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Acquisition of the stop-spirant alternation in bilingual Mexican Spanish–English speaking children: Theoretical and clinical implications

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Abstract

The purpose of this study was to identify characteristics of typical acquisition of the Mexican Spanish stop-spirant alternation in bilingual Spanish–English speaking children and to shed light on the theoretical debate over which sound is the underlying form in the stop-spirant allophonic relationship. We predicted that bilingual children would acquire knowledge of this allophonic relationship by the time they reach age 5;0 (years;months) and would demonstrate higher accuracy on the spirants, indicating their role as the underlying phoneme. This quasi-longitudinal study examined children's single word samples in Spanish from ages 2;4–8;2. Samples were phonetically transcribed and analyzed for accuracy, substitution errors and acoustically for intensity ratios. Bilingual children demonstrated overall higher accuracy on the voiced stops as compared to the spirants. Differences in substitution errors across ages were found and acoustic analyses corroborated perceptual findings. The clinical implication of this research is that bilingual children may be in danger of overdiagnosis of speech sound disorders because acquisition of this allophonic rule in bilinguals appears to differ from what has been found in previous studies examining monolingual Spanish speakers.

Keywords

Bilingualism; phonological acquisition; spanish; stop-spirant alternation

Introduction

According to the most recent United States Census report, Latinos are the largest minority group in America, accounting for 52 million individuals (U.S. Census Bureau, 2012). Children are the largest segment of this population, often numbering higher than any other group per state (U.S. Census Bureau, 2010). This means that the majority of children on the caseloads of speech-language pathologists (SLPs) in states such as Texas and California speak Spanish (either exclusively or in addition to English), with Mexican Spanish as the

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dialect most commonly used (Goldstein, 2001). In contrast, ~5% of clinicians certified by the American Speech, Language, and Hearing Association (ASHA) identify themselves as bilingual (ASHA, 2012). In addition to small numbers of bilingual clinicians, available data on typical speech development in bilingual Spanish–English speaking children and methods of identification of bilingual children with speech sound disorders are scarce (Hambly, Wren, McLeod, & Roulstone, 2013). This lack of normative data and proper clinical instruction in methods of best practice with bilingual populations leads to limitations in clinical competence for SLPs faced with identifying and treating speech sound disorders in bilingual children (Kritikos, 2003; Skahan, Watson, & Lof, 2007). Here, we will examine one particular aspect of Spanish phonology, the stop-spirant alternation (where voiced stops and fricatives alternate in certain phonetic contexts), to illustrate how bilingual phonological assessment can be challenging for American SLPs.

This clinical challenge is 2-fold: One facet of this issue stems from lack of knowledge of Spanish phonology on the part of the SLP and the other stems from between-language interaction in the speech of the bilingual child. Firstly, because American SLPs are, by and large, not trained in bilingual phonological assessment (Skahan et al., 2007), they could generalize their developmental knowledge of phonological pattern use, for example, *Stopping of Fricatives* in English, to the Spanish of bilingual children. SLPs know when English-speaking children should suppress this error pattern and therefore could apply the same developmental milestone to the Spanish productions of bilingual children. Clinicians could expect there to be a low percent occurrence of this pattern in the Spanish productions of bilingual preschoolers, even if a stop for a spirant substitute is considered acceptable for the interlocutors of Spanish-speaking children beyond the preschool years (Carrasco, Hualde, & Simonet, 2012). Secondly, bilingual children's use of a stop in place of a fricative could transfer from Spanish, where it is generally acceptable, to English, where it is not acceptable past ~3 years of age (Bernthal & Bankson, 1998). More specifically, bilingual children could apply the same phonological error pattern to productions in *both* of their languages, triggering clinical concern when found in the child's English productions. Goldstein and Yavaş (1998) state that best practice for phonological assessment of bilingual children is to look across both of the child's languages for evidence of disorder. Even for clinicians who engage in methods of best practice, if a bilingual child is applying his knowledge of the Spanish stop-spirant alternation in both of his languages, clinical error could still result. The clinical skill of identifying cross-linguistic effects aids SLPs in separating language difference (i.e. the influence of one language on the other) from language disorder (i.e. an underlying language learning disability); however, lack of knowledge of Spanish phonology and lack of awareness of between-language interaction in bilingual phonological acquisition could result in error inflation for bilingual children as compared to monolinguals.

The current study examines typical acquisition of a Spanish allophonic relationship, the stop-spirant alternation, in bilingual Mexican Spanish–English speaking children. This allophonic relationship does not exist in the English grammar; thus, in this particular population of bilingual children, an allophonic relationship is being acquired in one language and not in the other. In addition, it is unknown to what degree the two languages of bilingual children interact (Fabiano-Smith & Goldstein, 2010b; Paradis, 2001); therefore, it is possible that bilingual children could apply this rule in a manner that differs from published work on monolingual Spanish-speakers (Murillo, 1978). This study aims: (1) to address the characteristics of typical development of the Mexican Spanish stop-spirant alternation across various stages of phonological development in the Spanish of bilingual children learning both English and Spanish and (2) to address the theoretical debate that exists in the literature regarding the true underlying form of the stop-spirant allophonic rule (i.e. Is the voiced stop or the spirant the underlying phoneme?). We acknowledge that the underlying form of this allophonic relationship could differ for monolingual and bilingual Spanish speakers; however, because the clinical population of interest in USA is bilingual children, we will focus on identifying the underlying form for *bilingual* Mexican–Spanish-speaking children (discussed below).

These research questions are important to SLPs because if bilingual children persist in replacing spirants with stops past the preschool years (due to knowledge of an allophonic relationship that is still in the process of being acquired), an SLP could mistake a typical error pattern as delayed, contributing to overdiagnosis. Determining whether the stop or the spirant is the phonemic form is important clinically because speech-language pathologists need a guide for predicting typical phonemic inventory complexity at different ages. Knowing whether or not to expect the presence or absence of a phoneme in a child's inventory is essential for accurate diagnosis of phonological disorders and for planning effective treatment strategies.

Background

Bilingual phonological development—There is a paucity of research examining bilingual phonological development (Hambly et al., 2013); therefore, it is essential that typical patterns of phonological acquisition are documented in order to identify disorder within the bilingual system. In the absence of a well-established theoretical framework for bilingual phonological production, the *Processing Rich Information from Multidimensional Interactive Representations* model (PRIMIR) (Curtin, Byers-Heinlein, & Werker, 2011), a model for speech perception in bilingual children, is extended here to examine bilingual speech production. The PRIMIR model was developed to account for the fact that bilingual children may store some phonological forms specific to each language as the *same form*, or use some language-specific phonological knowledge in a similar manner in both language contexts. This model, however, does not account for speech *production* differences found between monolinguals and bilinguals. Interestingly, Fabiano-Smith and Goldstein (2010b) examined the speech sound productions of eight bilingual Spanish–English speaking 3-year olds and found that: (1) bilingual children were more accurate on sounds shared between their two languages than on those specific to either language (e.g. higher accuracy on sounds such as /p/ and /s/ versus the Spanish trill /r/ and English approximant /ɹ/) and (2) the use of language specific sounds (i.e. the English approximant /ɹ/ in a Spanish production) and rules (aspiration on initial voiceless stops in Spanish; deaspiration of initial voiceless stops in English) in the other language context. It appeared that between-language interaction was taking place in the *productions* of bilingual children much in the same way Curtin et al. (2011) argued processes related to speech *perception* in bilingual children were taking place.

Previous studies have demonstrated that bilingual children demonstrate lower accuracy on some manner classes as compared with their age-matched monolingual peers and a different developmental trajectory for individual phonemes due to interaction between the bilingual children's two languages (Fabiano-Smith & Goldstein, 2010a); however by age 5;0 (years;months), it appears that bilingual children demonstrate commensurate speech sound accuracy with monolinguals of the same age (Goldstein, Fabiano, & Washington, 2005). Although we see differences in development prior to the age of 5;0, bilingual children exhibit strikingly similar profiles to their monolingual peers once they enter Kindergarten. In the current study, we examine the acquisition of an allophonic relationship, the stop-spirant alternation, which exists in only one of the bilingual children's two languages: Spanish. Due to between-language interaction, we argue that *bilingual* acquisition of this rule needs to be documented because the developmental trajectory of this rule may differ from what has been documented in monolingual Spanish-speaking children (Macken & Barton, 1980) and adults (Murillo, 1978).

The Spanish stop-spirant alternation—The standard Spanish stop-spirant alternation occurs when voiced stops [b, d, ɡ] are spirantized, or produced as fricatives, in certain phonetic environments (Barlow, 2003). The *stops* [b, d, ɡ] are produced phrase-initially and after a homorganic nasal; in addition the voiced stop [d] is used when preceded by /l/ (e.g. "brinca" [bɾiŋka]; "gato" [gato]; "caldo" [kaldo]). The *spirants* [β, ð, ɣ] are produced in a post-vocalic environment, after the tap /ɾ/ (e.g. "árbol" [aɾβol]) and after various spirants and fricatives[1] (e.g. "abdomen" [aβðomen]). Some studies have suggested that this allophonic relationship is influenced by syllable stress markings, and not simply phonetic context (Cole, Hualde, & Iskarous, 1999; Murillo, 1978). In these studies, adults were found to be more likely to produce a spirant following a stressed vowel rather than an unstressed vowel. More recent work has suggested that the alternation can also depend on rate of speech, isolate or syllabic production, velocity of articulation and is highly dependent on dialect (Carrasco et al., 2012). Although the environments where the switch occurs are generally predictable, the underlying form of the rule is unknown. Some argue that the spirant is the underlying phonemic form, as it occurs in more phonetic contexts and seems to be more basic to the Spanish phonemic inventory (Bakoviç, 1994; Barlow, 2003; Hammond, 1976). The wider distribution of the spirant would create the foundation for a prototype, or the phonemic form, for the child learner, while the exception to the rule (i.e. occurrence of the voiced stops) would constitute the allophone. In addition to the distribution of the spirants versus the stops, the argument for the spirant as the underlying form is also due to a *fortition* account, or the strengthening of the weak spirant into a stronger voiced stop, rather than lenition, or the weakening of the voiced stop into a spirant. To illustrate, Barlow (2003) pointed out that on-glides are strengthened to obstruents in word-initial position in Mexican Spanish, a variety of Spanish which allows the spirant to occur in word initial position. If spirants, which are more approximant-like than fricative-like, follow the same trajectory, it is parsimonious to assume that the underlying spirant goes through a similar process to become the voiced stop in initial position.

[1]This context has also been considered to be one of free variation in some Spanish dialects (e.g. Schwegler, Kempff, & Ameal-Guerra, 2010).

Harris (1993), on the other hand, argued for a *lenition* account, or the weakening of a voiced stop into a spirant. According to Harris (1993) logical developmental progression is from stops to continuants; therefore, in the case of the stop-spirant alternation, the stronger voiced stop would become the weaker spirant in this allophonic relationship. The stop must be the underlying form because it is acquired earlier, is easier to produce (i.e. unmarked in comparison to the spirant) and has a phonetic context that is more predictable (i.e. a context upon which a rule could be formed). Most of the evidence for this position, however, comes from historical accounts of how the allophonic relationship has changed over time (Lózano, 1979). Barlow (2003) importantly points out child language learners do not have access to historical information on the language they are exposed to, making this argument less convincing.

Phonetic context also seems to play a role in stop versus spirant selection. Some studies have argued that accuracy of voiced stops may be aided by post-liquid and post-nasal contexts (Amastae, 1989; Lipski, 1994). In addition, syllable stress markings have been found to encourage use of the spirant in adult productions (Cole et al., 1999; Murillo, 1978). These studies found that the spirants were more likely to be produced following a stressed vowel rather than an unstressed vowel; therefore, phonetic context might also play a role in which sound children select.

In the context of bilingual phonological acquisition, within the framework of the *PRIMIR* model, the underlying form in this allophonic relationship could differ from what we predict in the context of monolingual Spanish acquisition. For example, the sounds [d] and [ð] are phonemically contrastive in English, but not so in Spanish. In Spanish, the spirants [β] and [ɣ] exist, but not in the English phonetic inventory. The *PRMIR* model suggests that bilingual children could organize some of these structures as common between English and Spanish, even though they are language-specific in monolingual speakers. In fact, Fabiano-Smith and Goldstein (2010b) found that in the productions of bilingual preschoolers, phonemes common to both languages demonstrated higher accuracy than those phonemes specific to either language, independent of frequency of occurrence in the language or phonetic complexity. In addition, they found that initial voiceless stops were systematically aspirated in the Spanish productions of bilinguals and deaspirated in some of their English productions. Therefore, it is possible that both segments and rules can transfer in a bidirectional way between languages. Identification of how bilingual children represent and utilize the stop-spirant alternation is of critical importance to clinicians because based on our theoretical model, we predict that the underlying form in the allophonic relationship could differ from published sources that have examined monolingual Mexican Spanish speakers (Anderson & Smith, 1987; Lózano, 1979).

Previous studies exist that have examined acquisition of the stop-spirant alternation in Mexican Spanish-speaking children and are helpful in addressing this theoretical divide. Macken and Barton (1980) examined acquisition of the voicing contrast for stop consonants in monolingual Mexican Spanish-speaking children, analyzing the degree of spirantization in their productions of voiced stop consonants. Three monolingual Mexican–Spanish speaking children were examined longitudinally from ages 1;7–2;2 and four Mexican Spanish-speaking children were examined in a cross-sectional manner at age 3;10. Children were recorded and their word-initial productions of voiced stops were analyzed acoustically for occurrences of sounds that were judged as [+ continuant], indicating some degree of spirantization. The authors found a pattern across children: voiced stops were being produced as the spirants [β, ð, ɣ] more often than voiceless stops. This finding indicated that very young children used the spirants in a greater variety of phonetic contexts as compared to the voiced stops.[2]

Barlow (2003) found similar results in her analysis of the Mexican Spanish productions of four monolingual Spanish and bilingual Spanish–English speaking children between the ages of 2;8–4;2. Children's single word samples were recorded and phonetically transcribed. Interestingly, a pattern of liquid [l] substitution was found for both voiced stops and spirants, but not for voiceless stops. Barlow argued that because an approximant is the preferred substitute for sounds in this allophonic relationship, that perhaps the underlying phoneme is not a spirant at all; perhaps the underlying form is an approximant (see also Bakoviç, 1994). Via the process of fortition, rather than lenition, children begin with a continuant that becomes an obstruent in some phonetic contexts. Spirants in Spanish pattern more like sonorants than obstruents, supporting the argument that the spirant is the more likely underlying phoneme.

Like Macken and Barton (1980), Lleó and Rakow (2005) performed a longitudinal analysis examining acquisition of voiced stops and spirants. Three bilingual Castilian Spanish–German Speaking children were examined between the ages of 1;3 and 4;0 in order to determine whether or not young Spanish-speaking children substitute the more marked spirants with less marked stops and if they used the spirants accurately. In the Castilian dialect of Spanish, like Mexican Spanish, the spirants are more widespread than the stops (Carreira, 1998). Like English, German does not have a stop-spirant alternation in its grammar. In order to examine use of the stop-spirant alternation in the children's Spanish productions, children's play samples were recorded and phonetically transcribed for phonemic accuracy. The authors found that bilingual Spanish–German speaking children demonstrated lower accuracy on spirants than on stops, with stops often serving as substitutes for the spirants. By age 4;0, acquisition of the stop-spirant alternation had not been achieved as bilingual children continued to demonstrate difficulty with accurate spirant production. The results of this study indicated that perhaps the voiced stops served as the underlying phoneme, as they were more accurate than and often used as substitutes for, the spirants.

Pilot work—The divergence of findings in previous studies motivated pilot work in anticipation of the current study. Fabiano-Smith (2010) examined eight typically-developing bilingual Puerto Rican Spanish–English speaking 3-year olds on a single word protocol for accuracy of production of stops and spirants in Spanish. Like Mexican Spanish, Puerto Rican Spanish, a Caribbean dialect, also exhibits a wider distribution of the spirants than the voiced stops [after Hammond's (1976) work on Cuban Spanish]. Children's single word productions were recorded and phonetically transcribed for analysis of accuracy. The

[2]Recall that the spirants are also found in word-initial position in the Mexican variety of Spanish (e.g. Barlow, 2003). Another related dialect feature in Mexican Spanish is the [v] for [b] sound substitution (Goldstein, 2001).

purpose of this study was to determine if bilingual children were more accurate on voiced stops (Harris, 1993; Lleó & Rakow, 2005) or spirants (Barlow, 2003; Macken & Barton, 1980). The author argued that the higher the accuracy for a particular manner class (voiced stops versus spirants), the earlier that class was acquired, suggesting its role as the underlying phoneme. The results of this analysis indicated that at age 3 years, as had been found in previous studies, bilingual children had not yet acquired the stop-spirant alternation. More specifically, bilinguals were equally accurate on stops and spirants, with the exception of [b] versus [β]; bilingual children were significantly more accurate on the voiced stop than the spirant for the bilabial allophonic pair. However, no general pattern of higher accuracy for one type of sound over another emerged.

The limitations of previous studies lead to the current study. Here, we aim to extend beyond the preschool years, and beyond perceptual analysis, to examine acquisition of the Mexican Spanish stop-spirant alternation with the aim of identifying: (1) the age at which we could expect to see bilingual Mexican Spanish-speaking children consistently demonstrate knowledge of this allophonic relationship and (2) demonstrate a consistent pattern of higher accuracy of one manner class over the other (voiced stops versus spirants) in order to shed light on the theoretical debate under discussion. Findings from this study will contribute to the cultural competence of our clinical workforce by providing: (1) suggested developmental information on age of acquisition of this form and (2) data that aid in separating out speech difference from speech disorder if bilingual children exhibit a high rate of stop for fricative substitutions in their Spanish productions.

Purpose

The purpose of this study was to: (1) characterize typical acquisition of the stop-spirant alternation in bilingual Mexican Spanish–English speaking children and (2) shed light on the theoretical discussion regarding whether the stop or the spirant is the underlying phoneme in this allophonic relationship for bilingual children.

Hypothesis 1

We predicted, based on our pilot work and the results of previous studies, that bilingual children would not have acquired the stop-spirant alternation before 3 years of age (Macken & Barton, 1980), but that bilingual children will acquire knowledge of this allophonic relationship by the time they reach age 5;0 (Goldstein et al., 2005). We predicted that as children matured (in the quasi-longitudinal context, in children older than age 4;0), we would observe high accuracy on both the voiced stops and the spirants in bilingual children's Spanish productions.

Hypothesis 2

We predicted that children would demonstrate higher accuracy on the spirants rather than their stop counterparts, supporting Barlow (2003) and Macken and Barton (1980). Because the spirants are more frequent and therefore more fundamental to the Spanish phonemic inventory, we predicted that children would have more experience with the production of the spirants and therefore would demonstrate higher accuracy on the spirants in their speech production. If children demonstrated higher accuracy on the voiced stops, then our findings would support the developmental argument put forth by Harris (1993), suggesting that the stop is the phonemic form and the spirant the allophone.

We also wanted to observe the types of substitutes used in place of the spirants in order to shed light on a possible underlying form (after Barlow, 2003). If bilingual children used approximants or fricatives as substitutes for the spirants, we could conclude that the underlying form was most likely the spirant. If the children used voiced stops in place of the spirants, it would suggest the underlying form was likely the voiced stop.

Methods

Participants

Nine typically-developing bilingual Mexican Spanish–English speaking children from the age of 2;4–8;2 were included in the study. Demographic information on study participants can be found on Table 1. Due to the quasi-longitudinal design of the study, children were selected based on their chronological age (CA) to represent a continuum of ages from ~2–8 years old, encompassing the range of phonological acquisition. Participants were recruited from a bilingual community in San Diego, CA, a border city between USA and Mexico. All children were identified as low socioeconomic status (SES) because data were collected in the San Diego area at: (1) a health care center that serves medically underserved populations (Health Center Program grantee under 42 U.S.C. 254b), (2) a school where the child received free lunch as indicated by parent report or (3) a Title I school where 90% of the student body receives free lunch. All of the participants were identified as bilingual speakers of Mexican Spanish and American English.

Typical development and bilingual language status were established through parental report. Parents reported that their children had no history of speech, language, cognitive, or neurological deficits for any of the participants and no children had ever received services for speech and/or language disorders. Using procedures described in Restrepo (1998) and duplicated by Fabiano-Smith and Goldstein (2010b), an extensive parental interview was administered to determine bilingual language status. The first author and trained bilingual graduate students administered the parental interviews over the phone or in person. Parents were asked to describe their child's schedule for a typical week (weekdays and weekends). Information recorded from these interviews included thorough descriptions of their child's waking hours, including activities in which they participated, communication partner(s) with whom they interacted, and languages typically used by both the child and communication partner(s) present. From this information, the number of hours for Spanish and English language exposure (i.e. input) and production (i.e. output) per day were obtained. A percent input (i.e. percent of time child was exposed to language) and output (i.e. percent of time language was spoken) for each language were then calculated. Percent input for each language was obtained by adding together the hours of exposure separately for English and Spanish, dividing these sums by the child's total waking hours in a week, and multiplying by 100. The same procedure was used to determine percent output for English and Spanish by substituting hours of production for hours of exposure.

Typical of bilingual language use, percent input and output in English and Spanish were variable across participants. This variability is representative of the heterogeneity of language use in bilingual communities. Because of the present study's focus on the acquisition of the stop-spirant rule in Spanish, the primary goal in recruitment of bilingual participants was that they had a requisite level of Spanish input. According to Pearson, Fernández, Lewedeg, and Oller (1997), bilingual children must receive at least 20% exposure to a language in order to use that language. In addition to parent report of language exposure and use, all participants were able to produce a spontaneous speech sample in Spanish (conversational play sample or narrative sample). While three participants had little to no reported English input and/or output, it is certain that all participants received some level of English exposure prior to entering the school system as well as during their enrollment in the San Diego Unified School District because they were all residing in the USA and English is the institutionalized language. Because the primary focus of the study was on the participants' Spanish language use, more variation in their English language use was accepted. Amount of language exposure and use was unavailable for participant S6; however, his overall consonant accuracy in English (76.11%) and Spanish (85.21%), as measured by Percent Consonants Correct (PCC) (Shriberg, 1993), was comparable to 5-year-old typically-developing bilingual Spanish–English speaking children (Goldstein et al., 2005), therefore he was included in the study.

Data collection

Single word speech samples in Spanish were collected from each child and used for phonological and acoustic analyses. To elicit the single word samples, the *Assessment of Spanish Phonology* (ASP; Barlow, 2003) was administered. The ASP is a picture naming task that probes each phoneme of the Spanish language at least five times in word-initial, intervocalic and word-final contexts. The full probe contains 155 target items with 38 opportunities to produce obligatory spirants and 39 opportunities to produce obligatory voiced-stops. The children in the current study all produced ~60 items but the number of words produced across the children was variable based on age and interest in the task. The bilingual English–Spanish speaking examiner elicited target item productions by presenting a cartoon-style picture of the item via laptop and asking the child to spontaneously label the item (i.e. *¿Qué es esto?* (*What is this?*)). If the child was unable to name the picture, delayed imitation was used to elicit the name of the item (Goldstein, Fabiano, & Iglesias, 2004).

Single word productions were recorded using a Dell Latitude 7200 laptop using Adobe Audition 1.5 software via a SONY ECM-MS907 omnidirectional electret condenser microphone. The recording parameters included a single-channel input, 16-bit resolution and a sampling rate of 44.1 kHz. The total number of opportunities to produce both the obligatory spirant and voiced-stop productions varied for each participant based on the number of items they produced on the protocol. Spirant production opportunities ranged from 7 to 34 (M = 22.22) and voiced-stop production opportunities ranged from 11 to 39 (M = 28) across participants. The single word productions were narrowly transcribed using the International Phonetic Alphabet (IPA) by native Spanish speakers trained in phonetic transcription. The *Logical International Phonetics Program* (LIPP; Oller & Delgado, 2000) was used for data transcription and analyses of accuracy and substitution errors.

Analyses

Reliability of phonetic transcription—Inter-judge reliability was completed for 100% of the single word samples collected. Four bilingual graduate students in speech-language pathology (all native or near-native speakers of Spanish and English) were trained in narrow transcription procedures using IPA and transcribed 100% of the samples. Inter-rater reliability of transcription was performed between two transcribers. When disagreement on a transcription occurred between the two judges, a third judge (the first author, a bilingual English–Spanish speaker trained in narrow IPA transcription) made the final decision on the transcription. Mean inter-judge agreement was 88.12% for the Spanish samples in this cohort.

Several analyses were performed in order to examine the acquisition of the stop-spirant alternation. Using LIPP, an overall percentage of consonants correct (PCC; Shriberg, Austin, Lewis, McSweeney, &Wilson, 1997) and a context free phonetic inventory for each participant was obtained. Several context-sensitive analyses were performed based on contexts found to be theoretically important in previous studies on bilingual children completed by Barlow (2003), Macken and Barton (1980), and work examining Spanish-speaking adults (Murillo, 1978).

Accuracy of voiced stop and spirant productions based on phonetic transcription—The purpose of this analysis was to examine accuracy levels of voiced stops and spirants in order to identify whether voiced stops or spirants were acquired first. The manner class with the higher level of accuracy was assumed to be the manner class acquired first. This analysis was based on previous analyses completed by Lleó and Rakow (2005) and Barlow (2003) who used phonetic transcription to determine phoneme accuracy. Using the target adult production of the Mexican dialect of Spanish, the total number of obligatory voiced stop and spirant productions within the ASP were identified. Spirant production in word-initial position was not considered an error production of the voiced stop due to its status as an acceptable dialect feature of Mexican Spanish (Goldstein, 2001). A relational analysis was then performed whereby each child's productions of these segments were compared to the adult target. The child's productions were then determined to be correct or incorrect. For example, the adult target for the word *tigre* (*"tiger"*) is /tiɣɾe/. This word includes an opportunity for the production of the voiced velar spirant [ɣ]. If the child produced [tiɡɾe], their production of the voiced velar spirant [ɣ] would be marked as incorrect. From the relational analysis, a percent correct measure of voiced stop and spirant productions was then calculated overall for stop and spirant manner classes and then individually for each stop-spirant allophonic pair based on the total number of opportunities present in the adult standard.

Accuracy of stops in the post-nasal phonetic context—The purpose of this analysis was to identify whether the accuracy of the voiced stops was influenced by preceding consonants. It has been suggested in previous studies that accuracy of voiced stops may be aided by post-liquid and post-nasal contexts (Amastae, 1989; Lipski, 1994). There were no opportunities in our data set for post-liquid productions; therefore, only post-nasal productions were examined. In order to isolate the influence of phonetic context from the phonemic role of the voiced stop, opportunities for the post-nasal context were identified in the ASP and accuracy of voiced stops in this context was calculated using *LIPP*. We also analyzed accuracy of the voiced stops in all other contexts to compare to accuracy on the voiced stops in the post-nasal context.

Accuracy of spirant productions in stressed and unstressed syllables—The purpose of this analysis was to identify whether the accuracy of spirant production was influenced by syllable stress markings, as has been found in previous studies on adult productions (Cole et al., 1999; Murillo, 1978). Previous studies examining adults have found that spirants are more likely to be produced following a stressed vowel rather than an unstressed vowel; therefore, we analyzed spirant accuracy within this phonological context. It is possible that stress could be driving accuracy of spirants rather than its phonemic or allophonic role. Spirants within stressed and unstressed syllables were identified within the ASP and percent spirants correct for stressed and unstressed syllables was calculated for each participant to rule out this possibility.

Substitution error analyses—The purpose of this analysis was to identify whether spirants patterned more like approximants or stops. More specifically, would we see the approximant [l] more often than a voiced stop as a substitute for the spirants? The present study's goal was to observe error patterns for the spirants and the voiced stops, which may shed light on the basic phoneme in the stop-spirant allophonic relationship. A substitution error analysis allowed for a thorough investigation of the participants' characterization of the voiced stops and spirants as sonorants or obstruents. To achieve this goal, the type and frequency of substitutions for spirant productions and voiced stops were identified and examined across participants.

Acoustic analyses—Due to the subjective nature of phonetic transcription, acoustic analyses were performed (after Macken & Barton, 1980) to corroborate the findings of the substitution error analysis. The purpose of this analysis was to explore acoustic variability in the production of post-vocalic spirants. Acoustic analysis has the benefit of allowing for objective, gradient measures which are not available from categorical phonetic transcriptions. However, there is not a straightforward metric for measuring the difference between a stop and a spirant based purely on the acoustic signal. For this analysis, we chose to use measures of relative acoustic intensity, which have been used in previous work to measure the relative degree of consonantal constriction (Ortega-Llebaria, 2004; Simonet, Hualde, & Nadeu, 2012). When there is a tight constriction of the vocal tract, as in a stop, there will be less energy in the signal than in more open, spirantized productions.

All acoustic analyses were performed using Praat, a free software for phonetic analysis (Boersma & Weenink, 2011). Acoustic analyses were based on our perceptual analysis, using our phonetic transcriptions as a guide when analyzing children's recordings. In order to maintain a phonetically controlled environment, we analyzed only productions of words with intervocalic voiced stops or spirants. We eliminated tokens which were too noisy for acoustic analysis (24 tokens) or which included errors (2 tokens), leaving 37 tokens. For these tokens, we manually labeled the target consonant and the surrounding vowels. The sound files were filtered with a pass Hann band filter (500–10 000 Hz) in order to eliminate the low-frequency energy resulting from f0 during the stop closure of voiced stops (after Simonet et al., 2012). We then generated an intensity contour using Praat. The relative intensity of the consonant with respect to its surrounding vowels was calculated by taking the average intensity of the maxima of the surrounding vowels and dividing this by the minimum intensity (i.e. point of maximal constriction) during the consonant. A stop-like consonant with tight constriction should therefore have a higher vowel-to-consonant intensity ratio than a spirant-like consonant with relatively open constriction.

In order to ensure that the intensity measure used here is a reasonable metric for measuring the difference between stops and spirants, we first manually verified that the tokens at the endpoints of the intensity ratio measurements (i.e. tokens with very high or low values) were unambiguously stops (for high values) and spirants (for low values).

Statistical analyses

We also performed logistic regression in order to determine whether the intensity measure ratio could predict the manual transcriptions; that is, whether higher vowel-to-consonant intensity ratios were more likely to be manually transcribed as stops, as would be expected if our metric correctly represented the degree of consonantal constriction. To do this, we first grouped the manual transcriptions into two groups: stops (tokens transcribed as [b], [d], or [ɡ]) and spirants ([β], [ð], [ɣ̞], or [v]). We omitted tokens in which the transcription indicated a substitution of another phone or a deletion. We then used a mixed-effects logistic regression model with Manual Transcription Category (stop or spirant) as the outcome variable and Intensity Ratio as the predictor variable, with Subject as a random factor and slope allowed to vary for each subject. Assigning subject as a random factor controls for assumption violations that accompany a small number of subjects (after Fabiano-Smith & Goldstein, 2010b).

Results

Analyses based on phonetic transcription

Results of the analyses examining accuracy of voiced stop and spirant productions can be found in Figure 1. From the youngest to the oldest child, participants achieved a higher mean PCC in their productions of voiced stops than in their productions of spirants. Notably, much more variation was observed in spirant production than in voiced stop production when comparing accuracy rates across ages.

Overall accuracy of voiced stops

Children had between 11 and 39 opportunities to produce the voiced stops (x = 28). All but one of the participants (S7) achieved a mean PCC for voiced stop production >90%. Surprisingly, ages from 2;4 to 8;2, the accuracy patterns observed did not follow an upward, positive slope (from low accuracy to high accuracy) as would be expected due to maturation. For example, participant S1 achieved a mean PCC of 91.4% in their production of voiced stops whereas participant S7 only achieved 88% accuracy. In addition, participant S1 achieved a comparable mean PCC for voiced stops (91.4%) to the oldest participant S9

(94.9%); however, it was clear that voiced stop productions in Spanish are mastered at an early age.

Accuracy of voiced stops in the post-nasal phonetic context

Accuracy of voiced stops was analyzed in the post-nasal context, and elsewhere, in order to account for the facilitative effect of phonetic context on consonant accuracy. The results of this analyses indicated that all children were highly accurate on voiced stops in post-nasal contexts (Figure 2). Children, across ages, also demonstrated high accuracy on the production of voiced stops in all other phonetic contexts as well; however, a facilitative effect was observed for the postnasal context as six out of the nine children demonstrated 100% accuracy on voiced stops in postnasal context and none of the children reached 100% accuracy on voiced stops in other contexts.

Substitution error analysis: voiced stops

Examples of error patterns for voiced stop productions can be found in Table 2. Substitutions were the predominant error pattern observed for all participants except for one participant (S2) who exhibited a high level of omission errors. Most likely due to being one of the youngest participants, errors for participant S2 were equally represented by substitutions (50% of errors) and deletions (50% of errors). This high rate of deletion was not observed in the voiced stop productions of other participants.

Participants were highly accurate in their production of the voiced stops. When the voiced stop was produced in error, participants S3, S4, S5, S7, S8 and S9 substituted either the fricative [v] or a spirant in its place. The youngest participant, S1, produced a variety of alternate substitutes 67% of the time and the English fricative [v] 33% of the time when producing a voiced stop in error. The majority of the substitutions for voiced stops made by participant S2 were spirants, representing 67% of substitution errors.

Overall accuracy of spirants

A comparison of accuracy for each allophonic pair can be found on Figures 3–5. Children had between 7 and 34 opportunities to produce the spirants (x = 22). Accuracy rates for spirant productions were lower than voiced stop productions across children. No participant achieved a mean PCC >50% for spirant production. In addition, a highly variable pattern was observed across ages. For example, participant S1 achieved a mean PCC of 24% whereas participant S7 achieved 10% for spirant productions. Our results suggest that spirant production may not be mastered by age 8;2 in bilingual Spanish–English speaking children.

Accuracy of spirant productions in stressed and unstressed syllables

Results of the analyses examining accuracy of spirant production in stressed and unstressed syllable position can be found in Figure 6. The participants exhibited highly variable accuracy rates, across ages, in their productions of spirants in both the stressed and unstressed syllable position, with unstressed syllable position demonstrating slightly higher accuracy than stressed syllable position. Overall, no clear pattern of accuracy was observed between the two contexts.

Substitution error analysis: spirants

Examples of substitution errors for spirant productions can be found in Table 3. Types and tokens of substitutes for each individual spirant can be found on Figures 7–9. Substitutions were the predominant error pattern observed for all participants, representing over 75% of errors made by all but one participant (participant S5; 60% of errors). Omission errors for the spirants were uncommon across children.

Stops were the primary type of substitute used when the target was a spirant. The second most often used substitutes for spirants were fricatives. This finding was surprising because Spanishspeaking children (both monolingual and bilingual) typically prefer to use an approximant as a substitute rather than a fricative for the spirant (Barlow, 2003; Goldstein, 2005); substituting a fricative for another fricative is a common English error pattern (Smit, 1993). For participants S4 and older, the only two types of substitutes observed were stops and fricatives. Notably, participants S4, S5 and S6 used stops as substitutes 100% of the time. For participants S1, S2, S3, S7 and S9, the only fricative substituted was the fricative [v] for the spirant [β]. Participant S8, substituted a fricative 36% of the time, commonly using the fricative [v] for the spirant [β]. Additional types of substitutes were observed, albeit infrequently, for the younger participants (ages 2;4 through 3;6). These substitutes included approximants ([j], [l] and [ɹ]), nasals and the flap [ɾ].

Accuracy based on acoustic analyses

Verification of intensity ratio measurement—The purpose of this analysis was to explore acoustic variability in production of intervocalic spirants. Examples of tokens with the highest and lowest intensity ratios are shown in Figure 10. Based on manual observation of high and low values, this metric appears to correctly separate unambiguous stops from unambiguous spirants. Results of the logistic regression analysis show that the metric predicts the manual transcription category to a certain extent, in that tokens with higher intensity ratios are significantly more likely to be manually transcribed as stops ($\beta = 0.13$, $z = 2.74$, $p<0.01$). However, as shown by the small beta-coefficient, the intensity ratio is not a *strong* predictor of manual transcription category, so these results should not be interpreted as showing that the intensity ratio measure alone accurately predicts the manual transcriptions. Nevertheless, the combination of regression analysis and the manual verification of the endpoints suggest that the intensity ratio is a reasonable metric by which to examine gradient effects of degree of constriction.

Intensity ratio measures across tokens—Results of the acoustic analysis, showing the distribution of intensity ratios across tokens, are shown in Figure 11. There is a bimodal distribution, with two clusters of tokens. If the participants are producing two distinct categories (stops and spirants), we might expect that one of these clusters (the one with higher ratio values) corresponds to stops, and the other (with lower ratios) corresponds to spirants. In order to verify this, we compared these with the manual transcriptions. The distribution across the two manual transcription categories is shown in Figure 12. While the tokens manually transcribed as spirants cluster together, five of the tokens manually transcribed as stops have low intensity ratios and seem to better pattern with the spirants. Upon manual observation of these tokens, they appeared very spirant-like. Although they were heard as stops by the manual transcribers, based on more objective acoustic measures, they might better be classified as spirants.

Discussion

The purpose of this study was to: (1) characterize typical acquisition of the stop-spirant alternation in bilingual Mexican Spanish–English speaking children and (2) shed light on whether the stop or the spirant is the underlying phoneme for bilingual Mexican Spanish-speaking children. We predicted, based on our pilot work and the results of previous studies, that bilingual children would not have acquired the stop-spirant alternation before 3;0 (Macken & Barton, 1980), but that children would acquire knowledge of this allophonic relationship by the time they reach age 5;0 (Goldstein et al., 2005). Or results did not support our prediction. Children 5–8 years of age: (1) demonstrated higher accuracy on the voiced stops than on the spirants, (2) did not demonstrate mastery of the spirants (demonstrated only ~50% accuracy) and (3) often used the voiced stops as substitutes for the target spirant. Both analyses of transcription and acoustic analyses corroborated these findings. Interestingly, our findings mirrored those of Lleó and Rakow (2005) who found similar error patterns in bilingual Spanish–German-speaking 4-year olds. Our participants exhibited highly variable mean accuracy levels, across ages, particularly in their productions of spirants, so developmental claims are purely speculative.

We predicted that bilingual children would demonstrate higher accuracy on the spirants rather than their stop counterparts, supporting Barlow (2003) and Macken and Barton (1980). Because the spirants are more frequent and therefore more fundamental to the Spanish phonemic inventory, we predicted that children would demonstrate higher accuracy on the spirants as compared to the voiced stops. Our findings did not support our prediction. Voiced stops were produced with higher accuracy than spirants overall, supporting Harris (1993) who argued that the stop to continuant path to phonological acquisition is most logical. When the voiced stops were produced in error, however, the fricative [v] appeared as a substitute for seven of the participants, possibly indicating knowledge of a stop-fricative relationship in that phonetic context. This substitution pattern could have been indicative of a type of between-language interaction referred to as phonological transfer (Paradis & Genesee, 1996), because the sound [v] does not exist in all Spanish dialects; however, it does in Mexican Spanish (Goldstein, 2001). Therefore, children could simply be applying a dialect feature instead of indicating any knowledge of a stop-spirant relationship or demonstrating the influence of English on Spanish. It is also possible that children over age 5;0, who are exposed to English orthography in Kindergarten and beyond, could be transferring the grapheme “v” into their productions of words such as “vaca” (Montrul, 2002). The use of [v] as a substitute for the voiced stop /b/ could be a function of dialect, exposure to written language and/or incomplete acquisition of the stop-spirant rule.

When we examined children’s productions in certain syllabic contexts, we found that accuracy of the spirants did not differ in stressed versus unstressed syllable position (contrary to the adult production findings of Murillo, 1978). There is a possible explanation for this pattern, however. In varieties such as Costa Rican Spanish, when the syllable preceding the target spirant is stressed, the stop is commonly selected in its place (Carrasco et al., 2012). This could result in higher accuracy of the stops as compared to the spirants. The weakness of this argument as it applies to the children in the current study is that the dialect in question, Mexican, is one in which the spirant is over-generalized, unlike certain Central American varieties that overgeneralize obstruent-like phones in most contexts. The children in this study were speakers of Mexican Spanish, in which the spirant is more likely to be found in post-vocalic contexts as it is more widely used across all phonetic contexts (Lózano, 1979). We concluded that stress was most likely not motivating high accuracy of stops in this particular population.

Finally, the linguistic model of the stop-spirant alternation in bilingual communities differs from monolingual environments due to the influence of English on Spanish (Stanford, 2008). Perhaps the adult speakers in the children's environment are applying the stop-spirant alternation in much the same way that we observe in the children's productions. Sociolinguistic influences on acquisition of the stop-spirant alternation are beyond the scope of this article, but these possibilities should be mentioned and examined in future studies.

Our findings, however, did not support Harris' (1993) position across all ages. It appeared the younger children's substitution patterns in the current study, which included a variety of approximants, aligned more with the findings of Barlow (2003), despite the fact that their production accuracy favored the spirants over the voiced stops. The children examined in her study were also preschoolers, suggesting that perhaps the underlying form is underspecified in very young Spanish-learners [for a detailed description of *Underspecification Theory*, see Archangeli (1988)]. At very young ages, it is possible that a wider distribution of prototypes is utilized, especially for bilingual children who are only receiving input in Spanish 50% of the time, at most [as is argued by Barlow (2003) as well]. Older participants' (ages 4;6 and above) predominant substitution of pattern of stops and the fricative [v] possibly suggests awareness of the allophonic relationship and cross-linguistic influences, but not a complete understanding and application of the stop-spirant rule, as has been described in previous studies on adults (Murillo, 1978).

Similarities were found between the current study and Barlow (2003) in the younger children, but differences were found when comparing older children in the current study to Barlow's data set. In order to address what might be motivating differences between the two studies, the connection between chronological age and bilingual phonological acquisition is discussed. It is important to point out that in USA, bilingual children typically hear and use Spanish at home until entering preschool at age 3 or 4 years. Their environments, however, are not devoid of English input due to its status as the institutionalized language of schools, hospitals and government facilities; therefore, predominantly Spanish-speaking children growing up in USA are not true monolinguals. As children progress through the educational system, they tend to prefer to use the language of their peers, in this case, English (Rojas, Bunta, Iglesias, & Goldstein, 2007), resulting in the weakening of Spanish skills (Montrul, 2008). It is possible that the younger children in this study demonstrated stronger phonological skills in Spanish than the older children who had already had exposure to English within the school system and might have been experiencing language loss in Spanish. However, because phonological acquisition in bilingual preschoolers is extremely variable in both of their languages, even when children are matched on language input, output and proficiency (Fabiano-Smith & Goldstein, 2010a), and is, at times, decelerated (i.e. demonstrates a slower rate of development) as compared to their monolingual peers (Fabiano-Smith & Goldstein, 2010b) the relative strength of the Spanish skills of the younger children in comparison to the older children would need to be explored further. What makes this possibility unclear is that Goldstein et al. (2005) examined 15 five-year-old bilingual Spanish–English speaking children residing in USA on a series of phonological measures and found that they demonstrated commensurate phonological skills when compared to their monolingual peers (when language input was sufficient in both languages). Unlike the 3-year olds examined in Fabiano-Smith and Goldstein (2010a, 2010b), no evidence of deceleration was observed. In addition, the parents of the older children in the current study reported that their children received the requisite amount of Spanish input for acquisition and use (>20%). Anderson (2004) details the major linguistic skills affected by language loss, and phonological skills are notably absent. Rather, lexical patterns, pragmatics, morphology, mood errors and syntax appear to stand out as linguistic aspects at risk of loss. Language loss in the realm of phonology is possibly behind differences between this study and Barlow (2003); however, data from future studies examining how language loss affects the acquisition of phonology are needed to definitively answer this question.

Additional differences between the findings of Barlow (2003) and the current study could be due to the bilingual status of the children included. Barlow (2003) included both predominantly Spanish-speaking children and bilingual Spanish–English-speaking children in her data set, but did not include percent exposure and use for each language; therefore, the language proficiency levels cannot be compared to the children in the current study to determine if language exposure and use in Spanish is at the root of differences in error patterns between the two studies. In addition, three of the children in Barlow (2003) were diagnosed with phonological delay, whereas the children in the current study were all typically-developing. In addition to Barlow (2003), only one study to date details the phonological error patterns in bilingual Spanish–English-speaking children with phonological disorders (Burrows & Goldstein, 2010); therefore little data exist on the differences between typically-developing Spanish–English-speaking bilingual children and those with phonological delay or disorder to make a definitive claim that phonological skill is driving differences between the two studies. Finally, because both studies examined a small set of children, differences between the two studies could be due to the individual variation across the subjects selected. Bilingual children, as a group, are a very heterogeneous population; therefore, individual differences could be driving differences in error patterns. The exploratory nature of this study has revealed a number of possible factors that can be evaluated in future studies to further detail the motivation for the error patterns observed.

To place our findings within the theoretical framework of the PRIMIR model and further examine the influence of between-language interaction on the phonological development of Mexican Spanish–English-speaking bilingual children, it is interesting to compare findings from the current study to Fabiano-Smith and Goldstein's (2010b) findings on both the Spanish *and* English productions of monolingual and bilingual 3-year olds. In their study, monolingual Mexican Spanish-speaking children were significantly more accurate than their bilingual peers on fricatives, which, like the spirants, are [+continuant] sounds. Monolingual English-speaking children were significantly more accurate than their bilingual peers on *only* two manner classes: stops and fricatives. It is possible, due to between-language interaction, that bilingual children demonstrate lower accuracy on voiced stops and spirants (or spirant-like sounds) in *both* of their languages due to the stop-spirant alternation. Because some sounds might be represented as the same between English and Spanish, as is posited in the *PRIMIR* model (Curtin et al., 2011), production of those sounds might be similar, if not identical, in both language contexts. Fabiano-Smith and Goldstein (2010b) found that bilingual 3-year olds demonstrated higher accuracy on sounds shared between their two languages, independent of frequency of occurrence in the language or order of acquisition, than on sounds specific to either English or Spanish. It is possible that bilingual children are generalizing the relationship between voiced stops and spirants from Spanish to English, causing lower accuracy in English on manner classes related to this allophonic relationship. This is clinically important because SLPs have expectations for English-speaking children to demonstrate high accuracy on stop consonants before age 5;0 and then high accuracy on fricative-like sounds at age 5;0 and older (Bankson & Bernthal, 2004). According to Skahan et al. (2007), 35% of SLPs who evaluate non-native English speakers use English-only standardized articulation tests to categorize children into typical or disordered categories (p. 251). A child who is in the process of acquiring the stop-spirant alternation, and is generalizing lack of knowledge of that allophonic relationship into his English productions, could demonstrate an inflated number of phonological errors, such as *Stopping of Fricatives*, as compared to what is expected for English-speaking children on a standardized test. With the majority of SLPs in America using standardized tests normed on monolingual English-speaking children to evaluate the speech skills of bilingual children (Skahan et al., 2007), inflation of phonological errors in this population is likely to occur, possibly contributing to overdiagnosis of disorder. Between-language interaction between Spanish and English should always be taken into consideration in the phonological assessment of bilingual Spanish–English speaking children. Furthermore, knowledge of the specific dialect of Spanish that is being assessed is crucial, as is illustrated by our results. For example, the use of [v] as a substitute for /b/ in “vaca” [vaka] could be transfer of a dialect feature *or* could be the result of the influence of English on Spanish (either phonetically or orthographically) for a speaker of Mexican Spanish and English. Either way, clinicians should be aware that such a production constitutes a language difference, not a language disorder, regardless of what mechanism is motivating its use.

The acoustic measure used in this study (ratio of intensity between the consonant and its flanking vowels) seems to be a reasonable measure of degree of constriction and can therefore be used to classify productions of intervocalic consonants on a stop-spirant continuum. Although there is gradient phonetic variability within categories, the fact that the intensity ratios fall into a bimodal distribution suggests that these children produced two distinct categories, as opposed to a continuum of productions ranging from stop-like to spirant-like (in contrast to Murillo, 1978). Methodologically speaking, the results of our acoustic analysis generally corroborated the results of our analyses based on phonetic transcription. By and large, our phonetic transcriptions were accurate representations of the type of sound children were using in their speech productions in a stop or spirant phonetic context. What is important to point out, however, was that the acoustic analyses indicated the presence of a spirant in five instances when the sound was transcribed as a stop. What is being perceived in bilingual children's speech might not *always* be accurately interpreted by the transcriber. SLPs should take extra caution in phonetic transcription of sounds in the phonetic context that triggers this allophonic rule in order to ensure accurate representation of bilingual children's speech.

Results suggested that: (1) bilingual children may not master the stop-spirant alternation by age 8;2 and (2) bilingual children most likely represent stop consonants as the underlying form of the spirant based on the participants' predominant use of stop consonants as substitutes for spirant productions across ages. Younger participants' (ages 3;6 and below) patterns of substitutions, which included additional manner classes, demonstrated a weaker grasp of the underlying form for this allophonic relationship than older participants; however, they still demonstrated higher accuracy on the voiced stops as compared to the spirants. Perhaps younger bilingual children do not specify an underlying form for this allophonic rule, but as children's phonological systems mature, an underlying form is established. Additional factors such as sociolinguistic influences, language loss, phonological ability and between-language interaction should be further investigated to make absolute claims on the process by which bilingual Mexican Spanish-speaking children acquire this phonological rule.

Clinically speaking, SLPs should: (1) give attention to detail in the phonetic transcription of bilingual children's speech so as to not misrepresent sounds that exist in an allophonic relationship, (2) establish expectations for consonant accuracy in stop, fricative and spirant manner classes based on published data on *bilingual* phonological skills rather than published data on monolinguals and (3) take note of the linguistic community in which a child resides, paying close attention to linguistic diversity due to dialect and between-language influences.

Study limitations and future directions

Because the current study included a small number of subjects and was quasi-longitudinal in design, a larger group of children examined via acoustic analysis in a true longitudinal manner is needed to corroborate the findings of this exploratory study. The development and dissemination of large-scale normative data for bilingual Spanish–English speaking children is essential to reducing the number of bilingual children misdiagnosed with speech sound disorders. In addition, comparing bilingual children's use of the stop-spirant alternation to the peer and adult models in their linguistic community and characterizing how phonology is affected by language loss would provide insight into why bilingual children exhibit the patterns of error that we see on this allophonic relationship. Finally, future research should further explore typical patterns of phonological acquisition that extend beyond the stop-spirant alternation in order to separate developmental differences from disorders.

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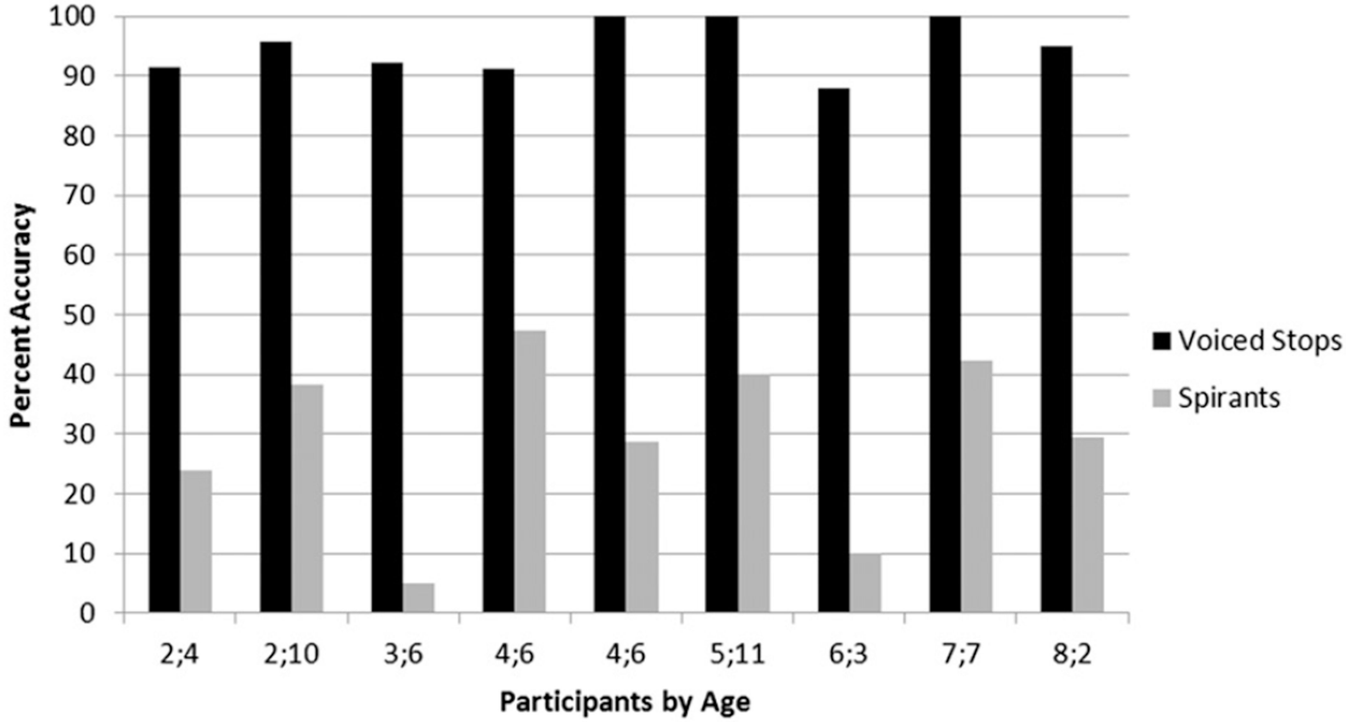

Figure 1.

Overall accuracy of voiced stops and spirants by participant.

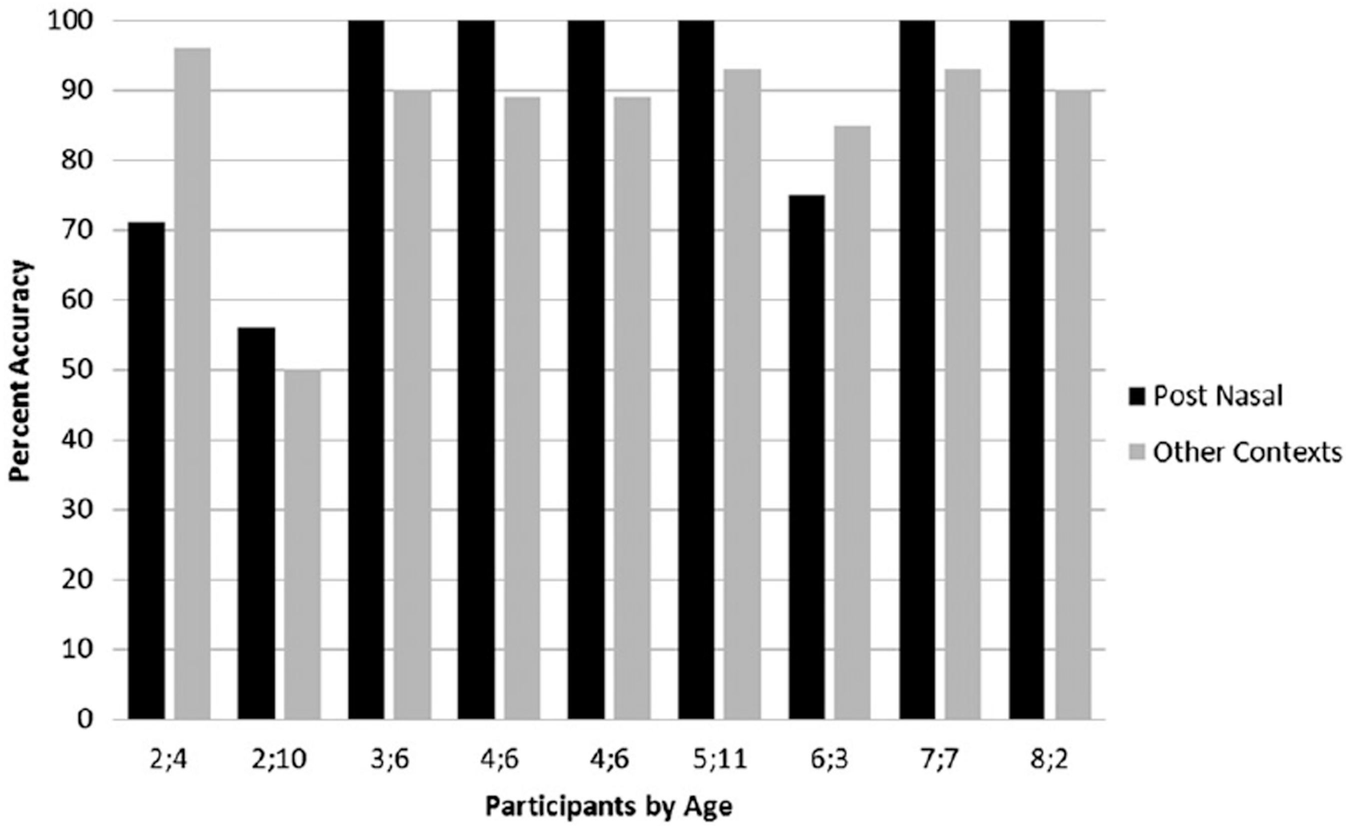

Figure 2.
Accuracy of voiced stops in post-nasal and all other contexts.

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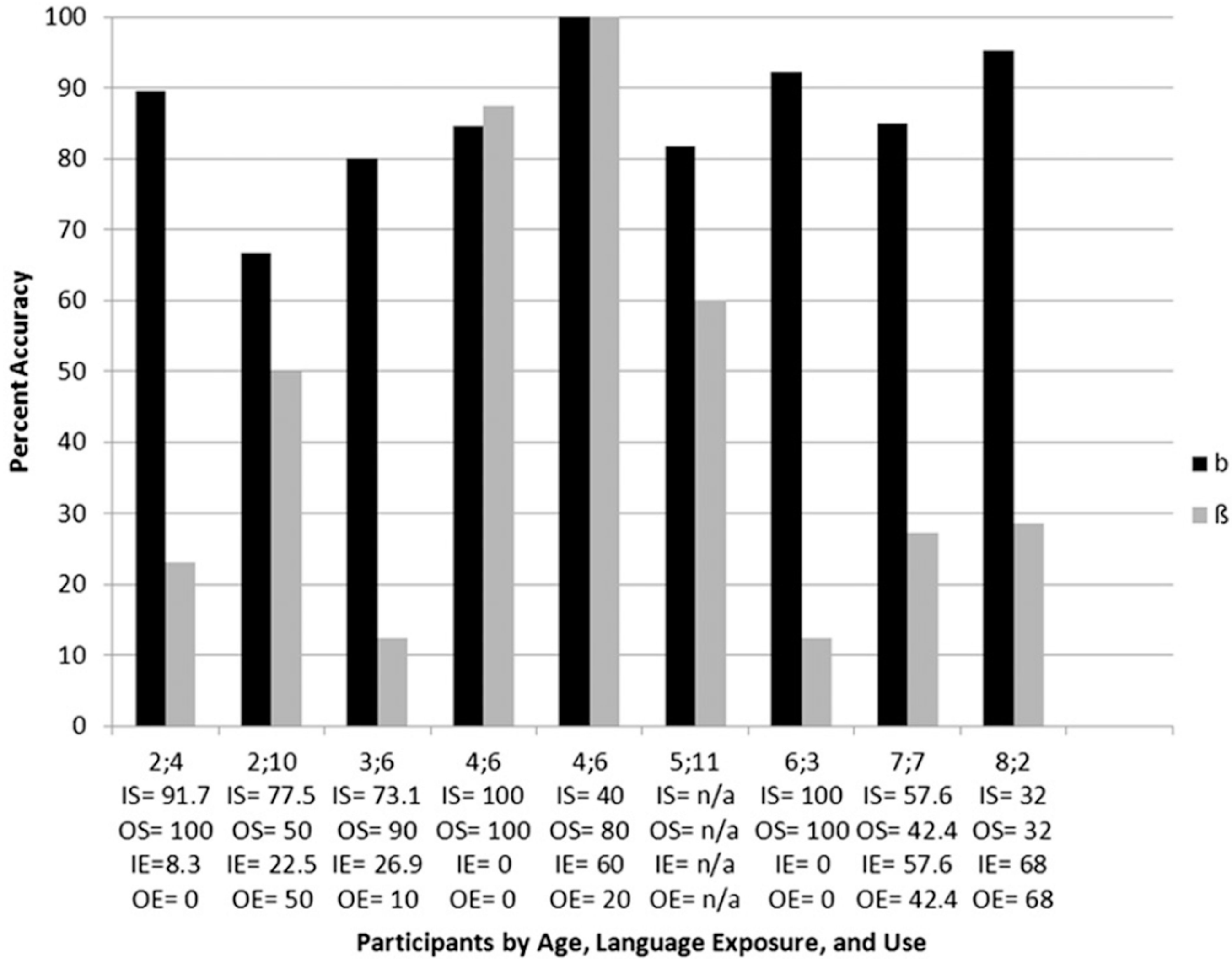

Figure 3.

Percent accuracy of the voiced stop /b/ and spirant [β] by participant. IS, Input Spanish; OS, Output Spanish; IE, Input English; OE, Output English.

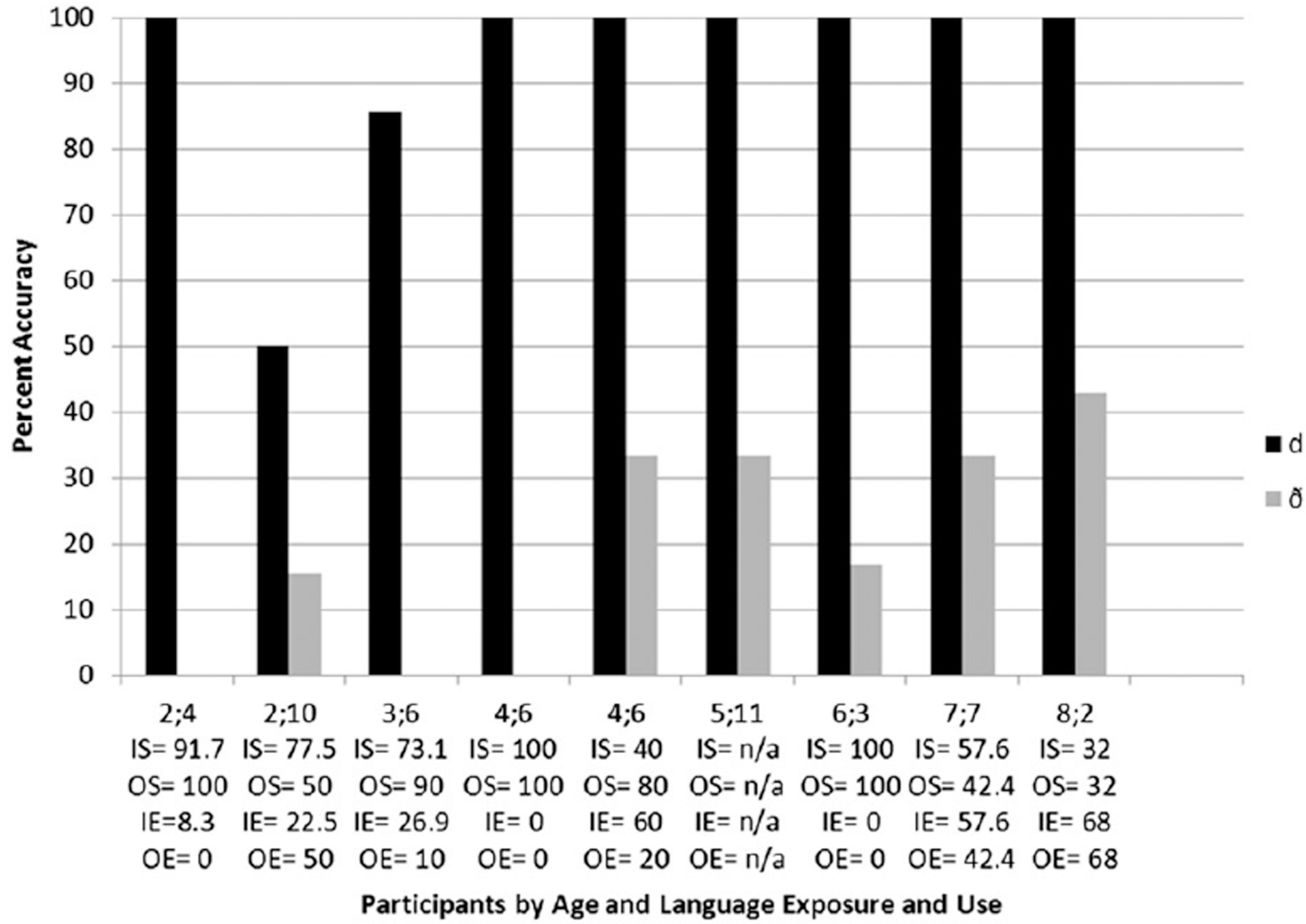

Figure 4.

Percent accuracy of the voiced stop /d/ and the spirant [ð] by participant. IS, Input Spanish; OS, Output Spanish; IE, Input English; OE, Output English.

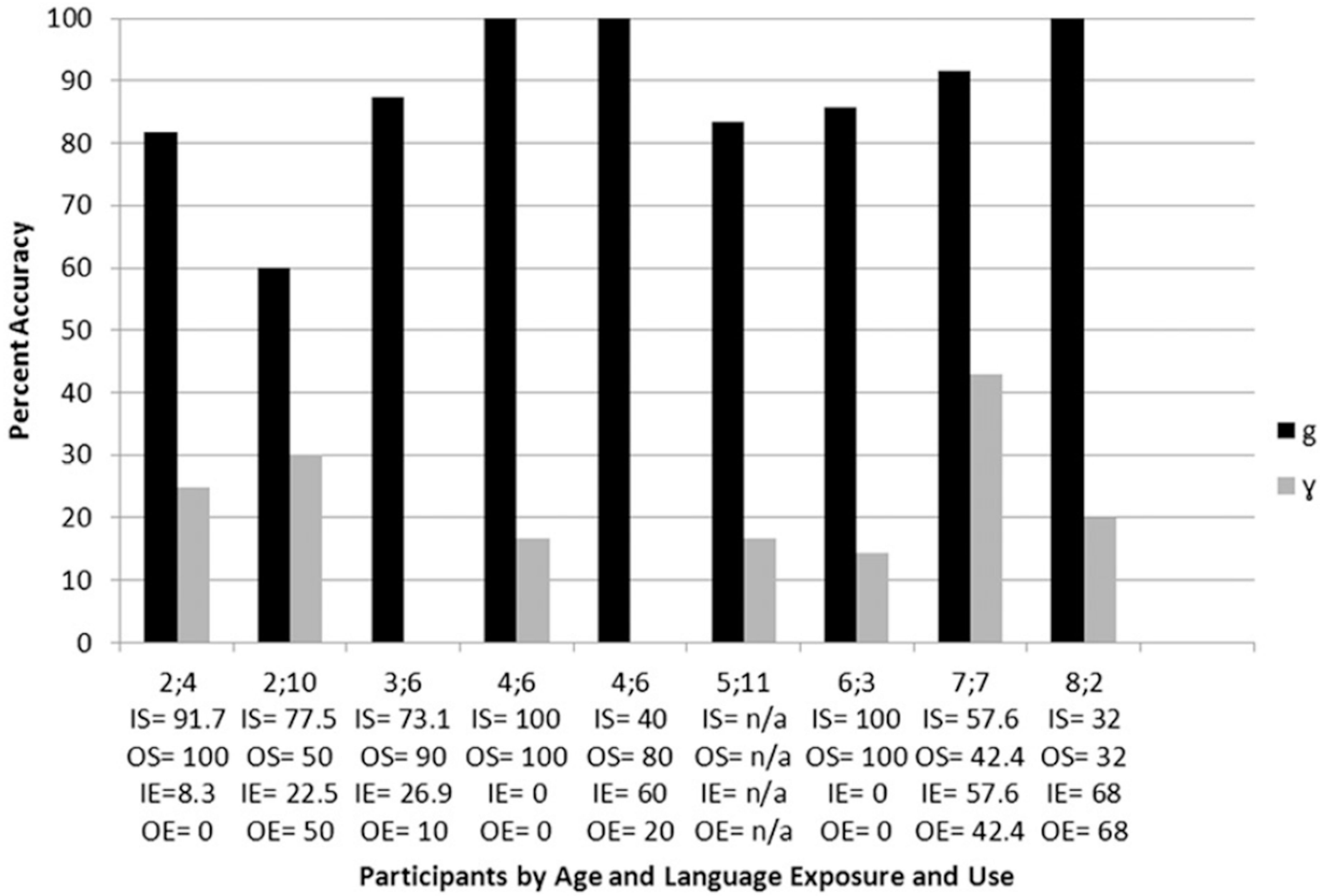

Figure 5.

Percent accuracy of the voiced stop /g/ and the spirant [ɣ] by participant. IS, Input Spanish; OS, Output Spanish; IE, Input English; OE, Output English.

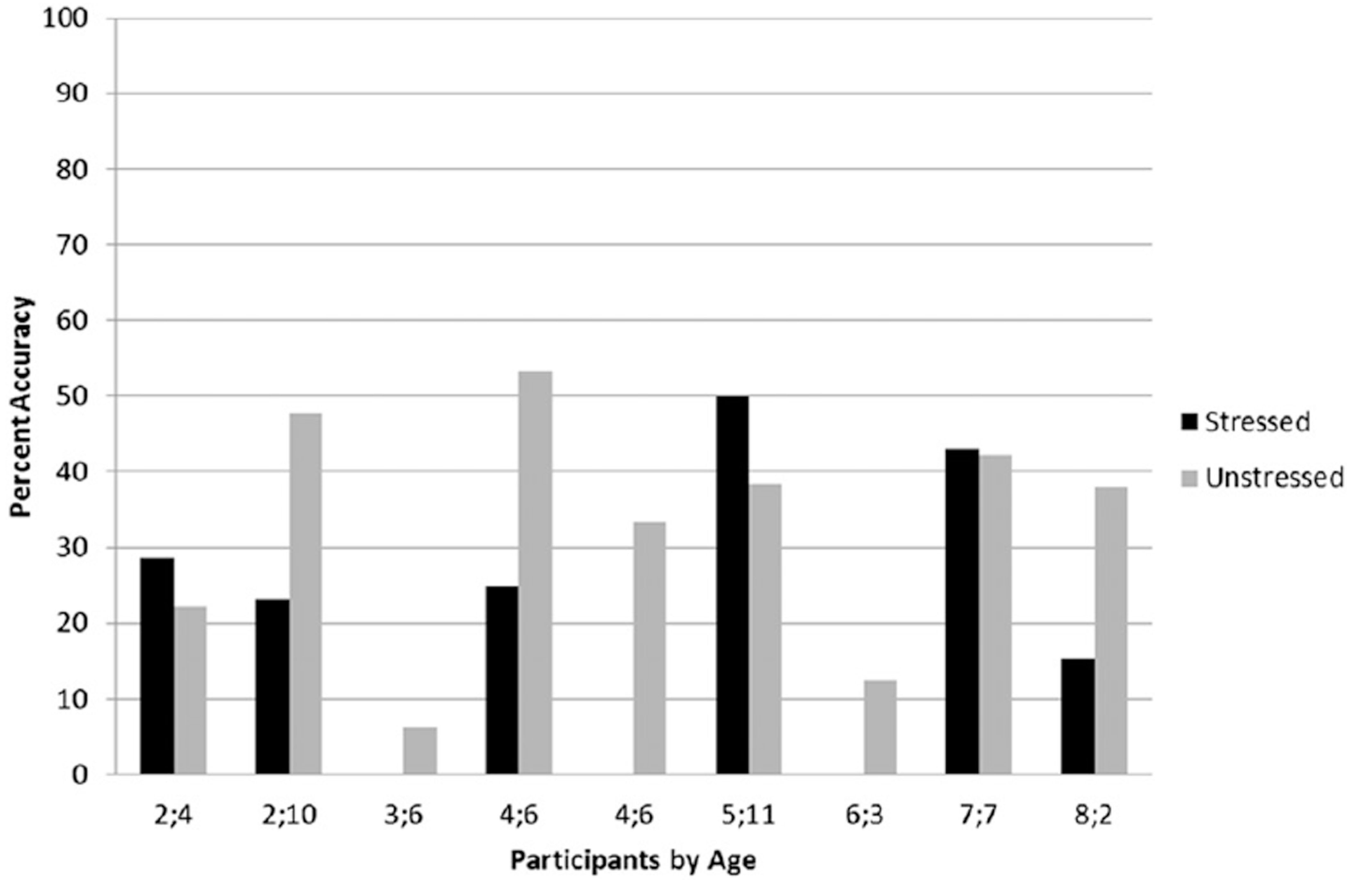

Figure 6.

Accuracy of spirant production in stressed and unstressed syllables.

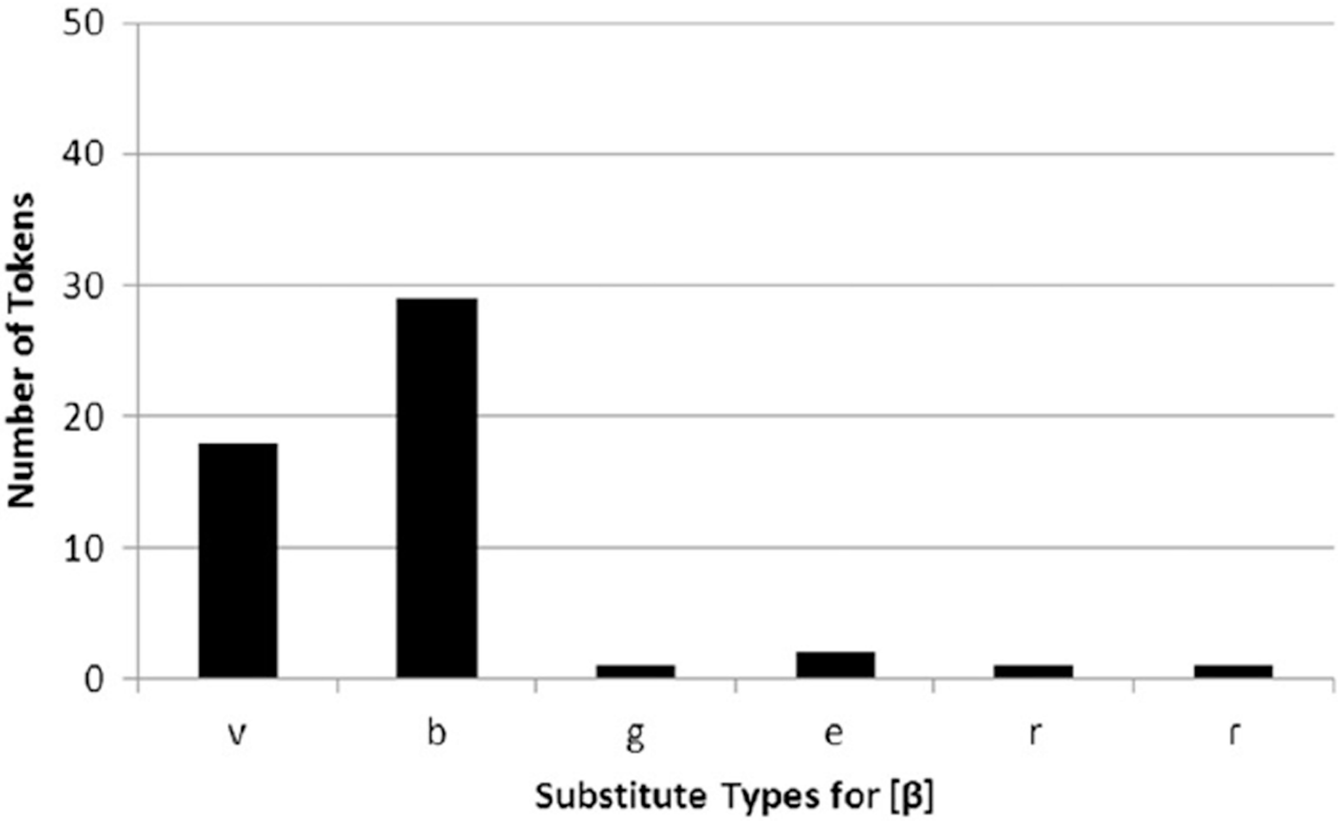

Figure 7.
Types and tokens of substitutes for [β] aggregated across participants.

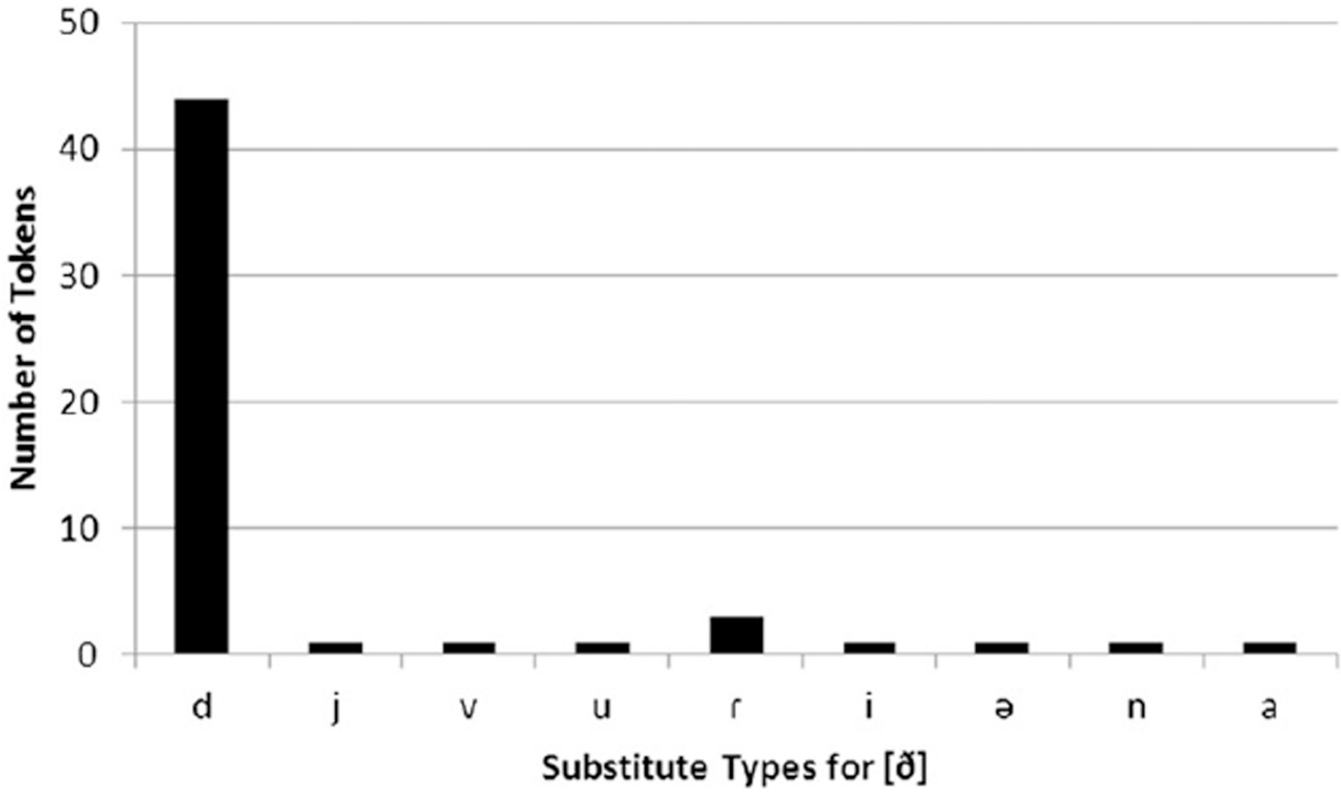

Figure 8.
Types and tokens of substitutes for [ð] aggregated across participants.

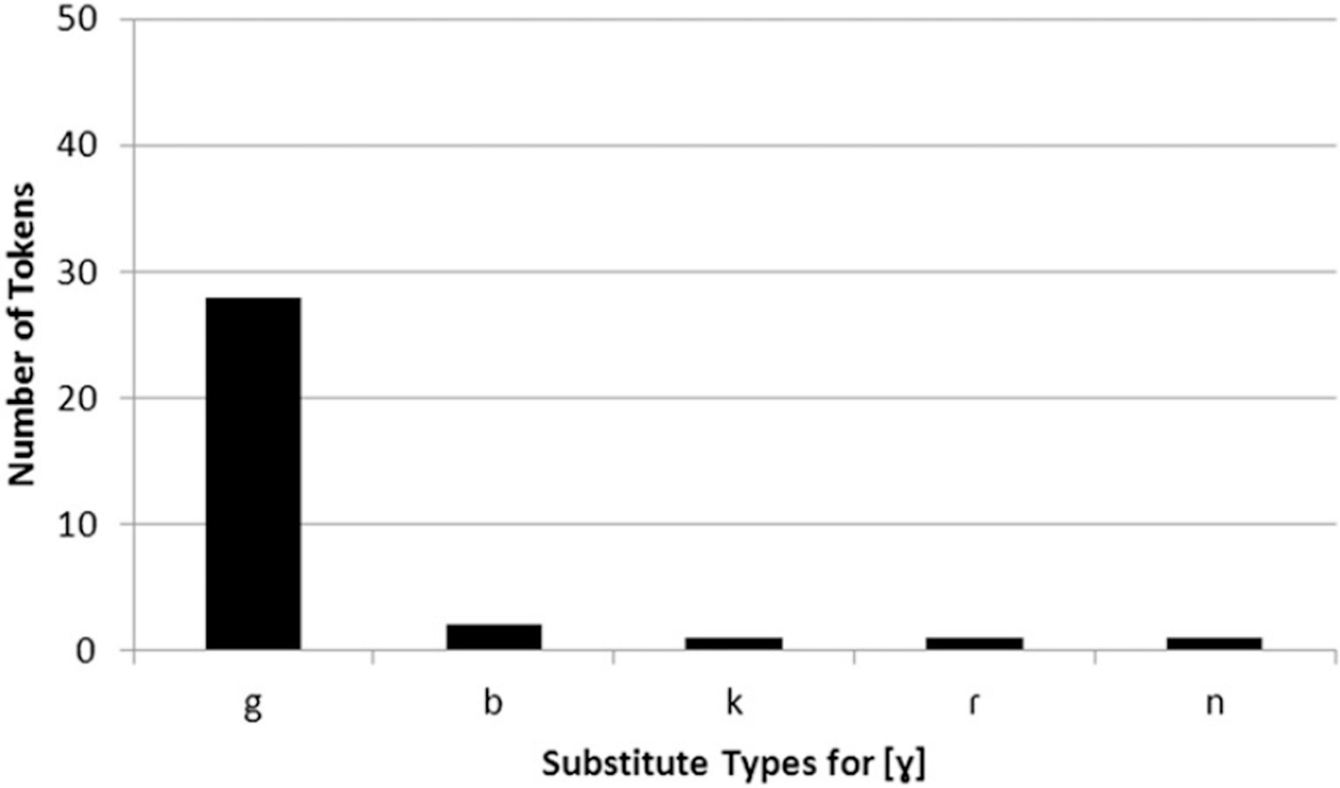

Figure 9.
Types and tokens of substitutes for [ɣ] aggregated across participants.

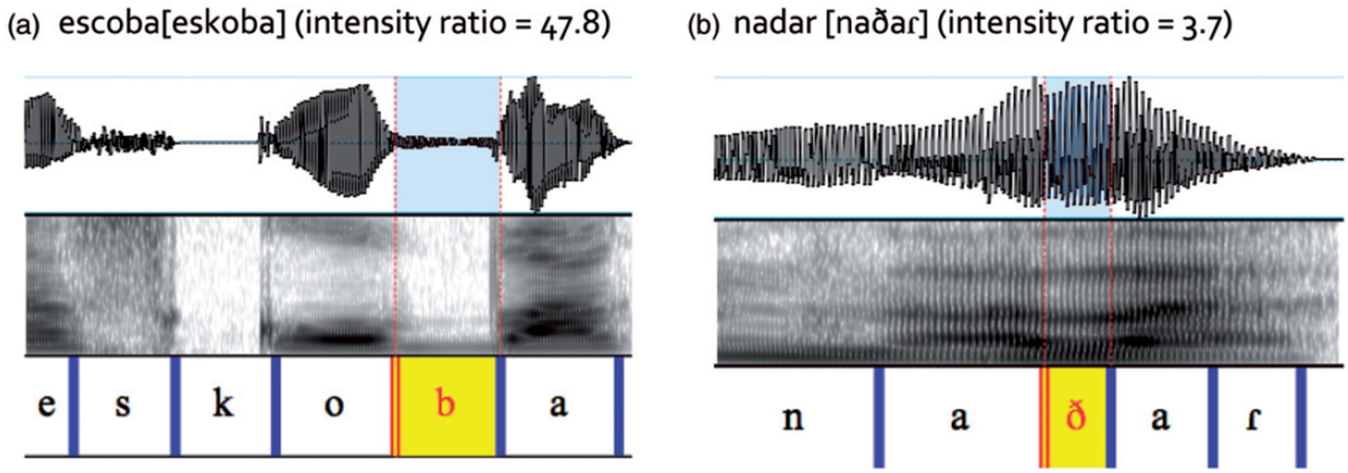

Figure 10.

Examples of highest and lowest intensity ratios for acoustic analysis. Waveforms and spectrograms of the two words with the highest (a) and lowest (b) intensity ratios. The intensity ratio measure was expected to correlate with degree of constriction, so high ratios should be stop-like and low ratios should be fricative-like. Orthographic segmentations of the spectrograms are given, and the target consonant is outlined in black.

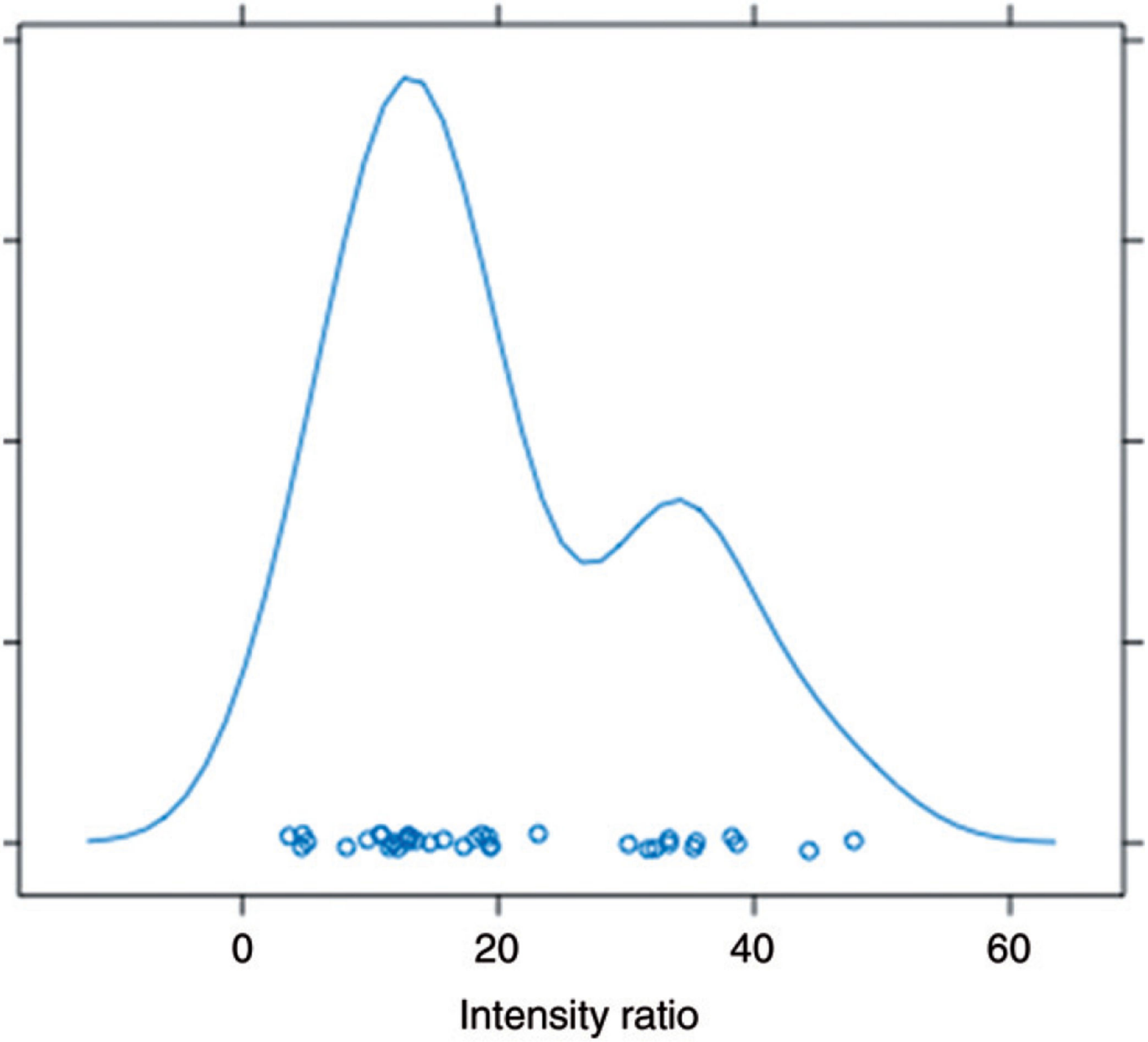

Figure 11.
Results of acoustic analysis examining distribution of intensity ratios for voiced stops and spirants. This shows the distribution of intensity ratios in the data set. Each point represents one token, and the *x*-axis represents the intensity ratio. The curve represents the density, or the average number of points, at each intensity.

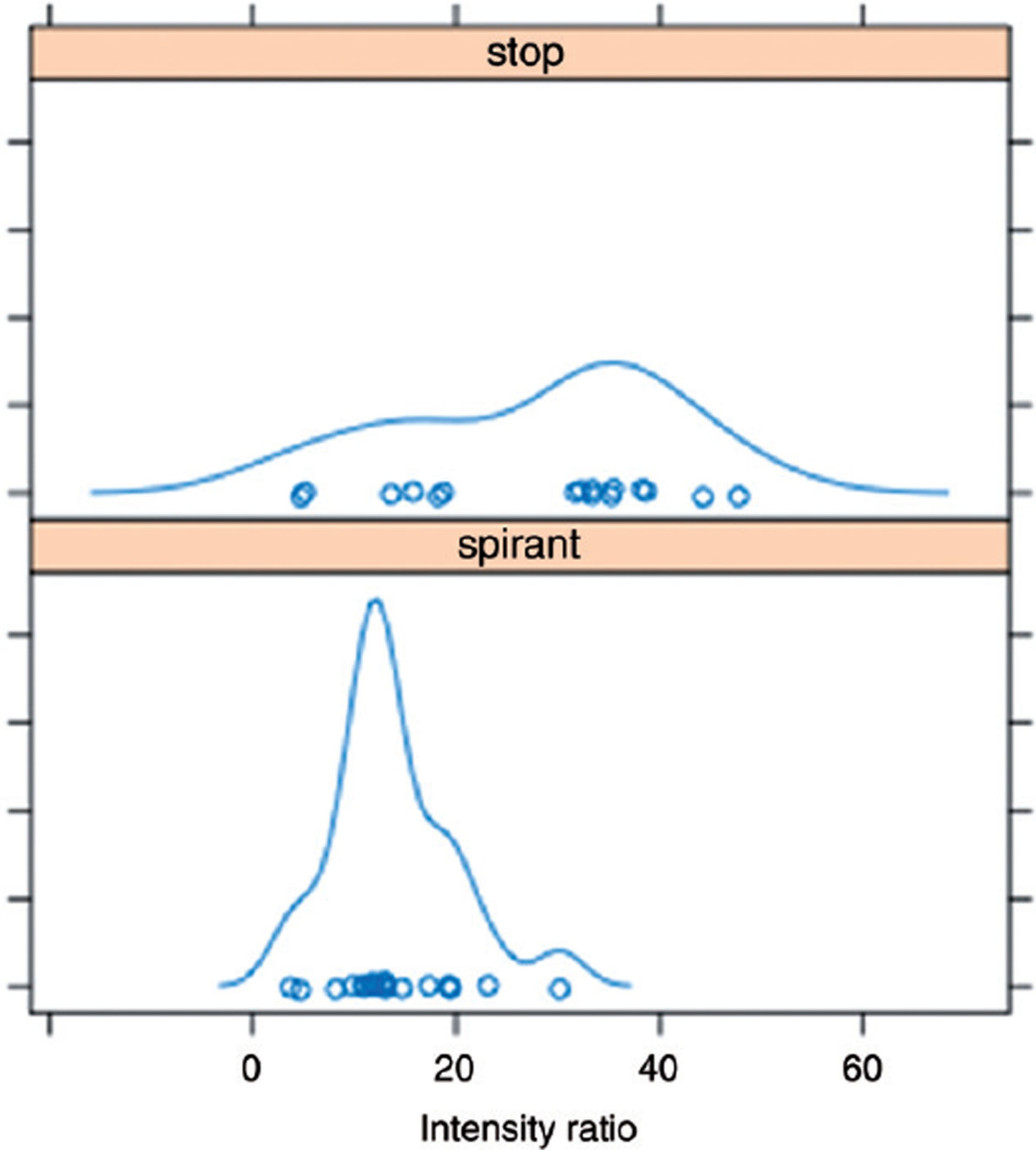

Figure 12.

Acoustic results by manual transcription type. This shows the distribution of intensity ratios in the data set for tokens which were manually labeled as stops (top) or spirants (bottom). Each dot represents one token, and the *x*-axis represents the intensity ratio. The curve represents the density, or the average number of points, at each intensity.

Table 1

Demographic information on participants.

Child ID	CA [years;months]	Gender	Percent Input Spanish	Percent Output Spanish	Percent Input English	Percent Output English
S1	2;4	Female	91.7	100	8.3	0
S2	2;10	Male	77.5	50	22.5	50
S3	3;6	Female	73.1	90	26.9	10
S4	4;6	Male	100	100	0	0
S5	4;6	Female	40	80	60	20
S6	5;11	Male	Not reported	Not reported	Not reported	Not reported
S7	6;3	Female	100	100	0	0
S8	7;7	Female	57.6	57.6	42.4	42.4
S9	8;2	Male	32	32	68	68

Table 2

Examples of substitution errors for voiced stop productions.

Category	Example 1	Example 2	Example 3
Word	verde	vaca	lengua
Transcription	[beɾðe]	[baka]	[leŋgwa]
Error	[veɾde]	[vaka], [waka]	[emwa]

Table 3

Examples of substitution errors for spirant productions.

Category	Example 1	Example 2	Example 3	Example 4
Word	fuego	llaves	Dedo	tigre
Transcription	[fweɣo]	[jaβes]	[deðo]	[tiɣɾe]
Error	[fwebos], [wego]	[javes]	[dedo]	[tigɾe], [tigeɾe]