PHONOLOGICAL TRANSFER DURING WORD LEARNING: EVIDENCE FROM BILINGUAL SCHOOL-AGE SPANISH-ENGLISH-SPEAKING CHILDREN

by

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Abstract

Purpose: This study examines potential cross-linguistic effects on accuracy of codas in newly learned English-like nonwords produced by bilingual Spanish-English-speaking children.

Methods: Forty-two bilingual Spanish-English-speaking second-graders (age 7-9) were matched individually with monolingual peers on age (+/- 6 months), sex, and percentile score on the Goldman-Fristoe Test of Articulation (GFTA-2; Goldman & Fristoe, 2000), and matched for group on mother's level of education. Participants named various sea monsters as part of computerized word-learning games. Sixteen syllable-final coda consonants were analyzed for accuracy. These were drawn from thirteen nonwords distributed across five word-learning tasks.

Results: Bilingual children were less accurate than monolingual children in production of both shared and unshared codas, though the gap was greater for unshared codas. Both bilingual and monolingual children were more accurate in production of shared codas than unshared codas.

Conclusion: The results suggest that native language phonotactics influence accuracy of coda production in bilingual Spanish-English-speaking school-age children during word learning. Influences of native phonology on word learning could potentially impact academic achievement through vocabulary learning in the classroom.

The purpose of the study was to investigate potential phonological production differences between bilingual Spanish-English-speaking and monolingual English-speaking children, ages 7-9, during a word learning task. While both monolingual and bilingual children at these ages typically demonstrate phonological accuracy similar to adults in regular speech, the difficulty of the word learning task may impact accuracy in phonological production and provide an opportunity to observe potential differences between bilingual and monolingual school-age children. Previous studies have linked phonological acquisition and word learning in children (e.g., Alt, Meyers, & Figueroa, 2013; Messer, Verhagen, Boom, Mayo, & Leseman, 2015; Ramachandra, Hewitt, & Brackenbury, 2011) as well as phonological and lexical processing in adults (e.g., Kan, Sadagopan, Janich, & Andrade, 2014; Kaushanskaya, Yoo, & Van Hecke, 2012; Stamer & Vitevitch, 2012). While several studies have addressed how phonotactic probability may impact word learning in monolingual and bilingual children, investigation into how specific phonological targets are produced in a word learning context has been limited. This study should better our understanding of interactions between speech and language in bilingual school-aged children and provide insight into the nature of bilingual phonological processing. The results of this study may also have implications for how we can better support bilingual Spanish-English-speaking school-aged children both in the classroom and in a clinical environment.

Bilingual Spanish-English-speaking children in the United States

In the past several decades, the number of Spanish speakers in the United States has increased dramatically, with 24.4 million more speakers in 2009 than in 1980 (Ortman & Shin, 2011). This increase in the Spanish-speaking population has particularly impacted the demographics of schools in the United States, and in 2011, 20% of the entire student population in the United States was Hispanic (US Census Bureau, 2013b). In grades 1-12, Hispanic children made up over 50% or more of the student population in California and New Mexico, and approximately 30-40% of the student population in Arizona, Colorado, and Nevada (US Census Bureau, 2013b). This means that many children in public schools are speaking Spanish either as their primary language or in addition to English. However, training and practice of speech-language pathologists in the United States have historically emphasized assessment and treatment appropriate for middle class, monolingual English-speaking children (Bedore & Peña, 2008; Roseberry-McKibbin, Brice, & O'Hanlon, 2005). Therefore, as a group, speech-language pathologists have been poorly equipped to provide culturally and linguistically appropriate services (Roseberry-McKibben, Brice, & O'Hanlon, 2005).

In order to improve our understanding of bilingual speech and language development as well as clinical practice, there has been a surge in research regarding the speech and language patterns of bilingual children (Anthony et al., 2009; Barlow, Branson, & Nip, 2012; Brice, Carson, & O'Brien, 2009; Fabiano-Smith & Goldstein, 2010; Fabiano-Smith, Oglivie, Maiefski, & Schertz, 2015; Goldstein, Fabiano-Smith, & Washington, 2005; Windsor, Kohnert, Lobitz, & Pham, 2010). In the United States, the majority of this research has focused on bilingual Spanish-English speaking children, due to Spanish being the most commonly spoken language in the United States after English (US Census Bureau, 2013a). Many studies investigating bilingual speech and language development target pre-school aged children or children in the early school-age years (six or younger) (Bedore, Peña, Gillam, & Ho, 2010; Brice, Carson, & O'Brien, 2009;

Cooperson, Bedore, & Peña, 2013; Fabiano-Smith & Goldstein, 2010; Gibson et al., 2014; Goldstein et al., 2005; Goldstein & Washington, 2001).

Because younger children have not yet developed speech and language that is adult-like, they may be seen as offering a unique window into the acquisition process, when differences between bilingual and monolingual children are likely to be evident. However, there is limited research regarding potential differences in speech and language between bilingual and monolingual school-age children older than six years (Alt, Meyers, & Figueroa, 2013; Fabiano-Smith, Oglivie, Maiefski, & Schertz, 2015; Girbau & Schwartz, 2008). In addition to being understudied, this population is of particular interest because of the changing role of language in the classroom as children progress through elementary school. In the later grades, academic content becomes more advanced and speech and language development, in many ways, slow down, as children are expected to be close to adult-like in their phonological and morphosyntactic abilities (Owens, 2012)

However, it is possible that the increased cognitive load associated with more difficult academic content may result in the expression of underlying differences between the speech and language of monolingual and bilingual children. Because bilingual Spanish-English-speaking children will likely, in many contexts, exhibit speech and language skills that are generally equivalent to those of their monolingual peers, potential differences in productions of newly learned words may not be recognized in the classroom. Unfortunately, if potential differences in word learning go unrecognized, Spanish-English-speaking bilingual children may not be able to be adequately supported by teachers, clinicians, and other educational professionals. Without adequate support, such differences in word learning have the potential to become weaknesses that may impact a student's academic achievement.

Challenges that may negatively affect the academic achievement of bilingual students are particularly important to attend to, as Hispanic students are already at a disadvantage in terms of academic achievement. Though Hispanics make up the most rapidly growing segment of the population, national achievement gaps in both math and reading between Hispanic and white students at the fourth and eight grade levels remained relatively unchanged between 1990 and 2009 (Hemphill & Vanneman, 2010). These achievement gaps do not, unfortunately, reduce for older students. While the percentage of Hispanic students that graduate high school and go on to college has increased, national high school dropout rates have remained consistently higher for Hispanic students than for white students (Ortiz, Valerio, & Lopez, 2012). In 1975, only 37.9% of Hispanic students graduated high school, compared to 64.5% of White students (Ortiz et al., 2012). In 2010, graduate rates increased for both groups, but a gap of more than 20% remained, with 62.9% of Hispanic students and 87.6% of White students graduating high school (Ortiz, Valerio, & Lopez, 2012). By determining areas in which Spanish-English-speaking children may demonstrate differences from their monolingual English-speaking peers, we can identify areas of learning in which bilingual children may experience unique difficulties, or move forward confident that we have not overlooked a learning opportunity. Once potential challenges for bilingual students have been identified, teachers, clinicians, other educators can work to more effectively support these students in their academic achievements.

Bilingual phonology

Multiple studies have documented how the phonologies of two languages may interact, particularly how the phonology of one language may influence the way sounds are produced in the other (Balukas & Koops, 2015; Fabiano-Smith et al., 2015; Fabiano-Smith & Barlow, 2010; Fabiano-Smith & Goldstein, 2010b; Kaushanskaya & Marian, 2007; Ramon-Casas, Swingley, Sebastián-Gallés, & Bosch, 2009; Tamburelli, Sanoudaki, Jones, & Sowinska, 2015; Yavas & Core, 2001), often referred to as phonological transfer. Paradis and Genesee (1996) define language transfer broadly as "the incorporation of a grammatical property from one language into the other" (p. 3). Phonological transfer occurs when a bilingual speaker uses sounds unique to the phonology of one language in the production of their other language (e.g., use of the Spanish trill in an English production of the word "rock") (Fabiano-Smith & Goldstein, 2010). Though phonological transfer between languages has been reported to be infrequent, it has been observed in bilingual children from various language backgrounds, including Spanish-English bilinguals (e.g., Fabiano-Smith & Barlow, 2010; Fabiano-Smith & Goldstein, 2010; Gildersleeve-Neumann & Wright, 2010; Goldstein & Bunta, 2011). Because both bilingual and monolingual children typically demonstrate high levels of phonological accuracy at young ages (e.g., Fabiano-Smith & Goldstein, 2010), research addressing phonological transfer in bilingual children typically focuses on phonological skills early in the developmental process. However, we cannot assume that the phonological systems of school-age bilingual children are organized identically to those of their monolingual peers even when phonological accuracy is high in both languages. It is possible that phonological differences between bilingual and monolingual children may manifest during more challenging tasks (i.e., those with an increased cognitive load), despite similar levels of phonological accuracy in other contexts.

Interactions between phonology and semantics

While a child's phonemic inventory is expected to be mostly acquired by the early school-age years, vocabulary and other areas of semantic knowledge are not (Owens, 2012). Recent studies have begun to investigate interactions between phonological and lexical development, most notably in preschool-aged children (e.g., Alt et al., 2013; Gray, Pittman, & Weinhold, 2014; Havy, Bouchon, & Nazzi, 2015; Messer et al., 2015; Ramachandra et al., 2011). (Also see Stoel-Gammon (2011) for a discussion of interactions between lexical and phonological development in monolingual children.) For the purpose of this paper, we will focus on interactions in phonological and lexical development in bilingual children.

In a study on phonetic processing in bilingual infants (16 months), Havy et al. (2015) demonstrated that bilingual infants may exhibit various phonological differences during word learning, depending on the degree of similarity between their two languages for a certain target. In this study, the authors investigated processing of voice onset time (VOT) in bilinguals exposed to languages with similar (French and Spanish, Italian, or Portuguese) and different (French and German or English) contrasts for voiced and voiceless stops during a receptive word learning task. The authors found that bilinguals in the similar contrast group were better able to distinguish between voiced and voiceless stops in French, suggesting that similarities between languages for this particular feature may be providing additional 'practice' for processing VOT in French. This research by Havy et al. (2015) highlights how differences between bilinguals and monolinguals may not be broadly generalized and how research findings may be strongly influenced by the languages used, as well as the particular feature being compared.

One aspect of phonology that may impact word learning is phonotactic probability. Phonotactic probability for an individual sound or sequence of sounds is determined by frequency which it occurs in the ambient language, with frequently occurring sounds having higher phonotactic probability than sounds that occur infrequently (e.g., Gray et al., 2014). Effects of phonotactic probability on word learning have been observed in groups of preschool children, with monolingual children generally demonstrating higher accuracy than their bilingual peers on words with high phonotactic probability in the shared language. For example, in a longitudinal study involving monolingual Dutch-speaking and bilingual Turkish-Dutch-speaking children ages 4-6, Messer et al. (2015) investigated differences in monolingual and bilingual children's performance on a nonword recall task. Throughout the longitudinal study, bilingual Turkish-Dutch children made significantly more errors than monolingual Dutch-speaking children on nonwords with high phonotactic probability in Dutch. However, the bilingual children performed equivalently to the monolingual children on nonwords with low probability in Dutch. The differences in the bilinguals' performance on the two types of nonwords suggested that increased experience with Dutch may improve preschoolers' ability to recall sequences of sounds that are common in Dutch.

In another recent study on phonotactic probability and word learning, Alt, Meyers, and Figueroa (2013) investigated how school-aged (7-8 years) Spanish-English bilingual children performed in comparison with monolingual children on a fast mapping task that manipulated phonotactic probability in English. While bilingual preschoolers (4-

5 years) in the same study were significantly less accurate in a naming production task than the monolingual preschoolers, the school-aged bilingual children performed equivalently to monolingual children. Alt et al. (2013) also found that more exposure to English correlated with better performance for bilingual children on the fast mapping task. In this study, however, as in the study by Messer et al. (2015), naming accuracy was calculated for each label as a whole; potential differences in accuracy at the phoneme or syllable level were not assessed.

Though infants and preschool children are more likely to demonstrate phonological patterns that may provide insight into the phonological process, interactions between phonology and semantics have also been observed in adults (Kan et al., 2014; Kaushanskaya & Marian, 2007; Kaushanskaya et al., 2013; Stamer & Vitevitch, 2012). For example, Kaushanskaya and colleagues (2013) found that native speakers of English learning Spanish as an L2 (second language) were better able to match familiar referents (pictures of animals) to newly learned nonword labels when the phonological forms of the nonwords were more English-like, or were 'phonologically familiar.' (The phonologically unfamiliar words contained sounds not present in either English or Spanish.) In a study on fast mapping, Kan and colleagues (2014) found that increased opportunities for 'speech practice,' or repetition of a new word with as accurate production as possible, improved word learning performance for both bilingual and monolingual adults. These studies suggest that an individual's language experience or amount of practice with certain sounds or sequences of sounds can influence his or her success in learning new words that contain those sounds, with phonological familiarity or increased practice facilitating word learning. However, the majority of adult research in this area involves either monolinguals or second-language learners, as opposed to bilingual adults who learned both languages in childhood, for whom 'phonological familiarity' may be more complicated. There is also currently very little research involving interaction between phonology and semantics in school-aged children. This limits our understanding of how phonology plays a role in lexical development of bilinguals after the preschool years.

As children progress through school, they are required to tackle increasingly complex material while continually learning and using new, more advanced vocabulary. For many bilingual children in the United States, classroom content is provided solely in English, only one of their languages. The task of learning advanced academic vocabulary and material in English may create enough of a cognitive load for some bilingual children to exhibit phonological differences from their monolingual peers. At higher grade levels, children are expected to learn an increasing number of academic and technical vocabulary terms. Many of these terms may sound similar to other words that are very different, or even opposite, in meaning, such as *waxing/waning* or *stalactite/stalagmite*. Therefore, successfully learning new words—and new concepts—during the school-age years may be closely tied to accuracy on individual phonemes. Because bilingual children essentially have more limited practice with English phonology than monolingual children, underlying phonological differences could potentially impact both their word learning and academic success.

Current study

Our study examines phonological transfer in the context of novel word learning during the school-age years. Because the tasks used involved only English-like nonwords, the results of our study may provide insight into how bilingual children learn unfamiliar vocabulary in the classroom, when instruction is provided solely in English. Though the children in this study have nearly adult-like phonologies in regular speech, language-specific patterns may emerge when under the pressure of a challenging novel word-learning task.

While we did not predict that bilingual children would produce more errors overall (Alt et al., 2013), we hypothesized that (1) phonological transfer from Spanish to English would lead to more errors on unshared codas in bilingual children and (2) monolingual English-speaking children would not demonstrate a difference in accuracy between the two coda groups.

Method

Participants

Eighty-four second-grade children (ages 7-9) with typically-developing speech and language participated in this study. Forty-two bilingual Spanish-English-speaking children were individually matched with monolingual English-speaking peers on age [+/- 6 months], sex, percentile score on the Goldman-Fristoe Test of Articulation (Goldman & Fristoe, 2000), and by group on mother's level of education. Parental consent was obtained for all children, as was child assent, as required by the Internal Review Boards of the University of Arizona and Arizona State University.

Nonword productions of all 84 participants were collected as part of a larger study (POWWER[1] see [Cabbage et al., in preparation]). Bilingual children in the study were

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[1] Participants in this manuscript represent a portion of the participants in a larger sample from the Profiles Of Word learning and Working memory for Educational Research (POWWER) study, funded by NIH NIDHC grant R01 DC010784. The POWWER study includes the groups reported, as well as children with

recruited from elementary schools in Nogales, AZ, and Tucson, AZ, where approximately 88% and 21%, respectively, of people over 5-years-old speak a language other than English in the home (U.S. Census Bureau, 2014). Monolingual children in the study were recruited from elementary schools in Tucson, AZ, and the greater Phoenix, AZ, metropolitan area. All children in the study were determined to have typical language development based on assessments using the English Clinical Evaluation of Language Fundamentals (CELF-IV) (Semel, Wiig, & Secord, 2003) and/or the Spanish Clinical Evaluation of Language Fundamentals (S-CELF-4) (Wiig, Semel, & Secord, 2006) and did not have history of speech or language disorders per parental report. The Goldman-Fristoe Test of Articulation (GFTA-2) was administered to assess articulation. Inclusionary criteria for all children in this study were as follows:

1. In 2nd grade at the time of the study (between 7- and 9-years-old)
2. Percentile of 31 or higher on the Goldman-Fristoe Test of Articulation (GFTA-2; Goldman & Fristoe, 2000)
3. Standard score of 96 or higher on the Test of Word Reading Efficiency (TOWRE-II; Torgesen, Wagner, & Rashotte, 2012), using grade-based norms
4. Nonverbal cognition within normal limits (standard score of 75 or higher) as assessed by the Kaufman Assessment Battery for Children (KABC-II; Kaufman & Kaufman, 2004).

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dyslexia or specific language impairment (SLI), and children with comorbid dyslexia and SLI. Participants in the POWWER study completed a total of six word learning games and a comprehensive battery of working memory tasks, completed over the course of at least six days.

5. Typically-developing language skills as measured by the English CELF and/or Spanish CELF (standard scores required and criteria described in greater detail below)
6. For bilingual children: The ability to carry out conversations in both English and Spanish, as indicated by parent report and supported by measures on the English CELF and Spanish CELF (see below for additional detail)

Inclusion for bilingual children required that they were able to have conversations in both Spanish and English. Spanish must have been spoken in the home by at least one caretaker, and schooling at the kindergarten and 1st grade level must have been in English or both English and Spanish. Schooling before kindergarten must have been in English, Spanish (if English was spoken in the home), or both languages. This information on language usage was obtained via parental report.

Inclusion criteria on the CELF for typically-developing monolingual children included in the study used English exclusively and were required to achieve a standard score of 88 or higher on the CELF-IV, in order to rule out language impairment. Inclusion on the CELF for bilingual children involved one of two possible paths. Bilingual children were qualified for this study if they achieved a standard score of 88 or higher on the English CELF and a scaled score of 6 or higher on the Spanish CELF Formulated Sentences (FS) subtest. A standard score of 88 on the English CELF ruled out potential language impairments, while a scaled score of 6 or higher on the Spanish CELF-FS ensured that the child’s Spanish skills were sufficient to have a conversation in both languages. Because typically-developing bilingual children may score lower than their monolingual peers on standardized tests based on monolingual English-speaking normative groups (Kohnert, 2010; Laing & Kamhi, 2003), alternative inclusionary criteria was designed to ensure that bilingual children demonstrated language skills sufficient to rule out language impairment and carry out conversations in both English and Spanish. Bilingual children who achieved a standard score between 78 and 88 on the English CELF qualified for the study if they achieved a scaled score of 6 or higher on the Spanish CELF FS subtest, and a standard score of 69 or higher on the full Spanish CELF, indicating sufficient language skills in both English and Spanish. The choice to use this cut-off point was data-based. Barragan, Restrepo, Castilla-Earlys, Olivares, and Gray (2013) collected data on over 200 bilingual children in the greater Phoenix area. Had they used a standard score cut-off of 85 (1SD below the mean), more than 60% of the children in their study would have been classified as having language problems, which is implausible. Thus, 69 was 1SD from their group mean, and resulted in a more reasonable 11% of children below that score. Exclusionary criteria for all children were as follows:

1. History of neuropsychiatric disorders (e.g., Autism Spectrum Disorder, ADHD) as indicated by parent report
2. History of speech or language impairment, special education, or repetition of a grade as indicated by parent report
3. Impaired near visual acuity (poorer than 20/32 or 20/40 in bad lighting conditions)
4. Impaired color vision
5. Failure to pass hearing screening administered at 20 dB for 1000, 2000, and 4000 Hz.

Descriptive data were also collected on reading ability and expressive vocabulary using Woodcock Reading Mastery Test-Paragraph Comprehension (WRMT-III;

Woodcock, 2011), Expressive Vocabulary Test (EVT-II; Williams, 2007), and Expressive One-Word Picture Vocabulary Test – Bilingual Edition (EOWPVT-IV; Martin & Brownell, 2010). Participant demographic information and scores are reported in Table 1.

Table 1. Participant description information.

Measure	Monolingual (*n*=41)		Bilingual (*n*=41)[b]	
	M	***SD***	***M***	***SD***
Age (years;months)	7;11	0;5	8;0	0;5
Mother's level of education (years)[a]	14.71	1.75	12.95[b]	2.73
GFTA-II percentile	48.73	5.41	46.88	7.52
TOWRE-II	107.46	7.82	107.78	8.10
KABC-II	113.34	11.87	108.17	12.05
English CELF-IV[a]	105.71	8.65	93.61	9.61
Spanish CELF-IV	n/a	n/a	95.47[d]	12.83
Spanish CELF-IV FS	n/a	n/a	11.26[d]	2.32
WRMT-III[a]	109.15	11.42	102.07	8.97
EVT-II[a]	109.51	11.16	94.89	8.67
EOWPVT-IV	n/a	n/a	115.48[c]	10.65

Note. Values are standard scores, with the exception of scores reported for the Goldman-Fristoe Test of Articulation (GFTA-2) and the Spanish CELF-IV Formulated Sentences (FS) subtest. The normative mean for standard scores was 100 (*SD*=15). Percentile scores are reported for the GFTA-2. Scaled scores are reported for the Spanish CELF-IV FS. The normative mean was 10 (*SD*=3). GFTA-II = Goldman Fristoe Test of Articulation, second edition (Goldman & Fristoe, 2000); TOWRE-II = Test of Word Reading Efficiency, second edition (Torgesen, Wagner, & Rashotte, 2012); KABC-II = Kaufman Assessment Battery for Children, second edition (Kaufman & Kaufman, 2004); English CELF-IV = English Clinical Evaluation of Language Fundamentals, fourth edition (Semel, Wiig, & Secord, 2003); Spanish CELF-IV = Spanish Clinical Evaluation of Language Fundamentals, fourth edition (Wiig, Semel, & Secord, 2006); Spanish CELF-IV FS = Formulated Sentences subtest of Spanish Clinical Evaluation of Language Fundamentals, fourth edition (Wiig, Semel, & Secord, 2006); WRMT-III = Woodcock Reading Mastery Test-Paragraph Comprehension (Woodcock, 2011); EVT-II = Expressive Vocabulary Test (Williams, 2007); Expressive One-Word Picture Vocabulary Test – Bilingual Edition (Martin & Brownell, 2010).

[a]Indicates group differences on a t-test with p < .01. [b]Descriptive information for some measures were not available for all participants; differences in number of participants are indicated as needed. [c]*n*=38 due to participant information on mother's level of education not reported. [d]*n*=40 due to participant scores on EOWPVT-IV unavailable. [d]*n*=15 for the complete Spanish CELF-IV and *n*=23 for the Spanish CELF-IV FS subtest alone. Spanish CELF-IV information not available for some participants.

Materials

Stimuli. Sixteen target codas from thirteen two-syllable CVCCVC nonwords were selected from a larger set of stimuli used as part of the POWWER study (see Alt et al., under revision) and divided into two categories: shared and unshared codas. See Appendix A for nonwords used. Nonwords were selected from the larger set of stimuli to represent a variety of sounds in coda position, differing in voicing, manner, and place of articulation.

Sounds in (syllable-final) coda position were selected for analysis because codas are less common in Spanish than in English, making them potentially more vulnerable to phonological transfer than other parts of a word. In addition, sounds that may occur in coda position in Spanish are restricted to significantly fewer sounds than in English. All sounds that occurred in coda position in this study occur in the phonologies of both English and Mexican Spanish, though only sounds labeled "shared codas" can occur in coda position in both languages. For example, /n/ may occur in (syllable-final) coda position in both Spanish (e.g., *razón* /rason/ ‘reason’) and English (e.g., *man* /mæn/), making it a shared coda. However, /k/, an unshared coda, can occur in syllable-final position in English (e.g., pick /pɪk/) but not in Spanish, though it may occur as an onset in Spanish (e.g., *carro* /karo/ ‘car’). Syllables for analysis were grouped according to whether or not the target sound was legal in coda position for Spanish and English (shared) or for English alone (unshared).

Stimuli were used from five different word learning games which involved manipulating different independent variables to determine their effects on word learning (e.g., degree of phonological similarity between nonwords, stable or variable location of referents). For each word learning game, children were presented with four novel sea monsters on a touch-screen computer. They would hear the name of a monster and have to touch the monster that represented that name. They received immediate feedback on their response in the form of a virtual coin for a correct answer, and a virtual rock for an incorrect response. There were four blocks of this type of learning. At the end of each block, children were presented with the image of a monster, and asked to produce the name of the monster, resulting in a total of four productions of each nonword. Data were audio-recorded and scored off-line by trained research assistants. Responses were scored for accuracy at both the whole-world level and the segment level. A minimum of 20% of the responses were double-scored, and there was a point-to-point reliability of .90-.93. (See Alt et al., under revision for more information on individual word learning games.) For the purposes of this study, only scores of select syllable-final segments (codas) were analyzed. Scores were analyzed as an average score of all four responses (one at the end of each learning block), or in the case of technical difficulties, an average score of all responses available.

Because these nonword stimuli were not originally designed to test hypotheses of shared vs. unshared codas, the only codas shared between Spanish and English that could be analyzed were nasal sounds (/n/ and /m/[2]). Unshared codas included voiced and voiceless stops, as well as /f/, /v/, and /m/. Codas to be analyzed occurred in either word-

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[2] /m/ was considered a shared coda only when followed by bilabial consonants (i.e., /p/ or /b/) to reflect nasal assimilation processes present in Spanish (e.g., in Spanish *impossible* 'impossible'). All other targets of /m/ in coda position, including word-final /m/, were considered unshared.

medial or word-final position. In some cases, multiple codas were analyzed for a single word (e.g., /m/ and /v/ in /gompæv/).

Procedures

After securing parental consent and participant assent, all inclusionary and descriptive testing was administered to participants to ensure they met the qualifications of the study. This typically took two to three sessions of 60-75 minutes each. Games began once children were qualified for the study, and children were tested over six sessions. For this study, production data were scored and analyzed for nonwords from five production tasks in order to examine evidence of language transfer during production.

Scoring. For the purposes of this study, production accuracy was scored only for the target codas being analyzed. Scoring was based on transcriptions of audio recordings made by trained research assistants, completed previously as part of the larger POWWER study. Transcribers aligned the sounds of a child's production with the phonemes of the target word. Alignment of the child's production with the target word were required to retain the syllable structure of the child's production. For example, if a child produced a CVCV word, deleting syllable codas, both consonants produced were required to be aligned with target onsets in transcription.

Productions of codas were scored as correct (score of 1) if they matched the target production (i.e., target /m/ was produced as /m/) in the target position of the syllable (coda). Productions of codas were scored as incorrect under several circumstances. First, if the child did not produce a response for the target referent (no response), the target coda was scored as incorrect (score of 0). If the child deleted the target sound or the target syllable, the target coda was scored as incorrect (score of 0). If the child produced a consonant in coda position of the target syllable that did not match the target coda (e.g., target /m/ was replaced with /k/), the coda was scored as incorrect (score of 0). Given that we chose children with age-appropriate speech skills, we did not have to worry about a child using a habitual phonological pattern for any of the phonemes in our stimuli.

In some cases, transcribers employed a strategy of ‘sliding’ a syllable to give maximum possible credit for an entire nonword response. For example, if the first syllable of the child’s production more closely matched the second syllable of the target word, the transcriber may score and provide credit for the first syllable of the child’s production based on the second syllable of the target word. In this case, no credit would be given for the second syllable of the child’s production. Target codas were scored as incorrect when syllable ‘sliding’ left the target syllable blank.

Results

Coda accuracy by group and coda type

For analysis of accuracy on coda productions, scores for each participant were averaged by coda group, resulting in average scores for shared codas and average scores for unshared codas. A repeated measures ANOVA was used with group as the between-subject measure and coda type (shared, unshared) as the within-group measure to determine whether differences in production accuracy were significant between and within groups. Significant main effects were found for group ($F(1, 80) = 4.89$, $p = .02$, $\eta^2 = .05$) and coda type ($F(1, 80) = 30.60$, $p < .01$, $\eta^2 = .27$). A post hoc t-test showed that the monolingual group was more accurate than the bilingual group ($t = 2.21$, $p = .02$) and a Fisher Least-Squares Difference test showed that all children were more accurate on shared codas compared to unshared codas ($p < .001$). However, the Group x Coda Type interaction was not significant ($F(1, 80) = 0.44$, $p=0.50$, $\eta^2 < .01$). Performance for monolingual and bilingual groups on shared and unshared codas is depicted in Figure 1.

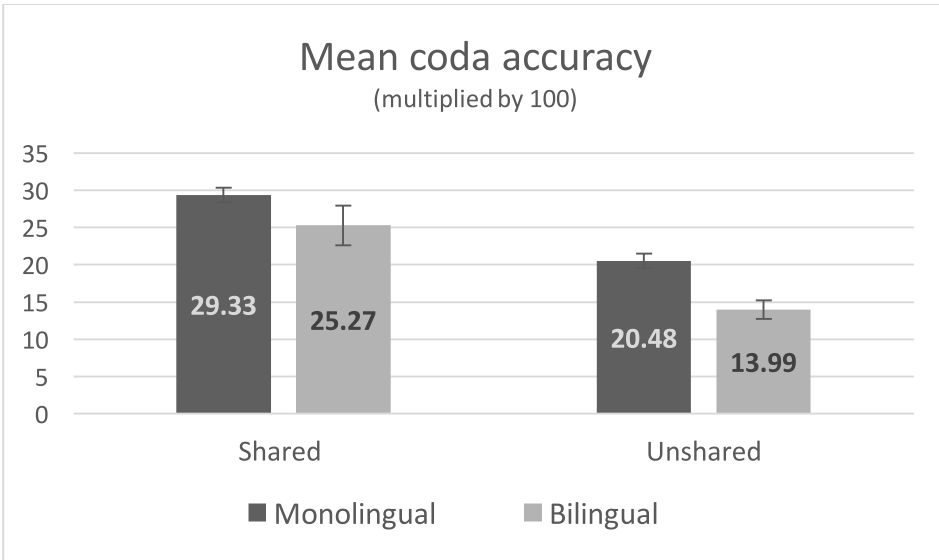

Figure 1. Mean accuracy scores for monolingual and bilingual participants on shared and unshared codas.

Given that we predicted a difference between group on the unshared coda type, a univariate tests of significance for planned comparison was performed. As expected, the planned comparison for shared codas revealed that there was no significant difference in group means for accuracy on shared codas ($F(1, 80) = 1.28$, $p=.26$), indicating that monolingual and bilingual children were equally accurate in production of shared codas. However, the planned comparison for unshared codas showed that bilingual children were significantly less accurate on unshared codas than their monolingual peers ($F(1, 80) = 8.25$, $p < .01$).

Correlational analyses

Additional Pearson product moment correlational matrices were generated for both monolingual and bilingual groups to determine correlations between accuracy on shared codas, unshared codas, and overall coda accuracy, as well as selected participant attributes (age, mother's level of education, and GFTA-2 percentile score and standardized measures (KABC-II, TOWRE-II, English CELF-IV, EVT-II, WRMT-III).

The monolingual group demonstrated several significant correlations ($p < 0.05$). For monolinguals, accuracy on shared codas correlated significantly with accuracy on unshared codas (r=0.34), and overall coda accuracy (r=0.86). Accuracy on unshared codas was significantly correlated with age (r=0.34) for monolingual children, with older children being more accurate on unshared codas than younger children. None of the standardized tests were correlated with performance on either type of coda.

For the bilingual group, accuracy on unshared codas was not correlated with accuracy on shared codas (r=0.25). Performance on shared codas predicted performance on unshared codas only for the monolingual group, suggesting that bilingual children, unlike their monolingual peers, treated the two coda types differently. As with the monolingual group, none of the standardized tests were correlated with performance on either coda type.

Mother's level of education was not correlated with accuracy on unshared or shared codas for either group. However, mother's level of education correlated with percentile score on the GFTA-2 for both the monolingual (r=-0.38) and bilingual group (r=-0.38). Though percentile score on the GFTA-2 correlated with both age and mother's level of education, it did not correlate with accuracy for either coda type or overall accuracy. This supports the idea that the patterns observed in this study are not necessarily reflected in a child's everyday conversational speech.

English phonotactic probability: Shared vs. unshared codas

Given the unexpected finding of monolingual children showing better performance on shared codas compared to unshared codas, we chose to explore the possible influence of English phonotactic probability on production accuracy of codas. Phonotactic probability at the segment level (the likeliness for a sound to occur in a particular position of the word) was calculated for target codas. An unpaired t-test (t=2.49) was performed to determine whether phonotactic probability values were significantly different between the two coda types. The shared codas in our sample had significantly higher phonotactic probability (mean=0.0695, SD=0.0238) than the unshared codas (mean=0.0335, SD=0.0254) (p=0.02). The results of this test indicate that phonotactic probability in English may also impact production accuracy of codas during word-learning.

Discussion

In this study, we examined whether differences in native language phonotactics may lead to differences in novel word productions by monolingual English-speaking and bilingual Spanish-English-speaking children during the school-age years. Because a more restricted set of sounds may occur in coda (syllable-final) position in Spanish than in English, we investigated differences between bilingual and monolingual children in production accuracy of codas of multiple English-like non-words.

While previous studies had demonstrated relationships between native language phonotactics and word learning (Alt et al., 2013; Kan et al., 2014; Kaushanskaya et al., 2013; Messer et al., 2015), research into such interactions in bilingual school-aged populations has been extremely limited. Additionally, while previous research investigating interactions between phonology and word learning have performed measures of lexical (whole-word) accuracy (e.g., Alt et al., 2013; Messer et al., 2015), our study was based on sublexical measures for the part of the novel word that we predicted would be vulnerable to cross-linguistic effects.

Overall coda accuracy: Monolingual vs. bilingual children

Based on previous research demonstrating that bilingual children were equivalent in whole-word production accuracy during a fast-mapping task (Alt et al., 2013), we did not predict that bilingual children would be less accurate than their monolingual peers for both coda groups. Bilingual children should have essentially more practice with codas that occur in both languages (shared codas) than those that occur in English only (unshared codas). Because monolingual English-speaking children, as a result of speaking only one language, should have more practice with unshared codas than the bilingual children do, we predicted that monolingual children would be more accurate at producing unshared codas than their bilingual peers. We did not expect monolingual children to be significantly more accurate at producing shared codas because the two groups of children would have more equivalent amounts of experience with these sounds in coda position.

However, we found that bilingual children demonstrated lower accuracy on both shared codas and unshared codas than monolingual children. For the purposes of this study, whole-word accuracy was not calculated, but previous research suggests that broader measures may not reflect phonological differences for school-age children. Previous research by Fabiano-Smith and Goldstein (2010) found that percent consonants correct (PCC) in English is equivalent for monolingual English-speaking children and bilingual Spanish-English-speaking children between ages 3;0 to 4;0. This may be similar to the way bilingual Spanish-English speaking children demonstrate equivalent production on whole-word accuracy measures when compared to their monolingual peers (Alt et al., 2013). Bilingual children may perform equivalently to their monolingual peers when looking at broader measures, either of whole-word accuracy or PCC in all word positions. However, cross-linguistic differences in the distribution of particular sounds may lead bilingual children to make not more errors but different errors than their monolingual peers.

We predicted that a restricted set of sounds permitted in coda position in Spanish would lead bilingual children to demonstrate lower accuracy on those sounds which are not permitted in coda position in Spanish. In addition to having a restricted set of sounds permitted in coda position, Spanish favors open syllables (without a coda) so that codas in general are less common in Spanish than in English (Whitley, 2002). This between-language difference in the distribution of codas could lead to the same practice effects that we expected to observe for shared vs. unshared codas. Less experience with codas in general may lead bilingual Spanish-English speaking children to be less accurate in production of codas during word learning than their monolingual peers.

Accuracy on shared vs. unshared codas

The results of our study supported our hypothesis that bilingual children would be more accurate on shared codas than on unshared codas. Because shared codas are sounds that occur in coda position in both Spanish and English, we predicted that the additional practice bilingual children have with the shared codas, compared to the sounds that occurred as codas only in English (shared), would lead to higher accuracy rates. The bilingual children in our study were significantly more accurate on shared codas than they were on unshared codas.

We did not predict that monolingual children would demonstrate any difference in accuracy between the two coda groups. However, our results indicated that the monolingual children, like the bilingual children, were also more accurate on sounds in the shared coda group. There are several possible reasons for this. One possibility is that differences in phonotactic probability impact production accuracy. When the two coda types were compared for phonotactic probability, the shared codas had significantly higher phonotactic probability in English than the unshared codas. It is likely that these differences in phonotactic probability within English also had an effect on production accuracy for the two coda types and were related to the monolingual group being more accurate on shared sounds than unshared sounds.

Another possible factor involved in coda accuracy is sonority, defined by Yavas and Core (2001) as “a sound’s relative loudness compared to other sounds with the same length, stress, and pitch” (p. 35). All shared codas investigated in this study were nasal consonants and are more sonorous than the majority of unshared codas in this study, which included voiced and voiceless stops and fricatives. Previous research found that monolingual-English speaking (Yavas & Gogate, 1999) and bilingual Spanish-English-speaking children (Yavas & Core, 2001) were better at segmenting stops and lower-sonority sounds than segmenting higher sonority sounds, such as nasals and liquids, in a task requiring them to delete codas of different sonority levels. Yavas and Gogate (1999) concluded that sonority is integral to phoneme awareness in young children. Though Yavas and Core (2001) predicted that Spanish-English speaking children may differ in their ability to segment codas of different sonority levels, they found that bilingual children were also more successful in segmenting lower sonority codas (e.g., stops) than higher sonority codas (e.g., nasals, liquids). Yavas and Gogate (1999) suggested that young children have better phoneme awareness of and learn to segment and manipulate low-sonority consonants before high-sonority ones. Low-sonority codas may be more salient and distinct from the vowel, and thus, easier to segment. However, it is possible that a coda that is less difficult to segment is also more closely tied to nucleus or the preceding vowel, making it less vulnerable to error in production. Because we did not code for accuracy of vowels, we were not able to test for this possibility in our current study.

It might be the case that the lower accuracy for unshared codas in the bilingual group was also the result of phonotactic probability. However, correlational analyses suggest this is not the entire explanation. These analyses showed that, for monolingual children, performance on shared codas predicted perfomance on unshared codas. For bilingual children, however, production accuracy for the two coda types was not correlated, suggesting that the two coda types (shared, unshared) truly function differently for bilingual children. This suggests that even if phonotactic probability in English, sonority, or other factors play a role in accuracy of different codas, cross-linguistic effects may also be observed.

Limitations and future directions

These results suggest that native language phonotactics influence production accuracy in word learning during the school-age years. Bilingual Spanish-English-speaking children are exposed to particular sounds in (syllable-final) coda position in only one of their two languages, referred to in this paper as 'unshared codas.' In a word-learning task targeting English-like CVCCVC nonwords, bilingual children were less accurate in production of unshared codas than shared codas, sounds which occur in coda position in both English and Spanish.

One of the major limitations of this study is that the stimuli used were not originally designed to test hypotheses related to shared and unshared codas. Ideally, stimuli designed to test this hypothesis would include more diversity in shared coda types beyond nasal consonants. It would also be of interest to include nonwords with codas that do not occur in any syllable position in Spanish, such as /z/. We expect that bilingual children would be least accurate on sounds that do not occur in Spanish in coda or any other syllable position, if production accuracy correlates with exposure to sound sequences in both languages.

In addition, the stimuli used in this study limited our ability to control for effects of sonority. This factor is of particular interest, as monolingual English-speaking children were also slightly more accurate at producing sounds categorized as shared codas, though not to the same extent as the bilingual children. As codas in Spanish are typically restricted to more sonorous consonants, the task of distinguishing the effect of shared codas from that of sonority is challenging. Including more sonorous sounds that do not occur in coda position in Spanish, such as /ŋ/, as well as less sonorous sounds that occur in coda position in both English and Spanish, such as /ð/ may be useful in separating sonority effects from cross-linguistic effects.

Another limitation is that we were not able to match participants exactly on mother's level of education. Matching mother's level of education, in particular, is made difficult by the demographic differences in the population for bilingual and monolingual children. This difference, however, likely did not have a large effect on the outcome of the study, given that maternal level of education was not correlated with performance on the task for either group.

Future studies investigating accuracy of coda production by bilingual Spanish-English-speaking children during word learning may include stimuli more selectively designed to test hypotheses regarding shared vs. unshared codas. In order to further our knowledge of how these differences may affect vocabulary learning in the classroom, future research may investigate accuracy of coda production of real words taught in a classroom setting where English is used as the primary or sole language of instruction.

Summary and implications

Little is known about how phonology and semantics continue to interact during the school-age years. This study demonstrates how native language differences in phonology can impact word learning for bilingual Spanish-English-speaking second graders. Bilingual children in this study were significantly less accurate in production of (syllable-final) codas that occur in English but not Spanish than they were in production of codas that occur in both of their languages. Though monolingual children demonstrated some difference in accuracy between the two coda groups, this difference was likely related, at least partially, to differences in phonotactic probability in English. These results suggest that despite both bilingual and monolingual school-aged children demonstrating nearly adult-like English phonology in everyday speech, differences in native language phonology can continue to manifest during word-learning, at the sublexical level. If not supported when necessary, these differences may negatively impact vocabulary learning and academic success. In the classroom, Spanish-English-speaking children may benefit particularly from increased visual and auditory cues and support for unshared codas, particularly when minimal sound changes could result in a change in meaning.

Appendix A: Shared and unshared codas

Table 1: Shared codas

Nonword	Target sound
/bɑnfep/	/n/
/fugboɪn/	/n/
/dimbaɪg/	/m/
/gompæv/	/m/

Table 2: Unshared codas

Nonword	Target sound
/tʌpwib/	/p/
/tughaʊt/	/t/
/jiktuf/	/k/
/tʌpwib/	/b/
/wʌgjed/	/g/
/jiktuf/	/f/
/gompæv/	/v/
/bʌvdep/	/v/
/buvjib/	/v/
/jevhaʊt/	/v/
/kaɪmjeg/	/m/
/jitgaɪm/	/m/

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