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A retrospective study of phonetic inventory complexity in acquisition of Spanish: Implications for phonological universals

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Abstract

This study evaluates 39 different phonetic inventories of 16 Spanish-speaking children (ages 0;11 to 5;1) in terms of hierarchical complexity. Phonetic featural differences are considered in order to evaluate the proposed implicational hierarchy of Dinnsen et al.'s phonetic inventory typology for English. The children's phonetic inventories are examined independently and in relation to one another. Five hierarchical complexity levels are proposed, similar to those of English and other languages, although with some language-specific differences. These findings have implications for theoretical assumptions about the universality of phonetic inventory development, and for remediation of Spanish-speaking children with phonological impairments.

Keywords

Spanish; phonetic inventory; complexity; typology; acquisition; universal

Introduction

A variety of normative studies have characterized the developing sound systems of children in attempts to determine a universal order of acquisition of sounds. In studies on developmental norms, identification of the order of acquisition of individual sounds is typically the goal (Templin, 1957; Sander, 1972; Prather, Hedrick, and Kern, 1975; Kilminster and Laird, 1978; Jiménez, 1987; Smit, Hand, Freilinger, Bernthal, and Bird, 1990; Shriberg, 1993; Amayreh and Dyson, 1998; Fudala, 2000; Goldman and Fristoe, 2000; Hua and Dodd, 2000). It is known, however, that children are highly variable in their development of sounds, and that the normative data derived from those studies do not necessarily reflect any one child (Sander, 1972; Turton, 1980; Stoel-Gammon, 1985; Smit, 1986; Lof, 2004).

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Because of this observed variability in phonological development, several researchers (Dinnsen, Chin, Elbert, and Powell, 1990; Dinnsen, Chin, and Elbert, 1992; Gierut, 1994; 1996; Gierut, Simmerman, and Neumann, 1994; Gierut and Morrisette, 1996; Amayreh and Dyson, 2000; Stokes, 2002; Stokes and To, 2002) have attempted to characterize phonetic and phonemic acquisition in terms of sound classes, or, more specifically, featural differences, similar to Jakobson's (1968) proposed universals of feature acquisition, shown in (1):

- (1) Phonological universals in the development of children (Jakobson, 1968), where '>' means 'acquired before'
 - a. voiceless > voiced
 - b. stops > fricatives > affricates
 - c. front consonants > back consonants (i.e. labial > alveolar > velar)

In this study, we consider the typological organization of phonetic inventories of Spanish-speaking children as a further test of these predictions of phonetic inventory development. First, however, it is important to review the details of these prior studies. Dinnsen et al. (1990) evaluated the phonetic inventories of 40 monolingual English-speaking children (aged 40–80 months) with phonological disorders that are functional in nature (that is, they had no known cause). Phonetic inventories were determined based on a two-time occurrence of a sound in a 306-item single-word speech sample. Each inventory was typologically characterized according to phonetic differences using Chomsky and Halle's (1968) distinctive feature system, in order to establish an implicational hierarchy that could describe the children's acquisition of natural classes.¹ Based on the description of the 40 children's inventories, a typology of five different levels of sound classes emerged. The specific inventory levels are illustrated in Table I.

Level A, the simplest one, includes labial and coronal stops, as well as nasals and glides. In terms of Chomsky and Halle's features, the major class features [$\pm$ consonantal], and [$\pm$ sonorant], as well as the place feature [$\pm$ coronal], are phonetically contrastive at this level. Because each sound class can be distinguished from the other based on only those three features, all other features for that level of complexity are considered redundant. (See also the default principles in (2), which are discussed below.) Specifically, [$\pm$ consonantal] is sufficient to distinguish the glides (or semi-vowels; e.g. [w j]), which are [–consonantal], from all other consonants, which are [+consonantal]. Within the [+consonantal] sounds, the feature [$\pm$ sonorant] distinguishes the nasal stops, which are [+sonorant], from the oral stops, which are [–sonorant]. Thus, the two features [$\pm$ consonantal] and [$\pm$ sonorant] are sufficient to distinguish among the three manners of articulation: stops, nasals, and glides. In terms of

¹Chomsky and Halle's (1968) feature system is generally used to distinguish among *phonemes* and phoneme classes, thereby serving a distinctive (contrastive) function. In Dinnsen et al.'s (1990) original study and in the present one, the feature system was used to describe sound classes of *phonetic* inventories; the phonemic contrastiveness of each sound in each child's inventory was not addressed. Indeed, a two-time occurrence is hardly sufficient to indicate any functional role of a sound. Nevertheless, the same feature system has also been used to indicate phonetic (or surface) properties of sound classes, such as when vowels are nasalized in English. Although [$\pm$ nasal] is not contrastive for English vowel phonemes, when a vowel precedes a tautosyllabic nasal, it becomes [+nasal]. In this sense, then, the [+nasal] feature, which is not a distinctive property of the language, is used to characterize a particular class of sounds when in a particular phonetic context. The feature system was used by Dinnsen et al. in this same sense for the characterization of children's phonetic inventories.

place of articulation, the feature [±coronal] is sufficient, in that it distinguishes the labials from the coronals. Again, the three features are sufficient for minimally characterizing the differing properties of the inventory. Thus, while there are nasals in a Level A inventory, the feature [±nasal] is *not* differentiated at that level, because the [±nasal] specification for stops and nasals is predictable based on their specification for the feature [±sonorant]. The same holds for other relevant features that are also not differentiated at this level, such as [±anterior], [±continuant], [±delayed release], [±lateral], and [±strident].

Level B is only slightly more complex, in that it adds a cognate to one or more of the stops. Thus, the feature [±voice] is differentiated at this level, due to the presence of both voiceless and voiced stops. Importantly, a cognate pair must be present for a Level B designation (e.g. [p b], [t d], or [k g]); however, not *all* cognate pairs need be present, as illustrated in the sample inventory in Table I. A [±anterior] difference is found in all Level B inventories, which, when combined with [±coronal] allows for a three-way difference among labials, coronals, and dorsals within the stop and nasal manner classes.

Level C adds fricatives and/or affricates, making the feature [±continuant] and/or the feature [±delayed release] differentiated at this level. The feature [±continuant] distinguishes the fricatives from the stops, while [±delayed release] distinguishes the affricates from the stops. A child can follow one of three paths here, adding fricatives only, affricates only, or both fricatives and affricates. Importantly, only one representative sound from any one of the classes is necessary to bring an inventory to Level C. Thus, *one* fricative or one affricate is sufficient.

Level D involves the addition of *one* liquid—either [l] or [ɹ]. At this level, there are now two types of [+consonantal, +sonorant] classes: nasals and liquids. Recall that, at Level A, the nasals were the *only* [+consonantal, +sonorant] manner class, which meant that the feature [±nasal] was not contrastive (it was predictable based on its [+consonantal, +sonorant] status). At Level D, however, with the introduction of another [+consonantal, +sonorant] manner class (the liquid), the feature [±nasal] now differentiates the nasals from the liquids.

Finally, Level E adds *either* a second liquid *or* a stridency difference among the fricatives *or* both. For Level E, the phonetic inventory must include *both* [l] and [ɹ], resulting in a [±lateral] difference. Alternatively, the inventory could include *both* [θ] and [s] *or both* [ð] and [z], illustrating a [±strident] difference. Importantly, the presence of strident [f] and non-strident [θ], for example, does not constitute a stridency difference, as the two sounds also differ by the feature [±coronal]. Similarly, the presence of [θ] and [z] does not constitute a stridency difference, as the two sounds also differ by the feature [±voice]. As with Level C, the child has three paths to follow to reach a Level E inventory: adding a second liquid, creating a stridency difference, or both.

An important aspect of this phonetic inventory typology is that, at every level of the hierarchy, there is the possibility for individual variation (Dinnsen et al., 1990). That is, there are no specific *sounds* that are associated with a particular level; there are only *sound classes* or *featural differences*. This allows for the observed variation that occurs in

developing sound systems, where each child masters the sounds of the target system in a unique but also clearly constrained manner.

Dinnsen et al. (1990) observed that the inventory levels increased in complexity in terms of phonetic featural differences, which resulted in an implicational and hierarchical relationship between the inventory levels. Specifically, featural differences characteristic of Level B imply those of Level A. Similarly, featural differences characteristic of Level E imply those of Levels A, B, C, and D.

Dinnsen (1992) characterized the typology in terms of hierarchical tree structures that perhaps better illustrate the implicational nature of the sound classes along with a set of corresponding default principles for each level (listed in (2) below). Adapted tree structures are provided in Figures 1(a–e) for Levels A–E, respectively. Each branch of the hierarchy corresponds to a [–] value of the feature on the left and [+] value of the feature on the right. Thus, [consonantal] branches to [–consonantal] glides on the left and [+consonantal] consonants on the right. As is illustrated, the topmost part of each tree represents those features that differentiate each of the major classes (e.g. glides vs consonants, obstruents vs sonorants). Additional features added to each increased level of complexity represent more fine-grained phonetic feature differences between sound classes at each level.

(2) Default principles for Level A (Dinnsen, 1992: 201)

- a. All consonants are stops
- b. All obstruents are voiceless and unaspirated
- c. All sonorant consonants are nasals

Because Level B adds a voice difference among the stops, the default principle in (2b) no longer holds at that level, although the other two principles remain. With Level C and the addition of a [continuant] difference, principle (2a) no longer holds, although (2c) still applies. Finally, at Level D, a [nasal] difference emerges, and principle (2c) no longer holds.

The implicational nature of the featural differences is reminiscent of the universal implicational laws proposed by Jakobson (1968). This is an important observation, as it suggests that, theoretically, no child can ever exhibit a phonetic inventory that includes feature differences of higher levels without also including phonetic differences of lower levels. Indeed, all 40 children in Dinnsen et al.'s study conformed to the typology in this way. Furthermore, the typology closely matched the characteristics of phonetic inventories of 30 additional children with phonological delay described by Gierut et al. (1994), as well as children acquiring English in a typical fashion described by Templin (1957), Grunwell (1982), Locke (1983), Stoel-Gammon (1985), and Dinnsen (1992), which provides further support for the universal nature of the typology.

Clinical implications

Acquisition studies such as these help us to understand better the potential differences that occur between children acquiring the same language (as well as different languages), as well as to determine the universal aspects of languages. In addition, they may help us to better

understand typical vs atypical phonological acquisition. In fact, the clinical implications of these findings are exciting, as they suggest that targeting featural differences associated with higher levels of phonetic complexity will result in the emergence of featural differences of lower levels of complexity. For example, consider a child who is at Level A, with only stops, nasals, and glides in her phonetic inventory. If she is trained on a liquid sound, such as [ɹ], that represents a phonetic contrast of Level D, it is predicted that a voice difference among the stops will emerge (Level B), and that fricatives and/or affricates will emerge also (Level C).

Indeed, in a follow-up study by Dinnsen et al. (1992), each of the original 40 children's sound systems was examined following remediation. Each of their phonetic inventories still conformed to the typology, regardless of the sound that was taught. Importantly, some children were trained on featural differences that skipped a level of complexity with respect to the individual child's pre-treatment phonetic inventory. All of them showed phonetic contrasts emerging at those simpler levels of complexity, as predicted by the hierarchy. In other words, treatment on one class of sounds resulted in the emergence of another sound class without direct instruction on that class.

Two studies have experimentally evaluated the predictions borne out of Dinnsen et al.'s (1990) typological predictions. Again, the typology predicts that if a child is trained on and learns a sound from a higher level of phonetic complexity, other sounds from lower levels of complexity must also emerge. Tyler and Figurski (1994) tested this claim with two children (aged 2;8 and 2;10), both of whose inventories were at Level B prior to treatment. Subject 1 was trained on /l/ to introduce a Level D [$\pm$ nasal] phonetic contrast, while Subject 2 was trained on /s/ to introduce a Level C [$\pm$ continuant] phonetic contrast. Following remediation, Subject 1 added 12 sounds, including the featural differences associated with Levels C and D: [$\pm$ continuant], [$\pm$ delayed release], and [$\pm$ nasal]. Subject 2, on the other hand, added only two new sounds, which did not include the treated sound. In fact, Subject 2's phonetic inventory remained at Level B, and only elaborated on the sound classes that were characteristic of Levels A and B. Apart from the differential results of the two children, the findings of Tyler and Figurski's study support the prediction that the introduction of higher-level phonetic contrasts results in the emergence of lower-level contrasts that were not directly targeted in treatment.

Powell's (1993) findings also support the Dinnsen et al. (1990) implicational hierarchy. In his study, the phonetic inventories of six children with phonological disorders were classified according to the hierarchy. Then the children were trained on two sounds: /ɹ/ and one other sound that targeted a Level E phonetic contrast specific to each child's inventory. Prior to treatment, there were two children at Level C, three at Level D, and one child at Level E. Following remediation, all six children's phonetic inventories were classified at Level E.

Taken together, the findings from these different studies on phonetic inventory complexity point to promising directions that research on phonological acquisition and phonological treatment can follow. Yet, these studies have only considered the universality of the typology as it applies to phonological acquisition of English (though see Keske Soares,

1998). An important direction for future phonological acquisition research is to test the cross-linguistic generalizability of the typology by evaluating the inventories of children who speak languages other than English. Only a handful of such studies have been conducted thus far.

Cross-linguistic tests of the typology: Comparisons and modifications

As a test of the universal nature of phonetic inventory organization and development, Amayreh and Dyson (2000) examined the phonetic inventories of 13 Jordanian Arabic-speaking children (aged 14–24 months) and compared them with the typology proposed by Dinnsen et al. (1990). They noted that the children in their study demonstrated several inventory characteristics in common with those of English-speaking children. In fact, most of the children could be assigned to one of the five levels of complexity, with all the necessary (implied) phonetic contrasts present.

Because of segmental differences between the two target languages, however, some (re-) interpretation of Dinnsen et al.'s (1990) typology was necessary. For example, a lateral-retroflex difference, associated with Level E in English, does not occur in Jordanian Arabic. Amayreh and Dyson suggest instead a lateral-tap/trill phonetic contrast as characteristic of Level E for Arabic. Furthermore, a strident–non-strident difference cannot be exhibited between alveolar and interdental fricatives in Jordanian Arabic as it is in English; instead, Amayreh and Dyson assume that the difference between [s] or [ʃ] with [ħ], [ʕ], or [χ] demonstrates the featural contrast. They also note that the emphatic consonants such as [d̥ t̥ s̥ ʔ q] do not have a place in Dinnsen et al.'s typology, since those consonants do not occur in English. They suggest that the emphatic–non-emphatic phonetic contrast occurs at a higher level of complexity (e.g. Level F).

Dinnsen et al.'s (1990) typology also has been tested with data from children learning Cantonese. Stokes (2002) considered the typology with 10 Cantonese-speaking children with phonological disorders, and, that same year, Stokes and To (2002) considered it with 122 typically-developing Cantonese-speaking children. As was the case with Amayreh and Dyson's (2000) study of Jordanian Arabic, Dinnsen et al.'s typology needed to be revised in order to accommodate the differences between Cantonese and English. Two separate typologies were proposed by Stokes (2002) and Stokes and To (2002), respectively; however, certain general observations may be made here. Specifically, Cantonese lacks the voiced–voiceless difference between plosives that would be characteristic of Level B in the original hierarchy. Cantonese does have a different type of laryngeal contrast, however, between aspirated and unaspirated sounds. Thus, in place of [±voice], Stokes (2002) proposed [±spread glottis] (this was a Level B difference in Stokes (2002), but a Level C' difference in Stokes and To (2002)). Further, Cantonese lacks a [±lateral] difference, including only one liquid, [l]. Likewise, no [±strident] difference occurs, as [f] and [s] are the only fricatives, which can be distinguished by [±coronal]. Thus, Level E associated with Dinnsen et al.'s typology was not deemed relevant to the evaluation of Cantonese-speaking children's inventories.

Aside from these differences, Cantonese-speaking children's phonetic inventories generally fit well with Dinnsen et al.'s proposed typology, though two important exceptions must be

noted. First, the affricate [ts] appeared to emerge prior to (rather than simultaneously with) the fricatives [f s]. Secondly, the lateral [l] appears to occur in children's inventories, even in the absence of a laryngeal featural contrast (Stokes, 2002; Stokes and To, 2002). Because [n] and [l] occur as allophones of the same phoneme in Cantonese, Stokes and To proposed that both sounds be associated with the same level of complexity (thus, [±nasal] would not be a phonetic contrast of the Cantonese inventory hierarchy). This very different role of [l] with respect to the organization of phonetic inventories is especially interesting: In English, [l] is associated with a very high level of complexity, while in Cantonese, it is less so. As will be shown in the current study, Spanish [l] differs from English [l] in this manner as well.

Thus far, the phonetic inventories of Spanish-speaking children have not been evaluated in great detail in the phonological acquisition literature. In fact, the application of Dinnsen et al.'s (1990) typology to Spanish-speaking children's inventories has only been noted twice (Greim, 2000; Goldstein and Cintrón, 2001); in both cases, the original typology was referenced, but language-specific modifications were not proposed. Toward that end, the goal of this retrospective study was to determine the applicability of Dinnsen et al.'s typology to the phonetic inventories of children learning Spanish, and to make a preliminary proposal regarding any necessary modifications to the typology. Our overarching goal is to add to the cross-linguistic evidence regarding the universality of hierarchical organization of phonetic inventories in phonological acquisition.

Before turning to the methodology of the current study, it is necessary to detail the phonemic and phonetic differences between English and Spanish, in order to best highlight potential aspects of Dinnsen et al.'s (1990) original typology that may require modification to accommodate the Spanish sound system. In Table II, the English and Spanish phonemic inventories are provided for comparison between the two languages. Note that, while the purpose of this study is to evaluate the phonetic inventories of Spanish-speaking children compared to those of English-speaking children, we list the phonemic inventories of the target languages here, because space limitations prevent inclusion of all the allophones of each phoneme, and because of the rather broad (phonemic) transcriptions that were used in Dinnsen et al.'s original study and in most of the studies that we evaluated for the present analysis. Each phoneme in each inventory in Table II thus represents a collection of allophones.

As is apparent from Table II, English and Spanish share a number of sounds, including /p t k f s tʃ m n l/, although /t/ in English is alveolar, while it is dental in Spanish (/t̪/). Also, while it appears that the two languages also share /ð/, an important distinction must be made here. That is, the /ð/, as well as /β/ and /ɣ/, which are commonly referred to as *spirants* in Spanish (Harris, 1969), behave acoustically, articulatorily, and phonologically more like approximants than fricatives (Bakovi, 1994; Widdison, 1997; Cole, Hualde, and Iskarous, 1999; Barlow, 2003c). Furthermore, it is assumed here, following findings from assumptions of numerous studies, that /b ð ɣ/ are basic phonemes of the Spanish language, while [b d g] are allophones that surface in predictable contexts (see, for example, Lozano, 1979; Bakovi, 1994; Barlow, 2003c). Because the current study focuses on phonetic inventories, rather than phonemic inventories, this phonemic status of the voiced spirants and stops ultimately does not impact the findings; however, the status of the spirants as approximants

is important for our analysis. One last point is that /θ/ is a sound that occurs in Peninsular Spanish, but does not occur in any of the dialects that are represented by the children in the samples used here; hence, it is excluded from Table II. Interestingly, [θ] does occur in some of the children's productions.

Methods

This retrospective study was based on 39 phonetic inventories taken from cross-sectional and longitudinal data from 16 children, with particular attention paid to the implicational and hierarchical organization of sound classes. The data were gathered from the archives of the Phonological Typologies Laboratory at San Diego State University (described in Barlow, 2002; 2003b; c; d, 2005a; b; 2007; Barlow and Gierut, 2008) as well as from published studies (Montes Giraldo, 1971; Amador Hernández, 1978; de Zuluaga, 1979; Greim, 2000). As such, the size and type of speech samples varied across subjects, since the data were originally collected for independent investigations; hence, the preliminary nature of this study. Specifically data from some of the children were cross-sectional in nature, reflecting only a single point in time for a given child. Data from other children, however, were longitudinal, collected over a period of months and, in some cases, years. Ideally, similarly-elicited speech samples obtained from a homogeneous population will serve as a better test of the typology. However, given that other major languages of the world such as English, Arabic, and Chinese have been described using Dinnsen et al.'s typology, the absence of studies for Spanish is a gap that needs to be filled. Moreover, even Dinnsen et al.'s typology, which was originally based on a homogeneous population of 40 children with phonological delay, was further evaluated by Dinnsen (1992) based on data of 20 typically-developing children from 16 separate studies. Thus, both homogeneous and heterogeneous data supported the typology for English. Once an adequate sample of more homogeneous data can be collected for Spanish, the typology can be evaluated further; for now, we rely on data from this variety of sources.

For these data, phonetic inventories at each point in time were analysed independently in order to evaluate the phonetic inventory typology proposed by Dinnsen et al. (1990). Thus, from the 16 children, a total of 39 separate inventories were studied. Details about each of these data sources follow.

Data sources

From the Phonological Typologies Archives, speech samples from seven different children were evaluated. Four children were bilingual in Spanish and English (as determined by an extensive parent questionnaire), and were developing in a typical fashion (see Appendix 1 for a summary of sources). The Spanish speech samples were collected from each child at a single point in time, and consisted of ~106–120 single-word utterances, which were elicited via picture- and/or object-naming tasks of the *Assessment of Spanish Phonology* (106 targeted words; Barlow, 2001), or both the *Southwestern Spanish Articulation Test* (80 targeted words; Toronto, 1977) and the *Assessment of Phonological Processes-Spanish* (APPS; 40 targeted words; Hodson, 1986). The children are labelled here as Inventory 1, 2, 3, and 4 (see Appendix 1), but are known as BL4, BL8, BL10, and BL11, respectively, in

the Archives and in prior published studies in which they are discussed (Barlow; 2002; 2003b; c; 2005b). As described in Barlow (2002; 2003c), these children did show some transfer from their Spanish to English productions, but appeared to be dominant in Spanish (in other words, the transfer was not bidirectional).

Speech samples from two additional children from the Phonological Typologies Archives were also evaluated. These monolingual Spanish-speaking children were phonologically delayed (as determined by parent and teacher report) and were part of a treatment study that experimentally assessed change in monolingual Spanish-speaking children's phonological systems following treatment. Aside from their phonological delay, the children were typically developing in all other respects as regards language, oral-motor structure/function, hearing, and cognition (for details, see Barlow, 2003b; d; 2005a; b; 2007). The speech samples of both children were collected at three separate points in time: prior to, during, and following phonological treatment. Each sample at each point in time consisted of, ~214 single-word utterances elicited via a picture-naming task, the *Assessment of Spanish Phonology-Revised* (Barlow, 2003a; 2005a). These children are identified as SD1 and SD2 in the Archives; their inventories are labelled here as Inventories 5, 6, and 7 for SD1 and 8, 9, and 10 for SD2, for pre-treatment, post-treatment, and 2 months post-treatment, respectively.

To summarize, 10 separate inventories from the seven children were obtained from these Phonological Typologies Archives. All seven children from the Archives spoke the Southern California dialect of Spanish (Hammond, 2001). In each case, the single-word utterances were elicited in the same manner, despite the use of different probe measures. Specifically, whenever possible, a non-imitative production was elicited. When necessary, though, a delayed imitation was obtained whereby a model was provided to the child followed by additional cueing prior to the child's attempt at the form (e.g. *Es una manzana. ¿Qué es?* 'It's an apple. What is it?'). All speech samples were narrowly transcribed by (near-) native Spanish-speaking judges who were trained in using the International Phonetic Alphabet (IPA) for the transcription of Spanish. Twenty per cent of each sample was transcribed by a second judge, with reliability averaging 89% across the samples. The renderings of the first judge were used for data analysis.

Additional data were drawn from published diary studies of children acquiring different dialects of Spanish. Specifically, longitudinal data from de Zuluaga's (1979) diary study of Juan, a typically-developing, monolingual Colombian Spanish-speaking boy, were also evaluated. The data from this study span the ages of 1;11 (years; months) to 2;9, and consist of 14 separate recordings sessions obtained roughly every 3 weeks. During the first 3 months of recording, de Zuluaga recorded Juan's speech for ~15 minutes per session; for the remaining months, 1-hour sessions were carried out. The child's productions were informally elicited with the use of toys, children's books, and pictures of animals. For the purpose of the current study, data from only seven of the 14 sessions are evaluated, due to insufficient utterances reported for the remaining seven points. The sessions included correspond to seven different inventories, specifically Inventories 11–17, which begin at age 1;11.24 (years; months. days) and end at 2;9.23. Refer to Appendix 1 for the specific ages of each Inventory. In order to maintain consistency across the different data sets evaluated in

the current study, the transcriptions from de Zuluaga's published study were adapted to the IPA. No transcription reliability was reported in the original study.

Longitudinal data from three additional typically-developing, monolingual Colombian Spanish-speaking children (Emilia, Joaquín, and Arturo) described by Montes Giraldo (1971) were also examined.² Observations and transcriptions were made from the ages at which the three children uttered their first words, and continued until age 5;1 for Emilia, 4;2 for Joaquín, and 4;7 for Arturo. For the current study, Emilia's data correspond to Inventories 18–21, spanning the ages of 1;8 to 2;0. Joaquín's data correspond to Inventories 21–26, spanning the ages of 2;1 to 2;9. Lastly, Arturo's data correspond to Inventories 27–29, spanning the ages of 0;11 to 2;8. (Refer to Appendix 1.) Other points in time were excluded due to insufficient data for determining inventories. As with the data from de Zuluaga (1979), the transcriptions from Montes Giraldo's original published study were adapted to the IPA. No transcription reliability was reported in the original study.

Cross-sectional data from four monolingual Mexican Spanish-speaking children described by Amador Hernández (1978) were also evaluated. Speech samples from two boys and two girls between the ages of 2 and 3 years were elicited with the use of pictures, toys, and children's books. All samples were audio-recorded and later phonetically transcribed according to the IPA. Per Amador Hernández, these children were typically developing. The four children correspond to Inventories 30 (Marcos, age 2;0), 31 (Concepción, age 2;1), 32 (Pablo, age 2;5), and 33 (Graciela, age 2;10). (See also Appendix 1.) No transcription reliability was reported in the original study.

Finally, longitudinal data from two additional children with phonological delay (MG1 and MG2), described by Greim (2000) and Barlow (2002; 2003c), were evaluated. These children, aged 4;2, were bilingual in the Southern Californian dialects of Spanish and English. For the purposes of the current study, we evaluated data from these children's responses to the APPS (Hodson, 1986) prior to, during, and immediately following phonological remediation (ages 4;0, 4;1, and 4;2, respectively). These three points in time correspond to Inventories 34, 35, and 36 for MG1 and 37, 38, and 39 for MG2 (see Appendix 1). The children's productions were transcribed according to the IPA. Inter-judge reliability across the data for the two children was 94%.

Inventory determination

From each of the 39 speech samples (from the 16 different children), phonetic inventories were determined independently of the target system, following the criteria of Dinnsen et al. (1990) as well as Stoel-Gammon (1987) and Dyson (1988). Specifically, a sound was assumed to be present in an inventory if it occurred at least twice in the speech sample, regardless of accuracy or target-appropriateness. That is, a given inventory could include sounds that were errors, or sounds that were not present in the adult system. For example, [l] could be included in an inventory in cases where one or both of the productions were errors, as with target *carro* /karo/ 'car' pronounced as [kalo]. Similarly, [θ] could be included in an

²A fourth child discussed by Montes Giraldo is not considered here due to insufficient amounts of data for reliable determination of inventories at any given point in time.

inventory, even though the sound does not occur in the dialect of Spanish that the child is acquiring (and thus the form would also be in error), as with target *bolsa* /bolsa/ ‘bag’ pronounced as [bolθa], or *cinco* /siŋko/ ‘five’ pronounced as [θiŋko].³ In addition, we assumed that certain sounds were present in Inventories 14–20 (de Zuluaga, 1979) and in Inventories 21–32 (Montes Giraldo, 1971) if the author specifically stated that those sounds were present at the relevant point in time, even in the absence of direct evidence (i.e. transcribed examples) in the published paper.

Once each inventory for each speech sample was determined, the inventories were then compared with Dinnsen et al.’s (1990) typology to evaluate the ways in which they conformed to and violated the typology based on English. Certain similarities were expected, such as stops and nasals being associated with the simplest of inventories. Certain differences were also expected, simply because of the differences between the two target languages (e.g. English /ɹ/ vs Spanish /f/ and /r/). Based on these differences, a typology was developed that better accounted for the Spanish data. To do this, each inventory was evaluated to determine any implicational relationships between sounds or sound classes. For example, if [f] was present in the inventory, did other sounds or sound classes also have to be present? Or, if fricatives were present, did other sounds or sound classes also have to occur? Specific observations were made following such evaluations of the inventories, resulting in a preliminary typology of Spanish phonetic inventory complexity.

Results

Comparison to Dinnsen et al.’s (1990) typology

The typology originally proposed by Dinnsen et al. (1990) was intended to allow for variation in terms of the order in which individual sounds emerged in children’s phonetic inventories. At the same time, it also constrained the possible inventories, allowing certain sound classes to emerge only once other sound classes were present. The typology has been successful in accounting for the range of attested phonetic inventories observed in the phonological acquisition of English.

With respect to the inventories of children learning Spanish, the focus of the current study, Dinnsen et al.’s (1990) typology was able to account for most, but not all inventories. This is perhaps not surprising, given that English and Spanish differ with respect to the presence/absence of certain sound classes. As illustrated in Appendix 2, 17 inventories were classified as Level D, 17 as Level E, and five could not be classified according to Dinnsen et al.’s typology. The primary reason that most inventories were classified as Level D or E, and that five others could not be classified, is due to the fact that *all* 39 inventories included the liquid [l]. Those five that could not be classified included [l] to the exclusion of fricatives and affricates, which is an inventory type that Dinnsen et al.’s hierarchy does not predict. In fact, one such example, Inventory 27, included only [b t m n l β], and that child was only 11 months of age. To address this different complexity of [l] for Spanish, and, moreover, to

³To clarify, in the case of [bolθa], this would not be a correct production in any dialect of Spanish; in the case of [θiŋko], this would be a correct production in Peninsular Spanish, but not in any of the Spanish dialects considered in the present study (Hammond, 2001).

account for those five inventories that could not be classified according to the typology, a new typology specific to Spanish is proposed.

Proposed typology for Spanish

Five hierarchical complexity levels were determined, similar to those of English and other languages, although with some language-specific modifications. Refer to Table III for the full typology with representative example inventories.

Level A includes oral stops, nasals, and approximants, as well as a labial-coronal place difference, representing the phonetic contrasts of $[\pm\text{sonorant}]$, $[\pm\text{coronal}]$, and $[\pm\text{nasal}]$. Similar to Dinnsen et al.'s (1990) typology for English, the occurrence of both stops and nasals indicates a $[\pm\text{sonorant}]$ difference, while the presence of both labials and coronals indicates a $[\pm\text{coronal}]$ difference. A divergence for the Spanish typology, however, relates to the occurrence of $[\text{l}]$ at Level A.⁴ We must assume there is a $[\pm\text{nasal}]$ difference, which distinguishes nasal $[\text{n}]$ from non-nasal $[\text{l}]$. (Note that $[\pm\text{nasal}]$ is a phonetic contrast associated with Level D in the typology for English.) In addition to $[\text{l}]$, at least one approximant also occurs. In the one example of a Level A inventory that occurs from the 39 inventories (Inventory 27), that approximant is $[\beta]$. The feature $[\pm\text{coronal}]$ is sufficient to distinguish that sound from $[\text{l}]$. It is important to note that some other, more complex inventories lack $[\beta]$ and include $[\text{j}]$ instead (e.g. Inventories 18 and 19, shown in Table III). Other features associated with those higher levels of complexity allow the occurrence of either of these two approximants. It appears then that a non-lateral approximant is an optional property of Level A inventories. Thus, while Level A for Spanish is similar to that of English in that it must include an approximant, for Spanish that approximant must be—at a minimum— $[\text{l}]$, while for English, that approximant must be one of the glides (i.e. $[\text{w j}]$). For the Spanish typology, the feature $[\pm\text{consonantal}]$, as was proposed for the English typology, does not appear to be necessary.

Level B for the proposed typology adds a $[\pm\text{voice}]$ difference within oral stops, and an $[\pm\text{anterior}]$ place difference among consonants, as with the typology for English. The $[\pm\text{voice}]$ difference is evident from at least one cognate pair, such as $[\text{p b}]$ and $[\text{k g}]$ in the case of Inventory 19 shown in Table III. The $[\pm\text{anterior}]$ difference is apparent from the occurrence of a three-way difference among the stops, as with $[\text{p t d k g}]$ for Inventory 18. Moreover, $[\pm\text{anterior}]$ also differentiates $[\text{l}]$ from $[\text{j}]$ for this inventory and Inventory 19, both of which lack $[\beta]$.

Level C of the proposed typology adds fricatives and/or affricates, representing a $[\pm\text{continuant}]$ and/or $[\pm\text{delayed release}]$ difference, as with the typology for English. Thus, a child could add a fricative (e.g. $[\text{f s h}]$, Inventory 35), or an affricate (e.g. $[\text{ts}]$, Inventory 19), or both (e.g. $[\Phi \text{ s x t f}]$, Inventory 11), as illustrated in Table III.

Level D adds a $[\pm\text{lateral}]$ difference, associated with the addition of non-lateral liquid $[\text{ɾ}]$ (Inventory 31), or a $[\pm\text{strident}]$ difference between coronal fricatives (Inventory 8), or both phonetic contrasts (Inventory 5), as shown in Table III. The phonetic contrasts associated

⁴Recall that this was also the case for Cantonese-speaking children's inventories (Stokes, 2002; Stokes and To, 2002).

with Level D for Spanish are identical to those of Level E for English. For English, Level D is associated with the addition of one liquid, either [l] or [ɹ]. In the case of the Spanish typology, recall, [l] is associated with the lowest level, A. Thus, the addition of another liquid ([ʎ]) represents the emergence of a [±lateral] difference at Level D. Note also that the [±strident] difference referred to the presence of [s] and [θ] in an inventory, despite the fact that the latter does not occur in any of the Spanish dialects represented in the database. Moreover, the occurrence of [θ] in the inventories was not unique to a particular dialect or source; in fact, it occurred in Inventories 3, 5, 8, and 10 (Southern Californian, Phonological Typologies Archives); Inventories 28 and 29 (Colombian, Montes Giraldo); and Inventory 33 (Mexican, Amador Hernández). This is especially interesting. Specifically, while in each case the occurrence of [θ] represents a non-target pronunciation (an *error*), the hierarchical organization of featural differences still appears to govern its occurrence in an inventory.

Finally, Level E adds a [±tense] differentiation, accounting for the emergence of trill [r], and the occurrence of all three Spanish liquids in the phonetic inventory, as illustrated with Inventory 17 in Table III. This represents a phonetic contrast that the English typology lacks, given that only two liquids occur in adult English.

As with the English typology, the hierarchical nature of the Spanish typology might best be represented in terms of tree structures, as shown in Figures 2(a–e), with their corresponding default principles in (3), modelled after those of Dinnsen (1992).

(3) Default principles for Level A:

- a. All obstruents are stops
- b. All obstruents are voiceless
- c. Non-nasal sonorants are lateral

Principle (3b) no longer holds at Level B with the emergence of the [±voice] difference between phonetic voiced and voiceless stops. Principle (3a) no longer holds at Level C, when a [±continuant] differentiation emerges within the obstruent class. Principle (3c) no longer holds at Level D when a [±lateral] difference emerges. At that point, however, another default principle is assumed to hold (shown in (4)), such that non-lateral liquids are [–tense], or the tap [ɾ]. This principle no longer holds at Level E, when the [±tense] difference emerges, thereby allowing both tap [ɾ] and trill [r].

(4) Default principle for Level D: Non-lateral liquids are non-tense

The relationship between complexity levels and inventory size

The average number of sounds per inventory level increased with inventory complexity, as would be expected given that, with increased complexity a greater number of featural differences are available for use by the sound system. Nevertheless, greater inventory complexity did not always translate into larger inventories: As illustrated in Figure 3, there was clear overlap across the levels with respect to inventory size.

Only one inventory was classified at Level A (Inventory 27), and that inventory had only six sounds. Four inventories were classified at Level B (Inventories 18, 21, 22, 23), and they

averaged nine sounds per inventory with a range of eight-to-10 sounds. Seventeen inventories were classified at Level C, averaging 15 sounds per inventory, with a range of 10–20 sounds. Seven inventories were classified at Level D, and they averaged 20 sounds per inventory, but ranged from as few as 13 sounds to as many as 27. Finally, 10 inventories were classified at Level E, and they averaged 24 sounds per inventory, but ranged from as few as 16 sounds to as many as 30. Thus, the inventories, particularly those at higher levels of complexity, varied substantially in terms of the number of sounds they exhibited.

The relationship between complexity level and child characteristics

Generally speaking, complexity level increased with age, although again there was a fair amount of overlap for ages across the levels. Age cannot reliably predict level of complexity, when one considers the degree of overlap at the different levels. Specifically, as shown in Figure 4, the average age of the children at Levels C, D, and E was 35 (range: 21–50), 39 (range: 25–50), and 40 (range: 24–55) months, respectively.

While the inability to predict the level of complexity from age might be expected for children who are phonologically delayed, it might not necessarily be expected for those who are developing in a typical fashion. Granted, while this might simply be due to the relatively small sample sizes, it still illustrates that younger, typically developing children could have more complex inventories than older, typically developing children. This is precisely what Dinnsen et al. (1990) observed in their original study of children learning English, and it further highlights the individual variation that occurs in phonological acquisition. Thus, assigning ages to achievement of specific levels of complexity (let alone specific sounds) should be done with extreme caution.

Discussion

In this study we compared 39 phonetic inventories of Spanish-speaking children with a typology of phonetic inventory complexity that was proposed by Dinnsen et al. (1990) for English phonological acquisition. We consider the theoretical and clinical implications of our findings next.

Toward a universal typology for acquisition

Numerous aspects of Dinnsen et al.'s (1990) original typology were consistent with phonological universals proposed by Jakobson (1968). As such, their typology was predicted to hold, more or less, across sound systems, regardless of the language. For the most part, it succeeded in doing so. Predictably, though, modifications to their original typology were necessary for acquisition of Spanish, simply due to inventory differences between English and Spanish. But what of [l]? The relative complexity of [l] for the two inventories was remarkably different, and the theoretical implications of this difference warrant discussion. In trying to account for the different timing of acquisition of [l] with respect to other sounds, one can invoke language-specific differences between English and Spanish, such as articulatory and allophonic differences, as well as frequency of occurrence and functional load. In what follows, we entertain these different hypotheses in turn.

Articulatory and allophonic differences—Normative scales for English indicate that the liquid /l/ is acquired as early as 5;6 (Goldman and Fristoe, 2000) or as late as 7;0 (Smit et al., 1990). Moreover, /l/ is generally prone to errors in acquisition for English speakers, most often surfacing as the glides [w] and [j] (Locke, 1983; Ingram, 1989). The relatively late acquisition of /l/ would suggest that it is relatively difficult to articulate (Kent, 1992). Yet, for Spanish (spoken in the US) normative studies show that /l/ is mastered as early as 2;6 or as late as 3;6 (Bedore, 1999); further, /l/ is a common *substitute* for other sounds, such as tap /t/, trill /r/, and /ð/ in Spanish (Eblen, 1982; Macken, 1986; Barlow, 2003c), as it is for different types of /r/ in a variety of languages, such as Hindi, Greek, and Sinhala (for a review, see Locke, 1983; Lust, 2006). The findings reported in the current study parallel those reported in normative data on speech sound acquisition. In other words, it appears that the later acquisition of /l/ for most learners of English may reflect a property of how /l/ patterns in the language, rather than any articulatory difficulty.

One might argue that distributional differences between adult languages may explain these language-specific differences in acquisition of the two languages. In English, /l/ exhibits a greater degree of allophonic variation: It is produced as the clear, or light, [l] in syllable-initial contexts, as in the pronunciation of the word *lip* [lɪp], or as the dark (or velarized) [ɫ] in syllable-final or syllabic contexts, as in the pronunciation of the word *pill* [pɪɫ] and *apple* [æpɫ]. On the contrary, /l/ exhibits less variation in Spanish, surfacing as the light, apico-alveolar lateral [l] in all contexts (variation due to place assimilation aside) (Barrutia and Schwegler, 1994; Hualde, 2005).

On the other hand, the two languages may differ with respect to the actual articulatory properties of [l]. In fact, Spanish and English already differ with respect to the acoustic and articulatory properties of [ð], which is best characterized as a fricative in English but an approximant in Spanish (as stated above; Bakovi, 1994; Widdison, 1997; Cole et al., 1999; Barlow, 2003c), despite the fact that they are perceptually similar. While most published resources make no mention of any differences in articulation of [l] between the two languages, Hammond (2001) does mention that Spanish [l] is best characterized as an apico-alveolar *palatalized* lateral, as the tongue body is raised toward the hard palate during its pronunciation. It is unclear whether this difference alone would be sufficient to account for the different acquisition patterns of /l/ for English- vs Spanish-speaking children. Moreover, if anything, one would expect that the added palatalized feature of [l] in Spanish would make the [l] *more*, rather than *less*, complex as compared to English [l].

Frequency of occurrence, linguistic function, and functional load—Other explanations for language-specific differences in acquisition such as this relate to the *frequency of occurrence* of sounds or structures in a language, or, more specifically, the input to the child (Pye, Ingram, and List, 1987; Ingram, 1989). Yet, [l] is a frequently-occurring sound in numerous dialects of English (Carterette and Jones, 1975; Mines, Hanson, and Shoup, 1978) and Spanish (Quilis and Esgueva Martínez, 1980; Wilson, 1984; Alarcos Llorach, 1991; Rojo, 1991; Alameda and Cuetos, 1995). Thus, frequency of occurrence is not a sufficient explanation for the different acquisition patterns in the two languages. However, combining the notion of frequency with linguistic function, researchers

also have offered explanations for language-specific differences in terms of the *functional load* of phonological units of a given language.

In its most general sense, functional load refers to the relative importance of linguistic units in marking contrasts. The term is typically applied to the role of phonemes in a given language, with respect to how many minimal pairs can be formed for a given phonemic opposition (King, 1967), or in terms of the potential neutralization of that opposition (Martinet, 1955). Martinet hypothesized that neutralizations would be less likely to occur in a given language if they jeopardized communicative need, that is, if the contrast had a high functional load. The assumption is that avoidance of homonymy has a strong influence on the way in which phonological systems may change.

King (1967), elaborating on Martinet's claims, hypothesized that historical sound mergers should occur in the direction of that sound whose frequency of occurrence is greater. Accordingly, if sound *x* has a higher frequency of occurrence than sound *y*, should the contrast between *x* and *y* be neutralized, sound *x* would prevail and sound *y* would be lost.

An interesting case in point is the voiced interdental fricative /ð/ in English. This sound occurs frequently in English, because it figures prominently in function words such as *the, this, that, these, those, they, them, and though*. Yet, in the whole English lexicon, /ð/ occurs in only a few words. Thus, we have a *type-token* difference: Tokens of /ð/ words are very common, but /ð/-type words are rare. Because of this, the functional load of /ð/ is considered to be relatively low. As a case in point, almost any /ð/-initial word in English could be pronounced with [d] without impacting communication; in fact, many dialects of English have merged the /ð/-/d/ contrast (Wells, 1982; Dubois and Horvath, 1998; Rickford, 1999; Fought, 2003).

Numerous cross-linguistic studies of phonological acquisition provide support for the role of functional load in language-specific differences in ages and order of acquisition of speech sounds in, for example, Jordanian Arabic (Amayreh and Dyson, 1998, 2000; Amayreh, 2003), Cantonese (So and Dodd, 1995; Stokes, 2002; Stokes and To, 2002), Vietnamese (Tang and Barlow, 2006), Quiché (Pye et al., 1987), Turkish (Topbaş, 1997), as well as numerous others (see, e.g. Locke, 1983; McLeod, 2007). Generally, results of these studies have been compared with those for English, illustrating noteworthy differences between ages of acquisition of sounds across languages. That is, although there are general (perhaps universal) trends of acquisition of sound classes that are observed across all languages, the cross-linguistic variation in acquisition of individual sounds is also high, and is attributed to the importance of those sounds in a given language. Given these observations, the fact that [l] appears to be less complex in the development of the phonetic inventory of Spanish in comparison to that of English is probably more related to the functional load of [l] in the two languages, and perhaps less to articulatory difficulty.

To illustrate this phenomenon, let us compare the phonemes /ð/ and /t/ in English. Despite the fact that /ð/ occurs frequently in the input to a child given the high /ð/-word token frequency, it is among the last sounds to be acquired; normative studies show that /ð/ is mastered, on average, no earlier than age 5;6 (Goldman and Fristoe, 2000) and as late as 8;0

(Sander, 1972). Compare these facts with the phoneme /t/ in English: /t/ occurs frequently in both word types *and* tokens in English; it has a high functional load in terms of phonemic contrasts for place of articulation, manner of articulation, and voicing, and in terms of marking regular past tense (e.g. *cooked* [kʊkt]); and it is acquired comparatively early (at age 2;0 or 3;0) (Sander, 1972; Goldman and Fristoe, 2000). Is the word-type frequency the determining factor in the earlier acquisition of /t/ (as compared to /ð/), or is it the functional load? Or is word-type frequency responsible for its functional load, which in turn is responsible for the earlier acquisition of /t/?

These questions notwithstanding, these facts lend some credence to the combined role of frequency and linguistic function in phonological acquisition. In that sense, one might argue that [l] has a greater functional load in Spanish, as it is not only frequently occurring (in types and tokens) like English /t/, but it also occurs in many articles and clitic pronouns: *el, la, los, las, le, lo, les* (e.g. *el gato* ‘the cat’, *los gatos* ‘the cats’, *la falda* ‘the skirt’, *las faldas* ‘the skirts’, *lo veo* ‘I see him’). Yet, if this were the explanation for the earlier acquisition of [l] in Spanish, then we might ask why the same is not true for the English phonemes /s/ and /z/, which are among the latest sounds to be acquired (Smit et al., 1990), though their functional load is high, both in terms of phonemic contrasts and occurrence in morphological markers (i.e. plural, possessive, third-person singular). Clearly, these issues are difficult to resolve.

Universal tendencies of fully-developed languages

Regardless of the explanation for the acquisition differences between the English and Spanish languages, one thing is clear: Although it may be the case that an implicational relationship occurs between the liquids (specifically /l/) and fricatives or affricates for English, as suggested by Dinnsen et al. (1990) and Dinnsen and O’Connor (2001), this is not so for Spanish. Thus, the implicational hierarchy cannot be claimed to be a linguistic universal, at least insofar as we assume the [l] in both languages to be linguistically equivalent. In this respect, it must be noted that the situation presented by the natural order of Spanish feature acquisition is quite atypical, in the sense that /l/ is acquired much earlier and independently of fricatives/affricates. English, on the other hand, presents a case that is much closer to the universal tendencies across languages, where the trend for fricatives (and affricates) to occur in inventories that also include /l/ is quite strong.

This can be corroborated with data from the 567-language database of the *World Atlas of Language Structures Online* (Haspelmath, Dryer, Gil, and Comrie, 2008). From this, one can see that if a language has /l/ it is very likely that it will have fricatives (62% vs 7% of the 69% that have /l/). On the other hand, if a language has fricatives, the likelihood that it will have /l/ is strong, but not so strong (62% vs 30% of the 92% total that have fricatives). Given these figures, it appears that children learning Spanish go through a stage that is only represented in 7% of the languages (i.e. those that include /l/ but lack fricatives), a marked solution.

Thus, while the majority of languages with /l/ also have fricatives, there are also several that do not. Beckman, Yoneyama, and Edwards (2003: 19) advocate retention of the concept of universality, ‘because some specific examples of such universals are valid generalizations,

particularly if we take the term “universal” to mean a strong numerical tendency rather than an absolute rule and are careful to interpret the example in terms of our better observational techniques today’. Of the 567 languages (Haspelmath et al., 2008), there does appear to be a strong tendency toward the implicational relationship between /l/ and fricatives, such that, if the language has /l/, it usually also has a fricative.

This means that the notion of ‘universal’ cannot be taken to mean ‘categorical’, but rather ‘cross-linguistically frequent’ in the description of adult sound systems. Rather than being impossible, languages with /l/ and without fricatives are highly infrequent. The interpretation of universality as a tendency also applies to child acquisition inventories, with the path for Spanish inventory development resulting in an infrequent, but not impossible, route. Indeed, of the 39 inventories evaluated in the current study, all 39 included /l/, and only nine (23%) of them lacked fricatives (four of those did include affricates). Still, we are left to wonder why it is that /l/ is associated with a much more complex inventory in the acquisition of English, and a much less complex inventory in the acquisition of Spanish. Moreover, why are there no cases of Spanish-speaking children who opt for the more frequent path (acquiring fricatives before /l/), given its stronger universal tendency? Assuming that universal tendencies of language are properties of Universal Grammar (Chomsky, 1975), or are ‘psychologically real’ in some sense (cf. Chomsky, 1980; Cook and Newson, 1996), we should observe evidence of them in acquisition, regardless of the language. A larger database of children’s inventories (from both languages) may shed further light on this issue.

Perhaps the ‘density’ of fricatives and affricates in the two languages as compared to that of liquids plays a role in the typological difference. English provides acquirers with plenty of evidence to deduce the fricative and affricate (Level C) features from no less than five pairs of cognates. Spanish has four fricatives and affricates total, none of which contrasts for voicing. On the other hand, there are only two liquid consonants in English (/l/ and /r/), while in Spanish, there are three (/l/, /ʎ/, and /r/). Perhaps the number of contrasts within a given sound class (or inventory level) plays a role in the hierarchical organization of children’s phonetic inventories. This remains to be further evaluated with languages of different-sized inventories.

Clinical implications

The differences observed between the Spanish and English phonetic inventory typologies have interesting implications for treatment of children with phonological delay. Recall that Dinnsen et al. (1990) made predictions about how their proposed typology for English may be incorporated into the selection of treatment targets. Most notably, the prediction is that an English-speaking child presenting with a Level B inventory (thus lacking fricatives, affricates, and liquids) would be expected to show widespread across-class change following remediation on a liquid. That is, the introduction of a /l/ (associated with a Level D contrast) would cause fricatives or affricates (associated with Level C) to emerge as well. As discussed above, numerous studies have supported their predictions.

Given the typology proposed for Spanish, however, the same prediction cannot be made for this language. Since /l/ is associated with the lowest level of complexity (Level A), no such

across-class change would be predicted for the child lacking fricatives and affricates. In fact, one would predict that a child would not require remediation on /l/, as it is an early-acquired sound (and was present in all 39 inventories). Remediation on tap /t/ (Level D) or trill /r/ (Level E), however, would be predicted to cause Level C sounds to emerge. This remains to be empirically tested, of course. Should we observe that treatment on /l/ in Spanish does in fact cause the same type of global change to occur in children's inventories, we might reconsider the relative complexity of /l/ in Spanish, and in turn attribute the findings reported in the current study to the relatively small and methodologically varied sample.

Conclusion

In this study, a typology of Spanish phonetic inventory complexity was determined from 39 speech samples from 16 different children. The inventories on which the typology was based represent both cross-sectional and longitudinal data from typically-developing and phonologically delayed children. The inventories also represent both Spanish monolingual and bilingual children's sound systems, and also different Spanish dialects (Southern Californian, Mexican, and Colombian). Finally, the inventories were determined based on different-sized datasets that were elicited and recorded in a variety of ways, and information about transcription reliability was not available in every case. As stated in the Methods, this study was based on very heterogeneous, and in some cases limited, data sources. Although this will allow for the findings to be generalizable beyond a very specific population (e.g. only Mexican Spanish speakers, or only monolinguals), the heterogeneous nature of the data on which the proposed typology is based nevertheless warrants further scrutiny, hence its preliminary nature. Most importantly, additional tests should be based on relatively larger speech samples that are collected in a uniform manner so that sample size and differences cannot be blamed for potential deviations from the proposed typology.

Also warranted is an evaluation of bilingual children's phonetic inventories in both languages. For instance, we might question whether Spanish-English bilingual children's phonetic inventories fit within the typologies of their respective languages, or whether the inventory complexity of one of a child's two languages is related to or influenced by the other. Is it possible for a bilingual child who has balanced proficiency in her two languages to have a complex inventory in Spanish, but a relatively simple inventory in English or vice versa? These and additional questions that are raised by the current study remain to be addressed in our future research.

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Appendix 1: Data sources, child demographics, and corresponding inventory numbers

Source	Child	Sex	Dialect	Bi-/ Monolingual	Age (mos.)	Inventory
Barlow (2002; 2003a; b; 2005b)	BL4	F	So. California	Bilingual	32	1
Phonological Typologies Archives	BL8	M	So. California	Bilingual	55	2
Barlow (2002)	BL10	M	So. California	Bilingual	50	3
Phonological Typologies Archives	BL11	F	So. California	Bilingual	51	4
Barlow (2003a; 2005b; 2007)	SD1	F	So. California	Monolingual	40	5
					45	6
					47	7
Barlow (2003a; b; 2005a; b; 2007)	SD2	F	So. California	Monolingual	44	8
					49	9
					52	10
de Zuluaga (1979)	Juan	M	Colombian	Monolingual	24	11

Source	Child	Sex	Dialect	Bi-/ Monolingual	Age (mos.)	Inventory
Montes Giraldo (1971)	Emilia	F	Colombian	Monolingual	25	12
					27	13
					27	14
					29	15
					31	16
					34	17
					20	18
	Joaquín	M	Colombian	Monolingual	21	19
					24	20
					25	21
					26	22
					27	23
					28	24
					31	25
Amador Hernández (1978)	Arturo	M	Colombian	Monolingual	33	26
					11	27
					30	28
					32	29
	Marcos	M	Mexican	Monolingual	24	30
					25	31
					29	32
	Concepción	F	Mexican	Monolingual	34	33
					48	34
					49	35
					50	36
Greim (2000), Barlow (2002; 2003b)	MG1	M	So. California	Bilingual	48	37
					49	38
					50	39

Appendix 2: All 39 phonetic inventories and their classifications according to the typologies for English and Spanish

Inv	p	q	t	d	k	g	Φ	f	v	θ	s	z	δ	ʒ	ʃ	z	ʃ	ts	q	x	h	ʃ	ds	m	n	h	ʃ	w	f	β	θ	Y	l	l	f	r	r	r	Eng	Span
1	p	p	t	d	k	g	Φ	f		s	z				ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						D	C
2	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
3	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	D
4	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
5	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						D	D
6	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
7	p	p	t	d	k	g	Φ	f	v	θ	s				ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
8	p	p	t	d	k	g	Φ	f		θ	s				ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						D	D
9	p	p	t	d	k	g	Φ	f		θ	s				ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
10	p	p	t	d	k	g	Φ	f		θ	s				ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
11	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						C	C
12	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						C	C
13	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						C	C
14	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						C	C
15	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						C	C
16	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						E	E
17	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l						E	E
18	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l					*	B	B
19	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						C	C
20	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l						C	C
21	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l					*	B	B
22	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l					*	B	B
23	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l					*	B	B
24	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l					D	C	C
25	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l					D	C	C
26	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l					D	C	C
27	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l					*	A	A
28	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ				h		ds	m	n			w	j	β	θ	Y	l					E	D	D
29	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l					E	D	D
30	p	p	t	d	k	g	Φ	f		s					ʃ		ʃ		x		h		ds	m	n			w	j	β	θ	Y	l					E	E	E

Inv	p	b	t	d	k	g	Φ	f	v	θ	s	z	g	z _L	f	z	x	h	ts	t _f	d ₃	m	n	u	ɲ	ɰ	w	j	β	ð	Y	ɭ	f	r	ɿ	Eng	Span
31	p	b	t	d	k	g		f		s	z			f	z	x				t _f	d ₃	m	n	u	ɲ	ɰ	w	j	β	ð	Y	ɭ	f	r	ɿ	E	D
32	p	b	t	d	k	g	Φ	f				g	z _L	f	z	x					d ₃	m	n	u	ɲ	ɰ	w	j	β	ð	Y	ɭ	f	r	ɿ	E	E
33	p	b	t	d	k	g	Φ	f	θ					f	z	x				t _f	d ₃	m	n	u	ɲ	ɰ	w	j	β		Y	ɭ	f	r	ɿ	E	E
34	p	b	t	d	k	g		f		s						h				t _f		m	n	ɲ		w	j	β	ð	Y	ɭ					D	C
35	p	b	t	d	k	g		f		s						h						m	n	ɲ		w	j	β	ð	Y	ɭ					D	C
36	p	b	t	d	k	g		f		s						h				t _f		m	n	ɲ		w	j	β	ð	Y	ɭ					D	C
37	p	b	t	d	k	g				s							x					m	n	ɲ	ɰ			j	β	ð	Y	ɭ				D	C
38	p	b	t	d	k	g				s							x					m	n	ɲ	ɰ	w	j	β	ð	Y	ɭ					D	C
39	p	b	t	d	k	g		f		s							x					m	n	ɲ	ɰ	w	j	β	ð	Y	ɭ					D	C

Figure 1.

Levels A–E of the phonetic inventory typology (a–e, respectively) for English represented in terms of hierarchical tree structures (adapted from Dinnsen, 1992).

Figure 2.
Levels A–E of the phonetic inventory typology (*a–e*, respectively) for Spanish represented in terms of hierarchical tree structures.

Figure 3. Average number of sounds at each proposed inventory level. Minimum and maximum numbers for each level are indicated by black lines.

Figure 4.
Average age of children at each proposed level of complexity. Minimum and maximum ages are indicated by black lines.

Table I

Typology of phonetic inventories (adapted from Dinnsen et al., 1990).

Level	Featural differences	Sample inventories
A	[±consonantal]	p t ? m n ŋ w j h
	[±sonorant]	
	[±coronal]	
B	[±voice]	p b t d k ? m n ŋ w j h
	[±anterior]	
C	[±continuant] and/or	p b t d k g ? f v m n ŋ w j h
	[±delayed release]	p b t d k g ? f v s z ʃ ts dz tʃ dʒ m n ŋ w j h
D	[±nasal]	p b t d k g ? f v θ ð ʃ tʃ dʒ m n ŋ l w j h
		p b t d k g tʃ dʒ m n ŋ ɹ w j
E	[±strident] and/or	p b t d k g ? f v θ ð s z ʃ tʃ dʒ m n ŋ l w j h
	[±lateral]	p b t d k g ? f v s z ʃ ts tʃ dʒ m n ŋ l ɹ w j h

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Table II

English and Spanish phonemic inventories.

Manner	English			Spanish		
stop	voiceless	p	t	k	t	k
fricative	voiced	b	d	g		
	voiceless		f θ s	f	s	x
	voiced		v ð z ʒ			
affricate	voiceless		tʃ			tʃ
	voiced		dʒ			
nasal		m	n	ŋ	m	ɲ
tap					ɟ	
trill					r	
approximant	central	w	r	h		ɣ
	Lateral		l			

Table III

Proposed typology of Spanish inventory complexity.

Level	Featural differences	Sample inventories ^a
A	[±sonorant]	27: b t m n β l
	[±coronal]	
	[±nasal]	
B	[±voice]	18: p t d k g m n l j
	[±anterior]	
C	[±continuant] and/or	35: p b t d k g f s h m n ɲ l w β ð j ʎ
	[±delayed release]	19: p b t k g tʃ m n l j
		11: p b t d k Φ s x tʃ m n ɲ l β j
D	[±lateral] and/or	31: p b t d b k g f s z ʃ ʒ x tʃ dʒ m n ɲ ŋ w j β ð ʎ l ʎ ɾ
	[±strident]	8: p b t d k g f θ s x tʃ dʒ m n ɲ l w β ð j
		5: p b t d k g f θ s x tʃ m n ɲ w β ð j ʎ l ʎ
E	[±tense]	17: p b t d k g Φ s ʃ x h tʃ dʒ m n ɲ ŋ w β ð j ʎ l ʎ ɾ

^aThe numbers preceding each inventory correspond to the Inventories in the Appendix 2.