CHANGES OVER TIME IN CROSS-LINGUISTIC INFLUENCES OF SPANISH ON ENGLISH IN SEQUENTIAL BILINGUAL PRESCHOOLERS

by

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Chapter I: Introduction and Statement of Purpose

Introduction

As more bilingual children seek speech and language services at clinics, hospitals, and schools, clinicians and researchers are recognizing the importance of understanding bilingualism. While many researchers have looked at bilingual language acquisition by examining syntax, morphology, and syllable structure, fewer researchers have extended this research to encompass speech, which some view as the beginning of expressive language acquisition.

Much research has examined bilingual phonological systems in children and adults who are bilingual first language (BFL) learners, also referred to as simultaneous bilinguals. Simultaneous bilinguals are exposed to two languages from birth (Genesee & Nicoladis, 2006). Although these studies on BFL learners are important, many children in the United States come from non-English speaking homes. According to the 2006 American Community Survey, nearly 55,000,000 people in the US who are 5 years or older, 19.7% of the population, speak a language other than English at home. In addition, children who are from non-English speaking homes are the fastest growing population in K-12 schools (English Language Learners, 2008).

Fewer studies have looked at these children from non-English-speaking homes, referred to as bilingual second language (BSL) learners or sequential bilinguals. Children are considered BSL learners if they begin learning their second language (L2) after they have a well-established or at least partially established first language (L1) system. Some define BSL learners as those who began learning their second language after the age of 2 or between the ages of 3 and 5, often after they begin school (Anderson, 2004; Holm & Dodd, 1999).

The field of speech-language pathology (SLP) has long used developmental norms to identify monolingual children for services for disorders or delays in areas such as speech development by targeting those who show developmental patterns outside of the typical range of expectations. Unusual error patterns are also examined since these may be indicative of a speech sound disorder. Literature shows that bilingual and monolingual language learners develop their phonological systems differently (Anderson, 2004; Gildersleeve-Neumann, Kester, Davis, & Peña, 2008; Goldstein & Washington, 2001; Goldstein & Yavaş, 1998; Kehoe, 2002; Keshavarz & Ingram, 2002). To accurately identify bilingual children who need services, it is important to understand typical errors that are produced by bilinguals and how they change over time.

The current study investigated possible cross-linguistic effects of L1 on L2 over time in 3 sequential bilingual Spanish-English speakers. If cross-linguistic effects are seen, as some of the literature predicts, the effects might be typical in these bilingual language learners and should not be considered errors for the purpose of identifying children for SLP services. This is particularly true for effects that disappear or lessen with further exposure to L2. Although cross-linguistic studies have been completed longitudinally, the English-Spanish studies have not included (a) a comprehensive analysis of both consonants and vowels, (b) an analysis of speech sounds in *both* languages, or (c) a homogenous group of children based on length or daily percent of exposure to L2. All children in the current study had their first exposure to English at the start of preschool, 2 to 3 months before the first time of data collection (T1). Non-target speech sounds produced in English, their L2, were analyzed for possible perceptual influence from L1. Spanish speech productions were examined as well to understand what the children are producing in their L1 and to help determine if any differences in English productions are most likely the result of influence from Spanish rather than articulatory or perceptual effects. In addition, examination of Spanish speech sounds helps to more fully understand similarities and differences between each child's English and Spanish as well as changes over time with greater exposure to English.

Purpose of this Study

Despite extensive research on young simultaneous bilinguals and on older sequential bilinguals, data are lacking on sequential bilingual speech development at the start of second language acquisition. It is unknown what speech sounds BSL children produce at this time. Research indicates that L2 learners typically do not perceive L2 speech sounds in the same manner as native speakers of the L1. This difference in perception has been shown to start in infancy beginning approximately at 4 to 6 months of age. As the child ages, we can hypothesize that, this difference in perceptual abilities affects L2 speech production and that L2 learners will therefore not produce sounds in the same manner as L1 learners. It is important for a speech-language pathologist to understand what new L2 learners perceive and therefore produce in order to accurately identify those children who have speech sound disorders versus those who are typically developing bilinguals. It is also important to identify what new L2 learners perceive and produce in order to have a theoretical framework for second language acquisition.

The purpose of this study is to help us understand the speech productions of sequential bilinguals, how their productions are affected by their L1, how their productions compare with monolingual English speakers, and how these productions change over time. Three theories of speech perception offer explanations that can lead to predictions for production. The perceptual magnet theory, Perceptual Assimilation Model, and Speech Learning Model can help us understand cross-linguistic influences in speech production of bilinguals. Based on the research and perceptual theories that will be outlined in the review of the literature section, it is anticipated that sequential bilingual children will not perceive L2 contrasts that do not exist in their L1. Therefore, these sequential bilingual children were predicted to produce consonants and vowels that are similar in each language as the same sound. For example, English L2 learners might replace the low front /æ/ of English with the low mid [a] of Spanish. The perceptual magnet theory, Perceptual Assimilation Model, and Speech Learning Model offer different explanations for these examples. This is one of many studies that can offer support for or provide evidence against the theories discussed.

Chapter II: Review of the Literature

Typical Speech Sound Production in Monolinguals

Monolingual English Learners

To distinguish between cross-linguistic effects of speech sounds and developmental errors, it is important to understand how monolingual English language learners develop English phonology. Arlt and Goodban (1976) studied articulation proficiency in 240 monolingual English-speaking children, ages 3 to 6 years, to determine the age at which 75% of children correctly produced consonants in all three word positions. Templin (1947, as cited in Stoel-Gammon and Dunn, 1985) adopted the same criterion studying children aged 3;0 to 7;0. Results of the two studies are shown in Table 1. Wellman, Case, Mengert, and Bradbury (1931, as cited in Stoel-Gammon & Dunn, 1985) studied vowel acquisition in monolingual English speaking children aged 2 to 6 years. Wellman et al. (1931) found that 75% of children produced /i/, /ɑ/, /u/, /o/, /ə/, and /ʌ/ correctly by 2 years; /ɛ/ and /ɔ/ by 3 years; and /ɪ/, /e/, /æ/, and /ʊ/ by 4 years of age.

In general, results of these studies suggest that the majority of children produce stops, nasals, and glides at all places of articulation as well as all vowels by 4 years of age and acquire fricatives, affricates, and liquids between the ages of 4 and 7. This sequence of development has been observed in other studies as well (Prather, Hedrick, & Kern, 1975; Sander, 1972; Smit, Hand, Freilinger, Bernthal, & Bird, 1990).

Table 1

Speech Acquisition of Monolingual English Speakers

At/before age	Phoneme	
	Arlt and Goodban (1976)	Templin (1957)
3;0	h f w p b t d k g n m ŋ	f w p n m ŋ
4;0	s z l v ʧ ʤ	b k j g ɹ
5;0	θ ð ɹ	s ʧ ʃ
6;0		t l v θ
7;0		ð z ʤ ʒ

Monolingual Spanish Learners

Research has also examined Spanish speech acquisition in monolingual children. Table 2 outlines speech sounds of the Spanish language and its allophones. Jimenez (1987) studied the speech sounds of 120 Spanish-speaking children ages 3 to 5 years. Data were analyzed for both the median level of production (age at which 50% of children correctly produced the sound) and at the 90% level. Results of her data are shown in Table 3. In general, these studies suggest that at least 50% of Spanish-speaking children produce stops, nasals, and glides at all places of articulation by 3;7, approximately the same age as monolingual English children. This timeline for speech acquisition has been confirmed by other studies of monolingual Spanish children (Acevedo, 1993; Macken, 1978). The study of vowel acquisition in typically developing Spanish-speakers is rare; however, Goldstein and Pollock (2000) studied vowel production in 14 Spanish-speaking children ages 3;10 to 4;4. Although all of the children had speech sound disorders, only 1 child made five vowel errors (79

Table 2

Spanish Phonology (Goldstein, 2000)

Consonants			Vowels		
Consonant Class	Phoneme	Allophones	Vowels	Phoneme	Allophone
Stops	p	p	Front	i	i
	b	b β		e	e
	t	t	Back	u	u
	d	d ð		o	o
	k	k	Mid	a	a
	g	g ɣ			
Nasals	m	m			
	n	n			
	ɲ	ɲ			
Fricatives	f	f ɸ			
	x	x h			
	s	s			
Liquids	l	l			
	ɾ	ɾ l			
	r	r			
Glides	w	w gw			
	j	j ʤ ʒ			
Affricates	ʧ	ʧ ʃ			

vowels were produced). The other 13 children each made one error, suggesting that Spanish-speaking children acquire all vowels between the ages of 3;10 and 4;4.

Thus, monolingual Spanish- and English-speaking children typically acquire many of the same phonemes as their first speech sounds. By the age of 3;3, most children produce stops (/p, b, t, d, k, g/), nasals (/n, m/), and at least one glide (/w/).

According to these studies, Spanish-speaking children typically acquire the consonants /ʧ/ and /l/ earlier than English speakers do, whereas English speakers acquire /s/, /f/,

Table 3

Speech Acquisition of Monolingual Spanish Speakers (Jimenez, 1987)

Age	Median	90%
<3;0	p b t k f j w m n ʧ	–
3;3	d g x l s	p b t
3;7	ɾ ɲ	k w m n
3;11	–	j l
4;3	–	f
4;7	r	ʧ d g ɾ
4;11	–	ɲ x
5;7	–	s
>5;7	–	r

and /d/ at a younger age. This information on typical speech acquisition in monolingual speakers of both English and Spanish will be important for data analysis in noting whether cross-linguistic influences are seen in sounds that a child of a particular age would typically have acquired or in sounds that are acquired later. The literature on cross-linguistic influences in children's speech sounds is reviewed below.

Cross-Linguistic Effects of Speech Sound Production in Bilinguals

Simultaneous bilinguals. Cross-linguistic effects of the speech sounds of two languages have been noted starting as early as infancy in BFL children. Keshavarz and Ingram (2002) studied the phonological development of the first author's son between the ages of 8 and 20 months. The participant was a simultaneous Farsi-English bilingual, exposed to both languages since birth. For the first 6 months of the study, he was primarily exposed to Farsi. Language samples taken informally and in experiments throughout the time period showed that he used the Farsi glottal stop [ʔ] in many English words in which the glottal stop is not allophonic (e.g., [ʔæpi] for /hæpi/ and [dɑʔi] for /dɑli/). Farsi speech sounds also showed some effects on his vowel system. He used the non-diphthong Farsi /o/ in place of English diphthongs such as /aʊ/ and /ɔɪ/. Effects of English on his Farsi phonological system were seen as well. The authors concluded that the two phonologies may influence each other in bilingual acquisition.

In another study showing influence of two phonological systems on each other in a bilingual child's development, Schnitzer and Krasinski (1994, 1996) studied their two sons: one from age 1;1 to 3;9 and the other from age 1;6 to 4;6. Both children were raised as simultaneous Spanish-English bilinguals. The older child displayed few cross-linguistic effects; however, the younger child showed many cross-linguistic effects of his speech sounds which lessened with time. Analysis of their speech samples ignored the alveolar /t/ and /d/ of English versus the dental /t/ and /d/ of Spanish, as well as the Spanish /a/ versus the English /ɑ/. Inclusion of these analyses might have increased the amount of influence discovered. Examples of influences seen, primarily in consonants, in the younger son are shown in Table 4 and Table 5 which summarize consonant and vowel effects in Spanish-English learners. Table 6 displays effects on vowels.

Table 4

Examples of Cross-linguistic Speech Sound Effects Observed in Spanish-English Bilinguals' Consonants: Use of Spanish Features in English Productions

Feature	Goldstein & Washington (2001)	Schnitzer & Krasinski (1994)	Fantini (1985)	Gildersleeve-Neumann et al. (2008)
/v/→[b]	/ʃʌvəl/→[ʃʌbəl]			
/n/→Ø	/klawn/→[klaw]			
/r/→[ɾ]	/tɹen/→[tren]			
/ʃ/→[ʧ]	/ʃʌvəl/→[ʧʌvəl]			
/p/→[β]		/æpəl/→[æβəl]		
/pʰ/→[p]		/pʰɪg/→[pɪg]		
/kʰ →[g]		/kʰ lɑk/→		
/ɾ/→[d]		/gɛɾɪt/→[gɛdɪt]		
/w/→[β]		/wʊf/→[βʊf]		
/ʃ/→[ʧ]		/fɪʃ/→[fɪʧ]		
/ð/→[t]			/ðiz/→[tis]	
/ð/→[d]			/ðiz/→[dis]	
/ʤ/→[s			/ʤɔɹʤ/→[soʃ]	
/h/→[x]			/haj/→[xaj]	
/ʃ/→[s]			/ʃɛɹən/→[saᶦɛts]	
/g/→/ɣ/				/dɑgi/→/dɑɣi/
/g/→/x				/dɑg/→/dɑx/
/k/→/x/				/kɪt/→/xɪt/
/k/→/x/				/tɚki/→/tɚxi/
/k/→/x/				/kejk/→/kejx/

Table 5

Examples of Cross-linguistic Speech Sound Effects Observed in Spanish-English Bilinguals' Consonants: Use of English Features in Spanish Productions

Feature	Goldstein & Washington (2001)	Schnitzer & Krasinski (1994)	Fantini (1985)	Gildersleeve-Neumann et al. (2008)
/r/→[ɹ]	/aros/→[aɹos]			
/ɾ/→[ɹ]	/floɾ/→[floɹ]			

Table 6

Cross-linguistic Speech Sound Effects in Spanish-English Bilinguals' English Vowels

Feature	*Schnitzer & Krasinski (1994)*	*Fantini (1985)*	*Gildersleeve-Neumann et al. (2008)*
/ɛ/ → [æ]	/pɛn/ → [pæn]		
/ɛ/ → [e]		/tɛksəs/ → [tesas]	
/ɛ/ → [i]		/dɛzɚt/ → /dise:t/	
/ɪ/ → [i]		/bɪli/ → [bili]	
/ʌ/ → [i]		/dəzɚt/ → [dise:t]	
/æ/ → [a]		/ɡɹæmpɑp/ → [illegible]	(Observed)
/ej/ → [e]		/bejbi/ → bebi	
/ʊ/ → [u]		/lʊk/ → [luk]	
/ɑ/ → [a]			(Observed)

Cross-linguistic effects have also been observed in vowels of BFL learners. Kehoe (2002) longitudinally studied the vowel systems of 3 monolingual German speakers, 2 monolingual Spanish speakers, and 3 BFL Spanish-German speakers from the ages of 1 to 3 years. The German language has 14 vowels and the Spanish language has 5 vowels. Short-long opposition and difference in formant frequencies of close vowels occur only in the German vowel system. Analysis of the spontaneous productions of these children revealed a similar system of development in Spanish vowel systems between the monolingual Spanish speakers and the bilingual German-Spanish speakers; that is, cross-linguistic effects were not observed in the Spanish vowel system which is considered simpler. However, the bilinguals showed slower development of their German vowels than the monolingual German speakers did. The monolinguals distinguished their vowels by length during the time studied, whereas the bilinguals did not. The authors attributed this influence of the bilingual development to the complexity of the German vowel system.

A similar complexity effect might occur in the vowel development of Spanish-English bilinguals due to the relatively simple, 5-vowel Spanish system versus the relatively complex 11-vowel English system (Bradlow, 1995). In a 10-year diary study of his simultaneous Spanish-English bilingual son, Fantini (1985) noted several effects of his son's Spanish vowel inventory on his English. Cross-linguistic effects were seen in consonant productions as well. The influence of Spanish on English changed over time; examples of effects observed are listed in Table 4.

Sequential bilinguals. Relative to studies done with simultaneous bilinguals, those studying sequential bilinguals are rare. The following section reviews the research involving cross-linguistic effects in speech production observed in sequential bilinguals or BSL learners.

Anderson (2004) studied 5 BSL children longitudinally, all of whom began learning L2 after the age of 3;0. Children's home languages were Russian, Korean and

French and they all spoke and heard English, their L2, at preschool and in the community outside of their homes. At the start of the study, children were aged 3;9 to 4;9. Children were given word-level phonological assessments in both their L1 and in English. Anderson found that children used all sounds shared by both languages in both their L1 and in English. She concluded that children use their knowledge of L1 to help them learn the phonological system of their L2 (English) and therefore that the L1 of all children in the study influenced their English.

Cross-linguistic effects were also found by Gildersleeve-Neumann, Kester, Davis, and Peña (2008) in the speech of English-only (E), predominantly English (PE) and Spanish-English (SE) bilingual children at two points in time. Children were between 3 and 4 years old and typically-developing at the start of the study (T1). A one-word picture naming task was administered in English at T1 and 8 months later (T2). The researchers found that both groups of bilingual children produced the Spanish voiced bilabial ([β]) and voiced and voiceless velar fricatives ([ɣ] and [x], respectively) in English words at T1, and continued to produce both of the velar fricatives but not the voiced bilabial fricative at T2. Both groups also used [ɣ], following Spanish rules of phonology at times and substituted [x] for: (a) /ɡ/ in word-final position, (b) /k/ in word initial position, (c) /k/ in word medial position, and (d) /k/ in word final position (see Table 4 for examples). In addition to these consonant influences of L1 on L2, some possible vowel effects were noted. As shown in Table 6, some of the children used the Spanish low central vowel, [a], primarily in place of the English low front and back vowels, /æ/ and /ɑ/ respectively. These vowel substitutions occurred at the same rate at T1 and T2 for the E and SE children but increased considerably in the PE children. These results suggest cross-linguistic influences from L1 to L2. The performance of the children in Spanish in order to compare patterns of substitution was not addressed.

Spanish-English bilingual children displayed cross-linguistic effects in a study by Goldstein and Washington (2001) in which 12 typically developing bilinguals completed a phonological assessment designed for bilingual Spanish-English speakers. Children attended preschool full-time and were between the ages of 4;0 and 4;11. This study focused on potential effects of English on Spanish and vice versa rather than initial effects and how these changed over time. They were considered bilingual based on the criteria that they had *knowledge* of more than one language; the percent of their day spent speaking and hearing English versus Spanish was not reported nor was the language they began learning first. Data were analyzed for possible influence of one language on the other. The following were considered Spanish-influenced English: stopping (/v/ → [b]), final consonant deletion (/n/ → Ø), tapping of prevocalic *r* (/ɹ/ → [ɾ]), and affrication (/ʃ/ → [tʃ]). These patterns were considered English-influenced Spanish: retroflexing of a tap (/ɾ/ → [ɹ]) and retroflexing of a trill (/r/ → [ɹ]). These results indicate that there are in fact cross-linguistic effects both from L1 to L2 and from L2 to L1 in Spanish-English bilinguals. Patterns of influence and examples of actual occurrences are shown in Table 4.

Yavaş (2002) studied the cross-linguistic effects of bilingualism on voice onset time (VOT) for the voiceless sounds /p/, /t/, and /k/ in Spanish-speaking children after 2 years of English exposure. VOT is the difference in time between the release of an articulator and the start of vocal fold vibration in a stop sound. Different VOT boundaries are phonemic in English and Spanish, with Spanish having shorter VOTs than English for voiceless sounds. The 10 children were all BSL learners who were in second grade and who spoke Spanish as their L1 and began learning English at the start of kindergarten (after age 5). Children repeated 15 sentences that were either completely in English or mixed English-Spanish sentences (e.g., *Pon el papel on the table* or *Put the tuna en la caja*). Yavaş expected Spanish VOT values to influence English values because children came from Spanish monolingual backgrounds and therefore heard and spoke Spanish for the majority of their lives. However, results indicated that each language influenced the other, shown by lower than typical English VOT values and higher than typical Spanish VOT values. Furthermore, 6 of the 10 children failed to produce significantly different VOT values in Spanish and English in one or two places of articulation, also indicating the influence of another language.

In a Spanish-English study, Gildersleeve-Neumann, Peña, Davis, and Kester (2009) also showed the effects of exposure to L2 on L1 in bilingual Spanish-English 3- and 4-year old preschoolers. Six sequential bilinguals were assessed at the time of initial exposure to their L2, English, and then after 8 months of exposure. Based on MacWhinney's 2004 *unified competition model*, the experimenters predicted that the English vowel system would affect vowel production in Spanish. This is because some of the vowels in English and Spanish overlap (as phonemes or allophones) and because the English vowel system is more complex than Spanish. Although they found developmental errors that are typical for monolinguals and simultaneous bilinguals which remained the same or lessened over time, they also found that Spanish vowel errors increased with more exposure to L2. Gildersleeve-Neumann et al. attributed vowel errors to a reorganization of the phonological system, not to loss of abilities. Differences between Kehoe's and Gildersleeve-Neumann et al.'s studies were that Kehoe studied simultaneous bilinguals whereas Gildersleeve-Neumann et al. studied sequential bilinguals. The latter study focused on the effects of L2 on L1 rather than effects of L1 on L2 in addition to those of L2 on L1.

Hecht and Mulford (1982) found both cross-linguistic effects and developmental effects in their 1985 study of a 6-year-old Icelandic-English bilingual. He was studied starting 10 weeks after his initial exposure to English. Although the researchers were attempting to describe the influence on English fricatives and affricates from his native language, they discovered that sound substitutions of fricatives and affricates were more developmental than influenced by Icelandic. The authors also noted several other patterns that they believed occurred due to cross-linguistic influence, including replacing English /ɹ/ with Icelandic trilled *r* ([r]) in words such as *clarinet*, *water*, and *broke*. The participant also produced the English velar allophone of /l/ as the Icelandic clear apical lateral /l/. Additionally, his English vowels were produced higher than their English correlates, and diphthongs remained monophthongs, both similar to Icelandic vowels.

Unlike the studies presented above that revealed cross-linguistic effects in the speech sound systems of bilinguals, a 1999 study by Holm and Dodd showed a lack of

L1 effects on L2. Holm and Dodd studied bilingual speech acquisition in two Cantonese-English sequential bilingual children raised in Cantonese home environments and first exposed to English around 2 years of age upon entering a childcare center. Spontaneous language samples in both Cantonese and English were collected every 4 weeks for a period of 8 and 11 months. Analysis for both children revealed that (a) different phonological processes were used for each language, (b) English phonemes were not used in Cantonese words and vice versa, (c) phonemes shared by the two languages were simplified differently in each language, and (d) phonemes that are shared by the two languages were usually produced first in Cantonese and acquired later in English. Although spontaneous productions of shared phonemes were acquired first in Cantonese, at the time of acquisition, the children were able to imitate the shared phonemes in English which suggests a possible perceptual component. The researchers also concluded that the phonological development of these sequential bilingual children in each language was different from monolingual development in each of the respective languages. This conclusion was based on analysis of phonetic accuracy as well as phonological processes and phoneme repertoires.

A study of older Spanish-English bilingual children also revealed few cross-linguistic effects of L1 and L2 (Goldstein, Fabiano, & Washington, 2005). Goldstein and colleagues analyzed the speech of predominantly English (PE), predominantly Spanish (PS) and equal (E) Spanish-English bilinguals who were classified based on percentage of output in each language as reported by parents. Each group consisted of

5 children between the ages of 5;0 and 5;5. Children in the PE group had up to 5 years exposure to Spanish and the PS group had up to 2 years of exposure to English. Only consonants were analyzed for cross-linguistic effects and although many substitutions were made, only two instances of cross-linguistic influence were noted in the E group. Both substitutions were in the Spanish productions; those were: (a) substituting [z] for /s/ and (b) substituting [v] for /ɣ/. This study focused on speech sounds of the dominant language; sounds of the non-dominant languages of these groups were not elicited. Both the frequency and variety of cross-linguistic effects observed in this study were minimal; however, vowels were not emphasized in this study. Additionally, these children were older and the age of these children might result in fewer cross-linguistic effects because their L1 might have been well-developed.

Explaining Cross-Linguistic Effects

Researchers have proposed numerous theories to account for cross-linguistic effects such as those described above on language and speech sound systems. Theories explain the influence of the production of one speech sound system on another through means such as articulation, processing mechanisms, and perception. While this study will explore speech production, it will also explore the perceptual theories. An argument follows for why it is valid to explain cross-linguistic influence in speech production perceptually.

Perception and Production of Speech Sounds

Speech Sound Perception in Infants

In order to acquire speech and ultimately language, infants must first be able to perceive slight differences in sounds that indicate different meanings; for example, they must differentiate phonemes such as /s/ and /z/ to be able to distinguish and produce words. Research supports the idea that infants are paying attention to and noting differences in the sounds that have not yet resulted in meaning for them. DeCasper, Lecanuet, Busnel, Granier-Deferre, and Maugeais (1994) showed that starting in the womb, preterm infants' heart rates decreased when listening to a familiar nursery rhyme to which they had been exposed repeatedly in previous weeks. In a 1986 study, DeCasper and Spence found that after they were born, infants showed preference for stories that had been read to them in utero. In addition, neonates have shown the ability to begin distinguishing between two languages that are rhythmically different (Nazzi, 1998).

Clearly infants retain some of the perceptual characteristics of familiar acoustic cues. Extensive evidence showing infants' abilities to perceive acoustic differences can help us understand perception at the beginning of speech acquisition. Thus, infants' first experience with speech, and therefore their first step to acquiring speech, is in perception. As presented below, evidence also supports the idea that perception precedes production even in older children and in second language learners.

Perception Precedes Production

Because there are many differences in speech sound inventories and frequency of speech sound usage in the languages of the world, the perceptual systems of young children must affect native language acquisition. According to several studies, the ability to perceive speech sounds occurs before the ability to produce the sounds in young children. Edwards (1974) assessed children aged 1;8 to 3;11 for their ability to discriminate between pairs of nonsense CVC syllables. Each set contained a minimal pair with one marked initial consonant and one unmarked initial consonant. Edwards concluded that overall children perceived the difference three times more often than they produced the difference in stops and fricatives. In pairs containing liquids and glides, children perceived the difference twice as often as they were able to produce the difference. Menyuk and Anderson (1969) also concluded that perception precedes production for young children in a study of 18 preschoolers and 18 adults. The researchers compared the children's and adults' abilities to identify and repeat pairs of synthetically produced CVC syllables with initial consonants arranged in steps from (A) *light* to *white*, (B) *light* to *write*, and (C) *white* to *write*. The initial consonant in each syllable was computed by interpolating equally spaced formant contours between /l/ and /w/, /l/ and /ɹ/, and /w/ and /ɹ/. Additionally, two more syllables were created by extrapolating formant contours outside of the phoneme pairs. In sets A and B, more children identified the synthesized steps that were closest to /l/, /w/, and /ɹ/ as the same than were able to repeat them. Furthermore, Menyuk and Anderson looked at the group of children above the mean age of 4;8 and those below the mean age and found that the older children both identified and repeated the targets correctly more than the younger children. They hypothesized that development of speech sounds in children begins with the inability to both identify and produce correct sounds, then the ability to identify but not produce particular sounds, and last the ability to both identify and produce sounds correctly.

As outlined above, perception might play a role in first language acquisition. We might also hypothesize that perception assists children and adults learning L2. In a study of native French, English, and Portuguese speakers, Rochet (1995) assessed perception and production of the vowels /i/ and /u/ which occur in all three languages and of the high front rounded vowel /y/ which falls between /i/ and /u/ and among the three languages only occurs in French. English and Portuguese speakers imitated the French /y/ in more than 50% of their attempts showing that articulation is not the only difficulty in producing the nonnative vowel /y/. Of the incorrectly imitated /y/ vowels, Portuguese speakers imitated 95% of them as /i/ and English speakers imitated 92% of them as /u/ as judged by a native French speaker. In the perception portion of the study, English and Portuguese speakers identified vowels on the continuum from /i/ to /u/ (/i/, /y/, and /u/) as /i/ or /u/. French speakers identified the same vowels as /i/, /y/, or /u/. Of those vowels on the continuum that French speakers identified as the vowel /y/ (F2 values ranging from 1300 to 1900 Hz), English speakers perceived most of them as /u/ and Portuguese speakers perceived them as /i/. Rochet therefore concluded that perception is key in producing L2 vowels. Three perceptual theories of speech acquisition are described below followed by evidence in second language acquisition that supports these theories.

Perceptual Theories of Speech Acquisition

Theories of perception posit that infants are born with an ability to perceive the speech sounds that make up the world's languages (Werker & Tees,1999) and attempt to explain which parts of speech sounds humans attend to and how perception changes with experience. Three perceptual theories commonly used by researchers to explain language acquisition are the Perceptual Magnet Effect, the Speech Learning Model, and the Perceptual Assimilation Model.

Perceptual Magnet Effect

In a 1991 study, Kuhl demonstrated evidence supporting a *Perceptual Magnet Effect* in both adults and 6- to 7-month-old infants. The *magnet effect* describes the effect that prototypical vowels have on humans. The prototypical vowels "attract" the vowels in the surrounding acoustical space, creating one large category of vowels that are all considered prototypical since people cannot distinguish the similar vowels from the actual prototypical vowel. However, for vowels not identified as prototypical, surrounding vowels are more easily identified as different.

The Perceptual Magnet Effect described and demonstrated by Kuhl (1991) posited that speech prototypes are innately determined for humans. If this theory were true, we could predict that the bilingual children in this experiment would produce vowels in English words that are acoustically close to Spanish vowels as the Spanish vowels because both the vowels in the similar pair will be perceived as the same, assuming they are close to the prototypical vowel determined by an innate speech mechanism. For example, the low central Spanish vowel /a/ is acoustically similar to the low front English vowel /æ/; therefore, these two vowels might be perceived as the same by a Spanish-English bilingual or a monolingual speaker of either language. If both /a/ and /æ/ are in fact perceived as the same vowel, the bilingual child might produce /a/ in place of /æ/, saying /kat/ instead of /kæt/ for example.

The Perceptual Magnet Effect, however, only considers the maternal language. Other researchers have explored how adult and child learners of second languages might perceive speech sounds of their new language. One such model is the Speech Learning Model.

Speech Learning Model

A well-known and commonly discussed theory of speech acquisition with similarities to the Perceptual Magnet Effect is the Speech Learning Model (Flege, 1987, 1995). In the Speech Learning Model, Flege proposed that L2 speakers do not sound like native speakers of the language primarily due to the inability to perceive phonetic differences between two L2 sounds, or between an L1 and an L2 sound, because perception becomes “attuned” to the sounds of L1, not because of an innate speech mechanism as proposed by the Perceptual Magnet Effect. The Speech Learning Model posits that the failure in discernment is due to (a) assimilation of pairs of L2 sounds to the same L1 category or (b) filtering out properties of L2 sounds that are unnecessary in L1 but necessary in L2. Flege posited that accurate perception of L2 sounds is needed in order to “guide the sensorimotor learning” of those sounds which will lead to accurate production. If a sound from L1 and a sound from L2 are assimilated to the same category or properties of an L2 sound are filtered out perceptually, then production of the L2 sound will reflect the L1 sound that is similar. One of the postulates of the Speech Learning Model is that “the mechanisms and processes used in learning the L1 sound system, including category formation, remain intact over the life span, and can be applied to L2 learning” (Flege, 1995, p. 239). This postulate is also called *plasticity* which refers to the brain’s ability to change (Bosch, Costa, & Sebastián-Gallés, 2000).

Based on the Speech Learning Model, we could predict that the children in this study might produce similar L1 and L2 vowels as the same, just as the Perceptual Magnet Effect predicts. However, we can predict that over time, as the children become “attuned” to the sounds of English and are able to distinguish between similar vowels, that they will begin producing each vowel more accurately instead of substituting the L1 vowel for a similar L2 vowel.

Perceptual Assimilation Model

Similar to the Speech Learning Model, the foundation of Best’s 1995 Perceptual Assimilation Model is that “non-native segments … tend to be perceived according to their similarities to, and discrepancies from, the native segmental constellations that are in closest proximity to them in native phonological space” (Best, p. 193). Best hypothesizes that nonnative speech sounds will assimilate (a) to a native speech sound category, (b) outside of a native speech sound category, or (c) not at all. Similar to the Speech Learning Model, the Perceptual Assimilation Model does not assume that there is an innate speech mechanism with predetermined prototypical vowels. However, the difference between the two models is that the Perceptual Assimilation Model predicts that speakers of a second language will always perceive the L2 sounds in how they are similar to or different than the speech sounds from their L1; whereas according to the Speech Learning Model, new speech sound categories can be formed over time.

Despite this difference, the Perceptual Assimilation Model also predicts that the children in this study will produce English speech sounds that are similar to Spanish sounds as the similar Spanish sound and therefore be considered an error. The difference between these two hypotheses might be determined by studying these children after years of exposure to English, their L2.

Perceptual Bilingual Speech Acquisition Research

Influence of Maternal Language on Perception in Monolingual Infants

It is clear that exposure to a language affects acoustic-phonetic organization beginning in infancy. Research shows that prior to approximately 4 to 6 months of age, infants process vowels at a language-general rather than language-specific level; that is, they can discriminate speech sounds from many languages of the world from other similar speech sounds. Between the ages of 4 and 6 months however, exposure to the maternal language comes to affect perception of the vowels of the maternal language (Bosch & Sebastián-Gallés, 2003; Kuhl, 1991; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Polka & Werker, 1994). At that time, infants perceive differences between vowel pairs of their maternal language but no longer perceive differences between those from other languages. Their perception becomes specific to the language of their environment. However, at 6 months, infants continue to perceive consonants in a language-general manner, not yet showing keener perception of consonants of their maternal language (Burns, Yoshida, Hill, & Werker, 2007; Werker, Gilbert, & Humphrey, 1981). Research shows that maternal language affects the perception of consonants by 8 to 10 months of age (Kuhl et al., 2006).

Influence of Bilingualism in Infants

In response to studies showing that infants begin with language-general perception of speech sounds which develops to language-specific perception within the first year of life, (Kuhl, 1991; Kuhl et al., 1992; Kuhl et al., 2006; Polka & Werker, 1994), Bosch and Sebastián-Gallés (2003) analyzed the development of bilinguals' perceptual abilities during the first year of life. They compared abilities to discriminate a vowel contrast in 4-, 8-, and 12-month-old infants from Catalan-Spanish bilingual environments (with 36, 36, and 12 children in each group respectively). The chosen vowel contrast /e/ – /ɛ/ is phonemic in Catalan, but not in Spanish. Results from the 4-month-old bilingual infants showed that they could distinguish the /e/ – /ɛ/ contrast, consistent with the monolingual studies described above, suggesting that infants 4 months of age have a language-general perceptual ability and can discriminate vowel phonemes of a variety of languages. The 8-month bilingual infants in Bosch and Sebastián-Gallés' 2003 study did not show the ability to discern the vowel contrast. This inability was not related to the language of the mother so that those who discerned the contrast had Catalan-speaking mothers and those who did not have Spanish-speaking mothers. The authors concluded that in a bilingual environment, speech sound distribution is more complex than in a monolingual environment and therefore perceptual reorganization for bilinguals depends on more than just exposure. The 12-month-old Catalan-Spanish bilingual infants showed the ability to discriminate the Catalan-only contrast, thus realigning with the monolinguals. The authors concluded that the development of phonetic representation occurs at a different rate in monolinguals and bilinguals.

Sequential Bilingual Adults

The effect of the maternal language on perception in monolingual infants continues into adulthood in bilingual second language learners. Bosch et al. (2000) demonstrated that the Perceptual Magnet Effect was a function of the listener's first language by testing 24 highly proficient Spanish-Catalan bilingual adults, 12 Spanish-dominant and 12 Catalan-dominant participants, all who began learning their second language at an early age (by the age of 6). Bosch and colleagues tested each Spanish-Catalan bilingual with (a) Catalan-/ɛ/; (b) Spanish-/e/, which is very close in the vowel space to the Catalan-/ɛ/; and (c) a vowel that is considered non-prototypical in either language. Both of the groups treated the non-native language vowel in the same manner that they treated the non-prototypical value. They discriminated vowels within small distances from the non-native target at a higher rate than they discriminated native vowel contrasts within the same distance demonstrating that any perceptual biases are from their maternal language. Bosch and colleagues concluded that phonemic representation of L1 has a "structured internal organization" and that L2 speech sounds do not necessarily have the same internal organization. They also noted that, as the Perceptual Assimilation Model would predict and the Speech Learning Model might predict, Spanish-dominant participants failed to discern phonetic differences between pairs of L2 sounds, which were very close to the target L1 vowel, because they were assimilated to the same L1 category. However, the Speech Learning Model also posits that category formation can occur throughout the life span. Therefore one might predict that highly proficient, early L2 learners would have formed new categories similar to a native speaker and therefore be able to discern the similar sounds. Because participants did not discriminate, Bosch et al. emphasized that new categories were not formed despite early exposure, formal education, and intensive, continuous use of L2 which they indicated suggests loss of plasticity and therefore disagreement with this postulate of the Speech Learning Model. However, Bosch et al. did not include monolingual Catalan or Spanish speakers as a control group. It is therefore unclear whether the bilinguals did display effects of plasticity which would be shown by better performance than the two monolingual groups.

Brain plasticity was addressed in a 2006 study by Højen and Flege in which they found evidence against loss of plasticity by testing 20 Spanish monolinguals, 20 English monolinguals, and 20 Spanish-English bilinguals, all adults. The bilinguals were all early learners of English, their second language. All groups were tested on their ability to perceive four pairs of English vowel contrasts that were rated easy or difficult to discriminate for native-Spanish speakers depending on whether or not the contrast exists in Spanish. They were (a) [i] – [u], which was considered easy; and (b) [ɪ] – [$\text{e}^{\text{ɪ}}$], (c) [ʊ] – [$\text{o}^{\text{ʊ}}$]; and (d) [ɑ] – [ʌ], all of which were considered difficult. Results showed that bilinguals' scores for all contrasts (mean 91%) were slightly lower than those of English monolinguals (96%), but significantly higher than those of Spanish monolinguals (65%), suggesting plasticity in early bilinguals. In addition, the authors noted that there was no overlap in the range of bilingual and Spanish monolingual scores which led them to investigate within group differences based on a survey completed by all participants. The surveys showed that the lowest scoring bilinguals reported first exposure to English between the ages of 5 and 10 years, whereas the highest scoring bilinguals reported exposure from 2 to 5 years. Also, most of the highest scorers reported using English more with friends over the past 5 years, higher use of English during their first 5 years of exposure, and attending school in the United Sates longer than the lower scoring bilinguals. Højen and Flege concluded that perceptual plasticity is possible for early learners of second languages and that perception may depend on factors other than whether L2 was acquired during childhood or after adolescence. In response to studies in which researchers did not include monolingual native speakers of the early learners' L1 as one of the control groups, such as Bosch et al. (2000), they suggested that plasticity cannot be determined.

In another study involving BSL learners, MacKay, Flege, Piske, and Schirru (2001) tested early and late Italian-English bilinguals to determine if they could perceive the short-lag voiced English phonemes /b/, /d/, and /g/. They defined early bilinguals as sequential bilinguals who began learning their second language during childhood or adolescence, usually by the age of 12. Late bilinguals were defined as learning their second language after adolescence. McKay et al. hypothesized that Italian-English bilinguals would perceive English /b/, /d/, and /g/ as /p/, /t/, and /k/ respectively due to the lack of prevoicing in English /p/, /t/, and /k/ as well as in English /b/, /d/, and /g/. The phonemes /b/, /d/, and /g/ are all prevoiced in Italian (McKay et al., 2001), that is, voicing begins before the release of the articulators in forming each phoneme. In English the same phonemes are formed with short-lag voicing and /p/, /t/, and /k/ are formed with long-lag voicing. In short-lag voicing, vocal folds begin vibrating just after the articulators are released; in long-lag voicing, more time passes prior to vocal fold vibration. MacKay and colleagues' hypothesis was confirmed for the late bilinguals when they found that late, but not early, bilinguals perceived /b/, /d/, and /g/ as /p/, /t/, and /k/. This result can be partly explained by the Speech Learning Model. The late Italian-English bilinguals filtered out the short-long lag distinction that is necessary in English to discern /b/, /d/, and /g/ from /p/, /t/, and /k/. In Italian, one only needs to perceive prevoicing versus lag voicing. However, because the early bilinguals did distinguish the sounds correctly, we can also conclude, as Højen and Flege (2006) did, that experience also plays a role in perceiving the sounds of L2.

The studies about perception, summarized above, along with research findings that perception of speech sounds is acquired before their production, support the idea that the influence of L1 on L2 in bilinguals may be due to lack of L2 native-like perception. Several of these studies showed that second language learners do not discriminate non-native speech sounds from similar L1 sounds. Therefore if children learning English as L2 do not hear the difference between the /ɑ/ produced by English speakers and the /a/ that they are used to hearing, they might substitute [a] for /ɑ/ when speaking English. Others studies indicate that native-like perception can depend on factors such as age of first exposure and frequency of exposure to L2. Therefore, when determining what can be considered *typical* development for bilingual children, it is important to define homogenous groups as expectations might be different depending on age and length of exposure to L2. It follows from these two types of studies that we need to know which English speech sounds children are not producing at the beginning of their exposure to L2, possibly due to not discriminating them from similar Spanish sounds, and how we can expect this to change over time.

Summary

This study analyzed the speech sounds produced by 3-year-old sequential bilinguals in their second language of English to find effects of their L1, Spanish. Approximately 100-word samples were collected at three or four points in time. If perception is crucial for developing speech sounds in sequential bilinguals and they do indeed perceptually collapse sounds from their second language into acoustically similar speech sounds of their first language, then typically developing bilingual children were expected to substitute Spanish sounds for similar English sounds in English words. Target words from their first language, Spanish, were also analyzed to ensure any differences observed are due to cross-linguistic influences rather than developmental substitutions. Monolingual English speakers were observed for general comparisons. The purposes of this study were to (a) determine whether knowledge of Spanish as a first language affects production of English in BSL learning preschoolers, (b) describe patterns of influence that might occur in these preschoolers for both perceptual and production-based reasons, (c) track the changes in cross-linguistic influence over time, and (d) compare the speech sounds of BSL English learners with those of monolingual English children.

Although similar studies of bilingual speech acquisition have been done (Gildersleeve-Neumann et al., 2008; Goldstein et al., 2005; Goldstein & Washington, 2001) these studies have not controlled for variables such as which language was learned first, age of or amount of time since initial exposure to the second language, and percent of weekly exposure to each language. Some of these studies also did not investigate speech sounds produced in both languages, did not analyze L2 speech sounds at the beginning of exposure, or elicited only a small number of target words.

Hypotheses

Based on previous research results, the hypotheses of this study were that (a) children's phonetic inventory will be the same initially in English and Spanish because they will assimilate similar sounds to the same perceptual category, (b) 3- to 5-year-old Spanish dominant Spanish-English bilinguals will produce Spanish-influenced English speech sounds and word shapes shown by substitution of Spanish speech sounds and word shapes for similar English speech sounds and word shapes, (c) these substitutions will lessen and accuracy will increase as these bilinguals are exposed to English for a longer period of time, and (d) bilinguals will produce more incorrect consonants and vowels in English than monolingual English speakers. While production-based factors were investigated, explanations for the findings were explored within a perceptual framework.

Chapter III: Method

Participants

All participants were children who were recruited from Head Start preschools in the Portland, Oregon metropolitan area. The children were 3 bilingual Spanish-English speakers ages 3;4 to 3;9 (mean=3;6) at the start of the study and 4 groups (10 to 15 per group) of children who speak English only (EO) within the same age range as the bilinguals at each point of data collection. The average score for the EO groups were used for comparison. All children were enrolled in English-speaking classrooms at one of five different Head Start locations. Parents of the children completed a survey that contained questions about the language background and development of their children. All children were from monolingual homes. The bilingual children had their first regular exposure to English upon entering preschool between the ages of 3;2 and 3;8 years.

The bilingual children were chosen from a group of 3-year-old children in a larger study on bilingual speech acquisition conducted by Christina Gildersleeve-Neumann. The bilingual children who were selected are described in Table 7. Data were collected each fall and spring with at least 3 months between collections. The children were required to be assessed using both English and Spanish during the fall of their first preschool year in order to be in the study. Of these children, bilingual children who participated at least three different times with both languages sampled during at least three of those times were selected for the current study. Children were then not considered if a child's speech was inaudible due to background noise, if one or more parent spoke another language in the home, or if one or more of the data

Table 7

Bilingual Participant Background and English Sample Information

Child	# of data points	Child born	Parents born	Lang. spoken to child	Sex	T1 age (# words)	T2 age (# words)	T3 age (# words)	T4 age (# words)
Gabi	7	USA	Mexico	Spanish	F	3;6(127)	3;10(83)	4;4(133)	
María	8	USA	Mexico	Spanish	F	3;5(23)	3;9(119)	4;5(131)	4;10 (91)
Sofía	7	USA	Mexico	Spanish	F	3;11(132)	4;3(80)	4;10(129)	5;2 (136)

Note. T1 = First time of data collection; T2 = Second time of data collection; T3 = Third time of data collection; T4 = Fourth time of data collection;

samples contained fewer than 20 words. Bilingual children are represented with pseudonyms in this paper. Monolingual children were chosen from the same sample if they were close in age to the bilingual children at one or more times of data collection. Monolingual comparison groups are described in Table 8. Monolingual English children were also not considered if the speech sample was inaudible or another language was spoken in their home.

Participant Backgrounds

Children with IFSPs related to speech, language, or hearing, were not considered for this study. Those who were exposed to a language other than English or Spanish on a regular basis were also not considered. If a parent, teacher or examiner indicated that they or someone they knew had concerns about a child's speech or language development, then the child was not included in the current study to lessen the likelihood that a child did not represent typical bilingual speech sound

Table 8

Monolingual Comparison Group Background Summary

	Mean age	Age range	# females	# males
		T1		
Bilingual	3;7	3;5 to 3;11	3	0
Monolingual	3;7	3;5 to 3;9	6	4
		T2		
Bilingual	4;0	3;9 to 4;3	3	0
Monolingual	4;0	3;9 to 4;3	7	6
		T3		
Bilingual	4;6	4;4 to 4;9	3	0
Monolingual	4;6	4;4 to 4;9	8	7
		T4		
Bilingual	4;11	4;9 to 5;2	3	0
Monolingual	4;11	4;9 to 5;2	7	8

development. If the child was not judged to be typically-developing, that particular child was not considered for this study.

Stimuli

The phonological and articulatory bilingual assessment (PABA, Gildersleeve-Neumann, unpublished) is a picture naming task consisting of object and attribute words with which preschool children are commonly familiar. The English stimuli are shown in Appendix A and the Spanish stimuli are shown in Appendix B. Words were selected that provide consonants, vowels, and clusters in a variety of word positions and contexts in each language. Because of the need to include a variety of sounds and to ensure linguistic appropriateness, different words were used in the English and Spanish tests.

Procedure

The PABA was given to each participant and recorded using a DA-P1 Digital Audio Tape Recorder or an Edirol R-09 24-Bit Wave MP3 Recorder. All recordings were transferred to a computer as wave sound files. Assessments were administered at five Head Start locations during the school day. Children were tested outside the classroom in the quietest place that could be found at the particular location.

Words were elicited by showing the child a picture and asking, "What's this?" or using a cloze phrase such as, "This is a _____." If the children did not respond or responded incorrectly, they were given two or three choices in an attempt to elicit a delayed imitation. For example, if the picture was of a dinosaur, the clinician might ask, "Is this a dinosaur or a mountain?" If the correct response was not elicited, the clinician said the word and asked the child to repeat it. Bilingual and monolingual children completed the same English assessment with Portland State University speech-language pathology graduate students who administered the test primarily in English but used some Spanish when necessary for instructing. Bilingual children also completed a Spanish assessment which was administered in Spanish by a graduate student.

Analysis

All samples given by each bilingual participant were listened to by the author. The transcriptions were reviewed as well. Data are presented in tables and graphs showing change over time.

Phonetic transcription

Samples were transcribed by listening to them on computer sound files using Sennheiser EH 1430 headphones. Files were transcribed using the International Phonetic Alphabet (IPA) and entered into *Logical International Phonetics Program*, version 2.02 (LIPP, Oller & Delgado, 2000). After each transcription was entered into LIPP by a graduate student of Speech and Hearing Sciences, a second graduate student transcribed the sample. Any major discrepancies between transcriptions were discussed and resolved. Finally, a Ph.D. level phonetician reviewed all transcriptions to ensure uniform transcription. The final transcriber changed fewer than 5% of the phonemes. The final transcriber made the final decision on correct transcription, verifying the decisions with Praat acoustic software (Boersma & Weenink, 2005) when there was a lack of clarity. For example, Praat was useful in distinguishing stops from fricatives and detecting vowel r-coloring.

Phonetic Inventory

A phoneme was considered part of the English children’s inventory if 75% of the English monolingual children produced it. Consonant and vowel inventories were described for each bilingual participant in both English and Spanish. It was noted if a child produced any Spanish phonemes in their English inventory as well as English phonemes in the child's Spanish inventory. The bilinguals' inventories were each compared with the monolingual group corresponding to their age at the time that the sample was collected to determine whether both groups of children had the same inventories or if there were notable differences. The bilingual samples were also compared with theoretical frameworks.

Accuracy

The accuracy of the children's speech productions were determined using percent consonants correct (PCC) and percent vowels correct (PVC, Shriberg, 1993; Shriberg, Austin, Lewis, McSweeney, & Wilson, 1997) for both the Spanish and English samples of the bilingual children. Averages were determined for both PCC and PVC for the English samples of the monolingual children. Calculations were determined with LIPP. Dialectical and individual features used by adults in the community were not considered errors. For example, both /ɔɹɪnʤ/ and /aɹɪnʤ/ were considered correct. Influences of Spanish speech sounds on English speech sounds were considered "errors" for the purpose of for comparing bilingual to monolingual speech sound development; it should be noted that these would not be considered errors if a child were being tested for a speech sound disorder.

Error Patterns

Rates of error patterns were reported for each child in a table, at both the syllable level and the segmental level. Additionally, specific examples of error patterns are illustrated in Appendix C. Error patterns were selected because of their frequency in typically-developing children and their likelihood of cross-linguistic effects based on Spanish phonology. The error patterns noted were: fronting, stopping, tap for r substitution, gliding, backing, spirantization, raising and lowering vowels, substitution of a tense for lax vowel, derhoticization, diphthong reduction, final consonant deletion, total consonant deletion, syllable deletion, cluster reduction, and total cluster errors. Frequently-occurring error patterns among bilingual children as well as those considered typical for monolingual English speakers were described for comparison. Results for each error pattern were compared within each child as well as between bilinguals and monolinguals. English samples produced by the bilingual children were then analyzed to identify influences of Spanish on the English productions of the children. The bilingual children's Spanish speech samples were explored to see similarities and differences between English and Spanish samples.

Speech sound substitutions, distortions, and deletions made by children were considered to determine if they indicated influence from the speech sounds of Spanish, a developmental stage, learning a new language, or a one-time pronunciation error. If a substitution, deletion, or distortion was used in an English production, the Spanish sample was cross-referenced to determine what the child produced in Spanish for a similar target to determine if the substitution was developmental or influenced by Spanish.

For each substitution made, the number of opportunities to produce the target was determined to find the percent of times that the target was incorrectly produced. This percent was compared with other points of data collection. Changes over time in error patterns were summarized for each child. Trends observed across children were recorded.

Chapter IV: Results

The results section of this study describes the bilingual children's current L2 speech productions, how the children's L1 has affected their L2, and how the influence changed over time. Additionally, the English productions of the bilingual children will be compared with the EO group to note differences in L1 and L2 development. First the independent analysis results of this study will be presented which includes consonant, vowel, and syllable shape inventories. In all cases, English data are presented first followed by Spanish data. Next, the relational analyses will be described beginning with percentage of consonants correct (PCC) and consonant errors such as stopping and voicing errors. Consonant errors will be followed by word shape errors such as cluster reduction and final consonant deletion. Finally, percentages of vowels correct (PVC) and other vowel errors will be described.

Independent Analysis: Phonetic Inventory

English Consonant Inventories

Phonemes. Table 9 shows the English consonant phonetic inventory of each bilingual participant and the average phonetic inventory of the EO children. All children, bilingual and EO, produced the phonemic stops [b, p, t, d, g, k]; liquids [l, ɹ]; glides [j, w]; and nasals [m, n, ŋ] at all collection points. The only exception was María who at T1 produced an abbreviated sample with no /d/ as a target. A phoneme was considered part of the EO average phonetic inventory if 75% or more of the children produced the sound at a particular time. The voiceless fricatives [h, f, s, ʃ], and affricate [ʧ], were also produced by all children at each data collection point.

The voiced fricatives and affricate were later occurring sounds for both the bilingual children and the EO. At T1 María and Sofía produced the voiced labiodental fricative [v]; at T2 Gabi and María produced [v]; and at T3 and T4 all of the children produced the phoneme. At T1 only Sofía produced the alveolar fricative [z] but by T2 all of the bilingual children produced the consonant and continued to produce it through T4. The EO produced [v] and [z] at all times from T1 through T4. The voiced palato-alveolar affricate [ʤ] was produced at all times by all bilingual and monolingual children except by María at T1 when she devoiced the sound and produced [ʧ]. This participant was only given one opportunity to produce the affricate due to her shortened sample whereas all other children had several opportunities to produce the sound and did not produce it every time.

Both the bilingual and the monolingual children produced the voiced and voiceless interdental fricatives [ð] and [θ] less consistently than all of the other phonemes. At T1 María and Sofía produced the voiceless [θ] which was not produced by the EO. At T2, Gabi and Sofía produced the phoneme as well as the EO. At T3 and T4 all children as well as the EO group produced [θ].

At T1 Gabi and Sofía produced the voiced [ð]; María did not have the opportunity to produce the sound due to the shortened sample. In contrast, [ð] was not produced by the monolingual aggregate. At T2, María and Sofía produced the [ð] as well as the EO; Gabi did not produce the consonant. At T3 all bilinguals produced the phoneme but the EO did not and at T4, the EO produced it as well as one of the two bilingual children.

Allophones. Bilingual children began using English allophones at the same time or just after their monolingual counterparts. María and Sofía as well as the EO produced the allophonic glottal stop, [ʔ], beginning at T1. Gabi and the EO produced the allophonic tap, [ɾ], beginning at T1. After T1, all children, bilingual and monolingual, produced the tap and the glottal stop in every sample given.

Spanish-influenced phonemes. One difference between the EO and the bilingual children consonant inventories is that the bilingual children used a few Spanish-only phones in English words. All bilingual children substituted Spanish consonants within English words. The voiced bilabial fricative was produced by Gabi and Sofía at T1 and by Gabi and María at T2. The voiceless velar fricative, [x], was produced by Sofía at T1, T3 and T4. Sofía produced [ɣ] and María produced [r] both at T3. The interdental fricatives were the least likely to be produced by both monolingual and bilingual participants. They were never produced by all bilingual children and the EO at any data collection point.

Spanish Consonant Inventories

María and Sofía produced all Spanish consonant phonemes in each of their Spanish samples. Gabi produced all Spanish consonant phonemes with the exception of the alveolar trill [r] at T1.

Table 9

Consonant Inventories: English Data (Arlt and Goodban, 1976; Templin, 1957)

	T1				T2				T3				T4			
	G	M	S	E	G	M	S	E	G	M	S	E	G	M	S	E
Acquired early																
b	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
p	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
t	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
d	X	*	X	X	X	X	X	X	X	X	X	X		X	X	X
m	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
n	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
f	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
w	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ŋ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Acquired later																
j	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
k	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ɡ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
h	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
v		X	X	X	X	X		X	X	X	X	X		X	X	X
s	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ʃ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ʧ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Acquired last																
ð	X	*	X			X	X	X	X	X	X				X	X
θ		X	X		X		X	X	X	X	X	X		X	X	X
z			X	X	X	X	X	X	X	X	X	X		X	X	X
ʤ	X		X	X	X	X	X	X	X	X	X	X		X	X	X
ɹ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
l	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Allophone																
ʔ	*	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ɾ	X			X	X	X	X	X	X	X	X	X		X	X	X
Spanish-influenced																
β	**X**	*	**X**	*	**X**	**X**	*	*	*	*	x	*		*	*	*
x	*	*	**X**	*	*	*	*	*	*	*	**X**	*		*	**X**	*
r	*	*	*	*	*	*	*	*	*	**X**	*	*		*	*	*
ɣ	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*

Note. X indicates phoneme produced, * indicates phone not targeted in sample, **X** indicates phone not targeted but produced; G=Gabi, M= María, S=Sofía, E=English only group.

English Vowel Inventories

All front vowels, both mid-central vowels, and back vowels with the exception of [ɑ], were produced in all samples at all data collection points. Table 10 displays the vowel inventories at T1 through T4 for each bilingual child and for the EO, also using 75% of all EO children as the criteria for production by monolinguals. At T1, the EO produced the low back vowel [ɑ], which occurs in English but not Spanish; Sofía produced [ɑ] and María did not have the opportunity at T1. All children, bilingual and monolingual, produced the vowel [ɑ] at T2, T3, and T4. In addition to the vowels that occur in both languages and only in English, each of the bilingual children produced the Spanish low mid vowel [a] at each point of data collection. EO children did not produce this vowel at any time.

Spanish Vowel Inventories

All bilingual children produced all five of the Spanish vowels; [i, e, a, u, o] in their Spanish samples at every data collection point.

Relational Analyses

Consonant Errors

Percent consonants correct. PCC was calculated to the nearest percentage point. Change in PCC over time is shown in Figure 1. The PCC value for the EO group steadily increased from T1 through T4 as expected. For each of the bilingual children, PCC also increased from T1 to T2 and then from T3 to T4. These increases in PCC range from 3% to 19%. However from T2 to T3, PCC essentially remained the

Table 10

Vowel Inventories: English Data

	T1				T2				T3				T4			
	G	M	S	EO	G	M	S	EO	G	M	S	EO	G	M	S	EO
i	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ɪ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
e	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ɛ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
æ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
a	**X**	**X**	**X**		**X**	**X**	**X**		**X**	**X**	**X**			**X**	**X**	
u	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ʊ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
o	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ɑ		*	X	X	X	X	X	X	X	X	X	X		X	X	X
ə	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
ʌ	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X

Note. X indicates phoneme produced, * indicates phone not targeted in sample, **X** indicates phone not targeted but produced; G=Gabi, M= María, S=Sofía, EO=English only group.

same. Data collection point T2 occurred near the end of the school year (in May or June) and T3 occurred at the beginning of the following school year (in October or November). Between T2 and T3, children were not exposed to English. The lack of change in PCC might have been because they did not hear or produce English regularly between the end of one school year (T2) and the beginning of the next (T3). Table 11 lists PCC values for the bilingual children and the EO group.

Table 11

Percentage of Consonants Correct

	Gabi				María				Sofía				English Only			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
age	3;6	3;10	4;4	-	3;5	3;9	4;5	4;10	3;11	4;4	4;10	5;2	3;7	4;0	4;6	4;11
C	61	78	79	-	60	79	79	87	69	85	84	87	79	86	89	92

Note. Ages for EO group are mean values.

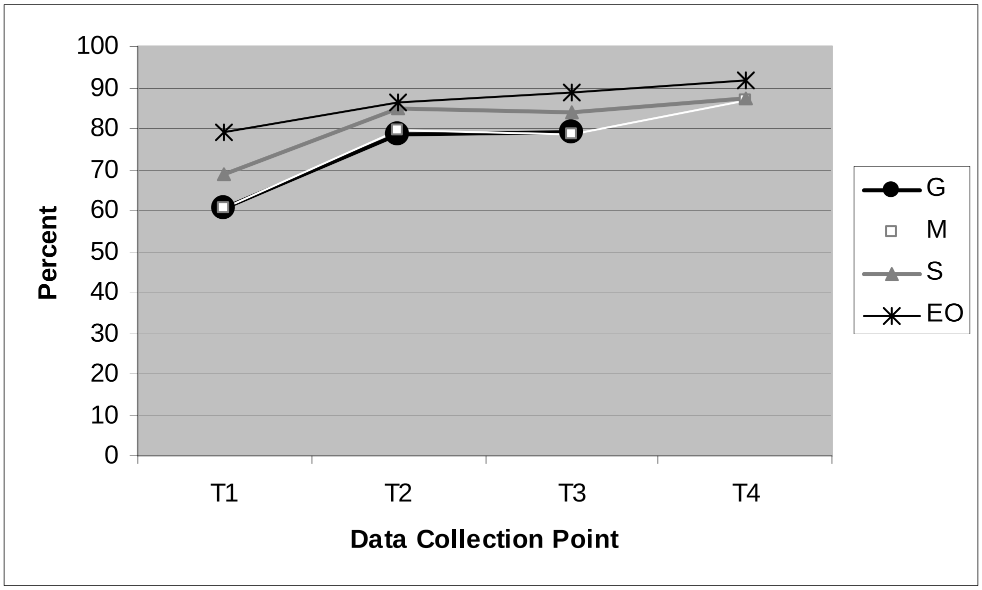

Figure 1 Percentage of consonants correct in English as a function of time.

Error Patterns

The error patterns that were predicted to occur in the children's speech did in fact occur. In some cases the error rates followed a pattern, generally decreasing with time; in others, rates were variable. The patterns that occurred in more than 10% of opportunities for at least two of the bilingual children during at least two of the data collection periods are described below. Error patterns that are still considered typical for monolingual English speakers at the age of 3 years, such as fronting, gliding, and stopping (Smit, 1993) are also described. Table 12 lists the incident rates of these error patterns in English. Table 13 lists rates of errors in Spanish. The following error patterns are described below: (a) consonant substitutions: stopping, velar fronting, gliding, and tap for /ɹ/ substitution; (b) word shape errors: final consonant deletion and cluster errors; and (c) vowel errors: derhoticization, raising and lowering, and lax to tense substitution. Examples of these patterns are listed in Appendix C. Other error patterns, namely backing, spirantization, diphthong reduction, consonant deletion, and syllable deletion did not meet the criteria described above and were therefore not explored further.

Table 12

Percent Occurrence of Error Patterns: English Samples

	Gabi				María				Sofía				English Only			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Consonants																
Fronting	9.3	3.1	1.7	-	50.0	1.9	6.8	6.3	6.6	0.0	10.0	6.6	11.5	2.2	2.6	2.2
Stopping	2.9	14.9	12.7	-	23.1	6.5	3.6	5.3	4.6	3.1	2.8	3.6	5.5	3.6	3.5	3.6
Tap for /ɹ/	5.9	0.0	0.0	-	0.0	0.0	11.1	25.0	0.0	12.5	0.0	4.8	0.0	0.4	0.3	0.0
Gliding	3.1	0.0	8.1	-	0.0	9.3	0.0	0.0	5.4	0.0	6.5	0.0	24.2	20.0	12.7	8.2
Backing	0.6	1.1	3.8	-	0.0	1.2	2.2	1.7	2.8	2.1	0.0	5.9	1.4	0.8	0.4	0.5
Spirantized	2.6	7.4	1.9	-	4.4	0.7	3.2	0.0	1.3	3.3	2.6	1.3	1.4	0.7	0.4	0.3
Vowels																
Raising	13.8	8.7	8.1	-	22.7	8.6	7.7	8.5	12.4	11.6	12.1	2.7	2.5	2.8	2.2	0.8
Lowering	7.5	14.6	8.7	-	26.1	9.2	13.6	8.9	13.1	15.2	9.7	12.8	4.5	3.3	2.2	1.0
Lax to tense	8.5	14.8	4.1	-	0.0	12.2	10.9	35.7	20.0	8.0	25.0	20	5.5	2.0	2.2	0.6
Derhoticized	15.2	25.0	14.7	-	0.0	25.0	6.1	5.9	17.7	18.8	12.5	11.4	29.6	20.6	26.7	16.5
Diph reduction	9.5	0.0	4.6	-	25.0	6.7	0.0	0.0	4.4	0.0	2.7	4.6	5.6	3.1	2.1	1.1
Word shape																
Final consonant deletion	18.2	19.0	16.3	-	46.2	14.7	17.1	13.1	26.3	5.5	2.4	7.0	8.7	8.2	5.9	3.8

Percent Occurrence of Error Patterns: English Samples (cont.)

	Gabi				María				Sofía				English Only			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Total consonant deletion	8.3	8.6	7.7	-	16.2	7.3	8.0	5.2	10.9	2.3	1.8	3.0	3.9	3.5	2.9	1.5
Syllable deletion	3.3	0.0	3.0	-	0.0	3.8	3.2	0.0	1.6	0.0	3.1	0.0	4.8	3.0	1.7	1.5
Cluster reduction	14.5	0.0	6.0	-	20.0	11.7	4.5	3.2	25.7	23.1	11.1	4.4	4.8	3.8	2.6	2.9
Cluster errors	67.0	56.0	58.0	-	100.0	61	61.0	45.0	72.0	50.0	50.0	41.0	-	-	-	-

Table 13

Percent Occurrence of Error Patterns: Spanish Samples

	Gabi				María				Sofía			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Consonants												
Stopping	6.3	6.1	12.4	3.5	9.2	5.3	6.0	9.5	4.3		1.8	1.8
Fronting	0.0	0.0	2.0	2.0	0.0	2.0	2.0	0.0	0.0		0.0	0.0
Backing	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Gliding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Spirantization	2.1	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0		1.1	0.0
Vowels												
Lax to tense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Raising	2.8	2.7	5.0	2.8	2.7	0.8	0.8	1.6	7.1		1.2	1.2
Lowering	4.2	3.8	2.1	1.1	1.0	0.0	0.5	0.5	0.5		0.5	0.6
Word shape												
Final consonant deletion	6.7	22.2	0.0	3.0	8.1	2.9	0.0	0.0	8.6		0.0	2.9
Total consonant deletion	4.0	4.4	1.9	0.8	1.5	0.8	0.4	0.0	1.5		0.4	1.2
Cluster reduction	2.7	0.0	1.3	1.4	0.0	0.0	0.0	1.3	2.6		0.0	0.0
Syllable deletion	6.3	1.9	3.7	1.6	5.2	5.4	0.0	0.6	4.7		0.0	2.3

Stopping. With the exception of Gabi, in general stopping errors decreased and then leveled out with time among the three bilingual children. The EO group showed a similar trend but leveled out before the bilinguals. Figure 2 shows how stopping rates changed over time for all children. At T1, María had more stopping incidences, 23.1%, than the EO which had 5.5%; Gabi with 2.9% had fewer, as did Sofía with a rate of 4.6% stopping. By T3, Gabi and Sofía had similar stopping rates, 3.6% and 2.8% respectively, to the EO average of 3.5%. Their stopping rates remained similar to those of the EO at T4. With the exception of Sofía, a similar downward trend was not observed in stopping rates of the Spanish data. Gabi's Spanish stopping rate was 6.3% at T1 and decreased to 3.5% by T4 but was variable in between. María's rates were similar at T1 and T4, 9.2% and 9.5% respectively, with lower rates at T2 and T3 (5.3% and 6.0%).

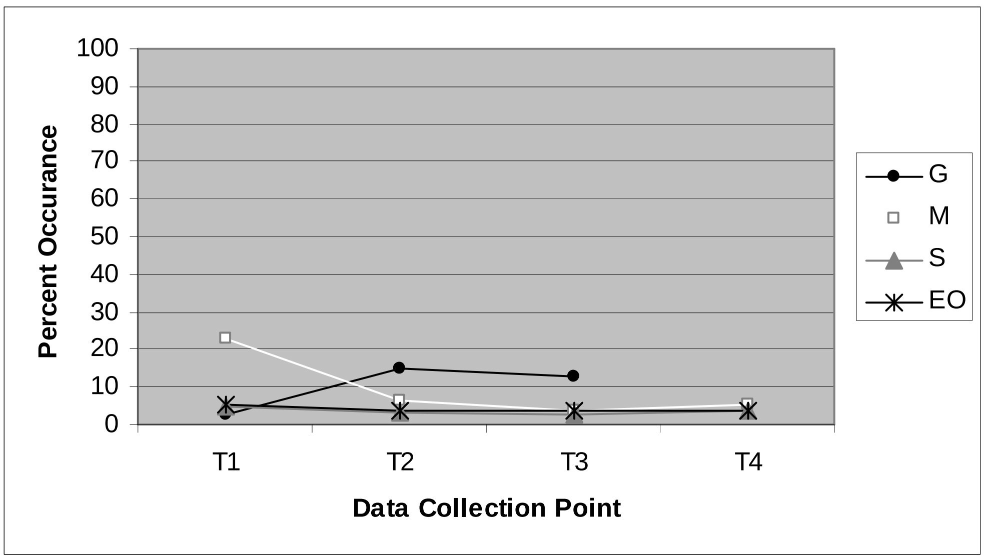

Figure 2 Stopping rates in English as a function of time.

Velar fronting. All children, monolingual and bilingual, produced fewer fronting errors at T4 than at T1. However at T2 there were fewer or the same number of instances as at T4. From T2 to T3, María, Sofía, and the EO increased their fronting errors; Gabi showed a decrease in fronting. Bilingual and monolingual children produced similar types of fronting errors, such as producing /g/ as [d] in the word *goose* (gus → dus). Additionally, bilinguals produced few fronting errors, ranging from 0% to 2% in their Spanish samples. See Figure 3 for fronting rates.

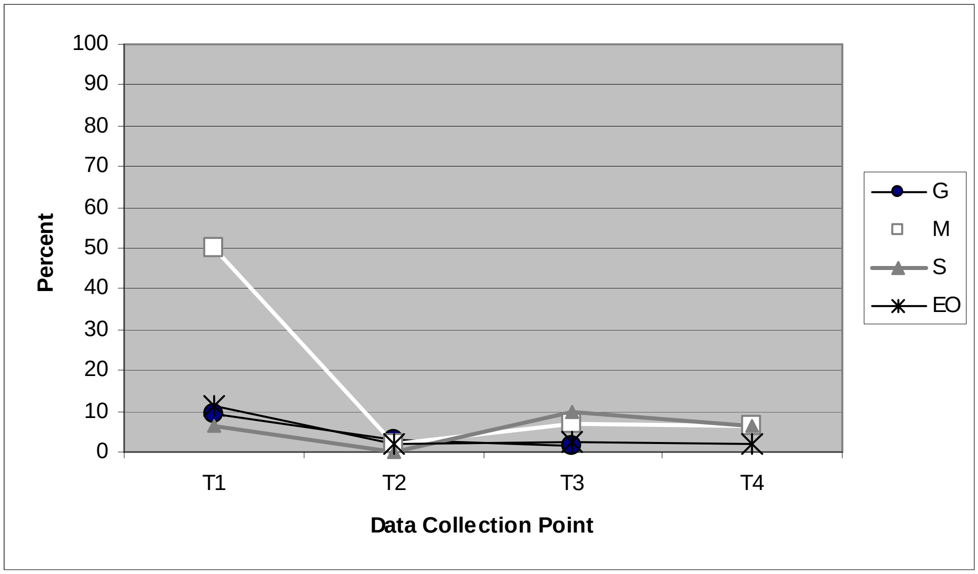

Figure 3 Velar fronting rates in English as a function of time.

Tap for /ɹ/ *substitution.* A common yet variable error noted was substituting the tap, [ɾ], for /ɹ/ in words such as *drum* (produced as [dɾʌm]). This pattern occurred in up to 25% of opportunities for María at T4 and not at all at T1 and T2. Gabi made the substitution in 5.9% of opportunities at T1 but not at all at T2 and T3 and Sofía substituted the tap in up to 12.5% of occurrences at T2 and not at all at T1 and T3. These error rates neither increased nor decreased consistently with time for the Gabi and Sofía but did increase with time for María. Throughout the study, the EO group had a tap for /ɹ/ substitution rate of less than 0.5%. See Figure 4.

Gliding. Gliding occurred at a considerably lower and more variable rate for the bilingual children than for the EO group. From T1 through T3 Gabi's rates were: 3.1%, 0%, and 8.1%. María's gliding rate was 0% at all points except T2 when it was

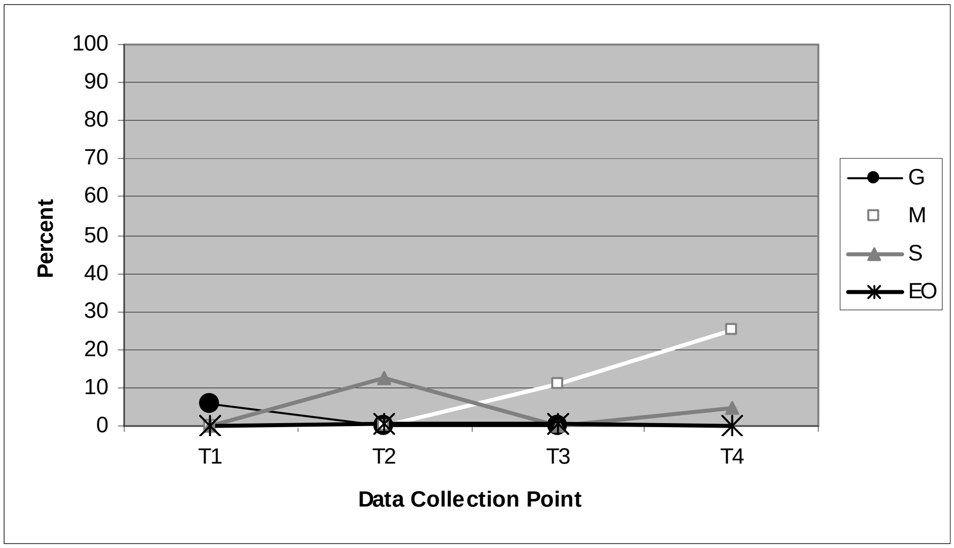

Figure 4 Tap for /ɹ/ substitution rates in English as a function of time.

9.3%. From T1 through T4 Sofía's rates were: 5.4%, 0%, 6.5%, and 0%. In most cases the bilingual children either substituted a tap or glide for /ɹ/, but not both. At T3 Gabi did not use the tap substitution but glided 8.1% of the time; Gabi did not use the substitution at T2 and Sofía did not use it at T1 and T3. Their gliding rates were 9.3%, 5.4%, and 6.5% at those times respectively. María did not use gliding at T3 and T4 and her rates of tap substitution were 11.1% and 25% respectively. Sofía did not substitute a tap for /ɹ/ at T1 and T3 but her gliding rates were 12.5% and 4.8% at those times. The EO group rates in order were 24.2%, 20%, 12.7% and 8.2%. Gliding was not observed in the Spanish samples. See Figure 5 for gliding rates.

Specific Consonant Accuracy Rates

Overall, monolingual accuracy rates for consonants were greater than bilingual rates in all samples. This was particularly true for the English-only phoneme /z/ which ranged from 0% to 33% correct at T1 for bilinguals and 73% for monolinguals and for

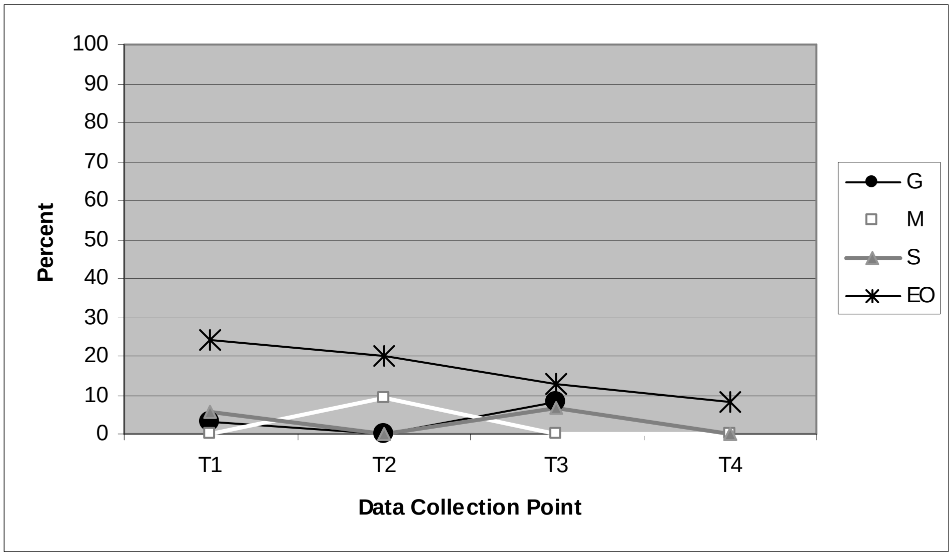

Figure 5 Gliding rates in English as a function of time.

the phoneme /ʤ/ which ranged from 38% to 50% for bilinguals at T1 and 81% for monolinguals. See Table 14 for rates. By T4 accuracy for /z/ was 0% for Gabi, 20% for María, 57% for Sofía, and 97% for the EO group. Accuracy for /ʤ/ was 29% for Gabi, 75% for María, 20% for Sofía and 92% for the EO group. Bilingual children produced other consonants with lower accuracy rates at T1 but had similar rates by T4. The English-occurring phoneme, /v/ for example, was produced accurately 0% to 50% of the time at T1 by bilinguals and 69% accurately by the EO group. By T4 both Gabi and Sofía had 67% accuracy rates and the EO accuracy was 69%. Additionally, by T4 all stops other than /d/ and /g/ were produced with similar accuracy rates ranging from 89% to 100% for the bilingual children and from 91% to 99% for the monolingual children.

In a few exceptions, bilingual children had higher accuracy rates than the monolingual children. For example, at T1 bilingual accuracy rates for /f/ ranged from 89% to 100% whereas the monolingual rate was 62% despite developmental norms suggesting that both Spanish and English speakers have mastered the sound by the age of 3 years. Also, /ɹ/ accuracy rates were higher for bilinguals at all data collection points. Bilingual accuracy ranged from 56% to 91% at T1, 50% to 88% at T2, 72% to 95% at T3, and 75% to 90%at T4. Corresponding monolingual English rates were 75%, 67%, 68% and 79% respectively.

Table 14

Individual Consonant Accuracy Rates: English

	Gabi				María				Sofía				English Only			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
b	73	70	100		44	74	86	93	74	100	80	90	94	96	96	98
p	85	100	89		100*	88	83	100	93	100	96	100	88	95	96	99
d	33	80	70		40	44	56	67	50	60	80	64	82	74	86	91
t	84	91	81		-	84	77	92	76	87	87	81	84	88	87	91
g	71	67	71		-	62	79	60	38	67	77	71	85	90	92	94
k	85	95	94		50	94	89	89	94	94	89	97	90	97	94	96
ʔ	-	-	100*		-	-	-	-	100*	100*	100*	-	100	100	100	100
ɾ	-	-	60		-	50	60	100*	0	-	100*	80	79	72	77	85
v	0*	33*	67*		0*	50*	33*	33*	50*	0*	67*	67*	69	58	68	69
f	89	91	90		100*	75	95	100	90	100	95	100	62	97	95	92
ð	0*	33*	50		-	20	29	0	100*	100*	33*	67*	50	47	31	58
θ	20	100*	0		0*	0	33*	67*	100*	100*	43	43	33	27	38	40
z	0*	0*	0		-	40	38	20	33	67	91	57	73	84	86	97
s	74	89	89		100	95	94	97	69	78	78	96	81	94	92	94
ʃ	25	75	0		-	100	100*	100	100	100*	100	75	73	89	84	83
h	67	100*	100		-	100	83	100*	67	50*	83	-	97	96	96	100
ʤ	50	25	29		-	43	75	75	38	100	67	20	81	92	88	92
ʧ	63	17	63		-	100	75	100	75	50	100	100	80	92	92	93
l	62	50	48		25	62	58	69	48	67	80	66	55	61	80	82
w	67	100	0*		-	67	86	100	67	100	-	100	84	91	95	94
ɹ	56	89	95		-	50	72	75	91	88	90	90	75	67	68	79
j	60	50*	100		-	50*	80	50*	100	100*	100	100	76	86	87	92

Individual Consonant Accuracy Rates: English (cont.)

	Gabi			María				Sofía				English Only			
m	93	50*	73	-	90	86	75	73	100*	90	100	95	96	96	97
n	100	88	92	71	81	84	100	57	100	100	100	94	96	96.	99
ŋ	50	75	80	-	100	83	67	36	75	60	80				

Note. * = value based on 2 or 3 production opportunities, - = no opportunities

Word Shape Errors

Final consonant deletion. Overall, final consonant deletion (FCD) errors decreased with time for both bilingual and monolingual children. With only two exceptions, Sofía at both T2 and at T3, all rates were higher for bilingual children than for monolingual children. Figure 6 shows FCD rates for all children. At T1 the EO rate, 8.7%, was dramatically lower than bilingual rates which ranged from 18.2% for Gabi to 46.2% for María. Bilingual rates of FCD came closer to those of the EO group with time. At all times in all children with the exception of one instance, bilingual children deleted a higher percentage of final consonants in their English samples than their Spanish samples. Gabi's rate of FCD in her Spanish sample ranged from 3.0% to 22.2%; María's ranged from 0% to 8.1%; and Sofía's ranged from 2.9% to 8.6%.

Total consonant deletion. In general, fewer consonants were deleted by both bilingual children and the EO group with time. Gabi's rate of total consonant deletion at T1 was 8.3% and by T3 it was 7.7%. María and Sofía's rates at T1 were 16.2% and 10.9% respectively and by T4 they were 5.2% and 3.0%. Both María and Sofía showed the same plateau as they did with PCC from T2 to T3. Figure 7 displays total consonant deletion rates as they change over time.*Clusters.* Incidences of cluster reduction in English samples decreased overall from T1 to T4 in both bilinguals and monolinguals, with the exception of Gabi who did not reduce any clusters at T2 but did reduce at T3. Cluster reduction rates are shown in Figure 4. Bilingual children's rates ranged from 14.5% to 25.7% at T1 and by T4 were down to 3.2% to 4.4%.

Additionally all cluster errors, including reduction, epenthesis, substitution, and deletion, also decreased from T1 to T4 for all bilingual children. Rates ranged from

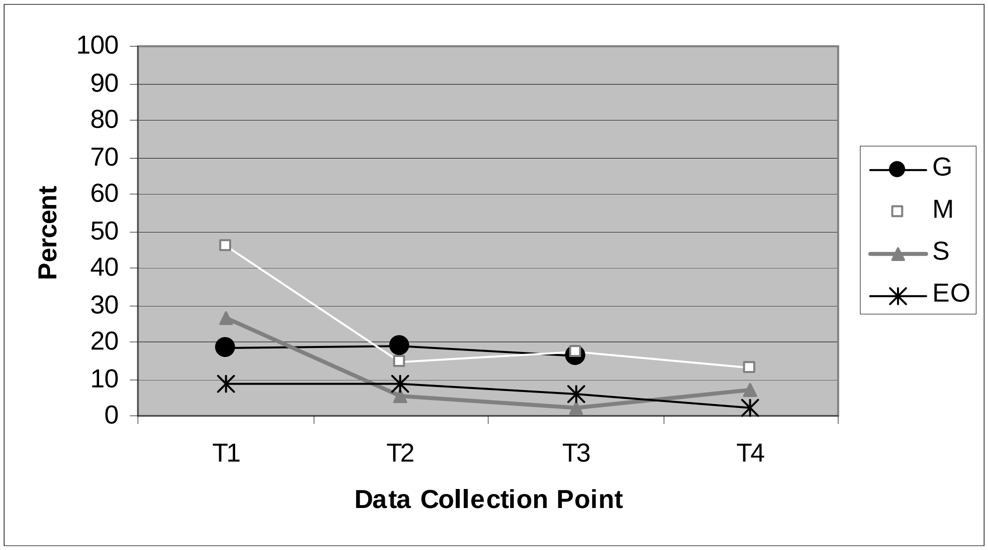

Figure 6 Final consonant deletion rates in English as a function of time.

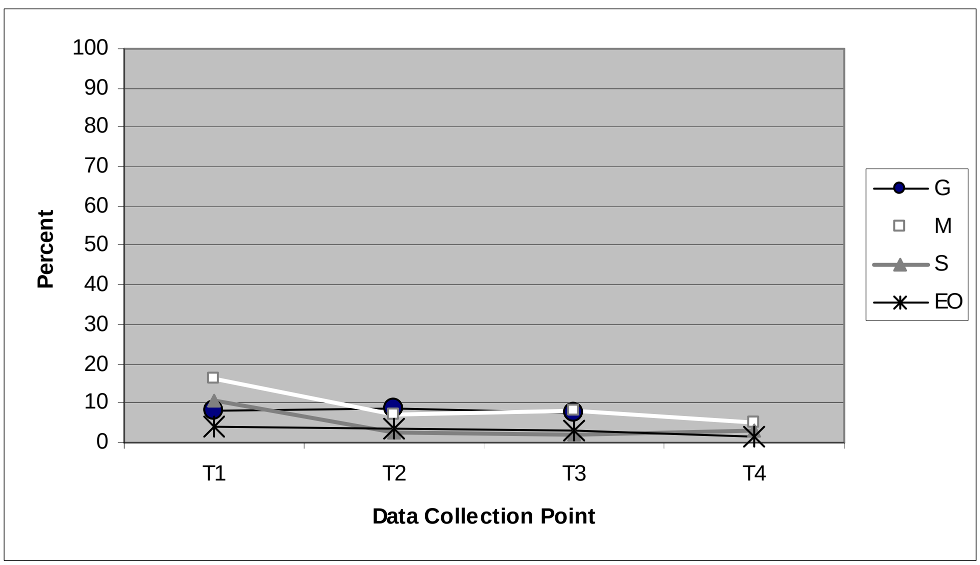

Figure 7 Total consonant deletion rates in English as a function of time.

67% to 100% at T1 and from 41% to 45% by T4. Cluster errors are shown in Figure 8. Interestingly, the error rate from T2 to T3 leveled out for all bilingual children similar to the change in PCC rates from T2 to T3.

Bilingual children reduced few clusters, and often none, in their Spanish samples. Zero clusters were reduced by Gabi at T2; by María at T1 through T3; and by Sofía at T3 and T4. Rates in all Spanish samples were less than 3% and the incidence of cluster reduction varied rather than increasing or decreasing with time.

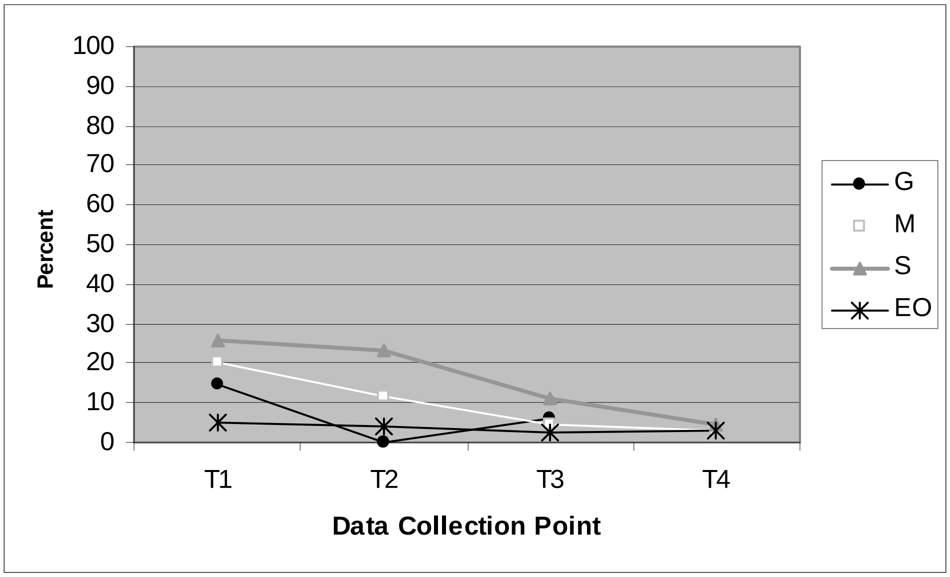

Figure 8 Cluster reduction rates in English as a function of time.

Vowel Errors

Percent vowels correct. Percent of English vowels correct (PVC) increased in all children at all time points, except for María whose PVC remained the same from T3 to T4. PVC is listed in Table 15. Values ranged from 53% to 64% at T1 to 73% to 77% at T4. The plateau shown in the increase of PCC values between T2 and T3 for bilingual children did not occur for PVC. Figure 9 shows how PVC values change with time. At each time of data collection PVC is higher for the EO, which was 84% at T1 and 92% at T4, than for the bilingual children. Also, the average difference between PVC values for the EO and for the bilinguals, 21%, is greater than the difference in PCC values for the two groups which is 9% on average.

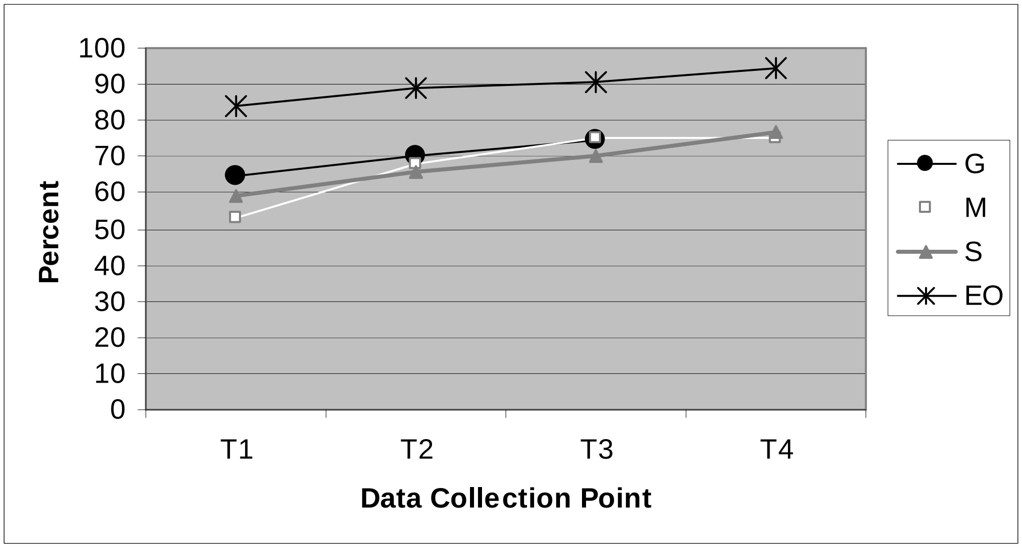

Figure 9 Percentage of vowels correct in English as a function of time.

Table 15

Percentage of Vowels Correct

	Gabi				María				Sofía				English Only			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
age	3;6	3;10	4;4	-	3;5	3;9	4;5	4;10	3;11	4;4	4;10	5;2	3;7	4;0	4;6	4;11
%	64	70	75	-	53	68	74	73	59	66	70	77	84	89	90	95

Note. Ages for EO group are mean values.

Derhoticization. Bilingual children substituted rhotic vowels, /ɚ, ɑɹ, ɔɹ, ɛɹ, ɪɹ/ with non-rhotic vowels with the same or lower frequency than the EO. At T1, monolinguals had a derhoticization rate of 29.6% and the highest bilingual rate was Sofía’s at 17.7%. Gabi had a 0% rate but she only had one opportunity to produce a rhotic vowel, in the word *four*, due to her shortened sample. Incidentally, María and Sofía both produced the rhotic vowel in *four* as well. By T4 both bilingual children as well as the EO had lower rates of derhoticization than at T1 with the bilingual children's rates, ranging from 5.9% to 14.7%, still slightly lower than the EO with a rate of 16.5%. Figure 10 displays derhoticization rates for all children. Rhotic vowels do not occur in Spanish.

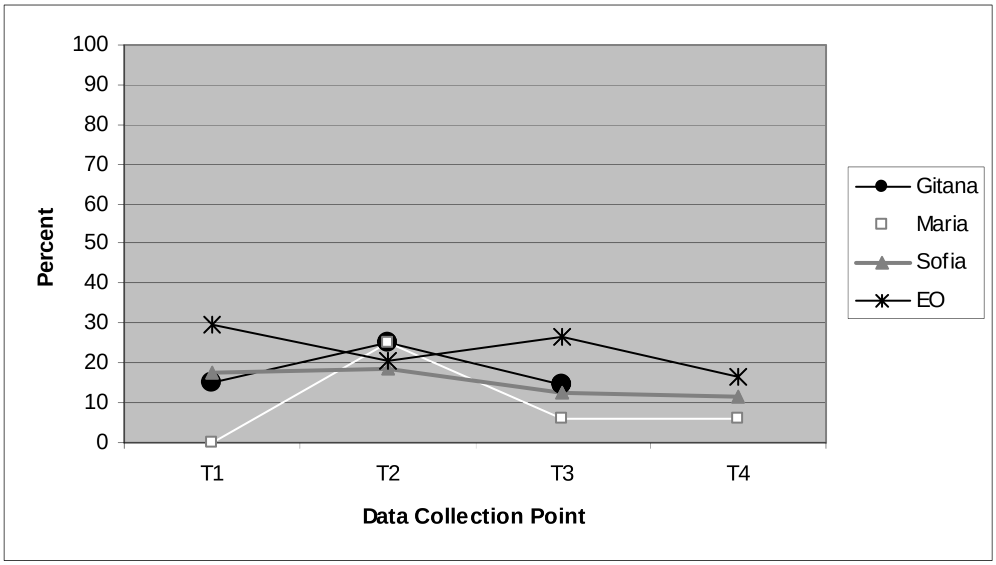

Figure 10 Derhoticization in English as a function of time.

Vowel raising and lowering. Overall the incidences of raising vowels decreased from T1 to T4, changing from 13.8% to 8.1%, 22.7% to 8.5%, and 12.4% to 2.7% for Gabi, María, and Sofía respectively. The vowel lowering rate decreased overall for María, from 26.1% to 8.9%, and remained about the same for Gabi and Sofía at approximately 8.0% and 13% respectively. In most cases, María and Sofía lowered their vowels more often than they raised them. Lowering rates for María from T1 through T4 were 26.1%, 9.2%, 13.6%, 8.9% and raising rates were 22.7%, 8.6%, 7.7%, and 8.5%. For Sofía the lowering rates were 13.1%, 15.2%, 9.7%, and 12.8% and raising rates were 12.4%, 11.6%, 12.7%, and 2.7%. The EO both raised and lowered fewer vowels than their bilingual counterparts at every point in time and showed a slow but steady decrease in these types of vowel errors. The EO group's rates of raising vowels were 2.5%, 2.8%, 2.2%, and 0.8% in order from T1 to T4. Their lowering rates in the same order were 4.5%, 3.3%, 2.2%, and 1.0%. Raising and lowering of vowels were uncommon in the Spanish samples. See Figures 11 and 12.

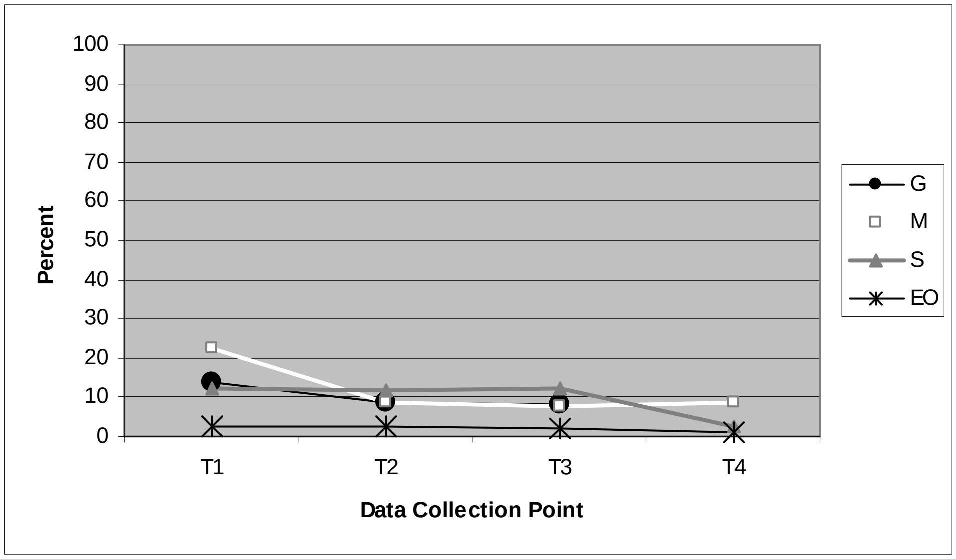

Figure 11 Vowel raising rates in English as a function of time.

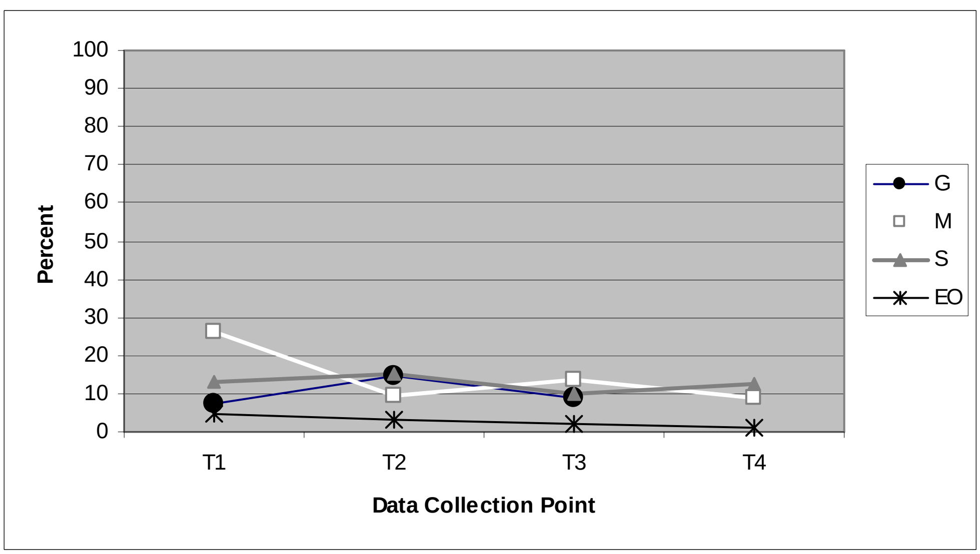

Figure 12 Vowel lowering rates in English as a function of time.

Lax to tense vowels. The occurrence of substituting a tense vowel for a lax vowel increased overall for María from T1 at 0% to T4 at 35.7%; decreased for Gabi from T1 at 8.5% to T4 at 4.1%; and remained the same at 20% for Sofía. At nearly all data collection points, the EO made fewer lax to tense substitutions, ranging from 0.6% at T1 and 5.5% at T4, than the bilingual children. The exception was at T1 when Gabi produced a shortened sample and did not make these substitutions. The majority of tense substitutions for lax vowels were raised from the target vowel. For example, a common error was to substitute the tense vowel /i/ for the lax vowel /ɪ/ in words such as *sick*. Figure 8 shows the change in tense for lax vowel substitutions with time.

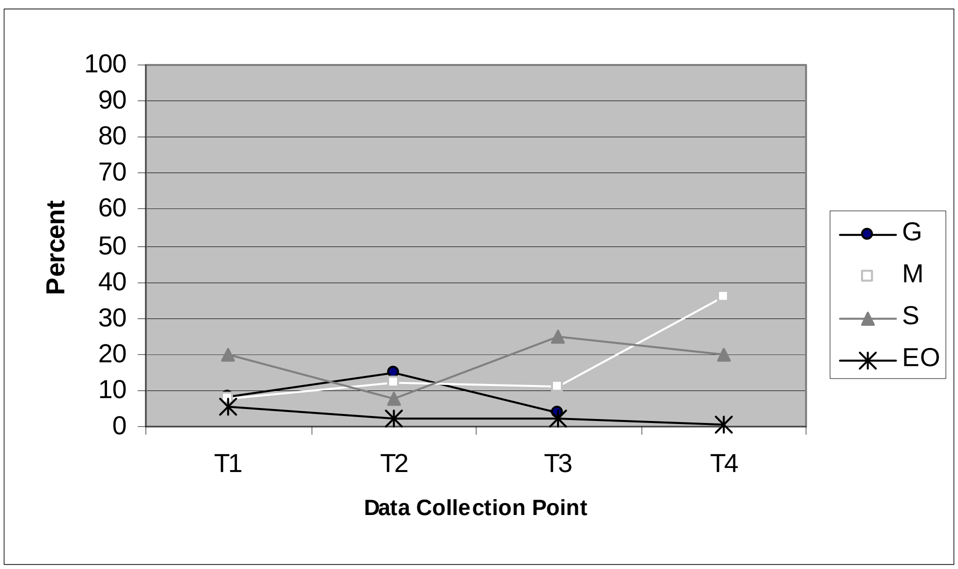

Figure 13 Tense for lax vowel substitution rates in English as a function of time.

Specific Vowel Accuracy Rates

Similar to consonants, vowel accuracy rates were greater for the EO group than for the bilingual children. They ranged from 82% to 99% for all vowels at all times for the EO group and from 0% to 100% for the bilingual children. See Table 16 for specific accuracy rates. The greatest differences were in the English-occurring vowels /ɑ/, /ʌ/, and /ə/ which had accuracy rates below 50% in more than half the bilingual samples and above 80% in all EO samples. See Figure 14, Figure 15, and Figure 16 for comparison. One exception was the English- and Spanish-occurring vowel /i/ which the monolinguals and bilinguals produced with similar accuracy from T2 through T4. See Figure 17. Bilingual rates ranged from 91% to 100% for all vowels compared to 98% to 99% for monolinguals at all times. Figures 14 through 19 illustrate the variability of the percentage of specific vowels produced correctly by the bilingual children. In contrast, the EO group rates gradually increase with time in each case.

Table 16

Individual Vowel Accuracy Rates: English

	Gabi			María				Sofía				English only			
i	55	100	91	67*	90	93	100	100	100	100	100	90	98	99	99
ɪ	90	75	84	-	81	61	50	67	85	79	63	88	92	92	98
e	60	100	100	100*	36	92	100	82	100	80	100	92	93	98	97
ɛ	92	63	87	100*	79	53	71	75	75	44	60	90	89	94	96
æ	35	57	53	0	67	59	91	56	71	79	70	83	95	97	97
u	90	100	80	100*	89	90	89	90	89	89	90	82	97	94	99
ʊ	0	0	100*	50*	75	33*	100*	75	100	75	100*	83	87	92	97
o	80	75	50	-	60	86	25	80	100	100	100	93	91	91	99
ɑ	0	29	43	-	18	75	75	33	43	7	100	91	92	92	98
ə	69	60	79	33	70	89	90	31	83	71	61	82	81	89	96
ʌ	50	50	2	-	20	50	44	18	29	18	42	90	93	92	98

Note. * = value based on 2 or 3 production opportunities, - = no opportunities

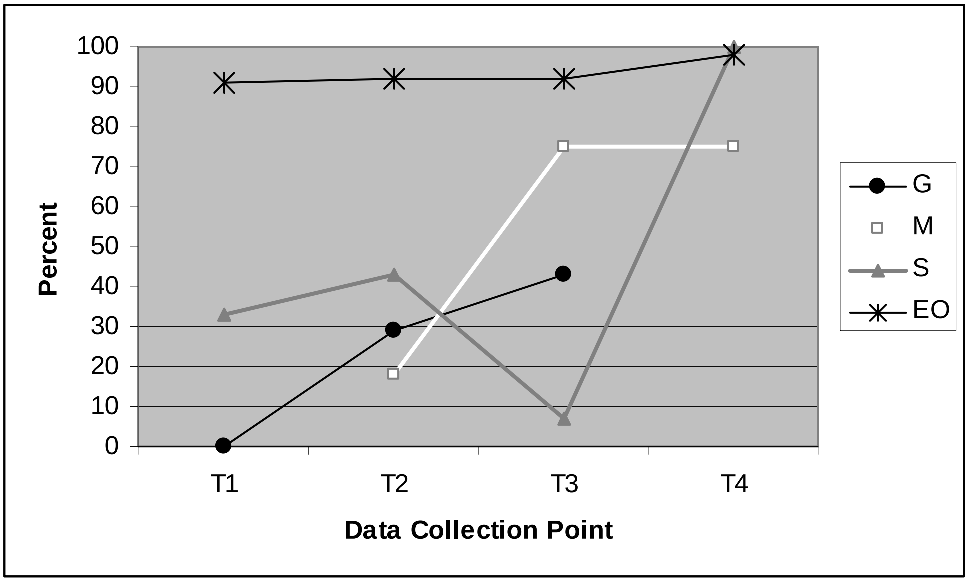

Figure 14 Percentage correct /*a*/ production in English as a function of time

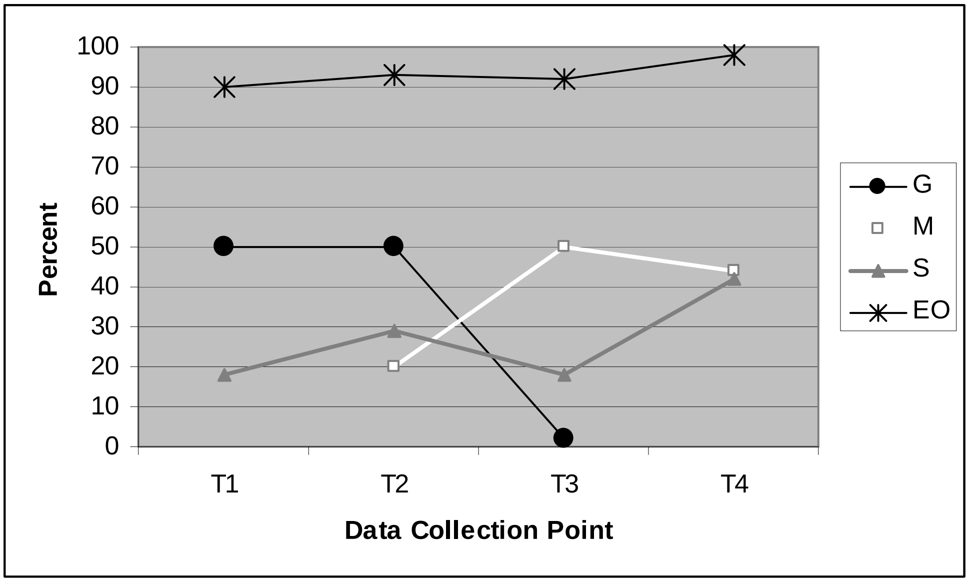

Figure 15 Percentage correct /ʌ/ production in English as a function of time

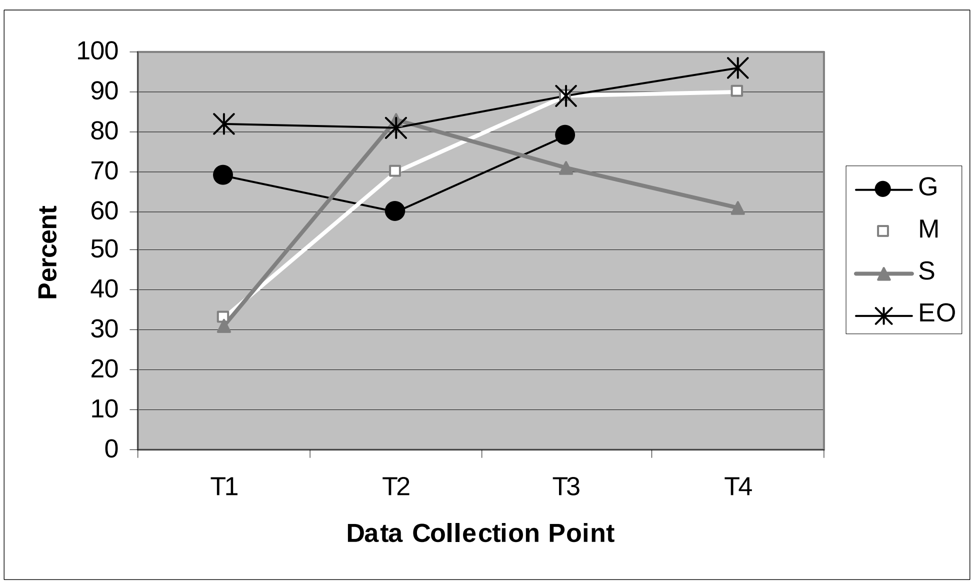

Figure 16 Percentage correct /ə/ production in English as a function of time

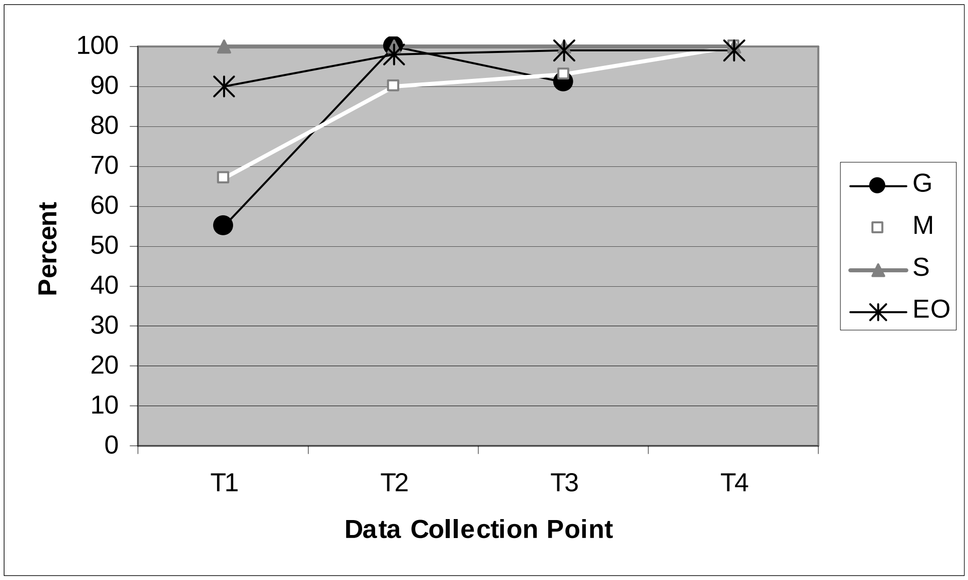

Figure 17 Percentage correct /ɪ/ production in English as a function of time

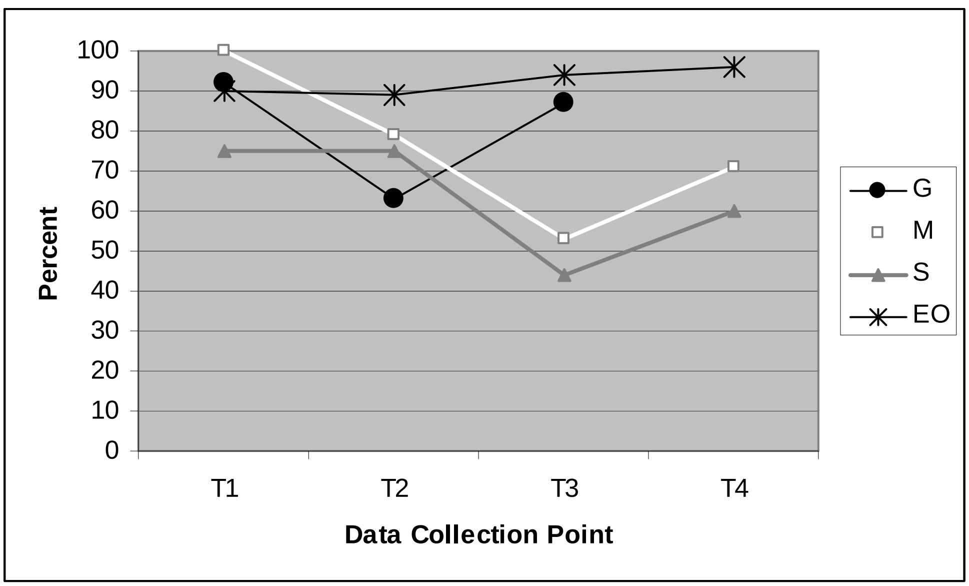

Figure 18 Percentage correct /ɛ/ production in English as a function of time

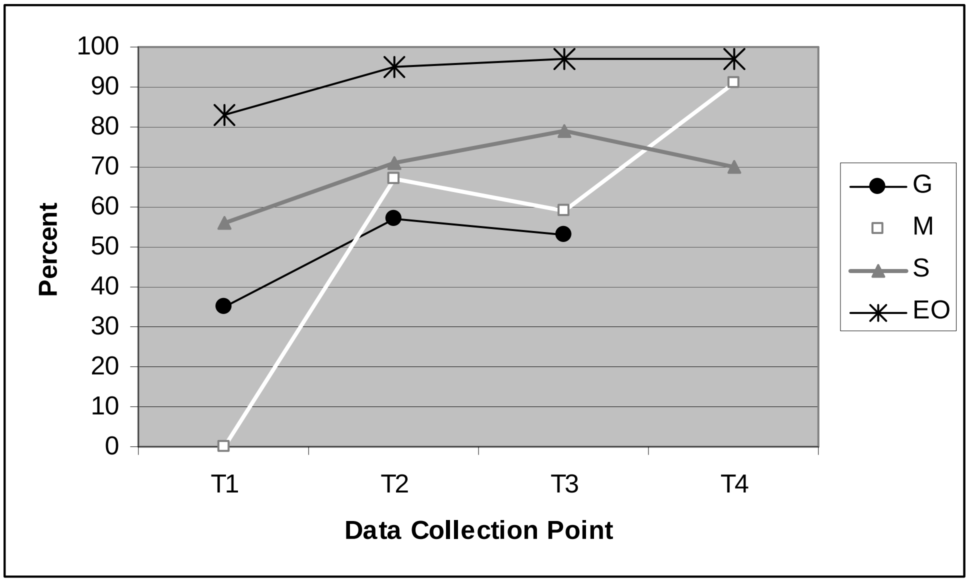

Figure 19 Percentage correct /æ/ production in English as a function of time

Chapter V: Discussion

The purpose of this study was to describe English speech sound characteristics of three sequential Spanish-English bilingual children as they began learning to speak English. The study began just after their initial regular exposure to English, between the ages of 3;5 and 3;11, and continued for almost 2 years until children were aged 4;10 to 5;2. Bilingual children's English productions and error patterns were analyzed and compared with their own Spanish speech sound productions as well as with average data from a group of monolingual English speakers within similar age ranges.

The first hypothesis of this study was that at T1, phonetic inventories would be the same in English and Spanish. This was not found to be true. The second hypothesis of this study predicted that Spanish-English bilingual children would produce Spanish-influenced speech sounds and word shapes while speaking English which was shown to be true. The third hypothesis, which was accurate, posited that errors would lessen and accuracy would increase as the bilinguals were exposed to English for a longer period of time. The fourth hypothesis, that bilinguals would produce more incorrect consonants and vowels in English than monolingual English speakers, was also true. Results suggest that (a) some errors that are typical for monolingual English children were also common for the bilingual speakers, (b) some errors seemingly occurred because English was not their first language and they had therefore just begun producing the new words and sounds of English, (c) other errors were influenced by the sounds and words of Spanish, their first language. Almost all errors decreased as children heard and spoke more English and with natural development. In general, bilingual children's errors tended to decrease more rapidly than monolingual children's errors.

The findings for each hypothesis will be presented below with descriptions of how the results changed over time and comparisons to the EO group. Specific examples will be given with possible reasons for the errors such as Spanish-influence or developmental factors. Next, the relationship between the results of this study and perceptual theories of speech acquisition will be outlined as well as implications for the results as they relate to the field of speech-language pathology. Finally, a possible framework for understanding sequential bilingual speech acquisition will be suggested and limitations of the study will be described.

Phonetic Inventory Comparison

The first hypothesis of this study was that at T1, the bilingual children's phonetic inventories would be the same in English and Spanish. The inventories were not the same, but they had several similarities. All of the bilingual children did use Spanish-influenced consonants and vowels that are not English phonemes in their English samples. Spanish-influenced consonants [β] and [x] were produced multiple times in English words at T1. Typically the substitution was correct for either place or manner; for example, /f/ was replaced by [β] in the word *butterfly*. In this instance, both the target and the production were fricatives, however the target was a labiodental whereas the production was a bilabial. All children also substituted the Spanish-influenced vowel [a] for vowels close in the vowel space, namely /æ, ɑ, ʌ, ə/. Additionally, all children used English-influenced phones in their Spanish samples that they had also produced for their English samples, such as [z, h, ʤ, ɪ, ɛ, ə, ʊ]. The most common English-influenced phoneme produced in Spanish samples was [ɪ], often substituted for /e/. These results also suggest similarity between the children's Spanish and English inventories and are similar to results found by Gildersleeve-Neumann, Peña, Davis and Kester (2009) as described above. Gildersleeve-Neumann and colleagues attributed vowel errors to a reorganization of the phonological system, not to loss of abilities, suggesting that these errors should not be viewed as regression in speech development. The results of this study, which show an overall improvement from T1 to T4 in both L1 and L2, despite variability in between, support this view and suggest that eventually bilinguals will approach the fluency of monolingual speakers in both L1 and L2.

Despite similarities in Spanish and English inventories, there were in fact Spanish-phonemes produced by participants in their Spanish samples but not in their English samples, including /r, ɣ, ɲ/, which leads to different Spanish and English inventories. All bilingual children also produced many English-only phonemes in their English samples that they did not use in their Spanish samples once again showing that their inventories were not the same in English and Spanish. These English-only phonemes included some of the phonemes that are later acquired in English monolinguals such as consonants [ʃ, ɹ, v] which are often not acquired until ages 4 to 6 years (Arlt and Goodban, 1976; Templin, 1957) as well as the allophonic glottal stop and vowels [ɑ] and [ʌ].

Spanish Influenced English

The second hypothesis of this study predicted that Spanish-English bilingual children would produce Spanish-influenced speech sounds and word shapes while speaking English. This hypothesis was shown to be true. All bilingual children used Spanish phonemes within their English samples beginning at T1, as described in the paragraph above, and continuing through T4, after almost two years of English exposure. Children continued to produce the target place, but changed the manner as in the case of the bilabial fricative [β] substituted for the bilabial stop /b/ which occurred several times. In other instances bilinguals produced the target manner but changed the place, for example, substituting the velar fricative [x] for the alveolar fricative /s/ in a word such as *dinosaur* (dajnɪsɔɹ→dajnɪxɔɹ). Another common influence of Spanish on English productions was tap for /ɹ/ substitutions in words such as *carrots* (kɛɹɪts→kɛɾɪts). While the EO group had tap substitution rates ranging from 0% to 0.4%, gliding more often than substituting the tap for /ɹ/, the bilingual children had greater error rates, substituting the tap 4.8% to 25% of the time. See Appendix C for other examples of Spanish-influenced phonemes produced in English words. Bilingual children also commonly raised and lowered vowels to produce an actual Spanish vowel, for example raising /ɪ/ to /i/ in the word *big*. Bilingual children also produced vowels that were closer than the English vowel to the Spanish vowel, for example slightly raising /ʊ/ to produce a vowel between /ʊ/ and the Spanish-influenced /u/ in the word *cookies*. EO group rates of raising and lowering vowels was considerably lower than those of the bilingual children's, as were their rates of lax to tense vowel substitution. These substitutions overlap with raising and lowering vowel rates in examples such as /bɪg/ to [big] described above. The English only low vowels, /æ/ and /ɑ/, and mid vowels, /ə/ and /ʌ/ were commonly substituted by the Spanish-influenced low central vowel [a]. For example, a bilingual child produced /kap/ in place of /kʌp/ whereas the EO group never made this error or similar ones.

As also predicted in the second hypothesis, bilingual children often deleted final consonants and reduced clusters to follow the phonotactic rules of Spanish. At T1, bilingual children's final consonant deletion rate ranged from 18.2% to 46.2% whereas the EO group had a rate of 8.7%. By T4 both remaining bilingual children had a reduced rate of final consonant deletion, ranging from 7% to 13.1%, which was still higher than the EO group rate of 3.8%. Children also deleted final consonants in their Spanish samples. This suggests that some of these errors are developmental while others might be influenced by Spanish. Cluster reductions also tended to create word shapes that would be permissible in Spanish, for example, changing the initial cluster /sn/ to [n] in the word *snake.* Final cluster reduction often reflected the Spanish phonotactic rule allowing only /l/, /ɾ/, /d/, /n/, and /s/ to end words, for example eliminating the last consonant in a final cluster, such as [d] in the cluster /nd/, so the word would end in [n]. At T1, all reduced clusters produced by two bilingual children were reduced so that the final consonant was permissible in Spanish. For the third child the rate was five out of nine clusters reduced in this manner.

Change in Accuracy

The third research hypothesis was that the errors described above would lessen and accuracy would increase as the bilinguals were exposed to English for a longer period of time. The occurrence of nearly all error patterns did lessen with time and exposure to English as well as with general development. Stopping errors lessened with time partially due to exposure to English and partially due to development. Bilinguals and monolinguals had similar rates of stopping consonants and bilinguals' Spanish samples also had similar rates as their English samples, suggesting developmental factors as the reason for stopping. In addition, bilingual and monolingual children made similar stopping errors in their English samples, such as substituting /t/ for /θ/ in words such as *three.* Bilingual children also produced some stopping errors in their Spanish samples that were similar to those in their English samples such as changing the bilabial fricative /β/ to /b/ in words such as *bebe* (beβe→bebe). Stopping errors in which English-only sounds were replaced by stopped sounds that occur in Spanish may be due to learning a L2. For example, when a bilingual child produced a stopping error in the word *seven,* (sɛvɪn → sɛbɪn) the English-only consonant /v/, which was a new sound for the bilingual children, was replaced by /b/ which occurs in Spanish, their L1. However, this error was also made by EO children and may have been developmental.

Both PCC and PVC also increased overall for all children, which indicate fewer errors. PCC increased by16% to 19% from T1 to T2 and by 3% to 8% from T3 to T4, but leveled-out between T2 and T3 for all bilingual children. The plateau observed in the bilingual children occurred after summer vacation, a time when bilingual children were not exposed to English. This lends support to Højen and Flege's (2006) conclusion that both length of time that bilinguals have been exposed to L2 and continually hearing and speaking L2 help bilinguals improve their L2 perception, in this case shown through production. The EO group steadily, but more slowly, increased PCC from T1 to T4; therefore despite higher consonant error rates in the bilingual children than the EO group, the bilingual children's error rates decreased more quickly.

In contrast to the decreasing error rates in the bilingual children's consonant production which approached the EO group's rates, the error rates in vowel production did not approach the EO children's rates. The bilingual children began with PVCs between 53% and 64% and at T4 had rates from 73% to 77%. The EO group began producing 79% of vowels correctly and by T4 accurately produced 92% of vowels. Furthermore, the rates were highly variable but with an overall decrease from T1 to T4 in general. For example, in order from T1 through T4 Sofía accurately produced the phoneme /ɑ/ in 33%, 43%, 7%, and then 100% of opportunities. Gabi produced the phoneme /ə/ with 69%, 60%, and then 79% accuracy at T1, T2, and T3 respectively.

The overall results of greater accuracy in vowel production at T4 compared to T1 in the bilingual children offer support to both the Perceptual Assimilation Model and the Speech Learning theory showing that children perceive the phonemes more accurately and therefore are able to correctly produce them. However, the seemingly random increases and decreases in accuracy from T1 through T3 suggest that both of these models are too simplistic. These results are comparable to Bosch and Sebastián-Gallés' (2003) results which suggested that perceptual reorganization in a bilingual environment is complex and therefore will not necessarily steadily increase or decrease. They might also be compared to the results of Gildersleeve-Neumann, Peña, Davis, and Kester's 2009 study also indicating a reorganization of the phonological system.

Lower Accuracy in Bilingual Children

The fourth hypothesis, that bilinguals would produce more incorrect consonants and vowels in English than monolingual English speakers, was also true, even though the bilingual children met monolingual English developmental norms for the production of all consonants. Starting at T1, within 2 to 3 months of English exposure, the bilingual children, as well as the monolingual children, produced all English stops, liquids, glides and nasals. The PCC and PVC values of the EO children, however, were lower at all data collection times than those of the bilinguals partly due to Spanish influence, for example substituting a Spanish-influenced sound for a similar English-only consonant, and partly due to the inexperience the bilingual children have in speaking their L2. This was particularly true for the consonants /z/ and /ʤ/ which do not occur as Spanish speech sounds. Although /ʤ/ does occur as an allophone in Spanish, it is not part of the dialect of the children in Bosch's study and was only used by one child at T3 when the examiner used the phoneme in her Spanish. See Table 14 for accuracy rates.

Production accuracy for consonants /d/ and /ɡ/ remained lower than other stops throughout the study as well. This might be due to confusion between English /d/ and /t/ and between /ɡ/ and /k/, similar to the perceptual confusion shown by the Italian-English bilinguals in MacKay, Flege, Piske, and Schirru (2001). Additionally, the percentage of correct productions for the vowels, /æ, ɑ, ə, ʌ/ remained considerably lower than the EO rates throughout the study. Besides being English-only vowels, these are also the phonemes that surround the Spanish phoneme /a/ in the vowel space. All the bilingual children substituted the Spanish vowel for each of the named vowels multiple times. Although the bilinguals' accuracy rates were typically lower throughout the study, the difference between the bilinguals' rates and the monolinguals' rates of correct consonant productions lessened with time. By T4, the bilinguals' correct consonant rate was only 5% lower than that of the monolinguals. Difference between the bilinguals' rates and the monolinguals' rates of correct vowel productions did not lessen with time.

Initially bilingual children produced the English-only consonants /v/ and /h/ with lower accuracy rates than the EO groups. However, by T3 or T4 the accuracy rates for /v/ and /h/ were the same or higher than the EO group. The English-occurring /ɹ/ was produced by the bilingual children with higher accuracy rates than the EO group at all data collection points. Based on the Speech Learning Model, Flege might suggest that the phoneme /ɹ/, for example, is not similar to any Spanish speech sound therefore the bilingual children did not assimilate the sound to a preformed speech category or filter out properties of the phoneme. He might further suggest that they used their knowledge of the speech mechanism and their speech production of their L1 to accurately produce the sound.

Data Collection Methods

In understanding the children's speech development, it is important to consider the changing elicitation format used in this study. At T1 and T2, most of the bilingual children's productions were in direct imitation of the examiner; Gabi, María and Sofía's direct imitation rates for T1 were 94%, 100%, and 92% and for T2 were 67%, 93%, and 93% respectively. See Table 17 for number of productions made spontaneously and in direct or delayed imitation. By T4 the bilingual children produced fewer words in direct imitation than they did at T1 and T2 (16%, 1%, and 49%). This might have had an effect on accuracy rates. For example, rates of derhoticization were lower at T1 and T2, when bilinguals had a model immediately before producing the rhotic vowel, than they were at T4 after almost two years of exposure to English. Even by T4 the bilingual children's rates of delayed imitation were much higher than the EO group who produced nearly all of the words spontaneously. María and Sofía's direct imitation rates for T4 were 64% and 38% respectively.

Perceptual Theories of Speech Sound Acquisition

Several of the errors that the bilingual children produced could be predicted using theories such as the Perceptual Magnet Theory, the Speech Learning Model and

Table 17

Number and Percent of Productions: Spontaneous, Delayed Imitation, Direct Imitation

	Gabi				María				Sofía			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Spont												
#	6	14	40		0	8	31	32	10	6	46	66
%	5	17	30		0	7	24	35	8	8	36	49
Delay												
#	1	13	72		0	0	36	58	0	0	49	51
%	1	16	54		0	0	27	64	0	0	38	38
Direct												
#	120	56	21		23	111	64	1	122	74	34	19
%	94	67	16		100	93	49	1	92	93	26	14
Total #	127	83	133		23	119	131	91	132	80	129	136

Note. Spont = spontaneous production; Delay = delayed imitation; Direct = direct imitation

the Perceptual Assimilation Model. All three of these theories predict that the children will produce L1 consonants and vowels, or similar ones, while speaking in their second language, English. The implications of some of the findings for theories of speech perception are explored below.

Perceptual Magnet Theory

According to the Perceptual Magnet theory, the Spanish low middle vowel /a/ might be considered a *prototypical vowel*. Therefore the closest surrounding vowels /æ/, /ɑ/, /ə/and /ʌ/ are drawn toward the /a/ and the substitution is made. In the speech samples of all three of the bilingual children, /a/ was commonly substituted for these vowels. However with time and more exposure to English, fewer of these substitutions were made which means that the sound /a/ is not likely a prototypical vowel but instead a phoneme in the L1 of the children. As explained above, Kuhl (1991) did not consider different languages when suggesting the idea of a prototypical vowel; data from the EO group offers further evidence that a prototypical vowel does not exist. None of the EO children substituted /a/ for any of the surrounding vowels which might still occur for a 3-year-old child if a prototypical vowel did actually exist as /a/. Kuhl does not address the idea of a prototypical consonant. Based on this information about vowels we might also conclude that a prototypical consonant also does not exist.

Speech Learning Model

Interpreting these /a/ substitutions using the Speech Learning Model, one might conclude that it is not important how far front or back the low vowel is because for Spanish speakers there is only one low vowel. Therefore early sequential bilingual children perceptually filter out the front/back property that is unnecessary in Spanish and produce /æ/ and /ɑ/ the same as their preformed Spanish speech sound category /a/. However, with more exposure to English the bilingual children produced both /æ/ and /ɑ/ more often, suggesting that new speech sound categories were formed as Flege (1987) would predict.

This pattern of initially substituting a Spanish-influenced sound followed by correct production of the English phoneme also occurred for several consonants. The phoneme /v/, for example, initially had a low accuracy rate among bilinguals. The voiced/voiceless contrast does not exist for Spanish labiodentals therefore the bilingual children may have filtered out the voicing property when listening to words that contain the phoneme /v/. However, by T4, bilingual production accuracy rates were similar to those of the EO group. It appears that by T4 the bilinguals perceived some of the English-only contrasts and were beginning to produce them. In the same manner, word shapes of the bilingual children became more like those of their monolingual counterparts. Cluster errors lessened with time as the bilingual children began to perceive and therefore form new word shape categories. For example, for words that begin with an s-cluster (e.g., *snake*) rather than a vowel followed by an s-cluster (e.g., *escuela*), children began producing /snek/ instead of [ɪsnek] as had been previously produced. To be certain that the reason for these newly formed category was perceptual, experimental studies specifically targeting this aspect of speech would need to be conducted.

Perceptual Assimilation Model

One can also look at some of the Spanish-influenced substitutions from the perspective of the Perceptual Assimilation Model. According to this model, bilingual children will assimilate a nonnative speech sound such as /ɹ/ to a similar native speech sound such as the tap, hence the high rate of tap for /ɹ/ substitutions. Children also used gliding as a substitution for /ɹ/. In most of their samples the bilingual children either substituted a tap for /ɹ/ or glided but not both. This might indicate that although children had already assimilated the phoneme to one category (tap or /j/) based on their perception they were experimenting with which native speech sound category to assimilate to.

The Perceptual Assimilation Model also posits that an L2 sound will assimilate outside of a native speech sound category. Several children produced the English-only phonemes /h/, /v/, and /ɹ/, possibly indicating that they perceived the phoneme as its own speech sound category different than any of the speech sounds of Spanish due to a greater acoustical difference.

Determining whether either the Speech Learning Model or the Perceptual Assimilation Model is correct would prove to be difficult. The Perceptual Assimilation Model predicts that speakers of a second language will always perceive the L2 sounds in how they are similar to or different than the speech sounds from their L1; according to the Speech Learning Model, new speech sound categories are formed over time. Based on the production results of this study, it appears that new speech sound categories can be formed, which supports the Speech Learning Model. For example, at T1 one of the bilingual children did not produce the English-occurring vowel /ɑ/ but by T4 produced it accurately in nearly half of all opportunities. Nevertheless, it is still not certain that this child has a perceptual category for /ɑ/. If these bilingual children were studied after 10 or more years of speaking and listening to English, perceptual experiments would still be required to determine how an English-only speech sound category such as [z], was perceived. It is possible that the bilinguals would perceive it as a [z] or they might still perceive it as a [s] with voicing. A production study could not tell us this because even if the bilingual participant produced the target [z], they could be accessing their [s] category and adding voicing. Bosch et al. (2000) suggested that adult bilinguals have not formed new perceptual categories. After more than 14 years of speaking their L2, the adults in this study still discriminated vowels within small distances from the non-native target at a higher rate than they discriminated native vowel contrasts within the same distance.

By analyzing the English speech of the bilingual children who participated in this study, one can make predictions about what characteristics of English speech they perceive. Based on the Speech Learning Model we can guess that children are filtering out some of the characteristics of English phonemes that are not used in Spanish, their L1, to distinguish between phonemes. From the perspective of the Perceptual Assimilation Model children are perceptually assimilating English phonemes to similar Spanish speech sound categories.

Implications

Although this study was of typically-developing sequential bilingual children, it is interesting to explore clinical implications for children with speech sound disorders. Frequently, speech-language pathologists do not use a bilingual speaker's L1 phonological system to diagnose the child as having a speech sound disorder; we often listen to their English speech sounds to determine whether their L1 phonological system should be assessed. This study shows us that a Spanish-English child who begins learning English at approximately 3-years of age should be able to produce many of the speech sounds of English. Some of these speech sounds will sound like those produced by monolinguals; for example, although /h/ was not used by the bilingual children in their Spanish samples, they produced the sound accurately in their English samples. Other speech sounds will likely sound influenced by Spanish for example, the lax vowel /ɪ/ might be slightly raised and produced as a sound between /i/ and /ɪ/. The study also suggests that children will likely use some of the phonotactic rules of Spanish in their English productions. Some might perceive this as evidence of a speech sound disorder or delay but as shown in this study, it may be a typical result of L2 acquisition. Because these children were studied longitudinally, the results also show that the errors described above lessen over time. Furthermore, unusual errors typically associated with speech sound disorders such as initial consonant deletion, glottal substitution, and backing did not occur frequently.

When observing a bilingual child speaking their L2 in order to determine if the child should be assessed for a possible speech sound disorder, we therefore need to consider the characteristics of their L1 to understand the types of errors to expect. Length of exposure should also be considered, with fewer errors generally expected after more exposure. Although the bilingual children's errors decreased more rapidly than the EO groups' errors, their error rates were not as low and their correct productions were not as high as those of the EO group even after almost two years of English exposure. Allowing for experimentation and practice by the child is also important; whereas the EO group's average rates tended to gradually increase or decrease over time, the bilinguals' individual rates were irregular with an overall trend of increased accuracy and decreased errors. One should also consider the manner in which words were elicited. When given a direct or indirect model before producing the word, children might be more accurate than if they are required to produce the word from memory.

The information in the current study can only be used as a general guideline for observing Spanish-English bilinguals and for ideas in what to look for in future studies. Larger studies are needed to determine typical error rate decreases and to describe both errors and which speech sounds should be correctly produced by these children. New studies should be conducted to describe these values for children whose first exposure to English is at an older age and/or of different duration and intensity.

Limitations

This study is limited by several factors including the data collection methods. All samples were transcribed at least two times for accuracy using acoustic software when a sound was not clear. However, if the equipment did not pick something up or if background noises occurred during the recording, even acoustic software could not be used.

Another limitation is the varying nature of the data samples. The number of target words produced ranged from 22 words to 136 words. Therefore the opportunities to produce particular speech sounds ranged from zero opportunities to many. Also, using direct imitation to elicit words might not give an accurate picture of what the child produces without the support of a direct model. At T1 and T2, the bilingual children produced almost all of their words after a direct model whereas the monolingual English speakers productions were nearly all spontaneous or with a delayed model.

Analyzing the speech sounds of only three bilingual children also limits the study. To truly understand the nature of speech sound development in bilingual children more children should be included. The use of statistical analysis would also help to ensure that the trends noted are significant.

Although a homogenous group of children was selected regarding the length and nature of their English exposure, all variables could not be controlled. For example some of the children might have had many absences which could significantly affect their English exposure at T1. Also, despite the attempt to select child-friendly words, some of the children might have heard some words for the first time whereas others from a different classroom might have heard the same words regularly. Better data could be collected if all children came from the same classroom and target words came from the stories read and activities of the class.

As noted previously, perceptual research is needed to actually know what bilingual speakers perceive in their L2 and larger studies would help support the results of this study. To get a better idea of how sequential bilingual children acquire L2 studies that include conversational speech samples from their natural environment would also be helpful.

Conclusion

This was an initial study intended to observe L2 acquisition in 3-year-old sequential bilingual Spanish-English speakers who had been recently exposed to English for the first time. The study looked at how their L2 speech changed over time, how it compared to their L1 speech, and how it compared to monolingual speakers of the same age. Results of the study indicate that despite some similarities with monolingual speakers in the development of English, many of the types and rates of error patterns and substitutions made by the bilingual children were different. As explained above, these substitutions and deletions that are called *errors* in this study are actually considered typical for L2 learners and would therefore not be considered errors in diagnosing a speech sound disorder. The error rates in the bilingual children's English samples were generally higher than those of the monolingual children as well as those of the same children's Spanish samples; the errors were often the result of Spanish-influence or of the newness of L2. However, over time the bilingual children's consonant error rates approached those of the monolingual children and after approximately a year and a half of English exposure error rates were often as low as or almost as low as the monolinguals' rates. If this pattern of improvement continues, due to continued exposure and practice, these children will likely become fluent speakers of English before adulthood.

Although this was not a perceptual study, information in the literature review illustrates that perception plays a part in speech acquisition. Two theories, the Perceptual Assimilation Model and the Speech Learning theory, offer possible explanations for some of the errors observed in the bilingual children. The children did likely not perceive all of the characteristics of the English phonemes and words needed to produce them accurately.

In order to have a complete understanding of bilingual language acquisition, we need to have knowledge of how both perception and production of L2 typically develop. Gaining understanding of both of these parts of L2 development might help L2 learners become fluent speakers of their L2 more quickly and easily. It will also allow for accurate diagnosis and more effective treatment of speech sound disorders in bilinguals. As the number of sequential bilingual children entering our schools continues to increase, these are important issues to consider for Spanish-English bilingual children as well as other bilinguals.

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Appendix A: English Stimuli

apple	soap	mouse
apples	clouds	cat
one	cookies	sock
two	dinosaur	dog
three	chocolate	puppy
four	fish	drinking
five	flower	cup
six	foot	drum
seven	toe	elephant
eight	fork	pancakes
nine	spoon	pants
ten	french fries	pencil
red	hamburger	pig
baby	giraffe	boot
planes	glasses	rainbow
jet	grapes	ring
balls	ship	school
this/that	guitar	teacher
little	frog	scissors
big	hammer	sheep
banana	stop	boat
yellow	hand	slide
feet	finger	face
bath	helicopter	smile
bathtub	horse	smoke
bird	house	squirrel
feather	door	stars
chicken	gate	strawberry
eggs	ice cream	string
goose	jacket	swinging
nest	zipper	cake
black	juice	pie
books	jumping	candle
boy	bike	throwing
girl	skates	tiger
brother	pool	orange
brush	kitchen	toothpaste
butterfly	lamp	toys
sick	leaf	truck
carrots	lips	soup
cars	mouth	vacuum
caterpillar	teeth	watch
pet	tongue	waterfall
chair	milk	fire
snake	mirror	firetruck
spider	mountains	

Appendix B: Spanish Stimuli

agua	columpio	mariposa
platano	verde	martillo
Amarillo	cuchara	montaña
anillo	cuerda	naranja
arena	dedo	negro
arco iris	labios	niño
ardilla	dientes	nubes
aspiradora	dinosaurio	ojo
aviones	doctor	oruga
azul	ducha	oveja
bebe	elefante	pájaro
bicicleta	escoba	pluma
blanco	escuela	pan
caballo	Maestro/a	pantalones
camion	espejo	papas fritas
casa	estrella	hamburguesa
arbol	flor	perro
cepillo	flores	pescado
chaqueta	fresa	pie
cierre	fruta	brazo
chico	galletas	pierna
grande	gallo	pluma
pequeño	girafa	ratón
pelota	guitarra	reloj
Pelotas	helado	resbaladera
chocolate	helicóptero	sapo
manzana	hoja	serpiente
uno	huevos	silla
dos	humo	sol
tres	iglesia	sonrisa
cuatro	jabón	feliz
cinco	juguetes	tambores
seis	jugo	tenedor
siete	lámpara	tigre
ocho	lapis	tijeras
nueve	leche	triste
diez	lentes	uvas
coche	libro	zanahorias
cocina	luna	anaranjado
		hermano

Appendix C: Error Tables

Examples of Errors

Child	Time	Feature	Example	Notes
			Consonants	
		Stopping		
María	T1	v→b	sɛvɪn→sɛbɪn	Developmental, L2 learning, Spanish influence
María	T1	θ→t	θɹi→tɹi	Developmental, L2 learning
Sofía	T1	ð →d	resβalaðija →resβladija	Spanish data
		Fronting		
EO	T1	g→d	gɪtaɹ→ dɪtaɹ	Developmental
Sofía	T2	g→d	gus→dus	Error also in EO, developmental
Sofía	T3	k→t	smok→smot	Error also in EO, developmental
		Gliding		
María	T2	ɹ →W	mɪɹəɹ→ mɪwɵ	Developmental
		Tap for /ɹ/		
María	T4	ɹ →ɾ	dɹʌm→dɾʌm	Spanish-influenced
Gabi	T3	ɹ →ɾ	fɛðəɹ→fɛðəɾ	Spanish-influenced
Gabi	T1	ɹ →ɾ	kɛɹɪts→kɛɾɪts	Spanish-influenced

Examples of Errors (cont.)

Child	Time	Feature	Example	Notes
			Word Shape	
		FCD		
María	T1	d→Ø	bɪɹd→bɪɹ	Spanish-influenced
Sofía	T1	k→Ø	fajəɹtɹʌk→fajəɹtɹa	Developmental, Spanish influence
Sofía	T1	b→Ø	bæθtʌb→bæθtʌ	Spanish-influenced
Sofía	T4	x→Ø	relox→relo	Spanish data, developmental
María	T1	z→Ø	lapiz→lapi	Spanish data, developmental
		Clusters		
María	T1	b→p	blæk→plak	Spanish influence
Gabi	T3	p→b	plens→blens	Spanish-influenced
Sofía	T3	sn→ɪsn	snek→ɪsnek	Spanish-influenced
Sofía	T2	sw→ɣw	swɪŋgɪŋg→ɣwɪŋgɪŋg	Spanish-influenced
Sofía	T1	bɹ→bəɹ	bɹʌʃ→bəɹaʃ	L2 learning

Examples of Errors (cont.)

Child	Time	Feature	Example	Notes
		Vowels		
		Derhoticization		
Gabi	T1	ɹ→Ø	titʃəɹ→titʃə	Developmental
EO	T1	ɹ→Ø	fɛðəɹ→fɛðɵ	Developmental
		Raising and Lowering		
Sofía	T3	ʊ→u	bʊk→buk	Raised, Spanish-influenced
María	T1	ɪ→ɛ	sɪks→sɛks	Lowered, error also in EO
		Lax to tense		
María	T2	ɛ→e	pɛt→pet	Raised, Spanish-influenced
María	T1	ɪ→i	sɪk→sik	Raised, Spanish-influenced
		/a/ Substitution		
Sofía	T3	ʌ→a	kʌp→kap	Lowered, Spanish-influenced
María	T1	æ→a	blæk→plak	Spanish-influenced
Sofía	T4	æ→a	hæməɹ→haməɹ	Spanish-influenced
Gabi	T3	ɑ→a	fɹɑg→ fɹag	Spanish-influenced
María	T1	ʌ→a	wʌn→wan	Spanish-influenced

50	51	58	59	68
50	51	58	59	68
50	51	58	59	68
50	51	58	59	68
50	51	58	59	68
50	51	58	59	68
50	51	58	59	68