Spring 3-1-2022

Comparing Measures of Phonological Development for Bilingual Speech Sample Analysis: A Descriptive Study

Julianna Ciccarelli
jmcicca@bgsu.edu

University Honors Project

Comparing Measures of Phonological Development for Bilingual Speech Sample Analysis: A Descriptive Study

Julianna M. Ciccarelli

Honors College, Bowling Green State University

HNRS 4990: Honors Project

Advisors: Virginia L. Dubasik, Ph.D., CCC-SLP and Francisco Cabanillas, Ph.D.

March 1, 2022

I would like to extend special thanks for the support I have received throughout this project.

Dr. Dubasik-- Thank you for constantly challenging me to reach new heights and for leaving no stone unturned during this project. Your dedication and countless hours of time are immensely appreciated.

Molly Bebko and Dr. Cabanillas-- Thank you for your patience and support while editing the drafts and data of this project. It truly never goes unnoticed.

Bowling Green State University Honors College—Thank you for providing me with an amazing opportunity to further explore my interests and to share my findings with others.

To my family, friends and Mat—Thank you for always lending a listening ear when I talk about my passions. Your support and kind words mean more than you know.

Comparing Measures of Phonological Development for Bilingual Speech Sample Analysis: A Descriptive Study

The American Speech-Language-Hearing Association defines phonology as the linguistic or language component of speech. Phonology is different from articulation, which is the motor component of speech sounds without regard to the context of speech (n.d.). Speech-language pathologists (SLPs) are responsible for determining whether a child's speech productions align with age expectations or are protracted. Differences in children's phonology are related to factors such as age (Shriberg & Kwiatkowski, 1982), sex (Goldman & Fristoe, 2015) and language(s) spoken (Goldstein & Swasey Washington, 2001). Studies of phonological development in monolingual children have offered insight into patterns of speech sound production and appropriate measures for assessment with this group. While evidence of phonological development of bilingual children is emerging, there are still unanswered questions regarding phonological patterns and measures that accurately depict phonology across languages of bilingual children. There are numerous measures of phonology for monolingual English speakers, however, finding and selecting appropriate measures for assessing children that speak other languages can be particularly challenging. Moreover, finding measures that can be used to examine both languages of bilingual children is even more difficult. Simply translating an assessment into a different language is not adequate or appropriate because vital information about a child's phonological abilities in different contexts may be missed. Additionally, measures can be costly which may limit accessibility. As a result, some SLPs may have access to a variety of tools and others may have limited options for assessing a diverse population of clients. The present study aimed to address the need for information about bilingual phonological development and phonological assessment. This work has clinical implications for SLPs who work with bilingual children, as the results may inform assessment tool selection for this group.

Background/Literature Review

The following sections contain a summary of three separate, but related literatures. First, a review of the work on developmental expectations for monolingual English and Spanish speaking children between the ages of 3 and 5 is provided to help the reader understand speech sound development in each language separately. Next, a summary of work on phonological development of Spanish-English bilingual children is provided to inform how the separate language systems might interact and influence each other. Finally, a brief review of measures used to examine phonological development is given.

Developmental Expectations for Monolingual Speakers

Spanish Monolingual Speakers 3-5 Years. Studies on the phonological development of young monolingual Spanish-speakers have informed developmental milestones of children in this group. Specifically, we now know the sounds that are produced and age of mastery for Spanish phonemes (Acevedo, 1993; Jimenez, 1987). Regarding phonemic repertoires, by age 3:6, monolingual Spanish speaking children reached 90% accuracy for the phonemes /m, n, ñ, w, p, b, t, k, f, j, l/. By age 4:0, they demonstrated 90% accuracy for the phonemes /d, s, x/, by age 4:6, the phonemes /tʃ, r̂ (tap)/, and by 5:11, the phonemes /g, r̄ (trill)/ (Acevedo, 1993).

Similarly, Jimenez (1987) found that typically developing monolingual Spanish-speaking children reached 90% accuracy of /p, b, t/ by 3:3, 90% accuracy of /k, w, m, n/ by age 3:7, 90% accuracy of /j, l/ by 3:11, /f/ by 4:3, /tʃ, d, g, r̂/ by 4:7, /x, ñ/ by 4:11, /s/ by 5:7 and /r̄/ past 5:7/.

In a study investigating Spanish-speaking children's sound accuracy using percentage of consonants correct (PCC), Fabiano-Smith, & Goldstein, (2010) found that the overall mean PCC for typically developing monolingual Spanish speakers ages 3;0 to 4;0 was 75.58 (SD = 5.49). Goldstein et al., (2005) found that typically developing monolingual Spanish speakers ages 5;0 to 5;5 produced sounds with 91.42% accuracy with a standard deviation of 3.9.

Monolingual English-Speakers 3-5 Years. Studies of English-speakers have examined phonological development in terms of expectations for specific ages. Shriberg (1993) examined speech sound development in typically developing children between the ages of 3;0 and 5;11. Specifically, the study aimed to determine consonant accuracy using PCC. Samples of conversational speech were obtained from 117 children. The samples were then transcribed and analyzed to determine the percentage of consonants correctly produced. Sounds were categorized into three groups of eight phonemes. The first eight phonemes produced in English includes /m, b, j, n, w, d, p, h/, the middle eight includes /t, ŋ, k, g, f, v, tʃ, dʒ/, and the final eight includes /ʃ, θ, s, z, ð, l, r, ʒ/. Results showed that participants PCC ranged from 75 to 85 and varied by sex. It should be noted that the /r/ phoneme in this case is not trilled and may be more appropriately transcribed as /ɹ/ (Shriberg, 1993).

According to another study, the average PCC-R reported for monolingual English speakers of children ages 5;0 to 5;5 was 96.54% with a standard deviation of 4.3; all children in the study were typically developing (Goldstein et al., 2005).

The overall mean PCC for typically developing monolingual English speakers ages 3;0 to 4;0 was 84.10 (SD = 8.20; Fabiano-Smith & Goldstein, 2010).

Developmental Expectations for Bilingual Speakers

Across studies of young bilingual Spanish-English-speakers results indicate that (a) many English and Spanish consonants are produced with accuracy (Fabiano-Smith & Barlow, 2010; Goldstein et al., 2005; Goldstein & Swasey-Washington, 2001; Scarpino, 2019), (b) error patterns and phonological processes are observed in one or both languages (Goldstein & Swasey-Washington, 2001; Montanari et al., 2018), and (c) speech sounds may be shared or influenced by one language or the other (Fabiano-Smith & Barlow, 2010),

Accuracy of Spanish and English Consonants. While studies reporting high degrees of consonant accuracy have differed in terms of measures, they have yielded comparable results. Goldstein et al., (2005) examined consonant accuracy in young bilingual Spanish-English speakers *(n* = 5) using PCC-R and found that by age 5.5, all participants were producing Spanish and English consonants accurately. Children's consonant accuracy was 95.2% in Spanish and 94.81% in English. Similarly, Goldstein & Swasey-Washington (2001) explored consonant accuracy in Spanish-English speaking 4-year-olds (*N* = 12) and observed high accuracy in consonant production in both languages. Children's English and Spanish consonant accuracy was 94.1% and 90.3%, respectively.

Montanari et al. (2018) conducted a study of typically developing bilingual children which found that the PCC-R of both languages are quite similar. Between ages 3;0 to 4;2 the PCC-R in English was 71.11 (SD = 14.60), and in Spanish was 76.19 (SD = 11.88). When measured again at a later time (between ages of 4;0 to 5;2) the PCC-R of singletons in English was 82.18 (SD = 9.36) and in Spanish was 80.64 (SD = 9.18). These results corroborate Goldstein & Swasey-Washington (2001) who found that typically developing bilingual 4-year-olds had an average PCC of 94.1% (SD = 3.7) in English and 90.3% (SD = 3.9) in Spanish, and suggest that PCC-R may increase with time and experience.

Fabiano-Smith & Goldstein (2010) found that the bilingual participants had a mean PCC of 65.77 in Spanish (SD = 6.95) and 72.31 in English (SD = 12.45). The participants of this study were all typically developing and between ages 3;0 and 4;0. The bilingual speakers of a study conducted by Goldstein et al. (2005) had a PCC-R of 95.22% with a standard deviation of 3.0 for Spanish productions, and a PCC-R of 94.81% with a standard deviation of 4.5 for English productions. The children from this study were all typically developing and were between ages

5;0 and 5;5. (Goldstein et al., 2005). The data collected from several studies suggest that PCC values between languages at a given age are quite similar.

Scarpino et al. (2019) measured consonant accuracy in preschool-age Spanish-English bilinguals using pMLU and found that children's productions were closely related to adult targets. Children's whole word accuracy in Spanish was 92% and 91% in English. With regards to pMLU, Scarpino et al. (2019) found that the average score for bilingual preschoolers in English was 5.99 (SD = .44) and the average score in Spanish was 7.23 (SD = .50). Additionally, the proportion of whole word proximity (PWP) in English was .91 (SD = .06) and in Spanish was .92 (SD = .06).

Speech Sounds and Language Transfer. In a study investigating shared and unshared sounds between Spanish and English, Fabiano-Smith & Goldstein (2010) found that while many sounds were shared, others were unique to each language. Shared sounds included /p, b, t, d, k, g, m, n, f, s, ð, tʃ, l, w, j/, sounds specific to English (unshared) were /ŋ, v, ʒ, z, ʃ, θ, h, dʒ, ɹ/, and those specific to Spanish (unshared) include /ɲ, β, ɣ, ɾ, r/. In terms of accuracy, the mean PCC of shared English sounds for bilingual speakers was 77.18 (SD = 11.43) and unshared English was 62.04 (SD = 18.99). The mean PCC of shared Spanish sounds for bilingual speakers was 75.90 (SD = 7.54) and unshared Spanish was 35.69 (SD = 9.62).

Studies investigating language transfer effects consistently indicate the influence of the Spanish on English speech sounds, English on Spanish speech sounds, and a mix of both. Fabiano-Smith and Barlow's (2010) were interested in comparing phonetic inventories of monolingual and bilingual children and language transfer in Spanish-English bilinguals between the ages of 3;0 and 4;0 and found that bilingual children acquired phonemes in the same amount of time as their monolingual peers, and that their inventories were equally complex.

They also described language transfer within the Spanish phonemes /ɾ/ and /β/, and English phoneme /ʒ/. Other reported phonemes in the bilingual Spanish inventory include /p, b, t, k, g, s, f, x, β, ð, ɣ, m, n, ɾ, l, j/ and in the bilingual English inventory include /p, b, t, d, k, g, f, θ, s, ʃ, tʃ, dʒ, m, n, ŋ, l, ɹ, w, h/.

Errors and Phonological Processes. Several errors have been observed within the speech of bilingual preschoolers. Observed errors within for singletons in English included devoicing and gliding, whereas observed errors in Spanish included flap/trill deviation and spirantization. Deletions, stopping, and others were observed in both languages (Montanari et al. 2018). When speaking English, some of the participants displayed the following features: /v/ to [b], /n/ to ø, /ɹ/ to [ɾ] and /ʃ/ to [tʃ]. When speaking Spanish, typically developing bilingual 4-year-olds in one study displayed the following features: /r/ (trill) to [ɹ] and /ɾ/ to [ɹ] (Goldstein & Swasey-Washington, 2001).

Phonological Assessment

Phonological assessment is conducted by speech-language pathologists (SLPs) for the purpose of determining acquisition and mastery of speech sounds (American Speech-Language-Hearing Association, n.d.). Phonological development of both monolingual and bilingual children can be assessed using several types of measures (e.g., standardized, descriptive) and depends on the information needed. For instance, if the goal is to compare children's performance to same age peers, a standardized norm-referenced tool should be selected. If the purpose is to describe phonological patterns, a more descriptive tool can be used. While some measures are language specific, and others are intended for use across multiple languages.

Common Measures of Phonology

Measures of English Phonology. Several language specific measures are commonly used to assess English speech sounds and among the most common are the Goldman-Fristoe Test

of Articulation 3 (GFTA-3; Goldman & Fristoe, 2015), the Bankson-Bernthal Test of Phonology-Second Edition (BBTOP-2; Bankson & Bernthal, 2020), the Arizona-4 (Fudala & Stegall, 2017), and the Diagnostic Evaluation of Articulation and Phonology (DEAP; Dodd, et al. 2006). The tools listed are administered in ~10-20 minutes and test sound accuracy in words and sentences.

The GFTA-3 is a standardized tool that uses a picture naming task to assess sounds-in-words and a story-telling task to assess sounds-in-sentences and provides information about intelligibility and stimulability. The test is intended for children ages 2;0 through adults ages 21;11. While the GFTA-3 is used to assess English speech sounds, 13% of the normative sample was bilingual speakers.

The BBTOP-2 assesses whole word accuracy, consonant production and error patterns using a picture naming task. The test consists of 80 items. (Bankson & Bernthal, 2020). The GFTA-3 and BBTOP-2 have both been updated in recent years to account for dialectal and/or cultural variations in speech. BBTOP-2 can be used for ages 3;0 to 9;11 (Goldman & Fristoe, 2015; Bankson & Bernthal, 2020).

The Arizona-4 assesses phonology and sound production in words and sentences. The client is shown an image and asked to name the item. If needed, repetition or modeling can be used to elicit the response. This normative sample included 3,192 and can be used for ages 1;6 to 21;11 (Fudala & Stegall, 2017).

The DEAP utilizes colorful images for a quick screening for articulation and phonology (10 pictures), though the full articulation (30 pictures), phonology/connected speech (50 pictures and 3 pictures, respectively) and oral motor screening may take longer. DEAP can be used for ages 3;0 to 8;11. assesses vowels and distinguishes between errors made in isolation versus continuous speech (Dodd, et al. 2006).

Measures of Spanish Phonology. As with English tools, there are a variety standardized norm-referenced measures for assessessing Spanish phonology such as the Registro Fonológico Inducido (RFI; Juarez Sanchez & Monfort, 2010) and the Escala de la Discriminación Auditiva y Fonológica (EDAF; Brancal et al, 2005a; Brancal et al. 2005b). The RFI is intended for children ages 3;0 to 7;0 (Juarez Sanchez & Monfort, 2010) and uses a naming task. Speech sounds are elicited with 57 colorful drawings. The assessment takes approximately 10-20 minutes to administer.

EDAF assesses sound discrimination of middle sounds (15 items), background figures (7 items), phonology in words (43 items), syllables (30 items), and auditory memory (15 items). The tool is administered in ~30 minutes and can be used with children 2;9 to 7;4 years of age. Both the RFI and the EDAF are based on European Spanish (Juarez Sanchez & Monfort, 2010; Brancal et al, 2005a; Brancal et al. 2005b).

Bilingual Measures of Spanish-English Phonology. While most measures of phonology can be used to assess a single language, there are few bilingual measures that can used to assess speech sounds in both languages of a bilingual speaker. For instance, the Bilingual Articulation and Phonology Assessment (BAPA; Fernandes et al. 2011) and the Bilingual English-Spanish Assessment (BESA; Peña et al. 2018) are two Spanish-English measures. The BESA can be used to assess 17 different Spanish dialects and 7 different English dialects. It also contains questionnaires regarding language exposure, is norm-referenced and individually covers phonology, morphosyntax, and semantics. The phonology subtest assesses individual words. The Spanish phonology subtest has 28 words, the English subtest has 31 words. Each subtest takes approximately 15-20 minutes and can be used for children ages 4 to 6 years (Peña et al. 2018).

The BAPA application physically highlights the phonemes being targeted and allows the clinician to tap on incorrect productions. The clinician is also prompted to indicate the type of

error for incorrect productions. Not tapping a phoneme means that the production was correct. The application scores productions based on what the clinician indicates. The BAPA may be more easily accessible since it is downloadable to a computer free of cost. It also provides valuable information on an individual's abilities in both languages, covers 50 phonemes/clusters and 49 words in Spanish, is norm-referenced and standardized. BAPA asks the clinician after 8 responses whether they would like to continue (similar to a test ceiling) and takes approximately 9 to 20 minutes to administer the full assessment. It can be used for all ages (Fernandes et al., 2011).

Present Study

Studies of Spanish-English bilingual children's phonology indicate that preschool-age children produce sounds with high levels of accuracy in both languages (Fabiano-Smith & Barlow, 2010; Goldstein et al., 2005; Goldstein & Swasey-Washington, 2001; Scarpino, 2019). While many studies of bilingual children's speech sound and error patterns have informed typical development using a variety of different measures, it was difficult to locate any studies that examine children's phonology using multiple measures. Comparing children's bilingual phonology on multiple measures could highlight unique aspects of sound production that may be overlooked with the use of a single measure. Although there are a wide variety of available options for phonological assessment, most tools must be purchased and are therefore not accessible to all clinicians.

A review of available phonological assessment tools resulted in two easily accessible and free measures that can be used to compare phonological development in both languages of bilingual children irrespective of languages; Percent of Consonant Correct-Revised (PCC-R; Shriberg et al. 1997; Shriberg & Kwiatkowski, 1982) and Phonological Mean Length of Utterance (pMLU; Ingram & Ingram, 2001). In addition to accessibility and no cost, the

measures require only simple training. Studies show that both PCC-R and pMLU have been tested and are appropriate for use with bilingual populations (Fabiano-Smith & Hoffman, 2018; Scarpino et al. 2019).

While research to date suggests that PCC-R and pMLU are both valid and reliable measures of phonology that can be used to assess phonology of bilingual children, what has not yet been determined is whether the measures yield comparable results. This information would inform SLP selection of one measure over the other. Because PCC-R and pMLU are calculated in similar ways, it is hypothesized the measures will yield similar results.

As such, the aims of the present study were to (a) explore bilingual children's phonology in both languages using two commonly used measures (PCC-R and pMLU) and (b) determine the extent to which phonological patterns are captured differently by using different measures. The following research question was addressed: How do bilingual children's Spanish and English single word productions compare on two measures of phonology?

Method

Participants

Participants were drawn from a larger study of speech and language acquisition of bilingual children with and without listening devices (Dubasik et al., 2015). The five participants whose de-identified data were included in the current analysis were between the ages of 42 and 60 months at the beginning of the study (*M* age in months = 55.4). Four participants were female and 1 was male. All participants had normal hearing. All participants were sequential Spanish-English bilinguals who began receiving initial systematic exposure to English upon entry to preschool. Participants attended a Head Start preschool program located in Columbus, Ohio. All families primarily spoke Spanish and were Latino and of Mexican (*n* = 2), Honduran-Mexican (*n* = 1) and Salvadoran (*n* = 2) descent.

Procedures

Speech samples were elicited during individual sessions using researcher created measures of English and Spanish phonology that involved a picture naming task. Both measures contained 81 common items pictured in black and white images. Children completed the task in English, then in Spanish. In English, the children were prompted to identify the image with "*What is this*?" and in Spanish, "*¿Qué es esto?*" Participant responses were recorded using a Marantz recorder (built in microphone) and Sennheiser microphone transmitter/receiver. Individual participant samples without identifying data were imported into LIPP™ (Logical International Phonetics Programs), a computer program that allows for transcription in IPA via the traditional keyboard (Oller & Delgado, 1999).

Measures

Percent consonants correct (PCC) is a segmental measure of phonology used to analyze phonological development at the phoneme level (Shriberg & Kwiatkowski, 1982). PCC is a quantitative approach, and the values calculated can be used to confirm the presence of a disorder and determine the severity. A PCC of <50% is considered severe, 50-65% moderate-severe, 65-85% mild-moderate, and 85-100% mild (Shriberg & Kwiatkowski, 1982). PCC has been used to determine accuracy of consonant production in bilingual children (Fabiano-Smith & Hoffman, 2018). In 1997 PCC was revised to account for common and uncommon sound distortions (PCC-R; Shriberg et al.).

Phonological mean length of utterance (pMLU) is a measure of whole-word complexity and is based on the number of segments in words and the correctness of the production (Ingram, 2002). The pMLU for the adult speaker (pMLU-T) and the child pMLU (pMLU-C) values are used to derive the proportion of whole word proximity (PWP; Ingram, 2002). For instance, the word "cat" or /kæt/ has 3 segments. Adult targets are given one point per segment and 1

additional point per consonant. In this example, the adult production would receive a score of 5. Child productions are assigned 1 point per segment and 1 additional point per correct consonant. If a child said [tæt], the production would receive a score of 4. Three points (1 per segment) + 1 correct consonant for a total pMLU of 4 (Ingram, 2002; *Phonological mean length of utterance (PMLU)*, n.d.). The PWP provides an estimate of how close the child's productions are to the target. For instance, a child pMLU score of 4 compared to an adult's pMLU score of 5 results in a PWP score of .80 or 80% (Ingram, 2002; Scarpino et al. 2019).

Analysis

Samples were analyzed to determine consonant accuracy (PCC-R) and phonological complexity (pMLU/PWP) of children's English and Spanish utterances. To determine PCC-R for each child in each language, words were analyzed for consonants produced accurately based on expectations of a typical English speaker from Ohio. The total number of correct consonants in the sample was divided by total number of consonant opportunities in the sample. The value was then multiplied by 100 to obtain a percentage of consonant accuracy in both languages (Shriberg et al. 1997).

To obtain the pMLU-T productions were scored using an English speaker from Ohio as the target. As described above, each segment in the word received 1 point and each consonant received a second point. The pMLU-C was derived similarly, except consonants received an extra point only if pronounced accurately. The phonological length of each word was calculated and then the sum of all individual word values was divided by the total number of words to derive the pMLU-T and pMLU-C for Spanish and English. The pMLU-C was then divided by pMLU-T to derive the PWP for Spanish and for English. Diphthongs were counted as a single phoneme. The procedures for how to calculate PCC-R and pMLU are displayed in Appendix A.

Reliability

Scoring reliability was based on a comparison of 100% of the samples and inter-rater reliability was 96%. Scoring was conducted by a bilingual undergraduate student in Communication Sciences and Disorders and re-scored by a bilingual graduate student in Communication Sciences and Disorders. All discrepancies were discussed and resolved by a third scorer, a bilingual certified Speech Language Pathologist and with expertise in child speech and language.

Results

To answer the research question, *How do bilingual children's Spanish and English single word productions compare on two measures of phonology?* a series of analyses were conducted. The variables of interest were Spanish PCC-R and pMLU/PWP and English PCC-R and pMLU/PWP. The Spanish and English PCC-R and pMLU/PWP for the target, a speaker from Ohio, and each child were computed, and values are shown in Tables 1 and 2, respectively.

Spanish and English PCC-R and pMLU/PWP scores were compared to determine differences across measures. In general, all participants had higher pMLU/PWP than PCC-R scores. Participants' Spanish PCC-R Min-Max scores were 81.74 and 91.59, respectively and English PCC-R Min-Max scores were 53.15 and 80.18. Individual participant data are shown in Table 1. The Spanish pMLU-T ranged from 7.94 to 8.16. A score of 0 was assigned to target words if the child did not produce the word so as not to underestimate the child's pMLU. Adult targets were approximately eight segments in length. Spanish pMLU-C ranged from 7.25 to 7.78. On average children in the sample were producing words between seven and eight segments in length and with high degree of accuracy as indicated by an average PWP over 93%. English pMLU-T was 7.16 (*SD* = 0.00). English pMLU-C ranged from 5.51 to 6.32. While the phonological complexity of the adult speaker was over seven segments in length, children in the sample were producing words with fewer segments and/or correct consonants. For instance,

Child 1 produced [sɑɪ] for /sɑk/ so they received a score of 3 instead of 5. On average, English pMLU-C was 6.08 (*SD* = .34) and PWP was approaching 85%.

Post Hoc Analyses

A post hoc analysis was conducted to examine differences in scores across measures when adult targets were speakers of individual children's Spanish dialects. The following question was addressed: *How do bilingual children's Spanish and English single word productions compare on two measures of phonology when Spanish dialect is considered?* Participants in the sample spoke different dialects including Mexican, Honduran, Salvadoran, or a combination of these. Dialect specific rules are listed in Appendix B. The same procedures were used to compute Spanish and English PCC-R and pMLU/PWP. The only difference was that pMLU-T was based on speakers of the child's dialect. Similar to the original analyses, all participants had higher pMLU/PWP than PCC-R scores. Spanish and English mean PCC-R scores were 87.12 (*SD* = 2.78) and 70.86 (*SD* = 10.74) when considering dialect. Spanish pMLU-T ranged from 7.94 to 8.15 and Spanish PWP was ~94%. English pMLU-T ranged from 7.11 to 7.16 and English PWP was ~85%.

We were interested in whether children's dialect specific Spanish and English scores were higher or lower relative to the original analysis that was based on productions from an English speaker from Ohio and whether children's scores in both analyses were within expected limits for bilingual speakers. Group mean scores and standard deviations from the original and post-hoc analyses along with the information regarding whether the scores were within expected limits (WEL) based on previous studies of bilingual children are shown in Table 5. Children's Spanish and English PCC-R scores were outside expected limits on both the original and post hoc analyses. Spanish PWP scores were within expected limits in both analyses and English PWP scores were outside expected limits in the original analyses, but within expected limits post

hoc analyses. Further examination of PCC-R scores for both initial and dialect specific data revealed 1/5 participants had Spanish scores within expected limits and 0/5 had English scores within expected limits. All participants had Spanish pMLU scores within expected limits and 3/5 participants has English scores withing expected limits.

Discussion

The current study set out to explore children's bilingual phonology using two different measures. Children in the small sample generally produced high levels of accuracy. However, across analyses for both languages, the participants' scores from this study were generally lower than other works for PCC-R. The current study did find that the scores were about the same for pMLU/PWP when compared to previous studies (Fabiano-Smith & Barlow, 2010; Goldstein et al., 2005; Goldstein & Swasey-Washington, 2001; Scarpino et al., 2019).

The participants generally demonstrated a high level of accuracy as suggested by PCC-R scores in Table 1, but these scores were not high enough to be considered WEL except for in one case. Scores were also generally consistent across the participants, except for Child 5's PCC-R English score. Though still the lowest, this participant's English score did not seem to vary as dramatically when assessed using pMLU/PWP. Participants seemed to display an overall higher degree of accuracy as suggested by pMLU/PWP scores in Table 2.

It is possible that using PCC-R as a measure for phonological abilities within a bilingual preschool population can identify more individuals at risk for a disorder due to its conservative nature, though further testing may be necessary. As such, we reject the initial hypothesis that PCC-R and pMLU will have similar accuracy and feasibility because the scores were consistently much higher for pMLU/PWP. However, this trend withstood across language, suggesting that both are still appropriate for use within a bilingual preschool population.

The Spanish pMLU and PCC-R scores were consistently higher than the English scores. It may be the case that due to the young age of the participants and the amount of time spent at home/around family, they still receive more Spanish input and use Spanish more frequently than English thus are practicing with those sounds whereby increasing accuracy.

When mean scores from the initial analyses were compared to the dialect specific analyses, only PWP in English changed WEL status. Initially the mean scores for English PWP were not WEL but shifted to WEL after dialectal variations were considered. Excluding the consistently higher pMLU/PWP scores, it is possible that the lack of identifiable trends within the dialect specific data is due to the participants exposure to English, as well as other dialects from a young age. In other words, there may be characteristics of English and/or other dialects influencing the participants' productions. Speakers of a given language or dialect also do not share all speech characteristics, therefore it would be unrealistic to expect that participants would produce all sounds the same way. Additionally, only dialectal variation was considered in the present study. As such, individual variations as a result of language transfer were not considered.

It is important to note that PCC and PCC-R (or Percentage of Consonants Correct-Revised) are calculated the same way, but the revised version counts both common and uncommon consonant distortions as correct. These differences may explain why studies that used PCC had lower percentages than those using PCC-R (Shriberg et al., 1997). PCC-R was used for this study.

Limitations and Future Directions

The method and results of this study, while informative and interesting, have limitations. There were occasional difficulties with variation within the transcriptions. For instance, there were subtleties across allophones, which may have lowered participants' scores. For instance, if targets contained /j̟/, [j] was counted as incorrect. Similarly, it was challenging to distinguish

omitted from aspirated phonemes for the Mexican dialect speakers since aspirated phonemes were not marked on the provided transcripts. Further, the sample size was small thus results cannot be generalized to all bilingual Spanish speakers.

Future studies might explore the effects of language transfer in addition to dialectal variation when using pMLU and PCC-R as measures. It would also be interesting to explore the utility of PCC-R and pMLU with older Spanish-English bilingual speakers.

References

Acevedo, M. A. (1993). Development of Spanish consonants in preschool children. *Journal of Childhood Communication Disorders, 15*(2), 9–15.

American Speech-Language-Hearing Association (n.d.) *Speech Sound Disorders: Articulation and Phonology.* (Practice Portal). Retrieved from www.asha.org/Practice-Portal/Clinical-Topics/Articulation-and-Phonology/.

Bankson, N. W., & Bernthal, J. E. (2020). BBTOP-2 Bankson-Bernthal test of phonology – second edition. Retrieved March 20, 2021, from https://www.proedinc.com/Products/14855/bbtop2-banksonbernthal-test-of-phonologysecond-edition.aspx

Brancal, M. F., Ferrer, A. M., Alcantud, F., & Quiroga, M. E. (2005a). EDAF - Evaluación de la discriminación auditiva y fonológica. Retrieved March 20, 2021, from https://www.libreriaimagina.com/libro/edaf-evaluacion-de-la-discriminacion-auditiva-y-fonologica_64488

Brancal, M. F., Ferrer, A. M., Alcantud, F., & Quiroga, M. E. (2005b). EDAF. Evaluación de la discriminación auditiva y fonológica. https://psicologia365.com/product/edaf-evaluacion-de-la-discriminacion-auditiva-y-fonologica/

Dodd, B., Hua, Z., Crosbie, S., Holm, A., & Ozanne, A. (2006). Diagnostic evaluation of articulation and phonology. Retrieved April 02, 2021, from https://www.pearsonassessments.com/store/usassessments/en/Store/Professional-

Assessments/Speech-%26-Language/Diagnostic-Evaluation-of-Articulation-and-Phonology/p/100000295.html?tab=product-details

Dubasik, V. L., Mapus, K. A., Devine, K., Bunta, F., & Spann, C. (2015, November 12-14). *Phonological complexity patterns in bilingual children with normal hearing and with cochlear implants* [Conference presentation]. ASHA Convention 2015, Denver, CO, United States.

Fabiano-Smith, L., & Barlow, J. A. (2010). Interaction in bilingual phonological acquisition: Evidence from phonetic inventories. *International Journal of Bilingual Education and Bilingualism, 13*(1), 81-97. doi: 10.1080/13670050902783528

Fabiano-Smith, L., & Goldstein, B. A. (2010). Phonological acquisition in bilingual Spanish-English speaking children. *Journal of Speech, Language, and Hearing Research, 53*, 160–178. https://doi.org/10.1044/1092-4388(2009/07-0064)

Fabiano-Smith, L., & Hoffman, K. (2018). Diagnostic accuracy of traditional measures of phonological ability for bilingual preschoolers and kindergarteners. *Language, Speech, and Hearing in Schools, 49*, 121-134. doi: https://doi.org/10.1044/2017_LSHSS-17-0043

Fernandes, B., Kester, E., Bauman, M., & Prath, S. (2011). Bilingual articulation phonology assessment - BAPA manual. Retrieved March 20, 2021, from http://www.smartyearsapps.com/Bilingual-Articulation-Phonology-Assessment.pdf

Fudala, J. B., & Stegall, S. (2017). (Arizona™-4) Arizona articulation and Phonology SCALE™, fourth revision. Retrieved March 20, 2021, from

https://www.wpspublish.com/arizona-4-arizona-articulation-and-phonology-scale-fourth-revision

Goldman, R., & Fristoe, M. (2015). Goldman-Fristoe test of articulation 3. Retrieved March 20, 2021, from https://www.pearsonassessments.com/store/usassessments/en/Store/Professional-Assessments/Developmental-Early-Childhood/Goldman-Fristoe-Test-of-Articulation-3/p/100001202.html?tab=faqs

Goldstein, B. (2001). Transcription of Spanish and Spanish-Influenced English. *Communication Disorders Quarterly*, *23*(1), 54–60. https://doi.org/10.1177/152574010102300108

Goldstein, B. A., Fabiano, L., & Swasey Washington, P. (2005). Phonological skills in predominantly English-speaking, predominantly Spanish-speaking, and Spanish-English bilingual children. *Language, Speech & Hearing Services in Schools, 36*(3), 201-18. https://search-proquest-com.ezproxy.bgsu.edu/scholarly-journals/phonological-skills-predominantly-english/docview/232583148/se-2?accountid=26417

Goldstein, B., & Swasey Washington, P. A. (2001). An initial investigation of phonological patterns in typically developing 4-year-old Spanish-English bilingual children. *Language, Speech, and Hearing Services in Schools*, *32*, 153-164. Retrieved from http://digitalcommons.wcupa.edu/comdis_facpub/3

Ingram, D. (2002). The measurement of whole-word productions. *Journal of Child Language*, *29*(4), 713-733.

Ingram, D., & Ingram, K. D. (2001). A whole-word approach to phonological analysis and intervention. *Language, Speech, and Hearing Services in Schools*, *32*, 271-283.

Jimenez, B. C. (1987). Acquisition of Spanish consonants in children aged 3-5 years, 7 months. *Language, Speech, and Hearing Services in Schools*, *18*(4), 357– 363.

Juarez Sanchez, A., & Monfort, M. (2010). Registro fonológico inducido. Retrieved March 20, 2021, from https://editorialcepe.es/titulo/registro-fonologico-inducido/

Lipski, J. M. (2008). Varieties of Spanish in the United States. Georgetown University Press.

Montanari, S., Mayr, R., & Subrahmanyam, K. (2018). Bilingual speech sound development during the preschool years: the role of language proficiency and cross-linguistic relatedness. *Journal of Speech, Language, and Hearing Research. 61*, 2467-2486. https://doi.org/10.1044/2018_JSLHR-S-17-0393

Morris, S. R. (2009). Test-retest reliability of independent measures of phonology in the assessment of toddlers' speech. *Language, Speech, and Hearing Services in Schools, 40*, 46-52. doi: 10.1044/0161-1461(2008/07-0082)

Oller, K., & Delgado, R. (2000). Logical international phonetics program (Version 2.02) [Computer software]. *Miami, FL: Intelligent Hearing Systems*.

Peña, E. D., Guiterrez-Clellen, V. F., Iglesias, A., Goldstein, B., & Bedore, L. M. (n.d.). BESA: Bilingual English-Spanish assessment. Retrieved February 17, 2022, from https://products.brookespublishing.com/Bilingual-English-Spanish-Assessment-BESA-P1044.aspx

Phonological mean length of utterance (PMLU). Phon. (n.d.). Retrieved December 2, 2021, from https://www.phon.ca/phon-manual/analysis/pmlu.html.

Scarpino, S. E., Scheffner Hammer, C., Goldstein, B., Rodriguez, B. L., & Lopez, L. M. (2019). Effects of home language, oral language skills and cross-linguistic phonological abilities on whole-word proximity in Spanish-English-speaking children. *American Journal of Speech-Language Pathology, 28,* 174-187. doi: https://doi.org/10.1044/2018_AJSLP-18-0050.

Shriberg, L. D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech, Language, and Hearing Research, 36*(1), 105-140.

Shriberg, L. D., Austin, D., Lewis, B. A., McSweeny, J. L., & Wilson, D. L. (1997). The percentage of consonants correct (PCC) metric: Extensions and reliability data. *Journal of Speech, Language, and Hearing Research, 40*(4), 708-722.

Shriberg, L. D., & Kwiatkowski, J. (1982). Phonological disorders III: A procedure for assessing severity of involvement. *Journal of Speech and Hearing Disorders, 47,* 256 -270.

Sundarrajan, M., Tobey, E. A., Nicholas, J., & Geers, A. E. (2019). Assessing consonant production in children with cochlear implants. *Journal of Communication Disorders, 84,* 1-12. doi: https://doi.org/10.1016/j.jcomdis.2019.105966

Wren, Y., Titterington, J., & White, P. (2020). How many words make a sample? Determining the minimum number of word tokens needed in connected speech samples for child speech assessment. *Clinical Linguistics & Phonetics,* 1-18.

Table 1

Percentage of Consonants Correct – Revised scores in Spanish and English by Child

Child:	Spanish PCC-R	English PCC-R
Child 1: (Age 4;10)	91.59%	75.68%
Child 2: (Age 4;11)	83.91%	72.97%
Child 3: (Age 4;5)	87.93%	80.18%
Child 4: (5;0)	88.26%	71.17%
Child 5: (Age 3;6)	81.74%	53.15%
Mean	86.69%	70.63%

Note: English expected for children 1-4: 94.81 +/- 4.5 (Goldstein et al. 2005); English expected for child 5: 72.31 +/- 12.45 (Fabiano-Smith & Goldstein, 2010); Spanish expected for children 1-4: 95.22 +/- 3.0 (Goldstein et al. 2005); Spanish expected for child 5: 65.77 +/- 6.95 (Fabiano-Smith & Goldstein, 2010)

Table 2

Phonological Mean Length of Utterance and Proportion of Whole Word Proximity scores in Spanish and English for Child and Target

Child:	Spanish			English		
	Child pMLU	Target pMLU	PWP	Child pMLU	Target pMLU	PWP
Child 1: (Age 4;10)	7.73	7.94	97.36%	6.31	7.16	88.13%
Child 2: (Age 4;11)	7.25	8.09	88.52%	6.01	7.16	83.94%
Child 3: (Age 4;5)	7.78	8.16	95.34%	6.32	7.16	88.27%
Child 4: (5;0)	7.68	8.12	94.58%	6.25	7.16	87.29%
Child 5: (Age 3;6)	7.43	8.09	91.84%	5.51	7.16	76.96%
Mean (SD)	7.57 (.23)	8.08 (.08)	93.53% (3.43)	6.08 (.34)	7.16 (0.00)	84.92% (4.78)

Note: English .91 +/- (.06) from .85 to .97; Spanish .92 (+/- .06) from .86 to .98 (Scarpino et al. 2019)

Table 3

Percentage of Consonants Correct – Revised scores in Spanish and English by Child with Dialect Specific Expectations

		Spanish			English		
Child:	Dialect(s)	Child PCC-R	Within Expected Limits (WEL)?	+/- from Ohio Score	Child PCC-R	Within Expected Limits (WEL)?	+/- from Ohio Score
Child 1: (Age 4;10)	Honduran/Mexican	91.15%	No	-.44	76.47%	No	+.79
Child 2: (Age 4;11)	Mexican	85.15%	No	+1.24	73.30%	No	+.38
Child 3: (Age 4;5)	Salvadoran	87.01%	No	-1.25	80.63%	No	+.45
Child 4: (5;0)	Salvadoran	88.26%	No	0	71.17%	No	0
Child 5: (Age 3;6)	Mexican	83.04%	Yes	+1.3	52.73%	No	-.42

Note: English expected for children 1-4: 94.81 +/- 4.5 (Goldstein et al. 2005); English expected for child 5: 72.31 +/- 12.45 (Fabiano-Smith & Goldstein, 2010); Spanish expected for children 1-4: 95.22 +/- 3.0 (Goldstein et al. 2005); Spanish expected for child 5: 65.77 +/- 6.95 (Fabiano-Smith & Goldstein, 2010)

Table 4

Phonological Mean Length of Utterance and Proportion of Whole Word Proximity scores in Spanish and English for Child and Target with Dialect Specific Expectations

Child:	Dialect(s)	Spanish					English				
		Child pMLU	Target pMLU	PWP	WEL?	+/- from Ohio Score	Child pMLU	Target pMLU	PWP	WEL?	+/- from Ohio Score
Child 1: (Age 4;10)	Honduran/Mexican	7.72	7.94	97.23%	Yes	-.13	6.32	7.14	88.51%	Yes	+.38
Child 2: (Age 4;11)	Mexican	7.27	8.06	90.20%	Yes	+1.68	6.00	7.14	84.03%	No	+.09
Child 3: (Age 4;5)	Salvadoran	7.73	8.15	94.85%	Yes	-.49	6.32	7.16	88.27%	Yes	0
Child 4: (5;0)	Salvadoran	7.68	8.12	94.58%	Yes	0	6.25	7.16	87.29%	Yes	0
Child 5: (Age 3;6)	Mexican	7.47	8.09	92.34%	Yes	+.5	5.51	7.11	77.50%	No	+.54

Note: English .91 +/- (.06) from .85 to .97 (Scarpino et al. 2019); Spanish .92 (+/- .06) from .86 to .98 (Scarpino et al. 2019)

Table 5

A Comparison of Group Mean Scores and Standard Deviations for Original and Post-Hoc Analyses by Language

	Spanish				English			
	Analysis 1	WEL 1?	Analysis 2	WEL 2?	Analysis 1	WEL 1?	Analysis 2	WEL 2?
PCC-R	86.69% (3.88)	No	87.12% (2.78)	No	70.63% (10.34)	No	70.86% (10.74)	No
pMLU-T	8.16 (.08)	--	8.07 (.08)	--	7.16 (.00)	--	7.14 (.02)	--
pMLU-C	7.57 (.23)	--	7.57 (.20)	--	6.08 (.34)	--	6.08 (.34)	--
PWP	93.53% (3.43)	Yes	93.84% (2.67)	Yes	84.92% (4.78)	No	85.12% (4.62)	Yes

Note: Analysis 1 indicates the original analysis whereas Analysis 2 indicates the post-hoc analysis

Appendix A

How to Calculate PCC-R

1. Obtain a large enough sample of utterances to appropriately calculate these data. Research suggests a need for at least 75-word utterances for PCC-R (Wren et al., 2020).
2. Count the total number of consonants in the sample. For example, the word “cat” or /kæt/ has two total consonants.
3. Count the total number of correct child productions in the sample. For example, if the child produces [tæt] for /kæt/ there would be one total correct consonant in this utterance.
    a. Note- for PCC-R distortions should be counted as correct, but substitutions or omissions should not (Shriberg et al., 1997; Sundarrajan, et al., 2019).
4. Divide the number of correct consonants by the total number of consonants in the sample, and then multiply this value by 100 to convert to a percentage, which will provide a value indicating the accuracy of the child’s productions. For our example of /kæt/ vs. [tæt], the PCC-R would be 50% (1 correct consonant / 2 total consonants x 100 = 50%) (Fabiano-Smith & Hoffman, 2018).

How to Calculate pMLU

1. Obtain a large enough sample of utterances to appropriately calculate these data. Research suggests a need for at least 100-word utterances for pMLU (Wren et al., 2020), but for the sake of this study and for consistency, we will be using a sample of approximately 80 words per child per language.
2. Count the total number of segments in the word as 1 point each and assign an additional point to each correct consonant. Similar to the example above, if the child produces [tæt]

for /kæt/ there would be 3 total segments, plus one total correct consonant in this production. The target pMLU = 5, whereas the child pMLU = 4.

3. Repeat for all words in the sample, and then calculate the mean score of all productions to determine the pMLU of the full sample (Ingram, D., & Ingram, K. D., 2001; Ingram, 2002).

Appendix B

Dialect Specific Rules

Mexican (Goldstein, 2001; Lipski, 2008)

- /b/ to [v]
- Omission of /k, g/
- Aspiration of /s/
- /x/ to [h]
- /r/ to [R]
- Weakened intervocalic /j/
- Syllable-final /ɹ/ to [s]
- /ɹ/ to tap or trill
- /tʃ/ to fricative

Honduran (Lipski, 2008):

- Weakened intervocalic /j/
- /x/ to [h]
- Before consonants, intervocalic, and word/phrase final position: /s/ to [h]
- Final /n/ to [ŋ]

Salvadoran (Lipski, 2008):

- Weakened intervocalic /j/
- /x/ to [h]
- Intervocalic /s/ to [h]
- Final /n/ to [ŋ]