingual language environments indicates that front and central unrounded vowels (e.g., /e e ə a x i/) predominate in first words, regardless of whether the language is English (Davis & MacNeilage, 1990; Stoel-Gammon & Herrington, 1990), French (Levitt & Aydelott-Utman, 1992), Korean (Lee, 2003), Brazilian Portuguese (Teixeira & Davis, 2002), or Ecuadorian Quichua (Gildersleeve-Neumann, 2001).

Growth in knowledge and use of ambient language phonological patterns occurs between ages 2 and 5. During this period, children learn to match precise ambient language phonemic and phonotactic characteristics. Monolingual English-learning children produce later developing sounds—fricatives, affricates, liquids, and velars—more frequently, mastering production characteristics for the majority of these sounds between ages 4 and 5 (Porter & Hodson, 2001; Stoel-Gammon & Dunn, 1985). At the same time, phonotactic complexity increases related to precise ambient language requirements, with consonant clusters, final consonants, and unstressed syllables produced accurately, resulting in a large increase in speech intelligibility (Stoel-Gammon & Dunn, 1985). Research on vowel development indicates that monolingual English children produce most vowels by age 2, except for lax and rhotic vowels (Stoel-Gammon & Herrington, 1990). By age 3, the English vowel system is nearly intact, with typically developing children producing all non-rhotic vowels with greater than 95% accuracy (Pollock & Berni, 2003).

In monolingual Spanish-learning children, phonological acquisition progresses similarly, with greater frequency of fricatives and consonant clusters in 2-year-olds reported than for monolingual English-learning 2-year-olds (Goldstein & Cintrón, 2001). Monolingual Spanish-learning 3- and 4-year-olds continue to simplify consonant clusters more than 10% of the time, also infrequently deleting the velar fricative /x/ and simplifying the tap and trill (Goldstein & Iglesias, 1996). By age 4, most Spanish-learning children produce the consonants of Spanish accurately, although some 4-year-olds exhibit difficulties with fricatives, the alveolar trill and tap, and velars (Acevedo, 1993; Goldstein, 1995; Jimenez, 1987). By age 5, the majority of monolingual Spanish-speaking children produce all consonants accurately except the alveolar trill /r/ and fricative /s/ (Jimenez, 1987) and infrequently exhibit cluster reduction, final consonant deletion, and unstressed syllable deletion (Anderson & Smith, 1987; Goldstein & Iglesias, 1996). Vowel accuracy is achieved early in typical Spanish-speaking 2-year-old children (Goldstein & Cintrón, 2001) as well as 3- to 4-year-old Spanish-speaking children with speech disorders (Goldstein & Pollock, 2000).

Growth in accuracy for ambient language patterns is related to maturation of speech production skill as well as to growth in phonological knowledge about the language. Spanish-learning children must master more articularly complex phonemes, such as trills and lateral liquids, and longer utterances with many multi-syllabic words. In contrast, syllable shapes in Spanish are simple (mainly CV), with fewer final consonants and less complex consonant clusters. In English, this period involves the mastery of phonemes that require complex articulatory postures, such as fricatives, affricates, and liquids, and more complex syllable shapes containing two-, three-, and four-element consonant sequences as well as final consonants. Speech acquisition appears to be a slow progression toward accurate production of the ambient language phonology, resulting in near adult-like proficiency by monolingual English-learning children by approximately age 6 (Sander, 1972; Templin, 1957).

The frequency of phonemes or phonotactic combinations in a particular language may also influence their earlier occurrence in child inventories. Children from language environments with a greater frequency of later developing sounds (based on studies of acquisition in English) have been reported to master these sounds earlier than English-learning children (e.g., Ingram, 1988; Pye, Ingram, & List, 1987; So & Dodd, 1995). For example, in Quichua (Gildersleeve-Neumann, 2001) and Brazilian–Portuguese (Teixeira & Davis, 2002) environments, dorsals and affricates are learned early relative to English, which does not have a high proportion of these types of sounds. The relatively earlier emergence of fricative and affricate manner and dorsal place of articulation suggest the potential influence of salience and general learning from the ambient language. Relative frequency of complex syllable and word shapes in a language may also result in earlier emergence in a child’s speech patterns. For example, early acquisition of final consonants may not be as salient for the Spanish learner as for the English learner because Spanish does not require as many final consonants as English. Four-year-old English learners frequently produce monosyllable words with CV and CVC syllable shapes (Stoel-Gammon & Dunn, 1985), whereas Spanish-speaking children of the same age produce a high proportion of two-syllable words made up of CV syllables (Anderson & Smith, 1987).

Bilingual acquisition requires mastery of the phonological knowledge base and the production system requirements for phonemes and syllable and word shapes in both languages. Although overall language acquisition in bilinguals appears to be similar in rate and achievement to the developmental milestones of their monolingual peers (Junker & Stockman, 2002; Pearson et al., 1997), the specific course and rate of acquisition of language-specific properties in bilingual speech sound acquisition is largely unknown. It is not clearly understood how cross-language effects, relative amount of exposure to each language, and differing phonological and production system properties affect the timeline and path of bilingual speech sound acquisition, particularly when acquiring each language. Bilingual toddlers, for example, produce similar sounds and syllable shapes in the two languages they are exposed to, primarily consisting of early-developing sounds that are similar in cross-linguistically. On the other hand, bilingual toddlers do not yet appear to accurately contrast phonetic differences between languages in either phonemes or phonotactic complexity (Redlinger & Park, 1979; Schnitzer & Krasinski, 1996; Vogel, 1975; Volterra & Taeschner, 1977), which is consistent with monolingual toddlers who also do not have overall mastery of their language’s phonology or requirements for sound production properties.

The specific languages to which children are exposed potentially affect their bilingual phonemic and phonotactic development. For example, Kehoe (2002) found that Spanish–German simultaneous bilingual children demonstrated production of the Spanish five-vowel system similar to their monolingual Spanish-speaking peers, but acquisition of the German long and short vowels was slower when compared to monolingual German children of the same age. In a follow-up study of these same Spanish–German bilingual
children, Kehoe and Lleó (2003) found that the more complex phonotactic patterns of German resulted in earlier emergence of complex syllable shapes in Spanish compared to monolingual Spanish peers. In a longitudinal study of 2 preschool-aged Cantonese–English bilinguals, Holm and Dodd (1999) found that these children developed sound inventories and exhibited many error patterns that were comparable to those exhibited by monolinguals in each language. Yet they evidenced unusual errors in English that suggested the influence of Cantonese phonological development and Cantonese phonology, including aspiration and backing. Findings of unusual errors in English have also been documented for bilingual children whose first language is Farsi (Keshavarz & Ingram, 2002), as well as Korean, Russian, or French (Anderson, 2004).

Most studies of bilingual phonological acquisition in preschoolers have examined children’s speech at a single time point. A few case studies of simultaneous bilingual children have examined change over time and suggested phonological growth in both languages, but with no comparison to growth patterns for their monolingual peers (e.g., Fantini, 1979; Schnitzer & Krasinski, 1994, 1996). A noteworthy exception is Kehoe (2002), who found that bilingual (Spanish–German) children acquired vowels at a rate that was similar to their Spanish monolingual peers but were delayed at all three time points in the acquisition of German vowel length contrasts when compared to monolingual German peers. Studies of sequential bilingual preschoolers also suggest slow growth in both languages, although without direct comparison to monolingual children. In longitudinal studies of 5 sequential bilingual preschoolers who were learning English as a second language, 1 each from Russian and French and 3 from Korean home environments, Anderson (2004) found that accuracy rates for consonants and phonemic inventories did not change in either language. Holm and Dodd (1999) examined phonological development in both languages of 2 Cantonese–English sequential bilinguals. One child showed little change in word shape error patterns in English from 27 to 37 months, but consonant accuracy increased from 55% to 80%. The second child also exhibited many substitution and word shape error patterns in English and decreases in error frequency after 38 months of age. Although limited in supporting generalizations, these case studies suggest slower phonological acquisition in both sequential and simultaneous bilinguals than in their monolingual peers.

Available data provide a partial picture of how bilingual preschoolers’ speech sound acquisition may differ from monolingual children. In the current study, English speech sound development in 3- and 4-year-old monolingual English children (E), English–Spanish children who were predominantly exposed to English (PE), and relatively balanced bilingual English–Spanish (ES) children were compared. Consonant, vowel, and word and syllable shape inventories, accuracy rates, and phonological error patterns for the three groups were compared based on single-word picture naming tasks. The following hypotheses were evaluated:

- Children from bilingual backgrounds (PE and ES) will exhibit a greater frequency of errors than their monolingual English peers. PE and ES children will exhibit error patterns in English productions, reflecting phonemic and word and syllable structure characteristics that are typical for children learning Spanish. They also may exhibit a higher rate of universal developmental error patterns in the acquisition of English properties that are more complex than Spanish, such as syllable shape complexity and vowel inventories.
- Children from all language groups will exhibit a decrease in errors and increase in accuracy over time.

METHOD

Participants

At study onset, the 33 participants were between ages 3;1 (years; months) and 3;10. All of the participants spoke English at the time of the fall testing and were further divided into English-only (E), predominantly English (PE), and balanced bilingual English–Spanish (ES) groups (see Table 1). They were enrolled at a Head Start program in central Texas. Typical language development was established based on their performance on English and Spanish versions of the Receptive and Expressive One-Word Picture Vocabulary Tests (Gardner, 1985, 1990), the Comprehension subtest of the Stanford Binet Intelligence Scale: Fourth Edition (Thorndike, Hagan, & Sattler, 1986), and dynamic assessment procedures as described by Kester, Peña, and Gillam (2001).

Spoken responses to a picture naming task (Appendix A) were collected at the beginning and at the end (8 months later) of the Head Start school year. Children were from English, Mexican English–Spanish, and Mexican Spanish home language environments. English was the language that was used in the Head Start classrooms under study, although some teachers and classroom assistants were bilingual. The use of English was encouraged by the teachers, and Spanish was rarely spoken by the teachers or children.

Children varied in their home language experiences. At the extremes were children from home environments where only English or only Spanish was spoken. The majority of the children, however, came from bilingual home environments, where extended family members spoke Spanish, English, or both. To appropriately categorize the children’s language exposure, the following information was reviewed: (a) parent report of languages spoken by extended family members, collected by Head Start program personnel in parent interviews; (b) teacher report on language exposure and use as provided to the primary researcher; (c) the average of the rating by six English–Spanish bilingual graduate student clinicians on children’s English–Spanish receptive and expressive knowledge based on their year-long regular classroom interactions with the children; and (d) language(s) spoken by the

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1The term “error pattern” describes inaccurate productions of adult targets. In most cases, error patterns describe errors that are typical for development and do not suggest disordered speech sound acquisition. A higher rate of errors as predicted for bilingual children does not imply greater risk for disordered speech sound development.
Table 1. Demographic information on study participants by language group and analysis period.

<table>
<thead>
<tr>
<th>Language group</th>
<th>English only (E)</th>
<th>Bilingual, more English (PE)</th>
<th>Balanced bilingual (ES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>10</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>By gender</td>
<td>7 F, 3 M</td>
<td>10 F, 10 M</td>
<td>2 F, 1 M</td>
</tr>
<tr>
<td>By ethnicity</td>
<td>2 H, 5 A, 3 C</td>
<td>19 H, 1 A</td>
<td>3 H</td>
</tr>
<tr>
<td>Fall average age (SD)</td>
<td>3.6 (0.3)</td>
<td>3.6 (0.3)</td>
<td>3.5 (0.1)</td>
</tr>
<tr>
<td>Fall age range</td>
<td>3:1–3:10</td>
<td>3:0–3:10</td>
<td>3:4–3:6</td>
</tr>
<tr>
<td>Spring average age (SD)</td>
<td>4.2 (0.3)</td>
<td>4.2 (0.3)</td>
<td>4.1 (0.1)</td>
</tr>
<tr>
<td>Spring age range</td>
<td>3:9–4:6</td>
<td>3:8–4:6</td>
<td>4:0–4:2</td>
</tr>
</tbody>
</table>

Note. F = female, M = male, H = Hispanic (Mexican descent), A = African American, C = Caucasian; ages (standard deviations) are shown in years/months.

Data Analyses

The primary author transcribed the data from the audiotapes and entered the information into the Logical International Phonetics Program (LIPP; Oller & Delgado, 2000). The second author retranscribed 20% of the data. The mean intertranscriber agreement was 94% for the transcribed data. Independent and relational analyses for each child and by language group were conducted using LIPP. Dialectal features of the adults in the community were not considered in the children’s productions. For example, both [dʒɪŋ] and [dʒʊŋ] were accepted for the word dog because the /dʒ/ is a phoneme in the English dialect that is spoken by many central Texans.

Independent analyses. Independent analyses explored consonant and vowel inventories, regardless of accuracy. Specific syllable shapes (such as CCVC) were not counted because there were limited opportunities for each in a sample of 65 words; instead, initial, medial, and final consonant singleton and sequence productions were counted. Descriptive analyses included consonant place and manner, vowel height and front/back dimensions, consonant cluster, and syllable and word shape characteristics as they were present in the single-word naming task that was employed. Because the speech samples were single-word responses to pictures rather than spontaneous speech samples, a consonant, vowel, consonant cluster sequence, or word shape type, was counted as being in a child’s inventory at each time point if it was produced at least twice. Group comparisons were for both time points and change over time.

Relational analyses. Children’s productions were compared to English and Spanish normative data with the intent of examining cross-linguistic effects. Relational analyses included analyses of accuracy by calculating the percentage of consonants correct (PCC; Shriberg, Austin, Lewis, McSweeney, & Wilson, 1997) and the percentage of vowels correct (PVC; Shriberg, 1993), and analyses of frequency by calculating the percentage of occurrence of 28 phonological error patterns (see Appendix B). These error patterns were selected based on their occurrence in English and Spanish speech acquisition. Statistical comparisons were made first of PCC and PVC with follow-up analyses for significant findings. There were 10 potential follow-up error patterns identified based on their greater than 5% occurrence in the sample of all phonological error patterns analyzed. Five of these error patterns were consonant substitution patterns (final devoicing, gliding, glottal

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substitution, stopping, and vocalization), two were vowel substitution patterns (vowel front/back changes, vowel tense/lax changes), and three of the patterns affected the syllable structure (final consonant deletion, cluster deletion, and cluster reduction).

Statistical comparisons of phoneme accuracy and the frequency of error patterns were conducted using the Statistical Package for the Social Sciences (SPSS, v. 14.0). Between- (group) and within-subjects comparisons (time and measure) were conducted using repeated measures analysis of variance (ANOVA). A multivariate solution is reported when Mauchly’s test indicated that analysis did not meet assumptions of sphericity. A significance level of $p < .05$ was adopted; trends of $.05 < p < .10$ are also reported as significant due to the exploratory nature of the comparisons. Post-hoc Bonferroni test comparisons were used to follow up on significant interactions. Effect size was calculated using partial eta squared ($\eta_p^2$), interpreting the effect as follows: $0.00$ to $0.09$ = negligible, $0.10$ to $0.29$ = small, $0.30$ to $0.49$ = moderate, and $.50$ and greater = large (Rosenthal & Rosnow, 1984).

## RESULTS

### Inventory Analysis

Consonant, vowel, and syllable shape inventories for the E, PE, and ES groups were compared descriptively at T1 and T2 to provide a background on the children’s accuracy in productions of phonemes and word shapes on these word targets. Consonant place and manner inventories for English were tallied. English vowel height and front/back dimension inventories as well as the specific vowels /ɪ ɛ ɛ æ ɔ ʊ oʊ oʊ a/ were also compared by group.

All of the children produced the full range of English vowel height and front/back dimensions. At T1, all E and most PE and ES children produced the English vowel phoneme inventory; 1 PE child did not produce /ɪ/ and 2 ES children did not produce /ɛ/. By T2, all participants in the three groups produced the complete English vowel phoneme inventory.

Children in each group produced most consonant place and manner categories at both T1 and T2. Appendix C presents consonant and syllable shape inventories by language group. At T1, all E and ES children and 95% of the PE children produced every consonant place category except interdental. At T1, interdental consonants were produced by 60% of the E children, 35% of the PE children, but none of the ES children. At T2, there was an increase in interdental use, with 100% of the ES children, 90% of the E children, and 80% of the PE children producing interdental. With respect to consonant manner, all children produced stops, nasals, glides, fricatives, and liquids at both T1 and T2. At T1, 90% of the children in the E and PE groups and 33% of the children in the ES group produced affricates. At T2, all of the E and PE children and 2 of the ES children produced affricates. All of the children produced mono- and multisyllabic word shapes and initial, medial, and final consonants at both T1 and T2.

Consonant cluster sequences proved more difficult for many bilingual children. All of the E children produced consonant cluster sequences in initial and final word position at T1 and T2; 90% of the E children produced medial clusters at T1, and 100% produced them at T2. Fewer of the PE and ES children produced consonant cluster sequences: 85% of the PE children produced initial and final clusters and 90% produced medial clusters at T1; the production of clusters by PE children increased slightly by T2, with only medial consonant cluster sequences produced by all of the PE children. Only 1 (33%) of the 3 ES children produced initial and medial consonant clusters and 2 (66%) produced final clusters at T1. At T2, the production of consonant clusters by the ES children had increased in initial and medial word position, although at T2, only 1 of the 3 children produced final clusters.

### Accuracy Analysis

#### Vowels and consonants

Accuracy for vowels and consonants was compared using a repeated measures ANOVA. Accuracy (PVC and PCC measures) and time (T1 and T2) were the within-subjects factors, and group (E, PE, and ES) was the between-subjects factor. Tests of within-subjects effects showed a main effect for accuracy, $F(1, 30) = 41.73, p < .001, \eta_p^2 = .582$, a large effect; a significant trend for group, $F(1, 30) = 2.68, p = .091, \eta_p^2 = .148$, a small effect; and a significant trend for Group × Accuracy interaction, $F(2, 30) = 2.93, p = .069, \eta_p^2 = .163$, a small effect. Change over time was not significant $F(1,30) = .223, p = .64, \eta_p^2 = .007$. Generally, all three groups were more accurate in the production of vowels (85.53%) than consonants (67.95%). Overall, the E group was more accurate than the ES group (83.13% vs. 68.87%), indicating a significant trend ($p = .100$); the PE group ($M = 78.22\%$ accurate) did not show statistically significant differences from either the E group ($p = .606$) or the ES group ($p = .390$). The Group × Accuracy trend was explored visually (see Figure 1). Here, it was noted that overall, the ES group (with the least exposure to English) was similar to the E and PE groups in vowel accuracy, but less accurate compared to the E and PE groups in consonant accuracy.

Consonant error patterns were explored by group and by time. The group comparison determined if children with a greater degree of exposure to Spanish made more frequent errors in English. Table 2 describes the frequency of consonant and syllable shape error patterns by language group and for all children at both points in time. The five consonant error patterns occurring at a rate of 5% or greater in any language group were compared statistically. Repeated measures ANOVA were conducted with time (T1 and T2) and consonant error (glottal substitution, e.g., /d/ → [t]); stopping, e.g., /k/ → [d]; gliding, e.g., /l/ → [w]; final consonant devoicing, e.g., /g/ → [k]; and vocalization, e.g., /i/ → [ɪ] as the within-subjects factors and group (E, PE, and ES) as the between-subjects factors. Multivariate tests revealed a main effect for consonant error, $F(4, 27) = 36.53, p < .001, \eta_p^2 = .844$, a large effect; a significant main effect for group, $F(2, 30) = 8.602, p = .001, \eta_p^2 = .364$, a moderate effect; a significant main effect for Consonant Error × Group, $F(8, 56) = 1.845, p = .088, \eta_p^2 = .209$, a small effect; and a significant trend for Time × Consonant Error, $F(4, 27) = 2.207, p = .095, \eta_p^2 = .246$, a small effect.

For consonant error types, pairwise comparisons using a Bonferroni adjustment for multiple comparisons indicated that children made proportionally more final consonant devoicing errors in comparison to all error types ($p < .001$ for all). For consonant errors, it was found that gliding errors occurred more often overall than glottal substitutions ($p = .003$). There were no differences in consonant error rates for vocalizations compared to glides ($p = .505$), glottal stops ($p = .792$), and stops ($p = 1.00$); or stops compared to glides ($p < .296$) and glottal stops ($p = 1.00$).
For consonant errors by group, pairwise comparisons using a Bonferroni adjustment showed that the E group produced the lowest overall average consonant error rate (6.74%) compared to the averages for the PE (10.76%) and ES (16.68%) groups. The differences between the E and PE groups ($p = .033$) and between the E and ES groups ($p = .001$) were significant; the difference between the PE and ES groups was a nonsignificant trend ($p = .054$). Note that the greatest variation in overall consonant error pattern was within the ES group, with an overall standard error of 2.2 in comparison to standard errors of 1.21 and .85 for the E and PE groups, respectively.

For the Consonant Error × Group trend, the error pattern rates shown in Table 2 demonstrate that final devoicing was the most frequent consonant error at both time points for all three language groups. For the E group, all other consonant error types averaged below 4% at both time points, except for gliding, which was 9% at T1. For the PE group, consonant errors for glottal substitution were similar to those for the E group at both time points. At T1, average rates of vocalization and stopping were higher for the PE group than for the E group; however, these differences were not significant. The frequency of gliding was similar in the E and PE groups.

### Table 2. Average phoneme accuracy and error pattern frequencies for each language group at both points in time.

<table>
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<th>Time 1</th>
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**Note.** PCC = percentage of consonants correct, PVC = percentage of vowels correct, FDV = final devoicing, GLD = gliding, GLT = glottal substitution, STP = stopping, VOC = vocalization, F/B = vowel front/back changes, T/L = vowel tense/lax changes, FCD = final consonant deletion, CD = cluster deletion, CR = cluster reduction.

For the comparison of overall percentage of vowels correct and percentage of consonants correct by language group. Differences between overall vowel and consonant accuracy were significant by language group, $F(1, 30) = 41.73$, $p < .001$, $\eta^2_p = .582$. Changes over time were not significant.
PE children at T1; however, the average rate of gliding for the E children had decreased at T2, but had not decreased for the PE children. Nonetheless, the standard deviations were large, indicating that there was likely a great deal of individual variation. At both time points, gliding and vocalization errors occurred more often in the ES group than in the PE or E groups and in comparison to glottal substitution and stopping errors made by the ES group. For the Consonant Error × Time trend, an inspection of the data found in Table 2 demonstrates that most consonant error rates did not differ from T1 to T2. Overall, gliding errors appeared to account for this trend, decreasing by 6.21%, although for the ES group, vocalization increased from 8.33 to 18.45, and final devoicing increased from 34.32 to 43.94 at T2. Even though overall vocalization errors increased by 2.73%, and average rate of vocalization increased from T1 to T2 in ES children, the increase does not appear to contribute to the trend. A large standard deviation rate, particularly for the ES children, reflects the effect of the small group size—one child produced all syllable-final rhotics /s/ as vowels, whereas the other 2 ES children produced almost all of these sounds correctly.

Descriptive error patterns within the data reinforce the overall statistical results for consonant accuracy. The ES and PE bilingual children produced the voiced bilabial Spanish allophone [b] in English words at T1 and the Spanish velar fricative phoneme /χ/ and voiced velar fricative [ɣ] in English words at T1 and T2 (see Appendix C). Additionally, the ES and PE children often substituted [ɣ] following the phonological rules for Spanish in their application to English word medial voiced stops (i.e., spirantization) in diminutives such as doggie and piggie. The voiceless velar fricative was also produced in final position for /ɡ/ (pig, dog) or in initial, medial, or final position for /χ/ (e.g., cake, bike, turkey, cracker, and rocking chair). At T1, 1 E child produced the [ɣ], producing this non-English sound for the final /ɡ/ phoneme in pig and dog. In most cases, the frequency of these non-English phones decreased or stayed the same over time, although the frequency of [ɣ] increased in both PE and ES children.

Vowel accuracy did not appear to differ by language group, but some English vowel productions suggested the effects of Spanish vowels on English targets. Some children produced the low central /a/ for English vowels. In the fall, 20% of the E, 25% of the PE, and 66% of the ES children produced English words with the vowel /a/. In the spring, the frequency of these vowel errors was stable for the E and ES children and increased to 40% in the PE children. Almost all of the /a/ substitutions were for the English /æ/ and /a/, although 1 E child and 1 PE child in the fall, and 2 PE children and 1 ES child in the spring, produced /a/ for /a/.

**Syllable and word structures.** To explore word-level accuracy, three syllable-level simplification patterns were compared statistically (frequency of these error patterns at each time point is presented in Table 2). As before, a repeated measures ANOVA was conducted with group (E, PE, and ES) as the between-subjects factor and time (T1 and T2) and syllable error (cluster deletion, e.g., /stip/ → [ip]; cluster reduction, e.g., /stip/ → [tip]; and final consonant deletion, e.g., /fit/ → [fɪt]) as the within-subjects factors. Multivariate tests indicated significant main effects for time, $F(1, 30) = 10.76, p = .003, η^2_p = .264$, a small effect; and syllable error, $F(2, 29) = 39.15, p < .001, η^2_p = .730$, a large effect; and a significant Time × Syllable Error interaction, $F(2, 29) = 4.49, p = .020, η^2_p = .236$, a small effect. Finally, there was a nonsignificant Syllable Error × Group trend $F(4, 60) = 2.240, p = .075, η^2_p = .130$, a small effect. Overall, this result indicates that the reduction from T1 to T2 in syllable errors was related to group.

The main effects are subsumed in the significant Time × Syllable Error interaction, thus post-hoc analyses focused on these effects. Children from all three groups produced a variety of syllable and word shapes. There was some evidence of English–Spanish effects in the types of syllable structures that were produced by the three groups. Children with the most exposure to Spanish (the ES group) produced the lowest frequency of consonant cluster sequences, suggesting the effect of the simpler syllable shapes of Spanish on the children’s productions of English words. There were no changes in cluster deletion error rate, which occurred at the lowest frequency at both T1 and T2 (see Figure 2). From T1 to T2, there was also a 4.17% decrease overall for cluster reduction (which had the highest error rate) and a 6.36% decrease overall.

**Figure 2.** Frequency of syllable-level errors at each point in time. Change was significant: $F(2, 29) = 4.49$, $p = .020, η^2_p = .236$. Language group differences in syllable-level errors were not significant.

Note. CD = cluster deletion, CR = cluster reduction, FCD = final consonant deletion.
for final consonant deletion. Examination of this trend indicates that all three groups produced similarly low rates of cluster deletion errors. The ES group produced a higher rate of final consonant deletions compared with both the E and PE groups. Differences in rate of cluster reduction were observed across the three groups, with the E group producing the lowest overall cluster reduction error rate ($M = 22.92\%$), followed by the PE ($M = 32.39\%$) and the ES ($M = 45.56\%$) groups.

Most cluster errors were simplifications of initial or final clusters, almost all of which followed typical patterns (initial s-clusters produced as the second phoneme only (e.g., [tʌˈvæ] for stove). ES children, with the least exposure to English, demonstrated a greater frequency of cluster error, with between 11 and 17 clusters in error per child at T1. Most of the words of ES children were produced with simple CV word shapes. At T2, cluster errors were still very frequent in ES children. Although few ES children’s cluster errors were substitutions, by T2, word shapes were becoming more complex and were often produced as CVC word shapes instead of CCVC (e.g., [bʌz] for spoon). At T2, cluster errors for E children had changed little in frequency or type—most children continued to reduce two- or three-element clusters. In contrast, T2 cluster errors had decreased in frequency in the PE group. Many of their errors were substitutions of one cluster member rather than omissions that resulted in simplification of the word shape (e.g., [ɡwɛsɔ] for glasses).

Group effects were pronounced related to English exposure at the onset of the study. Overall, E children’s responses showed the highest accuracy for consonants, vowels, and word shapes, at times differing significantly from their ES and PE bilingual peers. PE children generally had lower error rates than ES children, who had the lowest initial exposure to English. Time and error pattern frequency interacted; similar patterns for decreased error pattern frequency at T2 were observed in children from all three language groups, although 3 of the 8 error patterns increased for both bilingual groups (PE and ES) at T2.

## Discussion

Speech sound acquisition in children from monolingual English (E) and two bilingual English–Spanish backgrounds (predominantly English, PE, and equivalent English–Spanish, ES) was compared. Speech produced by children from all three language groups was similar in many ways. Regardless of language background or level of English exposure, these 3- and 4-year-old children produced most sounds of English in their single-word productions, as would be expected for overall speech development chronologically. As predicted, children had similar phonetic inventories in each language environment. The similarities in segmental inventories suggest that children from all three language backgrounds have age-appropriate speech production capabilities as well as phonological knowledge for English phonemes and combinations. The children with the greatest cumulative exposure to English predictably made the fewest errors on average, but the average rate of many error patterns decreased over time for children, with no significant differences among the three language groups.

Although error rates differed by language group, children in all three language groups increased in speech accuracy during this time period, demonstrating development toward a full phonological system. Both cross-linguistic competition and developmental production system effects are evident in the data. With respect to cross-linguistic group effects, some error patterns were observed that reflected a relative amount of exposure to English. In Spanish, the liquid /l/ and the tap and trill */ɾ/* sounds are produced differently than in English. The Spanish /l/ is produced with the tongue tip rather than the tongue blade, as in English, and has no velar /l/ equivalent in Spanish. Gliding of /l/ and /ɾ/ occurred most frequently in the ES group, where children had the least exposure to English. Vocalization (substitution of a vowel for */ɾ/* was also highest in frequency in this ES group. Both of these substitution processes indicate lower production system level of accuracy for phonemes that are different between English and Spanish. In the example of the trill and tap sounds, in Spanish, these are particularly late to be acquired and might not yet be in the production system inventory of these 3- and 4-year-old Spanish learners (Goldstein, 1995). The Spanish liquid /l/ is acquired relatively late as in English, after age 2, and mastered by approximately age 4 (Goldstein, 1995; Goldstein & Cintrón, 2001).

Additional effects of the Spanish phonemic inventory on the English inventory of the bilingual children included sounds that were produced by some ES and PE children that are not phonemes in English—the Spanish phonemes /ɾ/ and the allophones [ɾ] for the English sounds in the target words. Frequency of these sounds was greater in ES than PE bilinguals, and greater in both bilingual groups than in the E group. The production of Spanish-like allophones in our English data suggests cross-linguistic effects of Spanish home language environments on English word productions. These findings are consistent with a languages-in-contact theory, and are supported by cross-language */ɾ/* substitutions in English–Spanish bilinguals (Goldstein & Washington, 2001), articulatory pattern transfer from French and Korean to English in French–English and Korean–English bilinguals (Anderson, 2004), and English vowel productions in Farsi in a bilingual child (Keshavarz & Ingram, 2002).

The sounds [a] and [y] also occurred in a few of the E children’s productions in the fall; production of the [a] continued in 2 E children in the spring. Although it is possible that the [a] and [y] were produced because of their occurrence in Spanish, the presence of both at T1 and [a] at T2 in a few E children suggests that their production may not be purely a result of ambient language exposure. Although it is unlikely that the extremely limited production of Spanish in the classroom affected the English of the E children, it is possible that these children were exposed to Spanish outside of Head Start that was not reported to the researchers. What is also likely is that allophonic use of [a] in the E children is not unusual for E children during development. Productions of [a] were more likely to be noteworthy to the bilingual English–Spanish transcribers in this study than they would have been in studies of pure English phonological development, in which English phonemes are focused on and English vowel phonetic inventory has received little attention for this age range. Nevertheless, the occurrence of these vowel allophones was very low in the 2 E children.

In the case of word complexity, both final consonant deletion and cluster reduction show differences related to the amount of exposure to English. For final consonant deletion, the ES group had the least exposure to final consonants, as Spanish permits only five final consonants, and many word forms are open syllables (i.e., vowel final). In the case of cluster reduction, like final devoicing, all three groups were less accurate at both time points. But the trend
for less English exposure to be directly related to more errors is consistent with other error patterns. In this case, clusters are far less frequent in Spanish. In addition, cluster reduction is a late-disappearing production system effect, which is likely related to difficulty in producing differing consonant closures in a sequence. Because of the high rates of final consonant deletion and cluster reduction in all three language groups, and the highest rate of both error patterns for the children with the least English exposure, both distance, predicted by the languages-in-contact perspective, and mastering peripheral production system requirements likely play a role in the trend observed. In contrast, early resolved error patterns such as stopping and cluster deletion are mastered equally well across the three groups, regardless of language exposure. This across-group similarity suggests that if children have already mastered the production system requirements for a phoneme, they more readily transfer them to support word-level accuracy in a second language. It should be noted that vowels, another early-mastered aspect of the sound system, were comparably accurate across the three groups. Conversely, the ES group, with the least exposure to English, showed the highest maintenance of the Spanish patterns. Vocalization errors were also most frequent in the ES group. In this instance, the children had been confronted in their native language with r-sounds (e.g., the tap and trill) that require more precision in articulator placement for accuracy and are late occurring in production inventories of typically developing children. When they attempted English words with r-sounds, the children resorted to a vocalization substitution, which is consistent with developmental accounts for English and not cross-language influences.

Some between-group differences in error patterns were less clearly related to cross-linguistic effects. Final consonant devoicing was higher in the bilingual children at both time points and showed the highest error rate in the ES group. This sound pattern was one of the most difficult for all three groups. Typically, final consonant devoicing occurs because of the difficulty in sustaining a pressure drop across the glottis to maintain voicing at the end of utterances. It is possible that children take a longer time to master this articulatory–phonatory system coordination necessary for sound level accuracy (Ohala, 1983). Phonemic voice onset time distinctions for stop consonants differ between English and Spanish (Lisker & Abramson, 1964). Spanish only permits five final consonants, creating potential production system and phonological complexities for bilingual children in mastering this segmental and phonotactic aspect of English. Alternatively, what may be captured phonologically as final consonant devoicing may be an effect of shorter vowel productions, with shorter pre-final vowels resulting in the perception of final consonant devoicing (phonological rules of English result in allophonically longer vowels produced with final voiced consonants). Thus, the phonological realization of final devoicing may result from a lack of consonant voicing or shorter vowel duration. In either case, the PE group shows some effect and the ES group shows even more effects relative to their degree of exposure to English when compared to the English-only speakers. In each of these cases of differences, diversity between English and Spanish phonology as well as relative production system requirements for precision may have an effect on level of accuracy, which is consistent with a languages-in-contact perspective (Döpke, 2000). Acoustic analysis will be necessary to determine if vowel length or word-final consonant devoicing resulted in this language-specific difference.

The more frequent use of glottal stop [?] by the bilingual children than the monolingual children is not a cross-linguistic effect. Although many of the bilingual children used the glottal stop as a final consonant in productions of English words, the glottal stop is not used as a final allophone in Spanish and cannot be directly attributed to Spanish. It is more likely a universal development pattern, more frequent in bilingual English learners because they will have had less exposure to English, although further exploration of this issue with a larger sample or acoustic analysis would help clarify this question.

**Study Limitations**

This study has several limitations that should be considered in future studies of bilingual phonological acquisition patterns. Responses in English allow a window into only one of the two languages of the bilingual child. We have no knowledge of how Spanish is developing in these two groups of children, and whether some of the aspects showing greater error rates in English, such as syllable complexity, occur at lower rates in Spanish. That outcome would suggest application of the syllable complexity rule to Spanish, as has been suggested by previous researchers (e.g., Gawlitzeck-Maiwald & Tracy, 1996). In addition, the single-word picture naming task was limited for examining cross-linguistic effects or variability in occurrence of errors and accuracy, which may be an important facet of the unique course of development in bilingual children. There were limited opportunities to examine spirantization, the production of affricates and interdentals and words in all positions, and some error patterns (final devoicing, gliding, and vocalization). We also had differing group sizes and few children in the E and ES groups. The ES group was particularly small for comparing change over time and for comparing to the other language groups. The results for the small sample of ES children are only preliminary and suggest questions for future studies of bilingual speech sound acquisition in a larger cohort.

**CLINICAL IMPLICATIONS**

Our findings concur with those of previous studies indicating that the phonological rules of one language may transfer to the second language during acquisition. SLPs should be aware that language-specific error patterns may be typical for bilingual development in transferring into English usage, and not an indicator of clinical speech disorder or delay. In this study, this pattern was observed in bilingual children’s substitution of Spanish phonemes, such as /s/ and Spanish allophones, such as [β] and [γ], for English phonemes. In addition, a higher frequency of cluster reduction suggests an extension of Spanish phonotactic rules to the children’s English productions as well as persistence of immature patterns of production in producing clusters that are typical at this age. It should be expected that if a child has greater exposure to a second language such as Spanish, it is likely that the child may use Spanish knowledge in the acquisition of English phonology, particularly in areas where language properties differ.

Our results emphasize the importance of describing a child’s home language to understand speech acquisition in English. Application of monolingual expectations to bilingual children is not valid for supporting assessment and intervention protocols for this...
growing population. Clear definition of bilingual status is important to full description of the course of development, with differing expectations based on the degree of exposure to each language.

Because preschool-age children’s patterns were analyzed at two time points, it is difficult to know if it will take longer overall for a typical bilingual child to resolve developmental errors in English due to the complexities of learning two languages. The present findings examining change over time support the notion that children from all three groups learned English at largely the same rate even though they started out at different points based on differences in exposure to English and to Spanish. The different types of changes that children made were likely based on their level of exposure to the two languages. Additionally, the patterns that showed changes over time are those that one would expect due to the development of capacities of the speech production system during this age range. Cluster reduction and final consonant deletion decreased in all three groups, and gliding decreased in the E and ES groups and stayed the same in the PE group over this 8-month period. In contrast, final devoicing continued in frequency, and only the E group decreased in frequency during this same time period, suggesting that this process is difficult to resolve based on production requirements, regardless of language exposure.

Finally, it is important to note that our findings do not suggest that learning one language is better than learning two languages. Error rates decreased over time at the same rate for the entire group, which is consistent with expected developmental changes in this age range. Error patterns observed were likely due to a combination of development of sound system capacities as well as the requirements of second language learning. The end result for these children is likely to be adult-level competency in both languages.

ACKNOWLEDGMENT

The data for this study were collected while the first author was at The University of Texas at Austin. Funding for data collection was provided to the first author by a Department of Education Leadership Training Grant (H325D000029) that was awarded to Thomas Marquardt, Department of Communication Science and Disorders, The University of Texas at Austin.

REFERENCES


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### APPENDIX A. STIMULUS WORD LIST

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*Note.* A resource for many stimulus words was the Assessment of Phonological Processes—Revised (Hodson, 1986).
APPENDIX B. DEFINITIONS AND EXAMPLES OF DEVELOPMENTAL ERROR PATTERNS ANALYZED

Segmental-Level Error Patterns: Consonants and Vowels

- **Backing.** A consonant produced further back in the oral cavity.
  \[/d\alpha/ \rightarrow /\acute{\imath}/\]
- **Final Devoicing.** Final voiced consonant produced as its voiceless counterpart.
  \[/d\alpha g/ \rightarrow [\acute{\imath}nk]\]
- **Final Voicing.** A final voiceless consonant produced as its voiced counterpart.
  \[/d\alpha k/ \rightarrow [\acute{\imath}g]\]
- **Fronting.** A consonant produced further forward in the oral cavity.
  \[/\acute{\imath}g/ / \rightarrow [d\alpha']/\]
- **Gliding.** A liquid produced as a glide.
  \[/\acute{\imath}g\acute{\imath}li/ \rightarrow [\acute{\imath}\acute{\imath}\acute{\imath}l]\]
- **Glottal Substitution.** Any consonant produced as a glottal stop.
  \[/\acute{\imath}f/ \rightarrow [\acute{\imath}f']/\; /k\acute{\imath}p/ \rightarrow [k\acute{\imath}f]\]
- **Liquidding.** A glide produced as a liquid.
  \[/\acute{\imath}ks/ \rightarrow [\acute{\imath}s]\]
- **Medial Devoicing.** A medial voiced consonant produced as its voiceless counterpart.
  \[/\acute{\imath}be'\beta i/ \rightarrow [\acute{\imath}\acute{\imath}p\acute{\imath}i]\]
- **Nasal Stopping.** A nasal consonant released orally.
  \[/\acute{\imath}n\acute{\imath}m/ \rightarrow [\acute{\imath}\acute{\imath}m]\]
- **Spirantization.** A non-fricative produced as a fricative.
  \[/d\alpha k/ \rightarrow [z\acute{\imath}k]\]
- **Stopping.** A fricative or affricate produced as a stop.
  \[/\acute{\imath}j/ \rightarrow [\acute{\imath}j]\]
- **Vocalization.** A liquid produced as a vowel or glide.
  \[/\acute{\imath}l/ \rightarrow [\acute{\imath}\acute{\imath}w]\]
- **Vowel Diphthong Reduction.** A diphthong produced as a monophthong.
  \[/h\acute{\imath}a\acute{\imath}\acute{\imath}/ \rightarrow [h\acute{\imath}a]\]
- **Vowel Front/Back Dimension.** A high vowel produced as a mid vowel, or mid vowel produced as a low vowel, or vice versa.
  \[/\acute{\imath}p\acute{\imath}/ \rightarrow [\acute{\imath}p\acute{\imath}]; /\acute{\imath}o\acute{\imath}/ \rightarrow [\acute{\imath}t]\]
- **Vowel Front/Back Dimension – 2 levels.** A high front vowel produced as a back vowel, or vice versa.
  \[/\acute{\imath}b\acute{\imath}i/ \rightarrow [\acute{\imath}b\acute{\imath}i]\]
- **Vowel Height – 1 Level.** A high vowel produced as a mid vowel, or mid vowel produced as a low vowel, or vice versa.
  \[/l\acute{\imath}t/ \rightarrow [l\acute{\imath}t]; /l\acute{\imath}/ \rightarrow [l\acute{\imath}t]\]
- **Vowel Height – 2 Levels.** A high vowel produced as a low vowel, or vice versa.
  \[/l\acute{\imath}/ \rightarrow [l\acute{\imath}t]\]
- **Vowel Lengthening.** A short vowel produced as a long vowel.
  \[/\acute{\imath}d\acute{\imath}k/ \rightarrow [\acute{\imath}d\acute{\imath}k]\]
- **Vowel Shortening.** A long vowel produced as a short vowel.
  \[/\acute{\imath}i\acute{\imath}/ \rightarrow [\acute{\imath}t]\]
- **Vowel Small Rounding.** A round vowel produced as an unrounded vowel, or vice versa.
  \[/\acute{\imath}t/ \rightarrow [\acute{\imath}t]\]
- **Vowel Tense/Lax Changes.** A high tense produced as a mid lax vowel, mid tense as a mid lax vowel, high lax vowel as a mid tense vowel, low lax as a mid lax vowel, or vice versa.
  \[/\acute{\imath}k\acute{\imath}/ \rightarrow [\acute{\imath}k\acute{\imath}]; /\acute{\imath}k\acute{\imath}/ \rightarrow [\acute{\imath}k\acute{\imath}]\]

Syllable-Level Error Patterns

- **Initial Consonant Deletion.** The deletion of any consonant phoneme in initial word position.
  \[/\acute{\imath}g/ \rightarrow [\acute{\imath}]\]
- **Medial Consonant Deletion.** The deletion of any consonant singleton phoneme.
  \[/\acute{\imath}p\acute{\imath}/ \rightarrow [\acute{\imath}\acute{\imath}l]\]
- **Final Consonant Deletion.** The deletion of any consonant phoneme in final word position.
  \[/k\acute{\imath}t/ \rightarrow [k\acute{\imath}]\]
- **Cluster Creation.** A single consonant produced as a consonant cluster.
  \[/\acute{\imath}s\acute{\imath}/ \rightarrow [\acute{\imath}s\acute{\imath}\acute{\imath}k]\]
- **Cluster Deletion.* The deletion of a consonant cluster sequence.
  \[/\acute{\imath}w\acute{\imath}/ \rightarrow [\acute{\imath}m]\]
- **Cluster Reduction.** A consonant cluster sequence produced as a singleton consonant.
  \[/\acute{\imath}b\acute{\imath}k/ \rightarrow [\acute{\imath}b\acute{\imath}k]\]
- **Weak Syllable Deletion.** The deletion of an unstressed syllable in a multisyllabic word.
  \[/\acute{\imath}n\acute{\imath}n\acute{\imath}n\acute{\imath}/ \rightarrow [n\acute{\imath}n]\]

Note. The 10 asterisked (*) error patterns were statistically analyzed because they occurred at rates of 5% or greater in at least one language group at Time 1.
APPENDIX C. PHONETIC INVENTORIES FOR CONSONANT PLACE, CONSONANT MANNER, SYLLABLE SHAPE, AND NON-ENGLISH PHONES BY LANGUAGE GROUP AT TIME 1 AND TIME 2

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Note. Shown are the percentage of children in each language group producing the information in each category.